Tycho Brahe and Prague:
Crossroads of European Science

Acta Historica Astronomiae
Vol. 16

On behalf of the
Working Group for the History of Astronomy
in the Astronomische Gesellschaft

edited by
Wolfgang R. Dick and Jürgen Hamel

Tycho Brahe and Prague: Crossroads of European Science

Proceedings of the International Symposium
on the History of Sciene in the Rudophine Period
Prague, 22 - 25 October 2001

Edited by
John Robert Christianson, Alena Hadravová,
Petr Hadrava and Martin Šolc

Verlag Harri Deutsch

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This volume has been co-sponsered by the Research Center for the History of Sciences and Humanities, Prague, in the framework of the project LN00A041 supported by the Ministry of Education of the Czech Republic.

Die Deutsche Bibliothek - CIP-Einheitsaufnahme

Ein Titeldatensatz für diese Publikation ist bei
Der Deutschen Bibliothek erhältlich.

ISBN 3-8171-1687-X
ISSN 1422-8521

1. Auflage 2002

Druck: Rosch-Buch, Druckerei GmbH, Scheßlitz
Printed in Germany

The symposium was held under the auspicies
of the rector of the Charles University Prof. Ivan Wilhelm, DSc,
and the president of the Academy of Sciences of the Czech Republic
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All sessions were held in the Patriotic Hall of Carolinum, the historical building of the Charles University.

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Ne frustra vixisse videar ...

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J. R. Christianson et al. (eds.), © *H. Deutsch 2002*

Welcome Address of the Vice-Rector of the Charles University in Prague

Distinguished Guests, Ladies and Gentlemen, Dear Colleagues,

It is an honour for me to welcome you here on behalf of the rector in the historical centre of the Charles University. We meet in this ancient part of the former Charles College at an International Symposium on the History of Science in the Rudolphine period organized on the occasion of the 400$^{\text{th}}$ anniversary of Tycho Brahe's death. The symposium has been prepared by the Research Center for the History of Sciences and Humanities founded by Charles University and the Academy of Sciences of Czech Republic. The universal character of the personality of Tycho Brahe is reflected in the presence of many distinguished scholars both from abroad and from the Czech Republic representing astronomy, the history of science, as well as different domains of humanities.

Let me please exploit this meeting to make for some brief remarks about the pecularities of the scientific style of the epoch. The impetus for my considerations is the stylistic variety of Tycho Brahe's literary legacy – epistolography as well as his *Astronomiae instauratae mechanica* (including his autobiography) and *Astronomiae instauratae progymnasmata*. The Tychonic style including his mode of argumentation represented an interesting mixture of scientific presentation of empiric data with the style of rhetoric persuasion based on probable proofs, enthymemes, tropes and figures.

Tycho Brahe was a typical representative of a transition period in the history of science. Its milestones were on one side represented by the works of Copernicus, on the other side by Kepler, Galilei, Newton and many others. At the same time it was a period marked by disputes between theologians, philosophers and mathematicians. Who was better equipped as a source of a truth and certitude about the cosmos and for the presentation of the theories involving eccentrics and epicycles? The prevailing opinion was that the astronomer could do no more than collect some vague data based on arbitrary suppositions and, consequently, that these could be false. Only philosophers and theologians could grasp the nature of the heavenly bodies and the causes of their motions. The mere probability of conclusions drawn from empirical data was compared unfavourably to the syllogistic certitude of Aristotle's *Posterior Analytics* and *Physics*, which represented the backbone of university instruction throughout all of Europe. Therefore, the style of scientific treatises and passionate polemics of this period are characterised not only by mathematical and empirical evidence, but also by the frequent presence of persuasive strategies, rhetorical appeals, arguments from authority, unusual metaphors, etc.

Thus the accepted method for proving a scientific theory in the period before Copernicus was demonstration according to the principles established by Aristotle. Another constraint was given by the Holy Scriptures. The long lasting authority of Tycho Brahe was maintained by his theory that the planets move around the Sun but that this group together circled the Earth. This explained the movement of the stars as observed with the telescope in a way which the Ptolemaic system could not, but – very importantly – fitted prevailing theological opinion. Tycho Brahe's style is therefore balanced and much less polemic than the style of his successors who tried to ruin Aristotelian-Ptolemaic traditions more openly.

I tried very briefly to hint at the fact that the scientific presentations of Tycho Brahe and other scholars of the epoch can be considered as an interplay of science and rhetoric. The most striking example of this mixture is Galilei's *Dialogo sopra i due massimi sistemi del mondo*. This dialogue contains mostly rhetorical arguments, i. e. arguments based on the seemingly unproven assumption that the Earth is a wandering body. Even the genre of dialogue is a part of rhetorical strategy which enabled the author to present his ideas always with some reservations presented by the interlocutors. The role of interlocutors is carefully staged so as to highlight Galileo's viewpoint which leads the reader to recognize the obvious superiority of Copernican principles. This mode of presentation and reasoning proved the importance of rhetoric in the domain of science.

Historians of science are faced with the question whether science and rhetoric were completely opposed in further development of human knowledge. Some contemporary scholars do not believe this, and argue that there is no line which could be successfully drawn between rhetoric and scientific knowledge, saying with Jacques Derrida that "all science is text" and "all text is rhetorical". An attempt to answer this question might bridge the gap between scientists and humanists. The gap that perhaps does not exist at all.

Let me wish you during your Tychonian conference many fruitful discussions and a real success.

Prof. PhDr. Jiří Kraus, DSc.

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J. R. Christianson et al. (eds.), © *H. Deutsch 2002*

Tycho Brahe: Observational Cosmologist

Owen Gingerich, Cambridge, MA

In assessing the history of astronomy, John Flamsteed, the first Astronomer Royal, wrote:

> "It was also about the time of Mr Frobisher's first voyage [1576] that Tycho-Brahe, a Noble Dane, built his Observatory in the Isle of Ween in Denmark, where, having an ample Revenue of his own, besides Large allowances from the then King of Denmark Frederick the Second, he formed new Instruments much better, larger, and more proper then any the Ancients knew for rectifying the places of the fixed Stars, Luminaries and Planets; by reason of the rudeness of the ancient Observations, he was forced to begin all anew. And after 25 years Labour of himself, and 8 or 10 ingenious Assistants, left a Catalogue of the places of about 800 stars rectified by him, which was published in his *Progymnasmata* printed at Prague in the year 1602. But the *History* of his Observations was not printed till the year 1666, and then very carelessly, and so it abounds with Faults."[1]

Albert Curtius' *Historia Coelestis* (Augsburg, 1666), despite faults so severe that Tycho's biographer J.L.E. Dreyer compared it with the fabled Augean stables, nevertheless presents a dramatic testimonial to the impact of the noble Danish astronomer. The volume attempts to register *all* the positional observations from antiquity to about 1630, not just those of Tycho. The ancient and medieval observations require 99 pages at the beginning; those after Tycho's death to 1630 take another 67 pages. The lion's share, the transcriptions of the Danish measurements, make up the great bulk of the book, 912 pages. Tycho's overwhelming contribution can hardly be more convincingly displayed.

[1] Eric G. Forbes, Lesley Murdin, and Frances Willmoth (eds.), *The Correspondence of John Flamsteed, the First Astronomer Royal*, vol. 2, p. 633, with orthography and punctuation modernized, and the incorrect date (1614) of the *Progymnasmata* corrected.

Whereas Flamsteed concentrated on the star catalog from Hven, Tycho's own autobiographical account in his *Mechanica* is better balanced in presenting his astronomical achievements. He begins by saying:

> "In the year of Our Lord 1563, that is, 35 years ago, on the occasion of the great conjunction of the superior planets which took place ... when I had reached the age of sixteen years, I was occupied with studies of classical literature in Leipzig ... The reason why I go that far back in time is that I want to make it clear how it came about that I, who had at first occupied myself with the liberal studies, later on turned to Astronomy ..."[2]

He then describes how his natural inclinations led him to study astronomy more and more, and how with a simple instrument he began to measure the angles between planets and fixed stars or between planets themselves as they came into conjunction, and he began to compare the positions predicted by the Ptolemaic theory as embodied in the *Alfonsine Tables* with those of the Stadius ephemerides based on the Copernican tables.

> "Although this method of observation was not very accurate, yet with its help I made so much progress that it became quite clear to me that both tables suffered from intolerable errors. This was amply apparent from the great conjunction of Saturn and Jupiter in the year 1563 ... and this was precisely the reason why it became my starting point. For the discrepancy was a whole month when comparison was made with the Alfonsine numbers, and even some days, if only a very few, on comparison with those of Copernicus."

Indeed, the conjunction, which actually took place on August 24, is given in the Alfonsine ephemerides as on September 27. The situation is not so clear with respect to Copernicus – the claim is really the boast of a precocious teenager, or of an arrogant grown-up misremembering his youth. In reality the Copernican prediction was less than half a day off, and young Tycho did not even observe it on the day of the closest approach. But Tycho's memories had the essence of truth, for his long experience had correctly shown that the Copernican tables did from time to time generate substantial errors that could even surpass those of the *Alfonsine Tables*.

Ironically, in his own lifetime he did not succeed in making better tables for planetary positions – that remained to be the brilliant achievement of Johannes Kepler. Kepler was the pre-eminent cosmographer who es-

[2] HANS RAEDER, ELIS STRÖMGREN, and BENGT STRÖMGREN (trans. and ed.), *Tycho Brahe's Description of his Instruments and Scientific Work as Given in Astronomiae Instauratae Mechanica* (Copenhagen, 1946), p. 106.

sentially made the modern Copernican system. Tycho would surely have liked to be remembered as a foremost theoretical cosmologist, but his geo-heliocentric cosmological system, so beloved by the seventeenth-century Jesuits, proved to be a physical dead end. But Kepler's work would have been impossible without the foundation laid by Tycho, and the real strength of that foundation was that it was cosmologically driven, as I will try to explain in arguing that Tycho was a pre-eminent observational cosmologist. However, that evaluation must come later. Let me first turn to the accomplishments that Tycho listed in his *Mechanica*, and since these were made possible by the special instruments that he devised, it is necessary to interweave the story of building and improving the instruments.

Tycho hoped to measure positions to $1'$, which is close to naked-eye acuity. To graduate an instrument directly in minutes of arc, with approximately a millimeter per arcminute, requires a radius of approximately five meters. Tycho actually constructed such an instrument in Augsburg, a giant wooden quadrant that proved so unwieldy as to convince him that large size was not necessarily the best path to accuracy *(Figure 1)*. He experimented with alternative methods of graduating the scales and eventually settled on the use of transversals, diagonal lines that essentially magnified a six-minute division so that minutes or even fractions of minutes could be easily read. While others, going back to Levi ben Gerson, had proposed the use of this system, Tycho was the first to exploit the method extensively. Secondly, he needed a more accurate backsight so that the width of the eye pupil would not be the limiting factor. This he achieved with a pair of slits aligned with a cylinder or rectangular foresight of the same width as the separation of the slits. The alignment was determined when the star could be viewed equally with each slit.

Fundamental to any program of restoration of astronomy is establishing the basic coordinate system, which depends for its zero point on the motion of the sun. Tycho's favorite instrument for solar studies was his great mural quadrant, located in the living room of his Uraniborg castle and solidly fixed along the north-south meridian. Since observations with this instrument produced only altitudes, he had to deduce the solar longitudes from the solar theory itself, so his attack on the solar problem was a highly theory-laden boot-strap operation. The resulting theory was marred by his assumption of a measurable solar parallax (because he, like everyone else since antiquity, believed the sun to be 20 times closer than it really is). The corrections for solar parallax threw off his determination of when the sun crossed the equator, and led to a slightly erroneous value for the eccentricity of the sun's orbit (or the equivalent in the heliocentric system, the earth's orbit). This value was an improvement over previous results,

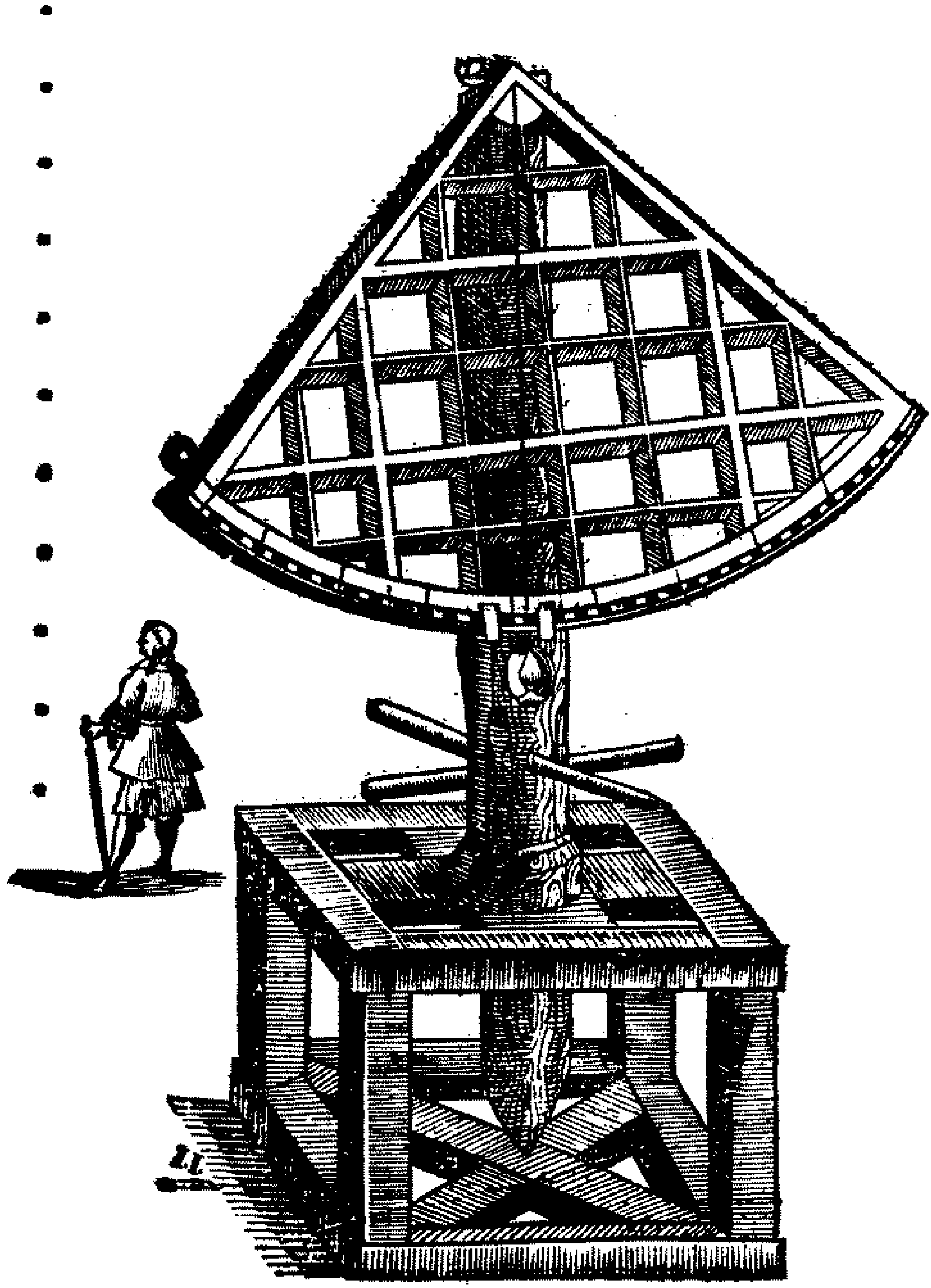

Figure 1: Tycho's great wooden quadrant built in Augsburg in 1572. The lower part of the frame was buried in the earth. This woodcut from Curtius' *Historia coelestis* adds a human figure for scale.

but nevertheless it ultimately became the poorest parameter in the *Rudolphine Tables* because Kepler never challenged his mentor's finding.

Given a solar theory, the next step was to connect the sun's position with the stars, a tricky procedure because the stars and sun are not visible at the same time. Ptolemy solved the problem by using lunar eclipses, but Tycho rejected this method as insufficiently precise. Instead, he used Venus as an intermediary, but only after careful tests showing that Venus did not have sufficient geocentric parallax to vitiate the procedure. Much of the work on the stars was done with his sextant, an instrument reversed from the normal device (for example, the Bürgi sextant in the Technical Museum in Prague) where a single observer could sight both stars simultaneously. The Tychonic form required two observers, but guaranteed that both stars could be aligned simultaneously – this was important because arcminute accuracy for stars near the ecliptic required that the stars be aligned within four seconds of time. Tycho's stellar observations were rather fitful – he worked on the stars when he didn't have any more pressing observations to make. As a consequence, when he packed up to leave to Denmark, he wasn't as completely finished as he had hoped to be, that is, he had wanted to match Ptolemy's thousand-star catalog, and he had only 777. (Part of the problem was of course that his more northerly latitude lost him many southern stars.)

Regarding the moon, Tycho's most important work was done relatively late in his career on Hven, in the 1590s. Previous observers had concentrated on the moon's position at syzygies (i.e., new or full) or at quarters. Tycho stumbled on the fact that there was an important systematic effect at the octants amounting to as much as 2/3 degree. He was the first to incorporate this phenomenon, now called the "variation," into a lunar theory.

Of course, it was Tycho's work on the nova of 1572 that first attracted attention to his extraordinary skill as an astronomer. His careful observations showed that the brilliant new star held to precisely the same celestial position regardless of its altitude, unlike the moon, whose position lowers by a degree when it is near the horizon. That is a substantial amount, and it was not so difficult for Tycho to show that the nova did not behave this way and hence that it was farther than the moon. Such a notion was contrary to the teachings of Aristotle, which placed mutable changes in the heavens within the earth's corruptible atmosphere rather than among the eternal ethereal spheres.

Five years later, as he was building his new Uraniborg Observatory on his fiefdom island of Hven, Tycho found a similar challenge with the bright comet of 1577. Finding the parallax (or lack thereof) was more difficult for the comet than for the nova because of the comet's own motion across the sky, but again, Tycho was able to place it well beyond the moon. These two discoveries were both highly significant in eroding trust in the traditional views of the cosmos.

Given his success with these two parallaxes, Tycho embarked on a bold and far more difficult project, to find the distance to Mars.[3] Again, he hoped to compare the position of Mars when it was high in the sky with the position when it was nearer the horizon, or more precisely, he hoped to compare evening and morning observations, which gave him a baseline comparable to the diameter of the earth (reduced however because he was not on the equator but at a higher latitude). Unlike the case of the large lunar parallax, for Mars he expected an effect of about $3'$ with the Ptolemaic arrangement, or about $5'$ instead if the Copernican system was correct (because Mars comes closer in the Copernican system). Today, armed with our modern knowledge of the size of the solar system, we know that his campaign was doomed to failure. But since Tycho, as previously mentioned, believed in a solar distance 20 times too small, he expected that the effect would be just within his range.

During the golden years at Hven, in the 1580s, his steadily improving instrumentation made possible his Copernican campaign. When Mars made its close approach at the end of 1582, he tried and failed to find the expected $5'$ parallax; Tycho announced to Heinrich Bruce in Rostock that his results contradicted the Copernican system. Nevertheless, Tycho persisted, and at the next Martian opposition, two years later, in 1585, he tried again. He was then disconcerted to find a *negative* parallax, implying that Mars was farther than infinity! Investigating this anomaly, Tycho began to suspect the role of refraction. Refraction raises the apparent altitude of a star or planet depending on how close the object is to the horizon. Tycho's Martian observations necessarily took place when the planet was rather close to the eastern horizon in the evening and to the western horizon in the morning. Because the comparison stars were at different altitudes than the planet, refraction affected them differently, introducing subtle errors in the derived positions of Mars.

Meanwhile, Tycho was also building a new underground observatory next door to his castle. The original instruments, supported atop the Uraniborg balconies by single tall, spindly columns, were insufficiently stable, and were buffeted by the wind. The new subterranean settings allowed the quadrants to be supported by armatures above the instruments, for

[3]For details see Owen Gingerich and James R. Voelkel, "Tycho Brahe's Copernican Campaign", *Journal for the History of Astronomy, 29* (1998), 1-34.

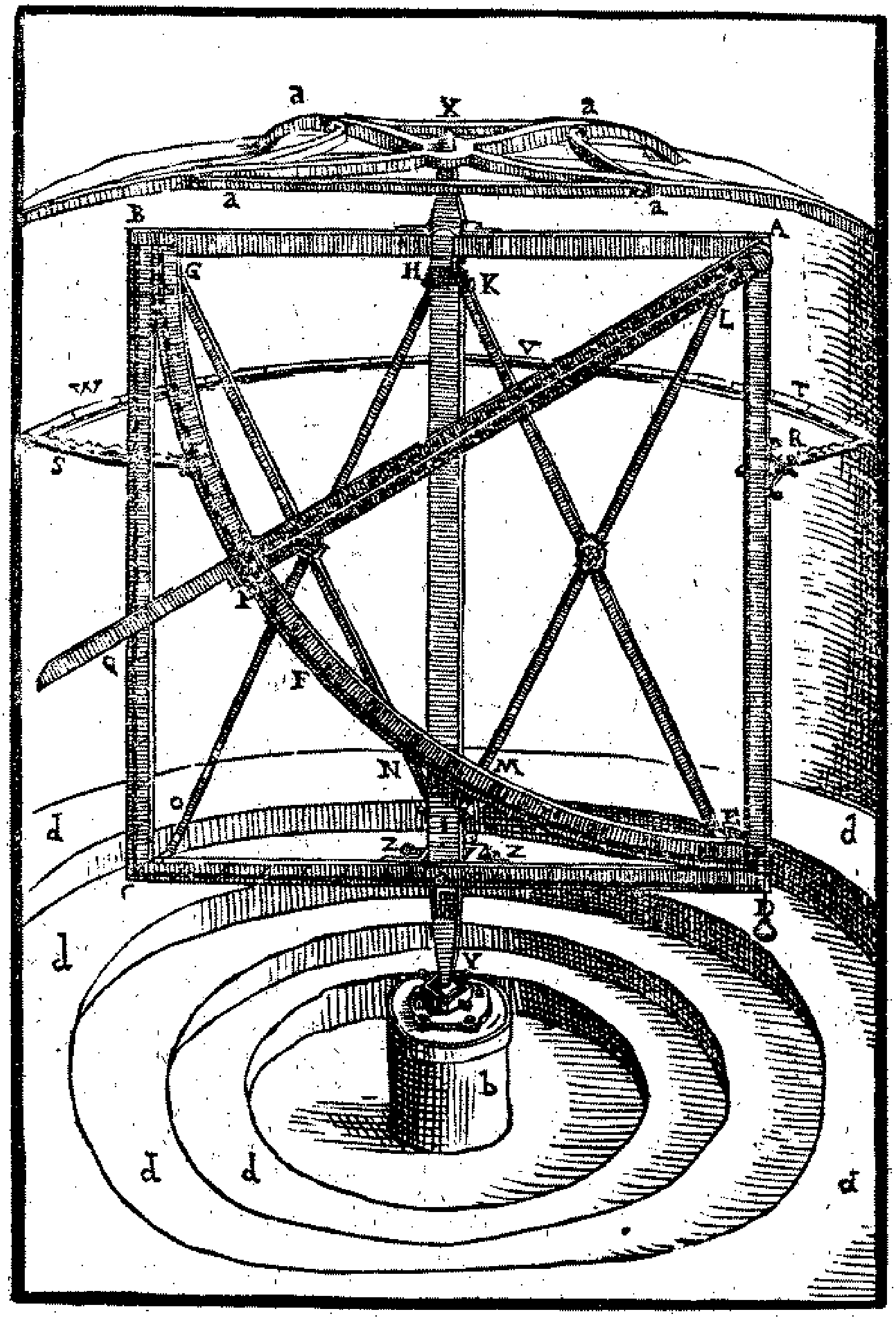

Figure 2: The great steel quadrant with overhead aperture, after it had been moved from Uraniborg to Stjerneborg, as depicted in Tycho's *Astronomiae Instauratae Mechanica.*

example (see *Figure 2*). Also included in the instrumentation of the new Stjerneborg facility was a large equatorial armillary, which allowed him to get directly the declinations of stars or planets, and this provided him with a device whereby he could establish a refraction table for stars or planets. For the sun, however, he preferred to rely on his mural quadrant, and as insinuated earlier, this theory-laden procedure resulted in an error of 5′ in the refraction for an altitude in the range 5-15°.

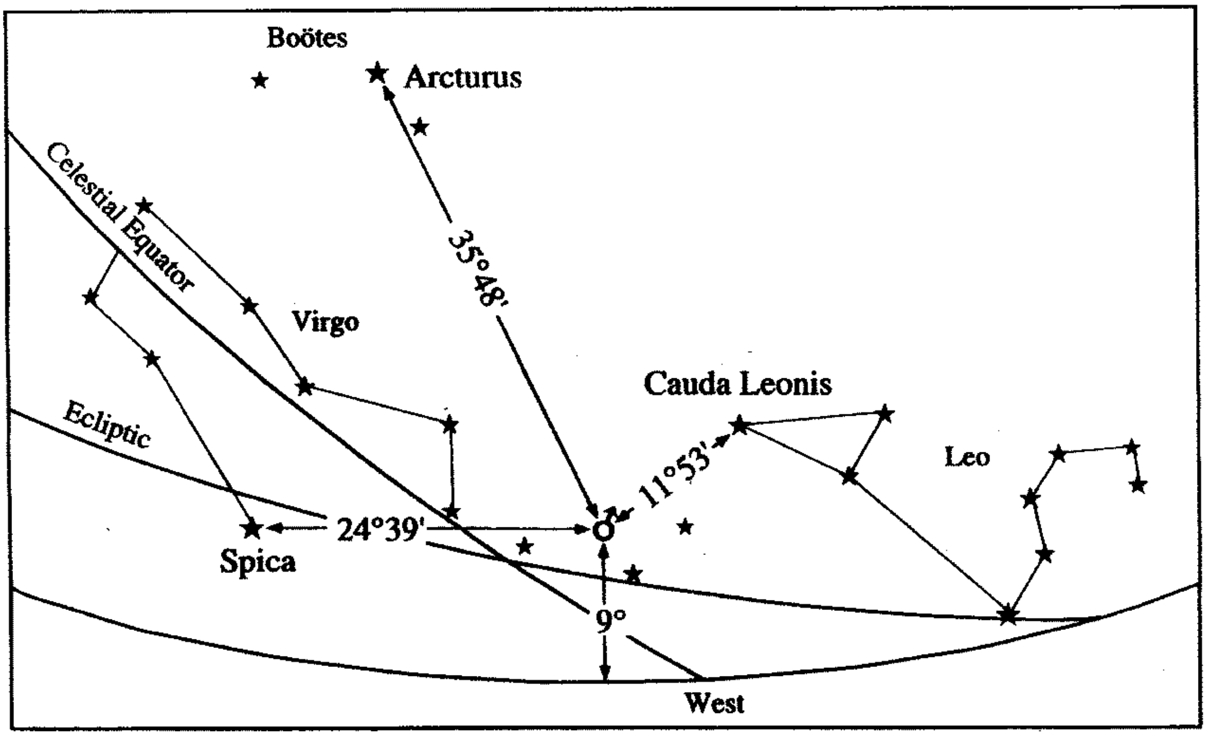

Figure 3: Tycho's triangulation for the position of Mars on the morning of 11 March 1587 gives essentially the same position regardless of which two stars are used. Diagram from the *Journal for the History of Astronomy, 29* (1998), 20.

Attacking the Mars problem yet again in 1587, Tycho now had his entire arsenal of instruments and a large staff at his disposal. Seated in the warm room at the center of Stjerneborg, Tycho could coordinate simultaneous observations being made by his assistants manning the great steel quadrant (for altitudes), the sextant (for distances between Mars and the reference stars), and the equatorial armillary (for declinations). The results, shown schematically on *Figure 3*, were robust. Any two pairs of distances from the reference stars sufficed to establish the position of Mars, so the position was determined in three possible combinations, each yielding the same position within 1′. But at this point Tycho faced a decision: should he use the solar refraction table, or the somewhat different one he had established for the stars? Using the erroneous solar refraction table, he deduced a parallax of $5'$ for Mars, precisely the Copernican number he was looking for, but unfortunately, actually just the error of the table!

Without yet recognizing the error at work, Tycho boasted of his finding in a letter to Caspar Peucer, Reinhold's successor as astronomy professor at Wittenberg. Because the letter also helped establish his observational credentials with respect to his newly proposed geo-heliocentric cosmology, Tycho made sure that copies of the letter were available for other astronomers, so that an important quotation from it later surfaced in Michael Maestlin's appendix to Kepler's *Mysterium cosmographicum*, a fact that surely did not escape Tycho's notice. However, Tycho was such a careful scientist that he did not let the matter rest there. He carefully observed Jupiter with his armillary to see if a planet's refraction behaved the same way as the sun's. Probably to his chagrin, he discovered that with a corrected planetary refraction table, his Martian parallax disappeared. He made no further claims concerning a large parallax for Mars, and even Kepler was left in the dark as to what had happened. And he mentioned neither the Mars campaign nor his work on refraction in his autobiographical list of achievements in his *Mechanica*. What did survive was an exquisite series of Mars observations that ultimately became the grist for Kepler's mill. It was Kepler who realized that Tycho's parallax observations demonstrated that the solar system was at least three times larger than the previous estimates.

Tycho would surely have liked to have tried yet again to obtain the parallax of Mars. Unfortunately, the pattern of oppositions had moved into the summer sky, with the nights too short and Mars too low in the sky for the procedure to work. By the time another appropriate Martin observation rolled around, Tycho was packing the instruments for his transfer to Prague, an unfortunate scheduling that Kepler explicitly lamented in his *Astronomia nova*.

Any evaluation of Tycho's impact must recognize that his treasury of observations completely revolutionized the amount of data that astronomy had at its disposal. But these were not random masses of observations. As a highly motivated observational cosmologist, Tycho planned his observational campaigns with specific goals in mind, for the reform of every aspect of positional astronomy: the solar and lunar theory, fundamental positions of stars, the place of comets and novae. It is one of the ironies of astronomical history that although his best-planned campaign failed, the data proved to be fully adequate in the hands of a great theoretical cosmologist, Johannes Kepler, for discoveries unimagined by Tycho and which turned the Copernican system into a consistent and far more accurate heliocentric cosmos.

Tycho Brahe and Prague: Crossroads of European Science, pp. 30–45,
J. R. Christianson et al. (eds.), © *H. Deutsch 2002*

Tycho and Sophie Brahe: Gender and Science in the Late Sixteenth Century

John Robert Christianson, Decorah

Tycho Brahe (1546-1601) and his youngest sister, Sophie Brahe (1559-1643), shared strong interests in the culture of science and interacted closely, but the gendered pattern of late sixteenth century élite education forced their scientific pursuits into different molds. Sophie's scientific culture was transmitted to a new generation of learned aristocrats, whereas his moved beyond aristocratic circles to find its place in academic and other professional institutional contexts.

Sophie Brahe was born at the Brahe family seat of Knutstorp Castle in the Danish province of Skåne, probably on 24 August 1559, and was thus some thirteen years younger than her oldest brother, Tycho. Despite the age difference, they developed a very close relationship and shared many interests, including astronomy, astrology, chemistry, gardening, history, and genealogy. In some of these fields, Sophie's proficiency exceeded that of Tycho, and in others, he was the expert. They discussed their learned interests and cultivated them together. Sometimes he instructed her, and sometimes she instructed him. Both of them pursued their learned interests at home, not at a school or university, because both were effectively barred from professional academic careers, she because she was a woman, and he because of noble birth and rank.

Tycho described his sister's learned interests and some aspects of their interaction in an essay written around the year 1594. "I have a sister by the name of Sophie," he wrote, "who became the widow of a good and honorable nobleman some six years past. She was quite young at that time and could take joy in her only child, a son, and ... she began to seek distractions that could cheer her up ... insofar as that was possible." Tycho went on to describe these "distractions" in some detail. "First, at Eriksholm, her house in Skåne, which is built as a fortified castle, she laid

Figure 1: Sophie Brahe (1559-1643)

out a marvelous, fair garden, which hardly has its equal in these northern regions of the world. ... After this work, she ... took on chemistry with the aim of preparing certain spagyric medicaments." By that, of course, he meant that she followed the medical philosophy of Paracelsus. "When she could not even by these means fulfill her spiritual ambitions ... she finally began with great zeal to pursue astrological predictions on the basis of horoscopes of nativities."

Tycho went on to describe their relationship with respect to these studies, and to say what he thought of his sister's learned pursuits. "I had myself in these first areas, though more in pyronomics [again, Paracelsian chemistry] than in gardening, which she understood well enough herself, supported her with instruction and guidance when she wished it, but astrological speculations I seriously warned her to avoid, because she should not pursue matters that are too abstract and complicated for feminine talents. But she, who has an unbending spirit and such great self-confidence that she will never yield even to men in intellectual matters, on the contrary threw herself ever more energetically into her studies, and in a short time learned the basic principles of astrology, partly from Latin authors whom she had translated into Danish at her own expense, and partly from German authors on the subject (for she has an excellent command of that language). When I saw clear signs of this, I ceased trying to work against it and was content to advise her towards moderation in her further studies."[1]

When Tycho later described his own education, he emphasized that he was self-taught in astronomy and pursued it against the wishes of his parents and preceptor.[2] The fact that both he and Sophie were autodidacts who persisted in the face of opposition was a trait that they had in common, as Tycho saw it.

Tycho wrote this essay about his sister because he wanted to include one of her letters in the second volume of his scientific correspondence. He wrote a lengthy introduction to explain why he included the letter, because it was so unusual to give women serious consideration as scientists. Unfortunately, the volume was never published, and the letter from Sophie Brahe has been lost, so all we have is Tycho's introductory essay.

Tycho Brahe's seat for twenty-one years was Uraniborg, his combined manor house, laboratory, and observatory on the island of Hven, which he

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[1] Quoted in PETER ZEEBERG, *Tycho Brahes "Urania Titani:" Et digt om Sophie Brahe* (Copenhagen: Museum Tusculanums Forlag, 1994), 170-73, translated by J. R. CHRISTIANSON.

[2] TYCHO BRAHE, *Instruments of the Renewed Astronomy*, trans. and ed. ALENA HADRAVOVÁ, PETR HADRAVA, and JOLE R. SHACKELFORD (Prague: KLP, [1598] 1996), 117-18.

held as a fief from the king of Denmark. Sophie Brahe's seat during most of those same years was her castle of Eriksholm in the Danish province of Skåne. These places were not far apart, and Sophie came frequently to Uraniborg, Tycho less frequently to Eriksholm.

The reason they pursued their learned interests at home and not at some learned institution was due to changes brought about, a generation earlier, as a result of the Protestant Reformation. Denmark became a Lutheran country in 1536, and cloistered religious communities of men and women were slowly dissolved in the decades that followed. This change had a powerful impact upon aristocratic families like the Brahes and their kin, because the aristocracy had previously dominated the convents, bishoprics, cathedral chapters, and monasteries of the realm. After 1536, noblemen were not appointed to bishoprics and university positions, while monasteries and convents were allowed to wither away.[3] Consequently, the Reformation had the effect of excluding élite men as well as women from institutional structures of learning. Noblemen like Tycho Brahe could and did still attend universities as students, but they did not take permanent positions as teachers; those positions fell to the educated middle class.[4] Noblewomen had previously made convents into important centers of women's culture, especially the large, well-endowed convents of the Brigittine Order, but now, under Lutheran supervision, those convents were declining rapidly.[5] Aristocratic learning was thrown back on the noble household by the effects of the Reformation.

It was at home or in the households of close relatives that noble children received their early education in late sixteenth-century Denmark.[6] Small boys and girls alike were dressed in long skirts and lace collars, and both genders played with pets and dolls, balls and rocking horses. From the

[3]The exception was cathedral chapters, which continued to allow access by nobles as well as commoners. On Tycho's canonry in Roskilde Cathedral, see J. R. Christianson, *On Tycho's Island: Tycho Brahe and His Assistants, 1570-1601* (Cambridge: Cambridge University Press, 2000), 24-25.

[4]Tycho Brahe's series of lectures on astronomy at the University of Copenhagen in 1574-75 was highly unusual and had to be validated by a special royal request, see J. R. Christianson, "Tycho Brahe's German Treatise on the Comet of 1577: A Study in Science and Politics," *Isis* 1979, 70: 111-13.

[5]In Roman Catholic countries, convents sometimes remained centers for women's scientific interests, see for example Dava Sobel, *Galileo's Daughter* (New York: Walker & Company, 1999).

[6]Birte Andersen, *Adelig opfostring: Adelsbørns opdragelse i Danmark 1536-1660* (Copenhagen: G. E. C. Gad, 1971), 18-31. Sophie's older sister, Margrete Brahe, was sent to Gudum Cloister at the age of seven to be raised by her maternal aunt, Sophie Clausdatter Bille, whose husband was the administrator of the convent and its landed estate.

age of six or seven, they learned to sing hymns and ballads, memorized their prayers and Luther's Small Catechism, learned to read and write the Danish language, and were taught elementary arithmetic.

Then the paths of girls and boys parted. In Tycho's and Sophie's generation, boys commonly were sent to serve in the households of noble kinsmen as pages, later advancing to squires while learning courtly manners and martial arts like riding, hunting, and swordsmanship. Tycho's four brothers followed this path, and all of them later served in armor in the Dutch wars before entering the service of the Danish crown. The venues of this form of education were noble castles, princely courts, and fields of battle. In traveling abroad, these young noblemen learned modern languages like German, Dutch, French, sometimes even Italian or English. This courtly pattern of education did not turn Tycho's brothers into natural philosophers or scientists, but it did prepare them to be polished courtiers, governors of fiefs and provinces, and even, one of them, a regent of the kingdom of Denmark.

In Tycho's generation, a minority of aristocratic boys were tutored in Latin at home and then sent to Latin school and on to the Danish university, later completing their education at one, or usually several, foreign universities. As nobles, they did not take university degrees, but they did study the same subjects as other students, in addition to instruction in aristocratic endeavors like dancing, fencing, and horsemanship. They mastered the classical languages, especially Latin, as well as the vernaculars of Germany, Italy, and France. This academic path of education was becoming more common for young noblemen of Tycho's generation, and those who followed it frequently became individuals of considerable learning.[7]

Meanwhile, their sisters stayed at home like Sophie, or went to the homes of aristocratic relatives, where tutors and older family members taught them what they needed to know. A few learned German along with Danish, as Sophie did.[8] Very few studied Latin, as Sophie did for a brief time. Their mathematics was limited to practical skills like figuring with Arabic and Roman numerals, learning weights and measures, coinage, calculating compound interest, and using the calendar.[9] Learning calendrics led naturally into astronomy and astrology for a young noblewoman like Sophie.

[7] ALBERT FABRITIUS, "Brahe†," *Danmarks adels årbog* 1950, part 2, 15-18. ANDERSEN 1971, 62-80.

[8] ANDERSEN 1971, 91-99.

[9] ANDERSEN 1971, 83-88. Along the way, they learned that the same symbol could stand for a planet, a metal, and a day of the week, depending on the subject. For example, ○ was the Sun, gold, and Sunday; ♂ Mars, iron, and Tuesday; ♀ Venus, copper, and Friday.

She was fourteen in 1573, when she helped her brother, Tycho, observe an eclipse from Knutstorp.[10] Noblewomen learned the Hippocratic theory of the four humors and the rudiments of health care, though in Sophie's case, her brother, Tycho, helped her to learn the alternative medical system of Paracelsus. Young noblewomen also acquired numerous practical recipes for elixirs, medicines, perfumes, cosmetics, and household preparations such as cleansers and solvents. In addition, they learned to lay out herbal and ornamental gardens and to gather healing plants from nature.

In short, young women of the aristocratic élite were raised to cultivate learning in certain directions that related to mathematics and the natural world. This was part of a pattern of education that prepared them to manage large households, raise their own and other noble children, and display courtly manners in the presence of aristocrats and royalty. Like most noble males, they did not usually learn the classical languages but frequently mastered two or three modern languages.

The next step for a noblewoman was marriage, and Tycho Brahe's sister married a person he referred to as a "good and honorable nobleman." His name was Otte Thott of Näs and Eriksholm.[11] She was twenty when they married in 1579. The marriage was arranged in the usual manner of the day. Otte was tremendously rich, while Sophie brought a substantial dowry and inheritance into the match.[12] Their only son, Tage Thott, was born the year after they were married. Otte Thott was sixteen years older than Sophie Brahe. He died in 1588, after only nine years of marriage, leaving the twenty-nine-year-old widow with an eight-year-old son.

This was when she, as Tycho put it, "began to seek distractions that could cheer her up" – herbal and floral gardening, chemistry, astrology, and family history. Let us take each of these areas in turn, in order to examine what Tycho learned from Sophie, and what Sophie learned from Tycho.

Tycho's description of his sister's learned interests makes it clear that she shared his Paracelsian-Hermetic world view, with its strong sense of

[10] ZEEBERG 1994, 254.

[11] Otte Thott's mother, Else Holgersdatter Ulfstand, was a sister of Sophie's maternal grandmother, Lisbet Holgersdatter Ulfstand, so Otte and Sophie were first cousins once removed. During the fifteenth century, the Thott family had been kingmakers in both Denmark and Sweden from their territorial base on the border of the two realms.

[12] Sophie's inheritance, besides a substantial dowry, was probably in excess of fifty copyhold farms scattered around Skåne and other parts of Denmark, see my analysis of her father's legacy in Victor E. THOREN with contributions by J. R. CHRISTIANSON, *The Lord of Uraniborg: A Biography of Tycho Brahe* (New York: Cambridge, 1990), 37-39. The patterns of aristocratic marriage and the nature of the betrothal gifts, dowry, and morning gift are discussed in CHRISTIANSON 2000, 173-77.

the individual human being as a microcosm. Renaissance gardening was one way to express this world view, for a garden could also be planned as a microcosm.[13] Sophie was a busy young mother and aristocratic wife when Tycho laid out the Uraniborg gardens and grounds around 1580. His plan expressed microcosmic ideals through symmetrical geometrical patterns of squares and circles in harmonious ratios. Uraniborg stood in the exact center within high ramparts aligned to the cardinal points. Inside the ramparts was an orchard of 300 trees, undoubtedly including many exotics like apricots, figs, quince, and walnuts. Between the orchard and the raked circle surrounding the house were four parterres of herbal, medicinal, and floral gardens.[14] Four pavilions for music, meditation, and summer meals stood amidst the parterres, and areas for lawn bowling and a ball game were in the orchard. Sculpture normally adorned a garden of this type, but at Uraniborg, all the sculpture was massed on the main building. Sculpted figures represented Astronomy and Chemistry; the four seasons, winds, qualities (hot, cold, wet, dry), and ages of man; and a figure of Pegasus swung in the wind on the highest spire.[15]

When the widowed Sophie Brahe, towards the end of that same decade, laid out her gardens at Eriksholm, she had the model of Uraniborg to draw upon. Unfortunately, good descriptions of her gardens have not survived, but Tycho said that they were unexcelled in all of Scandinavia. Presumably, not even his own gardens excelled them.

Soon after visiting Eriksholm in the late summer of 1590, Tycho Brahe rebuilt the ramparts of Uraniborg and redesigned his own gardens and grounds. Tycho's diary noted that Sophie Brahe visited Uraniborg in March of 1591, and that a servant of hers arrived on the day that she left and stayed for three days.[16] I have surmised that this servant may

[13] An international team of archeologists, botanists, landscape architects, and garden historians has thrown much new light since 1985 on Renaissance gardens in Scandinavia, as part of an effort to reconstruct the grounds of Uraniborg. The literature is summarized in J. R. CHRISTIANSON, "Tycho Brahe in Scandinavian Scholarship," *History of Science* 1998, 36: 471-73.

[14] Medicaments prepared by Tycho Brahe included angelica, blessed thistle, burnet (bloodwort), elecampane, gentian, juniper, medicinal rhubarb, prunella, saffron crocus, sweet flag, wormwood, and possibly valerian, all of which must have grown at Uraniborg, among many other plants. See JOHAN LANGE, "Hortikulterelt plantemateriale i 1500-tallets Danmark med specielt hensyn til Uraniborg-haven," in *Uraniborg, Renässansträdgård, Renässans växtmaterial: Rapport från ett seminarium på Alnarp 19 feb 1991*, ed. KJELL LUNDQUIST (Alnarp: Institutionen för Landskapsplanering, Sveriges Landbruksuniversitet, 1993), 22.

[15] See Tycho's birdseye view of the garden and grounds in CHRISTIANSON 2000, 111.

[16] I. L. E. DREYER and EILER NYSTRØM, eds., *Tychonis Brahe Dani Opera Omnia* (Copenhagen: Gyldendal, 1913-29) 9: 99. The diary, which was kept by one of Tycho's

have been her head gardener, possibly bringing planting plans, seeds, or rootstock.[17] Four days after he left, Tycho's diary noted that cuttings were put out in the garden.[18] These may have been boxwood cuttings for hedges to define new parterres, which would have made them some of the first box hedges in Scandinavia – possibly inspired by Sophie's garden at Eriksholm. Tycho's redesigned garden contained beds in the shape of circles, representing the cosmos, and stars, representing Paracelsian "stars within".[19]

Late-Renaissance gardens like those of Tycho Brahe and Sophie Brahe were designed to express complex intellectual programs.[20] First of all, the microcosmic garden with a source of water at its center was a model of paradise: Arcadia, Eden, and the Golden Age of the Hermetic philosophers, all at once.[21] The garden at Uraniborg, with its fountain at the very center of the plan, within the house, was designed to represent a paradise, and the same was undoubtedly true at Eriksholm. Secondly, a garden divided into four parts could be a microcosm containing plants from the four corners of the world, like the famous botanical garden of Padua, which Tycho must have visited during his Italian tour in 1575. Tycho divided his orchards and gardens into four parts, and Sophie Brahe's garden at Eriksholm may have reflected this line of thought as well. Finally, the late-Renaissance garden could be envisioned as an icon of chemical transformations, describing a path to wisdom that moved from life to death and on to rebirth. We know that Sophie's chemical laboratory or "distilling house" was in the garden at Eriksholm, which indicates that her garden had chemical overtones.

Because much more evidence survives regarding Tycho's garden than

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assistants, recorded meteorological conditions daily and also took note of visitors and other events. Sophie Brahe arrived on 27 March and departed on 31 March 1591. Her servant arrived on 31 March and left on 2 April.

[17] CHRISTIANSON 2000, 261.

[18] DREYER & NYSTRØM 1913-29, 9: 100: "Primi propagines in hortis inseruntur."

[19] See Tycho's birdseye view in CHRISTIANSON 2000, 154. Looking down upon herbal and flower beds in the shape of stars would bring to mind the maxim from the Hermetic Emerald Table that "the uppermost is like the nethermost, the nethermost like the uppermost ..."

[20] ALLAN GUNNARSSON, "Något om fruktträden i Renässansens trädgårdar och särskilt i Uraniborg," in *Lundquist* 1993, 41-63; and Kjell LUNDQUIST, *Växtsamlinger, växtförteckningar och botaniske verk från Renässansens Europe*, in Lundquist 1993, 65-116. See also CHRISTIANSON 1998, 471-72.

[21] Sophie's familiarity with the Hermetic and Paracelsian traditions is indicated by a manuscript in the Landsarkiv in Odense, Denmark, "Uraniæ epistel til Dianam om lapide philosophorum" (Karen Brahe's Library D III 15), which was probably written by her around 1590. It is in the Danish language, deals with the philosopher's stone, describes chemical processes, and quotes Paracelsus, Arnold of Villanova, and the Emerald Table of Hermes Trismegistos.

Sophie's, it is difficult to determine the direction that the influences ran. The chronology suggests that Tycho laid out his original garden first, in the years after 1580, and that Sophie designed her towards the end of that decade in a new style that excited the admiration, and possibly the emulation, of Tycho. In any case, we know that he redesigned his gardens extensively in the early 1590's. Both gardens expressed sophisticated cultural concepts of the Renaissance, and both were intended as pleasure gardens, emblems of prestige and wealth, microcosms of the universe, and sources of medicinal substances to be prepared by distillation and other laboratory processes. The general impression is that Tycho was a highly sophisticated garden planner, and that Sophie was even more so. He probably had learned a thing or two from her.

On the other hand, we have Tycho's own testimony that he instructed Sophie in chemistry. They both rejected the alchemy or goldmaking that obsessed Sophie's second husband, Erik Lange. Instead, they practiced a form of chemistry inspired by Paracelsus and called the ars pyronomica or ars spagyrica, which aimed at healing by spiritual means and by medicines (*medicamenta Paracelsica*) produced in the laboratory. As Tycho explicitly pointed out, Sophie "took on chemistry with the aim of preparing certain spagyric medicaments."[22] She was not the only woman to do so. A number of Danish noblewomen of her day established chemical laboratories to produce medicaments, and also to make perfumes, cordial liquors, and "hermetically" sealed preserves from domestic and exotic fruits.[23] In the area of chemistry, Sophie learned from Tycho, but she probably also cultivated these specifically female traditions in her laboratory.

Both Tycho and Sophie practiced astrology as well, though he tried to discourage her from doing so. Since ancient times, astronomy and astrology had been closely linked. Tycho Brahe linked them in his early work, though in time he grew increasingly skeptical of traditional astrology. The problem as he saw it was that astrology was frequently applied wrongly and based on inadequate astronomical data. As a result, astrologers made fools of themselves, as Tycho himself had done in his university days. He had learned his lesson. He knew that predicting celestial events was hard enough, in and of itself, without also trying to predict the influences that they would have on human affairs.

No wonder he grew leery when his sister, Sophie, whom he had himself

[22]Sophie was strongly attracted to Paracelsus. Years later, when she planned to visit a spa for her health, she wanted to go to Pfefferbad near Basel because Paracelsus had recommended it, even though her beloved brother, Tycho, was in Bohemia and offered to meet her in Karlovy Vary (Carlsbad).

[23]Andersen 1971, 88.

taught to observe the stars when she was young, moved on to astrology and "began with great zeal to pursue astrological predictions on the basis of horoscopes of nativities." He wondered why she set off on such a difficult path. Was it simply because she was so brilliant, inspired perhaps by some muse or genie, or was it because women were more superstitious and eager to know the future? Clearly, Tycho believed that the former and not the latter applied to his sister, but still, he tried to dissuade her, and when he could not, he advised her to use moderation. Sophie Brahe may or may not have taken his advice. She learned astrology on her own and remained an avid caster of nativities for years to come.

Finally, we need to consider history and genealogy, where Tycho and Sophie also shared interests, together with others in their inner circle. Two of Tycho's best friends and one of his former assistants became Royal Historiographers of Denmark.[24] Another of his former assistants was one of the first to arrange historical information in chronological tables.[25] Tycho was especially interested in data-based aspects of history like chronology and chorography, but he also had a strong sense of his family heritage. Sophie Brahe's interests moved in the direction of aristocratic genealogy, which she learned from older women in her family circle. Her research drew upon many sources, including heraldic paintings, funeral monuments, inscriptions, public and family records, chronicles, and histories, all of which she subjected to methodical critical analysis. When Tycho commissioned a portrait of himself around 1586, surrounded by the coats-of-arms of his sixteen great-great-grandparents, he got one of them wrong. Somebody corrected his ancestral heraldry, and he was obliged to commission a corrected portrait. That somebody must have been his sister, Sophie, who was already becoming the acknowledged authority on the family's genealogy.[26]

[24] Tycho's close friends, Anders Sørensen Vedel and Niels Krag, and his former assistant, Johannes Isaksen Pontanus, all served as Royal Historiographer of Denmark, see CHRISTIANSON 2000, 99, 199-200, 338.

[25] Cort Aslakssøn, inspired by astronomical tables, see OSKAR GARSTEIN, *Cort Aslakssøn* (Oslo: Lutherstiftelsens Forlag, 1953), 318-22.

[26] CHRISTIANSON 2000, 117-18. J. C. BILLE BRAHE, *Gravmindernes vidnesbyrd*, Heraldiske studier 2 (Copenhagen: Societas Heraldica Scandinavica, 1985), 14-33. In the position of his maternal grandmother's maternal grandmother, Tycho's first portrait showed the arms of Inger Torbernsdatter Galen/Bielke instead of Birgitta Vasa, although Inger should have been one generation further back on the family tree. Their descent from Birgitta Vasa (died after 1471) connected the Brahes to the Swedish and Polish royal house of Vasa in Tycho's day. Besides Sophie Brahe, another authority on Tycho's ancestral genealogy was Claus Lyschander (1558-1624), who later composed a rhymed genealogy of the maternal ancestors of Tycho and Sophie Brahe, but Lyschander was studying abroad at the time that Tycho's error was discovered, so he could not have been the one who found it, see HOLGER FR. RØRDAM, *Klavs Christoffersen Lyskan-*

In family history as in gardening, Sophie's learning exceeded that of her brother, Tycho.

In short, in the late sixteenth century, there were plenty of opportunities for members of the Danish high aristocracy like Sophie and Tycho Brahe to pursue learned interests in natural science, mathematics, historical research, and other fields. Although learning was not universally cultivated among the élite, neither was it universally scorned, and the normal patterns of élite education provided opportunities for highly motivated individuals to move deeper into learned studies than the majority of their social class. The springboard was there, though it still took some courage to jump, because if aristocrats became too seriously involved in learned matters, they might be tempted to wander from the paths that their positions in life laid out for them, and that would put them at odds with their social milieu and its expectations of them.

The role of learning in the context of their class was to enhance the aristocratic culture of rich and sophisticated men and women. Sophie's magical garden; her laboratory with its wealth of spagyric medicines, herbal liquors, and hermetically preserved fruits; her genealogies and nativities of numerous prominent individuals charmed visitors to Eriksholm, won the admiration of her peers, and reinforced her social status as a learned noblewoman. Such learning could be compared to that of queens and electresses, who also cultivated interests in gardening, chemistry, astrology, and genealogy. Her learning advanced her status in society. The same was true of Tycho Brahe's Uraniborg. Visitors flocked to the island of Hven to behold its marvels. The king and queen of Denmark, the king of Scotland, the dukes of Mecklenburg and Braunschweig, ambassadors of many lands, noblemen and students from half of Europe were among the marveling visitors. In this sense, the aristocratic social context of Sophie's and Tycho's learning was essentially the same: in both cases, their learned marvels advanced their status in society.[27]

But Tycho's learning did much more than that: It made him famous throughout Europe as the foremost natural philosopher of his generation. When he built his "philosophical house" of Uraniborg on the island of Hven, Tycho Brahe found innovative ways to integrate into an aristocratic lifestyle his far-ranging interests in astronomy, astrology, meteorology, mathematics, cosmology, cartography, chemistry, medicine, and a host of other fields

ders Levned (Copenhagen: Samfundet til den danske Litteraturs Fremme, 1868), 19-20, and VELLO HELK, *Dansk-norske studierejser fra reformationen til evevælden 1536-1660* (Odense: Universitetsforlag, 1987), 305-06.

[27]See JOY KINSETH, *The Age of the Marvelous* (Hanover NH: Hood Museum of Art, Dartmouth College, 1991).

including architecture, poetry, music, history, theology, and philosophy. At the same time, Tycho pursued his interests as a professional scientist and scholar, cultivated close personal ties to the University of Copenhagen to establish a virtual affiliation with that institution, kept in contact with learned men throughout the continent by means of extensive correspondence, related his work to the most difficult problems facing scientists in his day, and published his results. He had no precedent for this, but he managed to invent his own ways to do it. Other aristocratic and courtly centers of scientific activity in his day, such as the courts of Hesse-Kassel and Prague, were not concerned about contributing to academic learning, but Tycho was. He had attended five universities, spent many years in university studies, and knew how the academic mind worked. He continued to think like an academic, even while living like a nobleman, and he was able to invent a new lifestyle that combined the life of a great aristocrat with that of a scholar and scientist. In fact, he used the wealth, leadership ability, and social panache of a nobleman to solve classic problems in unprecedented ways, organizing whole teams of scholars and technicians to take on problems that no one individual could ever solve alone. Tycho Brahe was one of the great innovators of human history. He even intended to promote his sister's research in academic circles by publishing her letter.

Sophie Brahe never had a chance to do things like that. She was intelligent enough to teach her big brother a thing or two, and he was the first to admit it, but she never had the chance to be a professional researcher and scientist like he was. In the first place, although she started to study Latin when she was young, she had not been allowed to continue, and the language of instruction in sixteenth-century universities was Latin.[28] Tycho compared her to the famous Italian scholar, Olympia Fulvia Morata (1526-55), who had lectured at the University of Heidelberg. Olympia mastered Latin, Greek, and the classics in her native Ferrara, wrote both Greek and Latin, became a Protestant, and fled from the Inquisition to Germany. Her collected orations, dialogues, letters, and poems were published in several posthumous editions, beginning in 1558.[29] Tycho Brahe claimed that his sister Sophie's erudition matched and even surpassed that of Olympia Fulvia Morata, "because she has taught herself sciences that are too deep and abstruse to be comprehended within the eloquence that Fulvia cultivated, be it ever so Ciceronian ... As far as I know, no one has ever before heard of a woman who really understands astrology and practices it on a scientific

[28] ZEEBERG 1994, 176-77.

[29] VAL WEBB, "An Introduction to Olympia Morata, a Forgotten, Feminist Voice from Sixteenth Century Italy," http://www.wsrt.com.au/seachanges/volume1/webb.html (6 June 2001).

basis, for even among men who want to be considered learned, only a few possess a deep understanding of it. If my sister had not lacked knowledge of the Latin language, I have no doubt that she would have equaled this Olympia Fulvia Morata, or anybody else, in several of the fields that are handled mainly in that language."[30] Tycho added that he did not mean to denigrate the achievements of Olympia Fulvia Morata, who deserved even more recognition than she had received, but that he simply wanted to prove it was not impossible for a woman to write a letter like his sister's.

Tycho thought that his sister deserved more from her science and scholarship than a reputation as a gracious hostess. He described Sophie's letter in his introduction: "first and foremost, she gives an elegant survey of her progress in astrology and, on the basis of her chemical studies, attempts to show that she can also achieve insight into that science. I had warned her earlier that chemistry involved a long series of difficulties, but she had overcome them, and she had achieved good results in the production of these preparations, which she also discusses in detail. On the basis of this, she argues that astrology will not present such great hindrances that she cannot also overcome them and gain insight into the secrets of this science. She declares that she feels no shame over such knowledge, industry, and work, but rather, that she is seized with every passing day by a greater desire for it, and she begs with great devotion that I will help her further along the way she has chosen to follow, so that her knowledge can be greater and deeper. Finally, she presents three astrological problems – neither insignificant nor irrelevant problems – which she asks me to solve."[31]

Tycho said that he chose to include his sister's letter (along with his own reply) in the second volume of his astronomical correspondence "because it contains a great deal that can contribute to an understanding of the science of astrology, including more learned matters than one would have expected from a woman".[32] He added, "Some may doubt that this was really written by a Danish noblewoman, but I can affirm that it was written by my sister in her own hand and sent over to me from her house in Skåne, moreover and more importantly, that she possesses both great theoretical and practical knowledge of everything that the letter discusses, and much more, and that with every passing day she acquires deeper insight through continuing and tireless studies, to the extent that other responsibilities and domestic occupations allow."[33]

Sophie's letter never appeared in print because Tycho died before the

[30] Zeeberg 1994, 174-77, translated by J. R. Christianson.
[31] Zeeberg 1994, 172-73, translated by J. R. Christianson.
[32] Zeeberg 1994, 172-73, translated by J. R. Christianson.
[33] Zeeberg 1994, 174-75, translated by J. R. Christianson.

volume was completed. For her part, Sophie Brahe did not publish her correspondence, her numerous nativities, her medicinal recipes, her garden plans, the catalog of her library, or her huge genealogical tomes. All of this female learning served as an adornment to the nobility, and that alone was its justification. She and other learned noblewomen of her circle passed on their manuscripts and libraries from generation to generation of noblewomen, who continued to cultivate similar pursuits of learning as part of a refined aristocratic lifestyle. These learned noblewomen had only tangential contact with the professors of schools and universities, as when they occasionally engaged one of them, or the local Lutheran pastor, to translate a text from Latin into Danish. Aristocratic women's learning did not concern the academy, as Tycho's did. Its seat was in the castles and manors like Eriksholm that were the residences of the most cultivated and privileged families in the realm.

There it remained until the wealth and status of those families was jeopardized by changing times. Then, at last, it became necessary to give institutional structure to aristocratic women's culture. The form it took did not become part of a university, because those were still exclusively male institutions. What it produced was an institution called the noble Lutheran convent.

In the year 1716, Karen Brahe of Østrupgaard (1657-1736), an unmarried great-great-granddaughter of Tycho Brahe's brother, donated the medieval bishop's palace in the town of Odense to establish an institution that she gave the name of Odense Noble Maidens Convent. It was to be a private, non-profit corporation, loosely affiliated with the Lutheran state church. From her inherited wealth, Karen Brahe established an endowment, so that the convent could furnish a pious and respectable living for unmarried daughters of the Danish nobility.[34] Moreover, she donated to the convent her collection of books, manuscripts, and family portraits, the heritage of seven generations of cultivated aristocratic life among the women of the Brahe family and their relations.

Two hundred and fifty-five years later, in 1971, my wife and I visited Odense Noble Maidens Convent, which was finally nearing the end of its days. We saw Karen Brahe's collection of Brahe, Bille, and Gøye portraits, including a splendid portrait of Tycho Brahe.[35] We were taken into the library, where Karen Brahe's chair still stood by the table. The books and manuscripts had been moved to the security of the local state archive, but the furnishings of the library were as they always had been.

[34] H. D. Schepelern, *Portrætsamlingen i Odense adelige Jomfrukloster* (Frederiksborg: Det nationalhistoriske Museum, 1959), 13-15.

[35] Schepelern 1959, 56-59.

Karen Brahe's library is Denmark's largest surviving private collection of early modern books and manuscripts. It holds around 370 manuscripts and some 3,400 volumes of printed books, many containing more than one work. Among the books are incunabula, paleotypes, and unica, mostly in the Danish language, with some in German and a scattering in Latin, Dutch, French, English, and Swedish. Books by and about Tycho Brahe are found here. So are published books and manuscripts by Mette Gøye (1599-1664), a renowned gardener and genealogist, and her sister-in-law, Birgitte Thott (1610-62), who knew seven languages and translated Seneca into Danish.[36] Letters, translations, and manuscripts by twenty-three members of the Brahe family are in the collection. These include Sophie Brahe's arcane "Epistle of Urania to Diana on the Philosopher's Stone" and a number of Tycho Brahe's letters, poems, genealogies, and documents, including some that are preserved only in this collection.[37] The list goes on and on. Kings, queens, diplomats, bishops, clergymen, and nearly 200 Danish noblewomen and noblemen are included among the manuscripts in Karen Brahe's library, all of them going back to the period before her death in 1736.[38] Some went back further, but most had been collected over the course of four generations, beginning with Karen Brahe's great-grandmother, Birgitte Axelsdatter Brahe (1576-1619), a niece of Sophie and Tycho Brahe.[39] Birgitte Brahe left her collections to her daughter, Anne Gøye (1609-81), who augmented them tremendously with rare books and manuscripts, leaving the whole collection to her own grand-niece, Karen Brahe, whose name the collection bears today.[40]

The history of this collection is the story of what happened to the cultural tradition of women from Eriksholm and other family seats of the late sixteenth century, as it was nurtured by generations of noblewomen

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[36] "Mette Gjøe," *Dansk biografisk leksikon* (Copenhagen: J. H. Schultz, 1933-44), 8: 140, and "Birgitte Thott," *ibid.* 24: 38-39. Gøye is also spelled Gjøe or Giøe. Mette Gøye was a granddaughter of Tycho's brother, Axel Brahe. Her manuscripts are listed in Anne Riising, *Katalog over Karen Brahes bibliothek i Landsarkivet for Fyn: Håndskriftsamlingen* (Copenhagen: Ejnar Munksgaard, 1956), 50-51, 106, and Birgitte Thott's in *ibid.*, 21, 42-43.

[37] Riising 1956, 116, 117, 144-45.

[38] Additional letters by Sophie Brahe and other manuscripts from Karen Brahe's collection are at the Bille-Brahe-Selby seat of Rønninge Søgård, including the abridged Danish translation of Pierre Gassendi's Latin biography of Tycho Brahe that Magister Malthe made for her ...

[39] Susanne Lykke Vølzgen Nielsen, *Hiellp gudt: Birgitte Brahe (1576-1619) – en biografisk skitse og en bogreol*, Personalhistorisk tidsskrift 1996/2: 95-155.

[40] Lauritz Nielsen, *Anne Gjøes og Karen Brahes bibliotek*, in Danske privatbiblioteker gennem tiderne (Copenhagen: Gyldendal, 1946), 1: 96-123. Anne Gøye and Mette Gøye were sisters.

descended from those houses. From time to time, men have also cultivated this tradition. One was our host in 1971, the late Jørgen Christian Baron Bille Brahe of Risinge, an avid researcher, bibliophile, promoter of scholarship, and author of two books.[41]

Such was the legacy established by learned Danish noblewomen of the late sixteenth century like Sophie Brahe and carried on by successors like Karen Brahe into the eighteenth century and beyond. It was a far different legacy than that of Sophie's brother, Tycho Brahe. These two legacies, one male, the other female, traveled far different paths to the present, despite their common origins some four centuries ago. The one that Sophie Brahe represented was never allowed to break free from its social origins to benefit the world at large. Fortunately, his was.

[41] Bille Brahe 1985. J. C. Bille Brahe, *Kerteminde-Værn: En Egns Land-forsvarsstyrker fra November 1943 til Januar 1976* (Kerteminde: Kerteminde avis forlag, 1985).

Tycho Brahe and Prague: Crossroads of European Science, pp. 46–69, J. R. Christianson et al. (eds.), © *H. Deutsch 2002*

Providence, Power, and Cosmic Causality in Early Modern Astronomy: The Case of Tycho Brahe and Petrus Severinus[1]

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Recent work by Peter Barker and Bernie Goldstein, and William Donahue before them, has identified the important role of cosmological concerns, particularly the structure and substance of the heavens, in Tycho Brahe's astronomy.[2] Indeed, although the Dane is best known in the history of science as an astronomer, specifically for his exacting observational program and data analysis, it is now clear that he was engaged in a broader philosophical investigation of his world, which embraced meteorology, astronomy, medicine, astrology, alchemy, and possibly theology.[3] Therefore,

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[1] I wish to thank WILLIAM NEWMAN and FRANKIE SHACKELFORD for their useful comments on drafts of this paper. However, factual details and speculations herein remain my own responsibility.

[2] WILLIAM H. DONAHUE, "The Solid Planetary Spheres in Post-Copernican Natural Philosophy", *The Copernican Achievement*, ed. ROBERT S. WESTMAN (Berkeley: University of California Press, 1975), pp. 244-275; PETER BARKER, "Stoic Contributions to Early Modern Science", *Atoms, Pneuma, and Tranquility: Epicurean and Stoic Themes in European Thought*, ed. MARGARET J. OSLER (Cambridge: Cambridge University Press, 1991), pp. 135-54; IDEM, "Jean Pena (1528-58) and Stoic Physics in the Sixteenth Century", *Spindel Conference 1984: Recovering the Stoics*, ed. RONALD H. EPP, Supplement to *The Southern Journal of Philosophy* 23 (1985), pp. 93-107; PETER BARKER and BERNARD R. GOLDSTEIN, "Theological Foundations of Kepler's Astronomy", *Osiris*, ser. 2, 16 (2001): 88-113.

[3] On Tycho's broad research program and its implications, see JOHN R. CHRISTIANSON, *On Tycho's Island: Tycho Brahe and His Assistants, 1570-1601* (Cambridge: Cambridge Univ. Press, 2000); VICTOR THOREN, *The Lord of Uraniborg: A Biography of Tycho Brahe* (Cambridge: Cambridge University Press, 1990); and JOLE SHACKELFORD, "Tycho Brahe, Laboratory Design, and the Aim of Science: Reading Plans in Context", *Isis* 84 (1993), pp. 211-230. While these scholars conclude that Tycho was a Philippist Lutheran (a follower of Melanchthon's understanding of Lutheranism) and note the importance of Melanchthon's theology to the work of Tycho and his circle, a reference to Tycho's ownership of a Paracelsian biblical commentary suggests that

any attempt to comprehend Tycho's achievements within their proper historical context necessarily requires that we consider his astronomy as part of a more general natural philosophy, and that we examine his reflections on theories about the operational structure of the cosmos that were current in his intellectual milieu. One contributor to this milieu was Petrus Severinus, the only other sixteenth-century Dane to achieve international fame in scientific subjects. Together, Severinus and Brahe represent the cutting edge of inquiry into nature in Denmark during the last quarter of the century, and their writings offer us an opportunity to examine how such inquiry was embedded in Lutheran doctrinal views, a subject that Sachiko Kusukawa and others have recently brought into focus.[4] To appreciate the importance of both religious and philosophical issues to their scientific endeavors, it will be useful to consider their cosmos as they did – as a theatrical stage on which the processes of nature played out according to God's providential script. This stage or mundane scene, as his friend Severinus called it, was a unified microcosm and macrocosm in which agent-objects acted on patient-objects in a complex fabric of causality.[5] Examination of

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his interests may have extended to more radical Reformation formulations as well. See p. 300, n. 21 of JOLE SHACKELFORD, "Unification and the Chemistry of the Reformation, Infinite Boundaries: Order, Disorder, and Reorder in Early Modern German Culture", ed. MAX REINHART, *Sixteenth Century Essays and Studies* 40 (Kirksville, Missouri: Sixteenth Century Journal Publishers, Inc., 1998), pp. 291-312.

[4] SACHIKO KUSUKAWA, *The Transformation of Natural Philosophy: The Case of Philip Melanchthon* (Cambridge: Cambridge University Press, 1995). Scholars have for some time recognized the importance of Danish Lutheranism, in both strict Lutheran and Philippist interpretations, for shaping the intellectual and political climate of late sixteenth and early seventeenth-century Danish academic discourse. See, for example, SHACKELFORD, "Unification and the Chemistry of the Reformation", and IDEM, "Rosicrucianism, Lutheran Orthodoxy, and the Rejection of Paracelsianism in Early Seventeenth-Century Denmark", *Bulletin of the History of Medicine* 70 (1996), pp. 181-204.

[5] For example, PETRUS SEVERINUS, *Idea medicinæ philosophicæ fundamenta continens totius doctrinæ Paracelsicæ, Hippocraticæ et Galenicæ* (Basel: Henric Petri, 1571), p. 86: "Separatione igitur semina in Matricibus quiete delitescentia, digestis temporibus suscitantur, in mundanam Scenam prodeunt" (Therefore, by separation, *semina* quietly lying hidden in the wombs are aroused at the appointed times and come forth onto the world stage). On the significance of *semina* in Severinus' philosophy, see the discussion below. Severinus also likened nature's processes to a liturgy, suggesting a deeper analogy between the world and the church as a kind of theater or liturgical "stage", on which sacred rituals proceeded according to prescribed forms. Tycho Brahe, for example, refers to the world as the "very large theater of the whole world machine" [*Tychonis Brahe Dani opera omnia*, ed. J. L. E. DREYER. 15 vols. (Copenhagen: Gyldendal, 1913-29), hereafter *TBDOO*, vol. 1, p. 35: amplißimum totius Machinæ mundanæ theatrum]. JOHN CHRISTIANSON, *On Tycho's Island*, emphasizes the importance of the Renaissance concepts of love (*amicitia*) and the personal network binding the extended household (*familia*) in Tycho's social world and also noted that Tycho's scientific research was very

this causal fabric will provide clues to the interrelationship between religion and science in Tycho's world and illuminate his research.

As J. L. E. Dreyer remarked somewhat apologetically over one hundred years ago, one cannot understand Tycho Brahe's scientific effort or the times in which he lived without abandoning modern prejudices against astrology and taking it into consideration as a then-legitimate science.[6] Although the historiography of science has made a great deal of progress in this direction since Dreyer's prescient observation, the claim that astrology, broadly interpreted, was perhaps the unifying factor in Tycho's research program would still meet with a great deal of scepticism among today's historians of science, partly owing to the sheer quantity of painstaking observation, calculation, error analysis, and discussion of instrument design that characterizes much of his surviving work. In short, something about his surviving work *looks* to the modern scientist and historian to be the very model of exact science.[7] However, the centrality of astrology in late-sixteenth-century cosmology is understandable if one views astrology not mainly from the perspective of horoscopes and nativities, but as historians of medicine have come to understand it, namely as an integral part of medical theory and practice.[8]

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much a product of a collective program carried out in this familial context. I suspect that this social structure also reflected (or was reflected in) Tycho's understanding of the organization of the macrocosmic "theater of the world", where the actor-components play out their parts to fulfill the script that was foreordained by the divine playwright, to carry forward the metaphor. Severinus' reference to developmental processes as liturgical functions, or as acting out a comedy on the world stage, reflect a similar conception of the cosmos.

[6] J. L. E. Dreyer, *Tycho Brahe: A Picture of Scientific Life and Work in the Sixteenth Century* (1890; reprint, Gloucester, Mass: Peter Smith, 1977), p. *x*.

[7] However, one must acknowledge that it may have been Tycho's goal to *make* astrology an exact science, but that he failed in the attempt.

[8] Even though Tycho's biographers have come to appreciate his belief in astrology in theory, and to his program for empirically establishing connections between the celestial conditions and terrestrial weather patterns, they are sometimes reluctant to acknowledge Tycho's enduring commitment to astrology as a way of looking at the structure and function of the world around him. For example, Ingemar Nilsson, "At tyda himlens tecken: Tycho Brahe astrologen", *Tycho Brahe Stjärnornas Herre*, ed. Johanna Erlandson (Landskrona: Landskrona kommun, 1996), pp. 79-86, describes Tycho's involvement with various astrological projects, but states "Det gjordes inte alltid en klar åtskillnad mellan astronomi och astrologi, men Tycho var alltid noga att hålla de två isär. Astronomin var för honom en grundvetenskap, medan astrologin i bästa fall kunde ses som en än så länge bristfälligt utvecklad tillämpning." [There was not always a clear distinction between astronomy and astrology, but Tycho was always careful to keep the two separate. Astronomy was for him a fundamental science, while astrology at best could be viewed as a still imperfectly developed application.] (pp. 79-81). Thoren, *Lord of Uraniborg*, more accurately characterizes Tycho's attitude, noting that although

Philippist natural philosophy and ideas about causation in astrology

The importance of astrology to my inquiry is at once apparent when one considers that the causal connections between the stars and planets above and the changes in the "mundane scene" below were central to an astronomer's concern with natural philosophy. Astrology was integral to the medieval university curriculum already by the thirteenth century, when the assimilation of Arabic learning brought astrology into the mainstream of medical theory and practice.[9] By the fifteenth century, no credible practitioner of elite medicine could afford to be wholly ignorant of astrology, even if he were merely to reject its place in his own practice.[10] What concerns us here, however, is astrology specifically in Reformation Germany and the North, which forms the intellectual backdrop for the early education of Tycho Brahe, Petrus Severinus, and most all Danish students of their generation.

Martin Luther's hostility to astrology and his consequent condemning of "mathematics" is well known, as is his general subordination of reason to faith.[11] However, Philipp Melanchthon, who was anxious to create a Lutheran curriculum and was more receptive to rational study of nature

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Tycho's enthusiasm for casting horoscopes diminished over time, he remained committed to astrology in principle, but realized that it must be based on a reformed astronomy (pp. 84, 217-18).

[9] On medieval astrology in the academic curriculum, see ROGER FRENCH, "Astrology in Medical Practice", pp. 30-59 in *Practical Medicine from Salerno to the Black Death*, ed. LUIS GARCIA-BALLESTER, et al. (Cambridge: Cambridge University Press, 1994); RICHARD LEMAY, "The Teaching of Astronomy in Medieval Universities, Principally at Paris in the Fourteenth Century" *Manuscripta* 20 (1976): 197-217; and NANCY SIRAISI, *Medieval and Early Renaissance Medicine* (Chicago: University of Chicago Press, 1990), pp. 128-29, 134-36, *et passim.*

[10] DANIELLE JACQUART, "Theory, Everyday Practice, and Three Fifteenth-Century Physicians", *Osiris*, ser. 2, 6 (1990): 140-160, shows that even if a physician rejected the medical utility of astrology, he might choose to employ it for the sake of satisfying the patient's demands for it (see esp. p. 149); BRIAN COPENHAVER, "Astrology and Magic", pp. 264-300 in *Cambridge History of Renaissance Philosophy*, ed. CHARLES B. SCHMITT (Cambridge: Cambridge University Press, 1988), p. 271: "By the early fifteenth century, a tradition of secular Aristotelianism stimulated more by medicine than theology had established in these universities [viz. N. Italian, esp. Padua] a pattern of education in which astrology was a prominent ingredient in an arts curriculum strongly inclined towards natural philosophy. Graduates of these schools looked to the stars and planets as indices of regularity in physical causation." Furthermore, as German medical students brought these ideas home in the sixteenth century, a tension arose with Protestant theology, which Melanchthon's educational curriculum attempted to resolve (*Ibid.*, pp. 621-23).

[11] LEMAY, "The Teaching of Astronomy", p. 211.

and to scholastic Aristotelianism in particular, gave astrology a place in the curriculum of the University of Wittenberg, which served as a model for Lutheran schools elsewhere.[12]

As Richard LeMay has pointed out, medieval scholars provided astrology with an Aristotelian physical and metaphysical underpinning. This is particularly evident in medicine, where the action of celestial bodies on the parts of human bodies was interpreted and codified in terms of Galenic doctrine, as is clear from surviving diagnostic literature and bloodletting diagrams.[13] The causal significance of the heavens for an individual's health was taken for granted. Also, catastrophic diseases that affected large populations were often attributed, at least in part, to celestial aspects and to comets, as is manifest in pronouncements on the causes of epidemic plague and syphilis.[14] Such causation was presumed to be mediated by the air, bringing meteorology into consideration. Therefore, it is not especially surprising that an astronomer of Tycho Brahe's mettle would be interested in meteorology, medicine, and astrology as parts of his investigation of astronomy. And considering Tycho's early exposure to Paracelsian medical ideas, which suppose that changes in the body – just like changes in the macrocosm – are at root chemical, it is clear why he would embrace chemistry, too. Thus, concern for astrological causality might help explain the broad scope of Tycho's research program. Moreover, his approach can be interpreted as a product of Melanchthon's Lutheran science.

Philippism and Providence

Sachiko Kusukawa has argued that Philipp Melanchthon's interest in astrology was specifically grounded in his view that the Christian student's goal was to understand God's providential governance of creation; that Melanchthon gave mathematics a place in the Lutheran curriculum in order to prepare students for study of astronomy and astrology.[15] Melanchthon himself taught the *Tetrabiblos* and the *Almagest* from 1535 to 1545, which

[12] Kusukawa, *The Transformation of Natural Philosophy*, p. 26 *et passim*. In particular, Wittenberg, along with Rostock, was largely responsible for training Denmark's theology students in Tycho Brahe's generation.

[13] The use and mechanics of medieval medical astrology are explained in French, "Astrology in Medical Practice".

[14] Claude Quétel, *History of Syphilis*, trans. Judith Braddock and Brian Pike (Baltimore: Johns Hopkins Press, 1990), pp. 33-34. For astrological explanations in various fourteenth-century reports on the causes of plague, in English translation, see Rosemary Horrox (ed. and trans.), *The Black Death* (Manchester: Manchester University Press, 1994), pp. 158-93.

[15] Kusukawa, *The Transformation of Natural Philosophy*, pp. 134, 139, 144.

underscores the importance he assigned to study of the heavens.

Inasmuch as astronomy and astrology aimed mainly to reveal Providence in nature, they were fundamental to Melanchthon's idea of nature and natural philosophy. He praised Aristotle for subordinating natural philosophy to astrology on account of the natural subordination of the inferior realm to the superior realm, a sentiment that, incidentally, is coherent with the Hermetic view that the macrocosm is harmonically linked with the microcosm. But where the terse statements of the Hermetic writings stop short of a research agenda, Melanchthon's Aristotelian program aims to fathom these cosmic links as causal connections. This is suggested by his emphasis on causal investigation and his scholastic definition of such causes as acting remotely (remote causes) and locally (proximate causes). Study of remote causes is a subject of mathematical astronomy and formal astrology, while proximate causes fall under *physics*, which includes study of generation and corruption.[16] Medicine was interested in both.

The correlation of remote causes and proximate causes was an important topic for Tycho's friend Severinus, who elaborated a biological metaphysics that explained change as the growth and decay of substantial entities under providential guidance. Severinus drew mainly on Paracelsian ideas in creating his organic philosophy, but clearly he also incorporated Aristotelian, Galenic, and Neoplatonic concepts, and perhaps Stoic ones, too.[17] This philosophy took shape in his mind during the late 1560s and found expression in his influential *Idea medicinæ philosophicæ*, which was completed in 1570 and published at Basel in 1571.[18] In that same year, Severinus was appointed Royal physician to King Frederik II, Tycho's great patron.

Tycho and Severinus knew each other, and Tycho relied on the physi-

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[16] *Ibid.*, pp. 145-46. Although medical authors often interpret the microcosm as the human body and Paracelsus seems to have treated it this way – it is clear from the *Emerald Table* of Hermes that microcosm also referred more generally to the sublunary, elemental world.

[17] I have explored Severinus' physics and metaphysics, specifically the *semina* doctrine on which it is based, in JOLE SHACKELFORD, "Paracelsianism in Denmark and Norway in the 16th and 17th Centuries", (Ph.D. Dissertation, University of Wisconsin, 1989), parts of which are included in my book *A Philosophical Path for Paracelsian Medicine: The Ideas, Intellectual Context, and Influence of Petrus Severinus (1540/2-1602)*, Acta historica scientiarum naturalium et medicinalium 45 (Copenhagen: The Danish National Library of Science and Medicine, forthcoming), which examines Severinus' ideas and their influence on European thought in greater depth. In these works I have noted especially Severinus' use of Paracelsian and Hippocratic sources. The possibility that his ideas are partly compatible with Stoic ideas only recently occurred to me, after reading Peter Barker's studies of Stoicism's influence on Rothmann, Pena, and Tycho Brahe. I am grateful to Peter for sending me pre-publication drafts of several of these.

[18] See note 5 above.

cian's proximity to the king to facilitate his own communication with the court. Details of their friendship remain obscure, but it seems very likely that they shared an intellectual fellowship with Severinus' long-time friend and traveling companion, Johannes Pratensis. Tycho's closeness to Pratensis is documented, and that Severinus and Pratensis were both champions of Paracelsian theory is well established. Whatever differences may have come to alienate Severinus and Brahe during the 1590s probably arose well after Tycho's philosophical views were developed in the 1570s and 80s, and I conclude that it is plausible that those elements of Paracelsian and Neoplatonic philosophy that are evident in Tycho's writings owe something to common discussions among the three men.[19]

Tycho's notion of causality

Tycho did not systematically treat natural philosophy in his surviving treatises, and one must tease out his ideas on causation from various statements that he made in his publications on astronomy and astrology, in his correspondence, in his introductory oration to a course he offered at the University of Copenhagen, and finally in the works of his students, which may reflect his teachings. That Tycho in fact concerned himself with general physical and metaphysical principles, such as the material construction of the cosmos, its movements, and the causal system that accounted for changes, is a logical consequence of the chief contributions to a revolution in cosmology with which he is credited. These were 1) the determination that the *nova* of 1572 and the comet of 1577 – and by extension all comets – were in the celestial realm, and therefore necessitated abandonment of at least part of Aristotle's physics; and 2) the claim that the orbs that move the planets cannot be materially solid or impenetrable, an idea that he drew from Christopher Rothmann and which ultimately led to the abandonment of orbs altogether, in favor of unsubstantial, orbital paths.[20]

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[19] Tycho encountered Paracelsian ideas while a student at Rostock, if not before, so it is not possible to rule out the possibility that his interest in Paracelsian ideas predates his contact with Severinus and Pratensis. When the three became intellectual fellows is unclear, but probably this happened after 1571, when Severinus and Pratensis returned to Denmark, and by at latest 1574, when Tycho became involved in lecturing at the University or Copenhagen. There is no evidence that Severinus ever visited Hven, but then his job was at court and with the king, and Frederik II did not travel there, either. Most likely the three got together on Tycho's visits to Copenhagen or the royal castle at Kronborg. Tycho's very public remorse after the death of his friend Pratensis in 1576 is evidence of the love and esteem he bore toward the Paracelsian physician.

[20] Bernard R. Goldstein and Peter Barker, "The Role of Rothmann in the Dissolution of the Celestial Spheres", *British Journal for the History of Science* 28 (1995):

Thus, in the canonical version of the Scientific Revolution, Tycho's place is precisely that of the one who rendered the Aristotelian cosmos untenable on the grounds of careful astronomical observation and mathematical calculation. But how did Tycho himself see his achievements? How did he frame his ideas on causation in nature?

At the beginning of his German treatise on the comet of 1577, which he composed the following year, Tycho announced a familiar, if concise, story of creation: God created the heavens and populated them with the sun, moon, stars, and planets in various sizes and with diverse and distinct motions. He arranged the terrestrial world with four elements fire, air, water, and earth – beginning with the sphere of the moon and working inward.[21] With the exception of a statement about fire resulting from the ignition of the upper reaches of the air, owing to the rapid motions of the celestial spheres, Tycho described a fairly straightforward Aristotelian cosmology, familiar to any medieval student of natural philosophy, and then he went on to repeat Aristotle's claim that the upper world is unchanging and that therefore comets must be meteorological phenomena, generated in the zones of air or fire – definitely sublunary objects.[22] However, soon he introduced his claim that the new star that he had seen in Cassiopeia in 1572 was beyond the sphere of the moon, as shown by his observations and calculation of parallax, concluding that "this miracle has made it necessary for us to abandon the opinion of Aristotle and take up another: that something new can also be born in the heaven".[23] And so he did. But what theory replaces the Peripatetic? Given that he next entertained the possibility that the heavens are composed of fire and therefore can support generation and corruption, an idea he regarded as Paracelsian, one might suppose that he endorsed a Paracelsian cosmology.[24]

385-403. See also EDWARD ROSEN, "The Dissolution of the Solid Celestial Spheres", *Journal of the History of Ideas* 46 (1985): 13-31; and WILLIAM DONAHUE, "The Solid Planetary Spheres".

[21] Unless otherwise noted, I rely here on John Christianson's translation of Tycho's "Vonn der Cometten Uhrsprung was die alten vnnd neuen Philosophi inn denselben veramaint vnnd dauon zuhalten sei", *TBDOO*, vol. 4, pp. 381-396, in JOHN CHRISTIANSON, "Tycho Brahe's German Treatise on the Comet of 1577: A Study in Science and Politics", *Isis* 70 (1979): 110-140.

[22] *Ibid.*, pp. 132-33.

[23] *Ibid.*, p. 133.

[24] *Ibid.*: "The Paracelsians hold and recognize the heavens to be the fourth element of fire, in which generation and corruption may also occur, and thus it is not impossible, according to their philosophy, for comets to be born in the heavens, just as occasional fabulous excrescences are sometimes found in the earth and in metals, and monsters among animals." Despite Tycho's comments, this idea is not unambiguously grounded in Paracelsus' own writings, as is discussed in note 31, below.

While there are good reasons for supposing that Tycho was familiar with Paracelsian theory, it is interesting to note that he did not unambiguously support a Paracelsian causal theory for either the *nova* of 1572 or comets, both which he held to be special, "new and supernatural" creations of God.[25] In this same treatise, he also asserted that comets are made of "celestial matter", in the context of denying Aristotle's opinion that they are composed of terrestrial fire.[26] Barker points out that Tycho at one point in correspondence with Rothmann referred to the heavens as composed of something more like air, suggesting that he was leaning toward a Stoic cosmology rather than a Paracelsian one, but yet he sought to distance himself from the Stoicism of Pena that Rothmann propounded, again invoking the authority of Paracelsus and Plato.[27] Later, Tycho described the heavens as pure and liquid, something like elemental fire, but not the same thing.[28] The Paracelsian notion that the objects of the firmament are composed of a fiery substance, which is not the terrestrial (Aristotelian) elemental fire, but which nevertheless is found within terrestrial creatures as an astral presence, better agrees with Tycho's claim that this stuff is like fire but not fire. Indeed, Tycho may well have gotten his ideas about the composition of the celestial realm from an idiosyncratic reading of Paracelsus rather than from Pena or his classical, humanist sources. The attribution of fire to the heavens more generally, and not just to the firmament, seems to have been interpreted as a Paracelsian idea by Tycho and Severinus, and Tycho's student Christian S. Longomontanus apparently thought that Paracelsus followed the Stoics in regarding the heavens as composed of fire.[29] However, Paracelsus, in *Philosophia de generationibus et fructibus quatuor elementorum*, described the heavens as composed of air, with the

[25] *Ibid.*, p. 137: "They [comets] are rather a new and supernatural creation of God the Almighty." [*TBDOO*, vol. 4, p. 390: "Cometten ... sein ein neues vnnd ubernattürlichs geschepff von gott dem Allmechtigen zu seiner zeit an den himel gestelt."] In *De nova stella*, Tycho described the nova as God's portent, beyond the order of nature (Ostentum, præter omnem naturæ ordinem). See note 32 below.

[26] CHRISTIANSON, "Tycho Brahe's German Treatise", p. 135: "... celestial matter of which the head [of the comet] is fabricated ... Aristotle and all those who follow him cannot maintain their opinion, namely that the tail of a comet is a flame of rare fattiness which is burning above the air ..."

[27] BARKER, "Stoic Contributions", p. 145.

[28] *Ibid.*, p. 146.

[29] See KRISTIAN P. MOESGAARD, "Cosmology in the Wake of Tycho Brahe's Astronomy", *Cosmology, History, and Theology*, ed. WOLFGANG YOURGRAU and ALLEN D. BRECK (New York: Plenum Press, 1977), pp. 293-305, p. 296. Tycho's consideration of the celestial realm as composed of fire did not preclude him from considering air as part of the causal mechanism of astrology, as in his 1591 meteorological treatise (see BARKER, "Stoic Contributions", p. 146), because the idea that air as an elemental region mediated the effects of the celestial on the terrestrial was commonplace.

stars suspended in it, as seeds are suspended in a cucumber, etc., and moving about like birds flying through the air.[30] So, on this point Paracelsus and the Stoics agreed.[31]

In introducing the *nova* of 1572, Tycho noted that it was a "new" creation in the celestial realm, which had been presumed by Aristotle to be immutable. He briefly entertained the Paracelsian idea that the star may have preexisted in a potential state, in the primaeval state of matter that Paracelsus called "Iliadus", but then he dismissed philosophical speculation, claiming that it was enough to see the star as God's special creature, created in the beginning and revealed in due time.[32] This shows that he was fully aware of the Paracelsian basis of his friend Petrus Severinus' theory that all creations were original, but that their realizations might be delayed until predestined times, lying dormant in *Iliadic* matter as seed-like potencies called *semina*. It is possible that Tycho was alluding to such a latent cause for comets when he wrote that they "are a special creation that comes from nature's hidden causes, and it is unknown to us how [this creature] is born".[33] Tycho's wording implies that God created comets

[30] *Theophrast von Hohenheim gen. Paracelsus Sämtliche Werke*, Abt. I, vol. 13, ed. Karl Sudhoff (Munich and Berlin: Oldenbourg, 1931), pp. 16-17.

[31] Paracelsus described air and fire as being created in the initial creation (separation), and that heaven was made of air and firmament of fire (*Ibid.*, p. 20). The firmament is nothing other than stars (and presumably planets), and these give birth to snow, wind, hail, and other phenomena on the earth, which come out of the element fire, as a child comes from its mother. This element fire is located in the element air (*Ibid.*, p. 22: "dises element feur ist gesezt in das element luft"). Moreover, just as birds fly through the air, the sun moves in the heaven, that is, in the air (*Ibid.*: "Sonder gleich wie die vogel fliegen im luft, also ist der sonnen gang im himmel, das ist im luft"). These utterances sound Stoic in their basic conceptualization, and it may be that distinctions that scholars have drawn between Paracelsian and Stoic cosmology are not always supportable by the texts.

[32] *TBDOO*, vol. 1, pp. 18-19: "Scio tamen aliquos ex occultiori quadam, & nostro sæculo primum in lucem producta Philosophia aßerturos, poßibile eße hanc stellam in veteri Iliado (libet enim eorum vocabulis vti) hactenus latitaße, & nunc demum maturatione sui absoluta, mortalibus conspiciendam prodijße. ... Taceant igitur omnes Philosophi, seu veteres, seu noui: taceant ipsi quoque Diuinorum Mysteriorum interpretes Theologi", and finally "Sufficit enim demonstraße hanc nouam & inusitatam stellam, quæ nuper apparuit, nullam habere cognationem cum illa, quæ Magis conspiciebatur: nec poße eius generationis modum saluarj, vel a Theologis, vel a Philosophis, nec ab ipsis etiam Mathematicis. Reliquum igitur est, vt statuamus Dei totius Machinæ mundanæ opificis, admirandum hoc eße Ostentum, præter omnem naturæ ordinem, a seipso in initio constitutum: nunc demum aduesperascenti mundo exhibitum."

[33] *TBDOO*, vol. 4, p. 384: "das die Cometten seien ein sonnderlich geschepff gottes, das auß verborgenen vrsacken der nattur kombt, welches vnns vnbekanndt ist, wie es geboren wirt", my translation. C. Doris Hellman, *The Comet of 1577: Its Place in the History of Astronomy* (New York: Columbia University Press, 1944), pp. 124-25 paraphrased this as "that comets are a wonderwork of God, coming from a hidden

specially and that he may have done so by means of secondary, natural (albeit occult) causes, rather than as a direct efficient act, but that we cannot know how this creation (literally, "creature") comes about.[34] Tycho goes on to say that comets, because they are special creations by God, have special significance, beyond the normal astrological significance of the planets and stars. What such creations are predestined for is revealed by God through special means, discernible through astrology.[35] The idea that comets are predestined – that they appear as part of the fulfillment of the divine plan – is an important aspect of Tycho's philosophy, as I will argue below.

Tycho regarded comets, despite their supernatural generation, as autonomous, natural celestial bodies that acted in accordance with natural principles. This is apparent from his observation that comets are not engendered by the motions and influences of the planets and fixed stars, but in fact often act contrary to them, overpowering their influences.[36] It becomes clear from the rest of Tycho's account that he considered comets to have the same kinds of effects on the lower, elemental regions – on the weather and human affairs – that were traditionally elaborated under the Aristotelian theory, and that therefore they must logically act within the natural system.[37] But by placing these phenomena in the celestial region, Tycho required that they work causally on the sublunary world in much the same way as do planets, namely as what medieval astrologers and physicians regarded as remote efficient causes. This is suggested by his comment that the comet of 1577 will have unusually damaging effects, owing to its resemblance to Saturn, its passage near that traditional infortune (which would augment the effects), and other aspects of its astrological

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natural cause". CHRISTIANSON, "Tycho Brahe's German Treatise", p. 133, translates it as "that comets are a special creation of God which come from unknown natural causes, of which we do not know how they are born". Neither rendering seems wholly accurate to me, but the crucial point is whether *verborgen* refers to something being unknown or rather concealed. I suspect that Tycho is using *verborgen vrsachen* here to mean *occultæ causæ*, hidden causes in the medical and philosophical sense of the term, namely causes that are not visible to the senses and therefore can only be known from their effects. This would agree well with Severinus' theory of seminal causes.

[34] The subject of *vnbekanndt ist* and *geboren wirt* is *es*, namely *geschepff* (Geschöpf).

[35] CHRISTIANSON, "Tycho Brahe's German Treatise", p. 137; *TBDOO*, vol. 4, p. 390: "Was aber dasselbig sei, darzu si *predestiniert* vnnd was si auß zu furen haben, ist im rechten grundt keinem menschen eigentlich bewust, es wer im dann von gott dem Allmechtigen durch sonndere mittel geoffenbaret."

[36] CHRISTIANSON, "Tycho Brahe's German Treatise", p. 137.

[37] HELLMAN, *The Comet of 1577*, pp. 131-2, noted that Tycho did not attribute the astrological effects of comets to the planets, but regarded them as autonomous astrological agents.

circumstances.[38] In effect, Tycho, by showing that comets are celestial and not meteorological, was able to apply to them the elaborate theory of astrological causation that was developed by Ptolemy in the *Tetrabiblos* and which, tellingly, had a place in the curriculum of Philipp Melanchthon at Wittenberg.[39]

One of the first to hear Tycho's ideas on the *nova* of 1572 was his friend Johannes Pratensis, who was recently appointed to the second chair of medicine at the University of Copenhagen. It was partly at Pratensis' urging, Tycho claimed, that he published his short tract on the new star. That Tycho was anxious to share his findings and speculations with this Paracelsian physician reveals their personal and intellectual fellowship. Pratensis died in 1576, just prior to the founding of Uraniborg and a year before Tycho's next major breakthrough, the observation and interpretation of the comet of 1577, so we are deprived of what he would have made of this new celestial creation. In fact, Pratensis left little record of his Paracelsianism, which must be estimated from scattered historical tidbits and the assumption that he shared the basic theoretical suppositions and the development of ideas that are presented in the work of his long-time friend, fellow student, and traveling companion, Petrus Severinus. Severinus' Paracelsian medical theory, then, offers us a possible view of the medical philosophy that lay behind whatever discussions that he, Tycho, Pratensis, and others

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[38] CHRISTIANSON, "Tycho Brahe's German Treatise", pp. 137-38: "This comet, no less than former ones, brings and arouses the same evil effects and misfortunes here on earth, so much the more so because this comet has grown so very much greater than others and has a saturnine, evil appearance, which was revealed by its pallid appearance and unclearly shining color like the star Saturn. We thus conclude that this comet is of the nature of Saturn, towards which it also drew near and conjoined bodily in the beginning ... Likewise, on the evening when the comet first appeared after sunset, it was in the 8^{th} house, which astrology ascribes to death." Clearly Tycho has fully astrologized comets here.

[39] Tycho's commitment to a microcosmic-macrocosmic view, in which the celestial and terrestrial regions are linked by astrological causes, is evident both from his 1574 oration at the university of Copenhagen [see DREYER, *Tycho Brahe*, p. 76], the meteorological research program that he pursued at Uraniborg (for which a diary of correlations between planetary positions and aspects and terrestrial events was compiled), and from his correspondence with Rothmann, 17 August 1588 (*TBDOO*, vol. 6, p. 145): "Id esse septem Planetas in Cælo, quod sunt septem Metalla in Terra, quodque in homine ad vtriusque ideam fabricato, qui ob id Microcosmus recte appellatur, septem principalia membra, atque hæc omnia tam pulcra, & concinna similitudine inuicem colligata sunt, vt paria fere videantur habere officia easdemque proprietates & naturas." [There are seven planets in the heaven because there are seven metals in the earth, and because seven principal members are formed according to the idea of each [planet/metal], in man, who for that reason is rightly called *Microcosmus*. And all these are so excellent and mutually connected by a pleasing likeness, that they almost seem to have equal offices and the same natures and properties.]

of Tycho's intellectual community must have taken up on various occasions.

Semina and the operation of Providence in nature

Severinus' book, the *Idea medicinæ philosophicæ*, was one of the first scholarly efforts to accommodate Paracelsian theory to academic philosophy and medicine and as such it exerted a significant influence on late sixteenth and seventeenth-century theory. It aimed to explain normal and pathological biological processes in terms of Paracelsus' chemical philosophy and to make sense of this in the language of Neoplatonist and Aristotelian conceptual formulations.

The core of Severinus' theory is his notion of seminal development, which I call his *semina* doctrine. Severinus regarded all substantial existence and change as emanating from (or returning to) immaterial, dimensionless, causal *loci* that he called *semina*. He drew the idea of *semina* from Augustine's *rationes seminales* and Paracelsian seeds (*semina*) and possibly also from other authors writing in the Augustinian tradition.[40] Severinus applied his doctrine specifically to the transmission and internal development of diseases in the body and to chemical therapy that might be directed to combat them, but he clearly meant his theory to apply more generally. Of particular interest to the present study is his implication of astral agency in seminal development, creating a mechanism to explain the apparent connection between macrocosmic and microcosmic causes and effects. Indeed, Severinus in many places speaks of *semina* and *astra* together as the "stars" within. For example, speaking about the kind of *astra* that distinguishes individual types of animals, vegetables, and minerals, Severinus writes: "These are those bodies, seeds, roots, balsams, vital principles, and prime matters in which, as we have now said often and will say in the future, the universal medicine is situated."[41] This notion integrates Augustine's

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[40] Augustine's *rationes seminales* exerted a profound influence on medieval causal theory, as is readily evident in Henry of Langenstein's hexameral commentary, to cite one example. On Henry of Langenstein's use of *rationes seminales* to explain causation, see Nicholas H. Steneck, *Science and Creation in the Middle Ages* (Notre Dame, 1976), pp. 34, 95, 99, and 109. I have no reason to suspect any important intellectual link between Severinus' immaterial *semina* and the seed-atoms of Girolamo Fracastoro's pathology, which was influenced by the materialism of Lucretius and Galen. On Fracastoro, see Vivian Nutton, "The Seeds of Disease: An Explanation of Contagion and Infection from the Greeks to the Renaissance", *Medical History* 27 (1983): 1-34; and Idem, "The Reception of Fracastoro's Theory of Contagion: The Seed that Fell among Thorns?", *Osiris* ser. 2, 6 (1990): 196-234.

[41] Severinus, *Idea medicinæ*, p. 54: "Hæc sunt illa corpora, Semina, Astra, Radices,

rationes seminales, which were distributed by God at the initial creation and account for subsequent cosmic development, with the Paracelsian idea that humans and other terrestrial creatures have the power of the stars within them. For Paracelsus, the immaterial, astral body that coexists with the human elemental *corpus* links us with divinity. For Severinus, the presence of stars within things accounts for their celestial timings and the vital, cosmic power that he associated with vital balsam and healing. *Astra* or *semina* are bits of divinely-sown firmament that, like Paracelsus' fire-like firmament, have an ætherial presence throughout nature.[42]

Severinus' *semina* doctrine is fundamentally Neoplatonic in origin, inasmuch as the *semina*, which are dimensionless, incorporeal centers grow into bodies by drawing on nearby "convenient matter" to assemble around them material bodies. Conversely, bodies decay by disassembling and returning to their seminal centers. Severinus refered to this as a process of flowing forth from chaos to existence and reflowing back to material nonexistence.[43]

Balsama, uitalia principia, primæ materiæ, in quibus nunc sæpe diximus, & posthac dicemus, uniuersam Medicinam fundari".

[42] SEVERINUS, *Idea medicinæ*, p. 56: "Astra in plantis et animalibus contineri docebimus, astrorumque appellationem horum principijs consentaneam esse. Etenim siue statas motuum periodos quæsiueris, in omnibus actionibus naturalibus, herbarum, animalium & mineralium, in alimentorum concoctione, excrementorum separatione, in tota nutricatione, in augmentis, in procreationibus, motuum rata constantia & æquabilitas custoditur". [We shall teach that stars are contained in animals and plants and that the name "stars" agrees with their principles. For indeed, whether you seek the fixed periods of changes in all natural actions of herbs, animals, or minerals, or in the concoction of foodstuffs, in the separation of excrements, in all nutrition, in growth, or in procreations, you will find that the established constancy and uniformity of their changes is maintained.]

[43] *Ibid.*, pp. 135-36: "In summa, motorem adiungere oportet, Principium uitale, Scientia instructum, Formam, Speciem, Semen, Astrum, quomodocunque appellare libuerit: cuius potestate & infallibili Scientia, tam diuina Mixtionis officia administrari possint. Hoc est illud Principium, quod antea Generationum omnium fundamentum & radicem demonstrauimus. Huius Scientia & uitali potestate semina ex Iliado in mundanam Anatomiam, ex Orco in Lucem prodeuntia, Elementa & corporum Principia domestica sibijpsis constituunt, eaque ponderibus & mensuris soli Scientiæ notis permiscent. Idque non corporum mutua appositione: spiritualia enim adhuc sunt, dimensionumque legibus non subjecta." [In sum, one should add a mover, a vital principle furnished with a knowledge, form, species, seed, star, or whatever one wishes to call it, by virtue of whose power and infallible knowledge such divine functions of mixing can be managed. This is the principle that we demonstrated before to be the foundation and root of every generation. With its knowledge and vital power, seeds coming forth from the *Iliadus* onto the world stage, from *Orcus* into light, establish the elements and native principles of bodies for themselves, and they mix according to weights and measures known only to their knowledge. And this does not happen by the mutual approach of their bodies, for they are still spiritual and are not subject to the laws of dimensions.] Here, again, we see the conflation of the ideas of *semina* and *astra*.

Although reflecting Paracelsus' understanding that all beings possess a natural cycle from birth to maturity and death, Severinus formulated his ideas in a metaphysics of Neoplatonic emanation and return that is similar to Nicholas of Cusa's *explicatio* (unfolding) and *complicatio* (enfolding) from potency to actuality and back to potency, visualized as a motion from center to circumference and back.[44] As such, Severinus' seminal flow also has a clear Aristotelian reading as an actualization of a form, even if the idea is Augustinian and Neoplatonic in origin. This is to say that Severinus' *semina* doctrine can be interpreted in Aristotelian terms, as the progressive development of a body from full potency to final actuality through a process of formal development of base matter toward some developmental end. Severinus himself specifically rejected Aristotelian qualities and elements as a basis for his natural philosophy, embracing instead Paracelsus' three principles (salt, sulphur, and mercury), which he regarded as spiritual and vital, rather than as "dead", like the peripatetic elements and qualities. For Severinus, the four elements were merely convenient *matrices* or wombs in which the vital *semina* develop. They provide the matter for the growth of the inchoate body. One should note, however, that Severinus' distinction between active *semina* and passive elements is quite within the Aristotelian tradition of Hylozoism, and that his Paracelsian biological metaphor is quite compatible with Aristotelian ideas on sexual procreation and epigenesis, if we interpret Severinus' *semina* as formal in nature – that is, as programs for successions of forms rather than as substantial forms themselves.[45]

Semina are perhaps better understood by comparison to the genetic code of DNA; it is the sequence itself that is important to the growth of a com-

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[44]Nicholas of Cusa intended his theory of the natural world as an unfolding of the Creator to explain this particular relationship of the Craftsman to artifact, which exists in an a-temporal context (there was no "before" the artifact was created). But his metaphysical apparatus, in which actual beings are explained as "contractions" from the original universal unity of things, permitting objects to be "in" God and yet God to be "in" the objects, works well to explain the unfolding of specific forms from generalized, unformed potency. On Cusa's theory, see JASPER HOPKINS, *Nicholas of Cusa on Learned Ignorance*. 2nd ed. (Minneapolis: Banning Press, 1985), pp. 16-30.

[45]Aristotle's idea that the human male provides the active form of offspring while the female supplies the passive matter from which the foetus grows is not unlike Severinus' idea that bodies in general grow epigenetically through the cooperation of spiritual *semina* and the material, elemental *matrices* or wombs. However, when it came to human generation, Severinus followed a more Hippocratic notion that both parents contribute form to the child and that each of the sexes possesses characteristics of the other, in varying proportions, depending on how perfectly they were separated. Human generation is the subject of the tenth chapter of *Idea medicinæ*, pp. 147-69. On his use of the two-seed theory and sexual dimorphism, see esp. pp. 149-50, 165-66.

plex organism, not the material base *per se.* And just as the replication of the information coded in DNA may go awry, Severinus' *semina* may encounter exogenous factors that alter or interfere with their programming and therefore their production of material bodies. This is where *semina* doctrine becomes causally interesting: Normal seminal development can become altered by supervening "tinctures" or programming from other *semina.* Severinus uses this mechanism to explain how an organism's normal developmental or chemical processes – for this is how he interpreted the operation of Paracelsian *archei* – may become subverted by external processes and lead to diseases. Likewise, the "tinctures" in chemical drugs can be applied by the adept physician to support the body's domestic processes, to "eradicate" foreign disease processes, and to expel their morbific *semina.*[46]

All of this may seem remote from Tycho Brahe's cosmology, but the relevance becomes clear when one analyzes Severinus' *semina* doctrine in terms of Aristotelian causality. Inasmuch as Severinus regarded *semina* as original creations, as idea-*loci* sown into the cosmos at creation, they represent final causes for corporeal development and incorporate Aristotle's notion of teleology. In this respect, *semina*, which function much as Paracelsus' *archei* or inner craftsmen, more closely resemble Aristotle's inner artificers, which carry out nature's processes in a regular, dependable – one might say mechanical – way, than they do the external, transcendent craftsman of the Platonic and Neoplatonic philosophical traditions.[47]

Semina doctrine amply explains the operation of providence in nature, because all development, all "motion" in this sense, originates with the divine seminal programming or with supervening alterations that come from other *semina.*[48] Moreover, the intrinsic connection that Severinus

[46] *Semina* and their operation in both normal and pathological generation are described in chapter two of Shackelford, "Paracelsianism in Denmark and Norway", especially pp. 80-88, 94-111.

[47] I have noted the vitalist "mechanics" of Severinus' theory in Jole Shackelford, "Seeds with a Mechanical Purpose: Severinus' *Semina* and Seventeenth-Century Matter Theory", *Reading the Book of Nature: The Other Side of the Scientific Revolution*, ed. Allen G. Debus and Michael T. Walton, Sixteenth Century Essays and Studies 41 (Kirksville, Missouri: Sixteenth Century Journal Publishers, Inc., 1998), pp. 15-44. Severinus, like Paracelsus, may have thought of this causal scheme as Neoplatonic both because of his abhorrence of materialist philosophy and his desire to distance his theory from the pagan ideas of Aristotle. *Semina* theory was meant to be a Christian doctrine, prioritizing spirit and the divine over dead matter.

[48] A notable exception to this generalization are the morbific disease-*semina*, which first arose as toxic tinctures that supervened on original semina as a consequence of God's wrath at the disobedience of Adam and Eve, but these are a special instance, which Severinus took pains to explicate. On the theological concerns about Severi-

made between seminal development and astral processes provides a reason for the assumed linkage between the stars above and those internal to terrestrial matter, offering a causal mechanism for astrology. Tycho did not discuss causality in terms of *semina* or inner *astra*, but he did, as noted previously, hold that the celestial region and its contents were composed of something like fire, but not fire; something like air, but not air. Inasmuch as the Stoic concept of a kind of fire as the immanent agent for final causality explains the similarity between the stars above and the stars below, both being composed of divine fire or pneuma that unites and animates the world, Tycho's vision might well be derived from a nexus of Stoic and Paracelsian metaphysics.[49]

Tycho does not appear to have received any formal training in medicine, as did Pratensis and Severinus, but he may have taken an interest in medical aspects of natural philosophy during his student years, since it was in the medical curriculum especially that concerns about astrological causation arose.[50] There is more solid evidence for his familiarity with Paracelsian ideas and for his intellectual fellowship with Pratensis and Severinus. However, it is the nature of his chemical research that most strongly suggests a preoccupation with Paracelsian chemical philosophy. Surviving evidence indicates that Tycho's efforts in chemistry were more than merely pharmaceutical. The scale on which he undertook chemical work – comparable to his "celestial" astronomy – reinforces the idea that he was driven by important philosophical reasons.[51] The fact that Tycho's student, Kort

nus' *semina* doctrine, see JOLE SHACKELFORD, "Early Reception of Paracelsian Theory: Severinus and Erastus", *Sixteenth Century Journal* 26 (1995), pp. 123-35.

[49] FRIEDRICH SOLMSEN, "Nature as Craftsman in Greek Thought", *Journal of the History of Ideas* 24 (1963): 473-96, p. 496, notes that the Stoics identified nature with divine forethought or predestination and credits them with a vision of a cosmos driven by immanent final causality. In their view, fire-*logos* is the divine agency proceeding like a craftsman, but operating from within matter rather than shaping if from the outside, as the traditional craftsman analogy implied. See also n. 109. All this fits well with Severinus' Paracelsian cosmology and Brahe's ideas about the generation of stars, metals, and so on.

[50] JOHN CHRISTIANSON, "Tycho Brahe at the University of Copenhagen, 1559-1562", *Isis* 58 (1967): 198-203, notes that mathematics and astronomy were taught by the faculty of medicine at the University of Copenhagen and that Tycho's copy of Sacrobosco's *Sphere* is bound with his copies of a medical textbook and an herbal (see pp. 200-201). That Tycho was at least casually interested in medicine is evident from his preparation of elixirs and sharing of recipes with certain friends and relatives and by sporadic references, such as his comment in a letter to Rothmann that the Galenic principle that contraries cure contraries does not always apply, but that sometimes it is a matter of using similars. This is a hallmark of Paracelsian therapeutics. See DREYER, *Tycho Brahe*, pp. 130- 31.

[51] On Tycho's Paracelsianism, see JOLE SHACKELFORD, "Paracelsianism and Patronage

Aslakssøn, readily incorporated chemical ideas into his cosmology and religious perspectives also suggests a compatibility, if not similarity, between Tycho's views and those of Severinus.[52] If Tycho's philosophy did indeed reflect Severinus' theory about semina and astra, it would help explain his coupling an investigation of celestial astronomy to what he termed terrestrial astronomy (alchemy), for both sciences had the common aim of understanding the "motions" of the stars. Tycho expressed their complementarity succinctly and artfully in the twin emblems that he sent to Falche Gøye: By looking up, I am looking down; By looking down, I am looking up.[53] Clearly Tycho's intent to pursue this dual study was an enduring aspect of his research: He undertook both alchemy and observational astronomy at Herrevad Abbey in the early 1570s, institutionalized them in the observatories and laboratories at Uraniborg and Stjærneborg on Hven, and resumed them at the end of the century at Benátky in Bohemia, after leaving Denmark to join Emperor Rudolf's court.[54]

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in Early Modern Denmark", *Patronage and Institutions: Science, Technology, and Medicine at the European Court 1500-1750*, ed. BRUCE MORAN (Woodbridge, Suffolk: Boydell, 1991), pp. 85-109.

[52] On Aslakssøn's cosmology, see JOLE SHACKELFORD, "Unification and the Chemistry of the Reformation", *Infinite Boundaries: Order, Disorder, and Reorder in Early Modern German Culture*, ed. MAX REINHART, Sixteenth Century Essays and Studies, 40 (Kirksville, Missouri: Sixteenth Century Journal Publishers, Inc., 1998), pp. 291-312. I have not explored Longomontanus' views on these matters, but according to MOESGAARD, "Cosmology in the Wake of Tycho Brahe's Astronomy", p. 300, Longomontanus' cosmology also reflected Tycho's ideas: "It contains a fairly faithful summary of a complex of Pythagorean-Platonic, religious, and astrological convictions which Tycho himself intertwined with his own scientific experience and intended to put in the place of the no longer trustworthy peripatetic natural philosophy." Interestingly, Longomontanus regarded the substance of the heavens, which he called *expansum*, to be also found in the earth (p. 297). He rejected the idea, supported by Pena and Rothmann, that the heavens were composed of a kind of air (p. 298), and held that it should be cold and luminiferous. He also explained new celestial phenomena as engendered by seeds (p. 299), which are ejected into the *expansum* at times determined by Providence, giving rise to *novæ* and comets. Like Aslakssøn, Longomontanus drew on chemical theory to help explain the macrocosm (p. 299).

[53] These emblems came to the attention of Christopher Rothmann, who recognized their symbolic meaning and requested an explanation from Tycho, who replied: "You have guessed correctly that these are hieroglyphic; For they refer not only to both that superior, celestial astronomy, and that inferior terrestrial, but also to that more divine and less commonly used theology, and what is more, to the study of all Ethics, namely the distinction of virtues and vices." [Letter from Tycho to Rothmann, 17 August 1588, *TBDOO*, vol. 6, p. 144: "Hieroglyphica hæc esse recte coniectasti; Nam non saltem vtramque Astronomiam cælestem illam superiorem, & inferiorem terrestrem respiciunt, sed etiam ipsam diuiniorem minusque vulgariter vsitatam Theologiam, adeoque totius Ethices cognitionem, videlicet virtutum & vitiorum discretionem."]

[54] On Tycho's activities at Herrevad, see JOHN R. CHRISTIANSON, "Cloister and Observatory: Herrevad Abbey and Tycho Brahe's Uranienborg". (Ph.D. Diss., University

As noted at the beginning of this paper, Tycho's astronomy and Severinus' medicine were formulated in the context of Philippist religious and philosophical teachings, which under the influence of Niels Hemmingsen played a particularly significant role in shaping Danish intellectual life in the last decades of the sixteenth century. Moreover, astrology was an important component of Melanchthon's humanist program. By locating their study of causation in this context, I am suggesting that Tycho and Severinus had an intellectual need to resolve the metaphysical tensions of a providential creation in a rational natural philosophy that prioritized personal observation and hands-on experience as routes to knowledge. For Severinus, one of the crucial stress points was the explanation of diseases – evil beings – in a divinely-ordained world.[55] For Tycho, the age-old problem of astrological determinism in a Christian culture loomed: How can there be room for free will, both human and divine, in a predestined cosmos? Tycho himself tells us that this issue arose when he aired his ideas on astrology at the University of Copenhagen in 1574, where Hemmingsen's theological censure was a matter of concern to him. His traditional explanation that human souls are able to resist nature, that humans, like God, in some sense transcended determinism, apparently satisfied the grave Philippist theologian. But did such a commonplace *topos* really satisfy the problem of explaining contingency in a providential plan? Was it only human actors that seemed to, now and again, step out of the roles that nature assigned to them and proceed toward conclusions that seemed to conflict with normal teleology? Severinus' *semina* theory offered Severinus an explanation of how things – metabolic processes – can go awry and result in disease and death in a foreordained, divine order. It may be that it also offered Tycho an astrological mechanism that permitted contingency in an otherwise deterministic natural machine.

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of Minnesota, 1964). On Tycho's intention to recreate his Danish research facilities at Benátky, see his letter to his sister, Sophie Brahe, 21 March 1600, translated by John Christianson in Thoren, *Lord of Uraniborg*, pp. 507-511. Tycho's facilities on Hven are perhaps best described by himself, in *Instruments of the Renewed Astronomy.* English trans. (Raeder et al. 1946) revised and commented by Alena Hadravová, Petr Hadrava and Jole R. Shackelford. Clavis Monumentorum Litterarum (Regnum Bohemiae) 2, Facsimilia – Translationes 1. (Prague: Koniasch Latin Press, 1996) esp. pp. 141-160. However, the facilities are also described and interpreted in Thoren, *Lord of Uraniborg*, ch. 5; Christianson, *On Tycho's Island*, chh. 4 and 5; and Shackelford, Tycho Brahe, "Laboratory Design, and the Aim of Science: Reading Plans in Context", *Isis* 84 (1993), pp. 211-230.

[55] This problem is discussed in Shackelford, "Early Reception of Paracelsian Theory".

Finding God within: The internalization of final causality with the inner efficient. (Every actor has his script, and the playwright is known by his play.)

Tycho's views on causation in nature – specifically on the causal actions of the superior world on the inferior world – are of interest in themselves, as a body of theory held by one of history's greatest astronomers. But they are of more general importance in relationship to the wider intellectual concerns of early modern cosmology, inasmuch as Tycho contributed significantly to changing the way in which the structure and composition of the cosmos were conceived. As I have argued, the importance of harmonizing natural philosophy and religion within a Philippist Lutheran framework involved both Tycho and Severinus in concerns about causation in nature and how nature operated in the context of Melanchthon's emphasis on Providence. But, such concerns were not limited to Denmark, or even to students of Melanchthon, although they may well have first taken on major significance in this Reformation context. They can be understood as part of a larger, more sweeping change in emphasis on causality in early modern European thought that has recently been discussed by Margaret Osler.[56]

Osler's point of departure is the generalization that the elimination of final causes was one aspect of a key transformation of both ontology and epistemology that occurred during the period often described as the Scientific Revolution, namely the decline of Aristotelian natural philosophy and the rise of mechanical philosophy.[57] According to this idea, which she traces back to E. A. Burtt's *Metaphysical Foundations*, final causality was a main concern of medieval scholastic Aristotelian philosophy, but was either of no importance or else was actively rejected by seventeenth-century mechanical philosophers, whose aim was to determine efficient causality instead. She challenges this account, noting that in fact "many important seventeenth-century natural philosophers" did not reject final causes, but rather "reinterpreted the notion of final cause, retaining the concept as part of their insistence on providential Christianity as a framework for natural

[56] Margaret J. Osler, "From Immanent Natures to Nature as Artifice: The Reinterpretation of Final Causes in Seventeenth-Century Natural Philosophy", *The Monist* 79 (1996): 388-407.

[57] *Ibid.*, p. 389: "The elimination of final causes from science has thus become an unexamined presupposition of historical accounts of the decline of Aristotelianism and the rise of mechanical philosophy." Also Richard Taylor, "Causation", in *The Encyclopedia of Philosophy*, ed. Paul Edwards (NY: Macmillan, 1967), vol. 2, p. 57: "Partly because of the rise of physical science and the accompanying demise of Aristotelian modes of thought, the concept of a cause is now generally that of an efficient cause or, more specifically, what Mill called a 'physical' cause."

philosophy".[58] Specifically, she argues that while mechanical philosophers rejected *immanent* final causation – the actualization of forms within matter to achieve an end – they accepted final causation "as imposed on nature from without" by God. This, she claims, amounts to a "reinterpretation [of final causation] within a new concept of nature", whereby "the idea of individual natures that possess immanent finality was replaced with the idea of nature as a whole which is the product of the divine artificer".[59] Overall, this model describes a transition or transformation from a Christian Aristotelian organic view, where the cosmos and all the organisms it comprises strive for their final causes – teleological fulfillment – to the Deistic world of the early Enlightenment, mediated through the voluntarism of the mechanical philosophers and corpuscular philosophy.[60]

Osler focuses on the mechanical philosophers as agents in this transformation, noting especially the roles of Pierre Gassendi and Robert Boyle and the reemergence of Epicurean and skeptical philosophies. While I think that Osler's overall conclusions may be warranted and that her model has much to commend it, it does not lay adequate stress on the place of Paracelsian notions of causality, as evident in the work of Tycho and Severinus, in an earlier phase of this transition – during the second half of the sixteenth century. If indeed Tycho's research program reflects a commitment to understanding the *astra* without and their correspondence to the *astra* within – to a world view espoused and elaborated by Severinus in terms of *semina* doctrine – then we might ask how their views of causation fit into

[58] Osler, "From Imminent Natures", p. 389.

[59] *Ibid.*, p. 390. Also: "While it is probably accurate to say that immanent final causes ceased playing a role in the explanations of specific phenomena in the writings of most mechanical philosophers, it is not the case that all finality was rejected *per se*." Osler develops these ideas in "Whose Ends? Teleology in Early Modern Natural Philosophy", *Osiris*, ser. 2, 16 (2001): 151-68, where she notes (pp. 159-60) that Gassendi, while rejecting final causation as part of a body's inner nature, nevertheless permitted a kind of Aristotelian finality to enter into his matter theory, in the guise of seminal principles – an idea that he took from Severinus!

[60] Antonio Clericuzio, *Elements, Principles and Corpuscles: A Study of Atomism and Chemistry in the Seventeenth Century.* International Archives of the History of Ideas, 171 (Dordrecht/Boston: Kluwer Academic Publishers, 2000), has recently argued that Boyle's matter theory was greatly influential among both English and continental natural philosophers in the seventeenth century. Although he and Osler might disagree about the extent to which Boyle's matter theory carries through the program of mechanical philosophy, both scholars give Boyle a central role in disseminating corpuscularism. However, inasmuch as corpuscularian theories were elaborated by various early-seventeenth-century writers, notably the widely read Van Helmont and his followers, it is hard to disentangle Boyle's influence from that of others. On Van Helmont's matter theory, see William Newman, *Gehennical Fire: The Lives of George Starkey, an American Alchemist in the Scientific Revolution* (Cambridge, Mass: Harvard University Press, 1994), pp. 110-14, 141-48.

the model outlined by Osler. As I have suggested here, Severinus' *semina* theory offered a conflation of efficiency and finality that was located within nature; that is, seminal programming was internal to matter, without being itself material, and yet it could direct material processes toward predestined ends, while still being subject to contingencies imposed by other predestined processes. This causal theory thus explained both variability and apparent contingency in nature as a complex result of Providence.[61]

Severinus' doctrine has been viewed as mainly Paracelsian and Neoplatonic, and indeed Severinus' debt to Paracelsian thought is manifest in his *Idea medicinæ*. But on closer inspection, the functioning of *semina* bears a stronger resemblance to Aristotelian or perhaps Stoic teleology as a model for internal causation than it does to Platonic finality.[62] Consequently, Paracelsian chemical philosophy, with its emphasis on *archei* or inner efficient causes as agents of chemical change, may actually have helped sixteenth-century theoreticians to reformulate the Aristotelian notion of nature's operations from a medieval scholastic emphasis on finality to a Neo-Aristotelian emphasis on teleology, namely as the internal struggling of bodies to reach their destined ends, according to their *natures*.[63]

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[61] While I have not explored this particular problem in the works of Severinus' contemporaries, I can imagine that reconciling predestination with free will was a thorny problem for natural philosophers and physicians as well as theologians, since the Hippocratic-Galenic belief that one's health was fundamentally one's own moral responsibility implies that health outcomes were not viewed as absolutely foreordained and beyond individual control. By allowing for contingent "supervening tinctures" to alter seminal predestinations, Severinus created a causal model that implicitly accounted for willful alterations within a system that was predestined by God at creation.

[62] Fred Wilson, *The Logic and Methodology of Science in Early Modern Thought: Seven Studies* (Toronto: University of Toronto Press, 1999), pp. 23-4: For Paracelsus, the form to which a thing strives is external; for Aristotle, the striving is "intrinsically informed by the goal at which it aims". That is, the form is intrinsic.

[63] *Ibid.*, p. 19: According to Aristotle, "spontaneous growth is caused not by an external *telos* but by an internal *telos*, in which the entity develops so as to instantiate, or instantiate as best it can, a form". This differs from Severinus, who views the developmental process as the unfolding of a predestination, rather than the achievement of an end *per se*. Also, p. 20: "The *nature* of a thing is the form that constitutes the final cause; it can also act as an efficient cause". I have called this view of teleology Aristotelian, but its connection with Providence may indeed reflect Stoic variants. See Mario Vegetti, "Between Knowledge and Practice: Hellenistic Medicine", *Western Medical Thought from Antiquity to the Middle Ages*, ed. Mirko Grmek, trans. Antony Shugar (Cambridge, MA: Harvard University Press, 1998), pp. 72-103, p. 76: "Aristotelian teleology possessed practically none of the cosmic providentialism that was later to distinguish Stoic teleology and that was to be so broadly incorporated into the work of Galen." Donahue, "The Solid Planetary Spheres", pp. 247-48, pointed to "the intrusion of certain elements of the Stoic natural philosophy, as expounded by no less an authority than Galen, into the Aristotelian system". Given that students of medicine had at least some exposure to Galen's philosophy, he is another likely source

If this is true – and it will surely need a wider exploration before being acceptable – then the transformation that Osler describes began during a sixteenth-century process of sorting out Aristotelian causality in light of the needs of Lutheran philosophers. According to this scenario, the conflation of efficient and final causation was well under way in the last quarter of the sixteenth century, well before mechanical philosophy was given its canonical formulation, and these ideas may therefore have constituted an intellectual resource upon which Gassendi and others drew in the seventeenth century.[64]

It seems plausible that echos of this transformation existed in Catholic Aristotelian thought of the period as well. In the Peripatetic synthesis of Tycho's near contemporary, Francisco Suarez, we also find a concern for locating causality within matter as an intrinsic part of created nature:

> Trismegistus claimed that the world is God's instrument and that it received seeds from him in order that it might produce all things. ... Among the Fathers, Augustine, in *De Trinitate* 3, chaps. 7-9, seems to imitate the aforementioned philosophers' [i.e. Plato, Hermes, and Philo] manner of speaking when he says 'God put the seminal reasons of things into the elements and other created causes'. These seminal reasons are nothing other than those active and passive principles of natural generations and motions that God placed in created things as is elegantly explained by St. Thomas in *Summa Theologiæ* 1, q. 115, a. 2, and in *Sentences* 2, dist. 18, q. 1, a. 2.[65]

In this particular corner of matter theory, Severinus' Paracelsian theory seems very close to Suarez' Neo-Scholastic Aristotelian one, perhaps owing to the fact that both sought to employ Augustine's *semina* in order to solve the particular problem of locating divinity within natural processes.

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of Stoic ideas for Tycho and his contemporaries, besides Paracelsus and Cicero's *De natura deorum*, which BARKER, "Stoic Contributions", pp. 143-44, has identified as the origin of Pena's and Rothmann's Stoicism.

[64] As I have argued in "Seeds with a Mechanical Purpose", one must be careful in drawing too sharp a distinction between mechanism and vitalism, unless one takes care to determine what the words mean in different contexts. It may be that "mechanical philosophy" had at least one intellectual root in vitalist soil, even if it turned out to be something quite contrary. We know that Gassendi was familiar with Severinus' work and was very interested in Brahe's life and work, too. ANTONIO CLERICUZIO, *Elements, Principles and Corpuscles*, amply demonstrates that natural philosophers were developing corpuscular hypotheses before the mechanical philosophy of Gassendi and Descartes (pp. 36-37, 77), and that Gassendi's version of matter theory was not resolutely mechanical in the Cartesian sense (pp. 60-70).

[65] FRANCISCO SUAREZ, *On Efficient Causality: Metaphysical Disputations 17*, *18*, and *19*, trans. ALFRED J. FREDDOSO (New Haven, CT: Yale University Press, 1994), p. 40.

However, whereas Severinus explicitly denied matter any role in efficient causation – and here he served Paracelsus and Plotinus well – Suarez considered it possible that bodies as well as spirits might serve as efficients.[66] Pointing out that Augustine was speaking in the context of self-initiating efficient causes, Suarez concluded that "created causes cannot effect a substance according to itself as a whole ... but that they are nonetheless able to generate a substance from presupposed substantial matter by educing a substantial form; however, this sort of efficacy should be attributed to corporeal causes rather than to created spirits".[67] By attributing efficiency to bodies themselves, rather than their seminal spirits, Suarez took a step closer to the mechanical philosophers of the seventeenth century. He de-emphasized the necessity of efficient agents that transcend matter while being located within it, so to speak, and instead attributed such causality directly to the bodies themselves.[68] The abandonment of such causal transcendence was completed by corpuscularians in the seventeenth century, notably Robert Boyle, who regarded *semina* as molecular clusters of primary material particles, thereby more closely associating internal agency with matter itself.

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[66] *Ibid.*, p. 47: "I claim that not only incorporeal substances but also corporeal substances can have real and physical efficient causality."

[67] *Ibid.*, p. 48.

[68] NICHOLAS JARDINE, "Epistemology of the Sciences", pp. 685-711 in *Cambridge History of Renaissance Philosophy*, p. 703, notes that Jacopo Zabarella (1607) also emphasized external and internal efficient causes as mediating formal and final causation. I am now wondering if some of the perceived discrepancies between the emergence of the new science in Protestant and Catholic realms, which engendered the now generally discredited "Merton Thesis", might be in part explained by Protestant theorists' willingness to abandon, somewhat earlier than their Catholic counterparts, Thomistic emphasis on transcendental causality and instead more directly embrace nature as a source of knowledge about immanent divinity. If so, then this transformation would be a matter of timing rather than confessionally determined in some essentialist sense. Closer scrutiny of causality in the period between Luther and Suarez may shed light on this problem and its chronology.

Tycho Brahe and Prague: Crossroads of European Science, pp. 70–83, J. R. Christianson et al. (eds.),

Tycho Brahe and John Craig: The Dynamic of a Dispute

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In his important article of 1980, "The Astronomer's Role in the Sixteenth Century: A Preliminary Study", Robert Westman noted that in the course of his career Tycho Brahe entered into acrimonious dispute with four men: Nicolai Reymers Baer, called Ursus, Paul Wittich, Christoph Rothmann, and John Craig.[1] We have since learnt a great deal about Tycho's relations with all but one of these antagonists. Thus Tycho's dispute with Ursus has been the subject of books by the late Edward Rosen, Nicholas Jardine, and Miguel Granada;[2] his debates with Rothmann have been examined in articles by Bruce Moran and Peter Barker and Bernard Goldstein;[3] and of

[1] Robert Westman, "The Astronomer's Role in the Sixteenth Century: A preliminary study", *History of Science*, 1980, *18*: 105-147, p. 125.

[2] Edward Rosen, *Three Imperial Mathematicians: Kepler Trapped Between Tycho and Ursus* (New York: Abaris Books, 1986); Nicholas Jardine, *The birth of history and philosophy of science: Kepler's A Defence of Tycho against Ursus with essays on its provenance and significance* (Cambridge: Cambridge University Press, 1984; corrected edition 1988); Miguel Granada, *El debate cosmológico en 1588. Bruno, Brahe, Rothmann, Ursus, Röslin* (Naples: Bibliopolis, 1996), pp. 77-107.

[3] Bruce Moran, "German Prince-Practitioners: Aspects in the Development of Courtly Science, Technology, and Procedures in the Renaissance", *Technology and Culture*, 1981, 22: 253-274; idem, "Christoph Rothmann, The Copernican Theory, and Institutional and Technical Influences on the Criticism of Aristotelian Cosmology", *Sixteenth Century Journal*, 1982, *13*: 47-59; Peter Barker and Bernard Goldstein, "The role of Rothmann in the dissolution of the celestial spheres", *British Journal for the History of Science*, 1995, *28*: 385-403. The astronomical work at Kassel, where Rothmann was *mathematicus*, has also been treated by a number of other scholars. See, for example, John Leopold, *Astronomen, Sterne, Geräte: Landgraf Wilhelm IV. und seine sich selbst bewegenden Globen* (Lucerne: Joseph Fremersdorf, 1986); Jürgen Hamel, *Die astronomischen Forschungen in Kassel unter Wilhelm IV. Mit einer Teiledition der deutschen Übersetzung des Hauptwerkes von Copernicus um 1586* (Thun & Frankfurt am Main: Harri Deutsch, 1998). On Rothmann, see also Miguel Granada, "Il problema astronomico-cosmologico e la Sacre Scritture dopo Copernico: Christoph Rothmann e la 'teoria dell'accomodazione'", *Rivista di storia della filosofia*,

course, the "Wittich connection" has been explored by Robert Westman himself, working in collaboration with Professor Owen Gingerich.[4] But the dispute with John Craig has received very little attention in the last twenty-one years. It is discussed somewhat in Victor Thoren's biography, as well as in John Christianson's more recent book, and there is a brief summary in a study of Scottish-Danish relations in the early-modern period.[5] But to the best of my knowledge, no more detailed account has been published.[6]

In many respects this omission is quite understandable. Despite the scholars who, over the years, have dedicated time to Tycho's life and career, there is still much to be done in this area; and it is by no means obvious that Tycho's dispute with John Craig is the lacuna that most urgently needs to be filled. Whereas Ursus and Rothmann were figures of some distinction in the astronomical community to which Tycho belonged, and Wittich was also widely known and respected, Craig was an obscure Scots physician who succeeded in antagonising Tycho not because he competed with the Danish astronomer for credit in some innovation of mathematics or astronomy, but rather because he persisted in adhering to traditional Aristotelian principles of cosmology. Given the longstanding interest of historians of astronomy in describing the *evolution* of cosmological thought in the period, and even the increasing concern with mapping the community of astronomical practitioners in which Tycho participated, there are other individuals whose ability and prominence might seem to make study of their relations with Tycho of higher priority.[7] Nevertheless, I think that Tycho's exchanges with Craig repay close attention; and not least because

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1996, *51*: 789-828; IDEM, "L'eliminazione delle sfere celesti e lo status delle ipotesi astronomiche secondo un testo inedito di Christoph Rothmann del 1589. L'influenza non riconosciuta di Jean Pena e la polemica con Petrus Ramus", *Rivista di storia della filosofia*, 1997, *52*: 785-821.

[4] ROBERT WESTMAN and OWEN GINGERICH, "The Wittich Connection: Conflict and Priority in Late Sixteenth-Century Cosmology", *Transactions of the American Philosophical Society*, 1988, *78.7*.

[5] VICTOR THOREN, *The Lord of Uraniborg: A Biography of Tycho Brahe* (Cambridge: Cambridge University Press, 1990), pp. 312, 364, 407-408, 420; JOHN CHRISTIANSON, *On Tycho's Island. Tycho Brahe and His Assistants, 1570-1601* (Cambridge: Cambridge University Press, 2000), pp. 69, 273, 300, 316, 328-329; THOMAS RIIS, *Should Auld Acquaintance be Forgot ... Scottish-Danish Relations c. 1450-1707* (Odense: Odense University Press, 1988), vol. I, p. 123.

[6] Of course, there also exists material on the Tycho-Craig debate that was published before 1980. See JOHN DREYER, *Tycho Brahe: A Picture of Scientific Life and Work in the Sixteenth Century* (Edinburgh: Adam & Charles Black, 1890), pp. 208-209, 305, 369; WILHELM NORLIND, *Tycho Brahe: En levnadsteckning med nya bidrag belysande hans liv och verk* (Lund: CWK Gleerup, 1970), pp. 132-143.

[7] I mean, for example, figures such as Giovanni Antonio Magini, Thaddaeus Hagecius, and Michael Mästlin.

of what they can tell us about Tycho's relations with even such relatively well-studied contemporaries as Wittich, Ursus and Rothmann.

By stating that the dispute between Craig and Tycho can tell us something about his interaction with these more famous antagonists, I don't primarily mean that there are points of overlap in these three separate cases, although this happens to be true.[8] Rather I mean that Tycho's dispute with Craig displays features that can also be seen in one or more of these other relationships; features relating to each party's expectations, intentions, and behaviour. Twenty-one years on from "The Astronomer's Role", I think we are in a position to state that Tycho's disputes with Ursus, Rothmann and Wittich were very different in character.[9] Indeed, it is not clear to me that Tycho's behaviour towards Wittich can be described as that of a disputant at all; my own reading of events is that Tycho consistently praised Wittich as a mathematician, in order to support the claim he advanced for their shared role in the discovery of the mathematical technique of prosthaphaeresis, even as he criticised Wittich's abilities as an instrument-maker and observer.[10] But a great deal of the work of attempting to shape Wittich's reputation was carried out by Tycho after his death; so even if Wittich would have taken issue with his treatment by Tycho, he was in no position to contest it. Rothmann's disputes with Tycho, on the other hand, were genuine debates, and of real intellectual

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[8]Gingerich and Westman have, of course, noted Craig's connections with Wittich. See *The Wittich Connection* (*op. cit.* note 4), pp. 7, 11-12, and 40. The overlap with Rothmann, consisting of the discussion of the debate Tycho's letter to the former Hessen *mathematicus* of 14th January 1595 is discussed below. There is even an indirect connection with the dispute with Ursus, since in his letter to Craig of 14th November 1591, Tycho first revealed that he intended to publish the letter of 28th June 1590 sent to him by Jakob Kurtz which touched on this quarrel. The letter was actually published by Tycho in his *Astronomiae Instauratae Mechanica* (Wandsbek: 1598), sig. G2r-G3r, but it was also quoted by Ursus in the *De astronomicis hypothesibus, seu de systemate mundano, tractatus astronomicus* (Prague: 1597), sig. I3v. See John Dreyer (ed.), *Tychonis Brahe Dani Opera Omnia* (Copenhagen: Libraria Gyldendaliana, 1913-1929), 15 vols., (henceforth *TBOO*), vol. VII, p. 311.26-31.

[9]Westman's explanation of these disputes, however, that they were principally motivated on Tycho's part by a fear of losing the credit to which he felt entitled, still stands; see "The Astronomer's Role", (*op. cit.* note 1), p. 125. Indeed, Tycho's particular concern about Craig seems to have been that, as a talented mathematician, he might be given greater credence than those objectors to the Tychonic account of comets who possessed only philosophical training. See, for example, *TBOO* VII, 366.5-6, Tycho to Thomas Craig, 26th July 1594.

[10]On the matter of prosthaphaeresis, see Anton von Braunmühl, *Vorlesungen über Geschichte der Trigonometrie* (Leipzig: Teubner, 1900-1903), 2 vols., vol. I, pp. 193-194; John Dreyer, "On Tycho Brahe's Manual of Trigonometry", *The Observatory*, 1916, *39*: 127-131; and Victor Thoren, "Prosthaphaeresis Revisited", *Historia Mathematica*, 1988, *15*: 32-39.

substance. The letters they exchanged concerned such issues as the distinction between air and aether, the magnitude of atmospheric refraction, the cause of a slight discrepancy between the observations made at Kassel and those made at Uraniborg, and the true world-system: all issues on which Tycho and Rothmann differed, and hence argued very passionately.[11] Yet although coming close on at least one occasion, the correspondence between the two never quite crossed the line dividing an academic *disputatio* from highly emotional personalised conflict.[12] And in this respect, the contrast with Tycho's dispute with Ursus couldn't be more clear. For that quarrel was characterised by mutual loathing and personal insults from the very beginning, to the extent that the substantive intellectual content of the dispute, most notably Kepler's response to Ursus' radical scepticism about astronomical hypotheses, almost seems to emerge accidentally.[13] Moreover, as Kepler's involvement illustrates, the dispute between Tycho and Ursus was a quarrel conducted by proxy: once it began, Ursus only addressed Tycho in print; and Tycho seems to have been loathe even to entertain that much contact with his antagonist.[14] One of the things that is interesting and important about the Craig dispute, I would argue, is that at various stages it displays almost all of these features.

The similarity with the Ursus case is, unsurprisingly, most evident in the dispute's later stages. Tycho and John Craig began corresponding in May of 1589; in July 1594, Tycho made it clear, in a letter to *Thomas* Craig, that he would not be answering the letters of John, his brother.[15] And even two years before that, Tycho had given voice to the thought, in letters to the Imperial prochancellor Jacob Kurtz, the Imperial Physician Thaddaeus Hagecius, and the Scottish Chancellor, John Maitland of Thirlestane, that when it came to answering what Craig had to say

[11] See *TBOO* VI, *passim.*

[12] The moment of "closest approach" to that line probably came in Rothmann's letter of 22nd August 1589, when Rothmann understood Tycho to be accusing him of detracting from the authority of scripture, and in Tycho's subsequent responses. See *TBOO* VI, 181.9-184.3 and 185.1-200.12.

[13] See Jardine, *The Birth of History and Philosophy of Science* (*op. cit.* note 2).

[14] Thus, in his letter to Hagecius of 14th March 1592, Tycho asserted both that he had decided not to make any answer to the calumnies of Ursus, and that Hagecius should not allow him to write anything to Tycho. See *TBOO* VII, 326.21-28. In later letters, such as that to Longomontanus of 21st March 1599, and that to Daniel Cramer of 1st April 1600, Tycho was somewhat apologetic about asking even these individuals to contribute to a refutation of Ursus. See *TBOO* VIII, 150.8-13 and 292.17-26.

[15] *TBOO* VII, 366.9-14. Tycho to Thomas Craig, 26th July 1594. Thomas Craig (1538-1608), was a jurist and poet (he evidently wrote some verses for Tycho; see *TBOO* VII, 255.39-41). See the entry in the *Dictionary of National Biography* (London: Smith, Elder & Co., 1885-1900), 63 vols., vol. XII, pp. 448-451.

about Tycho's work, the response should be prepared by someone else, whether a friend or a student.[16] Indeed, although in the medium term Tycho would resort to writing a lengthy description of this dispute in a letter to Christoph Rothmann, knowing that that letter was one he was shortly going to publish in his astronomical letter-book, the task was eventually assigned to both Christian Longomontanus and Kepler.[17] Now it has been suggested that when Tycho prevailed upon his former students and current acquaintances to compose responses to the charges laid against him by Ursus, in the Dithmarschen mathematician's scandalous *Tractatus*, he did so in order to avoid exposing his own intellectual, and particularly mathematical, shortcomings.[18] But the occurrence of the same behaviour in the Craig dispute indicates rather that, whatever reasons Tycho gave in explanation, i.e. the low status of Ursus, or the fact that time used to reply to Craig could be much better spent, this simply *was* how he reacted when it came to dealing with individuals for whom he'd developed a very personal dislike.[19] And as would be imagined, that feeling became mutual: in 1598, after the publication of the letter-book, mention of Tycho was sufficient, according to one report, to provoke in Craig an angry outburst.[20] But how did things get to that stage?

The trigger for Tycho's dispute with Craig was the partial publication

[16] For example *TBOO* VII, 340.29-31: "Forte etiam prodibit suo tempore amicorum vel discipulorum meorum aliquis, qui hanc controversiam dirimere et ad invalidos Craigicarum obiectionum ictus retorquendos otium sibi sumat." Tycho to Maitland, 19$^{\text{th}}$ August 1592. See also *TBOO* VII, 343.31-34, Tycho to Hagecius, 28$^{\text{th}}$ September 1592, and *TBOO* VII, 349.26-27, Tycho to Kurtz, 19$^{\text{th}}$ April 1593.

[17] See *TBOO* VIII, 134.3-8, Tycho to Longomontanus, December 1598, which also indicates that Tycho still saw the completion of a refutation of Craig as an essential component of his second volume *De mundi aetherei recentioribus phaenomenis.* According to Christianson, *On Tycho's Island*, (*op. cit.* note 5) pp. 273 & 316, Longomontanus completed his manuscript refutation and presented it to Johannes Eriksen. Kepler's attempt at a refutation seems not to have been pursued very far; a transcript of it can be found in Christian Frisch (ed.), *Joannis Kepleri Astronomi Opera Omnia* (Frankfurt am Main & Erlangen: Heyder & Zimmer, 1858-1870), 8 vols., vol. I, pp. 279-281.

[18] See Jardine, *The Birth of History and Philosophy of Science* (*op. cit.* note 2), p. 32, note 12.

[19] For comments by Tycho on Ursus' worth and standing, see *inter alia*, the letters cited above in note 13. Tycho stated that his time could be much better spent than in replying to Craig, particularly by working on his *Progymnasmata*, in his letter to Kurtz of 19$^{\text{th}}$ April 1593; see *TBOO* VI, 349.17-21.

[20] See the letter of Patrick Gordon to Jon Jacob Venusin, of the 20$^{\text{th}}$ of March 1599, *TBOO* XIV, 151.5-15. From this letter, it would seem that Craig had heard about, but not seen, Tycho's letter about their dispute in the *Epistolae astronomicae* (Uraniborg: 1596); he objected both to this and to a complaint that he claimed Tycho had made against him to James VI. This is probably a reference to Tycho's comments in his later letters to Peter Young and John Maitland.

of his work on the comet of 1577. In 1588, Tycho distributed copies of this text to a number of astronomers and mathematicians, including Craig,[21] at that time a physician practising in Edinburgh.[22] Craig's response to Tycho's work, conveyed in a letter of May 1589, was courteous, but not entirely favourable. He rejected Tycho's claim to have demonstrated that comets were ethereal rather than meteorological phenomena, asserting amongst other things that the method which Tycho had used to calculate the distance of the comet from the Earth, the determination of its parallax, was invalidated by the failure to take proper account of the comet's own motion.[23] Furthermore, he objected to Tycho's new system of the world, also described in the 1588 text, on the basis that it dispensed with the solid celestial spheres in favour of an entirely fluid heaven.[24] As Tycho would put it, Craig was too devoted to the teachings of Aristotle to find these new cosmological theories in any way palatable.[25]

Tycho had gone to great lengths to ensure that his work on the comet would establish a consensus. Not only did the text contain his own interpreted observations, it also included the data and conclusions of a number of other scholars, subjected by Tycho to a masterful analysis.[26] The presence of this material in the text was partly responsible for the appearance of the book so long after the phenomenon it described;[27] and the result was a text so plausibly comprehensive that it constituted the basis for C. Doris Hellman's twentieth-century account of work on that comet.[28]

[21] Although it has been variously suggested that Tycho learnt of Craig through Duncan Liddel, or William Stuart, Craig's first letter to Tycho, of May 1589, makes it quite clear that while Stuart conveyed Tycho's work to Craig, it was Liddel who mentioned Craig to him. See *TBOO* VII, 175.10-23.

[22] Craig (d. 1620) had previously spent some time in Germany; he was professor of mathematics and logic at Frankfurt an der Oder. Subsequently he became royal physician, and accompanying James VI into England became a member of the London Royal College of Physicians in 1604, and was incorporated M. D. at the University of Oxford in 1605. See the entry in the *Dictionary of National Biography* (*op. cit.* note 14), vol. XII, pp. 447-448, and George Clark, *A History of the Royal College of Physicians of London* (Oxford: Clarendon Press, 1964-1966), 2 vols., vol. I, pp. 193 and 197. It is, however, evident from his correspondence with Tycho that, although he possessed contacts at court, he was not, at the time of their epistolary debate, a royal physician. It is also evident, *pace* Gingerich & Westman, *The Wittich Connection* (*op. cit.* note 4), p. 7., that Craig never visited Denmark.

[23] See *TBOO* VII, 177.3-180.5, Craig to Tycho, May 1589.

[24] *TBOO* VII, 180.7-11, Craig to Tycho, May 1589.

[25] See, for example, *TBOO* VII, 349.3-7, Tycho to Kurtz, 19th April 1593.

[26] See *TBOO* IV, 4-377, especially the tenth chapter, pp. 180-367.

[27] There were, however, other practical difficulties connected with Tycho's publishing enterprise; these have been fairly well-documented in V. Thoren's *The Lord of Uraniborg* (*op. cit.* note 5).

[28] C. Doris Hellman, *The Comet of 1577. Its Place in the History of Astronomy*

Craig's refusal to accept it as the last word on the subject might therefore have been thought likely in itself to trigger Tycho's ill temper; particularly since Craig had read the work closely enough to use the authors that Tycho cited as a source of evidence against him, and also as he made recourse to the undisclosed details of his own, presumably low quality, observations.[29] But this does not seem to be what happened.

Tycho replied to Craig with great politeness.[30] He sent with his letter a detailed rebuttal of the objections that Craig had raised against his account of comets, a rebuttal taking the form of a forty-page document that he referred to as his *Apologia* or *Apologetica Responsio*.[31] The letter itself, not needing to be occupied with the details of the dispute, was given over to other matters and pleasantries. Craig had requested that Tycho share with him some alchemical recipes;[32] Tycho gave his customary response to such enquiries, that he was most willing to do so in theory, but that the issue of communicating such dangerous material safely presented a practical obstacle. It would be best if Craig could visit Uraniborg, so that Tycho could instruct him orally.[33] Regarding mathematics, in which field Tycho would repeatedly and consistently describe Craig as particularly learned, the Dane thanked Craig for sending him what must have been some sort of trigonometrical material.[34] Indeed, he asked Craig to collect

(New York: Columbia University Press, 1944). TABBITA VAN NOUHUYS has indirectly noted the extent to which historians of astronomy have been persuaded by Tycho's interpretation of the significance of the 1577 comet in her *The age of two-faced Janus: the comets of 1577 and 1618 and the decline of the Aristotelian world view in the Netherlands* (Leiden: Brill, 1998), pp. 15-41; she dates this phenomenon from the eighteenth-century onwards.

[29]See *TBOO* VII, 180.14-181.30, Craig to Tycho, May 1589.

[30]At least, he did so eventually; Craig sent three letters to Denmark before Tycho found himself able to write one. This fact, however, reflects only the practical difficulty of maintaining even a modestly long-distance correspondence in the early-modern period.

[31]See *TBOO* IV, 417-476. The preface to the *Apologia*, a later composition, can be found in *TBOO* IX, 153-157. This preface makes it clear that Tycho intended to publish the letter he had received from John Maitland of 16th May 1592. Publication of letters was, of course, a common strategy amongst sixteenth-century scholars in general, including the international astronomical community, and of Tycho in particular. On the difference that this can make to our interpretation of these documents, see my "Tycho Brahe's Epistolae Astronomicae: A reappraisal", forthcoming in J. PAPY, T. VAN HOUDT and G. TOURNOY (eds.), *Self-Presentation and Social Identification. The Rhetoric and Pragmatics of Letter Writing in Early-Modern Times* (Leuven: Leuven University Press).

[32]See *TBOO* VII, 181.36-182.1, Craig to Tycho, May 1589.

[33]See *TBOO* VII, 195.30-34, Tycho to Craig, 25th October 1589. For another example of Tycho's reluctance to communicate alchemical secrets by letter, see his remark to Andreas Severinus of 18th May 1571, *TBOO* VII, 5.16-18.

[34]That Craig communicated to Tycho that John Napier was working in this area has

together all the *compendia triangulorum* known to him, in a little book illustrated with examples, and send it to Uraniborg; and in return for this favour, Tycho expressed himself ready to perform any kind of service that would be helpful.[35] More generally, he thanked Craig for his goodwill and his honesty, remarking that he would not fail to include him in his *album amicorum*.[36] In other words, in the exchange-economy of the *respublica litterarum*, this was business very much as usual.[37]

In his next letter to Tycho, of the 28th of February 1590, Craig wrote at length on trigonometry, asked once more for some alchemical material, and requested that he be recommended as a potential personal physician to Anne of Denmark, the newly-wed bride of James VI of Scotland.[38] The dispute about comets, however, was only touched on very briefly. William Fuller, a friend of Craig's travelling in the retinue of the Scots ambassador to Denmark, whom he had recommended to Tycho as "an excellent man, not unworthy of your friendship", had returned to Scotland after visiting Uraniborg and reading Tycho's *Apologia*. But when asked by Craig

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long been taken to be the case, principally on the evidence of the later testimony of Kepler. See WILLIAM MACDONALD (ed.), *The Construction of the Wonderful Canon of Logarithms* (Edinburgh & London: Blackwood, 1889), pp. xv-xvi, and Kepler's letter to Peter Crüger of 9th September 1624, in MAX CASPAR ET AL. (ed.), *Gesammelte Werke* (Munich: C. H. Beck, 1937-), in progress, vol. XVII, 210.483-485. The possibility that Craig contributed in some way to Tycho's trigonometrical manual, as described by DREYER "On Tycho Brahe's Manual of Trigonometry" (*op. cit.* note 9), deserves further consideration.

[35] *TBOO* VII, 196.3-13: "Pro communicatis quibusdam compendiis Triangulorum gratias habeo, licet ipsemet, ubi primus numerus est integer sinus, hæc satis antea perspecta habeam; ubi plura inquirere atque enodare tibi otium fuerit, feceris mihi rem gratam, si omnia quotquot eiuscemodi colligere poteris compendia, peculiari libello comprehensa et exemplis illustrata, mihi transmiseris, utque inventum illud quod tibi Helix Geometrica appellatur, una cum canonis confectione plenius aperias velim. Ego laboribus et sumptibus non parcam, ut per operarios sufficientes res hæc executioni mandetur, modo usufructus par sit labori, et si per me quidpiam rursus, quod tibi gratum sit, præstari poterit, invenies me perpetuo ad quodvis officii genus quam promptißimum." Tycho to John Craig, 25th October 1589.

[36] *TBOO* VII, 195.25-30: "Pro singulari autem illa tua erga me meaque studia benevolentia et candido iudicio plurimas tibi habeo gratias, et vicißim te diligere atque in albo amicorum meorum singularium numerare non intermittam ..." Tycho to John Craig, 25th October 1589.

[37] On the Republic of Letters and the associated exchange-economy of early-modern Europe, see *inter alia*, HANS BOTS & FRANÇOISE WAQUET, *La République des Lettres* (Paris: Belin, 1997); PAULA FINDLEN, "The Economy of Scientific Exchange in Early Modern Italy", in BRUCE MORAN (ed.), *Patronage and Institutions: Science, Technology and Medicine at the European Court, 1500-1750* (Rochester: Boydell, 1991), pp. 5-24; KRISTEN NEUSCHEL, *Word of Honor: Interpreting Noble Culture in Sixteenth Century France* (New York: Cornell University Press, 1989).

[38] *TBOO* VII, 239.19-242.20.

whether he recalled Tycho's responses in detail, Fuller said, "No; for many things defeated my comprehension. This only I perceived, that he adduces many proofs of his opinion."[39] Craig expressed himself ready to give way to these arguments, which he had evidently not yet seen, if they should be certain. Such demonstrations would, he declared, "have greater authority for me in this respect than ARISTOTLE, because authority ought to be judged from the truth, and not the latter from the former".[40] But if Tycho expected this capitulation to happen, he waited in vain. Having heard from Andreas Krag, professor of medicine at Copenhagen, and physician to Queen Anne, that Craig had discussed the *Apologia* with him, he nevertheless received nothing from Craig for some time.[41] Eventually, in November 1591, Tycho wrote a very lengthy letter in which he pointed out that silence was inappropriate whether Craig was defeated by Tycho's responses, or had further arguments to deploy. Tycho's language in this letter was self-consciously combative. "If you distrust the cause and your forces," he wrote, "and you have finally tried the walls of truth defended by us, and concede them to be unassailable, then of course you do as the thing itself demands, and as is fitting, you admit so."[42] Tycho pressed his advantage over Craig by quoting from several other scholars who supported his non-Aristotelian account of the position of comets, and who applauded

[39] *TBOO* VII, 239.25-33: "ANTE biduum nobis D. FULLERUS noster obviam factus inter alia retulit, quam honorifice abs te fuerit acceptus, quam admiranda viderit, et quod legerit, quæ ad primas meas responderis, ubi ego: iamdudum mihi constat, in illa Uraniæ arce cum summa humanitate eximiam scientiam habitare; sed sciscitatus sum, an meminerit, quæ de mota quæstione scripseris? Non, inquit, nam pleraque captum meum superabant; hoc tantum percepi, plures sententiæ suæ demonstrationes afferri." John Craig to Tycho, 28th February 1590. See also *TBOO* VII, 193.2-4, John Craig to Tycho, 18th June 1589.

[40] *TBOO* VII, 239.33-36: "Demonstrationes ego libenter intelligam, et si constiterint, facile iis cedam, quique hoc $o\tau\iota$ sic docuerit, maioris apud me authoritatis hac ex parte, quam ARISTOTELES erit, quod authoritas ex veritate æstimanda sit, non hæc ex illa ..." John Craig to Tycho, 28th February 1590.

[41] *TBOO* VII, 309.25-32: "Apologiam nostram, qua tuis obiectionibus luculenter respondebam, te iamdudum accepiße, nullum apud me est dubium. Nam et eruditißimus Dn. D. ANDREAS CRAGIUS, Medicus et Physicæ in Academia Hafniensi Profeßor, mihi e Scotia (quo cum serenißima Regina Sponsa eius atque adiunctæ nobilitatis Archiatrum agens, quando illac claße Danica deduceretur) reversus significabat, te motæ inter nos disputationis, huiusque meæ Apologiæ mentionem feciße." Tycho to Craig, 14th November 1591.

[42] *TBOO* VII, 308.30-34: "Si caußæ et viribus diffidis, veritatisque a nobis propugnatæ moenia inexpugnabilia eße, iam tandem expertus es atque concedis, equidem id quod res ipsa exigit, quodque decet, admittis." Tycho to Craig, 14th November 1591. Tycho elaborated somewhat on this theme later in the same letter; c.f. also his use of the siege and duel metaphor in his letter to Maitland of August 19th, 1592, in *TBOO* VII, 339.21-25.

his efforts in astronomy more generally: Hagecius, Kurtz, and Giovanni Antonio Magini.[43] And at the same time, Tycho revealed to Craig what some of these other scholars had known for many months, namely the nature of the value that he perceived in the continuation of their dispute. The contest was one that, ostensibly for the benefit of others who might want to know the truth, Tycho wished to introduce into the public arena.[44] Anything that Craig chose to add to his case, Tycho promised, would be printed along with the existing contributions to the debate; and all would be appended to his largely undistributed book on the 1577 comet.[45]

The limited audience to which Tycho had already made this material known, by sending out copies of Craig's letter and his own *Apologia*, included the Wittenberg polymath Caspar Peucer.[46] And it was Peucer whom, in July 1589, Christoph Rothmann rightly accused Tycho of trying to enlist on his side in the course of debate, by sending him copies of *their* epistolary exchanges.[47] What Rothmann evidently didn't know was that Tycho had sent copies of the Hven-Kassel correspondence not only to Peucer, but also to Heinrich Rantzau, Thaddaeus Hagecius and Jakob Kurtz, Heinrich Brucaeus, and perhaps certain others. Moreover, Tycho had been exhibiting such behaviour, which of course was not so unusual in humanistic epistolary culture, since the very beginning of their correspondence in the mid-1580s.[48] From circulation in manuscript to circulation in print was not such an imaginative leap; yet when he produced his letter-

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[43] See *TBOO* VII, 311.15-312.27, 312.28-315.21, & 315.29-317.28, Tycho to Craig, 14th November 1591.

[44] *TBOO* VII, 310.36-311.3: "Caußa autem, cur id eo enixius desiderem, est hæc, quod cum tuas literas, quatenus nostræ de Cometa supradicto Anni 77 lucubrationi nonnulla opponebant, una cum nostra Apologetica responsione, quibusdam excellentibus et eruditis in Germania Mathematicis simul inspicienda dijudicandaque transmisißem, illis sane hæc amica inter nos veritatis eliciendæ confirmandæque decertatio non displicuit nec indigna iudicabatur, quæ publici iuris fieret, ut et alii negotii penetralia eo profundius (hinc allecti) introspicerent atque veritatis involucra commodius eruerent, quidque citra dubium sentiendum foret, rectius constituerent." Tycho to Craig, 14th November 1593.

[45] *TBOO* VII, 311.3-7: "Proposui itaque hortatu aliorum eam partem literarum tuarum, quæ hac de re agit, una cum nostra Apologia, tomo secundo de hoc Cometa tractanti propediem subiungere. Quod tibi prius significandum censui, ut si quid in promptu eßet, quod hic ulterius inferre satagares, id mature expedire mihique mittere poßes." Tycho to Craig, 14th November 1593.

[46] Tycho states that he has sent his *Apologia* to Peucer, although he doubts that has received it, in his letter of 1590. See *TBOO* VII, 239.7-10.

[47] *TBOO* VI, 201.39-202.1: "Cognovi etiam ex literis fratris mei Iohannis, quod disputationes nostras ad Dn. D. PEUCERUM miseris, quodque Dn. PEUCERUS alia consilia proferat, nec mihi aut tibi suffragari velit." Rothmann to Tycho, 27th July 1589.

[48] See, on this, my "Tycho Brahe's *Epistolae astronomicae*" (*op. cit.* note 30).

book of 1596, Tycho used the encouragement of those friends who had already seen the material it contained as his pretext to publish.[49] Tycho's behaviour in the case of Craig was really very similar. Both Hagecius and Kurtz were sent Craig's letter and the *Apologia* to read in 1589, and asked to comment on the idea, already formed in Tycho's mind, of printing this material.[50] Were it not for lack of space, it would be interesting to comment on their responses, and on how Tycho was able to make use of them. In reply to Hagecius, for example, Tycho was obliged to point out that, actually, there was some merit in the criticism that Craig had levelled at the cometary treatise of Regiomontanus, that it did not take proper account of the comet's own motion when calculating parallax.[51] Kurtz, on the other hand, helpfully suggested that those purported Aristotelians who continued to dispute Tycho's cometary analysis, were only doing so for the sake of giving Tycho a target to tilt against.[52] Tycho did not fail to disclose this to Craig in his '91 letter.[53]

In writing of Craig, Tycho continued for some time to speak of him courteously, to praise his abilities as a mathematician, and to claim that he valued his sincere opposition and intellectual integrity. He commended him to James VI of Scotland, when he visited Hven, and in writing to Maitland, and to Peter Young, the Scots ambassador to Denmark.[54] Thus to Young, in 1590, he stated that, "I love the man that much more, because he dared to make an attempt of this sort, when all the learned

[49] *TBOO* VI, 21.19-22.1.

[50] See *TBOO* VII, 216.11-27, Tycho to Hagecius, 1st November 1589; *TBOO* VII, 222.4-6 & 224.2-4, Tycho to Hagecius, 25th January 1590; *TBOO* VII, 225.27-34, Tycho to Hagecius, 23rd February 1590. (In the first of these letters, Tycho asked Hagecius to refer the issue to Kurtz.) Tycho also informed Peucer of his intention to publish the material as an appendix to his second volume *De mundi aetherei recentioribus phaenomenis*; see *TBOO* VII, 239.9-14, Tycho to Peucer, 1590.

[51] This point was originally made by Craig in his letter of May 1589; see *TBOO* VII, 179.38-180.3. For Tycho's comments on the matter to Hagecius, see *TBOO* VII, 271.16-272.21, Tycho to Hagecius, 3rd August 1590.

[52] See *TBOO* VII: 120.2-14. Kurtz to Tycho, 28th June 1580, and 349.7-14, Tycho to Kurtz, 19th April 1593. Heinrich Brucaeus made a similar suggestion in his letter of 5th November 1592; see *TBOO* VII, 345.10-19. Indeed, the sentiment that Tycho's antagonists stimulated him to an even greater exposition of his views was also expressed in respect of other conflicts. See, for example, Hagecius' comment on Tycho's "plagiarist" (Ursus), of 1st/11th of June 1590, in *TBOO* VII, 246.21-23.

[53] *TBOO* VII, 313.13-20. In this letter to Craig, Tycho quoted not only from letters to him by Kurtz, Hagecius, Scultetus, and Magini, but also from a letter sent by Magini to Gellius Sascerides.

[54] See *TBOO* VII, 283.8-11, Tycho to Young, 27th October 1590; 07.25-308.17, Tycho to Maitland, 13th November 1591; 318.27-319.1, Tycho to John Craig, 14th November 1591.

mathematicians in Germany were retracting their earlier ideas, which I had overthrown, keeping quiet, and as it were becoming dumb".[55] The letter that Tycho wrote to Young, just under three years later, provides an informative contrast: Tycho asked Young to greet *Thomas* Craig on his behalf, but not his brother, calling John "too snappish, on account of his arrogant self-love, and an enemy of unvanquished truth".[56] The turning point, as Tycho's correspondence reveals, was the 22nd of May, 1592, on which date our astronomer received Craig's reply to his challenge to either fight-on or surrender. Craig chose the former, sending with his letter a document entitled the *Capnuraniae restinctio, seu cometarum in aethera sublimationis refutatio* (that is, *The extinguishing of smoky-Urania, or a refutation of the raising of comets into the aether*).[57] He instructed Tycho to accept and make use of this "balm for treating that burning in heaven kindled by you, sent by your friendly opposing physician".[58]

Tycho objected to both the tone of this document and its contents. Besides complaining of Craig's insolence to correspondents such as Hagecius, Kurtz and Brucaeus, forwarding to some of them the *Restinctio* so they could appreciate the full magnitude of its rudeness, he raised the matter with Young, as we have seen, and with Maitland the chancellor.[59] Undoubtedly Craig was made to feel uncomfortable about his continued resistance, because in 1594 Tycho received from John Craig, and from Thomas Craig on his brother's behalf, a complete capitulation.[60] Admittedly, Craig attempted to justify himself by arguing that he had only complied with Tycho's wishes in continuing to argue his case as forcefully as he could, and

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[55] *TBOO* VII, 283.14-18: "Sed hominem eo plus diligo, quod eiuscemodi attentare ausus sit, omnibus in Germania eruditis Mathematicis, suas priores conceptiones, quas dilui, retractantibus, silentibus et quasi obmutescentibus ..." Tycho to Young, 27th October 1590.

[56] *TBOO* VII, 355.41-356.2: "Fratrem eius, quem meum Antagonistam vocas, attingere non audeo, cum præ arroganti philautia nimis mordax veritatisque invictæ hostis existat." Tycho to Young, 11th September 1593.

[57] See, for the portion of this document that survives, *TBOO* IV, 477-488. For the date of its receipt by Tycho, see Dreyer's note to *TBOO* VII, 334.8. Tycho acerbically commented on Craig's neologising in his letter to Maitland of 19th August 1592; see *TBOO* VII, 339.4-11.

[58] *TBOO* VII, 335.38-41: "... hoc cerotum ad restinguendam illam in coelo phlogosin abs te accensam ab amico antagonista medico mißum benigne accipito et usurpato." Craig to Tycho, 27th March 1592.

[59] See *TBOO* VII, 339.4-341.31, Tycho to Maitland, 19th August 1592; 342.34-343.6, Tycho to Hagecius, 28th September 1592; 348.38-349.21, Tycho to Kurtz, 19th April 1593. I infer that Tycho complained to Heinrich Brucaeus about Craig from Brucaeus' letter to Tycho of 5th November 1592; see *TBOO* VII 345.10-17.

[60] *TBOO* VII, 362.2-364.18, John Craig to Tycho, 22nd April 1594, and 364.20-365.16, Thomas Craig to Tycho, 1594.

by suggesting that the Dane was not himself without blame in setting the tone of the debate. "There were things in your *Apologia*", he wrote, "which could have turned the stomach of anyone: such as being charged with lack of skill, ignorance, enslaved judgement, and similar things ..."[61] But he promised to alter whatever Tycho required in his *Refutatio*, to change, excise or cancel passages according as he was instructed;[62] and his brother Thomas even stated that since the Craigs had never circulated the work, it could be suppressed altogether.[63]

In its way, this capitulation represented a victory not for Tycho but for Craig. The suggestion that the *Refutatio* be suppressed was of no value to the astronomer, since as the Scotsmen probably knew, he had already ensured its dissemination in manuscript.[64] More importantly, the retraction of the text alone was not at all what Tycho wanted; instead he was hoping for Craig's retraction of his views. In other words, what Tycho must have been looking for was an admission of error such as the one he claimed to have obtained in his final debate with Christoph Rothmann.[65] A letter containing such an admission of error would have been eminently publishable; whereas the one that Craig actually sent made it fairly clear that in obtaining his pyrrhic victory, Tycho had relied not on superior arguments alone, but also, as he would attempt to do in his priority dispute with Ursus, on his greater social status.[66] The stinging attack on the unnamed Craig in the letter to Rothmann, to be published in the letter-book, was probably therefore a response born of a significant frustration.

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[61] *TBOO* VII, 362.26-29: "Occurrebant in Apologia tua, quæ stomachum cuivis commovere potuißent, ut imperitiæ, ignorantiæ, mancipati iudicii et similium insimulari ..." John Craig to Tycho, 22nd April 1594. Craig had previously claimed in his *Capnuraniae restinctio* that Tycho's arguments had made him nauseous, and it is in this context that his comments in this letter must be interpreted. See Tycho's remarks to Rothmann in the matter, in his letter of January 14th 1595, *TBOO* VI, 324.14-20.

[62] *TBOO* VII, 362.39-1, & 363.14-20, John Craig to Tycho, 22nd April 1594.

[63] *TBOO* VII, 365.5-9: "Scriptum illud nunquam exiit, et scio me apud fratrem poße ut perpetuo supprimatur, vel si malis cum honorifica tui nominis et eruditionis mentione, et omni felle purgatum exeat; immo ut cum HORATIO loquar, sive flammis mandare velis, sive mari Adriano, utrumvis pro tuo arbitrio expectabis." Thomas Craig to Tycho, 1594.

[64] In his letter to Maitland of 19th August 1592, Tycho had declared his intention to forward the *Capnuraniae restinctio* to various German mathematicians, so this news could well have been passed on to the Craigs. See *TBOO* VII, 340.20-28. It is difficult to say for certain whether the circulation of the text reported to Tycho by Cort Aslakssøn, on 23rd October 1594, was something for which Tycho himself was wholly responsible. See *TBOO* VII, 367.21-28.

[65] *TBOO* VI, 218.1-223.3.

[66] See JARDINE, *The Birth of History and Philosophy of Science* and ROSEN, *Three Imperial Mathematicians* (both *op. cit.* note 2).

By way of conclusion, it is worth pointing out that some of the features shared between the Craig dispute and Tycho's dealings with Wittich, Ursus and Rothmann, besides the ones that I have so briefly sketched, are not restricted to this small set of interactions. Each of these episodes in Tycho's life attests to the importance of the rich manuscript, and particularly epistolary, culture, for the conscious shaping of his own and others' reputation, and indeed for the practice of astronomy. These famous debates broke out within a more extensive community, constituted by scholars who corresponded extensively with one another, and it is the study of that community that now demands the attention of historians.

Tycho Brahe and Prague: Crossroads of European Science, pp. 84–94, J. R. Christianson et al. (eds.), © *H. Deutsch 2002*

Tycho Brahe's Attitude towards Astrology and his Relations to Heinrich Rantzau

Günther Oestmann, Hamburg

Abstract

Contrary to his astronomical works and observations the astrological activities of Tycho Brahe have received less attention and are usually treated as an aberration characteristic for an astronomer of the Early Modern Period. The paper deals with Tycho's astrological commissions for the Danish court, his attempts to create a reformed astrology and his relations to Heinrich Rantzau (1526-1598), who was himself an ardent believer in astrology.

Both Tycho Brahe and Heinrich Rantzau (1526-1598), Danish governor of Schleswig and Holstein, were of old and noble lineage. With his passion for books, his patronage in various fields of humanistic learning and art Rantzau was considered a black swan among contemporary noblemen. His father Johann, who was an influential politician and commander, became governor of Schleswig-Holstein and witnessed Luther's appearance at the Imperial Diet at Worms.[1] Deeply impressed he joined the Protestant camp and later on sent his son to study in Wittenberg. During his long stay for about eight years young Heinrich was influenced by Philipp Melanchthon, who was an ardent believer in astrology. Melanchthon had studied in Tübingen under the eminent astronomer Johannes Stoeffler (1452-1531) and Rantzau was but one of his numerous students who left Wittenberg

[1] Michael Beuther, *Kurtzbegriffene Anzeygung/ vom Leben/ Stannde und Wesen/ der Gestrengen/ Edlen und Vesten/ Herrn Johann Ranzawen Ritters/ trejer Könige zu Dänemarck/ etc. gewesenen FeldObersten: Hainrich Ranzawen/ seines Sohns/ Königlicher Mayestet zu Dänemarck noch jetziger zeit verordneten Statthalters/ in den Fürstenthummen Sleßwick/ Holsaten/ Dietmarsen/ etc.* [...], Basel 1582, p. 368.

with a staunch belief in the new faith and the old art of astrology.[2] After taking over the ancestral seat of Breitenburg near Hamburg in 1563 Heinrich Rantzau established a library, which finally contained 6300 volumes in the main fields of knowledge: Logic, Mathematics, Physics, Medicine, Law, Theology and History. The end of this magnificent collection came in 1627, when Wallenstein's troops besieged Breitenburg and caused a havoc. Major parts of Rantzau's library were carried off to Prague and later on fell into the hands of Swedish troops.[3] Thus single volumes have been dispersed all over Northern Europe, but a considerable number of Count Rantzau's books still can be found in the National and University Library at Prague.[4]

Even these remains preserved by chance indicate a very well assorted library in the field of astronomy and astrology. The Danish governor must have possessed almost every relevant astrological publication of the sixteenth century, not to speak of manuscripts and numerous scientific instruments.[5] Rantzau's collection formed the starting point for his own publications, for he was himself an ambitious and prolific writer of several textbooks covering all aspects of the art. The fact that Rantzau's books are mainly industrious compilations of other works (including manuscripts) is in itself significant: In astrology not originality but referring to established authors was demanded with the intention to advance the art by understanding it properly.

The astronomical activities on the island of Hven did not escape the attentiveness of the Danish governor. Because also Tycho busied himself with astrological occupations one would expect to find traces in the correspondence of the two noblemen, but the 13 letters extant of the period between 1585-1597 mainly deal with the problem of paper supply for Tycho's printing press which he hoped to get from Rantzau's paper mill.[6] In his first letter from 1585 Tycho also asked to get on loan a catalog of as-

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[2] For a more detailed account see the study *Heinrich Rantzau und die Astrologie: Ein Beitrag zur Kulturgeschichte des 16. Jahrhunderts* by the author (Postdoctoral thesis, Hamburg 2001; forthcoming as vol. 2 of *Disquisitiones Historiae Scientiarum: Braunschweiger Beiträge zur Wissenschaftsgeschichte*).

[3] Marcus Posselt, "Die Bibliothek Heinrich Rantzau's", *Zeitschrift der Gesellschaft für Schleswig-Holstein-Lauenburgische Geschichte*, 11, 1881, p. 69-124.

[4] Isak Collijn, "Rester av Heinrich Rantzaus bibliotek på Breitenburg i National- och Universitetsbiblioteket i Prag", *Nordisk Tidskrift för Bok- och Biblioteksväsen*, 26, 1939, p. 125-153; 27, 1940, p. 179-238; 28, 1941, p. 1-14.

[5] Peter Lindeberg, *Hypotyposis Arcium, Palatiorum, Librorum, Pyramidum, Obeliscorum, Cipporum, Molarum, Fontium, Monumentorum et Epitaphiorum, ab illustri et strenuo Viro Henrico Ranzovio, Prorege et Equite Holsato, conditorum* [...], Frankfurt/M. 1592, p. 23.

[6] *TBOO*, vol. 7, p. 89f. (Hven, 8. 1. 1585).

trological books preserved in the governor's famous library in the castle of Breitenburg.[7] Three years later Tycho sent a horizontal sundial (*Scioterricum horizontale*) to Heinrich Rantzau and thanked for his efforts to supply him with paper.[8] Shortly afterwards Rantzau had confirmed the receipt of the instrument and also of a device suitable to explain the Tychonic system of the world easily.[9] In 1589 Tycho Brahe set up a paper mill on Hven[10] and asked Heinrich Rantzau to get a paper-maker (*Chartopaeus*) for him.[11] The last letters from 1597 deal with Tycho's wish to settle down somewhere on Rantzau's estate after he had fallen out of favour with King Christian.[12]

Heinrich Rantzau was of the opinion that the only way to lay a solid foundation for astrology was the improvement of its astronomical requirements, i.e. more correct calculations of planetary positions, as he explicitly stated in a letter to Tycho at the beginning of 1587. In Rantzau's opinion Astronomy proper rests on solid foundations derived from observations, but also its conjectural part (i.e. astrology) is justifiable. Failures in predictions must not be ascribed to the art itself, but are the result of imperfect knowledge. Moreover, God is free to alter events prescribed in the course of the stars according to His own discretion. From Tycho's observatory and his instruments Rantzau expected advances in both areas of astronomy.[13]

Together with the rather casual remark on the book catalogue this is the only reference to a discussion of astrological matters between Rantzau and Tycho. But the correspondence is obviously incomplete. In 1594 Rantzau wrote to a certain Ludolph Riddershusen,[14] that he had discussed with Tycho at length methods of directions and the problem whether the effect of precession should be taken into consideration when setting up astrological predictions.[15] Later on Tycho himself was in contact with Riddershusen

[7] "*Si catalogum Astrologicorum tuorum librorum ex amplißima tua Bibliotheca descriptum mihi transmittere non displicuerit, rem feceris longe gratißimam*" (*TBOO*, vol. 7, p. 90).

[8] *TBOO*, vol. 7, p. 124-127 (Uraniborg, 13. 9. 1588).

[9] *TBOO*, vol. 7, p. 385-389 (Uraniborg, 21. 12. 1588).

[10] N. A. Møller Nicolaisen, *Tycho Brahes Papirmølle paa Hven: Udgravningen 1933-34 og forsøg til rekonstruktion*, Copenhagen 1946.

[11] *TBOO*, vol. 7, p. 299-301 (Uraniborg, 7. 10. 1590).

[12] *TBOO*, vol. 8, p. 5f. (Segeberg, 17. 9. 1597); vol. 14, p. 124f. (Wandsbeck, 13. 12. 1597).

[13] *TBOO*, Bd. 6, S. 29f. (Segeberg, 17. 1. 1587).

[14] Riddershusen was born 1551 in Bremen (*TBOO*, vol. 8, p. 221), but apart from the date of his marriage and the date of birth of four children nothing is known about his life and profession. Research in the Bremen State Archive was in vain.

[15] Schleswig, Landesarchiv Schleswig-Holstein: Abt. 127.21, Ms. 293, p. 1171-1173.

on house division and direction techniques.[16]

There is no comprehensive treatment of Tycho's astrological activities available.[17] In his inaugural lecture *De disciplinis mathematicis* delivered at Copenhagen University in 1574 Tycho Brahe advocated the legitimacy both of natural and judicial astrology.[18] As a court astronomer to King Frederik II of Denmark Tycho was to deliver an annual almanac and he was commissioned to cast horoscopes for the newborn princes, Christian in 1577,[19] Ulrik in 1579[20] and Hans in 1583.[21]

The horoscope for Prince Christian has not survived in original, but in two copies written after 1588, the year of his coronation. In the circular scheme customary used by Tycho a false date of birth is given; it should read April 12th. Tycho employed the Prutenic Tables for calculating the planetary positions and added a few corrections based on his own observations. Contrary to the majority of astrologers in the 16th century who used the "rational method" preferred by Regiomontanus he employed a system of house division commonly ascribed to Campanus of Novara,[22] i.e. posi-

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[16] *TBOO*, vol. 8, p. 216-221 (Bremen, 16./26. 12. 1599); p. 304f. (Benatek, 10./20. 4. 1600).

[17] Despite its promising title FRANZ STUDNICKA'S publication *Bericht über die astrologischen Studien des Reformators der beobachtenden Astronomie, Tycho Brahe: Weitere Beiträge zur bevorstehenden Saecularfeier der Erinnerung an sein vor 300 Jahren erfolgtes Ableben* (Prague 1901) is limited to facsimiles of some astrological notes in books owned by Tycho accompanied by very poor commentaries.

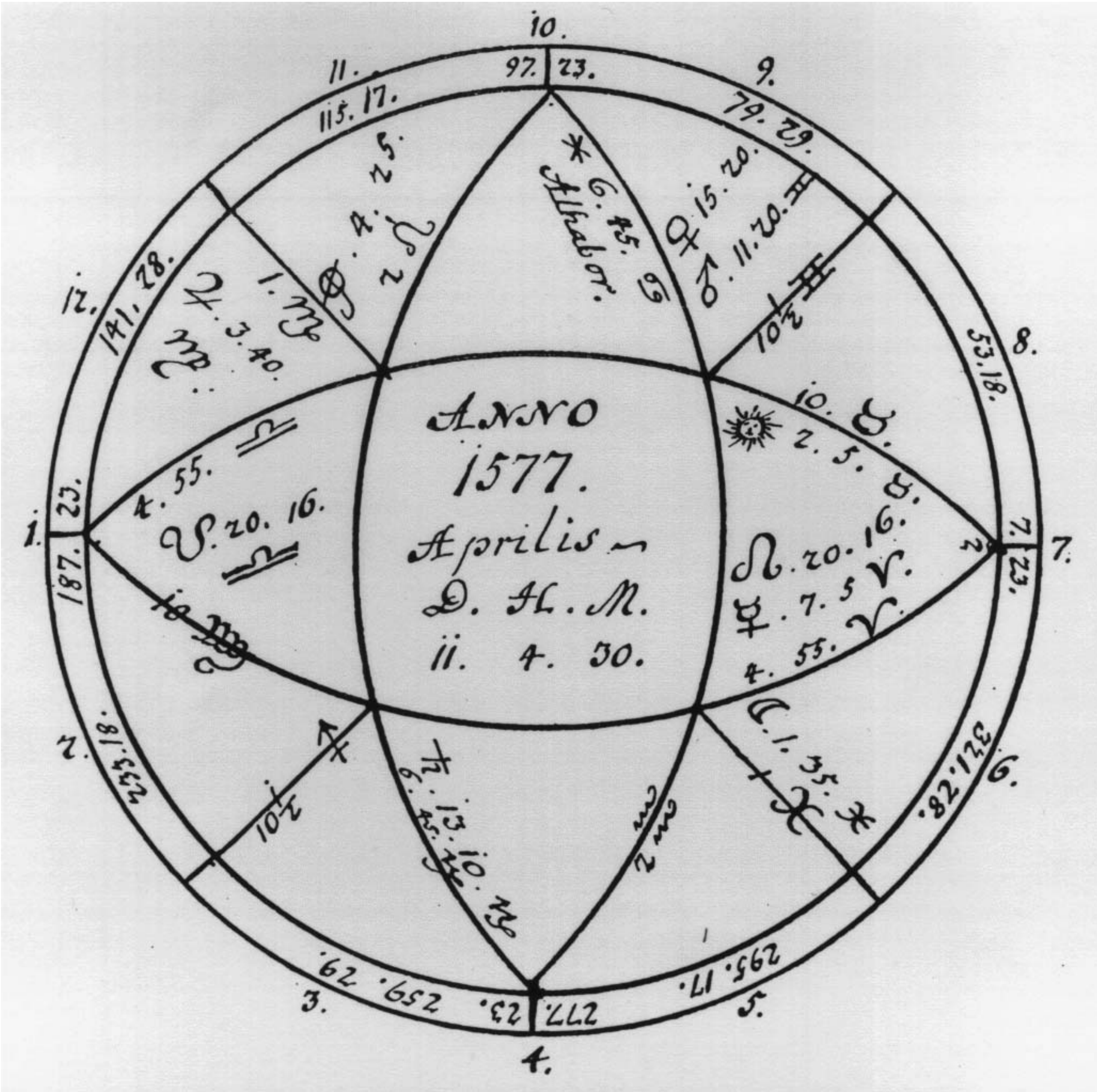
[18] *TBOO*, vol. 1, p. 143-173; for a summary of its contents see JOHN LOUIS EMIL DREYER, *Tycho Brahe: A Picture of Scientific Life and Work in the Sixteenth Century*, Edinburgh 1890 (2nd ed. New York 1963), p. 74-78. There is also a German translation by KARL ZELLER ("Über die mathematischen Wissenschaften: Eine Rede Tycho Brahes /De Disciplinis Mathematicis/", *Die Sterne: Monatsschrift über alle Gebiete der Himmelskunde*, 11, 1931, p. 100-122).

[19] *Horoscopus Regis Christian IV, ad mandatum Friderici II conscriptus in insula Hwena, a Tychone Brahe Uttonide, Cal. Jul. 1577 infanti Christiani inscriptus, nebst Astrolog. Urtheil von dieses jungen Herren Nativitet* (Copenhagen, Det kongelige Bibliotek: Gamle kongelig Samling, 1821 4°; *TBOO*, vol. 1, p. 179-208; German translation by SØREN PORSBORG in: LARS STEEN MICHAEL, ERIK MICHAEL and PER KJÆRGAARD RASMUSSEN, *Astrologie: Von Babylon zur Urknall-Theorie*, Wien/Köln/Weimar 2000, p. 248-268). See also DREYER (n. 18), p. 145-152.

[20] Copenhagen, Det kongelige Bibliotek: Gamle kongelig Samling, 1822 4° (*TBOO*, vol. 1, p. 209-250).

[21] Copenhagen, Det kongelige Bibliotek: Gamle kongelig Samling, 1823 4° (*TBOO*, vol. 1, p. 251-280).

[22] The method was already employed in Iran and Central Asia in the 11th century and preferred by al-Biruni (973-after 1050), who claimed to be its inventor; see JOHN DAVID NORTH, *Horoscopes and History* (= Warburg Institute: Surveys and Texts, vol. 13), London 1986, p. 29f., 32ff.; EDWARD STEWART KENNEDY, "The Astrological Houses as Defined by Medieval Islamic Astronomers", in: JOSEP CASULLERAS and JULIO SAMSÓ (Eds.), *From Baghdad to Barcelona: Studies in the Islamic Exact Sciences in Honour*



tional circles joining in the north and south point of the observer's horizon are laid at distances of 30° through the Prime Vertical, thus giving unequal sections of the ecliptic.

With the laborious task of calculating the positions of the planets and the cusps of the houses and examining the aspects – i.e. interpreting the radix horoscope – the astrologer's work was by no means finished. To foresee future events was most attractive. This was achieved by using methods of direction with the result of a distance measured along the celestial equator

of Prof. Juan Vernet, Barcelona 1996, vol. 2, p. 541.

which had to transformed into time.[23] Tycho's astrological interpretation of the geniture by using primary directions is divided into sections by topic: childhood, course of life, character, morals and disposition, body constitution, travels, marriage, children, friends and death. It concluded with the statement that no prediction is settled irrevocably but God disposes of everything according to His own will and judgement.

Tycho's book on the new star of 1572 also contains long astrological passages, in which the astrological significance of the event is discussed at length.[24] The horoscope Tycho cast for the event shows a system of eight houses which he obtained by dividing the Prime Vertical into steps of 45°.[25] By this time he obviously had completed an account on the various methods of house division, which was never published and is not extant in manuscript.[26] The same goes for a tract against contemporary astrological practice.[27]

Tycho was keenly interested in Astrometeorology and from 1582 onwards he kept long records of the weather which were correlated to planetary positions, the appearance of comets and the moon's phases.[28] His work in this field is characterized by a great concern for reliability. But in the course of time he got more and more sceptical mainly because of the insufficient precision to calculate planetary positions in advance. This is confirmed by a letter written in 1587 to Heinrich Below, Tycho's brother-in-law.[29] The Duke of Mecklenburg had obtained two prognostications issued by Tobias

[23]The rather complicated technical procedures cannot be expanded here at length. No comprehensive historical treatment is available with the exception of a publication by RÜDIGER PLANTIKO (*Primärdirektionen: Eine Darstellung ihrer Technik*, Mössingen 1996) which has to be read with some caution because of the author's obvious commitment to astrology.

[24]*De Nova et Nullius Aevi Memoria Prius Visa Stella, iam pridem Anno a nato Christo 1572 mense Novembrij primum conspecta, Contemplatio Mathematica,* [...], *TBOO*, vol. 1, p. 35ff.

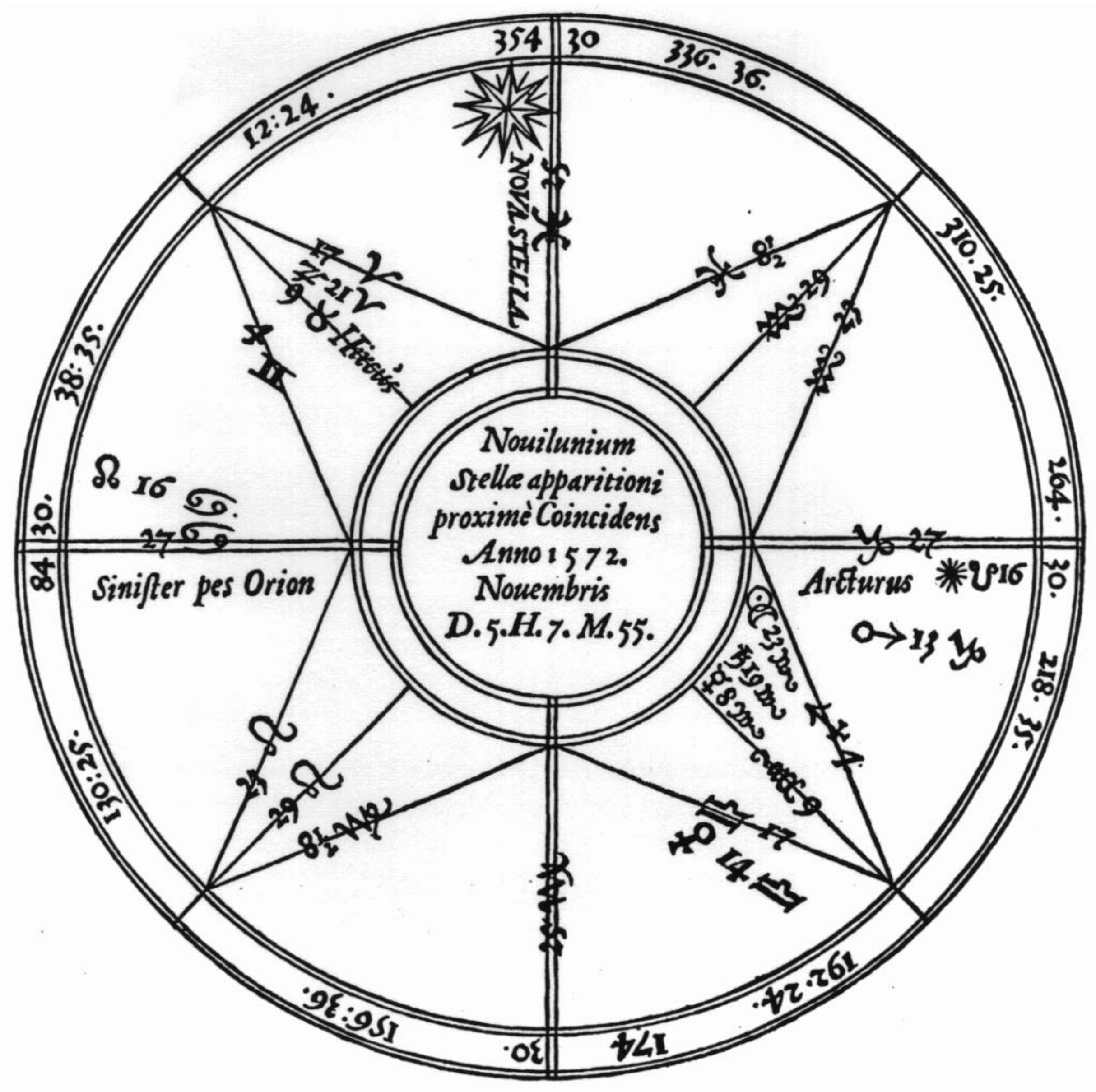
[25]*TBOO*, vol. 1, p. 33.

[26]*De variis astrologorum in coelestium domorum divisione opinionibus, earumque insufficientia* (*TBOO*, vol. 1, p. 38f).

[27]*Contra astrologos pro astrologia* (*TBOO*, vol. 1, p. 36).

[28]See PEDER JACOBSEN FLEMLØSE'S *Astrologia* (Uraniborg 1591), a booklet with weather predictions with a preface by Tycho Brahe, although it runs under Flemløse's name (JOHN ROBERT CHRISTIANSON, "Tycho Brahe's Cosmology from the Astrologia of 1591", *Isis: An International Review Devoted to the History of Science and its Cultural Influences*, 59, 1968, p. 312-318), and the *Diarium astrologicum et metheorologicum anni a nato Christo 1586* (Uraniborg 1586) which Tycho published under the name of another pupil, Elias Olsen.

[29]*TBOO*, vol. 7, pp. 116-119. The letter is printed also in: GEORG CHRISTIAN FRIEDRICH LISCH, "Tycho Brahe und seine Verhältnisse zu Meklenburg", *Jahrbücher des Vereins für mecklenburgische Geschichte und Alterthumskunde*, 34, 1869, p. 183-188, and DREYER (n. 18), p. 384-386.



Möller and Andreas Rosa for the year 1588 of which one predicted a year governed by two beneficial planets, the other by two malevolent ones and requested Below to inquire which of them were correct. Tycho explained this fact by pointing out that one judgement was based on the Alfonsine Tables, the other on the Prutenic Tables. Neither of these tables were accurate enough as he had found by comparing the calculations derived from them with his own observations so Tycho concluded neither prediction could be relied upon. The date for Below's question was not accidential. Already in 1564 Cyprianus Leovitius (1524-1574), court mathematician to

Count Palatine Ottheinrich,[30] had issued a booklet predicting horrible devastations, because in this very year (1588) twelve conjunctions in different signs of the zodiac and two occultations were to be expected.[31] This very popular prediction sometimes was ascribed also to Johannes Stoeffler or Johannes Schoener and handed down in popular rhymes.[32]

In his *Disputationes adversus astrologiam divinatricem* (1494) Pico della Mirandola had set out to demolish both the philosophical foundations of astrology and Ptolemy's astrological physics. He denied the antiquity of empirial records, i.e. he regarded the legendary observational tradition of the Chaldeans as fictitious. Moreover, Pico pointed out the inaccuracies of astronomical observations. Thus, astrologers in the 16th century were challenged to solve three problems: (i) the refinement of mathematical astronomy, (ii) the identification of a secure model of astrological physics, (iii) the necessity of defining reliable textual authority, and of establishing the correct reading of those texts.[33] Viewed in this broader context, Tycho Brahe's and Heinrich Rantzau's attitude towards astrology may be regarded as complementary. Concern for empirical reliability was characteristic for the astrological activities of both men, but while Tycho attempted to fulfil the first part of this "research program" by most accurate observations and his physico-astrological ambitions in meteorology, Heinrich Rantzau was engaged in publishing compilations and manuscript sources with the aim of establishing a secure foundation to the art. Finally in his description of the instruments Tycho employed on the island of Hven (*Astronomiae Instauratae Mechanica*, Wandsbeck 1598) he rendered account to the reader for his intentions and achievements. Concerning astrology he set out:

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[30] GÜNTHER OESTMANN, "Cyprianus Leovitius, der Astronom und Astrologe Ottheinrichs", in: *Proceedings of a symposium on Count Palatine Ottheinrich*, Neuburg an der Donau, Oct. 26th-28th, 2001 (*Pfalzgraf Ottheinrich: Politik, Kunst und Wissenschaft im 16. Jahrhundert*, Regensburg 2002, p. 348-359).

[31] *De conjunctionibus magnis insignioribus superiorum planetarum, Solis defectionibus, et Cometis, in quarta Monarchia, cum eorundem effectuum historica expositione* [...], Lauingen 1564; see JOSEPH MAYER, "Der Astronom Cyprianus Leovitius (1514-1574) und seine Schriften", *Bibliotheca mathematica: Zeitschrift für Geschichte der mathematischen Wissenschaften*, Series III, 4, 1903, p. 148-150.

[32] E.g. *Das tausent fünff hundert acht vnd achtzig jhar nimm war/ Geschicht nichts newes/ so vergehet die Welt gar*; see ERNST ZINNER, *Leben und Wirken des Johannes Müller von Königsberg, genannt Regiomontanus* (= Milliaria: Faksimiledrucke zur Dokumentation der Geistesentwicklung, vol. 10.1), 2nd ed. Osnabrück 1968, p. 205f.; ROBIN BRUCE BARNES, *Prophecy and Gnosis: Apocalypticism in the Wake of the Lutheran Reformation*, Stanford (Cal.) 1988, p. 163ff.

[33] As pointed out by STEVEN VANDEN BROECKE, *The Limits of Influence: Astrology at Louvain University 1520-1580*, PhD thesis Leuven 2000, p. 79, who examined the attempts for an astrological reform at Louvain.

"In the field of Astrology, too, we carried out work that should not be looked down upon by those who study the influences of the stars. Our purpose was to rid this field of mistakes and superstition, and to obtain the best possible agreement with the experience on which it is based. For I think that it will hardly be possible to find in this field a perfectly accurate theory that can come up to mathematical and astronomical truth. Having in my youth been more interested in this foretelling part of Astronomy that deals with prophesying and builds on conjectures, I later on, feeling that the courses of the stars upon which it builds were insufficiently known, put it aside until I should have remedied this want. After I at length obtained more accurate knowledge of the orbits of the celestial bodies, I took Astrology up again from time to time, and I arrived at the conclusion that this science, although it is considered idle and meaningless not only by laymen but also by most scholars, among which are even several astronomers, is really more reliable than one would think; and this is true not only with regard to meteorological influences and predictions of the weather *[natural astrology]*, but also concerning the predictions by nativities *[judicial astrology]*, provided that the times are determined correctly, and that the courses of the stars and their entrances into definite sections of the sky are utilized in accordance with the actual sky, and that their directions of motion and revolutions are correctly worked up. With regard to these points we have developed a method, based on experience, which differs from those used up to now. But we are not inclined to communicate this kind of astrological knowledge to others, since not a little has been made out by us in this field. For it is not given to everybody to know how to use it on their own, without superstition or excessive confidence, which is not wise to show towards created things. Therefore we shall not publish any, or at least very little, of the things that we have found out in this field."[34]

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[34]Hans Raeder, Elis and Bengt Strömgren (Eds. and transl.), *Tycho Brahe's description of his instruments and scientific works as given in his Astronomiae Instauratae Mechanica (Wandesburgi 1598)*, Copenhagen 1946, p. 117f. Latin text in *TBOO*, vol. 5, p. 117: "*In Astrologicis quoque effectus siderum scrutantibus non contemnandam locavimus operam, ut et haec, a mendis et superstitionibus vindicata, experientiae, cui innituntur, utplurimum consona sint. Nam exactißimam in iis adinvenire rationem, quae Geometricae et Astronomicae veritati par sit, minus duco poßibile. Cum vero huic Prognosticae Astronomiae parti, quae mantica et Stochastica est, in adolescentiâ impensius addictus fuißem, posteaque ob motus Siderum, quibus fundatur, non satis perspectos eam seposuißem, donec huic incommodo subveniretur; compertis demum exactius Siderum viis, eam subinde in manus resumendo, majorem subeße certitudinem huic cognitioni, utut vana et frustranea non solum vulgo, sed et plerisque Doctis, adeoque nonnullis inter eos Mathematicis habeatur, comperi, quam quis facile existimârit: Idque tam in influentiis et praedictionibus meteorologicis, quam Genethliacis, modo tempora rite constent, et motus Siderum atque ingreßus Coelo consoni adhibeantur, ac directi-*

Thus Tycho's astrological ambitions were more than an aberration supposed to be characteristic for an astronomer of the sixteenth century. His aim was the construction of a reformed astrology, but for a publication he thought time not yet ripe. Astrology and Alchemy were integral components of Tycho's cosmology and this view found an artistic expression in

ones atque revolutiones rite administrentur: In quibus duobus nos etiam aliam ab ipsâ experientiâ extruximus rationem, quam hactenus usitatum fuit. Sed nos istiuscemodi Astrologica non libenter aliis impertimur, quatenus haud pauca in his explorata habemus: siquidem non omnes eâ quâ decet circumspectione citra superstitionem et nimiam confidentiam, quae nullis creaturis tribuenda est, discrete uti nôrint. Ideoque aut nulla aut admodum pauca ex nostris inventis de his in publicum evulgabimus."

two vignettes for his books *De mundi aetherei phaenomenis* (1588), *Epistolarum astronomicarum* (1596) and *Astronomiae instauratae mechanica* (1598). Both vignettes show a man in reclining posture and a youth, but in one case the man is looking upward into the sky and leaning on a globe with a pair of compasses in his hands. In the other case he is accompanied by a chemical apparatus, holds a bunch of herbs in his hands and looks downward. The vignettes bear the meaningful captions SUSPICIENDO DESPICIO (By looking up I see downward) and DESPICIENDO SUSPICIO (By looking down I see upward).

IMPRESSVM WANDESBVRGI IN ARCE RANZOVIANA
PROPE HAMBURGUM SITA, PROPRIA AUTHORIS
TYPOGRAPHIA OPERA PHILIPPI DE OHR
CHALCOGRAPHI HAMBURGENSIS
INEUNTE ANNO M. D. IIC.

Tycho Brahe and Prague: Crossroads of European Science, pp. 95–101,
J. R. Christianson et al. (eds.), © *H. Deutsch 2002*

Tycho Brahe Censured

Michel-Pierre Lerner, Paris[1]

In his *Almagestum novum* published in 1651, the great Jesuit astronomer Giambattista Riccioli pronounced with rare severity on Tycho Brahe. Commenting on a wish expressed by the Danish astronomer on his death bed: *Ne frustra vixisse videar* ("Let it not be thought that my life was in vain"),[2] Riccioli asserted that because of his religious belief, Brahe could not have achieved eternal felicity. And as proof of Brahe's impiety, Riccioli referred to precisely three pages in Tycho Brahe's *Astronomiæ Instauratæ Progymnasmata* (Uraniborg – Prague 1602) where, according to Riccioli, Brahe excessively emphasized his propensity for Luther, Melanchthon and Chytraeus.[3]

The recent discovery of several documents in the Archives of the Congregation for the Doctrine of the Faith (ACDF) throws some light on Riccioli's denunciation of Brahe's impiety. A decree of the Congregation of the Holy

[1] Grateful thanks are expressed to Francesco Beretta – with whom I expect to publish a more detailed study on this subject – for bringing to my knowledge documents in the ACDF, as well as for his remarks on their significance, and to W.G.L. Randles for the translation of this text into English.

[2] The Danish astronomer's wish is known to us through Kepler's report published for the first time by W. Snell in his *Coeli & siderum in eo errantium observationes Hassiacae ... nunc primum publicante Willebrordo Snellio*, Lugduni Batavorum, 1618, p. 83-84. These words are to be found on Brahe's gravestone in the Tyn Church (Prague): *Tycho Brahe opera omnia*, J.L.E. Dreyer ed., vol. 14, "Epistolae et acta ad vitam Tychonis", n° 232, p. 241. On Brahe's death, see also E. Rosen, *Three Imperial Mathematicians: Kepler trapped between Tycho Brahe and Ursus*, New York, Abaris Books, 1986, p. 311-315.

[3] *Almagestum novum astronomiam veterem novamque complectens ... in tres tomos distributam* (Pars prior-posterior tomi primi), 2 vol., Bononiae, ex Typographia Haeredis Victorii Benatii, 1651: "Chronici pars II", Tomi primi pars prior, p. XLVI col. b, and Libri VIII Sectio I, Tomi primi pars posterior, p. 74, col. b. There is no general study on Riccioli; see the recent contribution by Ugo Baldini, "La formazione scientifica di Giovanni Riccioli" (with bibliography), in Luigi Pepe ed., *Copernico e la questione copernicana in Italia dal XVI al XIX secolo* (Pubblicazioni dell'Università di Ferrara IV), Firenze, Leo S. Olschki, 1996, p. 123-182.

Office promulgated on 12 August 1620 (feria IV) reveals that the three pages in the *Progymnasmata* mentioned in Riccioli's *Almagestum novum*, figured among those indicated as calling for correction in the anonymous censure accompanying the decree. But there is still an important point: although the decree was registered officially by a notary, Brahe's book never figured in the *Index librorum prohibitorum* published by Rome, even with the lesser sanction: "donec corrigatur". The fact that there was no publication of the censure is in itself surprising, considering that the problem posed by the *Progymnasmata* was submitted for examination by a very highly placed figure: the Jesuit Robert Bellarmine.

It is known that by a decree of the Congregation of the Holy Office going back to 1 July 1620 (feria IV), order had been given to the Inquisitor of Milan to forward a copy of Brahe's book to Rome. When Cardinal Bellarmine, who was also a member of the Congregation of the Index, as well as that of the Inquisition, received the dossier transmitted to him, examination of it led him to make a surprising judgement on the credo of the Danish astronomer. In a text of which the original has come down to us, Bellarmine first of all details the reasons proving that Brahe was a "heretic". But then later he admits that, for reasons which are to us indeed hardly convincing, Brahe could have been a "Catholic"! This he did without clearly settling for one or the other of the two possibilities. In conclusion, Bellarmine suggested that "the book could perhaps be corrected" by suppressing the praises addressed to heretics, as well as the letters written to the Landgrave of Hesse and those sent to "heretic princes".[4] Yet, after listening, during the session of 12 August 1620, to the "observations of the Illustrious Cardinal Bellarmine on Brahe's book", the members of the Congregation took a decision not entirely in agreement with Bellarmine's position as given in writing: they in effect decreed that in the *Progymnasmata*, "the names of heretics and the praises which accompany them be

[4]ACDF, Sant' Ufficio, *Censurae librorum 1607-1625*, fasc. 13, f. 51: "Quod hic auctor fuerit haereticus, videtur intelligi posse, tum ex laudibus, quibus ornat hereticos, Lutherum, Melancthonem, Bezam, Cythraeum: tum quia erat amicissimus Gulielmi Hassiae Landgravii, haeretici Lutherani.

Quod fortasse fuerit Catholicus, videtur colligi ex eo quod filii eius, post mortem ipsius, dedicant eius libros Rodulpho Imperatori; et vocant parentem suum, piae memoriae virum. Deinde ipse idem Imperator suis sumptibus iussit excudi aliqua eius opera, ut patet ex libro in folio edito, qui est quasi tertius tomus. Non est autem credibile, Imperatorem Catholicum iussisse excudi opera hominis haeretici.

Posset fortasse corrigi liber, sublatis laudibus haereticorum, et epistolis Principis haeretici, et epistolis ad Principes haereticos missis" (our transcription); see also Peter Godman, *The Saint as Censor. Robert Bellarmine between Inquisition and Index* (Studies in Medieval and Reformation Thought LXXX), Leiden-Boston-Köln, 2000, p. 307.

suppressed".

How was this decision of the Cardinal-Inquisitors put into effect? The corrections suggested in four places by the author of the anonymous censure, as conserved in the dossier such as it has come down to us, are far from corresponding with all the passages which it would have been necessary to correct in order to conform to the decree of 1620. As for Bellarmine's written suggestions specifically concerning the letters written by the Landgrave of Hesse William IV, or which are addressed to him, – they make up a non-negligeable part of the volume concerned – they were not followed.

Without being rendered official, the censure of Brahe's book was however partially put into effect, as can be seen from some copies of the *Progymnasmata* with handwritten corrections in the places indicated. These are copies which I have been able to consult. But the number of copies examined are still too few to be significant. It can nevertheless be conjectured that this censure was especially circulated in the Jesuit *milieux* and that many more corrected copies among the volumes coming from Jesuit libraries will be discovered. It was perhaps one of these copies which Riccioli had before him when he made his critical judgement on Brahe.

While absent from the Roman indexes, Tycho Brahe's *Progymnasmata* did figure in those published in Spain. In the Spanish indexes, Brahe's work was examined more extensively than was the case in Rome. In the different editions which I have been able to consult, the "Lutheran" Brahe is a banned author and reading him is only permitted on condition of certain corrections having been made. The corrections concern, not one but four of his works: the *Astronomiæ instauratæ progymnasmata*, the *De mundi Ætherei recentioribus phænomenis*, the *Epistolæ Astronomicæ* and finally the *De disciplinis Mathematicis oratio.*

I shall quote some examples of the corrections demanded by the Spanish censors in the 1640 edition of the Spanish Index. In the *De ... recentioribus phænomenis* order is given to add, after Michael Maestlin's name, the mention: "Auctor damnatus". In the *Epistolæ astronomicæ*, there should be added in the margin opposite the name of Christoph Rothmann, the defender with Copernicus of the earth's motion, the words: "Cave ab hac opinione iam in Ecclesia explosa". The *Progymnasmata* was more carefully gone through, since nine passages were identified (with instructions as to what should be said about them). Four of these already figured in the Roman censure of 1620, showing that the correspondence could not have been by accident.[5]

[5]See Plate I (*Index novissimus librorum prohibitorum et expurgandorum, iussu ac studio Illustrissimi ac R.D.D. Antonii a Soto Maior ...*, Madriti 1640, p. 939).

& Expurgat. T I. Claſſ. 939

TIMOTEVS Neocorus.

TIMOTEVS Poteratius.
Gallus, Theologus, Luthero-Zuinglian.

TRISTRAMVS Revell.
Anglus, Theologus, Lutheranus.

TVSANVS Berchotus.
Seu, *Toſſanus Berchetus*, ſeu, *Thoſſanus*, I. C. Calvin. Gallus Ligonienſis.

TYCHO Braha, *ſeu*, Brahe.
Danus, Aſtronomus, Lutheranus.

EIVS *Aſtronomiæ inſtauratæ progymnaſmata.*

Prima pars, quæ eſt, *De reſtitutione motuum, &c.* &, *De nova ſtella, &c.* excudi primum cæpta Vramburgi Daniæ, abſoluta Pragæ 1610.

Poſt adhibitam notam, *Damnati Auctoris, & permiſſi operis.*

In parte ſecunda, quæ incipit pag. 297. cap. 3. quod excurrit deinceps per multa folia, pag. 327. poſt quatuor lineas à principio, & poſt illa verba, *Prænunciam eſſe existimarunt*, dele quinque lineas ſequentes, cum ſequenti epigrammate ſexhaſtico.

Parte tertia cap. 8. inferius, in titulo ipſius epiſtolæ, qui conſtat quatuor lineis, expunge omnia, præter nomen Hieronymi Vvolphij. ═ Pag. 621. initio, poſt illa verba, *Vvolphangi Schuleri*, adde, *Profeſſoris Vitereyenẽſis damnatæ memoriæ.* ═ Pag. 712. initio ſolo retento nomine Davidis Chytræi Profeſſoris Academiæ Roſtochianæ, (cui adde Auctor damnatus) dele ſedecim lin. uſque ad, *De hac autem ſtella*, excluſ. ═ Pag. 713. poſt ſex lineas, ab initio, poſt illa verba, *Diſpoſitione procedant*, dele novem lineas, uſque ad, *Luna opinionum varietate, &c.* excluſ. ═ Pag. 716. ad medium, in titulo, *Guilielmus Poſtellus*, adde, *Auctor damnatus.* ═ Pag. 719. poſt initium, lin. 19. retento nomine, *Ioſephi Scaligeri*, dele duas lineas. ═ Pag. 751. ſub titulo, *Andreæ Nolthi*, linea 4. ab initio, poſt illa verba, *Ignoranter ſeducit*, dele duas lineas, uſque ad, *quibus enim invictis*, excluſ. ═ Pag. 776. 6. linea ante finem, poſt illa verba, *Odioſè interpretatur*, dele reliquum paginæ, cum ferè integro fol. ſequenti, uſque ad pag. 778. poſt medium, & linea 10. à fine, in illis verbis, *Et ſi enim vera*, excluſ. ═ In concluſione vero operis, pag. 807. linea 5. ab initio, poſt illa verba, *Suo tempore accelerabo*, dele reliquum pagin. uſque ad initium pag. 808. & ad illa verba, *Quod ſi qui mundi*, excluſ.

Ex Indice expunge, *Philip. Melancthon.*

EIVSDEM *De mundi Ætherei recentioribus Phænomenis*, liber ſecundus, excudi primum cœptus Vramburgi Daniæ, Pragæ Bohemiæ abſolutus 1610. permit.

Præfigenda nota Auctoris damnati, & operis cum expurgatione permiſſi.

Pag. 245. ſub Titulo, *Michael Moeſtlinus Goeppingenus*, adde, *Auctor damnatus.*

EIVSDEM *Epiſtolæ Aſtronomicæ*, Vramburgi 1610. permit.

Præfige notam ſolitam Auctoris, & operis. ═ Quæ vero in eadem Epiſtola Rothmannus ſcribit, de defendendo motu terræ cum Copernico, notanda ſunt appoſita ad marginem cautione, *Cave ab hac opinione iam in Eccleſia exploſa.* ═ Pag. 296. lin. 5. ab initio paginæ, poſt illa verba, *Me Vvithichiũ*, dele quatuor ferè lineas, uſque ad, *Sed lapſus, quibus*, excluſ. ═ Et tandem p. 309. *In parentatione Landigravij*, poſt, *Ambroſiaquè frui*, dele quatuor ultima diſticha.

EIVSDEM *De diſciplinis Mathematicis oratio.* Hamburgi 1621. permit.

Pag. 30. ad finem, lin. 3. dele vocem, *Fide.* ═ Et pag. ſequent. 31. linea 5. ab initio, poſt illa verba, *In abuſum deveniat*, dele 3. lin. uſque ad, *Idemquè in alijs*, excluſ.

EN INGLES.

THOMAS Adams, *ſeu*, Adamus.

KKKK 2 SE-

At the present stage of this investigation, a certain number of points remain to be cleared up. In particular:

1) Identification of the author of the denunciation (or denunciations) of the *Progymnasmata* which led Bellarmine to formulate his judgement on Brahe and to propose a remedy making the reading of the book inoffensive for Catholics.

2) Tracing out how the censure was circulated within the Jesuit Order and its impact on the copies of the *Progymnasmata* (including the Frankfurt printings of 1610 and 1648) acquired by Jesuit libraries.

3) Settling what connection there may have been between the Roman censure and the corrections required of Brahe's works in the Spanish indexes.[6]

Researches in the holdings of archives and libraries should enable an exact assessment to be made of the extent to which the censure of Tycho Brahe spread into the editions quoted above. However it is already possible to make a judgement on the significance and limits of this attempt, which in any case proved to be no more than empty gesticulation.

After Clavius' recognition in 1611 that the Ptolemaic system was no longer tenable as such, together with the condemnation in 1616 of Copernican heliocentrism, Catholic astronomers had hardly any choice. The only acceptable system was the geo-heliocentric model proposed by Tycho Brahe, which offered the advantage of satisfying the requirements of both astronomical calculation and physics, as well as the literal sense of Scripture. From the year 1610 onwards, the Jesuits began more or less overtly promoting the Tychonic system, in particular with Christoph Scheiner's *Disquisitiones mathematicæ* (Ingoldstadt 1614), Orazio Grassi's *De tribus cometis anni 1618 disputatio astronomica* (Rome 1618), his *Libra astronomica ac philosophica*, published under a pseudonym of Lotario Sarsi (Perugia 1619), and Johann Baptist Cysat's *Mathematica astronomica de loco, motu, magnitudine et causis cometae qui sub fine anni 1618. et initium 1619. in caelo fulsit* (Ingoldstadt 1619). Furthermore in an anonymous satirical work published in Milan in 1619 with the title *Assemblea celeste radunata novamente in Parnasso sopra la nova Cometa*, Tycho Brahe was praised as a "restorer" of astronomy as well as for his doctrine of comets and of fluid heavens, which was to be preferred to Aristotle's dogma.[7]

[6] On the censure of scientific works in Spain, see José Pardo Tomás, *Ciencia y censura. La Inquisición Española y los libros científicos en los siglos XVI y XVII* (Consejo Superior de Investigaciones Científicas), Madrid, 1991.

[7] See on this work the recent edition and commentary by Ottavio Besomi and Michele Camerota, *Galileo e il Parnaso Tychonico. Un capitolo inedito del dibattito sulle comete tra finzione letteraria e trattazione scientifica* (Biblioteca di Nuncius.

But there remained the inconvenient fact that Tycho Brahe was a Lutheran and this raised a difficulty in the eyes of a number of Catholics.[8] Proof of this appears in the Jesuit censors' reaction in 1614 to the manuscript of *Aristotelis loca mathematica* by Giuseppe Biancani s.j. (1566-1624), later printed (Bologna 1615). They demanded that the latter suppress all the praises that he had thought fit to discern to "heretical" authors such as Tycho Brahe, the Landgrave of Hesse, Michael Maestlin, Cornelius Gemma, Helisaeus Röslin, Christoph Rothmann and Kepler.[9] Five years later, Biancani published his *Sphaera Mundi*, the first Tychonic treatise written by a Catholic author, from which was carefully eliminated any praise of Brahe or of other Protestant writers. It is probably not a coincidence that the censure of the *Progymnasmata* dates from the same year 1620.

What basic conclusion can now be drawn from the above? Less than a decade after the appearance of the last edition of Clavius' *Commentary on the Sphere of Sacrobosco* (published in the third volume of his *Opera mathematica V Tomis distributa ...,* Moguntiae 1611-1612) followed shortly after by his death, the Tychonic system had become the official cosmological reference in Rome.[10] This system was the only one that could offer a rampart against Copernican heliocentrism which was being defended by Galileo and his disciples in Italy, and by Maestlin and Kepler in Germany (Kepler's *Epitome* was put on the Roman Index in 1619). Francesco Ingoli's *De situ et quiete terrae contra Copernici systema disputatio* written in 1616 and sent to Galileo and Kepler illustrates significantly this use of Brahe by a Catholic theologian against the heliocentric theory.[11] Making a serious issue out of Brahe's religion to condemn him, would thus have been inconceivable. For a long time already, the Church of the Counter Reformation had seen that in the case of books held to be useful, even if written by heretics, so long as the subject matter was not heretical, such as

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Studi e testi XLI), Firenze, Leo S. Olschki, 2000.

[8]In 1618, Girolamo della Sommaia, "provveditore" of the University of Pisa, wrote that according to some members of the Barnabite Order and other Catholics: "Tichone ha qualch'opinione heretica ..." (*Galileo e il Parnaso Tychonico*, op. cit. note 7, p. 154).

[9]Ugo Baldini, *"Legem impone subactis". Studi su filosofia e scienza dei gesuiti in Italia 1540-1632*, Roma, Bulzoni, 1992, p. 217-250, spec. p. 230-231: "Constat enim aut hos omnes, aut ex his plerosque, atque adeo ipsum Tichonem, quem tanti facit [i.e. Biancanus], aut hereticos fuisse, aut valde suspectos".

[10]Michel-Pierre Lerner, "L'entrée de Tycho Brahe chez les jésuites ou le chant du cygne de Clavius", in Luce Giard ed., *Les jésuites à la Renaissance. Système éducatif et production du savoir* (Bibliothèque d'histoire des sciences), Paris, P.U.F., 1995, p. 145-185.

[11]Massimo Bucciantini, *Contro Galileo. Alle origini dell'Affaire* (Biblioteca di Nuncius. Studi e testi XIX), Firenze, Leo S. Olschki, 1995, p. 88-97.

grammar or mathematics, the danger in reading them was minimal if not inexistent. Bellarmine, wishing to allay the scruples of a few consciences shocked by aspects that were secondary compared to the usefulness to be derived from Brahe's works, had realized that his book did not deserve to be put on the Index. At the most, slight corrections could be made in it, leaving intact the massive approval shown by Catholics for the Tychonic system. As for the apparently more severe treatment that the Spaniards reserved for Tycho Brahe, it in no way hindered the adoption of the system in the lands of the Catholic King.

Tycho Brahe and Prague: Crossroads of European Science, pp. 102–112,
J. R. Christianson et al. (eds.), © *H. Deutsch 2002*

Michael Mästlin and His Relationship with Tycho Brahe

Gerhard Betsch, Weil im Schönbuch and Tübingen

Michael Mästlin was Kepler's teacher, and an astronomer of high reputation at his time. I shall comment below on some of his scientific achievements. Concerning his relationship with Tycho Brahe we can say:

- Michael Mästlin observed the supernova of 1572 and the comet of 1577, and published treatises on these celestial objects – like Tycho Brahe. And in fact Tycho Brahe reviewed and commented the treatises by Michael Mästlin.
- Michael Mästlin was deeply involved in the publication of Kepler's first work, the *Mysterium Cosmographicum* of 1596. The only existing letter of Tycho Brahe to Michael Mästlin – of (21 April) 1 May 1598 – is related to the *Mysterium Cosmographicum.*
- Furthermore, a fairly complete collection of Michael Mästlin's observations is contained in the *Historia Coelestis* by Albertus Curtius, which is supposed to be a collection of observations by Tycho Brahe *and others* (!). Mästlin was very prominent among the "others". His observations are listed under the headline *Observationes Virtembergicae.*

It is the purpose of this note to give some details.

Biographical information[1] on Michael Mästlin (MM) in tabellary form

[1] This biographical information is based on the usual biographical dictionaries (*ADB, DSB*, Poggendorff ...) and on Jarrell 71, Kommerell, Steiff. For further details I refer to a forthcoming paper of mine.

Different spellings of Mästlin's name are: Maestlin, Moestlin, Maestlinus, Maeschtlinus, Mästle, Möschlin, Möschlinus, Möstlin. These different spellings are easily explained by the possible pronounciation of the name in the local dialect. Michael Mästlin was born on 30 September 1550 in Göppingen (40 km east of Stuttgart), and died on 20/30 October 1631 in Tübingen.

Training as a scientist, and first teaching experience

Ca. 1564-1569: MM attends the Lutheran monastic schools in Königsbronn (40 km north of Ulm) and Herrenalb (near Karlsruhe)

1569 March 30: BA. April: MM is accepted as a student to the Stipendium Ducale (Evangelisches Stift) in Tübingen

1571 August 1: MA

1573 January: MM completes his study of theology

1573-1576 Repetens Mathematicus (Tutor for Mathematical Sciences) in the Evangelische Stift in Tübingen

1575/76 Temporary Lecturer replacing the absent Philippus Apianus

Professional Career

1577-1580 Diaconus (Lutheran Second Pastor) at Backnang (30 km NE of Stuttgart)

1580-1584 Professor of Mathesis (Mathematical Sciences) at Heidelberg

1584-1631 Professor of Mathesis at Tübingen (for 47 years !)

Career as an Astronomer / Selected Works

1570 July 6: The student MM buys a volume from the widow of Victorinus Strigel containing *De revolutionibus orbium coelestium* (first ed. of 1543) by Copernicus and *De triangulis omnimodis ...* (1533) by Regiomontanus.[2] Cf. the date of Mästlin's Master degree: 1 August 1571.

1571 August 28 (date of preface): The young Magister Michael Mästlin completes the second edition of Erasmus Reinhold's *Tabulae Prutenicae*, with a preface, and a long and impressive list of corrections.

1573 *Demonstratio Astronomica Loci Novae Stellae ....* A short tract on the new star (the supernova) of November 1572; the tract appeared as an appendix to the *Consideratio Novae Stellae ...* by the Tübingen Professor Nicodemus Frischlin (1547-1590). Printed in Tübingen.[3] The position of

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[2] OWEN GINGERICH, "Mästlin's, Kepler's, and Schickard's Copies of 'De revolutionibus'", pp. 167-183, in particular 168-169. In: FRIEDRICH SECK (Ed.), *Zum 400. Geburtstag von Wilhelm Schickard.* Contubernium 41. Sigmaringen 1995.

[3] Contrary to THOREN 73, there do exist surviving copies of Mästlin's tract. Two copies are in Tübingen.

the new star is determined by Mästlin's "thread method", to be described below.

1578 *Observatio & Demonstratio Cometae aetherei, Qui Anno 1577, et 1578 Constitutus in Sphaera Veneris Apparuit ...*; appeared in Tübingen. A treatise on the comet of 1577, and perhaps the most important of Mästlin's works (Jarrell 71).

1580 *Ephemerides Novae, ab anno salutiferae incarnationis 1577, ad annum 1590, supputatae ex tabulis Prutenicis* (!). Ephemerides, computed for the horizon of Tübingen (longitude 29 degrees and 45′; latitude 48 degrees and 24′). Printed in Tübingen.

1582 *Epitome Astronomiae*. Appeared in Heidelberg. A textbook of astronomy for beginners, on a geocentric (!) base. 6 more editions were printed in Tübingen. This was the textbook used by the student Johannes Kepler. The latter refers to his teacher's book by naming his own monograph of 1618-1621 *Epitome Astronomiae Copernicanae*.

1589-1594 Johannes Kepler was a student in Tübingen.

1596 Kepler's *Mysterium Cosmographicum* [Correct title: *Prodromus dissertationum cosmographicarum continens Mysterium Cosmographicum ...*] appeared in Tübingen, with strong support, and substantial help of Mästlin.

Some Comments and Details

The Beginnings

Mästlin's interest in astronomy was apparent at a very early age. Still a student in the monastic school (at Herrenalb ?), he observed the solar eclipse of April 9, 1567.[4] The acquisition on July 6, 1570, of the volume containing Copernicus' *De revolutionibus ...* and *De triangulis omnimodis ...* by Regiomontanus was certainly an important step for the young scholar. It is also remarkable, that Mästlin completed the second revised edition of the *Tabulae Prutenicae* only four weeks after earning his Master Degree.

The *Demonstratio Astronomica Loci Novae Stellae* of 1573 is a very remarkable work of a still very young scholar. It involves Mästlin's *thread method*. Mästlin shows that the new star of 1572 must belong to the sphere of fixed stars, which means a sensational contradiction to Aristotelian natural philosophy.

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[4] *Hist. Coel., Lib. Prolegomenos*, p. LXXIV.

The Thread Method

Mästlin, lacking suitable instruments at the time, determined the position of the new star of 1572 by his thread method. A thread stretched by both hands, together with the observer's eye, determines a plane which intersects with the heavenly sphere in a main circle. Hence, if stars A, C, and E are on the same main circle of the heavenly sphere, then they must all "coincide" with the stretched thread at the same moment. This can be observed in darkness, and without fixing the thread by a stand.

Now Mästlin choose stars A, B, C, and D *of known position* such that A, C, and the new star E are "in line", i.e. on the same main circle; and such that B, D, and E are on the same main circle – which he could do stretching a thread. (Of course, A, B, C, and D have to be the vertices of a "non-degenerate" tetragon on the heavenly sphere.) Mästlin took the positions of A, B, C, and D from a star catalogue of Erasmus Reinhold.

To determine the position of the new star E means to compute – by the methods of spherical geometry/trigonometry – the position of the intersection point of the diagonals in a spherical tetragon. This problem was by no means trivial; it involved a series of theorems from the books Mästlin had bought on 6 July, 1570 from Strigel's widow.

Mästlin proved by his thread method, that the new star of November 1572 did not move with respect to the fixed stars in his neighbourhood (and hence belonged to the fixed star region); and he determined the position of the new star with admirable accuracy.[5]

However, a star position determined by the thread method could only be as accurate as the positions of the "base points" A, B, C, D taken from a star catalogue. Hence, Mästlin intended to get instruments as soon as possible and to make accurate measurements himself with his own instruments; in fact, from 1577/78 on he did have a quadrant, a large and very good radius astronomicus (staff of St. James), a camera obscura, and a fairly good clock.[6]

Book on the Comet of 1577 and the Ephemerides

The great comet of 1577 gained much attention, and prompted a long list of scientific tracts and pamphlets. Mästlin's *Observatio & Demonstratio Cometae Aetherei ...*, printed 1578, is possibly Mästlin's most important work. It is "the first published work to claim that comets could move in

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[5] THOREN 139 calls Mästlin's thread method "medieval compared with the modern methods that Tycho had developed", but goes on to say: "It was Mästlin's analysis of his results, rather than his methods of observation, that interested Tycho".

[6] JARRELL 71, 85/86.

orbits, the first to provide such an orbital calculation, and an offensive against peripatetic cometary theory. Its immediate effect was to buttress Tycho's theory of the comet, its long-range effect – via Kepler – was to initiate modern cometary astronomy".[7]

The only known criticism adressed directly to Mästlin's *Observatio & Demonstratio ...* is the letter of Thaddaeus Hagecius to Martinus Mylius, published in 1580.

In this book Mästlin for the first time openly supports the Copernican heliocentric view. He claims, that he took this stand involuntarily, against his intention. And the question is: Was Mästlin really forced, by observational data, to employ the Copernican theory, after trying every alternative hypothesis? Perhaps not. Jarrell makes a fine point, which I want to subscribe: "The 'Observatio and Demonstratio' has a strong aprioristic flavour; the suggestion is not that Mästlin tried everything and Copernicus worked, but that he tried everything to make Copernicus work".[8] It may also be conjectured, that "what underlay Mästlin's whole enterprise was the conviction that he had found an independent corroboration of the heliocentric theory".[9]

Mästlin's Ephemerides of 1580 for the years 1577-1590 were dedicated and presented to the Rector and Senate of Tübingen University already in 1576, possibly for the occasion of the University's centenary in 1577. The reason for the delay of printing until 1580 was probably the fact that Mästlin was busy with the comet of 1577; also, "bureaucratic" obstacles are conceivable. The book contains a Caesarean Privilege in printing, which informs on Mästlin's scientific plans.

Tycho Brahe's Comments on, and Reactions to Mästlin's Work

Supernova of 1572 and Comet of 1577

Tycho Brahe was the most prominent among astronomers who investigated the supernova of 1572 and the comet of 1577. The supernova quite frequently is called "Tycho's Star". And Tycho was the most prominent astronomer to claim that both celestial objects in question were *supralunar*, stressing the contradiction to peripatetic natural philosophy. Tycho saw in Mästlin a very able astronomer, whose findings were very close to his own, or were at least consistent with his own. He reviewed Mästlin's

[7] Jarrell 75, 15.
[8] Jarrell 75, 15.
[9] Again Jarrell 75, 15.

tracts, and commented on Mästlin's work.[10]

Mästlin's *Observatio et Demonstratio Cometae Aetherei ...* of 1578 was paraphrased and commented upon in a long section of Tycho's *De Mundi Aetherei Recentioribus Phaenomenis ...* of 1588. By means of Tycho's book Mästlin's tract gained a wider readership. Tycho speaks very favourably of Mästlin in *De Mundi*, since Mästlin reached a similar conclusion about the comet. Tycho also defended Mästlin's view against Thaddaeus Hagecius.[11] And Tycho sent a copy of his 1588 work to Mästlin via Gellius Sascerides; the latter, in a letter to Mästlin of 23 July 1588, speaks very positively of the Tübingen astronomer's abilities and achievements.[12] Only one letter of Tycho to Mästlin, of 21 April (1 May) 1598, still exists (cf. below). It is highly probable, however, that there was an exchange of letters between Tycho and Mästlin at various occasions.

Tycho's writings on Mästlin were incorporated into the posthumous *Astronomiae Instauratae Progymnasmata*:

Pars III (printed 1602), on the new star of 1572, contains on pp. 543-548 a full reprint of Mästlin's *Demonstratio Astronomica ...* of 1573, with an introduction and commentary.[13]

Pars II (printed 1610), on the comet of 1577, gives in Chapter X, pp. 244-287 a detailed report on Mästlin's book *Observatio & Demonstratio ...* and on his observations. Tycho says, that his detailed report on Mästlin was worthwile, and that he will be more brief about the others (Cornelius Gemma, Elisaeus Roeslin, and astronomers who believed that the comet was sublunar).

Kepler's Mysterium Cosmographicum

In 1596 Kepler's first work *Prodromus Dissertationum Cosmographicarum, continens Mysterium Cosmographicum* (short: *Mysterium Cosmographicum*) was printed in Tübingen. Mästlin made substantial suggestions and refereed the book for the Senate of Tübingen University; he supervised the printing (a very demanding task!), added the *Prima Narratio* of Rheticus, and contributed a preface to the *Prima Narratio* and a treatise *De Dimensionibus Orbium et Sphaerarum Coelestium Iuxta Tabulas Prutenicas, ex sententia Nicolai Copernici* (21 pages).[14]

This work prompted a letter of April 21 (May 1) 1598 from Tycho Brahe

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[10] Thoren 73, 139, and 257.

[11] *Tychonis Opera Omnia VII*, 205 ff.

[12] WLB Cod. Math. 2^{ndo} 14; cf. Jarrell 75, 15.

[13] *Tychonis Opera Omnia III*, 58-62.

[14] Johannes Kepler *Gesammelte Werke* Band 1. Herausg. Max Caspar. München 2. Aufl. 1993.

to Mästlin.

According to a note by Mästlin, the letter was "praesentiert von Strassburg 29 Maji 98". The main content of this letter is a critical discussion by Tycho Brahe on the *Mysterium Cosmographicum*, on Kepler's a priori construction of the planetary system, and on Mästlin's pertinent comments (in the preface to the *Narratio Prima*). A codex in Munich contains several marginalia to this letter from Kepler's hand.

Mästlin, in his own preface to the appended *Narratio Prima* praised Kepler's discovery: "Thus from this time forth, he who inquires into the motions ... can compare all his observations and all of his calculations". This statement brought a sharp rebuttal from Tycho who in his letter expressed his amazement to see Mästlin, for whom he had great admiration as an observer, agree with a theory not based upon rigorous observation. Mästlin's reply to Tycho's letter, if there was one, is lost.[15]

In the context of Kepler's becoming Tycho's assistant early in 1600 a complicated exchange of letters and messages between Tycho, Kepler, Mästlin, and others happened, which we exclude here, refering to Thoren.[16]

Conclusion

In this paper we had to restrict our consideration to those astronomical achievements of Michael Mästlin, which were "somehow" related to the work of Tycho Brahe. Of course, we did not give a survey of Mästlin's work in toto. We mention briefly the manuscripts and letters on astronomy contained in the Mästlin "Nachlass" in the Württembergische Landesbibliothek Stuttgart, Cod. Math 2^{ndo} and 4^{to}. Furthermore, the University Library at Erlangen has a manuscript containing lectures on sundials by Mästlin.[17]

As we mentioned above, Mästlin's observations are documented in the *Historia Coelestis* of 1666 by Albertus Curtius; they are also recorded in the Vienna MS Cod. Vindob. 10.887.

Mästlin's observations extended over an exceptionally long period: According to the *Historia Coelestis*, the 16-year old student Michael Mästlin

[15] This section is taken almost verbatim from Jarrell 75, 19.

[16] Thoren 432-435.

[17] Jarrell 71, pp. 206-207, mentions a manuscript *Tabula Motus Horarii* dated ca. 1586, to be found in the New York Public Library. This manuscript is possibly a bibliographic myth. A professional librarian, Mr. Gerald L. Gill from Carrier Library of the James Madison University at Harrisonburg, Virginia, kindly made an intensive search for this manuscript on my behalf, and could not find any trace of it.

observed the solar eclipse of April 9, 1567,[18] cf. the section on the beginnings. And the very old scholar Mästlin observed the lunar eclipse of January 20, 1628, and joined his colleague and former student Wilhelm Schickard in observing the lunar eclipse of November 19, 1630.[19] Hence the recorded *observationes Maestlinianae* extended over a period of more than 63 years!

Mästlin was not of the same calibre as Tycho Brahe or Kepler. But the Tübingen scholar Christoph Friedrich (von) Pfleiderer (1736-1821) may be right, who noted in his personal copy of Mästlin's *Epitome* (first edition): "Mästlin deserves – to the highest degree – to be counted among the reformers of astronomy. To him, astronomy owes several excellent new methods, important observations of eclipses, fine geometrical and trigonometrical tricks ... and finally the training of Kepler. [It was Mästlin] who as a young assistant pastor at Backnang only with a thread managed to observe as sharply and accurately as Tycho Brahe with his excellent instruments and apparatus." [Mästlin verdient in höchstem Grade zu den Reformatoren der Astronomie gezählt zu werden: dem die Astronomie mehrere vortreffliche neue Methoden, wichtige Verfinsterungsbeobachtungen und feine geometrische und trigonometrische Kunstgriffe, ... und endlich die Ausbildung von Kepler verdankt, und der als junger Helfer von Backnang bloß mit einem Faden so scharf und genau zu observieren (verstand wie ?) Tycho Brahe mit seinen vortrefflichen Instrumenten (und ?) Apparaten] (University Library Tübingen, Bd 45). And in the *Historia Coelestis* of Albertus Curtius (1666) we read:[20] "Moestlinus observed the heaven carefully, compared positions of planets with constellations of fixed stars, and examined eclipses with great experience. He thus showed what the skill of a sophisticated Mathematicus can achieve, even if it is not supported by the apparatus of instruments." [Moestlinus inspecto diligenter Coelo, comparatis Planetarum et fixarum congressibus, et Eclipsibus multa peritia examinatis ostendit, quantum artificis mathematici solertia proficere possit, etiam nullo adjuta instrumentorum apparatu.]

In fact, Michael Mästlin was an excellent astronomer who worked with relatively modest instruments. He was highly respected by Tycho Brahe, who – in contrast – had the best observatory of his time. It is certainly justified in the context of this meeting to remember the astronomer "Michael Mästlin and his relationship with Tycho Brahe".

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[18] *Lib. Prolegomenos*, LXXIV. The *Hist. Coel.* erroneously claims, that Mästlin made this observation "Tubingae" (at Tübingen). In 1567 Mästlin was still in the monastic school at Herrenalb (or Königsbronn?).

[19] *Lib. Paralipomenos*, 941 and 950.

[20] *Lib. Prolegomenos*, LXX.

Figure 1: Portrait of Michael Mästlin, from Erhard Cellius, Imagines Professorum Tubingensium, 1596. Courtesy of the Universitätsbibliothek Tübingen.

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M M M

G

Figure 2: Monogram of Michael Mästlin, as given at the end of his Epitome Astronomiae. The meaning is: Magister Michael Mästlinus Mathematicus Göppingensis. Notice that the monogram has the form of a cross.

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[21] Papers are quoted by the name of the author. – The usual biographical dictionaries (*ADB, DSB*, POGGENDORFF and others) were used without special reference. Mästlin's publications are (almost) completely present in the Universitätsbibliothek Tübingen (UBT), where I could liberally use them. For instance, the UBT has 3 copies of the first edition of *Epitome Astronomiae* (1582), and a copy of the tract of 1573 on the new star of 1572 – in strong contrast to claims of JARRELL 71. Cf. also footnote 3. The University Archives at Tübingen also have a lot of documents related to Mästlin. Mästlin manuscripts are in Stuttgart, Wolfenbüttel, Vienna, and Erlangen.

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Tycho Brahe's Stellar Observations. An Accuracy Test

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Abstract

We have determined the accuracy of Tycho Brahe's immediate observations by means of his measurements of the extreme altitudes of α UMi to be ca. $27''$ of arc deduced from his 125 satisfactory measurements (covering ca. 95% of all his measurements) and $13''$ as deduced from his most satisfactory ones which he employed for his determination of the altitude of the North Pole [ca. 23% of the satisfactory ones (29 out of 125)], all expressed in standard deviation, σ.

The above results were obtained by deducing Tycho's observational system to have been such that all his observations were quasi-normally distributed at the celestial object on which Tycho's sight was immediately fixed.

In the case of Tycho's observations showing still lower degrees of accuracy we should therefore search for other causes for their accuracy being inferior to what we claim as Tycho's "immediate observational accuracy".

Introduction

On Dec. 6, 1588 Tycho measured the altitude of α UMi at its upper culmination, twice almost simultaneously with two different instruments. On the difference $10''$ of arc between his two observed values he commented: "the true value must be slightly higher than the first and slightly lower than the second, just at their middle".[1] He thus considered an amount of $5''$ of arc significant in his observational activity. Similar comments are not infrequent; indeed, they are found throughout his observational accounts.

[1] *Op. om.* XI, 303.

In the historical development of astronomy as an observational science – in particular at the time of Tycho Brahe just between Copernicus and Kepler – observational accuracy was constantly considered the most crucial element, and a great number of investigations of this phenomenon have been made by modern scholars.[2] Their claims concerning Tycho's accuracy lie mostly around one minute of arc and this degree of precision is in fact mentioned at almost every occasion in relation to Tycho Brahe. Comparing this with Tycho's comment above on his own observations we find a great discrepancy both in accuracy and its definition: In the modern investigations "accuracy" mostly concerns the accuracy of stellar positions or of distances between two stars whereas in his comment it concerns more the degree of his own intensity to catch the very object within his smallest measurable sighting-range.

In the present paper we shall try to determine Tycho's observational accuracy precisely as indicated by that comment of Tycho, which we call "accuracy of Tycho's immediate observation", or, by extension, "Tycho's capability of defining a celestial object within a definite scale-range", and the numerical determination of the magnitude of this range will be our ultimate goal. For this reason we shall only treat the point-like celestial objects, the fixed stars. We shall aim at deriving as accurately as possible that situation where Tycho was immediately faced with each celestial point, and where a quasi-normal distribution of his observed values at the object might be expected.

Consequently, we shall take into account only those individual and immediate observations which Tycho himself considered *satisfactory* – here, an apparent accuracy relating to the modern values plays no role at all. All other observations presupposing two different observational conditions, such as distances between two stars and star-positions in coordinates, will not be considered.

Our study will be different from all previous investigations of Tycho's observational accuracy in three points: the objective, the way of selecting celestial objects, and the resulting accuracy of Tycho's observations.

Selection of a star

Since every celestial observation is operated at a definite place on the Earth's surface, the geographical latitude of the observing place is the most fundamental constant which the accuracy of all celestial positions to be deduced depends on. Undoubtedly Tycho therefore tried to determine,

[2] Cited in Dreyer 356f.; Thoren 190f.

most severely and most frequently, the altitude of the North Pole, first by means of the Sun[3] and later exclusively by means of some outstanding stars near to the Pole. Of these he employed most frequently α UMi, the Pole-Star as he called, for the reasons that, in his confidence, it is free of refraction due to its high altitudes and presumably also that the star, at its two extreme, similar altitudes, is supposed to be observable under very similar conditions, thus enabling him a high accuracy in determining the altitude of the North Pole. For the above reasons we shall treat below only Tycho's observations of the two extreme altitudes of α UMi.

Computation of Tycho's observational accuracy

Of all measurements of the extreme altitudes of α UMi those made in the years 1576-1583 show, comparing with the later ones, great irregularities. It is necessary to analyse them separately in three groups according to their very varying average deviations from the modern values: 1) 1576 – Jun. 1578; 2) Jul. 1578 – Jun. 1580; 3) Jul. 1580 – 1583 (Tab. lines 1∼6).

The average deviations change from $-0.03°$ to $+0.03°$ and further to $-0.04°$ (Tab. 1∼6-d, -e), amounting thus to a total difference of $0.07° \simeq 4'$ (lines 4-, 6-d), while the standard deviations remain in all three periods roughly around $1'$ (lines 1∼6-g). In those periods Tycho seems not to have been yet fully aware of the fundamental significance of the role which the North Pole would play in observational operations, and only occasionally he tried to determine the altitude of the North Pole by means of the stars near to the Pole.

Entirely different from this stage in accuracy and intensity Tycho started with his new determination of the North Pole in 1584 which he continued up to May 1591. Thereafter only in 1596 he observed four times the upper culmination of the same star, the accuracy of which is dubious, presumably due to his troublesome circumstances shortly before his exile from Hven in 1597.

We shall therefore set the analysis of his observational activities in the years 1584-1592 to our principal goal. As mentioned already above, we take, independently of their apparent accuracies, only those observations considered by Tycho as *satisfactorily made*[4] into account. Our study shows nearly the same distributions ($\sigma = 21.8''$, $26.6''$; Tab. 7-, 8-g) of his meridian-observations at two different culminations, lower and upper, of α UMi. This indicates that Tycho's observations at two different ex-

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[3] Cf. e.g. Maeyama (1974), (1998).

[4] Cf. note 5 to the Table.

	a	b	c	d	e	f	g
	Periods	Deviations of Tycho's observed altitudes from the modern values					
		Lower & upper culmin.	No. of obser-vations	Average deviations		Standard deviations (σ)	
				(°)	(″)	(°)	(″)
1	1576 –	Δh_1	5	−0.0288	−103.8	0.0224	80.6
2	Jun. 1578	Δh_2	6	−0.0343	−123.6	0.0148	53.3
3	Jul. 1578 –	Δh_1	4	−0.0080	−28.7	0.0049	17.6
4	Jun. 1580	Δh_2	10	+0.0301	+108.3	0.0142	51.0
5	Jul. 1580 –	Δh_1	8	−0.0231	−83.0	0.0074	26.6
6	1583	Δh_2	7	−0.0413	−148.9	0.0117	42.0
7	1584 –	Δh_1	70	−0.00489	−17.6	0.00605	21.8
8	1592	Δh_2	55	−0.01276	−45.9	0.00739	26.6
9	1584 –	Δh_1	17	−0.00424	−15.3	0.00354	12.7
10	1590	Δh_2	12	−0.01207	−43.5	0.00232	8.4

Table: Tycho's observation of the extreme altitudes of α UMi (Op. om. X-XIII).[5]

Analysis in 3 groups:

1) 1576 – 1583 (lines 1-6),[6]

2) 1584 – 1592 (lines 7-8),[7]

3) 1584 – 1590 (lines 9-10; observations for the determination of the North Pole).[8]

treme altitudes of the star, ca. 53° and 59°, were performed under the same conditions, and this fact decisively supports Tycho's original intention to determine the altitude of the North Pole, the geographic latitude of Uraniborg, by means of the nearest star to the Pole, α UMi.

[5] Modern values of min./max. altitudes ($h_{1,2}$) were computed accurately to one day according to *Sky Catalogue 2000.0* (Hirshfeld/Sinnot) and corrected for refraction. Independently of their accuracies all observations with no negative observational comments by Tycho were taken into account, and all others with dubious comments such as "cloudy or uncertain" were not taken into account.

[6] The measurements are mostly made to 1′ and the standard deviations remain around 1′ (1 ∼ 6-g); Great variations of the average deviations amounting to 0.071° ≃ 4.3′ [= 0.030° − (−0.041°); 4-, 6-d], attributable to the varying alignments of the instruments.

[7] The measurements mostly made to 10″ ∼ 15″, a great difference of ca. 30″ between the two average deviations (7-, 8-e), while the two standard deviations of similar magnitudes at ca. 25″ (7-, 8-g); Cf. text.

[8] Only the values employed for the determination of the North Pole; the two average deviations (9-, 10-e) are about the same as above (7-, 8-e) but the two standard devia-

For the contrary, however, we find a great difference of ca. $0.5'$ (Tab. 7-, 8-e) in the average deviations of Tycho's observations at the two different culminations of the star. Nevertheless, we have no reason whatever to believe that Tycho's observations at the lower and upper culminations of the star might have been operated differently. Since in the two cases in concern Tycho's observed values are equally distributed around their own average value as shown by their two standard deviations, we assume that his observations at two different altitudes of the same star were also equally conditioned. Hence, the cause of the difference of the two average deviations from the modern values has to be searched for not in Tycho's immediate observational operations but in some other elements unrelated to this. Thus the cause can only lie in the instruments or in the way in which they were set up.

An average deviation from the modern value corresponds to a systematic error. And if two different systematic errors arise simultaneously from the same instrumental system as in our present case, azimuth error has to be called into question.

Tycho in fact measured the altitudes of the star at the meridian which was instrumentally fixed and he frequently put the degree of accuracy of the meridian line into question. And he was fully aware of possible errors in the measured altitudes arising from errors of the meridian line.

According to our computation a deviation of $0.27° \simeq 16.2'$ of the meridian line from the true North-South line will yield an increase of ca. $15.2''$ and a decrease of ca. $13.1''$ in the altitudes respectively at the lower and upper culminations of α UMi on the average at the time in concern. This azimuth error would then transform the two different average deviations, $-17.6''$ and $-45.9''$ (Tab. 7-, 8-e), into an equal amount of ca. $-32.8''$ ($\simeq -17.6 - 15.2 \simeq -45.9 + 13.1$), which we now have to attribute to the systematic error of the horizontal plane in Tycho's observational system.

Our problem is now clear: In his golden years between 1584 and 1592 Tycho made hundreds of observations of the extreme altitudes of α UMi by means of his observation-system – with different instruments – which possessed, on the average, an error of ca. $16'$ at the meridian line (azimuth error) and that of ca. $33''$ on the horizontal plane, upward to the North. The accuracy of his immediate observations, relating only to his *satisfactory measurements* with a total number of 125 (Tab. 7-, 8-c), was at ca. $27''$ as shown by their standard deviations ($21.8''$ and $26.6''$; Tab. 7-, 8-g). According to his observation-system as analysed above Tycho's immediate

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tions (9-, 10-g) much smaller. 10-c: A small no. of observations (12) due to five unclear dates.

observations may now be assumed as quasi-normally distributed around his celestial object, α UMi, with no systematic errors – ca. 70% of all his *satisfactory measurements* within a range of ca. $\pm$ 27″ ($\pm \sigma$) and ca. 95% within a range of less than $\pm$ 1′ ($\pm$ 2 σ).

A further selection of Tycho's observations

Of his hundred observations of the extreme altitudes of α UMi made in the years 1584-1592 Tycho chose 17 pairs of the minimum and maximum altitudes and tried to determine the altitude of the North Pole at Uraniborg as accurately as possible. In these observations his most self-confident accuracy can therefore be expected.

Our computation in fact shows two similar standard deviations 12.7″ and 8.4″ (Tab. 9-, 10-g), a much higher accuracy than what we have seen above. Particularly interesting is the fact that this small number of his well-selected observations (17 and 12; Tab. 9-, 10-c) shows precisely the same tendency as his larger group of observations (70 and 55; Tab. 7-, 8-c) from which Tycho made his selection just mentioned: $-15.3''$ versus $-17.6''$ and $-43.5''$ versus $-45.9''$ (Tab. 7∼10-e). From this we can also deduce exactly the same conditions of how Tycho's observation-system must have been set up: an azimuth-error of $0.27° = 16.2'$ and a horizon-error of 30.4″ such that all altitudes to be measured at the northern meridian tended to be less by that amount. This agreement can serve as a definite support to our first claim above.

From the last analysis above we can draw our concluding remarks: Tycho Brahe was capable, given the satisfactory observational conditions according to his confidence, of defining every point-like celestial object within a circle with a radius of ca. 13″ ($= \sigma$; Tab. 9-g) and 25″ ($= 2\sigma$) of arc respectively where, according to the principle of the standard deviation from the mean, ca. 70% and 95% of the whole number of observations are supposed to be contained.

From Tycho's 17 determinations of the altitude of the North Pole ranging from 55°54′30″ to 55°54′59″ in the years 1584-1590 we obtain their average and the standard deviation as 55°54′42.5″ and $\sigma = 7.3''$. From the modern value, 55°54′26″, we may deduce the Pole altitude, 55°54′38″, – corrected for refractions (40.9″), the errors arising from the azimuth-error (1.1″ at $0.27° = 16.2'$) and the horizon-error ($-30.4''$) as we have demonstrated above – which Tycho must have faced to determine. Hence, the deviation of Tycho's average Pole altitude from the modern value above to be derived from his actual celestial object, α UMi, amounts only to 5″ of arc and the modern value as seen from his observation-system lies just within his observational range as defined by the standard deviation of 7″.

Tycho's two simultaneous observations of the maximum altitude of α UMi referred to in Introduction above show the deviations −51.1″ and −41.1″ from the modern value. Correcting for the two errors at the azimuth and horizontal plane as found by us above these deviations decrease by a sum of 13.1″ and 32.8″ amounting thus to −5.2″ and +4.8″. The mean value of the two measurements, 58°49′35″, which Tycho believed to be the truly accurate altitude,[9] thus shows a deviation of only −0.2″ of arc from the modern value. Tycho's critical comment that he put an accuracy of ±5″ into question of his own observational operation is thus fully justified, and we can assume that he actually faced his celestial object within that small sighting range. This agrees, though the two measurements in concern were not employed by Tycho for his determination of the Pole altitude, precisely with the standard deviations, 8″ and 13″ (Tab. 9-, 10-g), found by us in *his most satisfactory observations.*

This is what we claim as the accuracy of Tycho's immediate observations of the fixed stars, or his ultimate observational capability.

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[9] Cf. Note 1 above.

Tycho Brahe and Prague: Crossroads of European Science, pp. 120–127,
J. R. Christianson et al. (eds.), © *H. Deutsch 2002*

Testing Tradition: Tycho Brahe's Instruments and Praxis

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Abstract

Till the 18^{th} century the astronomical data's reliability was jeopardized by the absence of both dividing machines and precise clocks. Tycho's continuous search for better technical improvements and observational methods can be seen by analysing his devices, instruments and praxis.

Generally the telescope is considered the instrument that changed the course of astronomy: it extended human sight possibilities and, by careful observations, revealed unforeseen aspects of the Universe.

It must be underlined that the meaning of the word "observation" plays here a particular role. The meaning implies both that the telescope magnifies old celestial bodies and reveals their aspects, and the possibility to discover new celestial bodies. This is the usual meaning of the word "observation" since Galileo Galilei's astronomical activity.

However, to understand ancient astronomy, it is important to consider another meaning of the word "observation" in relation with the collection of data. Precise celestial co-ordinates were indispensable to develop planetary models and to compile star catalogues. Therefore ancient astronomers made graduated instruments and tried to improve them continuously.

The implementation of astronomical instruments by telescopic sights was not really useful before the 18^{th} century.[1] While pointing a star, the precision gained by telescopic magnification was lost by other faults. These were essentially due to the absence of both dividing machines and precise clocks. Therefore, from Hipparchus to Tycho, and even later, the collection of astronomical co-ordinates was subjected to the same kind of problems.

[1] Allan Chapman, *Dividing the circle; the development of critical angular measurement in astronomy 1500-1850*, Bodmin, E. Horwood Ltd., 1990, p. 12.

Astronomers had to increase data's reliability operating directly on devices, scales and praxis of the traditional graduated instruments.

In the following pages I will examine some of these problems related to Tycho's work.

Graduation of circular scales

Very little is known about ancient dividing methods. Allan Chapman found only one reference about circle's division in Thomas Fale's *Horolographia*, dated 1593.[2] Fale divides the circle in four quadrants and each of them in three half sextants. Then Fale iterates divisions for three, for two and for five. This means that the division process reaches the angle of 1° through the series: 90°, 30°, 10° and 5°.

The method seems very simple to be applied and agrees with graduated scales that can be seen on old instruments; in particular on their Zodiacal circles. But in practice the method raises some problems. For example, it is impossible to divide by ruler and compasses the half sextant in three equal parts of 10°. Therefore the above mentioned method causes approximation errors in division, some of which had been sorted out by Chapman's analysis of a group of European planispheric astrolabes.[3]

Precision instruments were probably divided in another way. Claudius Ptolemy says in *The Almagest* how he obtained his table of chords graphically. The difference of 12° between the angles of 72° and 60°, respectively subtended by the sides of the pentagon and the hexagon, is bisected more times by ruler and compasses obtaining the angles of 6°, 3° and 1.5°. The angle of 3° can be trisected with no relevant error even linearly.[4]

Not by chance Ptolemy sets this method and the table of chords before explaining how to make the meridian armillary. This is the first observational instrument with a graduated circle described in the history of astronomy. Moreover, the method is implicit in Ptolemy's words. He recommends to divide the instrument simply "into the normal 360° of a great circle, and subdividing each degree into as many parts as allows".[5] Grouping of degrees to read the data easier is another question.

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[2] Thomas Fale, *Horolographia; The art of Dialling*, London, 1593, p. 1; Allan Chapman, *cit.*, p. 21.

[3] Allan Chapman, "A study of the accuracy of scale graduations on a group of European astrolabes", *Annals of Science* 40, Basingstoke, Taylor & Francis, 1983, pp. 477-485.

[4] Claudius Ptolemy, *Ptolemy's Almagest* (ed. and trans. in Engl. by G. J. Toomer), London, Springer-Verlag, 1984, pp. 48-49 and 53. For Ptolemy's table of chords see: *ibid.*, pp. 57-60.

[5] *Ibid.*, p. 61; see too: *ibid.*, p. 218.

Nobody knows how Tycho divided his instruments. It is right to suppose his method was similar to the Ptolemaic one. Perhaps the question may be answered through a mathematical analysis of Tycho's observations.[6] When compared with reconstructed positions of celestial bodies, the data collected with a specific instrument would give some indications about the error curve of its graduated scales. This may be an interesting work to do.

Small divisions

The division problem is double sided: the one is making a circular scale as a whole, the other is to divide each degree in as many small parts as possible.

In 1564 Tycho saw the application of transversal divisions for the first time. Bartholomew Schultz explained him how to improve the cross-staff by a series of transversal segments drawn between main divisions.[7] Each segment could be easily divided again.

Tycho did not extend immediately transversals from the rectilinear to the circular case. In the 1570s he obtained small divisions using the method described by Pedro Nuñez in his *De Crepusculis*, published in 1542.[8] Later on he experienced similar methods conceived by Christoph Clavius in 1586,[9] and by Jacob Kurtz in 1590.[10] All these methods employed a number of auxiliary graduated scales. Therefore it is evident that, if it is difficult to obtain a careful scale, it is even more difficult to obtain 45 or even 90 of them at the same time, as required by Nuñez or by Kurtz. Tycho's final evaluation of such devices is well known: he rejected all of them.[11]

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[6] Tycho Brahe, *Tychonis Brahe Opera Omnia* (ed. by J. L. E. Dreyer), Copenhagen, Gyldendal, 1913-1929; reprint: Amsterdam, Swets & Zeitlinger N.V., 1972, vols. X-XIII.

[7] Johann Louis Emil Dreyer, *Tycho Brahe: A picture of scientific life and work in the Sixteenth century*, Edinburgh, A. & C. Black, 1890; anastatic reprint: New York, Dover Publications, 1963, p. 20; Allan Chapman, *Dividing the circle, cit.*, p. 17.

[8] Pedro Nuñez, *De Crepusculis*, Lisbon, 1542, prop. III, 2; see too: Christoph Clavius, *Fabrica et usus instrumenti ad horologiorum descriptionem peropportuni*, Rome, Bartolomeo Grassi, 1586, pp. 113-114. Tycho applied the nonius in his "quadrans minor orichalcicus", made in 1573, and in the "quadrans mediocris orichalcicus azimuthalis" he used on the comet of the year 1577; see: *Astronomiae instauratae mechanica*, in: Tycho Brahe, *cit.*, v. V, pp. 12-19.

[9] Christoph Clavius, *cit.*, pp. 112-132.

[10] See Jacob Kurtz's letter dated June 28, 1590; *Astronomiae instauratae mechanica*, in: Tycho Brahe, *cit.*, v. V, pp. 121-122.

[11] "Verum haec Nonniana ratio non est sufficiens in praxi: neque habet in recessu quod in accessu pollicetur: uti experiunti patebit"; *ibid.*, p. 15. See also Tycho's letter to Christoph Rothmann dated January 20, 1587: *Epistolarum astronomicarum, ibid.*, v. VI, p. 90. Tycho's judgement about Kurtz's method is similar: "Attamen hanc Dni.

Tycho's introduction of transversals in circular scales is an historical problem only partially solved. Transversals are present in Tycho's instruments since 1580;[12] but in the Istituto e Museo di Storia della Scienza in Florence there is a planispheric astrolabe implemented with transversals dated 1483.[13] In the early 1570s, Egnatio Danti drew transversals in a sketch of the marble quadrant he was preparing for the church of Santa Maria Novella in Florence,[14] and probably, in the late 1560s, he marked transversals on another planispheric astrolabe now at the Istituto e Museo di Storia della Scienza.[15] Moreover, Caspar Peucer is known to have applied transversals to some circular instruments in 1563.[16] Finally, it is well known that such transversals were used for the first time by Levi ben Gerson at the beginning of the 14th century.[17]

Did Tycho copy or re-invent transversals? In the *Astronomiae instauratae mechanica* Tycho claimed he invented them;[18] but in the *Astronomiae instauratae progymnasmata* he gave an ambiguous statement. He says that, when he built the great Augsburg's quadrant in 1570, he made it 14 cubits

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Curtij rationem admodum ingeniosam, utut Praxi non satis idoneam"; *Astronomiae instauratae mechanica, ibid.*, v. V, p. 122.

[12] Transversals are present in Tycho's "quadrans mediocris orichalcicus"; see: *ibid.*, pp. 16-19. The quadrant was made in 1577, but its scale was implemented by transversals in 1580; see: Victor E. Thoren, *The Lord of Uraniborg; a Biography of Tycho Brahe*, Cambridge, Cambridge University Press, 1990, p. 156, n. 28.

[13] This planispheric astrolabe (Istituto e Museo di Storia della Scienza of Florence, inventory n. 1096) is ascribed to the Hebrew physician, astrologer and mathematician Bonet de Latis; see: Mara Miniati (ed.), *Museo di Storia della Scienza; Catalogo*, Florence, Giunti, 1991, p. 8, n. 14. See also: Bernard R. Goldstein, "Levi ben Gerson: on instrumental errors and the transversal scale", *Journal for the History of Astronomy* 22, v. 8, pt. 2, Cambridge, University Printing Service, 1977, p. 104.

[14] Museo degli Uffizi of Florence, Gabinetto dei Disegni e delle Stampe, drawing n. 3946A; Maria Luisa Righini Bonelli, Thomas B. Settle, "Egnatio Danti's great astronomical quadrant", *Annali dell'Istituto e Museo di Storia della Scienza di Firenze* IV-2, Florence, Giunti, 1979, pp. 3-4 and 9-13.

[15] The so-called "Galileo's astrolabe" (Istituto e Museo di Storia della Scienza of Florence, inventory n. 3361) is ascribed to Egnatio Danti; Mara Miniati, *cit.*, p. 44, n. 27. Guglielmo Righini, "Il grande astrolabio del Museo di Storia della Scienza di Firenze", *Annali dell'Istituto e Museo di Storia della Scienza di Firenze* II-2, Florence, Giunti, 1977, pp. 50 and 59, dated the instrument astronomically to the year 1563. Gerard L'Estrange Turner, "The Florentine workshop of Giovanni Battista Giusti, 1556-c.1575", *Nuncius* X-1, Florence, Olschki, 1995, pp. 158-159, judges Righini's astronomical conclusion invalid. He gives the year 1570 as a more secure date of construction.

[16] Allan Chapman, *Dividing the circle, cit.*, p. 17.

[17] Bernard R. Goldstein, *cit.*, pp. 104 and ff.

[18] "Divisio autem ipsius circumferentiae erat solummodo secundum usitatam formam. Neque enim tunc aliam et commodiorem adinveneram, qua postea in alijs Instrumentis usus sum"; *Astronomiae instauratae mechanica*; in: Tycho Brahe, *cit.*, v. V, p. 89.

radius in order to obtain single minute of arc divisions, because he didn't know transversals yet.[19] Whatever the case may be, Tycho surely developed transversals. In particular he minimised construction errors finding the optimum ratio between the radius of an instrument and the width of its transversals.[20]

Sights

Some consideration needs to be given to the difference between ancient sights and Tycho's ones.

In antiquity sights were usually pinholes. They were conceived to observe the star exactly in the straight line that joins the upper to the lower pinhole. But these sights had a flaw. The star could be seen through pinholes even if the alidade of the instrument was not exactly pointed to it. The error, called eye parallax, could be reduced making very small pinholes. However, this issue prevented the observation of faint stars.[21]

The solution that Tycho adopted changed the terms of observation. He combined an upper square pinnula, or a cylinder, with a lower square pinnula bordered with four slits. The observation was performed properly when the star almost disappeared behind the upper pinnula.

The general idea was not original at all. In the *Astronomicum Caesareum*, published in 1540, the upper alidade of Peter Apian's torquetum had two sights. The lower one was a drilled pinnula; but the upper was a quite unusual one. It was the head of a nail.[22] In this case the observation was properly performed when the star disappeared behind the head of the nail.

Tycho knew Apian's work. Moreover, he visited Wilhelm IV, Landgrave

[19] "Neque enim subdivisionem illam graduum transversalem tunc cognoveram; sed saltem vulgari modo gradus ordine in sua minuta distribuebam"; *Astronomiae instauratae progymnasmata, ibid.*, v. II, p. 343.

[20] Tycho's ratio of 1 to 48 reduces transversals' construction error to $3''$; *Astronomiae instauratae mechanica, ibid.*, v. V, pp. 153-154.

[21] "Etenim per foramina more alias usitato stellae difficilime in eo praesertim quod maxime ab oculo remotum est perspiciuntur, nisi satis amplum fuerit: Et si hoc concedatur, aliquota particula gradus amitti potest, siquidem nescitur an plane Centralis fiat collimatio, quod sane miror ab antecedentibus Astronomis non esse animadversum, atque huic incommodo aliter provisum", *ibid.*, p. 155; see also p. 46.

[22] "Consultum tamen hic equidem iudicarim te non duas pinnulas hoc loco facere perforatas, sed unam tantum cum foramine unico, instar granuli lenticulae unius diducto, ex altera autem parte stilum tenuem erige, in eius summitate nodum fac paulo lenticula maiorem", Peter Bienewitz, *Astronomicum Caesareum*, Ingolstadt, 1540; (facsimile n. 337 by rare n. 819, Bayerische Staatsbibliothek) Leipzig, Leipzig Ed., 1967, II part, Compositio torqueti, enunc. IV.

of Hesse, in 1575. Wilhelm had at his disposal many brass devices derived from those of the *Astronomicum Caesareum*. He had also a torquetum.[23] So it is possible that Tycho had the basic idea for his sights from Apian.

It is obvious that Tycho could not be satisfied with Apian's simple solution. He analysed and improved the basic idea. So the final device that Tycho applied in his armillaries was able to split the measurement of declinations from those of right ascensions in order to take each co-ordinate under perfect control.[24] In earlier times and with old instruments, as the torquetum, this has been always an unreachable result.

Observational praxis

Some of the examples I just examined show Tycho's successful attempts to get over the difficulties rising from the absence of precise mechanical dividing methods. The evolution of Tycho's observational praxis testifies to his struggle against another great disadvantage common with all ancient astronomers: the absence of a precise clock.

Tycho made his first serious attempt to measure star positions when the new star of the year 1572 appeared. He measured with his half sextant the distances between the *nova* and some bright stars of Cassiopea.[25] With this method he did not solve any problem. In fact even if the distances were measured to $1'$ of arc, all reference stars' positions were considerably in error. Their co-ordinates were the same that in the 2nd century Ptolemy included in his star catalogue, merely corrected to take into account the precession of the equinoxes.

In 1572 Tycho had no clocks, but he bought some during the ensuing years.[26] When the comet of the year 1577 appeared, Tycho measured again its positions with respect to some reference stars; but now he also measured their co-ordinates. Among the various methods available, at least he preferred one combining the data of an azimuthal quadrant with the readings of a clock.[27] The declination of a star was obtained by its altitude at the meridian transit. The right ascension was found by the time elapsed between the meridian transit of the star and that of the Sun.[28]

Tycho's optimism on clocks was rapidly defeated by meagre results. In

[23] Johann Louis Emil Dreyer, *cit.*, pp. 79-80; Victor E. Thoren, *cit.*, p. 93.

[24] Mario di Bono, "Tycho Brahe e l'astronomia; per una nuova valutazione dell'astronomo danese", *Physis* XXIV-2, Florence, Olschki, 1982, pp. 181-182.

[25] *De nova stella*, in: Tycho Brahe, *cit.*, v. I, pp. 21 and ff.

[26] See: Victor E. Thoren, *cit.*, pp. 123 and 157-159.

[27] *De mundi aetherei recentioribus phaenomenis, ibid.*, v. IV, p. 21.

[28] *Ibid.*, pp. 29-30.

the following years he made many severe criticisms of clocks.[29] Therefore he found a new way for his star-cataloguing project looking at the past. He started again from the Ptolemaic observational method with the armillary astrolabe. The method required the subsequent measurement of the differences in longitude between the Sun and the Moon, between the Moon and a reference star, between the reference star and whichever other star or planet.[30] This method needs also a clock; but the time error was reduced thanks to the slow movements of the Sun and the Moon with respect to the stars.

Tycho rejected the use of the Moon, since for him it moved again too fast, it had a relevant diurnal parallax and it was not like a point.[31] From 1582 he employed his astronomical sextant, a great quadrant and an equatorial armillary to measure the differences in longitude between the Sun and Venus and between Venus and the bright star in the head of Aries. Then he extended his method to 21 other reference stars with surprising precision.[32]

It is interesting to note that Tycho's bad opinion of clocks was then the crucial point in his criticism of the observational praxis used by Wilhelm IV's astronomer Christoph Rothmann. From 1588 to 1590 Tycho worried the Landgrave and Rothmann telling them that their method, the same he optimistically used in 1577, was absolutely insufficient.[33]

Conclusions

I hope these sketches might be useful to suggest a new reading of Tycho's activity as instrument maker and observer. During his life at Hven, Tycho tried to solve technical problems whose ultimate cause was the absence of both dividing machines and precise clocks. Since these problems were common to the whole history of astronomy from Hipparchus to his times,

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[29] See for instance: *Astronomiae instauratae progymnasmata, ibid.*, v. II, p. 157.

[30] Claudius Ptolemy, *cit.*, pp. 218-219 and 339.

[31] *Astronomiae instauratae progymnasmata*, in: Tycho Brahe, *cit.*, v. II, p. 158; see also: Tycho's letter to Johann Georg Hertwart dated August 18 (28), 1600; *ibid.*, v. VIII, p. 349.

[32] *Astronomiae instauratae progymnasmata, ibid.*, v. II, pp. 162 and ff., pp. 233-234. Owen Gingerich, James R. Voelkel, "Tycho Brahe's Copernican campaign", *Journal for the History of Astronomy* 94, v. 29, pt. 1, Cambridge, University Printing Service, 1998, pp. 17-23, have pointed out that the use of simultaneous observations with the sextant, the quadrant and the equatorial armillary became common in Tycho's praxis. For an evaluation of the precision of Tycho's observations, see: Walter G. Wesley, "The accuracy of Tycho Brahe's instruments", *Journal for the History of Astronomy* 24, v. 9, pt. 1, Cambridge, University Printing Service, 1978, pp. 44-47.

[33] See for instance: Tycho's letter to Wilhelm IV dated August 16, 1588, in: Tycho Brahe, *cit.*, v. VI, p. 128.

Tycho examined carefully all technical solutions advanced by his predecessors. He carefully modified tradition from inside, and only by this mean he obtained astonishing results.

If we see Tycho's instruments, devices and praxis within this frame, they become important points of reference in the history of astronomy. Their study clarifies not only Tycho's activity, but also why ancient astronomers made some sorts of observational instruments and used them. Far from this frame, the risk is to give a superficial evaluation: to recognize in ancient practical astronomy only a series of strange or even incomprehensible devices and methods.

Tycho Brahe and Prague: Crossroads of European Science, pp. 128–136,
J. R. Christianson et al. (eds.),

Kepler as Astronomical Observer in Prague

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Abstract

Official histories of science have consistently perpetuated the rumour that Kepler's poor eyesight prevented him from undertaking astronomical observations. However the condition of his eyesight could not have been so serious for in 1582, when his father made it possible for him to see a lunar eclipse, Kepler saw the moon emerge clearly. We find quite a lot of his astronomical observations especially of the years in Prague, mostly left in his manuscripts and unpublished until now. They will be edited in Vol. XXI.1 of the Kepler-Edition in the next future. Kepler's astronomical observations in Prague were mostly initiated by spectacular phenomena in the sky. He was self-critical enough to know, that his observations could not compete with those of the best observers of his time. It was not necessary for him to come up to highest standard of accuracy, and it was not possible to do so because he did not possess proper astronomical instruments. But nevertheless it was important for him as a theorist of astronomy and as a philosopher of nature to take a view of the phenomena which he wished to study carefully.

Zusammenfassung

Hartnäckig hält sich in der wissenschaftsgeschichtlichen Literatur das Grücht, Keplers schlechte Augen hätten ihn daran gehindert, astronomische Beobachtungen auszuführen. Doch kann die Erkrankung der Augen so schlimm nicht gewesen sein. Denn als ihm der Vater im Jahr 1582 eine Mondfinsternis zeigte, tauchte der Mond deutlich vor seinen Augen auf. So gibt es auch eine Reihe eigener Beobachtungen, insbesondere der Jahre in Prag, die zum größeren Teil in seinen Manuskripten überliefert, bis heute unveröffentlicht geblieben sind und nun demnächst in Band XXI.1 der Kepler-Edition herausgegeben werden. Seine Prager Beobachtungen waren zumeist von spektakulären Himmelserscheinungen initiiert. Selbstkritisch,

> wie Kepler war, war es ihm klar, dass seine Beobachtungen sich nicht mit den besten seiner Zeit vergleichen ließen. Die höchste Genauigkeit zu erreichen war nicht notwendig und war auch nicht möglich in Anbetracht seiner bescheidenen Instrumente. Dennoch war es wichtig für ihn als astronomischen Theoretiker und Naturphilosoph, selber einen Blick auf jene Phänomene zu werfen, die er zu erforschen gedachte.

Prologue

Official histories of science have consistently perpetuated the rumour that Kepler's poor eyesight prevented him from undertaking astronomical observations. The popular biography by Gerlach / List says: "As an astronomer Kepler was quite handicapped by his weak, near-sighted eyes. He suffered from monocular polyopy, so that he did not see one moon but several."[1]

Reitlinger wrote more cautiously about the effects of the illness in his detailed description of Kepler's childhood and youth: "He was hovering between life and death, and nothing could be done to offer a cure for injuries to his hands and the blindness of his eyes. Throughout his life he suffered from a certain weakness of vision."[2]

However the condition of his eyesight could not have been so serious for in 1582, when his father made it possible for him to see a lunar eclipse, Kepler himself described how he saw the moon emerge clearly with a reddish colour. Years later he acknowledged the problems he experienced with his eyesight and recognized his own visual handicap.[3] The explanation of these matters may lie in the fact that Kepler usually made his observations in the company of others and only rarely by himself.

Already as a young student of astronomy Kepler took part in Maestlin's astronomical observations. Kepler made observations by himself in Graz from November 1594 until 25th May 1599, with an interruption in 1596 and in the first half of 1597. In 1596 he visited his grandfather *Sebald* who was sick and he returned then to Graz in July. After another journey to Linz in August Kepler was busy with the immediate preparations for his marriage to *Barbara Müller*. The wedding took place on 27th April 1597.[4]

In August 1600 Kepler sent his observations to Tycho Brahe in Prague

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[1] Walther Gerlach / Martha List, *Johannes Kepler*³ 1987, p. 18.

[2] Edmund Reitlinger / C. W. Neumann / C. Gruner, *Johannes Kepler*. Erster Teil. Stuttgart 1868, p. 46.

[3] "... confuso visu multum impedior", in: *De Stella Nova*, cap. XII (*KGW I*, p. 210).

[4] See letter No. 358, Kepler to David Fabricius, 11th October 1605, in: *KGW XV*, p. 269.

who added them to the records of his own observations. Kepler's observations start in Tübingen on 3rd October 1590 (Julian date) with a Martial covering by the moon and in Graz on 9th November 1594 with a determination of the locus of Saturn. These records end on 25th May 1599 with the mutual determination of the locus of Jupiter, Venus and Mercury.[5]

The fact that Brahe did give a certain acknowledgement to Kepler's observations shows Tycho's appreciation of Kepler's scientific work. Certainly, Kepler's observations could not be sufficient to the relatively high demands of accuracy of this time. His methods and instruments were too elementary and this limited the accuracy of his observations. Either he determined the planetary place according to Maestlin's method simply as section of two lines – each line being between two stars – along a stretched thread, or he could only use simple instruments with a rough graduation. There are mentions of instruments such as a paper astrolabe, a wooden quadrant of half a foot in radius and straight-edges of six up to eight feet in length. For a rough time measurement he looked to the town clock or he estimated the interval of time before sunrise.

In Graz Kepler started with a novel method of observation of eclipses by the construction of a special eclipse instrument on the occasion of the solar eclipse of July 10th 1600 *(Fig. 1)*. The method of construction corresponded with the traditional principle of a camera with projection on a screen, but was improved by Kepler in some details, e.g. by a swivelling axis of the instrument.[6] The recalculation of the eclipse observations being connected with some considerations of the *camera obscura* was of a fundamental importance for Kepler's astronomical optics.[7] He used the instrument also in later years, as e.g. for the observation of the solar eclipse on 10th August 1608 in Prague.

Kepler in Prague

In October 1600, when Kepler had to leave Graz as a result of the actions of the counter-reformation, he went to Prague accepting Tycho's invitation. He was confident of finding new employment in collaboration with the noble Dane, but Tycho's unexpected death[8] meant that Kepler was suddenly

[5]Mss. Royal Library Copenhagen, Brahe HS, Cod. I, fol. 160-166 (167-173). See the new edition: *KGW XXI.1*, No. A5: OBSERVATIONES KEPLERI 1594-1599. This Volume will be published in 2002.

[6]See *Astron. pars optica*, cap. XI (*KGW II*, 288 ff.).

[7]*KGW II*, 399 ff. and 426 ff.

[8]The Memorial Evening in Týn Church of Virgin Mary, October 24, 2001, was an impressive celebration for the participants of the international symposium "Tycho Brahe

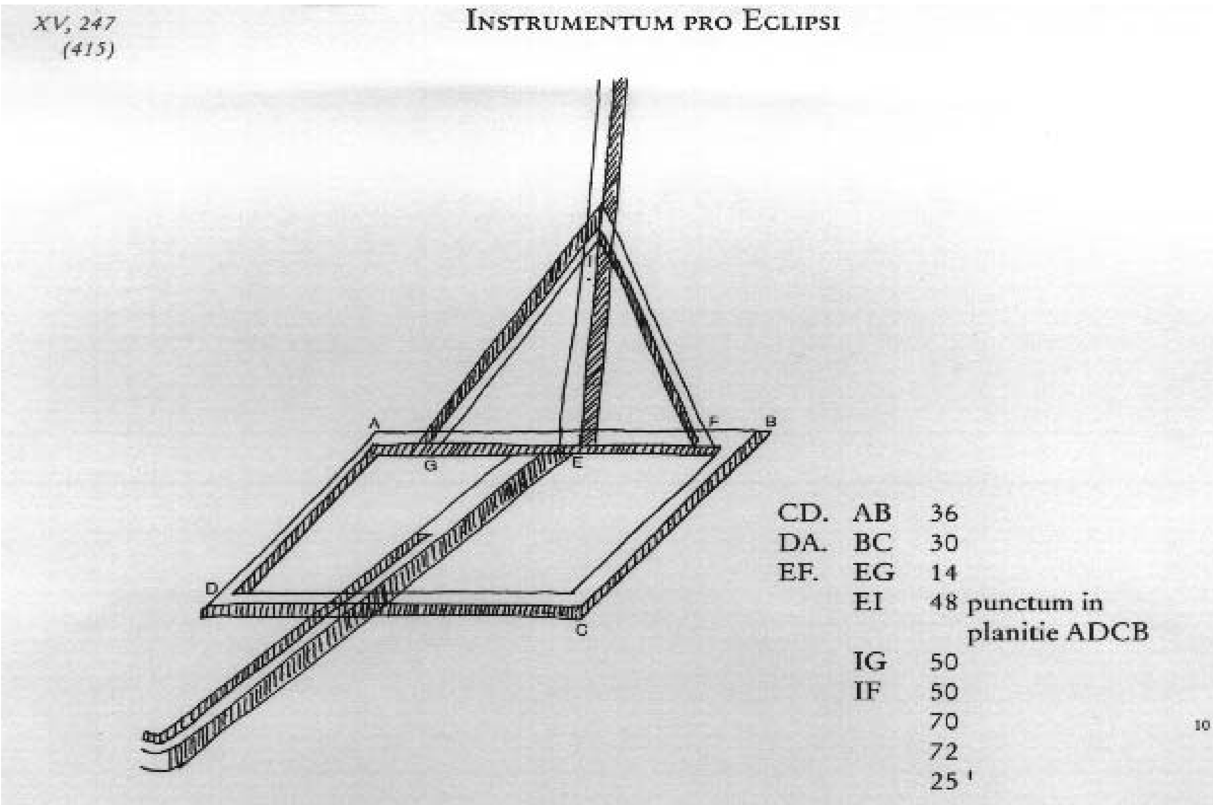


Figure 1: Kepler's eclipse instrument, Graz 1600 (Kepler-Mss. Pulkowo Vol. XV, p. 247).

plunged into the role of taking up Tycho's work and administering his scientific heritage. He was ordered to edit Tycho's incomplete writings and to look after the astronomical instruments. To carry out these obligations it was necessary to clarify the relationships with Brahe's family and heirs; they however claimed Tycho's scientific work including the astronomical instruments for themselves.

To understand Kepler's new situation we have to consider also his social position at the Imperial Court and his relationships with the nobles and the high-ranking officials. In relation to the noble Brahe family, he was in a rather weak position. In order to safeguard the records of Tycho's observations and in an attempt to retain Tycho's instrument for Kepler, a contract was drawn up with the heirs but did not materialize due to financial problems. Kepler took over all the available material left by Brahe

and Prague". For the moment I had the vision that such a celebration would be propriate to Kepler when he would be buried in the Cathedral of Regensburg. Why should I not ask the Bishop of Regensburg to find a place for a Kepler memorial in his Cathedral?

and started immediately to deal with the records of the observations and also to edit Tycho's writings.[9] Tycho's first recorded observation dated from 17th August 1563,[10] the last one – a measurement of the distance between Aldebaran and Procyon – from 11th October 1601.[11] By July 1602 Brahe's heirs appropriated some of Tycho's instruments but had no real interest in using them to make astronomical observations. So Kepler could only use them for a short time. Most of the instruments were packed up, or they disintegrated in the Imperial gardens in the open air.[12] It was obvious that most of the instruments were destroyed in the first years of the Thirty Years war. Only the big globe could be saved.[13]

Kepler's further activities in observation in Prague were not connected with his outstanding works in astronomy and optics on which he worked at that time but were initiated by spectacular phenomena in the sky, which were first observed by other astronomers. Such observations did not belong to Kepler's normal duties but as Imperial mathematician he felt obliged himself to repeat them as soon as possible and moreover to give a commentary. Obviously the starry sky did still belong to the most interesting fields of the environment for human knowledge and wisdom in those days. In autumn 1604 a supernova or – as usually designated in Kepler's time – a new star appeared and caused a sensation also in Prague. It was observed as a very bright star close by the big conjunction of Jupiter and Saturn, which on the other hand was of some interest for the astrologers because of its appearance in a fiery sign of the zodiac. Continuous observations of these two phenomena were also done by Kepler, who worked them out in his work *De Stella nova in pede Serpentarii* (Prague 1606). We have some manuscript material about the observations.[14] When *Johannes Brunowsky*, a highranking official in the service of the Imperial Vice-chancellor Rudolph Corraducius, communicated his observations of the new star to Kepler, the Imperial mathematician started immediately with his own observations together with his assistant *Johannes Schuler* or *Schueler*.[15] The records begin with the measurement of distances and

[9]See *IV. Catalogus librorum a Tychone Brahe conscriptorum*, in: *KGW XX.1*, p. 89-95.

[10] *Tycho Brahe opera omnia X*, p. 3.

[11] *Tych. Br. op. omn. XIII*, p. 282.

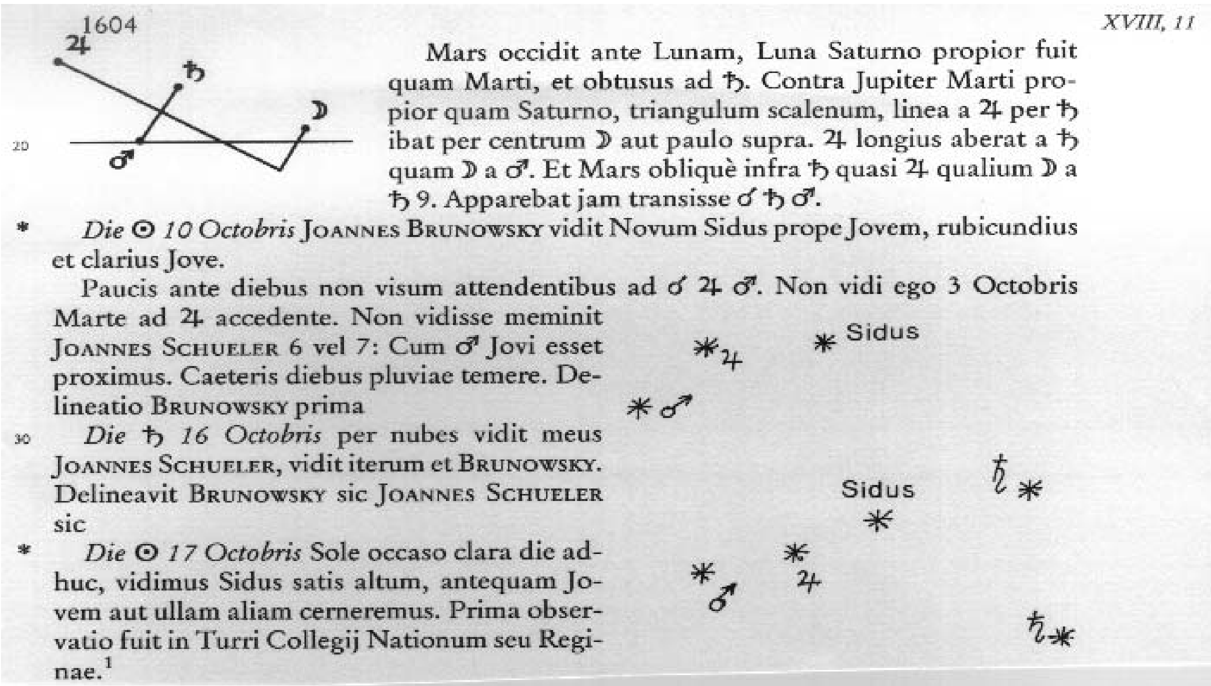
[12] "Instrumenta in horto Caesaris sub dio putrescunt", so wrote Kepler to David Fabricius in February 1604. See letter No. 281, in: *KGW XV*, p. 27.

[13]See J. L. E. Dreyer, *Tycho Brahe.* New York 1963, p. 365 f. German edition Karlsruhe 1894, S. 386.

[14]Kepler-Mss. Pulkowo XIII, 219-220v; XVIII, 19-15v and 44-45v. The material will be published in *KGW XXI.1*.

[15]See *De Stella nova*, cap. 1, in: *KGW I*, p. 158 f.

heights of the planets including Saturn and Jupiter in the constellation Ophiuchus in June 1603 and ended on June 2nd, 1605. In connection with his measurements Kepler drew some elucidating sketches *(Fig. 2)*. Since he was not allowed by Brahe's heirs, especially by the arrogant Tengnagel, to make use of Tycho's instruments, he observed with less reliable ones owned by Baron J.F. Hoffmann: and with a little quadrant and sextant. Occasionally he could also use one of Tycho's clocks and besides a little azimuthal quadrant of Tycho.[16] However the instrumental errors had to be corrected or to be calculated. Thus the vertical installation was controlled, and the sextant was continuously checked by the remeasurement of starry distances which were already calculated.[17]



XVIII, 11

1604

Mars occidit ante Lunam, Luna Saturno propior fuit quam Marti, et obtusus ad ♄. Contra Jupiter Marti propior quam Saturno, triangulum scalenum, linea a ♃ per ♄ ibat per centrum ☽ aut paulo supra. ♃ longius aberat a ♄ quam ☽ a ♂. Et Mars obliquè infra ♄ quasi ♃ qualium ☽ a ♄ 9. Apparebat jam transisse ☌ ♄ ♂.

* *Die ☉ 10 Octobris* JOANNES BRUNOWSKY vidit Novum Sidus prope Jovem, rubicundius et clarius Jove.

Paucis ante diebus non visum attendentibus ad ☌ ♃ ♂. Non vidi ego 3 Octobris Marte ad ♃ accedente. Non vidisse meminit JOANNES SCHUELER 6 vel 7: Cum ♂ Jovi esset proximus. Caeteris diebus pluviae temere. Delineatio BRUNOWSKY prima

Sidus

Die ♄ 16 Octobris per nubes vidit meus JOANNES SCHUELER, vidit iterum et BRUNOWSKY. Delineavit BRUNOWSKY sic JOANNES SCHUELER sic

Sidus

* *Die ☉ 17 Octobris* Sole occaso clara die adhuc, vidimus Sidus satis altum, antequam Jovem aut ullam aliam cerneremus. Prima observatio fuit in Turri Collegij Nationum seu Reginae.[1]

Figure 2: Kepler's observations of the New Star, October 1604 (Kepler-Mss. Pulkowo Vol. XVIII, p. 11).

Tycho's clock with weights and toothed gear was a special problem. As Brahe himself also Kepler had to observe the unreliable running of the clock[18] and compared the reading of time with observed starry heights and with clocks of the local spires.[19] Here we can find one of the rare passages

[16] Mss. XVIII, 44v.
[17] Mss. XVIII, 15v, 10 and 11.
[18] Mss. XVIII, 44v-45v.
[19] Mss. XVIII, 45.

in his manuscripts where Kepler himself occurs as a critical astronomical observer.[20] His observations of the new star, analyzed by himself,[21] must be, of course, of less accuracy compared with those of David Fabricius, but with the mean error of $4'$ they do still present a relatively good quality of observation.[22]

Since observations of the eclipses and the comets belonged to the normal astronomical work of routine, only a certain somehow surprising event could inspire Kepler's lively spirit to new activity in theoretical considerations.

In the years 1609 and 1610 such an event took place, when Galileo made his eminent discoveries in the sky by using a telescope. The way how the discoveries were made known to Kepler reads like the beginning of a thrilling story. The Imperial councillor Wackher of Wackenfels, who was passing by in a coach, shouted down to Kepler that Galileo had discovered four new planets, unknown until now. This rapidly given information fired Kepler's imagination. Could it be possible that more than six planets existed? In this case it would have been obviously that his intercalation of the regular polyhedrons between the planetary spheres could no more operate, that means his cosmological model in the *Mysterium cosmographicum* would be wrong. However the correct information about the four satellites of Jupiter was not disturbing Kepler's fundamental cosmological idea but meant rather a new fact which could hardly be included in the traditional philosophy of nature and in its idea of a single-centred universe. In May 1610, Kepler gave an enthusiastic consent to Galileo in his open letter *Dissertatio cum nuncio sidereo*, but wished to convince himself about the truth of Galileo's observations by viewing the phenomena. However his request for a telescope was not fulfilled by Galileo, and in Prague is was impossible to construct a telescope without good convex lenses. Finally Kepler obtained a telescope made by Galileo from Elector Ernst of Cologne for a short time, when Ernst took part in the Electoral assembly in Prague. Together with his assistant Benjamin Ursinus, with the Scot Thomas Segethus and partly with Tycho's son-in-law Tengnagel, Kepler observed the changing position of the satellites of Jupiter in relation to the planet in the time between 28th August and 9th September 1610. The records of the observations together with some sketches, entitled *Observa-*

[20] Here I wish to refer to some former observations of a new star in the constellation Cygnus, which Kepler made with the assistance of Johannes Ericksen in Prague in August 1602. The instrument was a sextant of Baron J. F. Hoffmann. See *De Stella tertii honoris in Cygno*, Prague 1606, p. 167 (*KGW I*, p. 309 f.).

[21] Mss. III, 2-20v; published in: *De Stella nova*, cap. XIII (*KGW I*, p. 211 ff.).

[22] Here the mean error was derived from 14 results of chapter XIII.

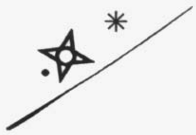
tio Mediceorum per Oculare Galilei, quod misit ad Electorem Coloniensem, are left in his manuscripts *(Fig. 3)*.[23] Obviously he was keenly interested in this verification of Galileo's observations; for already six weeks later the first printed copy of his little writing *Narratio de Jovis satellitibus* was sent to Galileo. It should be added that Kepler was able to continue his observations by an improved telescope made in Prague in the time between 4th October and 9th November 1610.[24] However the relation between Kepler and Galileo remained mostly a one-sided manner. While Kepler wanted to take part in the new scientific development and made his ideas generously known to Galileo, the noble Italian scarcely communicated with Kepler as with an equal colleague. By his new discoveries and by using a secret code for his information, Galileo kept Kepler in eager expectation for the whole of the year 1610. In August he learned that Galileo had observed the disc of Saturn as spread out to a flat oval. In the end of the year, when Galileo in a letter of December 11th to Julian of Medici wrote about his observations of the phases of Venus, not directly but hidden in an anagram, Kepler could scarcely repress his excitement. In a new letter to Galileo, dated 9th January 1611, Kepler suggested eight partly incomplete solutions of the anagram by imaginative variations.[25] It is most remarkable that Kepler's first attempt of a solution is equivalent to another observation which was made much later in 1878. Kepler wrote: "Nam Jovem gyrari macula hem rufa testatur"[26] (Namely that Jupiter rotates is testified by a red spot). Here imagination was combined with his astronomical knowledge. Thus he was able to assume that the planets have spots as well as the moon and the sun and that all the planetary bodies do rotate. The reddish colouration of Jupiter could arise by refraction of the light in the atmosphere, although at this time it was not yet clarified whether the planets would have their own atmospheres.

Kepler's genuine interest in astronomical observations

Kepler was self-critical enough to know, that his observations could not compete with those of the best observers of his time, as e.g. Tycho Brahe and David Fabricius. It was not necessary for him to come up to highest standard of accuracy, and it was not possible to do so because he did not possess proper astronomical instruments. But nevertheless it was important for him as theorist of astronomy and philosopher of nature to take

[23] Mss. XV, 394-395.
[24] Published from the manuscript records in *KGW IV*, p. 511-513.
[25] Letter No. 604, in: *KGW XIV*, p. 357.
[26] *KGW XIV*, p. 357.

Die 7 Septembris mane hora 4. Jupiter est visus cum duobus satellitibus, uno parvo et claro ad orientem sub ipsis radijs Jovis, altero quasi tertia parte instrumenti ampliati versus occasum. Testis URSINUS. Horâ quinta non amplius vidi orientalem, vidit tamen et agnovit Dn: TENGNAGLIUS, sed vicissim non vidit occidentalem. Erat Luna praesens. Mars stabat supra Lunam ferè duabus Lunae semidiametris, nondum in linea sectionis.



Die 9 Septembris hora 2 et 3 vidimus tres, duos occidentales, clarissimam quae Jovi propiorminus distantes, quam clarissima a Jove. Minus dimidio instrumenti distabat extima a Jove. Orientalis una sub radijs Jovis clara, dimidio a Jove ejus quod inter se distabant occidentales. SEGETHUS omnes tres vidit et eodem modo disposuit. D. SCULTETUS Fiscalis agnovit clarissimum occidentalium. '

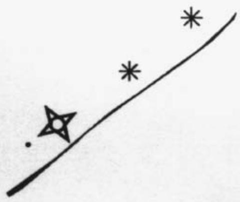


Figure 3: Kepler's observations of the satellites of Jupiter with his drawings, September 1610 (Kepler-Mss. Vol. XV, p. 395v).

a view of the phenomena which he wished to study carefully. The awareness of the practical difficulties in observing the sky helped him to value accurate astronomical observations which he required for the elaboration of the planetary astronomy and for his far-reaching considerations due to his genius. So we can find a close connection between practical needs and theoretical conclusions in Kepler's work partly based also in the pleasure of his own observations. Thus important problems of astronomical optics, e.g. the theory of the *camera obscura* and the theory of eclipses, were prepared by the construction and the use of his ecliptic-instrument. By the observations of the new star in the years between 1603 and 1605 he took the opportunity to reflect again on the place of the eighth sphere and on the structure of the universe never doubting its finiteness – in opposition to the ideas of Nicolaus of Cuse, Giordano Bruno and William Gilbert. And finally the intention to verify Galileo's telescopic discovery of the satellites of Jupiter has not its importance in itself, but can be understood as an expression of Kepler's efforts to find the correct *forma mundi* – according to Copernicus' view of the planetary system and in coincidence with Kepler's understanding of the principles of creation.

Tycho Brahe and Prague: Crossroads of European Science, pp. 137–149, J. R. Christianson et al. (eds.), copyright H. Deutsch 2002

The Great Quadrant of Lindholm – an Astronomical Instrument from the Time of Tycho Brahe

Felix Lühning, Hamburg

This paper deals with the so-called quadrant from Lindholm, an astronomical instrument, which has long been inaccessible to the public – imprisoned in the stores of the State Museum of Schleswig-Holstein at Gottorf Castle in Schleswig.

The State Museum acquired this quadrant in 1955 from the parish of the north Frisian village Lindholm. There it was kept for centuries in the little St. Michels church and used – not quite corresponding to its original purpose – as a wardrobe for the farmers. According to a delivery, the quadrant came from the property of the clergyman Albert Meyer, who was from 1553 to 1603 the preacher of that church. To understand the Lindholm quadrant as an astronomical instrument of its time, one has to begin far back. Since the purpose and significance of this implement appears best from its historical environs, here first of all shall follow a description of the life and work of Albert Meyer. Afterwards the quadrant shall be introduced.

Albert Meyer was born in 1528 on the island Pellworm. His father was the preacher Johann Meyer, who later became one of the first Protestant clergymen in Hamburg. Little is known about Albert's childhood and youth. At age 19 he began to study at the University of Copenhagen. Meyer possessed great talents, which even aroused the attention and the benevolence of king Christian III of Denmark. Already in 1550 he received his master's degree. King Christian even proposed him for a professorship in mathematics, but the University refused it because of his youth and lack of experience. Nevertheless it seems that Meyer taught mathematics for the following two years in Copenhagen.

At the latest in 1553 however he became a preacher in Lindholm. In

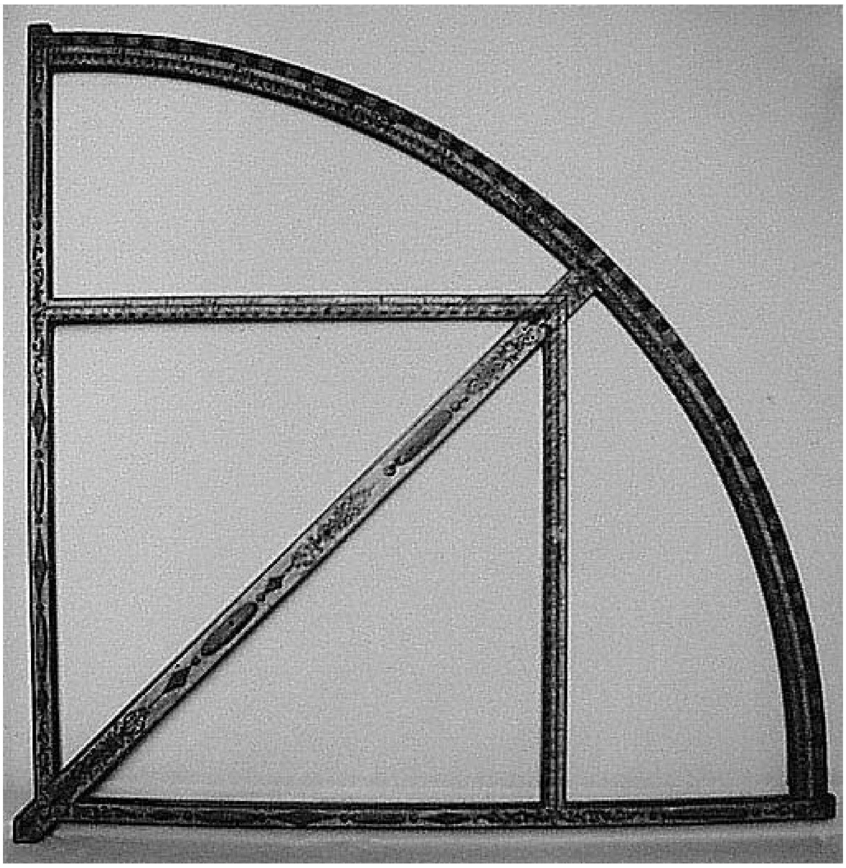


Figure 1: Present state of Lindholm quadrant.

the summer of the same year he married and soon buried all his plans to return to Copenhagen. In spite of his official duties he found enough time for other employments. His extended interests and his vivid impulse for research drove him – like many other learned men of his time – to astrological and alchemical, but also to cultural, historical and geographical studies. His research brought him into contact with Heinrich Rantzau (1526-1599), governor of the Danish king in Schleswig-Holstein, an intelligent diplomat and well educated humanist, who occupied himself intensively with astrology.

In connection with the quadrant we should here take an interest in Meyer's astrological and astronomical activities. One has to consider that in those times in Protestant countries there was a big need for well educated, humanistic-enlightened clergymen to spread the idea of Luther's Reformation. With regard to this, an occupation with astrology was nothing unusual for a preacher; one even did regard it as a way to get nearer to the nature of God. Albert Meyer even meant to underpin his astrological activities with citations from the Bible. We know that he used for casting his horoscopes the voluminous ephemerides of Cyprian Leovitius. On the other hand, we don't know, which experiments Meyer did perform in the alchemical field. They do not seem to have been significant, since he didn't report anything about it. Nevertheless it is no wonder that the parish of Lindholm followed his activities with suspicion and accused him with wizardry.

Only from his preserved letters we are told about some details of his life. In April 1558, for example, he was occupied with planting a maze in his garden. One year later, in March 1559, his beloved wife Cecilia died. In spite of the customary one year of mourning, Meyer decided to marry yet in the same year the daughter of a distinguished farmer in the village of Niebüll. The wedding had to take place on St. Martins-day 1559, since Meyer had found from Leovitius-ephemerides an auspicious constellation between Venus and the Moon. Ten years later, we see 'Magister Albertus' – beside his profession as a preacher and his other activities – riveted by a new object of research, which indeed could hardly lie farther: Meyer was occupied with Greenland.

In this connection it is necessary to begin far back, too. In Meyer's time, Greenland was a 'white spot on the globe', although this country had already been discovered in the 9th century and in the following colonized by the Vikings. At the latest in 1400, however, contacts between civilized Europe and faraway Greenland broke off again. King Frederick II of Denmark hoped to gain this country for the Danish crown. In 1568 the king published a proclamation, in which he declared his claim on Greenland. An expedition to Greenland, however, didn't take place, since the king needed his ships for action against the Swedish navy on the Baltic sea.

Evidently it was this proclamation, which drew Albert Meyer's interests to Greenland, and in consequence of this he began to collect all that was known about this country. He put together a 20-page manuscript, which contained – beside historical reports – two sailing-instructions to Greenland. And evidently in his mind grew the hope one day to lead an expedition there.

The first run for it he made in 1584. In that year a merchant in Antwerp planned, together with a Norwegian partner, to fit out a ship for a voyage to Greenland. Through Heinrich Rantzau, Meyer petitioned the Danish king to procure a place on this voyage. It is not known if the merchants really sailed to Greenland, in any case the preacher had to stay in Lindholm. Three years later it became known that John Davis had searched for the north west passage and that he had steered his ship to Greenland. This circumstance gave king Frederick II a broad hint that time was pressing, if he wanted to take possession of that country.

In the same year (1587) Meyer wrote – commissioned and supported by Heinrich Rantzau – the publication *Methodus Apodemica.* Considered on its own, this little booklet has nothing to do with countries in the polar regions. It is a catalogue of questions, disposed on different themes, to instruct travellers in foreign countries to make systematic observations to get a maximum of information about the concerning country. But if one regards this booklet together with Meyer's interests, one does get the impression that here the preacher of Lindholm was silently preparing himself for an exploring expedition.

In 1592 Meyer learned that the council of the Danish kingdom wanted to send two ships to Greenland that year. Thereupon the already 64 years old man wrote a long letter to Heinrich Rantzau with the urgent request to intercede with the king for him, so that he could take part at the expedition. The letter was composed in a submissive tone but contained a bold request: Meyer did not want to lead the expedition but the king should appoint him as the secular and religious governor of Greenland! If the expedition did not take place, Meyer requested the king to give him an opportunity for an exploring expedition to Norway, Iceland and the Faeroe Islands, where he wished to conduct geographical, cultural, historical and other research.

We don't know which hopes, wishes and feelings Meyer did connect with the expedition to Greenland, nor do we know, what was on his mind when he presented his high-flown plans with an imploring entreaty to the mighty governor Rantzau – disgust with his profession, difficulties with his parish, a need to get out of the daily humdrum, to explore and become famous? Concerning Meyer's talents it seems likely that he regarded himself with his job as a preacher in a rural parish as underemployed and saw in the voyage to Greenland a task in which he could finally play his abilities to the end.

How ever it may be – it is idle to think further about it, since the voyage to Greenland again didn't take place and Albert Meyer had to stay, where he was – in Lindholm. Until a high age he preserved good health and his interest for sciences. In 1600 he could report that he neither was suffering from dim eyes, nor missing teeth, nor flatulence or tired feet and that he was still studying eagerly in his books: *"Albertumque sehes in libros hengere nasum".* Three years were still granted to him. Around Whitsuntide 1603 he celebrated his 50-year jubilee as preacher, in August he and his wife were carried away within 11 days by the plague, which came suddenly to Lindholm. Since every contact with the infected village was forbidden for strangers, master Albertus had to be buried with uncommon quietness and without a sermon.

But let's come now to the main subject of my paper. It would be superfluous here to discuss the origin, handling and purpose of a quadrant. Shortly spoken: a quadrant was well suited for an orientation on heaven and earth; on travels to unknown countries it could be very useful if one wanted to know on which latitude of the globe one found oneself.

The Lindholm quadrant is completely worked out of oakwood. The radius of its limbus is 2.11 m. Already at the first sight it is apparent that its construction is quite fine compared with its size – especially if one compares it with other contemporary quadrants, for example, with those of Tycho Brahe. The limbus, which carries the dial, is held by three spokes or shafts. The middle one is somewhat stronger than the outside ones and stands out a little bit from the center of the circle-segment. In this way it forms a 'head' which contains the upper part of the backsight – a diopter with two holes. In addition to that, we find in the exact center of the limbus a rhombe-shaped hollow for the fitting of a plumb-line. Between the spokes of the shafts are two struts, which form a square. They carry a special dial, which shall be explained later.

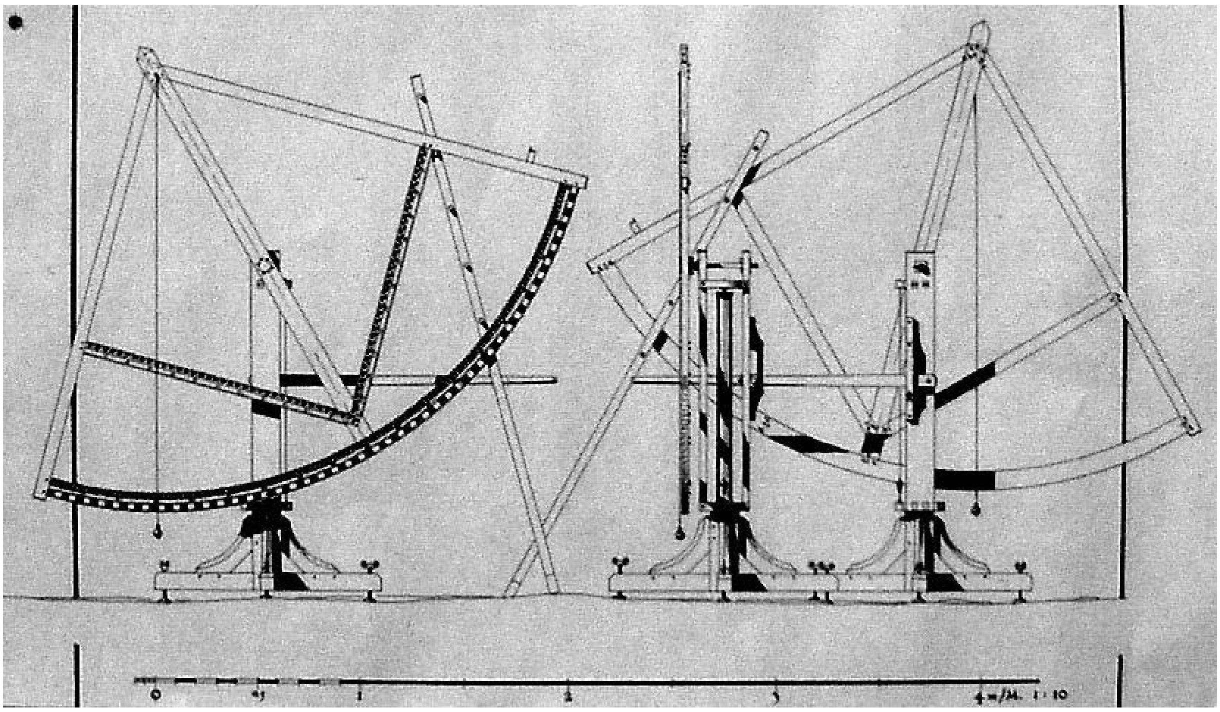


Figure 2: Scheme of the complete Lidholm quadrant.

The arc is put together from three segment-pieces. The parts are connected with slit and mortise, as all the other parts are mortised too. The connections are secured by oak-nails, which stand out a little bit on the back side; their tops are carefully rounded, so that they can be driven out by a stroke with a hammer without breaking or cleaving to dismantle the instrument. Glue wasn't used in any case.

All parts of the connections are numbered on the back side of the quadrant with clearly carved Arabian numbers – a circumstance, which shall become important later. The neatness and care that is applied to the whole instrument is telltale evidence that an excellent craftsman built it.

Figure 3: Detail of the scale of quadrant.

The dial on the arc is neatly carved in. The dial is divided into a chequered band of single degrees and further into thirds that means into steps of 20′ – 40′ – 60′ arc-minutes. The dials on the struts form a so-called 'shadow-square', a peculiar and in Meyer's time almost antiquated device. It was developed in the early Middle Ages by Arabian astronomers and served originally for measuring the length of the sunshadow. The European astronomers transformed it into two scales called "umbra recta" and "versa", and converted the measured distance on the scale into an angle by means of tangent and cotangent. On the Lindholm quadrant the "umbra recta" and "versa" dials are divided into 12 equal 'hours', which are further subdivided into 6 equal '10-minute steps'.

With each observation the quadrant delivers two complementary values: on the dial of the arc, the plumb-line gives the angle directly in degrees; on the square, we find a distance expressed in 'hours' and 'minutes', which has to be converted into an angle.

For astronomical observation it is necessary to aim and to bear the object exactly. The Lindholm quadrant has for this purpose a rear sight that is a two-hole diopter. The front part is preserved in its original state at the 'head' of the quadrant, while the back part has broken off and is lost now. However, it could be reconstructed without difficulty by the traces it left on the shaft. The 'head' of the quadrant has two holes one above the other. On the front side of the 'head' there is a diaphragm of sheet brass with two fine holes in it. The construction of the rear diopter must have been similar to that at the 'head': a wooden tap with two holes and a brass diaphragm with two small holes. Since both diaphragms moved in dovetail leadings, they were adjustable, so that the observer could really aim exactly parallel to the upper shaft of the instrument.

The painted version of the quadrant with its somewhat 'rural' decoration originates from a later time. The inscription on the limbus reads "RENOVIRT ANNO 1744 ALBERT PARENSEN". The back side of the quadrant remained unpainted. Albert Parensen (whoever he was) was the first one who furnished the quadrant with paint, for under the painting we don't find any earlier layers of paint. Presumably the intention to hang up the quadrant as a 'souvenir' in the church and to use it as a hatrack for the visitors gave the occasion for this 'renovation'. For this purpose its front side got decoratively painted, but on the back side the paint could be saved. The wrought iron hooks for the hats were driven in ruthlessly in the shafts, struts and the dial. They aren't present any more today, but they left very distinctive traces.

The evidence indicates that the quadrant was never finished. Also a mounting for this instrument isn't present. For what purpose did Albert Meyer want to use his quadrant? Although a connection with Meyer's astrological activities would be obvious, but the fact remains that a quadrant wasn't necessary for this at all. Casting a horoscope was purely a job for the writing-table, where we know that Meyer used the ephemerides of Leovitius. Moreover, the quadrant was an instrument that could only give information about the declination of the stars, but not about their angular distances in the ecliptic, which was standard for astrological predictions.

If one thinks again about its different uses, there obtrudes the suspicion that the Lindholm quadrant has to be seen in connection with Meyer's planned Greenland expedition. Of course the quadrant is too bulky for a

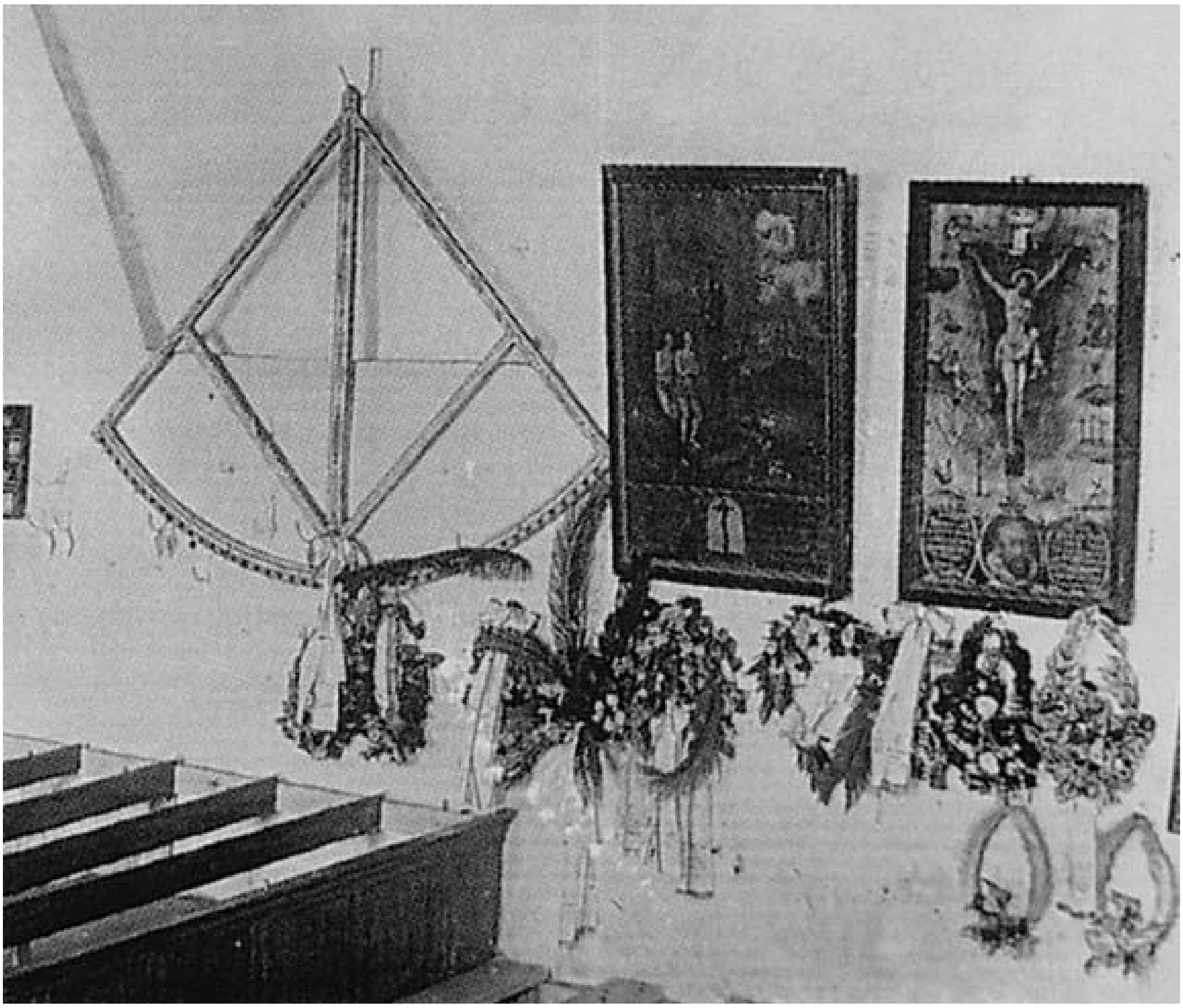


Figure 4: Photo of the quadrant at Lindholm St. Michels church in 1901.

transport on a narrow sailing vessel, but its simple construction, its carefully numbered connections and its removable wooden nails give us a broad hint that this quadrant actually was thought as an easy to dismantle expedition instrument. On the spot, it could be put together quickly by the numbers, aboard a ship it could be stowed away easily and wasn't endangered. Also the unfinished shape of the quadrant supports the argument of a connection with Albert Meyer's Greenland expedition: since the voyage didn't take place, Meyer lost all interest in completing the quadrant.

We don't know who built the quadrant. Even if it is possible, it is yet not very probable that a joiner in Lindholm did this job. We have to look for the maker in a nearby town – or in Meyer himself. Indeed, astronomers of that time were often good craftsmen and made their own instruments or

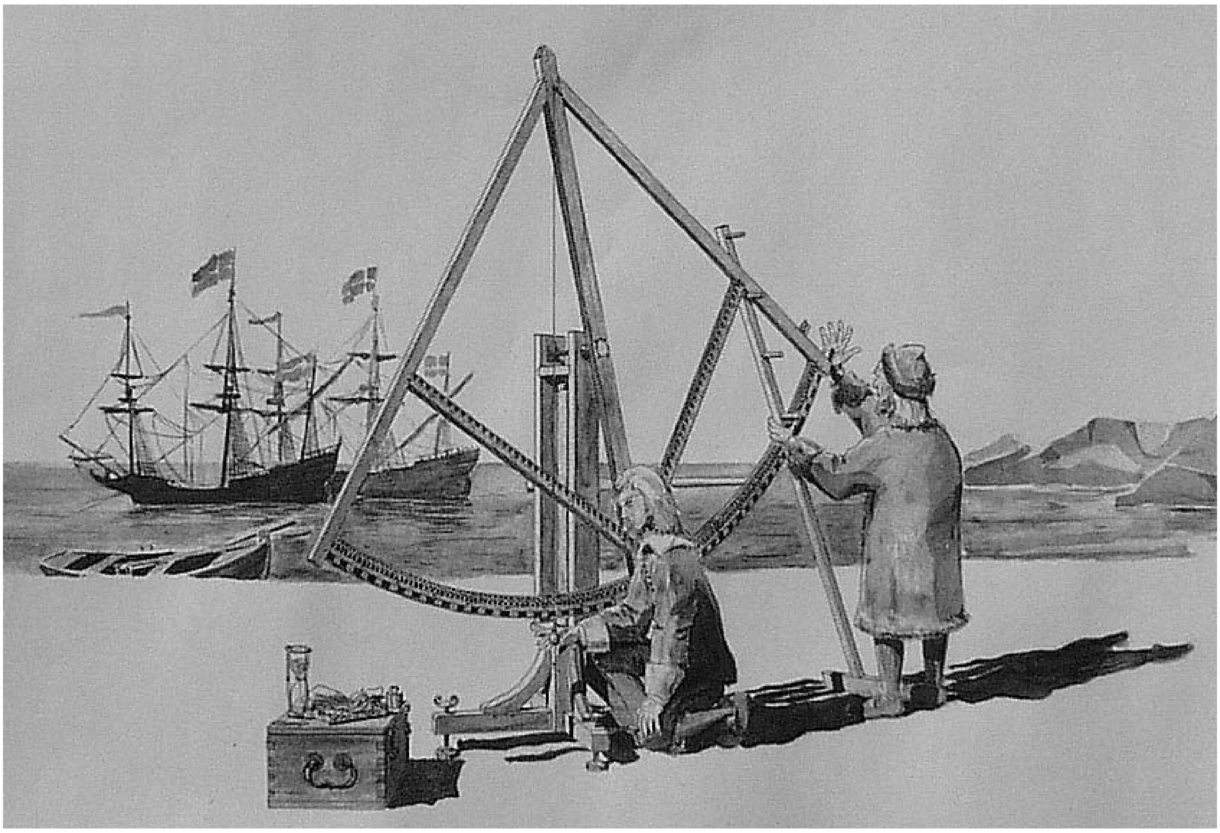


Figure 5: Supposed usage of the Lindholm quadrant as an expedition instrument. (Drawing by the author.)

at least lent a hand to the work. Astronomical instruments were not tools for daily use, and only the astronomers knew best, which shape was the most suitable for their instrument. So one can't exclude the possibility that Meyer himself did make the quadrant, even if he didn't report anything about it.

If one examines the question of influences on the Lindholm quadrant and prototypes for it, one almost necessarily comes to Tycho Brahe and his big instruments, which he designed from 1576 on for his observatory of Uraniborg on the island of Hven.

When Brahe built Uraniborg, he already had some experience with the construction and handling of big astronomical instruments; further improvements he could realize while furnishing his second observatory, the subterranean Stjærneborg. Brahe applied all care on his instruments. As building materials he chose steel, iron and brass, but in most cases wood. Although nearly all instruments preserved from that time are metal, wooden instruments must have been by far more common, since despite its inclination to warp, wood had some advantages: it was cheaper, it had a lesser weight and was more easy to work. Brahe was well aware of the pros and cons of wood. To preserve the wood against humidity, it was carefully painted several times with linseed oil or with oil paint or faced with sheet brass. But this was no perfect protection. The dials of Brahe's instruments were always made of brass, since on metal there could be made much finer divisions than on wood.

Even if it was said in the beginning that the Lindholm quadrant was built very carefully, its clear in comparison with Brahe's instruments, how much better designed, solid and precise the latter must have been than our quadrant. But one should remember that Brahe formed an exception: he disposed of rich resources and a well-equiped mechanical workshop with skilled craftsmen, while Meyer had to subsist on a modest wage and was dependent on the possibilities his surroundings could offer.

As a comparison to the Lindholm quadrant we can best use an astronomical sextant of Brahe, even if both instruments seem on the first sight to be entirely different. The radius of the sextant was about 2.40 m. It consisted of wood, but was completely covered with sheet brass. Its mounting consisted of wood, too, but was additionally secured by iron struts. For sighting the stars there was an alidade with a rim-diopter. The measured angle could be read on the dial up to single arc-minutes.

The similarity between Brahe's sextant and Meyer's quadrant is in their use: Brahe liked to take his sextant on his travels. The sextant was collapsible too; each connection was made by screws, only the dial remained as one piece. In travel, the single pieces were kept safely in compartments of several boxes. Since each connection was marked with a letter, the instrument could be rapidly put together on the spot. To save weight, the mounting was for the most part hollow, but could not be disassembled.

On his travels, Brahe used his sextant mostly for determinations of latitude. That the dial contained only 60° didn't disturb him, since his travels took place only in a reach of about 55° northern latitude. Against that, Albert Meyer wanted to 'climb high': his exploring expedition would have brought him to a latitude of 60° and beyond. Therefore, the polar star stands here in a steep declination between 60° and 70° over the northern horizon. The arc of a Tychonian sextant wouldn't have been useful any more in that case, only the quadrant was the right instrument here.

Between the preacher Albertus Meyer and the astronomer Tycho Brahe no direct contacts existed, neither of personal, nor of written kind. So we don't know, how Meyer got knowledge about Brahe, but we know from his letters that he had information about his activities. Finally the circle of learned men was small and easy to overlook at that time; Brahe carried on an extensive correspondence with respected persons, from whom some did correspond with Meyer, for example, Heinrich Rantzau. One can hardly presume that Meyer had a detailed knowledge about Brahe's instruments. If Meyer knew something about it, it was surely just second-hand reports – superficial descriptions, which only gave an impression about their size and their primary principles. Nevertheless it remains conceivable that in this way he got to know something about Brahe's travelling sextant and decided to build a more modest but a similar instrument, which was fit for a Greenland expedition.

However it may be – while Brahe's instruments vanished completely, Meyer's quadrant endured the change of times nearly without damage. One may say that the Lindholm quadrant is the last of the big wooden astronomical instruments of its time and of its kind. The Lindholm quadrant mediates to us an authentic idea of the dimensions of Brahe's instruments, their handling and last but not least the influence which Tycho Brahe exerted on his surroundings.

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Analysis of Tycho's Handwritings

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Abstract

A detailed study of the handwriting of Tycho Brahe was performed so as to be able to identify the persons who had written texts until now supposed to have been written personally by Tycho or by persons from his circle. The identification was used to determine the authorship of two important inscriptions appearing in books kept in the National Library, Prague. These books were owned by Tycho.

Our goals

In the year 1901 there was a fairly large celebration in Prague on the occasion of the 300-year anniversary of Tycho's death. On this occasion several papers were published. In particular, the studies of Fr. J. Studnička are at the centre of our interest. Studnička collected what he called "Prager Tychoniana". In his paper, Studnička (1901) judged all these documents to have been written by Tycho.

We have found that not all of these items kept in our libraries are written in Tycho's hand. The matter came up several years ago when we collected books from Tycho's famous library to be covered in an as yet unpublished book on the National Library of Prague. It was obvious that the manuscripts were written by several different persons. However, nothing is so misleading as 'obvious' results. From this lamentable discovery, i.e. that unfortunately several manuscripts supposed to have been written by Tycho were not written by him, our analysis started.

Our goal is to identify Tycho's handwriting. We want to be sure in future what was written by Tycho and what was not. We want to avoid any mistakes in the ascription of manuscripts to Tycho. Another aim is to decide who is the author of two short but important comments in books kept in the National Library, Prague.

Pillars

The manuscripts cited by Studnička make so disparate a sample that it was nearly impossible to decide which one of them was written by Tycho. Nothing was certain, so we had to find some samples which we are nearly one hundred percent certain were written by Tycho in person. Only by being absolutely sure at least in some cases could we enlarge the number of manuscripts which could be unambiguously attributed to Tycho.

We therefore chose four 'pillars', which it is nearly certain that Tycho wrote himself, and we compared them. They are:

- **VI F 44:**
  The Album of Tyge Brahe[1] the eldest son of Tycho Brahe, the astronomer. It is kept in the National Museum, Prague. Its shelf mark is Museum Regni Bohemiae VI F 44. It is a typical Renaissance album of a young nobleman. On page 2 – right hand side – is the coat of arms of the Brahe family with Tyge's handwriting:

  Tandem bona caussa triumphat.
  Tÿcho Brahe, Tÿchonis Filius,
  Dresdæ, Die 27 Novembris,
  Anno Domini 1598 s(cripsit).[2]

  – See *Fig. 1* which is in fact a good example of the handwriting of Tyge. He wrote this for himself.

  On the left hand side is a dedication from his father, the astronomer Tycho to Tyge:

  Disce puer virtutem ex me
  durumque laborem,
  Fortiter et sortis sustinuisse
  vices.
  Tÿcho Brahe

[1] We shall use the name Tyge to distinguish him from his father despite the fact that the astronomer was also baptised as Tyge, the name *Tycho* being only a Latin version of his name.

[2] We use the transliteration of the text conserving all written signs and conserving even the capitals and minuscules to enable perfect identification of all written letters and signs.

Filio
TYCHoni primogenito
scripsi
Anno 1599 Feb(ruarii) *28*
Vitebergæ.

– See *Fig. 2.*

Tycho wrote this text in Wittenberg during a journey from Wandsbeck (not far from Hamburg; Vandesburgum in Latin) to Prague. The famous *Astronomiæ Instauratæ Mechanica* was printed in Wandsbeck during his stay there in 1598. Tycho left Wandsbeck during autumn 1598 and started a move to Prague. However, Tycho only arrived in Prague in June 1599, because a stay in Wittenberg at the family of Jesenský (Jessenius), the future rector of Prague's Charles University, took longer than Tycho had originally thought. It has been said that there was a plague in Prague at that time. Fortunately, this was not true.

The album is extremely important because of the fact that it collects samples of the handwriting of important people from the sphere of Tycho's family, e.g. Otto Brahe,[3] Franciscus Ganzneb Tengnagel van Kamp (Ritter von Camp), (1573-1636), a pupil of Tycho and Westphalian nobleman, who married Tycho's daughter Elizabeth, and many others.

- **DG IV 25:**
  The Album of Sebald (Siebald) Plan. It is kept in the library of the Strahov Monastery, Prague. There is a text saying:

plures sapiunt palato
quam cerebro;
Tycho Brahe
scripsit Uraniborgi,
Anno 1591

– See *Fig. 3.*

Tycho wrote this text during the prosperous development of the observatory at the Uraniborg. In that year he had only a few problems with Rasmus Pedersen and in the following year, 3^{rd} July 1592, the young, fifteen-year-old Danish King Christian IV personally visited

[3] Otte Axelsen Brahe (1579-1611) was the son of Tycho Brahe's brother, Axel Brahe.

Tycho at Uraniborg. Tycho received a massive gold chain with Christian's portrait from the King. (Tycho made the last observation at Uraniborg much later, on 15 March 1597.)

Below this inscription is another one, a little bit forgotten:

Auxilium meum a Domino,
Qui salvos facit rectos corde.
Erick Langr, loco et die ut supra.

– See *Fig. 4.*

Erick Langr (Lange) was a friend and collaborator of Tycho. He was also his distant cousin. Later he married Tycho's sister, Sophia. He died in Prague in the year 1613. The text in the album of Sebald Plan is an important example of Erick's handwriting.

- **AG XI 56:**
  This is a copy of his *Astronomiæ Instauratæ Mechanica*, Vandesburgi 1598, which is kept in the above mentioned library of Strahov. At the beginning of the book there is – apart from a nice realistic portrait of Tycho – a dedication by Tycho to Johannes Hasenburg:

Illustrj ac Generoso Domino,
D(omi)*NO IOHANNI, LIBERO BARONI AB*
HASENBURG, in Budin, Brosan, et Hoste-
nitz, SOLARENENSIUM Capitaneo,
S(uae) *Cæsar*(eae) *Maiestatis â Consilijs,*
Domino et amico suo in
primis honorando,
d(ono) *d*(edi)*t*
Tÿcho Brahe.

– See *Fig. 5.*

The problem of this text lies in the fact that the whole first part of the dedication (i.e. till "... primis honorando") is not a typical example of a handwriting. It is more or less a piece of calligraphy, or "painting with letters". All personal features of handwriting are therefore lost in this part. Moreover, it is highly probable that this part was executed by a professional calligrapher. The book, with the dedication prepared in such a manner, was given to Tycho only for his signature.

- **III-a-18/1693:**

  This, like the preceding item, is a copy of his *Astronomiæ Instauratæ Mechanica*, Vandesburgi 1598, which is kept in the library of the castle of Křivoklát. This library forms part of the collection of the National Museum of Prague.

  At the beginning of this copy there is a dedication by Tycho to Desiderius Pruskowski:

  ILLUSTRI ET GENEROSO DOMINO, DOMINO
  Vldarico Desiderio Pruskowski, Libero
  Baroni de Pruskow, Domino in
  Altenburg et NeoBisthritz, sacræ
  Cæsareæ Maiestatis Came-
  rario et supremi magi-
  stri stabuli munus
  administranti,
  Amico Suo
  honorando,
  Dono dedit
  Tÿcho Brahe.
  Anno 1601,
  Martij
  12.

  – See *Fig. 6.* There was a tear on this page and during restoration the relative positions of the two parts were unfortunately shifted. This is to be seen in the words "magis*tri, sta*buli, administran*ti*".

  The problem of this text is practically the same as in the preceding case (the dedication from Strahov). Again, the whole first part of the dedication (i.e. till "... Dono dedit") is more or less a piece of calligraphy, and again, it is highly probable that this part was written by a professional calligrapher.

- **VENICE:**

  The next document probably falls into the same category. We received a copy after the conference held in Prague, thanks to Dr. G. Truffa. Unfortunately, but as is only natural, we have it only in electronic form of the jpg format. It is a dedication of the same book – *Astronomiæ Instauratæ Mechanica* – to the Republic of Venice. The text is:

INCLYTÆ ATQUE ILLUSTRISSIMÆ
VENETORUM
Reipublicæ
submisse dono mittit
Tycho Brahe
manu propria.

– See *Fig. 7.* For more details see the paper of G. Truffa.

All of these examples of handwriting (except that of Sebald Plan which is about 10 years older) are from the same period of Tycho's life – i.e. from the last period of his life before his death.

Results – signatures

We have found that all four signatures (and the signature from Venice too) differ from each other only within the normal parameters of spontaneous variation in the writing of one person's signature. Therefore, they were written by one person, and it is practically certain that this was Tycho Brahe.

A short comment on Tycho's signatures: He wrote the name Tycho as Tijcho in all cases except Strahov (DG IV 25). This transcription can be found in old documents. The letters 'ij' written together look like 'ÿ', which was used by us in our transcription above.

In the list of dedications of *Astronomiæ Inst. Mech.* made by G. Truffa there is also mentioned a dedication which is now in Detmold, Lippische Landesbibliothek, Germany:

Illustrissimo D(omi)*no, D*(omi)*no Simoni, Comiti*
et Nobili Domino in Lippa, s(suae) *Sa*(cr)*æ Cæs*(are)*æ*
Ma(iesta)*ti a consiliis, Aulæ Imperialis ac in-*
ferioris Circuli Saxonici Præfecto
bellico generalis Domino,
viro clementi,
Submisse offero
Tÿcho Brahe, T(ychonis) *F*(ilius).

– See *Fig. 8.*

This handwriting is in very good correlation with handwriting samples of Tyge (see VI F 44 – *Fig. 1*). It seems that it is practically certain that it was written by him. Moreover, there was not found any reason militating against this conclusion. 'Nihil obstat'.

To have a better and larger sample of Tycho's handwriting, we used the examples of his handwriting published by V. E. Thoren 1990 (*The*

Lord of Uraniborg). In the book they are given on pages 121, 126 and 323. The examples differ slightly from our 'pillars'. They were written earlier, and also quickly, whereas our 'pillars' were written more officially and slowly. Such handwriting is very difficult to compare. For that reason, these examples did not influence our conclusions. However, we cannot exclude the possibility that all of these examples were written by one hand, i.e. by Tycho personally.

By-Products

There are some old prints and manuscripts of our interest kept in the National Library, Prague. The first one to be mentioned is Sign. **NK 14 B 16**, N. Copernicus: *De revolutionibus ...*. In this printed book there are quite extensive and numerous marginalia. The book belonged to Tycho. For a long time it has been supposed that the marginalia were written by Tycho. A facsimile of this book was published by Z. Horský (1971). Gingerich and Westman (1981) concluded on the basis of this facsimile that the marginalia were written by Paul Wittich.

Our result is: The marginalia *were not written by Tycho.* We have no examples of Wittich's handwriting to be able to decide whether they were written by Wittich.

The other problematic manuscript is Sign. **NK 14 C 20** – *Triangulorum planorum praxis arithmetica*, Tycho Brahe 1591. Studnička decided that this manuscript was written by Tycho and published a facsimile. It is quite an interesting book (not printed, only a manuscript) on theoretical plane and spherical trigonometry. It demonstrates that Tycho, as its author, was very good at the reduction of measurements. This fact is often forgotten. Unfortunately this manuscript *was not written by Tycho* either. It was undoubtedly the work of a professional calligrapher. This does not change the fact that Tycho was the author of this pamphlet.

The last manuscript which was in doubt was Sign. **NK XII A 28** – *Brevissimum planimetriæ compendium.* It was decided by Studnička (1903) that this manuscript too was written personally by Tycho. It is also an unpublished paper on theoretical goniometry.

Our result, unfortunately, is that this paper *is not written by Tycho* either. It was also a professional writer who wrote it out, and moreover somebody other than the writer of Sign. NK 14 C 20.

As a result, not one of the manuscripts held by the National Library, Prague was written by Tycho's hand.

The Main Problem

T. B. O. (Tychonis Brahe Ottonidis) TABVLAE SINVVM 1582, Sign. **VI E 9**, Tres. M 1, Cim. D 82, dimen. 230 × 163 mm. 20 parchment folios, in the form of texts written across facing pages, so that it contains only 36 written pages. This manuscript, in Tycho's original leather binding, contains only numbers except in the cases described below. It is highly probable that the tables were written by a professional writer. To decide who wrote it is very problematic. However, it is certain that Tycho personally supervised the composition of these tables, and very probably he was the author of the algorithms for calculating them. Also, when they were ready he used the tables nearly daily. They are very much the worse for wear, especially for the angles up to 20°. This is the proof that they are damaged by everyday use and not by bad treatment in libraries.

They are tables of sines and cosines from 0° to 90° in increments of one minute of arc. The tables are calculated to seven decimal places (!) and contain also differences. One of us (Z. Š.) checked several tens of these values using a pocket calculator. The typical error of these tables is 1 in the last position, which follows from incorrect rounding of values. No other errors were found. The tables are therefore much more precise than the published tables of that time such as e.g. Sign. NK 14 C 20 (mentioned above) *Canon doctrinæ triangulorum* ..., Lipsiae, Ex Officina Wolf. Gunteri, 1551, which also belonged to Tycho. The step of one minute of arc of the VI E 9 is one of the proofs that Tycho wanted to measure all angles with this degree of precision, even without using any glass optics.

On the first page there is written in Greek *Oisteon kai elpisteon* (in English: "To endure and abide"). The last page of the tables has two inscriptions *Numerorum scientia* – see *Fig. 9.* The first one (left) is written in black ink and is hardly legible – it is cramped. The other one (right) is written in an unknown red colour which contains bubbles, visible with a magnifying glass.

These till now unpublished inscriptions reflect the attitude of the writer to the whole of science. It is the beginning of the 'hard' sciences where the most important thing is calculation (as in celestial mechanics, quantum mechanics, etc.) as opposed to the 'soft' sciences, where the most important thing is description, as in (e.g.) philosophy or history or other sciences with a literary technique. This fundamental approach of the writer to the sciences can also be found in the next case.

There is a book by G. Bruno preserved in the National Library, Klementinum – Sign. **NK 15 K 22** (Tres. M 50, Cim. E 98) *Iordani Bruni Nolani Camoeracensis Acrotismus seu Rationes articulorum physi-*

corum adversus Peripateticos Parisijs propositorum etc., Vitebergae, Apud Zachariam Cratonem, Anno 1588, dimen. 103 × 147 mm.

I. Kořán (1969) pointed out the dedication of the book to Tycho Brahe:

Omni nobilitatis gratiae insigni et famosiss(imo)
(ac) *illustrissimo et excellentissimo d*(omino) *Tichoni Dano in*
signum benevolentiae et obse(quii author).

The last part of the dedication is hardly visible. One of us (Z. Š.) photographed it in 1980, when it was still possible to identify the whole word *obsequii*.

This very humble and yet at the same time ornate dedication can serve not only as a good example of G. Bruno's spirit but also as a good example of his handwriting. The book was printed before the time when G. Bruno came to Prague from Wittenberg (where the book was printed). He stayed in Prague for half a year, from 17 April (Easter) until the autumn, when he went to Helmstedt, Germany. However, this was well before the time when Tycho came to Prague, so Bruno's book was given to Tycho somewhere in Germany and the dedication was written at that time. Maybe the book was only sent to Tycho. The book reached Prague later on, with Tycho.

What is remarkable is the inscription to this book. The last page contains an inscription saying:

Nullanus nullus
et nihil,
convenjunt rebus nomina
sæpe sujs.

– See *Fig. 10.* This is a hard and unkind condemnation of the author. Moreover, it is in verse. It is a joke based on Bruno's name – Nolanus. Bruno was born in Nola, Italy, not far north-east of Naples, so that he also used the word "Nolanus" as a cognomen – see the title of the book. The similarity of Nolanus to Nullanus (in English good-for-nothing or nullity) is strongly pejorative.

Again we can find in this inscription a whole attitude to the sciences. What is prized and appreciated are those sciences where theories are supported by measurements and by mathematical treatment. If you only speak without making measurements and using mathematics, like the philosopher Bruno, you will not be taken into account at all and moreover you will not deserve to be called a scientist.

The main question is: Who wrote this inscription? Was it Tycho personally? We know that Tycho considered himself to be a 'super scientist', so logically it could be written in Tycho's hand. Nevertheless, some people around Tycho thought in a similar manner. Was it one of them?

The result of the analysis of the handwriting is unfortunately ambiguous. *It could be written by Tycho, but it is not certain.* However, we cannot exclude Tycho as a possible author of this inscription.

Absolutely the same result is also valid for the red *Numerorum scientia* in IV E 9. We cannot give a proof that it was written by Tycho, but we cannot exclude him. More analysis and more specimens of his handwritings are necessary.

An example of one of the working sheets used for the analysis of handwriting (J. V.) is in *Fig. 11.*

Acknowledgement: We wish to thank Alena Hadravová for her very valuable help with Latin, GianCarlo Truffa for enabling us to have in our hands his materials including pictures, Shaw D. Kinsley for sending us the model examples by writing masters and Christopher Lord for linguistic advice.

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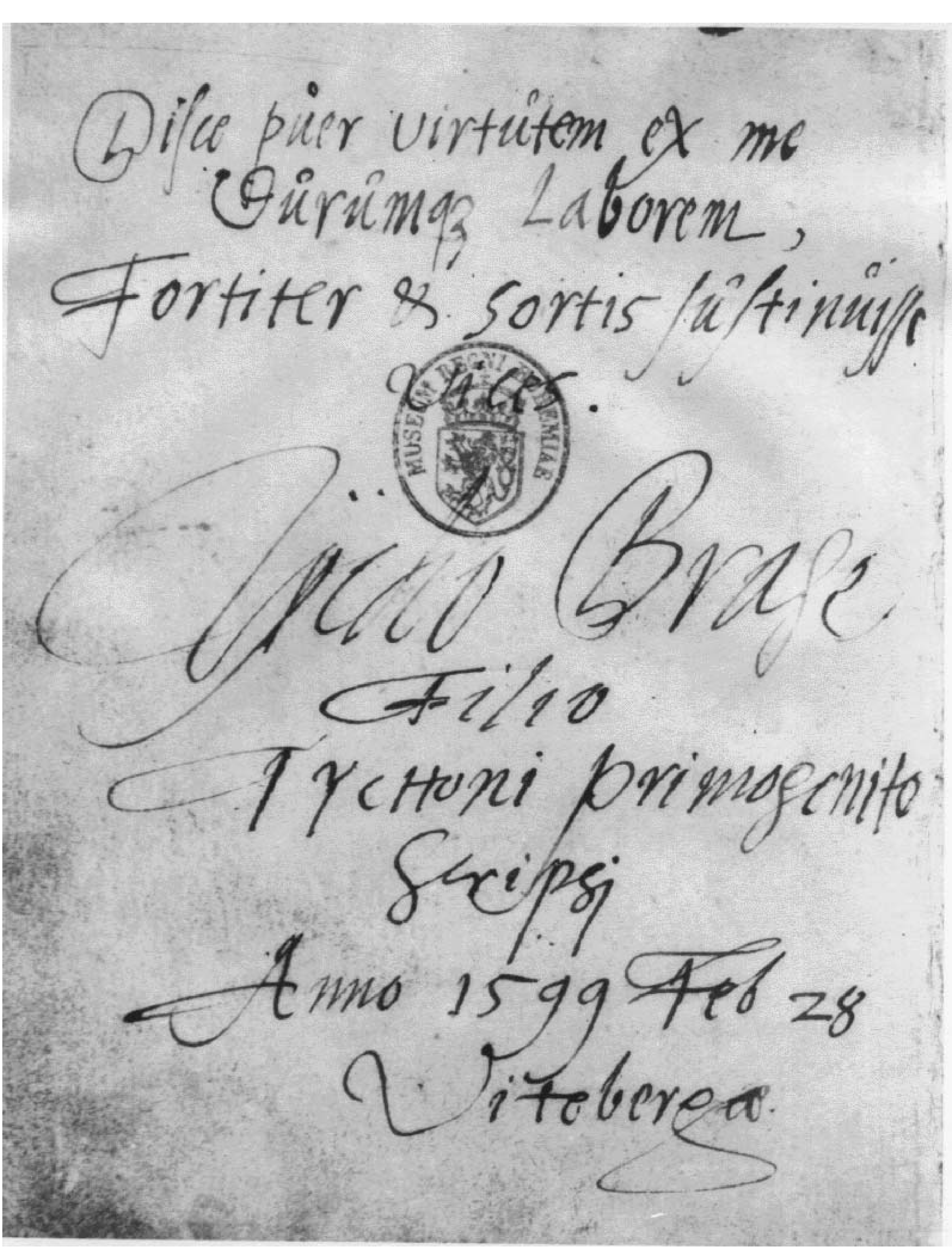
Emma Urbánková: *Rukopisy a vzácné tisky pražské Universitní knihovny.* Praha, SPN 1957.


Tandem bona caussa triumphat.
Tycho Brahe, Tychonis Filius,
Dresdae Die 27 Novembris
Anno Domini 1598.

Figure 1



Disce puer virtutem ex me
Verumq; Laborem,
Fortiter & sortis sustinuisse
vices.

Tycho Brahe
Filio
Tychoni primogenito
Scripsi
Anno 1599 Feb 28
Vitebergae.

Figure 2

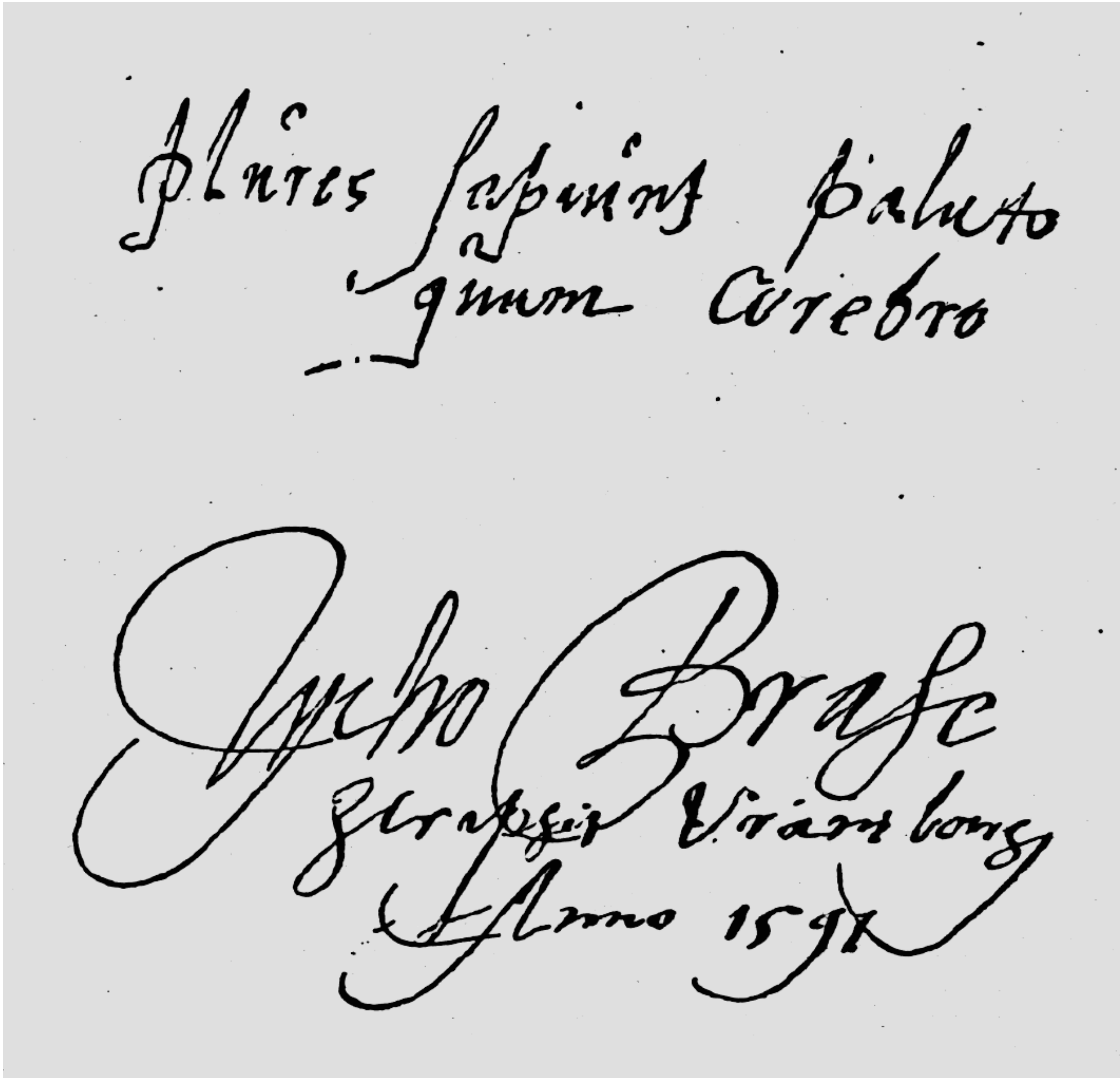


Figure 3

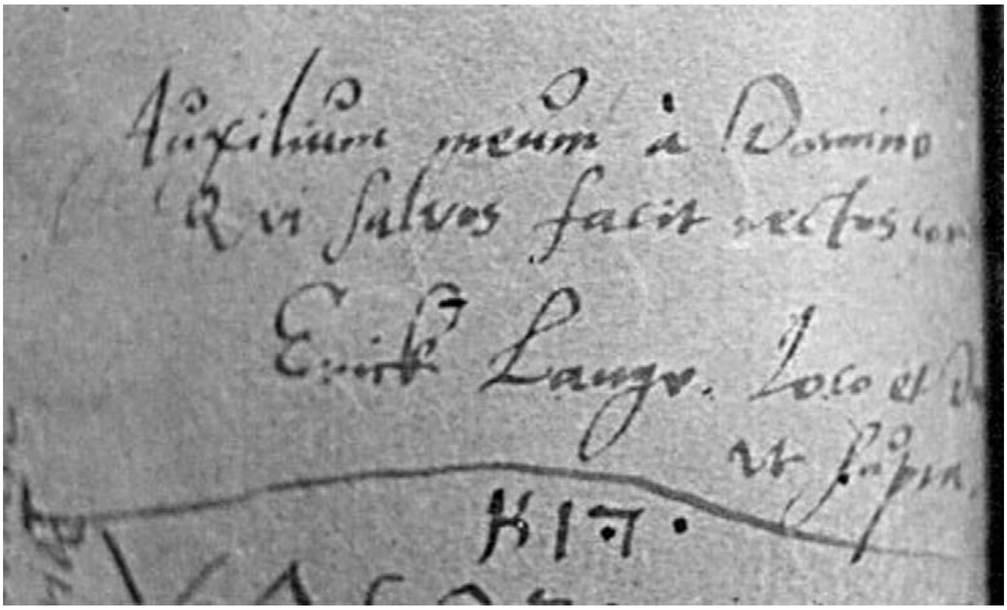

Auxilium meum à Domino
Qui salvos facit rectos
Erik Lange.

Figure 4

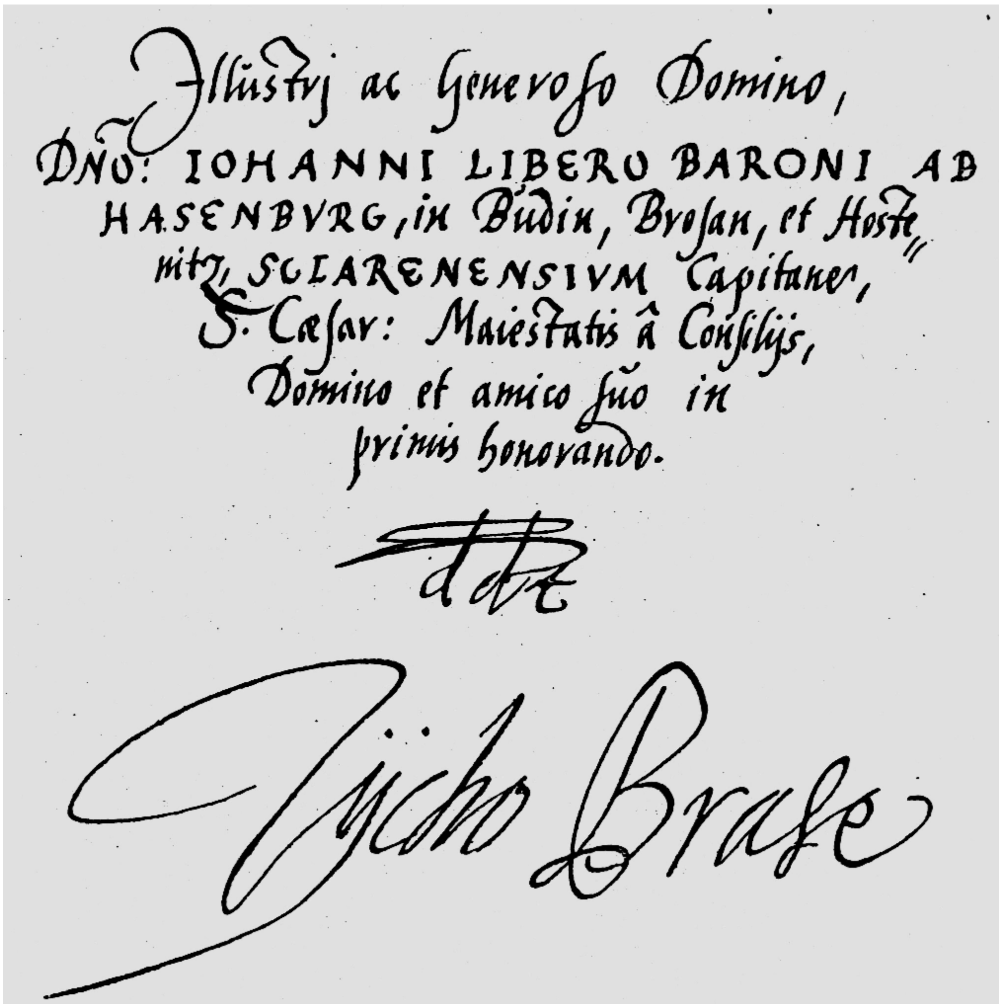
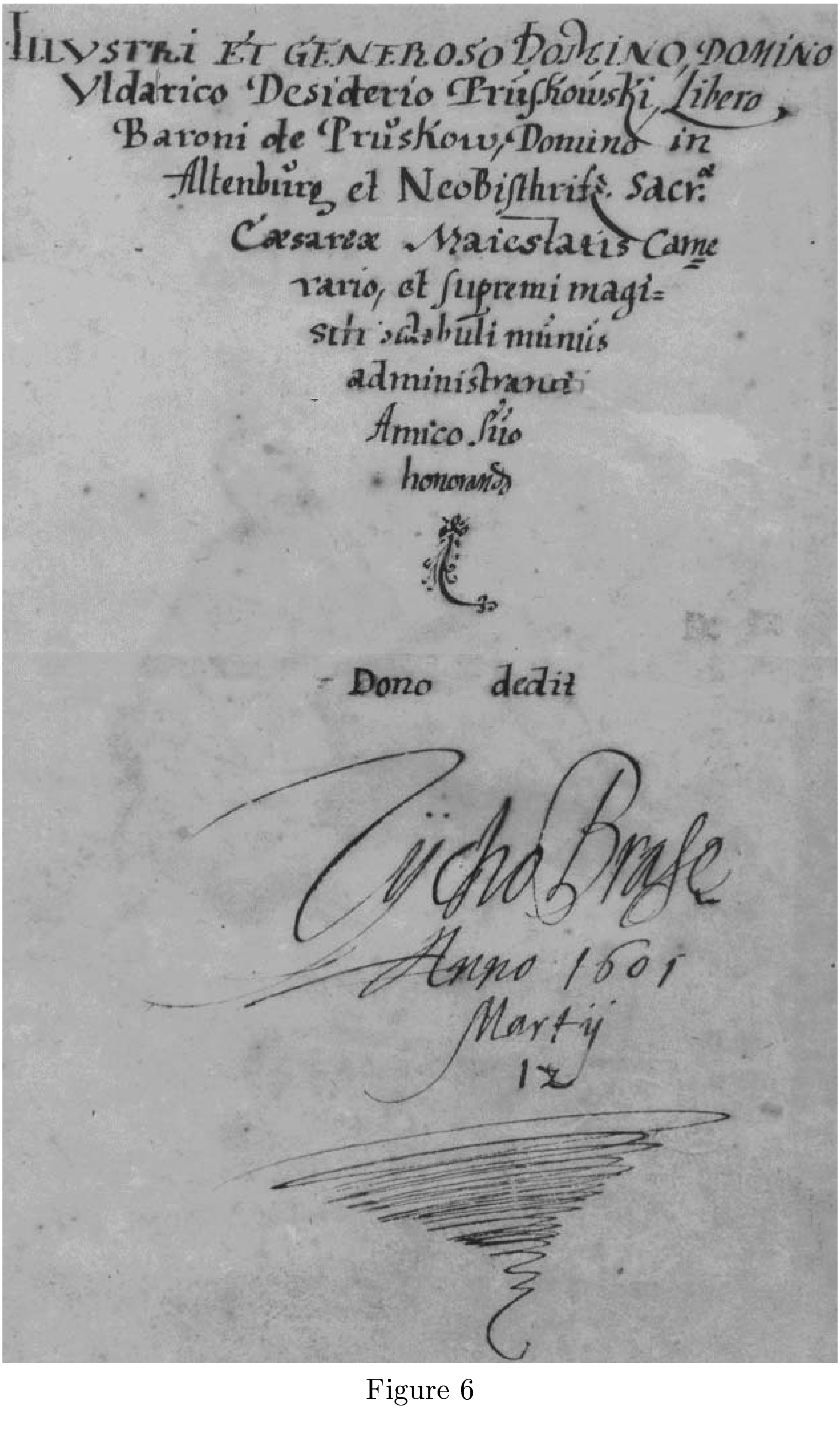

Illustrj ac Generoso Domino,
DNO: IOHANNI LIBERO BARONI AB
HASENBVRG, in Budin, Brosan, et Hoste-
nitz, SCLARENENSIVM Capitaneo,
S. Cæsar: Maiestatis à Consilijs,
Domino et amico suo in
primis honorando.
dedit
Tycho Brahe

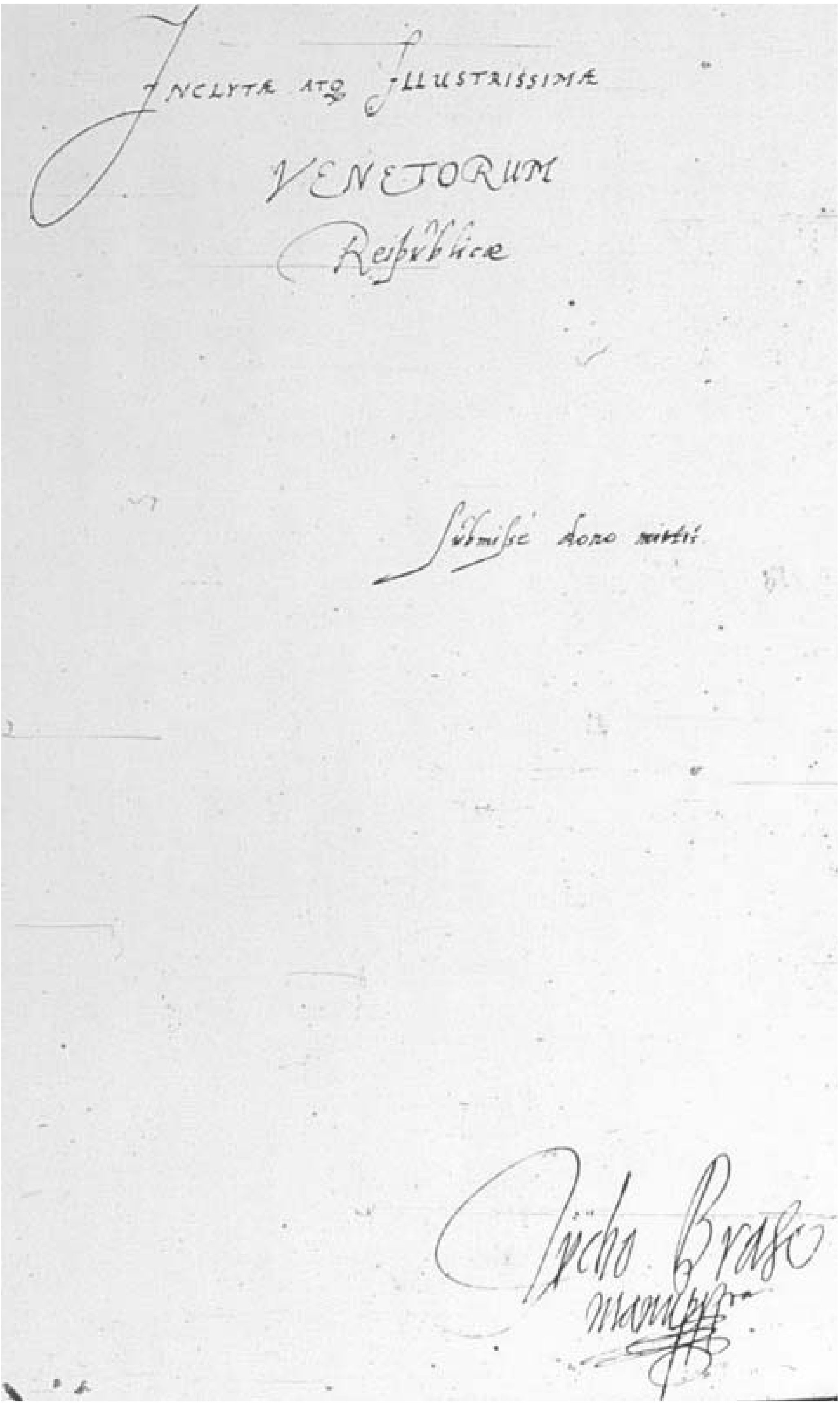
Figure 5


ILLVSTRI ET GENEROSO DOMINO, DOMINO
Vldarico Desiderio Pruskowski, Libero
Baroni de Pruskow, Domino in
Altenburg et Neobisthritz. Sacrae
Caesareae Maiestatis Came-
rario, et supremi magi-
stri stabuli munus
administranti
Amico suo
honorando

Dono dedit

Tycho Brahe
Anno 1601
Martij
12

Figure 6

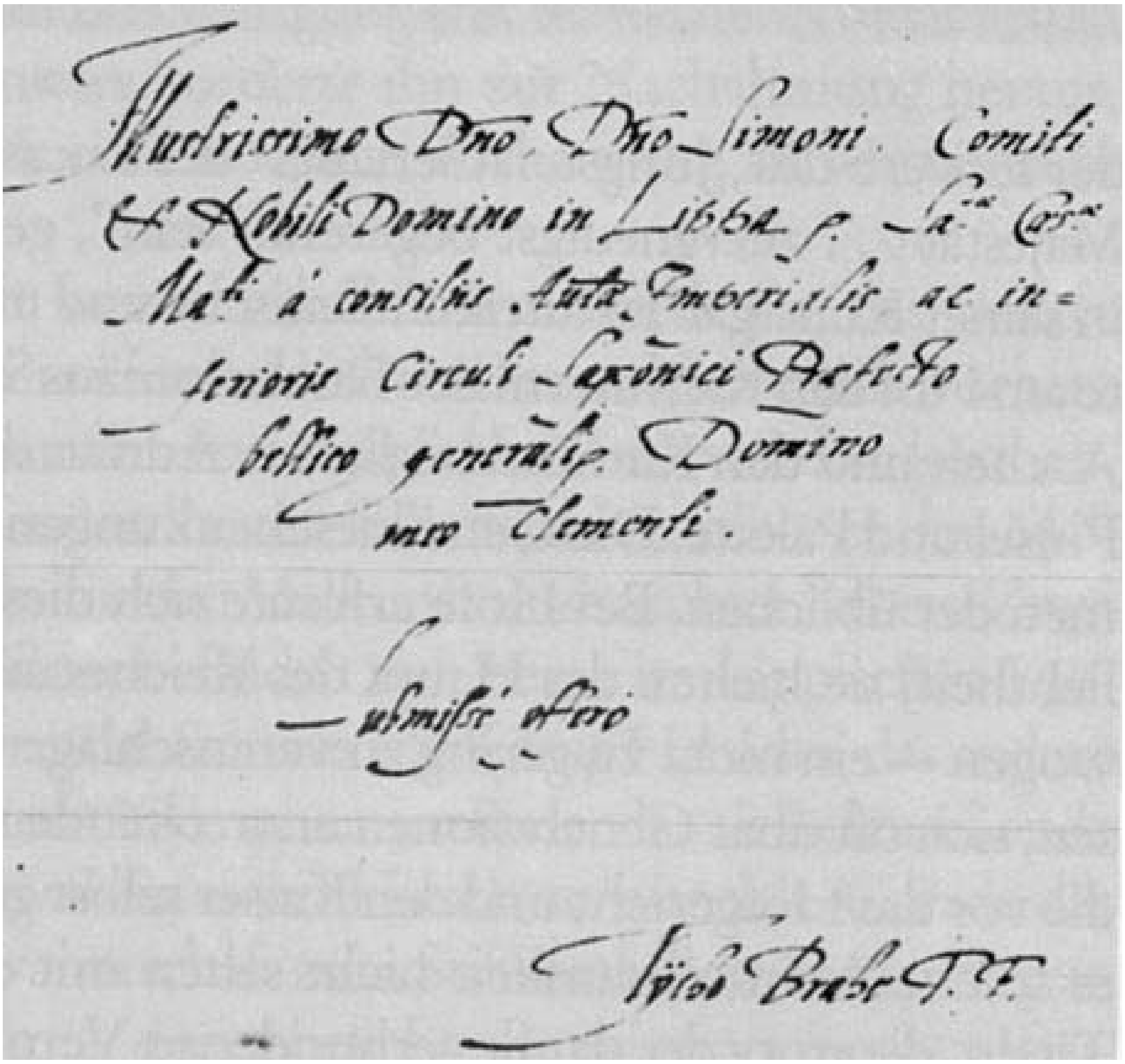


INCLYTÆ ATQ ILLUSTRISSIMÆ
VENETORUM
Reipublicæ

Submisse dono mittit

Tycho Brahe

Figure 7


Illustrissimo Dno. Dno. Simoni Comiti
Et Nobili Domino in Libba p. Sac. Caes.
Mati. a consiliis Aulae Imperialis ac in=
ferioris Circuli Saxonici Praefecto
bellico generali, Domino
meo Clementi.

Submisse officio

Tycho Brahe

Figure 8

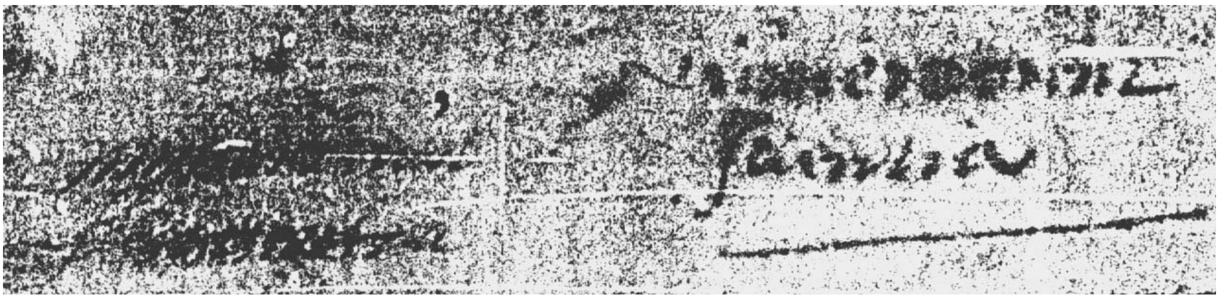


Figure 9

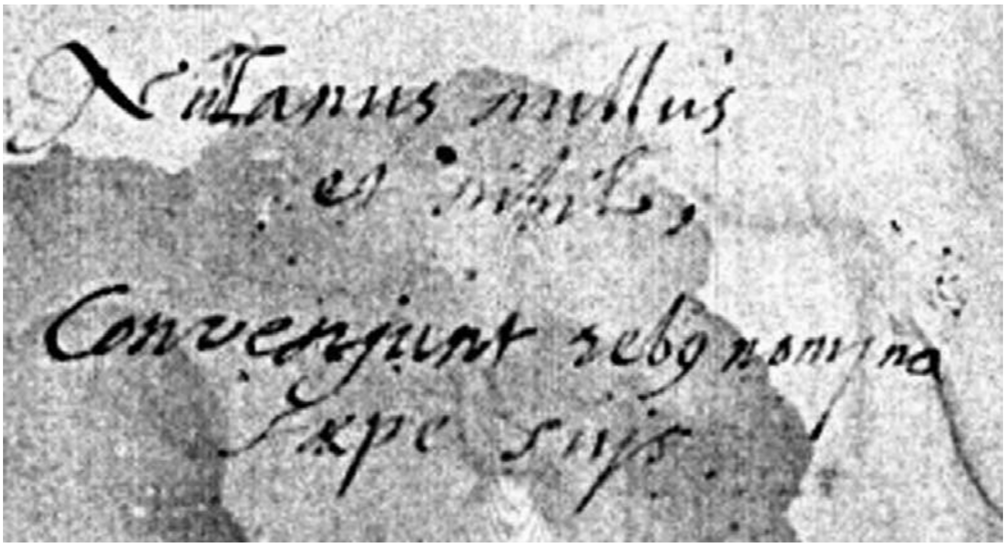


Figure 10

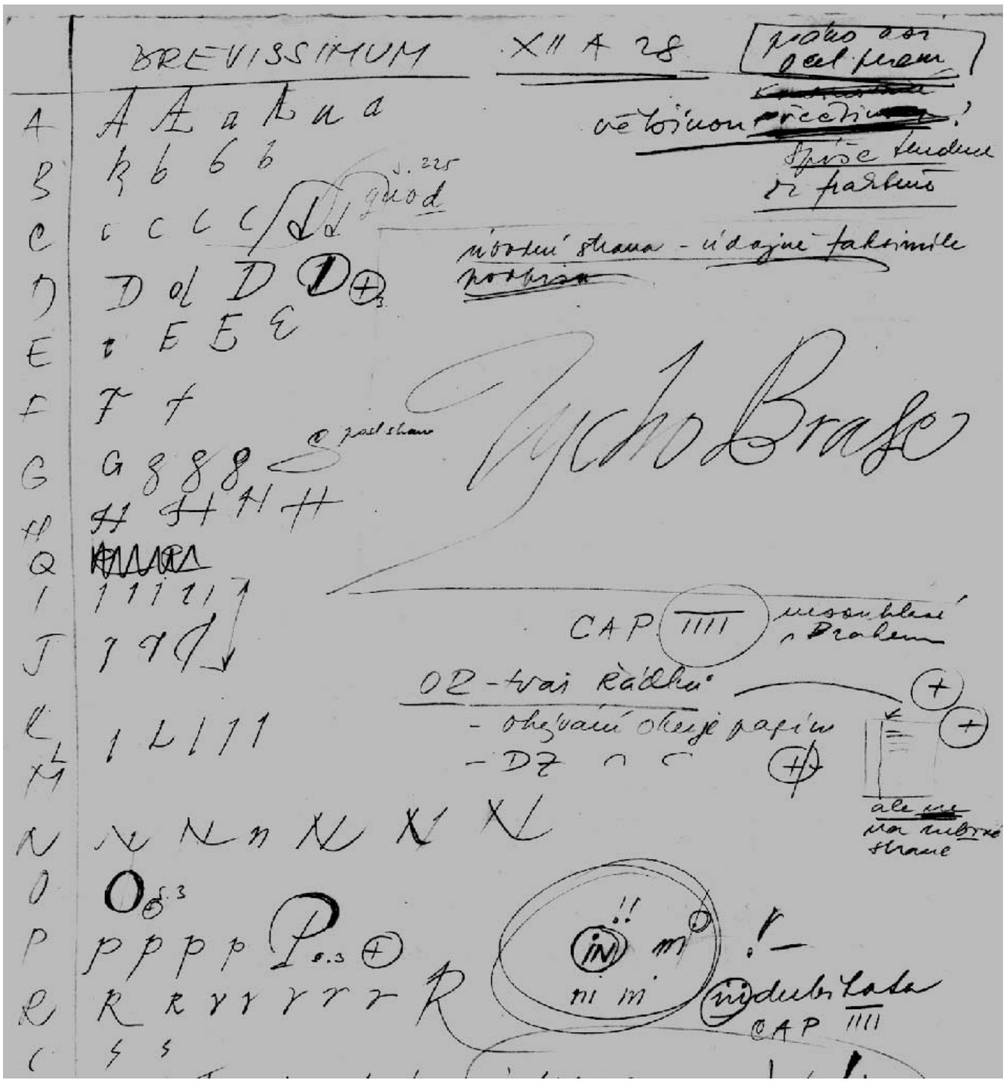


Figure 11

Tycho Brahe and Prague: Crossroads of European Science, pp. 168–177, J. R. Christianson et al. (eds.),

Tycho Brahe and Egnazio Danti. Observations and Astronomical Research at Prague and Florence at the End of the 16th Century

Carlo Triarico, Florence

In this paper I want to talk about the points of contact between the astronomical research done by Tycho Brahe and research done by Egnazio Danti in Florence. The important cultural exchanges and the debate that involved astronomers like Galileo and Kepler are well known. My paper will try to move the area of enquiry to the preceding years. The main point of discussion will be the comparison between the research carried out by Danti and Brahe, especially in the measuring of the obliquity of the ecliptic and its possible variation.

The Istituto e Museo di Storia della Scienza in Florence has a big astrolabe built at the end of the 1560s.[1] According to some scholars it is the work of Egnazio Danti, astronomer, cartographer, member of the Domenican order, a contemporary of Tycho.[2] Born in Perugia in 1536, Danti worked mainly in Florence, Bologna, and Rome. He died in 1586.[3] Among

[1] The instrument has the inventory number 3361 and is kept in the room III with the number 27. See Mara Miniati (edit.) *Museo di Storia della Scienza. Catalogo*, Firenze, Giunti, 1991, pp. 44, 45.

[2] About the instrument see: Guglielmo Righini "Il grande astrolabio del Museo di storia della scienza di Firenze", *Annali dell'Istituto e Museo di storia della scienza di Firenze*, II (1977), 2, p. 45-66; Marcello Felli, *L'Astrolabio di Galileo*, Firenze, Istituto e Museo di Storia della Scienza, 1983. See also a different opinion in Gerard l'E. Turner, "The Florentine Workshop of Giovan Battista Giusti". In *Nuncius. Annali di Storia della Scienza*, X (1995), 1, pp. 131-132 and 157-160.

[3] Works by Egnazio Danti are: *Trattato dell'uso et della fabbrica dell'astrolabio [...] con l'aggiunta del planisferio del Roias*, Firenze, Giunti, 1569; *La prospettiva di Euclide nella quale si tratta di quelle cose che per raggi diritti si veggono & di quelle che con raggi reflessi nelli specchi appariscono tradotta dal r. p. m. Egnatio Danti con alcune sue annotationi de' luoghi piu importanti insieme con la Prospettiua di Eliodoro Laris-*

seo cavata della Libreria Vaticana e tradotta dal medesimo nuovamente data in luce, Firenze, Giunti, 1573; *La sfera di Proclo Liceo tradotta da maestro Egnatio Danti [...] con le annotazioni & con l'Vso della sfera del medesimo*, Firenze, Giunti, 1573; *Usus et tractatio gnomonis magni, quem Bononia ipse in dive Petronii templo ex illustrium senatorum comitis Joannis Pepuli perpetui illius fabricae praesidis et collegarum autoritate confecit a.D. MDLXXVI mense Apr. ad amplissimum senatum Bononiensem*, Bononiae, apud Ioannem Rossium, 1576; *Le scienze matematiche ridotte in tavole dal rev. p. maestro Egnatio Danti*, Bologna, Compagnia della stampa, 1577; *Anemographia M. Egnatii Dantis [...] in anemoscopium verticale instrumentum ostensorem ventorum his accessit ipsius Instrumenti constructio, ut nihil hac materia amplius desideretur*, Bononiae, Ioannem Rossium, 1578; *Primo volume dell'uso et fabbrica dell'astrolabio et de planisferio di maestro Egnatio Danti, nuovamente ristampato & accresciuto in molti luoghi, con l'aggiunta dell'uso, & fabbrica di nove altri istromenti astronomici, come nella faccia seguente si contiene*, Firenze, Giunti, 1578; *Trattato del radio latino, istrumento giustissimo & facile piu d'ogni altro per prendere qual si voglia misura & positione di luogo, tanto in cielo come in terra [...] inventato dall'illustrissimo & eccellentissimo signor Latino Orsini con li commentarij del reverendo Padre maestro Egnatio Danti da Perugia & da esso di nuovo ricorretto & ampliato con molte nuove operazioni*, Roma, M. A. Moretti & I. Brianzi, 1586; *Le due regole della prospettiva prattica di m. Iacomo Barozzi da Vignola con i commentari del maestro Egnatio Danti*, Bologna, Gioseffo Longhi, 1682; "Letters of Egnatio Danti, Philippus Plegapheta, Philip Wingius to Abrahamus Ortelius", in Joannes Henricus Hessels (edit.) *Abrahami Ortelii et virorum eruditorum ad eundem et ad Jacobum Colium Ortelianum epistulae*, Cantabrigiae, Academiae sumptibus Ecclesiae Londino-Batavae, 1887, pp. 240-242, 481-483, 520-523. See also *La sfera di Giovanni Sacrobosco tradotta, emendata & distinta in capitoli da Piervincenzio Dante de' Rinaldi con molte et utili annotazioni del medesimo*, Firenze, Giunti, 1579.

About Egnazio Danti see: Gherardo Spini *Annotazioni intorno al Trattato dell'astrolabio et del planisferio universale del r. p. Ignatio Danti*, Firenze, Bartholomeo Sermartelli, 1570; Vincenzo Marchese "Del padre Ignazio Danti matematico, cosmografo, ingegnere e architetto", in *Memorie dei piu insigni pittori, scultori e architetti domenicani*, vol. 2, (1879), cap. 15, pp. 351-377; Del Badia, Iodoco *Egnazio Danti cosmografo e matematico e le sue opere in Firenze, memoria storica di Iodoco del Badia*, Firenze, M. Cellini, 1881; Maria Luisa Bonelli "Il globo terrestre di Egnazio Danti e la sfera armillare di Antonio Santucci", *Luci toscane*, I-II (1959), pp. 9-10; Gino Arrighi "Note di arithmetica speculativa con una lettera del p. Egnazio Danti", *Physis*, V (1963), 4, p. 464-473; Maria Luisa Righini Bonelli, "Egnazio Danti in Florence", *Florence*, XIV (1963), 4, pp. 12-14; Maria Luisa Righini Bonelli, Thomas B. Settle "Egnatio Danti's great astronomical quadrant", *Annali dell'Istituto e Museo di storia della scienza di Firenze*, IV (1979), 2, p. 5-13; Francesco Paolo Fiore "Danti, Ignazio", in *Dizionario biografico degli italiani*, vol. 32 (1986), pp. 659-663; Thomas Frangenberg "Egnatio Danti's optics: Cinquecento Aristotelianism and the medieval tradition", *Nuncius Annali di Storia della Scienza*, III (1988), 1, pp. 3-38; Thomas B. Settle "Egnazio Danti and mathematical education in late sixteenth-century Florence", in John Henry and Sarah Hutton (editors) *New perspectives on Renaissance thought: essays in the history of science, education and philosophy in memory of Charles B. Schmitt*, London, Duckworth, 1990, pp. 24-37; Giovanni Paltrinieri "Le meridiane e gli anemoscopi realizzati a Bologna da Ignazio Danti (1536-1586)", *Strenna storica bolognese*, XIV (1994), p. 367-386; Franco A. Levi – Gemma Rosa Levi Donati "Un astrolabio italiano del XV secolo", in Arcangelo Rossi (edit.) *Atti del XIV e XV Congresso nazionale di storia della fisica*, pp. 11-13, 1995; Thomas Frangenberg his most important contributions to knowledge there was the reform of the Julian calendar. To do this he built various instruments, especially the famous gnomon in the church of S. Petronio in Bologna.[4]

The astrolabe kept in the Florentine museum is one of the biggest in the world in terms of size and thus it is an instrument designed to make precise measurements. It is calibrated only for the latitude of 43° 40′, that according to Danti corresponds to Florence.[5] This leads us to think that the astrolabe was built to carry out accurate astronomical observations in the city. According to tradition Galileo himself used the instrument.[6] Besides, there is documentary evidence of use of the same instrument about a century after its building, by the academics of the Cimento, those followers of Galileo who set up the first western scientific academy.[7]

Together with its history and its features, there is a detail of the astrolabe that I would like to point out; it is the presence of a "transversal" or so called "Tychonian" scale along the graduation of the limb. So the astrolabe shows that the famous transverse system of division described by Levi Ben Gerson, adopted by Tycho Brahe and then improved by Jost Bürgi, was in use in Florence in the 1560s.[8] As we know the precise system,

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"Egnatio Danti on the history of perspective", in *La prospettiva: fondamenti teorici ed esperienze figurative dall'antichità al mondo moderno*, Firenze, Cadmo, 1998, pp. 213-223; Filippo Camerota (edit.) *Nel segno di Masaccio: l'invenzione della prospettiva*, Firenze, Giunti, 2001.

[4] About the Gnomon of Danti in Bologna see E. Danti *Usus et tractatio ...* cit.; Giovanni Paltrinieri *Le meridiane e gli anemoscopi ...* cit.; John Lewis Heilbron *The sun in the church. Cathedrals as solar observatories*, Cambridge (Mass.), Harvard University Press, 1999. In the Danti's *Primo volume ...* cit., at p. 325, the gnomon of Bologna is related with the research about the variation of the obliquity of the ecliptic: "il moto di trepidazione si potrà in pochi anni conoscere esattamente".

[5] The latitude indicated by Danti in his *Trattato* is the same of the astrolabe. The Florentine latitude today is 43° 45′.

[6] The possibility that the instrument was used by Galileo is mentioned by Guglielmo Righini *Il grande astrolabio ...* cit. and by Marcello Felli, *L'Astrolabio di Galileo ...* cit. The inventory of the Uffizi Gallery (*Manoscritti Bianchi*, secolo XVIII, cod. n. 20) describes the astrolabe like "un astrolabio di ottone, come fosse un tavolo da gioco, del Galileo".

[7] About the Accademia del Cimento see: Giovanni Targioni Tozzetti *Atti e memorie inedite dell'Accademia del Cimento e notizie aneddote dei progressi delle scienze in Toscana contenenti, secondo l'ordine delle materie e dei tempi, memorie, esperienze, osservazioni, scoperte e la rinnovazione della fisica celeste e terrestre cominciando da Galileo Galilei fino a Francesco Redi ed a Vincenzo Viviani inclusive*, Firenze, Giuseppe Tofani, 1780; William Edgar Knowles Middleton *The experimenters. A study of the Accademia del Cimento*, Baltimore, The J. Hopkins Press, 1971; Paolo Galluzzi (edit.) *Scienziati a corte. L'arte della sperimentazione nell'Accademia galileiana del Cimento, 1657-1667*, Livorno, Sillabe, 2001.

[8] Sources on the transversal scale are in Levi Ben Gerson, in his work *Séfer tekùnà*. See Bernard R. Goldstein, "Levi Ben Gerson. On instrumental errors and the

adopted to ensure precise data, was made famous in 1598 in the *Astronomiae instauratae mechanica*.[9]

I have decided to mention this instrument as a way of introducing the object of my report, which is to draw attention to some of the similarities between the themes of Tycho's work and those that appear in Danti's scientific research. Of particular interest seems to be the work that the two astronomers carried out to determine the obliquity of the ecliptic and about its possible slow variation.

The ecliptic is the plane determined by the orbit of the Earth around the Sun: it differs from the plane of the celestial equator by a certain angle. This angle, called the obliquity of the ecliptic, undergoes a slight variation, today estimated to be a reduction of $48''$ per century, that should be part of a still slower oscillation between increase and reduction of the angle. If the variation was a constant reduction there would be the straightening of the earth's axis and the cancellation of the seasons in the space of 2000 centuries.

Tycho knew from his reading about the possibility of a movement of the obliquity and personally observed possible evidence of it.[10] To do this he compared his own observations with some historical data. The definite existence of the movement of variation and its characteristics remained, however, uncertain. It is known that at first Tycho was inclined to measure the ecliptic as $23^\circ\ 27'$ and that he afterwards corrected this piece of data.[11] Having been able to measure the error caused by refraction and taking for true a mistaken value for the declination of the sun, he gave to the obliquity of the ecliptic the value of $23^\circ 31' 38''$, that is higher than the data of his contemporaries.[12] We will see further on how this fact influenced

transversal scale", *Journal for the History of Astronomy*, a. VII, 1977, 102-112. See also John Louis Emil Dreyer *Tycho Brahe. A picture of scientific life and work in the sixteenth century*, Edinburgh, A.C. Black, 1890.

[9]See pages 161-165 of Brahe's *Mechanica* in the English version by Raeder, revised and commented by Alena Hadravová and Petr Hadrava, Prague, KLP, 1996.

[10]About the obliquity of the ecliptic see the letters with Rothmann. In particular in J. L. E. Dreyer (edit.) *Tychonis Brahe Dani Opera Omnia*, Hauniae, Libraria Gyldendaliana, 1923, tomus II, p. 247; t. VI, pp. 54 ss.; 85-104, 110 ss.

[11]The measure of 27 minutes was calculated by Tycho in 1578. In the year 1584 he discovered the astronomical refraction and corrected the data in $23^\circ 31' 38''$. See Victor E. Thoren *The Lord of Uraniborg. A Biography of Tycho Brahe*, Cambridge, Cambridge University Press, 1990, Chapters 6 and 7.

[12]As an important result of his observations Tycho discovered an aberration caused by refraction. Another correction introduced was that of the declination of the sun. The erroneous data of the solar declination compromised the results. The value of the inclination of the ecliptic appeared to Tycho greater than the true and greater than the $23^\circ 28'$ found by Copernicus, Regiomontanus, Werner and Danti.

his opinion about a possible variation of the obliquity. Here it is enough to say that the new measurements made Tycho believe that the variation could not be that supposed by Copernicus and by Domenico Maria Novara with the movement of trepidation, but, if anything, corresponded to an extremely small decreasing.[13]

Egnazio Danti began his studies of the ecliptic in Florence in the 1560s. It must be said that two factors were vital in directing his research. The first is that he was interested in the reform of the Julian calendar in which he had an important role. In the attempt to clarify some of the celestial movements, Danti started research to measure the length of the tropic year and the precession of the equinoxes. He also studied the variation of the obliquity directly and asked himself about that movement of trepidation that had been proposed to explain the anomalies of the movement of the *eighth sphere*. In this perspective he studied the correct calculation of the latitudes. We will see further on that the correct calculation of the latitudes, carried out to understand the movement of the ecliptic, also interested Tycho. The second factor that is crucial for Danti's research is connected to a tradition in research that had its home in Florence. Already in 1475, in fact, the biggest gnomon ever built in a Christian church had been constructed in the Cathedral of Florence, built precisely to examine the possible movements of the *eighth sphere*.[14] Danti used this instrument a century later. But in particular he designed his instruments and consequently studied old instruments very carefully. His work in this field led to the publication of the *Trattato dell'uso et della fabbrica dell'astrolabio*,

[13]The ideas of Domenico Maria Novara, teacher of Copernicus, were well known by Tycho through the reading of GIOVANNI ANTONIO MAGINI *Tabulae secundorum Mobilium Coelestium*, Venetiis, Officina Damiani Zenarij, 1585. See the letter Uraniburgi of December 1st 1590 to Giovanni Antonio Magini, in ANTONIO FAVARO (edit.) *Carteggio inedito di Ticone Brahe, Giovanni Keplero e di altri celebri astronomi e matematici dei secoli 16. e 17. con Giovanni Antonio Magini, tratto dall'Archivio Malvezzi de' Medici in Bologna, pubblicato ed illustrato da Antonio Favaro*, Bologna, Zanichelli, 1886, *Supplemento al carteggio*, letter 5, p. 403: "Succurrit nunc, quod aliquando Tabularum tuarum Secundorum Mobilium legerim, te cum laudatissimae memoriae illo Dominico Maria Ferrariense, Copernici preceptore, in eadem esse sententia, quod latitudines locorum successive aliquatenus mutentur, [...] quas tamen ego (utriusque vestrum pace dixerim) non satis validas et ratas aestimo".

[14]About the gnomon built by Paolo dal Pozzo Toscanelli in 1475 see CARLO TRIARICO "La Cattedrale e la scienza. Saggio sulla Storia della Meridiana e della ricerca scientifica nel Duomo di Firenze", in *Atti del VII centenario del Duomo di Firenze*, Firenze, EDIFIR, 2001, vol. II, t. 2, pp. 673-686. About the tradition of the gnomons built in the catholic churches see JOHN LEWIS HEILBRON *The sun ...* cit. Here are also information about the Florentine gnomon and about the gnomon built by Danti in San Petronio in Bologna.

one of the earliest treatises on scientific instruments in Italian.[15]

In analogy with Tycho's *Astronomiae instauratae mechanica*, Danti, in the *Trattato*, shows particular attention for measuring instruments, makes a careful choice of materials, and attempts to modernize the tradition. These elements allow us to look at the *Trattato* as a sign of that interest for development of instruments and of observation of which Tycho was leader in the field at the time. The faith of these two astronomers in direct and repeated observation and the experimental approach, both empirical and critical, seems remarkable.

In the *Trattato* Danti said he had used the astrolabe to measure the obliquity of the ecliptic. It is possible that he also used the big astrolabe today kept in the Museum of Florence to do it. Besides, Danti built, in Florence in the 1570s, some instruments that he set up in the Santa Maria Novella church to get better results. They were an equinoctial armilla, a quadrant and also a gnomon that was going to be put in the church, but was never finished.[16] In fact, Egnazio Danti had to leave Florence suddenly because of difficult relations with the Grand Duke Francesco de' Medici.[17] He had, however, managed to carry out various observations that had allowed him to observe the variation of the obliquity of the ecliptic. In the 1569 edition of the *Trattato* he stated, in fact, that the obliquity of the ecliptic diminishes progressively. Danti had also measured the obliquity of the ecliptic at 23° 28″, obtaining data that corresponded to those of other contemporary astronomers and inferior to those of the previous century.[18] The conviction that there was a constant reduction no longer appears in the 1578 edition of the *Trattato*.[19] Danti shows that he is inclined to believe that the ecliptic diminished and then increased following a rhythm of seven

[15] EGNATIO DANTI *Trattato dell'uso* ... cit.

[16] About the scientific instruments and the gnomon in Santa Maria Novella see the 1578 edition of the *Trattato* (EGNAZIO DANTI *Primo volume* ... cit., p. 319). See also MARIA LUISA RIGHINI BONELLI, THOMAS B. SETTLE *Egnatio Danti's* ... cit.

[17] When Cosimo de' Medici died in 1574, Danti left Florence because of the difficult relationship with the son, the Grand Duke Francesco.

[18] Cfr. EGNAZIO DANTI *Trattato dell'uso* ... cit., p. 86: "Propositione XXX. Come si possi trovare la massima declinazione del Sole. [...] la massima declinazione del Sole, la quale continuamente si va scemando per rispetto del moto di trepidazione o di altra cagione posta dal Fra castoro. Perché al tempo di Arato era di gradi 24 e Tolomeo gradi 23 minuti 50 e ai tempi nostri è 23 gradi e 28 minuti, e in tanta altezza l'ho osservata io gia duoi anni alla fila".

[19] The *Propositione XXX. Come si possi trovare la massima declinazione del Sole*, is at p. 76 of the 1578 edition, but the progressive reduction is not mentioned. See also GHERARDO SPINI *Annotazioni intorno* ... cit. At page 33 there is a description of the *Proposizione XXX* where only the trepidation is mentioned with the problem of the latitudes measured by Tolomeo.

thousand years.[20] Like Tycho, Danti shows that he has still not formed definite opinions on the matter.

About the importance of the discovery of the variation of the obliquity and if it is to be attributed to Brahe or Danti, we must remember that there was an argument in the first half of the 19th century that has now long been forgotten. Guglielmo Libri said that the measurement of the obliquity of the ecliptic carried out by Brahe had been preceded by the work of Danti.[21] Libri also contested the popular belief that Tycho had been the first man to discover the variation of the obliquity. Our days the dispute seems of lesser interest than when it started, also for historical reasons.

We know that a variation had been supposed and remarked upon a long time before.[22] Besides, one cannot say that with the observations of Brahe and Danti a decreasing of the obliquity of the ecliptic was proved once and for all. An answer accepted by the scientific community on the definite existence of this movement of tiny dimensions was not obtained until the middle of the 18th century when scientists like Le Monnier still doubted its very existence.[23] The exact calculation of the variation of the obliquity we know, from the words of the same astronomers of the first half of the 19th century, that this information appeared to be far from being ascertained.[24]

[20] It is evident in DANTI *Le scienze matematiche ...* cit., p. 17: "All'ottavo cielo diedono quel moto della trepidazione, che in 7000 anni fa uno intero corso".

[21] See GUILLAUME LIBRI *Histoire des sciences mathématiques en Italie depuis la renaissance des lettres jusqu'à la fin du dix-septième siècle*, Paris, J. Renouard et c.ie libraires, 1838-1841, vol. IV (1841), p. 40, 41: "Il [Danti] publia aussi un traité de l'Astrolabe où l'on trouve une remarque capitale qui a été toujours attribuée à Tycho Brahe, savoir: la diminution de l'obliquité de l'écliptique, deduite de la comparaison des anciennes observations avec les modernes". See also JEAN BAPTISTE JOSEPH DELAMBRE *Histoire de l'astronomie moderne*, Paris: Courcier, 1821, t. 1, p. 182 "Il [Tycho] va maintenant prouver que les latitudes des étoiles varient par une suite du changement d'obliquit. C'est une remarque bien simple: il parait qu'elle n'avait encore été faite par personne". See also JEAN ÉTIENNE MONTUCLA *Histoire des mathématiques. Nouv. éd. considérablement augmentée, et prolongée jusque vers l'époque actuelle.* – Paris: H. Agasse, [1799]-1802, t. IV, p. 226.

[22] A variation called trepidation was supposed by Thabit ibn Qurrah (836-891), he proposed a model that was described by al Zarqali (1028-1087).

[23] PIERRE CHARLES LE MONNIER "Comparaison des hauteurs solsticiales aux environs du Tropique du Capricorne, observées en 1762 e 1764, avec celles qui ont été vues à l'obélisque du Gnomon de S. Sulpice en 1743 et 1744", in *Histoire de l'Académie Royale des Sciences année 1762*, Paris, Imprimerie Royale, 1768, pp. 432-434. See also ALEXANDRE ROLLIN JOMBERT, SAVERIEN *Dictionnaire universel de Mathématique et de Physique*, tome premier, Paris, 1753, pp. 317-319 and SIEGMUND GÜNTHER *Lehrbuch der Geophysik und physikalischen Geographie*, I. Band, Stuttgard, Ferdinand Henke, 1884, pp. 213-219.

[24] See JEAN BAPTISTE JOSEPH DELAMBRE *Histoire de l'astronomie au dix-huitième*

More interesting for us is the fact that Tycho and Danti did their research at the same time, that they were uncertain and that they had different results.

If Tycho and Danti's investigations on the obliquity of the ecliptic never actually met, we must also say that they came close to it, when Tycho hoped to receive support from the Grand Duchy of Tuscany for a scientific expedition to Alexandria in Egypt, to determine the possible variation of the obliquity.[25] The expedition aimed at verifying whether the earth's latitudes varied. At a first comparison of historical facts, especially as regarded the city of Rome, it seemed to Tycho that no variations had occurred since the time of Pliny.[26] However, he thought it was necessary to carry out the observations in Alexandria, where Ptolemy had carried out more precise observations. Tycho hoped to find support for his mission in Egypt from the Venetian Republic.[27] But he also hoped that he would get some help from the Tuscan Court of the Medici.

His appeal for help did not produce any useful results, but it is to it that we owe the exchange of letters with the Tuscan Court and probably with Galileo himself. In the last years of his life, in fact, Tycho came into contact with the then unknown Galileo, actually during negotiations about

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siècle, Paris, Bachelier, 1827, p. 406. Other information, about a research made in the 19th century at the observatories of Greenwich and Pulkovo, are in *Nature. A weekly illustrated journal of sciences*, 18, 25 September, 2, 9, 16 October 1884, pp. 501-508, 512, 536, 561, 582-583.

[25] About Tycho and Italy see by Antonio Favaro: *Carteggio inedito ...* cit. and "Ticone Brahe e la corte Toscana", *Archivio Storico Toscano*, serie V, Tomo III (1889), pp. 202-225 and "Di alcuni nuovi materiali per lo studio del carteggio di Ticone Brahe e delle sue relazioni con Galileo", *Atti del I. R. Istituto veneto di scienze, lettere ed arti*, serie VI, tomo VII (1889), pp. 199-215. See also F. R. Friis "Tyge Brahe og Italienerne", *Museum*, XI-XII (1891), p. 258-271; Wilhelm Norlind *Tycho Brahé et ses rapports avec l'Italie*, Milano, Turati Lombardi e c., 1995; Ottavio Besomi – Michele Camerota *Galileo e il Parnaso Tychonico. Un capitolo inedito del dibattito sulle comete tra finzione letteraria e trattazione scientifica*, Firenze, Olschki, 2000.

[26] See letter to Giovanni Antonio Magini, Uraniburgi, December 1st 1590, in Antonio Favaro (edit.) *Carteggio inedito ...* cit., *Supplemento al carteggio*, letter n. 5, pp. 394-406. At p. 403: "Certe sola Roma, quae eandem ferme adhuc, ex observatione Regiomontani, quam olim Plini tempore per proportionem gnomonis et umbrae facta pervestigatione [...] retinet latitudinem, altitudines polares non variari comprobat". Pliny in his *Naturalis Historiae*, cap. 72 gives the data for Roma, Ancona, Venezia.

[27] As is known Tycho was in Venice in 1575. The idea of the mission to Egypt is mentioned also in a letter in Tycho's *Mechanica*, in the *Descriptum Litterarum*: "Retulit etiam, Illustrissimos VENETOS in consilio rogatorum deliberasse, ut aliquis Matheseos peritus stipendio 300 Coronatorum in AEGYPTUM ablegaretur, qui pro TYCHONE isthic observaret. Tantae enim hic TYCHO certe est celebritatis, quantae nemo eorum, qui nunc vivunt. Datae Patavii 28 Decembris Anni 1592", in J. L. E. Dreyer (edit.) *Tychonis Brahe ...*, vol. V, p. 130. See pp. 130-133. See also Antonio Favaro *Ticone Brahe ...* cit.

the expedition to Egypt coming through Italy.[28]

Today the Collezione medicea of scientific instruments, kept in the Museo di Storia della Scienza in Florence, shows some record of the contacts that took place between the Grand Duchy of Tuscany and the Prague of Tycho and Kepler. Some instruments built by the constructors who worked for Tycho testify to the attention of the court. I can mention, for example, a gunnery instrument of Jost Bürgi.[29] Other instruments are also interesting, like a Pretorius' astrolabe and other instruments of Habermel.[30]

The idea of the expedition appears also in the pages of the *Astronomiae instauratae mechanica* where Galileo himself, then working in Padua, is mentioned.[31] Those pages record the exchange of letters that Tycho had around 1590 with Magini. Giovanni Antonio Magini, of the University of Padua and then of Bologna, as is known, had worked out a cosmological system composed of 11 spheres also aimed at explaining the variation of the obliquity of the ecliptic.[32] It is necessary to say that previously Egnazio Danti had adopted a cosmological system of 10 spheres that explained the movement of the obliquity of the ecliptic.[33] As Danti had done in some moments, Magini thought that the obliquity of the ecliptic had diminished and was destined to increase again in the future, on account of the movement of trepidation.[34] We have seen that Tycho, on the other hand, having introduced some corrections in the calculation, had obtained an erroneously higher value for the obliquity of the ecliptic. Such a value was similar to those of previous centuries. Tycho did not therefore agree with Magini's hypothesis and thought that the obliquity did not vary or, at the most, might undergo a very slight reduction.[35] Tycho's hypothesis

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[28] See ANTONIO FAVARO *Di alcuni nuovi* ... cit.

[29] Istituto e Museo di Storia della Scienza, inventory n. 2530 (room II. 38). See MARA MINIATI (edit.) *Museo di Storia* ... cit., p. 30.

[30] The astrolabe of Johannes Pretorius (Johann Richter), dated 1591, was made in Altdorf. It has the inventory number 2518 (room II. 68) and is mentioned in MARA MINIATI (edit.) *Museo di Storia* ... cit., p. 34. An instrument by Erasmus Habermel is a simple theodolite (inventory number 154, room II. 24) engraved with fine decorations. Other instruments are by Josua Habermel or attributed, like a small quadrant (inventory number 2518, room II. 26) and a gunner's sight and level, of brass and silver (inventory number 2539, room II. 25).

[31] See J. L. E. DREYER (edit.) *Tychonis Brahe* ... cit., tomus V, pp. 125-133. Galileo is mentioned at page 130.

[32] GIOVANNI ANTONIO MAGINI *Novae coelestivm orbivm theoricae congruentes cum obseruationibus N. Copernici*, Venetiis, Officina Damiani Zenarij, 1589.

[33] See EGNAZIO DANTI *Le scienze matematiche* ... cit., pp. 15-17.

[34] Magini supposed that the obliquity ranged from $23°28'$ to $23°52'$. See ANTONIO FAVARO (edit.) *Carteggio inedito* ... cit., p. 69.

[35] See the letter December 1st 1590 in ANTONIO FAVARO *Carteggio inedito* ... cit., appendice I, p. 402: "Taceo nunc quod ipsas stellas sua latitudines mutare, ad rationem

swung between these two possibilities. For example, in a letter to Gellius Sascerides, written in 1591, Tycho affirms that it is difficult to decide if the obliquity tends to diminish and to increase, but at the same time declares that he thinks it is probable that it tends to diminish very slowly.[36] On the contrary, in a piece written in 1600, on the obliquity of the ecliptic, the assertion that the obliquity is not subject to any variation appears to be clear.[37] Tycho's research on the obliquity of the ecliptic unfortunately remained unfinished, like other of his studies, because of his sudden death in 1601. His position differs from Magini's and Copernicus's. Only in appearance is it similar to Danti's hypothesis of 1569. Tycho and Danti thought, it is true, that there was a possible progressive reduction of the obliquity, but they thought very differently about its dimensions and its nature. It is above all necessary to say that they reached their conclusions because of various mistakes in their calculations.

In this paper I have talked about the long sequence of events that go from Danti's research to the contact between Tycho and Galileo. This continuity is emphasized so that others can evaluate the elements that connect it to the better known history of the important contacts between Florence and Prague in the first part of the 17th century.

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alteratae obliquitatis eclipticae (prout a nobis indubitate deprehensum est)".

[36] See the letter to Sascerides communicated to Magini of February 1st 1591. ANTONIO FAVARO *Carteggio inedito ...* cit., letter n. VI, p. 201: "An autem summa Eclipticae obliquitas in posterum aliquatenus accrescet vel coarctabitur, non adeo promptum est discernere. Nec enim Hypothesis Copernicea (utut admodum ingeniosa) circa Aequinoctium et huius obliquitatis mutationem, locum meretur. Verisimilium tamen duco, hanc Eclipticae ab Aequatore digressionem, subsequentibus saeculis paululum dilatatum iri." See also the letter by Magini to Sascerides, Bologna July 15, 1590, about the variation in Copernicus and Tolomeus. See ANTONIO FAVARO, *Carteggio inedito ...* cit., appendice I, doc. 2, p. 386.

[37] See J. L. E. DREYER (edit.) *Tychonis Brahe ...* cit., tomus V, pp. 228, 229: "... declinatio Eclipticae 23. 31. 38, quae utraque hodieque post 200 annos eadem inveniuntur. Prophatius Idaeus 100 annis ante eandem prodidit obliquitatem. Regiomontanus et Waltherus ex observatis suis bene adhibitis post 100 annos itidem eandemi." In a letter to Harwart (November 16, 1599), Tycho supposed in the historical data there was an error produced by the instruments. See J. L. E. DREYER (edit.) *Tychonis Brahe ...* cit., tomus VIII, 6, pp. 195, 196.

Tycho Brahe and Prague: Crossroads of European Science, pp. 178–186,
J. R. Christianson et al. (eds.), © *H. Deutsch 2002*

Medicean Telescopes. The Collection of the Istituto e Museo di Storia della Scienza, Florence

Mara Miniati, Florence

Throughout Europe princes and rich important families invested an enormous amount of money in acquiring not only natural or exotic curiosities, but also, and above all, artificial and mechanical ones. Quadrants, astrolabes, back staffs, compasses and dividers were engraved, embellished, gilded and transformed into "instruments to look at" and were kept from the 16th century in rich palaces together with sculptures, paintings, works of art and strange curiosities.[1] But between the end of the 16th and the early 17th century an important transformation in the world of science changed the direction of the scientific research and of collecting.

These are also the years of Tycho Brahe. He observed stars and skies, calculated the distances and the position of the celestial bodies, invented astronomical instruments to observe 'naked eye' and created a special building to host these instruments and to make observations. He had not the possibility to have and to know the new optical instruments.

[1]About the scientific collections see G. Olmi, "Dal 'Teatro del mondo' ai mondi inventariati: aspetti e forme del collezionismo nell'età moderna", in P. Barocchi, G. Ragionieri (eds.), *Gli Uffizi: quattro secoli di una galleria. Atti del Convegno internazionale di studi, Firenze, 20-24 settembre 1982*, Firenze, Olschki, 1983, 2 vols., vol. 1, pp. 233-269; A. Lugli, *Naturalia e mirabilia: il collezionismo enciclopedico nelle Wunderkammern d'Europa*, Milano, Mazzotta, 1983; O. Impey, A. MacGregor (eds.), *The origins of museums: the cabinet of curiosities in sixteenth- and seventeenth-century Europe*, Oxford, Clarendon Press, 1985; G. Olmi, "L'inventario del mondo: catalogazione della natura e luoghi del sapere nella prima età moderna", Bologna, Il mulino, 1992 (*Annali dell'Istituto storico italo-germanico*, Monografia, 17); A. Lugli, *Wunderkammer*, Torino, U. Allemandi &c., 1997; C. De Benedictis, *Per la storia del collezionismo italiano: fonti e documenti*, Firenze, Ponte alle Grazie, 1991 (rep. 1995); G. Olmi, "Il collezionismo scientifico", in *Il teatro della natura di Ulisse Aldrovandi*. Bologna, Compositori, 2001, pp. 20-50.

And the new devices born in the 17^{th} century steered the taste for collecting towards the sciences.

In this paper I will show one of these directions which constituted a very peculiar theme of collecting, why it was so researched, and the role it played in the Medicean Court.

The Florentine collection was rich in paintings and objects of art, rich in sculptures and medals, ivories and curiosities.[2] Over the years, members of the family had received fruits and fishes, plants and seeds, clothes and slaves, precious stones and animals from the newly discovered worlds. We can imagine the Uffizi Gallery, in which the majority of the collection was housed, as an incredible ensemble of things, mixed in with each other, in order to stupefy the visitors and the savants who could go there.[3]

The Room of Mathematics in the 17^{th} century showed mathematical devices, armillary spheres, sundials and other instruments beside statues and sculptures.

Galileo himself presented the Grand Duke with an exemplar of his sector and a copy of the Essay on its operation and use.[4] Galileo had been the teacher of the young prince. After his years in Padua, Galileo came back to Florence. This happened after the very important discovery of new celestial bodies around Jupiter, a discovery made with an instrument that was widely known but not highly considered at that time.[5]

We know the story of this instrument.[6] Of Dutch construction, there

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[2] About the Medicean collections see P. Barocchi, G. Gaeta Bertelà, *Collezionismo mediceo: Cosimo I, Francesco I e il cardinale Ferdinando, documenti 1540-1587*, Modena, Panini, 1993. On the Medicean scientific collections see M. Bacci, "Le collezioni scientifiche", in *Gli Uffizi. Storia e collezioni*, Firenze, Giunti, 1983, pp. 244-255; M. Miniati, *Museo di Storia della Scienza. Catalogo*, Firenze, Giunti, 1991, pp. X-XII, 2-4; M. Miniati, "Dallo stanzino al museo: strumenti scientifici a Firenze", in F. Gravina (ed.) *Le meraviglie dell'ingegno: strumenti scientifici dai Medici ai Lorena*, Firenze, Ponte alle Grazie, 1990, pp. 9-48.

[3] See P. Barocchi, G. Ragionieri (eds.), *Gli Uffizi*, cit.

[4] G. Galilei, *Le operazioni del compasso geometrico e militare*, In Padova, in casa dell'autore, per Pietro Marinelli, 1606. The original instrument is preserved at the Florentine Museo di Storia della Scienza, inv. no. 2430.

[5] Among the numerous biographies of the scientist, see L. Geymonat, *Galileo Galilei*, Torino, Einaudi, 1957; A. Banfi, *Vita di Galileo Galilei*, Milano, Feltrinelli, 1962; M. L. Righini Bonelli, *Vita di Galileo*, Firenze, Nardini Editore, 1974; W. R. Shea, *La rivoluzione intellettuale di Galileo, 1610-1632*, Firenze, Sansoni, 1974; S. Drake, *Galileo at work: his scientific biography*, Chicago, The University of Chicago Press, 1981.

[6] See H. C. King, *The history of the telescope*, London, C. Griffin, 1955; F. Scandone, *Galileo and the telescope*, Firenze, Officine Galileo, 1967; A. Van Helden, *Measuring the universe. Cosmic dimensions from Aristarchus to Halley*, Chicago, The University of Chicago Press, 1985; Idem, *The invention of the telescope*, Philadelphia, The American philosophical Society, 1977.

was a tube in wood or cardboard covered in paper or leather, and with a lens at either end. With it everybody could see distant objects as if they were very close. It was an amusing toy, children were so happy using it, as were adults. In Galileo's hands this innocent toy became a powerful "instrument" for observing and discovering. He understood that it could be perfected and its magnification capacity improved. He understood that lenses could be worked better and that the invention could become a source of income. Everybody could appreciate the benefit of seeing their enemies approaching, in discovering camps and both defending and attacking armies. And also: Galileo pointed his instrument to the sky, even though the eyes allowed us to observe and measure. Thanks to the instrument the sky changed and the number of celestial bodies increased. As Albert Van Helden wrote,[7] the telescope is the first device which extends a human sense, which prolongs and makes it stronger. We can look at the beauties of creation, but we can also dangerously discuss theories that are clearly defined. The objective and ocular lenses enlarged the universe and caused people to question the world as they knew it and its peaceful ends. A century after the enlargement of the ends of the terrestrial world, the celestial too lost its characteristics. The Earth was not the centre, but, as Galileo discovered with his telescope, there were other bodies with moons like the Earth.[8]

Galileo called his instrument 'occhiale', presented it to the Lincei in Rome and they called it 'telescope' because with it they could see things at a distance.

With this instrument, with lenses worked in Padua and then in Florence by talented craftsmen,[9] Galileo observed the Moon and its mountains, the sun spots, Venus and its phases, Jupiter and its satellites called by Galileo Medicean stars,[10] Saturn and its appearances.

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[7] A. VAN HELDEN, *Istituto e Museo di storia della scienza. Catalogue of early telescopes*, Firenze, Giunti, 1999, p. 7.

[8] On Galileo's discoveries there is an enormous bibliography. See the recently prepared "Galilean Bibliography" on the web site of the Istituto e Museo di Storia della Scienza, Florence (http://www.imss.fi.it/biblio).

[9] See V. VARETTI, *L'artefice di Galileo Ippolito Francini detto il Tordo. Contributi agli studi galileiani e alla storia dell'ottica*, Roma, G. Bardi, 1939. Off-print from *Rendiconti della classe di scienze morali, storiche e filologiche*, ser. 4, vol. 15, issues 3-4 (1939). Galileo had worked in Padova with the help of Marc'Antonio Mazzoleni.

[10] See G. GALILEI, *Sidereus Nuncius magna longeque admirabilia spectacula pandens … quae a Galileo Galileo … perspicilli nuper a se reperti beneficio, sunt observata in Lunae facie, fixis innumeris, Lacteo circulo, stellis nebulosis, apprime vero in quattuor planetis circa Jovis stellam disparibus intervallis atque periodis celeritate mirabili circumvolutis, quos, nemini in hanc usque diem cognitos, novissime author depraehendit primus, atque Medicea sidera nuncupandos decrevit*, Venetiis, apud Thomam

Aware of the revolutionary possibilities of this new instrument, even if dangerous because of its parallel with the human sense (are the eyes defective? is God an intentionally defective creator? is the telescope a deception?), the telescope immediately became an object to own and collect. After the death of the scientist (1642), the 'celestial discoverer', that is the lens with which Galileo had discovered the 'Medicean Stars', went to the patrimony of the Cardinal Leopoldo de' Medici and when he died (1675), his goods became part of the general patrimony of the family.[11] Also the telescopes are recorded in the Medicean inventories.[12]

At that time, this patrimony also had other telescopes, made by famous opticians and preserved in another palace in Florence, Palazzo Pitti.[13] Palazzo Pitti, in fact, was chosen as the perfect place to preserve optical objects and the beautiful collection of globes. In the same palace, the experimental Accademia del Cimento had had its working sessions using a furnace in the Boboli garden to blow its innovative and original instruments.[14] So, Pitti Palace was a concrete 'scientific space' in which other scientific objects could be preserved and shown.

Baglionum, 1610. The original Galilean idea had been to call the satellites "Cosmica sidera", pointing on the name Cosimo and on the ambiguity between this name and the word 'cosmo'. The Grand Duke preferred the connection with the Medicean House.

[11] See Archivio di Stato, Florence, *Inventario della Guardaroba Medicea*, n. 826, dated 1675. It includes the inventory of the goods owned by the Cardinal Leopoldo de' Medici. At p. 54 we can find the objective lens. It was framed in ivory by the artist Crosten in 1677 and remained at the Uffizi Gallery until 1793. It became part of the collections of the new Imperial and Royal Museum of Physics and Natural History, founded in Florence by the Grand Duke Pietro Leopoldo of Lorraine in 1775. See M. MINIATI, "Del baratto di due bronzetti con la lente di Galileo", *Annali dell'Istituto e Museo di Storia della Scienza*, IV (1979), 2, pp. 72-77.

[12] The surviving Galilean instruments are preserved at the Istituto e Museo di Storia della Scienza, Florence. See *Catalogo degli strumenti del Museo di Storia della Scienza*, Firenze, Olschki, 1954, pp. 19-26; M. L. RIGHINI BONELLI, *Il Museo di Storia della Scienza*, Milano, Electa, 1968, pp. 151-152; P. GALLUZZI, "Gli strumenti di Galileo", in M. MINIATI (ed.), *Museo di Storia della Scienza. Catalogo.* Firenze, Giunti, 1991, pp. 52-63; A. VAN HELDEN, "Origine e sviluppo del telescopio", in M. MINIATI (ed.), *Museo di Storia della Scienza*, cit., p. 72; A. VAN HELDEN, *Istituto e Museo di Storia della Scienza. Catalogue of early telescopes*, cit., pp. 30-33.

[13] See, M. CHIARINI, *Palazzo Pitti: l'arte e la storia*, Firenze, Nardini, 2000. Some fresco offers images of the scientific activity and of the objects there.

[14] About this experimental academy, see *Saggi di naturali esperienze fatte nell'Accademia del Cimento*, In Firenze, per Giuseppe Cocchini, 1666 (English translation: *Essayes of natural experiments made in the Academie del Cimento*, London, printed for B. Alsop, 1684, facs. edition 1964). See also W. E. KNOWLES MIDDLETON, *The experimenters. A study of the Accademia del Cimento*, Baltimore, The J. Hopkins Press, 1971; P. GALLUZZI (ed.), *Scienziati a Corte. L'arte della sperimentazione nell'Accademia Galileiana del Cimento (1657-1667)*, Livorno, Sillabe, 2001.

Figure 1: Objective lens by Galileo, beginning of 17^{th} century. Ivory frame by Vittorio Crosten, 1677. Istituto e Museo di Storia della Scienza, inv. no. 2429.

In the 1660's the research on telescopes and their optical aspects spread throughout Europe. Among the opticians involved in this work, some names are very important for our purposes.

Figure 2: Objective lens by Torricelli, 1647, Istituto e Museo di Storia della Scienza, inv. no. 2554.

Evangelista Torricelli,[15] a young pupil of Galileo who had developed his research on the vacuum and its effects, and who created the first barometer in 1644, unfortunately died in 1647. He had also found, they said, the secret to making perfect lenses, but nobody knew it. His lenses were in the Medicean patrimony as an example of how good he was. His telescopes, his oculars and his objectives signed and often dated, constituted an enviable and incomparable set to be preserved in a princely collection.

Soon after two other names became important in the same field: Eusta-

[15] Evangelista Torricelli (1608-1647), Mathematician to the Grand Duke and Lector of Mathematics at the University of Pisa after the death of Galileo, performed the experiment to demonstrate the effects of atmospheric pressure (1644). His lenses were of excellent quality and were avidly sought after. See E. Torricelli, *Opere*, Faenza, Stab. lito-tip. G. Montenari, 1919-1944, 5 vols.; V. Ronchi, "Evangelista Torricelli ottico", *Atti della fondazione Giorgio Ronchi*, n. 5/6 (1948), pp. 16; L. Tenca, *A proposito del segreto del Torricelli sulla lavorazione delle lenti*, Firenze, Scuola tipografica calasanziana, 1954 (Pubblicazioni dell'Istituto nazionale di ottica; 170); P. Galluzzi, "Evangelista Torricelli, concezione della matematica e segreto degli occhiali", in *Annali dell'Istituto e Museo di storia della scienza di Firenze*, A. 1, fasc. 1 (1976), pp. 71-95.

Figure 3: Objective lens by Divini, 1674, Istituto e Museo di Storia della Scienza, inv. no. 2557.

chio Divini and Giuseppe Campani,[16] both active in Rome, but born in different cities. They made beautiful and quality instruments, with special improvements. Everybody said that they were the best opticians and that their telescopes were better than those of Torricelli.

Ferdinando II de'Medici wanted to know the capacity of these instruments in comparison with the Florentine ones. He made some panels to be prepared with phrases taken from very well known writers (Tasso, Ariosto,

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[16] About Eustachio Divini (1610-1685) see G. Piangatelli, "Eustachio Divini", *L'Appennino camerte*, a. 63, n. 11 (1983), pp. 6; M. Bianchedi, *Eustachio Divini ottico e matematico del secolo XVII*, Firenze, Stab. tip. già Chiari succ. C. Mori, 1946, pp. 2-8. Off-print from "Bollettino dell'Associazione ottica italiana, Serie storica", vol. 1, n. 2 (1946). About Giuseppe Campani (1635-1715), see S. A. Bedini, "Giuseppe Campani, pioneer optical inventor", *Ithaca*, 26, 8 (1962), pp. 401-404; idem, "The optical workshop equipment of Giuseppe Campani", *Journal of the history of medicine and allied sciences*, vol. 16, n. 1 (1961), 38 pp.; M. L. Righini Bonelli, "Una eredità galileiana: i fratelli Campani di Spoleto", *Spoletium*, a. 14, n. 16-17 (1972), cc. 2.

Figure 4: Objective lens by Campani, 1665, Istituto e Museo di Storia della Scienza, inv. no. 2587.

Dante) and set up a competition.[17] The panels were read by readers using different telescopes: they could compare whether it was possible to read them with one telescope or another and how much better one was than another. But in the end the readers memorized the phrases and it was impossible to know which was the truth and which optician was the best. To solve the problem, the Grand Duke made the phrases to be combined and the words mixed up creating new nonsensical phrases. So, they created the Optotypes, well known in every modern optical cabinet.

The competition was held in Rome and the telescopes used were presented to the Grand Duke and became part of the Medicean collection in which they are still preserved.

We have recently recreated the competition[18] using electronic devices to examine the lenses and to discover who really was the winner. We could confirm Campani, but all the lenses are really very precisely worked, and they offer characteristics of modernity and precision not easy to understand. The Medicean collection of telescopes improved continuously thanks to presentation gifts, important and expensive acquisitions and legacies.

[17]See, M. L. Righini Bonelli, A. Van Helden, *Divini and Campani. A forgotten chapter in the history of the Accademia del Cimento*, Firenze, Giunti, 1981 (Supplement of *Annali dell'Istituto e Museo di Storia della Scienza*, IX /1981/, I).

[18]See V. Greco, G. Molesini, G. P. Puccioni, F. Quercioli, "The optical principles of telescopes", in A. Van Helden, *Catalogue of early telescopes*, Firenze, Giunti, 1999, pp. 99-111. The 'virtual' competition was held at the Institute of Optics in Florence in 1995.

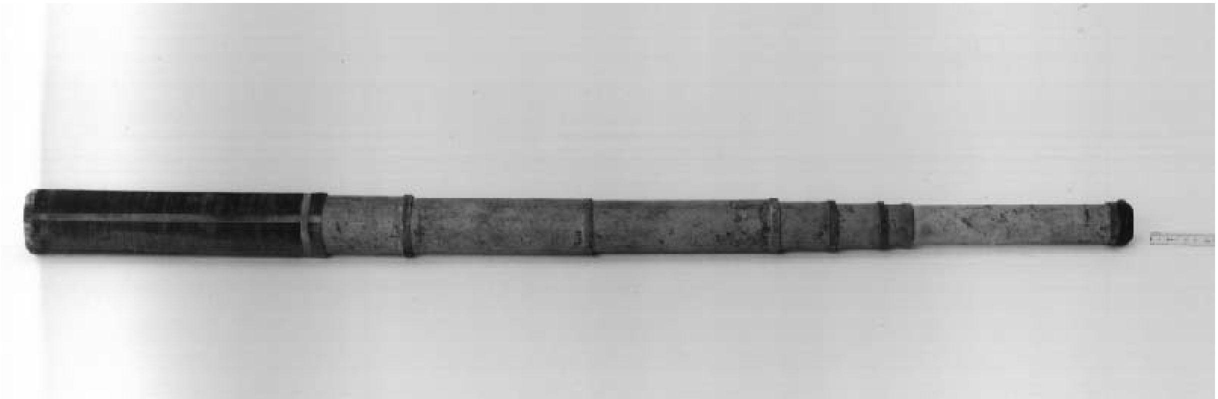

Figure 5: German telescope assigned to Johannes Wiesel, c. 1650, Istituto e Museo di Storia della Scienza, inv. no. 2562.

In conclusion, this collection was rich in both celestial and terrestrial telescopes. The firsts cover the most important part: they are signed by Divini, Campani, Torricelli, Francini and Mariani.[19] There are Italian telescopes, but also German and English, constructed differently but with the same characteristic of beautiful covers to be presented and made part of important collections.[20] Those of Divini present the improvement realized by the same maker and consisting in a small tube with lenses inside the telescope.[21] This tube made it possible to transform a celestial into a terrestrial telescope and vice-versa. It is an improvement invented in the 1660's which allowed for the change of fields and the change of possibilities offered by the same instrument.

The Italian makers were so famous and researched that they constructed a large number of instruments, not only telescopes, but also microscopes and optical devices, many of them for princely collections. By the end of the 17th century the Medicean collection boasted more than 30 telescopes including those of Galileo, the only existing original we know of.

[19] See A. Van Helden, *Istituto e Museo di Storia della Scienza. Catalogue of early telescopes*, cit., pp. 34-52.

[20] *Ibidem*, pp. 54-82.

[21] *Ibidem*, pp. 40-46.

Tycho Brahe and Prague: Crossroads of European Science, pp. 187–202, J. R. Christianson et al. (eds.), © *H. Deutsch 2002*

Tycho Brahe and the Republic of Venice: a Failed Project

Luisa Pigatto, Padua

Introduction

In his *Histoire de l'Astronomie Moderne* Jean Silvain Bailly (1736-1793) writes that Sciences "qui sont fondées sur l'observation et l'experience, qui par conséquent demandent des dépenses et des travaux suivis, comme l'étude du Ciel, n'ont jamais fait beaucoup de progrès dans les républiques [...]" (Bailly, 1775, 1787). Giuseppe Toaldo (1719-1797), professor of astronomy, geography and meteorology at the University of Padua, and first director of the Astronomical Observatory (Pigatto, 2000), felt himself obliged to defend the behaviour of Republics in general. In particular he defended his loved Venetian Republic in an essay (Toaldo, 1782) in which he mentions two main facts concerning what Venice had done in favour of astronomy. "Subject of the first" – Toaldo writes – "is the famous Tycho Brahe. Since the Senate had known about the prodigious work Tycho was conducting with the favour of King Frederick II of Denmark in order to reform the Astronomy, in 1592 it spontaneously issued a Decree, glorious for the honouring no less than for the honoured", to send to Alexandria in Egypt a competent person with the task of carrying out astronomical observations under Tycho Brahe's responsibility. And again: "About this splendid act of the Venetians, Gassendi speaks with praise in his biography of Tycho, and Tycho himself with transport in the Preface to his *Astronomia Meccanica*" (translated from Italian). So we know about this project from Tycho himself, who had this information third-hand: Giovanni Antonio Magini (1555-1617)[1] had spoken about it to a friend in Padua, who

[1]Giovanni Antonio Magini, professor of Mathematics at the University of Bologna, was born in Padua in 1555 and died in Bologna in 1617. He had been a pupil of Giuseppe Moletti (1531-1588), professor of Mathematics at the University of Padua from 1577 to 1588 (Favaro, 1883; Carugo, 1984), in the chair which Galileo obtained in 1592 after

mentioned it in a letter to a friend in Denmark, who had talked to Tycho; he, in turn, published an extract (*paucula*) of that letter, in the appendix to his *Astronomiae Instauratae Mechanica* of 1598. The letter states:[2]

> "Magini was here in Padua and in Venice for almost all the summer. Why, we do not know enough.[3] At the same time Galileo Galilei was called here to teach mathematics, and gave his opening lecture on the 7th of December.[4] The opening was splendid, in front of a crowded audience. Mr Pinelli kindly suggested to him that he could try to make the friendly acquaintance of Mr Tycho. You could arrange it, as far as possible, knowing Tycho's mind. Magini recently published a book to which he gave a title *Tabula Tetragonica* under the patronage of Tycho. He gave me a copy for you, which I will send to you on the first occasion. In addition, he reported that the Illustrious Venetians had decided to send to Egypt an expert Mathematician with a salary of 300 *coronati*,[5] to make observations there for Tycho. In fact, here Tycho has such a high reputation as none of his living contemporaries has. Padua, 28th December 1592."[6]

Gassendi mentions this project paraphrasing this letter in his biography of Tycho (Gassendi, 1654); Toaldo quotes[7] Tycho and Gassendi, Tiraboschi

four years of vacancy. Magini obtained the chair of Mathematics in Bologna in 1588 (Favaro, 1886).

[2] I include here an English translation from Latin of this letter, which is missing in the English edition of *Mechanica* (see Tycho Brahe, *Instruments of the Renewed Astronomy*, English translation (Reader et al. 1946) revised and commented by Alena Hadravová, Petr Hadrava and Jole R. Shackelford, KLP, Prague, 1996).

[3] We know (Toaldo, 1782; Favaro, 1946) that, at that time, Magini was negotiating with the Venetian patricians in order to obtain the chair of Mathematics in Padua, which was instead assigned to Galileo, in a decree dated September 26th, 1592.

[4] As Favaro states (Favaro, 1992), this is the sole testimony of the date of Galileo's opening lecture at the University of Padua; for this reason, Favaro had this page of *Mechanica* printed in *facsimile* for commemoration of the third centenary of the opening.

[5] The Latin term *coronatus* (crowned or crowned coin) used in this letter is vague: the official currency which was legal tender in the Republic of Venice were *ducati* (Papadopoli, 1906), more or less equivalent to the *crowns* of some European States.

[6] This unsigned letter was attributed to Gellius Sascerides by John Emil Dreyer in his biography of Tycho. Antonio Favaro (1992) states that it is probable, but not absolutely ascertained, that Sascerides was in Padua at the end of 1592. In any case, Tycho could not have mentioned the probable author of the letter, because of controversies with his son-in-law manqué since 1594. About Gellius Sascerides and relationship with Tycho, see also Christianson (2000).

[7] In his paper, Norlind (1955) assumes that Toaldo had reproduced the text from the German biography of Tycho by Philander von der Weistritz, and evidenced by an exclamation mark the word 'Preface' used by Toaldo, as a result of a literary distortion. In his Preface to Rudolph II, Tycho refers to letters added in the Appendix (*additis*

(TIRABOSCHI, 1796) quotes Toaldo and Tycho, Favaro (FAVARO, 1898) quotes Toaldo and Tycho, and lastly Norlind (NORLIND, 1955) quotes Favaro, Tiraboschi, Toaldo and others, but neither Favaro, nor Norlind, were able to find this decree.

Tycho's project

The idea and scientific meaning of astronomical observations in Alexandria of Egypt appear clearly in the first two letters exchanged between Magini[8] and Tycho Brahe. Magini was a very clever theoretical astronomer, and famous for computing astronomical ephemerides derived from Astronomical Tables, the starting-point for which was knowledge of the exact positions of the fixed stars and of the elements of planets such as the eccentricity and the apogee of their orbits. Magini was thus very interested in Tycho's observations, and Tycho was equally interested in Magini's calculations.

As a matter of fact, Magini was interested in calculating very precise ephemerides for astrological reasons,[9] and he believed, as did all those who believed in astrology, that the exactness of horoscopes depended on the exactness of the ephemerides. For this reason, he had derived his first ephemerides from the most precise astronomical tables of his epoch, i.e., "from *Prutenic Tables* by Erasmus Reinhold, founded on the hypothesis and suppositions of the illustrious Copernicus" (MAGINI, 1583, p. 27r). This does not mean, obviously, that Magini had accepted the theory of heliocentrism: in fact, in order to improve his astronomical tables, he had later elaborated a complex cosmological model founded on the Aristotelian physics of solid spheres and on the trepidation of equinoxes, following the

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paucis quibusdam Clarorum Virorum Epistolis, negotium, quod molimur, commendantibus [we have added a few letters of famous men who commend work to which we are devoted]. Toaldo is imprecise in using the term *Preface*, but he quotes first-hand; he was very well acquainted with the *Mechanica*, of which he had a copy of the second edition of 1602 in his library (now in the Library of the Observatory of Padua). From his paper, it appears that Norlind did not see Toaldo's essay, in which both the whole mentioned letter and a complete passage of Tycho's text are reproduced correctly. In addition, Toaldo did not know German, but of course he knew Latin very well.

[8] In his *Tabulae primi Mobilis*, Venice 1604, p. 79v, MAGINI writes: "The first letter by M^{r} Magini to very Illustrious M^{r} Tycho Brahe, being published by Tycho himself in his *Astronomiae Mechanica*, is not added here, but his answer to that one" (translated from Latin).

[9] In his *Efemeride de i moti celesti*, Venice, 1583, p. 1r, MAGINI states that astrology "not only is true, but is most worthy of being included among the other liberal Arts necessary to men" (translated from Italian).

Figure 1: Portrait of Giovanni Antonio Magini (1555-1617)

Arab astronomers.[10]

But he was also interested in Tycho's system, the crucial point of which – the eccentricity of planet Mars – was in contradiction with the solid spheres model. In his first letter to Tycho, Magini wrote: "I greatly approve of the System of the Universe invented by you, but I would prefer that the orbits of the Sun and Mars not to have to intersect each other".[11] Tycho's long and articulate letter[12] in reply is a small compendium of his deep beliefs about the constitution of the Universe, 'invented' by him a few years before (*a nobis ante non multos annos adinventum*).[13] If the sky was clear and transparent, without 'crystalline' spheres, where planets could move freely (*libere in liquidissimo aethere*), then the orbit of Mars could intersect that of the Sun, thus providing a plausible explanation to Magini's objection.

The scientific world remained to be convinced, and in this case his correspondent, that his cosmological model, based on the immobility of the Earth, could be confirmed if it were possible to demonstrate that the precession of equinoxes was constant, contradicting the *intricatum Axis Terreni motum*, that *summus ille Copernicus [...] ut mutationem obliquitatis eclipticae salvaret, ingeniose maginatus est* (Brahe, 1598, p. G4), ('the intricate motion of terrestrial axis that the great Copernicus had imagined in order to save changes of the obliquity of the ecliptic'). Thus, a constant value for the precession of the equinoxes explained the phenomenon as due to the simple, constant, direct motion of the sphere of fixed stars, compatible with the immobility of the Earth. In order to demonstrate this

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[10] Antonio Magini, *Novae Coelestium orbium theoricae*, Venetiis (Venice), Ex officina Damiani Zenarii, 1589. Simplifying, Magini's system comprises eleven spheres, of which the eleventh is responsible of diurnal motion, the tenth for poles librations, the ninth for libration in longitudes, the eighth for the medium precession whose value was, for Magini, of $50''12'''5''''$ per year.

[11] Brahe, 1598, p. G4, and Favaro, 1868, p. 393. This was the main objection to Tycho's system. For example, Clavius wrote to Magini (Rome, Jan. 27th, 1595): "It is not necessary to wait for what the Danish Tycho is doing, because it seems to me that he will never come to an end, that he confuses all Astrology [Astronomy] because he wants Mars to stay lower than the Sun" (translated from Italian) (Favaro, 1868, p. 215).

[12] Tycho Brahe to Magini, *Uraniburgi Calendis Dicembris, anni veteris Iuliani 1590* (December first of the Julian calendar = December 12th of the Gregorian calendar), Magini, 1604, 79v-82r; Favaro, 1886, pp. 394-406. It should be noted that Tycho signed all his letters following the Julian calendar; the Gregorian calendar was adopted in north Europe only in 1700.

[13] Tycho illustrates his system for the first time in *De Mundi Aetherei*, Uraniburgi, Typ. Authoris, 1583. He presents a diagram of his system with these words: *Nova Mundani Systematis Hypothesis ab Autore nuper adinventa, qua tum vetus illa Ptolemaica redundantia et inconcinnitas, tum etiam recens Copernicana in motu Terrae Physica absurditas, excluduntur, omniaque Apparentiis Coelestibus aptissime correspondent* (p. 189 of the edition of 1603).

last assumption, it was important to make comparisons between the latitudes of geographical points determined at different epochs: if they had not changed, then it meant that the inclination of the ecliptic in respect to the celestial equator was constant.

But how did Tycho convince himself about the constant value of the precession, in a cultural climate dominated by the revolutionary work of Copernicus, not because of his heliocentric system which was generally considered absurd, but because of the mathematical aspects which had produced the Prutenic Tables, much more precise than the ancient Alphonsine ones? An answer may be found in works which lie at the base of Tycho's scientific-astronomical training, mainly those in which the importance of exact, continuous astronomical observations obtained with very precise instruments is the founding principle of calculations. As is well known, the treatise which had represented an essential guide for all the astronomers and indeed for Copernicus himself, from 2nd until the 16th century, was Ptolemy's *Almagest*. In particular, European astronomers of the 12th-15th centuries used the Latin version translated from Arabic by Gherardo da Cremona (1114-1187).[14] George Peurbach (1423-1461), and later his pupil Johann Müller (Regiomontanus, 1436-1476) made a compendium (*Epitome*) of it. This *Epitome* was among the books in Tycho's library,[15] and it was here that Tycho learned astronomy, as frequent references in his works to Regiomontanus's methods demonstrate. There was a Latin version of the *Almagest*, made by Georgio Trapezuntio from a Greek codex of the Vatican, in circulation in Tycho's time, but the advantage of Regiomontanus's compendium lay in its use of the *sine* function instead of the *chord of an arc* used by Ptolemy.

Unlike Arab astronomers, Regiomontanus assumed that the length of the solar year was constant (thus, the precession of equinoxes), according to Ptolemy,[16] who ascribed the presumed variability of the year to uncer-

[14] For information on this author and his Latin versions see Boncompagni, 1852.

[15] The *Epitome* of *Almagest* of 1550 by Regiomontanus, is among Tycho's books now at the National Library in Prague (sign. 7 B 22). It is bound with four other treatises dealing with mathematics by Apianus, Peurbach and Regiomontanus, Finaeus, again Peurbach and Regiomontanus, mainly concerning *Tables of sines*. The first edition of the *Epitome* was printed in Venice in 1496, while the original version in manuscript is at the Biblioteca Nazionale Marciana of Venice; it was among cardinal Bessarione's books (Rigo, 1994) who corrected some errors, especially concerning names of ancient astronomers, which Gherardo da Cremona had translated erroneously from Arabic and Regiomontanus reproduced. For example, Hipparchus is translated as 'Abrachis', and this error occurs in the printed editions of the *Epitome*. I was able to verify Bessarione's handwritten corrections in the *Epitome* manuscript (Codex CCCXXIX, Ms. Lat. fondo antico, 39, Coll. 1843 provenienza Bessarione), on microfilm.

[16] Following Hipparchus, Ptolemy defines "the time of the year, the one which brings

tainty in determining the exact instant of equinoxes and solstices, to poor positioning of instruments, and to errors introduced by the observer.[17] As for Ptolemy, Regiomontanus's conviction was the result of experience in observations, so that an ideal link connects the three great observative astronomers – Ptolemy, Regiomontanus and Tycho – due to their awareness of the importance of accurate and repeated observations, and of the accuracy in constructing exact instruments.

Returning now to his letter, Tycho stated that he did not agree with the opinion of Maria Domenico Novara [from Ferrara], *Copernici Praeceptor*, who believed that geographical latitudes did change, since Regiomontanus had demonstrated with his observations that the latitude of Rome had not changed since the value given by Pliny[18] and that the difference of scarcely six minutes after so many centuries demonstrated that any perceptible variation did not exist. But additional proof of this could be obtained by measuring the latitude at Alexandria in Egypt where, almost 15 centuries previously, Ptolemy had determined it. So Tycho added: *Constitui Alexandriae poli quoque sublimitatem praecise dimetienda curare, ob quasdam Ptolemaicas institutas observationes* ("I decided to have a precise determination of Pole elevation done in Alexandria, because of observations made by Ptolemy"). *Ubi Alexandriae similiter facta fuerit, uti spero, inquisitio, utique Poli illic altitudinem non sensibiliter alteratam esse tot interlapsis saeculis manifestabitur, nisi quatenus in pauculis forte scrupulis ab ipso Ptolemaeo aberratum sit.* Once these observations had been made in Alexandria – so Tycho hoped – it would be possible to verify that the height of the Pole had not changed, or that some changes of a few minutes could due to Ptolemy's errors.

The above-mentioned scientific reasons had urged Tycho to plead for his mission to Alexandria, first of all to the Republic of Venice, because of

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the Sun, in its motion, from one point of its circle to the same point. The main points of the restoration in this circle are determined by equinoxial and solsticial points." *Almagestum*, Liber III, chap. II (Ptolemy, 1541). Thus, to state that the true solar year is constant means stating that the precession is constant.

[17]See *Almagestum, ivi.* It is unthinkable to compare (as Norlind seems to do) the trepidation of equinoxes, believed by Arab astronomers and also by Copernicus, and exclusively due to errors in observations, to the true nutation motion of the terrestrial axis discovered by James Bradley (1693-1762) in the telescopic epoch, the maximum amplitude of which is 9.2", well under the naked-eye capacity of separation of $1'$.

[18]In his *Naturalis Historia* (II, 182), Pliny the Elder states that in the equinox day *in urbe Roma nona pars gnomonis deest umbrae*, which means a ratio of 8 to 9 of the length of the shadow with respect to that of the gnomon. The method of determining latitude trigonometrically, by means of the ratio of the length of the gnomon and its shadow at the equinoxes, is described in the *Almagest*, Lib. II, chap. V. In his letter, Tycho reports a table of the values observed by Regiomontanus in 1492 in Rome.

the anonymous letter he had published in his *Mechanica* of 1598. After six years of complete silence on the subject from both Magini and the Venetians, he had tried to explain in two pages the scientific importance of these observations, and he had sent to the Republic his beautiful *Mechanica* together with a manuscript copy of his stellar catalogue *Stellarum octavi orbis inerrantium accurata restitutio*, with this dedication: *Inclitae atque Illustrissimae Venetorum Reipublicae submisse dono mittit Tycho Brahe manu propria.*[19]

The project of the Venetian Republic

In the light of the above considerations, we may ask ourselves whether this project had ever truly existed in the minds of the Venetian Senators. Why did the Republic of Venice decide to assign the task of performing very precise astronomical observations in Alexandria of Egypt, in order to derive the Pole elevation, i.e., the latitude, of that town, even though for the most famous astronomer of the time? This seems to be in contradiction with the cultural policy of the Republic, which was always interested in the pragmatic use of sciences.

As regards Astronomy, we must remember that, during municipal government, the first scientific chair of the Artist Faculty at the University of Padua had been *ad astrologiam* and that the first teacher of this discipline had been Pietro d'Abano,[20] who defined himself *artis medicine, philosofie, et astrologie professor*, i.e., first of all expert in medicine. Concerning the 'astrologer' or professor of 'astrology', the ancient Statutes of the University of Padua, had stated: *Quem tamquam necessarissimum habere omnino volumus.* This meant that astrology-astronomy was a necessary support in practising medicine: the astrological use of astronomy – following Ptolemy: "the prognostic through astronomy" – was based on scientific knowledge of the motion of the celestial bodies and, by means of horoscopes, it allowed medico-astrologers to derive the physical constitution of a disease and thus to provide diagnosis, prognosis and therapy. But the Republic of Venice[21] did not hesitate to suppress the chair of astronomy, combining it with that of mathematics,[22] as soon as the new discipline of Anatomy, with 'the dissection of corpse', came up, followed by gradual abandon of astrologic

[19] The manuscript is composed of 27 sheets (Valentinelli, 1871, p. 263-264).

[20] Pietro d'Abano (1250-1315) occupied the chair *ad astrologiam* from 1306 to 1315 (Favaro, 1883, pp. 3-13).

[21] Padua fell under the Venetian rule in 1406, and the University, founded in 1222, became the main cultural institution of the Republic.

[22] Decree of June 27th, 1506 (Favaro, 1883, p. 53).

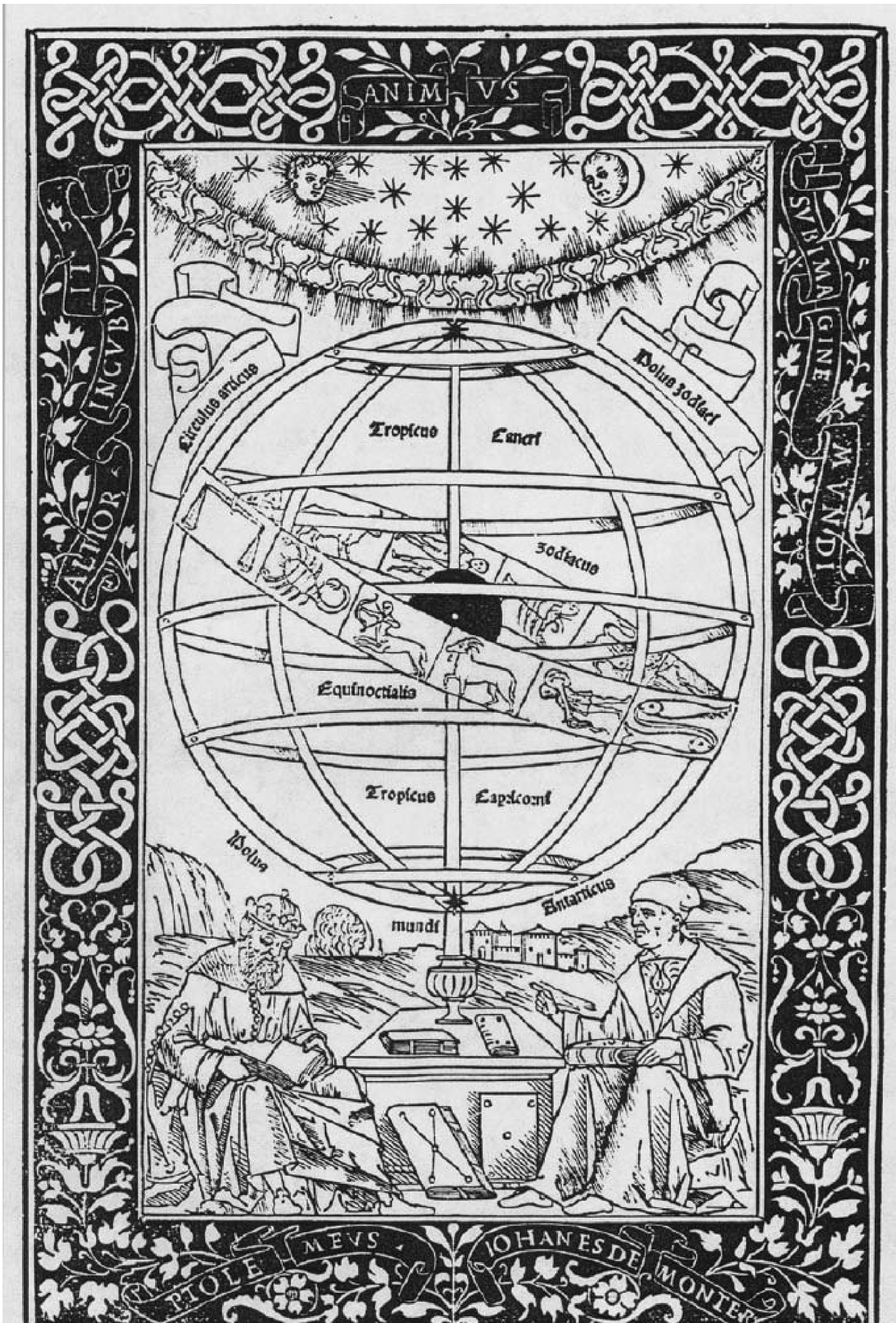

Figure 2: This plate, in the *Epitome* of Regiomontanus of 1496, representing the celestial sphere and below Ptolemy and Regiomontanus, is considered one of the most beautiful example of xylograph made in Venice. (Courtesy of the Biblioteca Universitaria of Padua.)

prediction in medicine. So the new medicine was based on knowledge of human body, rather than of the constitution of the individual.[23]

The pragmatic use of sciences on the part of the Venetian Republic is well described in Toaldo's words: presenting the program of his lessons at the University of Padua, he wrote that astronomy was free from the accusation of being a useless science: *Cum saepe quaerantur homines de sterile atque inani eruditorum doctrina, ac Serenissimus Princeps a scientiarum Professoribus, quas in hoc publico Gymnasio liberaliter alit, jure optimo ea quae ad usus humanae vitae pertinent in primis requirat; Astronomia [...] ab omni simul accusatione praestat immunem. Ejus enim non modo fructus, sed propagines ac partes sunt Geographia, Chronologia, Navigationis ars, sine quibus non modo commercia non exerceri, sed ne vita quidem socialis concipi potest [...]* ("Since men frequently inquire about the sterile and futile doctrine of the Erudites, and the Serene Prince with full right demands first of all from Professors of Sciences which in this public University he generously feeds, those ones that are useful for human life, certainly Astronomy [...] is completely free from any kind of such accusation. In fact, not only fruit, but ramifications and parts of it are Geography, Chronology and Art of Navigating, without which not only trade cannot be done, but not even social life may be conceived") (Toaldo, 1766). So, the interest of the Republic in a mission to Alexandria of Egypt, may have been of nautical-geographic nature: together with Beirut, in the past Alexandria had been the most important trading port for the *Serenissima* in the Mediterranean, but at the time of which we are speaking, the Mediterranean area was dominated by Ottomans, and the Venetian Republic daily had to face severe problems in order to safeguard her again flourishing trade and her possessions at sea continuously threatened as they were by Turkish danger.

Conclusions

In order to justify the following conclusions about the Alexandrine project, it seemed important to me to make a last search among documents in the State Archive of Venice, although I knew that, as already mentioned, neither Favaro (1898) nor Norlind (1955) had been able to find the quoted decree. Now, it seems to me important to indicate which criteria I adopted in my search, in order to support my conclusions.[24]

[23] About this subject see Favaro, 1883 and Carugo, 1984.

[24] Many thanks are due to Dr. Paola Benussi of the State Archive of Venice, for her useful suggestions in this research. I remember that, in Venice, the year started on the

I consulted the following registers of 1592 in which the decrees issued by the Senate of the Venetian Republic are listed and described: a) Register of decrees concerning the Republic's territories on *terra firma* (e.g., here, Galileo's appointment as professor of Mathematics is found, at the date of 26 Sept. 1592); b) Register of decrees concerning the Republic's possessions on the Mediterranean Sea;[25] c) Register of secret decrees, concerning appointments of *podestà*, captains and ambassadors and relative reports; d) Register of resolutions of Venetian Senate mainly concerning relationships with the *bailo*[26] of Constantinople during the period 1590-1594. The role played by the *bailo* was very important, since he represented direct contacts with Ottoman powers, and allowed Venice to control, as far as possible, trade routes in the Mediterranean and the Black Sea and in the nearest ports. The last register gives a panorama of the very numerous problems that the Republic had to face at that time, from attacks by pirates to ransom of prisoners (slaves), from maintaining good relations with the grand Vizier for permission to call at ports in the coastal towns of Asia Minor, and so on. Any mission to Alexandria in Egypt might require the intervention of the *bailo* in order to vouch for protection and safety to call at the ancient town and to work there.

I did not find any trace of our decree in those registers, but I realized that all the decrees concerning delivery of money, for whatever the reasons, were in favour of 'servants' of the Republic.

My final remarks derive from all these considerations:

1) The idea of a mission to Alexandria in Egypt had been Tycho's idea, as it appears in his writings, mainly in his letter to Magini of December 1590, in which it is evident that the sole aim of the great Danish astronomer was to find, through astronomical observations, that the precession of equinoxes was constant, as stated by Ptolemy in the *Almagest*, by Regiomontanus in his *Epitome*, and by himself: this confirmation would have given a fundamental support to the validity of his cosmological system.

2) In his letters to Tycho, Magini, who knew about the project, never mentions the possibility of obtaining funds from the Republic in order to perform astronomical observations in Alexandria. In addition, if this decree really had been issued during the summer of 1592, it is not clear why he

first day of March, as the Registers show, and finished at the end of February of the following year.

[25] At the time, the only Venetian possessions in the Mediterranean were: the islands of *Candia* (Crete), Cefalonia, Corfù, and part of the Dalmatian coast. Cyprus was conquered by the Turks in 1571, the year of the famous Battle of Lepanto, in which the Christians defeated the Turks.

[26] *Bailo* was the particular title given to the ambassador in Constantinople.

did not hasten to communicate the fact to Tycho who, in his *Mechanica* of 1598, writes that this information came only from an anonymous letter.

3) During the Summer of 1592, as the above letter states, Magini travelled to and fro between Padua and Venice, and we know why: the chair of mathematics in Bologna was due to expire after its three-year period of validity in 1592, and Magini was hoping to obtain the chair at Padua. But he needed strong support by friends among the Venetian patricians, and perhaps he counted on Francesco Sagredo who later became the best Venetian friend of Galileo. It is possible that Magini, in his private negotiations, was able to wring a promise of some funds for the mission to Alexandria. But it was necessary for Magini to become a 'servant' of the Republic, a situation which did not arise.

The above considerations convinced me, as an hypothesis, that the decree in question had never been issued, first, because the project did not enjoy direct patronage among the Venetian patricians, second, because the Venetian Senate was not in favour, in a land not controlled by the Republic, in a period politically very difficult in the Mediterranean area,[27] of supporting a project which in any case did not bring any practical advantage to the *Serenissima*.

Appendix: *The portrait of Tycho at the Observatory of Padova*

In 1773 Toaldo had the 'upper observatory' at the *Specula* painted (Pigatto, 1999) with the portraits of "eight famous astronomers: Ptolemy, Copernicus, Tycho, Galileo, Kepler, Newton, Montanari and Poleni". The eight life-size full-length portraits have clothing and face mainly based on the iconography of their period. Above each portrait, in smaller frames, are monochrome chiaroscuro scenes and figures, taken from mythology, the symbolic meaning of which are connected with those personages' works and can be guessed at in Toaldo's unpublished writings. About Tycho, Toaldo wrote: "Without Tycho, or someone like him, there would be neither modern astronomy nor celestial physics." In the portrait, derived from the engraving in the Mechanica of 1602, Tycho holds in the right hand a model of his world system. The figure above, represents Prometheus who had stolen fire from Zeus to give it to men. The light of illuminating fire is the symbol of knowledge, and Tycho's prodigious astronomical work contributed towards 'throwing light' on the system of the universe, even because he "supplied the materials for the edifice of the great architect Kepler, his disciple" (Toaldo, 1781) to 'construct' the laws of planetary motions.

[27] About this subject, see Zorzi, 1992.

Figure 3: Portrait of Tycho Brahe painted in fresco in the *Sala delle Figure* at the Astronomical Observatory of Padua.

Figure 4: Prometheus above portrait of Tycho Brahe in the *Sala delle Figure* at the Astronomical Observatory of Padua.

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TIRABOSCHI, GEROLAMO, *Storia della Letteratura Italiana*, Tomo VII, Parte II, In Venezia, 1796, p. 445 (Prima edizione veneta dopo la seconda di Modena, riveduta, corretta ed accresciuta dall'Autore).

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TOALDO, GIUSEPPE, "Del merito de' Veneziani verso l'astronomia, colla confutazione d'un passo del Sig. Di Bailly", in TOALDO, *Saggi di Studj Veneti*, Venezia, Per Gaspare Storti, 1782, pp. 7-27.

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The Observatories and Instruments of Tycho Brahe

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Tycho Brahe[1] (1546-1601) was the most important pre-telescopic observational astronomer. He was born into a wealthy noble family in Knudstrup, then Denmark but now in Sweden, in the Skåne (Scania) peninsula. A monument in nearby Helsingborg reminds us of Tycho's motto: *Nec fasces nec opes sola artis sceptra perennant* ("neither power nor wealth – only science is permanent").

I shall not discuss Tycho's formative years, nor his scientific activities as such,[2] but only his observatories and their instruments.

Important pre-Tychonian observatories and instruments

The first true observatories in the modern sense, with fixed instruments, arose in the medieval Islamic world. In the Middle Ages contacts existed between Islamic science and western learning; these contacts were particularly useful in relaying knowledge of Greek science to Europe.[3] Famous centers of Islamic astronomical science between the 9^{th} and 15^{th} centuries were, apart from Spain, in the Near East (Damascus in Syria, Bagdad

[1] Thoren, Victor E.: *The Lord of Uraniborg. A Biography of Tycho Brahe.* Cambridge, England 1991. Dreyer, J. L. E.: *Tycho Brahe: A Picture of Scientific Life and Work in Sixteenth Century.* Edinburgh 1890, New York 1963.

[2] A more detailed article can be found in German: Wolfschmidt, Gudrun: "Tycho Brahe – Instrumentenbauer und Meister der Beobachtungstechnik". In: *Florilegium Astronomicum. Festschrift für Felix Schmeidler.* Hrsg. von Menso Folkerts, Stefan Kirschner, Theodor Schmidt-Kaler. München: Institut für Geschichte der Naturwissenschaften (Algorismus, Heft 37) 2001, p. 293-323.

[3] Berggren, J. Lennart: "Historical Reflections on Scientific Knowledge: The Case of Medieval Islam". In: *Knowledge Across Cultures: Universities East and West.* Ed. by Ruth Hayhoe. Toronto: OISE Press 1994, p. 137-153.

in Mesopotamia and Marâgha as well as Iṣfāhān in Persia), in Central Asia (Samarkand in Turkestan), as well as in the Ottoman Empire (Istanbul), in Egypt (Cairo) and in Morocco (Fez).[4] For three observatories in Marâgha (1259) the instrumentation is described by Mu'ayyid al-Dīn al-'Urḍī (~ 1266), that of Uluġ Beg's Observatory in Samarkand (1425/28) is described by al-Kāshī and that of Iṣfāhān (about 1560) by al-Âmilî. Comparing the instrumentation in detail one notes that the mural quadrant, later called the Tychonic quadrant, was already in use at the Istanbul observatory in 1575, by Taqī al-Dīn, who called it 'libnah'. In the late Middle Ages Uluġ Beg (1394-1449) in Samarkand (now in Uzbekistan) used a huge sextant of 40 m radius for observing more than thousand stars with the help of his assistent al-Kāshī.[5] In both cases there was the aim of increasing the measurement accuracy by using huge dimensions, as Tycho was to do. It may be that Tycho had heard about these big instruments.

Very striking also is the similarity of the triquetrum, armillary sphere, sextant and quadrant described by al-'Urḍī for the Marâgha observatory, and also used by al-Âmilî in Iṣfāhān, with those in Tycho's *Astronomiae instauratae mechanica*. The same can be said for the instruments of Taqī al-Dīn, used at the Istanbul observatory. Terkeli's comparative study[6] shows the strong influence of Islamic instruments on Tycho's.

Tycho's observatories, instruments, and modern replicas

A stay at the court of Count Wilhelm IV (1532-1592) of Kassel, in 1575, changed Tycho's life.[7] The Danish King Frederik II (1559-1588) – following a recommendation of Wilhelm IV – donated the island of Hven (now Ven,

[4] Sayili, A.: *The Observatory in Islam.* Ankara (Publications of the Turkish Historical Society, Series VII, No. 38) 1960.

[5] Shevchenko, M.: "An Analysis of errors in the star catalogues of Ptolemy and Ulugh Beg". In: *Journal for the History of Astronomy* 21 (1990), p. 187-201. Uluġ Beg's measurements were not known in the West before the 17th century.

[6] Terkeli, S.: *Nasirüddin, Takiyüddin ve Tycho Brahe'nin Rasat Aletlerinin Mukayesesi.* Ankara: Türk Tarih Kurumu Basimevi (Ankara Universitesi Dil ve Tarih-Coğrafya Fakultesi Dergesi, 16) 1958, p. 301-393. Ihsanoglu, Ekmeleddin: "Ottoman Science: The Last Episode in Islamic Scientific Tradition and the Beginning of European Scientific Tradition". In: *Science, Technology and Industry in the Ottoman World.* Ed. by Ihsanoglu, Ekmeleddin; Djebbar, Ahmed and Feza Günergun. Turnhout: Brepols (Proceedings of the XXth International Congress of History of Science, Liège, 20-26 July 1997, Vol. VI) 2000, p. 11-48.

[7] Mackensen, Ludolf von; Bertele, Hans von; Leopold, John H.: *Die erste Sternwarte Europas mit ihren Instrumenten und Uhren. 400 Jahre Jost Bürgi in Kassel.* München: Callwey 1979, 2nd ed. 1982.

and belonging to Sweden), to Tycho, along with money for building an observatory, Uraniborg, was was to be finished in 1576 *(Fig. 1)*. The observatory measured 16 m × 16 m, with a 19 m tower and two small round towers to the north and south of diameter 6 m, with galleries around for the instruments.[8] In the cellar was Tycho's alchemical laboratory *(Fig. 4)*.[9]

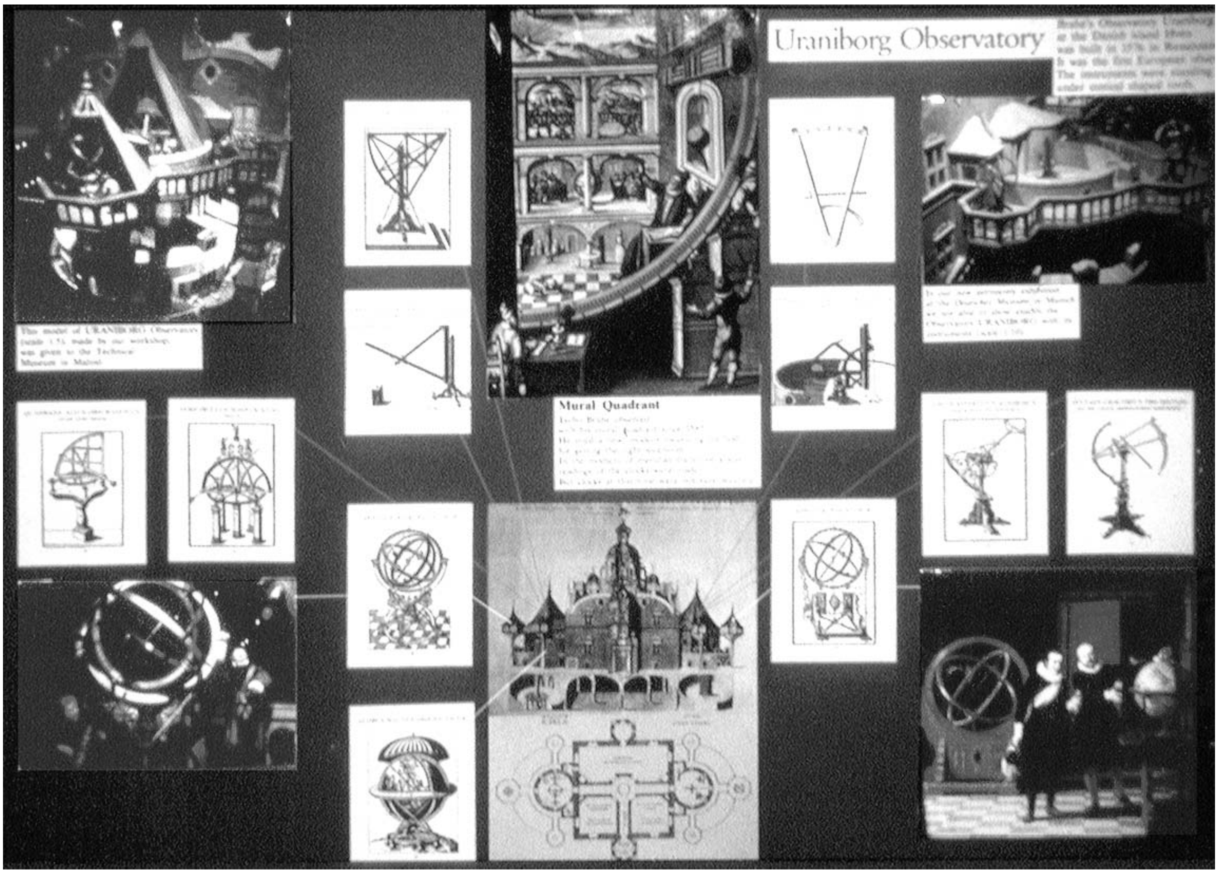

Figure 1: Tycho's Uraniborg Observatory and its Instruments (Wolfschmidt's poster), photo Wolfschmidt.

In 1584 Tycho founded a second observatory, Stellaeburgum (Stjerneborg, *Fig. 2*), – 80 m to the south of Uraniborg.[10] In its five round towers with

[8] These dimensions are based on the Tychonic cubit being equal to 39 cm (cf. ARREST, H. L. D': "Die Ruinen von Uranienborg und Stjerneborg im Sommer 1868". In: *Astronomische Nachrichten* 72 (1868), Nr. 1718, p. 209-224. See also: WOLFSCHMIDT, GUDRUN: "All-Wissen – Tycho Brahes Sternwarte Uraniborg". In: *Kultur und Technik* 20 (1996), Heft 4, p. 12-13.

[9] FIGALA, KARIN: "Tycho Brahes Elixier". In: *Annals of Science* 28 (1972), p. 139-176.

[10] Stjerneborg was reconstructed in 1951, with the foundations of the instruments previously excavated in 1823.

conical 'domes', called 'crypts' by Tycho, his instruments were well protected against the wind.

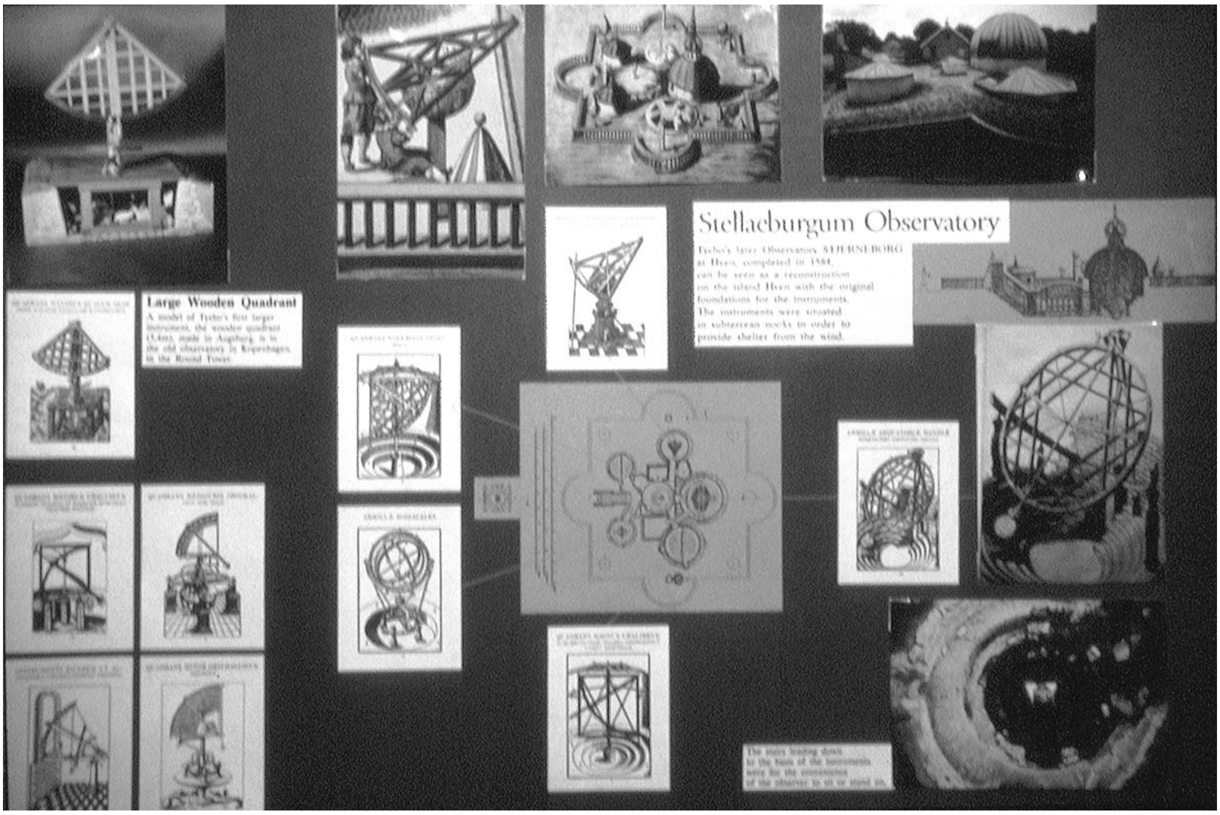

Figure 2: Tycho's Stjerneborg Observatory and its Instruments (Wolfschmidt's poster), photo Wolfschmidt.

After his patron, King Frederik II, died in 1588, Tycho had to leave Denmark. From 1597 to 1599 he stayed in the castle of Count Heinrich of Rantzau (1526-1599) in Wandsbek, now part of the city of Hamburg *(Fig. 5)*. Here Tycho Brahe published his book *Astronomiae instauratae mechanica*[11] (Wandsbek 1598, 2nd ed. Nuremberg 1602) describing his observatories and instruments in detail. Another nice illustrated book giving an insight into Tycho's observatories was published by his student Willem Janszoon Blaeu (1571-1638) together with his son Johann Blaeu (1598-1673): *Geographia Blaviana – Atlas Major* (Amsterdam 1662) and

[11] Raeder, Hans; Strömgren, Elis; Strömgren, Bengt: *Tycho Brahe's Description of his Instruments and Scientific Work as given in Astronomiae Instauratae Mechanica* (Wandesburgi 1598) Copenhagen 1946. Cf. *Tycho Brahe Instruments of the renewed Astronomy.* English translation (Raeder et al. 1946) revised and commented by Alena Hadravová, Petr Hadrava and Jole R. Shackelford. Prague: Koniash Latin Press (KLP) 1996.

12 volumes of *Le Grand Atlas* (Amsterdam 1663).

In the permanent astronomy exhibit, opened in 1992, of Munich's Deutsches Museum, the Uraniborg observatory and its instruments are shown at a scale of 1:10. A similar but larger model (scale 1:5) from the Deutsches Museum's workshop was given to the Technical Museum in Malmö, Sweden. Tycho's later observatory Stjerneborg can only be seen as a reconstruction on the island Hven (Ven in Swedish) along with the original foundations for the instruments.

Tycho was not very concerned with typical medieval instruments such as the astrolabe, torquetum and cross staff. His interest went back to those instruments invented in ancient Greece: the quadrant, the triquetrum (instrumentum parallacticum) and the armillary sphere – instruments also used by Copernicus.

Twenty-two principal instruments were presented in *Astronomiae instauratae mechanica* and carefully explained by Tycho: one half-circle of 2.3 m radius, eight quadrants up to 2 m radius including the mural quadrant, six sextants up to 1.6 m, four armillary spheres of 1.5 m radius including the great equatorial armillary sphere of 2.7 m, two triquetra and the great globe. A special invention of Tycho was the replacement of the zodiacal (ecliptic) armillary sphere with the equatorial armillary sphere, where one can read the stellar coordinates directly in right ascension and declination, i.e. in the equatorial system used today. The great computational celestial globe of 1.5 m diameter *(Fig. 4)* was finished around 1580 and from then until 1595 he engraved his measured stars on it. Some important instruments, in chronological order, are *(Fig. 3)*:[12]

1582 Great mural quadrant at Uraniborg (planned since 1576)
1576 Brass azimuthal quadrant
1581 Armillary sphere
1582 Triangular sextant
1585 Great equatorial armillary sphere
1586 Revolving quadrant
1588 Revolving steel quadrant.

His *Astronomiae instauratae mechanica* was dedicated to the Emperor Rudolf II (1576-1612), in the hope of thus finding a new patron. His wish was fulfilled, and Tycho arrived in Prague in the spring of 1599 and became Imperial Mathematician and court astronomer to Rudolf II. His instruments were transported to Prague but did not arrive until November 1600. Tycho now had three observing sites: Ferdinandeum (Belvedere)

[12] Thoren, Victor E.: "New Light on Tycho's Instruments". In: *Journal for the History of Astronomy* 4 (1973), p. 25-45.

Figure 3: Replicas of Tycho's instruments (scale 1:10) in the Deutsches Museum in Munich. Photo Wolfschmidt.

and Curtius' house in the city of Prague, and Castle Benátky nad Jizerou about 30 km away *(Fig. 5)*.[13]

Most of his high-accuracy instruments which he brought from Denmark were distroyed in the aftermath of the Bohemian civil war of 1619. Only the two sextants, made around 1600 by the prominent instrument makers Jost Bürgi (1552-1632) and Erasmus Habermel (died 1606) *(Fig. 6)*, survived and still exist in the Národní Technické Muzeum (National Technical Museum, or NTM) in Prague.[14] Tycho's great globe *(Fig. 4)* found its way back to Copenhagen, and remained in the University's observatory tower until that tower and all its contents were destroyed by fire in 1728.

[13] Tycho Brahe was buried in 1601 in the Teyn church in Prague. A copy of his gravestone is in the museum in Frederiksborg Palace in Hillerød, north of Copenhagen.

[14] Šíma, Zdislav: "Prague Sextants of Tycho Brahe". In: *Annals of Science* 50 (1993), p. 445-453. Cf. *Bulletin of the Scientific Instrument Society* No. 35 (1992), p. 7-10. Cf. Rankl, Richard: "Der Tychonische Sextant (von Bürgi) in der Sternwarte Kremsmünster". In: *89. Jahresbericht des Obergymnasiums der Benediktiner zu Kremsmünster.* Linz 1946, p. 3-15.

A model of the large wooden quadrant (5.4 m radius, made in Augsburg) is in Castle Benátky (scale 1:5), another replica of this Augsburg quadrant can be seen in the former observatory in Copenhagen, in the so-called 'Round Tower'. In Oldenburg University, Lower Saxonia, Germany, one can find a replica of a Tychonic sextant (*Sextans Astronomicus Trigonicus pro Distantiis*, around 1569) made by the institute "Hochschuldidaktik & Wissenschaftsgeschichte" (didactics and history of science) in the physics faculty. A replica (1:1) of one of the so-called Tychonic sextants (but actually made by Bürgi and Habermel) is in the Astronomical Tower of Clementinum in Prague. One of Tycho's armillary spheres has been reconstructed in the original size in the Steno Museum in Århus, Denmark, and in Malmö, Sweden.

Finally one should mention the following objects connected to Tycho Brahe in the Museum für Astronomie und Technik in Kassel (all three objects can be seen in the permanent exhibition):[15] An armillary sphere (Kassel Inv.-Nr. A 35), probably a gift by Tycho Brahe (1575), a painting (1577), which shows Tycho during his stay in Kassel in 1575, and finally a reconstruction of a sextant with transversals inspired by Tycho, which existed in the observatory of William IV of Hessen-Kassel.

Tycho's measuring innovations for high accuracy

With his new instruments and new observing methods, Tycho succeeded in significantly increasing measurement accuracy by the following means:[16]

- He increased the size of his instruments (e.g. a large wooden quadrant of 5.4 m and the mural quadrant of 2 m radius).
- He used metal and masonry rather than wood.
- He modified construction techniques to achieve greater stability.
- To provide shelter from the wind his instruments were in subterranean nooks in Stellaeburgum.

[15] Cf. Sticker, Bernhard: *Documenta Astronomica.* Eine Ausstellung historischer Instrumente und Dokumente zur Entwicklung der astronomischen Messkunst im Museum für Völkerkunde und Vorgeschichte Hamburg, 23. August bis 5. September 1964. Wiesbaden: Franz Steiner 1964, object No. 24 (image Tafel 1) and 70. I would like to thank Peter Schimkat (Kassel) for the information.

[16] Wesley, Walter G.: "The Accuracy of Tycho Brahe's Instruments". In: *Journal for the History of Astronomy* 9 (1978), p. 42-53.

- His instruments were permanently and solidly mounted.
- For better angular readings, he developed new subdivisions and sighting devices: Tycho used transversals to obtain the greatest possible angular resolution readings. His instrumental sights were specially designed to minimize errors.
- He carefully analysed all the errors. Tycho's aim was to reduce the uncertainty to less than one minute of arc (he really got about 30 to 50 seconds of arc).
- He preferred measuring equatorial coordinates directly instead of using the ecliptic system, i.e. using the equatorial armillary sphere instead of the zodiacal armillary sphere.
- He used fundamental stars for the first time. He determined for 21 stars the right ascension with an accuracy of $15''$. Then with a quadrant he measured the zenith distance on the meridian, and thus the declination. The angular separation of two stars (up to 60°) could be measured with a sextant, with the half-circle over the whole sky. Knowing the declinations of two stars and their angular separation, their difference in right ascension could be calculated by

$$\cos(\alpha_1 - \alpha) = (\cos\theta - \sin\delta_1 \sin\delta)/(\cos\delta_1 \cos\delta) \; .$$

- He took atmospheric refraction into account.
- He tried a new measuring method with clocks and his mural quadrant of 2 m at the wall of the south-east room in Uraniborg (1582), for determining the right ascension by timing the moment of the meridian transit of a star: But he was not successful, because clocks at that time were not accurate enough (at best about some minutes per day).[17] (This method was to become standard a century later, with the pendulum clock and Rømer's telescopic transit instrument.)

[17] Dreyer, J. L. E.: *Tychonis Brahe Dani Opera Omnia.* Tom. 1-15, Copenhagen 1913-1928, Vol. VI, p. 51; *Epistolarum* I, p. 23, Uraniborg 1596.

Tycho's legacy

Tycho's importance[18] is based on the accuracy and continuity[19] of his observations, which finally allowed Johannes Kepler (1571-1630) to derive Kepler's Laws (*Astronomia Nova*, Prag 1609, the third law in *Harmonices Mundi*, Linz 1619).

Tycho's catalogue of 777 fixed stars has a typical error smaller than 1′, smaller than earlier ones by a factor of 10.[20] Kepler called him the *'Hipparchos of the 16th century'* in the 8th chapter of his book *Ad Vitellionem Paralipomena* (Frankfurt am Main 1604). Thus Tycho's wish of not having lived without being *('Ne frustra vixisse videar')* was fulfilled, although Kepler, as a convinced Copernican, did not promote the Tychonic planetary system.

Tycho had a successor in the use of the instruments he developed, with Johannes Hevelius [Hewelcke] (1611-1687), who as late as 1661 compiled a star catalogue of high accuracy based on observations with 'Tychonic' instruments, without telescopic sights (cf. table).[21]

Astronomer	Error	Year
Hipparchos (190-127/120 B.C.)	$6'$	ca. 160 B.C.
Ptolemy, Claudius (∼ 100-170 A.D.)	$10'$	ca. 150 A.D.
Copernicus, Nicolaus (1473-1543)	$6'$–$10'$	ca. 1520
Brahe, Tycho (1546-1601)	$\frac{1}{2}'$–$1'$	ca. 1600
Hevelius, Johannes (1611-1687)	$10''$–$20''$	1661
Bradley, James (1692 a.St./1693-1762)	$1''$–$2''$	ca. 1740
Bessel, Friedrich Wilhelm (1784-1846)	$0\farcs7$	ca. 1840
Küstner, Karl Friedrich (1856-1936)	$0\farcs27$	ca. 1900

Another successor, in a sense, was the Jesuit astronomer Ferdinand Verbiest (1623-1688), in China, who in 1669 succeeded in convincing the Chinese Emperor that a new observatory with western-type instruments was necessary.

[18] From Tycho's other scientific acchievements should be mentioned his recognition that the 'new star' of 1572 (in fact, a supernova) was a fixed star, and his showing that comets are celestial bodies.

[19] Previously, observations of planets were often limited to special points in their orbits, such as oppositions and conjunctions.

[20] Chapman, Allan: *Astronomical Instruments and Their Users: Tycho Brahe to William Lassell.* England (Collected Studies, Cs 530) 1996.

[21] Hevelius, Johannes: *Prodromus astronomiae.* Danzig 1690. In 1679 Edmond Halley (1655-1742) visited Hevelius and checked the observing possibilities and results and was finally astonished that Hevelius was really able to determine stellar positions so well without a telescope.

China already had a long tradition in astronomy: In the 11th century Shen Kuo (1031-1095) had developed astronomical instruments. In the 13th century China came under Mongol-Islamic influence (Kublai Khan, a grandson of Genghis Khan, 1260 to 1294, started the Yuan dynasty 1279 to 1368). In 1279 Kuo Shou-Ching built a great armillary sphere and an equatorial torquetum for the 'ancient' Beijing (Peking) observatory.[22] These two instruments were copied in 1439 during the Ming dynasty (1368 to 1644) by Huangfu Chung-Ho.[23] But for over two hundred years there was no further interest in new instruments.

In the years 1670 to 1673 Verbiest built the new Beijing observatory *(Fig. 7)* with two armillary spheres, an azimuth circle, a quadrant, a sextant and a celestial globe – everything in the style of Tycho Brahe – and no telescope! Today in Beijing, on the 14 m high platform, one can see a series of eight great instruments from the Qing dynasty (1644 to 1912): sextant, quadrant, altazimuth, ecliptical armillary sphere, equatorial armillary sphere, celestial globe (all these instruments made for Verbiest in 1673) as well as an azimuth theodolite and a new armillary sphere (made in 1715).

[22] Johnson, M. C.: "Greek, Moslem and Chinese instrument design in the surviving Mongol equatorials of 1279 A.D". In: *Isis* 32 (1940), p. 27-43.

[23] They are since 1931 in the Purple Mountain Observatory in Nanjing.

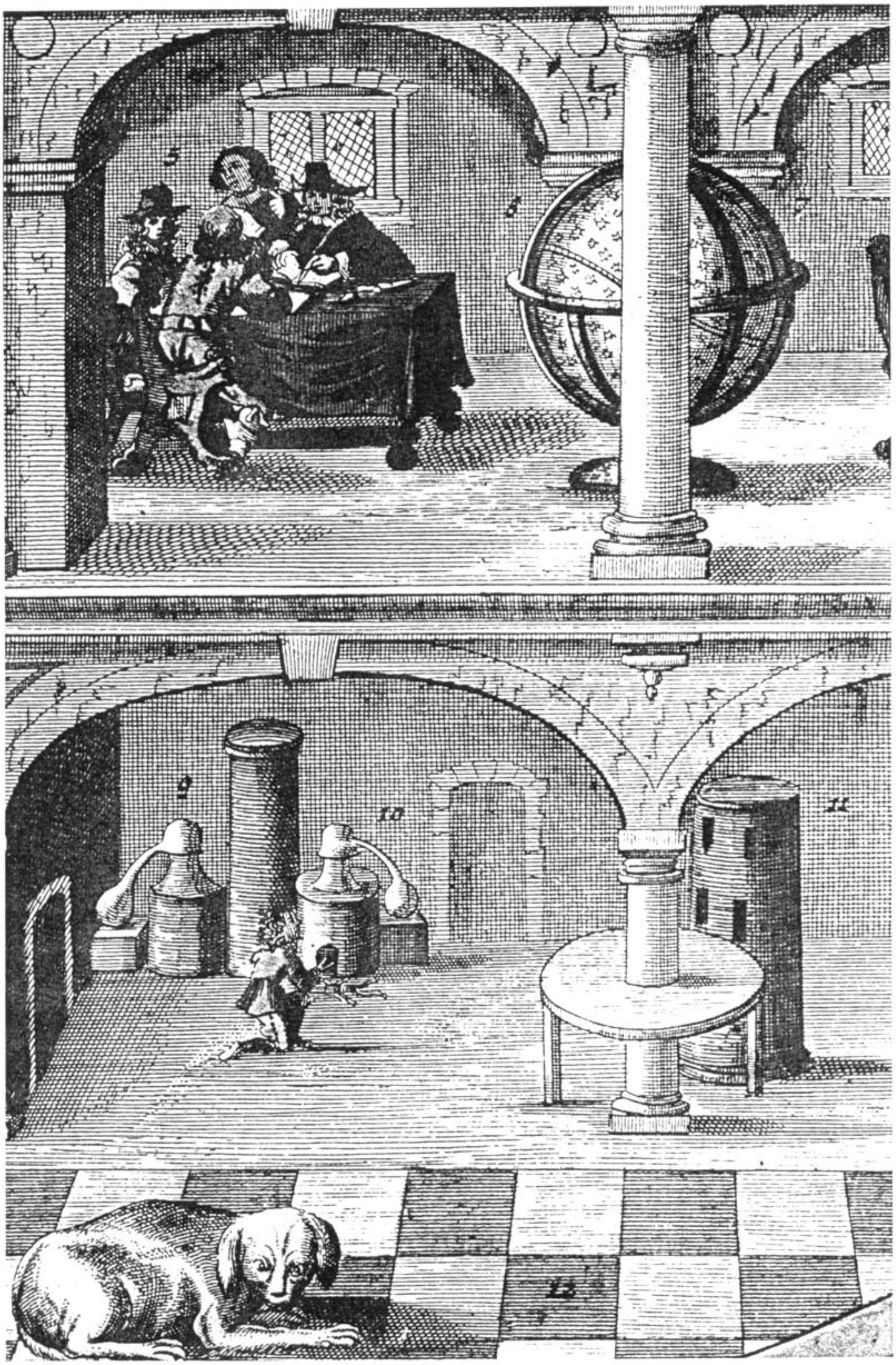

Figure 4: Great Globe in Tycho's library in Uraniborg in the ground floor and in the cellar the alchemical laboratory. BLAEU, JOHANN: *Le Grand Atlas.* Amsterdam 1663 (Facsimile 1970), p. 84.

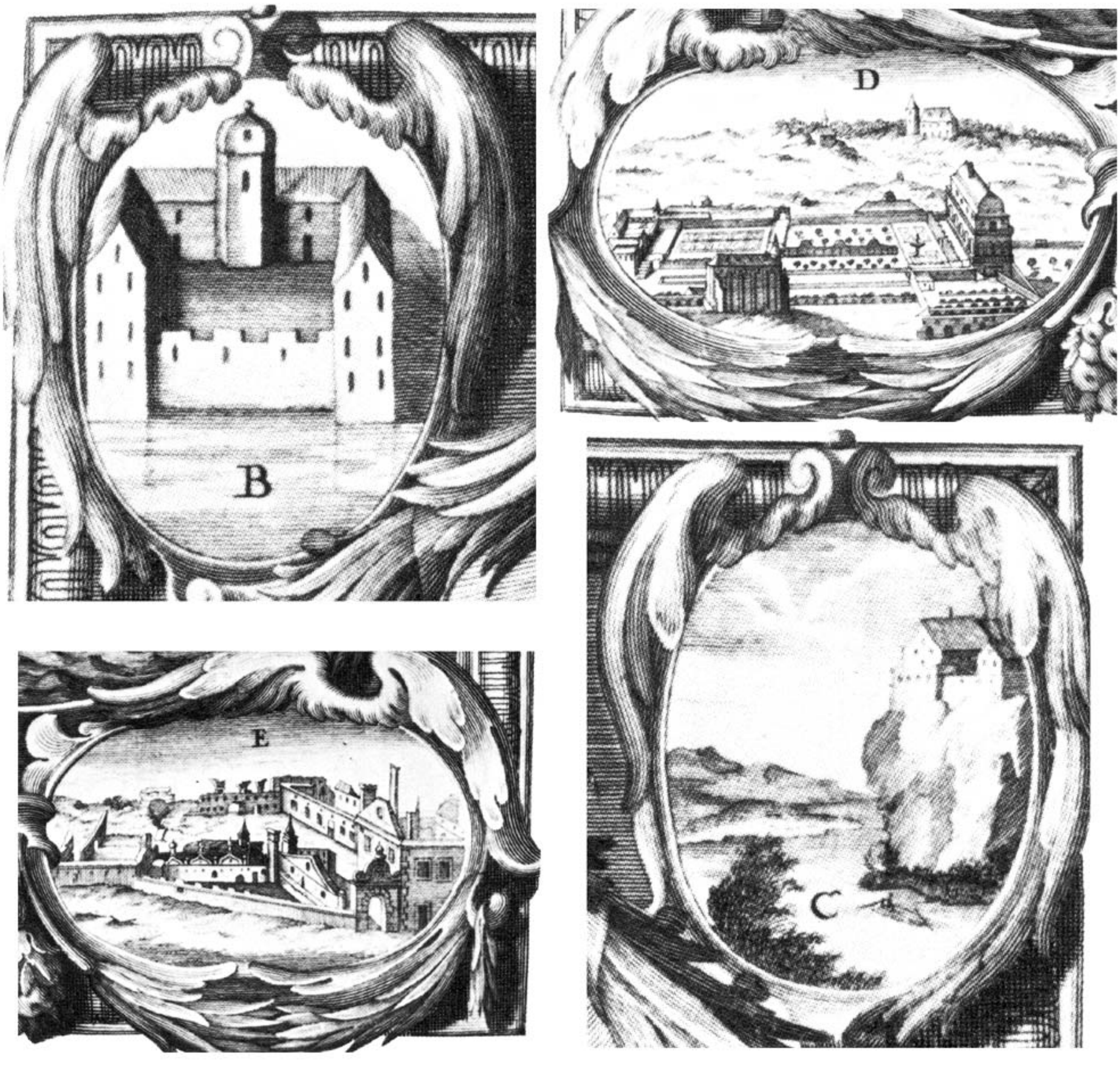

Figure 5: Tycho's observatories in Hamburg and Prag:
upper left (B): Wandsbek near Hamburg,
upper right (D): Ferdinandeum (Belvedere) in Prague,
lower left (E): Curtius' house in Prague,
lower right (C): Castle Benátky near New-Benatek.
Copper engraving by Ph. Kilian in: *Historia Coelestis. Ex libris, Commentariis, manuscriptis observationum vicennalium ... Tichonis Brahe.* Ed. by L. Barettus (A. Curtius). Augsburg: printer Utzschneider 1666, 2nd frontispice.

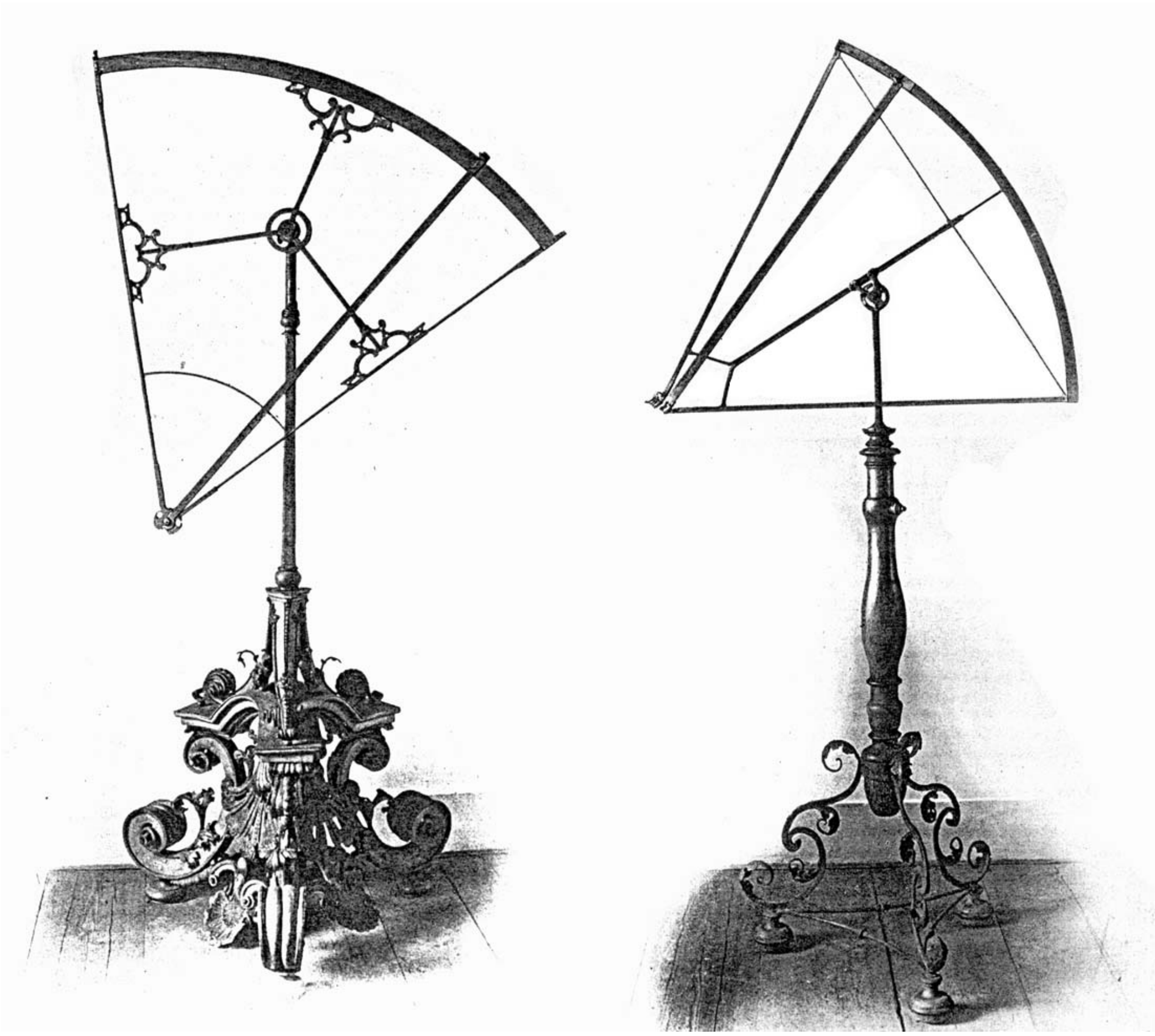

Figure 6: Tycho's sextants in Prague, made by Jost Bürgi and Erasmus Habermel.

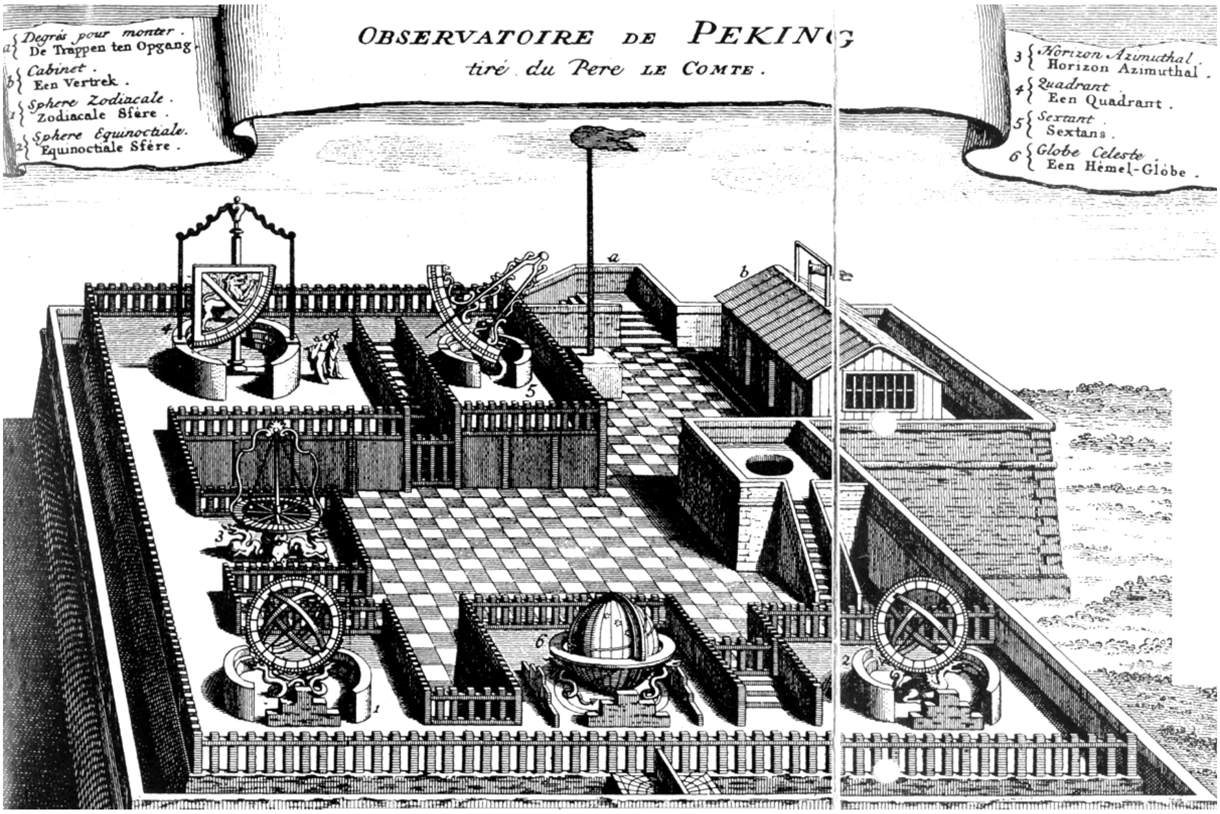

Figure 7: Beijing (Peking) observatory (17^{th} century) with the instruments inspired by Tycho. ZINNER, ERNST: *Geschichte der Sternkunde.* Berlin: J. Springer, 1931. VDI-Nachrichten (1987), Nov., p. 38-39.

Tycho Brahe and Prague: Crossroads of European Science, pp. 217–223,
J. R. Christianson et al. (eds.), © *H. Deutsch 2002*

The Death of Tycho & The Scientific Revolution

Joseph P. McEvoy, London

Abstract

The sudden death of the Renaissance astronomer Tycho Brahe 400 years ago had a major impact on the Scientific Revolution of the 17^{th} Century.

Here in the Renaissance capital of Prague, it is wholly fitting that historians of science from all over the world gather to commemorate the death of the world's greatest naked-eye astronomer, Tycho Brahe. The Danish polymath, who died eight years before Galileo turned the telescope to the sky, has become a legendary figure in the history of science, particularly in this city. An arrogant aristocrat with a silver plate on his nose, he carried out systematic studies of the heavens for 20 years on a small island near Copenhagen from a palace/observatory bequeathed to him by King Frederick II. After Tycho's death on 24 October 1601, these observations were passed by default to his assistant, Johannes Kepler, who then developed his well-known laws of planetary motion. As a result of this work, the earth-centered cosmology of Ptolemy based on the observations of Hipparchus and consistent with the philosophy of Aristotle, was destined for the dung heap of history after 14 centuries of use.

Tycho set the example for today's large-scale science as a powerful organizer and an active innovator carrying out long-range systematic studies from his private island compound, a kind of national laboratory. He designed the facilities and instruments, trained his assistants and developed advanced techniques for measurements of vastly improved accuracy. It is naturally appropriate that at this meeting in Prague commemorating his death, there are many glowing tributes to this giant of the Renaissance. Yet Tycho's death can also be seen in a slightly different context. Though acknowledging the accolades paid to the *Great Dane* for his pioneering work, certain scholars will remember his sudden demise for another reason. This was the opportunity it gave Kepler to gain access to his treasure of hundreds of accurate observations on the positions of the planets and to get on with the next stage of the scientific revolution, i.e. develop his laws of planetary motion. In this part of the story, it is interesting to reflect on the fact that if *Fate* had not played such a timely role, Tycho and Kepler may never have collaborated and the formulation of the planetary laws would have been delayed by decades. It seems plausible that as a result, Newton might not have discovered Universal Gravitation. What then of the 17^{th} century's epoch-making scientific revolution?

Tycho was a self determined and confident *stargazer* from his university days. He became frustrated in 1563 by the inaccurate prediction of a Jupiter/Saturn conjunction using the accepted tables of Ptolemy which were over 1000 years old. The young nobleman knew he could do better and secretly began recording the positions of the planets in the night sky when he was expected to be studying jurisprudence. This was in the face of strong resistance from his aristocratic family, who expected him to follow a career as a court diplomat, not a lowly *stargazer*. After his foster father died he was more independent, travelling in Germany and Switzerland and meeting other astronomers. By 1572 he had set up a laboratory in an old abbey for the scientific study of astronomy and alchemy with his mother's brother, the supportive uncle Bille. Here he realized his first break when a bright new star appeared in the sky. He became known throughout Europe for his precise determination of the position of the new star, now called a *supernova*, proving it was *indeed* a star and positioned well outside the orbit of the moon. He thus demonstrated that the starry heavens were not immutable as Aristotle had insisted.

A few years later, when King Frederick heard that Tycho was planning to leave Denmark for better astronomical facilities in Basel, the crown made an offer he couldn't refuse. The king would give Tycho the island called *Hven* in the middle of the Sound near Copenhagen, on which he could build his own observatory. The island would also be his personal fiefdom for perpetuity with all appropriate incomes. Naturally, Tycho accepted the offer at once and moved to the island, personally supervising the construction of *Uraniborg*, his private palace/observatory, and starting astronomical measurements. For the next twenty years, he and his assistants carried out systematic observations of the sky, amassing a treasure of data on the motion of the planets and the positions of the stars. When his benefactor Frederick died suddenly in the middle of this historic tenure, Tycho managed to wrangle an agreement from the Regency Council to secure the fiefdom for his heirs. This was in spite of the *illegitimate* status of their birth, a result of Tycho's marriage to a commoner which was not recognized by the nobility.

Finally in 1597, Tycho fell out with the new king, Frederick's son Christian IV, who was now coming of age. Apparently, the Lord of Uraniborg had been treating the island inhabitants harshly and neglecting the upkeep of a chapel where the young kings father and grandfather were interred. Difficulties with Christian IV continued and soon Europe's best known astronomer fell into disgrace with the Danish court. He left Hven the next year for Copenhagen, threatening to travel into voluntary exile. Much to his surprise, the young king let him go, effectively banishing him from his own homeland. The arrogant and determined astronomer then transported his movable instruments and extensive entourage to Germany whilst seeking a new sponsor and a place to work.

Waiting on the continent whilst promoting his services to several European courts, he received a startling book on the structure of the universe from Johannes Kepler, a teacher of mathematics in a provincial Austrian town. Struck by the young mans boldness and obvious mathematical prowess, he immediately invited Kepler to join him as an assistant. However, Kepler had just married a local widow in Graz and Northern Germany was just too far for him to consider.

Nevertheless, *Fate* was now working overtime to bring Tycho and Kepler together. When the Dane accepted an invitation as Imperial Mathematician to the eclectic court of Emperor Rudolph II in Prague, it brought him much closer to Kepler. Now, the Lutheran schoolteacher in Catholic Styria, increasingly under severe persecution by the Counter Reformation, could take Tycho's offer more seriously. In 1599, he refused to become a Catholic and he too was banished. Frantically, he accepted the invitation of Tycho who was now in Prague, only a few days journey away. As the new century dawned, the two exiles in Bohemia were about to start a *Golden Age of Astronomy.*

The two astronomers finally met on 3 February 1600 in Benátky Castle, 22 miles northeast of Prague where Tycho was trying to build another *Uraniborg.* Radically different in background and temperament, the meeting was tense. In Arthur Koestler's words, they *"... met face to face, silver nose to scabby cheek; ... opposites in every respect but one: the irritable, choleric disposition which they shared".* Once down to work, Tycho decided to challenge the young upstart by assigning the difficult orbit of Mars and parsing out to only small bits of orbit information at a time. Arguing regularly with Tycho for several months, Kepler became aware he was being patronized as a beginner and decided to leave. He pleaded with his former professors for an academic position at his old university at

Tübingen but was refused. This left him no other option but to continue under the thumb of the overbearing Tycho, Imperial Mathematician to the Habsburg Emperor.

Not the least of Kepler's frustrations, was Tycho's constant nagging him to use the strange cosmological system the Dane had devised in which most of the planets circled the sun but the sun and moon went round the stationary earth. This was almost too much to bear for the headstrong German who was convinced of the validity of Copernican heliocentric system from his student days at Tübingen.

And then something unexpected happened. *Fate* took complete control.

During a banquet on 13 October 1601 at the home of Petr Vok in Hradčany Palace, Tycho was indulging in his usual excessive eating and drinking. Feeling the urge to relieve himself, he waited in customary deference to his host who was still at table. Suddenly, the corpulent nobleman collapsed on the banquet floor with a severe bladder ailment and by the time he returned home, he could not urinate. After five days of sleepless agony with acute uremia, he was on his deathbed surrounded by his common law wife Kirsten and a few associates, including Kepler. As fate would have it, Tycho's two closest colleagues, the trusted long-term assistant Christian Longomontanus and Tycho's son-in-law Franz Tengnagel, were both far away from Prague. Realizing he was dying, the 56 year-old Dane had no option but to promise the legacy of his astronomical treasure to the unsuspecting Kepler, imploring him to use Tycho's own hybrid system of the world – half ancient geocentric and half new heliocentric – in calculating the planetary orbits. *Don't let me have lived in vain*, he cried as he sank into unconsciousness on that fateful October morning.

Kepler had no intentions of considering Tycho's world system, a cumbersome, model which could not possibly be explained by a physical force emanating from the Sun, a concept at the heart of his thinking. He believed that if he could only get his hands on the volumes of data which Tycho had been hoarding for all these years, he could prove the heliocentric scheme and his physical ideas to be correct. Now fate intervened yet again. Immediately following Tycho's elaborate burial ceremony in the grand Týn Church on Prague's Old Town square, the Emperor Rudolph II shocked the Habsburg court by appointing the inexperienced Kepler as Imperial Mathematician. Rudolph charged him with completing the colossal task begun by Tycho, generating the great mathematical tables to predict the planetary positions for all time. With the autonomy of his prestigious position and access to all of the measurements from *Uraniborg* for the very first time, Kepler now set out to revolutionize man's view of the universe. He hoped to develop the correct description of the motion of the planets which he believed was caused by the force of the sun. This was to be a new conceptual framework, a physical astronomy.

After five years of agonizing analysis on Tycho's measurements of Mars, Kepler found he could not fit all the measured positions to a modified Copernican orbit which was both uniform and circular. He was faced with a small but persistent discrepancy of about 8 minutes of arc, only a fraction of a degree. But Kepler knew that Tycho's accuracy was such that only an error margin of much less than that, perhaps only 2 minutes of arc, could be tolerated. On this basis, he decided to discard the entire ancient system of cosmology and start anew. With great conviction, he wrote at the time:

> *After the divine goodness had given us in Tycho Brahe so careful an observer, that from his observations the error of calculation amounting to eight minutes betrayed itself, it is seemly that we recognize and utilize in thankful manner this good deed of Gods, we should take the pains to search out at last the true form of the heavenly motions ...*

Later, in one of the most exhilarating moments of the Renaissance, he wrote:

> *These eight minutes showed the way to renovation of the whole of astronomy.*

By 1605, Kepler was able to show that the orbit was not a perfect circle as Aristotle and the ancients had insisted, but another mathematically perfect geometric figure, an *ellipse.* Furthermore, the planet did not move uniformly through space as Ptolemy's and also Copernicus system had decreed. Its speed increased and decreased depending on the planets distance from the sun, clearly confirming his physical hypothesis. Kepler had used Tycho's precise measurements, a veritable treasure of natures secrets of the cosmos, to confirm a modified version of the controversial sun-centered system of Nicholas Copernicus against the wishes of his mentor. Strange stirrings were reported from the nearby crypt of Prague's Týn Church where Tycho was resting somewhat uneasily.

Cleverly disguising in the *Astronomia Nova* of 1609, his unwavering acceptance of the Copernican scheme, Kepler tried to show how he attempted to fit the data to the other world systems of Ptolemy and Tycho before considering the heliocentric model. He also pretended to stumble across the discoveries of his planetary laws as a last resort. This was a ploy to get past the obstinate resistance of Tycho's heirs and supporters, most notably Tengnagel and Longomontanus, to publish his conclusions on the perplexing orbit of the planet Mars.

After 14 centuries of unchallenged acceptance, Kepler had discarded for all time the Earth-centered system of uniform, circular orbits described by merely mathematical constructs. He replaced this with an astronomy of causes in which a force emanating from the sun moves the planets according to a new set of laws confirmed by the unassailable evidence of Tycho's precise measurements. Eighty years later, his idea of physical astronomy and his laws of motion would enable the English mathematician Isaac Newton to use the planets in the solar system to synthesize and demonstrate his theory of universal gravitation.

Kepler's *Astronomia Nova* ranks with Copernicus *De Revolutionibus* and Newton's *Principia* as the seminal works of the 17$^{\text{th}}$ century's scientific revolution. In fact, a deeper appreciation of Kepler's role in this development, now evident in the scholarship of contemporary science historians, should ensure that his name will be mentioned first in future discussions of the Scientific Revolution, mans greatest achievement in scientific thought.

On the 24$^{\text{th}}$ of October 2001, scholars gathered to commemorate the 400$^{\text{th}}$ anniversary of the death of Tycho in Prague's *Carolinum*, the very building where Kepler produced his *Astronomia Nova*. No doubt at that time, many in attendance recalled an aristocratic teenager's obsession with accurate celestial measurements and his insistence on complete objectivity in the observance of nature. This was Tycho's contribution, the true beginning of the method which would become the hallmark of Western science and technology.

On Hradčany Hill in Prague, Tycho Brahe, the world's first modern observational astronomer, and Johannes Kepler, the worlds first astrophysicist, stand proudly together near the site where the imperious Dane gasped his last breath exactly 400 years ago.

Ellipse: Johannes Kepler and the Discovery of Modern Cosmology, by J. P. McEvoy is to be published by Fourth Estate in Autumn 2002.

Figure 1: Monument on Hradčany Hill

Tycho Brahe and Prague: Crossroads of European Science, pp. 224–236, J. R. Christianson et al. (eds.), © *H. Deutsch 2002*

Briefwechsel zwischen Tycho Brahe und Thaddaeus Hagecius – Anfänge

Josef Smolka, Prag

Zu Brahes Zeit, in der zweiten Hälfte des 16. Jahrhunderts, gab es keine Zeitschriften, desto weniger Fachzeitschriften, gab es keine wissenschaftlichen Gesellschaften, keine Konferenzen und so vieles, was heute eine rasche Kommunikation zwischen den Wissenschaftlern ermöglicht. Die neuen Ergebnisse konnten schon damals durch die gedruckten Bücher mitgeteilt werden; diese wurden aber nur in kleinen Verlagen herausgegeben, sie waren sehr teuer, und die Geschwindigkeit solcher Kommunikation war auch nicht so groß. Deswegen war das beste, was es damals gab, die direkte Korrespondenz.

Ähnlich wie die anderen Gelehrten dieser Epoche, z.B. Galilei oder Kepler, führte auch Tycho Brahe (1546-1601) einen ausgedehnten Briefwechsel.[1] Die Sammlung seiner – sowie der an ihn adressierten – Briefe stellt für die Geschichte der Astronomie eine der interessantesten Quellen dar. Trotzdem ist sie bis heute relativ wenig bekannt und nur selten zitiert. Das gilt in vollem Maße auch für die böhmischen Autoren. Diese Tatsache hängt sicher damit zusammen, dass dieser Briefwechsel bis heute eine modernere, kritische Ausgabe erwartet.

Brahe selbst hat sich um seine wissenschaftliche Korrespondenz zielbewusst gesorgt. Zum Ende seines Lebens hat er sie zusammengestellt und unter dem Titel *Epistolae astronomicae* im Jahre 1596 in drei Bänden herausgegeben. Wie ausgedehnt sie sich darstellt, zeigt nur eines: in Dreyers

[1] Aus den neueren Büchern, wo man mehrere Hinweise auf die ältere Literatur finden kann, geben wir an: Christianson J. R., *On Tycho's Island (Tycho Brahe and his asistents 1570-1601)*, Cambridge 2000. Wahrscheinlich die beste Biographie wurde geschrieben von Thoren V.E., *Lord of Uraniborg*, Cambridge 1990. Eine neue Arbeit erschien vor kurzer Zeit auch im Tschechischen: Jáchim Fr., *Tycho Brahe (Hvězdářova odysea z Dánska do Čech – Des Astronomen Odyssee von Dänemark nach Böhmen)*, Praha 2000. Dieses Buch wurde aber durch die Fachkritik nur unter vielen Vorbehalten angenommen.

Ausgabe der *Opera omnia*[2] fasst sie mehr als anderthalb Tausend Seiten des größeren Formats.

Brahes fleißigste Korrespondenten waren der hessische Landgraf Wilhelm IV. und sein Hofastronom Christoph Rothmann (die Geschichte der Wissenschaften kennt und schätzt ihn besonders als einen der ersten Anhänger des heliozentrischen Copernicanismus). Wilhelm ließ in Kassel eine Sternwarte bauen – historisch eine der ersten – und fing mit dem systematischen Beobachten des Sternhimmels an. Und das war genau das, was Brahe interessierte. Er war mit Wilhelm und Rothmann innerlich eng verbunden und in ständigen Kontakten. Ihre Briefe nehmen einen ganzen, den VI. Band von Brahes *Opera omnia* ein, ungefähr ein Drittel seiner Korrespondenz. Brahes Kontakte mit Hessen sind den Historikern der Astronomie relativ gut bekannt.

Weniger bekannt ist, dass nach Wilhelm und Rothmann an dritter Stelle – gemessen an der Menge der Briefe – unter mehreren Dutzend von Korrespondenten der Prager Arzt und Astronom Thaddaeus Hagecius (1526-1600) figuriert.[3] Und gerade von diesem Briefwechsel, der beginnend im Jahre 1576 bis zum Ableben der beiden Astronomen dauerte (also ein Vierteljahrhundert, es handelt sich insgesamt um 35 Briefe), wollen wir ein paar Worte sagen. Dabei müssen wir uns auf die ersten sechs Jahre begrenzen, mehr ermöglicht uns der Umfang dieses Sammelbandes nicht.

Die Freundschaft zwischen Brahe und Hagecius war nicht nur langjährig, sondern auch – wie wir später sehen werden – sehr tief und offen, ungeachtet dessen, dass Hagecius genau 20 Jahre älter war. Gleich am Anfang dieser etwas ungewöhnlichen Beziehung steht ein Fragezeichen: Es ist nicht völlig klar, wie diese Freundschaft entstand. In der älteren Literatur liest man überall, dass sich die beiden Wissenschaftler in Regensburg persönlich kennengelernt haben, und zwar bei der Krönung von Rudolph II. zum römisch-deutschen König (nicht Kaiser, wie oft falsch tradiert wird). Diese fand am 1. November 1575 statt. Hagecius soll bei dieser Gelegenheit Brahe eine copernicanische Handschrift – bekannt heute unter dem Namen *Commentariolus*[4] – übergegeben haben, eine kurze Darlegung der coperni-

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[2] Brahe T., *Opera omnia* (ed. Dreyer J.L.E.). Brahes Korrespondenz ist in Bd. VI.-VIII. enthalten.

[3] Für die beste Hagecius-Biographie hält man bis jetzt eine ältere Arbeit von Vetter Q., "Tadeáš Hájek z Hájku (Ke čtyřstému výročí jeho narození – Zu seinem vierhundertsten Geburtstag)". *Říše hvězd*, Jhrg. VI (1925), S. 169-185. Viele neue Momente enthält ein Sammelband herausgegeben zu seinem 400. Todestag: *Tadeáš Hájek z Hájku* (ed. Drábek P.). Práce z dějin techniky a přírodních věd – Arbeiten aus der Geschichte der Technik und der Naturwissenschaften, Bd. 1, Praha 2000.

[4] Der ganze Titel der Handschrift heißt *Nicolai Copernici de hypothesibus motuum coelestium a se constitutis.* Manche Autoren (z.B. Birkenmajer A.L., *Mikolaj*

canischen Lehre, die um 1510, viele Jahre vor der Ausgabe des Hauptwerkes *De revolutionibus orbium coelestium ...* entstand.

Von dieser Begegnung haben wir ein direktes, wenn auch nur lakonisches Zeugnis in der Tychonischen Schrift *Astronomiae instauratae progymnasmata ...*, wo man lesen kann: "... dasselbe machte auch Copernicus in einem Traktate von seinen eigenen Hypothesen, die Handschrift davon hat mir einstens ... Hagecius übergegeben".[5] Brahes direktes Zeugnis ist für uns natürlich sehr wichtig, trotzdem ist sehr viel unklares darin. Die ältere Literatur – wie gesagt – nimmt ohne weiteres an, dass die Regensburger Begegnung den ersten Kontakt der beiden Astronomen darstellte. Überlegen wir aber und stellen wenigstens zwei Fragen: Nimmt jemand – wie in unserem Falle Hagecius – ohne weiteres eine wertvolle Handschrift auf eine relativ lange Reise mit? Und weiter: Widmet jemand einer unbekannten Person seine wertvolle Handschrift? Uns scheint, dass die Antwort auf die beiden Fragen am ehesten negativ sein wird.

Für Hagecius, der als Arzt zu Rudolphs Kaiserhofe gehörte, war die Reise nach Regensburg mehr oder weniger Pflicht. Wie aber Brahe dorthin kam, ist nicht so offensichtlich. Eine der möglichen Erklärungen ist – und diejenige verteidigt z.B. Dreyer – dass sich Tycho hier mit seinem Freund, Landgrafen Wilhelm, treffen wollte.[6] Die Wahrscheinlichkeit dieser Meinung wird nur durch die Tatsache entwertet, dass ihn Brahe im selben Jahre schon besucht hatte. Von ihm aus reiste er nach Basel (wo er sich eine gewisse Zeit ansiedeln wollte), weiter nach Frankreich, Venedig und über Augsburg und Regensburg in seine Heimat zurück. Aus dem ganzen Kontext scheint es uns, dass Hagecius von Brahes erwartetem Besuch in Regensburg schon vorher gewusst hatte. Und weiter, dass Tycho für Hagecius kaum eine völlig unbekannte Person war, wenn er ihm aus seiner Sammlung die copernicanische Handschrift übergeben wollte. Es kann ja sein, dass sich die beiden in Regensburg wirklich persönlich zum erstenmal begegnet sind, wir müssen aber voraussetzen, dass sie schon vorher von einander

Kopernik, Bd. 1, Cracoviae 1900, S. 70) vermuten, dass dieser Titel der namenlosen Handschrift von Hagecius oder Brahe gegeben wurde. Eine kritische Ausgabe dieses Textes wurde besorgt von Prowe L., *Nicolaus Copernicus*, Bd. II, Berlin 1884.

[5] "... idem quoque fecit Copernicus in tractatu quodam de hypothesibus a se constitutis, quem mihi Ratisbonae aliquando impertiit ... Hagetius". Brahe T., *Astronomiae instauratae progymnasmata ...*, Francofurti 1610, S. 505. Diese Begegnung bestätigt Brahe auch anderswo, z.B. in seiner Korrespondenz (vergl. *Tychonis Brahei et ad eum doctorum virorum epistolae ...*, ed. Friis F.R., Havniae 1876-1886, S. 87 u.a.), wir können sie deswegen für "sehr gut nachgewiesen" halten.

[6] "Tycho hoffte seinen Freund, den Landgrafen, und andere bedeutende Gelehrte dort zu treffen ...". Dreyer J.L.E., *Tycho Brahe. Ein Bild wissenschaftlichen Lebens und Arbeitens im sechzehnten Jahrhundert*, Karlsruhe 1894, S. 86-87. Zuletzt war aber Brahe enttäuscht, da der Landgraf Wilhelm IV. nicht nach Regensburg gekommen war.

wissen mussten, wir denken sogar an eine Mitwirkung einer dritten Person, die den beiden bekannt war. Leider gibt es kein schriftliches Material, das uns diese Fragen beleuchtet, und so bleiben uns in diesem Moment nur die angedeuteten Fragezeichen.

Es gibt aber weitere Fragen: Brahe verwendet in dem lateinischen Texte des oben angeführten Zitates das Zeitwort "impertire", das nicht ganz eindeutig ist: Einerseits bedeutet es "geben, schenken", andererseits aber nur "leihen", "verleihen". Wir sind leider nicht im Stande zu entscheiden, welche von diesen Bedeutungen die richtige sein soll. Außerdem spricht Brahes Nachricht nur von der Handschrift, ohne zu präzisieren, ob es sich um ein Original, d.h. Autograph, handelte oder nur um eine Abschrift.

Des historischen Interesses halber führen wir als Anmerkung noch eine Tatsache an. Das oben gegebene Zitat setzt weiter mit der Information fort, dass Tycho den Inhalt der von Hagecius erhaltenen Handschrift einigen Mathematikern in Deutschland mitgeteilt hat.[7] Damit ist eine völlig paradoxe Situation entstanden: Brahe, dessen Weltsystem konservativ, geozentrisch war und immer nur mit der unbeweglichen Erde in der Mitte des Weltalls rechnete, zögerte nicht die copernicanische Abhandlung weiter zu schicken und auf diese Art und Weise die heliozentrische Lehre faktisch zu propagieren.

Das Übergeben der copernicanischen Handschrift war aber keineswegs das einzige Thema der Begegnung der beiden Astronomen. Brahe erwähnt, dass er gleichzeitig von Hagecius eine Abschrift des Briefes erhielt, den ihm Hieronymus Munnosius aus dem spanischen Valencia gesandt hat. Diesen weniger bekannten Astronomen schätzte Hagecius hoch, was allerdings auch von Tycho galt.[8] Ausführlich wurde offensichtlich auch Hagecius' Affäre mit einem Astronomen aus dem italienischen Verona, Hannibal Raymundus, diskutiert – wir kommen dazu noch später. Raymundus' Ansichten über den neuen Stern 1572 haben Hagecius in Zorn gebracht. Er griff sie schon vorher in seiner Hauptschrift *Dialexis* an,[9] Raymundus antwortete ihm im Druck mit verletzender Schärfe, und infolgedessen be-

[7] "... ego vero eundem postea aliis quibusdam in Germania mathematicis communicavi". BRAHE, ... *progymnasmata* ..., S. 479-480.

[8] *Ibid.*, S. 567. Davon zeugen wenigstens zwei Tatsachen: Erstens, Hagecius hat einen Ausschnitt aus Munnosius' Briefe an den Wiener Astronomen Reisacher in seine Schrift von der Nova 1572 eingefügt (vergl. HAGECIUS T., *Dialexis de novae et prius incognitae stellae inusitatae magnitudinis* ..., Francofurti 1574, S.11), zweitens, als er später die Schriften von dieser Nova bewertet hat, äusserte er sich "... et Hieronymus Munnos mecum sentit" (vergl. HAGECIUS T., *Epistola ad Martinum Mylium* ..., Gorlicii 1580, S. A2 r). Brahe schätzte besonders die Genauigkeit von Munnosius' Beobachtungen (vergl. BRAHE, ... *progymnasmata* ..., S. 565-572).

[9] Vergl. HAGECIUS, *Dialexis*, S. 113f.

reitete jetzt Hagecius eine neue Erwiderung gegen Raymundus vor. Brahe bemühte sich seinen Ärger zu mildern, mahnte ihn, dass so eine Angelegenheit keiner Antwort würdig sei,[10] hatte aber keinen Erfolg: Ein Jahr später erschien Hagecius' Schrift in Prag.

Vor hundert Jahren tauchte die Meinung auf, dass schon damals in Regensburg der Wunsch ausgesprochen worden wäre, dass Brahe am Hofe des Kaiser arbeite: "In dieser alterthümlichern Stadt führte die direkte Berührung beider dieser Beobachter des neuen Sterns vom J. 1572 zu dem Wunsche, der kaiserliche Mecenas möge auch Tycho für seinen Prager Hof gewinnen und so die beiden befreundeten Astronomen zusammenbringen, aber die Zeit war noch nicht dafür gereift ..."[11] Diese Meinung war in einer Festrede durch den damaligen Präsidenten der Akademie der Wissenschaften Prof. Studnička ausgesprochen worden, zeigte sich aber bis heute als grundlos.

Überlassen wir aber jetzt die aufgeworfenen Fragen den künftigen Forschern und gehen zu dem eigentlichen Briefwechsel zwischen Brahe und Hagecius über. Dieser wird von Hagecius eröffnet: Der erste Brief, der uns zur Verfügung steht, ist datiert am 23. August 1576, d.h. erst drei Jahresviertel nach der Regensburger Begegnung der beiden Astronomen.[12] Nach einer ausgedehnten Einführung voll von Versicherungen seiner freundschaftlichen Gefühle zu Brahe widmet sich Hagecius größtenteils einer von seinen Handschriften. Wir entnehmen daraus, dass Hagecius eine Abhandlung verfasste und jetzt einen Verleger suchte. Kein genauer Titel wird angegeben, Hagecius spricht nur "de opere Trapezuntii", von Trapezuntius' Werk. Und so wissen wir nicht, worum es sich genau handelte, ob um eine Ausgabe vom Trapezuntius' Text oder um Hagecius' Kommentare dazu. Wir wissen auch nicht, was Hagecius zu diesem Werke bewegen konnte: In seinen gedruckten Schriften ist Trapezuntius' Name nicht zu finden. Wir treffen ihn auch in keiner der bisherigen Hagecius-Biographien. Bis heute trat dieser Name nicht in das Bewusstsein der tschechischen Gelehrten.[13]

Wer war überhaupt dieser halbvergessene Astronom Georgius Trapezun-

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[10] "... sui ipsius oblitus, paulo acrius, praeter solitam moderationem, in ipsum vicissim invectus sit ... nulla responsione digna censuisse. De quo etiam Thaddaeum, cum Ratisbona essemus, admonui". BRAHE, *... progymnasmata*, S. 734.

[11] *Bericht über die Saecularfeier der Erinnerung an das vor 300 Jahren erfolgte Ableben des Reformators der beobachtenden Astronomie Tycho Brahe*, Prag 1902, S. 16.

[12] Zu diesem Brief vergl. *Brahei ... epistolae*, S. 34-35.

[13] Davon zeugt auch die Tatsache, dass es sehr schwierig war, wenigstens die Grundinformationen über diesen Autor zusammenzubringen – wenigstens in Prag. Für die freundliche Hilfe gehört mein Dank meiner Kollegin A. Hadravová und besonders meinem Freunde G. Betsch aus Tübingen.

tius? Er wurde geboren am 4. April 1396 auf der Insel Kreta und starb irgendwann in den Jahren 1484-86 in Rom. Nach den Universitätsstudien wirkte er in Griechenland, Venedig, in Neapel am Hofe des Königs Alphons V., aber besonders in Rom.[14] Hier wurde er zum Professor der Philosophie und der Literatur, später zum Sekretär des Papstes Eugen IV. Auf Wunsch seines Nachfolgers, Papst Nikolaus IV., hat Trapezuntius im Jahre 1451 die Übersetzung des griechischen Textes des Ptolemäischen *Almagest* in das Lateinische übernommen – diese ergänzte er noch durch eigene Auslegungen, bearbeitet natürlich im aristotelischen Geiste. Trotz seines späten Erscheinens – das Werk wurde erst im 16. Jahrhundert gedruckt, lange nach dem Tod des Autors[15] – hat es gleich nach der Vollendung eine scharfe Polemik hervorgerufen: Man hat ihm die Qualität der Übersetzung sowie viele astronomische Irrtümer vorgeworfen, das Werk war völlig unbrauchbar. Zu den Kritikern gehörten besonders d'Angiolo, Regiomontanus[16] und ein Kreis von Gelehrten um den Kardinal Bessarion. Letzterer war es, der den Papst auf die Oberflächlichkeit dieser Arbeit aufmerksam gemacht hatte. Infolgedessen wurde Trapezuntius vom Papst aus Rom verwiesen; es hatte nichts geholfen, dass das Werk dem ungarischen König Matthias gewidmet wurde. Es handelte sich aber nicht nur um die Qualität der Übersetzung und der Kommentare: In dem ganzen Streit widerspiegelte sich eher der Kampf zwischen dem traditionellen Aristotelismus, den auch Trapezuntius vertrat, und dem Renaissanceplatonismus, für dessen Belebung und Neueinführung in die europäische Gedankenwelt in dieser Zeit gerade Bessarion sehr viel getan hatte.

Wir möchten natürlich gerne wissen, was Hagecius zum Interesse an Trapezuntius' Werk bewogen hatte. Das wissen wir aber nicht. Wenn es um ein Jahrhundert eher gewesen wäre, könnten wir vermuten, dass er sich zu Trapezuntius' Kritikern gesellen wollte. Wir würden auch später gerne lesen, dass er sich gegen die aristotelisch-ptolemäische Konzeption gestellt hatte. Man würde meinen, dass in der zweiten Hälfte des 16.

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[14] Näher von Trapezuntius' Tätigkeit vergl. Pedersen O., *Early Physics and Astronomy. A Historical Introduction*, Cambridge 1996, S. 254, 338f., eine gute Information bringt auch Jöcher Ch.G., *Allgemeines Gelehrten-Lexicon*, 2. Th., Hildesheim 1961, Sp. 933-934. Weitere Erwähnungen vergl. Zinner E., *Leben und Wirken des Johannes Müller von Königsberg genannt Regiomontanus*, Osnabrück 1968 oder Mett R., *Regiomontanus – Wegbereiter des neuen Weltbildes*, Stuttgart – Leipzig 1996.

[15] Poggendorff J.C., *Biographisch-literarisches Handwörterbuch zur Geschichte der exakten Wissenschaften*, I. Bd., Leipzig 1863, Sp. 875-876 gibt an, dass es in Venedig 1525 und 1528 war.

[16] Zu dieser Zeit verbreitete sich sogar ein wenig wahrscheinliches Gerücht, dass Regiomantanus vergiftet wurde, und zwar von Trapezuntius' Söhnen, die sich an ihm für die Polemik gegen den Vater rächen wollten.

Jahrhunderts die ganze Angelegenheit schon ziemlich verblasst sein musste, wahrscheinlich war dies aber nicht der Fall.[17]

Kehren wir jetzt aber zu Hagecius' Handschrift, die Trapezuntius gewidmet wurde, zurück. Dem Brief vom 23. August 1576 entnehmen wir, dass Hagecius sie bei den Basler Druckern herausgeben wollte; diese haben aber seine Erwartung enttäuscht. Später wollten seine Freunde mit dem Haus Plantin verhandeln. Da kam aber eine unerwartete Nachricht: Sein Buch, gedruckt, sollte sich schon in Italien verbreiten. Erst später zeigte sich, dass diese Nachricht falsch war, sein Buch wurde offensichtlich nie herausgegeben. In dieser Situation war aber kein Drucker zum Risiko bereit ein Buch herauszugeben, das angeblich schon gedruckt worden war. Die ganze Trapezuntiussche Angelegenheit ist natürlich nur eine Episode, trotzdem bedeutet sie eine gewisse Bereicherung von Hagecius' Biographie.

Noch von einem Misserfolg hat Hagecius seinen Kollegen benachrichtigt. Wir wissen schon von seiner Absicht eine Schrift gegen Hannibal Raymundus und seiner Fassung des neuen Sternes 1572 vorzubereiten. Erinnern wir den Leser daran, dass die historische Bedeutung des Studiums dieses neuen Sternes besonders darin bestand, dass es zum Verwerfen eines der aristotelisch-ptolemäischen Dogmata führte: Dieses behauptete, dass es in der sog. supralunaren Äthersphäre keine Veränderungen gibt, die Veränderungen geschehen nur in der Sphäre zwischen dem Mond und der Erde. Neben einer ganzen Reihe von europäischen Astronomen kam auch Hagecius zu dem Schluss über die Veränderlichkeit der Sphäre über dem Mond. Hannibal Raymundus war einer der wenigen Astronomen, der die neue Feststellung nicht angenommen hatte und dafür kämpfte, dass die Nova kein neuer, sondern ein alter Stern sei. Hagecius hat eine scharfe Antwort zusammengefasst, die er den Veronenser Ratsherren gewidmet hat. Er wollte sie ursprünglich bei dem Frankfurter Verleger Wechel herausgeben, der trat aber später von dem Druck zurück. Und so hat Hagecius seine Handschrift dem Prager Drucker Georg Nigrinus anvertraut, wo sie auch unmittelbar im Jahre 1576 erschien.[18] Jetzt schickt er ein Exemplar an Brahe und bittet ihn um eine freundliche Kritik. Diese hat aber das Licht der Welt wahrscheinlich nie gesehen, und wir verstehen warum. Schon vorher, bei der Regensburger Begegnung, war doch Brahe dagegen,

[17] In einem Konvolut, dass Brahe im Jahre 1576 binden ließ (das heute zu den Überresten der sog. Braheischen Bibliothek gehört, aufbewahrt im Prager Klementinum, Sign. 14 J 190) ist in einer astrologischen Schrift *Artis divinatricis, quam astrologiam vocant …*, Parisiis 1549, S. 148-165, Trapezuntius' Traktat *Libellus cur astrologorum iudicia et plurimum sint falsa* abgedruckt. Brahe musste Trapezuntius gekannt haben.

[18] Der abgekürtzte Titel dieser Schrift heisst HAGECIUS T., *Responsio ad virulentem et maledicum Hannibalis Raymundi … scriptum …*, Pragae 1576.

dass sich sein Freund mit dieser Angelegenheit überhaupt befasse.

Das war also der erste Brief aus unserem Briefwechsel, ein Brief vom Jahre 1576. Wir sehen, dass er für Brahe nicht besonders interessant sein konnte, und so waren die Anfänge der Korrespondenz keineswegs übereilt. Auf Brahes Antwort musste man mehr als 4 Jahre warten:[19] Brahe hat sie mit dem 4. November 1580 datiert. Gewissermassen kann man die Gründe der so späten Antwort begreifen: Im Jahre 1575 schenkte ihm der dänische König Frederik II. die Insel Hven. Und im nächsten Jahre hat Brahe mit dem Aufbau seiner geliebten Sternwarte Uraniborg angefangen. Wir verstehen, dass es nicht einfach war und dass sich Brahe in diese Sache sehr intensiv vertiefen musste. Brahe stattete Uraniborg nicht nur mit den neuen Apparaten eigener Konstruktion aus,[20] sondern auch mit einer Bibliothek, Druckerei, Werkstätten usw. Das alles war eine geschichtliche Tat und man kann verstehen, dass diese Arbeit Brahe weit mehr lockte als Trapezuntius oder Raymundus, die ihm Hagecius vorgelegt hat. Und so blieb Hagecius' Brief beiseite liegen, desto mehr, als er keine dringende Antwort erforderte.

Verlassen wir jetzt die Zeitachse der einzelnen Briefe und machen wir einen Exkurs in die nächsten Jahre: Brahe reagierte also keineswegs auf die Informationen aus Hagecius' erstem Brief – wenigstens nicht gleich – aber zu Trapezuntius (nicht zu Raymund) kehrte er später zurück. Es geschah in seinem Briefe vom 25. August 1585, also nach unglaublichen 9 Jahren, nachdem inzwischen mehrere Briefe ausgetauscht worden waren, in denen kein Wort von Trapezuntius gefallen war. Zu unserer Überraschung bietet Brahe Hagecius nach diesen langen Jahren unerwarteterweise die Möglichkeit, dass er die Handschrift – wenn sie nicht anderswo erschienen ist – auf eigene Kosten in seiner Druckerei in Uraniborg drucken lässt.[21] "Deine Angelegenheit wird es jetzt sein, dass Du ... den Steinblock bewegst, damit ich das Privilegium von der kaiserlichen Maiestät möglichst bald erhalte",[22] befiehlt Brahe.

Hagecius antwortet rasch – sein Brief trägt das Datum vom 13./23. Dezember desselben Jahres (zum erstenmal wird hier der neue Kalender benützt) – dass das Werk noch nicht erschienen ist, "es ist aber nicht meine Schuld", sagt er, "dass die Verleger die astronomischen Sachen nicht gerne

[19] Vergl. *Brahei ... epistolae*, S. 54-57.

[20] Der tschechische Leser hat heute eine bequeme Möglichkeit die neuen Apparate in einer authentischen Form kennenzulernen. Brahes Schrift haben vorzüglich übersetzt, kommentiert und herausgegeben Alena Hadravová und Petr Hadrava, vergl. Brahe T., *Přístroje obnovené astronomie – Astronomiae instauratae mechanica*, Praha 1966.

[21] "Fieri enim potest, ut propriis impensis editionem eorum instituam ...". *Brahei ... epistolae*, S. 88.

[22] *Ibid.*, S. 89.

drucken lassen".[23] Die Handschrift sendet er aber nicht, es ist überhaupt fraglich, ob er sie besaß. Statt dessen bietet er Tycho eine andere Handschrift über die Bestimmung der Parallaxen. Es scheint aber, dass eine Schrift mit so einer Thematik nie erschienen ist. Im nächsten Brief vom 9. Mai 1586 berichtet Hagecius, dass er schon im Besitz dieses Privilegiums ist; es war aber schwierig, ohne vorgelegte Handschrift werden die Druckprivilegien nicht erteilt.[24] Als Hofarzt konnte Hagecius hier seinen Einfluss am Hofe zur Geltung bringen. Leider war alles vergeblich: Über die Ausgabe dieser Trapezuntius-Handschrift verhandelte man noch in den folgenden Briefen (vom 1. Juli 1586 und 25. Januar 1587), zum Druck kam es aber offensichlich nie.

Kehren wir jetzt nach diesem Exkurs in die Zeit zurück, als Hagecius eine Antwort auf seinen Brief vom 23. August 1576 erwartete. Brahe schrieb seinen ersten Brief an Hagecius also nach mehr als 4 Jahren. Auch dazu brauchte er aber von seinem Partner noch einen schriftlichen Anlass. Es war ein Brief – dieser erhielt sich aber leider nicht und so ist uns sein genauer Inhalt nicht bekannt – in dem Hagecius seinem Freunde einen Asistenten, der im Uraniborg arbeiten wollte, empfohlen hat. Es war der Mathematiker und Astronom Paul Wittich aus Breslau (das als Teil von Schlesien damals zur böhmischen Krone gehörte). Er war kein Professor, sondern ein privater Gelehrter, wie wir heute sagen würden. Er veröffentlichte nichts und war praktisch unbekannt. Es ist bezeichnend, wie inhaltsarm sein biographisches Schlagwort ist, das der Münchener Mathematikhistoriker Kurt Vogel ins prestigevolle *Dictionary of Scientific Biography* geschrieben hat.[25] Erst die relativ neue Arbeit von Gingerich und Westmann[26] hat die historische Bedeutung von Wittich erforderlicher-

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[23] *Ibid.*, S. 91.

[24] *Ibid.*, S. 97.

[25] Vol. 13, New York 1980, S. 470-471.

[26] Vergl. Gingerich O. – Westman R. S., "The Wittich Connection: Conflict and Priority in late Sixteenth-Century Cosmology". *Transactions of American Philosophical Society*, Vol. 78 (1988), Part 7. Diese ausgedehnte Abhandlung, die mehrere Vorarbeiten zusammenfasst, weist nach, dass die handschriftlichen Randbemerkungen in dem sog. Prager Exemplar von Copernicus' Schrift *De revolutionibus orbium coelestium ...*, Basileae 1566, nicht von Brahe stammen, sondern von Wittich. Dadurch wurde eine patriotische Legende widerlegt, die um die Wende des 19. und 20. Jahrhunderts in Prag entstand und die alle tschechischen Autoren übernommen haben. Dieser Tradition erlag auch der beste Kenner der Prager Braheischen Bibliothek, die dänische Forscherin Flora Kleinschnitz ("Ex bibliotheca Tychoniana collegii Soc. Jesu ad S. Clementem". *Nordisk Tidskrift for Bok- och Biblioteksväsen* 20 /1933/, S. 71f.) ebenso wie z.B. Zdeněk Horský, der das Faksimile der oben genannten Schrift von Copernicus (Pragae 1971) herausgegeben hat. Die ganze Legende gründete nur auf eine Anmerkung des jesuitischen Bibliothekars vom J. 1642 (!), dass der Band aus der Braheischen Bibliothek stammte.

weise hervorgehoben: Ich halte sie für die beste Studie auf dem Gebiete der Geschichte der Naturwissenschaften in den letzten Jahrzehnten.

Mit Recht könnten wir die Frage stellen, wie Hagecius überhaupt Wittich kannte, dazu noch so, dass er ihn an Tycho empfehlen konnte? Paul Wittich war ein sehr vertrauter Freund des humanistischen Polyhistoren und vielseitigen Gelehrten und Philosophen Andreas Dudith (1533-1589), der sich nach vielen Lebensperipetien in Breslau niedergelassen hat. Die beiden waren in täglichem Kontakt. Wittich lebte eine gewisse Zeit wahrscheinlich in Dudiths Haus, wo er u.a. die Rolle eines Beirats für die exakten Wissenschaften spielte, mit dem Dudith alle europäischen Neuerscheinungen auf diesem Gebiet gründlich durchgenommen hat. Diese schöpfte er nicht nur aus Büchern, sondern auch aus einer ausgedehnten Korrespondenz, die er fast mit dem ganzen gelehrten Europa geführt hat. Sehr fleißig korrespondierte Dudith auch mit Hagecius,[27] indem er seinen Prager Freund praktisch in jedem Brief über Wittichs astronomische Tätigkeit informierte. Es war übrigens Wittich, der als einer der ersten Hagecius' Aufmerksamkeit auf die Beobachtungsfehler lenkte, die er in seiner *Dialexis*, seiner Schrift von dem neuen Sterne 1572, begangen hatte. Hagecius wusste also von den engen Beziehungen, die die beiden schlesischen Freunde verband, deswegen zögerte er nicht lange und machte alles, um dem Freunde seines Freundes den Zutritt nach Uraniborg zu erleichtern: Er sandte einen Empfehlungsbrief nach Breslau, den Wittich bei Brahe abgeben sollte.

Der Autor dieser Zeilen muss bekennen, dass die Beziehung zwischen Tycho und Hagecius für ihn – wenigstens in den Anfängen – etwas unbegreiflich ist. Formal genommen waren die bisherigen Kontakte der beiden Gelehrten bis zu dieser Zeit, d.h. bis zum Jahre 1580, keineswegs besonders umfangreich: Sie trafen sich vor 5 Jahren in Regensburg, im nächsten Jahre 1576 hat ihm Hagecius einen Brief geschrieben, sein Partner antwortete aber 4 Jahre nicht. Und das war – so weit wir wissen – alles, was sich zwischen ihnen abgespielt hat. Von einer Freundschaft, die sich beide gegenseitig versichern, kann man, würde ich sagen, nicht sprechen.

Wittich kam im Sommer 1580 nach Uraniborg, wo Tycho Hagecius' Empfehlung gleich angenommen hat und dem neuen Asistenten sein volles Vertrauen schenkte. Das war wichtig, da die Informationen von den kürzlich konstruierten Beobachtungsapparaten leicht missbraucht werden konnten. Brahe brauchte gerade jetzt einen geschickten Mitarbeiter. Einerseits

[27] Ein Teil dieses Briefwechsels ist in Kopien im historischen Archiv des Observatoriums (Ondrejow – südlich von Prag) aufbewahrt. Näheres zu dieser Korrespondenz siehe Smolka J., "Hájkův přítel a korespondent Andreas Dudith (1533-1589) – Hagecius' Freund und Korrespondent Andreas Dudith (1533-1589)". *Tadeáš Hájek z Hájku* (ed. P. Drábek), S. 125-168.

hatte er für die nächsten Jahre weitgehende Beobachtungspläne, in denen die neuen Apparate keine geringe Rolle spielen sollten, andererseits passte ihm Wittich noch aus einem anderen Grunde: Die Beobachtungen müssen gleich berechnet und ausgewertet werden. Aber gerade in der Rechenkunst war Wittich sehr stark. Seine Methode, genannt "Prostaphaeresis", die das Multiplizieren auf Addition und das Dividieren auf Subtraktion reduzierte, war für die mühevollen Berechnungen eine sehr geeignete Erleichterung. Wittich gehört deswegen historisch zu den bedeutenden Vorläufern der Logarithmen.

Nach Wittichs Ankunft bei Brahe in Uraniborg kam es zu einer Episode, die für Hagecius' Biographie wichtig ist. Wittich, der den Inhalt von Hagecius' Briefen an Dudith ausführlich kannte, schilderte Tycho das, was er in Dudiths Breslauer Hause erfahren hat. Das Lesen von Hagecius' Briefen wurde hier zu einem kleinen Fest: Es war öffentlich und spielte sich in einem Kreis von Freunden ab, die Dudith eingeladen hatte, und war mit einem Abendbrot verbunden. Hagecius hat in dieser Zeit nach Breslau geschrieben, dass sich seine Lage als Arzt am Kaiserhof ziemlich verschlimmert hatte, sein Stipendium wurde ihm abgesagt, er verdiente wenig und fürchtete, wie er in Zukunft seine relativ zahlreiche Familie ernähren könnte. Bis heute wissen wir nicht genau, was am Kaiserhofe geschehen ist. Im Hintergrund standen wahrscheinlich religiöse Gründe. Hagecius gehörte und bekannte sich offen zu den protestantisch orientierten Böhmischen Brüdern, korrespondierte z.B. auch mit Melanchthon. In der Atmosphäre eines wachsenden religiösen Druckes und stärker werdender Rekatolisierung, die ihren Beifall gewissermassen auch beim Kaiser gefunden haben, fing man langsam an, den Hof zu "reinigen". Dadurch wurde Hagecius nach längerem Zögern zu einer schwierigen Entscheidung geführt, nämlich Prag und Böhmen zu verlassen und ins Ausland zu gehen. Und es war gerade der schon oben genannte Dudith, der für Hagecius im Ausland eine Betätigung suchte.

Das alles wusste Wittich und nach seiner Ankunft erzählte er es Brahe. Dieser handelte energisch: In seinem Brief vom 4. November 1580 – es war sein erster Brief an Hagecius – hat er ihn nach Dänemark eingeladen. Die Einladung betraf aber keineswegs Hagecius als Astronomen, sondern Hagecius als Arzt. Brahe verspricht ihm, ihn beim dänischen König einzuführen und in den Kreisen des dortigen Adels eine gute Klientel zu finden. "Zuletzt wirst Du bei uns weit besser leben, als in Deiner bisherigen Heimat", beruhigt ihn der großzügige Tycho.[28]

[28] *Brahei … epistolae*, S. 65. Die Zeitangaben in dieser Nachricht (gemeinsam mit einer noch mehr inhaltsreichen Information in Hagecius' Brief vom 13. Dezember 1585,

Hagecius informierte von dieser Einladung unmittelbar seinen Breslauer Freund. Am Anfang war die Reaktion von Dudith ganz eindeutig: Die Einladung sieht vielversprechend aus, es ist nötig sie gleich anzunehmen, hat er Hagecius geraten. Aber in dem nächsten Brief, der eilig folgte, war Dudith schon weit vorsichtiger: Bevor er die Einladung annahm, sollte Hagecius nach Dänemark fahren und die Situation an Ort und Stelle erkunden. Und in dem dritten Brief, der kurz danach in Prag einging, nimmt Dudith schon ganz eindeutig eine ablehnende Stellung ein. Es wäre interessant zu wissen, was Dudith zu solcher Ansichtsveränderung bewogen hat. Möglicherweise waren es die persönlichen Komplikationen, zu denen es zwischen Brahe und Wittich nach seinem relativ kurzen Aufenthalt in Uraniborg gekommen ist – und Dudith hing an seinem Freund Wittich unendlich sehr.

Jedenfalls hat Hagecius auf die Einladung nicht zu eilig reagiert. Noch bevor er seine Antwort abgeschickt hat, kam noch ein Brief Brahes. Er ist relativ lang und befasst sich überwiegend mit dem Kometen, der im Jahre 1580 erschien. Es war nach dem Jahre 1577 ein weiterer Komet, der Brahe sehr stark fesselte. Von der Einladung fällt kein Wort. Hagecius antwortete erst am 1. Mai 1582, also nach anderthalb Jahren. Wir wissen, dass es zu dieser Zeit zu einer Postverspätung gekommen ist (das war auch eine der Ursachen des Missverständnisses zwischen Brahe und Wittich, es hat sich aber später geklärt). Das war aber kaum der Hauptgrund, warum Hagecius erst nach einer längeren Zeit geantwortet hat – es handelte sich um eine komplizierte, verwickelte Lebensentscheidung. Seine Antwort war aber eindeutig: "Ich bin schon zu alt, ich lebe schon das 56. Jahr. Ich bin Vater von mehreren Kindern. Und ins Ausland zu übersiedeln ist mit einer ganzen Reihe von Schwierigkeiten verbunden: wir verstehen weder die Sprache, noch die Sitten Deines Landes".[29]

Das alles könnte man verstehen. Hagecius fährt aber fort und geht zu der formalen Seite der Einladung über: Er findet sie zu wenig würdig für so eine Persönlichkeit, wie er ist, für jemanden, dessen Dienste der schwedische König, die hohen steirischen Behörden und der polnische König verlangten. "Ohne eine ehrenvolle Einladung von dem dänischen König kann ich Deine Einladung nicht annehmen", endet er lakonisch. Der Autor dieser Zeilen muss gestehen, dass er sich beim Lesen dieser Worte gewissermaßen enttäuscht fühlte: kein Wort des Dankes, der Anerkennung oder Schätzung von Brahes gutem Willen, dem Freunde in den Schwierigkeiten zu helfen,

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vergl. *ibid.*, S. 91) ermöglichten uns ein Datum, das bis heute unbekannt blieb, nämlich Hagecius' Geburtstag auf den 1. Oktober 1526 festzulegen. Vergl. SMOLKA J., "K datu narození Tadeáše Hájka – Zum Datum von Hagecius' Geburtstag". *Dějiny věd a techniky* 4 (2001), S. 271f.

[29] *Brahei … epistolae*, S. 65.

den Brahe durch seine Einladung äußerte, statt dessen eine Tirade zur eigenen unterschätzten Würdigkeit. Trotzdem ist auch diese Äußerung wichtig: Einerseits ermöglicht sie uns, ein wenig in Hagecius' Inneres hineinzusehen, andererseits bringt sie uns einige – bis jetzt unbekannte – Steinchen zum Mosaik seiner Biographie, und zwar durch Einladungen, die Hagecius hier zitiert.

Hagecius' Offenheit hat Brahe nicht berührt, in seiner Antwort vom 23. September 1582 blieb er nicht weniger großzügig. Ruhig antwortet er: "von Wittich habe ich erfahren, dass Du ein neues Leben suchst, jetzt verstehe ich, dass es Dir in Deiner Heimat wieder besser geht und ich gratuliere Dir dazu ...".[30] Nach dieser Episode, die die bisherige Hagecius-Literatur nicht gekannt hat, sind die beiden Wissenschaftler in ihrem Briefwechsel für drei Jahre verstummt. Ihre freundlichen Beziehungen sowie die folgende Korrespondenz blieben aber durch diese Unterbrechung unberührt. Im Gegenteil, in den nächsten Jahren, 1586-1591, war die Frequenz des Briefwechsels überhaupt die größte.

Wir sind im kurzen die ersten fünf Briefe der beiderseitigen Korrespondenz unserer Wissenschaftler durchgegangen. Ihre Anzahl ist, wie wir schon gesagt haben, weit größer, ingesamt 35 Briefe. Diese gründlich zu analysieren und für Hagecius' Biographie unbekannte und wichtige Momente in ihnen aufzufinden gehört zu den Aufgaben, die die tschechischen Wissenschaftshistoriker ihrer größten Persönlichkeit des 16. Jahrhunderts – Thaddaeus Hagecius ab Hayck – bis heute schulden.

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[30] *Ibid.*, S. 68.

Tycho Brahe and Prague: Crossroads of European Science, pp. 237–247,
J. R. Christianson et al. (eds.), © *H. Deutsch 2002*

Tycho Brahe and Iohannes Šindel

Alena Hadravová, Prague – *Petr Hadrava*, Prague

Abstract

The connections of Tycho Brahe with Czech astronomers is reviewed. In particular, the work of Iohannes Andreae, dictus Šindel is introduced and the use of his observations by Tycho Brahe is analyzed. It is found, in agreement with Tycho, that Šindel's measurements are surprisingly accurate.

It is generally known that owing to Tycho Brahe and Johannes Kepler the Rudolphine period was the epoch when Prague became a centre of top significance for the progress of astronomy and science in general. The writings and correspondence of Tycho Brahe testify to his early connections to several astronomers working in Prague or to the astronomers of Czech origin working abroad, like Thaddaeus Hagecius, Nicolaus Raimarus Ursus, Cyprianus Leovitius a Leovitia, who lived and worked in Lauingen, or vicechancellor of the Emperor Rudolph II Jacob Kurz of Senftenau with active interests in astronomy (e.g., his solution of the quadrant scale is described in Tycho's *Mechanica*).[1]

This shows that leaving his island of Hven and searching for new patronage, Tycho had a good reason to choose Prague not only for the emperor's money (as it is commonly accepted, despite the fact that Rudolph's promises often exceeded the final reality), but it was also the academical environment which attracted Tycho to Prague. Tycho quickly enlarged

[1] *Tychonis Brahe Astronomiae instauratae mechanica*, Wandesburgi in arce Ranzoviana prope Hamburgum, propria authoris typographia 1598, fols. G3a-b. Facsimile: Praha, KLP 2000. – English translation: Hadravová Alena – Hadrava Petr, "Tycho Brahe and Prague". In: *Science and Technology in Rudolphinian Time.* Acta historiae rerum naturalium necnon technicarum, Vol. 1, New series, Praha, NTM 1997, pp. 79-89.

his connections to other Czech scientists like masters and rectors of the Charles University Iohannes Iessenius or Martin Bacháček of Neuměřice. From Bacháček Tycho got references and access to old Czech astronomical treatises, in particular to a manuscript written by the author of the Prague Astronomical Clock, Iohannes Šindel, in the beginning of the 15th century.

We can thus see that already the previous high tide of Prague astronomy during the first century of the Charles University (in the oldest building – the Carolinum – of which the present symposium was held) prepared conditions also for the much more famous Rudolphine epoch.

Let us mention that the same Prague roots of pre-Copernican astronomy in Poland have been already studied by Polish historians. The links between Prague and Viennese astronomical schools are studied e.g. by Beatriz Porres de Mateo from Brussels.[2]

It is surprising how seriously Tycho took into account Šindel's measurements. However, before coming to details, let us briefly introduce Master Iohannes Andreae, known as Šindel. His basic biographical data are the following: He was born in Hradec Králové (east Bohemia) in 1375. He became bachelor at Charles University in 1395, master of arts 1399. From 1406 he was the rector of St. Nicholas school in Lesser Town in Prague. Then he studied medicine and taught mathematics in Vienna. He became professor of astronomy, doctor of medicine, rector of the Charles University, physician of the king Wenceslas IV, canon of Prague from 1418. He stayed in exile (Olomouc in Moravia and Nürnberg), 1423-1436 (?). From 1432, he was a private physician of the Emperor Sigismund. Dean of Vyšehrad chapter in 1441. He died between 1455 and 1458. He was referred and appreciated as an excellent astronomer also by Enea Silvio Piccolomini, the pope Pius II.

We would like to emphasize two points:

1) Master Iohannes Šindel made his name as the originator of the idea of the Prague Astronomical Clock *(Fig. 1)*, constructed by the clockmaker Nicolaus of Kadaň. The Prague Astronomical Clock (i.e. its astrolabe) is dated – as established by Zdeněk Horský – to as early as 1410.[3] (By the way, it is the period when Master Cristannus of Prachatice was lecturing on the subject of the astrolabe at Prague University and when he wrote

[2] Cf. contribution published in this volume: Beatriz Porres de Mateo, "Astronomy between Prague and Vienna in the 15th century: the case of John Šindel and John of Gmunden", p. 248.

[3] Horský, Zdeněk – Procházka, Emanuel: "Pražský orloj". *Sborník pro dějiny přírodních věd a techniky (Acta historiae rerum naturalium necnon technicarum)* IX. Praha, Nakladatelství ČSAV 1964, pp. 83-146; Horský, Zdeněk: *Pražský orloj.* Praha, Panorama 1988.

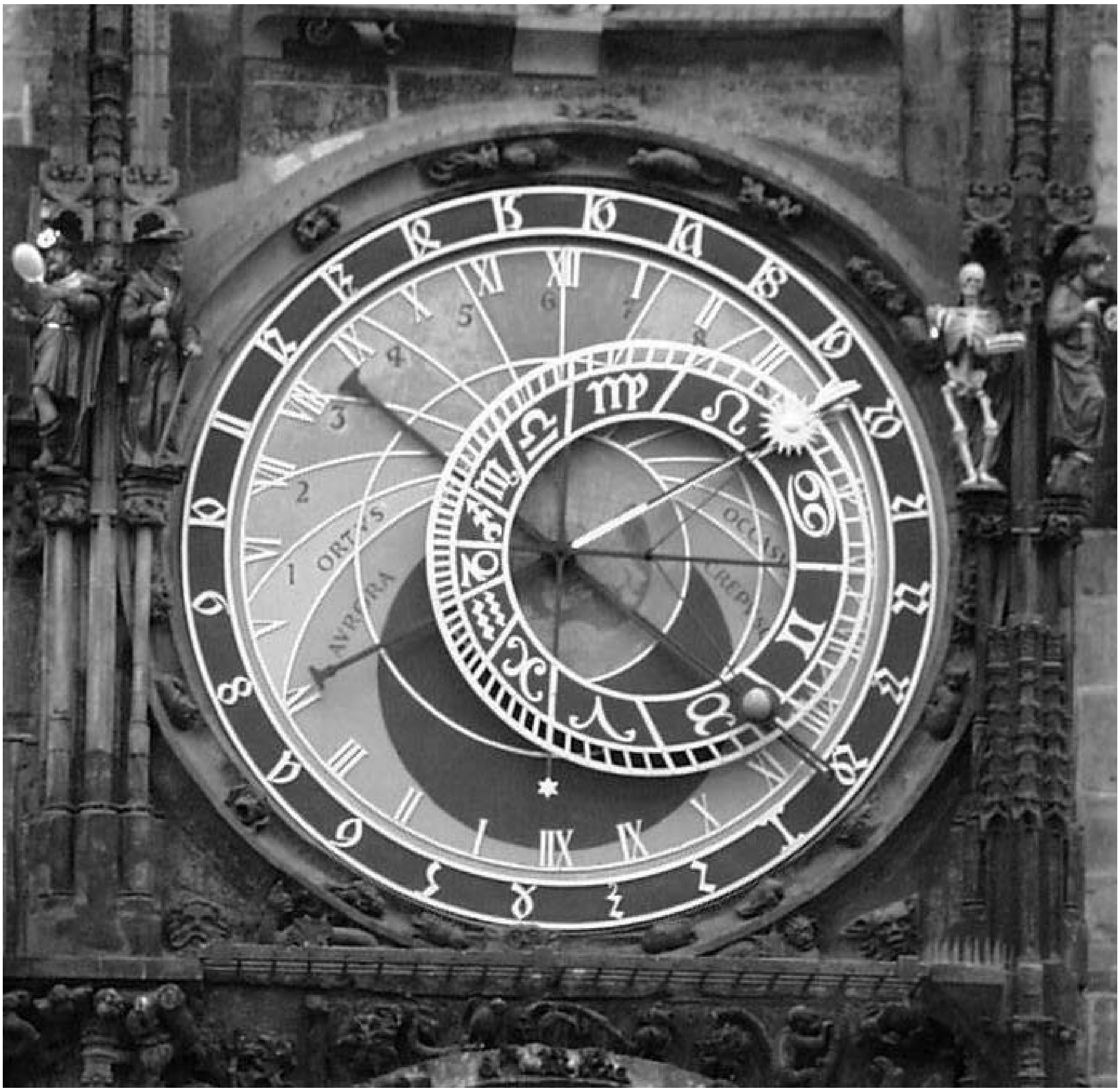

Figure 1: The Astronomical clock of Prague ("orloj") designed by Šindel in 1410.

his very famous and widely spread treatise on the composition and use of this instrument.)[4]

2) Šindel's most important astronomical treatise is *Canones pro eclipsibus Solis et Lune per instrumentum ad hoc factum inveniendis Magistri Iohannis Šindel* ("The rules for calculation of the Sun's and Moon's eclipses according to the instrument invented by Iohannes Šindel"), which is added to several manuscript copies of the treatise called *Albion* by Richard of Wallingford (who lived in the 14th century), enlarged by Šindel's contemporary, Master of the Viennese University John of Gmunden in the 15th century.

Šindel's instrument (or rather a nomogram for demonstration), which is described in his treatise, was designed for a calculation of the conjunctions and eclipses of the Sun and Moon *(Fig. 2)*. This is not the place to explain technical details of this instrument, but the critical edition of the treatise with commented translation is in preparation by the authors of this contribution.

It is worth noting that a picture of very similar instrument can be found in the print of Iohannes Schöner[5] in his work *Opera mathematica* (1551 and 1561) *(Fig. 2)*. Schöner's woodcuts of the instrument for measurement of an eclipse correspond with Šindel's description.

Tycho's references to Šindel

In Dreyer's edition of Tycho's works[6] we can find two references to Šindel, both regarding the same measurement of the meridian altitude of the Sun. The first one is a brief note added after the observations of Sun performed by Tycho in Prague in 1599 (the last of them dated July 31) and before his subsequent observations from the castle of Benátky nad Jizerou on September 11th. This note states: *In 1416, the experienced astronomer Doctor Šindel from the Czech nation observed the altitude of Sun in the summer solstice 63°26′, the altitude of the pole 50°3′40″.*[7] The second and more detailed note dates to 1600[8] – we give its translation in the Appendix.

[4] *Křišťan z Prachatic, Stavba a Užití astrolábu. (Cristannus de Prachaticz, Composition and Use of the Astrolabe.)* Edd. ALENA HADRAVOVÁ and PETR HADRAVA. Praha, Filosofia 2001.

[5] Schöner (1477-1547) is known as an editor of the works of many astronomers, including Regiomontanus and Walther; he was also a teacher of Rheticus.

[6] Cf. *Tychonis Brahe Dani Opera omnia I-XV* [hereafter *TBOO*], ed. I. L. E. DREYER, Hauniae 1913-1929 (reprint: Amsterdam, Swets & Zeitlinger 1972).

[7] Cf. *TBOO* XIII, p. 161.

[8] Cf. *TBOO* V, pp. 228-229.

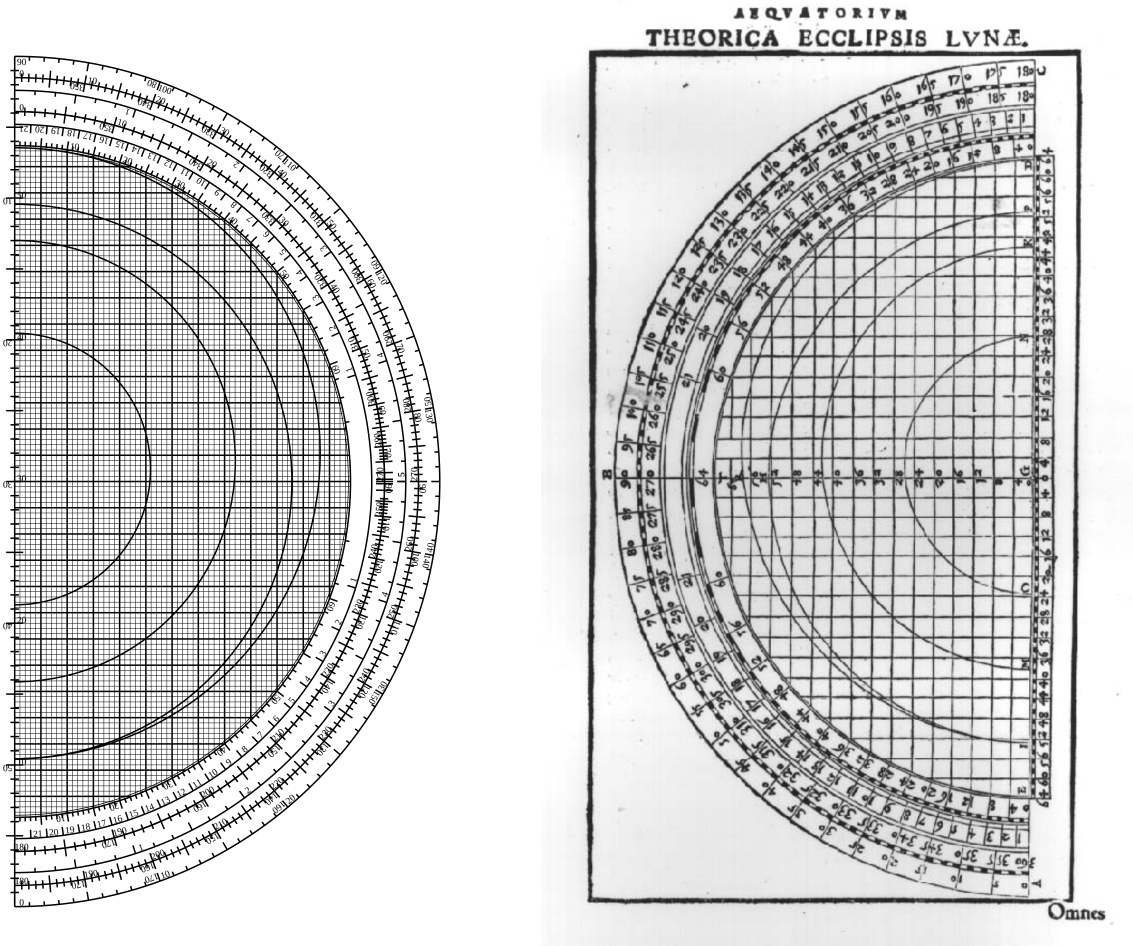

Figure 2: Reconstruction of part of the Šindel's instrument (left) and similar figure from Schöner's treatise (right).

Let us note first (in agreement with Dreyer), that the same measurement is listed by Riccioli between 17 other historic determinations of the obliquity of ecliptic, but it is attributed by him to Wenceslas de Nova Pilzna – a person who is not known to us from any other source.[9] We thus cannot be certain of Šindel's authorship of the discussed measurements. However, what is the most essential point, both sources yield evidence for astronom-

[9] Ioann Baptista Riccioli: *Astronomiae reformatae tomi duo, quorum prior observationes, hypotheses et fundamenta tabularum, posterior praecepta pro usu tabularum astronomicarum et ipsas tabulas astronomicas CII continet ...*, Bononiae 1665, Ex typographia haeredis Victorii Benatii, p. 21: *In Alberti Linemanni 'Memoria saeculari' 9 reperio Venceslaum de Nova Pilzna anno 1416 magno quadrante et regulis Ptolemaicis ferreis quadricubitis Pragae observasse Solis in principio Cancri altitud(inem) meridianam grad(us)* 63.26′, *cui si demas altitud(inem) aequatoris gr(adus)* 39.55′30″, *restat distantia tropici gr(adus)* 23.30′30″.

ical observations performed in Prague at the beginning of the 15^{th} century. Regarding the variety of astronomical instruments used, it seems to be quite probable that the observations were not done by a single person.

The first surprising feature of Tycho's study is the high credit which he bestowed upon Šindel's measurements. The use of these measurements, which Tycho got by chance, could be understood as a substitute for his projected Egyptian expedition intended for measurement of possible secular changes of the pole elevation.[10] To discover or disprove a secular change of latitude (and of obliquity of ecliptic), it was necessary to compare new observations with some old measurements, which should be as much old as possible, but at the same time sufficiently precise and performed at stand-point known with a comparable accuracy in geographic coordinates. The later condition was the weak point of Tycho's idea of Egyptian expedition.[11] The epoch of Šindel was almost ten times closer to Tycho then Ptolemy's epoch. On the other hand, the stand-point of Šindel's observations was very accurately determined to the Carolinum. Concerning the precision of measurements, Tycho needed to rely on his predecessors in any case. However, the statement that Šindel's measurements were more precise than any previous to Tycho's own measurement is a striking change in comparison with his criticism to all predecessors which is apparent from his autobiography in *Mechanica* published two years earlier. Let us now reinvestigate the real accuracy of Šindel's measurements.

The present latitude of the Carolinum is $50°05'12.0'' \pm 0.5''$. The secular motion of the pole has a rate of about $0.35''$ per century, however in the direction nearly perpendicular to the Prague meridian.[12] Consequently, the change of the latitude from Šindel's epoch is negligible. This value of latitude refers to the tower in the northernmost corner of the old Rotlev palace *(Fig. 3)*, while the southernmost corner of the palace has the latitude $50°05'9.0''$. The difference of these values is also far below the precision needed for our next discussion, nevertheless the question of

[10] Cf. Luisa Pigatto, "Tycho Brahe and the Republic of Venice: a failed project", in this volume, p. 187.

[11] It is obvious from his description in *Astronomiae instauratae mechanica*: *I wish … a young man understanding and knowing these problems would be sent to the Egyptian town once named Alexandria, nowadays Alkaira, to observe there very precisely, first of all, the altitude of the pole … I would think, that this should be done and tried especially in Alexandria, where Ptolemy, the main scientist in astronomy, most probably once (about fifteen centuries ago) measured very precisely the latitude …* (*TBOO* V, p. 131; Czech translation: Tycho Brahe, *Přístroje obnovené astronomie.* Transl. Alena a Petr Hadravovi. Clavis monumentorum litterarum (Regnum Bohemiae) 2, Facsimilia – Translationes 1. Praha, KLP 1996, p. 140.)

[12] Cf. R.S. Gross, J. Vondrák, *Geophysical Res. Ltrs.* 26, p. 2085.

Figure 3: Tower of the Rotlev palace: view from the west (top-left) and its top above the roof of main entry (right). Detail from panoramic view of Prague by Folpert van Ouden-Allen from 1685 shows small towers on the roof of Carolinum (bottom; the dark towers in front belong to the St. Gallus' Church).

Šindel's exact observing standpoint is interesting. Tycho's writings provide us with one more indirect evidence in this respect. In his letter to Christian Longomontanus[13] (written from Benátky *die æquinoctij autumnalis 99*) Tycho wrote: *Eclipsis Solis in Iulio huius Anni circa ortum visa meis instrumentis, Pragæ quoque in turricula veteris Collegii observata est per Iohannem meum Hamburgensem, adstantibus aliis, deprehensusque est Sol, cum elevaretur 2 gradibus ...* It means that in Tycho's time a tower in Carolinum was available for astronomical observation in presence of several people. It is supposed that Carolinum had several towers before the reconstruction by F.M. Kaňka in 1718 and small towers on the roof can be seen in old pictures of Carolinum.[14] However, these seem to be too small for observations by several people with larger instruments and the northeastern horizon could not be visible from most of them. It seems to be most probable that Tycho's observer used the northern tower, and the same is likely for Šindel's observations (although the use of portable instruments in a yard cannot be excluded for Šindel's meridian observations).

The above given latitude and error were obtained by the present authors using GPS, i.e. it is the coordinate in geodetic system WGS 84. The deflection of the vertical in latitude is $\xi = +4''$ at the position of Carolinum, it means that the true altitude of the pole at Carolinum is $50°05'16''$. This is in striking agreement (with the error of $6''$ only!) with the result $50°5'22''$ obtained by Šindel. However, as we shall show later, it is partly a coincidence, and the true precision of Šindel's measurements was not quite so miraculous.

Let us turn our attention to Šindel's first value first, i.e. to the altitude $63°26'$ of the Sun at the summer solstice 1416. The declination of the Sun at the Prague noon[15] that day (the 12th of June, JD 2238414.96) was $23°31'4''$. Consequently, the meridian altitude of the Sun was $63°25'44''$ if we take into account also the correct value of the parallax, which is about $4''$. Note that Tycho's correction of $79''$ for parallax spoiled Šindel's value, which had an error of $16''$ only.[16] Surprisingly, Tycho did not try to include a correction for refraction, although he was aware of its importance.[17] The

[13] *TBOO* VIII, p. 183.

[14] Cf. *Dějiny univerzity Karlovy 1348-1990.* I (1347/48-1622). Ed. Michal Svatoš. Praha, Karolinum 1995.

[15] Its value in the true solstice was $23°31'6.6''$, however, it was nearly midnight in Prague.

[16] Cf. the discussion by Owen Gingerich ("Tycho Brahe: Observational Cosmologist", in this volume, p. 21) of ancient estimates of astronomical unit, according to which it was just 20-times smaller.

[17] Cf. Owen Gingerich *ibid.*; Victor E. Thoren: *The Lord of Uraniborg.* Cambridge, Cambridge University Press 1990, p. 235; Tycho Brahe, *Instruments of the*

true value of refraction for this measurement (calculated for 200m above sea level and a mean wavelength, atmospheric conditions etc.) is about 30″, so that the apparent altitude of the Sun was 63°26′14″. There is no evidence of knowledge of refraction before Bernhard Walther, hence we cannot expect Šindel's value to be corrected for refraction. We thus find the error of this measurement 14″.

Concerning the second Šindel measurement, we must agree with Tycho that the value given up to the precision of seconds of arc is most probably a result of some correction.[18] As far as we have neither the original measurement nor any evidence about the correction applied to it by Šindel, our estimate of precision of the measurement is more uncertain. The true difference in longitude between Toledo and Prague is about 18°30′, i.e. $1^{\mathrm{h}}14^{\mathrm{m}}$, not $1^{\mathrm{h}}48^{\mathrm{m}}$ as Tycho used for his correction.[19] In the year 1416 the autumn equinox occurred the 14th of September at $7^{\mathrm{h}}57^{\mathrm{m}}$ UT, JD=2238508.8313. At the Prague noon, $11^{\mathrm{h}}2^{\mathrm{m}}$ UT, the declination of the Sun was already −3′2″ (and the ecliptical length 180°7′29″). Taking into account also the parallax, which is about 7″ at this altitude, we find the true altitude of the Sun at noon 39°51′29″ and with the correction for refraction (approximately 71″) the apparent altitude is 39°52′40″. Even if we would suppose that Šindel's value 39°54′38″ is the direct result of measurement without any correction, the error is about 2′. If we suppose that it is a result of correction for declination only (with refraction and parallax neglected), then the overall error of the measurement and calculation of declination is about 1′ in the opposite direction.

We can see from the above results, that both Šindel's measurements have a precision of about 1′, which is taken as a threshold of naked eye. Further investigation of preserved manuscripts should clarify if this is a mere chance or if the precision, which is commonly taken as the unprecedented Tycho's achievement was accessible not only to Walther one century before Tycho, but already to astronomers at the beginning of the 15th century.

Renewed Astronomy [hereafter *Instruments ...*]. English translation (Raeder et al. 1946) revised and commented by Alena Hadravová, Petr Hadrava and Jole R. Shackelford. Clavis monumentorum litterarum (Regnum Bohemiae) 2, Facsimilia - Translationes 1. Praha, KLP 1996, p. 129.

[18] The alternative hypothesis that the angular value is a result of some trigonometric calculation from a reading on a linear scale of some instrument does not explain our particular case.

[19] The correct value (11° for Toledo and 29°30′ or 29° for Prague) is a tradition in many manuscripts from Prague and Cracow (e.g. ms. Prague, NK XIII F25, III C 2, ms. Cracow, BJ 551, BJ 1915), while Tycho's value ($-1^{\mathrm{h}}24^{\mathrm{m}}$ for Toledo and $0^{\mathrm{h}}24^{\mathrm{m}}$ for Prague) can be found e.g. in ms. Prague, NK XIII C 17 with zero longitude set to Nürnberg.

This would not be the only case, when the fame of Tycho's instruments proves to be exaggerated in comparison with some of his predecessors. Another example is the case of the transversal scales discovered already by Levi ben Gerson.[20] However, even if we would be forced to reduce our admiration of the preeminence of Tycho's instruments, it does not diminish Tycho's role in the history of science. On the contrary, the comparison of Tycho's tremendous observational work with scanty (although probably mostly lost) results obtained by Šindel, who was probably also equipped with quite capable instruments, shows the power of Tycho's modern approach to the study of nature. It was his high-aiming project of renewing astronomy on the basis of observational verification of all assumptions that showed the way to find and to prove the truth and to overcome the previous, contemporary (including his own) as well as future mistakes.

Acknowledgement

The authors are grateful to Michal Svatoš for helpful discussions on the history of Carolinum and to Jaroslav Klokočník, Jan Kostelecký, Ivan Pešek and Jan Vondrák from the Center for Earth Dynamics Research for consultations and providing with computational codes. This work has been supported by grant of GA ČR no. 405/00/1543 and by project LN00A041 of the Ministry of Education of the Czech Republic.

Appendix: On the obliquity of the ecliptic

Extract from a manuscript book of the old Prague college, communicated to Tycho by M. Bacháček.

In the year 1416, at the beginning of Cancer was searched its maximum meridian altitude using iron quadrant and Ptolemaic rulers, similarly also the quadrangular. It was found by both mentioned instruments to be $63°26'$ above the Prague horizon, in particular above the house of Charles College of Prague University. And it is more precise than any other previously made by myself.

Doctor Šindel, experienced astronomer of Czech origin, has it as follows. In the same year 1416, the 14$^{\text{th}}$ of September, on the day of Holy Cross,[21]

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[20] Cf. Bernard R. Goldstein, "Levi ben Gerson: On Instrumental Errors and the Transversal Scale", *Journal for the History of Astronomy* VIII, 1977, pp. 102-112; Carlo Triarico, "Tycho Brahe and Egnazio Danti. Observations and astronomical research at Prague and Florence at the end of the 1500s", the contribution in this volume, p. 168; *Instruments ...*, p. 163.

[21] I. e. *dies Exaltationis sanctae Crucis.*

the altitude of the head of Aries was 39°54′38″ and the altitude of pole was 50°5′22″.

A consideration on the subsequent observation
performed by Šindel in Prague in the year 1416:

He puts the solstitial altitude of Sun	63°	26′	0″
Add the parallax at this altitude		1	19
Correct altitude	63	27	20

When he said that on the day of Holy Cross the altitude of the head of Aries was 39.54.38 and its complement attributes to the altitude of the pole, it follows from here that he deduced the calculation of equinox from *Alphonsine tables*, which give it before the noon of that day. If you assume that Prague is H. 1° M. 48′ eastward from Toledo, you find that the Sun is in 0°3′50″ of Libra at the noon of the Prague horizon the 14th of September of the year 1601,[22] and its declination is 1′32″. He thus observed the noon altitude as he did before in the solstice. If he would assume that the Sun is in 3.50 of Libra and its declination is 1′32″, namely for which the meridional altitude of the Sun is smaller than the altitude of the equator, he would add this declination to the observed altitude to get the altitude of the equator, which he calls the altitude of the Head of Aries, i.e. of the points of Aries and Libra. It follows from the secondary data which cannot be distinguished by the quadrangular instrument and hence it was accessible by calculation only, that the observer thought just this way. Subtract thus the declination, which he added, $\begin{array}{r}39\ 54\ 38\\ 1\ 32\\ \hline\end{array}$, there remains 39 53 6. If he used a slightly different difference of the meridians and Ptolemaic inclination of ecliptic he had declination of the Sun precisely 1′38″, hence he observed altitude 39°53′; I do not doubt at all that he found it so on his instrument. Add the parallax of this altitude 2′18″. You will get the true meridional altitude for that day 39°55′18″. And already from the Tychonian calculations take the motion of Sun for that day in 0.1.0 of Libra – the difference of meridians does not matter – add to the declination 24″ so that the altitude of the equator is 39.55.42, of the pole 50°4′18″, inclination of ecliptic 23.31.38. Both these results can be found even today, after 200 years. Profatius Iudaeus determined the same obliquity 100 years earlier. Regiomontanus and Walther confirmed the same by their well performed observations 100 years later.

[22] Obviously should be 1416.

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Astronomy between Prague and Vienna in the 15th Century: the Case of John Šindel and John of Gmunden

Beatriz Porres de Mateo, Brussels

In 1952, in her work[1] on the history of cartography at Vienna in the 15th century, D. B. Durand wrote that "The development of science at Prague still remains an unwritten story". As far as astronomy goes, her book contained a chapter of that history. Another one was written by J. Dobrzycki[2] in 1987, when he published an article on the diffusion of the *Tabulae Resolutae* from Wrocław (Breslau) to Prague and from there to Cracow in the 15th century. I will try to add now to that chapter by showing that Prague had an important (though not exclusive) role in the transmission of astronomical knowledge not only to Cracow, but also to Vienna, as attested by extant manuscripts.

From Prague to Vienna

The first professor to have worked at the University of Vienna as a full-time astronomer was John of Gmunden, who had a long career as a professor of mathematics and astronomy between 1406 and 1442. He produced a consistent set of astronomical tables and canons, as well as a good amount of treatises on astronomical instruments. None of his works were completely original; in fact, he often reworked and improved other authors' texts. The question is: where did he get his material from? A

[1] D. B. Durand, *The Vienna-Klosterneuburg Map Corpus of the Fifteenth Century: A Study in the Transition from Medieval to Modern Science*, Leiden, 1952, p. 39.

[2] J. Dobrzycki, "The Tabulae Resolutae", in *De astronomia Alphonsi Regis.* Actas del simposio sobre Astronomía Alfonsí celebrado en Berkeley (Agosto 1985) y otros trabajos sobre el mismo tema, M. Comes, R. Puig and J. Samsó eds., Barcelona, Universidad de Barcelona, 1987, pp. 71-77.

closer look at astronomers and manuscripts from Prague will give us an answer, albeit partial, to that question.

Astronomers and their books

Any examination of exchanges of astronomical knowledge between Prague and Vienna should take into account the wider frame of relationships between both cities. Those relationships were not only scientific but also artistic: we know that at the monastery of Klosterneuburg, close to Vienna, an intense astronomical and cartographic activity was developed from ca. 1380 to 1442 under the priorate of Georg Müstinger, a close collaborator of John of Gmunden, to the point that historians talk about a "Vienna-Klosterneuburg school of astronomy".[3] But Klosterneuburg was not only a centre for scientific studies, but also an important scriptorium which, under Habsburg patronage, produced illuminated manuscripts. We know of the exchange of copyists and illuminators from and to Prague.[4]

If we concentrate only on astronomy, we have just a few names of people studying it in Prague in the first half of the 15th century. But it is on the basis of these names, the works attributed to them and especially the manuscripts they copied or possessed that we can attempt to reconstruct the spread of Prague astronomical activity to Vienna and vice-versa.

One of these names is Reinhardus Gensfelder of Reichenbach, a Benedictine monk who was born at Nuremberg and died in Tegernheim, near Regensburg, in 1450 or 1457. He studied at Prague University in 1400, where he became *magister artium* in 1408. After leaving Prague because of the Hussite controversy, he spent some time in Padua and then several years in Vienna and Klosterneuburg. Reinhard acted as one of the members of the cartographical team there.[5] He copied a large number of scientific manuscripts, many of them containing the works of the Vienna-Klosterneuburg school of astronomy (among them, works by Gmunden, Müstinger and John Šindel). I will mention only München BSB Clm 10662, containing, among others, John of Gmunden's treatises on the cylinder and the quadrant and two lists of stars for 1430, one by Gmunden and the other by Georg Müstinger. It was copied in 1436.[6]

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[3]See Durand, *passim*, and P. Kunitzsch, "The Star Catalogue Commonly Appended to the Alfonsine Tables", *Journal for the History of Astronomy* 17 (1986), 89-98.

[4]See H. Lülfing, *Johannes Gutenberg und das Buchwesen des 14. und 15. Jahrhunderts*, Leipzig, VEB Fachbuchverlag, 1969.

[5]Durand, p. 45 ff.

[6]See P. Kunitzsch, *Typen von Sternverzeichnissen in astronomischen Handschriften des zehnten bis vierzehnten Jahrhunderts*, Wiesbaden, Otto Harrassowitz, 1966 p. 5 n. 8 and pp. 111-112.

Related to Reinhard Gensfelder is John Coppel, probably a student in Prague. His name is found in manuscript Vatican, BAV, Palat. lat. 1374, an astronomical book copied by Reinhard containing astronomical tables annotated by someone adding recalculations of *radices* by Coppel, Šindel and Gmunden.[7]

A third astronomer we know of is Johannes Schwab of Buczpach, another master at Prague university who left Prague for Vienna in 1409 due to the religious controversy. In 1412 in Vienna he copied some astronomical tables and canons, today kept in manuscript München, Universitätsbibliothek, 4° 737, f. 139v. This same manuscript also contains one of the versions of John of Gmunden's astronomical tables and canons, copied in 1444.

Apart from these relatively obscure characters, there were two Prague astronomers who might have been influential in Viennese astronomy, namely Cristannus of Prachaticz and John Šindel. And the Viennese astronomer who seemed to have mostly benefited from their works was again John of Gmunden.

Indeed, it has been demonstrated that Gmunden's treatises on astronomical instruments such as the astrolabe, the albyon, the cylinder or the turquetum, to name but a few, were based on similar works by his predecessors. Cristannus and Šindel have been recently identified as the source of two of Gmunden's treatises, respectively on the astrolabe and on the albyon, which were reworked and improved by our Viennese astronomer.[8]

Gmunden and Šindel

An example of the connections between Prague and Vienna astronomical schools is the ms Vienna ÖNB 5303, containing John of Gmunden's treatise on the cylinder followed by another treatise on the same instrument attributed to John Šindel.[9] To this and to the list made by Zinner in his *Verzeichnis der astronomischen Handschriften*,[10] I wish to add also Vatican, BAV Palat. lat. 1376, containing again works by Šindel (a *Tractatus de quantitate trium solidorum*,[11] dated 1420) and Gmunden (a version of his astronomical tables and canons, ff. 1r-184r, and one of his treatises on the quadrant, ff. 343r-349r). The manuscript was copied by Friedrich of St. Emmeram (Regensburg) between 1445 and 1458. The same work by

[7] F. 9r ff.

[8] A. Hadravová – P. Hadrava, *Křišťan z Prachatic: Stavba a užití astrolábu*, Prague, Filosofia, 2001. For these authors' current research on Šindel, see http://www.asu.cas.cz/~had/sindel.html.

[9] *Ibidem.*

[10] Num. 9411-24.

[11] F. 184v.

Šindel, together with works belonging to the Viennese astronomical school (Gmunden and Peuerbach, among others), is in Vienna, ÖNB, 5277, ff. 92r-100v, and München, BSB 14783, ff. 495r-505v.

However, Prague influence on Gmunden can be seen not only in the cases mentioned above, but also on his most important astronomical work, i.e. his astronomical tables and canons.

Gmunden's astronomical tables belong to the mainstream of tables used everywhere in his time, that is, the Alfonsine Tables. These were constantly modified and recast to adapt them to different times and meridians. However, despite the difficulty of determining their original form, the underlying parameters were never altered, and that is what has allowed modern scholars to continue to consider them "Alfonsine Tables", or, to use a more precise term which was recently proposed,[12] as part of the "Alfonsine corpus".

How and when did the Alfonsine Tables reach Vienna? Erfurt university is a good candidate for that, but the relationships between Erfurt and Vienna deserve a full study of their own. It has also been suggested[13] that the basic astronomical material of the time arrived in Vienna for the first time with Henry of Langenstein, a German theologian and astronomer, master at Paris University who left the city after the Great Schism of 1378 and settled in Vienna as one of its theology teachers until his death in 1397. It is reasonable to suppose that he would have come to Vienna bringing with him some astronomy books, among which at least some of the tables by the well known Parisian 14th century astronomers John of Saxony, John of Murs and John of Lignières, the authors of the recalculation of the Alfonsine Tables for the meridian of Paris ca. 1320. In their version they presented the Alfonsine Tables in a fully sexagesimal form, opening with a large set of calendaric tables to allow for the conversion of dates from any era into the Christian one. These tables were intended to be used in any time and place. This format is the one chosen for the *editio princeps* of the tables, published in Venice in 1483. One example of this presentation, which no doubt Viennese astronomers were aware of, can be seen in BAV Pal. lat. 1374 and in Vienna ÖNB 2352, copied in 1392 for the king of Bohemia Wenceslaw IV (d. 1419).

However, astronomical tables in Vienna were produced, for the most

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[12] See the works of scholars such as B. R. Goldstein, J. North and J. Chabás, which give an account of the enormous diversification among the different sets of tables used all through medieval Europe, despite their basic common parameters, and of the impossibility of tracing them back to a single common source.

[13] C. Kren, "Homocentric Astronomy in the Latin West. The *De reprobatione eccentricorum et epiciclorum* of Henry of Hesse", *Isis* 59, 3 (1968), 269-281.

part, according to a different format, one which seemed quite wide-spread in the first half of the 15th century.[14] These tables are known as *Tabulae Resolutae*. Astronomical tables evolved continuously, so that it is never easy to define their contents. I will just summarise here their characteristics and the tables they usually include according to recent descriptions[15] and to my own examination of manuscripts:

- signs of 30° are used;
- the underlying parameters are Alfonsine;
- they present no calendaric tables for the conversion of eras (they are intended for a single place and time);
- the mean motions and mean arguments of the planets are computed at 20 year intervals, and not in a sexagesimal base for their calculation in days;
- the tables for the mean motions are followed by tables of oppositions and conjunctions of the Sun and the Moon arranged for the same 20-year interval and the tables for the apogees (*auges*) are tabulated in the same way;
- the tables of equations of the planets and the eighth sphere are taken directly from the Alfonsine Tables;
- the table of division of the twelve astrological houses is a simplified one, calculated for a single latitude;
- there is only one table for the rising times and for the length of the day, namely the one for the 7th climate (the other climates are omitted) and it is taken directly from the Toledan Tables,
- they include a selection of the tables for spherical astronomy by John of Lignières.

The *Tabulae Resolutae* were calculated for the meridian on Wrocław for 1424. Their author, Petrus Cruciferus, came from Silesia, but he had studied in Padua and Prague.[16] He has been identified by E. Zinner[17] as Peter Rein (or Teyn) of Zittau, a Silesian astronomer also mentioned by Durand as possibly connected with the Prague school.[18] One of his manuscripts is Vienna ÖNB 5240.[19]

[14] Dobrzycki, *op. cit.*

[15] See J. Chabás, "Astronomy in Salamanca in the Mid-Fifteenth Century: the *Tabulae Resolutae*", *Journal for the History of Astronomy* 29 (1998), pp. 167-175.

[16] Dobrzycki, *op. cit.*

[17] *Verzeichnis der astronomischen Handschriften ...* 8933 ff.

[18] Durand, p. 40.

[19] *Tabulae Codicum Manu Scriptorum praeter Graecos et Orientales in Bibliotheca Palatina Vindobonensi Asservatorum*, edidit Academia Caesarea Vindobonensis, Vienna, 1864-1869, vol. IV, p. 71.

In any case, the *Tabulae Resolutae* that were introduced in Prague had the year 1428 as initial epoch, as attested by the tables contained in two manuscripts and attributed, without full certitude, to John Šindel: Prague, Nár. Knih. X.B.3. (1832) (ff. 79r-126v) and München, Universitätsbibl. 4° 738. Šindel is considered to have calculated them in Nuremberg in 1427 or 1428, possibly with the collaboration of Nicholas Heybeck and Reinhard Gensfelder.[20] The München manuscript has also a *Tractatus mathematicus* (ff. 141r-149r) written in 1452 by Mathias Rem of Weinsberg (Swabia), a disciple of John of Gmunden. He left Vienna after Gmunden's death. He was the owner also of a manuscript already mentioned, i.e. München Universitätsbibl. 4° 737. As we saw, this manuscript contains the third version of the astronomical tables by Gmunden as well as tables by another Prague astronomer, John of Schwab, dating from 1412. That this Mathias of Weinsberg owned and possibly copied at least two manuscripts containing the works of Vienna and Prague astronomers gives us yet another example of the circulation of Prague astronomical production.

Šindel spent some years in Vienna, as we know. There he surely met and worked with John of Gmunden and, in fact, practically all of his works are found in manuscripts containing the works of Gmunden or belonging to his scientific milieu. The relationship between Šindel's treatise on the albyon and Gmunden's work on that same subject has already been mentioned. It is not to be excluded that Šindel influenced the composition of Gmunden's astronomical tables, whose format is quite similar to the description of the *Tabulae Resolutae*. Maybe a proof of such influence could be seen in the fact that Gmunden's table for the velocities of the Sun and the Moon in one hour, for whose values no precedent can be found,[21] seems to have a common origin with the same table preserved in Prague X.B.3.[22] In this same sense, Gmunden's tables for mean syzygies, computed for cyclical *radices* every 20 years (*anni collecti*), begin in 1428, the same year as in Šindel's corpus.[23]

Gmunden's tables are not, however, exactly the same as the *Tabulae Re-*

[20] DURAND, pp. 42 and 45.

[21] B. R. GOLDSTEIN, "Lunar Velocity in the Middle Ages: A Comparative Study", in *From Baghdad to Barcelona.* Studies in the Islamic Exact Sciences in Honour of Prof. Juan Vernet; J. CASULLERAS and J. SAMSÓ eds., Barcelona, Instituto Millás Vallicrosa de Historia de la Ciencia Árabe, 1996 (Anuari de Filologia 19), vol. I, pp. 181-194.

[22] F. 129v. In Šindel's table, minimum and maximum values for the Sun are 0; 2, 22, 30°/h - 0; 2, 33, 46°/h; for the Moon, they are 0; 29, 37, 11°/h - 0; 36, 53, 21°/h. The values for the Moon are identical in Gmunden's table; as for the Sun, the extreme values are the same and there are some divergencies in intermediate values. I am indebted to Prof. B. R. GOLDSTEIN for his valuable comments and suggestions on this table.

[23] See tables computed from that same *radix* in Prague X.B.3, ff. 92v-93r.

solutae. These seem to be intended just for the construction of calendars, while Gmunden's tables are a large corpus of tables and seem to be intended for more complex calculations. They contain more and much more detailed material than the tables usually found in the *Tabulae Resolutae*, such as three different sets of tables for eclipses, a detailed list of geographical co-ordinates (in this he benefited from Klosterneuburg cartographic activity), two different lists of fixed stars (for ecliptic and equatorial co-ordinates), a table for the true position of the Sun calculated for Vienna in 1437, three different sets of tables of planetary equations, double-argument tables for planetary latitudes, a table for the velocity of planets in one day, a table for the velocity of the Sun and the Moon in one hour, a table for the equation of the astrological houses at Vienna, parallax tables and several sets of tables for interpolation. All this material amounts to a corpus of 109 tables with their canons, an impressive work of which we keep three different versions and on which Gmunden spent at least 12 years, between 1429 and 1441 (he died in 1442).

A last example, an anonymous one, of the transmission of astronomical knowledge from Prague to Vienna as attested in the work of John of Gmunden is found in the manuscript Brussels, Bibliothèque Royale 926-40.[24] It contains a set of Alfonsine Tables (ff. 165v-186r) with *radices* for Prague, copied in 1419.[25] Among them I could find a table for the semidiameters of the Sun, the Moon and the Earth's shadow which is the only precedent I know for that same table in Gmunden's corpus.[26]

From Vienna to Prague

Gmunden's works are kept in a large number of manuscripts now preserved in libraries all over Europe: no less that 171, a really impressive number for a medieval author in a quickly evolving discipline. Many of them are dated well after his death and attest the circulation of his works over a vast geographical region. At least two of them illustrate Gmunden's presence back in Prague or, in general, in Bohemia: this is the case of Prague 280, a collection of astronomical and medicine texts copied in 1488 by Crux of Telcz, a monk in Třeboň (Bohemia). One of the tables in the manuscript is calculated for the meridian of Prague (f. 227r)

[24] R. Calcoen, *Inventaire des manuscrits scientifiques de la Bibliothèque Royale de Belgique*, Bruxelles, Bibliothèque Royale, 1965, vol. I.

[25] See the colophon in f. 186r: *expliciunt tabule illustris regis Alphonsi regis Castelle in Hyspania scripte anno ere incarnacionis Christi 1419 sole tercium gradum Arietis perambulante* (the third day after the beginning of Spring).

[26] I am grateful to Prof. J. Chabás for drawing my attention to this manuscript.

and the volume contains Gmunden's treatise on the cylinder, copied by a Stephanus de Scheibs. A second example is Prague XIV.F.10 (2581), one of the manuscripts containing the third version of Gmunden's astronomical tables; it was also copied after his death, in 1446, in the monastery of Tegernsee and later it came to be preserved in Prague.

Disentangling the ways in which scientific knowledge spread in late medieval Europe is not an easy task. In the case of Prague and Vienna, astronomy travelled along routes not always visible, as we are only aware of a few of the names of those who studied and circulated it. And as we have seen, sometimes astronomy travelled in round trips. The challenge is not only to find out where was the departure point and where the destination, but, more importantly, to show that, between Prague and Vienna, a continuous scientific interaction took place. It was such interaction among ordinary monks and university professors that created the intellectual conditions from which better known names, such as Peuerbach, Regiomontanus or Copernicus, emerged.

Acknowledgments

I am grateful to J. Chabás, P. Hadrava, A. Hadravová, P. van de Paverd and M. Wells for helping in various ways in the preparation of this paper.

Tycho Brahe and Prague: Crossroads of European Science, pp. 256–263,
J. R. Christianson et al. (eds.), © *H. Deutsch 2002*

Art, Astrology and Astronomy at the Imperial Court of Rudolf II (1576-1612)

Andrea Bubenik, Kingston

In memory of STUART PIERSON.

In 1594, presenting counsel at a court masque, the English philosopher Francis Bacon (1561-1626) discussed what he perceived to be the ideal method for achieving a conquest of nature, a conquest that involved possession and study of all that had been created by man and existed in nature. In order for the collector to have a model of the universe made private, a microcosm, Bacon recommended the establishment of a library, a garden, a stable for rare beasts, a cage for rare birds, a lake for fish, a house for instruments and vessels, and a cabinet that would contain man-made and natural objects. According to Bacon, only a monarch would have the means and authority to establish such an all encompassing collection. In terms of Renaissance cosmology, such a collection would afford knowledge of the microcosm assembled, and by extension the macrocosm of the world, thereby enabling an increase in the monarch's power.[1]

Francis Bacon is the figure most readily associated with the reformulation of scientific research in the seventeenth century, which involved that science have a public, democratic and collaborative character. However, his remarks in 1594 are indicative of his advocacy of collecting practices that cannot be described as anything short of private and magical in scope – terms that have not been easily associated with Bacon in past historiography. Situated as a figure of his time, it becomes apparent that Bacon retained interest in the manner of collecting so characteristic of the period, not as an idle pursuit or mere curiosity, but rather as an attempt to organize diverse objects in a way that would reflect their original disposition

[1] FRANCIS BACON, *Gesta Grayorum*, 1688 (Oxford reprint, 1914), pp. 34-35.

and their place in the chain of creation.[2]

The implications of Bacon's claims for the practice of collecting, and by extension, art and science at the court of Rudolf II, remain to be explored in fuller detail. Today, art and science are often treated as incommensurable realms of experience. However, under the universal patronage of Rudolf's court, the maintenance and use of the imperial collection, henceforth referred to as the *Kunstkammer*, meant that a strict dichotomy between art and science as realms of experience was not maintained or even recognized. While no image of Rudolf's *Kunstkammer* survives, inventories for the court attest to both the range and breadth of knowledge represented in this precursor of modern museums.[3] At Rudolf's court paintings were housed in close proximity to objects ranging from scientific instruments to medicines to rare gems to fossils to animal specimens, all stored in decorated boxes, cabinets, tables and chests. As Holy Roman Emperor, Rudolf possessed one of the largest and most all encompassing collections of his day, and gathered together an eclectic group of artists and scientists. The vast potential and significance of the Prague *Kunstkammer* was recognized in 1604 by Karel van Mander, who described Rudolf as the greatest patron in the world, and owner of "a remarkable number of outstanding, precious, curious, unusual and priceless objects."[4]

Both the imperial *Kunstkammer* as a site of knowledge and the universal patronage of Rudolf II offer the historian the opportunity to explore art and science in terms of their intersecting histories. Working within the cosmological framework of the court, the creations of artists often overlapped with the experiments of scientists through the use of a common visual language. Practices of art, astrology and astronomy, show that Rudolf's court was a site where activities now considered disparate were linked together. Specifically, aspects of the work of Tycho Brahe (1546-1601), as well as the astral iconography employed by the court artists Georg Hoefnagel (1542-1600) and Bartholomäus Spranger (1546-1611) run counter to the notion of two cultures, the scientific and artistic, and are suggestive instead of the lines of communication that existed between them. As Bacon's own adherence to both the private and public, the magic and scientific

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[2] THOMAS DACOSTA KAUFMANN also relates Bacon's remarks to a Hermetical or magical view of collecting in his *Mastery of Nature* (New Jersey, 1993), pp. 184-188.

[3] See ROTRAUD BAUER & HERBERT HAUPT, "Das Kunstkammerinventar Kaiser Rudolfs II, 1607-1611", *Jahrbuch der Kunsthistorischen Sammlungen in Wien* 72 (1976), pp. vii-191; ELIŠKA FUČÍKOVÁ, "Rudolf II: Einige Bemerkungen zu seinen Sammlungen", *Umění* 18 (1970), pp. 128-33; KLARA GARAS, "Zur Geschichte der Kunstsammlungen Rudolfs II", *Umění* 18 (1970), pp. 134-41.

[4] KAREL VAN MANDER, *Het Schilderboeck*, 1604, HESSEL MIEDEMA, trans. (Dornspijk, 1994), fol. iv.

shows, seeming paradoxes were resolved under the rubric of thought peculiar to the period. While it has become increasingly hazardous to speak of a unified 'world view,' the court of Rudolf II continues to defy contemporary nomenclature and classification in its seemingly all-encompassing cosmology. Understanding this cosmology requires an exploration of images ranging from natural history illustrations to horoscopes to allegories, images that often remain unclaimed by the histories of art and science.

To begin with the concept of universal patronage, the career of Tycho Brahe affords remarkable insight into the manner in which patronage functioned at court. Rudolf II sponsored Tycho's work and writings in the last years of the astronomer's life. Appointed Imperial Mathematician in 1598 and remaining in Prague until his death in 1601, Tycho wrote favorably of his new home to Johannes Kepler in 1599, and urged Kepler to join him in Prague: "You have no doubt already been told that I have most graciously been called here by his Imperial Majesty and that I have been received in the most friendly and benevolent manner. I wish that you would come here, not forced by the adversity of fate, but rather on your own will and desire for common study."[5] The support afforded to Tycho continued after the astronomer's death with the succession of Holy Roman Emperors: Ferdinand II, Ferdinand III and Leopold I. Respectively these emperors preserved and put Tycho's writings into tables, saved them during the Thirty Years War, and published them.

Indeed, Tycho Brahe's castle-observatory Uraniborg on the island of Hven was in structure imbued with cosmological principles not unlike the *Kunstkammer*. With its surrounding plantations and ponds, Uraniborg was constructed to represent the microcosm of universal harmonies.[6] Tycho states that the central building was "symmetrically arranged, as required with architecture if the work is to be executed in a proper manner according to the rules of art."[7] A more literal architectural realization of a temple for the astronomer's muse was provided for in Johannes Kepler's publication of the *Rudolfine Tables*, in the illustration known as the *Temple of the Astronomers* (Ulm, 1627). The development of astronomy is characterized by means of an analogy with architecture: in the temple there is

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[5] Tycho Brahe as cited in JOHANNES KEPLER, *Johannes Keplers Gesammelte Werke*: vol. XIV Briefe 1599-1603, WALTHER VON DYCK & MAX CASPAR, eds. (München, 1938-), p. 89.

[6] For a detailed analysis of Uraniborg as microcosm see MARTIN KEMP, "Temples of the Body and Temples of the Cosmos", *Picturing Knowledge: Historical and Philsophical Problems Concerning the Use of Art in Science*, Ed. BRIAN S. BAIGRIE (Toronto, 1996), p. 75.

[7] TYCHO BRAHE, *Astronomiae Instauratae Mechanica*, 1598, HANS RAEDER, ELIS STRÖMGREN AND BENGT STRÖMGREN, trans. and eds. (København, 1946), p. 131.

an architectural progression from the rustic supports at the back, followed by the polished Doric column that Copernicus stands next to, and finally the Corinthian column, the base of which Tycho rests his left arm upon, while pointing with his right to a diagram inscribed upon the ceiling of the temple depicting his own version of the heavenly system.

The growing emphasis on the realm of experience and observation of nature was of course central to the burgeoning mathematical astronomy with its quantifiable approach to nature as exemplified by Tycho Brahe. However, it is equally noteworthy to historians of Rudolf's court that astrology, complete with its emphasis on mythological deities and symbols, remained an integral aspect of court life and the ideology of rule. In the period under scrutiny, it is often difficult to segregate the role of court astronomer and astrologer. If astronomy is defined as the observation of the constitution and movements of celestial bodies, and astrology is the study of how such celestial phenomena influence human affairs, it is fair to say that these practices were intertwined well into the early modern era. As the historian Keith Thomas has observed, "it is certain that until the mid-seventeenth century, astrology was no private fad but a form of divination to which many educated people had recourse."[8]

Tycho Brahe's own adherence to matters astrological was part of a context in which courtly apotheosis often involved astral symbolism. The work of Georg Hoefnagel, court artist for Rudolf from 1590 to 1600 is especially demonstrative of this aspect of Rudolfine patronage. During his employ in the court, Hoefnagel, a Dutch artist skilled in natural history illustrations, emblems, and miniature illustrations, presented the emperor with at least six books and numerous independent miniatures. His *Allegory of Rudolfine Heavens* (Vienna, Österreichische Nationalbibliothek, cod. min. 31, fol. 2r), a watercolor presented to Rudolf II in 1600, is dominated by a celestial sphere, upon which are inscribed the mythological characters associated with the constellations. Holding the sphere upright are symbols of the zodiac: Leo, Rudolf's birth sign, and Capricorn, birth sign of Emperor Augustus who epitomized universal rule and the benevolence of the Roman Empire.

Rudolf II as a patron was very serious about astronomical precision for his own astrological prognosis.[9] The desire to study celestial bodies remained bound to the belief or fear that their movements affected human activity. The role of such beliefs in stimulating scientific change cannot be underestimated – for an accurate horoscope, increasingly precise in-

[8] Keith Thomas, *Religion and the Decline of Magic* (London, 1971), p. 335.

[9] On the activities of astrologers and astronomers at the court, see R. J. W. Evans' seminal work, *Rudolf II and his World: A Study in Intellectual History* (Oxford, 1979).

strumentation and observations were necessary, thus contributing to the invention of instruments such as the telescope. In this context, the visual horoscope for Rudolf II, also by Georg Hoefnagel, remains testament to an important dialogue between art and science, as well as a vital document for understanding Rudolf's court and sixteenth century science in general. From the same suite of miniatures as the *Allegory on Rudolfine Heavens*, the *Horoscope for Rudolf II* (Vienna, Österreichische Nationalbibliothek, cod.min. 31, fol. 1r) dates to 1600, when fears of the new century were likely part of the reason for its creation. In the horoscope, two angels are depicted holding a disk upon which the emperor's horoscope is inscribed. There are a number of Hebrew words positioned around the disk, suggestive of a cabalistic significance. The bottom of the image is filled with numerous creatures symbolizing the universal and encyclopedic rule of Rudolf II. It is rare to find discussion of such astral imagery in the art historical scholarship surrounding the period, and the particulars of this horoscope in the context of the court of Rudolf II remain to be discerned in greater detail.

The manner in which astrology remained a deeply influential system of belief, powerful in both speech and illustration, concomitant with new emerging scientific methods opens up a variety of questions when interpreting artistic production at the court. The example of astrology and astronomy is demonstrative of a context in which seemingly antithetical approaches to nature were practiced concurrently. The *Kunstkammer* that housed objects and instruments of scientific import along with works of art afforded a context peculiar to courts in this period, in which approaches to nature were richly characterized by an advocacy of encyclopedic thoroughness, and in expression remained resplendent with mythological symbols and allegories. The allegorical figure of *Hermathena*, a unification of the gods Hermes and Athena who represent eloquence and wisdom, was advocated by artists and scientists at Rudolf's court as emblematic of their encyclopedic activities. An engraving by Aegedius Sadeler after Georg Hoefnagel from circa 1590 (Budapest, Szepemüvészeti Museum, inv. no. 33.171) gives visual representation to the mythological deities as epitomizing the harmony of activities at the court and unity of the diverse approaches to nature. By using the medium of engraving (which allows for a maximum number of imprints to be made), the public manifestation of this allegorical figure at the court was assured. Indeed, a fresco by Bartholomäus Spranger in the "White Tower" in the Prague castle from about 1585 also depicts the two deities intertwined. This further public display of *Hermathena*, in conjunction with the wide audience that could have been reached through distribution of the *Hermathena* print, suggest that this hybrid mythological figure was rich in meaning and significance for the artists and scientists active at the court in Prague.

This perceived unity between diverse activities at the court and the context of the collection has a number of implications for how we discuss the mythological imagery that was so popular at the court. In this regard, the observations of Jean Seznec should be highlighted. Seznec claims that the role of mythological figures should not be mistaken for a purely decorative one. In his analysis it is important to understand the pagan gods not only as artistic symbols, but as invoking more profound meaning in the period under scrutiny.[10] Central to the assumption that there was a natural pattern of things intimately bound to ideas of a cosmic hierarchy were the symbols and language of mythology. Johannes Kepler would refer to the "act of divine providence" that had led Tycho to assign him to study Mars, the study of which enabled him to derive his laws of planetary motion. Mars had defied both Tycho and Kepler in their studies of the heavens, for as Kepler states "[Mars] is the mighty victor over human inquisitiveness, who made a mockery of all the strategems of astronomers, wrecked their tools, defeated their hosts... wherefore Pliny, specially indicted him 'Mars is a star who defies observation'."[11] Kepler's description of his victory over Mars takes the form of an allegory. He describes a war begun under Tycho's supreme command, pursued in spite of dangers and handicaps, to the triumphant end when the Imperial mathematician, riding a chariot, leads the captive enemy to the emperor's throne.

The allegorical way in which Kepler articulated his discovery of one of the most important laws of observational astronomy emphasizes the relevance of mythological imagery at the court of Rudolf II. The importance of the hybrid figure of *Hermathena* has already been discussed. It seems relevant at this point to consider anew the numerous mythological paintings created for and collected by Rudolf II. In his taste for contemporary art, it is indisputable that Rudolf's tastes ran to the mythological. However, while mythological paintings by the leading court artist Bartholomäus Spranger may have functioned in part as entertainment, they were also part of a collection that was an important expression of and consolidation of the complex cosmological ideas about collecting as outlined by Bacon. In Spranger's *Triumph of Wisdom* (c. 1591, now in the Vienna Kunsthistorisches Museum) Athena is shown victorious over ignorance, represented by the beheaded body at her feet. Representations of the arts surround her,

[10] Jean Seznec, *The Survival of the Pagan Gods* (New York, 1953), p. 5.

[11] Johannes Kepler, *Johannes Keplers Gesammelte Werke*: vol. III "Astronomia Nova", Walther von Dyck & Max Caspar, eds. (München, 1937-), preamble to table of contents.

for example the figure of astronomy holding the armillary sphere. Again, a variety of approaches to nature are symbolized as united under the rubric of wisdom. In the cosmological context of the court, Spranger gave visual expression to the unity in diversity that Rudolf's patronage afforded.

Spranger also depicted numerous pairings from Ovid's Metamorphoses, love mythologies that have often contributed to assumptions that as patron Rudolf was interested in erotic imagery at the expense of all else. However, when placed in context these images cannot be dismissed as private aberrations. Spranger developed images that are rich in contrasts in terms of body types, physicality and age. Most illustrative of this are his *Glaucus and Scylla* (1581) and *Salmacis and Hermaphrodite* (1581), both in the Kunsthistorisches Museum in Vienna.[12] Seemingly opposing figures or deities are brought together. In the case of Glaucus and Scylla, the elderly sea god pleas with the young nymph Scylla to stay with him. In Ovid's tale, Scylla is repulsed and flees. In the tale of Salmacis and Hermaphrodite, the water nymph is shown spying on Hermaphrodite, son of Hermes and Aphrodite. Struck with love for the decidedly younger Hermaphrodite, Salmacis secretly observes him sitting on the edge of her magic pool. As the story continues in Ovid, when Hermaphrodite finally dives into the pool, Salmacis cannot contain herself, follows him in and embraces him. Hermaphrodite struggles to escape and Salmacis prays that they will never be parted. Her prayer is quite literally answered and their bodies are fused together.

These two works were likely intended to be displayed as companion pieces in the *Kunstkammer*. As part of the carefully organized display of natural and artificial objects, Spranger's Ovidian love stories depicting the attractions and repulsions of deities, could have been viewed in terms of principles basic to cosmology, namely, the attraction and repulsion of elements. It is certainly no accident that Jupiter, King of the Gods, adorned the ceiling of the room near the *Kunstkammer*, depicted as master of the four elements and twelve months on the walls of the room, as well as the encyclopedic contents of the collection. Just as the variety of objects housed in the *Kunstkammer* functioned as more than mere "curiosities," these paintings could have functioned on a more profound level than has been previously acknowledged.[13] Mythological characters had survived from

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[12] The contrasts prevalent in this pair of images are discussed by LUBOMÍR KONEČNÝ, "Sources and Significance of Two Mythological Paintings by Bartholomäus Spranger", *Jahrbuch der Kunsthistorischen Sammlungen in Wien* 85/86 (1989/1990): pp. 22-40.

[13] This argument is the basis of Thomas DaCosta Kaufmann's discussion of mythological imagery at the court; see THOMAS DACOSTA KAUFMANN, "Eros et Poesia: la Peinture à la cour de Rodolphe II", *Revue de l'Art* 18, no. 69 (1985): pp. 29-46.

antiquity through the Middle Ages in conjunction with astral science, as evidenced by calendars and zodiacs. The tenacity of these symbols in art and science raise a number of questions for the art works of the period. Can it be simply coincidence that the pagan gods were depicted with frequency in artistic circles at a time when astrology and astronomy were so integral to court activities?

The broad scope of such a question illustrates how the concerns of artists and scientists at the court of Rudolf II epitomize a set of problems that transcend current academic disciplines and boundaries. I began this paper with Francis Bacon and his discussion of an encyclopedic collection as the means to gaining knowledge of the world, and by extension power over it. Bacon is often characterized in very different terms, as an advocate of the theoretical necessity for order, and the inventor of rules for governing nature. Supposedly in this paradigm, the languages of art and science became incompatible and antithetical visions of the world. However, as has been shown with images from Rudolf's court, mythological symbols were important to artistic and scientific endeavors alike in the sixteenth and seventeenth centuries. The languages of court artists and scientists were in some ways still compatible. Such communication requires the transgression of borders that are now in evidence around academic disciplines. Further, it seems important to acknowledge that artistic or scientific styles do not lose relevance if the limits of the questions they imply, or the issues they bring to the fore are replaced with new ones. Rather, these styles remain testament to a successful dialogue.

Tycho Brahe and Prague: Crossroads of European Science, pp. 264–269,
J. R. Christianson et al. (eds.), © *H. Deutsch 2002*

Physicians at the Prague Court of Rudolf II

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The topic of this contribution seems to have no connection with astronomy. This view is not quite right, because medicine of that time was very close to astrology as well as astronomy. Many astronomers studied medicine as well – e.g. a good friend of Tycho Thaddaeus Hagecius and many others.

However, the work and lives of physicians of that period are known less than the work and lives of astronomers. In the course of my study I specialized in a large group of physicians who looked after the health of Rudolf II. Although at that time they were certainly Europe's top experts, no conference could be held on most of them due to lack of explored material. Of course, there are exceptions, e.g. Thaddaeus Hagecius or Johannes Jessenius, but such cases are rare.

I found out that various sources mention approximately 15 Emperor's personal doctors and 9 court doctors.[1] Some names of those physicians are hardly known and it is not possible to find out the exact dates of their stay at the court. Putting together a complete list of doctors working for Rudolf II and his court – as well as mutual relations between the Emperor and them, relations between personal doctors and court doctors, their inner hierarchy and many other questions – will involve time-consuming research.

I would like to focus only on one of the most important among Rudolf's doctors – Christophoro Guarinoni. I intend to use him as an example to demonstrate our poor state of knowledge of this part of history and our ability to get a better knowledge of history by studying the life and work of physicians as well as their patients.

The Italian surname Guarinoni cannot be overlooked, because it appears three times in the records of doctors at the Prague court. Christophoro

[1] An uncomplete list of those physicians see, among others: EVANS, R. J. W., *Rudolf II. a jeho svět. Myšlení a kultura ve střední Evropě 1576-1612*, Praha, 1997, passim; PICK, F., *Johannes Jessenius de Magna Jessen*, Leipzig, 1926, pp. 177-178; TRUNZ, U., *Wissenschaft und Kunst im Kreise Kaiser Rudolfs II. 1576-1612*, Neumünster, 1992, passim; HAUSENBLASOVÁ, J., *Dvůr císaře Rudolfa II. Edice dvorských seznamů*, in print.

Guarinoni was the most important representative of that surname and as one of the leading diagnostics of his time he is listed in various biographical dictionaries[2] and other works.[3] A lot of information given in those dictionaries and works is however inaccurate and incomplete. There are such Guarinoni's biographical data that could be found in dictionaries.

Christophoro Guarinoni (?-1604) was born near Verona. He studied philosophy and medicine in Padua. He is said to have taught philosophy and practised medicine after his return to Verona. Later he was summoned by Rudolf II to his court in Prague. Here he founded a medical academy where he taught medicine. Some sources say the academy was established in 1576.[4] He died in Prague and his tomb slab is in St. Vitus cathedral.[5] Guarinoni wrote a lot of scientific works, e.g. an appreciated commentary to Aristotle's 1st book *de historia animalium* and also a collection of *consilia* that I am going to write about later.

Most of historians, even famous ones such as Janáček and others confused the above mentioned facts with biographical data of two other physicians of the same surname – Bartholomeo and Hippolyto Guarinoni. It is not known for a fact whether they were related to Christophoro. However, it is certain that the third mentioned Hippolyto (1571-1654) was a son of Bartholomeo Guarinoni and that he was born in Trent. He grew up in Prague and later moved to Hall in Tyrol where he worked as a doctor.[6] His father Bartholomeo, as well as Christophoro, was one of the personal doctors of Rudolf II.

Bartholomeo Guarinoni (1534-1616) belongs to Rudolf's physicians "inherited" from Maxmilian II and he remained in Prague until at least 1604.[7] However, we do not know about him much more than about Christophoro. Nevertheless we can learn a lot about his stay in Prague through his correspondence with a friend Crato von Craftheim.[8] Johannes Crato von Craftheim (1519-1585) was a personal physician of the Emperor Maxmili-

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[2] E.g. Hirsch, A. – Wernisch, A., *Biographisches Lexikon der hervorragenden Ärzte aller Zeiten und Völker*, Bd. 2, Wien – Leipzig, 1885, p. 674.

[3] E.g. Evans, R. J. W., *Rudolf II. a jeho svět*, Praha, 1997, pp. 234-245; Janáček, J., *Rudolf II. a jeho doba*, Praha, 1987, pp. 226, 340; Polišenský, J., *Jan Jesenský – Jessenius*, Praha, 1965, p. 154; Hasner, J., "Zur Geschichte der Medicin in Böhmen", 2. In: *Vierteljahrschrift für die praktische Heilkunde*, 109, Prag, 1871, p. 142.

[4] Hirsch, A. – Wernisch, A., *Biographisches Lexikon der hervorragenden Ärzte aller Zeiten und Völker*, Bd. 2, Wien – Leipzig, 1885, p. 674.

[5] See Hausenblasová, J. – Šroněk, M., *Urbs Aurea. Praha Rudolfa II.*, Prag, 1997, pict. no. 169.

[6] Evans, *Rudolf II.*, p. 245; Bücking, J., *Kultur und Gesellschaft in Tirol um 1600*, Lübeck, 1968, p. 8.

[7] Evans, *Rudolf II.*, p. 244.

[8] See, among others, Evans, *Rudolf II.*, passim.

an II as well as of Rudolf II and one of the most significant public figures of that time. A fragment of their correspondence is kept in the library of Wrocław University.[9] Through a profound study of these documents we could gather invaluable information about the life of Bartholomeo Guarinoni as well as life at the court in general.[10]

Now we shall go back to Christophoro Guarinoni in more detail. For Czech historians there are two extremely important facts connecting Christophoro with Prague. The first one is the above mentioned foundation of a medical academy which is called a school of anatomy by some historians.[11] It is significant because it implies a possibility of acquiring certain medical knowledge at a time when the Prague Medical Faculty did not exist.[12]

The second one is his collection of medical *consilia*, where we can find a lot of interesting facts about our history. It was published in Venice in 1610, which is 8 years after the author's death.[13] Taking into account that literature of *consilia* is not widely known, I find necessary to describe it briefly.[14]

Consilia were an important area of professional medical literature for the Middle Ages, Renaissance and baroque periods.[15] They are one of the best sources for the study of history of medicine and the history of daily social life of the higher society. *Consilium* is an essay with a typical standard structure, it contains an account of a particular case and patient, the symptoms of his or her disease, and doctor's advice or a record of treatment. Authors of *consilia* were respected doctors, who were consulted by physicians for advice via written requests containing basic information about the symptoms of the illness.

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[9] Unfortunately to this day there are only 10 letters left and 18 extracts made by an archivist S. B. Klose at the end of the 18th century. The rest is said to be destroyed at the end of the second world war.

[10] E.g. Guarinoni wrote to Crato about coming and career of another physician Simon Simonius (sig. R 241/32, 38), about a sudden death of a famous historian Johannes Sambucus (R 241/39) or about a wedding of a humanist Peter Monau (R 241/45).

[11] E. g. Hasner, J., "Zur Geschichte der Medicin in Böhmen", 2. In: *Vierteljahrschrift für die praktische Heilkunde*, 109, Prag, 1871, p. 142.

[12] For the condition of the University at this time see: Svatoš, M., "Pokus o reformu a zánik karolinské univerzity 1556-1622", In: *Dějiny Univerzity Karlovy*, I., Praha, 1995, p. 269-289.

[13] By full title *Consilia medicinalia in quibus universa praxis medica exacte pertractatur, auctore Christophoro Guarinonio Veronensi, viro clarissimo ac Sacrae Caesareae Maiestatis a cubiculo Medico primario. Cum privilegio eiusdem Sacrae Caesareae Maiestatis, Serenisssimi Senatus Veneti et aliorum Principum.* Venetiis 1610.

[14] There is a literature of juridical *consilia* as well, but those *consilia* enjoy permanent interest of juridical historians.

[15] On this theme see the unique work Agrimi, J. – Crisciani, Ch., *Les Consilia medicaux, Typologie des sources du moyen âge occidental.* Fasc. 69, Louvain, 1994.

Guarinoni's collection of *consilia* contains 622 items.[16] 93 of them have a date and place of origin written on them. The oldest dated *consilium* was written on the 8th of October 1571 in Verona.[17] The last dated *consilium* was written on the 5th of March 1596 in Prague.[18] Most of other dated *consilia* were written in Italian towns Verona, Urbino, Fossombrone and Pesaro in the seventies and eighties, 16 *consilia* were written in Prague in the nineties of the 16th century. This offers us some possibility to indicate the places of Guarinoni's stay and movement approximately. Of course, the thus acquired statements will not be perfect, because 93 *consilia* are only a small fragment of the complete number of Guarinoni's *consilia* and there are several gaps.[19] Nevertheless we can try to reconstruct – with a certain circumspection of course – moves of Guarinoni in Italy and a possible date of his coming to Prague.

The last dated *consilium* written in Italy bears the date of the 19th of July 1590 and was written in Verona.[20] The first *consilium* from Prague was written on the 20th of November 1590.[21] It is possible to establish that Christophoro Guarinoni likely came to Prague in 1590. This datum seems to be confirmed by some notes of another physician Johannes Jessenius.[22] Therefore it was impossible for him to have founded a medical academy in Prague in the year of 1576. If there was a medical school at the time at all, it must have been founded by Bartholomeo Guarinoni. The last dated *consilium* of the collection was written on the 5th of March 1596 in Prague.[23] But Christophoro Guarinoni lived in Prague until his death in 1604. Why is 1596 the last year in the collection? Is it just an accident or did Guarinoni stop writing *consilia* that year? Did he get into some trouble at the court as some small complaints of his last *consilia* indicate?[24] And

[16] *Consilia* are called *consultationes* there; they are arranged according to the kinds of illnesses (not according to data of their origin) and they are designated by Roman numbers. I follow this signification in my footnotes.

[17] *Consultatio CCCXLV.* There are some older dated *consilia*, but the places of their drafting are absent. *Consultatio CCXXVI.*, written on 15th of July 1563 probably in Italy, is the oldest dated *consilium* in the collection.

[18] *Consultatio DCXXI.*

[19] Total enumeration is this: 1571 – 1 *consilium*, 1572 – 2 *consilia*, 1573 – 5 *c.*, 1574 – 9 *c.*, 1575 – 2 *c.*, 1576 – 5 *c.*, 1577 – 7 *c.*, 1578 – 7 *c.*, 1579 – 9 *c.*, 1580 – 6 *c.*, 1581 – 11 *c.*, 1582 – 0, 1583 – 3 *c.*, 1584 – 1 *c.*, 1585 – 0, 1586 – 2 *c.*, 1587 – 1 *c.*, 1588 – 1 *c.*, 1589 – 1 *c.*, 1590 – 5 *c.*, 1591 – 4 *c.*, 1592 – 5 *c.*, 1593 – 2 *c.*, 1594 – 2 *c.*, 1595 – 0, 1596 – 2 *c.*

[20] *Consultatio DLXI.*

[21] *Consultatio DLXVII.*

[22] See Pick, F., *Johannes Jessenius a Magna Jessen*, Leipzig, 1926, p. 121.

[23] *Consultatio DCXXI.*

[24] E. g. *Consultatio DCXX. "De meo discessu scias ... Sic apud suam Sacram Caesaream Maiestatem consilium habitum, quid effectum, non rescivi, alterorum mecum*

if so, why did he not leave Prague? Such questions and many others must wait for the answer.

Now we shall examine the *consilia* in detail. As was already stated, a standard *consilium* usually contains a description of the patient and his disease. Guarinoni did not strictly follow the rules of *consilia*, but his brief notes can also be helpful. It can be presumed that most of Guarinoni's patients were of high social level. Only those people could afford his services. We can find many *consilia* produced for cardinals as well as dukes e. g. Duke of Mantua,[25] Duke of Bavaria[26] or Duke of Urbino.[27] One *consilium* was written for the Queen of France herself.[28]

People who ordered *consilia* also affected Czech history. It enables us to gain a lot of interesting information completing our knowledge about significant representatives of public life in the period before the Battle of White Mountain. Some patients from Bohemia cannot be identified because their given titles, function of the person etc. are very general, for example *Pro nobili Bohemo*.[29] Fortunately, there are a lot of *consilia*, where the patient is obvious. For example, the *consilia* for the rector of Prague Jesuit college,[30] or for the "Hofmeister",[31] or for the Spanish legate to the Emperor's Court.[32] Another, very interesting *consilium* is also the one requested by a famous physician with links to Prague, Petrus Andrea

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ne hiscit quidem ..."

[25] *Consultatio CCCCXXXX. Pro tuenda valetudine pro S. Guilelmo Mantuae Duce.*

[26] *Consultatio CCCXI. Pro valetudine tuenda Ser. Guglielmi Bavariae ducis.*

[27] *Consultatio CCCCXVI. Pro Ser. Guido Ubaldo S. Urbini Duce Ven., CCCCXI. Pro Exc. Urbini Principe DD Lucretia Estensi de rheumate cum febre, etc.* Numerousness of *consilia* for the Duke of Urbino, for members of his family and Guarinoni's cordiality seem to acknowledge the allegation that Guarinoni was a personal doctor of Duke of Urbino.

[28] *Consultatio DLXXVIII. De peripneumonia pro Christianissima Regina Galliae Elisabeth Austrina.*

[29] *Consultatio DLXXX. De magna cordis agitatione per circuitus redeunte. Pro nobili Bohemo.*

[30] *Consultatio DLXXXIV. De dolore in hypochondriis pro Rectore Societatis Iesu Pragae cum Simonio et Sigismundio.*

[31] *Consultatio DLXXXV. De dolore ventriculi pro Illustrissimo Curiae Magistro Regni Bohemiae.*

[32] *Consultatio VI. De Ill. D. Don Guilhelmo a Santo Clemente; Consultatio VII. De eodem Ill. D. Guilhelmo a Santo Clemente; Consultatio DLXXXXVII. De nervorum debilitate pro Ill. DD Guilhelmo a Santo Clemente Regis Hispaniarum Consiliaria et apud Caesarem Oratore, etc.; Consultatio DLXXXXVIII. De nervorum debilitate pro Ill. DD. Guilhelmo a Santo Clemente Comendatorio et Regis Catholici statuum Consiliario, atque apud Imperatorem Oratore; Consultatio DCXII. De debilitate artuum pro Ill. DD. Guglielmo a Santo Clemente Hispan. Regis a Consilii et apud Caesareum Oratore.*

Mattioli.[33]

Nevertheless, I would consider the two *consilia* concerning our most powerful politician of the period before the Battle at White Mountain, Vilém z Rožmberka (von Rosenberg),[34] as the most significant. The one called *De Prorege Bohemiae Guglielmo Rosimbergio in hydropem labente*,[35] is a typical *consilium* that includes a guideline for the treatment of this patient. Guarinoni had written it in December 1591 in Prague, six months before Rožmberk died. It is devoted to a colleague who was an attending physician of this important nobleman. Besides scientific analysis and prescriptions we can find in this *consilium* also many interesting notes about quacks, whose services were used by Vilém z Rožmberka. The other *consilium* that concerns Vilém z Rožmberka is a letter to Guarinoni's friend in Urbino.[36] Guarinoni described in detail last minutes of this nobleman's life, the moment he witnessed as the only physician. Both of those *consilia* bring interesting information of the physical as well as psychic state of one of our most important politicians and we cannot find it anywhere else. These brief characteristics of the contents reveal some possibilities of use of *consilia* as historical sources for both the history of medicine and the history of politics.

In this short contribution, I have tried to feature the life destiny of one of Rudolf's physicians who belonged to the best. Through him I have proved how little we know about him and about the group of his colleagues who were active on the Emperors' court and who were appreciated at their time maybe even more than astronomers. We know little not only about these doctors but also about their work. And it is more profound knowledge of their writing that may bring more information about themselves and about the events on the turn of the 16th and 17th centuries. Also the *consilia* by Christophoro Guarinoni can serve as the evidence of this. Better knowledge of medical work will then, of course, benefit not only by enriching medical history but also, as I have outlined, 'great' history and history of other sciences created by the patients of physicians.

This result of the project LN00A041 was supplied with subvention, resp. supported by The Ministry of Education of the Czech Republic.

[33] *Consultatio CCCXLV. Excellentissimo Mathiolo, febre quartana laboranti.*

[34] About the life of this personage see Pánek, J., *Vilém z Rožmberka. Politik míru*, Praha, 1998.

[35] *Consultatio DLXXVII.*

[36] *Consultatio DLXXXXI.*

Tycho Brahe and Prague: Crossroads of European Science, pp. 270–275,
J. R. Christianson et al. (eds.), © *H. Deutsch 2002*

Scientifica in der Kunstkammer Rudolfs II.

Beket Bukovinská, Prag

Die Kunstkammer Rudolfs II. war den zeitgenössischen theoretischen Vorstellungen verpflichtet und entsprach in ihrer idealen Ordnung den Kunstkammern z.B. in München oder Ambras. Sie war enzyklopädisch angelegt und sollte die kosmische Ordnung des Universums widerspiegeln. Im Unterschied aber zu den oben genannten bestand ihre Eigenart nicht nur in der Reichhaltigkeit und Breite der Sammlungen, sondern auch in der Zusammenstellung und Präsentation der Gegenstände. Es handelte sich dabei weniger um eine für den Besucher übersichtlich aufgestellte und organisierte Schausammlung, sondern viel eher um eine Studiensammlung, die der weiteren Forschung und Erkenntnis dienen sollte.[1]

Wie wir wissen, überlebte die Kunstkammer Rudolfs II. in ihrer Vollständigkeit ihren Gründer nicht lange, und von ihren reichen Beständen blieb auf der Prager Burg nichts übrig.[2] Das großzügig entfaltete Programm der rudolfinischen Kunstkammer ist aber in dem erhaltenen authentischen Inventar aus den Jahren 1607-1611 festgehalten.[3] Die Objekte sind nicht nach ihrer Aufstellung in den Räumen der Kunstkammer aufgenommen, sondern in vielen größeren oder kleineren Abschnitten nach ihrem Inhalt und ihrer sachlichen Zugehörigkeit zusammengestellt. Wir finden nacheinander die Objekte aus den Bereichen der *naturalia* – die Gebilde der Natur, der *artificialia* – die Werke des menschlichen Schöpfer-Talents und der *scientifica* – die Produkte menschlichen Erfindungsgeistes.

Gelegentlich der Ausstellung “Rudolf II. und Prag”, die im Jahre 1997

[1] E. Fučíková, “The Collection of Rudolf II at Prague: Cabinet of Curiosities or Scientific Museum”, in: *The Origins of Museums: The Cabinet of Curiosities in Sixteenth- and Seventeeth-Century Europe*, ed. O. Impley – A. MacGregor, Oxford 1985, S. 47-53.

[2] B. Bukovinská, “The Kunstkammer of Rudolf II: Where it Was and What it Looked Like”, in: *Rudolf II and Prague: The Court and the City*, Aust. Kat., London 1997, S. 199-208.

[3] R. Bauer – H. Haupt, “Das Kunstkammerinventar Kaiser Rudolfs II. 1607-1611”, *Jahrbuch der kunsthistorischen Sammlungen in Wien*, LXXII, 1976.

in Prag stattfand, wollte ich die Bedeutung und Breite der usprünglichen Kunstkammerbestände so klar wie möglich vermitteln.[4] Für die Auswahl und Aufstellung der Exponate nutzte ich die Eigenart des Inventars, die mir eine logische Konzeption erlaubte. Ich mußte aber meine Aufmerksamkeit auch mehreren Gebieten widmen, die weit über die Grenzen meines Fachgebietes hinausführten. Neben dem umfangreichen und in verschiedene Richtungen laufenden Bereich der *exotica*, der im Inventar unter der Bezeichnung "indianische sachen" vorkommt und Objekte aus dem Orient, aus Afrika und Amerika beinhaltet, waren es z.B. auch *scientifica*, die die Mitarbeit eines entsprechenden Spezialisten erforderlich machten. Diese Zusammenarbeit brachte öfters interessante Anregungen. Eben bei dieser Gelegenheit wurde mir bewußt, daß die Bedeutung der rudolfinischen Kunstkammer im allgemeinen wohl anerkannt ist, daß aber das Inventar und die Informationen, die man aus den Eintragungen gewinnen kann, bei weitem nicht so bekannt sind und deshalb auch nicht hinreichend ausgewertet werden, und so erlaube ich mir auch bei dieser Gelegenheit auf Informationen aufmerksam zu machen, die aus dem Inventar der Kunstkammer Rudolfs II. aus den Jahren 1607-1611 zu entnehmen sind und anregend sein könnten.

Bevor ich einen kurzgefaßten Einblick in diesen Abschnitt des Inventars vorlegen werde, erlauben Sie mir nur ganz kurz, die wichtigsten Fakten über die Kunstkammer selbst zu rekapitulieren, auch wenn diese wohl bekannt sind. Die Bestände der Kunstkammer Rudolfs II. gelangten mit größter Wahrscheinlichkeit nach dem Jahr 1606 an ihren endgültigen Platz und zwar in die vier hintereinander liegenden Räume im ersten Stock des nicht sehr breiten Verbindungstraktes zwischen dem südlich, gegen die Stadt gelegenen Wohnpalast des Kaisers und dem nördlichen Trakt der Prager Burg, in dem der sog. Spanische und der Neue Saal mit einer über zwei Stockwerke reichenden Höhe angelegt worden waren.

Wie aus Quellen und alten Plänen zu entnehmen ist, waren die drei Räume, die auch erstes, zweites und drittes "Gewölb" oder die "vordere Kunstkammer" genannt werden, vom größten Raum der Kunstkammer durch das Stiegenhaus zum Mathematischen Turm getrennt, wobei ihre Verbindung nur mit einem schmalen Durchgang möglich war. Zusammen waren die vier Räume der Kunstkammer 100 Meter lang und 5 Meter breit. Leider steht uns bis heute keine zeitgenössische Beschreibung der Kunstkammer zur Verfügung, und so können wir nur an Hand der Inventare feststellen, daß die Räume mit mehreren Kästen oder Almarn, vielen verschieden großen Schreibtischen oder Truhen und einer Reihe von Tischen

[4] *Rudolf II and Prague: The Imperial Court and Residential City as the Cultural and Spiritual Heart of Central Europe*, Prag, 30. 5. – 7. 9. 1997.

ausgestattet waren. Die einzelnen Objekte standen frei oder in Behältern auf den Möbeln, aber auch am Boden, die meisten wurden außerdem in unzähligen Kästchen und Schachteln in den Regalen und Schubladen der Möbelstücke aufbewahrt.

Die einzelnen Eintragungen im rudolfinischen Inventar aus den Jahren 1607-1611 sind in den meisten Fällen sehr aufschlußreich, sie enthalten treffliche Beschreibungen oder Charakteristika der Objekte, und wir begegnen oft auch den Namen der betreffenden Künstler, Händler oder Spender, und manchmal den Daten der Fertigstellung oder der Übergabe in die Kunstkammer, in einigen Fällen z. B. auch Anmerkungen, daß der Kaiser dieses oder jenes Stück zu sich genommen habe. Die einzelnen Gruppen wurden, auch wenn sie nur ganz wenige Gegenstände enthalten, meistens auf selbständigen Folien aufgenommen, wobei zwischen ihnen oft ganze Seiten frei blieben. Man hat sichtlich damit gerechnet, daß zu den einzelnen Gruppen noch weitere Gegenstände hinzukommen werden, was auch häufig geschah, da manchmal die Eintragungen neuer Akquisitionen mit anderer Tinte hinzugefügt wurden.

Eine bemerkenswerte Eigenart des Inventars ist, daß den Eintragungen an verschiedenen Stellen kleine Zeichnungen und auch verschiedene Zeichen beigefügt sind, die dem Verfasser des Inventars wahrscheinlich zur Klärung oder als Betonung der Eigenart von einzelnen Objekten dienen sollten.[5] Interessant ist auch, daß etliche Objekte mehrmals in den Eintragungen vorkommen und zwar immer an der Stelle, wo sie noch in einem anderen Zusammenhang zur Geltung kommen könnten. In solchen Fällen wird beiderseits auf das diesbezügliche Folio hingewiesen.

Was den Bereich der *scientifica* anbelangt, finden wir im Inventar größere Einheiten von verschiedenen Uhren, Automaten sowie geometrischen und astronomischen Instrumenten, die auch meistens noch in kleinere Gruppen aufgeteilt werden und selbständig auf einzelnen Folien beschrieben sind. So kommt auf dem Folio 338 ein Abschnitt mit der Überschrift: "VON UHRN UND DERGLEICHEN REDERWERCKEN" vor. Diese Gruppe enthält über 50 Objekte. Das erste davon ist z.B.: "Ein groß uhrwerck mit einem *astrolabio* sambt dem jahrzaiger herumb, darauf ein *sphera* sambt ihren *circulis planetarium* sambt anderer zugehor und ein geschribens tractetlin darzu, steht auff der tafel in der kunstcammer, hatt Jobst Bürgius gemacht, von h. von Braunschw: Ihr Mt: verehrt."[6]

In derselben Gruppe folgen unter anderen zwei Uhren, bei denen als

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[5] Als Verfasser des Inventars und Autor dieser Zeichnungen wird heute schon allgemein der Miniaturmaler und kaiserliche Antiquar Daniel Fröschl angesehen, siehe zuletzt *Rudolf II and Prague* (wie Anm. 2), passim.

[6] BAUER – HAUPT (wie Anm. 3), S. 110, Nr. 2183.

Autor Christoph Margraf genannt wird und wo auch der Mechanismus beschrieben ist: "Ein ander uhrwerckh von C. Marggrafen mit einer perspectif und gemalten landschafft, darin laufft helffenbainin kügelin hin und wider uff 2 stähline saitten, zeigt und schlegt stet uff seinem futter oder kästlin."[7] Wie wir wissen, waren es gerade diese Eintragungen, die es Erwin Neumann und Herbert von Bertele ermöglichten, die Persönlichkeit Margrafs zu erfassen und das Kugellauf-Prinzip in seinen drei Werken in den Sammlungen des Kunsthistorischen Museums aufzuklären.[8] Margraf war der Erfinder dieses Prinzips, wofür er im Jahre 1595 ein kaiserliches Privileg erhielt. Im Antrag auf dieses Privileg betont er, daß das Kugellauf-Prinzip eine genauere Zeitmessung erlaube, als mit den damals üblichen Uhren möglich war.

Es folgen dann weitere Uhren und auch Automaten mit Uhrwerk in verschiedenen Formen und Gestaltungen. Viele von ihnen sind mit einem Kalender oder mit einem Astrolabium versehen, mehrere haben die Form eines Globus oder enthalten einen Mechanismus, der den Globus in Bewegung bringt. Zu ihnen gehören auch die heute noch existierende Globusuhr von Emoser[9] und der in Wien aufbewahrte mechanische Himmelsglobus von Georg Roll und Johann Reinhold.[10] Genannt wird z.B. auch der Mathematiker Christian Heiden aus Nürnberg: "Ein *globusuhr*, ist aussen die erdkugel und inwendig die himelskugel, zaigt den sonnen und des monds lauff, alles von silber, zu fussen sein 2 figur knockendt und ein trach dabey, von Christian Heiden angefangen, von Jobst Bürgi außgemacht, der schlissel darbey."[11] Die folgende Gruppe auf einem weiteren Folio Nr. 344 bezeichnet als: "UHRWERCK VON BILDERN UND ANDERN KURTZWEYLIGEN SACHEN" enthält nur vier figürliche Automaten mit Uhrwerk wie z.B.: "Ein messin vergulten hund ligendt mit uhrweck, ligt uff ebenim kestlin, riert die augen, dabey ein Türck, zaigt mit seinem stab die stund, hatt ein schlagwerckh vom Jerg Frommüller."[12]

Die nächsten Folien enthalten eine große Einheit, die "ASTRONOMISCHE UNND GEOMETRISCH INSTRUMENTA, CIRKULI" benannt ist, und da sind auf den nächsten neun Seiten (Fol. Nr. 347-351) fast hundert verschiedene Instrumente aufgenommen. Neben den schön ad-

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[7] *Ibid.*, Nr. 2141. Margraf ist im Inventar noch zweimal genannt: Nr. 2140 a 2145.

[8] H. von Bertele – E. Neumann, "Der kaiserliche Kammeruhrmacher Christoph Margraf und die Erfindung der Kugellaufuhr", in: *Jahrbuch der kunsthistorischen Sammlungen in Wien*, LIX, 1963, S. 39-98.

[9] Bauer – Haupt (wie Anm. 3), Nr. 2158; *Prag um 1600: Kunst und Kultur am Hofe Rudolfs II.*, Kat., Freren 1988, Nr. 445.

[10] Bauer – Haupt (wie Anm. 3), Nr. 2160; *Prag um 1600* (wie Anm. 9), Nr. 447.

[11] *Ibid.*, Nr. 2163.

[12] *Ibid.*, Nr. 2195.

justierten Stücken wie z.B. "Zwen messin vergultte *proportional* und sonsten noch ein anderer *geometrischer* circul, auch vergultt, beysamen in einem nidern futral"[13] kommen auch einfachere vor "Ein futral, darin ein reißzeug von lautter messine circul, winckelmaß, richtscheitl, bleyfederr, ist nichts vergults darin".[14] Mehrmals wurden Namen erwähnt wie "Ein circul oder compas, so des sig: *Fabricii Mordenti* compas genant, mit andern mehr sachen dabey ligendt, alles vergult uber messing in einem futral";[15] Mordente kommt noch dreimal vor. In drei Fällen wird auch Habermel genannt, z.B. "Ein nidertrechtig gefiert futral, darin ein vergultter ligender compas oder sonnenuhr mit sehr vil schönen *observationen* von *Erasmo* Habermel darunder die beschreibung ligt."[16] Auch in diesem Abschnitt wird nochmals der Mathematiker Christian Heiden erwähnt: "Ein schön klein vieregget niderer compas von silber, darinnen gar vil sachen zu observirn, schier wie ein *astrolabium* und *sphera*, darbey auch ein klein büchlin, die beschreibung uff pergamen, glaub sey vom alten Heiden."[17]

Welche aus dieser großen Auswahl von Instrumenten für die weitere Forschung interessant sein könnten, überlasse ich den Spezialisten, die sich damit vielleicht weiterhin näher beschäftigen wollen. Ich möchte nur noch auf eine Stelle des Inventars aufmerksam machen, wo Objekte aus Glas und Bergkristall aufgenommen sind. Da findet man neben den Augengläsern – die in einem Fall auch an der Seite aufgezeichnet sind – selbständige Abschnitte, benannt: "SPIEGEL ALLERLEY GROSS UNND KLEIN VON CRISTALL UND GLAS, DIE GROSS MACHEN", als auch "AUGENGLESER ODER SPIEGEL, DIE VERKLEINEN". Weiter dann unter der Bezeichnug "STRAVEDERI, INSTRUMETI IN DIE WEITTEN ZU SEHEN EIN DING, SAMB WERE ES NAHENDT" kommen dann auf Folio 198 insgesamt achtzehn "instrumenta allerly gattungen zum durchsehen in die weitten, je eines besser als das ander, mit leder, theils mit samet überzogen."[18] Also ein sicher nicht unbedeutender Beleg, daß der Kaiser schon unmittelbar nach der Entdeckung des Fernrohrs mindestens 18 dieser Instrumente in seinem Besitz zur Verfügung hatte. An einer anderen Stelle können wir lesen: "In einem nidern weissen schechtelin ein groß auf einer seitten mugelt glaß, zu den durchsehenden instrumenten oder *stravederi*, dabey noch 3 kleine, welche alle der von Taxis Ihr Mt: von Venedig bringen

[13] *Ibid.*, Nr. 2202.
[14] *Ibid.*, Nr. 2212.
[15] *Ibid.*, Nr. 2203.
[16] *Ibid.*, Nr. 2220.
[17] *Ibid.*, Nr. 2224.
[18] *Ibid.*, Nr. 1293.

lassen."[19] Die Stravederi oder Ferngläser sind im Inventar noch auf einer anderen Stelle erwähnt und zwar auf dem Folio 350 unter den oben schon besprochenen Geräten: "Ein messiner fuß mit einer braitten runden platten und hohem uffrechtem stil, darein man die *stravederi* zum weittsehen richten thut."[20] Und nochmals weiter: "Ein ring, darein man die *stravederi* hefft, mit einer wendenden kugel und schraufen."[21]

Weiter folgen mehrere Gruppen von Spiegeln bezeichnet als "CRISTALLINE SPIEGEL, GLATT ODER IN QUADRO", "STÄHLINE ODER METALLINE SPIEGEL, GLATT IN QUADRO" als auch "RUNDE EINGETIEFFTE AUCH AUSGEWELBTE FEWER ODER METALLINE SPIEGEL". Unter diesen mehr als dreißig Stücken von verschiedener Art, Adjustierung und Größe findet sich auch z.B. "Der gar große metalline Spiegel in quadro, welcher oben auf dem obern gang steht."[22] Aus den Sammlungen Rudolfs II. stammt der enorm große Spiegel, der sich heute im Armeemuseum in Stockholm befindet. Er hat einen Durchmesser von 190 cm und ist mitsamt des Gestells 240 cm hoch. Er wurde im Jahre 1966 auf der Austellung gezeigt, die der Persönlichkeit und den Sammlungen der Königin Christine gewidmet war.[23]

Und zum Schluß – um mit dem Thema dieser Tagung wenigstens einen konkreten Zusammenhang zu präsentieren, möchte ich auf die folgende Eintragung aufmerksam machen, die im letzten großen Abschnitt des Inventars vorkommt, wo nacheinander die Truhen aufgezählt werden, in denen die Bände mit den Zeichnungen, Radierungen und Büchern über alle möglichen Wissenschaftsgebiete aufbewahrt waren. Da steht: "Drei bücher, die 2 geschriben von der hand, das dritte gedruckht *Anth: Tichonis Brahe*, sein alle drey in gulden stuckh gebunden mit seiden nestell und guldenen stefften."[24]

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[19] *Ibid.*, Nr. 1292.

[20] *Ibid.*, Nr. 2274.

[21] *Ibid.*, Nr. 2285.

[22] *Ibid.*, Nr. 1310.

[23] *Christina Qeen of Sweden: a Personality of European Civilisation*, Aust. Kat., Nationalmuseum Stockholm, 1966, Nr. 1/266, "Burning glass on a wooden stand H. 240, Diam. of mirror 1.90, Stockholm, Armémuseum. Provenance: Rudolf II, Christina 1652. The mirror was captured during the Thirty Years War. It was most probably used for chemical and alchemic experiments. By facing the mirror towards the sun, a hight temperature could be generated at its focal point."

[24] Bauer – Haupt, (wie Anm. 3), Nr. 2717.

Tycho Brahe and Prague: Crossroads of European Science, pp. 276–281, J. R. Christianson et al. (eds.), © *H. Deutsch 2002*

The Belvedere in Prague as Tycho Brahe's Musaeum

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For more than ten years, we have had Czech translations of diaries and memoirs written by three French cavaliers who visited Prague in the late 16^{th} and early 17^{th} centuries and noted down their impressions of that which attracted them in the city. The three men were personalities with different backgrounds of education; they pursued different interests and experienced different circumstances when it came to access to the doors of the Imperial Residence. It is, therefore, entirely natural that they viewed Prague Castle from different angles.

Francois de Bassompierre, later a marshal and then a prisoner of the Bastille in Paris, who came to Prague in 1604 left us a captivating account of the conduct, or rather misconduct, of the military and the aristocracy at the Imperial Court.[1] He played real tennis with the courtiers in the Royal Garden and the sole objects of his attention were beautiful women and career opportunities in the Emperor's army. Therefore, his memoirs are of little relevance to the subject of our present research.

Jacques Esprinchard, a young lawyer from La Rochelle, had travelled across half of Europe before he arrived in Prague.[2] Thanks to recommendations obtained through his contacts from Leyden, this educated humanist with a wide range of interests found truly prominent guides at Prague Castle. Bartholomeus Spranger and Hans von Aachen were court painters of Rudolph II and the Emperor's confidants who could take their guest to all those places that were off limits even to many high-ranking official visitors

[1] De Chantérac, *Journal de ma vie. Mémoires du maréchal de Bassompierre.* Première édition conforme au manuscrit original publiés avec fragments inédits, Tome Premier, Paris 1870, p. 132-144. Visit in Prague published in Czech in: *Tři francouzští kavalíři v rudolfínské Praze*, ed. Eliška Fučíková, Josef Janáček, Praha 1989.

[2] Léopold Chatenay, *Vie de Jacques Esprinchard Rochelais et Jornal de ses voyages au XVIe siècle*, Paris 1957. For Czech edition see note 1.

to the Emperor and his Court. Thanks to the two artists, Esprinchard was allowed to see the Emperor's collections in the Palace and he also toured the Royal Summer Palace where – as he mentioned in his notes – he saw outstanding paintings and two life-size statues portraying Mercury and Venus. If there had been any exceptional feature in the decoration of the Summer Palace, Esprinchard – as the erudite humanist scholar that he was – would have certainly noticed it. However, his visit to Prague took place at the time when the construction of the so-called Gallery Building, designed specifically for the Emperor's collections, was nearing completion. Definitive installation of the collections in the new premises was not undertaken until the turn of the century; consequently, it was another French visitor to Prague – Pierre Bergeron – who saw a different decoration of the Summer Palace, undoubtedly adapted to the new installation, in the year 1603.[3] This was not Bergeron's first visit to Prague. Three years earlier, he had already spent several pleasant weeks at the Imperial Court in the company of the cream of the Prague society and officials pursuing diplomatic missions when, as an assistant to Louis Potier, the French Secretary of State, he was a member of a delegation headed by Marshal Urbain de Laval that was sent to Emperor Rudolph II by King Henry IV of France. Bergeron's accounts of lavish feasts, calls on beautiful women and rides across the city provide invaluable evidence on life in the Imperial Residence in Rudolph's times. During his second visit to Prague, Bergeron was no longer so fortunate as to spend it in aristocratic circles. We do not know why he returned to Prague but it is certain that he stayed in the city for only one week and moved around as an ordinary tourist – the doors of palaces remained closed to him. His extensive records reflect his observations concerning the history of the city and the places that he visited; among other things, they include a detailed description of the garden and of everything that could be seen there. "Next to the garden," he says, "there is a graceful palace to which the Emperor occasionally retires when seeking diversion, with several bronze statues inside. The grand hall houses a sculptural group portraying Oreithya being abducted by Boreas; ... In the arcaded galleries on the ground floor of the Summer Palace, you can see countless spheres, globes, astrolabes, quadrants and thousands of other mathematical instruments, mostly of bronze and pewter, and of amazing

[3] Pierre Bergeron, *Voyage d'Allemagne et d'Italie 1600, Voyage à Prague 1603.* Paris, Bibliothèque Nationale, manuscrits français, sign. 5562. Partly published by F. G. Pariset, "Pierre Bergeron à Prague" (1600), in: *Relations artistiques entre les Pays-Bas et l'Italie a la Renaissance.* Études dédiées à Suzanne Sulzberger. Études d'histoire de l'art publiées par l'Institut belge de Rome IV, Bruxelles-Rome, p. 185ff. For Czech edition see note 1.

size. They include analemmata, quadrants, spherical triangles, dioptres and Ptolemy's gauges for precise determination of the altitude, the distance and the constellation of the Sun and stars. They are divided into many smaller parts and into sexagesimal degrees. Various aids for measuring of weight are kept there as well. All this was manufactured in the times of the great Tycho Brahe, Danish mathematician who was the Emperor's guest for a certain period of time. In Prague, Brahe made his interesting and precise astronomical observations and he died here several years ago. In one of the rooms in the Summer Palace, you can see a portrait showing him with Euclid's bust in his hand; portraits of King Alfonso X of Spain, Charles V, Rudolph II and Frederik II, King of Denmark, are placed next to one of the large instruments. Ptolemy, Albategnius, Copernicus and Tycho himself are also portrayed there."[4]

The paintings in the Summer Palace also included portraits of two precious Indian horses donated to the Emperor that had perished. Bergeron mentioned them, too, at the beginning of his notes on the Summer Palace, but it is fairly obvious that he saw them merely as a curiosity that briefly caught his attention. However, he immediately proceeded to a detailed account of the crucial features in the Palace – the astronomical, mathematical and other instruments whose installation together with the portraits of eminent astronomers and patrons of astronomy clearly suggests that after the death of Tycho Brahe, who had conducted his measurements in the arcades of the building, something like a memorial was established in the Summer Palace as a tribute to the distinguished astronomer. It was not a museum in today's sense of the word. After the reinstallation, the Summer Palace housed that part of Rudolph's collections that was dedicated to astronomy and other exact sciences; the articles placed there had practical applications and were used for practical purposes. As was usual also in other sections of the Emperor's collections, the final arrangement combined the articles directly representing individual branches of human activity with a display of other objects – books, works of art, etc. – that were linked to the principal subject either thematically or iconographically and illustrated the historical background or the related symbolical associations. In this case, the latter role was played by the portraits of distinguished astronomers and their patrons, with two paintings of Tycho Brahe himself. Possibly, the sculpture showing Oreithya's abduction by Boreas also signified more than a mere decoration. Unlike Zephyr – a mild west wind favourable to good harvest that was depicted fairly often – Boreas, also one of the most widely known deities of the winds, was represented in art only rarely. This

[4]Translated and quoted from Czech edition, see note 1, p. 83.

stormy north wind, meant to cause the ruin of the Persian fleet, was even the object of a State cult in Athens. As a personified natural phenomenon, it was obviously related to the contemporary purpose of the Summer Palace more closely than the classical deities of Greek or Roman Antiquity.

When studying the inventory of the hall known as the *Kunstkammer* from the years 1607-1611 and the catalogue of the entire collection of 1619, we cannot overlook the fact that they included relatively few astronomical instruments.[5] This is rather surprising in an Imperial Residence where astronomy and astronomical observations received so much attention. Only some articles are listed with the note that they were destined "zum observieren" and, with the exception of certain larger items, they could all be fitted into one cabinet and one desk. We may therefore justifiably conclude that after the reinstallation of the collections the articles placed at the Belvedere were mostly instruments serving practical purposes. The site was suitable for observation and, thanks to the distance separating it from the bustling court, it offered the scholars a quiet environment for their research efforts. Habermel's beautiful instruments may have been perceived rather as artefacts *sui generis* and, therefore, were placed in the *Kunstkammer* but they could be taken out of there if they were actually needed for practical purposes.

Due to a lack of sources of reference, we cannot state precisely how long this astronomical department, or "Astronomical Museum", at the Belvedere remained in existence. At the very end of the year 1627 Johannes Kepler came to Prague to present his *Tabulae Rudolphinae*, that had just been printed, to Emperor Ferdinand II.[6] Here Kepler met with Giovanni Pieroni, Imperial architect, mathematician and astronomer and a pupil of Galilei's. A few days later, at the beginning of 1628, the two men carried out several observations in the Royal Garden. At the same time, Pieroni sent Kepler's *Rudolphine Tables* to Galilei. Shortly thereafter, the two scholars were reunited for a longer period of time in the employ of Albrecht of Wallenstein but that is already another chapter in the history of astronomy and astrology.

Records of a review of the Imperial collections in 1635 indicate that the section previously placed in the Belvedere had already been moved out of there and joined to the other collections in the Gallery Building. Actually,

[5] R. Bauer – H. Haupt, "Das Kunstkammerinventar Kaiser Rudolfs II. 1607-1611", *Jahrbuch der Kunsthistorischen Sammlungen in Wien*, LXXII, 1976; Jan Morávek, "Nově objevený inventář rudolfinských sbírek na Hradě Pražském", (1619) in: *Památky archeologické* (řada historická), nová řada II, 1932, III, 1933, IV/V, 1934/1935.

[6] Z. Horský, *Kepler v Praze*, Praha 1980, p. 227-242; J. Krčálová, "Giovanni Pieroni – architekt?", *Umění*, XXXVI, 1988, str. 511-540.

we can draw this conclusion merely on the basis of the known number of cabinets – at that time, astronomical, mathematical and other instruments filled three cabinets and one chest. Furthermore, an "*astronomisches instrument*" by Jost Bürgi, located in today's Spanish Hall, was mentioned already in an inventory of 1621.[7] Compared with the other instruments placed there, this must have been a large piece. It was probably identical with the large "quadrant" from the catalogue of the *Kunstkammer* that was made by order of the Commission of Protestant Estates in 1619. While the other "quadrants and sextants" were valued at forty to eighty times three-score groschen, the value of this piece was set at 600.

A gradual liquidation of the Rudolphine collections began immediately after Rudolph's death in 1612. The most precious articles from the "scientific" collection were among the items that were gradually transported to Vienna.[8] A part of the objects, especially those from Habermel's workshop, ended up after 1615 in Archduke Albert's collection in Brussels and probably also in possession of other persons who had access to the premises of the *Kunstkammer*.[9] In 1648 Swedish troops took from Prague Castle to Stockholm all those items that could be of interest to their Queen. Bereft of those treasures, the rooms of Rudolph's famous *Kunstkammer* and Gallery offered a sad picture of ruin; however, they were not completely empty.[10]

An inventory made in the Gallery and *Kunstkammer* premises in 1650 states that two large geometrical instruments were kept in the Armoury.[11] It is fairly likely that these instruments were two sextants, manufactured by Habermel and Bürgi, that the Swedes had found unsuitable for transportation because of their large size. According to a 1737 inventory, only the base was left of the former, while the contemporary description of Bürgi's instrument corresponds to its present condition.[12] The situation remained unchanged until the auction under Joseph II in 1782, when both articles were acquired by Franz Leonard Herget, regular public teacher of

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[7] E. Zimmermann, "Das Kunstkammmerinventar der Prager Schatz- und Kunstkammer vom 6. Dezember 1621, nach den Akten des h. und k. Reichsarchiv", *Jahrbuch der Kunsthistorischen Sammlungen des Allerhöchsten Kaiserhauses*, XXV/2, 1905, where also the inventory 1635.

[8] Transports to Vienna published by Zimmermann, quoted in the note 7.

[9] M. de Maeyer, *Albert en Isabella en de schilderkunst*, Bruxelles 1955, p. 316-319.

[10] E. Fučíková, "Das Schicksal der Sammlungen Rudolfs II. vor dem Hintergrund des Dreissigjährigen Krieges", in: *Krieg und Frieden in Europa*, ed K. Bussmann, H. Schilling, Münster / Osnabrück, 1998, 176-180.

[11] K. Köpl, "Urkunden, Regesten und Inventare aus dem K.K. Statthalterei-Archiv in Prag", *Jahrbuch der Kunsthistorischen Sammlungen des Allerhöchsten Kaiserhauses*, X, 1889, II. Teil, Reg. 6231.

[12] *Ibid.*, Reg. 6234

all mechanical and hydraulic sciences.[13] Thus began the last phase in the history of Bürgi's, and Brahe's, instrument that, after a series of subsequent peripetias, eventually ended up in the collections of Prague's National Museum of Technology. This precious article, which – as I have tried to prove in the previous text – obviously never left Prague, has served as a fine memento of the famous era of astronomy at the Imperial Court at Prague Castle.

[13] *Ibid.*, Reg. 6238.

Tycho Brahe and Prague: Crossroads of European Science, pp. 282–291,
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The Comet of 1618: Eschatological Expectations and Political Prognostications during the Bohemian Revolt

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The comet of 1577 is a cause célèbre of the history of science. Tycho Brahe's famous observations of this comet contributed substantially to the breakdown of the Aristotelian model of the cosmos and historians of astronomy have devoted considerable attention to this episode.[1] The comet of 1618 has not such a prominent place in the study of the birth of modern science; nonetheless, it plays an important role in the broader context of the intellectual, religious and political history of the period. As it occured at the beginning of the Thirty Years War, it was considered by many contemporaries to be a portent of this conflict.[2]

The comet of 1618 became the subject of a wide variety of writings published between 1618 and 1620. Ernst Zinner's bibliography of the astronomical literature published in Germany from the mid-15$^{\text{th}}$ century until

[1] See e.g. C. Doris Hellman, *The Comet of 1577: Its Place in the History of Astronomy* (New York, 1944); Victor E. Thoren, "The Comet of 1577 and Tycho Brahe's System of the World", *Archives Internationales de l'Histoire des Sciences* 29 (1979), pp. 53-67; Peter Barker and Bernard R. Goldstein, "The Role of Comets in the Copernican Revolution", *Studies in the History and Philosophy of Science* 19 (1988), pp. 299-319. An important article by J.R. Christianson, "Tycho Brahe's German Treatise on the Comet of 1577: A Study in Science and Politics", *Isis* 70 (1979), pp. 110-140, pays useful attention to political and religious aspects of Brahe's thought on the comet.

[2] For the astronomical context, see Stillman Drake and C.D. O'Malley (eds.), *The Controversy on the Comets of 1618. Galileo Galilei, Horatio Grassi, Mario Guiducci, Johann Kepler* (Philadelphia, 1960). For religious, political and astrological context, see esp. Tabitta van Nouhuys, *The Age of Two-Faced Janus: The Comets of 1577 and 1618 and the Decline of the Aristotelian World View in the Netherlands* (Leiden, Boston and Cologne, 1998); R. B. Barnes, *Prophecy and Gnosis: Apocalypticism in the Wake of the Lutheran Reformation* (Stanford, California, 1988), esp. pp. 168-175, 178-181, 252.

the 1630s gives more than one hundred titles explicitly dealing with the comet.[3] Some of them appeared in the lands of the Bohemian Crown or were written by Bohemian, Moravian and Silesian authors. However, Zinner's list is far from being complete, and it must be supplemented with items compiled from Czech bibliographies and sources.[4] The provisional list of publications on the comet (some 14 titles) demonstrates the important scholarly and cultural position of Wrocław (Breslau) in the ongoing astronomical discussion. Prague with its university, the Palatine court and several printing houses, was another natural centre of such production. Obviously, comets attracted the attention not only of astronomers but also of preachers, physicians, and historians and consequently became a subject of works of various literary genres – scholarly tracts, almanacks, sermons, prognostications, news, broadsheets and pamphlets. Certainly many of them discussed the comet of 1618 in connection with the ongoing Bohemian Revolt.[5] It started with the famous defenestration of Prague in May 1618, only half a year before the appearance of the comet, and developed into the anti-Habsburg uprising of the Protestant Estates which was finally defeated at the Battle of the White Mountain two years later.

Let me now focus on four works published in Bohemia during the discussed period. Their authors, Daniel Basilius (1585-1628), Andreas Haberweschel of Habernfeld (before 1590-after 1645) and Simeon Partlicius (ca 1590-after 1640) were all Protestant intellectuals of burgher origin sympathetic to the uprising of the Protestant estates. I will especially focus on political prognostications based on astrological parts of their works but will also trace a position of each of the authors in the discussion of the nature of comets and particularly in one case in relation to Tycho Brahe's cometary theory.

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[3] Ernst Zinner, *Geschichte und Bibliographie der astronomischen Literatur in Deutschland zur Zeit der Renaissance* (2. Auflage, Stuttgart, 1964), esp. pp. 369-383.

[4] Čeněk Zíbrt, *Bibliografie české historie* I (Prague, 1900), Nos 1240-1251, IV (Prague, 1909), Nos 4503-4530; another indispensable source of information is Josef Hejnic and Jan Martínek (eds.), *Enchiridion renatae poesis Latinae in Bohemia et Moravia cultae / Rukověť humanistického básnictví v Čechách a na Moravě*, 5 vols. (Prague, 1966-1982), hereafter abbreviated as *RHB*.

[5] An account of chiliastic prophecy in Bohemia which is not focused on the comet of 1618 gives an important article Nicolette Mout, "Chiliastic Prophecy and Revolt in the Habsburg Monarchy during the Seventeenth Century" in Michael Wilks (ed), *Prophecy and Eschatology* (Oxford and Cambridge, Mass., 1994), pp. 93-109, esp. 97-102 (on Bohemia). For an interesting example of a Polish treatise on the 1618 comet reacting to the defenestration of Prague, see Andrzej T. Klubiński, "'Ukrutní Čechové ...' Pražská defenestrace v polském astrologickém tisku (Funkce popisu)", *Kuděj* 2000, No 2, pp. 9-20.

The doctor of laws and professor of physics, Daniel Basilius of Deutschenberg, came to Prague from Upper Hungary (present-day Slovakia) probably between 1600 and 1609. From 1609 we have evidence of his scholarly career which was closely tied up with the University of Prague where he studied and, from 1615, taught. In 1616, 1619, and 1621 he was elected dean of the Faculty of Arts. After the transfer of the university to the hands of Jesuits, he converted to the Catholic faith and continued his career as a wealthy burgher of the Lesser Town of Prague until his premature death.[6]

From 1615 Basilius taught arithmetic, geometry, physics and astronomy at the university. The compilation of almanacks also belonged among his duties. Therefore, it was natural that soon after the appearance of the comet at the end of November 1618 he published his little treatise in Czech *Soud hvězdářský přirozený: O strašlivé s ocasem kométě* (A natural astronomical judgement: On a terrifying comet with a tail). A German translation followed the same year.[7]

The treatise is divided into three parts dealing 1) with comets in general, 2) with the comet of 1618, and 3) giving a chronological list of cometary appearances from the fifth century BC until 1596. Basilius's account of the nature of the "hairy stars" was firmly based on Aristotelian theory of comets as burning terrestrial vapours and exhalations.[8] The explanation of the origin of comets was meteorological; according to Basilius they usually appeared in the autumn after a hot and dry summer.[9] As regards the effects of comets, he followed the authority of Ptolemy and from the modern scholars he quoted Girolamo Cardano. It might seem surprising that he chose Cardano who had been an opponent of Aristotelian cometary theory and believed that comets were located above the moon. But he followed Cardano's classification of the effects taken from his *Aphorismi astronomici*

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[6] On Basilius's life and work, see *RHB* I, pp. 168-173; and most recently Eva Frimmová, *Daniel Basilius (1585-1628)* (Bratislava, 1997).

[7] *Soud hvězdářský přirozený: O strašlivé s ocasem kométě, kteráž se po velikém proti sobě patření Slunce s Hladolétem 28. dne měsíce listopadu, na znamení Váhy, v létu tomto bouřlivém a zkormouceném 1618 vyskytla. ... Vytištěný v Praze u Jana Stříbrského* [1618]. I have used a copy of the National Library, Prague (NK: 14 J 139/3). The dedication was dated as early as 30 November 1618, which was only two days after Basilius had seen the comet (*ibid.*, fol. A2a). Cf. *Knihopis českých a slovenských tisků od doby nejstarší až do konce XVIII. století* II/2 (Prague, 1941), No 998, p. 27. *Astronomisch gut düncken. Von dem schrecklichen Cometen ... Aus dem Böhmischen ins Deutsche verfertiget. Gedruckt zu Prag bey Johann Stribrsky* [1618]. I have not consulted this version. Cf. Frimmová, *Daniel Basilius*, pp. 121, 123.

[8] *Soud hvězdářský*, fol. A4b.

[9] *Ibid.*, fols. A4b-B1a. Such exhalation and fume from the burning Vltava river-side in Prague in the autumn 1617 contributed, according to Basilius, to the genesis of the comet.

(1547), and not his explanation of the nature of comets found in *De subtilitate* (1550).[10] Basilius, however, did not mention Tycho Brahe's discussion of comets.

Basilius's prognostications took just a small part of his work and dealt with the short term – the coming year 1619. He predicted in a very traditional way meteorological changes (winds), pestilence and various dissensions. He also suggested that the comet revealed the imminent death of a great prince or monarch.[11] According to Basilius, the position of the comet in relation to the constellation of Leo showed that the next year 1619 would be difficult mainly for the Kingdom of Bohemia but the end of that year and the beginning of 1620 would see a victory of the Bohemian Lion over the enemies.[12] The form of these predictions is quite simple and similar to those published usually in almanacks. There is no direct reference to political development or allusion to the situation in the autumn of 1618 with perhaps one exception: the prediction of the death of a monarch might have been an allusion to the illness of the emperor Matthias.

Only a few months after the publication of Basilius's treatise, a polemical reaction appeared under the title *De asterisco comato magico theosophica Consideratio* after March 1619. It was an anonymous book without any indication of place of publication or publisher.[13] At least some contemporaries, however, recognized the anonymous disputant and even Basilius might have known his identity. According to Georg Rem, a humanist from Nuremberg (Nürnberg) and acquaintance of many educated Bohemians, the author of the *Consideratio* was a Prague physician Andreas Haberweschel (Ondřej Habervešl) of Habernfeld.[14]

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[10] *Ibid.*, fols. B3a-B3b, B4b. Basilius also quoted from two medieval Arabic authors Al-Battani and Haly Abenragel (Ibn Abi al-Rigial) (*ibid.*, fols. B1b, B4b, C1a). On Cardano's cometary theory cf. VAN NOUHUYS, *The Age of Two-faced Janus*, pp. 85-87.

[11] *Soud hvězdářský*, fol. B4b.

[12] *Ibid.*, fol. C1a.

[13] *De asterisco comato magico theosophica Consideratio. Cum Praefatione admonitoria de absurdis cujusdam immaturi astrophaebi, quae de cometa ad diem 4. Novemb. Anni 1618 apparenti, conscripserat. Et magico politico quodam Bohemi leonis nivei sub finem annexo consilio. Currenti calamo depicta per H.F.C.M.A.D.C.H.R. Anno MDCXIX.* I have consulted a copy of the National Library, Prague (NK: 49 D 57). The exact time of appearance of the book is unclear. While the title page has a year 1619 and the dedication is dated in March 1619 (fol. a1a), one of the poems printed in the book is dated February 1620 (fol. a3b).

[14] There is no space here to analyze possible meanings of the initials from the title page of the *Consideratio* which are printed in a circle but the letters HAH which form vertical axis of the circle might mean Haberweschel ab Habernfeld. For the identification of Haberweschel by Rem, cf. *Epistola consolatoria celeberrimi viri domini Georgi Remi ... ad Cl. M. Petrum Fradelium* (Pragae, s.a. [1620]), the copy of the National Museum Library, Prague (KNM: 49 B 44/9). Petrus Fradelius was a prorector of the University

To place the dispute within its proper context, I must say few words about the career of Haberweschel.[15] He was born at the end of the 1580s into a Prague patrician family. From 1606 he studied medicine at the University of Helmstedt, then continued in Basle where he took his doctorate in November 1609.[16]

In the 1610s he lived in Prague and established himself as a physician. In 1614 he took part in discussions of Rosicrucian tracts. Haberweschel's reply to the first Rosicrucian manifesto, the famous *Fama fraternitatis*, was dated 1 September 1614 but its original has not survived. Nowadays it is known from the Dutch edition of the *Fama*, published most probably in 1615, which includes several replies to the manifesto. Haberweschel considered the *Fama* to be a magico-cabbalistic tract and hoped that the Rosicrucian fraternity would gain the Light of Grace through the Light of Nature.[17] We can find similar allusions to the mysticism of Light in his *Consideratio* on the comet of 1618.

The content of polemic was partly known from Basilius's reply but Haberweschel's *Consideratio* has been considered lost until recently.[18] I

of Prague and a close friend of both Remus and Basilius.

[15] As far as I know, there is no single biographical study on Haberweschel. He is well known as the author of historico-political work *Bellum Bohemicum* (Leiden, 1645). See esp. Bedřich Šindelář, *Vestfálský mír a česká otázka* (Prague, 1968), pp. 125-8, 141-2; and *Historie o válce české 1618-1620. Výbor z historického spisování Ondřeje z Habernfeldu a Pavla Skály ze Zhoře*, ed. J. Polišenský (Prague, 1964). For further bibliography cf. *Lexikon české literatury. Osobnosti, díla, instituce* 2/I (Prague, 1993), pp. 15-16; and work by Gellner cited below, note 18.

[16] P. Zimmermann (ed.), *Album Academiae Helmstadiensis*, vol. 1 (Hannover, 1926), p. 187; H.G. Wackernagel (ed.), *Die Matrikel der Universität Basel*, 5 vols. (Basel, 1951-80), iii, 1601/02-1665/66, p. 97. Haberweschel matriculated in Basle as 'Andreas Hobrweschel de Hobrnfeld, Pragensis' in January 1609.

[17] "Ontdeckinghe van een onghenoemde Antwoorde op de Famam Fraternitatis des Rosen-Cruyces, van een Autheur der Hermetischer Medicijn-konst toeghedaen ... Andreas Hoberveschel van Hobernfeld etc. ... Tot Praghe den 1 Septembris 1614," in *Fama Fraternitatis ...* (s.l. [Amsterdam], s.a. [1615]), fols. K3r-K6r. I would like to thank Dr. Henk van Oort and Dr. Govert Snoek for sending me a xerocopy of this rare document. Cf. the introductory study by Carlos Gilly to the new edition of *Fama Fraternitatis* (Haarlem, 1998), pp. 51-53; G.H.S. Snoek, *De Rozenkruisers in Nederland voornamelijk in de eerste helft van de 17e eeuw. Een inventarisatie* (Dissertation – Utrecht, 1997), pp. 35-36, 51-52; and an exhibition catalogue *Johann Valentin Andreae 1586-1986. Die Manifeste der Rosenkreuzerbruderschaft* (Amsterdam, 1986), No 22, pp. 74-5.

[18] Čeněk Zíbrt still included the *Consideratio* in his *Bibliografie české historie* I, No 1246. Later authors considered it lost; see esp. Gustav Gellner, *Životopis lékaře Borbonia a výklad jeho deníků* (Prague, 1938), pp. 161-162, n. 5; *RHB* I, pp. 171-172. The most recent work that discusses the polemic is Frimmová, *Daniel Basilius*, pp. 59-66. Frimmová does not know Haberweschel's work, but only a later reply by Basilius (see below, note 25).

have found a (probably unique) copy in the National Library in Prague, and the following section of my paper presents this work for the first time.

The treatise is divided into ten parts, including a long preface which is, in fact, a sharp polemic with Basilius.[19] Haberweschel attacked twelve points of Basilius's cometary theory and commented on them with corrosive irony. He rejected the theory of burning terrestrial vapours, flouted an opinion that comets appeared usually in the autumn and questioned also several of the comet's effects described by Basilius.

His own position is difficult to establish in astronomical terms because it seems that his main purpose was to place the comet in an eschatological and apocalyptic framework. He sketched an analogy between the biblical new star which had announced the birth of Christ, and the new comet which should have been a sign of his Second Coming. Haberweschel was aware of similar speculations about the new stars of 1602 and 1604, perhaps even of Kepler's fascination with this topic.[20] However, for Haberweschel an astronomy based only on measurements was a "Pharisaic art", while *astronomia prophetica* derived from Scripture could reveal arcane wisdom.[21]

Haberweschel identified Frederick of the Palatinate with the Lion of the North who, according to the biblical prophecy, would defeat the Eagle.[22] The symbolism was obvious: Frederick was elected by the rebellious Estates as King of Bohemia in August 1619, five months after the presumed publication of Haberweschel's book,[23] and many Protestant enthusiasts, like Haberweschel, expected that the king would defeat the Catholic Emperor. According to the apocalyptic expectations, these political events would prepare the way for the Second Coming of Christ, and this was considered to be the main message of the comet of 1618.[24]

Haberweschel's book provoked a scathing reply from Basilius in his second treatise *Lixivium pro abluendo male sano capite anonymi* published the following year.[25] The book was dedicated to Petr Mülner of Mülhaus,

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[19] *Consideratio*, Praefatio admonitoria, fols. B1a-E1b.

[20] *Ibid.*, fols. E4a-E4b. On Kepler's comparison of the star of Bethlehem with the new star of 1604, see most recently HOWARD HOTSON, *Paradise Postponed: Johann Heinrich Alsted and the Birth of Calvinist Millenarianism* (Dordrecht, Boston, and London, 2000), pp. 44-45; cf. also ZDENĚK HORSKÝ, *Kepler v Praze* (Prague, 1980), pp. 171-175.

[21] *Consideratio*, fols. M2a-M3a.

[22] *Ibid.*, fols. L3a-L3b. For the main source of the prophecy of the Eagle and the Lion, see the 4th book of Ezra 11-12; cf. HOTSON, *Paradise Postponed*, pp. 57-60.

[23] For possible doubts about the exact time of publication of *Consideratio*, cf. above note 13.

[24] For a broader context and other figures of similar views see BARNES, *Prophecy and Gnosis*, passim and esp. pp. 199-202, 223-226; HOTSON, *Paradise Postponed*, pp. 59-60.

[25] *Lixivium pro abluendo male sano capite anonymi cuiusdam pseudosophi, qui tracta-*

one of the Protestant *directores* at the beginning of the Bohemian revolt and a vice-chancellor of the kingdom during the reign of Frederick of the Palatinate.[26] In his polemic, Basilius received strong support from his colleagues from the university – especially Jan Campanus and Petr Fradelius – who extolled him in Latin poems printed in his tract.[27] Basilius defended his Aristotelian position, accused the anonymous author of cabbalism, branded him a "pseudosoph, theosoph, cacosoph, moromagus" and even proposed that he be quartered as a traitor.[28] This call for a capital punishment might appear to be a mere rhetorical strategy to intimidate an opponent or an extremely affected expression of Basilius's hate for his opponent. But in the context of the ongoing civil war, the attack on the dean of the University might have been viewed as a dangerous lack of confidence in the authorities. The closing section of the book, which might have been written by a different author, contains a suggestion that Haberweschel was influenced by the theosophical learning of Paul Nagel, a Lutheran dissenter whose apocalyptic astrology certainly had features in common with Haberweschel's tract.[29]

It is difficult to answer the question whether this intellectual quarrel had any deeper political background. Both of the disputants were adherents of the Revolt. Differences appear if we compare dedications of their works. Haberweschel sought patronage in courtly circles, interested in the hermetic arts. His book on the comet was dedicated to Christian of Anhalt, the leading Palatine politician and diplomat who became the commander-in-chief of the Bohemian estates army.[30] After the battle of the White Mountain, Haberweschel left Bohemia in the entourage of king Frederick and later he lived at the exiled Palatine court in the Hague. Basilius, on the other hand, found his patrons among the rich burghers of Prague and

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tu Considerarationis (sic) *suae de Asterisco Comatomagico conscriptae in praefatione admonitoria scriptum modestum de cometa anno 1618 apparente conceptum virulento perstringit calamo Praeparatum studio Danielis Basilii de Deutschenbergk Academiae Pragensis Mathematum Professoris pub. Cum adnexa sub finem scommatum analysi de statu controversiae. Pragae typis Pauli Sessii, typographi academici. Anno 1620.* I have used the copy of the National Museum Library, Prague (KNM: 49 B 44/7). Cf. *RHB* I, pp. 171-172; and FRIMMOVÁ, *Daniel Basilius*, pp. 60-65.

[26] *Lixivium*, fols. 2a-4b. The dedication is dated 1 June 1620.

[27] *Lixivium*, fols. F2a-F4b, Iab.

[28] *Lixivium*, fols. A1b, B2a, E2b, D4b.

[29] *Lixivium*, fols. E1b-F1b, F1b (on Nagel). On Nagel, see BARNES, *Prophecy and Gnosis*, esp. pp. 177-180, 245. One of Nagel's prognostications was translated into Czech and published in Prague, see *Knihopis* II/5, No 6001.

[30] Anhalt patronized such outstanding Paracelsian physicians as Oswald Croll and Michael Maier. Cf. FRANCES A. YATES, *The Rosicrucian Enlightenment* (London, 1972), pp. 53, 81-82.

Kutná Hora and was firmly rooted in the burgher milieu. For his response to Haberweschel, he turned to the more influential patron – Petr Mülner of Mülhaus.

The burgher milieu was also important for the third intellectual, Simeon Partlicius.[31] Partlicius was born into a Protestant family in the small Moravian town of Třešť around 1590. He studied at the Lutheran gymnasium of Görlitz in Lusatia and later continued his studies at the University of Prague under Martin Bacháček of Nauměřice, a leading figure of Bohemian academic life of the period, mathematician and a close friend of Kepler. While still a student, Partlicius became a teacher at several Latin schools in Bohemian towns and later was engaged as a praeceptor in the prominent Bohemian Lutheran family of the Lords of Fels whose members belonged among the leading figures of the Bohemian Revolt. Partlicius accompanied the young Lords of Fels on their studies in Germany, and it was in Penig, near Chemnitz, where he made his observations of the comet.[32]

The next year, in 1619, he was back in Bohemia, became an administrator of the school in Hradec Králové and published there his *Tractatus Cometographicus*, dedicated to the leaders of the Estates revolt, the twenty seven *directores* – nine of whom were lords, nine knights and nine prominent burghers.[33] The dedication was written in May and mentioned the Diet of March 1619, where opponents of the Revolt were accused of betraying the *patria*. Thus for Partlicius, as for Haberweschel whose tract was published probably about the same time, political context was very important.

In nine chapters the author not only discussed comets in general and the comet of 1618 in particular, he also defended astrology while giving scholarly support to the Revolt and establishing its place in a historico-

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[31] The fundamental biographical work on Partlicius remains that by J. Smolík, *Časopis Českého Musea* 45 (1871), pp. 319-325; 46 (1872), p. 461. For other relevant works, see *RHB* IV, pp. 101-107. Cf. also recent articles Vladimír Urbánek, "Simeon Partlicius and His Works: Rudolfine Mood in Bohemian Exile", in L. Konečný, B. Bukovinská, and I. Muchka (eds.), *Rudolf II, Prague and the World* (Prague, 1998), pp. 291-296; id., "Simeon Partlicius a jeho příspěvek k politickému myšlení doby bělohorské", *Studia Comeniana et historica* 29 (1999), Nr. 62, pp. 61-75; id., "Proroctví, astrologie a chronologie v dílech exulantů Paula Felgenhauera a Šimona Partlice", in M. Hrubá (ed.), *Víra nebo vlast? Exil v českých dějinách raného novověku* (Ústí nad Labem, 2001) pp. 156-173.

[32] *Tractatus Cometographicus. O dvou nových hvězdách aneb kometách, které se spatřovali na konci roku MDCXVIII. Item o jejich a zatměních měsíce oučincích, které se povlekou až do léta 1624 ... Sepsaný a vydaný od Magistra Simeona Partlicia, ...* [Hradec nad Labem, 1619], fol. F5b. I have used the copy of the National Museum Library, Prague (KNM: 28 F 15).

[33] *Tractatus Cometographicus*, Dedicatio.

astrological chronology of world history. In his defence of astrology, Partlicius built on the Paracelsian theory of macrocosmos and microcosmos and on the views of Philipp Melanchthon.[34]

He examined the theories of various scholars on comets including Julius Caesar Scaliger, Franciscus Vallesius, Tadeáš Hájek of Hájek, Bartholomeus Scultetus of Görlitz, and Tycho Brahe. Partlicius admitted that he had not believed in the possibility of the appearance of new stars and comets in the firmament but was convinced by certain authors including Brahe as well as by his own observations of the 1618 comet.[35] In fact, Partlicius took a compromise position: according to him, there were two types of comets. The first was basically Aristotelian, located in the sublunary region and created of vapours, the second belonged to superlunary bodies and its matter was not created from the elements but from the ether.[36] Here Partlicius explicitly quoted Brahe's opinion (to which he inclined) that comets consisted of heavenly matter.[37]

Accordingly, trying to explain his own observations, Partlicius suggested that there appeared two comets in 1618. He located the first, that of November 1618, in the air and the second, which according to him appeared in December, in the firmament, the eighth heavenly sphere.[38] This solution was based on comparison of ten cometary features but also on parallax measurements.[39]

The effects of these two comets also differed. The short-term effects of the first were quite similar to those predicted by Basilius and many other authors. The comet would bring war, disease and epidemics (especially in Bohemia and neighboring lands) and meteorological phenomena such as intense frost and heavy snow. Partlicius did not forget to point out the deaths of Bohemian Queen Anne of Tyrol and King (Emperor) Matthias, which had been presaged by the hairy star.[40] The effects of the second comet seemed to be less dire. Partlicius predicted a new king of Bohemia who was to be elected at the end of 1619 or the beginning of 1620. This hero would bring justice and new laws. After a period of calamities, the Czech nation would enjoy improved fortune, gaining strong allies and an

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[34] *Ibid.*, fols. B7b-C1a. For Melanchthon, cf. S. CAROTI, "Melanchthon's Astrology", in PAOLA ZAMBELLI (ed.), *"Astrologi hallucinati": Stars and the End of the World in Luther's Time* (Berlin and New York, 1986), pp. 109-121.

[35] *Tractatus Cometographicus*, fol. E2b.

[36] *Ibid.*, fols. D8a-E2b (sublunary comets), E2b-E5a (superlunary comets).

[37] *Ibid.*, fols. E7b-E8a.

[38] *Ibid.*, fols. F5a-F6b, G2a-G4b.

[39] *Ibid.*, fols. E4b-E5a, F6a-F6b, G4b.

[40] *Ibid.*, fols. F6b, G1b.

enhanced reputation.[41]

This optimistic short-term prognostication was incorporated into the larger chronological and apocalyptic scheme. Apart from the traditional chronology of four monarchies and the idea of fatal periods corresponding to the conjunctions of planets, Partlicius employed another periodization, dividing world history into twenty four stages.[42] According to this scheme, the twenty third period began in 1453 with the fall of Constantinople, while its end, accompanied by great changes, was heralded by the comets of 1618 and the Bohemian Revolt. The predicted new Bohemian king would play an important role in the twenty-forth period, beginning in 1621 or 1624, since he would defeat both the Turks and the Roman Antichrist.[43] In this final period, the Jews and heathens would convert to the Christian faith and this would be a sign of an imminent end of the world.[44]

Although the eschatological expectations of Partlicius were as high as those of Haberweschel, he differed substantially from the latter in his attempt to create a comprehensive chronology based on sacred and profane history as well as on the astronomical cycles of the great conjunctions.[45] His treatise on the comet was written in Czech and therefore afforded the opportunity to present various opinions on comets, including some ideas of Tycho Brahe, to a broader readership.

To conclude I must stress that the three intellectuals I have discussed were not especially important in the history of science. Around 1620, Bohemia had no astronomer comparable to Tadeáš Hájek of Hájek, the leading scholar of the Rudolfine era. My purpose has been to show that they were interesting representatives of broader intellectual currents in post-Rudolfine Bohemia: Basilius represented traditional natural philosophy, Haberweschel a mystical current and Partlicius a late Renaissance tendency to harmonize all learning in such projects as encyclopedias or universal comprehensive chronologies.

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[41] *Ibid.*, fols. E7b, G5a, G6b, G7b.

[42] *Ibid.*, fols. I7a-K1b, H8b-I6a.

[43] *Ibid.*, fols. I6a, G7b. For other astrological speculations on the downfall of the Antichrist, see Barnes, *Prophecy and Gnosis*, pp. 168, 174, 226.

[44] *Tractatus Cometographicus*, fols. M1b-M2b.

[45] Partlicius devoted to the chronology of great conjunctions his later work *Metamorphosis mundi* (Leiden, 1626). See Urbánek, "Proroctví, astrologie a chronologie v dílech exulantů Paula Felgenhauera a Šimona Partlice", pp. 156-173.

Tycho Brahe and Prague: Crossroads of European Science, pp. 292–301,
J. R. Christianson et al. (eds.), © *H. Deutsch 2002*

The Relations between Tycho Brahe and the Jesuits in Prague

Georg Schuppener, Leipzig

General remarks

Only a few years Tycho Brahe worked as an imperial astronomer at the court of Rudolph II in Prague until his death there in 1601. In cooperation with his assistant Johannes Kepler he continued his former detailed observations of the planets and the stars during these years in Prague. His results built the basis for the later discovery of the three planetary laws of Kepler.[1] However Brahe's importance in the history of astronomy consists not only of the precision of his observations and of his role as a mentor of Kepler, but also of his trial to preserve the idea of a geocentric planetary model. The importance and the deep influence of that kind of model on the astronomical thinking, especially in the first half of the 17th century, results from religious doubts against Copernicus' new heliocentric planetary model. The Catholic Church did not accept the idea of the Sun, and not the Earth as the center of the cosmos.[2]

In fact the observations of the 16th century, and especially those of Brahe, have shown that the traditional geocentric planetary models were not able to explain all of the data, beginning with the movement of the planet Mars.

As a consequence of this the only chance to keep a geocentric system was to modify it. Such a modification of the former system is the one of Brahe: he combined both systems by constructing his system with the Moon and the Sun having their orbits with the Earth in the center, but the known planets Mercury, Venus, Mars, Jupiter and Saturn with heliocentric orbits.

This kind of planetary model, which includes still the position of the Earth as its center, fascinated religious astronomers, especially in the

[1] Cf. Gottwald – Ilgauds – Schlote, p. 73f.
[2] Cf. Nový, p. 69f.

Catholic world, first of all the Jesuits. Most of the Jesuits did not accept fundamental changes of the traditional geocentric conceptions of Aristotle and Ptolemy. As late as the end of the 16th century the most famous Jesuit mathematician of this time, Christopher Clavius, presented in his *Sphaera* (Venice, 1596) a completely traditional model of the cosmos with the Earth at the center of the spheres.[3] At the beginning of the 17th century other Jesuits accepted Brahe's modified geocentric planetary model and integrated it in their astronomical work.[4] His model remained the accepted one for a long time, though some Jesuits expressed their sympathy for Copernicus' heliocentric system even in the middle of the 17th century.[5] Some years after Brahe the Jesuit Riccioli developed a rather similar planetary model. Jesuits and other Catholic astronomers used both models in their considerations.[6]

In the Catholic world during the 16th, 17th and 18th centuries, it was primarily the Jesuits, who were engaged in astronomy.[7] Especially in Bohemia during and after the Counter-reformation Jesuits played an important role in astronomical observation and research. Good examples for this phenomenon are the Jesuit astronomers Georg Schönberger (1597-1645), Valentin Stansel (1621-1705), Johannes Zimmermann (1632-1701) and Joseph Stepling (1716-1778).[8]

The Jesuit academy in Prague and Brahe

Because the court of Rudolph II in Prague, where the first Bohemian college and later academy of the Jesuits had been founded in 1556, was the last station of Brahe's life and work, it seems to be a relevant question, how the relations between Brahe and the Jesuits in Prague were. At the first view this question could be answered very quickly and simply: No evidence for direct contacts between Brahe and the Jesuits in Prague could be found in the archives. The same fact can be seen in the (not existing) relations between Kepler and the Jesuits in Prague a few years later.[9]

The reason for this fact is that during the Rudolphinian era mathematics and astronomy were only on a very elementary level at the Jesuit academy.

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[3] Cf. Lattis, p. 39.

[4] Cf. e.g. Krayer, p. 135ff. Some examples that Jesuits preferred the system of Brahe are given by Toepell, pp. 66, 77.

[5] Cf. Russo, p. 865.

[6] Cf. Nový, p. 70f., Lerner, p. 150ff.

[7] Cf. Schreiber, passim.

[8] Cf. Nový, p. 70ff., Wydra, passim, Čornejová – Fechtnerová, passim.

[9] Cf. Schuppener, p. 57ff.

Mathematical lessons were indeed part of the educational curriculum at Jesuit colleges in that time and at the Jesuit academy in Prague, too, but a special interest in astronomy first grew at the Prague Jesuit academy some decades after Brahe's death, probably in the 1630's and 1640's. Just this later development of astronomical interest bears the basis for a deeper and more intensive reception of Brahe's scientific work at the Jesuit academy in Prague.

Now, a short overview of the influence of Brahe's planetary model in Jesuit astronomy in Prague should be given:

The first relevant sources, which show this influence, are the manuscripts and printed books preserved in the National Library at the so-called Klementinum, the former Jesuit college and academy of the Old Town of Prague. The library at the Klementinum owns approx. 20 manuscripts from the 17th and the first half of the 18th century dealing with mathematical and astronomical topics, written by Jesuits. Finally the historical fundus of the Jesuit library contains an uncounted number of printed mathematical and astronomical books, surely more than 300. Under those are some, which belonged originally to Brahe's library and came later into the ownership of the Jesuit library in Prague.

At the Jesuit dominated universities in Prague and Olomouc (Olmütz) the geocentric concept of the cosmos was prevalent until the middle of the 18th century.[10] During the 17th century a significant number of Jesuit astronomers recognized that the traditional opinion about the planetary system had to be changed. By accepting the model of Brahe they were able to avoid problems between the official position of the Catholic Church and the observational results of the newer astronomy.[11] Therefore in Prague these differences and developments are reflected in the astronomical manuscripts of the Jesuits. So it is evident that there was a great interest on the part of the Jesuits in Brahe's astronomical results. Prominent Jesuit mathematicians and astronomers who were taught in Prague like Valentin Stansel, also used this model as a basis for their considerations. Stansel, who was born in Olomouc, was a professor for mathematics at the Jesuit academy in Prague and later spent the major part of his life as a missionary in Brazil.[12]

The example of Stansel shows that not only Brahe's planetary model influenced Jesuit astronomers, but also the other parts of his astronomical work. Stansel, for example, accepted Brahe's explanation of the comets

[10] Cf. Horský, p. 241.

[11] Cf. Casanovas – Keenan, p. 323.

[12] About his astronomical observations cf. Casanovas – Keenan, p. 319ff.

and based the conclusions of his own observations on it.[13]

Brahe's planetary model in Jesuit manuscripts in Prague

One interesting manuscript in this context is entitled *Tractatus Astronomicus De Planetis*. This manuscript on ff. 1r-54v is the first part of the volume with the signature XII G 9 c.[14] The additional remark on the front page "Dictante R. P. Joanne Hancke exceptus et scriptus a Casparo Pfliger" shows who the author was. Caspar Pfliger (1665-1730) and Joannes Hancke (1644-1713) worked as professors of mathematics at the Jesuit college in Prague. The manuscript includes comprehensive remarks on the technique of astronomical observations and a lot of observational data. Further, several opinions about the movement of the planets are discussed there. In the discussion the geocentric planetary models of Brahe and Riccioli play the main role. As a consequence of that the Sun and the Moon are treated like planets in the whole manuscript.

Rather similar is the situation in the case of the manuscript XII G 28.[15] This manuscript was written in the beginning of the 18th century and contains a treatise about astronomy divided in two greater parts (83 ff.), some additional remarks (ff. 83v-95r) and a treatise on optics (ff. 96r-126r). An explicit reference to Brahe is given mainly in the third and fourth paragraph of the treatise about astronomy (ff. 36v-44r, 44r-57v). First, the most important different planetary systems are described there, also that of Copernicus. In the following chapters it seems to be evident that the author prefers the model of Brahe. The manuscript is without any doubt of Jesuit origin, though the author's name is not given in the manuscript.

Several mathematical and astronomical lectures are collected in the manuscript XII G 6.[16] They were written in Olomouc and Wrocław (Breslau) between 1668 and 1691. The Jesuit author of this manuscript compares the planetary models of Ptolemy, of the Egyptians, of Copernicus and Brahe in a treatise with the title *Sphaerosophia Cosmo-Astronomica* (ff. 181r-206r). At least he concludes that the one of Brahe would be the best of all.

Brahe's astronomical work is also cited in another Jesuit manuscript, which is served under the signature XIV G 26 in the National Library in

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[13] Cf. Casanovas – Keenan, p. 324.
[14] Cf. Truhlář, II, p. 207.
[15] Cf. Truhlář, II, p. 211.
[16] Cf. Truhlář, II, p. 206.

Prague.[17] The manuscript is written in the 17th century and contains on ff. 40r-65r a *Tractatus physicus de meteoris*, in which several observational data of Brahe and Kepler from the end of the 16th and the beginning of the 17th century are cited and discussed. This and some other hints make it possible that the text is written in Prague.

Another interesting manuscript of a Jesuit author is preserved in the library of the monastery Strahov in Prague under the signature DD IV 22. The author of this work, with the title *Apiaria Mathematica*, was Matthaeus Coppylius (1642-1682). He presents all the different planetary models and also those of Copernicus, Brahe and Riccioli. In this manuscript he did not show any preference for one of these, but in his *Cursus Mathematicus* he manifested his sympathy for Brahe's system.[18]

Furthermore, in astronomical printed books written by Jesuits there are several references to Brahe, especially to his planetary model. Some examples can be given here: Valentin Stansel discussed the different planetary models in his books, and indeed he preferred the one of Brahe.[19] He also knew Brahe's observations of comets and cited them in another work.[20] Georg Schönberger, first professor in Freiburg, then in Prague, too, based major parts of his important work *Sol illustratus* on Brahe's planetary model and his observations.[21]

Books from Brahe's library in the Jesuit library

Many years after Brahe's death his heirs handed over the remains of his library to the Jesuits in Prague. The heirs of Brahe lived in serious financial problems, and it was their only possibility to sell instruments and books from their inheritance.[22]

On the other hand in the period of the Counter-Reformation the financial resources of the Jesuits in Prague grew rapidly. But it is a fact that parts of the library have been given to the Jesuits in Prague and Chomutov (Komotau) as a donation.[23] Furthermore, in the fourth decade of the 17th century some well educated Jesuits improved the status of scientific research and education at the Jesuit academy at the Klementinum.[24]

[17] Cf. Truhlář, II, p. 337.
[18] Cf. Mačák – Schuppener.
[19] Cf. Stansel (1685).
[20] Cf. Stansel (1683).
[21] Cf. Schönberger.
[22] Cf. Šolc, p. 150.
[23] Cf. Kleinschnitzová, p. 76.
[24] Cf. Schuppener, p. 69f.

These reasons explain why the Jesuits had enormous interest in parts of Brahe's library. In this way the books came into the Klementinum.[25] In 1642 the volumes were inscribed in the catalogue and in the 18$^{\text{th}}$ century they were integrated in the collections of the so-called "Mathematical Museum".[26]

Though the books from Brahe's library constitute the biggest known preserved part with more than 110 printed books and 5 manuscripts in 52 volumes altogether, it is quite certain that those are only a small fraction of the former library of Brahe.[27] The printed books contain nearly all of the most important astronomical publications of that time.[28] Especially some very rare books are included in this collection.[29] Further there are works on geography, history and astrology. Publications with literature and poems are almost completely missing, a remarkable fact, because Brahe had a good knowledge of this field.[30] Possibly the Jesuits had no interest in those works of literature when they got the books, or Brahe's family did not want to sell them.

The small section of the Klementinum library, originally depending on Brahe's ownership, is very well analyzed. Books from Brahe's library came not only into the Jesuit library in Prague, but also into several other important libraries all over Central Europe. Even from those books, which were first integrated in the Prague Jesuit library, only a part is preserved there today. Others came after the abolition of the Jesuit Order in 1773 to the private flats of former Jesuits. Joseph Stepling, for example, an important mathematician and former director of the Jesuit "Mathematical Museum", used a lot of mathematical books, some from Brahe's library, after the abolition at his private home.[31] It is almost certain that several volumes were lost, since the Jesuits got parts of Brahe's library.[32]

Especially from the former Jesuit library at the Klementinum the National Library acquired several historical copies of different works of Tycho Brahe, e. g. his *Astronomiae instauratae progymnasmata* from 1602 and his *De mundi aetherei recentioribus phaenomenis* from 1588.

Today there are also 19 books from Brahe's library, which were originally

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[25] Cf. Kleinschnitzová, p. 75ff., Šolc, p. 150.
[26] Cf. Šolc, p. 150.
[27] Cf. Šolc, p. 149ff. A short overview over the preserved books is given by Kleinschnitzová, p. 83ff.
[28] Cf. Šolc, p. 151.
[29] Cf. Wydra, p. 32f.
[30] Cf. Šolc, p. 151.
[31] Cf. Kleinschnitzová, p. 80.
[32] Cf. Kleinschnitzová, p. 78ff.

given to the Jesuit college in Chomutov in northern Bohemia.[33] They were inscribed in the catalogue there in the years between 1671 and 1675.[34] When the Jesuit Order was abolished in 1773, the books of the college in Chomutov came into the library in the Klementinum.[35] The same fate befell some books from other Bohemian Jesuit colleges. At least it should be mentioned that the Klementinum library got four additional books from Brahe's library by private donations.[36]

Astronomical instruments from Brahe in Jesuit collections in Prague

After Brahe's death his astronomical instruments were confiscated for the imperial collections. In 1604 nearly all instruments had been transported to Vienna.[37] So, most of them left Prague and only a few remained there.

In 1722 the Jesuits founded the so-called "Mathematical Museum", which built the official institution for the numerous objects of the scientific collections of the Jesuits in Prague.[38] These collections also had several astronomical instruments, among which included a few originally from Brahe's astronomical equipment. It is not clear how the instruments came into the stocks of the Jesuit college.[39] It is also uncertain how many instruments the Jesuit Order could acquire from Brahe's scientific equipment. Among the preserved sextants and octants there are instruments used by Tycho Brahe, e. g. a very big sextant made for him by Erasmus Habermel in 1600 and another smaller one made by Jost Bürgi.[40] Possibly the acquisition of Brahe's astronomical instruments initiated the collection of scientific instruments, which were later preserved in the Mathematical Museum.[41]

After the abolition of the Jesuit Order in 1773 the museum was closed and its collection was divided and dispersed. Today, most of the instruments are preserved in different Czech institutions.[42] The mentioned big sextant belonged to the collections of the Klementinum until 1951 and was handed over then to the exhibition of the National Technical Museum in

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[33] Cf. Kleinschnitzová, pp. 76, 89ff.
[34] Cf. Šolc, p. 150.
[35] Cf. Šolc, p. 150.
[36] Cf. Šolc, p. 150.
[37] Cf. Kleinschnitzová, p. 75.
[38] Cf. Mačák, p. 74ff.
[39] Cf. Seydl, pp. 24f., 43.
[40] Cf. Majer, p. 23, Nový, p. 41, Seydl, pp. 22ff., 49.
[41] Cf. Mačák, p. 75.
[42] Cf. Majer, p. 23ff.

Prague. In recent years the Klementinum acquired replicas of the sextants.

Conclusion

In general it can be concluded that the Prague Jesuits adopted not only Brahe's conception of a renewed and reformed geocentric planetary system in their works and education about astronomy, but even integrated parts of his material heritage such as books and astronomical instruments in their scientific collections. So Brahe meant one of the most important intellectual roots of the astronomy of the Jesuits in Prague and not only there, but even decades after his death.

How much the Jesuits esteemed Brahe and his astronomical results is obvious by the fresco paintings in the old mathematical hall in the Klementinum: Brahe holding a sextant in his hand is figured there in a prominent and special position that gives him an important role among the other astronomers portrayed there.[43] This is remarkable, because, although the protestant Brahe worked in Prague, his influence on the Jesuits in Prague was neither personal nor direct, but a result of his ideas and conceptions.

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[43] A photo is given by Voit, p. 77, and by Horský, after page 126.

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Tycho Brahe and Prague: Crossroads of European Science, pp. 302–309,
J. R. Christianson et al. (eds.),

Tycho & the Telescope

Robert Warren, Greenwich

Introduction

It might seem strange, at a conference dedicated to Tycho Brahe, to discuss someone who was not born until almost fifty years after Tycho's death. What I want to address however, is not Tycho as an individual nor his work in astronomy, but his importance to a modern, forward-thinking astronomer of the late 17$^{\text{th}}$ century. In this presentation, I want to talk about my early steps in researching the influence of Tycho Brahe on the career of the first Astronomer Royal, John Flamsteed. In particular I want to look at how influential Tycho was both personally and professionally, to one of his biggest supporters and harshest critics.

Throughout Flamsteed's career it seems that Tycho was a central figure in some form or other. Flamsteed has often been accused of being difficult and certainly if one looks into his well-known disputes with his contemporaries as Frances Willmoth, Adrian Johns, and others have done in recent years, this is easy to see. I do not want to address here the extent to which Flamsteed was or was not difficult, but what I find interesting is that during these times of disagreement he appears to draw upon Tycho as an ally and without whom he seems unable to stand his ground. By contrast, in his early years Flamsteed sees Tycho in a very different way. As an ambitious and self-confident observer with a clear grasp on the requirements of a modern astronomer, Flamsteed seems to treat Tycho as very much a part of the past, and a past that must necessarily be discarded if astronomy is to develop. His belief in the utility of optics was central to cementing his belief in the need for progress, and Tycho is respectfully represented as exemplifying this need.

So, it is from these two contrasting viewpoints I wish to look at Tycho within the life of John Flamsteed. At the end I want to consider whether seeing and using Tycho in this way was endemic to a man who was ultimately deeply insecure with a profound dislike for many of his peers, or whether his attitude simply exemplified the behaviour of those within a profession undergoing what Thomas Kuhn would call a paradigm shift.

Flamsteed's Early Interests

Tycho died in 1601, almost a decade before the first use of the telescope; Flamsteed was born in 1646. After being unable to attend university due to the poor health that would remain with him throughout his life, he became interested in astronomy, immersing himself in every aspect of the subject.

He was specifically interested in the practical side of astronomy; the instrumentation as well as the actual application of observing to facilitate ideas and conclusions about the universe. Tycho had realised the benefits of long-term, systematic observation programmes, and Flamsteed took this on as an early philosophy. Similarly, he made his own instruments and ground and polished his own lenses. From this type of practical experience he understood the importance of accuracy in the construction of instruments as well as accuracy in observation. This was an area in which Tycho excelled.

In particular, Flamsteed was interested in error, and the extent to which he saw it pervade astronomical observations, both modern and ancient. He saw accuracy as important for two reasons. Firstly, accuracy was an essential aspect of providing a sound basis for discovery and a better understanding of the universe. What was available to Flamsteed, that had not been to his predecessors was the use of telescopic optics. This was a revolution, but it was a revolution that did not happen quickly. Though telescopes had been around for over half a century when Flamsteed began observing, using the telescope as a quantitative instrument, as opposed to an instrument of description, was quite new. Improvements in lens-making techniques and to the use of the micrometer in the late 17th century however, helped change the way in which the telescope was used.

Secondly, it was also an essential way in which an unknown astronomer could begin to make his mark. By adding calculations and tables to the pool of astronomical research Flamsteed was able to be seen as making a contribution. Indeed, even in his very earliest requests for the publication of his tables to the Royal Society he emphasised their superior accuracy. Obviously the more accurate this type of contribution was the better, and Flamsteed's reputation began to grow. Although it can be argued that the need for accuracy became an obsession and increasingly worked against him in later years, as a young and ambitious astronomer finding his way he was making all the right noises.

Tycho's Critic

Aged twenty-three, Flamsteed begins to correspond with the Royal Society in 1669. During these early exchanges, with the society and with other individuals such as John Collins and Richard Towneley, he is regularly critical about the errors he finds in astronomical measurements. In particular, he is most vocal about errors in Tycho's work. To illustrate this I have a couple of quotes from Flamsteed. The first is from a letter to Oldenburg at the Royal Society, dated 16th November 1672:

> "Having observed the distances and positions of the three stars by which Venus has made his transit I find that Tycho erres by five minutes at least in both place and latitudes of them compared with one another – and certainly he erres as much in many others."

Again, in a letter to Cassini, dated 7th July 1673:

> "Tycho often strayed from the truth both in the places and in the latitudes he assigned to certain stars by two or three, and sometimes four or five full minutes of arc and until these errors have been removed we shall study in vain."

There are many other examples in this early correspondence and by commenting in this manner, as someone who had yet to establish a name for himself, he is doing two things.

First, he is trying to get noticed. He is an up and coming astronomer who wants to get on, and what better way of getting noticed than to show that he is able to show that the work of the great astronomers is flawed. This in itself was not unique, others had access to similar optics and drew the same conclusions, but Flamsteed was nevertheless putting himself into the arena as a modern astronomer capable of accurate judgement and criticism.

Second, he writes not only that there are many errors to be found in Tycho's work but particularly of the need to *rectify* those errors. Flamsteed's concern here is I think, that astronomy was being 'held up'. The margin of error within available data, especially in the light of the use of optics, was no longer acceptable. Inaccuracy had implications for any prediction, discovery, and theory within the pool, and until error was substantially reduced progress could not be made. With the advantage of the great improvements in instrumentation since Tycho's death however, the substantial reduction of error was possible for the first time.

Obviously he could not be directly critical of Tycho on his plain-sight observations since there was no alternative in the 16th century, but to his contemporaries using the same methods Flamsteed is very animated. In his correspondence with the Danzig astronomer Johannes Hevelius there is a long-running dispute (later provoked by the opinions of Robert Hooke) over the use of plain-sights for serious observations.

By taking a very unambiguous position on the need for optics Flamsteed is commenting on the place and use of positional astronomy and at the same time, criticising those methods used by Tycho. Plain-sighted observations are a thing of the past; the technology of optics, as well as instrumentation, will take astronomy to a new level. For that to happen however, the new technology had to be carefully examined, wholly embraced and ruthlessly exploited.

During the early part of his career Flamsteed is using and criticising Tycho and his methods for his own ends. I don't think Flamsteed's admiration for Tycho as an observer is in doubt, but at the same time he is not being sentimental in his active attempts to consign Tycho to an era that had all but passed, while at the same time putting himself at the forefront of what he saw as a new era in astronomy. He wants to be seen in this position, and he is using Tycho to achieve it.

There is a danger in simply singling out Tycho as the single focus of Flamsteed's early work. He also championed those he saw as working on the practical aspects of astronomy. Thus, other early influences found in his correspondence were the likes of Jeremiah Horrocks, an English astronomer particularly interested in errors and their reduction. Other important names include Richard Towneley and William Gascoigne. Tycho was undoubtedly central to much of Flamsteed's critical analysis, but so too were those he saw as concerned with improvements in instrumentation and the improvement of accuracy in observation.

The Royal Observatory

Although the establishment of the Royal Observatory was still some way off in 1673, Flamsteed was aware that such a place might be built. In a letter to Oldenburg in 19$^{\text{th}}$ April 1673 we not only see again his concerns with Tycho's errors but there is also more than a hint of Flamsteed's wider ambitions:

> "Had I onely a large 7 foot Wall quadrant, a Sextans or octans of the same radius, a convenient place for observing, one good pendulum clock and a ready assistant, I should not doubt in a few nights. To rectify a many of Tychos errors and add some stars to his cataloge."

Here Flamsteed is suggesting that given the right conditions he could make improvements to Tycho's catalogue. He is not only putting himself forward, should such a position became available, but he is also saying that he could improve on Tycho's catalogue with ease, maintaining his confident air that he demonstrated to Oldenburg four years before. He goes on:

> "But this apparatus beyond my facultys, I can onely, astronomy it were, dreame of, and wonder that amongst so many ingeneous persons of large estates there should be none that dares adventure at so small a charge, astronomy this provision requires, to undertake this worke whereby hee may raise him a selfe a name greater then Tychos, and a monument with posterity – *aere perennius* [more enduring than bronze]."

Although he talks in the third person here I don't think there is any doubt what is on his mind. Not only is he outlining what might be necessary for an observatory, he is also clearly claiming that he is the one to take the mantle from Tycho.

Flamsteed's confidence and opinion paid off and within two years he was offered the position of Astronomer Royal. When asked to comment on a way of finding longitude at sea – a version of the 'lunar distance method', presented by Sieur de St. Pierre, he was quick to reiterate his opinions, this time before the King, Charles II.

An idea that used celestial measurements at sea, and compared those measurements to others taken from a known location was, he concluded, a reasonable assumption, and was an idea already known to him. He conceded it could be done, but that it would require a systematic revision of known star positions for it to succeed, and to a much greater degree of accuracy. He added characteristically, that it was a good idea, but given the opportunity he could do better. Although Flamsteed was clearly interested in his own career, he also wanted England to emulate European observatories, particularly that which Tycho had created at Uraniborg one hundred years before. In addition he was also interested in what was going on in his own time in Danzig and Paris.

The King's observatory was completed in 1676 and John Flamsteed was installed as the 'Royal Observator'. Flamsteed was now emulating Tycho in a number of ways. He was in charge of a purpose-built observatory, with royal patronage, and dedicated to a sustained programme of observation. In addition, The Royal Observatory was completed exactly one hundred years after Tycho's; a significant coincidence for Flamsteed.

Flamsteed was now not only in a position of great status, but also of great responsibility since he held the key to solving the greatest scientific problem of the day. To find longitude was generally accepted as a virtual impossibility; yet Flamsteed had the solution within his grasp. All that was required was the production of a highly accurate catalogue of the heavens and, in 1676, he felt he had both the resources and the skill to achieve it.

For Flamsteed, Tycho had been the perfect platform from which to launch his own career. Tycho's work was considered the best that was available to astronomy in the late 17th century, yet Flamsteed had continually showed the astronomical community his ability to challenge that authority. And now, having used Tycho to get himself into a position of some reputation, Flamsteed could not only emulate but surpass him as a natural successor. The original warrant of the observatory, dated 4th March 1674-75, shows just that:

> "Whereas, we have appointed our trusty and well-beloved John Flamsteed, master of arts, our astronomical observator, forthwith to apply himself with the most exact care and diligence to the rectifying the tables of the motions of the heavens, and the places of the fixed stars, so astronomy to find out the so much desired longitude of places for the perfecting the art of navigation."

Flamsteed's job was to *rectify* the tables available to astronomers; primarily, to rectify the tables of Tycho Brahe.

Tycho as an Ally

From the time of his appointment as Astronomer Royal the single-minded and confident attitude of Flamsteed appears to change. The position of Astronomer Royal and the environment in which he worked gave the impression of another Uraniborg, and this is clearly how Flamsteed originally saw it. His position was however, a novel and unproven one in England and there were many who were critical both of the appointment of Flamsteed and of the position itself. According to Flamsteed, some of these critics were actively going out of their way to provoke him into failure.

One of the earliest problems for Flamsteed was the fact that he was expected to furnish the observatory with instruments and assistance from his own pocket. In addition, Sir Jonas Moore, a generous patron and a loyal colleague, died in 1679. This not only added to his difficulties financially; now Flamsteed was without his powerful and influential ally.

Over the years disputes with his contemporaries were commonplace and although not free from blame himself, Flamsteed's position became increasingly difficult. Despite his professional status he did not enjoy the respect that he felt should come with such a position. He had been afforded the status of a Royal observer but as such he felt he was being unfairly treated and criticised by his contemporaries, and in a way in which it was impossible to respond. He was unable to retaliate or easily defend himself from what he saw as, not only unfair, but ungentlemanly behaviour. In particular, against the likes of Halley, Newton and Hooke, Flamsteed was somewhat alone and it was in this context he sought Tycho as an ally; someone who did command respect.

That Tycho was dead clearly presents a problem for him to act as an ally, but Flamsteed used him as idealising ‘the astronomer’. He saw diligence, dedication, and the application of practical skills as essential elements, not only in the pursuit of knowledge, but also in the behaviour of the gentleman philosopher. Although Flamsteed *had* to behave correctly, as was fitting his position, he felt this left him open to be continually out-manoeuvred. By using Tycho as an ally Flamsteed was able to take the only course available to him, to take a higher moral position. Unable to use the underhanded and ungentlemanly ways of the likes of Robert Hooke, he tried to stand above it and at the same time hope to show them up for what they were. By positioning himself alongside the ‘Noble Dane’, Flamsteed was able to be seen to attack his opponents without compromising his own position. Since he saw himself and Tycho as exemplifying the way to behave, as a gentleman and as a serious astronomer, anyone he put outside of that was necessarily behaving badly, and should therefore not be taken seriously. This shift in the way he saw Tycho needs to be seen in the specific context of Flamsteed’s increasing weakness in the face of what he saw as an almost endless variety of disputes. Tycho’s elevation to heroic status was a result of Flamsteed’s own continual struggles against his peers, his displeasure for the problems he encountered in securing state sponsorship, and his very singular protection of all his astronomical work which he considered his own property rather than data to be used by the wider community. All these factors appear to have pushed Flamsteed into seeing Tycho as the model astronomer.

Conclusion

To end this piece of early investigation, I briefly want to look at the question I raised at the beginning. That is, was Flamsteed’s use of Tycho – first as exemplifying the past, then as exemplifying what an astronomer should be in the present – unique to a man who seemed to have contempt for most of those around him (he once referred to Wren as one of the few honest people he had ever met).

As I said earlier, Flamsteed was not the only one to understand and address the problems of errors in observational data; Horrocks and Hevelius for example, worked specifically in this area. Tycho, to the general astronomical community of the late 17th century, was as Flamsteed saw him

– a great astronomer who's observations were once unsurpassable. In this sense Flamsteed was no different, seeing Tycho as the standard by which he should judge himself. That he used Tycho to effectively highlight his own abilities and ambitions to such extent does seem somewhat calculated but it does not appear to be either extreme or unusual. That he returned to Tycho in later years however, and positioned him as an ally after working so hard to consign him to the past, is I think, more telling.

Astronomy was still a fledgling discipline and was a long way from being a profession in its own right; Hooke and Wren held astronomical posts within their own institutions but Flamsteed was the first to work specifically as a paid astronomer. It is the elements of the unknown and the unproven that helped make his position so problematic with his peers. In this sense and particularly after Moore died, Flamsteed was in his own eyes at least, professionally isolated in England. As disputes large and small gradually reduced his confidence he took what was perhaps the only route that was open to him. Since he could not use the same low tactics of his peers he instead rose above it. Tycho although dead, did command respect and Flamsteed used this as a prop and took on in the present what Tycho represented.

I think the optical revolution, of which Flamsteed and his contemporaries were part, took some years to pan out. In that time, the one hundred years following the death of Tycho Brahe, the elements of the revolution needed time to settle into a new paradigm, that of optical astronomy. Perhaps one might argue that Flamsteed simply found himself at the centre of this period of change and was to an extent the scapegoat of the revolution; his later use of Tycho certainly seems to suggest this. Perhaps Flamsteed was the natural successor to Tycho in the late 17^{th} century, but he was unable to consign him to the past quite as quickly as he would have liked.

Acknowledgements for background information

E. G. Forbes, L. Murdin, F. Willmoth (eds.), *The Correspondence of John Flamsteed.* Vols. I & II. Bristol 1995 and 1997.

F. Willmoth (ed.), *Flamsteed's Stars.* Woodbridge, Suffolk 1997.

A. Johns, *The Nature of the Book.* Univ. of Chicago Press 1998.

Tycho Brahe and Prague: Crossroads of European Science, pp. 310–322,
J. R. Christianson et al. (eds.), © *H. Deutsch 2002*

The First Printed Edition of Tycho's 1004 Star Catalogue

Giancarlo Truffa, Milan

One of the most important contributions to astronomy by Tycho Brahe has been the preparation of a star catalogue based on new observations.

It is known in two versions. The shorter, with 777 stars, was inserted in the first volume of the *Astronomiae Instauratae Progymnasmata*, published by his heirs in 1602 after Tycho's death.

Tycho himself distributed the longest version, containing 1004 stars, in manuscripts sent only to princes and other influential people, as testified by the extant copies with Tycho's autograph dedication.

Kepler is commonly considered the first to have printed this version in 1627 as an appendix to the *Rudolphine Tables*. In fact, it was printed in 1604 by a little known Italian mathematician, Francesco Pifferi, who, using the manuscripts sent by Tycho to Giovanni Antonio Magini and to the Republic of Venice, inserted the new star catalogue in his Italian translation of Clavius' *In Sphaeram Ioannis de Sacro Bosco commentarivs*. This work had very little distribution and the few references to it in contemporary works did not mention the new additions so it was completely forgotten.

The Ancient Star Catalogue

Until the end of XVI century only one catalogue of star positions was known in Europe, the star catalogue contained in the *Almagest* composed in the II century A.D.[1] In the XVI century the star catalogue, with the

[1] For the history of the Ancient Star Catalogue and its transmission to Islamic and Latin world see KUNITZSCH P. *Der Almagest. Die Syntaxis Mathematica des Claudius Ptolemäus in arabisch-lateinischer Überlieferung*, Wiesbaden, Harrassowitz 1974 and KUNITZSCH P. *Der Sternkatalog des Almagest, vol. I Die arabisch-mittelalterliche Tra-*

longitudes corrected for precession, was available in several textbooks:

- in the *Alfonsine tables*, printed for the first time in 1483 in Venice and published several times in the XVI century;[2]
- in Giorgio Valla's *De expetendis et fugiendis rebus Opus* printed in 1501 in Venice, an edition based on a faulty manuscript and containing several errors but important because later Copernicus used it;[3]
- in the printed versions of the *Almagest*; the first, dated 1515, was the edition of the Latin translation from the Arabic, while the Greek text was published in 1538;[4]
- in Iohann Schöner's *Globi stelliferi, sive sphaerae stellarum fixarum usus et explicationes* printed in 1533 in Nuremberg, one of the first texts on the construction and use of the celestial globe;[5]
- in Copernicus' *De revolutionibus orbium coelestium* published in 1543 in Nuremberg. He selected γ Arietis as standard star (longitude 0,0) and changed consequently the longitudes of all the other stars;[6]
- in Erasmus Reinhold's *Prutenicae Tabulae Coelestium Motuum*, printed in 1551 in Tübingen, where he corrected the several errors contained in Copernicus' star catalogue;[7]
- in Christoph Clavius' *In Sphaeram Ioannis de Sacro Bosco commentarivs* published in Rome in 1570 and frequently reprinted. Clavius initially followed the edition contained in the *Alfonsine Tables* but later he used Copernicus' edition.[8]

These works presented many discrepancies because of the scribal errors accumulated through the ages plus the errors done in the original observations.

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dition, Wiesbaden, Harrassowitz 1986. *II: Die lateinische Übersetzung Gerhards von Cremona*, Wiesbaden, Harrassowitz 1990. *III: Gesamtkonkordanz der Sternkoordinaten*, Wiesbaden, Harrassowitz 1991.

[2] Kunitzsch P. "The star catalogue commonly appended to the Alfonsine Tables", *Journal for the History of Astronomy*, vol. 17, 1986, pp. 89-98.

[3] Dobrzycki J. "Katalog gwiazd w De Revolutionibus", *Studia i materialy z dziejów Nauki Polskiej*, C7, 1963, pp. 109-153.

[4] See note 2.

[5] Swerdlow N.M. "A star catalogue used by Johannes Bayer", *Journal for the History of Astronomy*, vol. 17, 1986, pp. 189-197.

[6] See note 3.

[7] Gingerich O. *Erasmus Reinhold and the Dissemination of Copernican Theory*, Studia Copernicana, vol. 6, 1973, pp. 43-62, 123-125.

[8] Lattis J. *Between Copernicus and Galileo: Christoph Clavius and the Collapse of Ptolemaic Cosmology.* Chicago 1994, p. 164 n. 55.

Tycho's Star Catalogue[9]

Tycho's observations of comets, of the new star of 1572 and of other celestial phenomena for which measurements were taken from fixed stars, made him realize the necessity of a new catalogue of star positions.

The work of new observations of stars proceeded very slowly. Tycho began in 1581/1582 with many observations linking α Arietis (which he chose as standard star) to the sun by means of Venus. Then he selected 20 other stars distributed around in the sky as reference stars for the observations. During this time he also realized Copernicus' theory of precession was wrong and he adopted a constant of precession of $51''$ by year.

The main observational efforts were done in 1589, 1590 and 1591, and in 1592 the star catalogue with 777 stars, published posthumously in the *Astronomiae Instauratae Progymnasmata*,[10] was ready. Then there was probably a pause, and the work to observe up to 1000 stars was continued only in 1595 and 1596. In 1597 it was completed, but we do not know if it was before or after the departure from Hven at the end of March 1597.

The complete catalogue of 1004 stars[11] was not printed, a lengthy introduction dedicated to the emperor Rudolph II was composed at the beginning of 1598 and several manuscript copies were sent, in many cases together with the book on the astronomical instruments, the *Astronomiae Instauratae Mechanica*, to princes, other influential people who might be helpful in his self-imposed exile, friends and scientists with whom Tycho was in correspondence.[12]

Tycho and Italy[13]

Tycho sent some copies of the star catalogue also to Italy.

He had visited the Northern part of Italy, including probably Venice,

[9] The best account of Tycho's work on the star catalogue is THOREN V.E. *The Lord of Uraniborg: A biography of Tycho Brahe*, Chicago 1991, pp. 294-300, 383.

[10] TYCHO BRAHE, *Astronomiae Instauratae Progymnasmata*, Uraniburgi – Absoluta Pragae 1602, ff. 257v-272r; *Tychonis Brahe Opera Omnia*, vol. II, Copenhagen 1915, pp. 258-280.

[11] JOHANNES KEPLER, *Tabulae Rudolphinae*, Ulm 1627 Jonae Saurii, pp. 105r-114v; BAILY, F. "The Catalogues of Ptolemy, Ulugh Beigh, Tycho Brahe, Halley and Hevelius, Deduced From the Best Authorities, With Various Notes and Corrections", *Memoires of the Royal Astronomical Society* 13, 1843, pp. 128-159; *Tychonis Brahe Opera Omnia*, vol. III, Copenhagen 1916, pp. 344-373; KEPLER, JOHANNES *Gesammelte Werke* Vol. X: *Tabulae Rudolphinae*, München 1969, pp. 105-129.

[12] See the appendix for a list of the known copies.

[13] NORLIND, W. "Tycho Brahe et ses rapports avec l'Italie", *Scientia*, vol. 49, 1955, pp. 47-61.

during his last foreign journey for education at the age of 29 in 1575.

Later he tried to come in contact with one of the preeminent mathematician in Italy, Giovanni Antonio Magini.

Originally from Padua, Giovanni Antonio Magini (1555-1617)[14] was professor of mathematics in the University of Bologna from 1588 to his death in 1617 and he was already famous for the ephemerides, the planetary and mathematical tables he had published.

Tycho was obviously interested to get in touch with him. The first occasion was the foreign journey of Gellius Sascerides,[15] one of his assistants in Hven, who later became professor of medicine in the University of Copenhagen. After a period in Germany and Switzerland, he went to Padua where in 1589 he matriculated at the university. After initial difficulties, Sascerides came in contact with Magini; he delivered to him a copy of *De mundi aetherei recentioribus Phaenomenis* 1588 and he maintained a correspondence with him and Tycho until his departure from Padua at the beginning of 1593.[16] During his stay in Padua he had also occasions to meet Magini, he constructed some observational instrument, probably a sextant, and together they made astronomical observations later reported in Tycho's observational logs of 1591 and in Kepler's *Astronomia Nova*.[17]

The main arguments treated in the correspondence were the Tychonic world system, the new computational and observational techniques used in Hven and Tycho's idea to send an astronomer in Egypt to make astronomical observations. In the *Mechanica*, Tycho wrote the Senate of the Republic of Venice approved an expense of 300 ducati for this project but no document has been found in the Venetian archives.

No document testifies further contacts between Tycho and Magini after the departure of Sascerides from Padua until November 1598 when Tycho sent another emissary to Italy, Franz Tengnagel.[18] He met Magini in

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[14]For information on the life and works of G.A. Magini see: FAVARO A. *Carteggio inedito di Ticone Brahe, Giovanni Keplero e di altri celebri astronomi e matematici dei secoli 16. e 17. con Giovanni Antonio Magini*, Bologna 1886, pp. 1-187; BONOLI F., PILIARVU D. *I Lettori di Astronomia presso lo Studio di Bologna dal XII al XX secolo*, Bologna 2001, pp. 143-147.

[15]For information on the life and works of G. Sascerides see: CHRISTIANSON J.R. *On Tycho's Island. Tycho Brahe and His Assistants*, 1570-1601, Cambridge 2000, pp. 351-353.

[16]A. Favaro published the correspondence of Magini in 1886 (see note 14). The letters between Tycho and Magini were published in *Tychonis Brahe Opera Omnia*, vols. VII and VIII.

[17]*Tychonis Brahe Opera Omnia*, vol. XII, Copenhagen 1925, pp. 148-149; KEPLER, JOHANNES *Astronomia nova* 1609; *Gesammelte Werke* Vol. 3: *Astronomia Nova*. Ed. M. CASPAR. 1937, p. 211.

[18]For information on the life and works of F. Tengnagel see: CHRISTIANSON J.R.

Bologna giving him the copy of the *Mechanica* now in the National Central Library of Florence and some excerpts from the *Progymnasmata*.

Tengnagel visited also Venice where he was created Knight of S. Marco, he went to Florence to the Court of the Grand Duke of Tuscany and in Rome where he met Clavius. He delivered to the Doge of Venice the copy of the *Mechanica* now in the Bodleian Library of Oxford, to the Republic of Venice the copy now in the Marciana Library of Venice, to the Grand Duke of Tuscany one of the copies now in the Royal Library of Copenhagen.

Tengnagel probably tried again to obtain the support of the Republic of Venice to Tycho's project to make observations in Egypt without success. Therefore Tycho sent him to the court of Florence with his gifts and later he wrote to the Grand Duke requesting his support for the expedition in Egypt and also to permit some astronomical observations in Tuscany by Tycho's son. He received a refusal probably because of the false notices diffused about his participation to the expulsion of Capucins from Prague.

The correspondence between Tycho and Magini continued in 1600 and 1601. The last letter we have from Tycho to Magini was delivered by Tycho's son who went to Italy among the suite of an English nobleman, ambassador of the king of Persia in Europe. We know from a letter Magini sent to Clavius in 1600[19] that he planned to include the star catalogue in one of his works, but later he gave his manuscript copy of Tycho's catalogue to Francesco Pifferi and never worked on the star catalogue.

Francesco Pifferi[20]

Francesco Pifferi was a Camaldolite monk, born probably in 1548 in Monte San Savino, a small town in Tuscany. We know nothing about his education, but from his academic career we can argue he obtained at least a degree in mathematics and one in theology. The first notice we have is about his participation in four unspecified degrees in 1579/1580 in the University of Pisa.[21]

On Tycho's Island. Tycho Brahe and His Assistants, 1570-1601, Cambridge 2000, pp. 366-372.

[19] Giovanni Antonio Magini to Clavius in Rome, Bologna February 23, 1600 *Christoph Clavius, Corrispondenza* a cura di U. Baldini e P.D. Napolitani. - Pisa 1992 vol. IV, pp. 110-112, notes pp. 58-61.

[20] For information on the life and works of F. Pifferi I am indebt to the biography published in *Christoph Clavius, Corrispondenza* a cura di U. Baldini e P.D. Napolitani. Pisa 1992, vol. VII, pp. 78-79.

[21] Schmitt Ch.B. "The Faculty of Arts at Pisa at the Time of Galileo", *Physis*, 1972, pp. 243-272; Schmitt Ch.B. "Filippo Fantoni, Galileo Galilei's Predecessor as Mathematics Lecturer at Pisa Science and history": *Studies in honor of Edward Rosen.* (Studia Copernicana, 16), 1978, pp. 53-62; a cura di Del Gratta, R. *Acta graduum*

After 1586/7 and probably in the following year, he substituted for Filippo Fantoni, the teacher of mathematics who had been elected general of the order of Camaldolites.

In that year he taught Euclid and the "theorica planetarum". In 1587/8 he was sponsor to 5 degrees in theology.

Fantoni died in 1589 and Galileo succeeded him. Pifferi instead was elected teacher of mathematics in 1593 in the University of Siena and was confirmed in this position every year until his death in 1612.[22]

In Siena he lived in the convent of his order, called S. Mustiola della Rosa, and sometime he was recorded as Francesco della Rosa. He continued his activity as theologian and preacher, in Siena and in Florence where he stayed in the convent of S. Maria degli Angeli, another convent of the Camaldolites. Among his pupils in Siena there were several noblemen, in particular Pope Alexander VII Chigi. He also gave private lessons to prince Cosimo de' Medici, the future Grand Duke Cosimo II of Tuscany.

A manuscript with his lectures is preserved in the Vatican Library.[23] It is dated 1602 and contains texts on the *Elements* of Euclid, military architecture and geometrical instruments. Two letters written by Pifferi are preserved among the correspondence of Christoph Clavius in Rome. The first, dated 7 February 1601,[24] is concerned with a book probably about the calendar reform sent to Clavius; it is interesting because in a note he acknowledges his debt to Clavius as his master. The second, dated 24 November 1603,[25] contains some question about units of measure.

He was also a member of the two literary academies in Siena, the Misurati and the Intronati. Pifferi died in the first months of 1612[26] because in May the Senate of the University of Siena elected a new teacher of mathematics.

I would add that at least three periods of Pifferi's life are related to

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Academiae Pisanae, I, Pisa 1980.

[22] PRUNAI, G. "Lo studio senese nel primo quarantennio del principato mediceo", *Bullettino senese di storia patria*, vol. 66 (s. III,18) 1959, pp. 79-160 [pp. 113, 156-157]; MARRARA D. *Lo studio di Siena nelle riforme del Granduca Ferdinando I (1589 e 1591)*, Milano 1970.

[23] Citta' del Vaticano, Rome, Biblioteca Apostolica Vaticana, ms. Chigi F.VIII.189.

[24] Francesco Pifferi to Clavius in Rome, Siena 7 February 1601, Rome, Archivio Pontificia Universita' Gregoriana, ms. 529 cc. 196r-v, 197ter r-v. *Christoph Clavius, Corrispondenza* a cura di U. BALDINI e P.D. NAPOLITANI. - Pisa 1992 vol. IV, pp. 122-123, note p. 68.

[25] Francesco Pifferi to Clavius in Rome, Siena 24 November 1603, Rome, Archivio Pontificia Universita' Gregoriana, ms. 529 cc. 197r-197bis v. *Christoph Clavius, Corrispondenza* a cura di U. BALDINI e P.D. NAPOLITANI. - Pisa 1992 vol. V, pp. 92-93, note p. 43.

[26] MITTARELLI G.B. – COSTADONI A. *Annales Camaldulenses Ordinis Sancti Benedicti* Venetiis 1755- ... vol. VIII, pp. 237-238.

Galileo. The first was when Galileo lived and studied in Pisa; in this period, as said before, Pifferi was teaching there and later Galileo himself taught there. The second was when Galileo, during his period in the University of Padua, was a private teacher of prince Cosimo de Medici in the summer vacations, as Pifferi was. The third was when Pifferi participated in the famous banquet offered in Rome by Federico Cesi to Galileo and the other members of the Academy of Lincei on 14 April 1611.[27]

But strangely no reference to Pifferi can be found in Galileo's works and correspondence.

Pifferi published several theological books, translations from Latin of hagiographical works[28] and two scientific texts: The first, *Monicometro instromento da misurar con la vista stando fermo* printed in Siena in 1595,[29] dedicated to the Duke of Urbino, Francesco II della Rovere, containing the illustration of a new instrument, the monicometro, to measure distances and altitudes standing on a fixed point. He did not considered it a new invention,[30] but an improvement upon them because its use was greatly simplified. *Sfera di Giovanni Sacro Bosco tradotta e dichiarata da Don Francesco Pifferi Sansavino Monaco Camaldolense, e Matematico nello Studio di SIENA. Misurato Intronato. Al Serenissimo Don Cosimo Medici gran Principe di Toscana. Con nuoue aggiunte di molte cose notabili, e varie demostrazioni vtili, e dilettevoli* printed in Siena in 1604[31] and, as indicated in the long title, dedicated to prince Cosimo de Medici. The title can be translated as "Sphere of John of Holywood, translated and

[27] Gabrieli, G. *Il carteggio Linceo della vecchia Accademia di Federico Cesi* Roma 1938-42, p. 161 n. 900; Gabrieli G. *Contributi alla storia dell'Accademia dei Lincei* Roma 1989, p. 877, 1589; Drake S. *Galileo Studies: Personality, tradition, and revolution*, Ann Arbor 1970, cap. 4 "The Accademia dei Lincei"; Drake S. *Galileo at work*, Chicago 1978, p. 166, 488 n. 23.

[28] The other works ascribed to F. Pifferi are:

– *Don Francesco Pifferi Mon°. C. Di Pisa, contro gli critici*; Rome, Biblioteca del Convento di S. Isidoro, ms. 1/128 Codex chartaceus n. 1;

– *Istoria del m. r. p. fr. Alfonso Giaccone* [Chacon, Alonso] *nella quale si tratta esser vera la liberazion dell'anima di Traiano Imperatore dalle pene dell'Inferno, per le preghiere di S. Gregorio Papa. Fatta volgare, & aggiuntoui alcuna cosa intorno alla medesima materia dal m. r. p. Maestro Don Francesco Pifferi, monaco camaldolense.* Nella stamperia del Bonetto: Siena, 1595 [dedicated to Usimbardo Usimbardi "primo episcopo Collensi"];

– Pifferi, Francesco *Brieve Discorso sopra i misteri della Corona del Signore, etc.* Matteo Florimi: Siena, 1602 [dedicated to Cristina, Grand Duchess of Tuscany];

– Pifferi, Francesco *Manifestazioni e primi prodigi della Madonna de'Monti* Memorie tratte da inedito ms. del 1583, Orvieto 1858.

[29] In Siena, nella Stamperia di Luca Bonetti, 1595.

[30] He cited other instruments like the *archimetro* of Ostilio Ricci (a teacher of Galileo), the *olometro* of Abel Foullon and the *radio latino* of Latino Orsini.

[31] In Siena: Appresso Silvestro Marchetti, 1604.

explained by don F. Pifferi, from Monte San Savino, Camaldolite monk, and Mathematician in the University of Siena, Member of the Academies of Misurati and Intronati, dedicated to Don Cosimo Medici, great prince of Tuscany. With the addition of many notable things and several useful and delightful demonstrations".

This work is mainly a translation in Italian of Christoph Clavius' *In Sphaeram Ioannis de Sacro Bosco commentarivs*,[32] one of the most famous textbooks between the end of the XVI century and the beginning of the XVII century. Besides Tycho's star catalogue, Pifferi added personal annotations and other parts taken from many modern authors.

The edition of the Star Catalogue. Grienberger and Kepler

The star catalogue, which covers all the 48 Ptolemaic constellations, is contained between the pages 121 and 178. For each constellation, starting from Ursa Minor, an introduction about its mythological background is given. Then there is the list of the stars, with the descriptions translated in Italian, the longitudes, latitudes, magnitudes and astrological natures.

Pifferi used, as testified in the note preceding the catalogue, Tycho's star catalogue contained in the manuscript sent to Magini[33] and compared it with the other sent to the Republic of Venice[34] and, at that time, in the hands of Girolamo Diedo, a notable Venetian statesman with literary and scientific interests.

The manuscript owned by Magini probably was never returned because a hand-written note *Liber Joh. Antonii Magini* is crossed out in ink and according to a mutilated label inside the front cover the volume belonged to the Monastery of S. Maria de Florentia.[35]

Tycho was able to observe only four stars in Centaurus and none in Lupus, Ara, Corona Australis and Piscis Australis, because they were not visible from Hven; therefore Pifferi used Clavius' star catalogue for these constellations.

In total Pifferi's star catalogue contains 481 northern stars, 335 zodiacal

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[32] Clavius, Christoph *In Sphaeram Ioannis de Sacro Bosco commentarivs.* First edition: Romae: Apud Victorium Helianum, 1570.

[33] Norlind W. "On a copy of Tycho Brahe's 'Mechanica' and of his great star catalogue", *The Observatory*, vol. 75, 1955, pp. 254-255.

[34] Valentinelli G. *Bibliotheca Manuscripta ad S. Marci Venetiarum. Codices mss. Latini*, Venice, 1868-1871, 6 vols., vol. IV, p. 263-264.

[35] I think it could be the Convent of S. Maria degli Angeli and not the Cathedral of S. Maria del Fiore, as reported by Norlind.

stars and 278 southern stars, 88 more than Tycho.

The first reference I found to Pifferi's star catalogue is contained in the fifth edition of Clavius' *In Sphaeram Ioannis de Sacro Bosco commentarivs*, published in 1606. Clavius reported, in the note preceding his star catalogue,[36] the notice of the new catalogue prepared by Tycho and published by Pifferi, but he continued to publish his old star catalogue.

Later another Jesuit professor of mathematics in Rome, Christoph Grienberger (c. 1564-1636)[37] published in 1612 a small textbook, *Catalogus veteres affixarum longitudines ac latitudines conferens cum novis, imaginum caelestium prospectiva duplex*[38] containing a star catalogue and a celestial atlas consisting of 26 charts.

The star catalogue is arranged in a complicated way. For each constellation he identified the stars with the same description in *Progymasmata's* star catalogue and in Clavius' star catalogue, and listed Tycho's data first for each star and in the following line Clavius' data, followed by the other stars in the constellation taken from Pifferi and finally the stars taken from Clavius. The numbering is progressive based on Pifferi and Clavius, but divided between stars inside and outside ("informes") the constellation.

Grienberger listed in total 471 northern stars, 389 zodiacal stars and 365 southern stars, 767 taken from Tycho, 218 from Pifferi and 240 from Clavius with a grand total of 1225 stars. Grienberger added many mistakes to the possible errors done by Pifferi in his transcription of the manuscripts and then in the printing of the work.

Kepler probably received a copy of Grienberger's work in 1613 from Odo

[36] Clavius, Christoph *In Sphaeram Ioannis de Sacro Bosco commentarivs* Romae 1606, p. 176: *Tycho Brahe Danus, excellens nostra aetate Astronomus, observavit in Dania plures stellas, quam 1022, pauciores tamen, quam 1100. & in quibusdam ex illis 1022 longitudines invenit, latitudinesque differentes nonnihil ab illis, quae in sequenti nostra tabula notatae sunt. Qui ergo eius observationibus magis fidendum esse censet, quam aliorum Astronomorum, consulere poterit, vel ipsius Tychonis opera, quae iam impressa sunt, vel certe spheram F. Francisci Pifferii, italice conscriptam, ubi stellas descripsit ex sententia Tychonis. Equidem supervacaneum puto, eam tabulam hisce nostris Commentariis attexere, tum ne liber maior, quam par est, evadat, tum etiam, quia non est tanta inter Tychonis stellas, ac nostras differentia, ut notabilem errorem possit in instrumentis, atque observationibus inducere: praesertim cum, ut dixi, alibi stellas ab ipso observatas possit invenire, & conferre cum nostris.*

[37] For information on the life and works of C. Grienberger see: Baldini U. "Legem impone subactis": *Studi su filosofia e scienza dei Gesuiti in Italia, 1540-1632.* Rome 1992, p. 178 n. 8, pp. 576-577 n. 8, n. 9.

[38] Romae apud Bartholomaeum Zannettum, 1612. The Star Catalogue entitled *Catalogus stellarum fixarum complectens nomina omnium constellationum, quae a zodiaco ad eius polum boreum vergunt una cum earum numero, ac ordine, nec non longitudinibus, latitudinibus, & magnitudinibus, tum veteribus, tum novis* is published on pp. 1-51.

Maelcote[39] (1572-1615), a Jesuit mathematician then living in Bruxelles. Kepler replying to the accompanying letter noted the numerous errors, misplaced numbers and omissions he had found in Grienberger and ascribed to Pifferi.[40]

Five times Pifferi is quoted in the star catalogue contained in the *Rudolphine Tables*,[41] as *Piferus* or *Pif.*, indicating a different reading between Tycho's manuscript Kepler owned and Pifferi's catalogue.

I checked these data in the manuscripts used by Pifferi, in Pifferi's and Grienberger's works. Kepler's data are correct compared to the manuscripts; Pifferi is correct for the first two stars in Orion, while the three other stars are wrong and the data in Grienberger are all wrong as reported by Kepler.

This result could support my impression Kepler had at his disposal only Grienberger's work and not the original work by Pifferi. After Kepler Pifferi was completely forgotten, while Tycho's great work remained unsurpassed for all the XVII century.

In conclusion this episode represents one of the first witnesses of Tycho's influence and it can well illustrate the relations between Tycho Brahe and Italy.

Acknowledgements

I wish to thank prof. P. L. Napolitani of the University of Pisa, who kindly provided me with copies of Pifferi's and Magini's letters to Clavius and the bio-bibliographical notes on Pifferi contained in the edition of *Clavius' Correspondence* published by U. Baldini and him.

[39] Odo Maelcote to Kepler in Linz, Bruxelles 11 December 1612. Kepler, Johannes *Gesammelte Werke*, Vol. XVII: *Briefe 1612-1620* ed. M. Caspar. München 1955 p. 46 note p. 456; for information on the life and works of O. Maelcote see: Baldini U. “Legem impone subactis”: *Studi su filosofia e scienza dei Gesuiti in Italia, 1540-1632.* Rome 1992, p. 178 n. 9.

[40] Kepler to Odo Maelcote in Bruxelles, Linz 18 July 1613. Kepler, Johannes *Gesammelte Werke*, Vol. XVII: *Briefe 1612-1620* ed. M. Caspar. München 1955, pp. 63-65, note p. 461.

[41] Kepler, Johannes *Gesammelte Werke* Vol. X: *Tabulae Rudolphinae*, München 1969, pp. 127 and 129. The stars are Orion 53, 56, 57, Eridanus 14, Crater 6.

Appendix: list of known manuscripts of Tycho's Star Catalogue[42]

Austria

Wien, Österreichische Nationalbibliothek
 Lat. 10705; dedication to Archduke Mattia, later Emperor
 Lat. 10706
 Lat. 10707, 1-25; dedication to Rudolph Corraduc Procancellario
Ref.: ZI 1613, 1614, 1615, N1.9, N3

Denmark

Copenhagen Royal Library
 Gl.kgl.S. 306, 2o.; dedication to Christian IV, King of Denmark
 Gl.kgl.S. 307, 2o.; dedication to Adolph, bishop of Lübeck
 19 - 107 2o.; dedication to Ferdinand, Grand Duke of Tuscany
Ref.: ZI 1610, 1611, N1.3, N3, K.III

France

Paris, Bibliothèque Nationale
 NA Lat. 17865; dedication to Maurice, Prince of Orange-Nassau
 RES-V-230 *; dedication to Wolfgang Dietrich von Raitenau, Archbishop of Salzburg
Ref.: N1.7, N3

Germany

Detmold, Lippische Landesbibliothek

[42] The symbol * indicates the copies bound with *Astronomiae Instauratae Mechanica*, Wandsbeck 1598. Sigla:
ZI: Zinner E. *Verzeichnis der Astronomischen Handschriften des deutschen Kulturgebietes* München: C.H. Beck, 1925;
N1: Norlind W. "Om manuskript exemplaren av Tycho Brahes stora stjarnkatalog" *Nordisk Tidsskrift for bok-och biblioteksvasen*, vol. 40, 1953, 1-15. The second number indicates the position in the list prepared by Norlind;
N2: Norlind W. "On a copy of Tycho Brahe's 'Mechanica' and of his great star catalogue", *The Observatory*, vol. 75, 1955, 254-255;
N3: Norlind W. "Tycho Brahe, en levnadsteckning med nya bidrag belysande hans liv och verk". *Skaansk senmedeltid och renaessans*, vol. 8. Lund 1970, pp. 295-296;
K: Kristeller P.O. *Iter Italicum*, Brill 6 vols., 1960- ...; the Roman number indicates the volume. I used the CD-Rom version where the indication of the pages of the printed version is not reported.

ms.21; dedication to Simon VI, Duke of Lippe
Ref.: K.III

Dillingen, Studienbibliothek
4o. 4
Ref.: ZI 1605, K.III

Gotha, Forschungsbibliothek
Memb.I 110; dedication to duke Friedrich Wilhelm I. of Sachsen-Weimar -Altenburg, Elector of Saxony
Chart.A 984; dedication to Ulrich, Duke of Mecklenburg
Ref.: ZI 1607, 1608, N1.1, K.III

Göttingen, Niedersachsische Staats- und Universitätsbibliothek
Philos. 28; 28a *; dedication to Heinrich Julius of Braunschweig, Univ. Helmsted Fundator
Ref.: ZI 1616, N1.2

Osnabrück, Niedersachsisches Staatsarchiv coll. Karlsgymnasium
45 (M e 10) *
Ref.: ZI 1606, N1.5, K.III

Italy

Firenze, Biblioteca Nazionale Centrale
II.II.529 *; dedication to Giovanni Antonio Magini
Ref.: N2, N3

Venezia, Biblioteca Marciana
Lat. VIII, XXXVI * (2686); dedication to Republic of Venice
Ref.: N1.8, N3, K.II

Netherlands

Leyden, Univ.Bibl.
Scal. 13; dedication to Joseph Scaliger
Ref.: ZI 1609, N1.4, K.IV

United Kingdom

Oxford, Bodleian Library
Arch. B.c.3 * (olim Arch.Bodl. D 32); dedication to Marino Grimani, Doge of Venice
Ref.: ZI 1612, N1.6

Other copies are probably lost, including those sent to Rudolph II of Habsburg, Christian Longomontanus, Johannes Kepler, the Duke of Parma and Piacenza, the Archbishop Ernst of Cologne, two copies listed in Montfaucon's catalogue of the manuscripts owned by Christine Queen of Sweden (MONTFAUCON *Bibliotheca bibliothecarum manuscriptorum*, vol. I, Paris 1739, p. 25, nos. 509 and 510; N3, K.II).

Tycho Brahe and Prague: Crossroads of European Science, pp. 323–328,
J. R. Christianson et al. (eds.), © *H. Deutsch 2002*

Recent Notes on Tycho Brahe's Library

Owen Gingerich, Cambridge, MA

Today the locations of approximately 120 books from Tycho's astronomy library are known. After Tycho's death in 1601 the mathematical/astronomical books went primarily into the hands of the Jesuits (Tycho's son-in-law, Tengnagel, having converted to the Catholic faith), and later many of the dispersed groups of books found their way back to the Jesuit University in Prague. The lion's share are now found in the Clementinum in Prague, approximately 110 titles bound in some fifty volumes. These books must represent only a small part of Tycho's entire library. Wilhelm Norlind, Tycho's bio-bibliographer, has listed 216 titles that would likely have been in Tycho's library, based both on the existing volumes and on books mentioned by Tycho in his writings.[1]

On 21 March 1597, a few days after Tycho left his Uraniborg castle for the last time, an inventory was taken of his books; the meteorological logbook states simply "Registeret vi alle junker's bøger."[2] Whether this brief message refers to his library or his stock of partially printed volumes in his printing shop is not clear, though it very likely does mean that the books in his library were counted. Norlind found in one of Tycho's books the number 2781, which he took to be a registration number,[3] suggesting that there were at least approximately 3,000 books in the library, but similar numbers are apparently not found in the other surviving volumes, so Norlind's deduction is at best speculative.

Nevertheless, a Tychonic library of 3,000 titles would not be unreasonable. Another Danish nobleman, Heinrich Rantzau, had a library of 6,000 titles,[4] of which only about a hundred are specifically identified today

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[1] Wilhelm Norlind, *Tycho Brahe: En levnadsteckning med nya bidrag belysande hans liv och verk* (Lund, 1970), 336-66.

[2] J. L. E. Dreyer (ed.), *Tychonis Brahe Dani Opera Omnia* [= *TBOO*], IX (Copenhagen, 1927), 146.

[3] Norlind, *op. cit.*, p. 335.

[4] John Robert Christianson, *On Tycho's Island* (Cambridge, 2000), 212.

from his distinctive book bindings. The Elizabethan magus and Tychonian contemporary, John Dee, had the largest library in England, nearly 4,000 printed volumes, of which 2,700 are attested by his surviving library inventory (plus a thousand manuscripts), though only about 20% of his personal copies can be located today.[5] In Prague Tycho had access to the library of Baron Hoffman, whose books numbered 4,000, and another of his acquaintances there, Peter Vok Rozmberk (his host on that fatal banquet in 1601), had 10,000 books and manuscripts.[6] We know that Tycho was fond of books, that he visited the famous Frankfurt book fair and he sent agents there, and that his correspondence includes attempts to acquire books, so he could well have had a library comparable to some of the other large collections of his day. His tastes ran far beyond mathematics and astronomy, so we can expect him to have had a diverse collection in which the non-scientific books are far less likely to be identified.

Concerning the volumes in the Clementinum, 16 have his initials TBO stamped into the bindings, 6 have his supralibros portrait stamped into the binding, and 12 more have his inscribed initials. Finally, there are two books identified by author's presentations to him (e. g. Giordano Bruno and J. J. Scaliger). Incidentally, there are a number of books elsewhere authored by Tycho with his portrait stamped on the cover, but these are typical of his presentation copies and are probably not from his personal library. A number of the Clementinum books have marginal annotations, but because Tycho acquired used books, these notes are typically from other readers. In only a few instances are there clear examples of Tycho's own marginalia, for example in the section on Martianus Capella in Jacob Ziegler's *In C. Plini de naturale historia* (Basel, 1531) and in Bartholomaeus Scultetus, *Cometae anno ... 1577* (Gorlitz, 1578).

This paucity of Tychonic writing in Prague, apart from a few indubitable presentation inscriptions, has given Czech scholars some serious problems in understanding the marginalia of the Clementinum collection. In 1886 F. J. Studnička published a facsimile of the trigonometrical manual, believing it to be in Tycho's hand.[7] There is no question but that this manuscript was part of the standard reference collection at Uraniborg, and probably existed in multiple copies, but as J. L. E. Dreyer already noted in 1913, this was definitely not in Tycho's hand.[8] Later, in 1973, a careful facsimile

[5] Julian Roberts and Andrew G. Watson, *John Dee's Library Catalogue* (London: The Bibliographical Society, 1990).

[6] Victor Thoren, *The Lord of Uraniborg* (Cambridge, 1990), 467.

[7] F. J. Studnička, *Tychonis Brahe Triangulorum planorum et sphaericorum praxis arithmetica* (Prague, 1886).

[8] J. L. E. Dreyer, *TBOO*, I (Copenhagen, 1913), 315-18.

of Copernicus *De revolutionibus*, also in the Tychoniana collection, was published under the assumption that the annotations were written by Tycho. It took several years before Robert Westman and I were able to show that the annotations are actually in the hand of Paul Wittich, an itinerant mathematician and tutor from Wratislavia (Wrocław).[9]

The story of Wittich's books and how they came to be part of Tycho's library is quite remarkable. Wittich brought multiple annotated copies of *De revolutionibus* with him when he visited Hven for a few months in the summer and early autumn of 1580. Later, when Tycho learned that Wittich had died, he tried repeatedly (for a period of ten years), through Thaddeus Hagecius in Prague and Jacob Monaw in Wrocław, to buy Wittich's library, or at the very least, "the three copies of Copernicus' book that had certain annotations by himself".[10] Eventually Monaw replied that Tycho's wishes would be met,[11] and in October of 1600 he brought the Copernicus books to Prague. Subsequently some of these volumes were dispersed. One copy must have gone into Rudolf's collection, which was in turn captured by General Hans Christoph Königsmarck during the Thirty Years War and taken to Sweden. There it became part of Queen Christina's library, and when she abdicated and went to Rome, she took it with her as part of her library, which was in turn sold to Pope Alexander VIII, the former Cardinal Pietro Vito Ottoboni whose collection eventually became part of the Vatican Library. It is there that I found it in 1973. Another of the Wittich/Tychonic copies was perhaps acquired by a Belgian Jesuit working in Prague, for today it is found in the University Library in Liège. Let me return to this routing later.

Some of the Tychonic books fell into private hands in Moravia and may have stayed for quite some years in the vicinity of Prague. One book was purchased many years ago by Wilhelm Prandtl, a distinguished chemist and collector in Munich, whose collection was acquired in the 1950s by the University of Texas. Thus we find Tycho's copy of Conrad Gesner's *De omni rerum fossilum genere, gemmis, lapidibus, metallis et huiusmodi* in Texas.[12] Another, a copy of the 1561 edition of Petrus Apianus' *Cosmographia*, was sold by a Munich antiquariat to an undisclosed location in

[9] Owen Gingerich and Robert S. Westman, *The Wittich Connection: Conflict and Priority in Late Sixteenth-Century Cosmology* (Transactions of the American Philosophical Society, 78, part 7, 1988).

[10] Brahe to Monaw, 31 December 1599, *TBOO*, VIII (Copenhagen, 1925), 237, lines 10-11.

[11] Monaw to Brahe, June 1600, *TBOO*, VIII, 325-26.

[12] See Wilhelm Prandtl, "Die Bibliothek des Tycho Brahe", *Philobiblion, Zeitschrift für Bücherliebhaber*, 5 (1932), 291-99, 321-29.

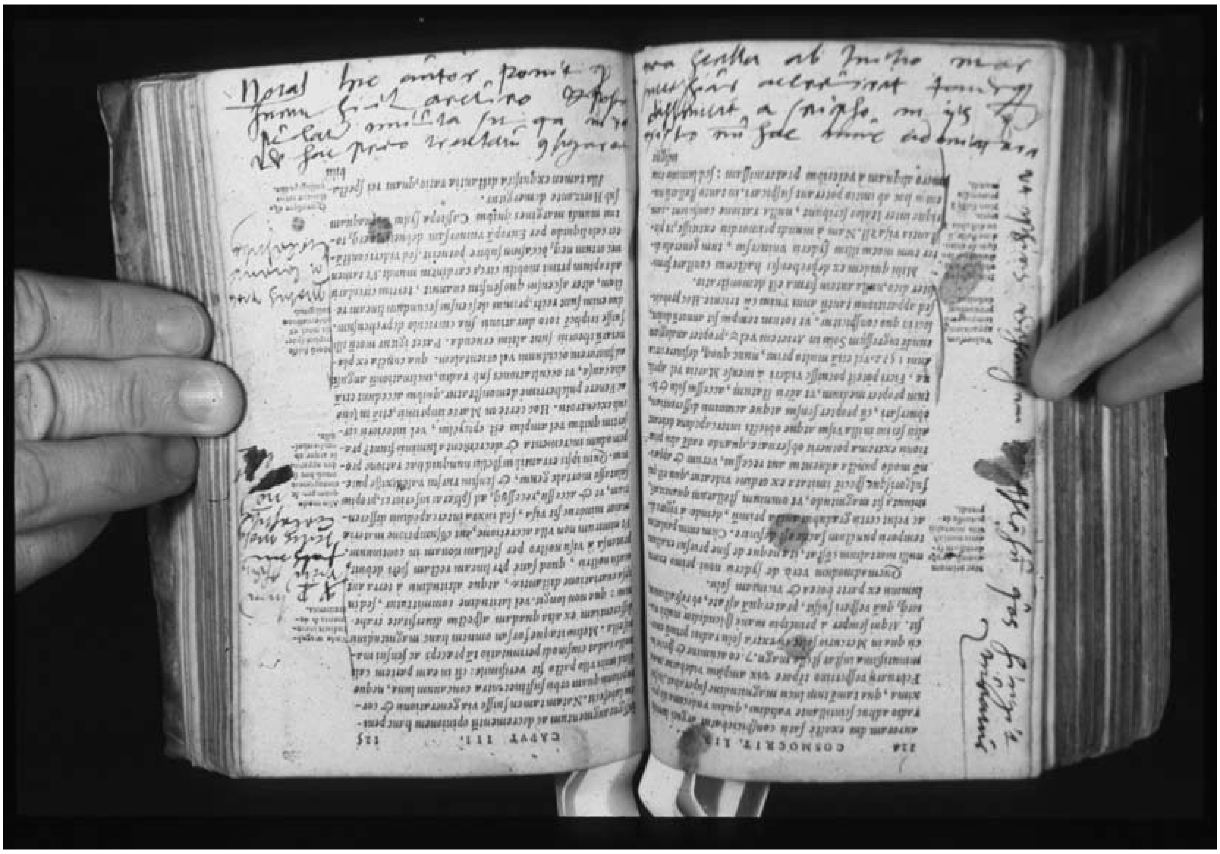


Figure 1: Tycho's annotations in his copy of CORNELIUS GEMMA'S *De naturae divinis characterismis* (Antwerp, 1575), Book II, pp. 124-125. It is very unusual that he chose to write a long note upside down in the lower margin of the page. (Courtesy of a private American collector.)

America[13] – it could possibly be in a public institution but without publicity. A further Tycho volume was recorded in the collection of Harald Mortensen in Copenhagen in 1932, Henricus Cornelius Agrippa's *Opera*.[14] Around 1955 the same collector had yet another of Tycho's books.[15] This volume, Cornelius Gemma's *De naturae divinis characterismis* (Antwerp, 1575) has recently resurfaced in the hands of a New York book dealer, Martayan Lan, where it was offered for $300,000.[16] This book contains

[13] NORLIND, *op. cit.*, 338.

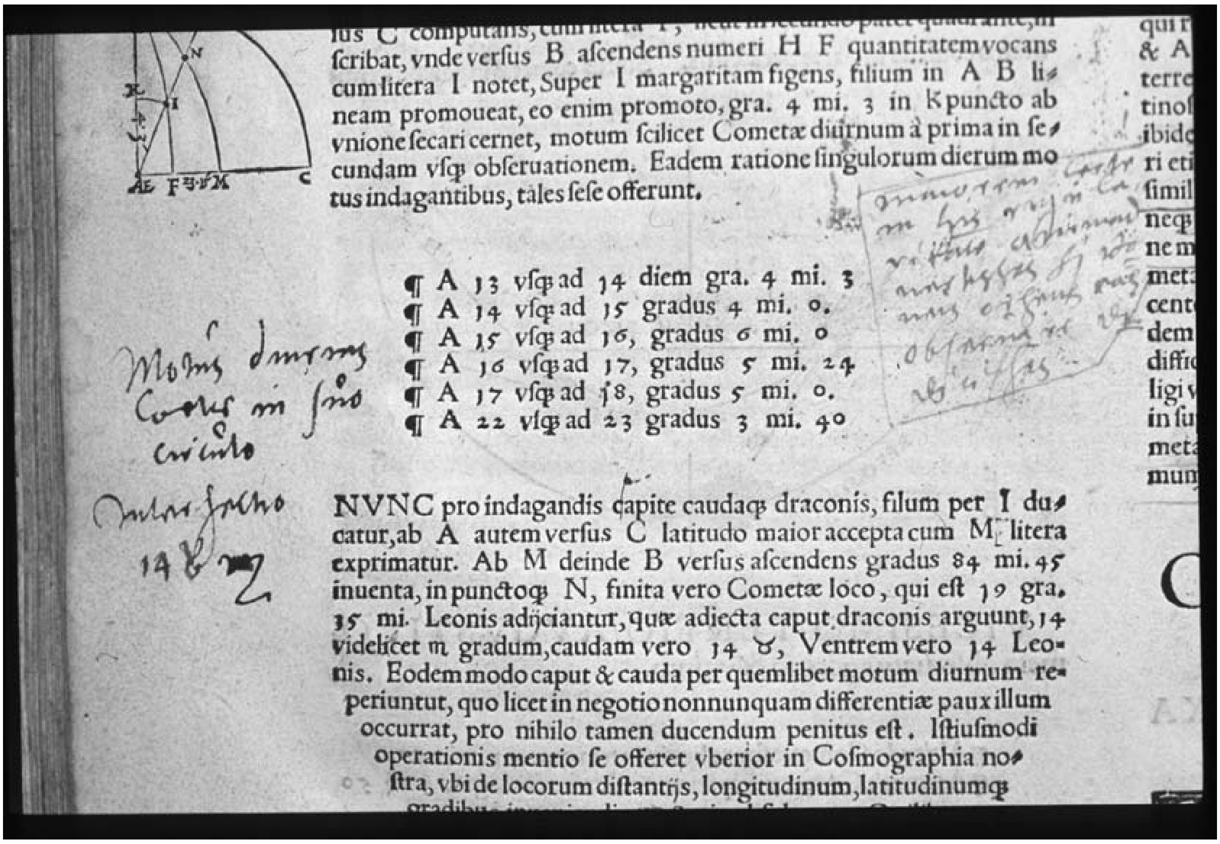
[14] PRANDTL, *op. cit.*

[15] Recorded by HARALD MORTENSEN, "Fra Tycho Brahes Bogsamling", *Fund og Forskning I Det kgl. Biblioteks Samlinger* (1955), 25-32.

[16] *Martayan Lan Catalogue* 28 (New York, [2001]), item 55; an opening with Tycho's extensive annotations is shown in color as the frontispiece. This book is now in the hands of a private American collector.

some particularly interesting annotations, for Tycho annotated heavily the section on the Spanish astronomer Munosius's observations of the new star of 1572, and has quoted this passage explicitly in his *Progymnasmata.*

The most spectacular discovery of a book from Tycho's library came about almost accidentally. When Paul Wittich was leaving the island of Hven, Tycho gave him a truly princely gift, a copy of the most lavish book from Apianus' private press in Ingolstadt, the *Astronomicum Caesareum.* He later complained that the book had cost him 20 florins, which by today's standards would probably exceed $4,000. The copy given to Wittich with Tycho's presentation inscription is now in the University of Chicago Library. Presumably Tycho retained another copy, but where was it? I had personally examined over a hundred copies of this remarkable tour de force of printing without finding a copy associated with the Danish astronomer.



ſcribat, vnde verſus B aſcendens numeri H F quantitatem vocans cum litera I notet, Super I margaritam figens, filium in A B lineam promoueat, eo enim promoto, gra. 4 mi. 3 in K puncto ab vnione ſecari cernet, motum ſcilicet Cometæ diurnum à prima in ſecundam vſque obſeruationem. Eadem ratione ſingulorum dierum motus indagantibus, tales ſeſe offerunt.

¶ A 13 vſque ad 14 diem gra. 4 mi. 3
¶ A 14 vſque ad 15 gradus 4 mi. 0.
¶ A 15 vſque ad 16, gradus 6 mi. 0
¶ A 16 vſque ad 17, gradus 5 mi. 24
¶ A 17 vſque ad 18, gradus 5 mi. 0.
¶ A 22 vſque ad 23 gradus 3 mi. 40

NVNC pro indagandis capite caudaque draconis, filum per I ducatur, ab A autem verſus C latitudo maior accepta cum M litera exprimatur. Ab M deinde B verſus aſcendens gradus 84 mi. 45 inuenta, in punctoque N, finita vero Cometæ loco, qui eſt 19 gra. 35 mi. Leonis adiiciantur, quæ adiecta caput draconis arguunt, 14 videlicet ♏ gradum, caudam vero 14 ♉, Ventrem vero 14 Leonis. Eodem modo caput & cauda per quemlibet motum diurnum reperiuntur, quo licet in negotio nonnunquam differentiæ pauxillum occurrat, pro nihilo tamen ducendum penitus eſt. Iſtiuſmodi operationis mentio ſe offeret vberior in Coſmographia noſtra, vbi de locorum diſtantiis, longitudinum, latitudinumque

Figure 2: Tycho's annotations regarding comets in his copy of Peter Apianus' *Astronomicum Caesareum* (Ingolstadt, 1540), detail from f. O1 verso. (Courtesy of another private collector.)

Then, about two years ago, there came from Belgium an e-mail inquiry regarding Apianus' *Astronomicum Caesareum*, a copy bound with an even rarer equatorium, an earlier one by Johann Schöner. Why, asked the owner, would books printed in 1521 and 1540 be in a binding stamped 1583? And why would the initials TBO appear above the date? Of course I immediately recognized this as Tycho's identification. Further inquiries revealed that the Apianus had several annotations by Tycho, all in the comet section near the end of the book. Particularly useful for establishing the later history of this copy were some additional early annotations in other hands. On the planisphere the star names were written in French, and on the facing page was an annotation partly in Dutch and partly in Flemish. This threefold combination strongly suggests that the book was in the area around Antwerp or Brussels for a very long time, and until around 1960 it had been in a monastery library. I could well imagine that the book migrated to the Low Countries via same Jesuit hands that brought the Wittich Copernicus, now in Liège. This extraordinary volume has changed hands again, to an anonymous American collector who must have paid close to a million dollars for it. It is hard to imagine that any comparable Tychonic treasure will soon turn up.

Tycho Brahe and Prague: Crossroads of European Science, pp. 329–332, J. R. Christianson et al. (eds.), © *H. Deutsch 2002*

Bibliotheca Tychoniana – Books from Tycho Brahe's Possession in the National Library of Czech Republic in Prague Clementinum

Martin Šolc, Prague

Some of the books from the private library of Tycho Brahe remained in Prague after his death and nowadays they belong to the most valuable treasures of the National Library. The collection is known as *Bibliotheca Tychoniana*, the name that can be found on title pages of many of those books, together with the year of 1642, when Jesuit librarians incorporated the donation from Tycho's heritage into the University library of the Clementinum College. Unfortunately, no inventory was preserved from this time and nothing was also found from the following two centuries. After the suppression and abolishment of the Jesuit order in 1773, the collection was mixed with other volumes on mathematics and natural sciences (and ordered by size). Later, at the time of about 1900, several librarians attempted to reconstruct the *Bibliotheca Tychoniana* step by step. This effort has been crowned by Flora Kleinschnitzová who identified 97 prints and manuscripts bound in 47 volumes.[1] Until today, the numbers increased to about 110 titles in 50 volumes.[2] Of course, this is not comparable with the assumed number of all Tycho's books (about 3000 volumes),[3] but nevertheless the Clementinum collection does represent the largest preserved fragment of the original library and moreover, it implies also a broad spec-

[1] Flora Kleinschnitzová, "Ex Bibliotheca Tychoniana Collegii Soc. Jesu Pragae ad S. Clementem" (*Nordisk Tidskrift för Bok- och Biblioteksväsen*, 20, 1933), 3-27; this paper is hereafter denoted as FK.

[2] Martin Šolc, "Bibliotheca Tychoniana" (*Handbuch deutscher historischer Buchbestände in Europa*, Hildesheim – Zürich – New York, Georg Olms Verlag AG. 1999), 149-151.

[3] Wilhelm Norlind, *Tycho Brahe: En levnadsteckning med nya bidrag belysande hans liv och verk* (Lund, 1970), 336-366. — Owen Gingerich, "Recent Notes on Tycho Brahe's Library" (in this volume, p. 323).

trum of Tycho's scientific and cultural interests. Hence the *Bibliotheca Tychoniana* possesses a privileged place in the Clementinum library, beside the books owned once by other Renaissance learned men close to Tycho Brahe or Johannes Kepler: Heinrich von Rantzau[4] and Wacker von Wackenfels.[5]

Even if the description of individual bands in FK-paper is in most cases short, it goes in some details and includes the following data of the books or prints bound together: author, title, printing office and town, year, the type and characteristic features of the binding (brown leather, white parchment, paper, wood etc., supralibros etc.), important annotations and comments. In the next paragraphs we shall concentrate on titles that are not mentioned in FK-paper (here marked by •):

FK3,[6] Sign. 1 H 56, 4°, another text by the same author is in the first of four prints: *Henrici Ranzovii Catalogus imperatorum, regum, ac virorum illustrium, qui artem astrologicam amarunt, ornarunt et exercuerunt, quibus addita sunt Testimonia, quae ostendunt elementa ...*, Lipsiae 1584
• *Item: Astrologicae quaedam praedictiones. Adiectus est praeterea tractatus De annis climactericis ...*

FK15, Sign. XIV H 190, 4°, two dialogues follow after prints 1 and 2:
1. Paduanus Joannes: *Viridarium mathematicorum*, Venetiis 1563
2. Maurolycus Franciscus: *Cosmographia*, Venetiis 1543
• Antimachus
• Nicomedes

FK16, Sign. XIV J 28, 4°, (Alfraganus: *Rudimenta astronomica*; Albategnius: *De motu stellarum ... ex observationibus cum proprijs tum Ptolemaei ...*, Norimbergae 1537) contains texts:
• *Item oratio introductoria I de Regiomonte*
• *Epistula P. Melanchthonis*

FK21, Sign. XIV K 70, 8°, (Peucerus Casparus: *Elementa doctrinae de circulis coelestibus et primo motu recognita et correcta*, Vitebergae 1563; Brucaeus Henricus: *De motu primo libri tres*, Rostochii 1573) has a text:
• *Brevis explicatio doctrinae sinuum* followed by tables, frequently used,

[4]Libuše Šimandlová, "Bibliothek Heinrich von Rantzau" (*Handbuch deutscher historischer Buchbestände in Europa*, Hildesheim – Zürich – New York, Georg Olms Verlag AG. 1999), 153-154.

[5]Vladislav Kotek, "Bibliothek Johann Mathaeus Wacker von Wackenfels" (*Handbuch deutscher historischer Buchbestände in Europa*, Hildesheim – Zürich – New York, Georg Olms Verlag AG. 1999), 154-155.

[6]It is number 3 of the FK-paper (and similarly hereafter).

as can be seen on the edges.

FK27, Sign. V H 65, 4°, binding brown leather, TBO 1576
1. Ptolemaeus Claudius: *Liber De analemmate a F. Commandino ... instauratus*, Romae 1562
• *Federici Commandini Urbinatis Liber de horologium descriptione*
2. Pitatus Petrus: *Compendium super annua solaris*, Veronae 1560
3. Valesius Augustus: *De terrae motu liber*, Bononiae 1571

FK32, Sign. IX B 135, 4°,
1. Alma, Eleirdus de: *Bellum giganteum*, Heidelbergae 1588
2. Candidus Pantaleon: *Bohemais, hoc est De ducibus Bohemicis libri duo*
• the same author: *De regibus Bohemicis libri quinque*, Argentorati 1587

Remark to FK35, Sign. XIV B 11, 2°, other sign. TB 36:
Gauricus Lucas: *Opera omnia*, Basileae 1575 (frontispiece *T.B., Collegij Societatis JESU Commotouiensis Cat. inscr. A. 1675*).
In FK-paper, brown leather binding with TBO 1576 is mentioned, but now the book has a new paper cover.

FK46, Sign. XIV H 192, 4°. In the FK-paper only the names of authors are given.
Dissertationes de cometis novae
1. *De cometarum significationibus indicium Thomae Erasti*
2. *De cometa in universum*, Marcus Squarcialup
3. *Thomae Erasti Defensio 1579*
4. *De cometae significatione 1578*, Andreas Duditius
5. *Commentarii duo: De ignitis meteoris unus, Alter de cometarum causis*, Simon Gry(i)naeus 1578, 1579
• *De meteoris comment(arii) II* (below are initials T O Δ)
• *Commentarius I*
6. *Commentarius II*
7. *De cometis et eorum natura opiniones*
8. *Thomae Erasti Epistolarum liber*

• Sign. XV K 22, 8°, other sign. 8 I 70, on spine G III
Bruno Giordano: *Camoeracensis acrotismus seu Rationes articulorum physicorum*, Vitebergae, Zacharias Crato 1588. This booklet with dedication to Tycho was sent probably from Prague in 1588. On the last page, there is the famous annotation written by Tycho's hand: *Nullanus, nullus et nihil, Conveniunt rebus nomina saepe suis.* The cover is a brittle, dirty white leather.

• Sign. XXXI H 26

1. Manuscript initials – twice: *T.B.* and *T B*
2. Guillermus Vaarillong(?) *super quattuor libris sententiae ...*
initials – *T B, Coll. Comm.*
3. Manuscript, probably in two different hands.
Wooden cover, spine white leather or parchment.

• Sign. XIV B 38
1. *Vitellionis mathematici ... De ratione projecti radiorum Lib. X*, Norimbergae 1585
2. *Alberti Düreri Geometriae Lib. III*, Lutetiae 1582.
Two pages contain annotations – verses. The front and rear cover is wooden, bound by brown leather on the spine (with the inscriptions *Vitellio Mathematicus, Albertus Durerus ...*). Initials *T O O* are on the left side of the front cover. *Collegij Caesarei Societatis JESU Pragae A(nn)o 1636. Musei mathematici* (in a different hand).

From this complement to the FK-paper, only the last two volumes are probably less known. Since several years, a project of digital recording of manuscripts, old prints, posters, etc. is going on in Clementinum. By this occasion the old volumes are inspected page by page and so it can not be excluded that some more books of Tycho Brahe's library will appear.

Acknowledgments

The possibility to display some books from the collection *Bibliotheca Tychoniana* for the conference participants, generously enabled by the Director of the National Library of Czech Republic and Head and members of the Dept. of Manuscripts and Old Prints, is highly appreciated.

The work on the present paper has been supported by project LN00A041 of the Ministry of Education of the Czech Republic.

*Tycho Brahe and Prague: Crossroads of European Science, pp. 333–355,
J. R. Christianson et al. (eds.),* © *H. Deutsch 2002*

Tycho Brahe's Paper Mill on Hven and N. A. Møller Nicolaisen's Excavations, 1933-1934

Jens Vellev, Aarhus

In the winter season of 1936-37, the "Hvidehus" bookshop in Vejle put out a brochure advertising a lecture by the amateur astronomer N. A. Møller Nicolaisen (1874-1954): *Tycho Brahe, his contemporaries, and the historical excavations on Hven. Illustrated with coloured slides.* That is now more than sixty years ago, and most people today would probably imagine that the lecture was on the effort in the service of astronomy that made our noble countryman (1546-1601) world-famous. However, that is not the case. Møller Nicolaisen's theme was Tycho Brahe's production of paper. The brochure tells of the beginning of what was called an archaeological sensation of that time:

> "Urged on by his historical interest in Tycho Brahe, he visited Hven for the first time in 1929, and thus began the great adventure. When walking about the grounds, Møller Nicolaisen's attention was drawn to a large mound which did not seem to be a geological structure, but rather the work of human hands, and after giving it some thought, he became convinced that this was the place where Tycho Brahe's storied paper mill had fallen into ruin. This interesting discovery induced The Scandinavian Tycho Brahe Foundation to grant financial aid to the great work of excavation led by Møller Nicolaisen. The result of the excavations was of such an impressive character that it attracted attention in scientific circles throughout Europe ... After completing the excavations, Møller Nicolaisen delivered his first lecture, on the actual site, to an exclusive circle of interested scientists. The lecture was attended by the Swedish Crown Prince and Princess, who were most interested in seeing the remains of our ancestors' work, of

> which Tycho was the soul ... The lecture was later delivered in 'The Astronomical Society' in Copenhagen and several other places. The lecturer gives his lecture a more popular stamp, though on the scientific background, and the press as well as the audience – not least the youth – are very enthusiastic over the lecturer's vivid and exciting narrative, and over the approximately 100 colour slides, which include both historic figures, the actual work on the excavations, the rare findings, and a series of extraordinarily beautiful landscapes."

The above-mentioned examinations on Hven were carried out in two excavation campaigns in 1933 and 1934. Until then, Tycho Brahe researchers had certainly been occupied with the extraordinary site, but so far their interest had been concentrated on the controversial nobleman's famous buildings – *Uraniborg* and *Stjerneborg* – in the centre of the island, which he received as a fief from the Danish king in 1576. The main house, a combined castle and observatory, was completed in 1580, while the partially buried observatory could be put into use four years later. In the course of a few years he had changed the previously almost unknown island into a centre for advanced research on the stars and planets. The outcome of the numerous nocturnal observations was published in a wonderful set of books, the product of his own printing house. One serious problem, however, soon surfaced: He was dependent on deliveries of paper from European mills, which were far from always in a position to deliver the goods. He therefore decided to start his own production. The construction of a small factory must have already been well under way in 1589, since he wrote to a friend in Germany:

> "You mention the paper mill which I said I wanted to build so that the paper, which was to come from Germany, would not cause delays to my publications so often and for so long ... The above-mentioned mill is already finished. A high, wide embankment regulates the water supply, which suffices in summer as well as in winter. The wheel, which is approximately 7 meters in diameter, is powered by the least possible amount of water, and besides the manufacture of paper, is the source of power for two industries. A number of fishponds are also laid out, so that these may also supply water for the mill when it is needed. And only a few years ago, this was all just dry land."

However, despite the clarity of these words, which possibly should be regarded as wishful thinking, the mill does not seem to have been completed until a few years later. After completing the work, a self-satisfied Tycho placed a monument on the embankment acclaiming the extraordinary project, here translated from Latin:

> "This embankment and paper mill with all their fixtures as well as the ponds situated opposite were built by Tycho Brahe of Knutstorp in a place where earlier there were no such things, from his own plans, under his own leadership, and at his own cost, for the benefit of the country, himself and his descendants. Begun in 1590, completed in 1592."

The monument was – probably in 1740 – moved to Knutstorp, where it can still be viewed, although in a somewhat battered state.

After disagreeing with the king, Christian IV, Tycho left the island in 1597, and after some time settled in Prague, where he died in 1601. The buildings on Hven soon decayed. The paper mill was demolished in 1602. Its approximate position on the southeast side of the island was known from cartographic surveys of the time. The actual site was not located until when, during his visit in 1929, Møller Nicolaisen, while walking on the beach, with his penetrating powers of observation was able to determine that a tremendous, straight-sided embankment could not have been made by nature but must be the remains of the construction mentioned in Tycho's letter and on the monument.

In the following years the enthusiastic amateur astronomer threw himself into the task of getting permission to carry out archaeological explorations at the site – and at the same time raising the money for the project. He succeeded, and work began on 24 July 1933. Labour was recruited and a Swedish museum official, Torsten Mårtensson from Helsingborg was attached to the project, among other things to carry out the measurements. Work progressed quickly, and soon the first pieces of tiles and glazed flagstones appeared. They were on the right track. However, they did not find a clear building construction until a couple of metres down, where they found vertical poles and collections of fieldstones.

When the site was cleared, it turned out to be a stone-built trench filled with mud. At the bottom a piece of shaped wood appeared. And on 1 August, after it had been cleaned, it turned out to be the remains of the mill rim, apparently preserved at the bottom of the wheel chamber. Their enthusiasm was great, and before nightfall the workers had freed the fragment, which was approximately 2.5 m long.

Møller Nicolaisen published his results in several issues of *Nordisk Astronomisk Tidsskrift* (The Scandinavian Astronomical Magazine) from 1930-38. However, although a special edition of the articles was printed, the author felt that there was a need for a complete account. And this he was finally able to have published by Gyldendal in 1946: *Tycho Brahe's*

Paper Mill on Hven, on the occasion of the 400th anniversary of the famous astronomer's birth. Most of the text is taken word for word from the previously published articles, but the explorations had now been brought to a worthy conclusion.

Work on the excavations and the following collation played an important role in Møller Nicolaisen's daily life. He built his own observatory in Vejle, from where he devoted himself to his hobby. On the walls hang pictures, which were mainly enlargements of his own photographs. Obviously, they were taken in black and white, but several of them had been coloured by hand with unusual accuracy. And his extensive material with relation to the excavations could be found in drawers and cabinets: measurements, photographs, correspondence, newspaper articles and the colour slides mentioned in the brochure from the 1936-37 lecture season. The observatory still exists, including much of Møller Nicolaisen's material, amongst it a few findings from the explorations on Hven. The large private archive, which the heirs had preserved, was given to this author in 1996.

The investigation of the paper mill on Hven is still worthy of considerable attention. Through it, we are given insight into a piece of trade history with far more than local significance. A renewed treatment of the extensive source material – findings, maps, photographs, notes, correspondence – will provide surprising new approaches to the understanding of the earliest years of Danish paper production. At the same time, we will also see a more varied picture of a somewhat overlooked side of Tycho Brahe's multifaceted activities.

The many finds from the excavations are today kept partly in a small museum on Hven, and partly in the Museum of Cultural History in Lund, together with material from the excavations of Stjerneborg and Uraniborg. Material from reports, such as photographic negatives from the Swedish archaeologists who were attached to the examination is kept in various institutions in Helsingborg and Stockholm. The broad, if scattered material, is now being registered by the present author in connection with an investigation of Danish paper production in the 1500s and 1600s. Here twelve of Møller Nicolaisen's slides are shown, supplemented with a few other photos, giving an idea of the process and results of the successful excavation.

Notes

There is extensive literature on Tycho Brahe. Here I refer only to three works – in Danish – in which the quoted passages can be found:

N. A. Møller Nicolaisen's little book of 72 pages from 1946: *Tycho Brahe's Paper Mill on Hven* (Tycho Brahes Papirmølle paa Hven), has been quoted in the present article.

Tycho Brahe. Stjärnornas Herre, which, with Johanna Erlandsson as editor, was released in connection with the exhibition in Landskrona in 1996. The articles here give new and as yet overlooked approaches to research on Tycho Brahe.

Alex Wittendorff's extensive monograph (328 pages) from 1996, *Tyge Brahe*, gives a good view of his life and activities. It concludes with three pages of references.

The present account must be seen in connection with a more thoroughgoing investigation of paper production in Denmark in the 1500s and 1600s. Apart from the study of Tycho Brahe's paper mill, it treats the works established south of Aarhus in 1635 by Hans Hansen Skonning. The site has been rediscovered, and in 1997 and 1998 the author began archaeological excavations there.

Besides the mill facilities, the paper produced, preserved in books and letters, has also been included in the investigation. The slides from Møller Nicolaisen's archive, on which the illustrations used in the article are based, are from a series of 56, measuring 8.2 × 8.2 cm, which formed the basis for the many lectures he gave throughout the years.

The archive also includes another series of 55 slides with the theme "Tycho Brahe as an astronomer".

Finally, I would like to thank the Bodil Pedersen Foundation, which supported the author's studies on Hven as well as a trip to study paper museums and factories in Switzerland and Italy in 1998.

The present article was translated from Danish by Patricia Lunddahl, "Center for Cultural Research, University of Aarhus". A Danish version of the article appers in "Grafiana. Årbog for Danmarks Grafiske Museum / Dansk Pressemuseum", Odense 2000: *Tycho Brahes papirmølle på Hven – og om N. A. Møller Nicolaisens udgravninger 1933-34*, p. 27-37.

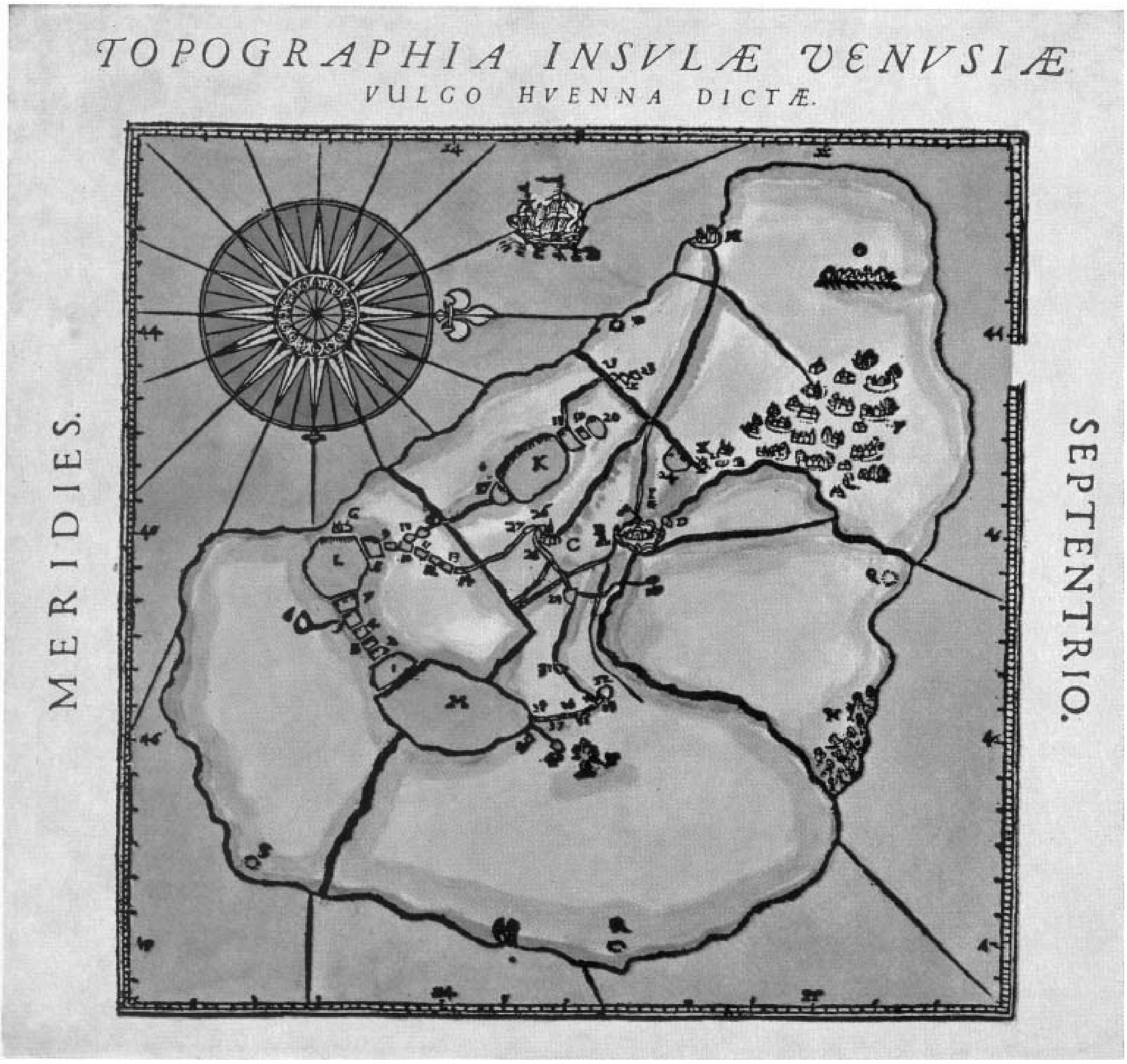


Figure 1: Map of Hven as the island looked at the time of Tycho Brahe, with many dammed-up ponds leading rainwater to the paper mill at the coast. The hand-coloured map was printed and published on Hven in 1596.

Figure 2: The mill embankment as photographed by Møller Nicolaisen in 1929. The small building situated on the left in the photo was later demolished. In other versions of the photo, the house has been retouched away – it blocked the view of the actual site where the paper mill had been.

Figure 3: A photograph from the first day of the excavation: 24 July 1933. The question was whether anything at all was preserved. It was. After only a few hours of digging finds surfaced: roof tiles.

Figure 4: It was soon necessary to expand the area and dig deeper. The leaders of the excavation consult in the foreground while digging goes on.

Figure 5: More expansions were necessary before the shape of the building could be seen. Here they are digging in its south-western part.

Figure 6: August 1, 1933 was a remarkable day for the excavation team. That is when the first end of the mill's water wheel appeared in the wheel chamber. The wood was very well preserved, and after preservation by the National Museum in Copenhagen, it could be transported back to Hven, where it can still be seen in the small museum located near Uraniborg. Analyses of the wood showed that the shovel cases were made of pine, while the 26 cm-wide wheel rim with its punched out grooves was made of oak. The fragment found was 2.5 m long. The diameter could be quite accurately calculated to 6.94 metres.

Figure 7: Møller Nicolaisen inspects the last clearing during the excavations in 1934. Shortly after, the cleared area was covered over. The location of the building was marked with four concrete posts, which still mark the place where the most remarkable industrial facility of the Scandinavian Renaissance lay.

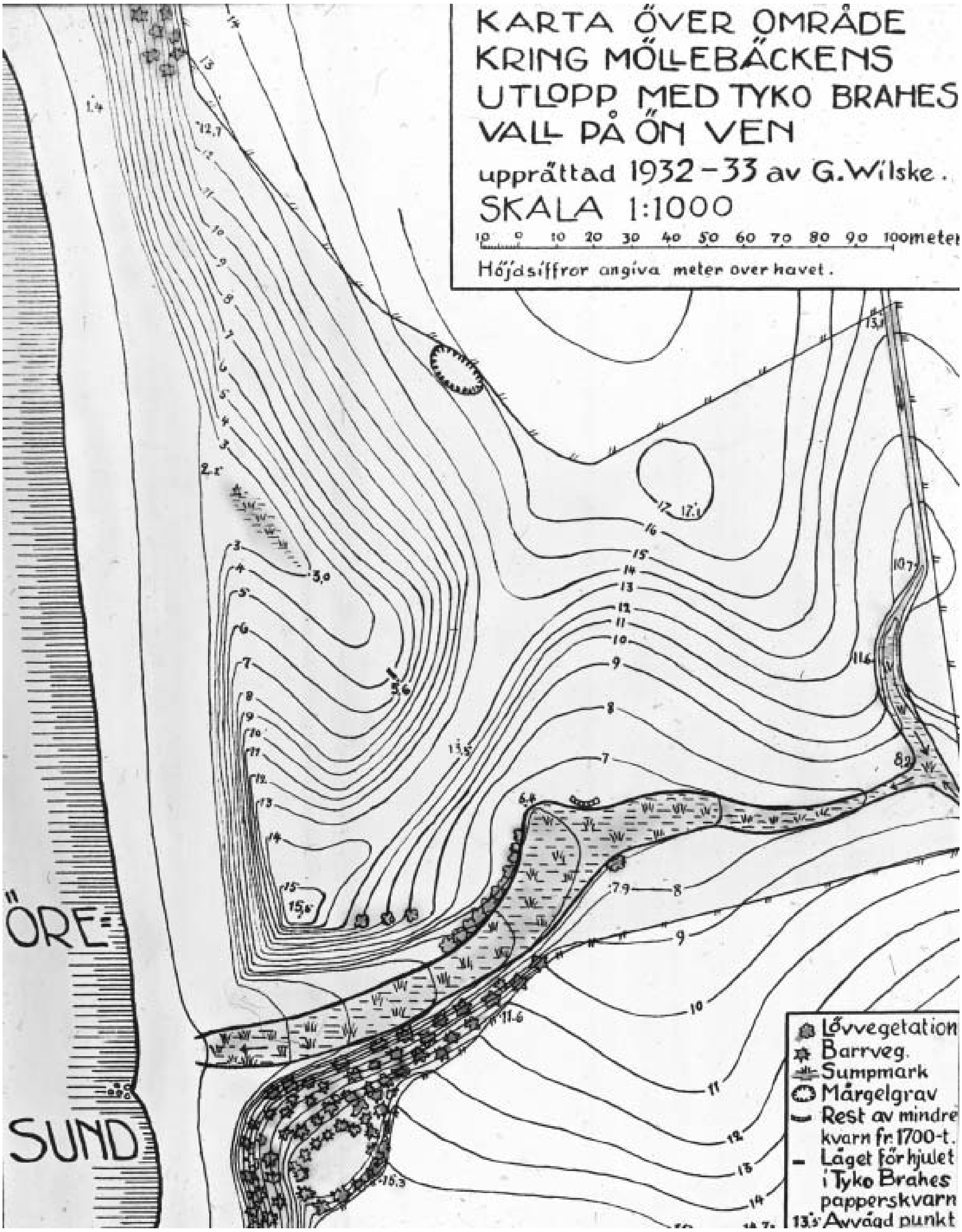


Figure 8: A contour map of the area by the mill river. Previous researchers had all thought that the mill lay on the river's present outfall into the Sound (Øresund). On his visit in 1929, Møller Nicolaisen could establish that the site should be localised to an area approximately 80 metres further north, at the bottom of the embankment whose maximum level was at the thirteen-metre contour. He localised the mill at the five-metre contour.

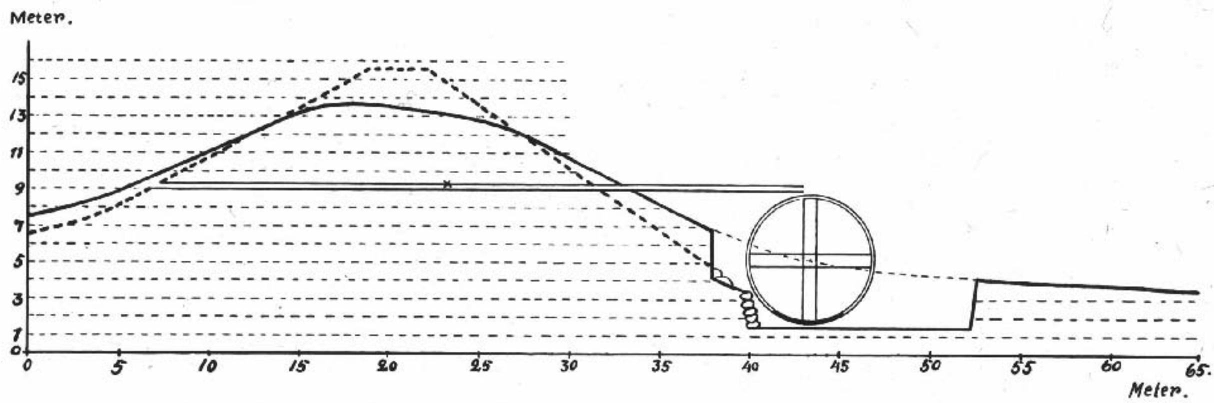


Figure 9: The huge so-called overshot wheel was supplied with water from the last big millpond before the main dam, which was supplied with a passage in the shape of a pipe near the bottom of the millpond, so that the accumulated water could be led out over the wheel. Møller Nicolaisen carried out an excavation from the top of the dam, and four metres downwards, where at the expected height he found remains of the passage in the shape of wood and iron fittings. The site is marked with an × on the profile drawing.

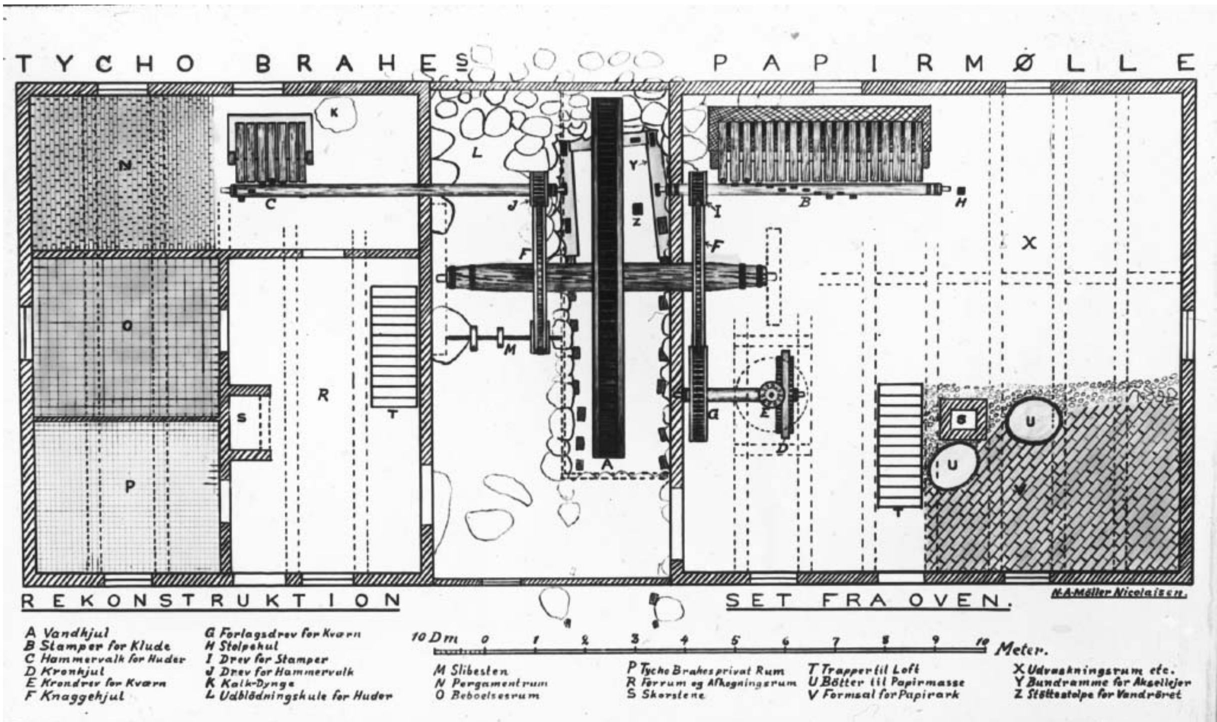


Figure 10: After completing the excavation, Møller Nicolaisen continued working on the material collected. With the measurements as a starting point, he reconstructed the ground-plan, showing the functions of the various rooms of the building in so far as they were known from Tycho Brahe's descriptions in books and letters. It was not an easy task, and almost all the solutions can be questioned. However, overall, the attempt gives an inspiring impression of the excavator's ability to familiarise himself with a complicated research field. – Text in box: Reconstruction / Seen from above: A. water wheel, B. beater for cloth, C. hammer mill for hides, D. crown wheel, E. main drive gear for grindstone, F. spoke wheel, G. drive for grindstone, H. posthole, I. drive for beater, J. drive for hammer mill, K. limestone piles, L. soak-hole for hides, M. grindstone/whetstone, N. parchment room, O. living quarters, P. Tycho Brahe's private quarters, Q. chopping room, R. chimneys, S. stairs, T. drums for pulp, U. forming room for sheets of paper, V. room for rinsing, etc., Y. frame for axel, Z. supporting post for water-pipe.

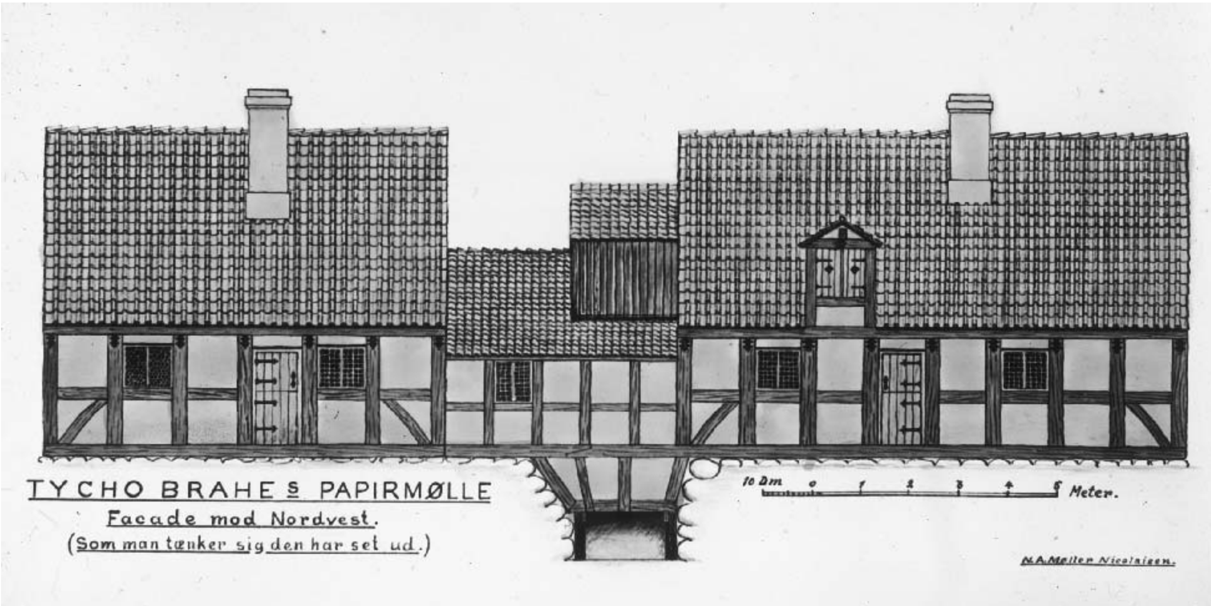


Figure 11: Møller Nicolaisen was also able to give an account of the exterior of the building. Many of the reconstruction's suggestions for individual solutions must, of course, be seen in connection with the reconstruction of the ground plan. – Text in box: Tycho Brahe's paper mill. North-west façade, as we imagine it.

Figure 12: The excavations received remarkably extensive attention in the daily press. Møller Nicolaisen was able to collect an impressive number of newspaper articles in voluminous folders. Many interested spectators turned up at the site, where Nicolaisen willingly held forth. July 22, 1934 was a special day, when he could show the Swedish Crown Prince and Princess around the site. Shown here on the stairs in front of Kungsgården, together with a large following.

Figure 13: The monument with Latin inscription which Tycho Brahe had erected next to the paper mill on Hven was – probably in 1740 – moved to Knutstorp in Scania, where the later so famous astronomer was born in 1546. There it still hangs on the outside of the preserved main building. The Latin inscription is extremely worn, the monument is split in half from top to bottom, and the back half has disappeared. Old studies of the inscription, together with a more recent study of the preserved part in 1996 have given better insight into the monument's fascinating story.

Figure 14: The photographs preserved from the excavations show that Møller Nicolaisen often wore a light-coloured suit, including a hat, while working. A preserved 6 × 6 cm negative marked 1934 was probably been sent to him by one of the interested visitors. The photo shows the excavator studying some of the finds. The best of those are today exhibited in the small museum on the island, while the rest, comprising many boxes filled with pottery, tiles, flagstones etc., after having been kept in the loft of the museum, can now be seen in the storage rooms of the Museum of Cultural History in Lund.

Figure 15: The large fragment of the paper mill's wheel, found in the excavation 1 August 1933, is now, after restoration at the National Museum in Copenhagen, exhibited in the museum on Hven. Photo: JV, Aug. 24, 1996.

Figure 16: Selected findings from the excavations are exhibited in a small showcase in the museum on Hven. The bearing stone with clear traces of wear gives a glimpse of everyday life in the mill, information not found in contemporary written sources. Photo: JV, Aug. 24., 1996.

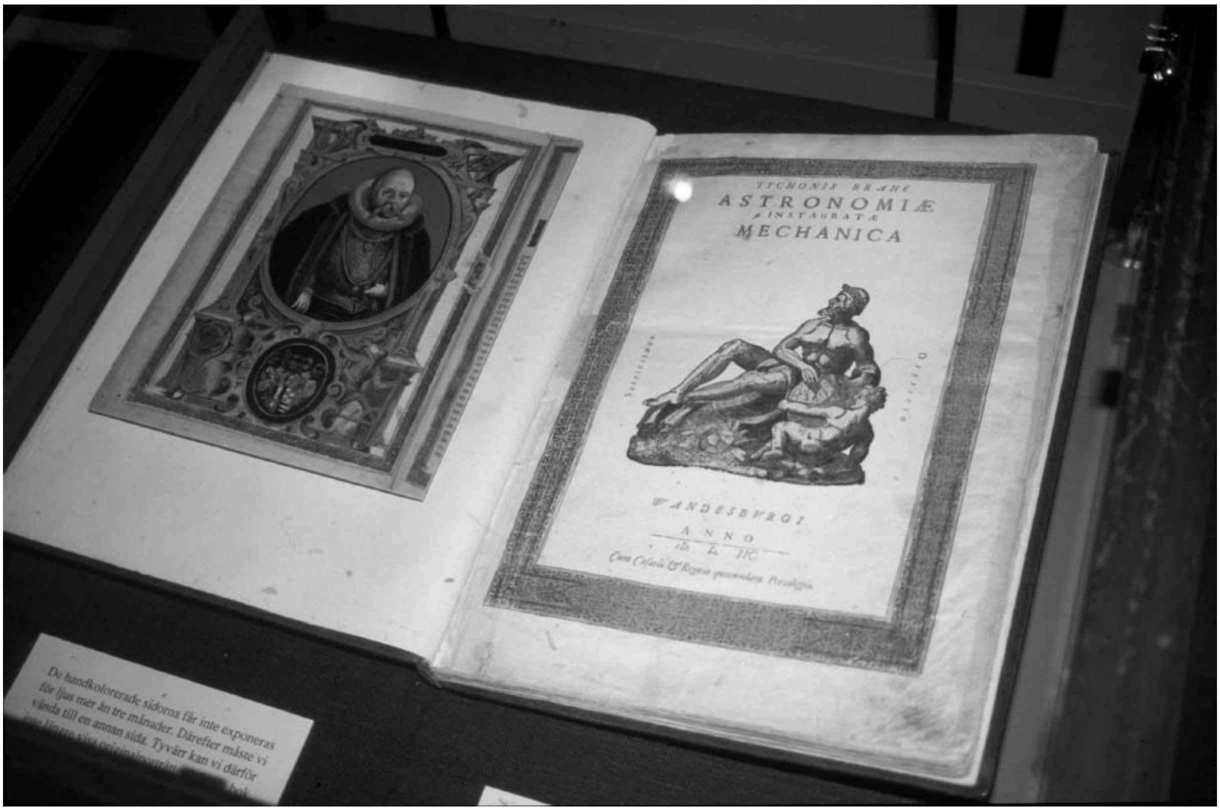


Figure 17: On the occasion of the 450th anniversary of Tycho Brahe's birth in 1996, a series of outstanding exhibitions was arranged, using a wealth of original material to describe the famous astronomer, instrument maker, paper producer and printer in great detail. It began in Landskrona with "Tycho Brahe. Stjärnornas Herre" (Tycho Brahe, Master of the Stars), then with a slightly different focus, the exhibition was shown at the Ole Rømer Museum near Copenhagen and finally at The Steno Museum in Aarhus. The latter exhibitions were called "Tycho Brahe 450 years of age. The New Star". The story of the paper mill was told in brief, with the aid of a newly built copy of a part of the millwheel. The art of printing was demonstrated through a series of original books. Here we see *Astronomiae instauratae Mechanica* from 1598. Opposite the title page, with its often used woodcut of "Astronomy" with the words "Svspiciendo – Despicio" (by looking up I am looking down) the vain author's self-portrait is placed. Photo: JV in Landskrona, Sept. 10., 1996.

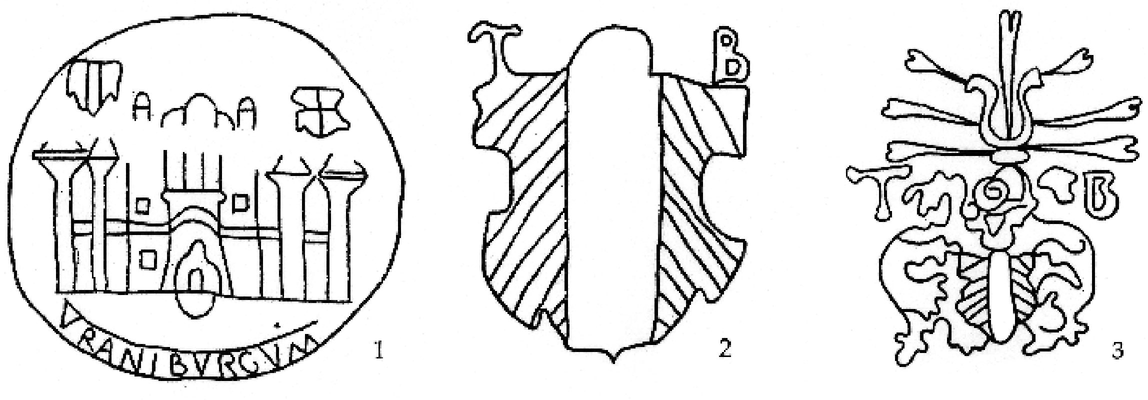


Figure 18: The study of the paper produced in the paper mill on Hven, is, despite more than a hundred years of research, far from being complete. New findings appear on a regular basis, but a complete account is still lacking. Here, three of the most famous watermarks are shown. It appears that mark one and two were used for the production of books, and mark three for writing paper. Mark no. one shows, as the text VRANIBVRGVM says, the castle on Hven, whereas marks nos. two and three show the coat of arms of the Brahe family.

Tycho Brahe and Prague: Crossroads of European Science, pp. 356–359,
J. R. Christianson et al. (eds.), © *H. Deutsch 2002*

Anthropologische Untersuchung der körperlichen Überreste Tycho Brahes im Jahr 1901

Michal Šimůnek, Prag

Am 11. Oktober 1901 wurde in der Sitzung der königlichen böhmischen Gesellschaft der Wissenschaften in Prag ein Bericht über die Untersuchung der körperlichen Überreste Tycho Brahes vorgelegt, die anlässlich der Restaurierung seines Epitaphiums in der Teynkirche durchgeführt werden konnte.[1]

Sein Hauptverfasser war damals der Dozent der physischen Anthropologie am tschechischen Teil der Prager Universität, Dr. Jindřich Matiegka (1862-1941), der auch wissenschaftlicher spiritus rector der ganzen Untersuchung war. Dank seiner ausführlichen Beschreibung stehen uns heute präzise Angaben über den Zustand und die Authentizität der Überreste des bekannten Gelehrten zur Verfügung. Seinerzeit gab es nämlich Zweifel, ob Tychos Überreste – als eines Nichtkatholiken – nicht in der Zeit der Gegenreformation im XVII. Jahrhundert aus der Teynkirche entfernt wurden. Überdies war es auch möglich, dass bei der im Jahr 1721 erfolgten Restaurierung des Steinpflasters die möglicherweise vorgefundenen Überreste beschädigt bzw. sogar entfernt worden sein konnten. Wie berechtigt die zuletzt erwähnte Vermutung war, bestätigte übrigens auch der im Jahr 1901 vorgefundene Durchbruch des Gruftgewölbes und die teilweise Verschüttung der Gruft.

Die Untersuchung der körperlichen Überreste Tycho Brahes wurde am 26. und 27. Juni 1901 in der Teynkirche unter Hinzuziehung zweier Sachverständiger, nämlich des Univ. Prof. Dr. Andreas Schrutz und des schon

[1] Jindřich Matiegka, *Bericht über die Untersuchung der Gebeine Tycho Brahe's.* Erstattet von Dr. Heinrich Matiegka. Prag 1901. In meiner kurzen Darstellung gehe ich in erster Linie von dieser Arbeit aus. Einige Materialien zum Thema befinden sich auch im Archiv des Nationalen Museums in Prag.

erwähnten Univ. Doz. Dr. Jindřich Matiegka, bei Anwesenheit einer städtischen Kommission und unter Ausschluss der Öffentlichkeit vorgenommen.

Das Grab Tycho Brahes wurde am 24. Juni 1901 offiziell geöffnet. Unter dem Steinpflaster befand sich die Ziegelwölbung, die einen länglichen viereckigen Gruftraum, der an der Westseite eingebrochen war, deckte. Erst nach der Entfernung des Schuttes wurden die Überreste zweier, ursprünglich in hölzernen Särgen bestatteter Leichname aufgedeckt: Direkt zu Füßen des Grabsteines befand sich die männliche Leiche (Tycho), neben ihr dann auch die weibliche Leiche (die Gattin des berühmten Astronomen).

Der Kopf des männlichen Leichnames war mit einem Samtbarett, das mit einer sehr beschädigten Bronzedrahtspange geschmückt war, bedeckt und ruhte auf einem Polster. Den Körper deckte ein dunkelroter Seidenrock. Die Füße steckten in langen, bis an die Knien reichenden Zwirnstrümpfen und Schuhen.

Von den Überresten hatte sich die untere viel besser als die obere, vom Schutt stärker verschüttete Hälfte erhalten. Das Skelett war ausgestreckt, das Ellbogengelenk im spitzen Winkel gebeugt, so dass die Hand auf der oberen Brustgegend ruhte; das linke Ellbogengelenk war rechtwinkelig gelagert, so dass die linke Hand etwas tiefer in der Oberbauchgegend lag.

Vor der Untersuchung des Skeletts wurde auch die Gesamtlänge desselben bestimmt: Es fand sich eine Länge von 168 bis 170 cm. Dann wurde zur Reinigung und Herausnahme der körperlichen Überreste geschritten.

Die Gebeine wurden zuerst in eine Schachtel zusammengelegt und dem Hauptpfarrer der Teynkirche zur Verwahrung übergeben. Das Schädelfragment übernahm Matiegka zur Aufweichung der anhaftenden Massen und Reinigung der betreffenden Nasengegend in eigene Verwahrung.

Was die Knochen betrifft, waren besonders die Wirbelsäule und das Becken gut erhalten. Sie waren stark, massiv, mit mächtigen Höckern und Muskelansatzstellen versehen.

Vom Kopf war nur ein Teil des Gesichtes erhalten und zwar ein Teil der Stirnschuppe, die Nasenknöchelchen, das linke Jochbein, zum großen Teil der linke, zum kleineren Teil der rechte Oberkieferknochen mit den dazu gehörigen Zähnen. Vom übrigen Schädel hatte sich nichts erhalten – nur einige, fester zusammenhängende Stückchen, die das Aussehen jener Masse hatten, in welcher Matiegka die Gehirnreste erkannte.

Besondere Aufmerksamkeit wurde bei der Untersuchung dem Nasenfragment gewidmet: Bei der Ansicht von der Seite war ganz augenscheinlich der mittlere Teil des unteren Randes der Nasenknöchelchen deutlich nach vorne und nach unten geneigt, so dass der eingebogene Nasenrücken plötzlich unten durch eine kleine, stärker gesenkte Fläche abgeschlossen wurde. Der Rand der Nasenöffnung, besonders auf der eben beschriebenen, sichelförmigen Stelle und der nächsten Umgebung, aber auch tiefer bis zum unteren Drittel der Nase war hell grünlich gefärbt, wobei diese Färbung vom Nasenrand auf die Nasenknöchelchen und den Oberkieferknochen bis auf 7-15 mm verfolgt werden konnte, wo sie stufenweise in der braunen Farbe des Knochens verschwand.

Am 6. Juli 1901 wurde dann das Schädelfragment mit allen dazu gehörigen Zähnen und der erhaltene Bartrest von Matiegka in ein Glasgefäß mit eingeschliffenem Deckel eingelegt und luftdicht verschlossen, d. h. verklebt und verkittet.

Am 29. Juli konnten endlich die gesamten Gebeine samt dem Glasgefäß mit den erhaltenen Schädelfragmenten und einem zweiten Glas mit den vermeintlichen Gehirnresten, sowie die vorgefundenen Kleiderreste in den unterdessen hergestellten Zinnsarg geschlossen und an demselben Ehrenplatz in der Teynkirche in die inzwischen hergerichtete Gruft beigesetzt werden.

Aufgrund der Untersuchung der erhaltenen Leichenreste und besonders der erhaltenen Teile des Gesichtes konnte Matiegka im Jahr 1901 folgende Schlußfolgerungen ziehen:

1) Der gesamte Habitus des Skelettes und auch alle einzelnen Knochengebilde sollten den Formen und der Gestalt, die nicht nur die bekannten Abbildungen Tycho Brahes sondern auch z. B. der Grabstein in der Teynkirche zeigen, entsprechen.

2) Nach der starken Abnützung des erhaltenen Gebisses könnte man auf ein Alter schließen, welches für den genannten Gelehrten angegeben wird (55 Jahre).

3) Was den ganz spezifischen Charakter der Nase betrifft, war seiner Meinung nach klar, dass die kleine sichelförmige Fläche am oberen Rande der Nase sichere Zeichen der Reaktion nach einer vergangenen Verletzung aufweist, die augenscheinlich durch jenen unglücklichen Hieb beim Duell erzeugt wurde, durch welchen Tycho Brahe nach den Berichten seiner Biographen eine Nasenverstümmelung erlitt.

4) Die grünliche Färbung der Ränder der Nase sollte zeigen, dass an diesen Knochenteilen lange Zeit ein kupferhaltiges Element befestigt wurde, von dem sie durch Kupfersalze imprägniert wurden. Dieses kupferhaltige Element war – wie mit großer Wahrscheinlichkeit angenommen werden kann – die oft erwähnte Nasenprothese (die künstliche Nase von Brahe). Diese Prothese sollte nach Meinung Matiegkas leicht, also nur aus sehr dünnem Blech hergestellt gewesen sein, das im Laufe der Zeit vernichtet werden konnte, so dass man trotz eifriger Nachforschung von ihr im Jahr

1901 schon keine Spur mehr fand.

5) Das zweite, in der Gruft der Teynkirche vorgefundene Skelett stammte von einer älteren Frau, wohl der Gattin Tycho Brahes, die drei Jahre nach ihm starb und an seiner Seite bestattet wurde.

Tycho Brahe and Prague: Crossroads of European Science, pp. 360–375,
J. R. Christianson et al. (eds.), © *H. Deutsch 2002*

Tycho Brahe as a Meteorologist

Jan Munzar, Brno – *Jan Pařez*, Prague

It seems sometimes too daring and inaccurate to introduce a scholar by using the word "as", particularly if the personality in question used to be known for running activities in extensive parts of the scientific spectrum of his / her historical era. Nevertheless, speaking of famous Danish Tycho Brahe (1546-1601), we would not be exhaustive enough to present him just as an outstanding astronomer. And this is a reason for us to discuss his contribution to meteorology.

Tycho Brahe had several reasons to be interested in the subject of meteorology. First, he knew that quality of his sky observations depends on atmosphere conditions and he tried to reveal their rules. Second, we know that his attitude to astrology was altogether sceptical. Monitoring of meteorological phenomena and comparing them to astrological predictions was the way by which he wanted to verify the credibility of astrological conclusions. Finally, the basic methodological premises of Tycho Brahe were formed by Paracelsian philosophy, hermetic sciences and neo-Platonism. Relations between macrocosmos and microcosmos and their intersection in the fifth essence (*quinta essentia*) represented by humans, an understanding of the world in this context, and the discovery of a universal harmony in the cosmos – all this we can trace in the attitudes of Renaissance scholars.[1] From this point of view, seemingly non-related sciences were combined during the process of research of nature. For example, Oswald Crollius (c. 1550-1609), a physician of Rudolf II, described in his *Tractatus de signaturis internis rerum*[2] relations between humans and the sky. According

[1] PAGEL, W.: *Paracelsus. An Introduction to Philosophical Medicine in the Era of the Renaissance.* 2nd, revised edition, Basel – München – Paris – London – New York – Tokyo – Sydney 1982. About Tycho's philosophical background see CHRISTIANSON, J. R.: *On Tycho's Island. Tycho Brahe and His Assistants, 1570-1601*, Cambridge University Press 2000, and of course, J. SHACKELFORD'S contribution in these Proceedings. The recently published work dealing with this problem in Czech language is the work by B. D. HAAGE, *Středověká alchymie. Od Zosima k Paracelsovi*, Praha 2001.

[2] CROLLIUS, O.: *Tractatus de signaturis internis rerum, seu de vera et viva anatomia*

to this work, the general appearance of the sky corresponded to the human physiognomy, earthquake to fever, tempest to epilepsy. This trend of hermetic philosophy culminated in the work of Robert Fludd (1574-1637)[3] and also influenced John Amos Comenius (1592-1670).[4]

However, some scholars did not abandon these opinions up to the end of the 17th century, which we can prove, for example, in the printed defence of Johannes Bernard Celestin, imperial count of Rodern. In his *Meteorologia philosophico-historica* (Augsburg 1698) he described astronomical, meteorological, geophysical and geological phenomena and sought their parallel in social and political life.[5]

Tycho saw the atmosphere as a transitional zone between heavens and earth. He had compiled daily meteorological observations in an attempt to determine what the atmosphere was really like, and how it served to link heavens and earth.[6]

We focused our interest on Tycho Brahe's meteorological observations, however, from different points of view. The first part deals with this subject in general, while the second with one small individual text of astrological-meteorological content.

Weather on Hven in the years 1582-1597

The contribution of Tycho Brahe to meteorology falls into the second period of its development, i.e. from the 16th century to the mid-17th century when systematic everyday weather observations were started without the main meteorological instruments (barometer and thermometer) because they had not been invented yet. This era is therefore called the era of visual observations although there was a wind vane already appearing in Brahe's observatory in Uraniborg to measure wind direction. The importance of these observations consists both in their duration and in the fact that they were made at one place. Certain parts of the above mentioned period of time were covered also by observations made in Europe by the astronomer David Fabricius (1564-1617) in eastern Friesland and by the abbot Leonhard III Treuttwein (1529-1595) in Bavaria *(Fig. 1)*.

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majoris et minoris mundi, Pragae 1608.

[3] Fludd, R.: *Utriusque cosmi maioris scilicet et minoris metaphysica, physica atque technica historia ...*, Oppenhemii 1617.

[4] Červenka, J.: *Die Naturphilosophie des Johann Amos Comenius*, Praha 1970.

[5] See Pařez, J.: "Zemětřesení v roce 1590 v Čechách ve světle několika soudobých tisků. Příspěvek ke zkoumání raně novověké mentality", *Documenta Pragensia* 16, 1998, pp. 187-196.

[6] Christianson, J.R.: *On Tycho's Island*, p. 144.

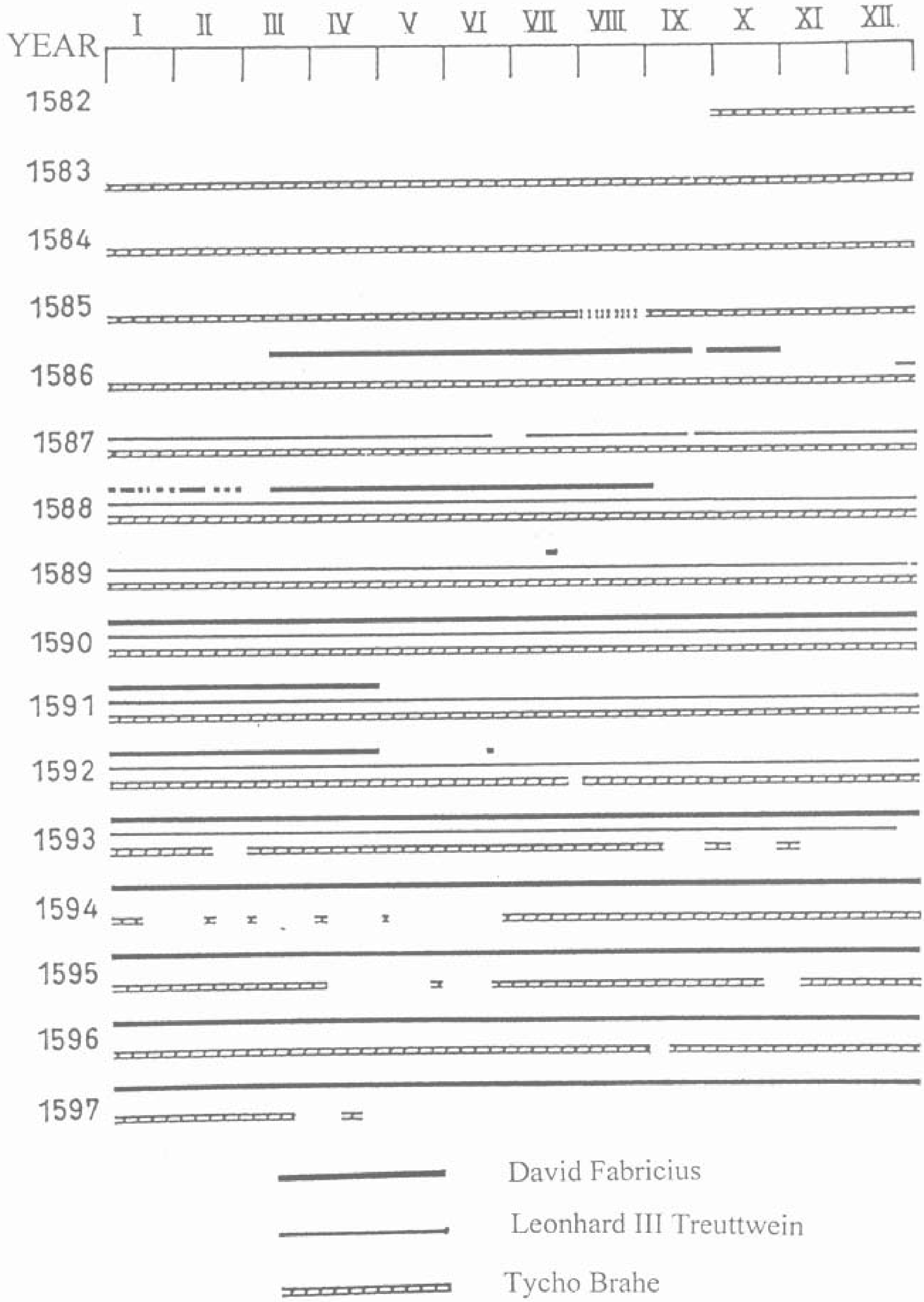

Figure 1: Survey of weather observation series duration in eastern Friesland and Bavaria as compared with Hven according to W. LENKE (1968).

The preserved meteorological diary was first edited *in extenso* in the year 1876 and later included by J. L. E. Dreyer in his edition of Tycho's writings, which are the subject of our analysis.[7]

It seems that a majority of researchers disregarded the fact that the series of observations from Hven is dated in the Julian calendar; this means that with regard to the Gregorian correction by 10 days the weather observations in the diary start from 1 (11) October 1582 and end 22 April (2 May) 1597 as Denmark adopted the Gregorian calendar as late as in the year 1700 (Bohemia in 1584).

Also, the statement that the meteorological diary is written in Danish[8] is not accurate enough since some extensive parts of entries are written in Latin and there are also several daily records with German entries. For example, right on the second day of observations – 2 (12) October 1582 – the entry in Danish "*Rain and heavy storm (gale) from the West lasting the whole day*" is followed by an additional note in Latin "*There were many shipwrecks during the storm on the coast of Skåne between Helsingør and Landskrona*" (transl. PhDr. L. Kysučan). The piece of information *(Fig. 2)* apparently had to be added later. Numerous weather surveys for periods with missing daily records are also written in Latin, and in the period from 5 (15) August to 5 (15) October 1585 the diary is written exclusively in this language. The diary contains a total of nearly 5000 entries of which 4900 are daily entries. The nearly 15-year Tychonian series of observations could not avoid occasional interruptions *(Fig. 1)*. The weather information is entirely missing for 109 days, i.e. for 2% of the whole period. The daily observations are sometimes substituted with a brief weather survey relating to several days – in 6% of all days in the series. The longest break dates *de facto* from 1 (11) May to 22 July (1 August) 1584 since the observation was not made on Hven but during an expedition to Frombork, organized to detect the precise latitude of the astronomical observatory of Nicholas Copernicus.

Although the last weather entry is made on 22 April (2 May) 1597, the last observation from Hven dates back to 21 (31) March 1597 and is glossed by the following note written in Latin: "*In the following days the weather was unsettled, but we could not make the observation or recording due to other commitments.*" (transl. L. K.). The weather entries for the period from 11 to 22 April of the Julian calendar undoubtedly relate to Copenhagen.

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[7] Dreyer, J. L. E. – Raeder, I.: *Tychonis Brahe Dani Opera Omnia*, Vol. 9, pp. 1-146. Hauniae 1927.

[8] Pfister, Ch. et al.: "Daily weather observations in sixteenth-century Europe". *Climatic Change* 43, 1999, p. 126.

MUTATIONES AERIS INCIPIENTES MENSE OCTOBRI ANNI 1582.

OCTOBER.

1. Mørcktt formiddag och tørtt, men efftermiddag regn vndertijden medt weſten bleſt.
2. Regn och weldig Storm then ganttſke dag aff weſten. *Illa tempeſtate non pauca ſunt facta naufragia ad littora Scanica inter Coroniam et Helſingoram.*
3. Medt mørcktt och klartt beblanditt medt ſtor ſtorm aff Nordueſt, dog minder Storm ind den forgangen dag.
4. Mørcktt och klartt beblanditt, tørtt och ſtille norden wehr.
5. Mørcktt och klartt beblanditt, tørtt medt ſtille Norden wehr, dog imodt afftenen naagitt graaendis.
6. Mørcktt och tørtt den ganttſke dag medt ſtille Norden wehr.
7. Smuchtt klartt och ſtille norden wehr om dagen, om afftenen Sudueſt graae, och om natten regn.
8. Mørcktt och tørtt medt temmelig graae af Sudueſt.
9. Om morgenen Norden, ſiden vdt paa dagen weſten, naagitt graaendis och mørcktt den ganttſke dag.
10. Formiddag klartt och ſtille Norden, om efftermiddagen naagitt mørckere medt ſtille weſten. Om Natten bleſt.
11. Mørcktt och tørtt den ganttſke dag medt temmelig bleſt aff veſtſudueſt. ||
12. Mørcktt och tørtt den ganttſke dag medt ſterck Synden bleſt.
13. Mørcktt medt ſterck Synden graae den ganttſke dag, om efftermiddag regn.
14. Mørcktt och tørtt inthill imodt afftenen, ſiden klartt medt graaendis nordueſt.
15. Mørcktt medt ſtercktt Øſten werd, om efftermiddagen och om natten regn.
16. Mørcktt den ganttſke dag medt ſamme warendis Øſten bleſt, och ſachte regn iblantt.
17. Mørcktt och tørtt then ganttſke dag medt lempelig graae aff Veſten.
18. Mørcktt och klartt beblandett tørtt medt ſtille veſten wehr.
19. Mørcktt och ſachte regn iblantt medt ſtorm aff Sudoſt.
20. Mørcktt och tørtt medt temmelig Sudoſt windt.
21. Smucktt klartt och Sudueſt om formiddagen, om efftermiddagen mørcktt och klartt huerandenſtund medt Synden bleſt.
22. Mørckt och tørtt den ganttſke dag, dog om formiddagen naagitt klartt, medt ſterck Synden bleſt, om afftenen regn.
23. Mørcktt den ganttſke dag medt regn och taage iblantt och Sudueſt.
24. Mørcktt inthill imodt middag, ſiden klart then ganttſke dag, medt ſmucktt ſtille Nordueſt, om afftenen naagen tijdt lang mørcktt och weſten, ſiden klartt och Nordueſt igien. ||
25. Smucktt klartt och ſtille Nordueſt then ganttſke dag.
26. Mørcktt och tørtt den ganttſke dag medt ſtorm aff Veſten, om afftenen naagitt klartt.
27. Førſt om formiddagen mørcktt, ſiden klartt den ganttſke dag, och ſtille nordueſt.
28. Mørcktt och tørtt den ganttſke dag medt temmelig graae aff Veſten, om formiddagen naagen tijdt lang taagitt.
29. Mørcktt och tørtt medt Sudueſt wind.
30. Mørcktt och tørtt den ganttſke dag medt veſten bleſt.
31. Mørcktt dagen ygiennom, om afftenen ſilde regn, medt idelig ſtorm aff veſten och Sudueſt.

NOUEMBER.

Figure 2: Facsimile of the first page of Tycho's meteorological diary from the edition of J. L. E. Dreyer and I. Raeder (1927).

Winds on Hven and their measurement

The sole meteorological instrument at Uraniborg – wind vane – is mentioned in Tycho's work called *Astronomiae instauratae mechanica* in a following way: "*There is a gold-plated Paegasus placed on the tower, which points with its rotating indicator placed under the ceiling of the highest located room from where the winds flow*" *(Fig. 3)*.[9]

Where Tycho Brahe got his inspiration for the assembly and installation of the apparatus is not known. What is known, however, is the fact that a simple wind vane was used already by Vikings at their sailings – the fact speaking for the Scandinavian tradition. In the South of Europe, the wind vane with an axis elongated into the room and together a wind direction indicator was known to the polyhistor M. T. Varro as early as in the 1st century B. C.[10] At the time of the Tychonian observations, a wind vane was installed by the Czech nobleman Petr Vok of Rožmberk at his manor house in Bechyně (southern Bohemia), but details of the construction are not known.

It follows from a preliminary analysis into the observed wind directions that there was a total of sixteen of them. In addition to identifying the winds by cardinal points, the Latin-written part of the diary from August to October 1585 also contains historical Latin names without any specification of cardinal points, occasionally a combination of the two designations.

For the purposes of the history of meteorology we mention the names of winds in the chronological order along with the identification of their directions in brackets: Boreas (N), Vulturnus (NE), Subsolanus (E), Euronotos (SE), Notos (S or SSE), Austroafricus (SSW), Libonotus (W) and Corus (NNW or WNW). It is an interesting mixture of names from the Latin and Greek wind roses with three of the winds originating from the 24-mark wind rose of the Roman builder P. Vitruvius from the era of Caesar and Augustus. It is therefore possible to assume that Tycho Brahe and a builder working for him at Uraniborg employed the knowledge of Vitruvius' work *De architectura libri decem*.

In the era of sailing vessels, the observation of wind directions was very important for the traffic on Hven as well as in Øresund in general. This can be documented by a Latin note originating from the year 1593: "*Nearly whole these two weeks* [= 8-22 September of the Julian calendar] *had nearly similar weather – misty and rainy with the heavily flowing Zephyr* [= W]

[9] Hadravová, A. – Hadrava, P., eds.: *Tychonis Brahe Astronomiae instauratae mechanica – Přístroje obnovené astronomie*, Praha 1996, pp. 154-155.

[10] Pejml, K.: *The 200th Anniversary of the Prague-Clementinum Meteorological Observatory* (in Czech – English summary), Praha 1975, p. 7.

Figure 3: Copper-engraving of Uraniborg with a wind vane on the top of a central turret. *Astronomiae instauratae mechanica* (1598).

and Caurus [= NW]. *Even the ships that were to head for Copenhagen were held in Helsingør for several days*" (transl. L. K.).

Meteorologists at Uraniborg

A work generally referred to is the meteorological diary by Tycho Brahe; however, it is not clear to what extent he personally participated in the weather observations. According to Lenke,[11] the diary was run by his assistants Olsen and Goldschmidt. This assumption was fleshed out by using data from the monograph by J. R. Christianson.

The first of the assistants, Elias Olsen Morsing (1550?-1590), was both an astronomer and meteorologist. On his arrive on Hven in spring 1583, he was appointed by Tycho Brahe to do meteorological observations, which he made for a greater part of the period from April 1583 to April 1589.

The surname Goldschmidt does not appear in the diary at all; the only explanation being an assumption that the person was Tycho's goldsmith and mechanic Hans Crol (also referred to as Johannes Aurifaber) who is spoken of as a sharp-eyed observer with a lot of astronomical diaries written in the period 1586-1590, who died on Hven towards the end of the year 1591. He most probably did the weather observations in the years 1589-1591; nevertheless, who launched the series of observations and who was the last one to end it still remains a question. From October 1582, the weather observations were most probably made by Peter Jacobsen Flemløse (1554-1598) who was at Tycho's services in the years 1577-1588 being considered his most trusted assistant also for meteorology. When the King Frederick II requested a handbook of weather prognostication in 1588, Tycho assigned the task of composing it to Flemløse. The publication – based on astrometeorology and issued on Hven in 1591 – contains a foreword by Tycho, which was to demonstrate practical applications of the meteorological research to the sovereign, patron of sciences.

An occasional observer was apparently also the German student Sebastian Borussus in April 1590 when the entries for several days are written in German. It is assumed that it was himself who translated the handbook by Flemløse into German.

Another weather observer in the 1590s was presumably Christian Sørensen Longomontanus (1562-1647) who was at Tycho's services on Hven in the years 1589-1597 and later in Bohemia in 1600-1601. He was a practical

[11] Lenke, W.: "Das Klima Ende des 16. und Anfang des 17. Jahrhunderts nach Beobachtungen von Tycho de Brahe auf Hven, Leonhard III. Treuttwein in Fürstenfeld und David Fabricius in Ostfriesland", *Berichte des Deutschen Wetterdienstes*, Nr. 110, 1968, 49 pp.

astronomer whose instructor was however Elias Morsing. It was Longomontanus to whom Tycho dictated his foreword for the handbook written by Flemløse.

Nevertheless, the question of the personal share of Tycho Brahe in the weather observations still stands open and the answer is not easy. We have to bear in mind that the great astronomer succeeded in having implemented team research in the modern sense. The force of events transformed his role into that of administrator, project initiator, author and supervisor. Much of the day-to-day scientific work fell on the shoulders of his *familia* of scholars and craftsmen under the leadership of the senior assistants. If it was today, the research results would be presented as by Tycho Brahe et al. We assume therefore that Tycho most probably did not participate in the every-day observations; he could however be the author of some Latin entries.

T. Brahe was aware of the importance of weather for astronomical observations. It was mostly the effect of weather on the instrumentation at Uraniborg that became a reason for building the second observatory at Stjerneborg where measuring instruments were installed below the terrain horizon in order to suppress permanent effects of wind (vibration) as well as the fluctuation of air temperatures outside. Apart from this, there are two concrete notes written in Latin found in the meteorological diary, concerning the adverse influence of weather on the work of the astronomers in summer 1585 and in 1592. Detailed observations of polar auroras and halo phenomena with sketches document a serious interest in the phenomena occurring between the heaven and earth.

In 1585, Morsing was appointed by Tycho Brahe to prepare an astrometeorological almanac for 1586. The manuscript was already in press when a comet was sighted in October 1585. An appendix on this comet, with a part of astrological prognostication written by Tycho, was added to the calendar. The work came out under the name of Morsing.

Tycho's friend in Prague, Tadeáš Hájek z Hájku (1525-1600) took astrometeorology for a mathematical science – not taking into account its failures – and himself produced weather forecasts on its basis.[12] The science of astrometeorology culminated and practically ended in Bohemia with Johannes Kepler (1571-1630) who made a lot of weather observations for these purposes at numerous places during his stay but preserved are only his observations made on the margin of ephemerides for 14 years. In their time, the work in meteorology had its scientific significance which

[12] Krška, K.: "Tadeáš Hájek z Hájku jako meteorolog". In: Drábek, P. (ed.): *Tadeáš Hájek z Hájku*, Praha 2000, pp. 61-66.

consisted in the observation of actual weather and its comparison with the weather forecast.[13] Or the astronomers attempted at an additional explanation of weather extremes on the basis of a reconstruction of the constellation and mutual position of planets, which for example relates to the severe winter of 1495/96.

Unknown Tycho Brahe's meteorological note about the winter 1495/96

After Tycho Brahe's death in 1601, his private library was scattered. Forty years later, one part of it came to the Prague Jesuit college of Klementinum. Jesuit librarian identified Tycho's books and marked them with a note "*Ex bibliotheca Tichoniana*" *(Fig. 4)*.[14]

Many years later, but probably not before the abolition of the Jesuit Order in 1773, some books were bought by the Strahov Abbey (by the way, there are five books from Tycho's library in the Strahov book collection). Among them is the incunabulum of Johannes Regiomontanus' *Ephemerides.*[15] On the leaf a2 we can see the inscriptions "*Collegii Caesarei Societatis JESU Pragae Anno 1642°*" and "*Ex bibliotheca Tichoniana*", what indicates that this book was originally saved in the library of the Jesuit college of Klementinum, Prague. On another leaf of this book, 75v, we can find an entry about weather conditions in northern Germany and Denmark written – as we presume – by Tycho Brahe's own hand. This text was discovered in 1913 by the Strahov librarian Cyril Straka.[16] However, in the following years this *Tychonianum* had been marginalized until it was remembered several years ago in a concise paper about *Tychoniana* in the Strahov Library.[17]

Now, let us turn our attention to the content of the note. Interpreted abbreviations are put in brackets, original orthography is preserved. The form of signs & and *&* for the Latin word *et* were left *(Fig. 5)*.

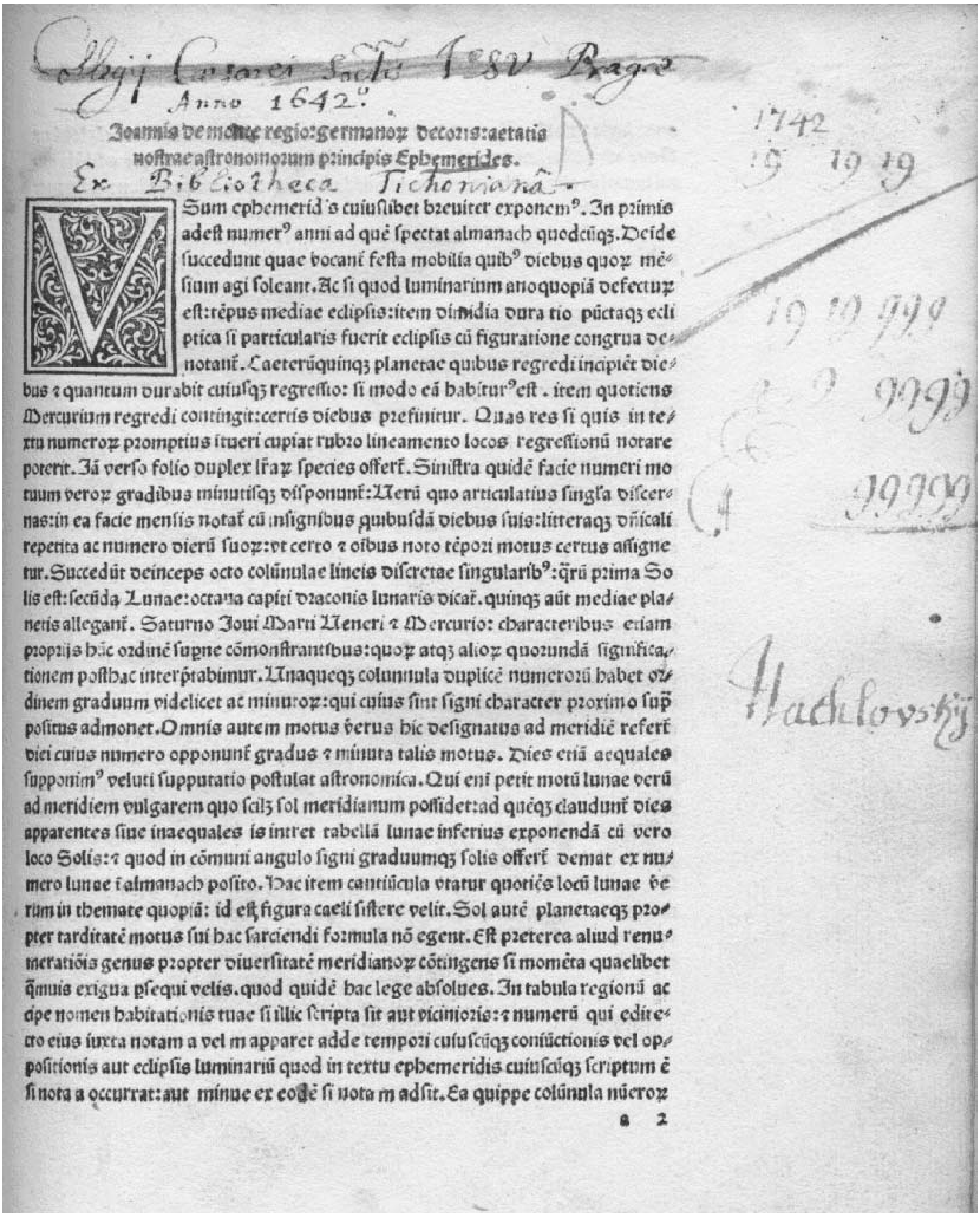
[13] Krška, K. – Šamaj, F.: *The History of Meteorology in the Czech Lands and in Slovakia* (in Czech – English summary), Praha 2001, 564 pp.

[14] Kleinschnitzová, F.: "Ex bibliotheca Tychoniana Collegii soc. Jesu Pragae ad s. Clementem", *Sonderabzug aus Nordisk Tidskrift för Bok- och Biblioteksväsen* 20, 1933, Uppsala 1933.

[15] Strahov Library, Prague, sign. AG VII 84. Regiomontanus, J.: *Almanach ad annos xv accuratissime calculata [1492-1506].* S.l. s.d.

[16] Straka, C.: "Zápis Tychona Brahe v knihovně strahovské", *ČČM* 87, 1913, pp. 382-384.

[17] Pařez, J.: "Tychoniana ve Strahovské knihovně", in: *Dr. Bedřišce Wižďálkové přátelé a spolupracovníci k významnému životnímu jubileu, Příspěvky ke knihopisu* 11, Praha 1996, pp. 89-96.



Anno 1642.

Joannis de monte regio: germanorum decoris: aetatis nostrae astronomorum principis Ephemerides.

Ex Bibliotheca Tichoniana

Usum ephemerid's cuiuslibet breuiter exponem⁹. In primis adest numer⁹ anni ad quē spectat almanach quodcūqȝ. Deide succedunt quae vocant festa mobilia quib⁹ diebus quorum mēsium agi soleant. Ac si quod luminarium anoquopiā defectur est: tēpus mediae eclipsis: item dimidia duratio pūctaqȝ ecliptica si particularis fuerit eclipsis cū figuratione congrua denotant. Caeterūquinqȝ planetae quibus regredi incipiāt diebus & quantum durabit cuiusqȝ regressio: si modo eā habitur⁹ est. item quotiens Mercurium regredi contingit: certis diebus praefinitur. Quas res si quis in textu numerorum promptius ītueri cupiat rubro lineamento locos regressionū notare poterit. Iā verso folio duplex literarum species offert. Sinistra quidē facie numeri motuum verorum gradibus minutisqȝ disponunt: Verū quo articulatius singula discernas: in ea facie mensis notant cū insignibus quibusdā diebus suis: litteraqȝ dñicali repetita ac numero dierū suorum: vt certo & oibus noto tēpori motus certus assignetur. Succedūt deinceps octo colūnulae lineis discretae singularib⁹: quarū prima Solis est: secūda Lunae: octaua capiti draconis lunaris dicat. quinqȝ aūt mediae planetis allegant. Saturno Ioui Marti Veneri & Mercurio: characteribus etiam proprijs hāc ordinē supne cōmonstrantibus: quorum atqȝ aliorum quorundā significationem posthac interpretabimur. Unaquaeqȝ colunnula duplicē numerorū habet ordinem graduum videlicet ac minutorum: qui cuius sint signi character proximo suppositus admonet. Omnis autem motus verus hic designatus ad meridiē refert diei cuius numero opponunt gradus & minuta talis motus. Dies etiā aequales supponim⁹ veluti supputatio postulat astronomica. Qui eni petit motū lunae verū ad meridiem vulgarem quo scilȝ sol meridianum possidet: ad quēqȝ claudunt dies apparentes sive inaequales is intret tabellā lunae inferius exponendā cū vero loco Solis: & quod in cōmuni angulo signi graduumqȝ solis offert demat ex numero lunae ī almanach posito. Hac item cautiūcula vtatur quotiēs locū lunae verum in themate quopiā: id est figura caeli sistere velit. Sol autē planetaeqȝ propter tarditatē motus sui hac sarciendi formula nō egent. Est praeterea aliud remuneratiōis genus propter diuersitatē meridianorum cōtingens si momēta quaelibet quamuis exigua psequi velis. quod quidē hac lege absolues. In tabula regionū accipe nomen habitationis tuae si illic scripta sit aut viciniorīs: & numerū qui e directo eius iuxta notam a vel m apparet adde tempori cuiuscūqȝ coniūctionis vel oppositionis aut eclipsis luminariū quod in textu ephemeridis cuiuscūqȝ scriptum ē si nota a occurrat: aut minue ex eodē si nota m adsit. Ea quippe colūnula nūerorum

a 2

Figure 4: Page from REGIOMONTANUS' *Ephemerides* with a note *Ex bibliotheca Tichoniana.*

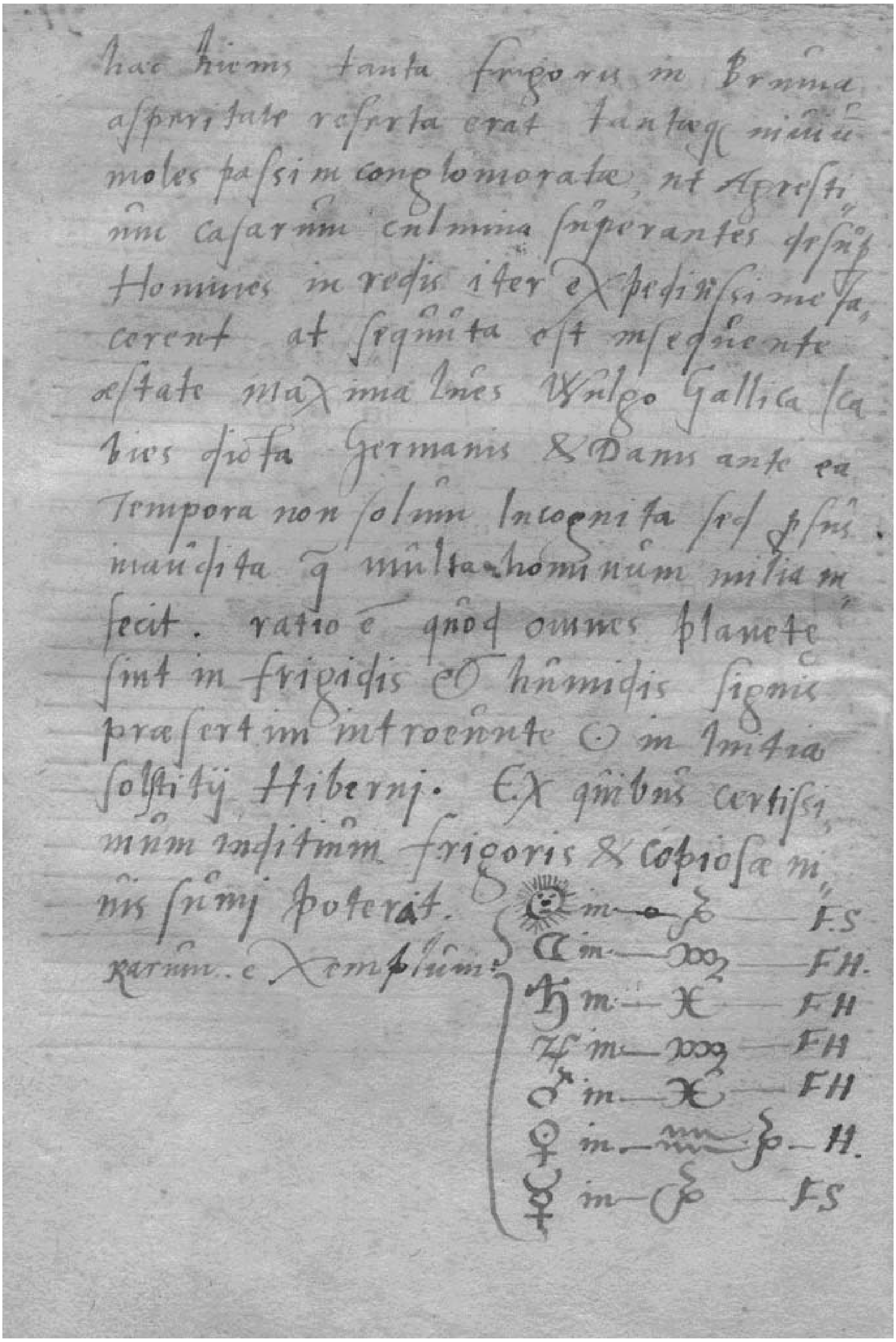

hac hiems tanta frigoris in bruma
asperitate referta erat tantaeque nivium
moles passim conglomoratae, ut Agresti-
num casarum culmina superantes [illegible]
Homines in redis iter expeditissime fa-
cerent at sequuta est in sequente
aestate maxima lues vulgo Gallica sca-
bies dicta Germanis & Danis ante ea
Tempora non solum Incognita sed [illegible]
manifesta quae multa hominum milia in-
fecit. ratio est quod omnes planetae
sint in frigidis et humidis signis
praesertim introeunte ☉ in Initio
solstitij Hiberni. Ex quibus certissi-
mum inditium frigoris & copiosae ni-
vis sumi poterat.
Rarum exemplum

Figure 5: Entry about winter 1495/6 in Regiomontanus' *Ephemerides*.

Haec hiems tanta frigoris in Bruma asperitate referta erat tantaeq(ue) nivium moles passim conglomoratae [sic!], *ut agrestium casarum culmina superantes desup(er) homines in redis iter expeditissime facerent at sequuta est in sequente aestate maxima lues wulgo gallica scabies dicta Germanis & Danis ante ea tempora non solum incognita sed pro(r)sus inaudita q(uod) multa hominum milia infecit. Ratio e(st) quod omnes planete sint in frigidis & humidis signis praesertim introeunte ☉ in initia solstitii hibernii. Ex quibus certissimum inditium frigoris & copiosae nivis sumi poterat.*
Rarum exemplum.

[Astrological symbols expressing the position of the planets in stellar constellations of zodiac and their effect are explained in the text below]

"This winter abounded hard frosts in the time of solstice and such plenties of snow piled everywhere so that people comfortably went by sleighs over the highest tops of peasant houses. And in the following year came a great plague, generally called French scabies, about which Germans and Danes had had no knowledge nor had heard anything, and affected many thousand people. The cause of that was that all planets were situated in humid and cold signs, especially after entry of Sun into the beginning of winter solstice. From that we can deduce a sure prognosis of frost and abundance of snow. Rare case."

[Sun in the sign of Capricorn caused humidity and dryness.
Moon in the sign of Scorpio caused cold and humidity.
Saturn in the sign of Fish caused cold and humidity.
Jupiter in the sign of Scorpio caused cold and humidity.
Mars in the sign of Fish caused cold and humidity.
Venus in the sign of Aquarius and Capricorn caused cold and humidity.
Mercury in the sign of Capricorn caused cold and dryness.]

Briefly said, Tycho Brahe explained in an astrological way the causes of an extremely cold winter season in northern Germany and Denmark.

And here we have to put two questions. Was it really Tycho's hand that wrote the note? Did this note really relate to the year 1495?

Palaeographical analysis was based on comparing our text to several other Tycho's inscriptions, especially his motto in *liber amicorum* of Sebald Plan,[18] his dedication to the Bohemian astrologist Jan Zajíc of Házmburk

[18] Strahov Library, Prague, ms. DG IV 25.

in the Strahov copy of *Astronomiae instauratae mechanica*,[19] and another Prague text of Tycho, *Triangulorum planorum et sphaericorum praxis arithmetica.*[20] Unfortunately, the last named work isn't probably Tycho's autograph and two small inscriptions, written on different occasions and with differently prepared quills, don't offer enough material to be compared. Moreover, humanistic semi-cursive, used by Tycho Brahe, was very uniform, and the shape of some letters oscillates between two forms according to their position in a word.

Very close similarity can be demonstrated especially on letters a, b, c, i, l, m, n, o, p, r, s, t, u (including u-identification mark over u). *Ductus* and general form of our entry is also very close to Tycho's indisputable hand. Conclusions of palaeographical analysis confirmed that this entry was written with a high probability by the hand of Tycho Brahe. However, we are sure the entry was written by a person from Tycho Brahe's immediate milieu, if he was not the author.

And the second answer. As today, book owners often wrote their current comments to the old calendars and other types of chronological books. However, we have one precondition and one piece of meteorological evidence indicating that the correct date is really the year 1495. As we can read above, Tycho kept records about weather for many years. If he did it in a such detailed way, he had no reason to put an entry about the winter of 1595 in one hundred year old *ephemerides.*

Furthermore, we know the winter of 1495/6 was severe, very bitter. Snow appeared as early as in November 1495 and it was very cold from Christmas to March. In February 1496, frosts were so bitter that the Danzig Bay got covered with ice and sleighs could be driven on it from the town of Danzig (Gdańsk) to as far as the Peninsula of Hel.[21]

In the West, written sources mention frozen sea between Pomerania and the Danish isles. At that time, inhabitants of Pomerania were able to go by sleighs to the isle of Falster as well as the isle of Møn southward from the big isle of Sjaelland.[22] The frozen Gulf of Finland enabled Russian

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[19]Strahov Library, Prague, sign. AG XI 56. See Horský, Z. – Tenorová, D.: *Soupis tisků předních pražských astronomů 16.-17. století v historických knihovnách ČSR*, Scripta astronomica 5, Praha 1990, pp. 61-62.

[20]Studnička, F. I. (ed.): *Tychonis Brahe triangulorum planorum et sphaericorum praxis arithmetica*, Pragae 1886.

[21]See Glaser, R.: *Klimageschichte Mitteleuropas. 1000 Jahre Wetter, Klima, Katastrophen*, Darmstadt 2001, p. 82.

[22]Girguś, R. – Rojecki, A. – Strupczewski, W.: *Wyjątki ze źródel historycznych a nadzwyczajnych zjawiskach hydrologiczno-meteorologicznych na ziemiach polskich w wiekach od X do XVI*, Warszawa 1965, pp. 87-89.

troops to attack Viborg by surprise from the sea.[23]

The author of the entry used information about meteorological condition that he had learned from the historical documents. The position of planets recorded in Regiomontanus' ephemerides indicating cold weather in the year 1495 started Tycho Brahe's interest in confirming astrological prediction by historical reports. Probably, he retrospectively detected the meteorological situation of the winter 1495/6 and then wrote it in ephemerides. It was demonstrated from a number of independent sources that Tycho's entry in the ephemerides really does relate to the severe winter of 1495/96 rather than to the generally normal winter of 1595/96 in his own time.

A check and reconstruction of the mentioned constellation and mutual positioning of planets made by J. Hollan speaks for the winter of 1495/96. Except for a small deviation in the constellation of the Moon, the arrangement of planets as mentioned in Tycho's entry is unambiguously appurtenant to the mentioned solstice. Also, there cannot be any doubt that the great infection by venereal diseases – up to that time unknown by Germans and Danes – affected this part of Europe according to P. Svobodný (Archives of the Charles University / RCHSH, Prague) towards the end of the 15th century, not a hundred years later.

In any case, the opinion of Brázdil and Kotyza[24] that the entry made by Tycho Brahe relates to Bohemia and the weather described is that of 21 December 1495 is erroneous. It is an additional astrometeorological reconstruction aiming at the explanation of reasons of the severe winter in 1495/96. The only information originating from Bohemia is a chronicle entry about flour mills in Prague and its surroundings stopping their work (after 29 January 1496) due to heavy frosts and ice cover on water courses and standing still the whole month of February.[25]

Significance of Tycho Brahe's meteorological bequest

The significance of the preserved series of weather observations on Hven from the end of the 16th century left by Tycho Brahe and his assistants is not only cultural or historical. It is less known that the series of weather observations helped during the last 120 years to make partial weather re-

[23] Lindgrén, S. – Neumann, J.: "Crossings of ice-bound sea surface in history". *Climatic Change* 4, 1982, pp. 71-97.

[24] Brázdil, R. – Kotyza, O.: "History of Weather and Climate in the Czech Lands I: Period 1000-1500". *Zürcher Geographische Schriften*, H. 62, 1995, p. 251.

[25] Porák, J. – Kašpar, J. (edd.): *Ze starých letopisů českých*, Praha 1980, pp. 272-273.

constructions and to learn the climate of northern Europe in the past.

V. V. Betin and Ju. V. Preobrazhenskij[26] in their survey of winter severity in Europe and ice conditions on the Baltic Sea from the year 177 B. C. for example based their work for the period 1583-1596 on the weather data from Uraniborg.

In 1978-1979, a team of experts from the Norwich University led by H. H. Lamb made a reconstruction of the weather in western Europe from May to October 1588 using the meteorological observations from Hven in attempt to explain the influence of weather on the naval war for hegemony on the sea between Spain and England, which is known to have ended with the defeat of Spanish invaders.

As to the climatic situation, winds prevailing on Hven at the time of Tycho were those flowing from the south-east. Towards the end of the 19th century, meteorological observations made at the place of the former famous Tycho's astronomical observatory recorded south-western winds predominating for most months of the year.[27] The different wind directions would assume also a different distribution of pressure systems, which would correspond with a more frequent occurrence of anticyclones over Fennoscandia. This would suggest that winters in the North should have been more severe. According to Ekholm's estimate, February and March were by about 1.4° C and 1° C, resp. colder towards the end of the 16th century than 300 years later.

What to say in the end? We conclude with a statement that apart from his main line of science the greatest astronomer of the second half of the 16th century deserves recognition also for his work in meteorology, lesser in terms of its extent but yet notable. The meteorological bequest of Tycho Brahe is therefore still alive.

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[26] Betin, V. V. – Preobraženskij, Ju. V.: *Surovosť zim v Evrope i ledovitosť Baltiki*, Gidrometeoizdat Leningrad 1962, 109 pp.

[27] Ekholm, N.: "On the variations of the climate of the geological and historical past and their causes". *Quart. J. Roy. Met. Soc.*, 27, 1901, pp. 1-61.

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J. R. Christianson et al. (eds.),

Giordano Bruno to Rudolph II

Ivan Štoll, Prague

The purpose of my short contribution is to draw attention to an interesting historical document connected with a short visit of Giordano Bruno in Rudolphinian Prague. It is well known that Bruno published two books while in Prague, one of them dedicated directly to the Emperor, Rudolph II. Bruno's dedication is far from formal, reflects the bitter experience of his longtime wandering through Europe as well as his relation to and maybe even hope put in Rudolph's personality.

Giordano Bruno came to Prague at Easter time 1588 and left in autumn the same year. We can only make a guess as to his whereabouts, contacts and occupation there. He left traces, however, in the form of his work.

The first of his writings published in Prague is a thin booklet, just 22 pages, entitled *Jordanus Brunus Nolanus de specierum scrutinio et lampade combinatoria Raymundi Lullii, doctoris heremitae omniscii prope modumque divini*, i.e. something like "Jordanus Brunus of Nola on the concept-examination and combinatory art of Raimundus Lullus, the omniscient and all but divine hermit scholar". Roughly, the booklet contains some specific exercises in Latin grammar. Using only three basic concepts (goodness, greatness, duration), Bruno produces 64 combinations in various grammatical cases and categories – goodness is long lasting, duration of greatness is good, etc.

Bruno was fascinated by Lullus' analysis of the structure of languages. In addition, the general contemporary interest in medieval mysticism played its part and Lullian philosophy was quite a vogue in Bruno's time. Bruno's interest in Lullus sometimes tends to be exaggerated and Bruno is presented as an ardent adherent of his mysticism. It seems more likely, however, that his attitude was analogous to Kepler's relation to astrology. He was definitely convinced of its validity but, in particular, he looked upon these doctrines of vogue as an important means to attract the interest of influential people and gain at least some material support.

Bruno, therefore, made it a rule, after arriving in a residential city, to write up a treatise on Lullus' combinatory art and present it to the local ruler as a sort of calling card. At the same time he offered to provide more information on secret sciences and instruction in a fast-and-easy way of learning foreign languages. No wonder that the ruler was amazed, looked kindly on Bruno, donated him some money and recommended him to the officials of the local university. This contact usually turned out to be a disaster. In an ardent and fiery disputation at the university Bruno attacked Aristotelian doctrine. In the same time he labelled the present academicians and professors donkeys and cattle disguised in university gowns. Then he had to take French leave as quickly as possible, find some other refuge and start to compose another booklet on the art of combinations of the learned hermit. Unfortunately, a similar situation occurred repeatedly, too many times in Bruno's life.

In Prague this scenario was changed slightly. Shortly after his arrival, Bruno got his book on combinations printed by a well-known Prague printer Jiří Černý (Nigrinus) of Nigro Ponte. It was not dedicated to the Emperor but to the Spanish ambassador to Rudolph's court, Don Guillen de San Clemente. In fact, San Clemente was a Catalanian, he may have considered himself a distant descendant of Lullus and have provided financial support to some Bruno's editions. San Clemente, an outstanding member of diplomatic corps in Prague, had relatively easy access to the Emperor and could possibly mediate the highest audience for Bruno. Later on, in 1600, San Clemente was present in Rome by chance and witnessed Giordano Bruno's death on the stake. As a faithful Catholic he then rejected his teachings. He was not touched by this terrible experience at all, but observed cynically that Bruno, now turned into smoke, could visit his infinite distant worlds.

In Prague Giordano Bruno managed to write (or rather edit) another, larger book of 118 pages, concerned with mathematics and astronomy. Its full title, *Jordani Bruni Nolani articuli centum et sexaginta adversus huius tempestatis mathematicos atque philosophos centum item et octoginta praxes, ad totidem problemata, caeteris quaedam ardua, quaedam vero impossibilia, possibili et faciliore negotio persequenda*, can be roughly translated as "One hundred and sixty articles against contemporary mathematicians and philosophers and also one hundred and eighty examples and problems which some consider difficult or even unsolvable, as easily solved by Jordanus Brunus of Nola".

The book is filled with geometrical figures and phantastic pictures often bearing poetic or caballistic captions: *Star Flower, Lock of Saturnus, Ring of Gyges, Key of Saturnus* etc. It is not easy to read at all and the author had to work on its final shape in hectic haste. In fact, the book represents a geyser of mathematical axioms, theorems, articles, definitions, theses, examples and problems with too complicated numeration and we are often at a loss about which figure applies to which construction. Bruno ridicules contemporary geometricians, unable to cope with certain geometrical problems such as the construction of a regular heptagon or nonagon, or the division of an arbitrary angle into a given number of equal parts. He presents, literally gushes, tens of geometrical constructions, most of them merely approximate, of course, still fairly nice and it is hard to identify their sources. In Bruno's broad and self-confident renaissance mind, everything is possible, nothing seems difficult. He labels contemporary geometricians as "geameters", i. e. incapable of proper measuring, and philosophers as "philasophers", i. e. unable to pursue real wisdom.

Most remarkable of his concepts is the one of the infinite universe. The universe has no end, no edge and no centre at all. "All stars are fires similar to that of the Sun, circled by many planets ... No crystalline spheres exist, as the spiritually poor ones contrive and depict", says Bruno in the last article of his Prague writings. Bruno puts forward also a theological argument: it would not be worthy the almighty God's efforts to create anything less than just the infinite universe. To imagine the infinity of the universe and to accept the idea that we are in fact lost on a small lump of clay and stone rushing to unknown space is not easy and takes a good deal of courage.

The astronomers and physicists such as Tycho Brahe or Galileo Galilei could not accept this idea just because their astronomical devices did not allow them to measure the distance even to the nearest of the stars and they in principle refused to consider hypotheses not supported by experimental evidence. Johannes Kepler, who was similarly as Bruno influenced by mysticism of numbers, gave many deep thoughts to the problem of infinity and always felt dazzled by the idea. Kepler could not accept Bruno's concepts and called them horrible. He had scientific objections to raise, as well: should the universe be infinite, with the regularly spaced infinite number of stars, the sky would necessarily be overbrightened by them day and night.

The book *Articuli centum et sexaginta* drawn up by Bruno in Prague was printed by Jiří Dačický (Daczicenus) and dedicated to Rudolph II. We do not know what was Rudolph's reaction to the book and unconventional dedication. We suppose that Rudolph granted Bruno an audience but we can only guess if he had any discussion with him and what its subject was. Bruno's dedication is daring. On one side, he ascribes to the Emperor a wide outlook and knowledge in sciences and even considers him competent to remedy the intellectual atmosphere of Europe in that time. On the other side, he addresses the Emperor throughout as an equal. The Emperor could have felt offended by some formulations as well as flattered by other ones; he seems, however, to have been aware of the outstanding personality of the dedicator. Maybe he had had some preliminary information of Bruno. On the other hand, Bruno was a heretic, fugitive Dominican monk roaming through Protestant Europe and Rudolph as a Habsburg Emperor was destined to defend the Catholic confession. It must have been very difficult to foresee the reaction of the impredictable Emperor.

His reaction was a surprise for everybody. He gave Bruno 300 thalers. It was an amount equal to a whole year's income of a lower-rank court official and Bruno could buy ten horses, one thousand pairs of shoes or 100 000 pints of beer with the money. The Emperor's generosity must have made the people around wonder, it had a deeper reason and in a way it adds up to the characteristics of Rudolph's controversial personality.

Eccentric and in some periods of his life doubtless mentally ill, Rudolph was not only a passionate collector and a credulous victim of alchemists, astrologers and other tricksters. Though himself an amateur, Rudolph took a keen interest in the mystery of nature and scientific discoveries. It was he who made it possible to establish a real centre of contemporary science in his imperial palace in Prague, as a counterpart to the miserably surviving university.

At the beginning of the 17th century news about a new invention, "Dutch instrument", a telescope consisting of one focusing and one defocusing lenses, spread over Europe. The Dutch, as its first users, tried to apply the telescope in military and seafaring practice. They never arrived at the crazy idea of looking through the telescope at the sky to observe the Moon or the stars. According to historians of science, Galileo was the first man to turn the telescope upwards to the sky and discover new worlds for astronomers. However, just recently Josef Smolka drew attention to Kepler's remark noting that it was Rudolph who observed the Moon through the telescope as early as January 1610, i. e. at the same time as Galileo did. Rudolph asked for an explanation of the "continents" and "seas" observed on the Moon and was obviously much more interested in them than in the possible use of the telescope for controlling troops motions.

In this context, one remarkable personality of Rudolph's court deserves to be mentioned, namely Johann Mathias Wacker of Wackenfels (1550-1619). He came from a Protestant family in Constance, studied law in Strasbourg and Geneva and was engaged in tutoring in a noble family in Wrocław, Silesia. His extraordinary capabilities and erudition soon attracted the attention of the Court. In 1594 he was knighted and in 1595 invited to the Court as a counsellor. He played the role of Emperor's scientific ambassador and informed him of important discoveries and inventions made across Europe. It is likely that it was him who brought the news about the telescope to Rudolph.

Though Wacker formally converted to Catholicism, he remained impartial in the questions of religion and became one of the so-called "jordanists", adherents to the teachings of Giordano Bruno. He happened to be present in Rome in 1600 and witnessed Bruno's heroic death. He brought to Prague the hot news about the execution and about Bruno's extraordinary courage in the last moments of his life. Wacker tried to persuade Kepler of Bruno's concept of the universe and their discussions led to a close friendly relationship between the two men. Wacker possessed vast knowledge and a large private library. It housed a number of books by Giordano Bruno and Kepler took advantage of exploiting this source. Wacker was lucky not to be alive to experience the events following the fatal defeat in the battle at the White Mountain in 1620. His library was one of the first targets of Jesuit censorship. It is no surprise, therefore, that Bruno's book *Articuli centum et sexaginta* dedicated to Rudolph II was not preserved in Prague; it became a bibliographic rarity and today only three copies are available – in the Bavarian State Library in Munich, the Rumiantzev Museum in Moscow and the National Library, Paris.

As we read Bruno's dedication to Rudolph, we can feel all the bitterness of the life experience of a solitary fighter for his own truth. It reveals disappointment of the gloomy intellectual situation in Europe of that time, regardless of whether in Catholic, Lutheran, Calvinist or Anglican circles, it presents his complaints of human narrow-mindedness, meanness, envy, malice and intolerance. His mentions of the "sects, evil, hostile demons and devilish Erinyes in the disguise of peace envoys who feed the flames of strifes among nations" and people of different creeds sounds unfortunately too familiar to us nowaday.

The author addresses the ruler not as a representative of secular power, but as a personality possessing intellectual and moral competence to accept and understand this message, if not even to change the state of affairs, at least within his reach. Maybe this confidence impressed Rudolph, who lived in spiritual loneliness far above his companions and from the heights of Prague Castle looked down at the human swarming in the city.

Tycho Brahe and Prague: Crossroads of European Science, pp. 381–387,
J. R. Christianson et al. (eds.), © *H. Deutsch 2002*

Teaching Astronomy at the Prague University in the 14th and 15th Century

Michal Svatoš, Prague

If we are to understand the system of teaching at the Prague University in the era of Tycho Brahe, which is discussed in the essay of B. Neškudla,[1] it is necessary to return to the very beginnings of the Prague University, as the method and contents of lectures did not undergo any significant changes for the whole so-called scholastic era. At new universities located north of the Alps and east of Paris, joining the European network of universities within the first "founder wave" starting with the establishment of the Prague University in 1347/48, Cracow (Kraków), Vienna (Wien), Heidelberg, Cologne (Köln) and the university fundation in the north-German Rostock in 1419, the base of teaching was identical to the system of the previous centuries.[2] Maybe there was only the exception that the importance of preparatory education in the arts faculty that used to be a path to studies of so-called higher disciplines – medicine, law and theology – was much more common than at classic universities of Bologna and Paris type. Mastering the seven liberal arts used to be the aim of university studies for nearly two-thirds of students in the Empire, while obtaining an academic title used to be an unreachable aim for most of them. Lectures in the arts faculty used to be the base for the whole medieval university curriculum: these included mastering seven basic branches consisting of the popular *trivium* and *quadrivium*. The preparatory stage of university studies consisted of knowledge of Latin language, its grammar, stylistics, retorics and the general method of a medieval scholar, that was called *scholastica* according to its place of origin

[1] Neškudla, Bořek: *Astronomy and Astrology at Prague University before the Battle of the White Mountain*, pp. 388-392 (in this volume).

[2] *A History of the University in Europe I. Universities in the Middle Ages.* Ed. by Hilde de Ridder-Symoens, Cambridge 1992, pp. 55-60, 253-277 (German version: *Geschichte der Universität in Europa I. Mittelalter.* Hrsg. von Walter Rüegg, München 1993, pp. 279-320).

and use, while the second stage of university preparation included lectures on philosophy, geometry and astronomy and music.[3] According to an extant statute of the arts faculty established in approximately 1367,[4] even in Prague the teaching of *artes* was based on knowledge of Aristotle's writings and comments on them. There was a clear superiority of the *trivium* branches, while among the branches of *quadrivium* there was a preference for philosophy, then called metaphysics. Astronomy also took an important place in the Prague University course – its numbers of lectures took – together with philosophy – a second place, following philosophical lectures. Astronomy belonged to the branches the knowledge which were required for the students to be admitted to bachelor and master examinations.[5] As well as in other medieval teaching institutions, the core of teaching at the Prague University was based on lectures on individual disciplines. As the scholastic method put significant stress on memorising, the presented texts used to be dictated to students in parts or there were written authorised copies used for studies. At first, the student had to attend obligatory lectures required for obtaining of academic titles. Only then it was possible to start exercises (*exercicia*), that usually included comments on individual passages of presented books. Finally, the presented topic was discussed again within professor's discussion with students called *disputatio*. An annual disputation represented a top event of the medieval teaching and it represented a kind of exam in which all the masters and students of the faculty participated and all the period knowledge was applied. Teachers and students had to answer questions related to the topics discussed. Oblig-

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[3] Tewes, Götz-Rüdiger: "Dynamische und sozialgeschichtliche Aspekte spätmittelalterlicher Artespläne". In: *Artisten und Philosophen. Wissenschafts- und Wirkungsgeschichte einer Fakultät vom 13. bis zum 19. Jahrhundert.* Hrsg. von Rainer Ch. Schwinges, Basel 1999, pp. 105-128. About teaching astronomy see North, John: "The Faculty of Arts. The Quadrivium. Astronomy". In: *A History of the University in Europe I. Universities in the Middle Ages.* Ed. by Hilde de Ridder-Symoens, Cambridge 1992, pp. 348-350 (German version: "Die Artes liberales. Das Quadrivum. Astronomie". In: *Geschichte der Universität in Europa I. Mittelalter.* Hrsg. von Walter Rüegg, München 1993, pp. 312-314) and Schöner, Christoph: "Arithmetik, Geometrie und Astronomie/Astrologie an den Universitäten des Alten Reiches: Propädeutik, Hilfswissenschaften der Medizin und praktische Lebenshilfe". In: *Artisten und Philosophen. Wissenschafts- und Wirkungsgeschichte einer Fakultät vom 13. bis zum 19. Jahrhundert.* Hrsg. von Rainer Ch. Schwinges, Basel 1999, pp. 83-104.

[4] "Statuta facultatis artium studii Pragensis". In: *Liber decanorum facultatis philosophicae Universitatis Pragensis ab anno Christi 1367 usque ad annum 1585.* Monumenta historica Universitatis Carolo-Ferdinandeae Pragensis I, Pragae 1830, pp. 35-123.

[5] Kavka, František: "Organisace studia na pražské artistické fakultě v době předhusitské". In: *Acta Universitatis Carolinae – Historia Universitatis Carolinae Pragensis* 8/1, 1967, pp. 7-39.

atory lectures in the arts faculty were divided into two parts. The first part took more than two years and it was necessary to master the books required for bachelor studies. In the second part, the bachelor listened to *artes* for nearly three years and only then he was allowed to proceed with the final master exam. Only then he was entitled and obliged to join the professors of the faculty. The term of duration of reading (*leccio*) represented an important feature not only for students but also for teachers as the length of lectures set the sum of the professor's salary, the payment of which represented an unavoidable condition of final exams.[6] In consulting the Prague medieval regulations for teaching we learn that attention was paid to astronomy from the very beginning of the studies. In the end of the first (bachelor) course, there was required reading of the book *Sphera* (apparently the popular work of *Iohannes de Sacrobosco* or *John of Hollywood, Tractatus de spera materiali,* or maybe the anonymous *Spera theoretica*),[7] that took three months of courses. In the first year of *magister* studies, the students were to enrol for explanations of Aristotle's work *De coelo et mundo*[8] and the discussions took three or four months, followed by two months of reading of Aristotle's *Meteororum.*[9] At the end of the studies, attention was given to the work *Theorica planetarum* by *Iohannes Campanus de Novara.*[10] The *magister* candidate heard lectures on it for two months. Thanks to happily preserved lists of lectures of Prague students we can compare the statutory regulations with reality at the end of the 14th century. Lists found by F. Šmahel show that the Prague students of the arts faculty kept more or less the prescribed course even though it is possible to see some deviations. First of all it is necessary to say that the number of astronomical lectures did not comply in full with the "standard".[11] There were usually presented the works of *Theorica plane-*

[6] Šmahel, František: "Fakulta svobodných umění". In: *Dějiny Univerzity Karlovy I. 1347/48-1622.* Red. Michal Svatoš, Praha 1995, pp. 109-119 (English version: "The Faculty of Liberal Arts". In: *History of Charles University I. 1348-1802.* Ed. by Ivana Čornejová and Michal Svatoš, Prague 2000, pp. 97-110).

[7] *Statuta facultatis artium*, p. 92 and Kavka, František: *Organisace studia*, p. 16-18.

[8] *Statuta facultatis artium*, p. 91 and Kavka, František: *Organisace studia*, p. 16-18.

[9] *Statuta facultatis artium*, p. 92 and Kavka, František: *Organisace studia*, p. 16-18.

[10] *Statuta facultatis artium*, p. 92 and Kavka, František: *Organisace studia*, p. 16-18.

[11] Šmahel, František: "Fakulta svobodných umění". In: *Dějiny Univerzity Karlovy I. 1347/48-1622.* Red. Michal Svatoš, Praha 1995, pp. 114-116 (English version: "The Faculty of Liberal Arts". In: *History of Charles University I. 1348-1800.* Ed. by Ivana Čornejová and Michal Svatoš, Prague 2000, pp. 103-106) and especially

tarum in the bachelor course and the work *Meteororum* to the larger extent than prescribed. In Prague, we can find documents on lectures about other astronomical works that did not belong to the prescribed obligatory course. In 1412 there was presented the popular *Almagest Ptolemai* and we have also documents on lectures of an Arabian scholar *al-Quabīsī* (in Latin *Alcabicius*) from the middle of the 15th century. Practically oriented works *Almanach* and *Computus cirometralis* or *ecclesiasticus* aimed at setting of a religious calendar and knowledge of chronological tables were also very popular in Prague. There is also documented reading of the *Perspectiva communis* by *Master John Pekham.*[12] We can find astronomical works at the Prague University also in the catalogues of the college libraries of the Charles college and the students' Reček's college.[13] Their traces can be found in preserved manuscripts. Beautifully illuminated astronomical manuscripts were a part of a popular Royal library of King Wenceslas IV[14] and it is highly probable that Prague masters who had frequent contacts with the Prague royal premises had a chance to become familiar with the codices. Observatories that were so important in astronomy of the later period can not be documented in the initial stage of the Prague University although we know that at least the King Wenceslas college had its own astronomical observatory in the 16th and 17th centuries. The observatory was located in a tower and university astronomers as well as Rudolph's astronomers Johannes Kepler and maybe also Tycho Brahe watched the stars from there. But we can consider proved that watching and measuring of the sky was directly related to university teaching as well as compiling the calendars and chronological tables that became – from the moment of the development of printing – one of the most important ways that academic sciences penetrated into the public consciousness.[15] Both the calendaria of the university and of the arts faculty specified in the Prague Univer-

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ŠMAHEL, FRANTIŠEK: "Zwei Vorlesungsverzeichnisse zum Magisterium an der Prager Artistenfakultät aus der Blütezeit". In: *Jahrbuch für Universitätsgeschichte* 4, 2001, pp. 194-207.

[12] HADRAVOVÁ, ALENA – HADRAVA, PETR: "Mistr Křišťan z Prachatic: jeho život a dílo v dobovém kontextu". In: *Křišťan z Prachatic: Stavba a užití astrolábu.* Edd. ALENA HADRAVOVÁ and PETR HADRAVA, Praha 2001, pp. 29-36.

[13] *Katalogy knihoven kolejí Karlovy university.* Edd. JOSEF BEČKA and EMMA URBÁNKOVÁ, Praha 1948 and ŠMAHEL, FRANTIŠEK: "Knihovní katalogy koleje Národa českého a koleje Rečkovy". In: *Acta Universitatis Carolinae – Historia Universitatis Carolinae Pragensis* 2/1, 1961, pp. 59-85.

[14] KRÁSA, JOSEF: *Rukopisy Václava IV.* Praha 1974, pp. 180-200 and KRÁSA, JOSEF: "Astrologické rukopisy Václava IV." In: KRÁSA, JOSEF: *České iluminované rukopisy 13.-16. století.* Praha 1990, pp. 180-203.

[15] WINTER, ZIKMUND: *O životě na vysokých školách pražských knihy dvoje. Kulturní obraz XV. a XVI. věku.* Praha 1899, pp. 336-345.

sity statutes are a clear proof of knowledge of medieval chronometry and astrology.[16] Astronomy found its place in Prague from the very beginning of university instruction.[17] Among the names of the first generation of the arts faculty masters (usually graduates of old European universities), we can find the name of professor *Johannes Jenconis de Praga*[18] and it is documented that he was engaged in astronomical discussions. It was the same with royal physicians Master *Gallus de Monte Sion (de Praga)*[19] and *Albicus de Uniczov*,[20] and with other local scholars in the 15^{th} century – *Petrus de Tyn Horssoviensis*[21] and *Johannes de Borotin.*[22] The most famous astronomical works – separate and well preserved works – were written by the Masters of the Bohemian university nation – *Johannes Andree dictus Schindel (Šindel)*[23] and *Christannus de Prachaticz.*[24] Schindel's career was typical for a Prague graduate of the arts faculty. He obtained the bachelor degree in 1395 and four years later he obtained the master degree. He combined his university career with teaching at the Prague city school at St. Nicholas Church in Malá Strana, he was a canon of the Prague metropolitan church, a dean of the chapter house in Vyšehrad – Prague and he also worked as a city physician in Nuremberg (Nürnberg). He finished his complex life at the royal court – at first he became a personal physician of King Wenceslas IV and since 1432 he was a physician of king's brother, Emperor Sigismund. He studied medicine in Vienna but most of his academic activities were connected with Prague where he obtained all

[16] "Liber decanorum facultatis philosophicae Universitatis Pragensis ab anno Christi 1367 usque ad annum 1585". In: *Monumenta historica Universitatis Carolo-Ferdinandeae Pragensis I*, Pragae 1830, behind p. XVI and "Statuta Universitatis Pragensis". In: *Monumenta historica Universitatis Pragensis III.* Edd. ANTONIUS DITTRICH et ANTONIUS SPIRK, Pragae s.d., pp. IX-XVI.

[17] About Prague professors of astronomy and their work compare TŘÍŠKA, JOSEF: *Životopisný slovník předhusitské pražské univerzity 1348-1409 (Repertorium biographicum Universitatis Pragensis praehussiticae 1348-1409).* Praha 1981. Newly and thoroughly SPUNAR, PAVEL: *Repertorium auctorum Bohemorum provectum idearum post Universitatem Pragensem conditam illustrans I.* Wrocław – Warszawa – Kraków – Gdaśk – Łódĺ985, pp. 97-145 (*Medici et astronomi*).

[18] SPUNAR, PAVEL: *Repertorium*, pp. 51-53.

[19] SPUNAR, PAVEL: *Repertorium*, pp. 97-103.

[20] SPUNAR, PAVEL: *Repertorium*, pp. 103-115 and ŘÍHOVÁ, MILADA: *Dvorní lékař posledních Lucemburků. Albík z Uničova, lékař králů Václava IV. a Zikmunda, profesor pražské univerzity a krátký čas i arcibiskup pražský.* Praha 1999.

[21] HADRAVOVÁ, ALENA – HADRAVA, PETR: *Mistr Křišťan z Prachatic*, p. 36.

[22] SPUNAR, PAVEL: *Repertorium*, pp. 140-145 and HADRAVOVÁ, ALENA – HADRAVA, PETR: *Mistr Křišťan z Prachatic*, pp. 38-39.

[23] SPUNAR, PAVEL: *Repertorium*, pp. 133-140 and HADRAVOVÁ, ALENA – HADRAVA, PETR: *Mistr Křišťan z Prachatic*, pp. 36-38.

[24] SPUNAR, PAVEL: *Repertorium*, pp. 116-132 and HADRAVOVÁ, ALENA – HADRAVA, PETR: *Mistr Křišťan z Prachatic*, pp. 13-72.

his university degrees and the position of rector. Schindel is also said to be author of the book *Canones pro eclipsibus Solis et Lune per instrumentum ad hoc factum*, discussing calculations and measuring related to Sun and Moon eclipse. He is also known to be an author of astronomical tables. But John Schindel got into the history of astronomy thanks to a much more important act as the latest specialised literature considers him to be an author or co-author of the popular well-preserved Prague astronomical clock that dates back probably to the year 1410 and it can be found on the Town Hall Tower of the Old Town.[25] Another celebrated name in the Prague astronomical school was Master Christannus de Prachatic, a physician and astronomer, whose work has been intensively studied by Mr. and Mrs. Hadrava, who recently published an edition of his works *Composicio astrolabii* and *Usus astrolabii*.[26] Master Křišťan's whole life was connected with the Prague University where he obtained the bachelor degree *in artibus* at the end of the 1380's. Later he obtained the degree of a master of liberal arts, doctor of medicine and became professor of theology. He was a friend of Master John Hus and a supporter of the Calixtine religion. Many works of his extensive mathematical, medicine and astronomical work – especially medicine and herbalistic – were later printed and that is why his works represented a permanent part of libraries of educated people up to the beginning of the 17th century.

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To summarise, we can say that astronomy did not belong to official branches at the Prague University in the 14th and 15th centuries. But its importance is documented by the fact that manuscripts of Prague provenience can be found even in Cracow University thanks to local astronomical studies. Even though no branch specialisation existed at the medieval Prague University, similarly to other medieval European universities, and the masters really presented "de quolibet", it is apparent that some interests or personal specialisation of professors somehow affected the contents of lectures. It can be seen especially in relation to doctors who often combined their medicine lectures with astronomical explanations – we can see it e.g. in case of Gallus de Monte Sion, Albicus de Uniczov or Christannus de Prachatic. And that is another significant feature of the Prague astronomy: that was closely related to other subjects of the *quadrivium* (mathematics)

[25] Horský, Zdeněk: *Pražský orloj.* Praha 1988.

[26] *Křišťan z Prachatic: Stavba a užití astrolábu.* Edd. Alena Hadravová and Petr Hadrava, Praha 2001.

and also to medicine. Astronomy was more strongly oriented “on practice” than other purely speculative scholastic disciplines and it was one of the main parts of the university natural sciences – medicine, botany, physics etc., that – together with humanistic disciplines – created a base of teaching at the Faculty of Philosophy of the Prague University in later periods.

This work has been supported by project LN00A041 of the Ministry of Education of the Czech Republic.

Tycho Brahe and Prague: Crossroads of European Science, pp. 388–392,
J. R. Christianson et al. (eds.), © *H. Deutsch 2002*

Astronomy and Astrology at Prague University before the Battle at White Mountain

Bořek Neškudla, Prague

The 16$^{\text{th}}$ century found mathematics and therefore astronomy in decline in Bohemia; it was astrology that became the central interest within the mathematical and astronomical studies. Even the scholars at utraquistic Prague University aimed their scholarly research at publishing of calendars, which recorded the expected celestial phenomena and appended to them astrological prophecies. The astronomical observations and research were to serve as a basis for more correct and exact procedures when creating a horoscope.[1] Neither did the establishment of the competing Jesuit college of Klementinum in 1556 bring any improvement. The college taught arithmetic and geometry from 1561 and astronomy from 1581. Mostly they studied revolutions of planetary motions and ephemerides, the problems of comets and the studies of the new star in the constellation of Cassiopeia from the year 1572. During the 16$^{\text{th}}$ century there was an increase in astronomical publications. Indeed it was also a result of the spread of book printing.[2] The spread of astronomical publications also contributed to the fact that at that time astronomy stopped being closely linked with the university, but it continued to be pursued by the university graduates. Apart from books of science other works were published in Bohemia, like calendars, weather lore and special works published in connection with some outstanding phenomenon, especially comets. Mostly they combined some basic astronomical information important for creating a calendar with astrological prognosis. They were published in a great number of copies, usually in common speech (i.e. in Czech and/or German), which was caused by their general popularity. Sometimes non-professionals, often the print-

[1] Vetter Q., *Dějiny matematických věd v českých zemích od založení university v roce 1348 až do roku 1620*, p. 83.

[2] Nový, *Dějiny exaktních věd v českých zemích do konce 19. století*, Praha, 1952, p. 33.

ers themselves (these were former students and graduates of the university or secondary schools, which were still linked to Prague University), wrote these publications, which of course resulted in inaccuracy. Here we should not omit the argument of Tadeáš Hájek of Hájek with the Prague printers in the year 1577, when he criticised their non-scientific approach towards the interpretation of the comet of that year.

> "Although I oppose foretelling of all manners I am not against any moderate and sober judgements, which are derived from the hidden treasures of Nature and which don't rebel against the Word of God. The comet may import warm weather and drought, yet I never render from it anything about wars, riots and fall of kingdoms, since the faith of us all lies in the hands of God."[3]

Yet these publications seldom brought an revolutionary discovery, the only exceptions were some reports about comets and the information about the new star in Cassiopeia in the year 1572.

The complaint about the decline of mathematical studies was expressed above all by Šimon Proxenus of Sudet (1539-1613) who drew attention to the fact that a first-class university cannot do without high quality teaching of mathematics and astronomy, especially a university like the one in Prague, which had had such a rich tradition in the field.[4] In Bohemia of the second half of the 16th century the Aristotelian view was still maintained within astronomy, even though Copernicus' work was known here. First of all, mathematics, and within its scope also astronomy, were taught by teachers educated as medical doctors because it was thought that the celestial bodies affect in many ways the human body and even the will and human reason are influenced by the different constellations.

At the beginning of the second half of the 16th century Tadeáš Hájek of Hájek (1525-1600) was active at Prague University. Hájek studied medicine in Vienna with Andreas Perlachius, then, in Prague, he studied mathematics and astronomy with Mikuláš Šud of Semanín and Jan Zahrádka of Vyšetín. In 1551 he obtained the title of Master of Arts (*magister artium*) and he went to Bologna, Italy to study medicine. During his stay in Italy he met Hieronymus Cardanus in Milan. From 1555 he taught mathematics at Prague University but started to be preoccupied with astronomy only from the beginning of the 1570's. One of his students was Martin Bacháček of Nauměřice, later a renowned astronomer. Hájek introduced the method of assessing coordinates of stars during the transit of the meridian. Hájek

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[3] Smolík, "Mathematikové v Čechách od založení university Pražské do r. 1620", *Živa* 1864.

[4] Vetter Q., *l. c.*, p. 84.

was in contact with Tycho Brahe, but only after he had finished teaching at the University. They met at the coronation of Rudolph II in Regensburg, Bavaria in 1575, where Hájek accompanied the Emperor Rudolph II as his personal physician. Tycho called Hájek *vir tam virtute quam doctrinarum excellentia praestantissimus* and *clarissimus et eruditissimus vir.*[5] He became renowned in science thanks to his observations and measurements of the new star in Cassiopeia in 1572; Tycho Brahe considered his measurements as the most exact (except for his own measurements). Also significant were his observations of comets in the years 1577 and 1580. Hájek asserted that comets were not condensed vapours in the higher levels of atmosphere, but that they were a part of the ethereal sphere as Milky Way and not a part of the sublunary sphere.[6]

The position of astronomer and mathematician at the University after Hájek was held by Petr Codicillus of Tulechov (1533-1589) who did not produce any prominent original work. He was the author of several calendars and posters, which described interesting celestial phenomena. Another teacher was Matyáš Gryll of Gryllov (1551-1611), the author of a document that brought an outline of comets known from the year 646 B.C. till the year 1577 and their effect on the Earth and people.[7] Václav Zelotýn of Krásná Hora (†1585), another teacher at the University, issued a calendar in 1583 where he published parallel data following the Gregorian and Julian calendar, and that before the official issue of the Gregorian calendar.

Martin Bacháček of Nauměřice (1540-1612) obtained the title of Master of Arts in 1582 and the same year he became a professor at Prague University. Apart from basic academic courses he also taught mathematics, astronomy, cosmography and geography. During his university career he held all the university offices, that he could hold, and several times he was the rector. From the year 1603 until his death in 1612 he held this office almost without interruption. Bacháček's interest and the breadth of scope with which he studied astronomy is expressed in his letter to the German vice chancellor Rudolph Coraduzzo in Rome by which he was seeking Dreses' globe of the Earth and heaven and the treatise *De motu stellarum* by the Arab author Albategnius. He assumed that these were to be found in the Vatican library. Nevertheless Bacháček himself left no academic thesis.

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[5] STUDNIČKA, *O mathematickém učení na Universitě pražské od jejího založení až do počátku našeho století*, Praha 1888, p. 8.

[6] *Astronomie v Československu od dob nejstarších do dneška*, Praha 1952, p. 13.

[7] *O kometách, kdy a ktereych let se ukazowaly a gaké účinky a proměny w swětě s sebou přinášely, z rozličných hystorij sebráno*, Praha 1578.

Bacháček also devoted himself to astrology because this was a means of gaining favour with important people. They asked for an interpretation of stars, like the interpretation for an important Czech nobleman Václav Budovec of Budov (10. 11. 1604) concerning the comet of the 3rd November 1604, which, it was said, meant a God's punishment.[8] Bacháček became very excited by the conjunction of Jupiter with the heart of Leo. He wrote several letters about the phenomenon, which he addressed to both university and town teachers (e.g. to Melichar Kolidius Solnický in Kutná Hora) to notify them about it and remind them to show it to their pupils.[9]

Martin Bacháček was a provost of Wencelaus's College and he accommodated there his friend Johannes Kepler in 1604. Bacháček's contacts with Kepler continued later when Kepler moved away from Bacháček and together they conducted observations in a provisional observatory, which Bacháček had built of wood in the garden of Queen Hedvika College.[10] These contacts are also reflected in their correspondence. In 1604 Bacháček described his and Kepler's common observations of a new star, "that might bring upon us something pernicious".[11] In 1604 Bacháček wrote to Vratislav of Mitrovic that "in his flat a student will learn more of astronomy and mathematics in half a year than at other academies in many years".[12]

At Easter 1605 Kepler donated one copy of the book *Ad Vitellionem Paralipomena* to the University; probably as a token of gratitude to Prague Academy, since he himself received an Easter hamper from the University (containing meat, eggs, game and the like).[13] In 1612 Bacháček tried to convince Kepler to take up teaching of astronomy at the University and Kepler's name appeared on *Ordines lectionum.*[14] Yet finally, Kepler declined this offer to teach and probably his interest was more aimed at exerting pressure on the imperial court that held back his salary. Yet another attempt was made to gain Johannes Kepler for Prague University by rector Jan Jessenius in 1617 but at that time Kepler was in Linz, Austria and was not any longer interested in teaching in Prague.[15]

We cannot exclude among the Czech astronomers of the second half of the 16th century Cyprián Lvovický of Lvovic (Leovitius, 1514-1574) who

[8] Winter, *O životě na vysokých školách pražských*, Praha 1899, p. 339.
[9] Winter, *l. c.*, p. 340.
[10] Hanzal, "Johannes Kepler a předbělohorské Čechy", in: *Dějiny vědy a techniky*, 1971, p. 8.
[11] Dvorský, *Paměti o školách českých*, p. 270.
[12] Winter, *l. c.*, p. 179.
[13] Hanzal, *l. c.*, p. 11.
[14] Horský, *Kepler v Praze*, Praha 1980, p. 225.
[15] Hanzal, *l. c.*, p. 11.

was working at the University of Lauingen in Bavaria and who was the court mathematician and astronomer of the Duke of Bavaria, Henry Otto. His most important work is tables for assessment of the eclipse of the Sun and Moon as far as the year 1750. In 1565 Lvovický returned to his birthplace, the town of Hradec Králové and introduced there a new curriculum at the local school. He even planned to settle down and teach at the school, while his wife would cook for the pupils. Finally he decided to return to Germany. Since we know that during the period before the Battle of White Mountain (1620) the town schools were in close contact with Prague University, we may consider his activity in Hradec Králové as a university position.

Bacháček's activity was a climax of astronomical teaching at Prague University. After him the doctor of law Daniel Basilius of Deutschenperk (1585-1628) still taught astronomy in Prague. Despite the fact that Hájek had proved that comets are not of terrestrial origin, Basilius, in 1618, published a work *Opinion astronomical and natural about the horrendous comet with a tail*, in which the comet of that year is ascribed to the hot summers of 1616 and 1617 and "the comet is a fume and vapour from the Earth, greasy and dry, by the effect of the Sun and other planets launched into the skies". He judged by the comet, which could be seen in the sign of Libra, that there will be wind, absent-mindedness and riot, yet the Czechs will be the victorious ones.[16]

This foretelling, which was refuted by the defeat of the Bohemian armies at the Battle of White Mountain two years later we may consider it as an unfortunate finale of the astronomical and astrological research at utraquistic Prague University.

This work has been supported by project LN00A041 of the Ministry of Education of the Czech Republic.

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[16] WINTER, *l. c.,* p. 341.