Köln

I. Physikalisches Institut der Universität zu Köln

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0 Allgemeines

Die Arbeiten am Institut konzentrieren sich auf astophysikalische Fragestellungen im Submillimeter-, Fern- bis Nahinfrarot-Spektralbereich. Die Forschung umfasst drei Schwerpunkte: *(i)* die Astrophysik der interstellaren Materie, der Sternentstehung und der Kerne von Galaxien, *(ii)* die Entwicklung von Empfängersystemen, Spektrometern und Kameras und *(iii)* die höchstauflösende Laborspektroskopie an astrophysikalisch relevanten Molekülen und Molekül-Ionen.

1 Personal und Ausstattung

1.1 Personalstand

Direktoren und Professoren:

Prof. Dr. A. Eckart (geschäftsführender Direktor) [3546], Prof. Dr. J. Stutzki [3494], Prof. Dr. L. Labadie [3493](Rufannahme, Dienstantritt Anfang 2011), Prof. Dr. R. Schieder [3568] (Emeritus), Prof. Dr. P. Schilke [1935], Prof. Dr. S. Schlemmer [7880], Prof. Dr. G. Winnewisser (Emeritus).

Wissenschaftliche Mitarbeiter:

Dr. M. Akyilmaz-Yabaci [7020], Dr. O. Asvany [3560], Dr. S. Falter [5933], Dr. S. Fischer [3552], Dr. M. Garcia Marin [7788], Prof. apl. Dr. T. Giesen [4529], Dr. U. Graf [4092], Dr. M. Justen [3489], Dr. N. Honingh [4528], Dr. C. Iserlohe [7791], Dr. K. Jacobs [3484], Dr. M. Justen [3489], Dr. F. Lewen [2757], Dr. H. S. P. Müller [4528], Dr. Y. Okada [1334], Priv.-Doz. Dr. habil. V. Ossenkopf [3485], Dr. P. Pütz [3769], Dr. M. Röllig [3485], Dr. F. Schlöder [5823], Dr. R. Simon [3547], Dr. G. Sonnabend [6147], Dr. C. Straubmeier [3552], Dr. N. Volgenau [3549],

2 Wissenschaftliche Arbeiten

2.1 Astrophysikalische Forschung

Großräumige Verteilung und Struktur des Interstellaren Mediums

Leiter: J. Stutzki
Bearbeiter: M. Cubick, M. Miller, V. Ossenkopf, M. Röllig, R. Simon

Zentrales Thema sind spektral hochauflösende Beobachtungen der globalen Verteilung des interstellaren Mediums (ISM) in der Milchstraße und in nahegelegenen Galaxien. Ziel ist es, die Struktur, Dynamik, den Energiehaushalt und die Chemie des ISM besser zu verstehen. Dazu werden physikalische Modelle photonen-dominierter Regionen (PDRs) entwickelt, sowie Methoden die statistischen Eigenschaften der beobachteten turbulenten Struktur zu charakterisieren. Interpretationsgrundlage sind Beobachtungen galaktischer und extragalaktischer Molekülwolken mit den NANTEN2, KOSMA, APEX, IRAM-30m, FCRAO Millimeter- und Submillimeterteleskopen. Diese Arbeiten sind komplementär zu den Messungen mit dem Herschel Satelliten und mit SOFIA (ab 2011).

Voraussichtlicher Abschlusstermin: offen

Fördernde Institutionen: MWIFT/NRW, DFG

Kooperationen: AIfA (Uni Bonn); Caltech, Pasadena, US; Cerro Calan Observatory, Universidad de Chile Ecole Normale Superieure, Paris; Observatoire Bordeaux; Harvard-Smithsonian CfA; IRAM Grenoble/Granda; MPE; MPIfR; Nicolaus Copernicus Astronomical Center, Torun; OAN, Madrid; Peking University, China; SRON and Kapteyn Astronomical Institute Groningen; Sterrewacht Leiden; University of Nagoya; UNSW, Sidney, Australia.

HIFI/Herschel

Leiter: J. Stutzki
Bearbeiter: M. Akyilmaz, A. Eckart, T. Giesen, Y. Okada, V. Ossenkopf, M. Röllig, R. Simon

HIFI/Herschel führt spektral hochauflösende Beobachtungen von Linienstrahlung des interstellaren Mediums im bisher unerschlossenen Ferninfrarot-Bereich durch. Das Institut ist an den "key projects" aus garantierter Beobachtungszeit "The warm and dense ISM", "HEXOS: Herschel Observations of EXtra-Ordinary Sources: The Orion and Sgr B2 Star-Forming Regions", "PRISMAS: PRobing InterStellar Molecules with Absorption line Studies", "The HEXGAL (Herschel EXtraGALactic) Key Project: Physical and Chemical Conditions of the ISM in Galactic Nuclei" und dem *open-time key project* "HERMES: Herschel M33 Extended Survey" aus offener Beobachtungszeit beteiligt. Das Institut ist standort des deutsche Herschel/HIFI-ICC (Instrument Control Center)-Knotens.

Voraussichtlicher Abschlusstermin: offen

Fördernde Institutionen: DLR/BMBF, DFG

Kooperationen: PI-Institutes: SRON Groningen; Caltech, Pasadena; CESR, Toulouse; Consortium: Centro Astronomico Yebes, Guadalajara; CSIC, Madrid; IAS Paris; IRAM Grenoble, John Hopkins University, Baltimore. JPL, Pasadena; Kapteyn Astronomical Institute, Groningen; LERMA Paris; Nicolaus Copernicus Astronomical Center, Torun; OAN Madrid; Sterrewacht Leiden;

[Cologne Database for Molecular Spectroscopy – CDMS

Leiter: S. Schlemmer, J. Stutzki
Bearbeiter: H.S.P. Müller, T. Giesen, C. Endres.

Die CDMS ist eine Internet/Browser zugängliche Datenbank der Molekülspektroskopie.

Zusammen mit der komplementären Datenbank am JPL, Pasadena, US) ist die meistgenutzte astrophysikalische Referenz zur Molekülspektroskopie. Sie ist im Rahmen von Herschel/HIFI eingebunden in das HSPOT observing planning tool. Sie deckt spektroskopisch relevante Daten von gut 300 Spezies fi¿½r den Frequenzbereich von mm-Wellen bis zum Infraroten ab.

Voraussichtlicher Abschlusstermin: offen

Fördernde Institutionen: Grundausstattung, DLR/BO

Das galaktische Zentrum - Sterne und Schwarzes Loch im Zentrum der Milchstraße

Leiter: A. Eckart
Bearbeiter: M. Bremer, R.M. Buchholz, D. Kunneriath, N. Sabha, C. Straubmeier, G. Witzel

Stellardynamische Untersuchungen belegen, daß sich im Zentrum unserer Milchstraße ein super-massives Schwarzes Loch mit einer Masse von 3 bis 4 Millionen Sonnenmassen befindet. In diesem Projekt werden die Dynamik der Sterne, der Staub- und Gasemission, möglicher Sternentstehung, sowie die Emission der kompakten Radioquelle Sagittarius A* im Nah- und Midinfrarotbereich untersucht. Ziel ist es die stellaren Populationen zu analysieren und deren Entstehung dort zu erklären, den Gas- und Staubeinfall, sowie die genaue Masse des Schwarzen Lochs sowie die 'Cusp'-Dynamik zu untersuchen. Simultane Radio-, Infrarot, Röntgen-Beobachtungen helfen den Ursprung der Ruhestrahlung und der Strahlungsausbrüche zu untersuchen.

Voraussichtlicher Abschlusstermin: offen

Fördernde Institutionen: Grundausstattung

Quasare und ultraleuchtkräftige Galaxien - Dynamik und Sternentstehung in QSOs

Leiter: A. Eckart
Bearbeiter: S. Fischer, M. Garcia-Marin, C. Straubmeier, M. Bremer

Molekulares Gas und die Infrarotemission stellarer Populationen werden in Galaxien mit quasi-stellarem Kern und ultraleuchtkräftigen Galaxien untersucht. Dabei werden Interferometrie im Millimeterbereich, sowie Kartierungen und Spektroskopie mit Infrarot-Teleskopen im nahen Infrarotbereich eingesetzt. Die Untersuchungen werden auf Stichproben von nahen Galaxien mit aktivem Kern, sowie nahen Quasistellaren Objekten (QSOs) durchgeführt. Diese Beobachtungen dienen dazu die Dynamik von Gas und Sternen, sowie den Sternentstehungsprozess in diesen Objekten zu untersuchen. Aus diesen Messungen können dann Rückschlüsse auf die Entstehung und Entwicklung von Galaxien und deren aktiver Kerne gezogen werden.

Voraussichtlicher Abschlusstermin: offen

Fördernde Institutionen: DFG SFB956

2.2 Instrumentierung

Stratospheric Observatory for Far-Infrared Astronomy (SOFIA) - Instrumentierung

Leiter: J. Stutzki
Bearbeiter: U. Graf, E. Honingh, K. Jacobs, M.Justen, P. Pütz, M. Röllig, F. Schlöder, M. Schultz, R. Simon, J. Stutzki, S. Wulff

Das deutsch- amerikanische Stratosphärenobservatorium für Infrarotastronomie (SOFIA), ein 2.7m-Teleskop in einer Boeing 747SP, hat nach reichlichen Verzögerungen nun 2010 den Beobachtungsbetrieb aufgenommen (first light: Ostern 2010; first science flights mit dem amerkanischen FORCAST-Instrument: Dezember 2010). Es wird durch regelmäßige Flüge in Höhen von bis zu 13 km der astronomischen Forschung den gesamten infraroten

Spektralbereich erschließen wird. Das I. Physikalische Institut ist an der Entwicklung und am Bau der Heterodyn-Empfangssysteme GREAT beteiligt, dass für erste wissenschaftliche Flüge mit SOFIA im Frühjahr 2011 eingeplant ist.

Voraussichtlicher Abschlusstermin: offen

Fördernde Institutionen: DLR/BO

Kooperation: MPIfR, MPS, DLR-WP, MPE, DSI/IRS Stuttgart, USRA at NASA Ames Research Center.

Entwicklung von Submm/FIR Detektoren für astronomische Anwendunge

Leiter: Karl Jacobs
Bearbeiter: E. Honingh, S. Wulff, M. Schmidt.

Das Kölner Mikrostruktur-Labor entwickelt SIS- und HEB-Mischer für astronomische Anwendungen im Submm- und FIR-Spektralbereich. Die Heterodyn-Detektoren reichen in der Empfindlichkeit nahe an die fundamentale quantenmechanische Grenze heran. Sie kommen an verschiedensten Observatorien zum Einsatz, insbesondere auf Herschel und SOFIA, an APEX, NANTEN2, KOSMA.

Voraussichtlicher Abschlusstermin: offen

Fördernde Institutionen: DLR/BO, Verbundforschung/Astronomie

Kollobarationen: MPIfR Bonn; DLR Berlin; SRON Groningen; University of Cambridge, UK; Caltech/JPL, Pasadena, US.

Entwicklung von Submillimeter– und Terahertz–Empfängern

Leiter: Urs Graf
Bearbeiter: Bernhard Schmidt, Oliver Ricken, Michael Brasse

In diesem Projekt werden radioastronomische Empfänger entwickelt für den Einsatz an verschiedenen nationalen und internationalen Observatorien. Im Vordergrund steht der Aufbau von leistungsfähigen Multipixel–Empfängern. Der Zweifrequenz–Empfänger SMART (500 und 800 GHz) ist nun mit 16 Empfangskanälen am NANTEN2-Teleskop in der Atacama in Chile voll einsatzbereit. Gemeinsam mit dem MPIfR Bonn arbeiten wir weiter an der Entwicklung eines Zweifrequenz–Empfänger (300 und 500 GHz) und, gefördert von der Verbundforschung/Astr onomie an einem 1.1 THz-Array-Empfänger für das APEX–Teleskop in Chile. Für das fliegende Observatorium SOFIA stellten wir den 1.9 THz Kanal von GREAT fertig.

Voraussichtlicher Abschlusstermin: offen

Fördernde Institutionen: DLR/BO, Verbundforschung/Astronomie

Kollobarationen: MPIfR Bonn, DLR Berlin, MPS Lindau, Universidad de Chile, University of Nagoya, Seoul National University, CSIRO Epping/Australien, Université de Neuchâtel, IAP Bern

Kölner Observatorium für Submillimeter Astronomie (KOSMA)

Leiter: J. Stutzki
Bearbeiter: M. Miller, V. Ossenkopf, M. Röllig, R. Simon

Das Institut betrieb bis Juni 2010 in Zusammenarbeit mit dem Argelander Institut fi¿$\frac{1}{2}$r Astronomie der Universität Bonn das 3m-Submillimeterteleskop auf dem 3100 m hohen Gornergrat bei Zermatt in der Schweiz. Das Teleskop einschließlich aller Komponenten (außer der Kuppel) wurde im Sommer abgebaut und Tibet transportiert, wo es in Zusammenarbeit mit dem National Astronomical Observatory China, Peking, und einer Reihe

von Partner-Universitäten in Yangbajing, 90 km nördlich von Lhasa/Tibet in 4300m Höhe wieder aufgebaut wird. Dazu wurde ein Vertrag zwischen der Universität zu Köln und den National Astronomical Observatories der Chinesischen Akademie der Wissenschaften (NAOC) im Februar 2009 unterzeichnet.

Abschlusstermin: Sommer 2010

Fördernde Institutionen: MWIFT/NRW, International Foundation Jungfraujoch & Gornergrat in Bern

Kollobarationen: AIfA, Universität Bonn; ETH Zürich; NAOC Peking/China; Universität Peking; China; Universität Nanjing, China.

NANTEN2

Leiter: J. Stutzki
Bearbeiter: U. Graf, N. Honingh, K. Jacobs, M. Miller, V. Ossenkopf, M. Röllig, R. Simon.

Dieses internationale Projekt kombiniert das japanische NANTEN2 (Nanten=jap. für Südhimmel) 4m submm-Teleskop mit am I. Physikalischen Institut entwickelten Empfängern (490/810 GHz), Spektrometern und Software zur Steuerung des Teleskops und der Datenaufnahme auf dem exzellenten Standort Pampa la Bola in 4865 m Höhe in der chilenischen Atacama Wüste. Aufgabe von NANTEN2 ist die großräumige Untersuchung von Molekülwolken der Milchstraße und von nahen Galaxien am bisher wenig erforschten Südhimmel komplementär zu den detaillierteren Beobachtungen größerer Teleskope. Die Aktivitäten konzentrieren sich auf Beobachtungen von Übergängen des CO Moleküls und des atomaren Kohlenstoffs bei Frequenzen von 100 bis 880 GHz, sowie die Interpretation der Daten mit Modellen der Chemie und Struktur der Wolken. Nach einer Reihe von Hard- und Software Verbesserungen, insbesondere des 800 GHz Kanals, sind nun systematische Beobachtungen mit dem SMART Empfänger in beiden hochfrequenten Empfangskanälen möglich. Die Haupt-Beobachtungsprojekte sind Messungen im galaktischen Zentrum, in massearmen und massereichen Sternentstehungsregionen der südlichen Milchstraße, in den beiden Magellanischen Wolken und in nahegelegenen Galaxien.

Voraussichtlicher Abschlusstermin: offen

Fördernde Institutionen: MWIFT/NRW

Kooperationen: Nagoya University, Japan; Osaka Prefecture University, Japan; Argelander Institut für Astronomie, Bonn; Seoul National University, Korea; ETH Zürich, Schweiz; University of New South Wales, Sydney, Australien; Universidad de Chile

Nahinfrarot Interferometrie - Beobachtungen und Instrumentierung zur Nahinfrarot-Interferometrie: VLTI-GRAVITY

Leiter: C. Straubmeier
Bearbeiter: C. Araujo-Hauck, A. Eckart, S. Fischer, C. Straubmeier, M. Wiest

Das I. Physikalische Institut beschäftigt sich intensiv mit der Nutzung und Weiterentwicklung des Very Large Telescope Interferometer (VLTI) der Europäischen Südsternwarte auf Cerro Paranal in Chile. So wurden mit den beiden bereits in Betrieb befindlichen Kameras AMBER und VINCI unter anderem die ersten interferometrischen Signale von Quellen im galaktischen Zentrum aufgezeichnet. Zur weiteren Verbesserung der interferometrischen Fähigkeiten des VLTI finanzierte das Institut einerseits die Beschaffung, Erprobung und Inbetriebnahme der vierten Star-Separator Einheit (STS), und ist zudem an der Entwicklung, dem Bau und der Inbetriebnahme der interferometrischen Nahinfrarot-Kamera GRAVITY beteiligt. Mit Hilfe von GRAVITY soll das Licht von allen 4 Haupt-Teleskopen interferometrisch kombiniert und eine einzigartige astrometrische Präzision von 10 Mikrobogensekunden erreicht werden können. Der Hardware-Beitrag des Kölner Instituts zu GRAVITY besteht aus der Entwicklung, Fertigung und anschließenden Kommissionierung

der beiden Spektrometereinheiten des Kamerasystems.

Voraussichtlicher Abschlusstermin: 2013 (GRAVITY)

Fördernde Institutionen: HBFG, Verbundforschung

Kooperationen: MPE Garching, MPIA Heidelberg, Observatoire de Paris LESIA, European Southern Observatory ESO

James Webb Space Telescope - Instrumentierung für die Midinfrarot Kamera MIRI des neuen NASA-ESA Weltraumteleskops

Leiter: C. Straubmeier
Bearbeiter: A. Eckart, S. Fischer, M. Garcia-Marin, C. Straubmeier

Das James Webb Space Telescope (JWST) ist das zukünftige Weltraumteleskop von NASA und ESA für den nah- und midinfraroten Spektralbereich und direkter Nachfolger des überaus erfolgreichen Hubble Space Telescope (HST).) Aufgrund des äußerst straffen Zeitplans des mehr als eine Milliarde Euro teuren JWST Projekts bestritten die beiden beteiligten deutschen Forschungsinstitute, das MPI für Astronomie und das I. Physikalische Institut der Universität zu Köln, die Kosten für die notwendigen Entwicklungen und Tagungsreisen seit dem Start des Projekts im Herbst 2003 bis zum Förderbeginn durch das DLR im April 2005 aus ihren jeweiligen Institutsmitteln. Der Hardware-Beitrag des Kölner Instituts zu MIRI besteht aus der Entwicklung, Fertigung und anschließenden Weltraumqualifizierung der mechanischen Halterung des niederauflösenden Doppelprismas des abbildenden Teils des Kamerasystems. Dieser Projektbeitrag wurde 2008 erfolgreich abgeschlossen. Parallel dazu ist das Institut Mitglied des MIRI Test-Teams und somit an der Entwicklung der Test-Prozeduren und der Durchführung der Tests des Verification Model und des Flight Model an den Rutherford Appleton Laboratory (RAL) nahe Oxford (UK) beteiligt. Ebenso sind die Kölner MIRI Mitarbeiter aktiv im MIRI Science Team engagiert.

Voraussichtlicher Abschlusstermin: 2014

Fördernde Institutionen: DLR

Kooperationen: Centre Spatial de Liege (CSL), Rutherford Appleton Laboratory (RAL), Commissariat l'Energie Atomique (CEA), Astrium

Nahinfrarot Interferometrie - Beobachtungen und Instrumentierung zur Nahinfrarot-Interferometrie: LINC-NIRVANA

Leiter: J. Zuther
Bearbeiter: A. Eckart, B. Franke, M. Horrobin, S. Rost, C. Straubmeier, E. Tremou, I. Wank, J. Zuther

In enger Zusammenarbeit mit dem MPI für Astronomie, dem Osservatorio Astrofisico di Arcetri und dem MPI für Radioastronomie ist das I. Physikalische Institut maßgeblich an der Entwicklung und am Bau von LINC-NIRVANA, der interferometrischen Nahinfrarot-Kamera des Large Binocular Telescopes (Mt. Graham, USA) beteiligt. Die Hardware-Beiträge des Instituts umfassen den voluminösen Kamera-Dewar, den leistungsstarken 60 K Helium-Kühlkreislauf, und eine dreidimensionale Positioniereinheit zur Nachführung des Detektors des Fringe-and-Flexure-Trackers (FFTS) auf einer astronomischen Referenzquelle. Zusätzlich ist das Institut verantwortlich für die Entwicklung der computergestützten Echtzeit-Regelschleife zur Bild- und Piston-Analyse des FFTS.

Voraussichtlicher Abschlusstermin: 2014

Fördernde Institutionen: HBFG, Verbundforschung

Kooperationen: MPIA Heidelberg, MPIfR Bonn, Osservatorio Astrofisico di Arcetri (Italy)

Infrarot-Heterodynempfänger THIS

Leiter: G. Sonnabend
Bearbeiter: M. Sornig, P. Kroetz, D. Stupar

Beobachtungskampagnen zu direkter Beobachtung von Wind und Temperaturen in den oberen Atmosphären von Mars und Venus wurden fortgesetzt. Der Empfänger THIS ('Tuneable Heterodyne Infrared Spectrometer") wurde bei drei Beobachtungsläufen am Mc--Math-Pierce Teleskop des National Solar Observatory in Arizona/USA eingesetzt, um um die Venusatmosphäre bei verschiedenen Beobachtungsgeometrien zu untersuchen.

Fördernde Institutionen: DFG SO879/1-2

Kooperationen: Gruppe um Th. Kostiuk (GSFC/NASA), Francois Foreget (LMD Paris), Luca Montabone (Open University), Miguel Lopez-Valverde (IAA Granada)

2.3 Dissertationen

Abgeschlossen:

Olczak, Christoph (2009): Star-Disc Encounters in Young Star Clusters: Environmental Effects on the Evolution of Protoplanetary Discs

Kaczmarek, Thomas (2009): Evolution of the binary population in young dense star clusters

Sornig, Manuela (2009) Investigations of Upper Atmosphere Dynamics on Mars and Venus by High Resolution Infrared Heterodyne Spectroscopy of CO2

3 Veröffentlichungen

3.1 In Zeitschriften und Büchern

Olczak, C. and Pfalzner, S. and Eckart, A.: Stellar interactions in dense and sparse star clusters In: Astron. Astrophys. **509** (2010), Art.-No. A26

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Sipilä, O. and Hugo, E. and Harju, J. and Asvany, O. and Juvela, M. and Schlemmer, S.: Modelling line emission of deuterated H_3^+ from prestellar cores In: Astron. Astrophys. **509** (2010), Art-No. A26

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Casasola, V. and Hunt, L. K. and Combes, F. and García-Burillo, S. and Boone, F. and Eckart, A. and Neri, R. and Schinnerer, E.: Molecular gas in NUclei of GAlaxies (NUGA) XIII. The interacting Seyfert 2/LINER galaxy NGC 5953 In: Astron. Astrophys. **510** (2010), Art.-No. A26

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Sabha, N. and Witzel, G. and Eckart, A. and Buchholz, R. M. and Bremer, M. and Gießübel, R. and García-Marín, M. and Kunneriath, D. and Muzic, K. and Schödel, R. and Straubmeier, C. and Zamaninasab, M. and Zernickel, A.: The extreme luminosity states of Sagittarius A* In: Astron. Astrophys. **512** (2010), Art.-No. A2

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ra: Terahertz Spectroscopy of Oxygen, O_2, in its $^3\Sigma_g^-$ and ^{1} electronic states: THz Spectroscopy of O_2 In: J. Quant. Spectrosc. Radiat. Transfer **111** (2010), 1167–1173

Ivanov, S. D. and Asvany, O. and Witt, A. and Hugo, E. and Mathias, G. and Redlich, B. and Marx, D. and Schlemmer, S.: Quantum-induced symmetry breaking explains infrared spectra of CH_5^+ isotopologues In: Nature Chem. **2** (2010), 298–302

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Schödel, R. and Najarro, F. and Muzic, K. and Eckart, A.: Peering through the veil: near-infrared photometry and extinction for the Galactic nuclear star cluster. Accurate near infrared H, Ks, and L' photometry and the near-infrared extinction-law toward ... In: Astron. Astrophys. **511** (2010), Art.-No. A18

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J. Krieg, V. Lutter, F.-X. Hardy, S. Schlemmer, and T. F. Giesen: The ν_5 antisymmetric stretching mode of linear C_7 Revisited in High Resolution In: J. Chem. Phys. **132** (2010), Art.-No. 224306

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