Recruitment 2021 LIO PhD position

Formation of the first stars: collapse and fragmentation of primordial gas clouds.

JOB DESCRIPTION

Short description

The PhD position is proposed for a 3-year period (36 months). The legal **net salary is €1768 per month** (plus social benefits). An annual €2 000 package for travels and equipment will be allotted. The candidate is expected to submit a thesis manuscript to the university of Lyon for a formal presentation in front of a jury before the end of the 3-yr period.

Starting date of the contract: October the 1st, 2021

Research project

Context

Pop III stars are the first stars that form in the Universe, out of gas of pristine composition. Their intense radiation ionises their environments, and their explosions releases the first heavy elements in the Universe. This sets the initial conditions for the formation of the next generations of stars (Pop II) and the first galaxies. While the properties of the present day stars are well-established by observations and increasingly understood by theory, little is known about the Pop III stars since their observation remains hypothetical. In particular, the mass distribution of the first stars is currently highly debated. In the early 2000s, with the apparition of the first 3D simulations, it was thought that the Pop III stars were all massive and short-lived (*e.g.* Abel et al. 2002). It has been recently shown that both accurate primordial cooling modelling and magnetic fields greatly impact the fragmentation of primordial gas clouds and possibly allows low-mass Pop III to form which could be still observable today (Sharda et al. 2020). These results can dramatically change the impact of Pop III stars on their environments and thus on the birth sites of the first galaxies. On top of this, current large scale cosmological reionization models assume a present day Initial Mass Function (IMF) to calibrate star formation and feedback whereas first stars could still be at play (*e.g.* Rosdahl et al. 2018).

It is thus of prime importance to constrain the Pop III star IMF to understand the formation of the large scale structures in the Universe. We propose to take over these pioneering studies, using an updated chemical network for primordial chemistry, based on theoretical chemistry works, needed to accurately estimate the cooling by H_2 and hydrogen deuteride HD (*e.g.,* Galli & Palla 2013, Bossion et al. 2018), coupled to a state-of-the-art 3D radiation-magneto-hydrodynamics (RMHD) numerical framework built upon the expertise developed at CRAL in the past years.

Proposed research plan

The first part of the PhD work will be devoted to the implementation of a state-of-the-art chemical network for primordial chemistry in the RMHD code *RAMSES* (Teyssier 2002) which is intensively used and developed at CRAL. The numerical development will be applied to the collapse of isolated massive primordial clouds which a focus on the fragmentation and disk/outflow formation in order to determine the star formation efficiency. In a second part, the numerical framework will be adapted in a prototype code such as "*mini-ramses*", designed for exascale computing. We aim to provide proof-of-concept large numerical models, starting from a cosmological environment with a deep AMR hierarchy and designed to study the IMF of Pop III stars.

Research field(s)

Astrophysics, star formation, cosmology, magneto-hydrodynamics, radiative transfer, high performance computing

Thesis supervisor and contact

Name: Dr. Benoît Commerçon
Laboratory: Centre de Recherche Astrophysique de Lyon (CRAL) - ENS Lyon
Phone number: +33 4 72 72 89 17
Email: benoit.commercon@ens-lyon.fr
The PhD project will be co-supervised by Dr. Joakim Rosdahl (karl-joakim.rosdahl@univ-lyon1.fr), permanent researcher in the Galpac team at CRAL.

WORKING ENVIRONMENT

Job location and description

The PhD project will be mainly conducted at Centre de Recherche Astrophysique de Lyon. The student will join the AstroENS team, located in Ecole Normale Supérieure de Lyon. The AstroENS team is composed of 20 researchers (1/3 permanents, 1/3 postdocs, 1/3 students), whose research cover a wide expertise: cosmology, galaxy formation and evolution, star and planet formation, dense plasma physics. Part of the work will be conducted in the GALPAC team, located in the historical Observatory site in Saint Genis Laval (about 20 km from Lyon). The GALPAC team is composed of 20 researchers as well (11 permanents, 2 postdocs, 7 students), whose research cover a wide expertise: large scale structures formation and evolution, dark matter and dark energy. The PhD project will take benefit from the combined expertise in computational cosmology and star formation of the CRAL.

Team

Collaboration with staff members of the AstroENS (Fensch) and GALPAC (Blaizot, Michel-Dansac) teams will complement the supervision.
Dr. Benoît Commerçon is currently supervising one postdoctoral project. Dr. Joakim Rosdahl is currently supervising 1 PhD student.

Allocated resources

The student will have access to the local supercomputing centre PSMN at ENS Lyon (http://www.ens-lyon.fr/PSMN/doku.php?id=en:accueil), which has been partly equipped with CRAL and LabEx LIO resources. The PSMN facilities host a total of 18000 cores with 130 To of RAM, and 4 Po of storage. Access to the Centre Blaise Pascal will also be possible for exploratory work towards exa-scale computing.

The student will be equipped with a laptop and a desktop adapted to post process simulation results.

Recent publications of the team

- "Protostellar collapse: the conditions to form dust-rich protoplanetary disks", Lebreuilly U, **Commerçon B,** Laibe G, *Astronomy & Astrophysics*, Volume 641, id.A112, 2020
- "A new hybrid radiative transfer method for massive star formation", Mignon-Risse R, González M, **Commerçon B and Rosdahl J**, *Astronomy & Astrophysics*, 635, A42, 2020
- "The Geometry and Dynamical Role of Stellar Wind Bubbles in Photoionised HII Regions"., Geen S, Bieri R, **Rosdahl J** & de Koter A, MNRAS, 2020 in press
- "Numerical Methods for Simulating Star Formation", Teyssier R and **Commerçon B**, *Frontiers in Astronomy and Space Sciences*, 6, 51, 2019
- "EDGE: the mass–metallicity relation as a critical test of galaxy formation physics", Agertz O, Pontzen A, Read JI, Rey MP, Orkney M, **Rosdahl J**, Teyssier R, Verbeke R, Kretschmer M & Nickerson S., *MNRAS*, 491, 1656–1672, 2020
- "Fragmentation properties of massive protocluster gas clumps: an ALMA study", Fontani F, **Commerçon B** et al., *Astronomy & Astrophysics*, 615, A94, 2018
- "A simple model for molecular hydrogen chemistry coupled to radiation hydrodynamics", Nickerson S, Teyssier R & **Rosdahl J**., *MNRAS,* 479, 3206–3226, 2018
- "The SPHINX Cosmological Simulations of the First Billion Years: the Impact of Binary Stars on Reionization", **Rosdahl J,** Katz H, Blaizot J, Kimm T, Michel-Dansac L, Garel T, Haehnelt M, Ocvirk P & Teyssier R. , *MNRAS,* 479, 994–1016, 2018
- "RAMSES-RT: Radiation hydrodynamics in the cosmological context", **Rosdahl J,** Blaizot J, Aubert D, Stranex T & Teyssier R., *MNRAS,* 436, 2188–2231, 2013
- "Radiation hydrodynamics with adaptive mesh refinement and application to prestellar core collapse. I. Methods", **Commerçon B,** Teyssier R, Audit E, Hennebelle P and Chabrier G, *Astronomy & Astrophysics*, 529, A35, 2011

Description of LabEx LIO

In 2011, The Lyon Institute of Origins LabEx was selected following the first "Laboratory of Excellence" call for projects, part of the "Investissement d'Avenir" program for forward-looking research. It is one of 12 LabExes supported by the University of Lyon community of universities and establishments (COMUE). LIO brings together more than 200 elite researchers recruited throughout the word and forming 18 research teams from four laboratories in the Rhône-Alps region, all leaders in their fields, under the auspices of the University Claude Bernard Lyon 1 (UCBL), the Ecole Normale Supérieure de Lyon, and the CNRS. LIO's goal is to explore questions about our origins, operating in a broad field of study that ranges from particle physics to geophysics, and includes cosmology, astrophysics, planetology and life.

SELECTION PROCESS

The successful candidate will be selected in partnership with the Doctoral School « Physics and Astrophysics » of the University of Lyon.

Condition for admission to doctoral studies

The candidates must hold a national master degree or equivalent.

Application deadline

May the 1st, 2021

Requested documents for application

The candidates must submit their application with (i) their academic curriculum of the last three years, (ii) a letter of motivation, (iii) a CV and (iv) a letter of recommendation, to labex.lio@universite-lyon.fr before **May the 1st, 2021.**

Candidates on the short list will be informed by the end of May. They will be interviewed in June.