Max-Planck-Institute for Astronomy
Königstuhl 17, 69117 Heidelberg, Germany
http://www.mpia.de/en/careers/internships/summer
e-mail: internship@mpia.de

Heidelberg, December 10, 2020

Summer 2021 Internship projects

Summer intern applicants should chose 3 projects from this list, which they are interested in. **Write a total of 1 page (!)**, why these 3 projects have caught your interest and why you are qualified to work on these projects.

Title: Eruptive events forming our elements

Inferring the contribution of likely SN1a channels to the overall chemical enrichment of the Galaxy using Galactic Chemical Evolution models and elemental abundance data in a Bayesian framework. Alternatively channels for r-process nucleosynthesis can be tested, e.g. Neutron star merger.

Title: The Big Splash - Earth Magma Ocean Evolution after Moon formation

It is currently assumed that the Moon formed after the impact of a Mars-sized body into the young Earth This impact not only changed our night sky forever providing us with a close-by relatively large rocky companion, it also changed the Earth. The energy of the impact probably eroded the atmosphere that was already there and melted the mantle so that a global magma ocean covered the Earth. From this magma ocean gas arose gas (interior outgassing) and build a new atmosphere. The evolution of this post-impact magma ocean thus determined the further evolution of the Earth. What is this new atmosphere made of? How thick is it? How did the Moon influence the magma ocean evolution and change the atmosphere?

These processes can be investigated with the open source code VPLANET and the module MAGMOC (available by supervisor) and the module VPLANET/TIDE (open source).

The code is written in C++, visualization with python. Knowledge of one (any) programming language would be good, but is not strictly required.

Title: Investigating the co-evolution of supermassive black holes and their host galaxies

The idea is to look at the connection between supermassive black holes accreting gas efficiently (the so called AGN) and the properties of their host galaxies/halos. We will use data from several large-scale cosmological simulations (e.g., Illustris, TNG, EAGLE, SIMBA), for which we have thousands of galaxies/halos. The project includes both comparisons between the different simulations, but also comparisons with observations. The study will pave the way for the upcoming Athena space mission, which will be launched in a few years and will observe AGN in X-ray.

Title: Chemical Torus Imaging

Through SDSS-IV and SDSS-V we have measured the surface element abundances of hundreds of thousands of stars, orbiting in the Milky Way. These surface abundances are (nearly) invariant as the stars orbit in the Milky Way. As each star orbits, it changes its orbital phase, but not the dynamical invariants that define its orbit. The invariance of the surface abundances and the invariance of the conserved dynamical quantities can be linked to deliver new maps of the orbital structure of the Milky Way. In this project, the world's best data will be combined with these ideas to produce the most precise maps ever made of the dark matter in the Milky Way.

Title: Design and implementation of a control panel for METIS Adaptive Optics (AO) RTC

MPIA builds the real-time computer (RTC) for the adaptive optics (AO) system of the instrument METIS for the Extremely Large Telescope (ELT) in Chile. The current version of RTC is a terminal application without a control panel. Having a control panel is beneficial because it displays the current RTC status and provides a intuitive command interface. Since the RTC executes time-critical operations, the risk must be minimized that a control panel will disturb the RTC real-time operation.

In this project, a control panel for the METIS RTC will be designed and implemented. Furthermore, it will be used in practice to visualize the RTC performance in real-time.

Student's benefit

- He/she will work in the exciting domain of adaptive optics.
- He/she will gain insight into the real-time aspect of AO.
- He/she will get to know the ELT project METIS.

Preferable skills

- Basic knowledge about adaptive optics.
- Operating system: Unix (Linux, BSD)
- Programming languages: Python or C++11 or JavaScript for HTML + CSS
- Version control: SVN or Git

Title: Numerical simulations of dust grains in protoplanetary disks

Dust grains in protoplanetary disks grow eventually into planets. During this process, grains have naturally a somewhat complex shape which is not necessarily considered in most of today's disk models. In this project, a student can take first steps in the field of 3D numerical simulations of radiative transfer in protoplanetary disks, expand the model by new dust properties, and produce predictions of observations for instruments such as SPHERE/VLT or ALMA.

Title: Using N-Body simulations to reassess analytic planetesimal accretion equations

The state of the art models of planet formation are still relying on equations describing the amount of accretion of solids that were last updated 20 years ago. Back then, a Japanese group built a computer whose architecture was dedicated to calculate the gravitational interactions between many bodies (so called N-body simulations of planetesimals and protoplanets, see Sugimoto et al., 1990; Ito et al., 1991; Ida&Makino, 1992a;b; Inaba et al. 2001). The resulting computation speed was astonishing for their time and was not surpassed for more than a decade. Nowadays, it starts to become feasible to run simulations with a similar amount of particles on a single, off-the shelve GPU.

The applicant will get accustomed to the open-source N-body code GENGA (Grimm&Stadel, 2014) and run it on the high-performance computing (HPC) facilities of the Max Planck Society with access to hundreds of GPUs. The probability of particles colliding with each other will be analyzed and compared to the literature.

The successful applicant will be able to learn about using modern HPC clusters and GPU based code, will get first experiences with code written in CUDA C, and work on the fundamental basis of planet formation.

Title: How often do we really measure pattern speeds?

The pattern speed of a bar (or spiral arm) is a fundamental parameter of a galaxy, setting resonance locations and associated with the evolution of a galaxy. However, these pattern speeds are not directly observable, and must be measured indirectly. The most popular of these is the Tremaine-Weinberg method, but the assumptions in this method may not be satisfied in most realistic cases. This project will see the intern carrying out tests on this method on state-of-the-art simulations, to perform essential checks on the reliability of pattern speed measurements. The intern will work closely within the PHANGS team, an international collaboration of world-leading experts in Galactic and extragalactic astronomy.

Title: When did the Universe become ionised?

Inter-galactic space was filled with neutral hydrogen and helium at the time when the first stars began forming, which has all become ionised by the present day. Understanding this process called 'reionisation' is currently a major goal of cosmology. The physical conditions in the intergalactic medium are studied by using absorption in front of extremely distant bright sources, such as the first quasars. This requires robust reconstructions of the light of these objects before it is affected by reionisation.

Earlier this year, our team designed a significantly improved method for reconstructing intrinsic quasar light, based on machine-learning methods including Principal Component Analysis. We can now measure how much light is absorbed by neutral gas on its way to Earth much more accurately than before.

We need a student intern to help apply this new technique to a large sample of quasars, and produce the most accurate measurements of neutral gas in the intergalactic medium. Knowledge of (python) coding or willingness to learn is a requirement; basic knowledge of spectroscopy is preferable but not required. If completed successfully, this work will be included in an upcoming publication.

Title: From chains of Super-Earths to lonely hot Jupiters?

Recent N-body integrations and theoretical work showed that a change of the planetary masses can lead to an instability of a resonant chain of super-Earths. In this project, we would apply this idea to the formation of hot Jupiters from super-Earths. One idea of the formation of hot Jupiters is that they start as Super-Earths which accrete their gas locally in the inner disc. At the same time, Super-Earths are expected to form multi-resonant chains. We will thus consider such a chain in which one planet starts to accrete gas to become a hot Jupiter, and investigate the evolution of the system using N-body simulations. The outcome will then be compared to the observed multiplicity of hot-Jupiter-hosting systems.

Title: The impact of stellar multiplicy on protoplanetary disk masses in Orion

Multiple systems of young stars are common, and there is some evidence that the largest and most massive protoplanetary disks are only found around single stars. This can have important consequences for the architecture (in terms of masses and orbits) of these stars' eventual planetary systems. However, studies of how binary stars affect disk masses are so far focused mostly on relatively small samples in nearby star-forming regions. This makes it difficult to precisely characterize how these populations differ. The idea for this internship is to solve that problem, by combining published data on young stellar object multiplicity across the Orion clouds with the largest sample of ALMA observations of protoplanetary disks in a single region to date.

Title: Turbulence and magnetization in the early phases of star formation

The life-cycle of stars is of fundamental astrophysical importance. It underpins our understanding of everything from galaxies to planets. To understand the initial phases of this process we must first understand the origins of structure in the star-forming interstellar medium. This internship will combine numerical simulations with statistical techniques to determine the relative importance of turbulence and magnetic fields in structuring the gas in the early phases of star formation. The ultimate goal would be to apply this new knowledge to observational studies of some of the most extreme environments within the entire Galaxy.

Title: Mapping the birth places of young stars in the Milky Way

Stars in our Milky Way are thought to form in beautiful and complex structures, called giant molecular clouds. Soon after their births, stars decouple from their parent cloud, drift away and eventually disperse in the Galactic disk. How can we link stars back to their birth structure and understand their formation conditions? By knowing the positions and velocities of stars at present, and the gravitational potential driving their dynamics, we can trace stars back in time to their birth places, and learn about the structures in which they were born. The 3rd data release of the Gaia space mission in December 2020 provides precise 3D positions and 2D velocities for millions of stars in our Milky Way. Such data will constrain their orbits, leaving us the non-trivial task to find their dynamical birth places.

The student will work with a sample of young stars around the Sun, calculate their orbits (e.g., their so-called 'orbital actions'), find their trajectory in the Galactic disk, and trace them back to their birth places.

The student will get an introductory knowledge of astrophysics and Galactic dynamics, acquire research experience, integrate a research group and participate in the life of the institute (e.g. seminars and group meetings). This project will make use of ground breaking data, some pen-and-paper work, coding, plotting, reading, writing and talking (in English).

Basic knowledge of "classical mechanics I" and of coding in e.g., python would be advantageous, or the motivation and curiosity to learn them.