https://www.univie.ac.at/dynamics/

universität wien ‣ Department of Astrophysics ‣ Dynamics of Stellar Systems

Stellar Dynamics

research group at the University of Vienna

- Group Members
- Research Opportunities
- Publications
- News & Activities
- DYNAMITE
- ERC: ArcheoDyn

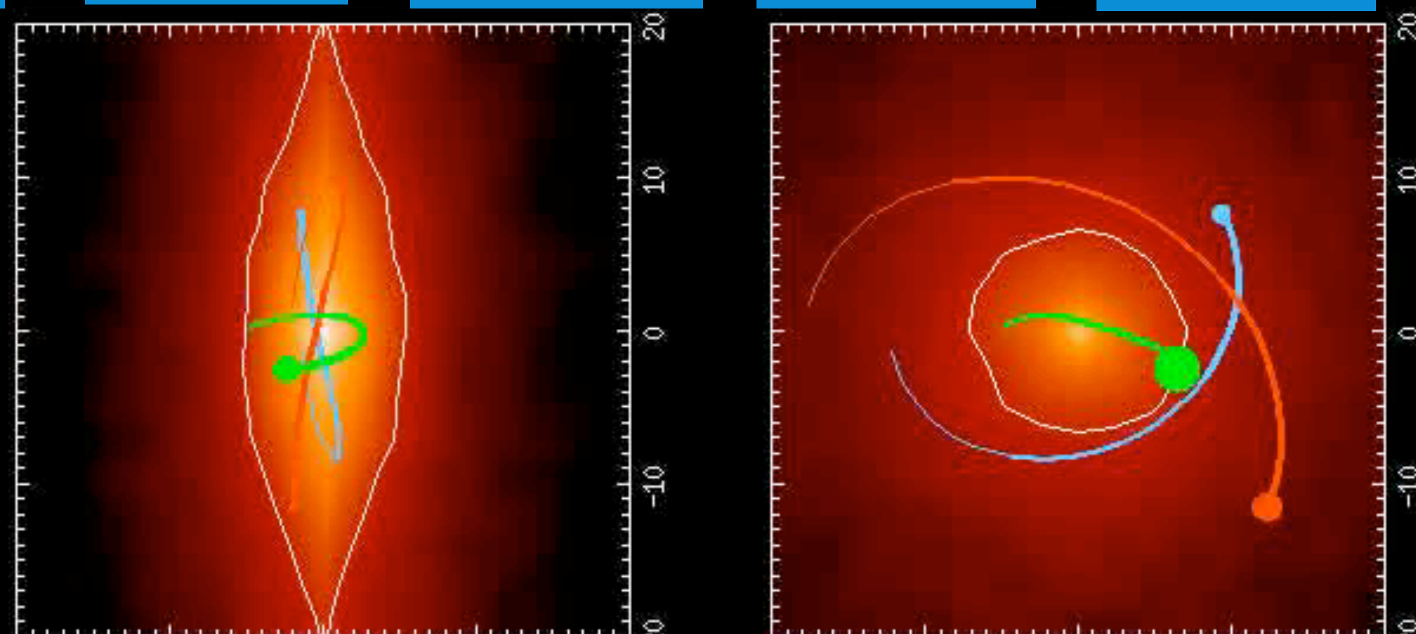
Dynamics of Stellar Systems

The research in our group focuses on understanding the dynamical structure and evolution of stellar systems. In nearby galaxies and stellar clusters, we look for the 'fossil records' of their formation by constructing realistic dynamical models that fit their photometric and spectroscopic observations in detail. The latter include integral-field spectroscopy, observed motions and properties of individual stars, as well as (strong) gravitational lensing observations. Our individual research interests are listed below - for information, see group members' websites or look at some of our recent papers.

erc · universität wien

Group Members & DYNAMITE code

NGC 1
NGC 1404



DYNAMITE code (publicly released)

https://www.univie.ac.at/dynamics/dynamite_docs/

Predicting Galactic Orbits with Deep Learning

RESERVED

Supervisor: Dr. Prashin Jethwa

Contact information: prashin.jethwa@univie.ac.at

Co-supervisors: Dr. Phillipp Petersen (mathematics dept.)

Expected duration: 9 months

Project description & Goals:

Orbit-based (aka Schwarzschild) models are amongst the most flexible dynamical models used in astronomy, making them suitable for high-quality kinematic datasets such as IFU datacubes of nearby galaxies. In the stellar-dynamics group, we develop an orbit-based model [1] which has been applied widely [2] revealing the assembly histories and dark matter distributions of galaxies. A drawback to orbit-based models is that they require numerical integration of large numbers of orbits, which can be slow to evaluate. This limits their use to relatively small samples and prohibits a complete exploration of the interesting parameter space. In this project, we will aim to develop deep-learning tools to speed-up orbit calculation, with the broader goal of making orbit-based models more widely applicable.

This is an interdisciplinary project at the intersection of astronomy, dynamics and deep-learning, and will be jointly supervised by the astrophysics and mathematics departments. There have been several recent demonstrations of the power of deep-learning to predict complex gravitational dynamics [3,4], providing timely motivation to propose this project now. The goal is that the student will learn aspects of galactic dynamics, orbit-based modelling, and will develop, train, and test a deep-learning model for orbit prediction. Candidates with enthusiasm for any or all aspects of this interdisciplinary project are welcome.

Searching for the origin of metals in galaxies small and large

Supervisor: Dr. Ryan Leaman

Contact information: ryan.leaman@univie.ac.at

Co-supervisors: Dr. Prashin Jethwa

Expected duration: 9 months

Project description & Goals:

The elements we measure from the spectra of stars are produced in several energetic nucleosynthetic sites, from supernovae, to winds from pulsating stars, to rare mergers of neutron stars. These events produce different mixtures of elements, occur with different frequencies and have different spatial distributions. Understanding these factors offers a way to peer into a galaxy's past using present-day observations. This is particularly challenging in the smallest dwarf galaxies which are known to form rapidly, and often show peculiar chemical signatures indicating inhomogeneous enrichment. To tackle this exciting problem we are interested in working with a student who will use a novel statistical chemical evolution model together with newly made observations of multi-element abundances in nearby galaxies to recover the spatial clustering and inferred frequency of these nucleosynthetic events. This would offer one of the first looks at how these key enrichment events were responsible for modulating the star formation, abundance gradients, and even dark matter halos of these most extreme low-mass 'ultra-faint dwarf' galaxies. Finally, the same methodology will be applied to galaxies even more massive than our Milky Way – spectroscopically observed with the flagship MUSE instrument on the VLT telescope as part of the TIMER and F3D surveys. The student would have an opportunity to work with this cutting edge astronomical data as well as extend the analysis on the low mass resolved galaxies to a new mass and data regime. Together both aspects will provide new insights on how heavy metals are produced and mixed within the complex baryonic structures of galaxies in the early universe.

Constraining the nature of dark matter via new dynamical modeling methods

Supervisor: Dr. Ryan Leaman

Contact information: ryan.leaman@univie.ac.at

Co-supervisors: Dr. Sabine Thater

Expected duration: 9 months

Project description & Goals:

Dark matter (DM) is the most important contributor to the mass budget in the Universe and instrumental in the formation of large galactic structures - including our Milky Way. However we still do not have constraints from expensive collider experiments (e.g., LHC) on what properties this fundamental particle has (e.g., mass, interaction strength). Astrophysical studies of galaxies offer a unique and complementary way to answer this question. The largest challenge in this field is then to disentangle effects due to the DM particle, from the complex baryonic processes which also alter galaxies and their DM halos (such as star formation and energetic feedback from exploding stars). Our group has developed a new way to break these degeneracies by leveraging gas and stellar kinematic data of galaxies jointly in a single dynamical model (Leung et al. 2020). By combining these two kinematic tracers of the galaxy potential (stellar velocities and kinematics of neutral or molecular hydrogen gas) in one dynamical model, we can recover key parameters of the DM distribution (DM halo flattening, inner density profile slope) which constrain DM particle properties (interaction cross-section, particle mass). To prepare for upcoming VLT-MUSE data of galaxies we are excited to work with a student who wants to develop and apply this method to simulations, as well as existing spectroscopic data of nearby galaxies. Together this will let us assess the robustness of this novel method, apply it to extant observations and investigate what type of data fidelity, galaxy properties and numbers of observations lead to unique constraints on these important cosmological parameters describing our Universe.

Investigating substructures in stellar and gas kinematics of nearby galaxies

Supervisor: Dr. Sabine Thater

Co-supervisor: Jonelle Walsh (A&m University)

Contact information: sabine.thater@univie.ac.at

Expected duration: 9 months

Project description & Goals:

Resolved stellar and gas kinematics of galaxies combined with dynamical models can provide important constraints on galaxy components that are not observable on their own, like the central black hole and dark matter. In this project, the student will analyse detailed optical and near-infrared stellar and gas kinematics maps after extracting them from integral-field spectroscopic observations. Stellar and gas kinematic maps sometimes have misaligned axes with the photometric axes (e.g., https://arxiv.org/abs/1802.00014) which can give indications of the previous formation history of the galaxies. In this work, we will investigate the fraction of kinematic misalignment in a sample of 20 galaxies (of different mass ranges) and then analyse the kinematic maps with a python-version of Kinemetry (https://arxiv.org/pdf/astro-ph/0512200.pdf) to investigate underlying substructures in those maps like spirals or inflow to the central massive black hole in those galaxies. The data set is unique as we cover both the central regions of the galaxies with high resolution as well as larger scales of the galaxies. The student will be part of a large international collaboration, results of this work are planned to be published and later used in order to build dynamical models and measure central black hole masses.

Questions? Ask us!

Research Group *Dynamics of Stellar Systems*

https://www.univie.ac.at/dynamics/