Bachelor’s projects

1. Spectral decomposition of galaxies with population-orbital correlations

Supervisor: Prashin Jetwah

A galaxy’s spectrum retains information about its evolution, and by decomposing the spectrum we can piece together a story of how the galaxy was built. Spectral analysis methods are therefore vitally important, and as the quality of our data increases, increasingly accurate methods are required. The most popular methods today, however, make a strong assumption: that different populations of stars in the galaxy share the same orbit. We know this assumption is incorrect, but we don’t know how this biases our measurements. In this project we aim to assess this bias. If found significant, this result will be an important motivation for developing better analysis methods in the future.

In slightly more detail, stellar populations and orbits imprint distinct features onto spectra. Different populations imprint absorption lines of varying strength, whilst different orbits give rise to different velocity distributions, which imprint varying line broadening profiles. Current spectral fitting techniques assume population-orbital independence. In this project, we will interrogate this assumption by simulating data with intrinsic population-orbital correlations. This will involve developing simple mathematical models, programming in Python, and is suitable for students interested in any one of statistics, dynamics, or stellar populations.

Associated ipython notebook: https://ucloud.univie.ac.at/index.php/s/2YP2fOAvlTXs8b
2. The imprint of the shape of dark matter haloes in gas velocity fields - Glenn

Supervisor: Glenn van de Ven

While the shape of baryonic matter is often oblate axisymmetric, a robust prediction from cold dark matter simulations is that the shape of dark matter haloes is typically prolate triaxial. In an oblate axisymmetric gravitational potential, gas will move on circular orbits and give rise to regular spider-diagram-like velocity fields. Non-circular motions in observed gas velocity fields are then typically ascribed to bars or spiral arms causing deviations from axisymmetry. The goal of this project is to investigate whether a prolate triaxial dark matter halo can cause similar non-circular motions, and when observed in galaxies without bars or spiral arms can be used to constrain the shape of dark matter haloes.

3. The radial profile of cold and warm dark matter haloes

Supervisor: Glenn van de Ven

The radial profile of the mass distribution predicted by cold dark matter simulations is commonly described by a so-called generalised NFW double power-law with inner cusp that might become cored due to baryonic effects. An alternative is the so-called Einasto profile with smoothly varying inner slope like a Sersic profile fitted to observed surface brightness profiles. Both profiles have a scale radius which together with the virial radius leads to the definition of a concentration. Together with the total halo mass this leads to a 3-parameter family.

Warm dark matter instead is never cusped and the core size depends on the ‘temperature’ of the dark matter. The goal of this project is to investigate analytical radial profiles that can describe both warm and cold dark matter with at most 3 parameters.

4. The total mass distribution of galaxy clusters by fitting redshifts and colours of galaxies

Supervisor: Glenn van de Ven

The inferred total mass distribution of galaxy cluster, dominated by dark matter, is often based on a velocity dispersion profile estimated from the radially binned measured relative redshifts of galaxy members. Such a velocity dispersion estimate is very sensitive to interloper galaxies that are not (yet) part of the galaxy cluster.

Instead, the velocity dispersions predicted by a dynamical model can be compared directly
to the discrete redshifts and simultaneously allow to include a model for the observed colours as well as for the interlopers. The goal of this project is to investigate how much such a discrete population-dynamical model can improve the total mass distribution of galaxy clusters and the membership probability of individual galaxies.

5. Testing the black hole scaling relations with the most complete and accurate black hole database

Supervisor: Sabine Thater and Francisco Aros

Robust black hole mass measurements have been derived for about 150 galaxies in the nearby universe. The methods, data and robustness of the measurements are very inhomogeneous, which make it difficult to compare and evaluate them with each other. However, all data is usually combined to analyse the black hole mass - sigma scaling relation which links the black holes with their host galaxy. Learning about the origin of this scaling relation is of importance to understand the interplay between black holes and their host galaxies in the past (e.g. coevolution, feedback). The most recent databases were published in 2016, but since then a number of new masses with novel methods and state-of-the-art data have been published. It is the goal of this project to create the most complete black hole database and evaluate the goodness of existing black hole measurements from different methods (including globular clusters).

As such this is an ideal project for four or five students who will each specialise on one of the different methods to derive black hole masses. We will then together complete the black hole database with different host galaxy properties and test whether earlier conclusions on correlations and outliers are driven by measurement inaccuracies. For the future, we anticipate publishing our database on a webpage to also be accessible to other researchers. (Francisco: see the M-Sigma plot at the end).

6. Finding intermediate-mass black holes in globular clusters via gravitational microlensing

Supervisor: Francisco Aros

The presence or absence of intermediate-mass black holes (IMBHs) at the centres of Milky Way’s globular clusters (GCs) is still an open question, and no strong evidence has been found from stellar kinematics and radio signals. An alternative method could be gravitational microlensing. If the GC has an IMBH in its centre, such IMBH will behave as a gravitational lens that, in turn, will magnify the light of stars passing behind it. This change in the luminosity of the stars passing behind the IMBH could then provide evidence for the presence of such object and its mass. The idea of this project is first to estimate the rate of occurrence of microlensing events given different IMBH masses, stellar density and velocity dispersions of the GC hosting the IMBH. Then we will explore the feasibility of
observing such an event (i.e. is it possible to observe the change of photometry of a lensed star in a crowded field?)

7. The globular cluster luminosity function of early-type galaxies in Virgo and Fornax cluster

Supervisor: Tadeja Veršič

Motivation: Galaxies have complex systems of globular clusters that reflect their formation history and are correlated with the mass of the host galaxy. The magnitude distribution of globular clusters can be reasonably approximated by a gaussian and has a well-defined peak at the turn off magnitude (TOM). The value of TOM is best understood for early-type galaxies, appears to be universal and can be used as a distance indicator. Observationally we are limited to brightest globular clusters in early type galaxies, with better-understood completeness, located on the outskirts of the galaxies. The survey selection function can strongly affect the determination of the TOM.

Aim: get familiar with the importance of globular cluster systems in galaxies and its use as distance indicators. Get an understanding on how to build luminosity function and how to account for incompleteness of a survey of globular clusters.

Data: ACS survey of GC in Virgo and Fornax globular clusters

Sources:

Master’s projects