List of available Master projects in 2021
Dwarf Galaxies and the Galactic Halo (DGGH) Section
Milky Way and Local Volume (MWLV) Section
(projects are listed in alphabetical order by title)

Title: Analysing the orbits of stars in the Milky Way as a function of their chemical signature
Supervisor: Prof. Dr Matthias Steinmetz
Abstract: Different stellar populations in the Milky Way can be discriminated by their chemistry and by their kinematics. Thanks to the Gaia astrometric satellite mission, it is for the first time possible to track larger number of stars by their 3-dimensional orbits. This enables us to directly analyse the orbits of stars as function of their chemical abundance signatures. The project foresees to perform this analysis and compare findings with analogue relations seen in large-scale computer simulations of galaxy formation.
References: Buck, T., 2020 MNRAS 491, 5435; Guiglion, G., et al, 2020, A&A 644, 168; Steinmetz, M., et al, 2020 AJ 160, 183; Wojno, J., et al., 2018, MNRAS, 477, 5612

Title: Bar formation and evolution in the Local Group
Supervisor: Dr Ivan Minchev
Abstract: Central bars are present in about 2/3 of disk galaxies, including our Milky Way. Numerical simulations have shown that they are very important for the galactic chemo-dynamical evolution. This project will study the conditions under which bars form, using cosmological disk formation simulations. The time evolution of bar parameters, such as the pattern speed, length, and strength, will be linked to the disk phase-space structure discovered in the Gaia data, for the first time in the correct Local Group environment. The angular momentum redistribution induced by the bar in conjunction with the inner spiral structure will also be quantified. An ultimate goal of the project will be to resolve the longstanding controversy about the Milky Way's bar length and pattern speed – is it long and slow or short and fast?
References: Minchev, I., et al., 2012, A&A 548, 126; Sanders, J. L., et al. 2019, MNRAS 488, 4552

Title: Calibrating the luminosity evolution of asymptotic giant branch stars in the near-infrared using star clusters in the LMC and M31
Supervisor: Dr Roelof de Jong
Abstract: The asymptotic giant branch (AGB) is the last evolutionary stage of intermediate-mass (1-8 M_sun) stars. The stars in this stage are extremely bright, so AGB stars are important luminosity contributors in stellar systems with intermediate ages (1-3 Gyrs). The luminosity contribution of AGB stars becomes even larger in near-infrared wavelengths due to their red colours. Models predict their luminosity and colour evolution, but they have significant uncertainty due to the complex internal stellar structure evolution, their rather cool atmospheres resulting in absorption lines of many elements and molecules, and circumstellar dust absorption effects. However, in preparation for the James Webb Space Telescope era it is important to calibrate the near-infrared luminosity and colours onto the models. Star clusters are useful tools to investigate the evolution, as they are assumed to have approximately the same age. There are resolved star photometry of stars clusters in the Large Magellanic Cloud and Andromeda galaxies, publicly available in the literature. We will select AGB stars in the star clusters in each galaxy, and investigate their luminosity and colour evolutions in Colour-Magintude Diagrams. Detailed age-dependent properties, such as luminosity and colour of individual AGB stars, and total luminosity of AGB stars in star clusters in a given age bin, will be derived.
References: Radburn-Smith, D. J., et al. 2014, ApJ, 780, 105

Title: Galactic seismology: mystery of the Milky Way phase-space
Supervisor: Dr Sergey Khoperskov
Abstract: One of the most important discoveries to emerge from the ESA Gaia astrometric survey is the "phase spiral" pattern detected in the $z - Vz$ plane throughout the solar neighbourhood in the Milky Way (MW). Since its discovery two years ago, up to a dozen independent research papers seek to explain or shed light on the phase-spiral phenomenon. Vertical and in-plane oscillations induced by a massive disc-crossing perturber has received the majority of attention to date, not least because the Sagittarius (Sgr) dwarf spheroidal galaxy is observed to be undergoing disruption as it crosses the disc. In this project we aim to develop a wide range of models of the MW - Sgr dwarf interaction, taking into account uncertainties in the mass and orbital parameters of the perturber and at the same time varying the MW density and velocity ellipsoid. We plan to study the MW

phase-space evolution and connection of the 'phase spiral' to the galactic spiral arms and bending waves.
References: Antoja, T., et al 2018, Nature, 561, 360

Title: Metal poor candidates from StarHorse using Gaia
Supervisor: Dr Cristina Chiappini
Abstract: Metal-poor stars in our Galaxy (those stars with at least 10 times smaller metal fraction than the Sun) hold important clues on the first steps of the formation and assembly of the Milky Way. It is now possible to use Gaia Mission Data Release 2 information combined with photometric information to find good candidates of metal-poor stars. This can be tested with samples for which the metallicity is known via spectroscopy (from many publicly available surveys). We will also study the effects of the different stellar evolutionary tracks on the outcome of the low metallicity candidates near and far way. This is a project to be carried out with the StarHorse code designed to determine stellar parameters (e.g., temperature, metallicity) from photometric and astrometric input values of millions of stars.
References: Queiroz, A., et al. 2018, MNRAS, 476, 2556

Title: Reddenings, distances and luminosities of a new sample of galactic Cepheids for probing the Milky Way and calibrating the extra-galactic distance scale
Supervisor: Dr Jesper Storm
Abstract: Cepheids are young pulsating variable stars which follow a tight relation between their pulsational period and luminosity. This makes them excellent distance indicators and tracers of young (~100Myr) stellar populations. The Gaia mission early Data Release 3 has provided parallaxes for thousands of Cepheids and for a sample of 150 galactic Cepheids we also have new distances from the infrared surface brightness method. To use these stars to calibrate the extra-galactic distance scale or as probes of the young stellar population in the Milky Way accurate measures of the absorption (interstellar reddening) towards them is necessary. The task to be undertaken by the student is to determine reddening and critically discuss the different estimates towards these stars from a new method (Madore, Freedman, and Moak 2017), the StarHorse code (Queiroz et al. 2018) and classical reddening estimates.
References: Madore, B., Freedman, W., and Moak, S., 2017, ApJ, 842, 42; Queiroz, A., et al., 2018, MNRAS, 476, 2556, 201

Title: Statistics of the galaxy population behind the Small Magellanic Cloud
Supervisor: Dr Cameron Bell
Abstract: Despite the obvious difficulties in undertaking extragalactic studies in the direction of the Magellanic Clouds, they represent an under-utilised opportunity to study the background galaxy population owing to the available range and depth of photometric data. As part of our studies using background galaxies to infer the intrinsic reddening of the Small Magellanic Cloud (SMC) we have constructed a large catalogue of likely extragalactic spectral energy distributions (SEDs) of objects behind the SMC covering an area of about 45 sq. deg. This project aims to use these SEDs to perform the largest analysis of galaxy properties behind the SMC to date. The student will use these SEDs in conjunction with existing extragalactic SED-fitting routines to first create a cleaned sample of extragalactic sources (i.e. remove likely stellar contaminants) and then use this sample to determine large-scale statistical distributions, including photometric redshift, galaxy age/type and stellar mass. The student will learn about galaxy types, large-scale photometric surveys and statistical tools.
References: Ilbert, O., et al. 2006, A&A, 457, 841; Wright, A., et al. 2019, A&A, 632, A34

Title: Stellar populations in external galaxies: clues to radial migration and star formation
Supervisor: Dr Sergey Khoperskov
Abstract: Unlike the Milky Way and some nearby galaxies, due to large distances, individual stars can not be resolved in external galaxies. Therefore, our knowledge about their structure, dynamics and chemical composition is based on averaged properties of stellar populations extracted from spectra of groups of stars captured in the same location. However, over their lifetime stars can migrate far away from their birthplaces thus being mixed together representing different epochs of evolution and various galactic environment. The project aims to understand the impact of stellar radial migration on the properties of unresolved stellar spectra which is the key tool in reconstruction of star formation histories in external galaxies. We plan to analyze a set of galaxies from cosmological simulations where radial migration is a natural outcome of internal (spiral arms, bar) and external (interaction with satellites and mergers). In these models we will use the information about chemical abundances, ages and kinematics to create mock spectra catalogue where knowledge of stellar birthplaces will allow to highlight the impact of stellar migration on spectra of galaxies to be compared with IFU observations (CALIFA, MANGA surveys).
References: Minchev, I., et al. 2013, A&A, 558, 9; Sánchez, S. F., et al. 2012, A&A, 538, 8

Title: The last major merger in the history of the Milky Way
Supervisor: Dr Sergey Khoperskov
Abstract: The Milky Way is the only spiral galaxy where we can obtain full phase-space information for a significant number of stars. The Gaia satellite mission is giving us parallaxes, proper motions and line-of-sight velocities with unprecedented precision and therefore allows us to quantify the complex dynamical processes driving the evolution of the Milky Way. The first two Gaia releases discover that the MW stellar halo is not only formed by the oldest stars in the Galaxy but is also made up of stars that have the age and abundance typical of disc populations. Running a series of major merger simulations between the Milky Way progenitor and a massive satellite (Gaia-Enceladus-Sausage, GES) we will attempt to understand how compact and on what orbits the merger remnant stars can be distributed and what is the impact of the merger on the further chemical evolution of the MW disk.
References: Belokurov, V., et al. 2018, MNRAS, 478, 611; Haywood, M., et al. 2018, ApJ, 863, 113

Title: The structure and formation of galactic disk outskirts
Supervisor: Dr Ivan Minchev
Abstract: The stellar structure in the outermost regions of disk galaxies contains important clues about the disk formation and evolution. This project will involve examining a set of ~33 high-resolution disk formation simulations in the cosmological context, aiming to understand how the outer regions of galactic disks form and evolve with time. The student will write a code to split simulated stars by angular momentum, age, and chemical composition, and study the evolution of these parameters with cosmic time. The goal of this work will be to (1) understand the physical causes for the formation of different types of observed stellar density profiles: Type I (single exponential), Type II (downturning), and Type III (upturning) and (2) to find observational relations that can be used to distinguish different formation scenarios in observations of external galactic disk outskirts.
References: Minchev, I., et al. 2012, A&A 548, 126