Project 1: Modelling low mass star-forming galaxies

Supervisors: Prof. Ivan Baldry (I.Baldry@ljmu.ac.uk), Dr. Andreea Font

We can analyse galaxies individually or as a population. Focusing on the latter allows us to empirically track galaxy evolution since, if we measure demographics of galaxy populations at different distances, we are viewing the universe at different epochs. Measurements of galaxy populations can also be compared with cosmological-scale simulations to test the validity of the standard cosmological model. Galaxy demographics are key for empirically describing and understanding the processes of galaxy formation and evolution and can also play a role in constraining the nature of dark matter or dark energy.

One key demographic measurement is the “galaxy stellar mass function” (GSMF), which generally depends on the properties of the environment that the galaxies inhabit (e.g., whether galaxies live in the field, in galaxy groups or in clusters). In particular, the stellar mass function of low mass (“dwarf”) galaxies places an important constraint on cosmological models. Detecting and characterizing the low-mass galaxy population is currently at the frontier of astrophysics research.

However, the observational measurements of the GSMF at the low mass end are particularly challenging because of the typical low surface brightness (SB) of dwarf galaxies. In this project, two new approaches are proposed to pin down the distribution of dwarf galaxies: 1) using multi-band deep imaging as input to a new spectroscopic survey (4MOST), and 2) a novel selection via core-collapse supernovae (SNe) (LSST) as ‘signposts’ to star-forming galaxies.

The primary aims of this project are: to obtain definitive measurements of the galaxy stellar mass function (GSMF) to the lowest possible masses, and determine the star-formation rate density (SFRD) as a function of galaxy mass. Additionally, the GSMF measured from observations will be compared with predictions of state-of-the-art cosmological hydrodynamical simulations (developed in collaboration with the Virgo Consortium; https://virgo.dur.ac.uk/). This approach will test the physics of galaxy formation and evolution in a totally new regime and it will help us constrain the nature of dark matter.

As part of this project, you will have the opportunity to join three major international surveys, which the Lead Supervisor is part of: WAVES (https://wavesurvey.org), which is a large spectroscopic survey of 1.6 million galaxies planned to be carried out as part of the 4MOST (https://www.4most.eu/cms/collaboration/consortium/) Consortium; an Euclid (https://www.euclid-ec.org) Independent Legacy Science project; and will have access to LSST data via LSST:UK participation group in the large collaboration (https://www.lsst.ac.uk).

Throughout the project you will have access to the Astrophysics Research Institute's postgraduate training programme, as well as to targeted training in data science provided by the Centre for Doctoral Training LIV.INNO. You will also be given the opportunity to carry out an industry placement of six months to broaden your wider research and career skills. You will also have priority access to high-performance computing resources at Liverpool John Moores University for your research.

This project will be carried out over 48 months and is fully funded (tuition fees + stipend set by UKRI guidelines
+ a research/training budget), inclusive of the 6-month industry placement.

Lead supervisors: Prof. Ivan Baldry (…), Dr. Andreea Font (a.s.font@ljmu.ac.uk)

Applying: Please send a CV, research statement (max. 1 page), transcripts, and arrange for two letters of reference to be sent to Prof Baldry (I.Baldry@ljmu.ac.uk).

Project 2: How do supermassive black holes affect their host galaxies?

Supervisor: Prof. Ian McCarthy (I.G.McCarthy@ljmu.ac.uk)

Supermassive black holes are capable of injecting vast amounts of energy into their surroundings via relativistic jets and radiation-driven winds. This “feedback” can lead to significant quantities of gas being ejected from the host galaxy, affecting how the galaxy subsequently evolves and impacting the distribution of matter on large scales. Models of galaxy formation and large-scale structure tests of the standard model of cosmology (LCDM) therefore need to carefully take into account the role of energetic feedback from supermassive black holes.

In this project, you will use state-of-the-art weak gravitational lensing data (including from the Dark Energy Survey and the Kilo Degree Survey) and of the hot ionised gas component (from cosmic microwave background surveys, including from the Planck, SPT, and ACT facilities) to directly measure the impact of supermassive black holes on galaxies over a wide range of redshifts and mass scales. You will compare these measurements with in-house state-of-the-art cosmological hydrodynamical simulations from the FLAMINGO and BAHAMAS projects (developed in collaboration with the Virgo Consortium; https://virgo.dur.ac.uk/) to assess the realism of black hole feedback in current simulations and its impact on galaxy formation and cosmology.

Throughout the project you will have access to the Astrophysics Research Institute’s postgraduate training programme, as well as to targeted training in data science provided by the Centre for Doctoral Training LIV.INNO. You will also be given the opportunity to carry out an industry placement of six months to broaden your wider research and career skills. You will also have priority access to high-performance computing resources at Liverpool John Moores University for your research.

This project will be carried out over 48 months and is fully funded (tuition fees + stipend set by UKRI guidelines + a research/training budget), inclusive of the 6-month industry placement.

Applying: Please send a CV, research statement (max. 1 page), transcripts, and arrange for two letters of reference to be sent to Prof McCarthy (I.G.McCarthy@ljmu.ac.uk).

Project 3: Using neural networks and clustering algorithms to understand the mass flows and energy cycles at the heart of our Galaxy

Supervisors: Prof. Steven Longmore (LJMU, S.N.Longmore@ljmu.ac.uk), Dr. Qizhou Zhang (CfA)

The inner few thousand light years of the Milky Way – the Central Molecular Zone (CMZ) – hosts the nearest supermassive black hole, largest reservoir of dense gas, most massive/dense stellar clusters, and highest volume density of supernovae in the Galaxy. As the nearest environment for which it is possible to simultaneously observe many of the extreme physical processes shaping the Universe, it is one of the most well-studied regions in astrophysics. However, the potential of the CMZ as a laboratory of extreme physics is fundamentally limited by the lack of a unified framework to understand how global processes determine the location, intensity and timescales for star formation and feedback.

This joint PhD project with the Harvard-Smithsonian Center for Astrophysics will involve working with an international team of researchers to analyse data from the world's foremost mm-wave telescope, ALMA, intended to overcome this limitation. The project will involve developing both supervised and non-supervised machine learning tools to quantify the range and variation in the physical, kinematic and chemical properties of the gas in the CMZ, and relate these to global processes controlling the mass flows and energy cycles in the centre of the Galaxy.

Throughout the project you will have access to the Astrophysics Research Institute's postgraduate training programme, as well as to targeted training in data science provided by the Centre for Doctoral Training LIV.INNO. You will also be given the opportunity to carry out a placement at the Harvard-Smithsonian Center for Astrophysics for 12 to 18 months to broaden your wider research and career skills.

This project will be carried out over 48 months and is fully funded (tuition fees + stipend set by UKRI guidelines + a research/training budget), inclusive of the 12- to 18-month placement at the Harvard Smithsonian Center for Astrophysics.

Applying: Please send a CV, research statement (max. 1 page), transcripts, and arrange for two letters of reference to be sent to Prof Longmore (S.N.Longmore@ljmu.ac.uk).