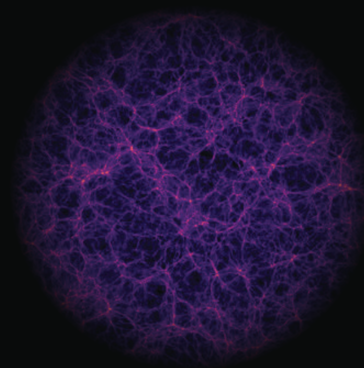
Astronomy PhD & MScR Projects at Durham

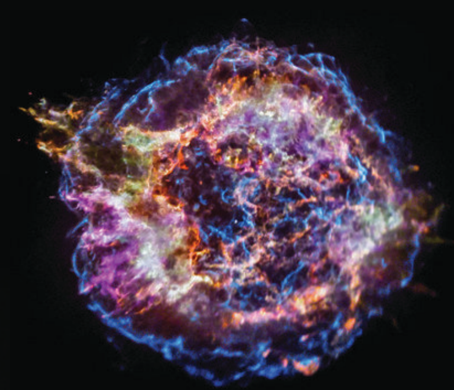
2023

ICC

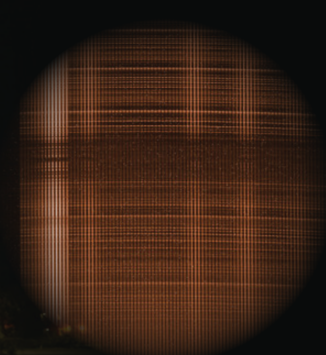


Durham University

Durham Centre for Extragalactic Astronomy



CfAI



PHD & MSCR PROJECTS IN ASTRONOMY FOR AUTUMN 2023 START

Introduction

List of STFC/Durham funded PhD Projects

Alexander: Why are (some) quasars special? Towards an understanding of the evolution of quasars

Chadwick: The extreme universe with CTA and SWGO

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- Using galactic bar dynamics to probe the nature of dark matter

Frenk: Cosmological constraints on the mass of the neutrino

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List of additional PhD Projects with other funding opportunities

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INTRODUCTION

Durham University is a UK-leading centre for astronomical research with world-class groups working in a wide range of fields covering the observational, theoretical and instrumentation aspects of astronomy. Durham has been ranked ranked Number One in Europe and sixth in the world for our research into Space Science (which covers research into astronomy and astrophysics) over the decade 2002–2012, according to Thomson Reuters. In 2014 we were ranked 5th in the world (1st in Europe) in terms of research impact in space sciences. The Clarivate Analytics Highly Cited Researchers 2018 list puts Durham's astronomers and cosmologists first in the UK, second in Europe and sixth in the world for the quality and influence of their research in space science.

There are 38 academic staff across the combined astronomy groups, with over 100 people involved in astronomy research, which includes postdocs, postgraduate students and support and technical staff. Our main areas of expertise are extragalactic astronomy and cosmology (observational and theoretical), advanced instrumentation, and high-energy astrophysics. Astronomy in Durham is split over three closely connected groups within the Physics Department and which are now all located to a large extent within the newly built Ogden Centre for Fundamental Physics. The three groups consists of the Centre for Advanced Instrumentation (CfAI), the Centre for Extragalactic Astronomy (CEA) and the Institute for Computational Cosmology (ICC).

We are seeking now graduate students to undertake research within our PhD and MSc by Research programmes, starting from October 2023. We particularly encourage applications from members of the community that are under-represented in physics.

Fully Funded PhD Studentship Options

This booklet outlines primarily PhD projects for which we can provide full funding (fees plus a stipend) over 4 years typically, but not exclusively. For those projects with funding associated, we provide brief details on the funding below.

Science and Technology Facilities Council (STFC) studentships. These up to 4-year long PhD studentships are available to any student meeting the qualification criteria thanks to financial backing from Durham University. We note that there are quotas on the number of international students that can be funded. We refer candidates to enjoy the clarity of the information and eligibility rules that applies to STFC studentships. We expect to offer up to 5 STFC-funded studentships this year, based on previous years STFC allocations. According to the rules in place at the time of writing this could imply up to 2 international studentships.

Durham University Astro Particle Scholarship. We expect this 4-year studentship to be available to any student, irrespective of their fee status. Funding for one home fee Astro Particle studentship is guaranteed.

Other PhD Studentship Options

We can offer an even broader range of PhD projects and supervisors for graduate students that have obtained their own funding or are in the process to apply for funding. For details of other potential projects and a full list of potential supervisors, please see the Postgraduate Opportunities link off of our web page. Some specific projects have been included in this booklet.

Two potential funding routes are provided by Durham University through the **Durham Doctoral Studentships (DDS)** and **China Scholarship Council (CSC)** schemes. The application deadline for DDS and CSC scholarships is such that nomination letters by staff based on the applicant's submitted material needs to be in place by typically at the end of December / start of January, for an autumn 2023 start. The official CSC deadline has been announced now as January 15$^{\text{th}}$ 2023. We note that by the deadline we need to have received reference letters in support of the application, something we request directly from the referees once an application has submitted, as well as relevant language certificates. Therefore we encourage interested graduate students to contact us well in advance of this deadline to ensure maximum success, as well as to explore other potential sources of funding. Hence we recommend DDS/CSC applications to be submitted by **early/mid December 2022** to receive full consideration.

Bell Burnell Graduate Scholarship Fund. The IOP and leading physicist Professor Dame Jocelyn Bell Burnell launched the Bell Burnell Graduate Scholarship Fund to encourage greater diversity in physics. It is a scholarship fund to support full or part-time graduates who wish to study towards a doctorate in physics and are from groups that are currently under-represented in physics. As host university, Durham can put forward a maximum of two students for the Fund. To be considered, candidates needs to have applied and be nominated by a staff member by the internal physics deadline usually in early January (exact date TBC, but typically 2 weeks ahead of the BBGSF application deadline of January 20$^{\text{th}}$ 2023). Hence we recommend applicants interested to be considered for the *Bell Burnell Graduate Scholarship Fund* to submit their application by **early/mid December 2022** to receive full consideration.

In past years prospective PhD students have been successful in securing funding from various national and international funding bodies with support from academic staff in Durham, including *Van Mildert College Trust*, *Team Durham Graduate Programme*, *CONACYT* and *CONICET* PhD scholarships. For more details, please see the Postgraduate Opportunities link off of our web page.

PhD application process

PhD studentships are awarded on the basis of academic record and research aptitude, which are assessed via an on-line application and an interview (in person in Durham or remotely depending on the situation). We expect to interview shortlisted candidates for funded studentships from February through to mid-March (see our web-pages for up-to-date information regarding possible interview days and effective deadlines to meet).

We recommend you to indicate several projects for which you wish to be considered, or your general area of interest (simulations, observations, etc), to help us identify potential supervisors for the interview days. Your application is not expected to include an original research proposal, but rather to indicate which of the described projects you wish to pursue. In practice, these descriptions provide a starting point for each project; the ongoing direction of your research will adapt naturally over the course of study.

MSc by Research Studentship Options

We can offer an equally broad range of MSc by Research (MScR) projects and supervisors for graduate students that have their own funding. For details of other potential projects and a full list of potential supervisors, please see the Postgraduate Opportunities link off of our web page. Currently there is no guaranteed funding available for MScR projects, but for residents in England the UK government has a scheme to apply for post-graduate loans. For more specific details of the scheme, please consult the UK government webpages https://www.gov.uk/postgraduate-loan.

Arthur Browne Bursary 2023. The Bursary awards are based on academic merit and will be selected on a competitive basis, with one award per year expected. The University has directed that the funds (£6,000 for the academic year 2022/23) are to be used towards fees and/or towards other course or living expenses (including research-based travel). Deadline for applications for the 2023 round will be announced in September 2023, with all eligible MScR students in Physics invited to submit a one page application for the Bursary.

Follow the post-graduate opportunities link from our web site or contact our astronomy post-graduate administrator (Prof. Peder Norberg; peder.norberg@durham.ac.uk; Ogden Centre West 129) for further details.

WHY ARE (SOME) QUASARS SPECIAL? TOWARDS AN UNDERSTANDING OF THE EVOLUTION OF QUASARS

Supervisor: Prof. David Alexander d.m.alexander@durham.ac.uk
Office: Ogden Centre West 119
Funding: STFC and all other funding schemes (DDS, CSC, ...)

Description:

Quasars are the most luminous subset of the overall population of Active Galactic Nuclei (AGN) and can be seen out to the edge of the observable Universe. They are powered by mass accretion onto a super-massive black hole, the same basic power source for all AGN, and are thought to have had a profound impact on the overall formation and evolution of galaxies. However, despite being discovered over half a century ago, we still have limited knowledge on how different subsets of the quasar population are related to each other; e.g., the connection between obscured and unobscured quasars.

The relationship between less powerful obscured and unobscured AGN appears to be due to the orientation of an optically and geometrically thick structure (often referred to as the "dusty torus") towards our line of sight. An AGN is observed to be obscured when the "torus" intercepts the line of sight while the AGN is unobscured when the "torus" is orientated away from the observer. This model is known as the "unified model of AGN" (see Netzer 2015 for a recent review). However, although referred to as a "unified model", we have recently found that this model does not apply to all quasars.

We have found that red quasars, a subset of the quasar population obscured by dust and gas, have fundamentally different radio and X-ray properties to normal quasars (Klindt et al. 2019; Fawcett et al. 2020; Rosario et al. 2020; Igo et al. in prep). This evidence points towards red quasars being a phase (probably early in the life of a quasar) in the evolution of quasars rather than being normal quasars aligned away from our line of sight. However, although our results are clear and conclusive, we lack details about this phase such as the duration, whether it is episodic, and the trigger mechanism. The leading model for the evolution quasars is shown in the figure below; however, we do not know whether it is correct.

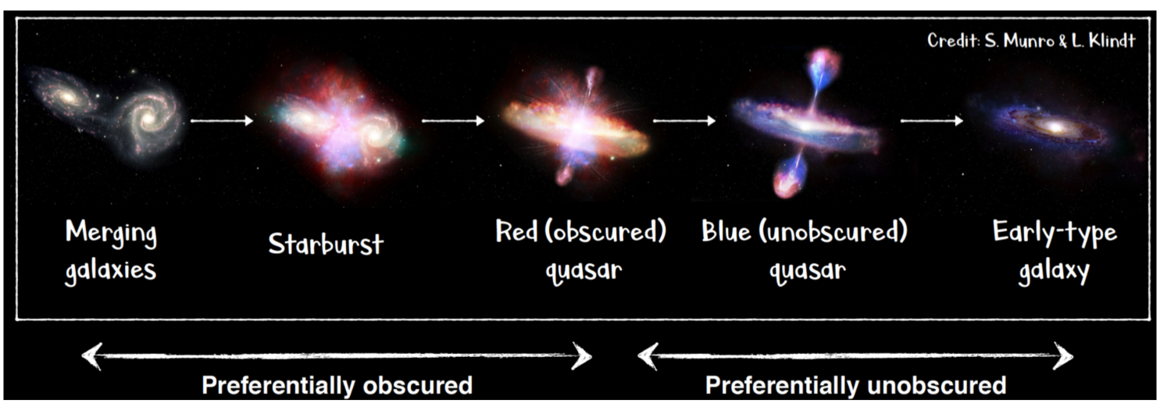


Figure: The leading evolutionary model for quasars. The sequence is triggered by huge amounts of gas inflow (potentially from a merger of two galaxies) which leads to a burst of dust-obscured star formation and a heavily buried (i.e., obscured) quasar. As the quasar ages it drives out energetic winds which blows away the obscuring dust, revealing a red quasar and then ultimately revealing an unobscured quasar (see Alexander & Hickox 2012 and Hickox & Alexander 2018 for reviews). Eventually the huge amount of energy formation and forms a "red and dead" early type galaxy. Schematic produced by S. Munro and L. Klindt.

I am looking for a student to extend our understanding of the evolution of quasars . This research will exploit our membership of the on-going 4-year Dark Energy Spectroscopic Instrument (DESI) survey (Dey et al. 2019) and the future 4-year AGN survey using the 4MOST instrument (Merloni et al. 2019). Each of these surveys will detect over 1 million quasars and AGN, pushing deeper than current surveys and extending to more extreme systems. You will undertake systematic analyses using a variety of multi-wavelength datasets to quantify the differences between normal and red quasars. For example, utilising the previous Sloan Digital Sky Survey (SDSS) you will investigate how often quasars change from normal to red (and vice versa) over a decade-long timescale, providing key insight on whether the red-quasar phase is episodic and providing the first constraints on the duration of the red-quasar phase. You will also analyse deep multi-wavelength observations to measure the physical properties of red quasars such as the amount of obscuring dust, the black-hole mass, and the black-hole accretion rate.

Notes:

THE EXTREME UNIVERSE WITH CTA AND SWGO

Main Supervisor: Prof. Paula Chadwick p.m.chadwick@durham.ac.uk
Office: Rochester 125c
2nd Supervisor: Dr. Anthony M. Brown anthony.brown@durham.ac.uk

Funding:

Description:

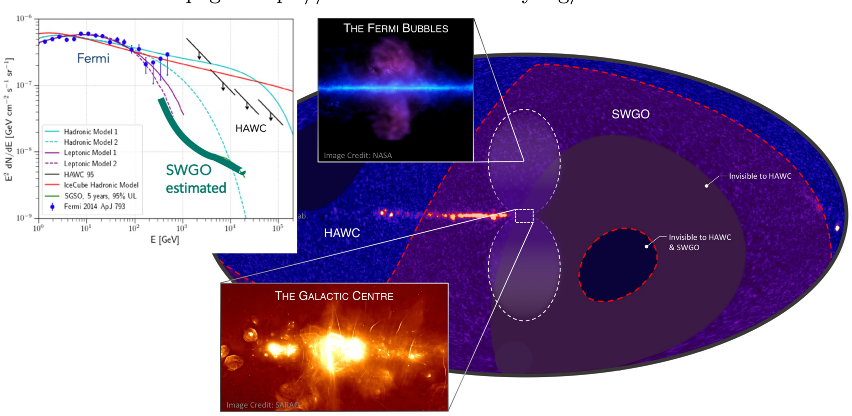
Over the last 10 years, very high energy (VHE) gamma ray astronomy has opened a new window on the extreme universe. The catalogue of known VHE-emitting objects has grown by an order of magnitude and includes many different classes of objects - supernova remnants, pulsars, binary star systems, star formation regions and active galaxies - while other objects remain a mystery. The VHE radiation from these systems is produced by non-thermal particle acceleration, but the mechanisms by which this occurs have not been established.

The group at Durham has pioneered this field, and is presently involved in two projects: the Cherenkov Telescope Array (CTA) and the Southern Wide-field Gamma-ray Observatory (SWGO). CTA will consist of two arrays, one in the southern hemisphere and one in the north. CTA will have sensitivity around 10 times better than any gamma ray telescope now in operation, will cover 4 orders of magnitude in energy and have better angular resolution than anything we have built before. Prototyping and construction of the first telescopes and instrumentation has already begun; the first telescope of the northern array is already in place, and construction of the southern array is expected to start in 2023.

Some gamma-ray objects cover large areas of the sky and many are transient - sudden, bright events that are very difficult, if not impossible, to predict. We need an instrument that is able to survey the sky over a wide area and at all times, even when the Sun is above the horizon. This is why the international SWGO project was founded in 2019. This will be a gamma-ray observatory based on ground-level particle detection, located in South America at a latitude between 10 and 30 degrees south and at an altitude of 4.4 km or higher. It will cover an energy range from 100s of GeV to 100s of TeV, and aims to provide survey and wide-angle capability to complement observatories like the Cherenkov Telescope Array.

As founder members of CTA and SWGO, the Durham group is involved in many different aspects of the telescopes. Students can choose from a range of possible projects, including science studies relating to active galactic nuclei, multi-messenger (gamma-ray/neutrino) studies, dark matter etc. in preparation for CTA (primarily using data from the Fermi Gamma-ray Space Telescope), telescope calibration using UAVs, simulations of array performance (particularly for SWGO), SWGO calibration, and the construction of cameras for the small telescopes of CTA. Students can also expect to be involved in work on preliminary data from the first CTA telescopes.

The SWGO homepage: https://www.swgo.org/SWGOWiki/doku.php
The CTA homepage: https://www.cta-observatory.org/



The SWGO will have unprecedented coverage of transients such as gravitational wave events and the ability to image extended objects, including the Galactic centre and the Fermi bubbles.

Notes:

GALACTIC ARCHAEOLOGY AT THE HEART OF THE MILKY WAY: DIGGING FOR ANCIENT MERGER RELICS

Main Supervisor: Dr. Francesca Fragkoudi francesca.fragkoudi@durham.ac.uk
Office: Ogden Centre West 127
Funding: STFC and all other funding schemes (DDS, CSC, ...)

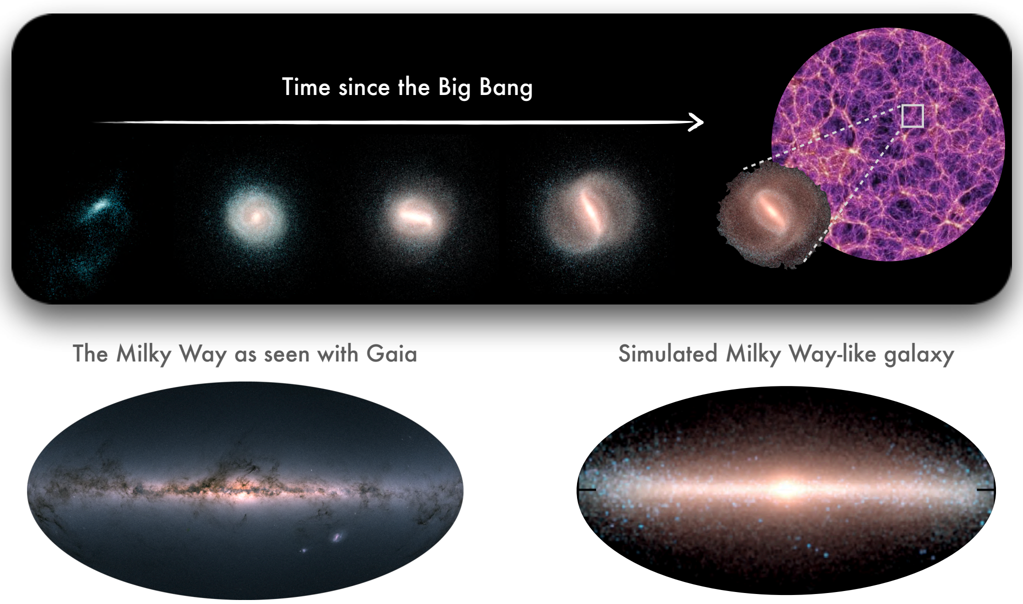
Description:

Our home galaxy, the Milky Way (MW), is a massive spiral galaxy, which we are able to study in unparalleled detail, on a star-by-star basis. This makes it an ideal test-case for our current theories of galaxy formation and evolution. While the MW has had a relatively quiescent merger history over the last 9 billion years or so, many open questions remain about its early assembly. In order to reconstruct the full formation history of the Galaxy, we need to explore its innermost regions – which are the first to assemble – to uncover the relics of its most ancient accretion events. There are a number of ongoing and planned surveys over the next few years (e.g. Gaia, 4MOST, MOONS, SDSS-V MWM) that will provide an unprecedented view of the inner MW. To interpret these data, and in particular, the chemo-dynamical properties of the most metal-poor and ancient stars in the bulge, we need sophisticated models that trace the formation of MW-like galaxies in the full cosmological context. For this we will use the newly developed Auriga Superstars simulations, a suite of high resolution, magneto-hydrodynamical cosmological zoom-in simulations of MW-mass galaxies, to answer questions such as:

- What do the chemo-dynamical properties of the most metal-poor stars reveal about the MW's early assembly history?
- How can we identify substructures, i.e. the building blocks of our Galaxy, in this complex region where dynamical timescales are short and multiple components overlap?
- Can we disentangle different components, such as the disc, bulge and halo, in the innermost regions, and is there a smooth transition between them?

The student involved in this project will be a member of the Auriga Superstars collaboration, will have the opportunity to run their own cosmological simulations, and to compare these models to current and upcoming observational data.

Review on the Milky Way
Chemo-dynamics in cosmological simulations: On the Milky Way's quiescent merger history



Using cosmological simulations we can track the formation and evolution of MW-like galaxies through cosmic history. We can then use these models to interpret the chemo-dynamical properties of stellar populations in the centre of our galaxy.

Notes:

USING GALACTIC BAR DYNAMICS TO PROBE THE NATURE OF DARK MATTER

Main Supervisor: Dr. Francesca Fragkoudi francesca.fragkoudi@durham.ac.uk
Office: Ogden Centre West 127
Funding: STFC and all other funding schemes (DDS, CSC, ...)

Description:

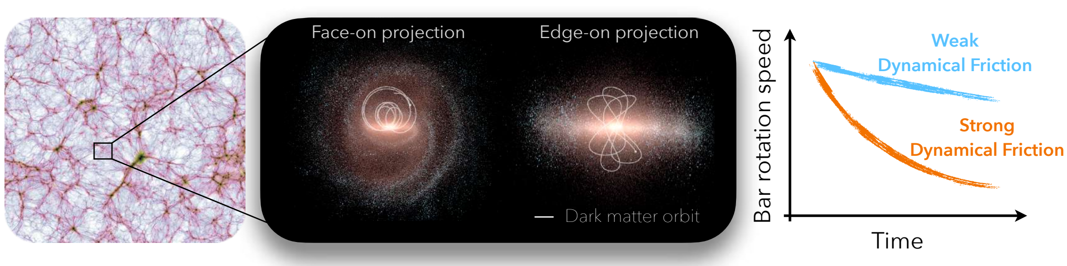
The nature of dark matter – the elusive substance making up 85% of the mass of the Universe and one of the pillars of the standard Lambda Cold Dark Matter (ΛCDM) cosmological model – remains a major unsolved mystery of modern physics. While its fundamental properties are as of yet unknown, its existence and properties can be inferred through its gravitational influence on normal (baryonic) matter. Dark matter interacts gravitationally with stars in spiral galaxies in two intriguing ways: i) it stabilises stellar discs against the formation of elongated, rotating structures, called galactic 'bars' (e.g. Ostriker & Peebles 1973) and, ii) when bars do form, dark matter inflicts a drag force on them, i.e. 'dynamical friction', causing them to slow down (e.g. Tremaine & Weinberg, 1984b). As these processes are mediated via resonant interactions between the bar and dark matter particles, the fraction of galaxies hosting bars, and the bar rotation speed itself, will be highly dependent on the existence and properties of dark matter (see Figure 1).

This PhD project will focus on using state-of-the-art models to shed light on the nature of dark matter via its effects on the stellar and gaseous dynamics of spiral galaxies, such as our own Milky Way. This is particularly timely as we are currently living in a golden era of galactic dynamics, thanks to exquisite data of the Milky Way and nearby galaxies from Gaia and ground-based spectroscopic surveys. We will develop and use state-of-the-art cosmological simulations in ΛCDM and alternative dark matter scenarios, as well as gas-dynamical models to answer questions such as:

- What are the signatures of the resonant interaction between dark matter and bars?
- How do these signatures depend on the nature of dark matter?
- What is the effect of different dark matter scenarios on the dynamical friction exerted on galactic bars?
- How much dark matter is there in spiral galaxies (both low- and high-mass) in the local Universe?

The student involved in this project will have the opportunity to develop and work with cosmological simulations and/or gas-dynamical models, and compare these models to current and upcoming observational data.

Paper on bars in cosmological simulations
Paper on dynamical modelling of barred galaxies



Left and Middle: *Using cosmological simulations we can understand the connection between dark matter and the dynamical properties of barred spiral galaxies, such as the Milky Way.* Right: *Different dark matter scenarios will have distinct effects on the dynamical friction imparted on galactic bars.*

Notes:

COSMOLOGICAL CONSTRAINTS ON THE MASS OF THE NEUTRINO

Main Supervisor:	Prof. Carlos Frenk CBE FRS	c.s.frenk@durham.ac.uk
Office:	Ogden Centre West 225	
Other supervisors:	Prof. Adrian Jenkins	a.r.jenkins@durham.ac.uk
	Prof. Baojiu Li	baojiu.li@durham.ac.uk
	Prof. Silvia Pascoli	silvia.pascoli@unibo.it

Funding:	Durham University Astro Particle Scholarship

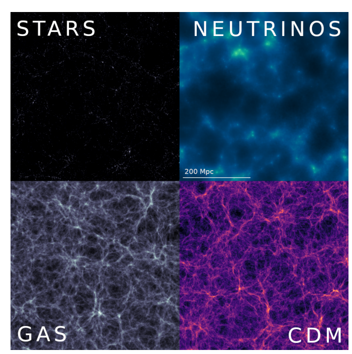
Description:

Various experiments have shown that neutrinos have a small mass. (The 2015 Nobel prize in Physics was awarded to Takaaki Kajita and Arthur B. McDonald for the discovery of neutrino oscillations, which demonstrate that neutrinos have a mass.) Thus, neutrinos are the only identified form of dark matter particles. As such, they affect the formation of cosmic structures such as galaxies and clusters. Cosmological diagnostics, particularly temperature fluctuations in the cosmic microwave background radiation and the large-scale clustering of galaxies, can be used to set an upper limit on the neutrino mass. The best current upper limit is about 0.3 eV and this implies that neutrinos contribute at most a few percent of the total dark mass in the Universe. The rest is very likely a cold dark matter particle. In the early universe neutrinos behaved like hot dark matter because when they emerged they moved at relativistic speeds. Their main effect is to modify the shape of the primordial spectrum of density perturbations on large scales. This is subsequently reflected in the galaxy distribution.

While the best constraints on the neutrino mass come from cosmology, neutrino experiments also provide mass limits. As the sensitivity of both approaches continues to improve, their combination provides a powerful test for cosmology and could play an important role in addressing the current tensions between measurements of cosmological parameters. These tensions have grown in significance in recent years and could indicate a need for new physics. Many attempts at resolving the tensions involve extensions of the standard cosmological model that modify the expansion history of the Universe, thereby changing the inferred neutrino mass, while others involve the neutrinos directly, such as through interactions with dark matter.

This project has two main goals. The first is to produce the best predictions to date of the effect of massive neutrinos on the large-scale distribution of galaxies at different cosmic epochs and for different cosmological scenarios. Willem Elbers, a finishing PhD student who will stay on as a postdoc and contribute to the student's supervision, has developed a novel technique that enables very large cosmological simulations with neutrinos to be carried out. For this project, the student will perform supercomputer simulations and will analyse them to follow the evolution of the dark matter and galaxies. These will be used to develop and test new statistics of the dark matter and galaxy distribution that are sensitive to the neutrino mass.

Armed with robust theoretical predictions, the second goal of the project is to apply the results to real data. The ICC is a partner in DESI, the "dark energy spectroscopic instrument" survey. This is an international venture that is carrying out the largest and most detailed survey of galaxies and quasars ever performed over a large range of cosmic epochs. DESI has already acquired more galaxy redshifts than all previous surveys combined and will continue to deliver exquisite data during the period of this project. Comparing the clustering pattern of galaxies in the DESI survey at different epochs with the simulation results will enable the student at least to set the best upper limits on the neutrino mass and, at best, to measure the neutrino mass. In either case, the project will have huge implications for particle physics and may reveal physics beyond the standard model.



The distributions of stars, neutrinos, gas and cold dark matter in a slice of a large cosmological simulation carried out as part of Virgo's Flamingo project. Courtesy of Willem Elbers.

Although this project is primarily astrophysical and cosmological, given its implications for particle physics, the supervisory team involves a particle physicist, Prof. Silvia Pascoli (currently based in Bologna). The student will make use of the ICC's large supercomputer (the "Cosmology Machine"), as well as resources provided by the "Virgo consortium", Europe's premier collaboration for cosmological simulations, which is based at the ICC.

Frenk, C. S. & White, S. D. M, 2012, Annalen der Physik, vol. 524, 507
Elbers, W. et al., 2021, MNRAS, vol. 507, 2614

Notes:

MITIGATING THE EFFECTS OF SATELLITES AND THE ATMOSPHERE ON ASTRONOMY

Supervisor:	Prof. Gordon Love	g.d.love@durham.ac.k
Office:	MSCS 2007	
Other Supervisors:	Dr. James Osborn	
Funding:	STFC and all other funding schemes (DDS, CSC, ...)	

Description:

Depending on the interest of the student this project could go in two directions. Both are concerned about improving the effects of ground based observations.

The Effect of Satellites:

The impact of satellites, and large scale constellations in particular, is a major concern for ground–based astronomers. In recent years there has been a significant increase in the number of satellites in Low Earth Orbit and this trend is set to continue. The large number of space objects (such as satellites, rocket bodies and debris) increases the probability that one will enter the field of view of a ground-based astronomical telescope at the right solar angle to appear bright enough that it can corrupt delicate measurements.

Here we will concentrate on optical ground-based observatories and aim to develop an early warning system to enable astronomers to mitigate the effects of satellite contamination by avoiding, shuttering or post-processing.

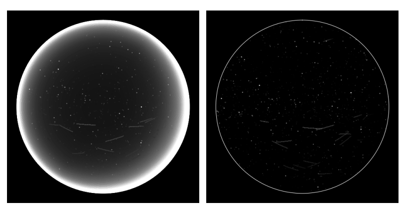


Fig. 1. *Simulated mock data of a full-sky image in Durham for a 30 second exposure during twilight (left, sun at 6 degrees below horizon) and after twilight (right, sun at -18 degrees below horizon). Satellites can be seen as streaks. The system will detect these streaks and extrapolate the trajectory and brightness for the pointing of a nearby telescope field-of-view.*

One solution is to use knowledge of the positions of satellites at any given time and then schedule observations accordingly. But the tolerances on the locations of known satellites is often larger than the field of view of telescopes and therefore we are proposing to use an instrument to identify satellites in the sky as they approach the telescope field-of-view, even on short-notice, and use this information to shutter the observation for a short period.

Atmospheric Turbulence:

The student will engage with the development, deployment and exploitation of site-testing instrumentation at observatory sites around the world, to improve our understanding of the effects of the Earth's atmosphere on astronomical observations. They will look to apply these results to improve the performance of adaptive optical or scintillation (the twinkling of the stars) correction systems, or to the forecasting of optical turbulence conditions at observatory sites. This work will be directly applicable to the next generation of giant telescopes, such as the 40 metre European Extremely Large Telescope in Chile. Enabling them to reach their science goals including discovering extra-solar planets, reconstructing the formation of galaxies, and even elucidate the nature of dark matter and dark energy.

Whichever project is undertake the student will join the dynamic environment of the Centre for Advanced Instrumentation (CfAI), within the Physics Department at Durham University. The CfAI is a world leading research centre with a large and successful Astronomical Instrumentation group, including Adaptive Optics and Space Science technologies. The Adaptive Optics group has significant experience in analysing atmospheric turbulence and the use of computer modelling of complex optical systems to design optical instrumentation to some of the world's premier astronomical observatories.

SIMULATING THE EFFECTS OF AGN FEEDBACK ON GALAXY FORMATION

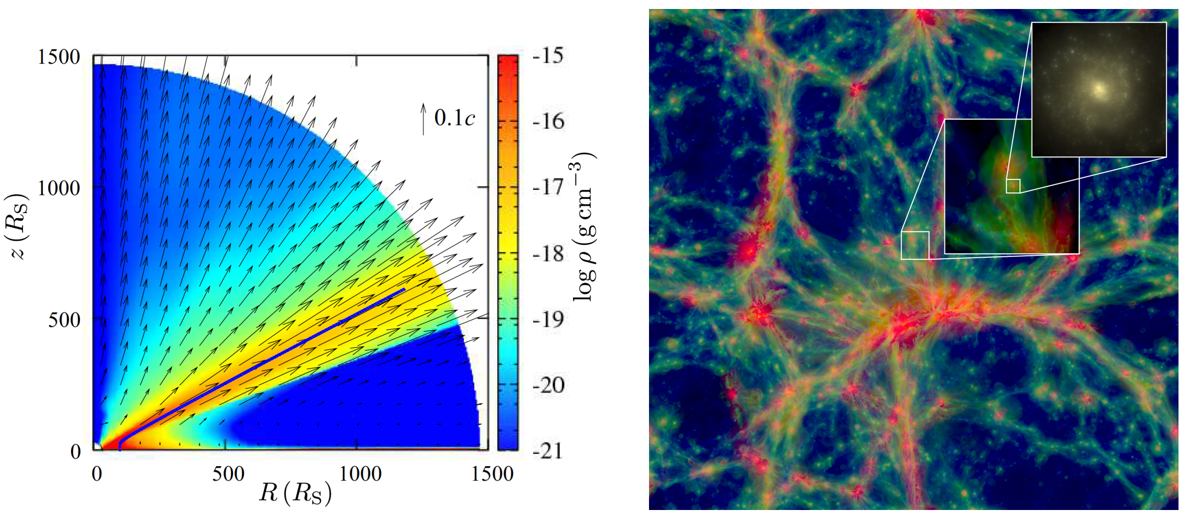
Main Supervisor: Prof Cedric Lacey cedric.lacey@durham.ac.uk
Office: Ogden Centre West 216
Funding: STFC and all other funding schemes (DDS, CSC, ...)

Description:

One of the most important discoveries of recent years is that massive galaxies in the nearby universe nearly all host supermassive black holes at their centres. These black holes grow by accreting gas, and in doing so release enormous amounts of energy, making them visible as active galactic nuclei (AGN). This energy release is thought to play a crucial role in galaxy formation and evolution, limiting the growth of galaxies through AGN feedback. One form of this feedback is from relativistic winds driven off black hole accretion disks by radiation pressure.

Current cosmological simulations of galaxy formation, despite their successes, still treat black hole evolution and AGN feedback in a very simplified way. The aim of this project is to develop improved treatments of these processes in the successors to the EAGLE gasdynamical simulation of galaxy formation. Recent theoretical modelling work at Durham (Quera-Bofarull et al 2021) has greatly advanced our understanding of radiation-driven winds from black hole accretion disks, providing detailed predictions for mass and energy ejection rates, which are very different from what has previously been assumed in cosmological simulations of AGN feedback. In addition, these winds are predicted to be strongly collimated in angle, an effect which is also generally not included in cosmological simulations. The aim of this project is to incorporate these predictions into a new model for black hole evolution and AGN feedback in cosmological simulations of galaxy formation, and investigate the effects on the evolution of galaxies and their black holes.

Schaye, J. et al. 2015, The EAGLE project: simulating the evolution and assembly of galaxies and their environments
Quera-Bofarull, A. et al. 2021, UV line-driven accretion disc wind models for AGN feedback



Left: Numerical simulation of radiatively-driven wind from black hole accretion disk (Nomura et al 2018). Right: EAGLE cosmological simulation. Main panel shows gas density distribution in a 100 Mpc region, coloured from blue (cold) to red (hot). Gas flows into halos along filaments. It is heated by shocks on infall, and also by feedback from supernovae and AGN, which drive outflows. (Schaye et al 2015)

Notes:

FINDING EXTRASOLAR PLANETS, BY SAVING ROMAN FROM RADIATION

Main Supervisor:	Prof. Richard Massey	r.j.massey@durham.ac.uk
Office:	Ogden Centre West 115	
Funding:	STFC and all other funding schemes (DDS, CSC, ...)	

Description:

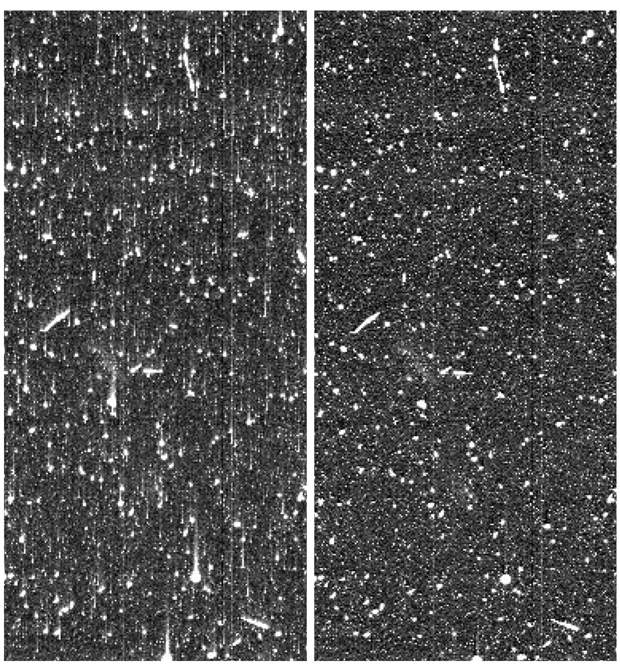
Above the protection of the Earth's atmosphere, electronic equipment is gradually degraded by high-energy radiation. Damage is particularly apparent to the sensitive cameras of the Hubble Space Telescope and NASA's future Roman Space Telescope. An effect of the radiation damage, known as Charge Transfer Inefficiency, blurs all images they obtain. Distant galaxies that Hubble used to see clearly, now appear distorted; the faint glimmers of light from habitable planets that Roman is designed, may be blurred away entirely.

The Roman mission is scheduled for launch in 2026. It is designed to map dark matter, trace the history of dark energy, and find habitable planets. To achieve this, it must test several new technologies in space together for the first time: including a coronagraph and Electron-Multiplying CCD detectors (which were designed and built in the UK). Roman will need to push this new hardware to extreme limits, and literally count one photon at a time from a habitable planet, next to the billion photons from the star it is orbiting.

It is possible to un-blur images from space telescopes, and to improve/restore their performance, if the Charge Transfer process can be accurately modelled. This involves understanding the electronics and detector hardware used inside these cameras. We have developed models of the Hubble Space Telescope that work well (see the figure). This project will extend those models to Roman's new operating regime, make recommendations to NASA and UKSA about their scientific optimisation, and contribute to the analysis of the telescope's first data.

This project is offered as a PhD project, coinciding with the duration of the Roman mission (and the early plans for NASA's subsequent flagship mission currently called IrOUv).

Description of the software model of damaged CCDs (old but brief paper)
More details about what causes the damage



Left: Raw images from the Hubble Space Telescope are really showing its age. The blurring is artificial, and caused by damage to the sensitive detectors, from radiation damage in the harsh environment of space.

Right: By modelling the radiation damage, and its effect on scientific data, it is possible to restore as-new performance. Our correction process is now applied to every image taken by Hubble. This project will try to understand and optimise the hardware in NASA's next big mission, the Roman Space Telescope.

Notes:

RESOLVED STELLAR POPULATIONS IN NEARBY GALAXIES

Main Supervisor: Dr. Anna McLeod anna.mcleod@durham.ac.uk
Office: Ogden Centre West 120
Funding: STFC and all other funding schemes (DDS, CSC, ...)

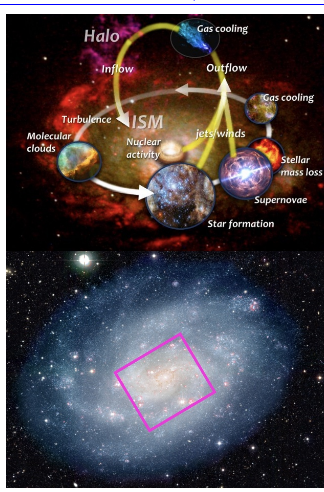
Description:

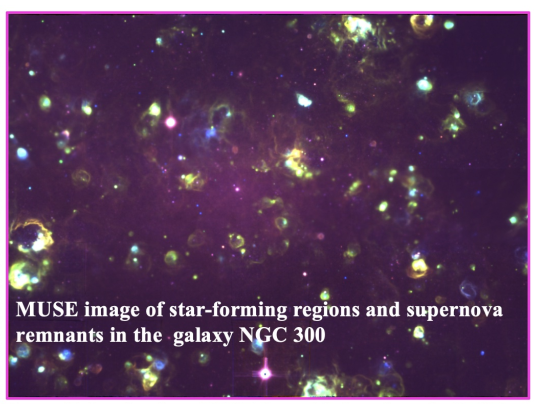
The life-cycle of star-forming galaxies is very complex: cold gas is turned into stars; the formed stellar populations stir, mix, enrich, heat, and expel the gas via stellar winds, radiation, and supernova explosions; the gas can then fall back onto the galaxy, cool, and form new generations of stars. While we qualitatively understand the involved physical processes governing the gas recycle, we still do not have a clear quantitative description of them. As a consequence, constraining how galaxies turn their gas into stars, how feedback from these stars disrupts gas and regulates the growth of galaxies, and how these processes have changed with galactic environment across cosmic time, is one of the fundamental problems in modern astrophysics.

In this project you will address a key part in solving this problem by revealing and studying stellar populations in nearby galaxies. Indeed, nearby galaxies are our best laboratories to study the interplay between stars and gas: they provide the necessary numbers to study star formation across many different environments and, crucially, on the small and resolved scales at which the relevant physics happens. By combining data from the highly competitive MUSE on the Very Large Telescope with data from the Hubble Space Telescope, you will study the stellar population of the nearby galaxy NGC 300 at unprecedented levels of detail. For this, you will develop an automated algorithm to identify and classify the stars and star clusters in the galaxy. Once in place, the developed analysis methods can then be applied to other nearby galaxies (observed e.g. with the SITELLE instrument on the Canada-France-Hawaii Telescope), therefore providing a framework to quantify the galactic life-cycle of gas and stars. You will then directly connect the stellar population to the star-forming gas reservoir and the star formation history of this galaxy.

The results from this work will serve as important empirical benchmarks for state-of-the-art numerical simulations of star cluster formation and galaxy evolution. You will get the opportunity to write proposals to obtain new observations, and closely collaborate with leading experts in the field at world-class institutes.

More about this topic:
Stellar Feedback and Resolved Stellar IFU Spectroscopy in the Nearby Spiral Galaxy NGC 300
SIGNALS: the Star formation, Ionized Gas, and Nebular Abundances Legacy Survey





MUSE image of star-forming regions and supernova remnants in the galaxy NGC 300

By combining the above MUSE data with data from the Hubble Space Telescope, the stellar and gaseous content of the galaxy can be studied simultaneously at unprecedented high resolution.

Upper left. *The galactic lifecycle: cold molecular clouds form stars; the combined feedback from these stars (together with feedback activity from the nuclear region) disrupts the gas and drives galactic outflows; the feedback-affected gas can then cool and form new generations of stars (credit: SPICA collaboration).* **Lower left.** *ESO/WFI image of the nearby star-forming galaxy NGC 300, bright pink traces regions in which massive stars have formed (credit: ESO). The white region corresponds to the footprint of the MUSE image.* **Right.** *MUSE integral field mosaic of the central part of NGC 300 tracing regions in which gas is being ionized by star-formation and supernova events. This data is the central focus of this PhD project.*

Notes:

STARS AND THEIR FEEDBACK AT LOW METALLICITIES

Main Supervisor: Dr. Anna McLeod anna.mcleod@durham.ac.uk
Office: Ogden Centre West 120

Funding: STFC and all other funding schemes (DDS, CSC, ...)

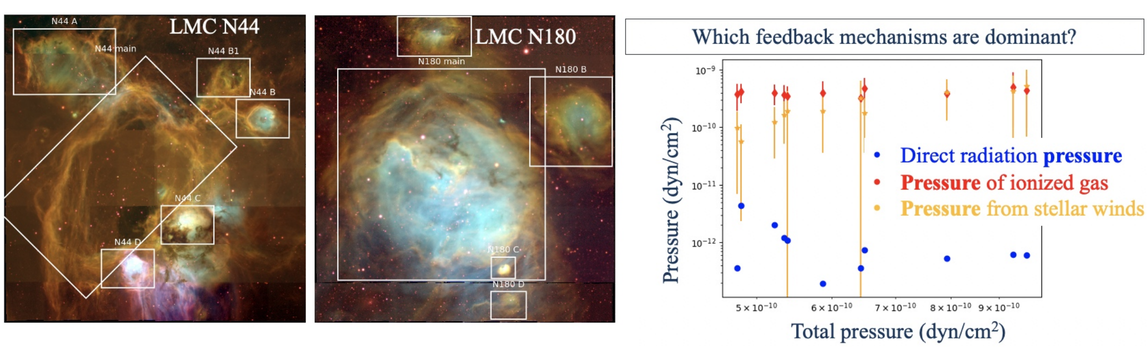
Description:

The energetics of stellar feedback, and its role in regulating how galaxies convert gas into stars, are among the most unconstrained problems in modern astrophysics. So much so that even our best computer simulations cannot reproduce the observed Universe without accounting for stellar feedback. What is feedback? Throughout their short lives, massive stars (with masses of more than 8 times that of the Sun) have a deep impact on their surroundings via e.g. strong stellar winds, ionizing radiation, and supernova explosions. These so-called feedback mechanisms drive the evolution of galaxies: the energy and momentum produced by massive stars can disrupt entire star-forming regions, control how galaxies turn their gas into new generations of stars, deposit heavy elements into their surroundings, and even facilitate the destruction of planetary systems as they are forming.

Yet, despite a qualitative understanding of feedback from massive stars, our quantitative knowledge of stellar feedback is severely lacking. For example, we know that these feedback mechanisms depend not only on the exact type and number of massive stars present, but also on the characteristics of the environment the massive stars form in, like the location within the galaxy, the gas and dust content, and the amount of metals in the interstellar medium. Understanding how the environmental properties influence the effects of feedback from massive stars is crucial to our understanding of star formation and galaxy evolution. In project you will first analyse data of massive star-forming regions in the low-metallicity Magellanic Clouds taken with the highly competitive MUSE instrument on the Very Large Telescope. With this data you will characterize the properties of the stars residing in the regions. Then, using a combination of data sets ranging from the X-rays to the infrared and millimeter regime, you will analyse the gas in these regions to quantify stellar feedback in these low-metallicity environments such as the Magellanic Clouds, directly relating the feedback-driving stars to the feedback-driven gas. In the second part of this project you will extend your studies to other nearby dwarf galaxies.

The results from this work will serve as important empirical benchmarks for state-of-the-art numerical simulations of star cluster formation and galaxy evolution. You will get the opportunity to write proposals to obtain new observations, and closely collaborate with leading experts in the field at world-class institutes like the Space Telescope Science Institute in Baltimore.

More about this topic:
Feedback from massive stars at low metallicities: MUSE observations of N44 and N180 in the Large Magellanic Cloud
The Young Massive Star Cluster Westerlund 2 Observed with MUSE. I. First Results on the Cluster Internal Motion from Stellar Radial Velociti
The Young Massive Star Cluster Westerlund 2 Observed with MUSE. III. A Cluster in Motion—The Complex Internal Dynamics



Left. *Star-forming regions in the Large Magellanic Cloud observed with the VLT MUSE instrument. The two images are mosaics of 64 individual telescope pointings each, amounting to a total of about 12 million spectral pixel! By identifying and classifying the feedback-driving massive stars and simultaneously characterizing the feedback-driven gas, these data can be used to quantify stellar feedback.* **Right.** *This is shown on the right, where three feedback-related pressure terms are compared to each other to evaluate which ones are dominant in these regions. In this project you will use similar data to extend this kind of analysis to other types of environments at low metallicities.*

Notes:

SIMULATIONS OF PLANETARY IMPACTS

Main Supervisor:	Dr. Vincent Eke	v.r.eke@durham.ac.uk
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2nd Supervisor:	Dr. Azi Fattahi	azadeh.fattahi-savadjani@durham.ac.uk
Funding:	Non-STFC funding schemes (DDS, CSC, ...)	

Description:

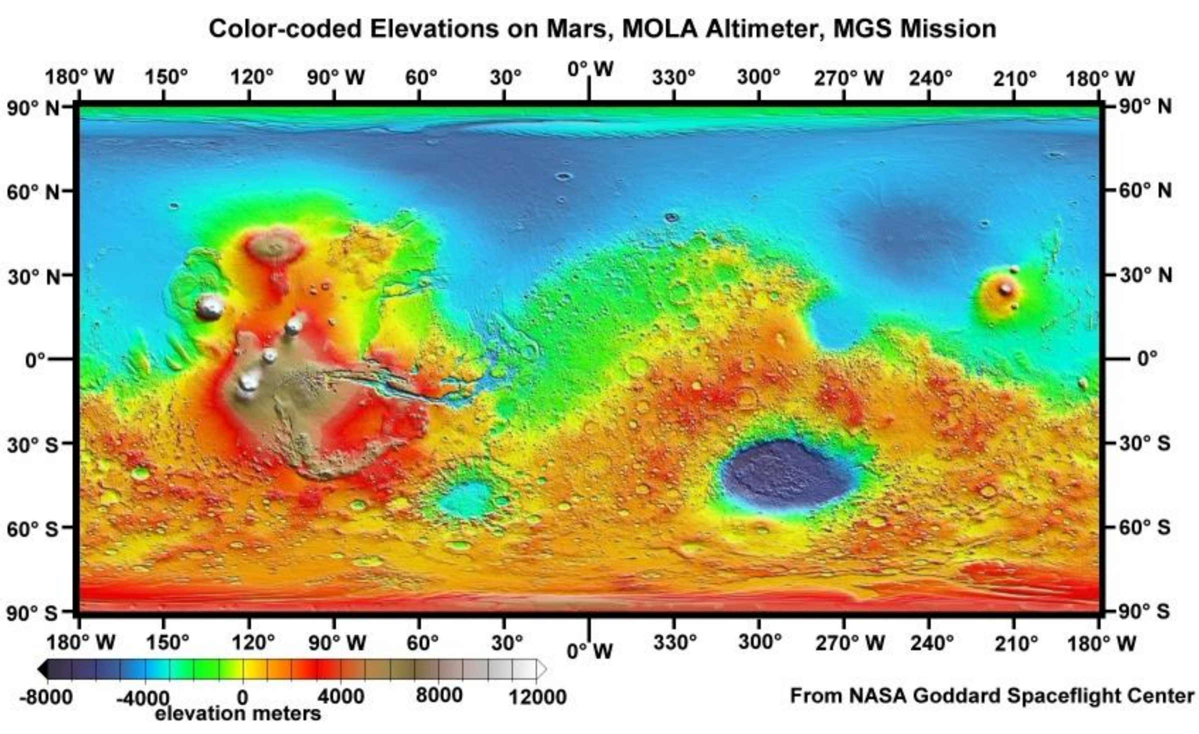
The early Solar System was a violent place where energetic collisions between planetesimals were rife. These impacts represent the most dramatic part of the planet formation process, an understanding of which is required to determine the frequency of exoplanets in habitable zones around other stars.

Observations of the current state of the Solar System provide abundant evidence of past giant impacts; e.g. the relatively large core of Mercury, the similar isotope ratios of the Earth and Moon, and the surprising rotation axis of Uranus. The Martian interior structure and crustal thickness is currently being studied using NASA's InSight mission, and JAXA's upcoming MMX mission will explore the Martian moons. Thus, a timely question is could the Martian dichotomy, whereby the northern hemisphere is typically much lower than the southern hemisphere, be connected with the presence of Phobos and Deimos?

One of the competing hypotheses to explain the Martian dichotomy is a large asteroid hitting the northern hemisphere at a grazing angle, removing some of the crust. An alternative hypothesis involves a south pole strike by a lunar-sized body, causing a hemispherical magma ocean that solidified to form the thicker crust in the south.

The detailed evolution of impacting systems can only be followed using numerical simulations. Durham's astronomy group is involved in running the world's largest numerical simulations in both planetary impacts and extragalactic astrophysics, and the ICC hosts a significant part of the national DiRAC supercomputer facility.

This project, which involves a collaboration with researchers at NASA Ames Research Center, will use the SWIFT state-of-the-art Smoothed Particle Hydrodynamics (SPH) code. While previous Martian impact simulations have used up to a million particles, we will improve the mass resolution by 2 orders of magnitude. With these superior numerical capabilities, we will be able to resolve the Martian crust as well as determining the internal structure of the resulting Mars and the satellite-forming debris disk with unprecedented detail.



Notes:

BUILDING ROBUST MACHINE LEARNING MODELS FOR LARGE ASTRONOMICAL DATASETS

Main Supervisor: Dr Simone Scaringi simone.scaringi@durham.ac.uk
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Funding: non-STFC funding schemes (e.g. DDS, CSC, ...) for PhD; none defined for MScR.

Description:

The volume of astronomical data is growing at an eye-watering rate doubling every 1.5 years. This project will exploit several large surveys with the aim of producing robust and reliable machine learning tools for both classification and regression tasks. This may include development and testing of a classification pipeline for the 4MOST optical spectroscopic survey which will obtain spectra for over 25 million objects within the initial 5 years of observations. Other large datasets ripe for exploitation include lightcurves obtained by the *TESS* space-based observatory, which in conjunction with the parallax, brightness, and proper motion information provided by *Gaia*, is allowing for the discovery of specific populations of objects which would not have been promptly identified if not for the *TESS*/*Gaia* synergy.

This project will adopt several machine learning algorithms based on the dataset at hand as well as the nature of the task (classification vs. regression). Methods will include Deep Learning, Convolutional Neural Networks, Transformer Networks and Generative Adversarial Networks. Curating and developing reliable training datasets will also be important for the success of this project.

4MOST
TESS Guest Investigator Website
Gaia Website

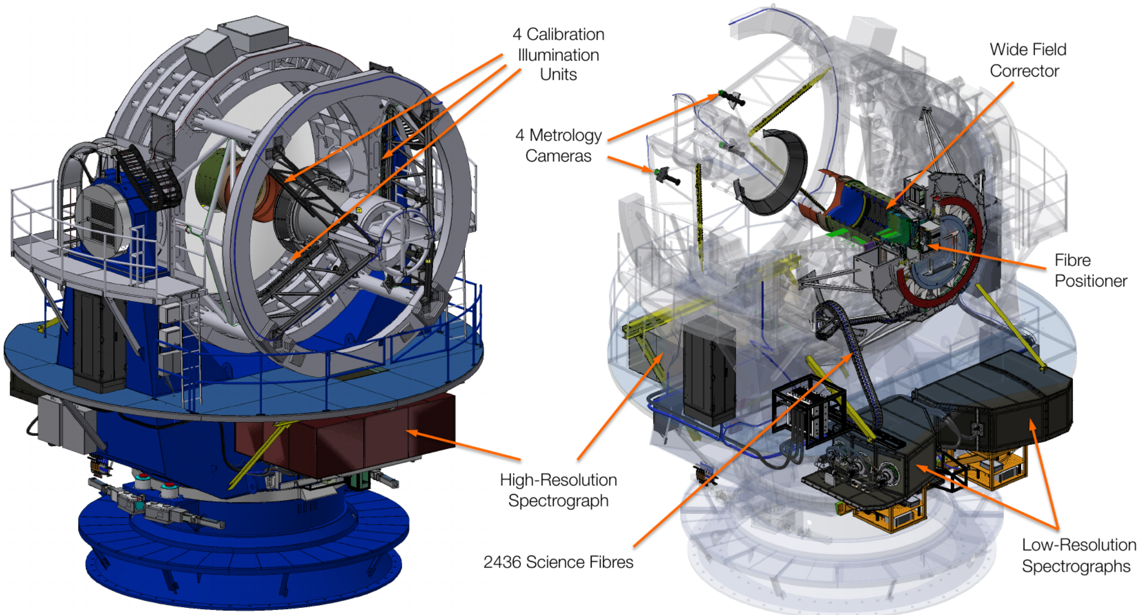

Fig. 1. *With ≈2400 fibres in a ≈4 square degree field-of-view on the 4m-class VISTA telescope and with spectrographs of resolution R≈5000 and R≈20,000 covering most of the optical wavelength range, 4MOST is foreseen to cover in a 5-year survey most of the Southern sky 2-3 times resulting in more than 20 million spectra. The main scientific drivers for 4MOST are drawn from experiments benefitting from the wide survey area covered by this facility thanks to its multiplexing and field of view. This project may include development of robust classifiers for the 4MOST classification pipeline.*

Notes:

EXTREME APPETITES AND VIOLENT OUTBURSTS: THE PHENOMENOLOGY OF COMPACT OBJECTS IN NEARBY GALAXIES

Main Supervisor: Prof Tim Roberts t.p.roberts@durham.ac.uk
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Funding: non-STFC funding schemes (e.g. DDS, CSC, ...).

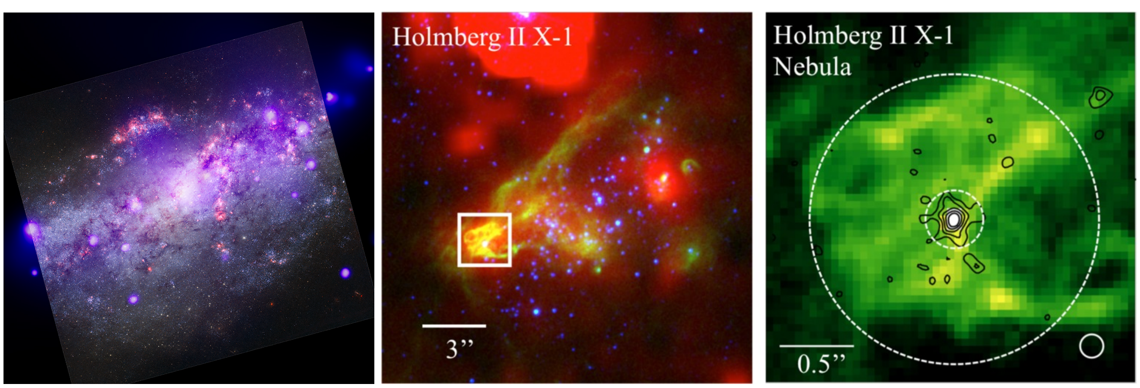
Description:

The sky is a spectacular sight when viewed in X-rays; it glows bright from the X-ray emission of super-heated gas close to the event horizons of many billions of black holes, reaching far back into cosmic history. Imprinted on that background our own Galaxy shines bright, lit up by its own populations of feeding black holes, neutron stars and white dwarfs, and the hot debris of stellar explosions. Over the last two decades we have been treated to an unprecedented view of these exotic phenomena from dedicated X-ray astronomy missions such as NASA's *Chandra* and ESA's *XMM-Newton* observatories, and smaller satellites such as *Swift*, *NuSTAR* and *eROSITA*. Together they continue to build up a wealth of data on the hot and violent regions of the Universe that shine bright in X-rays.

The PhD projects I am offering will make use of the unparalleled data now available to conduct studies of X-ray phenomena in the nearby Universe, focussing on the black holes and neutron stars in relatively nearby galaxies that we suspect to be the most rapacious accretors of material from companion stars, the *ultraluminous X-ray sources*, or ULXs. The projects will use both new and archival data, looking at X-rays and at complementary multi-wavelength data from across the whole electromagnetic spectrum, and will include the opportunity to exploit new ULX catalogues including one currently being constructed from the *eROSITA* all-sky survey. We will use these to address the most pressing issues in understanding ULXs and their effect on the wider universe. These could include, but are not limited to:

- Can we determine whether individual ULXs contain a neutron star or a black hole?
- What fraction of the ULX population overall is composed of neutron stars, and does this vary by environment?
- What are the physical mechanisms that permit neutron stars and black holes to reach the extreme accretion rates inferred for ULXs?
- What effect do ULXs have on their immediate environments (via radiative and/or mechanical feedback), and what are the implications of this method of feedback for the evolution of small galaxies throughout cosmic history?

Review paper on ULXs
Recent ULX catalogue drawn from three separate mission archives



Left: *Composite Hubble Space Telescope optical colour (red, green & blue) and Chandra X-ray (purple) image of the centre of the galaxy NGC 4490. Several of the brightest point X-ray sources in this galaxy are ULXs. Credit: NASA/CXC/SAO/STScI.*
Centre and right: *Optical and IR images of the nebula powered by a ULX in the dwarf galaxy Holmberg II, seen in ionised hydrogen gas (green) in both panels (with the right panel a zoom of the centre). It also shows mid-IR emission in red (central panel) and near-IR contours (right panel), as well as starlight (blue, central panel). From Lau et al. (2019).*

Notes:

STRUCTURAL DECOMPOSITION OF NEARBY AND DISTANT GALAXIES

Main Supervisor: Dr. Dimitri Gadotti dimitri.a.gadotti@durham.ac.uk
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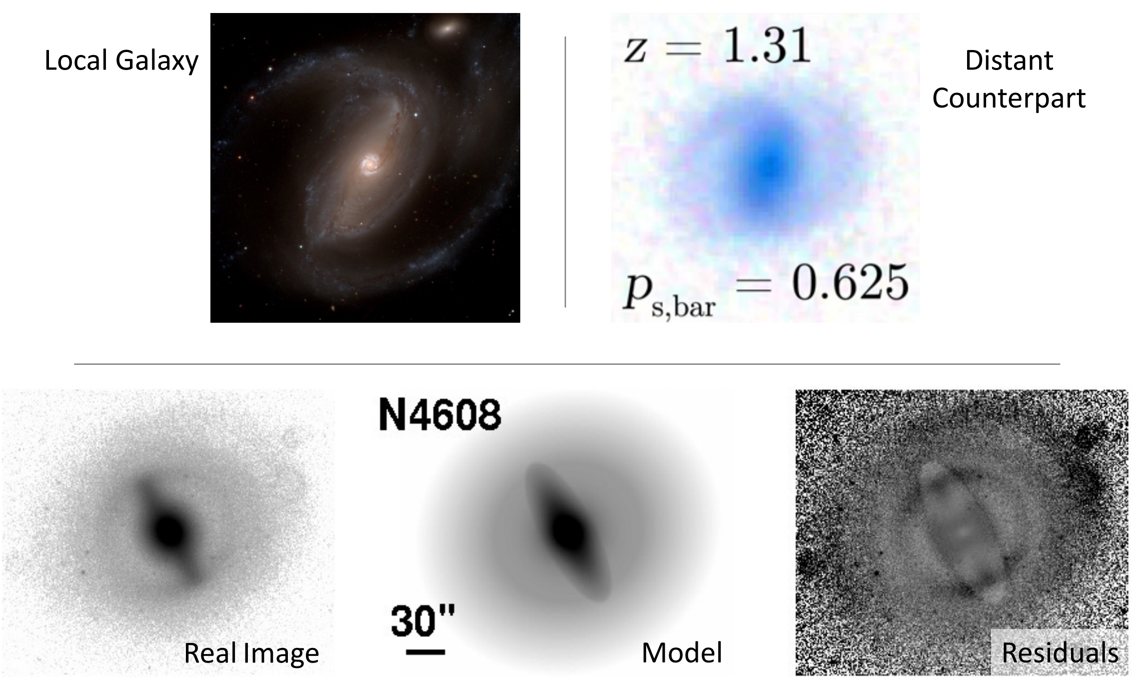
Funding: none defined for MScR projects.

Description:

Disc galaxies host a variety of stellar structures. Apart from the disc, often showing spiral arms, structures such as a central spheroid (or bulge), a bar, rings and a nuclear disc are frequently present. These structures hold important clues to understand the evolutionary paths of galaxies. However, they may be difficult to probe in more distant galaxies, due to a decrease in the physical spatial resolution, amongst other effects (see top left and right panels in the figure below). An important tool to quantify the presence and physical properties of these structures is through galaxy image decompositions. In these, a dedicated image analysis software is used to separately model the different stellar structures in the galaxy (see the three bottom panels in the figure). The goal of this project is to understand better how well this technique works for distant galaxies. In the first stage of this project, you will learn how to use a dedicated software and apply this methodology to determine the structural properties of nearby galaxies. Next, we will simulate the effects that affect images of distant galaxies, and rerun the software on these mock images to establish how these effects impact the results obtained from the image decomposition.



Nearby galaxies (top left) often show a variety of stellar structures that hold important clues to understand their formation and evolution. However, even with the best telescopes and instrumental setups, these structures may be difficult to investigate in more distant galaxies, mainly due to the reduced physical spatial resolution (top right). A powerful tool to quantify the properties of such stellar structures is through galaxy image decompositions. The three bottom panels show, respectively, from the left: an image of a nearby barred galaxy, a model obtained by fitting the galaxy image with separate models for the different structural components (bulge, disc and bar), and a residual image, obtained by subtracting the model from the real galaxy image. The residual image shows further, secondary structural components that are not included in the model.

Notes:

ACCURATE MAPPING OF DARK MATTER DISTRIBUTION IN GALAXY CLUSTERS

Main Supervisor: Professor Mathilde Jauzac mathilde.jauzac@durham.ac.uk
Office: Ogden Centre West 126
2nd Supervisor: Dr Anna Niemiec anna.niemiec@durham.ac.uk

Funding: Non-STFC funding schemes (DDS, CSC, ...)

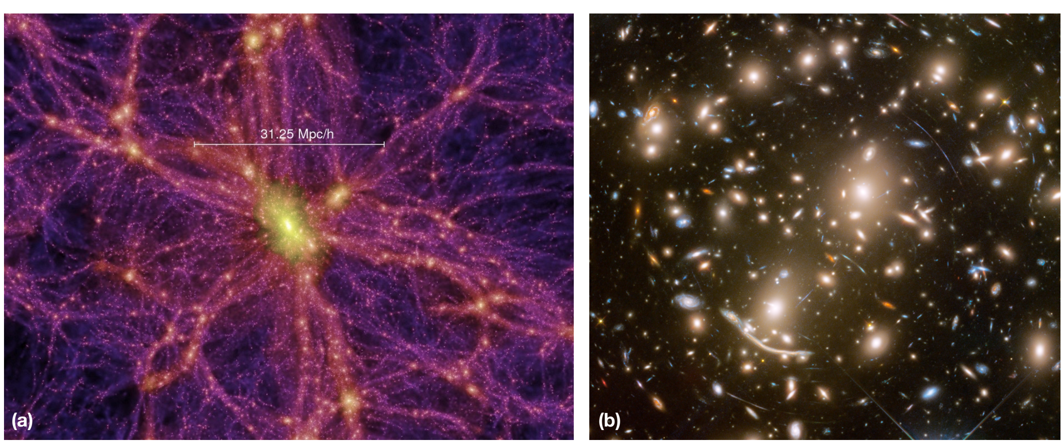
Description:

While easy to detect thanks to their different observational tracers (galaxies, X-ray gas), galaxy clusters are an important probe of the formation history of the Universe. Indeed, as the most massive gravitationally bound objects, they represent the latest stage to date of the hierarchical structure formation, and reside at the nodes of the cosmic web that fuels their growth. Adding to that, clusters are excellent laboratories for probing the physical mechanisms underlying the evolution of the Universe, and they are in particular a privileged location to study the nature of dark matter.

However, in order to use clusters as probes of these different processes, it is first essential to detect the different (sub)structures they are made of, and measure the distribution of matter within them. For the baryonic component of clusters (i.e gas and stars), this is done by combining multi-wavelength observations, from optical imaging tracing galaxy populations, to the hot gas emitting in the X-rays or interacting with the Cosmic Microwave Background (CMB) through the Sunyaev-Zeldovich (SZ) effect. The dark matter component is more elusive, and can for now only be detected indirectly. One way to do so, and a particularly powerful one, is gravitational lensing, that allows to probe a gravitational potential from the bending of passing light rays.

Our team is at the forefront of the study of galaxy clusters using gravitational lensing techniques (Jauzac et al. 2016, 2018). We have developed a new method to model galaxy clusters at all scales, using both strong and weak gravitational lensing constraints, and applied this new technique on very simple simulated clusters (Niemiec et al. 2020). We recently performed a first attempt at using it on real observational data (Niemiec et al. 2022, sub.) using very high quality observational data from the *Hubble Space Telescope* (*HST*) BUFFALO programme (Steinhardt et al. 2020). However, it is now important to perform detailed analyses on the different possible systematic errors that could affect these measurements. The goal of the proposed project is to use mock clusters to precisely calibrate our modeling methods. Through this project, the student will have the opportunity to deepen their understanding of the physics of gravitational lensing and galaxy clusters, as well as develop their coding skills. While initially designed for a MSc project, the analysis proposed can easily be broadened for a PhD.

Paper on the new modeling method - Niemiec et al. 2020
Paper on the HST BUFFALO programme - Steinhardt et al. 2020
Paper on the use of clusters as dark matter probe 2 - Jauzac et al. 2018
Paper on the use of clusters as dark matter probe 1 - Jauzac et al. 2016



(a) *Giant galaxy cluster located at a node of the cosmic web, taken from the Millenium numerical simulation.* ***(b)*** *HST image of the cluster Abell 370. Strong gravitational lensing is visible in the form of giant elongated arcs.*

Notes:

ACCURATE SEPARATION OF STAR FORMATION AND ACTIVE GALACTIC NUCLEI (AGN) ACTIVITY THROUGH FORWARD MODELLING

Main Supervisor: Dr. Leah Morabito leah.k.morabito@durham.ac.uk
Office: Ogden Centre West 124
Funding: none defined for MScR projects.

Description:

Observational evidence and cosmological simulations both agree that super-massive black holes co-evolve with their host galaxies, but we do not understand the details of this process. It is widely thought that most, if not all, super-massive black holes go through an active phase which can help regulate both their growth and also impact their host galaxy. When in this active phase, super-massive black holes are feeding on their host galaxy, which can provide the fuel to produce powerful outflows such as winds or jets, with observational signatures from X-rays to the radio. When we see these observational signatures, we call this an Active Galactic Nucleus (AGN).

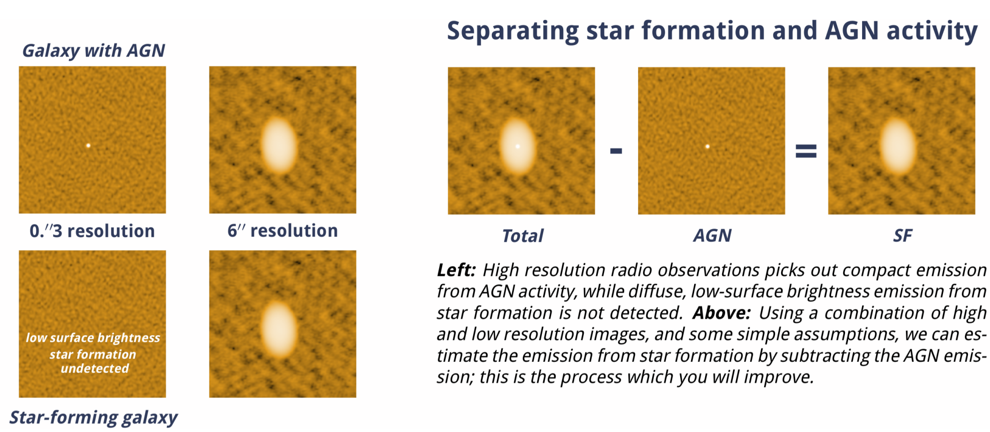
To understand how AGN can impact their host galaxies, we need to track both AGN activity and host galaxy growth. Galaxies grow through star formation, which is the critical parameter to track. An ideal way to track star formation is via radio observations, since radio waves penetrate dust and provide an orientation-free measurement of the star formation rate. However, AGN activity can also produce radio emission, from jets, outflows, or coronal processes. The only way to distinguish between radio emission from AGN activity and radio emission from star formation is through high resolution radio observations. Recent advancements from the LOw Frequency ARray (LOFAR) show that it is possible to do this over a wide field of view (Morabito et al., 2022), but the separation of AGN activity and star formation is quite simple.

You will build a forward-modelling solution to the problem of separating star formation and AGN activity, by starting from first principles to create a model galaxy, using distributions of properties like size and star formation rate, that can be 'observed' with the addition of different levels of AGN luminosities. By comparing a suite of models with observed data, you will be able to place meaningful constraints on the radio emission from star formation and AGN activity.

This project can be extended into a PhD project by building on the complexity of these models to include low-frequency absorption, and by using the results to investigate how star formation and AGN activity evolve together in observed samples where you have used your models to measure these two processes. All of this work is completely new, and will add to our overall understanding of galaxy evolution.

You will learn transferable skills such as dealing with large data sets, computing in a cluster environment, and how to translate physical laws into programming language.

More reading:
Paper 1: https://ui.adsabs.harvard.edu/abs/2022MNRAS.515.5758M/abstract
Paper 2: https://ui.adsabs.harvard.edu/abs/2013A%26A...556A...2V/abstract
Meet the team: https://lmorabit.github.io



Left: *High resolution radio observations picks out compact emission from AGN activity, while diffuse, low-surface brightness emission from star formation is not detected.* ***Above:*** *Using a combination of high and low resolution images, and some simple assumptions, we can estimate the emission from star formation by subtracting the AGN emission; this is the process which you will improve.*

Notes:

PROBING THE STELLAR CONTENT OF ELLIPTICAL GALAXIES USING POISSON FLUCTUATION SPECTROSCOPY

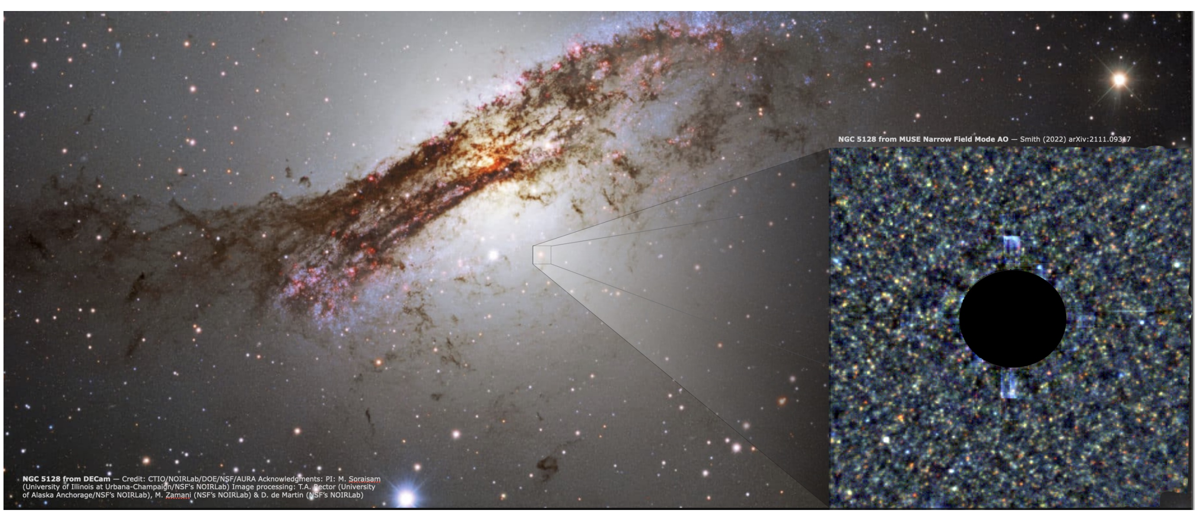
Main Supervisor: Dr Russell Smith russell.smith@durham.ac.uk
Office: Ogden Centre West 110
Funding: None defined (MScR).

Description:

The goal of this project is to develop an innovative method for studying the brightest stars in elliptical galaxies, by analysing the statistical fluctuations in the spectra measured at different locations.

While most stars in external galaxies are individually faint, and present in huge numbers, the most luminous giants are individually bright, but much rarer. The small number of giant stars sampled by each pixel is subject to significant Poisson fluctuations; e.g. while on average we might see 10, some pixels will actually contain 12, or 7 or 15. As a result, the *spectrum* of the galaxy shows variations from pixel-to-pixel which carry the "fingerprints" of the giant stars, which can be extracted using statistical techniques like principal components analysis (PCA). Our recent work has explored this technique using "fake" data generated from an idealised model, and we have also proved that it works in practice, using optical VLT observations for a particularly nearby galaxy, where the fluctuations are easiest to measure (see Smith 2022, MNRAS, 509, 5737).

With the recent launch of the James Webb Space Telescope, and eventually with the next generation of giant ground-based telescopes like the ESO Extremely Large Telescope, we will be able to deploy this novel method in the cores of massive elliptical galaxies. Such observations will probe the origin of several puzzling discrepancies between models and observations for such galaxies. In this project you will first develop a suite of realistic synthetic datasets, tuned to the JWST and ELT characteristics, to determine what information can be retrieved from real data, and what observational configurations are most sensitive for what applications. From there, you will be in a position both to analyse archival data already in hand, and to develop a future programme of ELT observations with the HARMONI instrument, which Durham is involved in building.



A field of stars in the nearby peculiar galaxy NGC 5128 (top left), as seen in ground-based imaging (main) and with MUSE on the VLT in its high-resolution mode (inset). The brightest giant stars are visible in this image but too faint to obtain spectra for individually. A bright foreground star at the field centre is used for the adaptive optics correction. The detailed spectral information in the MUSE data (not shown here) can be harnessed by our Poisson-fluctuation spectroscopy technique to extract the ensemble-average properties of the cool giant stars. In this project, you will help develop the method for application to distant elliptical galaxies with the James Webb Space Telescope and/or the ESO Extremely Large Telescope.

Notes: