CONTENTS

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.

There are 28 academic staff across the combined astronomy groups, with over 100 postdocs, postgraduate students and support and technical staff involved in astronomy research. Our main areas of expertise are extragalactic astronomy and cosmology (observational and theoretical), advanced instrumentation, and high-energy astrophysics. Our research is centred around the physics department (the Rochester building), the Institute for Computational Cosmology (ICC; the Ogden Centre), and the Centre for Advanced Instrumentation (CfAI; the Rochester building and the NetPark research institute). We are seeking graduate students to undertake research within our PhD and MSc programmes, starting from October 2015.

Fully Funded Studentship Options

This booklet outlines PhD projects for which we can provide full funding (fees plus a stipend) over 3.5 years. We provide brief details on the funding below.

Science and Technology Facilities Council (STFC) studentships. These 3.5 year studentships are only available to citizens of the UK and to EU nationals; see the STFC web site for more details: http://www.stfc.ac.uk. We expect to offer $\approx$ 7 STFC-funded studentships this year.

Durham Astro Particle Physics Studentship. This 3.5 year studentship is available to UK students. We have 1 studentship this year.

Other Studentship Options

We can offer an even broader range of projects (PhD and MSc) and supervisors for graduate students that have obtained their own funding; see http://astro.dur.ac.uk for details of other potential projects and supervisors. Two potential funding routes are provided by Durham University through the Durham Doctoral Studentships (DDS) and China Scholarship Council (CSC) scheme. However, we encourage interested graduate students to also explore other potential sources of funding. For more details please see the Postgraduate Opportunities link off of our web page: astro.dur.ac.uk

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Follow the post-graduate opportunities link from our web site or contact our astronomy postgraduate administrator (Prof. David Alexander; d.m.alexander@durham.ac.uk) for further details.

AGN FEEDING AND FEEDBACK - THE MONSTERS GROWING AT THE CENTRES OF GALAXIES

Supervisor: Prof. David Alexander d.m.alexander@durham.ac.uk
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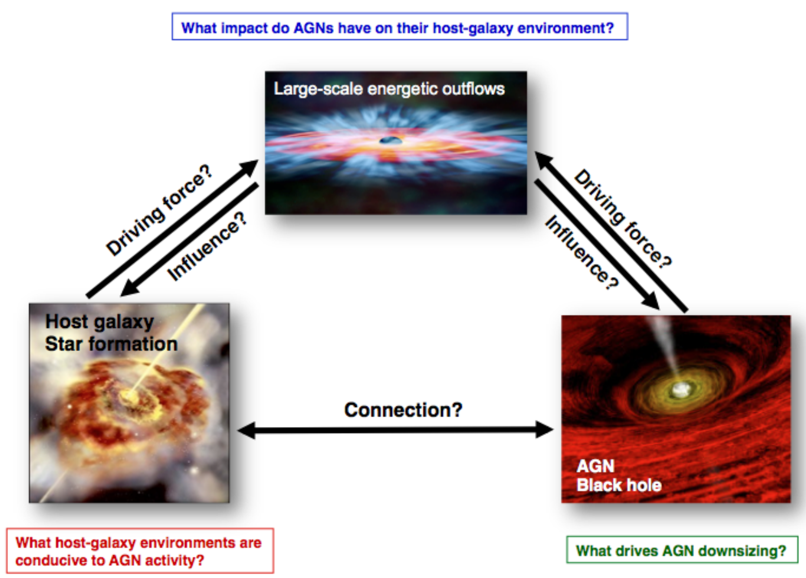
Funding: STFC

Description:

Over the last two decades there has been a seismic shift in our understanding of the role that Active Galactic Nuclei (AGNs; the sites of growing black holes: BHs) have played in shaping how the Universe looks today. AGNs are no longer viewed as rare "exotic" phenomena driven by extreme gravity, they are now seen as key players in the formation and evolution of galaxies. The primary evidence comes from (1) the identification of tight relationships between the mass of the BH and various host-galaxy properties for nearby galaxies, (2) the requirement for leading cosmological simulations to implement AGN-driven outflows (jets; winds) to regulate or shut down star formation in galaxies (AGN feedback). Whilst a compelling picture, it is largely constructed from indirect evidence and requires direct observational proof, particularly in the distant Universe where the bulk of BH and galaxy growth has occurred.

The aim of this PhD project is to address the primary questions of AGN feeding and feedback: What host-galaxy environments are conducive to AGN activity? What drives AGN downsizing? What impact do AGNs have on their host-galaxy environment? In your PhD thesis you will address these questions using state-of-the-art observations at X-ray-radio wavelengths and new ground-breaking data from NuSTAR, ALMA, and VLT-KMOS. You will achieve these ambitious aims by (1) constructing the most complete census of AGN activity to date, identifying AGNs bright at X-ray, infrared, and radio wavelengths over the redshift range $z \approx 0$–3, (2) measuring the host-galaxy properties (morphology; colour; star-formation rates) to define the morphology-colour-SFR plane for AGNs and galaxies, and (3) identifying and measuring the properties of energetic outflows in distant AGNs and galaxies to determine the impact that AGNs have on their host-galaxies. Addressing these three fundamental questions will drive forward our understanding of the role of AGNs in the formation and evolution of galaxies.



A schematic diagram showing the possible connections between the growing BH (the AGN), the host galaxy, and energetic outflows, which are predicted to affect the evolution of the host galaxy. The three key questions related to understanding these connections, the impact that AGNs have on their host galaxy and vice versa, are highlighted. The objective of this PhD project is to address these questions using state-of-the-art observations.

Notes:

GALAXY FORMATION IN NONSTANDARD COSMOLOGIES

Supervisor:	Prof. Carlton Baugh with Dr. Baojiu Li	c.m.baugh@durham.ac.uk
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Funding:	STFC	

Description:

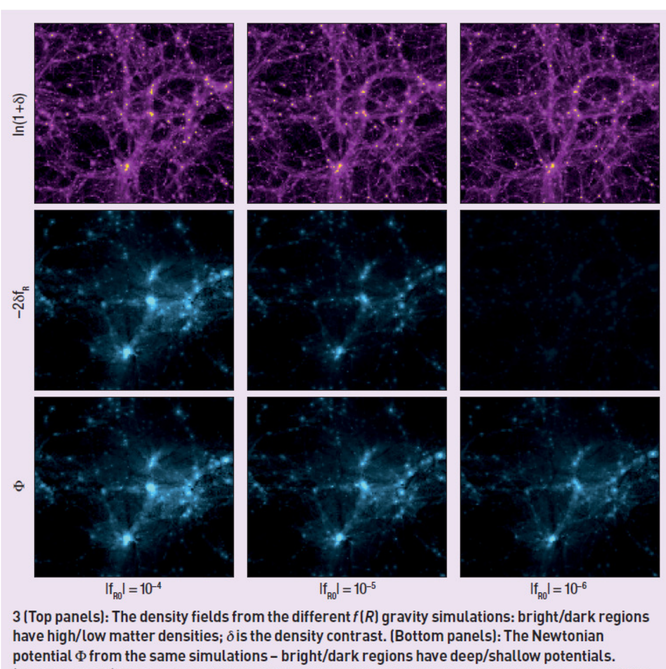
Several large galaxy surveys are underway which aim to determine what is behind the accelerating expansion of the Universe, such as the Dark Energy Spectrographic Instrument survey and the European Space Agency's Euclid mission. These are challenging measurements which require accurate theoretical models to compare and rule out different scenarios.

Much effort has been devoted to modelling the formation and evolution of galaxies in the "standard" cosmology: a cold dark matter universe with a cosmological constant and a general relativity description of gravity. To date, little work has been done on developing predictions for the appearance of galaxies in cosmologies in which the accelerating expansion is the result of a change in the form of gravity.

The goal of this project is implement the highly successful semi-analytical model of galaxy formation developed at Durham, called GALFORM, into N-body simulations of structure formation in modified gravity cosmologies, run with the ECOSMOG code.

The production of a fully consistent model will be broken down into steps: i) the impact of modified gravity on dark matter halo merger trees, ii) changes to the spin and structure of halos, iii) changes to the dynamics of the galactic disk and bulge, iv) variations in the evolution of stars due to changes in gravity.

The end point will be a model of galaxy formation that captures all of the important influences of the gravitational force and can be used to make synthetic galaxy catalogues which can be tested against the data from galaxy redshift surveys.



3 (Top panels): The density fields from the different $f(R)$ gravity simulations: bright/dark regions have high/low matter densities; δ is the density contrast. (Bottom panels): The Newtonian potential Φ from the same simulations – bright/dark regions have deep/shallow potentials. (Middle panels): The scalaron field from the same simulation. Here we have plotted $-2\delta f_R$, where δf_R is f_R minus its background value; note that bright regions have larger $|\delta f_R|$ and therefore smaller scalaron field f_R, as is expected from the chameleon effect. The three columns are for three different $f(R)$ models, the chameleon effect increasing from left to right.

Notes:

GAMMA-RAY ASTRONOMY AND THE CHERENKOV TELESCOPE ARRAY

Supervisor: Prof. Paula Chadwick p.m.chadwick@durham.ac.uk
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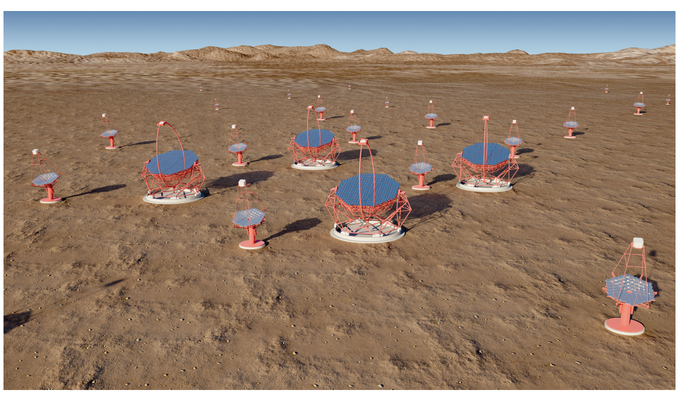
Funding: STFC

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. Observations of the more distant objects provide us with a probe of the extragalactic background light, of intergalactic magnetic fields and even of the structure of space-time itself. VHE gamma rays may also be one of the ways in which we detect the presence of dark matter in the Universe.

However, we have really opened this new window only a little way, and so some 1200 scientists from 29 nations are joining together to create a new instrument: the Cherenkov Telescope Array (CTA). Consisting of a 100-telescope array in the southern hemisphere and a 50-telescope array 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 of telescopes and instrumentation has already begun, and the construction of the array is expected to start in 2016, with 'first light' data from the seed array becoming available shortly thereafter.

As founder members of CTA, the Durham group is involved in many different aspects of the telescopes. Students can choose from a range of possible projects, including science studies in preparation for CTA (primarily using data from the Fermi Gamma-ray Space Telescope), simulations of array performance, the development of new analysis algorithms and the design and testing of instrumentation. We are particularly involved in the construction of an innovative dual-mirror design for the small telescopes of the array. Students can expect to be involved in the testing and commissioning of the prototype telescope in Paris and of the pre-production telescopes, which are expected to go on the final site of the southern array, likely to be in Namibia or Chile.



A computer-generated mock-up of the Cherenkov Telescope Array, CTA.

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SIMULATIONS OF PLANETARY IMPACTS

Supervisor:	Dr. Vincent Eke with Dr. Richard Massey	v.r.eke@durham.ac.uk
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Funding:	STFC	

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.

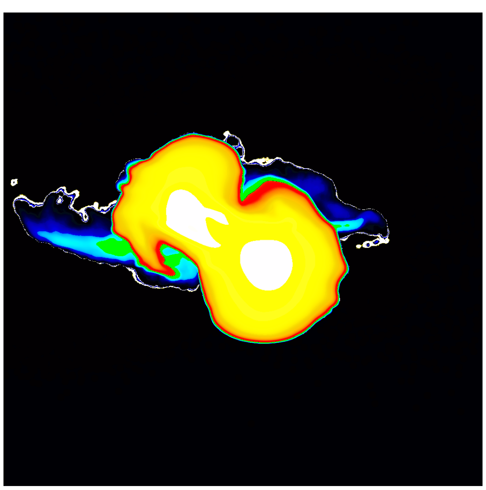
The best available tests of planetary evolution models come from observing the current state of the Solar System. Two big remaining mysteries for such models are:

1. what are the details of the Giant Impact that is hypothesised to have led to the formation of Earth's Moon? Similar isotope ratios for these two bodies suggest a common origin, but the currently favoured models produce an Earth-Moon system with too much angular momentum.

2. what type of impact led to Uranus having its axis of rotation lying so near to the ecliptic, and how might this have affected any pre-existing satellites?

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 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, Los Alamos National Laboratory and the University of California Santa Cruz, will use a state-of-the-art Smoothed Particle Hydrodynamics (SPH) code and improve the mass resolution of planetary impact simulations by a factor of ~ 1000. Such unprecedented resolution will, for instance, enable the Earth's crust and a thick ocean to be added to the simple core+mantle models used in current studies of the collision that formed the Moon. More detailed supercomputer calculations also offer the prospect of tracking individual atomic species from the impactor and target bodies. This will lead to new tests to distinguish between competing theories about the Moon-forming impact. Previous simulations, using only $10^5 - 10^6$ particles, have yet to produce numerically converged results for the iron content of the Moon-forming disc or the amount of material orbiting wholly beyond the Roche limit. This project will produce numerically converged results and more realistic impact scenarios, providing insight into the impact that led to the formation of the Moon.



A snapshot from a new 10^8 particle SPH simulation of the impact of a Mars-sized body on the proto-Earth. The impactor, incident from the upper-right in this panel, has struck a glancing blow to the proto-Earth and is in the process of merging. Some of the material flung out during the collision will subsequently coalesce to form the Moon.

Notes:

THE NATURE OF DARK MATTER

Supervisors:	Prof. Carlos Frenk (ICC)	c.s.frenk@durham.ac.uk
	Prof. Carlton Baugh (ICC)	c.m.baugh@durham.ac.uk
	Prof. Silvia Pascoli (IPPP)	silvia.pascoli@durham.ac.uk
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Funding:	Durham Astro Particle Physics Studentship	

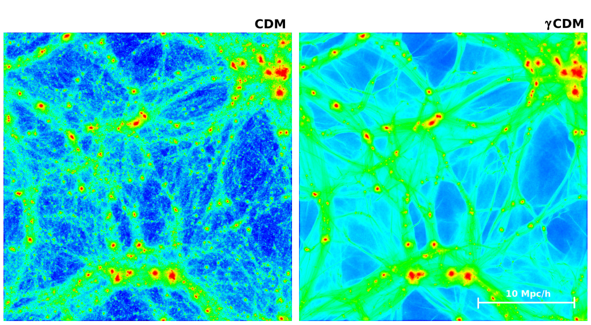
Description:

Ever since the idea that the dark matter is non-baryonic was put forward in the early 1980s, identifying its nature has been a pressing objective. The best studied hypothesis is the cold dark matter (CDM) model, in which the dark matter is a cold, collisionless particle, such as the lightest particle in supersymmetric theories of particle physics, or an axion. Experimental and astrophysical evidence is beginning to build up against the simple CDM hypothesis. For example, the mass of the Higgs boson is larger than expected in the simplest models of supersymmetry; direct laboratory searches for dark matter and indirect searches with gamma-ray telescopes have so far produced negative results, even though the sensititivity of these experiments is in the region where a discovery might have been expected; finally, the structure of dwarf galaxies (which because of their low baryon content are ideal dark matter laboratories) does not seem to conform to predictions from cold dark matter N-body simulations.

This project will address extensions to the simple CDM model which are motivated by particle physics and by the need to explain the observed Universe on galactic scales. One theme concerns the motion of the dark matter particle. Cold dark matter particles have negligible thermal velocities during the era of structure formation. These, however, are not the only kind of particles that could have been produced in the early universe. Sterile neutrinos, if they exist, would have appreciable velocities at early times, and thus behave as warm, rather than cold dark matter. Different production mechanisms are predicted to give rise to different velocity distributions for these particles. Warm particles free-stream out of small initial density perturbations, affecting the way in which galaxies build up. Similarly, if the dark matter is not completely collisionless but has a weak interaction with photons or neutrinos, this will also reduce the amplitude of fluctuations on small scales. In principle, observations on the scale of the Milky Way and the Local Group could hold the key to the identity of the dark matter.

The overall goal is to search for observable properties that might constrain, or perhaps even reveal the identity of the dark matter. This will be done by performing cosmological N-body simulations of galactic dark matter halos. The simulations are challenging and will make use of the ICC's Cosmology Machine supercomputer, as well as resources provided by the "Virgo consortium", Europe's premier collaboration in cosmological simulations.

This project will be jointly supervised by researchers from the ICC and the Institute for Particle Physics Phenomenology (IPPP). The candidate will follow a carefully tailored set of course drawn from the postgraduate programs of the two institutes during the first year, to provide the necessary background in particle physics and cosmological simulations.



The left panel shows the simulated distribution of dark matter in cosmologically representative volume of the universe in a calcuation assuming the standard model, in which the dark matter is assumed to be collisionless and interacts only through gravity. The colours reflect the density of the dark matter, with warmer colours indicating higher density. The right panel shows the same volume when a weak interaction takes place between photons and dark matter. This is important in the early universe and erases small mass halos.

Notes:

THE FRONTIER BETWEEN COSMOLOGY AND GALAXY FORMATION

Supervisor: Dr. Adrian Jenkins A.R.Jenkins@durham.ac.uk
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Funding: STFC

Description:

The development of the ΛCDM model is one of the most impressive advances in physics of the last thirty years. The Λ in ΛCDM refers to Einstein's cosmological constant, while CDM stands for "cold dark matter", a form of elementary particle that accounts for five sixths of the gravitating matter in the Universe. In this model all the structure we see today in the Universe arises from the gravitational amplification of small irregularities in the primordial energy density created by quantum processes during an early rapid expansion phase of the universe. This simple model, formulated in the 1980s can account for a wide range of observational data, from fluctuations in the temperature of the microwave background radiation to the large-scale distribution of galaxies. In spite of its spectacular successes, the foundations of the ΛCDM model are anything but solid because (i) there is no accepted physical basis for the cosmological constant and (ii) there is no direct evidence for the hypothesized cold dark matter particles. Furthermore, the model has yet to be tested convincingly on the scales of astronomical objects such as galaxies. Over the next decade there will be huge improvements in the quantity and quality of observational data particularly for the Milky way itself which allow new ways to test ΛCDM and to learn about the nature of dark matter and the physics of galaxy formation.

The project will involve running and analysing state-of-the-art simulations of the formation of individual galaxies and making comparisons with observational data. The ICC has its own large supercomputer (the "Cosmology Machine") as well as resources provided by the Virgo Consortium for cosmological simulations, Europe's premier collaboration in the subject.

The Virgo consortium has begun an ambitious programme of ultra-high resolution simulations of the formation of individual galaxies in a ΛCDM universe, with a goal of modelling at least one galaxy with over a billion resolution elements. The timing of this programme, which is a collaboration including Durham, MPA Garching and HITS Heidelberg, is well suited for PhD projects starting in October 2015.

These simulations will be extremely rich in detail and suitable for a wide range of possible PhD projects on topics such as probing the nature of dark matter through the properties of satellite galaxies, tidal and hydrodynamical stripping of satellite galaxies, the role of turbulence in the mixing of metals in the galaxy halo, and stellar dynamical modelling of the Milky Way galaxy.

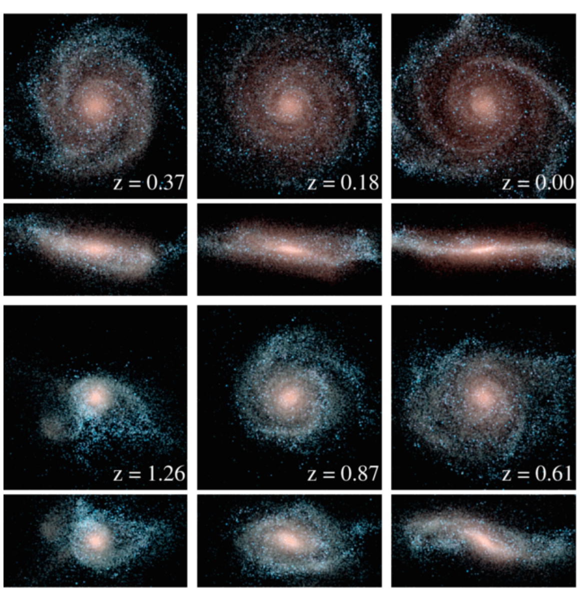

Image made from a simulated spiral galaxy created using the AREPO N-body/hydrodynamic code. This simulation shows the appearance of the galaxy over time from two perpendicular view points. This galaxy is one of set of 40 run jointly in Durham and in Heidelberg. Picture Credit: David Campbell 2014)

Notes:

THE ROLE OF SUPERMASSIVE BLACK HOLES IN GALAXY FORMATION

Supervisor:	Dr. Cedric Lacey	cedric.lacey@durham.ac.uk
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Funding:	STFC	

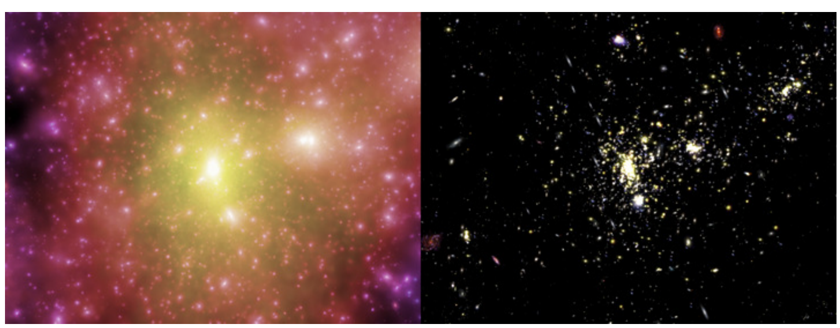
Description:

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 the process of doing so, they release enormous amounts of energy in the form of radiation, high-velocity gas outflows and relativistic jets, and are visible as active galactic nuclei (AGN). Crucial questions in galaxy formation theory are: How did these black holes form? What is the effect of the energy release in AGN on the evolution of their host galaxies?

Theoretical models of galaxy formation have started to include the effects of *feedback* from AGN. For example, it is now thought that the heating of gas in galaxy halos by relativistic jets from accreting black holes plays a central role in limiting the growth of massive galaxies. However, the way in which this mode of feedback operates is still poorly understood, and other modes of AGN feedback have been little explored so far. The idea of this project is to calculate the growth of supermassive black holes and explore the effects of different models for AGN feedback on the evolution of the galaxy population, using a state-of-the-art theoretical model of galaxy formation.

This work will use a simulation approach called “semi-analytical modelling”, in which the assembly of the dark matter halos hosting galaxies and AGN is calculated using cosmological N-body simulations, but the more uncertain physics of the baryons (e.g. gas cooling, star formation, and feedback from supernova explosions and AGN) are treated using simplified analytical models. The result is a complete model of galaxy formation that is: (1) computationally fast enough to make predictions for the evolution of the whole galaxy population, which can be directly compared to observational data; and (2) flexible enough to easily allow investigating the effects of varying the modelling assumptions for some of the physical processes.

This project will involve exploring the effects of different ideas for black hole formation and different models of AGN feedback, within a theoretical framework for galaxy formation. It could also involve exploring other aspects of galaxy formation physics using the same semi-analytical framework. By comparing the theoretical predictions with observations of the galaxy and AGN populations at different redshifts, we hope to learn which mode of AGN feedback (from relativistic jets, gas outflows or radiation) is most important, and to put better constraints on how and where these different forms of AGN feedback operate. Examples of observational data used would include the luminosity functions of galaxies and AGN, the relation between black hole and galaxy mass, and the environments and clustering of AGN, from the nearby universe out to high redshifts.



Left panel: Combined optical and radio image of the massive elliptical galaxy Centaurus A, showing the emerging radio jet. The radio emission is due to relativistic jets generated by an accreting massive black hole at the centre of the galaxy. The jets are thought to be heating the gas halo surrounding the galaxy. (Image credits: VLA/NASA). Right panels: Image of the dark matter distribution in an N-body simulation (left), and the distribution of galaxies predicted by our galaxy formation model for the same region (right). (Image credits: Volker Springel/Mark Swinbank).

Notes:

REAL-TIME SIMULATION AND CONTROL SYSTEM DEVELOPMENT FOR EXTREMELY LARGE TELESCOPES

Supervisors:	Prof. Richard Myers with Dr. Alastair Basden	r.m.myers@durham.ac.uk
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Funding:	STFC	

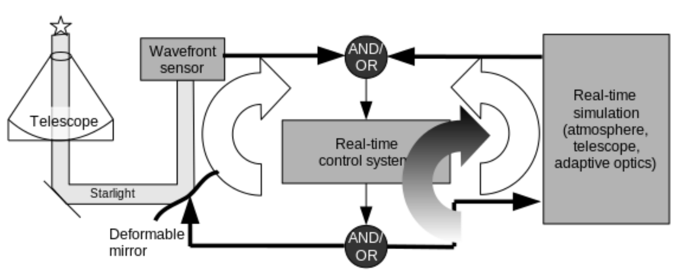
Description:

The optical effects of atmospheric turbulence, known as "seeing", are a major limitation for ground???based optical astronomy, reducing the image resolution that can be achieved with large telescopes. One of the main thrusts of instrumentation development for astronomy is currently the use of adaptive optical (AO) systems to correct the effects of seeing and improve image resolution in real time. The successful development and application of AO technology is critical to the science programs of modern large telescopes such as the ESO VLT and the planned European ELT. The Centre for Advanced Instrumentation (CfAI) in the Physics department at Durham is centrally involved in the development of complex AO systems for large telescopes.

A key component of any AO system is the real-time controller which uses wavefront sensors to estimate wavefront shape and then apply a suitable correction to a deformable mirror. Because the atmosphere is continuously changing, this estimation and correction sequence must occur repeatedly on millisecond timescales, representing a significant computational challenge for future AO systems. The testing and verification of these systems represents a serious challenge for the European ELT, since the required deformable mirrors and wavefront sensors are either too large or too expensive to be available for full system testing. The solution to this is a real-time simulation facility which will model the atmosphere, telescope and AO system, providing inputs and outputs to the real-time control system.

We are seeking a student who will engage in the development and testing of an ELT-scale real-time simulation facility, building on existing tools. The student will have the opportunity to develop hardware acceleration expertise, including graphical processing units (GPUs) and many-core architectures such as the Intel Xeon Phi. Opportunities for real-time control system development will also be available. The development of algorithms will be necessary to deliver high fidelity simulations, which will then be used to test real-time control system capabilities and to explore the extensive AO performance parameter space. This is crucial for realising the full potential of these AO systems, enabling important scientific discoveries to be made in areas such as cosmology, string theory, star and galaxy formation and the study of extra-solar planets.

This project has significant opportunity for paper writing, including techniques used, algorithms developed, and results obtained using the simulation tool. It also presents the opportunity to have input into the design and testing of European ELT real-time control systems.



A diagram demonstrating the AO real-time simulation concept, allowing real and simulation components to be interchanged around the operation of a real-time control system.

Notes:

WATCHING MASSIVE GALAXIES FORM - THE MOST EXTREME STARBURST GALAXIES AT HIGH REDSHIFTS

Supervisor: Prof. Ian Smail ian.smail@durham.ac.uk
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Funding: STFC

Description:

Many of the stars we see today in local galaxies formed at much earlier times, 7–10 billion years ago, corresponding to a redshift, z, of $z = 1$–3. Galaxies at these early times were forming stars typically 10–30 $\times$ faster than average galaxies today. This period has therefore been herald as the "epoch of galaxy formation". The subsequent decline in the star-formation activity of galaxies over the last ~ 7 billion years since $z \sim 1$ appears to be driven by a reduction in the amount of cold molecular gas available within galaxies, as this material is converted into stars or heated and expelled from the galaxies.

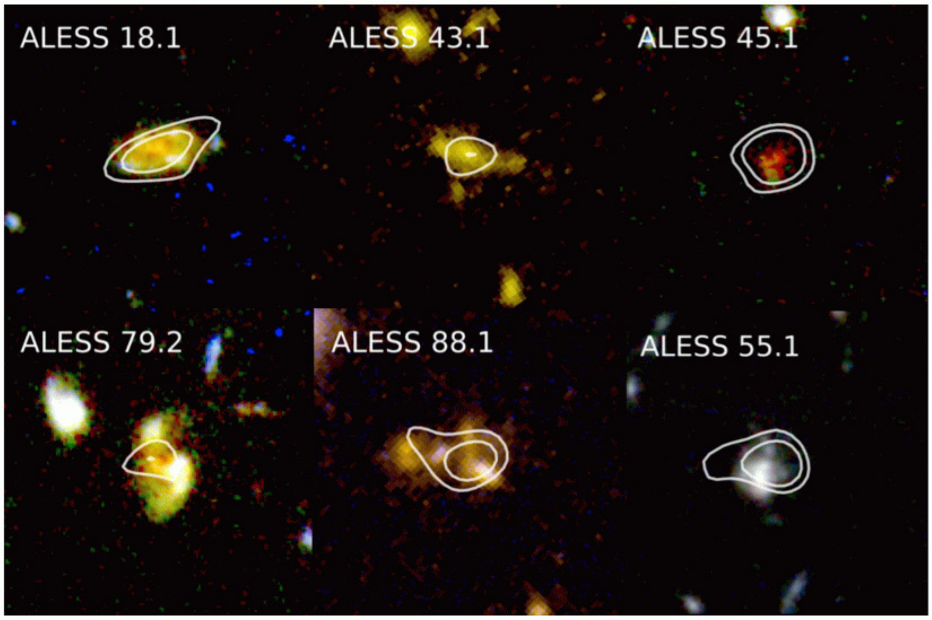
Amongst high-redshift star-forming galaxies, the most active examples are converting their gas reservoirs into stars 100–1000 $\times$ faster than the Milky Way currently does. Such extreme rates of star formation are seen in less than one per cent of galaxies at the present day, but such active systems appear to be much more common in the early Universe. It has been suggested that up to half of all of the stars seen in local galaxies formed in these intense events at $z \sim 2$–4, making them a crucial phase for understanding galaxy formation.

Despite their high star-formation rates, this population of vigorous star-forming galaxies are in fact some of the hardest to study. This is because a by-product of intense star formation is the creation of large amounts of dust, which forms in the atmospheres of massive stars during the later phases of their evolution and death. This dust absorbs the light from other young stars, making these galaxies very faint in the optical and ultra-violet wavebands which are typically used to survey the distant Universe. However, the dust grains which absorb this optical/ultra-violet light heat-up and subsequently re-emit the radiation in far-infrared and sub-millimetre wavebands. This emission makes these galaxies some of the most luminous far-infrared sources known, allowing us to pin-point the sites of immense starbursts early in the life of the Universe. The physical processes occuring within these galaxies will be very different to those which operate in the declining phase of "galaxy formation" since $z \sim 1$ and we need to understand and model these processes if we are to build a complete theory of galaxy formation and evolution.

To this end we are leading a survey campaign to study this enigmatic population of dusty starburst galaxies seen in the high-redshift Universe. These surveys combine tracers across a broad swathe of the electromagnetic spectrum, from the radio, sub-millimetre and far-infrared, through the mid- and near-infrared, into the optical, ultra-violet and out to X-rays. This multi-wavelength approach allows us to investigate the growth of this population through both their star formation, the growth in their stellar mass and the attendant decline in their gas content, as well as the accretion which occurs onto black holes within these systems. Our goal is to derive an empirical description of the evolution of the population of luminous, dusty starbursts and so to test their part in the formation of the massive, passive elliptical galaxies at the present-day, as well as links to the luminous Quasar population, whose activity also peaked at $z \sim 2$–3.

This is an observationally-driven PhD project and the successful student will be expected to use a range of observational facilities, including travel to Hawaii, Chile or Europe to obtain data for their thesis. The PhD will provide training in interferometric data reduction and analysis, based on data from the JVLA and *e*-MERLIN radio interferometers and the Plateau de Bure and ALMA millimetre interferometers, as well as the exploitation of integral field spectroscopy (from KMOS and SINFONI on VLT) and wide-field imaging and spectroscopy. There will also be opportunities to relate the observational results to theoretical models being developed at Durham.

See also: http://www.astro.dur.ac.uk/∼irs and http://www.astro.dur.ac.uk/∼ams



Hubble Space Telescope images of dusty starburst galaxies in the distant Universe. Overlayed on each of these are contours showing the sub-millimetre emission from these systems, as detected by the Atacama Large Millimeter Array (ALMA). ALMA is able to identify both the most active galaxies and indeed to pin-point those regions of vigorous star formation within these galaxies, even though these systems appear unremarkable in the optical and near-infrared. Our on-going studies with ALMA and other observatories seek to understand the cause of this intense activity in young galaxies at high redshifts and to test the link between this population and the formation of both elliptical galaxies and Quasars.

Notes:

EAGLE - SIMULATING A POPULATION OF GALAXIES

Supervisor: Prof. Tom Theuns tom.theuns@durham.ac.uk
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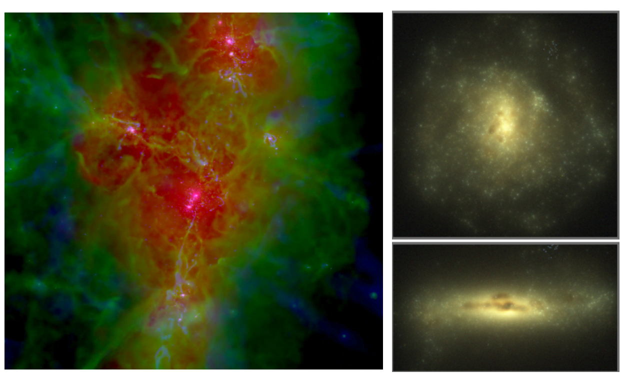
Funding: STFC

Description:

The basic model for how galaxies form within the framework of a cold dark matter cosmogony has been established for many years, however many crucial aspects are still poorly understood. For example, what physical processes determine galaxy stellar masses and galaxy sizes? How do these properties evolve throughout cosmic history? How do stars and AGN regulate the evolution of galaxy properties? Numerical simulations and theoretical models are a valuable tool for exploring these questions, but the huge dynamic range involved, and the complexity of the plausible underlying physics, limits the *ab initio* predictive power of such calculations.

The EAGLE simulations[1], performed on the DIRAC supercomputer in Durham and on CURIE in Paris, produced a population of galaxies with properties very simulated to those observed. EAGLE has been a tremendous improvement over previous simulation projects, however the limited numerical resolution still prevents us from examining important aspects of galaxy formation. For example what are the detailed properties of the high redshift, $z \sim 10$, population of galaxies that are a major target for the *James Webb Space Telescope* and are thought to be the driver of reionisation, a key science area of LOFAR. Can simulations reproduce the detailed properties of Milky Way-like galaxies (bulge/disk properties, occurrence of bars, stellar halos, properties of satellites of galaxies) - an important research area in the context of GAIA. Simply increasing resolution is not an option because current codes do not scale to the thousands of cores of current supercomputers, nor can they exploit the new generation of hardware accelerators such as INTEL's Phi and NVIDIA's GPU.

This project will take advantage of the new SWIFT code, developed in Durham in collaboration between the ICC, Computer Science, and INTEL in the context of Durham's status as Intel Parallel Computing Centre (IPCC). SWIFT[2] uses task-based parallelism, asynchronous communication, and is designed to take advantage of AVX, with extensions to Phi and GPUs in progress. You will contribute to developing SWIFT, in particular adapting it to include the galaxy formation modules from EAGLE. You will then use the new code to perform zoomed simulations of individual galaxies and clusters of galaxies at unprecedented realism. Comparing these to observations will provide crucial tests of the ΛCDM paradigm on the small scales that are not currently accessible to simulators.



Left: *Visualisation of a forming galaxy in the* EAGLE *simulation. Gas is colour coded according to temperature, from green and blue for cooler gas, to red for the hotter gas compressed in dark matter haloes. Galaxies are coloured pink.* Right: *visualisation of a Milky Way-like galaxy from* EAGLE *in optical colours, with dust obscuration modelled using ray-tracing.*

[1] http://icc.dur.ac.uk/Eagle/

[2] http://sourceforge.net/projects/swiftsim/

Notes:

UNDERSTANDING HOW QUASARS WORK, AND THE BROADER IMPLICATIONS

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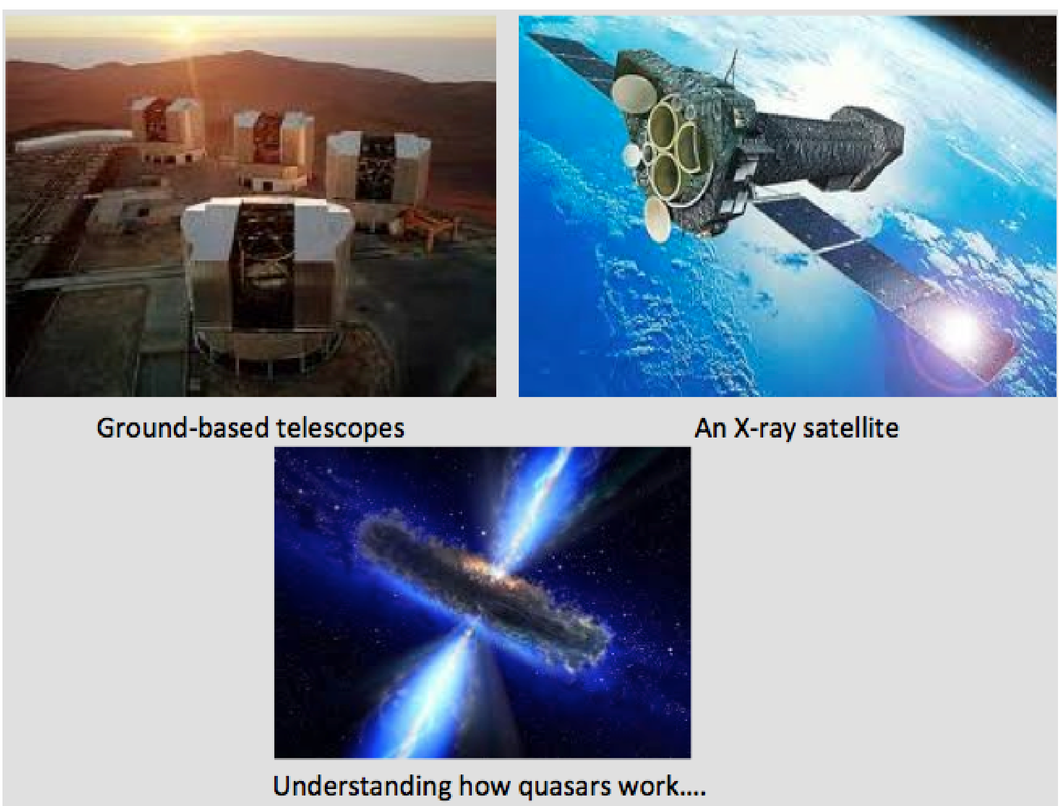
Funding:	STFC	

Description:

Quasars are the most luminous objects in the Universe. Their fundamental energy source is accretion onto a super-massive black hole.

This project will build on previous successful thesis work on understanding the inner regions of quasars (and active galactic nuclei in general). By investigating the physical processes operating close to the black hole, using state-of-the-art models developed here in Durham, and with multi-frequency data as input, the aim is to gain a holistic view of the central engine and its influence on the inner regions and beyond. By use of carefully selected small samples of representative quasars, and studying them in forensic detail, we can apply the knowledge gained to much larger and more distant quasar samples, for which the available data are sparse. This will feed into work on quasar evolution and related issues.

The supervisor and associated post-doc have several active international collaborations, and research visits to Tenerife/Spain and China, are a possibility. Applications for new data will be made to both ground-based and satellite facilities, as well as use of existing archival data. Towards the latter stages of the thesis project, the results will provide input into preparation of observing programmes for the *James Webb Space Telescope (JWST)*.



A montage of figures illustrating the facilities and scientific focus of the PhD project.

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