Durham-Edinburgh eXtragalactic Workshop X

9–10 January 2014

Thursday 9^{th} January

Session 1: Building towards the peak of activity

Michele Fumagalli
Durham

Investigations of the gaseous environment of distant galaxies

The evolution of high-redshift galaxies is regulated by the balance between the inflow of fresh fuel that is required to form new stars and the outflow of metal-polluted material that is ejected from star-forming regions. For this reason, the circumgalactic medium between galaxy disks and the intergalactic medium has been recognized as one of the most fundamental components in a galaxy. In this talk, I will discuss recent progress at the interface between theory and observations to characterize the gaseous environment of distant galaxies. I will focus on the emergent theoretical picture according to which galaxies at high redshifts are fed by extended streams of cold gas in a smooth component and in merging satellites. I will compare and contrast the findings of numerical simulations with observations of high-redshift galaxies and I will discuss the prospects of mapping the circumgalactic medium with absorption line systems, presenting results from recent and ongoing observations.

Rebecca Bowler
Edinburgh

The bright end of the galaxy luminosity function at $z \sim 7$

In the last decade, a succession of deep ground and space-based near-infrared surveys has led to the discovery of hundreds of galaxies at $z > 6$, allowing the first detailed studies of the properties of these early galaxies. In a broader context, reproducing the observed prevalence of galaxies at high redshift, parameterised by the rest-frame UV luminosity function, is a key test for models of galaxy formation. However, to date, very few bright ($L > 2\,L_{\star}$) galaxies have been uncovered at high redshift due to the rarity of such objects over the typically small field of, for example, Wide Field Camera 3 on HST. Hence the form of the bright end of the galaxy luminosity function, where results from lower redshifts indicate that there is an exponential cut-off in the number density, is still highly uncertain at $z = 7$. With the combined 1.7 square degrees of the UltraVISTA and UDS surveys, we have now detected a sample of ∼30 bright galaxies at $z \sim 7$ and hence can provide the first constraints on the form of the luminosity function out to $\sim 10\,L_{\star}$. The multi-wavelength data also gives us a glimpse of the properties of these extremely luminous and therefore arguably massive galaxies at a time less than 1 billion years after the Big Bang.

Andrew Davis
Edinburgh

FiBY Project: Cores and cusps in the first galaxies

I will present results from a recent study of the effect of baryons on the inner dark matter profile in a large statistical sample of the first galaxies using the First Billion Years simulation between $z = 16$–6. We find that the dark matter profiles during the early evolution of galaxies is not static. The central profile can change from a core to a cusp and back again as gas moves in and out of the halo center. We study three physical models which relate the baryonic motion to that of the dark matter.

Stuart Muldrew
Nottingham

Different views of star forming galaxies in protoclusters

At low redshift, galaxy clusters are known to have a lower fraction of star forming galaxies compared to the field, highlighting the role environment plays in galaxy evolution. Galaxies in clusters undergo a number of environmental processes such as tidal truncation, ram-pressure stripping and harassment which results in their star formation rates being suppressed. At high redshift, clusters are not the virialised structures we see in the local Universe. Instead they are protoclusters, collections of haloes that are going to merge to make up the final cluster. Studying protoclusters allows us to understand when environmental processes start to take effect and over what timescale they act. In this talk I will use semi-analytic models to explore the protocluster environment, investigating different definitions of their galaxy membership and how this affects the apparent properties of protocluster galaxies. I will also present recent observational results of a $z \sim 2.5$ protocluster which displays an absence of low mass galaxies relative to the field. Combining this result with the semi-analytic models, I will explain how different selection techniques can resolve discrepancies in the star forming fractions and how star formation is suppressed in the forming cluster.

Pratika Dayal
Edinburgh

Assembling the earliest galaxies

Over the past few years, instruments such as the Hubble Space Telescope have provided tantalising glimpses of a time when the earliest galaxies were just assembling in an infant Universe. Using the latest state-of-the-art simulations, I will show how HST-detected and JWST-detectable galaxies assemble in mass and build up their luminosity, and quantify the effects of their chaotic assembly on observables such as the ultraviolet luminosity functions (UV LFs). Our work suggests that the apparent "luminosity evolution" depends on the luminosity range probed: the steady brightening of the bright end of the LF is driven primarily by genuine physical luminosity evolution and arises due to a fairly steady increase in the UV luminosity (and hence star-formation rates) in the most massive LBGs. At the faint end, the evolution is much more complex and involves a mix of positive and negative luminosity evolution (as low-mass galaxies temporarily brighten then fade) coupled with both positive and negative density evolution (as new low-mass galaxies form, and other low-mass galaxies are consumed by merging).

Lunch

Session 2: The build-up of metals and dust in galaxies

Omar Almaini
Nottingham

Galaxy metallicity during the epoch of peak activity

Studies of metallicity evolution provide a powerful probe of the balance between gas inflow and outflow in distant galaxies. For many years it has been known that a tight relationship exists between gas-phase metallicity and stellar mass, but recently new evidence has emerged to suggest a further strong (inverse) relationship between metallicity and star formation rate, forming the so-called Fundamental Metallicity Relation (FMR). I will present a new study of the *stellar* metallicity of galaxies in the redshift range $1 < z < 3$, based on the spectroscopic follow-up of K-band selected galaxies from the UKIDSS Ultra-Deep Survey. Using an independent method we confirm the presence of a strong relationship between metallicity, stellar mass and star formation rate. The presence of this relation requires a fine balance between the inflow of metal poor gas, the formation of new stars, and the resultant galactic outflows. Implications and opportunities for further study will be discussed.

Fergus Cullen
Edinburgh

Mass-metallicity-SFR relation at $z \sim 2$

I will present results on the Mass-Metallicity Relation (MZR) and Fundamental Metallicity Relation (FMR) at $z \sim 2$ using data from the 3D-HST grism spectroscopic survey in three CANDELS fields (GOODS-S, UDS, COSMOS). The presentation will include an update on the observed consistency of the FMR up to $z \sim 2$ and its apparent evolution at higher redshifts. I will place the results in the context of new insights into the evolution of physical conditions in star-forming galaxies at high redshift by investigating the ionization state of the HII regions and discussing $z \sim 2$ galaxies in the BPT diagram. Finally I will discuss the implications of the evolution of ionization conditions on the metallicity indicators commonly used to study the MZR and FMR at high redshifts.

Lee Patrick
Edinburgh

Red supergiant stars as metallicity tracers in external galaxies

Direct stellar metallicity estimates in external galaxies are vital for deriving fundamental galaxy properties such as the mass-metallicity relation. With a technique using low-resolution near-infrared spectroscopy from VLT-KMOS we are deriving metallicities using red supergiant stars in external galaxies out to ~ 2 Mpc. Red supergiants are ideal for these measurements owing to their intrinsic brightness at near-infrared wavelengths. An extension to this technique is to use massive super-star-clusters, which are dominated by red supergiants at near-infrared wavelengths, to derive metallicities out to distances up to a factor of 10 larger. I will present first results from our KMOS Science Verification observations of 19 red supergiants in NGC 6822 (at $d = 500$ kpc), representing the first step using this method outside the Magellanic Clouds. I will also outline our plan for continuing this work out to larger distances.

Hidenobu Yajima
Edinburgh

Lyman-alpha emission from high-redshift disk galaxies

Strong Lyman-alpha emission lines have been detected in star-forming galaxies at redshift $z \sim 0$–8. Revealing the emission and escaping mechanisms of the Lyman-alpha photons is quite important for understanding galaxy formation. The escaping mechanism sensitively depends on the gas distribution. Recent observations have shown some fraction of high-redshift galaxies have had extended gas disks. Once the gas disk forms, the radiation properties can be significantly changed with viewing angle. Here, we investigate Lyman-alpha properties of disk galaxies at $z \sim 3$ with the wide mass range of $M = 10^{10-13}\,M_{\odot}$ by combining hydrodynamics simulations with radiative transfer calculations. As a result, we find the Lyman-alpha properties significantly change with the halo mass and viewing angle. A large fraction of gas is quickly blown out from the low-mass galaxies due to supernova feedback, leading to the higher escape fraction of Lyman-alpha photons. On the other hand, gas in massive galaxies is trapped within the virial radius due to the deep gravitational potential, hence most of Lyman-alpha photons are absorbed by dust after scattering process. However, even for the massive galaxies, some fraction of Lyman-alpha photons can escape along the normal direction to the gas disk because of the lower dust column density. This orientation effect can explain the observed Lyman-alpha lines from massive dusty galaxies, like sub-millimeter galaxies.

Various

Collection of short presentations

Coffee

Session 3: Cosmic star formation I

Andy Lawrence
Edinburgh

AGN vs star formation activity in *Herschel*-ATLAS and GAMA

I will compare the host galaxy properties, the star formation indicators, and the AGN activity indicators, for a large sample of 250 μm-selected *Herschel*-ATLAS galaxies that have also been spectroscopically observed with GAMA. I will then put this into a broader context of what we know so far about links between AGN and star forming activity.

Chian-Chou Chen
Durham

Faint SMGs: ultra-dusty low-luminosity galaxies at high-redshift

We obtained SMA observations of eight faint (intrinsic $S_{850\mu\mathrm{m}} < 2\,\mathrm{mJy}$) submillimeter galaxies (SMGs) discovered in SCUBA images of the massive lensing cluster fields A370, A2390, and A1689. In total, we have 6 SMA sources, all of which have de-lensed fluxes $< 1\,\mathrm{mJy}$ with estimated total infrared luminosities $L_{\mathrm{IR}} = 10^{10-12}\,\mathrm{L}_{\odot}$, which are comparable to luminous infrared galaxies (LIRGs) and normal star-forming galaxies. Based on the latest number counts, these galaxies contribute $\sim 70\%$ of the 850 μm extragalactic background light and represent the dominant star-forming galaxy population in the dusty universe. Surprisingly, our recovery fraction of the faint SMGs in mid-infrared and radio images, which have de-lensed depths comparable to those of the deepest fields observed by *Spitzer* (such as the GOODS-S) is low at $30 + 22\%$. The near-infrared counterparts of the faint SMGs are statistically dimmer than those of the bright SMGs, with F125W AB magnitudes spanning the range 24–29. Our findings suggest that many faint SMGs could be very dusty sources at high redshifts, representing a star-forming galaxy population that could not be found by many infrared and radio surveys even at these lower luminosities.

William Cowley
Durham

Mock surveys of submillimetre galaxies

Sub-millimetre galaxies (SMGs) are generally understood to be high-redshift, dust enshrouded galaxies exhibiting prodigious star-formation rates. Theoretical models have historically struggled to simultaneously explain both the number density of SMGs at $z \sim 2$–4 and the local ($z = 0$) galaxy population. However, there is recent observational evidence to suggest that the coarse angular resolution ($\sim 20''$) of single dish telescopes at sub-mm wavelengths has skewed the observed number counts by blending multiple sub-mm sources. We use lightcones derived from an implementation of the GALFORM semi-analytic model, including a self-consistent dust calculation, in the Millennium-WMAP7 *N*-body simulation to generate mock SMG surveys of varying angular resolution. This allows us to make amongst the first theoretical predictions for the effect of angular resolution on sub-mm number counts, and the properties of the blended population. We also use this method to investigate predictions for the effect of field-to-field variations on sub-mm observations.

David Nisbet
Edinburgh

HiZELS: fact or fiction?

HiZELS, the High-*z* Emission Line Survey, is a wide-field, narrow-band survey designed primarily to study star-forming galaxies at redshifts of 0.84, 1.47 and 2.23. The project has to date generated over twenty research publications, providing valuable insights into features of galaxy formation and evolution. However, is an assumption that underpins much of the research flawed? And, if so, does this compromise some conclusions from the research?

Michelle Furlong
Durham

Star formation rates and downsizing in Eagle

We use a state-of-the-art 100 cubic Mpc hydro-dynamical simulation to explore the observed downturn in star formation since $z = 2$. Our baryonic simulations implement advanced subgrid physics, including radiative cooling, metal enrichment, supernova and AGN feedback and black hole growth. They reproduce, to an unprecedented degree, the $z = 0$ galaxy stellar mass function, along with many other $z = 0$ galaxy properties. We find an excellent agreement with observations for the stellar mass growth from $z = 4$ to $z = 0$, and reproduce the shape of the star formation rate history. Using this virtual Universe we have created, we can now trace galaxy populations, and understand what drives the decline in global star formation since $z = 2$. I will present the details of our simulation, along with the results of what we find in this study.

Madusha Gunawardhana
Durham

The H-alpha luminosity function and star-formation rate history of the local Universe

The low redshift star formation history has been traced using star formation rate (SFR) indicators across a broad wavelength range. Measurements of the cosmic SFR density indicates a large dispersion (~ 0.5 dex) in SFR densities at a given redshift, perhaps more intriguingly between individual measurements of the same SFR indicator. I will present the H-alpha luminosity functions (LFs), and the bivariate LFs based on GAMA (Galaxy And Mass Assembly) spectroscopic data, which provide significant insight in to explaining some of the discrepancies we see in the observed star formation history. The large range in SFR covered by this unique data set allows us not only to extend the low redshift LF by ~ 1 order of magnitude in luminosity towards both fainter and brighter luminosities than other published results to date, but also, for the first time to observationally demonstrate that the Schechter function is not a good representation of star forming LFs. Instead they are best represented by the Saunders function, used to fit radio and infrared LFs for star forming galaxies.

Friday 10th January

Session 4: Cosmic star formation II

Jim Dunlop
Edinburgh

Cosmic star-formation overview

I will present a brief review of recent progress in our understanding of the star-formation history of the Universe, with special emphasis on how our knowledge of star formation in the first ~ 2 billion years has been improved by the deepest near-infrared images obtained with the Hubble Space Telescope (HST). After summarizing our current knowledge of comoving star-formation density out to redshifts $z \sim 3$, I will highlight the impact of the Hubble Ultra Deep Field (HUDF) 2012 campaign in improving our knowledge of the evolution of UV luminosity density at early times. I will then explore the extent to which these results are consistent with the requirements for cosmic reionization, and with new measurements of the growth of stellar mass density. Much of the remaining confusion and uncertainty is related to the evolution of the dust properties of galaxies, and so I will conclude with a description of our planned ALMA Cycle-1 millimetre imaging of the HUDF. This first deep ALMA mosaic should be an important step towards completing our understanding of cosmic star-formation history.

Peter Mitchell
Durham

The mass assembly process of star-forming galaxies in hierarchical models

In recent years, many studies from the literature have shown that the specific star formation rates of star forming galaxies inferred from observations decline much more rapidly after $z \sim 1$–2 than is predicted by hierarchical galaxy formation models. We use the GALFORM hierarchical galaxy formation model to study the cause of this deficiency in the models. By exploiting observational evidence for a star forming sequence of star forming galaxies, we infer the average stellar mass assembly histories of star forming galaxies implied by the data. Unlike global diagnostics of the galaxy population such as the Madau diagram, taking the approach of only considering star forming galaxies has the advantage of removing any impact from various uncertain physical processes, including quenching. Whereas GALFORM and other models predict a roughly constant stellar mass growth with cosmic time for star forming galaxies, the observational evidence favours a scenario where star formation is delayed relative to the halo mass assembly process, resulting in a peak at intermediate redshifts. We discuss how the parametrisations used in galaxy formation modelling to model gas ejection by supernova feedback and the subsequent reincorporation of ejected gas are currently inadequate to reproduce the observational trends. We go on to explore how the modelling of these physical processes might be improved in the future.

Joao Ferreira
Edinburgh

Extreme emission line galaxies at $1 < z < 2$ in CANDELS-UDS

Deep multiband photometry Optical–NIR surveys are the most efficient way to study global galaxy demographics and stellar mass assembly. The extra depth given by HST J and H uncovers a galaxy population with very strong nebular emission contamination, up to 1 mag in J and H at specific redshfits. Using models with and without emission lines, one can convert this excesses into a distribution of equivalent widths comparable to those obtained with grism surveys. Using a broadband-selected sample we find that the fraction of ELGs is very high (at least 20% above 200 Å) for galaxies with estimated masses above $\sim 9^{10}\,\mathrm{M}_\odot$, indicating that starbursts play a significant role in star formation at these redshifts.

James Simpson
Durham

The properties of SMGs uncovered by interferometry

Abstract TBC

Cheng-Jiun Ma
Durham

Reversal of the star-formation density relation and the densest environment in clusters at $z \sim 1.5$

The densest environment of clusters are well known to be hostile to star forming galaxies. Even though the total star formation rate in clusters may increase at higher redshifts, previous studies showed that the star-forming galaxies are mostly in-falling and avoid cluster cores. However, some recent works discovered rich mid-IR or emission line sources located at the center of a few clusters at $z \sim 1.5$, and have indicated, controversially, that the star formation rate in the densest environments could exceed the fields at similar redshifts. The estimations of star formation rates, on the other hand, may be difficult based on optical emission lines and mid-IR measurements, due to the uncertainty of dust obscuration, the contamination of AGN activity, and the mix of PAH emission and Silicate absorption redshifted to the 24-μm wavelengths. We will report the new SCUBA-2 results on XCSJ2215, one of the few "mature" clusters with many star-forming galaxies near its center. The total SFR estimated based on the FIR/submm SED exceeds $1500\,\mathrm{M}_\odot\,\mathrm{yr}^{-1}$ in galaxies within 0.3 virial radii of the cluster core. One or some of these heavily star-forming galaxies may evolve into the brightest central galaxy of the cluster.

Coffee

Session 5: AGN and the peak of activity

Tom Theuns
Durham

A simple model for QSO near zones

A QSO switching on at high redshift will eke out a highly ionised region around it - a QSO near zone. Even if the Universe were already reionised by previous sources, the QSO will dominate the ionisation rate in regions near enough to the source. At $z > 6$, say, it is likely that the QSO itself will be responsible for the HeIII region around it. I present a simple model of how such near zones look when using Lyman-alpha absorption as a probe of the HI neutral fraction, contrasting two ways in which the transmission in the near zone joins the mean transmission at that redshift depending on when this happens inside, or outside the HeIII zone. I show that this simple model looks qualitatively the same as that obtained using a full radiative transfer calculation - and that observed QSO near zones also display similar shapes.

Ismael Botti
Nottingham

Obscured quasars in the UKIDSS Ultra-Deep Survey

I will present a sample of heavily obscured quasars at high redshifts ($1 < z < 4$) selected in the mid-infrared from an SED decomposition to reveal the hidden AGN emission. I will also present some host galaxy properties as well as large scale structure of these sources in the UDS.

Flora Stanley
Durham

Constraining SFRs of AGN host galaxies

The connection between AGN activity and the galaxy's star formation activity is thought to be a key point in galaxy evolution. Many theoretical models and simulations studying this evolution find that, to reproduce the observed galaxy properties, there needs to be an interaction between the two. The idea most favoured is that of the suppression of the galaxy's star formation due to enhanced activity of the AGN. However, observational studies looking at luminous AGN and how they may affect star formation have failed to reach a definitive result on this matter, with their results being divided between suppression, enhancement, or even no effect. Here we are taking a step back and we first actually measure, or at least constrain, the star formation rates (SFR) of these galaxies individually. We use mid-IR to far-IR photometry of a sample of X-ray selected AGN up to a redshift of 3 to do SED fitting for each one. The advantage of our approach is the use of SED fitting that includes decomposition of the far-IR emission between the AGN and the host galaxy, which helps avoid the overestimation of the SFR values. By constraining the SFRs of the whole sample we are able to use the actual distribution of the SFR to retrieve as much information as possible for our sample and try and understand more about this population of galaxies and the connection between AGN and star formation.

Yetli Rosas-Guevara
Durham

Evolution of AGN in the EAGLE simulation

One way to study the connection between the growth of BHs and the evolution of galaxies is to examine AGN evolution across time. The global histories of AGN activity and star formation (SF) evolve in a similar way. This can be studied using simulations which give us the opportunity to follow simultaneously AGN activity and the environments around the active BHs. As preliminary results, I will present AGN luminosity functions of the EAGLE simulation which takes into account angular momentum in the calculations of black hole accretion rates. This state-of-art simulation was created to match the stellar mass function of the local galaxies. Remarkably, the AGN luminosity functions show a good agreement with observations in hard, soft X-rays bands and bolometrically at different redshifts. Because of this good agreement with observational data on both galaxies and quasars, these simulations will allow us to fully understand the interactions between black holes and the galaxies that host them.

Michael Hogan
Durham

Active radio cores in brightest cluster galaxies - the beating heart of the beast

AGN feedback from the centrally located brightest cluster galaxy (BCG) in galaxy clusters is believed to counteract runaway cooling in these environments, resolving the issue of these clusters having central cooling times substantially less than the Hubble time yet typically a sink of star formation and molecular gas accounting for only ~ 10–15% of that expected were cooling to proceed uninhibited. It is mechanical energy from radio-jets inflating "cavities" in the hot ICM that is widely believed to couple the AGN energy released to the environment, hence radio observations play a crucial role in understanding the processes at play. Here I will discuss our work showing the striking environmental differences in the radio properties of BCGs hosted by settled "cool-core" clusters and those in more dynamically disturbed systems. Drawing from a large sample of X-ray selected clusters for whose BCGs we have obtained broadband radio coverage, I will focus on a subset of sources that have currently active "core" components. I will discuss the high radio frequency properties and variability of these active sources, which are generally missed by large radio surveys at lower frequencies. Additionally, for a sample of over 50 of these we have VLBA observations allowing discussion of the parsec-scale radio properties.

Lunch

Session 6: The evolving morphologies and properties of galaxies

Victoria Bruce
Edinburgh

Morphological bulge-disk galaxy decompositions at $1 < z < 3$

I will present results from the largest Sersic light-profile fitting morphological decomposition analysis to date at redshifts $1 < z < 3$. This study comprises ~ 400 galaxies with $M_\star > 1x10^{11}\,M_\odot$ with HST WFC3/IR and ACS data from the CANDELS survey in the UDS and COSMOS fields. By decomposing the morphologies of these galaxies into their separate bulge and disk components, and extending this decomposition across multiple bands to allow SED fitting of the separate components, we have been able to combine our morphological analysis with individual stellar-mass and star-formation rate estimates for the bulge and disk components. This has enabled us to explore how these separate components evolve with redshift and has provided new insights into how the sizes of the passive and star-forming sub-populations evolve with redshift. We also confirm the presence of a significant population of passive disk-dominated galaxies, which has interesting implications for proposed quenching mechanisms.

Jamie Ownsworth

Nottingham

Star formation vs mergers: the stellar mass growth of massive galaxies from $z = 3$ using number density selection techniques

We present a study of the stellar mass growth of the progenitors of local massive galaxies in the redshift range $0.3 < z < 3.0$. We select the progenitors of massive galaxies using two number density selection techniques: a constant number density selection, and one which is adjusted to account for major mergers. We find that the direct progenitors of massive galaxies grow by a factor of four in total stellar mass over this redshift range. On average the stellar mass added via the processes of star formation, major and minor mergers account for 23%, 17% and 35%, respectively, of the total galaxy stellar mass at $z = 0.3$ – therefore 52% of the total stellar mass in massive galaxies at $z = 0.3$ is created outside of the local massive galaxies. We examine the dominance of the three processes across this redshift range and find that $z > 1.5$ star formation is the dominant form of stellar mass growth. At $z < 1.5$, mergers take over as the dominant form of stellar mass growth. Separating the mergers into minor and major events we find that minor mergers alone are the dominant form of stellar mass growth at $z < 1.0$. We also explore the implication of these results on other galaxy formation process such as the cold gas accretion rate and size evolution of the progenitors of most massive galaxies over the same redshift range.

Caterina Lani

Nottingham

The peak activity in the Universe as seen from the perspective of environment and galaxy size

The redshift range $z = 1$–3 coincides with the occurrence of the peak activity in the Universe. This is also an important regime, however, for two major transformations in the galaxy population: the quenching of star-forming galaxies and the puffing-up in size, by a factor of 2–4, of massive quiescent galaxies. Therefore, this is the key epoch to investigate how the environment shapes the star formation-density relation, as well as galaxy structural properties. In my talk I will show that a colour-environment relation is already established at $z \sim 2$, with quiescent galaxies inhabiting denser environments than star-forming galaxies. I will also present compelling evidence for a strong correlation between galaxy size and environment to $z \sim 2$, with massive quiescent galaxies from the highest density environments being $\sim 50\%$ larger (on average) than those from the lowest density environments. Finally I will present new results from a detailed analysis of stacked galaxy images, comparing the light profiles of galaxies as a function of environment. Drawing together recent findings, I will highlight the physical processes which drive the size evolution of galaxies.

Evelyn Johnston

Nottingham

Clues to the formation of lenticular galaxies from the quenching of star formation in spirals

Lenticular ($S0$) galaxies have long been thought of as evolved spirals, but the processes responsible for quenching the star formation in the spiral arms are still unclear. Mechanisms have been proposed, such as ram-pressure stripping, harassment, starvation and minor mergers, all of which would affect the bulge and disc of the galaxy in different ways. Therefore, the individual study of each component can provide valuable clues as to the formation history of the final lenticular galaxy. To this end, we have developed a new technique of spectroscopic bulge-disc decomposition, in which the spatial light profile in a two-dimensional spectrum is decomposed wavelength-by-wavelength into bulge and disc components, allowing separate one-dimensional spectra for each component to be constructed. We have applied this method to a sample of lenticular galaxies from the Virgo Cluster to obtain clean, high-quality bulge and disc spectra for each galaxy, from which we have been able to study the individual star formation histories of each component. In this talk I will present the results from our investigation of the bulge and disc star formation histories, and what these tell us about the formation of lenticular galaxies and their transformation from spirals in cluster environments.

Bruno Rodriguez Del Pino
Nottingham

K+A galaxies as a link between spiral and $S0$ galaxies in clusters

'K+A' galaxies had their star formation truncated 0.5–1.5 Gyr ago. Disk K+A cluster galaxies could thus represent an intermediate stage in the transformation of spiral galaxies into $S0$'s, retaining the disk of their progenitors but with suppressed star formation. We use Integral Field Spectroscopy observations carried out with FLAMES/GIRAFFE at the VLT to analyse spatially-resolved spectra of a sample of disk K+A galaxies in a cluster at $z \sim 0.3$. Studying the spatial distribution and kinematics of the old and young stellar populations we learn about the processes responsible for the truncation of the star formation and morphological transformation. Galaxies in a close encounter or interaction tend to have their young stellar population in the central regions of the galaxy, whereas in isolated galaxies the young stars are distributed throughout the disk. In this talk I will present these and other recent results of our study, and will discuss the consequences for our understanding of galaxy morphological transformation.

Esther Mármol-Queraltó
Edinburgh

Satellites around massive galaxies: the infalling pieces of the puzzle

Accretion of minor satellites has been postulated as the most likely mechanism to explain the significant size evolution of massive galaxies over cosmic time. A direct way of probing this scenario is to measure the frequency of satellites around massive galaxies at different redshifts. Here I will present our study of satellites around massive galaxies ($M_\star \sim 10^{11} M_\odot$) up to $z \sim 2$. We find that the fraction of massive galaxies with satellites down to 1 : 10 mass ratio is $\sim 15\%$ ($\sim 30\%$ down to 1 : 100), not varying with redshift (Mármol-Queraltó et al., 2012). We also find that our satellites are younger than their central galaxies at low z (Mármol-Queraltó et al., 2013). Then, if minor merging is acting to form massive galaxies, their ourtskirts should be younger than their cores. The challenge is now to find this age gradient in nearby massive galaxies.

End of workshop