Durham-Edinburgh eXtragalactic Workshop XI:
Big Surveys + Big Simulations = Big Science
8–9th January 2015

Thursday 8th January

Session 1: Galaxy Formation
11:00 – 13:00
Chair: Alice Mortlock

Catherine Heymans
Edinburgh

Welcome talk

Jim Dunlop
Edinburgh

The first galaxies
TBC

Rebecca Bowler
Edinburgh

Rapid evolution in the bright end of the galaxy luminosity function between $z = 5, 6$ and 7
At very high redshift ($z > 6$), the shape of the bright-end of the luminosity function (LF), be it plunging exponentially or a more gentle power law decline, depends on the onset of feedback and/or dust obscuration that acts to quench or obscure the most massive galaxies. Unfortunately, the *HST* surveys typically used to select samples of $z = 5 - 8$ Lyman-break galaxies have insufficient area to well constrain the number densities of the brightest (and rarest) objects, and instead wider-area ground-based surveys are required. We have used the combined ~ 1.7 square degrees of deep multi-wavelength data in the COSMOS/UltraVISTA and UDS/SXDS surveys, the largest area of appropriate-depth near-infrared imaging available to date, to provide the best constraints on the bright-end of the LF at $z = 6$ and 7. We find an evolution in the characteristic magnitude between $z \sim 5$ and $z \sim 7$ of $dM^{\star} \sim 0.4$ mag, and show that a double power-law or a Schechter function can equally well describe the LF at $z = 6$. Furthermore, the bright-end of the LF appears to steepen from $z \sim 7$ to $z \sim 5$, which could indicate the onset of mass quenching or the rise of dust obscuration, a conclusion supported by comparing the observed LFs to a range of theoretical model predictions.

Esther Mármol-Queraltó
Edinburgh

New insights on the evolution of H-α equivalent width and sSFR up to $z \sim 5$
The evolution of the physical properties of galaxies such as the stellar mass and the star formation rate (SFR) have been (and are) extensively analysed using photometric data in a wide range of redshifts. However, these results rely on fitting their spectral energy distributions (SEDs) where rest-frame optical nebular emission lines (e.g., H-α) may contaminate the broad-band fluxes and bias the results inferred. Actually, recent works have shown that the specific SFR seems to evolve far less rapidly than expected in most theoretical models. In addition, it has been claimed that the equivalent width (EW) of H-α evolves rapidly with redshifts, which it is difficult to understand since the H-α EW should be a reasonable proxy for the sSFR. In this work, we combine the best-available broad-band photometry in CANDELS with new near-infrared spectroscopy taken from the 3D-HST survey for a sample of star-forming galaxies at intermediate redshifts ($z \sim 1.3$) to robustly test a method to infer reliable measurements of H-α from the flux excess between observations and SED fitting.

Following this method, we revisit the photometric data available for galaxies up to $z \sim 5$ to trace the evolution of the equivalent width of H-α. I will show here that, in contrast with previous works, we find a mild evolution of H-α, much slower than the expected from the extrapolation of observations at lower redshifts. Moreover, we find that certainly the H-α EW follows the evolution of the sSFR. Finally, I will discuss these results and their implications for our understanding of galaxy evolution.

Jun Hou
Durham

Reionization and the Milky Way satellite luminosity function

The flat faint end of the galaxy luminosity function indicates a low galaxy formation efficiency in low mass halos. Galaxy formation models usually achieve this low efficiency by a strong enough supernova feedback. On the other hand, to reionize the universe at high enough redshift, i.e. $z_{re} \sim 10$, by starlight, the low mass halos need to have a significant galaxy formation efficiency. Thus the reionization redshift provide an upper limit on the supernova feedback strength, and together with the galaxy luminosity function, puts strict constraint on supernova feedback. In this talk I will discuss the results from several variants of the GALFORM semi-analytical galaxy formation model about the reionization redshift, the Milky Way satellite luminosity function and the field galaxy luminosity function, and what we learn by combining these different observational constraints.

Avery Meiksin
Edinburgh

Gas around galaxies: Enzo vs Gadget simulations

We perform cosmological simulations of the intergalactic medium (IGM) at redshift $z \sim 3$ using the numerical gravity-hydrodynamics codes GADGET-3 and ENZO for the purpose of modelling the gaseous environments of galaxies. The density and temperature of the gas within the instantaneous turn-around radii of the haloes are highly sensitive to the treatment of unresolved, rapidly cooling gas. The gas mass fraction within the virial radii is severely depleted by star formation in the GADGET-3 simulations and the residual gas much hotter compared with the ENZO simulations.

Charles Finn
Durham

The connection between the intergalactic medium and galaxies at $z < 1$

I present the results of ongoing work to explore the connection between the intergalactic medium (IGM) and galaxies at low redshifts ($z < 1$). Combining galaxy redshifts from the SDSS, 2dFGRS, GAMA, VVDS and VIPERS surveys and our own pencil-beam surveys with absorption line probes of the IGM from 59 QSOs observed with *HST*/COS, we compute the 2D two-point cross-correlation function between galaxies and both HI and OVI absorbers. Comparing the cross-correlation functions with the autocorrelation functions of these three populations, we constrain the statistical connection between the IGM and galaxies as a function of absorbing column density and galaxy star formation activity. We make quantitative comparisons of our results with similar calculations performed on the cosmological hydrodynamical simulation EAGLE, and use these comparisons to investigate the nature and environment of HI and OVI absorption systems. We conclude by placing our results in the context of the heirarchical galaxy formation paradigm.

Lunch

Session 2: Galaxy Surveys
14:00 – 16:00
Chair: Yan-Chuan Cai

Tom Shanks
Durham

Status of VST ATLAS

We describe the status of the VST ATLAS, an ESO Public Survey. ATLAS now covers some 3500 deg^2 out of its full 4700 deg^2, to SDSS depth. However the resolution is much improved over SDSS with median seeing of 0.8-arcsec FWHM, compared to 1.4-arcsec FWHM for SDSS. As well as the original cosmological aims of quasar clustering and detecting the acceleration of the Universal expansion via the ISW effect, the improved resolution opens up the possibility of detecting strong lensing from rich galaxy clusters and better constraining galaxy morphological evolution. ATLAS also covers the GAMA G23 area where 23,000 galaxy redshifts are available to calibrate photo-z from ATLAS *ugriz*, VHS YJK and WISE $W1$, $W2$. ATLaS is also ideal for searching for MW dwarf satellites and stellar streams.

Ami Choi
Edinburgh

Weak lensing wioth KiDS

The Kilo-Degree Survey (KiDS) is an ongoing 1500 deg^2 optical imaging survey on the European Southern Observatory's VLT Survey Telescope. The excellent image quality delivered thus far enables a wide range of studies from environmental dependence of halo mass profiles to tests of gravity on large scales. I will discuss the survey status as well as the first round of science projects that take advantage of a ~ 100 deg^2 overlap with the spectroscopic Galaxy and Mass Assembly (GAMA) Survey to investigate the matter distribution within galaxy- and group-sized halos.

Michele Cirasuolo
Edinburgh

MOONS: a third-generation multi-object spectrograph for the VLT

I will present a science and technical overview of the new Multi-Object Optical and Near-infrared Spectrograph (MOONS) designed for the Very Large Telescope (VLT) at the European Southern Observatory (ESO). I will highlight the main science cases of MOONS: from chemical abundance measurements of stars in the Milky Way and follow-up of the Gaia mission, to the evolution of galaxies and structure over $>$ 12 billion years of the history of the Universe. Finally, I will present the technical solutions and developments envisaged for MOONS and its overall design.

Nicholas Boardman
St. Andrews

Early-type galaxies with VIRUS-P

Early-type galaxies (ETGs) represent a crucial test for galaxy evolution scenarios. With integral-field spectroscopy, one can investigate both a galaxy's mass distribution and stellar populations in a time-efficient way, before relating derived properties to underlying theory. Integral-field observations out to ~ 1 effective radius are now plentiful, but similar observations out to larger distances remain sorely needed to fully investigate theories of ETG formation. Here, I present our most recent work concerning both the dark matter haloes and stellar populations of ETGs. We selected a subsample of twelve ETGs from the ATLAS3D survey and observed them with the Mitchell Spectrograph IFU, formerly VIRUS-P. We mapped both the kinematics and stellar populations with the resulting spectra, before constraining the dark haloes using multiple methods. Our data reaches beyond two effective radii in nearly all cases, making it highly complimentary to the work of the ATLAS3D collaboration.

Lingyu Wang
Durham

The infrared luminosity function and its dependence on the host halo mass

We study the infrared luminosity function of optically (r-band) selected galaxies in different redshift bins from the GAMA survey, using a stacking method in the *Herschel*-SPIRE maps.

We also investigate the dependence of the infrared luminosity function on the host halo mass by using the GAMA group catalog which has weak lensing calibrated halo mass estimates. We find the total infrared luminosity to halo mass ratio decreases with increasing halo mass but increases with increasing redshift. We also find the characteristic infrared luminosity in the luminosity function peaks in halos in the mass range 10^{12}–$10^{13}\,L_{\odot}$, in the redshift range probed ($0 < z < 0.4$). We that estimate halos of mass $> 10^{12}\,L_{\odot}$ contribute $\sim 70\%$ to the cosmic SFR density. Finally, we compare our observations with semi-analytic models generated using different feedback recipes.

Lizzie Eardley
Edinburgh

The cosmic web and its influence on galaxy properties
TBC

Coffee

Session 3: Parallel I (Extragalactic)
16:30 – 18:00
Chair: Vivienne Wild

Carolin Vilforth
St. Andrews

The host galaxies of AGN - are there signs of a connection between mergers, starbursts and AGN?
Active Galactic Nuclei are believed to play an important role in the evolution of galaxies. However, the processes that trigger AGN activity in galaxies as well as the effect that AGN have on star formation in their host galaxies remain poorly understood. Theoretical models suggest that mergers of galaxies trigger both starbursts and AGN activity. Accurate observational tests of such models require understanding both the morphological properties of their host galaxies and the properties of their stellar populations. I will present results from high resolution imaging studies that show that merger features are not prevalent in AGN host galaxies over a wide range of AGN luminosities. However, such lack of merger features can also be explained by a long delay between the merger event and the AGN activity. If this is the explanation for the morphologies of AGN host galaxies, signs of aged starbursts are expected in their stellar populations. I will present preliminary results from a spectroscopic study of AGN host galaxies that allows to determine the ages of stellar populations in AGN host galaxies. Combining these two approaches allows us to better understand the connection between AGN and their host galaxies.

Jose Sabater
Edinburgh

Triggering optical AGN: the need for cold, dense gas, and the indirect roles of galaxy environment and interactions
We present a study of the prevalence and luminosity of Active Galactic Nuclei (AGN; traced by optical spectra) as a function of both environment and galaxy interactions. For this study we used a sample of more than 250,000 galaxies drawn from the Sloan Digital Sky Survey and, crucially, we controlled for the effect of both stellar mass and central star formation activity. Once these two factors are taken into account, the effect of the local density of galaxies and of one-on-one interactions is minimal in both the prevalence of AGN activity and AGN luminosity. This suggests that the level of nuclear activity depends primarily on the availability of cold gas in the nuclear regions of galaxies and that secular processes can drive the AGN activity in the majority of cases. Large scale environment and galaxy interactions only affect AGN activity in an indirect manner, by influencing the central gas supply.

Chris Harrison
Durham

AGN outflows and feedback across cosmic time

AGN-driven outflows are believed to be an integral part of galaxy evolution. Whilst it is now well established that galaxy-wide outflows can be found in AGN there are important outstanding issues: (1) How common are these outflows across the global galaxy population?; (2) What physical mechanism couples the energy from the AGN to the gas?; (3) Do these AGN have a long lasting impact on the evolution of galaxies? To address these issues we are undertaking a systematic observational program. At low redshift ($z < 0.2$) we have built up a statistical picture of the prevalence and properties of ionized outflows in AGN by exploiting the SDSS survey and using follow-up IFU observations. (VIMOS/GMOS). Our high-resolution radio data (with JVLA and *e*MERLIN) of sub-samples of these targets are revealing that radio jets are common and that they drive the gas kinematics, even in "radio-quiet" AGN. At high-redshift we are using KMOS to search for, and to characterize, outflows in hundreds of galaxies and AGN. This enables us to compare AGN to the galaxy population and to the low-redshift Universe. We are comparing our results to the outflows found in the EAGLE cosmological hydrodynamical simulation to place fundamental constraints on the role of AGN outflows and AGN feedback in galaxy evolution. In this talk I will summarise our program and present our latest observational and theoretical results.

Kate Rowlands
St. Andrews

Post-starburst galaxies: pathways to the red sequence?

One of the key problems in modern astrophysics is understanding how and why galaxies switch off their star formation, building the "red-sequence" that we observe in the local Universe. Post-starburst ("E+A") galaxies, where a galaxy has recently undergone a massive starburst, are sufficiently common at $z \sim 1-2$ that they may contribute significantly to the growth of the red-sequence at this important epoch (Wild et al., 2009). Understanding how star formation is shut off in these post-starburst is important for understanding both their origins (e.g. gas-rich mergers or secular processes) and how rapidly, if at all, these galaxies will enter the red-sequence. We present the evolution of the cold ISM properties of a sample of low-redshift post-starburst galaxies selected to span an age sequence from ongoing starburst to 1 Gyr after the starburst ended, using both CO and *Herschel* observations (Rowlands et al., *submitted*). Our results show that although a strong starburst may cause the galaxy to ultimately have a lower specific star-formation rate and be of an earlier morphological type, multiple such episodes may be needed to complete migration of the galaxy from the blue- to red-sequence.

Violeta Gonzalez-Perez
Durham

Colours on top of the EAGLE's guts

We have developed a new flavour of the GALFORM semi-analytical model developed on the EAGLE Dark Matter only *N*-body simulation, performed with the Planck cosmology. We have used this model to explore several aspects: i) the effect of the time and mass resolution of the *N*-body simulation on the results from the galaxy model, ii) the dependency of galaxy colours on different key processes of the galaxy evolution model, and iii) how semi-analytical models compare to the EAGLE hydrodynamical simulation and what can we learn about galaxies from this comparison.

Session 3: Parallel II (Cosmology)
16:30 – 18:00
Chair: Alexander Mead

Chris Duncan
Edinburgh

Cluster mass profiles with size and flux magnification

The use of gravitational lensing has provided the means of accurately probing the mass profiles of foreground lenses on a large range of scales, from galaxy scales to superclusters and the large scale mass reconstruction of the CFHTLenS field. Most frequently, these studies are undertaken using galaxy shape as the observable, however recent studies have turned their attention to the various methods extracting information from the magnification signal, such as through galaxy clustering, source redshift enhancement or changes in source size and flux. Further, theoretical studies suggest there is significant gain from the combination of such measures with traditional shear analyses. In this talk, I will present a method of Bayesian mass profile determination using magnification information from measures of source size and magnitude, with an application to large clusters using HST data and will discuss how this method can be applied to different lens mass scales such as galaxy-galaxy lensing. I will show how the use of this information can be used to produce accurate constraints on cluster mass profile parameters, to an accuracy comparable to shear analyses, detail the limitations of such an analysis, and discuss the combination of such a measure with shear data.

Holger Israel
Durham

Reconciling *Planck* cluster counts and cosmology? *Chandra*/*XMM* instrumental calibration and hydrostatic mass bias

The mass of galaxy clusters can be inferred from the temperature of their X-ray emitting gas, T_X. Their masses may be underestimated if it is assumed that the gas is in hydrostatic equilibrium, by an amount $b^{\rm hyd} \sim (20 \pm 10)\%$ suggested by simulations. We have previously found consistency between a sample of observed Chandra X-ray masses and independent weak lensing measurements.Unfortunately, uncertainties in the instrumental calibration of Chandra and XMM-Newton observatories mean that they measure different temperatures for the same gas. In this paper, we translate that relative instrumental bias into mass bias, and infer that XMM-Newton masses of $\sim 10^{14}\,{\rm M}_\odot$ ($\gtrsim 5 \cdot 10^{14}\,{\rm M}_\odot$) clusters are unbiased ($\sim 35\%$ lower) compared to WL masses. For massive clusters, Chandra's calibration may thus be more accurate. The opposite appears to be true at the low mass end. We observe the mass bias to increase with cluster mass, but presence of Eddington bias precludes firm conclusions at this stage. Nevertheless, the systematic *Chandra–XMM-Newton* difference is important because Planck's detections of massive clusters via the Sunyaev-Zeldovich (SZ) effect are calibrated via *XMM-Newton* observations. The number of detected SZ clusters are inconsistent with *Planck's* cosmological measurements of the primary Cosmic Microwave Background (CMB).Given the *Planck* cluster masses, if an (unlikely) uncorrected $\sim$20% calibration bias existed, this tension would be eased, but not resolved.

Ruari Mackenzie
Durham

The ISW effect with the VST ATLAS survey

In standard cosmology the accelerated expansion of the universe due to the presence of a cosmological constant should create a correlation between the observed Cosmic Microwave Background and foreground galaxy clusters, the Integrated Sachs-Wolfe (ISW) effect. We discuss work on the cross-correlation of Luminous Red Galaxies (LRGs) selected from

the VST ATLAS survey and the Cosmic Microwave Background (CMB) temperature maps produced by Planck to test for the detection of the ISW effect. VST ATLAS is a new $\sim$ 4700 deg^2 survey of the extragalactic sky in the southern hemisphere. ATLAS offers SDSS like depths with improved seeing. We use *griz* colour cuts on the ATLAS photometric catalogues which were calibrated to SDSS colours using Stellar Locus Regression to select $0.2 < z < 0.8$ LRGs. The $0.8''$ seeing of the ATLAS survey, can benefit star galaxy separation. Additionally the WISE W1 mid-infrared band was used with ATLAS to further reduce stellar contamination.

Matthieu Schaller
Durham

The impact of baryons on the large scale structures and internal structure of halos

We use the high resolution cosmological hydrodynamical series of state of the art simulations EAGLE (Shaye et al., 2014) to study the density profile of halos between 10^{10} and $> 10^{14}$ M$_\odot$. The simulations are able to reproduce a large series of observations of the galaxy population as a whole and can hence be used as a virtual Universe to make predictions for the Λ-CDM model from close to first principles. We find that the correct treatment of baryons in the simulation leads to a significant change in the masses of the halos which directly impacts the halo mass function. We also find that the DM within halos is well fit by an NFW profile with a slight contraction due to the build up of gas in the halo. The total matter profile in the inner 5% of the halos is cuspier than NFW predicts due to the dominant contribution of stars. We propose a new universal profile to describe the total matter profile over the whole halo mass range and at all redshifts.The differences seen between these simulation results and previous studies based on simulations including only DM will have an impact on future precision cosmology probes based on lensing or cluster physics.

Wojciech Hellwing
Durham

The Copernicus Complexio: a high-resolution census of the small-scale dark Universe

I am going to present in details the latest results from our new series of an intermediate high-resolution zoom-in simulation series "COpernicus COmplexio". For the first time a detailed census of DM halo and subhalo properties is obtained with a very high-resolution and reasonable statistics (resolved cosmic volume). Such a new approach to N-body simulations is bridging two common strategies adopted so far. An intermediate zoom-in simulation benefits from both high-resolution attained usually only in small volume high zoom-in simulations with a reasonable number statistics connected to cosmological volume simulations. Thanks to this we are able to analyse in high details properties of DM haloes and subhaleos spanning 8 orders of magnitude in mass. We focus on the issues central to modern small-scale CMD structure formation: halo density profiles, mass-concentration relation, subhalo populations and "too big to fail" problem for MW-mass hosts.

Lars Koens
Edinburgh

Galaxy bias from weak lensing

Weak gravitational lensing is a powerful probe of galaxy bias, since cosmic shear is directly related to the dark matter distribution, which can be compared to the spatial distribution of galaxies. I will present galaxy bias results for two large spectroscopic surveys, BOSS and WiggleZ, derived from cross-correlations with the shear from the overlapping RCS Lensing Survey. BOSS is a sample of red galaxies, which have higher bias compared to the blue emission line galaxies of WiggleZ. The correlation of WiggleZ galaxies with the total matter field is found to be lower than that for BOSS. I will also show the implications of my galaxy bias results for Redshift Space Distortion measurements of the growth rate.

Friday 9th January

Session 4: Parallel I (Extragalactic)

09:00 – 10:20

Chair: Victoria Bruce

Derek McLeod
Edinburgh

$z \sim 9$ galaxies in the Hubble Frontier Fields survey

The Hubble Frontier Fields (HFF) survey has recently begun to deliver ultra deep *HST* imaging of massive low-redshift galaxy clusters. The key science goal of the HFF project is to use the gravitational lensing of the foreground clusters to identify and study faint background galaxies at redshifts $z > 7$. Here I present the results of a recently submitted paper, which uses a photometric redshift analysis to identify a robust sample of $z \sim 9$ galaxies from the first two clusters targeted by the HFF survey. This sample significantly improves on previous determinations of galaxy number densities at $z \sim 9$ and allows us to provide tighter constraints on the decline in star-formation density within the epoch of reionization.

Shegy Parsa
Edinburgh

The faint end of the UV luminosity function of $z = 2$ galaxies from *HST* and ground-based observations

We present UV luminosity functions (LFs) at 1500 Å derived from the ground-based optical photometry and the *HST* optical and deep near-IR data acquired over 175-arcmin^2 of the CANDELS/GOODS-S and the HUDF. Our reliable photometric redshifts are determined by applying Le-Phare (a template fitting technique) on two comprehensive photometric catalogues of GOODS-S and the HUDF12 surveys and are used to obtain our LFs in the redshift range $z = 1.5 - 2.5$ to study the evolution of $z \sim 2$ galaxies. With our new samples, we are able to directly probe the LF down to $M_{1500} = -14$, hence setting new improved constraints on the faint-end slope. We compare our findings to recently published results derived with the aid of gravitational lensing and from galactic archaeology.

Joao Ferreira
Edinburgh

Emission line galaxies in CANDELS: Equivalent width distributions from broad-band photometry at $z < 2$

We present a general technique to estimate equivalent widths of very strong nebular emission lines ([OII], [OIII] and H-α) at $z < 2$ exclusively from multiband photometry guided by a set of stochastic burst models based on BC03 SEDs. Offsets between CANDELS-UDS photometry and line-free simulated galaxy continuum colours up to 1 magnitude are used to derive equivalent width distributions reaching above 500 Å. Because of the wealth of deep multiband coverage, the method is efficient in selecting large numbers of emission line galaxies (ELGs) over large comoving volumes for demographic studies and for identifying extreme equivalent width objects (EW > 500 Å) for potential spectroscopic follow-up. This subpopulation comprises up $20 - 30\%$ of galaxies with $10^9\,M_\odot < M < 10^{11}\,M_\odot$ and is found to be almost exclusively under 1 Gyr old and $A_V < 0.5$. There seems to be a transition between moderate and extreme ELGs which shifts from $M = 10^{8.5}\,M_\odot$ at $z < 1$ to $M = 10^9\,M_\odot$ at $1 < z < 2$. The method is generally consistent and complementary with existing narrowband and spectroscopic surveys and agrees with other models including nebular emission.

William Cowley
Durham

Clustering measurements from mock surveys of submillimetre galaxies

Recent observational evidence suggests that the coarse angular resolution of single dish telescopes at submm wavelengths significantly biases observations taken using such instruments.

We generate mock surveys taking into account this angular resolution using lightcones generated from an updated version of the GALFORM semi-analytic model. The model shows good agreement with data from the recent interferometric ALESS survey, which was targeted at single dish sources. Particularly it reproduces the difference between number counts derived from the single dish and interferometric surveys and the redshift distribution of the interferometric sources. We further this methodology to present predictions for the clustering of SMGs. We find the angular clustering of the single dish sources appears amplified with respect to the underlying galaxy population, due to confusion effects introduced by the single dish beam. However, the angular correlation function of the submm imaging can provide useful information, provided the spectral properties of the noise are well understood. Redshift information can also improve matters, the model shows agreement with previous observations of the spatial clustering of SMGs.

Milena Pawlik
St. Andrews

Merger, starburst, post-merger, post-starburst... red-sequence?
Galaxies that show evidence of a historical rapid increase and subsequent quenching in star formation could be a result of gas-rich major merger processes. Studying the properties of galaxies with strong post-starburst stellar populations can lead to a better understanding of the role of mergers in galaxy evolution: did they originate from mergers, and will they evolve into red-sequence galaxies? The aim of this work is to quantify morphological changes in local galaxies that are passing through a post-starburst phase. Using visual classification we find a clear excess of post-merger features, and the excess declines steadily with increasing starburst age. However, we find that traditional methods of morphology measurement do not reliably identify post-merger features that are visible by eye. In this talk, I will present a new, robust and physically meaningful automated method for the quantitative study of such features and show first results of its application to local post-starburst galaxies. Ultimately, the new method will be used to show how the evolution of the morphology of galaxies passing through the post-starburst phase resembles that of galaxy mergers modelled using hydrodynamic simulations.

Session 4: Parallel II (Cosmology)
09:00 – 10:20
Chair: Wojciech Hellwing

John Peacock
Edinburgh

Photometric redshifts with *WISE*
TBC

Marika Asgari
Edinburgh

Cosmic shear analysis: from theory, to simulation, to data
CFHTLens is a 154 square-degree multi-colour optical survey optimised for weak lensing analysis. We apply COSEBIs and conpressed-COSEBIs (CCOSEBIs) to the CFHTLens tomographic data to constrain cosmological parameters. COSEBIs (Complete Orthogonal Sets of E-/B-Integrals) is an accurate and efficient cosmic shear analysis method, which separates the E- from B-modes in weak lensing data. B-modes are a source of systematics in cosmic shear analysis, while the E-modes contain weak lensing information. In the presence of tomography the number COSEBIs modes needed in an analysis increases rapidly as a result data compression becomes crucial. We apply our compression method on data for the first time and show the preliminary results.

Andrew Robertson
Durham

Dark matter self-interactions through Cosmic time

Motivated by particle physics models with a rich dark sector, and some potential problems with CDM on small scales, we investigate the effect of a dark matter particle with a non-negligible self-interaction cross section. Assessing the effects of dark matter particle phenomenology on structure formation requires detailed cosmological simulations. However these simulations can only access a finite range of objects due to their limited resolution. We use analytical mass functions to investigate the importance of low mass haloes, looking both at the high redshift universe as well as substructure at later times. Our results allow us to calculate the contribution to the total dark matter scattering rate of haloes of varying size. This can be useful as a test of cosmological self-interacting dark matter simulations, as well as offering an insight into the importance of unresolved objects.

Idranil Banik
St. Andrews

Dynamics of Local Group galaxies in Λ-CDM and MOND

Cosmic expansion has locally been slowed down or even reversed by the gravity of the Milky Way and Andromeda, which dominate the Local Group. Here, I present a detailed timing argument analysis of it, using restricted N-body simulations. The MW & M 31 along with thousands of test particles are started comoving with the Hubble flow, centred on the LG barycentre. The final resulting velocity field is then projected onto the direction towards us. This radial velocity prediction is compared with observations of non-satellite galaxies. I find that no plausible combination of masses can account for the observations. The main reason is the simulated velocity field is fairly smooth but observations suggest a disturbed velocity field. My model suggests that an extra velocity dispersion along the line of sight of $\sim 50\,\mathrm{km\,s^{-1}}$ is required to reconcile the model with the data. This value seems unphysical within the context of Λ-CDM, because LG dwarf galaxies typically have much smaller rotation velocities/velocity dispersions. MOND implies a past encounter between the Milky Way and Andromeda. This would have caused substantial dynamical heating of the Local Group, which may help to explain the observations. I will show results from a simulation which approximately incorporates this modification to gravity.

Alexandre Barreira
Durham

Cosmological tests of gravity

Theories of modified gravity offer one plausible explanation for the mysterious speed-up of the expansion of the Universe today. The premise is to explore the freedom to modify Einstein's theory of General Relativity on large length scales (where it has never been tested) to come up with ways to accelerate the Universe, without the need for a cosmological constant or exotic dark energy components. These theories need therefore to be put to test. Using my results from suitably modified Boltzmann codes, N-body simulations and semi-analytical models of structure formation, I will describe the way modified gravity models typically impact a series of cosmological observables. To illustrate this, I will use the Galileon gravity model, which has been gathering much attention recently in the theoretical community. I will show that this model can fit the CMB, BAO and SNIa with the same flying colors as Λ-CDM, but with very different cosmological parameter values, namely neutrino masses. I will also describe the model predictions for the nonlinear regime of structure formation using N-body simulations, which will be used to perform a Halo Occupation Distribution analysis of galaxies in these models. One of the main messages will be that models in competition with standard Λ-CDM must be studied to the same extent in order to guard against biased interpretations of current and future data.

Coffee

Session 5: Galaxy Formation
10:50 – 12:30
Chair: Alasdair Thomson

Richard Bower
Durham

Star formation and quenching in models
TBC

Michelle Furlong
Durham

Extreme star-forming galaxies in hydrodynamical simulations
Sub-mm galaxies (SMGs) are very highly star-forming galaxies obscured by dust. Such galaxies are observable up to high redshift by taking advantage of the negative *k*-correction. While observations of the redshift distribution of SMGs and the properties of these galaxies are ever improving, especially with the commissioning of ALMA, the theory behind such highly star forming galaxies is poorly understood. For example, the recovered redshift distribution of the SMGs has proven difficult to reproduce in simulations of galaxy formation, without invoking variations to star formation in environments where SMGs are expected. We revisit the redshift distribution of SMGs, using the state of the art hydro-dynamical simulation EAGLE. EAGLE consists of a $100\,\mathrm{Mpc}^3$ simulation box, with a resolution of 700 pc, making it one of the largest simulations with such high resolution. We find, when applying a simple estimate for the submm flux from the simulated galaxies, a redshift distribution that is peaked around $z \sim 2.5$, similar to that observed. A comparison of the properties of the observed submm galaxies to those selected from the simulation reveals many similarities, showing that the simulated galaxy population is representative of those observed. We use this galaxy population to consider the triggering and quenching mechanisms of highly star forming galaxies in the simulation, and the evolution of these intermediate redshift galaxies to the present day.

Fernando Buitrago
Edinburgh

The low surface brightness haloes of massive galaxies in ultra-deep imaging and their relative importance
The most massive galaxies of the Universe remain as mysterious objects, in particular as their size evolution with redshift has been the subject of debate because of the impact of surface brightness dimming at high-z. To investigate this issue, we have undertaken a study of the morphologies of the six most massive galaxies at $z \sim 1$ which lie in the Hubble Ultra Deep Field 2012 (HUDF12) WFC3/NIR imaging and its optical ACS counterpart. This is the deepest ever view of the Universe, allowing the exploration of surface brightness profiles down to $31\,\mathrm{mag\,arcsec}^{-2}$ ($29\,\mathrm{mag\,arcsec}^{-2}$ restframe). This surface brightness depth translates into > 25 effective radii, or 100 kpc for some of these objects. Once we have finally access to this previously missed low surface brightness component, our galaxy sample display similar masses and sizes to previous determinations in shallower surveys. Regardless of the large spatial extent of these haloes, their total contribution to the galaxy light and mass is reduced (20% beyond 10 kpc). I will review these results in the context of massive galaxies' inside-out growth, showing also some preliminary results about the size-mass relation of massive galaxies in ultradeep H- and K-band imaging at $2.5 < z < 4.5$, where cosmological dimming could really bias these measurements. A comprehensive understanding of massive galaxy sizes throughout redshift (and our observational limits) could constrain Λ-CDM predictions, and these faint haloes provide evidence about the mass assembly for these extreme objects.

Flora Stanley
Durham

A remarkably flat relationship between AGN luminosity and the SFR of X-Ray selected AGN

One of the outstanding problems in astronomy is the coevolution of the central BH and its host galaxy, and how the growth of one can affect the other. To explore this we investigate the relationship between AGN luminosity, tracing the growth of the BH, and SFR, tracing the growth of the host galaxy, over a wide redshift range covering the peak of both activities. With a sample of 2139 X-Ray selected AGN in the redshift range of $0.2 - 2.5$ we use SED fitting to deblended FIR *Herschel* photometry, including decomposition of the AGN and SF contributions, to accurately constrain the individual SFRs of the whole subsample. We find that the relationship of SFR with AGN luminosity is consistent with being flat for a wide range of AGN luminosity and redshift. Our results are in contradiction with predictions of the relationship between SFR and AGN luminosity from simple empirical models, but we can reconcile our results when considering the timescales of stability for the AGN and star formation.

Agnese Del Moro
Durham

Heavily-obscured accretion in star-forming galxies at $z \sim 2$

Understanding the connection between supermassive black holes (SMBH) and host galaxies requires exploring SMBH accretion and star-formation processes at each phase of their cosmic co-evolution, especially at high redshift at the peak of their activity. However, this is not trivial as most of the SMBH growth seems to occur in heavily-obscured systems, which makes them difficult to identify even in the deepest X-ray surveys. With detailed SED decomposition using deep *Spitzer* and *Herschel* infrared (IR) data in the GOODS fields, we identified a sample of IR bright quasars ($\nu L_{(6\,\mu\mathrm{m})} > 6 \times 10^{44}\,\mathrm{erg\,s^{-1}}$) at $z = 1 - 3$. About 30% are undetected in the extremely-deep *Chandra* X-ray data, and are candidates to be Compton-thick AGN. X-ray spectral analysis reveals that the large majority of these sources ($\sim 80\%$) are obscured ($N_\mathrm{H} > 10^{22}\,\mathrm{cm^{-2}}$) or heavily-obscured ($N_\mathrm{H} > 5 \times 10^{23}\,\mathrm{cm^{-2}}$) quasars, a much higher fraction than those previously found in several X-ray and optical selected samples. Our results support the evolutionary model predictions of a large population of heavily-obscured AGN at high redshifts, when the SMBH and host galaxy are undergoing a phase of very active accretion and star formation, embedded in large amounts of dust and gas.

Lunch

Session 6: The Dark Universe
13:30 – 15:45
Chair: Richard Massey

Catherine Heymans
Edinburgh

Testing beyond Einstein Gravity models with 2dfLenS

TBC

Alexander Mead
Edinburgh

Re-scaling cosmological simulations from standard to modified gravity

Modified gravity theories aim to explain the accelerated expansion of the cosmos without adding a cosmological constant into the Einstein field equations. Typically these theories have a close to standard expansion history but a modified growth rate of perturbations, and then some form of screening mechanism to ensure the return of gravity to the standard in solar-system and milky-way type environments. *N*-body simulations of such models are required in order to generate realistic mass maps and mock galaxy catalogues; so as to be able to test such theories with current and forthcoming cosmological surveys. I will show how it is possible to generate approximate simulations of modified gravity models using only a standard gravity simulation as a starting point.

Yan-Chuan Cai
Edinburgh

Testing gravity using cosmic voids

Cosmic voids found in large-scale structure have emerged as a new area of study in cosmology. I will briefly summarise major activities on this frontier in both theory and observations, and highlight the challenges. I will demonstrate the unique power of voids for distinguishing General Relatively from chameleon type of modified gravity. The dark matter content in voids is among the most useful and interesting measurement, which requires the combination of a large spectroscopic redshift survey with a weak lensing over the same area of the sky.

Nuala McCullagh
Durham

Extracting non-Gaussian information from large-scale structure

As future surveys such as DESI and Euclid prepare to deliver vast amounts of clustering data, exploiting the full cosmological information from this data will become increasingly important. The two-point statistics of the matter density field have been widely used as probes of cosmological information. However, because the nonlinear density field is non-Gaussian, additional information resides in higher-point statistics of the distribution. Extracting this information requires accurate modeling of both nonlinearity and redshift-space distortions. First, I will discuss the challenges associated with modeling these effects in higher-point statistics of the density field. Next, I will show how density transformations may simplify this picture by restoring much of the non-Gaussian information to the 2-point statistics.

Marius Cautun
Durham

A new spin on disks of satellite galaxies

I will present an investigation into the angular and kinematic distributions of satellite galaxies around a large sample of bright isolated primaries in the spectroscopic and photometric catalogues of the Sloan Digital Sky Survey (SDSS). We detect significant anisotropy in the spatial distribution of satellites. To test whether this anisotropy could be related to the rotating disks of satellites recently found by Ibata et al. (2014), we repeat and extend their analysis. Ibata et al. found an excess of satellites on opposite sides of their primaries having anticorrelated radial velocities. We find that this excess is sensitive to small changes in the sample selection criteria which can greatly reduce its significance. In addition, we find no evidence for correspondingly correlated velocities for satellites observed on the same side of their primaries, which would be expected for rotating disks of satellites. We also compare our observational data to the Λ-CDM Millennium simulations populated with galaxies according to a semi-analytic model. We find excellent agreement with the spatial distribution of satellites in the SDSS data and the lack of a strong signal from coherent rotation.

Mathilde Jauzac
Durham

Hubble Frontier Fields: a new era for gravitational lensing

The Hubble Frontier Fields (HFF) initiative constitutes the largest commitment ever of *HST* time to the exploration of the distant Universe via gravitational lensing by massive galaxy clusters. This program devotes 140 orbits of *HST* time to deep imaging observations of each of six cluster lenses reaching $m \sim 29$ (AB) uniformly in all pass-bands

(10–30 orbits per filter – 3 ACS and 4 WFC3 pass-bands). The full set of data on Abell 2744 ($z = 0.308$) has been taken in October–November 2013 with WFC3, and May–July 2014 with ACS. The second target, MACS J0416.1–2403 ($z = 0.397$) has been observed with ACS in January-February 2014, and with WFC3 in July-August 2014. I will present the new gravitational lensing pictures of these two complex systems using this exquisite set of data coming from the HFF program. We have demonstrated that we are now able to "weigh" these clusters' cores down to the percent level precision (recently published works), serving our quest for the high-redshift Universe. However, while the depth of these datasets makes these clusters amazing Cosmic Telescopes, it also enables us to get an unprecedented understanding of the cluster physics...

Richard Massey
Durham

Workshop summary

End of workshop