2016 ANNUAL SCIENTIFIC CONFERENCE

The Changing Face of Galaxies: Uncovering Transformational Physics

19th-23rd September 2016, Hobart, TAS, Australia

TALK ABSTRACT BOOKLET

Session I: Physical Reasons behind Morphological Transformations

Carmen Marcella Carollo (Review)
ETH Zurich

The Rise of Quenched Bulges from the Fall of Star-Forming Disks

I will review recent results on how stellar mass builds up with time inside galaxies in the active phase of their life, while they grow on the 'Star-Forming Main Sequence'. I will then present the perspective that emerges, which unifies three major open questions in galaxy evolution, namely: (1) when and how massive galaxies grow their dense bulges, (2) when and how they quench their star formation activity, and (3) what is the physical origin for the growth in size with cosmic time of the quenched galaxy population.

Paul Torrey (Invited talk)
MIT

What are the Physical Reasons behind Morphological Transformations?

Observed galaxy populations contain a rich diversity of morphologies. Empirical correlations have been shown to be present between morphology and mass, star formation rate, and environment. However, a clear and unified picture for the origin of galaxy morphology and the transformation of galaxies between different morphological types is not yet established. I will discuss some of the most interesting outstanding questions about galaxy morphology evolution with a focus on lessons learned from modern hydrodynamical galaxy formation simulations.

Adriana de Lorenzo-Cáceres
University of St. Andrews

Transforming Galaxies through Bars: Possible Evidence Bar Growth

Bars have traditionally been considered key drivers of evolutionary processes in disc galaxies, since they are theoretically able to transport material (gas and stars) along them, inwards and outwards. This material flow may cause formation of central structures and secular evolution, and mixing of

disc stellar populations. Furthermore, stellar bars may drastically evolve themselves, as pointed out by numerical simulations. They may grow in size or even be destroyed at some stage of their lifetimes. Despite the great amount of projects devoted to characterise the properties and frequency of bars, much is yet unknown about their own formation and evolution. We are performing a thorough study of the star formation histories of a sample of barred galaxies extracted from the CALIFA survey. The integral-field nature of CALIFA allows to investigate the impact of bars on the host galaxies at all scales. Preliminary results confirm that bars do grow in length through the so-called ansae structures present at the bar edges, in agreement with results from numerical simulations conducted by our group. The effects of secular evolution due to bars will be discussed.

Connor Bottrell
University of Victoria

Observational Morphologies of Simulated Galaxies: Computational Cosmology as Seen through a Telescope

The current generation of large-scale hydrodynamical cosmological simulations are valuable instruments for understanding the formation and evolution of galaxies. However, the crux in the interpretive power for such simulations is in whether they are fundamentally able to reproduce the observed properties of galaxies. Furthermore, it is crucial that any comparison between simulated and real galaxies is fair. To facilitate a valid comparison, simulated galaxies must be anchored to the court of reality and adopt the observational biases that burden galaxies seen in the real Universe. We put galaxies from the Illustris simulation directly in the context of observational galaxy astronomy using an unprecedentedly rigorous suite of observational realism in the Sloan Digital Sky Survey (SDSS). Parametric photometry and structural analysis of simulated galaxies with observational realism are performed using the same pipeline that was used in the analysis of 1.12 million real galaxies in the SDSS — which collectively forms our comparison sample. In this talk, I will discuss promising similarities along with intriguing contrast between real and simulated galaxy populations. I will also highlight the broader applications of our methods — as such conjunctions between observational and computational astronomy stand to provide a wealth of feedback to each community alike.

Session II: Physical Reasons behind Morphological Transformations (continued)

Luca Cortese (invited talk)
International Centre for Radio Astronomy Research (ICRAR) - University of Western Australia

What are the Physical Reasons behind Morphological Transformations at z~0?

Understanding how the Hubble sequence formed and evolve remains one of the most outstanding challenges in extragalactic astronomy. When and how do disk galaxies grow bulges, exhaust their gas supply and become `red-and-dead' early-types? Can bulges accrete gas, rebuild their disk and follow the inverse path?

Despite tremendous progress in the last decades, we are still struggling to obtain a coherent picture of the evolutionary paths that galaxies can follow across the Hubble diagram. In this talk, I will review recent progress in our understanding of the physical processes driving galaxy transformation in the local Universe. I will also highlight the main challenges that this field is facing, and showcase the critical importance of resolved multi wavelength datasets to isolate the key physical processes behind galaxy transformation.

Alister Graham
Swinburne University of Technology

Compact Massive Galaxy Evolution through Disc Growth

It has frequently been advocated that the population of compact massive galaxies seen at z ~ (2 +/- 0.5) went extinct by z ~ 0 because of merger events which transformed them into large elliptical galaxies. Here I present evidence for a different scenario in which many of these galaxies may have instead evolved by growing discs, to become today's lenticular galaxies.

Song Huang
Kavli-IPMU, University of Tokyo

Structure and Assembly History of Massive Central Galaxies through the Eye of Hyper-Suprime Camera

Under the most popular formation scenario, the structures of massive central galaxies depend on environment at fixed stellar mass due to different assembly histories shaped by their host halos. Yet, clear evidence of such effect is still lacking. Using deep, multi-band images for a large sample of massive galaxies at $0.2 < z < 0.5$ from the Hyper-Suprime Camera (HSC) survey, we discover subtle, but systematic structural difference for massive galaxies in low and high mass halos. The differences are consistent with richer merger history in more massive halos. We show that the average profiles of mass, shape, and color, along with relations among masses within different radius (as proxy of mass assembled at different time) can help us gain more insights of their assembly history, and the weak lensing analysis enabled by HSC survey further helps us connect the differences we find to the average halo properties.

Kenichi Tadaki
Max-Planck-Institut fuer extraterrestrische Physik

ALMA Reveals Rapid Formation of a Dense Core for Massive Galaxies at z~2

At z~2, massive quiescent galaxies are extremely compact with a dense core while the majority of star-forming galaxies have a more extended stellar disk. However, it remains unknown how the dense core is formed and how galaxies are transformed. We have made 1kpc-resolution ALMA observations at 870 um for 25 massive galaxies on the star formation main sequence at z~2, and compared the spatial distribution of the rest-frame far-infrared emission with stellar mass maps derived from spatially resolved stellar population modelling. The 0.2"-resolution ALMA data reveal that the dust continuum emission is mostly radiated from single region close to the galaxy center and its half-light radius is more compact by a factor of 2-3 than the rest-frame optical light and stellar component. Given extremely high SFR surface densities measured within a central 1 kpc, the compact starburst can build up a dense core in only a few hundred Myr. We may be witnessing one of evolutionary pathways from extended star-forming disks to compact galaxies.

Amanda Moffett
ICRAR, University of Western Australia

Galaxy and Mass Assembly (GAMA): Stellar Mass Build-up in Galaxy Spheroids and Disks

We build on the recent morphological classification and photometric decomposition analysis of nearly 8,000 low-redshift GAMA survey galaxies and derive the stellar mass functions of individual spheroid and disk populations down to a lower mass limit of 10^8 Msun. We find that the spheroid and disk mass distributions for individual galaxy morphological types are well described by single Schechter functions but that combined spheroid/disk mass distributions are better represented by functions with multiple Schechter components. We derive estimates of the total stellar mass density found in spheroids (rho = 1.24x10^8 Msun/Mpc^3) and disks (rho = 1.20x10^8 Msun/Mpc^3). This translates to approximately 50% of the local stellar mass density assembled in spheroids and 48% in disks. The remaining stellar mass is found in the dwarf "little blue spheroid" class, which is not clearly associated with either classical spheroid or disk populations. We also consider the variation of component mass ratios with galaxy mass and environment and find that disks dominate the galaxy stellar mass budget below galaxy mass ~10^11 Msun and group halo mass ~10^13 Msun, likely reflecting the dominance of in situ mass growth processes in this regime. The observed balance between galaxy mass assembled in spheroid and disk structures and the variation of this balance with galaxy mass/environment are important constraints on the physical processes that govern spheroid and disk mass build-up in simulations. With ongoing efforts to integrate new deep/high-resolution imaging into GAMA's multi-wavelength database, we also seek to extend this analysis beyond z~0 to chart the build-up of mass in galaxy structures as a function of cosmic time.

Session III: Drivers of Kinematic Transformation

Michele Cappellari (review)
Oxford University

Observational Signatures of Kinematic Transformation

Andy Green
Australian Astronomical Observatory

Studying the Changing Face of Galaxies with the First Data Release of the SAMI Galaxy Survey

The first major public data release of the SAMI Galaxy Survey includes data for 850 galaxies. The sample is selected from the GAMA Survey, and therefore has detailed environment measurements and multi-wavelength photometry. The data release includes both spatially resolved and aperture spectra, plus a variety of "value-add" data focused on the gas emission in these galaxies. The value

added data include star formation rates, emission fluxes for strong optical emission lines, and classification of the galaxy line emission (AGN, star formation, etc). This talk will provide an overview of the data and how it can be used to better understand the changing face of galaxies.

Jesse van de Sande
Sydney Institute for Astronomy, Sydney University

Revisiting Galaxy Classification with SAMI through Higher Order Stellar Kinematics

Recent cosmological hydrodynamical simulations suggest that with integral field spectroscopy it is possible to connect the observable higher-order stellar kinematic moments h3 (skewness) and h4 (kurtosis) in galaxies to their cosmological assembly history (Naab et al. 2014). Here, we assess these result by using stellar kinematic measurements from the SAMI galaxy survey. I will show that there is a good correspondence between fast and slow rotators and regular and non-regular rotators as based on luminosity-weighted angular momentum (lambda_r) and kinemetry measurements. Regular rotators furthermore show a strong anti-correlation between the higher-order moment h3 (skewness) and V/sigma, whereas less-regular and non-regular rotators show a more vertical relation between h3 and V/sigma. Next, I will explore a new approach for classifying galaxies based on their individual h3 versus V/sigma signatures alone. I will present the higher-order kinematic classes that we find within the SAMI galaxy survey, and compare how our new classes correlate with other global galaxy properties. Finally, I will show that our new way of classifying galaxies from their higher-order stellar kinematics signatures alone shows great potential for revealing recent mergers and bars in galaxies.

Jairo Mendez Abreu
St Andrews University

The Merger Origin of Field S0 Galaxies Decoded through Integral Field Spectroscopy

The relevance of galaxy bulges as central pieces in the study of galaxy formation is nowadays well settled. This role is still more manifest in lenticular (S0) galaxies where, by definition, bulges account for a significant fraction of the galaxy mass. Despite the huge amount of literature on S0 galaxies several basic questions still need to be answered: are S0 galaxies formed by major mergers of galaxies, or did they form through slow galaxy processes including minor satellite accretion or secular evolution?; are they the final steps in the evolution of late-type galaxies due to environmental mechanisms?

In this talk, I will present the results of a project aimed at fully characterising the 2D photometric and dynamical properties of the S0 bulges present in the CALIFA survey. Combining a detailed photometric analysis of the galaxy bulges together with the kinematic information about their rotational support (angular momentum), we suggest that our field S0 galaxies were formed through a major merger event at high redshift followed by a rebuilding of their galaxy disk. The formation of our S0 galaxies will also be discussed in the general context of merger vs. fading of spiral galaxies. We show how internal and/or external quenching of the star formation are unlikely to reproduce our observed galaxies, and how internal secular evolution after the merger-induced formation of the S0 has produced little impact on their evolution.

John Blakeslee
NRC Herzberg Astronomy & Astrophysics

The Massive Galaxy Survey

Massive early-type galaxies are central to our understanding of large-scale structure, stellar populations, and supermassive black holes, but their detailed formation histories remain poorly understood. The recently initiated MASSIVE Galaxy Survey is a volume-limited, integral-field spectroscopic and photometric survey of the structure and internal dynamics of the ~100 most massive early-type galaxies within 100 Mpc. The combination of integral-field spectroscopy on sub-arcsecond and large scales (out to two effective radii) allows us to perform simultaneous dynamical modelling of the supermassive black holes, stars, and dark matter. We also have an ongoing Hubble program to image a high-priority subsample of the MASSIVE galaxies. The ultimate goals of the survey include understanding variations in dark matter fraction and stellar IMF, the connection between black hole accretion and galaxy growth, and the late-time assembly of galaxy outskirts. I will describe the survey design and observational strategy, as well as present first results on black hole mass measurements, stellar populations, and molecular gas detections in MASSIVE Survey galaxies.

Alfonso Aragon-Salamanca
University of Nottingham

The Formation and Evolution of the Brightest Cluster Galaxies

Brightest Cluster Galaxies (BCGs) are the most massive galaxies in the Universe. Understanding their formation and evolution is essential if we want to understand how massive galaxies and the structures they inhabit came to be. In this talk I will present some interesting results on the relationship between the internal properties (stellar masses, structural parameters and morphologies) of BCGs and their environment, both at low and high redshift. We find that most present-day cDs BCGs started their life as ellipticals, which subsequently grew in stellar mass and size due to mergers. In this process, the cD envelope developed. Furthermore, the growth of the BCGs in mass and size seems to be linked to the hierarchical growth of the structures they inhabit: as the groups and clusters became denser and more massive, the BCGs at their centres also grew. This process is nearing completion at the present time.

Session IV: Drivers of Kinematic Transformation (continued)

Emily Wisnioski (invited talk)
MPE

Tracing High-z Galaxy Kinematics from Turbulent Disks to Quenched Spheroids

The representative selection and depth of the KMOS3D Survey, an integral field survey of over 600 galaxies at z=0.7-2.7 using KMOS at the VLT, has allowed us to study in unprecedented detail rare galaxies at z>1 that may be in the process of quenching. The short timescales associated with the quenching process make it difficult to catch galaxies “in the act” of shutting down their star formation. Compact star-forming galaxies, making- up ~7% of our sample, are selected to have properties aligned with already quenched galaxies at the same or lower redshifts, e.g. stellar mass, density, and sizes, but forming stars at rates 2-10x higher. We measure resolved kinematics of ~30 of these galaxies within the KMOS3D survey. Our results - the first resolved spectral data of such objects - show that compact star-forming galaxies are rotationally-dominated systems, providing strong evidence that recently quenched galaxies at these epochs are likely to be “fast rotators”. The majority of compact star-forming galaxies show evidence that they host an active galactic nuclei indicative of secular quenching processes.

Raymond Simons
Johns Hopkins University

From Disk Assembly to Disk Settling: Observations of the Internal Kinematics of Star-Forming Galaxies to z~2

We report on observations of the internal gas kinematics of star-forming galaxies over the last 10 billion years, from z~2 to now. Data are taken with the DEIMOS and MOSFIRE spectrographs on Keck as a part of the DEEP2 and SIGMA surveys, respectively. We find that star-forming galaxies have evolved from thick and turbulent systems at z~2 to well-ordered disks at z~0 by, on average, smoothly declining in velocity dispersion and increasing in rotation velocity. We show that the typical velocity dispersion declines at a remarkably similar rate at all masses and galaxies develop rotational support through 'kinematic downsizing’, wherein high mass galaxies form settled disks first. We will discuss how this kinematic transition gives important clues to the physical processes behind the formation and evolution of disk galaxies.

Francesco D'Eugenio
Australian National University

The SAMI Galaxy Survey Scaling Relations

The SAMI Galaxy Survey (SGS) is the largest Integral Field Spectroscopy Survey to date. We present relatively simple dynamical models of the SGS galaxies, and use them to construct three fundamental scaling relations: the Fundamental Plane, the Mass Plane and the Mass vs Angular Momentum relation. These results are then used to suggest strategies for upcoming and future surveys spectroscopic surveys of galaxies.

Jessica Victoria Bloom
The University of Sydney

The SAMI Galaxy Survey: Disturbed Things Come in Small Packages - Asymmetric Kinematics in Low Mass Galaxies

Spatially resolved kinematics provide a means to probe the underlying physics of galaxies, adding information beyond that provided by morphology alone. We are able to quantify the kinematic asymmetry in the Hα gas of galaxies in the SAMI Galaxy Survey sample, which consists of spatially resolved kinematics for an unprecedentedly large sample of low redshift galaxies, with a

wide range of stellar masses and morphological types. Using the SAMI data, we have investigated statistical links between kinematic asymmetry and other properties.

We will discuss the strong inverse correlation between stellar mass and kinematic asymmetry found for galaxies in the SAMI Galaxy Survey sample. Possible causes for this include perturbation of smaller interacting partners by more massive neighbours and high gas fractions found in low stellar mass galaxies, shown to lead to the formation and collapse of bubbles, causing increased turbulence.

A further finding is that the distance to first nearest neighbour is inversely correlated with kinematic asymmetry, and galaxies close to their nearest neighbour are more likely to be kinematically disturbed. However, low mass galaxies have higher median kinematic asymmetry than high mass galaxies regardless of the distance to their first nearest neighbour. We will discuss this evidence that demonstrates low stellar mass galaxies are disturbed by factors other than environment.

Ryan Leaman
MPIA

Disentangling ISM Turbulence and Latent Dynamical Heating in Galaxies

We analyse age-velocity dispersion (AVR) relations from kinematics of individual stars in 10 Local Group galaxies ranging in mass from 10^6 < M_star < 10^11. Observationally the AVRs can be interpreted as dynamical heating of the stars by giant molecular clouds or merging subhalos; alternatively the stars could have simply been born out of a more turbulent ISM at higher redshifts and retain that large velocity dispersion till present day - consistent with recent IFU studies. In order to ascertain the dominant mechanism and better understand the impact of instabilities and feedback, we develop models using the observed SFHs of these Local Group galaxies to create an evolutionary formalism which describes the ISM velocity dispersion due to a galaxies evolving gas fraction. The analytic models fit the AVR data of low mass galaxies without any fine tuning, using only the observed SFHs as input. The higher mass galaxies show a larger contribution from latent dynamical heating in excess of the ISM turbulence model, in order to reproduce their AVRs. At masses greater than Mvir ~ 10^11 galaxies appear to require excess dynamical heating from, for example mergers, above the prediction of the gravitational disk instabilities. We further confirm using the SFHs that SNe feedback does not appear to be as important a driver of the gas velocity dispersion compared to gravitational instabilities. Using the kinematic record preserved in these Local Group galaxies offers a complementary window into the high redshift universe, and our results point to stars being born with a velocity dispersion close to that of the gas at the time of their formation, with latent dynamical scattering operating with a mass dependent efficiency. These semi-empirical relations from our analysis may help constrain the efficiency of feedback and its impact on the ISM in SPH galaxy formation simulations.

Session V: Drivers of Kinematic Transformation (continued)

Matthew Colless
ANU

Exploring Angular Momentum in Galaxies with the SAMI Survey

After mass, angular momentum is the next most important determinant of galaxy properties, having a key role in in the formation of structure and morphology. For regular oblate rotators, angular momentum can be determined from Jeans anisotropic models as well as from direct estimates of the projected angular momentum. We compare these approaches using galaxies from the SAMI survey. We examine integrated angular momentum, and angular momentum distributions, as a functions of galaxy mass, morphological and kinematic type, ellipticity, and other properties. These relations provide insights on the mass assembly histories of galaxies that can be compared to simulations.

Kyle Westfall
ICG, University of Portsmouth

Trends in Asymmetric Drift across the Blue Cloud

We present a novel study of asymmetric drift (AD), the rotational lag of the stellar disk with respect to the circular speed of the gravitational potential, in ~400 galaxies from the SDSS-IV/MaNGA survey. Our galaxy sample is only a small subset of observed MaNGA galaxies, the largest sample of galaxies observed with integral-field spectroscopy to-date, and have been selected to have high-quality kinematic geometry measurements. Our sample of predominantly disk galaxies is spread across the full color-magnitude range of the blue cloud and spans a significant range in stellar-mass ($10 < \log(M/M_{sun}) < 11$). We compare our AD measurements with a surfeit of available data, drawn from the MaNGA datacubes themselves and beyond. A number of trends emerge. Most of these trends can be traced back to well-known empirical scaling relations, such as the Tully-Fisher relation, and the expectation from dynamical theory that AD is fundamentally tied to the total gravitational potential and the stellar velocity dispersion profile. The latter correlation is of particular interest, and we provide a new scaling relation that allows one to predict stellar velocity dispersions to ~0.1 dex (30%), if one can measure both the gas and stellar rotation curves. This is particularly exciting in the upcoming era of moderate-to-low spectral resolution observations of galaxies at moderate redshifts using, e.g., JWST, where direct measurements of stellar velocity dispersion will be limited.

Evelyn Johnston
ESO, Chile

Spectroscopic Bulge-Disc Decomposition of Galaxies

With the availability of large integral-field unit (IFU) spectral surveys of nearby galaxies, there is now the potential to extract spectral information from across the bulges and discs of galaxies in a systematic way. This information can address questions such as how these components built up with time, how galaxies evolve and whether their evolution depends on other properties of the galaxy such as its mass or environment. We present two new approaches to separating the light spectroscopically from the bulge and disc within a galaxy. The first technique uses GALFITM, a modified form of GALFIT that can fit multi-waveband images simultaneously, to separate the light profile of the galaxy over the full wavelength range into the bulge and dis components, while the second technique focuses on disentangling their kinematics with PPXF. When combined, these two techniques give us a deeper insight to the bulges and discs were built up with time, and thus how the galaxies have evolved and transformed into what we see today.

These new approaches to galaxy fitting have been developed and tested using commissioning data from the SDSS-IV Mapping Nearby Galaxies at APO (MaNGA) survey and publicly available CALIFA data. We will present an overview of these new techniques and along with some preliminary results for the bulge and disc star-formation histories of lenticular galaxies within the MaNGA survey.

Trevor Mendel
MPE Garching

A Census of Stellar Kinematics at z~2

Demographics of the galaxy population change rapidly from z = 2 to 1, when the Universe transitions from the peak of star formation at z > 2 to an era where quenching shapes galaxies as we know them today. In this talk I will describe our recent efforts to constrain the formation and evolution of quiescent galaxies at these redshifts using deep NIR spectra obtained with KMOS on the VLT. The combination of kinematic measurements from KMOS and structural parameters derived using deep 3D-HST/CANDELS imaging allow us to probe the evolution of well-known scaling relations out to z~2. Finally, I will highlight several of our recent results which tie quiescent galaxies to their progenitors and descendants through a combination of stellar populations, kinematics, and structural properties.

Sarah Brough
AAO

The SAMI Cluster Kinematic Morphology - Density Relation

The angular momentum of early-type galaxies as quantified by their rotation has been shown to decrease with increasing environmental density: the kinematic morphology - density relation. This implies that the formation mechanisms for early-type galaxies are dependent on environment. However, galaxy properties also depend on stellar mass so it is not yet clear whether mass or environment drive the observed relationship. To-date there have not been large enough galaxy samples to disentangle the effects of mass AND environment on rotation. The SAMI cluster sample provides kinematic morphologies for 350 early-type galaxies. I will present the analysis of the kinematic morphology - density relation in fixed mass bins - focussing on the role galaxy mass plays in this key relationship.

Session VI: Processes Controlling the Quenching of Star Formation

Yingjie Peng (review)
Kavli Institute for Astronomy and Astrophysics, Peking University

Star Formation Quenching and the Star Forming Main Sequence.

Understanding the processes controlling the quenching of star formation is one of the central issues in modern astronomy. Star-forming galaxies can be quenched by internal (e.g. AGN feedback, stellar feedback) and/or external processes (e.g. various environmental effects). Different quenching mechanisms can work at different stellar masses and at different epochs. I will present recent progresses in studying quenching from multi-wavelength sky surveys. I will show that the analysis of the stellar metallicity in large sample of local galaxies reveals that “strangulation” (or “starvation”, i.e. the lack of gas inflows) is the primary mechanism responsible for quenching star formation. This result is further supported independently by the stellar age data and simulations. I will also show that the simple analytic gas regulation model is a powerful tool to study quenching and the star formation main sequence at different epochs. Finally I will discuss plans to explore quenching with forthcoming observing facilities (e.g. JWST, MOONS).

Jorge Moreno (invited talk)
Cal Poly Pomona & Harvard University

What are the Processes Controlling the Quenching of Star Formation?”

In this talk I will review the role of simulations in our understanding of galaxy quenching. I will compare statistical results from the Sloan Digital Sky Survey against predictions from the Illustris Simulation and the L-Galaxies Semi Analytic Model. We find that whilst the fraction of quenched central galaxies increases with stellar mass and halo mass, the best predictor for quenching is bulge velocity dispersion. This is indirect evidence of AGN feedback being the primary driver of star formation quenching, which is consistent with the two aforementioned models, as well as with the EAGLE simulation. We also report local galaxy density as the leading environmental mechanism for quenching. Density peaks are known to be the sites for galaxy-galaxy interactions. For the second part of this talk, I will unveil results from our suite of galaxy merger simulations with FIRE (“Feedback In Realistic Environments”). We report that interactions do trigger enhancements in nuclear star formation and suppression at large galactocentric radii, in line with recent CALIFA observations.

David Maltby
University of Nottingham

Post-Starburst Galaxies in the Early Universe: Their Importance in Determining Routes for Galaxy Quenching

Despite decades of study, we still do not fully understand why some massive galaxies abruptly switch off their star formation in the early Universe, and what causes their rapid transition to the red sequence. To determine the quenching mechanisms responsible, we require a large sample of galaxies that are caught in the act of transformation. The rare class of post-starburst galaxies (E+A, k+A) provide a rare opportunity to study this transition phase, but currently only limited numbers have been spectroscopically identified at high-redshift ($z > 1$). Recently, however, a new photometric technique has been developed that can identify post-starburst (PSB) candidates based on the Principal Component Analysis of galaxy SEDs. When applied to the photometric data of the UKIDSS Ultra Deep Survey (UDS), this method has led to the identification of over 900 candidate PSBs at redshifts between 0.5 and 2. In this talk, I will present spectroscopic verification of this selection technique and demonstrate that ~80 per cent of the photometrically-selected PSB candidates show spectral signatures characteristic of this population (arXiv: 1603.08941). I will also present some initial results on the morphological structure of these PSB galaxies, obtained from a combination of deep ground- and space-based imaging (UDS UKIRT WFCAM and CANDELS HST ACS/WFC3). Using both 2D Sersic modelling and an independent isophotal analysis, I will show that the light profiles for PSB galaxies are surprisingly compact and spheroidal at high redshift ($z > 1$), similar to the old passive population. I will also discuss what these results can tell us about the potential quenching mechanisms operating in this important transitional population.

Katherine Alatalo
The Carnegie Observatories

Catching Quenching Galaxies: Following the Roads Less Travelled to Galaxy Transformation

Modern day galaxies are found to be in a bimodal distribution, both in terms of their morphologies, and in terms of their colours, and these properties are inter-related. In colour space, there is a genuine dearth of intermediate coloured galaxies, which has been taken to mean that the transition a galaxy undergoes to transform must be rapid. Given that this transformation is largely one-way (at z=0), identifying all initial conditions that catalyse it becomes essential. I will discuss a new way we have identified to find such transitioning galaxies (through the Shocked Poststarburst Galaxy Survey), which is able to pinpoint transitioning galaxies at an earlier stage of transition than other traditional searches. I will also discuss new findings about the feedback between the interstellar medium in transforming galaxies and their transformations, in particular, the presence of star formation suppression being discovered taking place in the molecular gas reservoirs of these sources. Between identifying new transforming galaxies, and providing new insights into the internal processes within transforming galaxies, a new window has been opened into this nearly one-way process.

Bruno Henriques
ETH - Zurich

The Physical Mechanisms Responsible for Star Formation Quenching at Different Epochs

I will present results from the recent major release of the Munich galaxy formation model, Henriques et al. 2015. With respect to previous versions, significant modifications were introduced in the treatment of AGN and supernova feedback and of the environmental effects acting on satellites. Among other problems, these were targeted at correcting the too early formation of low mass objects and the too late quenching of massive galaxies. I will show how the new implementations result in a model that is consistent with the observed evolution of the stellar mass functions of all, red and blue galaxies from z=3 to z=0, while roughly matching the evolution of the star formation rate densities and the main sequence of star formation. In addition, I will compare the model with detailed observations of stellar mass and environmental quenching trends. In detail, I will look at quenched fractions as a function of stellar and bulge mass, halo mass, local density, distance to group centres and at different epochs.

In doing so, I will attempt to build a comprehensive model capable of explaining the mechanisms responsible for the observed transformation of galaxies from the star forming to the passive population and for how this transformation scales with different properties at different times. I will give particular emphasis to a new model for gas outflows due to supernova feedback, and subsequent inflows, and show how it moves mass-assembly and star formation in low-mass galaxies to later times. I will present the details on how AGN feedback is able to replicate some observed trends of quenching as a function of stellar mass and how the combination of different processes acting on satellites (lack of primordial infall, ram pressure and tidal stripping) results in different quenching efficiencies in different environments.

Session VII: Processes Controlling the Quenching of Star Formation (continued)

Adam Schaefer
University of Sydney

The Impact of Galaxy Environments on Their Star Formation

The role of the local environment in the formation and evolution of galaxies is not well understood. While previous surveys (e.g. Lewis et al. 2002, Patel et al. 2009, von der Linden et al. 2010, Wijesinghe et al. 2012) agree on a decline in the global star formation rate within galaxies at higher environment densities, the quenching timescales and mechanisms that affect this relationship remain elusive. Some have argued that this trend is driven by the changing fraction of star forming galaxies in high density environments, while others claim the overall level of star formation is reduced in these objects. We use spatially resolved extinction corrected H-alpha measurements from the Sydney-AAO Multi-object Integral Field Spectrograph (SAMI) to quantify the distribution of star formation in ~200 galaxies. This sample covers three orders of magnitude in both stellar mass and environment density and is the largest of such samples that has been made to date. For each galaxy, drawn from the GAMA survey regions, we compute the total integrated star formation rate and star formation radial profile from the 3D distribution of H-alpha.

Our data show evidence for the quenching of star formation in galaxies in high density environments.

Our data suggest that both the star forming fraction and the star formation rate in star forming galaxies declines in higher density environments. In addition, we see evidence for a change in the radial star formation gradient due to the environment and discuss this in the context of current galaxy formation models.

Samantha Penny
Portsmouth

Discs All The Way Down: The Origin of Quenched, Low Mass Galaxies Using MaNGA IFU Spectroscopy

Despite being the dominant galaxy population by number in groups and clusters, the formation timescale and mechanism of lower mass galaxies, including dwarf galaxies, remains unknown. Are quenched dwarfs the remnants of hierarchical galaxy assembly, or are they formed at later times via the morphological transformation of more massive galaxies? To address this question requires spatially-resolved spectroscopy to uncover their kinematics and formation timescale. Using data from the first year of the SDSS-IV MaNGA IFU survey, we identify a sample of 39 quenched, low mass (dwarf) galaxies with M* < 5x10^9 Msun, selected independently of morphology and environment. This is the first large scale Integral Field Unit (IFU) study of such low mass quenched galaxies outside of the cluster environment. In this talk, I will show the majority of quenched dwarf galaxies exhibit coherent rotation in their stellar kinematics, and several host disc or spiral features, inconsistent with a primordial origin. Several exhibit kinematically distinct cores which must form via gas infall and accretion. I will discuss an origin for these dwarfs as quenched low-mass disc/spiral galaxies, supporting the hypothesis that galaxy-galaxy or galaxy-group interactions quench star formation in low mass galaxies. I will also show that despite being the "simplest" galaxies in our current models of galaxy formation, quenched dwarf galaxies are a diverse population, with detailed spectroscopy crucial to understand their origin.

Julie Nantais
Universidad Andrés Bello

Stellar Mass Functions and Reduced Environmental Quenching Efficiency at z ~ 1.5

We present the stellar mass functions (SMFs) of passive and star-forming galaxies with a limiting mass of 10^{10.1} M_sun in four spectroscopically confirmed Spitzer Adaptation of the Red-sequence Cluster Survey (SpARCS) galaxy clusters at 1.37 < z < 1.63. The clusters have 113 spectroscopically confirmed members combined, with 8-45 confirmed members each. We construct Ks-band-selected photometric catalogs for each cluster with an average of 11 photometric bands ranging from u to 8 micron. We compare our cluster galaxies to a field sample derived from a similar Ks-band-selected catalog in the UltraVISTA/COSMOS field. The SMFs resemble those of the field, but with signs of environmental quenching. We find that 30 +/- 9% of galaxies that would normally be forming stars in the field are quenched in the clusters. The environmental quenching efficiency shows little dependence on projected cluster-centric distance out to ~ 4 Mpc, providing tentative evidence of pre-processing and/or galactic conformity in this redshift range. We also compile the available data on environmental quenching efficiencies from the literature, and find that the quenching efficiency in clusters and in groups appears to be declining with increasing redshift in a manner consistent with previous results and expectations based on halo mass growth.

Dale Kocevski
Colby College

Insights on the AGN-Galaxy Connection from CANDELS & X-UDS

I will summarize the insights gained from the CANDELS and X-UDS surveys regarding the demographics of the AGN host population out to z~2. In particular, I will focus on 1) the high frequency of disturbed morphologies among heavily obscured, Compton-thick AGN at z~1-2 and 2) the prevalence of luminous AGN in compact, star forming galaxies at z=2.5. The former result suggests that merger-triggered AGN at z~1 are heavily obscured, which may help explain why it has been so difficult to clearly establish an AGN-merger connection. The latter result suggests SMBH growth, and possibly AGN feedback, was ubiquitous in “blue-nugget” galaxies at z~2. Based on their size, stellar mass, and star formation rates, these galaxies appear to be the direct progenitors of the compact quiescent population observed at this epoch. Our findings suggest the first generation of quenched galaxies emerged in the early Universe directly following a phase of rapid SMBH growth. I will discuss what these observations reveal about the connection between AGN activity and the rise of the red sequence at z~2.

Remco van den Bosch
MPIA Heidelberg

Co-Evolution of Super-Massive Black Holes and Galaxies

The coevolution of galaxies and their super-massive black holes in their centres is commonly linked through bulge growth scenarios. The evidence for this is the tight correlation between the BH mass and the bulges in early-type galaxies. I will present a set of galaxies that host over-massive black holes for their host galaxies luminosity. These objects have the same properties (size, mass, stellar pop.) as the quiescent at z>2. As such these passive evolved relics allow us to study the galaxy formation at early epoch. Furthermore, I will show that the total mass of the galaxy does not correlate well with black holes mass. And will show that the bulge is not the primary correlator with BH mass. Instead, it is set by the global processes of galaxy formation. The velocity dispersion of the host galaxy appears to set the black hole mass, and not the bulge or galaxy mass.

Session VIII: AGN and Star-Formation Feedback

Chris Power (review)
International Centre for Radio Astronomy Research, University of Western Australia

How Feedback Changes the Faces of Galaxies: A Review from a Theoretical Perspective

---

Lisa Kewley
Australian National University

The Role of Starburst and AGN Feedback

Throughout the history of the universe, starbursts and supermassive black holes have fundamentally shaped their host galaxies. Starbursts enrich the interstellar medium, and can drive energetic galactic-scale winds. Supermassive black holes are “messy eaters”, swallowing some matter which falls through the event horizon and releasing energy to ionise the surrounding medium, while other material is ejected at relativistic speeds. AGN-driven outflows have been shown to drive significant amounts of material into the surrounding intergalactic medium and they may quench star formation. Despite the importance of star formation and supermassive black holes on galaxy assembly, we still lack a detailed understanding of the physics of starbursts, supermassive black holes and their interactions with their host galaxies. In this talk, I will show how our understanding of starburst and AGN driven galactic outflows is currently being transformed by large integral field spectroscopic surveys.

Darshan Kakkad
European Southern Observatory

Insights into AGN Feedback at High-z using ALMA & SINFONI

Galaxies at redshift 1-3 have become the prime focus of many observations. This is the peak epoch for both star formation and black hole growth in the cosmological history, and therefore it is an ideal laboratory to test the impact that AGN radiative feedback may have on their host galaxies. We will present two independent approaches to test AGN feedback: a) CO(2-1) observations from ALMA in a sample of "main sequence" AGNs to compare the star formation efficiency and gas fractions in active and inactive galaxies. b) SINFONI-IFU observations of a representative sample of high redshift quasars for which we observe intermediate to high velocity kiloparsec-scale outflows using [OIII]5007 line diagnostics. We will discuss the constraints on the source of such detected outflows (AGN or star-formation) using simple outflows models. The combination of these SINFONI and ALMA observations allows us to test the impact of AGN feedback on both ionised and molecular gas content of their host galaxies.

Kevin Schawinski
ETH Zurich

The AGN Life Cycle, Flickering and Feedback

New observations indicate that massive black holes grow via a large number of brief ~100 kyr accretion phases during which they are visible as luminous, radiatively efficient AGN. I will discuss recent observational evidence which support this emerging picture with new data from X-rays, radio and optical telescopes. Hanny's Voorwerp and its cousins are tracing the "switch-off" phase of this AGN life cycle and I will show evidence for significant energy injection associated with this switch-off phase. On the other side of the cycle, observations indicate that there is a population of "switch-on" AGN where the AGN has reached its present-day luminosity in the last few thousand years. I use these new insights to explain why tracking down the impact of AGN on galaxy evolution and transformation has been so challenging, and outline new approaches to investigating this problem using a multi-scale and multi-wavelength approach.

Session IX: AGN and Star Formation Feedback (continued)

Joss Bland-Hawthorn
Sydney Institute for Astronomy

Baryonic Astrophysics in Galaxy Evolution - Inflows and Outflows

Baryonic astrophysics in galaxies is both a blessing and a curse. Its richness and complexity means that we're going to be busy for decades to come. Its curse is one we can identify from many fields of physics - how do we decide when the job is done? Just what do we mean by a theory of galaxy formation? Numerical simulations are casting some light on this difficult problem but are profoundly handicapped by limited dynamic range and resolution. So where can we expect real progress in the next decade. We review recent developments in observation and theory, and point the way forward.

Stas Shabala
University of Tasmania

We Should Care About the Environment, Especially When Quantifying Jet-Mode AGN Feedback

Active Galactic Nuclei (AGN) play a key role in the formation and evolution of galaxies through so-called AGN feedback. Over the last half of Hubble time, the dominant mode of this feedback is through synchrotron-emitting radio jets. Quantifying the magnitude (and even the sign) of jet feedback, however, is difficult. Two parameters play a key role in determining feedback efficiency: (1) the kinetic power of AGN jets, which set how much energy is available for feedback; and (2) the timescales related to their injection, which determine the efficiency with which this energy is deposited in the surrounding gas.

A popular method of measuring jet kinetic power involves using the energetics of X-ray deficient radio bubbles; our recent work (Godfrey & Shabala 2016) shows that this approach in fact suffers strongly from selection effects, and does not provide a good measure of jet power. I will outline a recent alternative approach (Turner & Shabala 2015) in which we combine models describing the dynamical evolution of observable radio AGN properties with semi-analytic galaxy formation models. We find that the mapping between radio luminosity and jet power is strongly environment-dependent, and also evolves substantially over AGN lifetime; these findings have important ramifications for interpretation of data from current and future radio continuum surveys. We have used this technique to determine the physical properties of low-redshift AGN, and are currently extending our approach to higher redshifts. I will conclude by briefly describing how the combination of our models and data from the Radio Galaxy Zoo citizen science project provide a unique way of testing the jet-environment interaction, particularly through studies of asymmetric double radio sources.

Rainer Weinberger
Heidelberg Institute for Theoretical Studies

Modelling AGN Feedback in the Next Generation Cosmological Volume Simulations

Feedback from active galactic nuclei (AGNs) is often applied in cosmological simulations of galaxy formation to obtain the observed decrease in star formation efficiency with halo mass for halos more massive than the Milky Way. Yet, the models for AGN feedback suffer from limited resolution and theoretical uncertainties. Because of this, models have difficulties in reproducing both stellar and gas properties simultaneously. This is particularly challenging in large cosmological volume simulations as they model the formation halos of a wide range of different masses and gas properties.

I will present a new model for AGNs in cosmological simulations in the moving-mesh magneto-hydrodynamics code Arepo which will be used in the next generation cosmological volume simulation, improving what has been achieved in the Illustris project. The model capable of quenching star formation in the most massive systems close to the observed value and keep realistic gas fractions in the halos. At the same time, the resulting galaxy population shows a clear dichotomy of “red and dead” vs. blue, star-forming galaxies, which tend to have elliptical and disk

morphologies, respectively. I will discuss the key points we find to be necessary to achieve this and the implications for our understanding of black hole physics. Furthermore, I will discuss the modelling uncertainties arising from the limited resolution and the poorly constrained parameters of the model.

Rosalie McGurk
Max Planck Institute for Astronomy

High Resolution Near-Infrared SINFONI Spectroscopy of Shocks and Outflows in Low Star-Formation Galaxies

The first galactic-scale outflows were discovered only in systems with extreme star formation (SF) or Active Galactic Nucleus (AGN) activity, suggesting that normal SF rates were not capable of driving gas any significant distance. However, optical integral field surveys such as the SAMI Galaxy Survey are finding outflows and winds in galaxies with SF rate surface densities (SFRSD) 10-100 times below the canonical threshold. The powerful spectral resolution of SAMI makes it excellent at detecting outflows and winds, but its low spatial resolution and seeing-limited nature (2.0”–2.5”) leaves holes in our understanding of the morphology of the winds and outflows and their underlying driving mechanisms. Since the near-infrared is much less affected by dust extinction than the visible, near-infrared spectroscopy will provide a more unobscured view of the outflows than is provided by the SAMI data. We are using the near-infrared VLT SINFONI integral field spectrograph assisted by Laser Guide Star Adaptive Optics to map 7 low SFRSD galaxies with unique outflow morphologies: biconical outflows, kpc-scale winds, and off-nuclear outflows. These observations will determine the outflows’ multiphase gas structures, photoionization parameters, and driving mechanisms, and we will compare our features to the outflows from extreme systems.

Edoardo Tescari
University of Melbourne

Galactic Winds in EAGLE Simulations and SAMI Observations: The Second Part of the Story

I will present the latest results of a joint EAGLE-SAMI project on galactic outflows driven by stellar feedback. We extract main sequence disc galaxies at redshift z = 0 from the highest resolution cosmological simulation of the EAGLE set and produce synthetic SAMI observations. In particular, we apply to the simulated sample an observationally motivated prescription previously adopted to identify wind-dominated SAMI galaxies (Ho et al. 2016). I will describe strengths and weaknesses of this method and discuss how numerical models are essential to explore the physics of galactic winds and interpret IFS observations.

Session X: Gas Accretion and Re-Fuelling

Barbara Catinella (review)
ICRAR, University of Western Australia

The Gas Cycle of Galaxies across Environments

While it has become increasingly clear that there is a strong connection between galaxies and their environment, we are still struggling to understand to what extent nurture shapes galaxy evolution, and which are the dominant physical mechanisms involved. Studies of the cold gas in and around galaxies hold the key to reveal the nature and extent of environmental effects, as demonstrated by neutral hydrogen surveys of galaxy clusters such as Virgo. However, what happens to the gas in the more common group environment is still unclear, due to the lack of large surveys deep enough to probe the gas-poor regime across all environments.

I will review the current status of studies of the impact of environmental effects on the cold gas reservoirs of local galaxies, with emphasis on the intermediate densities typical of galaxy groups, and highlight a few results based on surveys or techniques that are allowing us to make progress in this field.

Claudia Lagos (invited talk)
International Centre for Radio Astronomy Research

Gas in Galaxies: The View from the EAGLE Cosmological Hydrodynamic Simulations

Observations of the gas content of galaxies, such as carbon monoxide, far-infrared lines, and 21cm, are becoming common place, with thousands of galaxies at a wide range of cosmic epochs being studied. This has pushed galaxy formation simulations to start addressing how the different phases of the gas inside and outside galaxies correlate with other galaxy properties and how they evolve in the cosmological context. There are several observational results that need to be addressed by simulations, such as (i) galaxies early on in the evolution of the Universe have higher molecular gas fractions and star formation rates than local galaxies, (ii) scaling relations show that the atomic-to-stellar mass ratio decreases with stellar mass in the local Universe, with early-type galaxies exhibiting a remarkable wide range of gas fractions, (iii) the global abundance of atomic hydrogen evolves weakly. I will show how modern cosmological simulations of galaxy formation attempt to put together these pieces and highlight how we are treating this problem using the EAGLE hydro-dynamic simulations.

David Fisher
Swinburne University of Technology

DYNAMO: A Window into Processes in Turbulent Disk Galaxies

In this talk I will discuss properties of extremely gas rich, turbulent disk galaxies in the DYNAMO survey. DYNAMO is an IFU survey of Halpha in ~100 galaxies at z~0.1, selected to have the highest Halpha luminosity at their redshift, yet are not AGNs. Follow up programs with HST, PdBI(NOEMA), Keck/OSIRIS and Gemini allow us to identify a set of galaxies are clumpy, gas-rich (fgas~20-40%), rotating disks, with large internal velocity dispersion, extremely similar to galaxies at z=1-2. We use DYNAMO galaxies as a laboratory for physical mechanisms that are transforming main-sequence galaxies during the clumpy, turbulent phase of galaxy evolution. Because our galaxies are so close we can study physical properties that are inaccessible in high-z galaxies, even in lensed systems. In this talk I will discuss our new result on the role of the violent disk instability in setting the properties of clumps. Using data from HST, Gemini, Keck and NOEMA we have found a direct connection between clump properties and predictions from the model in which these galaxies are marginally stable (Q~1) systems. I will also discuss our new result that angular momentum may be a relavant factor in the

transforming the properties of these galaxies. These results are directly complementary to high-z surveys of main-sequence galaxies, and put together can help us understand how the morpho-kinematic transformation from gas rich, turbulent disks galaxies to more typical Hubble sequence spiral galaxies and S0s takes place.

Session XI: Gas Accretion and Re-Fuelling (continued)

Charlotte Christensen (invited talk)
The University of Arizona

Simulating the Gas Cycle in Galaxies

Galactic outflows enrich the circumgalactic medium through the redistribution of metals from the disks of galaxies. We examine the history of this enrichment by analyzing the outflows of twenty high-resolution simulated galaxies spanning two and a half orders of magnitude in halo mass. These simulations self-consistently generate outflows, and they match many observed trends, including the mass-metallicity relation. By tracking particles in the simulations, we follow the removal and reaccretion of mass and metals between redshift 3.5 and 0. We quantify the importance of ejective feedback to setting the stellar mass, and determine the mass and metal loading of outflows as a function of halo mass. Finally we compare the redshift zero metal census to observed values. Recycling of ejected material is ubiquitous in our simulated galaxies; nevertheless, the vast majority of metals produced by the galaxy lie outside the disk.

Steven Janowiecki
ICRAR/UWA

Unusually Gas-Rich Central Galaxies in Small Groups

Observations of gas in galaxies have shown dramatic differences between rich clusters and isolated field environments. However, pre-processing in intermediate group environments is expected to be responsible for much of the transformation between gas-rich blue and gas-poor red galaxies. We investigate this by taking advantage of the deepest observations to date of atomic and molecular gas in local galaxies from the GASS and COLD GASS surveys and their extensions to low stellar masses. This sample is uniquely suited to quantify gas and star formation properties of galaxies across environments, reaching the gas-poor regime of groups and clusters. We present the scaling relations of gas content for central and satellite galaxies as a function of halo mass, and show that central galaxies in small groups are more gas rich (in both HI and molecular gas) and star-forming than galaxies in isolation.

Anshu Gupta
Australian National University

First Detection of a Cluster-scale ISM Metallicity Gradient: A New Outlook on Environmental Impact on Galaxy Evolution

Understanding the effect of cluster environment on galaxy formation and evolution is a central topic in extragalactic astronomy. The interstellar medium metallicity can trace the impact of environment on galaxy evolution because both the star formation history and the galactic inflow/outflow modulate the metallicity. Current observations of the mass-metallicity relation show minimal dependence on the large-scale environment. In this talk, I will present the radial distribution of interstellar medium (ISM) metallicity in galaxy clusters, as an alternative method to study the impact of environment on galaxy evolution. I will present the first observation of cluster-scale negative abundance gradients in two CLASH clusters at z~0.35: MACS1115+0129 and RXJ1532+3021. Our observation presents the highest metallicity enhancement in galaxy cluster on the mass-metallicity relation to date. Most strikingly, we discover that neither the radial metallicity gradient nor the offset on the mass-metallicity relation show any obvious dependence on the stellar mass of cluster members. The radial abundance distribution is also a strong indicator of the dynamical state of the cluster. I will investigate the different physical processes in the cluster environment such as ram-pressure stripping, galaxy harassment and strangulation that can lead to the observed cluster-scale negative abundance gradient in ISM metallicity.

Glenn Kacprzak
Swinburne University of Technology

Cold-Mode Accretion: The Cause of the Fundamental Mass Metallicity Relation at z=2

Using the MOSFIRE/Keck ZFIRE galaxy evolution survey, we will show that the stellar mass and gas-phase metallicity relation as z=2 is dependent on galaxy star formation rate. We will further show that this fundamental mass-metallicity relation (and its intrinsic scatter) is driven by the cold-mode gas accretion. Or data are in complete agreement with cosmological simulations. These results demonstrate the direct relationship between cosmological accretion and the fundamental properties of galaxies.

Sree Oh
Yonsei University

Tracing the Star Formation History of Early-Type Galaxies via Various Scaling Relations

Many studies from the Galaxy Evolution Explore (GALEX) ultraviolet (UV) data have demonstrated that the recent star formation is more common in early-type galaxies (ETGs). The UV is one order of magnitude more sensitive than the optical to the presence of young stellar populations. The near-ultraviolet (NUV) lights of ETGs, especially, are used to reveal their residual star formation history. Here we present the GALEX UV images of 81 nearby massive early-type galaxies ($\log(M/M_\odot)>10.5$) from the SAURON and SAMI. Roughly 30% of the galaxies in this sample show blue UV-optical colours suggesting recent star formation (RSF). These RSF galaxies are drawn from the lower stellar velocity dispersion and bias the slopes of scaling relations (colour-magnitude relations and fundamental planes). More interestingly, most of them appear to have sub-solar metallicity due to the metal-poor populations that are likely to have formed from the material accreted from a gas-rich satellite galaxy during a recent merger and/or interaction. Furthermore, they show differences between the stellar and gaseous kinematics. We compare our results with the prediction from the hierarchical merger paradigm and attempt to understand the overall assembly history of ETGs.

Session XII: Gas Accretion and Re-Fuelling (continued)

Charlotte Welker
ICRAR, UWA

Mergers and Gas Accretion onto Galaxies: The Imprint of the Cosmic Web

In this talk I will present in details the major features that govern the geometry and dynamics of cosmic flows on Mpc scales, and further develop the consequences of for mergers and gas inflows on galactic scales. In particular, I will explain how the dynamical and anisotropic nature of the cosmic web imprints the cold gas steams and their later accretion onto galaxies, and how it affects the satellite distribution, spin and morphology of galaxies over a wide range of redshifts. To perform this analysis, I will rely on both insights from lagrangian theory and recent results drawn from the analysis of the 100Mpc box « full-physics » hydrodynamical cosmological simulation Horizon-AGN.

O. Ivy Wong
ICRAR, University of Western Australia

Constant-Q Disk Stabilities Result in Uniform Star Formation Efficiencies

We examine the H I-based star formation efficiency (SFE), the ratio of star formation rate to the atomic Hydrogen (HI) mass, in the context of a constant stability star-forming disk model. Our observations of HI-selected galaxies show SFE to be fairly constant across ~5 orders of magnitude in stellar masses. Using a 2-fluid Toomre Q-parameter to describe the stability of a galactic disk, we find that the uniformity of the star formation efficiency can be well-described by a marginally stable disk model. Our model is the first model that links the uniform SFE observed in galaxies at low redshifts to star-forming disks with HI constant marginal stability. While the rotational amplitude Vmax is the primary driver of disk structure in our model, we find the specific angular momentum of the galaxy may play a role in explaining a weak correlation between SFE and effective surface brightness of the disk. (Ref: Wong, O. I. et al 2016, accepted for publication in MNRAS)

Brent Groves
RSAA, ANU

Metallicity and Gradients along the Galaxy Main Sequence

The gas-phase metallicity traces the growth of a galaxy through the build-up of abundances from star formation and evolution, and the accretion of pristine gas to fuel the next population of stars. The metallicity gradient traces how this growth occurred. Yet while galaxies show varied star formation histories, recent work suggests metallicity gradients are consistent across galaxies. Here I present recent work from the SAMI integral field survey of galaxies, demonstrating the observed global trends of metallicity across the main sequence plane of stellar mass and specific SFR, yet the consistency of the gradient once a galaxies size has been taken account of.

Session XIII: External and Internal Processes in Galaxy Formation

Sara Ellison (review)
University of Victoria

The Triggering Mechanisms of Star Formation and Active Galactic Nuclei

Both star formation and the triggering of an active galactic nucleus (AGN) require the delivery of gas as fuel. In this talk I will summarize how this fuel supply can be supplied within a galaxy, both through internal and external conduits. These mechanisms include bars, disk instabilities, galaxy mergers and cosmic accretion through gas flows. The talk will have an emphasis on multi-wavelength studies, which reveal complementary aspects of star formation and AGN activity, as well as the connection between the two processes.

Callum Bellhouse
European Southern Observatory (Chile), University of Birmingham

Untangling Jellyfish: Ram-Pressure Stripped Galaxies in different environments with MUSE and GASP

For many years, the evolution of galaxies has been known to be driven by a combination of internal and environmental processes. Spectacular examples of environmental quenching at play are the so-called "jellyfish" galaxies, whose asymmetric morphology is suggestive of intense ram-pressure stripping. Studies of these objects are thus key in understanding the fundamental mechanisms of gas-stripping processes. I will present first results from the GASP (GAs Stripping Phenomena in galaxies with MUSE) ESO Large program, and demonstrate the diagnostic power of MUSE IFU data in constraining and characterising properties and kinematics of jellyfish galaxies.

Tadayuki Kodama
National Astronomical Observatory of Japan

The Changing Face of Proto-Clusters

Galaxies are changing their faces due to environmental influences in galaxy clusters as well. Clusters themselves are also changing their faces as they grow by assembly of surrounding materials along the filamentary structures. We have been mapping out the large scale structures in and around the clusters and star formation activities therein at $0.4<z<3.2$ across the peak epoch of galaxy formation in the Universe, by using wide-field instruments on Subaru and their unique sets of narrow-band filters Mahalo-Subaru project). We show that all the clusters have prominent substructures characterized by clumps and filaments indicating their early assembly phase, and that star formation activity in the cluster cores increases dramatically as we go to higher redshifts. A significant fraction of such star formation is hosted by red, dusty star forming galaxies, which tend to favour the densest cores/clumps of the proto-clusters at $z>2$. Such strong activities in the cores decline sharply as time progresses as $(1+z)^6$, and the peak of star formation activity, red or blue, is shifted outwards to surrounding lower density regions, clearly indicating the ``inside-out'' quenching of galaxy clusters. Using HST imaging, AO-assisted narrow-band imaging (Ganba-Subaru), and ALMA observations (Gracias-ALMA), we are now at the stage of resolving internal structures of individual galaxies to know the physical processes of galaxy formation in action and their environmental dependence. I will also review all these on-going projects as well as introducing the up-coming 1-sq.deg. SWIMS-18 survey using 18 filters (6 narrow-bands, 9 medium-bands, and 3 broad-bands).

Session XIV: External and Internal Processes in Galaxy Formation (continued)

Sukyoung Yi (invited talk)
Yonsei University

Relative Importance of Internal Vs. External Effects on Galaxy Evolution: From the Spin Perspective

Morphology has been adopted as the most convenient selection criterion in galaxy studies for nearly a century. But this may change soon. Recent IFU studies found that the traditional morphology-spin relation is not clear anymore and in fact spin might be a better and more fundamental property of galaxies. In the current favourite hierarchical merger paradigm, the morphology-spin connection seems plausible. The role of mergers is highly suspected as the main driver of the galaxy spin evolution, but the details are scarcely known. I present new and unexpected findings on this issue and discuss the role of internal and external effects.

Matt Owers
Macquarie University and Australian Astronomical Observatory

The SAMI Galaxy Survey: The Impact of the Cluster Environment on the Star Formation of Infalling Galaxies

It is well-known that the star-forming properties of galaxies that reside in the dense cores of galaxy clusters are remarkably different from those in the field; quiescent early-type galaxies are much more prevalent in cluster cores whereas star-forming spirals dominate in the field. These differences must be reconciled with the hierarchical nature of large-scale structure formation, where the cluster galaxy population increases by the accretion of galaxies from lower density environments. The dominant mechanism responsible for transforming infalling galaxies, whether it be due to pre-processing prior to infal or due to cluster specific mechanisms, remains elusive. Getting to the heart of this issue requires a robust definition of galaxy environment which is closely related to the physical mechanisms which may be at play, along with resolved information on the recent and ongoing star formation of the infalling galaxies.

The SAMI Galaxy Survey will provide resolved spectroscopy for around 3600 galaxies. Of those galaxies, 700 have been selected to be members of eight massive clusters of galaxies. These eight clusters were the subject of a deep redshift survey using the Anglo-Australian Telescope's AAOmega multi-object spectrograph, providing a 2300 strong sample of spectroscopically confirmed cluster members that have been used to characterise the dynamical properties of each cluster (galaxy membership, cluster mass and substructure). In particular, the redshift survey has allowed a robust characterisation of the projected phase-space distribution of the clusters. The position of a galaxy in projected phase-space can be used as a proxy for the time since infall for a galaxy. In this talk, I will present an analysis of the resolved star forming properties of SAMI cluster galaxies which, based on their position in projected phase-space, are very likely to be encountering the cluster core for the first time. The majority of these galaxies show evidence for young (<1Gyr) stellar populations with no ongoing star-formation in the outer parts of the disk, indicating that star-formation has recently stopped there, while also showing ongoing star formation in their centres. This indicates the galaxies are having their star formation quenched from the outside-in, likely due to the effects of ram-pressure stripping as they traverse the clusters.

Julia Bryant
University of Sydney/AAO

SAMI Galaxy Survey: Gas Stellar Misalignment in Galaxies and the Impact of Morphology and Environment

The degree of alignment between the stellar and gas kinematics of a galaxy can indicate whether the gas is of external or internal origin and hence how it has shaped the formation of the galaxy. Based on ionised gas and stellar kinematics in the SAMI Galaxy Survey galaxies, we have investigated the relationship between dynamical misalignments and the galaxy morphology and local and global environments. We will discuss the influence of these properties on dynamical timescales and the origin of gas in galaxies. SAMI is a large IFU survey of nearby galaxies and is therefore ideal to test previous findings (e.g. from ATLAS 3D) on a larger sample.

Session XV: Key Physical Process of Galaxy Formation Change with Cosmic Time

Robert Crain (review)
Liverpool John Moores University

The Processes that Shape Galaxies in Simulations

Martin Bureau (invited talk)
Oxford University

Connecting High and Low Redshift via Integral Field Surveys

David Wake
The Open University

Connecting Galaxy Stellar Mass and Star Formation Rate to Dark Matter Halo Mass at $0.6 < z < 2$ using UltraVISTA, CANDELS and 3D-HST.

I will present new measurements of the stellar mass and specific star formation rate dependent clustering of galaxies from a series of near-IR selected galaxy surveys with complimentary depths and areal coverage (UltraVISTA, CANDELS and 3D-HST). The combination of these data sets enables the extension of such measurements to lower masses and higher redshifts than ever before. Using the halo model I derive the stellar halo mass relation (SHMR) at $0.6 < z < 3$ and by combining it with measurements at lower redshifts show how this relation evolves over the last 11 Gyrs. Such measurements are of vital importance in understanding how galaxies are assembled along with their host dark matter halos and provide direct insight into the evolution of the SHMR relation, which is increasingly used to link progenitor and descendent galaxies at differing epochs.

Rachel Cochrane
Institute for Astronomy, Royal Observatory Edinburgh

The Clustering of Star-Forming Galaxies across Cosmic Time with Hizels

The deep near-infrared narrow band survey HiZELS has yielded identically-selected samples of H-alpha emitters at 4 epochs spanning the decline of the cosmic star formation rate density (z~0.4, z~0.8, z~1.5 and z~2.2). Narrow band samples have well-defined redshift distributions and are therefore ideal for clustering analyses. Using these samples, we probe the clustering of star-forming galaxies back ~11Gyr. At individual epochs, our samples are large enough to bin by both star formation rate and stellar mass. Fitting two-point correlation functions with sophisticated dark matter halo models, we identify the typical properties of the host haloes of different populations of H-alpha emitters. We constrain effective halo masses and central/satellite fractions as a function of star formation rate, stellar mass and cosmic epoch. In this talk I will present a detailed analysis of star-forming galaxies and their host dark matter haloes over cosmic time, and the implications of this for galaxy transformation.

Session XVI: Key Physical Process of Galaxy Formation Change with Cosmic Time

Adebusola Alabi
Swinburne University of Technology

Mass Distribution and Dark Matter Halo Parameters of Early Type Galaxies

As part of the SLUGGS survey, we present the mass distribution within and beyond 5 Re in a sample of 30 ETGs (with log stellar mass from 10.2 - 11.7 Msun) using their GC kinematic data, extending on average out to ~13 Re. We find that dark matter fraction increases from 0.6-0.8 for low- and high-mass galaxies with some intermediate mass galaxies having low dark matter fraction of 0.3. We show that these results are independent of the adopted orbital anisotropies, stellar M/L ratio and the assumed slope of the gravitational potential. These low dark matter fraction galaxies are at odds with simple star + DM galaxy models but agree with the cosmological simulations of Wu et al. They also have very diffuse DM haloes, suggesting that they formed late.

We furthermore obtain the virial masses and halo concentration parameters for our galaxy sample and find that the galaxies with low dark matter fraction have low halo concentrations, again confirming that they assembled late. The remaining galaxies in the sample have higher-than-predicted halo concentrations, which cannot be accounted for by stellar M/L and adiabatic contraction.

Andrew Cole
University of Tasmania

Galaxy Transformation at the Faint End of the Luminosity Function: A Local Perspective

Low-mass, low-luminosity systems are at the forefront of efforts to understand the evolution of galaxies in the Universe. Multiple theoretical and observational efforts have independently identified galaxies less massive than the Small Magellanic Cloud (stellar mass <10^9 solar masses at z = 0) as critical systems for tests of concordance cosmology, important contributors to cosmic reionization, and attractive targets for direct detection of dark matter. Because of their faintness, the *only* way to characterise the evolution of these small galaxies over time is in the Local Universe. Through photometric measurement of individual stars down to the oldest main-sequence turnoff with HST, combined with spectroscopic abundance studies of stars of all ages from ground-based 8-10m telescopes, the star formation and chemical evolution histories of dwarf galaxies can be reconstructed from the present-day all the way back to the oldest surviving stellar populations. I present a summary of recent results for Local Group dwarf galaxies spanning a range of mass, morphology, and environment and compare our findings to the results of cosmological simulations of galaxy growth. Because of the confounding effects of disturbance by massive neighbours, I will concentrate on the properties of isolated systems at the fringes of the Local Group.

Hector Ibarra
Instituto de Astronomia

The Global and Local Stellar Mass Assembly Histories of Galaxies from the MaNGA Survey

By means of the fossil record method implemented through Pipe3D we reconstruct the global and radial stellar mass growth histories (MGHs) of a large sample of galaxies in the mass range 10^8.5 to 10^11.5 solarM from the ``Mapping nearby Galaxies at the Apache Point Observatory" survey. We find that the main driver of the global MGHs is mass, with more massive galaxies assembling their masses earlier (downsizing). The global mean MGHs also segregate on average according to their color, specific star formation rate (sSFR), and morphological type. The spatially-resolved mean MGHs depend more on these properties than on mass, with blue/star-forming/late-type galaxies having on average a more pronounced and regular inside-out formation mode than red/quiescent/early-type galaxies. For the latter, the outermost MGHs (up to 1.5 R_50) present a large diversity of shapes, in many cases with signs of older stellar populations than in the innermost regions. For most galaxies in their late evolutionary stages (or high fractions of assembled mass) the innermost regions formed earlier than the outermost ones (inside-out). At earlier epochs, the radial MGHs of galaxies more massive than 10^10 solarM shorten the differences between them or even transit to an outside-in mode, specially the red/quiescent/early-type ones. For less massive galaxies, specially the dwarf ones, their radial MGHs are very diverse most of the time, with periods of outside- in and inside-out modes (or strong radial migration), evidencing this an episodic and stochastic formation. We discuss our results in the light of the processes of galaxy formation, quenching, and radial migration. We discus also on the uncertainties and biases of the fossil record method and how they could affect our results

---

Christina Baldwin
Macquarie University

Early-Type Galaxy Stellar Populations in the Near-Infrared

The near-infrared is a little-studied, but information-rich, regime for understanding the stellar content of galaxies. It contains tracers of important but poorly understood phases of stellar evolution, such as the Thermally Pulsating Asymptotic Giant Branch phase, as well as tracing the faint low-mass stars that, by number and combined mass, dominate the stellar populations of galaxies.

We have obtained high quality near-infrared spectroscopy using the GNIRS spectrograph on Gemini North to study a subset of galaxies from the ATLAS3D Survey, with the aim of characterising their near-infrared properties. In this talk, I will present the results of full-spectral fitting of these data, as well as the measurement of a number of spectral indices. Specifically, I will compare and contrast the star-formation histories derived from the near-infrared and optical regimes, and compare predictions from different stellar population models. Preliminary results comparing the IMF measured from these spectra with that inferred from dynamical modelling will also be presented if time permits.

Nicholas Scott
The University of Sydney

Extragalactic Archaeology with SAMI

The stellar population of a galaxies encodes a record of its entire formation history. This history can be unravelled using optical spectroscopy combined with modern stellar population modelling techniques. The SAMI Galaxy Survey is a large, spatially resolved spectroscopy survey of galaxies spanning a broad range in mass, environment and morphology. Using SAMI data, we show how the age, metallicity and abundance patterns of the local galaxy population depend on their structure and environment. Taking advantage of SAMI's spatially resolved data, we extend this analysis to radial gradients in stellar age and metallicity, and examine how stellar population gradients can constrain possible formation scenarios for different morphologies and environments.
