The Many Pathways to Galaxy Growth

Monash University Prato Centre
22-26 June, 2015
Abstract Booklet
# The Many Pathways to Galaxy Growth

## Monday

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<td>8:30-8:55</td>
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<tr>
<td>8:55-9:00</td>
<td>Welcome</td>
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<tr>
<td>9:00-10:30</td>
<td>Taylor (Invited), What we think we know: the phenomenology of galaxy evolution from studies of galaxy demographics</td>
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<td></td>
<td>Moran, The Progenitors of Today’s Ultra-massive Galaxies Across Cosmic Time</td>
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<td>Feldman, Growth and Quenching of Massive Galaxies at z&gt;2</td>
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<td>10:35-11:25</td>
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<td>11:25-1:05</td>
<td>Nipoti, Cosmological growth of massive early-type galaxies</td>
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<td>Hudson, Co-evolution of galaxies and their dark matter haloes from weak lensing</td>
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<td>Fraser-McKelvie, The Early State of Star Formation in Local Universe Brightest Cluster Galaxies</td>
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<td>Carlott, The Build-Up Of The Red Sequences in High Redshift Galaxy Clusters</td>
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<td>1:05-2:30</td>
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<td>2:30-4:00</td>
<td>Monaco (Invited), Coupling small and large scales: how massive and dying stars drive the formation of a galaxy</td>
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<td>van de Voort, The effect of strong stellar feedback on galaxy evolution</td>
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<td>Lacey, Galaxy vs halo growth: insights from galaxy formation models</td>
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<td>4:00-4:30</td>
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<td>4:30-5:45</td>
<td>Pillepich, Building Late Type Spiral Galaxies and their Stellar Haloes by In-Situ and Ex-Situ Star Formation</td>
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<td>Rodriguez-Gomez, The merger rate and stellar assembly of galaxies in the Illustris Simulation</td>
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<td>Mundy, Connecting the most massive galaxies across cosmic time</td>
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## Tuesday

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<td>9:00-10:30</td>
<td>Wiersma (Invited), Tracing High-z galaxy kinematics: evolution of turbulent disks to quenched spheroids</td>
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<td>Stott, The KMOS Redshift One Spectroscopic Survey: The resolved Dynamics, Star Formation and Chemical Properties of 1000 z~1 star forming galaxies</td>
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<td>Quadri, The growth histories of M* galaxies: star formation and quenching</td>
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<td>Jurin, Bar effects on centralized gas properties in disc galaxies</td>
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<td>10:35-11:25</td>
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<td>11:25-1:05</td>
<td>Croom, The formation history of massive galaxies in dense environments</td>
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<td>Weisz, An Extreme Starburst in the Core of a Rich Galaxy Cluster at z ~ 1.7</td>
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<td>Noble, The Phase Space of z~1.2 Clusters: Probing Dust Temperature and Star Formation Rate as a Function of Environment and Accretion History</td>
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<td>Zhao, Exploring the progenitors of Brightest Cluster Galaxies at z~2</td>
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<td>2:30-4:00</td>
<td>Masters (Invited), Galaxy Zoo: the role of internal structures in the quenching of star formation in disc galaxies</td>
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<td>Fontanot, On the Hierarchical Origin of Galaxy Morphologies</td>
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<td>Lfelt, Beyond Bulges and Disks: Tracking the Metamorphosis of Galaxies at z&gt;2.5</td>
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<td>4:30-5:45</td>
<td>Pawel, Merger, starburst, post-merger, post-starburst... red sequence?!</td>
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<td>Terrazas, The Growth and Evolution of Milky Way-like Galaxies</td>
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<td>Soros, The manifestations of Hierarchical assembly: galaxy structure, morphology and stellar populations</td>
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<tr>
<td>9:00-10:30</td>
<td>Jogee (Invited), Transforming Galaxies since z~3 via Mergers, Gas Accretion, and Secular Processes</td>
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<td>Nelson, Spatially resolved H-alpha maps of 2000 galaxies at z~1-3: Evidence for the inside-out formation of disk galaxies</td>
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<td>Fossati, The role of environment on the growth of galaxies at z~1-2.5 from the KMOS-3D survey</td>
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<td>Wilman, An inside-out growth and outside-in truncation of star forming disk? Testing the role of star formation driven size growth with resolved H-alpha maps from KMOS-3D and HAGOS at z~0</td>
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<td>10:35-11:25</td>
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<td>11:25-1:05</td>
<td>Afree, Merger Versus Disk-Dominated ULRG Formation to z=2</td>
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<td>Crosswell, Slow and Fast Quenching in Groups using U-V-V maps</td>
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<td>Rowlands, Post-starburst galaxies: Pathways to the red sequence?!</td>
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<td>de Lorenzo-Caceres Rodriguez, The Importance of secular processes in the evolution of disc galaxies: star formation history of double bars</td>
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<td>Free Afternoon</td>
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<tr>
<td>6:00</td>
<td>Conference Dinner (Villa Antinori)</td>
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<td>Buses leave at 6pm from the Piazza dell’Arsenale, in front of the Castle (150 metres south of the Monash Prato Centre).</td>
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<td>9:00-10:30</td>
<td>Popping (Invited), The gas content of galaxies and fueling of star formation over cosmic time</td>
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<td>Serna, The cold gas content of early-type galaxies</td>
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<tr>
<td>10:35-11:25</td>
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<td>11:25-1:05</td>
<td>Grillo, Coming in from the Dark - Gas-fuelling and Star-Formation in the Group Environment</td>
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<td>T. Brown, The Effect of Star Formation and Environment on the Cold Gas Content of Nearby Galaxies</td>
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<td>Knijnman, The multiscale nature of galactic star formation across cosmic time</td>
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<td>Shabala, AGN triggering and feedback of milliarcsecond resolution</td>
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<td>2:30-4:00</td>
<td>Gentile, The unusually M-rich galaxy: GASS 3505</td>
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<td>Lulu, How do galaxies accrete gas and form stars?</td>
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<td>M. Brown, New Star Formation Rate Calibrations Derived from a Multi-wavelength SED Atlas</td>
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<td>4:30-5:45</td>
<td>Owers, The SAMI Galaxy Survey: Cluster properties and the impact on galaxy star formation</td>
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<td>Zucker, Tracing the Accretion History of the Milky Way through Chemical Tagging</td>
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<td>Mendez-Abreu, The Growth of S0 Galaxies: Fading vs mergers</td>
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<tr>
<td>9:00-10:30</td>
<td>Boylan-Kolchin (Invited), Adventures at the Low-Mass Threshold of Galaxy Formation</td>
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<td>Sherwood, The Role of Dwarf-Dwarf Interactions in the Assembly History of Galaxies</td>
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<td>Kazzurek, Slingshot Dwarf Galaxies at z ~ 1: UV Colors, Stellar Masses and Star Formation Rates</td>
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<td>Penny, Quenched void galaxies in the Galaxy and Mass Assembly (GAMA) survey</td>
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<td>11:25-1:05</td>
<td>Guarantucci, Nuclear Star Clusters: an illustration of scale coupling in dwarf galaxies</td>
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<td>Croom, Many views of quenching from SAMI</td>
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<td>Scott, Stellar metallicity gradients as a function of maps, morphology and environment</td>
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<td>Bloom, Dangerous Liaisons: Asymmetry in Gas Kinematics in the SAMI Galaxy Survey</td>
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<td>2:30-4:00</td>
<td>Karataş, Study of the growth of massive galaxies based on their outer stellar populations</td>
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<td>Sironi, The masses of galaxy group satellites through weak gravitational lensing with KiDS: Evidence for tidal stripping</td>
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<td>Forbes, The Growth of Massive Bipolar Galaxies (Closing Remarks)</td>
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## The Many Pathways to Galaxy Growth

### Poster Program Summary

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<td>Swinburne University</td>
<td>The effects of environment on the growth of Galaxies at z=1-2</td>
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<td>Josh</td>
<td>University of St Andrews</td>
<td>Insights into bulge evolution during the last ~10 Gyr.</td>
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<td>Robert</td>
<td>Swinburne University of Technology</td>
<td>Extremely Star-Forming z=0.1 Galaxies as Probes of High Redshift Disk Formation</td>
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<td>Nina</td>
<td>McGill University</td>
<td>The Infrared Spectral Energy Distribution of SpARCS Brightest Cluster Galaxies</td>
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<td>Nicolas</td>
<td>Monash University</td>
<td>What Shapes the Local 1.4 Gla Galaxy Luminosity Function?</td>
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<td>Emanuelu</td>
<td>Purple Mountain Observatory, Nanjing [China]</td>
<td>Do Brightest Cluster Galaxies and Intra-Cluster Light grow through the same mechanisms?</td>
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<td>Luca</td>
<td>Dipartimento di Astronomia, Universita di Padova</td>
<td>Studying the Intrinsic Shape of 50 Bulges to Unveil their Formation Process</td>
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<td>Tim</td>
<td>Monash University</td>
<td>A Signature of Merger Driven Star Formation in Spiral Galaxies</td>
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<td>Michael</td>
<td>University of Queensland</td>
<td>Galaxy types and galaxy growth in the group environment</td>
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<td>Fangela</td>
<td>Purple Mountain Observatory, Chinese Academy of Sciences</td>
<td>Properties of high-z emission-line galaxies and escape fraction of Lyman-alpha photons from star-forming galaxies at z=2.24</td>
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<td>Dane</td>
<td>Monash University</td>
<td>The Neutral Hydrogen Content of Early-type and Late-type Galaxies.</td>
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<td>Thomas</td>
<td>KIG, Portsmouth</td>
<td>The evolving demographics of the red sequence since z=1</td>
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<td>Alessio</td>
<td>Peking University</td>
<td>Multicolour evolution of galaxy populations as seen from a hydro-cosmological simulation and a semi-analytical model</td>
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<tr>
<td>Giulia</td>
<td>Swinburne University</td>
<td>Galaxy visection and the intimate black hole-bulge connection</td>
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<td>Sarah</td>
<td>KIAA, ANU</td>
<td>An adaptive optics view of the morphological evolution of galaxies during 1 &lt; z &lt; 2.</td>
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<td>Bryan</td>
<td>University of Michigan</td>
<td>The Growth and Evolution of Milky Way-like Galaxies</td>
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<td>Sebastian</td>
<td>University of Zurich</td>
<td>Radiation feedback and the halo fountain as a pathway for the growth of galaxies at z=1</td>
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<td>Zhangheng</td>
<td>Purple Mountain Observatory</td>
<td>Probing Asymmetric Structures In The Outskirts of Galaxies</td>
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1 Monday 22 June

Invited Talk - What we think we know: the phenomenology of galaxy evolution from studies of galaxy demographics
Edward Taylor, University of Melbourne
9:00am Monday

Quantitative studies of galaxy demographics provide the empirical bedrock on which theoretical models of galaxy formation and evolution are founded. The quality of a cosmological model of galaxy formation is judged by its ability to reproduce the most basic demographics of real galaxy samples. This includes univariate distributions like the mass or luminosity functions, and/or bivariate distributions like the size-mass, colour-mass or mass-density relations. The field of galaxy formation and evolution is thus largely data-driven, and is likely to remain so for the foreseeable future.

In this talk, I will review some more and less recent observational results that, for better or worse, have helped shape our understanding of the physical processes that drive and govern galaxy formation and evolution. I will pay particular attention to attempts to quantify and elucidate the apparently fundamental dichotomy between the “developing” and “developed” galaxy populations, as a function of mass and environment. I will also present some of my own attempts in this direction.

The Progenitors of Today’s Ultra-massive Galaxies Across Cosmic Time
Cemile Marsan, Tufts University
9:40am Monday

Using the UltraVISTA catalogs, we investigate the evolution in the 11.4 Gyr since $z=3$ of the progenitors of local ultra-massive galaxies ($M_{\text{star}}=6\times10^{11} \text{Msun}$; UMGs), providing a complete and consistent picture of how the most massive galaxies at $z=0$ have assembled. By selecting the progenitors with a semi-empirical approach using abundance matching, we infer a growth in stellar mass of a factor of 3.5 since $z=3$. At $z < 1$, the progenitors constitute a homogeneous population of only quiescent galaxies with old stellar populations. At $z > 1$, the contribution from star-forming galaxies progressively increases, with the progenitors at $2 < z < 3$ being dominated by massive ($M_{\text{star}}=2\times10^{11} \text{Msun}$), dusty ($A_V=1-2.2$ mag), star-forming (SFR = 100-400 Msun/yr) galaxies, but also including quiescent (i.e., post-starburst) galaxies. Most of the quenching of the star-forming progenitors happened between $z=2.75$ and $z=1.25$, in good agreement with fossil records of $z=0$ UMGs. The progenitors of local UMGs, including the star-forming ones, never lived on the blue cloud since $z=3$. We propose an alternative path for the formation of local UMGs that refines previously proposed pictures and that is fully consistent with our findings. Preliminary results on the structural evolution and the environment of the progenitors of local UMGs will be also presented.
Growth and Quenching of Massive Galaxies at $z > 2$
Robert Feldmann, University of California, Berkeley
10:05am Monday

Observations show a prevalence of high redshift galaxies with large stellar masses and predominantly passive stellar populations. A variety of processes have been suggested that could reduce the star formation activity of such galaxies to the observed levels, including quasar mode feedback, virial shock heating, cosmological starvation, or galactic outflows driven by stellar feedback. However, the quenching mechanism that operates in the majority of massive galaxies has yet to be properly identified.

I will shed new light on this question with the help of a recent, ultra-high resolution (10 pc) suite of cosmological simulations, the MassiveFIRE project. MassiveFIRE simulates the evolution of dozens of massive galaxies at $z > 2$ in a large cosmological volume with state-of-the-art stellar feedback models. I will discuss how the various physical processes affect star formation and stellar mass growth in these galaxies and highlight the role of the local galactic environment.

Probing the growth of massive quiescent galaxies with KMOS
Trevor Mendel, MPE
10:30am Monday

Demographics of the galaxy population change rapidly from $1 < z < 2$, when the Universe transitions from peak star formation at $z > 2$ to an era where quenching shapes galaxies as we know them today. In this talk I will discuss recent progress studying the rest-frame optical properties of quiescent galaxies at this critical epoch using KMOS - a multi-IFU near-infrared spectrograph on the VLT - and in particular highlight recent results from the VIRIAL survey, whose aim is to provide a census of quiescent galaxies at $1.5 < z < 2$. I will focus here on results from the first year of survey data. The combination of kinematic measurements from KMOS and structural parameters measured from deep CANDELS and 3D-HST imaging allow us to place constraints on evolution of the fundamental plane at high redshift.

Coffee Break
10:55am-11:25am Monday
Cosmological growth of massive early-type galaxies
Carlo Nipoti, Bologna University
11:25am Monday

Massive early-type galaxies (ETGs) are on average more compact (smaller size and higher velocity dispersion) at higher redshift. Galaxy mergers are believed to contribute substantially to this cosmological galaxy growth. I will present the results of theoretical models for the joint evolution of mass, size and velocity dispersion of ETGs in a LambdaCDM universe, based on cosmological and binary-merging N-body simulations. Models and observations are consistent at $0 < z < 2$, while there is tension at $z > 2$, in the sense that real galaxies evolve in size faster than expected. At lower z further observational constraints derive from the measurement, in lens ETGs, of the total mass density slope within the Einstein radius, which is found to be almost constant at $z < 1$. When compared with these observations our models support a scenario in which the outer regions of massive ETGs grow by accretion of stars and dark matter, while small amounts of dissipation and nuclear star formation conspire to keep the mass density profile approximately isothermal.

Co-evolution of galaxies and their dark matter haloes from weak lensing
Michael Hudson, University of Waterloo
11:50am Monday

Galaxy-galaxy weak lensing is a direct probe of the mean matter distribution around galaxies. The depth and sky coverage of the CFHT Legacy Survey yield statistically significant galaxy halo mass measurements over a much wider range of stellar masses and redshifts ($0.2 < z < 0.8$) than previous weak lensing studies. We find, for the first time from weak lensing alone, evidence for significant evolution in the stellar-to-halo mass ratio (SHMR): the peak ratio falls as a function of cosmic time, and shifts to lower stellar mass haloes. These evolutionary trends are dominated by red galaxies, and are consistent with a model in which the stellar mass above which star formation is quenched “downsizes” with cosmic time. In contrast, the SHMR of blue, star-forming galaxies is well fit by a power law that does not evolve with time. This suggests that blue galaxies form stars at a rate that is balanced with their dark matter accretion in such a way that they evolve *along* the SHMR. This can be used to constrain the mean star formation rate of the galaxy population over cosmic time.

The Rarity of Star Formation in Local Universe Brightest Cluster Galaxies
Amelia Fraser-McKelvie, Monash University
12:15pm Monday

Brightest cluster galaxies (BCGs) are the most massive galaxies in the local Universe, located in extreme environments. While it is well known that the bulk of BCGs are red, there is a well studied portion with vigorous star formation, sometimes coupled with AGN activity. In the low redshift Universe, Perseus A is a prime example, displaying a SFR $> 30$M$_\odot$/yr, whilst being the archetypal example of AGN feedback. The exact portion of star forming BCGs in the local Universe is unknown however, as is the significance of this star formation. The Wide-Field Infrared Survey Explorer (WISE) AllWISE Data Release provides the first measurement of the 12 micron star formation indicator for all BCGs in the nearby Universe. We assemble a sample of 245 BCGs that constitute a volume limited sample at $z < 0.1$ from clusters with X-ray luminosity $> 10^{44}$ erg/s to measure BCG star formation rates. 93% of the sample possesses IR SFRs of $< 1$M$_\odot$/yr, while just 1% display SFR $> 10$M$_\odot$/yr. Perseus A is in the tiny minority of vigorously star forming BCGs, an outlier in a mostly passive population (FraserMcKelvie et al., 2014).
The Build-up Of The Red Sequence in High Redshift Galaxy Clusters
Pierluigi Cerulo, Swinburne University of Technology
12:40pm Monday

Clusters of galaxies are the most massive virialised cosmic structures. The diversity of their environmental conditions, from the dense cores to the sparse outskirts, allows them to be used as observational laboratories for the study of the environmental drivers of galaxy evolution. Furthermore, they host the widest range of galaxy masses, from giant ellipticals to dwarf spheroids. I present the results of the studies of the build-up of the red sequence and of the morphological transformation of galaxies in a sample of 9 clusters at $0.8 < z < 1.5$ from the HAWK-I Cluster Survey (HCS). The comparison with the $z = 0.05$ clusters of the WINGS survey shows that the cluster red sequence was already assembled at $z \sim 1$ down to magnitudes $V = -19.0$ mag with no deficit of galaxies at the faint end. We find that unlike nearby clusters, in which S0 galaxies become the most frequent type on the red sequence at magnitudes $V > -21.0$ mag, the HCS red sequence is dominated by elliptical galaxies at all luminosities. Interestingly, the bright end of the red sequence ($V < -21.0$ mag) is dominated by ellipticals at low and high redshift. Our results suggest that the cluster red sequence underwent a fast build-up as a consequence of the enrichment from quenched (preprocessed) galaxies accreted with satellite groups on to a main proto-cluster at $z > 2$. Our analysis supports the notion that elliptical and S0 galaxies follow different evolutionary paths, with the latter being the result of the morphological transformation of quiescent disc galaxies on the red sequence. I discuss possible scenarios for the evolution of the red sequence in high redshift clusters and for the relations between red sequence build-up and morphological transformations in dense environments.

Lunch
1:05pm-2:30pm Monday

Invited Talk - Coupling small and large scales: how massive and dying stars drive the formation of a galaxy
Pierluigi Monaco, Universit di Trieste
2:30pm Monday

Star formation and its associated feedbacks take place at very small, sub-pc scales, yet they extend their influence on very large scales, shaping the host galaxies and leading to the ejection of gas and metals from dark matter halos to the Inter-Galactic Medium. I will first review the microphysics of this process, highlighting the various forms of feedback that emerge from star formation: radiation pressure, ionising light, stellar winds, SN explosions not to mention the production of metals and dust. The expansion of correlated blasts and the effect of radiation pressure are the main responsible for the efficiency of feedback in driving thermal heating and turbulence of the ISM, and massive gas outflows or fountains. I will quickly describe how these processes are implemented in semi-analytical models and in cosmological simulations where resolution does not allow to fully resolve the ISM, and will discuss how different choices lead to different formation histories of galaxies. Finally, I will comment on how stellar feedback behaves at high redshift, highlighting a possible bimodal behaviour of star formation and discussing how the cycle of baryons in relatively small dark matter halos ($10^{10}$ to $10^{12} M_\odot$) is probably the most crucial process to produce realistic galaxies.
The effect of strong stellar feedback on galaxy evolution
Freeke van de Voort UC Berkeley & ASIAA
3:10pm Monday

Galactic winds are necessary to reduce the star formation rate in simulated galaxies to match observations. However, these outflows can be so violent that they completely destroy the gas disc. Maintaining a gas disc for a sufficiently long time in order to form a stellar disc thus becomes difficult. I will show results from a cosmological zoom-in simulation of a Milky-Way mass galaxy with efficient feedback, part of the Feedback In Realistic Environments (FIRE) project, which does form a stellar disc at low redshift. The formation of this disc is directly connected to the galaxy’s star formation history, its accretion history, and the redshift-dependent intensity of galactic winds. I will contrast this with the formation of a more massive elliptical galaxy in a group environment, also part of FIRE. This galaxy shows high inflow and outflow rates even at low redshift, which change its morphology. Interestingly, it maintains a relatively low star formation rate, even though only stellar feedback and no black hole feedback is implemented. The outflows generated by supernovae can shock, reach high temperatures, and emit X-ray radiation. However, X-ray binaries in the galaxy and diffuse halo gas heated by the virial shock of the halo also contribute to the total X-ray luminosity. I will show the X-ray properties of these simulated galaxies and how they depend on star formation and feedback and discuss how X-ray observations can be used to constrain the contribution of galactic winds to the hot halo gas.

Galaxy vs halo growth: insights from galaxy formation models
Cedric Lacey, Durham
3:35pm Monday

I will use semi-analytical models of galaxy formation to explore the connection between the growth of stellar mass in galaxies and the growth of their host dark matter halos. I will focus in particular on our recent work on the evolution of the star-forming sequence and on the evolution of the stellar mass vs halo mass relation. Observations imply that specific star formation rates of star-forming galaxies increase steeply with lookback time to z=2. We find instead that our hierarchical galaxy formation model, when using standard formulations for supernova feedback and gas return to halos, predicts a slower evolution. We find that the origin of this discrepancy is that current models predict that, for a given galaxy, the growth of stellar mass approximately tracks the growth of halo mass. This is a result of a balance between gas cooling and accretion on the one hand, and star formation and gas ejection by supernova feedback on the other, and happens even though the net efficiency of converting baryons into stars is a strong function of halo mass. Investigating possible solutions to this problem, we found that changing the dependence of supernova feedback efficiency and star formation timescale on galaxy properties, while retaining a fit to the present-day galaxy stellar mass function, did not help. Instead, it seems that the timescale for gas ejected by supernova feedback to be reincorporated into galaxy halos may need to have a more complicated dependence on halo mass and redshift than normally assumed. On the other hand, our standard model predicts a stellar mass vs halo mass relation that evolves only weakly with redshift, in agreement with current observational results, but this appears quite sensitive to the modelling of supernova feedback in particular. I will discuss how these results on the evolution of the star-forming sequence and the stellar mass vs halo mass relation can be reconciled within the framework of hierarchical galaxy formation.

Coffee Break
4:00pm-4:30pm Monday
Building Late Type Spiral Galaxies and their Stellar Haloes by In-Situ and Ex-Situ Star Formation
Annalisa Pillepich, Harvard University
4:30pm Monday

In the standard LambdaCDM scenario, hierarchical clustering leads to complex galaxy assembly histories, and the paths leading to the build up of each major stellar component may be different. In particular, galactic stellar haloes are thought to be the direct evidence of the hierarchical growth of structure and numerical simulations have been able to reproduce their broad features from the debris of accreted and disrupted satellite galaxies. In the talk, I will adopt two complementary techniques with the specific purpose of understanding how baryonic physics and the hierarchical clustering leave imprints on the stellar assembly and the stellar distributions within haloes. On the one side, I will show the results of the detailed analysis of the Eris simulation, the first N-body+SPH simulated galaxy to result in a close analog of the Milky Way: I will give an account of the relative contributions of 'in-situ' (within the main host) and 'ex-situ' (within satellite galaxies) star formation to each major Galactic component of such close Milky Way analog. On the other side, I will support such findings by tackling a statistically-meaningful analysis of a large sample of galaxies from the Illustris Simulation. Illustris is a state-of-the-art simulation which combines the statistical power of a 106 Mpc-side cosmological volume with gasdynamics, prescriptions for star formation, feedback, and kpc resolution. For example, in the first work of a series (Pillepich 2014MNRAS.444..237P), we show that by solely measuring the power-law slope of the stellar density profile of the stellar haloes, quantitative information can be obtained regarding the total mass, density profile, formation time, and merger history of the underlying DM haloes.

The merger rate and stellar assembly of galaxies in the Illustris Simulation
Vicente Rodriguez-Gomez, Harvard-Smithsonian Center for Astrophysics
4:55pm Monday

We use the Illustris Simulation – a state-of-the-art hydrodynamic cosmological simulation which includes a realistic galaxy formation model – to investigate the stellar assembly of galaxies with different stellar masses. We have constructed merger trees by tracking the baryonic content of galaxies in Illustris. We use these merger trees to determine the galaxy-galaxy merger rate as a function of the stellar masses of the merging objects and redshift [reference here]. We compare our results with observations and predictions from semi-empirical models, and also provide an analytic fitting formula. Additionally, we have created a stellar assembly catalog which we use to address the following questions: (1) what fraction of the stellar mass of a galaxy was formed in other galaxies, (2) how does this ex-situ fraction depend on environment and merger history, as well as galaxy properties such as morphology, color, and star formation rate, (3) what fraction of the ex-situ stars was formed in galaxies after becoming satellites but before being quenched or disrupted.

Connecting the most massive galaxies across cosmic time
Carl Mundy, The University of Nottingham
5:20pm Monday

Understanding how galaxies become so massive and how and why their properties evolve are important questions in astronomy. Ideally, to answer these questions one would prefer to track the same galaxies over time, however this is not possible observationally. Even so, various sample selection methods are employed to try and connect galaxies across cosmic time. The efficacy of these selection methods has not been fully explored across a range of semi-analytical models (SAMs), dark matter merger trees and cosmology - all of which influence the growth of simulated galaxies. Using a suite of publicly available SAMs applied to the output of the cosmological Millennium Simulation, I will quantify and compare how well galaxy sample selections at a constant cumulative number density (in stellar mass) and above a constant stellar mass limit recover the evolution in the average physical properties of progenitor and descendant galaxy populations over the redshift range 0 < z < 3.
Invited Talk - Tracing high-z galaxy kinematics: evolution of turbulent disks to quenched spheroids
Emily Wisnioski, MPE
9:00am Tuesday

Kinematics and structural properties have revealed that the majority of ‘normal’ star-forming galaxies at z 1-3 host disk-like structure. Using recent observations from large near-infrared galaxy surveys, I will discuss the formation and evolutionary paths of high redshift disks. In particular, I will present results from the KMOS$^{3D}$ survey, a new integral field survey of over 600 galaxies at z=0.7-2.7 using KMOS at the VLT. KMOS$^{3D}$ utilises synergies with multi-wavelength ground and space-based surveys to trace the evolution of spatially-resolved kinematics and star formation from a homogeneous sample over 5 Gyrs of cosmic history. The un-biased selection of KMOS$^{3D}$ allows us to explore galaxy dynamics both on and below the star-forming ‘main sequence’ opening up new avenues in investigating evolutionary links between turbulent disks and quenched spheroids.

The KMOS Redshift One Spectroscopic Survey: The resolved Dynamics, Star-Formation and Chemical Properties of 1000 z 1 star forming galaxies
John Stott, Oxford
9:40am Tuesday

I will present the first results of KROSS, a major UK-led KMOS GTO survey to observe the redshifted H-alpha emission in 1000 star-forming galaxies at z=1. Selecting galaxies from the star-forming “main-sequence” (stellar masses 1e9.5 - 1e11.5 Msol and SFR 1-30 Msol/yr), KROSS will measure the resolved dynamics, chemistry and star formation in a statistical sample of galaxies in to address: (i) How does the fraction of disks evolve as a function of z and environment? (ii) are major (and minor) mergers more prevalent at high-z ? (iii) How does the relation between the star-formation, stellar mass and dark halo evolve with z and environment? (iv) How does the angular momentum of galaxy disks evolve with z, stellar mass and environment; (iv) Are chemical abundance gradients of early disks stronger or weaker than local spirals? These are critical issues for developing models of galaxy formation, in particular to determine if stellar mass assembly is dominated by secular isolation or via merger-induced growth. In this talk I will show the first 500+ galaxies from the sample, which already constitutes the largest ever resolved H-alpha survey at this redshift.

The growth histories of M* galaxies: star formation and quenching
Ryan Quadri, Texas A&M University
10:05am Tuesday

Despite a tremendous amount of discussion over the years, we still have very little understanding of the processes that quench star formation in galaxies. I will present new results on the star-formation histories of galaxies with present-day stellar masses near M*. These galaxies pass through a blue star-forming disky phase at early times, become redder and IR-bright at intermediate times, and the quenched fraction increases rapidly at later times. But what physical process is responsible for quenching the star formation? Environmental measurements suggest that halo mass may not be the dominant driver. On the other hand, there is an intriguing relationship between the evolution of galaxy structure and the efficiency of star formation.
Bar effects on central ionized gas properties in disc galaxies
Almudena Zurita, Universidad de Granada
10:30am Tuesday

We present recent results on the analysis of the central nebular emission for a sample of face-on disc galaxies with available SDSS spectra, for barred and unbarred galaxies separately. We find statistically significant differences in the central ionized gas properties, which imply a larger dust content, star formation rate per unit area, electron density and nitrogen-to-oxygen abundance ratio in the centres of barred galaxies than in the unbarred counterpart. However, there is no difference on the central oxygen abundance of barred and unbarred galaxies. The observed differences are larger for lower mass systems, while the bar seems to have a lower impact on the central gas properties of galaxies with total stellar mass above $10^{10.8} \, M_\odot$. Our results have important consequences for bulge formation and evolution, and support the hypothesis that bar–induced gas flows is the dominant mechanism for bulge formation and growth in later–type galaxies.

Coffee Break
10:55am-11:25am Tuesday

The formation history of massive galaxies in dense environments
Elizabeth Cooke, University of Nottingham
11:25am Tuesday

High redshift galaxy protoclusters are the precursors of today’s massive clusters; the sites of formation of the most massive galaxies in the present-day Universe. In this talk I will examine the formation history of massive galaxies within high redshift protoclusters. I have obtained a sample of 37 dense clusters and protoclusters at $1.3 < z < 3.2$, using radio-loud AGN as beacons for these galaxy overdensities. I use optical $i$-band, and infrared $3.6 \, \mu m$ and $4.5 \, \mu m$ images to statistically select sources within these protoclusters and measure their average observed $i-[3.6]$ colours. I find the abundance of massive galaxies within these overdensities increases with decreasing redshift, suggesting these objects form an evolutionary sequence, with the lower redshift (proto)clusters having similar properties to the descendents of those at high redshift.

I find that the high redshift protocluster galaxies have an approximately unevolving observed $i-[3.6]$ colour across the examined redshift range. I compare the evolution of the $<i-[3.6]>$ colour of massive cluster galaxies with simple galaxy formation models. Taking the full cluster population into account, I will show that the majority of massive galaxies in clusters formed over an extended period, lasting at least 2 Gyr, and peaking at $z \approx 2-3$. From the average $i-[3.6]$ colours I will show that the star formation in these massive galaxies must have been rapidly terminated to produce the observed red colours. Finally, I will show that massive galaxies at $z > 2$ must have assembled within 0.5 Gyr of them forming a significant fraction of their stars. This means that the formation mechanism of massive galaxies in clusters is redshift dependent: at $z > 2$, few massive galaxies formed via dry mergers, whereas at $z < 2$ dry merging is a more important formation mechanism.
An Extreme Starburst in the Core of a Rich Galaxy Cluster at $z = 1.7$

Tracy Webb, McGill University
11:50am Tuesday

We announce the discovery of a rich galaxy cluster at $z = 1.708$ with a star-bursting core. The system, SpARCS104922.6+564032.5, hereafter called SpARCS1049+56, was detected within the Spitzer Adaptation of the Red-Sequence Cluster Survey (SpARCS), and is confirmed through Keck-MOSFIRE spectroscopy with 22 members across a 6×3 arcminute field-of-view. The halo mass is not yet well-constrained, however the rest-frame optical richness measurement of $N_{\text{gal}}(500\text{kpc}) = 30\pm8$ implies a substantial system of $\sim 3.8\pm1.2\times10^{14} \, M_\odot$, comparable to the handful of other clusters known at or above this redshift.

The cluster is located within the SWIRE-Lockman field and thus there is a wealth of ancillary data available, including CFHT optical, UKIRT-K, Spitzer-IRAC/MIPS, and Herschel1-SPIRE. We add to this new submillimeter imaging with the SCUBA2 bolometer array on the James Clerk Maxwell Telescope and near-infrared imaging with the Hubble Space Telescope (HST). The mid/far-infrared (M/FIR) data have detected an Ultra-luminous Infrared Galaxy coincident with the cluster core, with an estimated luminosity of $L_{\text{IR}} = 6.6\pm0.9\times10^{12} \, L_\odot$. The detection of polycyclic aromatic hydrocarbons (PAHs) at $z = 1.7$ in an archival Spitzer-IRS spectrum of the source implies the infrared luminosity is dominated by star formation, with a rate of $\sim1140\pm162 \, M_\odot$ yr$^{-1}$. The optical responsible for the IR emission is ambiguous because of the uncertainty in the IR-derived position, but it is likely a chain of neighbouring objects revealed by the HST. This structure is composed of $>10$ individual clumps embedded in diffuse emission and arranged as “beads on a string” over a linear scale of 66 kpc. Its morphology and proximity to the BCG imply a gas-rich interaction at the centre of the cluster which may have triggered the extreme starburst. This system is the first observational indication that wet mergers of gas-rich galaxies may be an important process in forming the stellar mass of BCGs at early times.

The Phase Space of $z=1.2$ Clusters: Probing Dust Temperature and Star Formation Rate as a Function of Environment and Accretion History

Allison Noble, University of Toronto
12:15pm Tuesday

Understanding the influence of environment is a fundamental goal in studies of galaxy formation and evolution, and galaxy clusters offer ideal laboratories with which to examine environmental effects on their constituent members. Clusters continually evolve and build up mass through the accumulation of galaxies and groups, resulting in distinct galaxy populations based on their accretion history. In Noble et al. 2013, we presented a novel definition for environment using the phase space of line-of-sight velocity and cluster-centric radius, which probes the time-averaged density to which a galaxy has been exposed and traces out accretion histories. Using this dynamical definition of environment reveals a decline in specific star formation towards the cluster core in the earliest accreted galaxies, and was further shown to isolate post-starburst galaxies within clusters (Muzzin et al. 2014). We have now extended this work to higher-redshift clusters at $z=1.2$ using deep Herschel-PACS and -SPIRE data. With a sample of 120 spectroscopically-confirmed cluster members, we investigate various galaxy properties as a function of phase-space environment. Specifically, we use 5-band Herschel photometry to estimate the dust temperature and star formation rate for dynamically distinct galaxy populations, namely recent infalls and those that were accreted into the cluster at an earlier epoch (Noble et al. in prep). These properties are then compared to a field sample of star-forming galaxies at $1.1 < z < 1.2$ to shed light on cluster-specific processes in galaxy evolution. In this talk I will discuss the various implications of a phase-space definition for environment, and present our most recent results, focusing on how this accretion-based definition aids our understanding of quenching mechanisms within $z=1.2$ galaxies.
Exploring the progenitors of Brightest Cluster Galaxies at $z \sim 2$
Dongyao Zhao, University of Nottingham
12:40pm Tuesday

The evolution of BCGs is important to understand the merging history in galaxy clusters, but observationally it is hard to select the progenitors of BCGs beyond $z \sim 1$. In this work, by discussing the correlation between BCG progenitors and their environments at $z \sim 2$ in simulation, we propose a method which could select BCG progenitors at $z \sim 2$ more easily by observational data. Applying this method to UDS data, the size evolution of BCGs is discussed. Our assumption on the BCG progenitors is that at high redshift the candidates of progenitors are the most massive galaxies in the densest regions (our density is the overdensity measured by galaxy counts in fixed aperture). Testing it in simulation, we find only less than 50% of local BCGs can be traced back to their real progenitors at $z \sim 2$. The fraction is similar by using the density measured in different fixed aperture. If the top-two and top-three massive galaxies in the densest regions are also considered as the candidates of the BCG progenitors, the fraction that can find the real progenitors does not increase significantly. These imply that at $z \sim 2$ the real BCG progenitors neither have a distinct stellar mass nor reside in a distinct region. Although the environmental density is not a strong tracer to find the real BCG progenitors, statistically the size/stellar mass distribution remain similar if we contaminate the real BCG progenitors with other most massive galaxies in densest regions. This implies that our method that selecting the most massive galaxies in densest regions can be still applied to observational data that the statistical properties of the selected galaxies can represent the value of real BCG progenitors. We apply this method to UDS data. Comparing with the local BCGs, we find that from $z \sim 2$ the BCGs have grew in size by a factor of 4. By using this method, we can also study the mass assembly of BCGs in future.

Lunch
1:05pm-2:30pm Tuesday

Invited Talk - Galaxy Zoo: the role of internal structures in the quenching of star formation in disc galaxies
Karen Masters, Portsmouth
2:30pm Tuesday

Important clues to the formation history of galaxies can be found in their morphologies. These data provide complimentary information to the star formation history and chemical composition as revealed by photometry and spectra. The sheer size of recent extragalactic surveys had until a few years ago made the visual classification of galaxy morphologies impractical, and computer algorithm proxies were limited. The Galaxy Zoo project (www.galaxyzoo.org) solved this problem by asking members of the public to help classify galaxies via an internet tool, and has been part of a reinvigoration of interest in the morphologies of galaxies and what they reveal about the evolution of galaxies. The morphological information collected by Galaxy Zoo has shown itself to be a powerful database for studying galaxy evolution, with more than 60 peer-reviewed papers on a variety of topics. In this talk I will discuss results which combine visual morphologies from the Galaxy Zoo project with other information about the galaxies to investigate the physical processes which quench star formation in spiral galaxies.
On the Hierarchical Origin of Galaxy Morphologies.
Fabio Fontanot, INAF - OATs
3:10pm Tuesday

I consider predictions from semi-analytic models (SAMs) of galaxy formation, which implement different prescriptions for bulge formation, in order to quantify the relative importance of the different physical processes leading galaxies to acquire their observed morphologies. I will show the distribution of morphological types as a function of stellar and halo mass and discuss the evolutionary paths leading to the formation of specific galaxy populations, such as elliptical galaxies and bulgeless galaxies, with particular emphasis on the reported tensions between observations and model predictions. I will also show that the fraction of star forming and passive galaxies are both well reproduced in SAMs, and that argue that these discrepancies are a direct consequence of the assumed modeling of the morphological transformation associated with galaxy mergers. I will then discuss possible revisions of SAMs prescriptions, based on the results of recent high-resolution hydrodynamical simulations of binary mergers, and their implication for our understanding of the process leading to the formation of spheroids. The results clearly indicate that the main tension between theoretical models and data does not stem from the survival of purely disc structures (i.e. bulgeless galaxies), rather from the distribution of galaxies in different morphological types, and as a function of their stellar mass.

Beyond Bulges and Disks: Tracking the Metamorphosis of Galaxies at $z < 2.5$
Jennifer Lotz, STScI
3:35pm Tuesday

A galaxy’s assembly history is encoded in its stellar mass, star-formation history, kinematics, and morphology. The structures of galaxies provide direct insight into their most recent assembly events, as well as longer timescale secular processes that drive star-formation and quenching. Thanks to SDSS and HST, we now have a broad-brush picture of how galaxy structures evolve over the past 10 billion years. Yet the processes for bulge formation, star-formation quenching, and early-type galaxy assembly remain unclear. Coarse bulge/disk/irregular structural classifications fail to capture the complex processes responsible for the morphological transformation of galaxies. I will present new quantitative non-parametric methods for measuring structure and classifying galaxy morphology, which make minimal assumptions about the intrinsic shapes and statistical distributions of galaxies. When applied to galaxies at $z > 1$, this approach naturally separates quenched compact galaxies from larger, smooth proto-elliptical systems, and star-forming disk-dominated clumpy galaxies from star-forming bulge-dominated asymmetric galaxies. At $> 5 \times 10^{10}$ $M_{\odot}$ and $z > 1$, smooth extended bulge-dominated systems are more likely to be star-forming than compact galaxies; this is broadly consistent with cosmological zoom-in simulations that predict the minor-merger triggered appearance of extended star-forming disks at $z \sim 1 - 1.5$ around compact cores formed at $z > 2$. We track the observed $0.5 < z < 2.5$ evolution of fixed non-parametric morphological classes, and find that much of the size evolution of Sersic-classified bulges and disks may be explained by the preferential quenching of disks in the smallest bulge + disk systems at a given epoch. These observational results are consistent with the theoretical picture derived from correlations among galaxy structure, star formation, mass, and kinematics at $z = 0$ in the Illustris simulation: quenching and the resulting morphological transformations are natural consequences of the stellar + AGN feedback required to produce consistent global star-formation and halo occupation functions.

Coffee Break
4:00pm-4:30pm Tuesday
Merger, starburst, post-merger, post-starburst... red sequence?
Milena Pawlik University of St Andrews
4:30pm Tuesday

Galaxies that show evidence of a rapid increase and subsequent quenching of star formation could be the result of gas-rich major mergers, and may be transitioning between the ‘blue cloud’ and the ‘red sequence’. Studying the properties of galaxies with post-starburst stellar populations will lead to a better understanding of the role of mergers in galaxy growth.

The aim of this work is to quantify the morphological evolution of galaxies passing through the post-starburst phase. Using visual classification we find a clear excess of post-merger features in our post-starburst sample, with the excess declining steadily with increasing starburst age. However, we find that traditional methods of automated morphology measurement do not reliably identify post-merger features that are visible by eye. I will introduce a new, robust and physically meaningful automated method for the quantitative measurement of morphology of post-mergers. Combining visual and automated approaches we find presence of tidal features in 50% of young local post-starburst galaxies (< 0.1 Gyr) and a decline of such features over the following 0.5 Gyr. We use our new method to compare the evolution of the morphology of post-starburst galaxies to those from hydrodynamic simulations of galaxy mergers.

The Growth and Evolution of Milky Way-like Galaxies
Bryan Terrazas, University of Michigan
4:55pm Tuesday

We use the semi-analytic model developed by Henriques et al. 2014 in order to gain insight on the evolution of Milky Way-mass galaxies. Tracing their growth histories back to z=2, we find there is an enormous diversity of progenitor masses, indicating the existence of a myriad of pathways to the Milky Way’s stellar mass at the present day. Our study focuses on clarifying where this physical scatter in growth histories comes from. Separating those galaxies that are star-forming at the present day from those that become quiescent, we find that quiescent galaxies grow significantly more stellar mass at earlier times. In addition, the halo masses of galaxies that become quiescent are in general significantly larger than those of galaxies that have always been star forming. In fact, in the context of this model, halo mass plays an important role in determining when systems stop growing their stellar mass. Namely, the larger the halo mass, the earlier it stops forming stars, or quenches. The staggered quenching that occurs as a result of halo mass in the context of this model leads to a large range of stellar masses from which galaxies can eventually grow to have masses similar to that of the Milky Way. The quenching of galaxies also seems to depend heavily on black hole mass which grows via radio mode accretion. We analyze the connection between black hole mass and halo mass in the context of this model and relate this to quenching mechanisms. Our results provide a possible explanation for what may cause the diversity of growth histories and how we can understand it in the larger context of galaxy formation and evolution.

The manifestations of hierarchical assembly: galaxy structure, morphology and stellar populations
Chiara Tonini, University of Melbourne
5:20pm Tuesday
I will present the predictions of a new hierarchical model of galaxy formation, that focuses in detail on the growth of galaxies through different channels of mass accretion, determined by their assembly history. These include 1) the quiescent steady cooling of gas that leads to disk galaxies, 2) the assembly histories in more turbulent environments that lead to perturbations in the galaxy structure - the so-called secular processes - and the consequent evolution of morphology and the formation of bulges, and 3) the dramatic transformations and mass accretion due to galaxy mergers. I will present the physics that allows the model to follow these different channels of growth, and discuss how these influence the structural parameters of galaxies (size and mass distribution) and their star formation history, manifested in the stellar populations that compose them. I will also discuss the observational signatures that these different channels of mass growth imprint on the galaxy population.
Wednesday 24 June

Invited Talk - Transforming Galaxies since $z \geq 3$ via Mergers, Gas Accretion, and Secular Processes
Sharda Jogee, University of Texas at Austin
9:00am Wednesday

In this talk, I will review how galaxies grow and restructure their baryonic and dark mass over cosmic time through different growth pathways, including major and minor mergers, gas accretion, and secular processes. I will review the impact of these modes on the star formation activity, active galactic nuclei (AGN) activity, structural transformation and chemical evolution of galaxies over the last 90% of cosmic time. Tensions and agreements between observations and theoretical predictions from hierarchical models will be outlined. I will end with a discussion of prospects for future progress.

Spatially resolved Halpha maps of 2000 galaxies at $z \sim 1$: Evidence for the inside-out formation of disk galaxies
Erica Nelson, Yale University 9:40am Wednesday

Imaging surveys with HST have demonstrated that many galaxies attained their current forms at $z \sim 1$. Key to understanding this process is a direct measurement of the distribution of star formation within galaxies at this crucial epoch. This is now possible with the WFC3 grism capability on HST, as it provides Halpha maps of all galaxies at $0.7 < z < 1.5$ in its field of view. Using Halpha maps for $\sim 2000$ galaxies, we show where star formation is distributed in galaxies across the star formation - mass plane (the “main sequence”). We find that Halpha is always distributed in exponential disks, and that the disk scale length of Halpha is larger than that of the stellar continuum emission. This is a direct demonstration that galaxies at this epoch grow inside-out. In galaxies with higher than average star formation rates, Halpha is enhanced throughout the disk; similarly, in galaxies with low star formation rates Halpha is depressed throughout the disk. We discuss these results in the context of several proposed mechanisms for enhancing and quenching star formation. We also show first results of the spatial distribution of star formation at $z \sim 2-3$. 


The role of environment on the growth of galaxies at $z \sim 1$-2.5 from the KMOS$^{3D}$ survey
Matteo Fossati, Universitaet Sternwarte Munchen / MPE
10:05am Wednesday

Galaxy disks form as gas cools, conserving the angular momentum of the accreting gas from its environment. At high redshift, high gas fractions drive high star formation rates, but also a variety of disk morphologies from compact to larger than the stellar disk, which relates to the external environment of the galaxy. We investigate the growth of galaxies above and below the main sequence using spatially resolved maps of Halpha and stellar continuum from the KMOS$^{3D}$ spectroscopic survey of 600 mass-selected galaxies at $z \sim 0.7$-2.5. We derive the local environment for KMOS$^{3D}$ galaxies by leveraging on the synergy with the 3D-HST survey that provides accurate redshifts for a deep and complete sample thanks to their HST spectroscopic observations. A robust definition of environment also requires accurate calibrations that I will present, using the most up to date semi-analytic model derived from the Millennium simulation. In this framework I present our first results on the importance of mechanisms driving the truncation of disks in dense environments. Those results are complemented and contrasted to the growth of galaxies in underdense environments across the full range of redshift and stellar mass probed by KMOS$^{3D}$.

An inside-out growth and outside-in truncation of star forming disks? Testing the role of star formation driven size growth with resolved Halpha maps from KMOS$^{3D}$ and HAGGIS at $z \sim 0$
David Wilman, USM/MPE
10:30am Wednesday

Galaxies grow in mass via star formation in their disks, moving them along the main sequence. Their overall growth appears to have been inside-out such that sizes increase with cosmic time. Until now it was not known whether this stellar size growth simply tracks a growth of the star forming gas disk, or if it is driven by internal redistribution of stars and external accretion via mergers as the halo grows. I will answer this question with data from H-Alpha Galaxy Group Imaging Survey (HAGGIS) at $z \sim 0$ and the KMOS$^{3D}$ survey at $z \sim 0.7$-2.5. Both surveys target samples of hundreds of galaxies representing all locations on the SFR-mass plane, and provide maps, and radial profiles of star formation via the Halpha emission line. Comparisons with stellar continuum profiles shows that disk star formation happens within or coincident to pre-existing stellar disks in most cases, and that a pure star formation driven growth in size is quite rare, limited to the most massive star forming objects. Many galaxies have a compact Halpha morphology relative to their stars, and we can explain these via a variety of physical scenarios.

Coffee Break
10:55am-11:25am Wednesday
Merger Versus Disk-Dominated ULIRG Formation to z=1
David Atlee, NOAO
11:25am Wednesday

In the local universe, ultra-luminous infrared galaxies (ULIRGs) represent a tiny fraction of star forming galaxies (SFGs), and they are largely a curiosity that allows us to examine how star formation behaves in extreme conditions. At high redshift (z ~ 2), they represent a much larger fraction of SFGs, and there are indications that they can form from normal disk galaxies instead of appearing in the remnants of gas-rich, major mergers, as they do today. Their clustering properties suggest that both ULIRGs and quasars at z ~ 2 are the parent population of massive elliptical galaxies seen today. We would therefore like to understand how ULIRGs form at high redshift. However, there are some inherent difficulties in studying the transition of ULIRGs from merger remnants to disks, including morphological K-corrections, which make it much harder to identify merger remnants at z=2 compared to z=0. We have used results from the MIPS AGN and Galaxy Evolution Survey (MAGES) to determine the frequency of ULIRGs in a galaxy population of fixed stellar mass. We use this frequency to determine the rate at which the ULIRG population grows relative to the major merger rate in their parent population as a function of redshift to z=1. This provides a statistical determination of the importance of major mergers to ULIRG formation over the relevant redshift range and allows us to probe whether disk-dominated ULIRGs become an important part of the ULIRG population by z=1 or whether this transformation happens at still earlier epochs.

Slow and Fast Quenching in Groups using NUV-r
Jacob Crossett, Monash University 11:50am Wednesday

While it is commonly accepted that most galaxies on the red sequence contain largely older stellar populations, it has been known that small amounts of star formation will still be present in these galaxies from their NUV-r colours (Yi et al. 2005; Kaviraj et al. 2007; Schawinski et al. 2007). This residual star formation has been found both Elliptical galaxies, and in optically red spiral galaxies (Crossett et al. 2014). This suggests that two different kinds of transitions are occurring within this population of red sequence galaxies, that may depend on morphology (analogous to Schawinski et al. 2014). I will present results using the NUV-r colour as a way to investigate the differences within this low star formation population in groups using Galex NUV data and SDSS (Martin et al. 2005; Yang et al. 2007). I show that when separated by light curves, the properties of these galaxies represent different pathways onto the red sequence. I will demonstrate that disk galaxies are preferentially undergoing a slow, isolated quench, compared to the recent burst of their bulge dominated counterparts.

Post-starburst galaxies: Pathways to the red sequence?
Kate Rowlands, University of St Andrews
12:15pm Wednesday

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 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-starbursts 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 molecular gas and dust 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 (Rowlands et al. 2015). Our results show that although a strong starburst may cause the galaxy to ultimately have a lower specific SFR 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.
The importance of secular processes in the evolution of disc galaxies: star formation history of double bars
Adriana de Lorenzo-Caceres Rodriguez, University of St Andrews
12:40pm Wednesday

With bars being considered the main drivers of secular evolution, double-barred galaxies are the perfect benchmark to test how important secular processes are in the evolution of disc galaxies. To this aim, we are carrying out a detailed study of double-barred galaxies, with special focus in their stellar populations. Our approach consists in combining integral-field and long-slit spectra in order to get the single stellar populations properties and star formation histories (SFH), respectively. Three different SFH codes are used, so our results are tested against fitting degeneracies and the virtues of each code are shown. Finally, the match of the stellar population analysis with the 2D kinematics allow us to recover a complete picture of the formation and evolution of double-barred galaxies.

Free Afternoon

Conference Dinner (Villa Artimino)
Evening, Wednesday

Buses leave at 6pm from the Piazza dell Carceri, in front of the Castle (150 metres south of the Monash Prato Centre).
4 Thursday 25 June

Invited Talk - The gas content of galaxies and fuelling of star formation over cosmic time
Gerg Popping, ESO
9:50am Thursday

A full understanding of galaxy growth requires a detailed knowledge of the gas evolution of galaxies and how this gas fuels star formation. With the advancements of the current and next generation of radio and sub-mm instruments a new era in astronomy will start soon, in which the gas properties for large numbers of galaxies at unexplored epochs will be revealed. In this talk I will first discuss the results of past and current surveys of the atomic and molecular hydrogen content of galaxies. I will highlight the evolution of the atomic and molecular gas mass of galaxies, atomic and molecular gas density of our Universe, gas consumption time scales, the relation between gas surface density and star-formation rate surface density, and the pros and cons of different observing strategies. In the second part of this talk I will discuss the main developments in the theoretical modelling of the multiphase gas content and star formation in galaxies and how predictions made by these models lead the way for future observations with the newest generation of instruments. I will finish by discussing some of the key gas information missing that will be necessary to further expand our theories of galaxy growth.

The cold gas content of early-type galaxies
Paolo Serra, CSIRO Astronomy & Space Science
10:20am Thursday

When viewed through their interstellar medium, early-type galaxies (E/S0s) constitute a surprisingly complex and diverse family – to some extent much more intriguing than that of gas-rich spirals. I will discuss recent results obtained in this field as part of the Atlas3D survey.

About half of all early-type galaxies host between $10^7$ and many times $10^9$ M(sun) of atomic/molecular hydrogen gas, reaching up to 10% of the stellar mass of the host. This gas is typically distributed on a disc with radius from a few to many tens of kpc. Surprisingly, gas discs are found around both fast- and slow rotators. Unsettled gas distributions are also common, in particular in dense environments. They reveal episodes of interaction between early-type galaxies and their surroundings which would go unnoticed at optical wavelengths.

This cold gas fuels low-level star formation both in the inner regions and at the outskirts of the stellar body. Furthermore, the variation of gas morphology and kinematics as a function of environment density shows that the gas accretion history of early-type galaxies is very different for objects living in isolation, in groups or in clusters.

A rich probe of this accretion history is the angular momentum misalignment between gas and stars. We find that gas and stars corotate in only half of the cases. In the remaining half the gas is distributed in a polar, counterrotating or warped configuration. This diversity may reflect the stochastic nature of gas accretion from satellites and from the intergalactic medium. Yet, LCDM hydrodynamical cosmological simulations – which should incorporate such stochastic gas accretion – do not reproduce the observed diversity of angular momentum misalignments. I will discuss recent and ongoing work in this area.
The complex cold gas properties of early-type galaxies highlight a diversity of formation histories which may be lost in the relative simplicity of their inner stellar morphology and kinematics. Future neutral hydrogen surveys with the SKA and its pathfinders will greatly expand this line of research by delivering much larger samples of objects across a range of lookback times.

**Coffee Break**
10:55am-11:25am Thursday

**Coming in from the Dark - Gas-fuelling and Star-Formation in the Group Environment**
Meiert Grootes, Max-Planck Institut fuer Kernphysik
11:25am Thursday

Accretion of onto galaxies (gas-fuelling) is a crucial yet so poorly constrained element of galaxy evolution. We address this using the Galaxy And Mass Assembly (GAMA) spectroscopic and multi-wavelength survey, in combination with novel, purpose built techniques of morphological classification and radiative transfer modeling of large samples of galaxies, to study the impact of the group environment on the current star-formation of non-interacting local universe \((z < 0.13)\) spiral galaxies. Contrary to the standard paradigm, gas-fuelling of satellite galaxies is found to be ongoing, with a rate similar to that found for non-grouped galaxies and almost independent of group halo mass. Furthermore, we empirically quantify the group-wide impact of AGN on the star-formation of galaxies in galaxy groups.

**The Effect of Star Formation and Environment on the Cold Gas Content of Nearby Galaxies**
Toby Brown, Swinburne University of Technology
11:50am Thursday

The importance of cold gas in the picture of galaxy evolution is well known, as is its role as a probe of recent environmental effects on galaxies in the nearby universe. However, the extent to which structure, star formation and environment impact the gas cycle of galaxies remains unclear. In this talk I will describe results based upon an unparalleled, multi-wavelength sample of 25,000 nearby galaxies, selected according to stellar mass and redshift from the Sloan Digital Sky Survey, and with atomic hydrogen \((\text{HI})\) data from the ALFALFA survey, spanning the full range of environments from isolation to cluster. Taking advantage of the powerful HI spectral stacking technique to quantify the gas content for the entire gas-poor to -rich regime, I will present HI scaling relations with key structural, star formation and environmental metrics. Such relations provide strong constraints for galaxy formation and evolution models by disentangling the influence of these properties on gas content. I will discuss the importance of specific star formation as a tracer of gas content and give observational evidence for significant and systematic gas suppression across the group regime, well before galaxies enter the dense cluster environment. I will comment on the implications of these results for our understanding of the gas cycle in galaxies.
The multi-scale nature of galactic star formation across cosmic time
Diederik Kruijssen, MPA
12:15pm Thursday

A wide range of recent work shows that galactic star formation (SF) relations between the gas mass (density) and the star formation rate (density) develop substantial scatter or even change form when considered below a certain spatial scale. In this talk, I will show how this multi-scale behaviour of galactic SF relations can be exploited to determine ill-constrained, cloud-scale quantities such as the cloud lifetime, SF/feedback time-scales, SF efficiencies, and gravitational instability lengths, using galaxy-scale observations. The method is validated using high-resolution numerical simulations of SF in disc galaxies. I will then present the first results of applying the formalism to observations, providing statistically representative measurements of the molecular cloud lifetime in M33, M51 and M31, as well as using high-resolution ALMA Cycle 2 observations of the nearby flocculent spiral NGC 300. These lifetimes are used to put direct constraints on the star formation efficiency in molecular clouds and the emergence of the galaxy-scale SF relation.

In the ALMA era, our new technique will enable the detailed characterisation of the SF process on the cloud scale in galaxies out to \( z \sim 4 \), i.e. across a cosmologically representative part of the galaxy population rather than the limited sample of Local Group galaxies where these measurements were previously possible. This enables the systematic study of SF physics as a function of the cosmic environment.

AGN triggering and feedback at milliarcsecond resolution
Stas Shabala, University of Tasmania
12:40pm Thursday

Feedback from radio Active Galactic Nuclei (AGN) is now recognised as a key mechanism in regulating star formation in massive galaxies over the last half of the Hubble time. AGN presence is also often a signpost for dynamical processes such as galaxy interactions, which can trigger both star formation and AGN activity.

We examine the connection between AGN and star formation by studying a large (350) sample of low-redshift SDSS galaxies at the milli-arcsecond resolution of Very Long Baseline Interferometry (VLBI). Because a VLBI detection unambiguously identifies an AGN, our approach is not biased against systems with comparable radio luminosity due to the AGN and star formation components.

Our VLBI AGN are preferentially located in early-type galaxies on the red optical-UV sequence, and are more likely to show disturbed morphologies than non-AGN galaxies in a mass-matched control sample. We find similar results for the much smaller population of spiral galaxies hosting radio AGN, and interpret this as evidence for interaction-triggered AGN activity. Short (\(< 10 \) Myr) AGN lifetimes and red colours of AGN host galaxies suggest that the AGN are not triggered promptly in these interactions, and we conclude that AGN feedback in the local Universe is not efficient at suppressing merger-triggered star formation.

Lunch
1:05pm-2:30pm Thursday
Galaxies that are possible candidates for recent gas accretion can be identified based on their unusually high neutral hydrogen (HI) content. The GALEX Arcibo SDSS Survey (GASS, Catinella et al. 2010) neutral hydrogen (HI) observations of 800 galaxies have recently made it possible to predict the ‘HI normalcy’ for galaxies by quantifying the average scaling relations between HI gas fraction and the linear combination of NUV-r color and stellar mass surface density. GASS 3505 is an outlier galaxy displaced above the scaling relations, deviating by more than 3sigma from the average. Its unusually high HI reservoir of $10^{9.9} \, M_{\odot}$ makes GASS 3505 one of the most interesting candidates for studying how galaxies accrete and maintain their cold gas content. In order to understand such outliers from the gas fraction plane, we need to study these systems in detail and determine how they acquired their gas - was it recently accreted from the environment, or the gas has stayed in equilibrium for Gyrs without forming stars. We are using HI mapping, Galaxy Evolution Explorer (GALEX) UV data, deep optical imaging, and resolved stellar kinematic measurements obtained with the Wide Field Spectrograph (WiFeS) to study the connection of accretion and gas accumulation processes in this system. Very Large Array (VLA) and GALEX observations show that the HI in GASS 3505 is distributed in a rotating gas ring, which is forming stars at very low efficiency. Kitt Peak National Observatory (KPNO) deep optical imaging reveals that the star-forming HI ring is connected to a long (∼60 kpc) stellar stream, suggesting a connection between accretion processes and the presence of HI gas in this system. Our observations show that GASS 3505 is a complex system, where the large HI reservoir is affecting the evolutionary processes and morphological appearance of the galaxy.

How do galaxies accrete gas and form stars?
Katharina Lutz, Swinburne University of Technology & ATNF / CSIRO
2:55pm Thursday

When comparing the gas content of galaxies with their current star formation rate, it has been found that the gas consumption time scale is much smaller than the age of galaxies. This discrepancy leads to the conclusion that galaxies must replenish their gas reservoirs by accretion to sustain star formation. In order to investigate the process of gas accretion in more detail we target galaxies that contain at least 2.5 times more atomic hydrogen (HI) than expected from their optical properties using scaling relations. For this set of galaxies, we are building a multiwavelength data set consisting of deep ATCA HI interferometry, SSO 2.3m WiFeS optical integral field spectroscopy and publicly available photometry from GALEX (ultraviolet), WISE (infrared) and DSS-II (optical). This rich data set will enable us to distinguish between multiple scenarios that might lead to an excess in HI content, among them a phase of elevated gas accretion, minor mergers or an inefficient conversion of gas into stars as well as investigating the refuelling of galaxies in great detail. In my talk I will first compare the HI excess galaxies to the general galaxy population with respect to star formation, stellar mass and gas phase oxygen abundance and then present first results of the kinematic analysis of the ATCA HI data combined with the optical WiFeS spectroscopy.
New Star Formation Rate Calibrations Derived from a Multi-wavelength SED Atlas
Michael Brown, Monash University 3:20pm Thursday

One of the principal means of measuring galaxy growth is with star formation rates derived from ultraviolet, mid-infrared and radio continuum imaging. We present revised calibrations of these star formation rate indicators using an atlas of 129 galaxy spectral energy distributions. The spectral energy distributions combine spectra and matched aperture photometry to consistently measure spectral energy distributions over a broad wavelength range. We find that star formation rate calibrations must be systematically revised upward by 10% to 30%, relative to the commonly used calibrations of Kennicutt et al. (2009). Relative to calibrations from the prior literature, we find that dwarf galaxies star formation rates derived from radio continuum and mid-infrared luminosities need to be revised upwards by a factor of $\sim 2$.

Coffee Break
4:00pm-4:30pm Thursday

The SAMI Galaxy Survey: Cluster properties and the impact on galaxy star formation
Matt Owers, Macquarie University and Australian Astronomical Observatory
4:30pm Thursday

The SAMI Galaxy Survey will provide resolved spectroscopy for around 3000 galaxies. Of those galaxies $\sim 600$ 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 AAOmega multi-object spectrograph with the aim of characterising the cluster dynamical properties (galaxy membership, cluster mass and substructure). Several of the clusters also have existing Chandra and/or XMM-Newton X-ray data. This talk will describe the global characteristics of the clusters using the combination of the redshift and X-ray data. Moreover, these data are used to provide a more physical description of galaxy environment local to the SAMI targets. Preliminary results will be presented on the environments of galaxies with evidence for environmentally impacted star formation properties as indicated by the resolved information provided by the SAMI data.

Tracing the Accretion History of the Milky Way through Chemical Tagging
Daniel Zucker, Macquarie University
4:55pm Thursday

In recent years, ample evidence of the accretion of dwarf galaxies and globular clusters onto the Milky Way has been discovered both spatially (in the form of stellar streams on the sky), and kinematically (in the form of stellar overdensities in phase space). Over time these spatial and velocity signatures can be blurred by dynamical processes within the Galaxy. However, the elemental compositions of these stars remain virtually unchanged from birth, and can be used as a kind of stellar DNA to identify stars of a common origin, yielding critical clues as to whether they formed in an accreted dwarf galaxy, an accreted globular cluster, or in situ in the Milky Way itself. I will review the ideas behind this chemical tagging technique, and discuss the potential of the next generation of large-scale high-resolution stellar surveys – e.g., Gaia-ESO and GALAH, which will obtain detailed abundances for $10^5$ and $10^6$ stars, respectively – for constraining the accretion history of the Milky Way.
The Growth of S0 Galaxies: Fading vs mergers
Jairo Mendez-Abreu, University of St Andrews
5:20pm Thursday

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 first results of a project aimed at fully characterising the 2D photometric and kinematic properties of the S0 bulges present in the CALIFA survey. A careful morphological analysis has been carried out using available SDSS images in order to obtain robust measurements of the bulge photometric structure. We found that S0s encompasses a zoo of morphological structures (single and double bars, broken exponential profiles, lenses,..) and their bulges follow this diversity in terms of a wide range in mass and concentration (i.e., Sersic index). Therefore confirming that they cannot be considered as a homogeneous class of objects. Their stellar kinematic properties, as obtained from the 2D spectroscopy of the CALIFA survey, show also a variety of behaviours when referring to the angular momentum. We found both slow and fast rotators bulges in our sample. This diversity, together with a lack of correlation between the photometric and kinematics properties, suggests a complex scenario for the formation of S0s. I will discuss the most likely mechanisms compatible with the observations in this talk.
Invited Talk - Adventures at the Low-Mass Threshold of Galaxy Formation
Mike Boylan-Kolchin, University of Maryland
9:00am Friday

Low-mass galaxies are unique testing grounds for our knowledge of galaxy formation physics, as a complex interplay of diverse processes is required to produce the diversity of morphologies, star formation histories, and internal dynamics observed in dwarfs. I will review some of the recent developments in our understanding of how dwarf galaxies form and evolve, what these galaxies can tell us about the epoch of reionization, and how they may challenge our paradigms of galaxy formation and cosmology.

The Role of Dwarf-Dwarf Interactions in the Assembly History of Galaxies
Sabrina Stierwalt, University of Virginia
9:40am Friday

I will present the initial results from TiNy Titans, the first systematic study of interacting dwarf galaxies and the mechanisms governing their star formation and subsequent processing of the ISM. Mergers of massive galaxies provide a significant mode of galaxy evolution and are observed to inspire intense starbursts and significant rearranging of the galaxies’ gas and dust. However, mergers among low mass galaxies are expected to outnumber those between massive ones and thus likely play an important role in galaxy growth over cosmic time. Little is known about whether mergers among the shallower gravitational potential wells of dwarf galaxies proceed similarly to those between more massive galaxies. A few intriguing examples of dwarf-dwarf interactions exist in the literature, but the efficiency of gas removal and the enhancement of star formation in dwarfs via pre-processing (i.e. dwarf-dwarf interactions occurring before the accretion by a massive host) has never been studied for interacting dwarfs as a population. Our multiwavelength approach gathers high resolution optical, UV, and radio imaging to probe the effects of interactions on the star formation and ISM in a complete sample of dwarf pairs selected from the Sloan Digital Sky Survey. We find star formation is enhanced in paired dwarfs over isolated dwarfs and that a large fraction of interacting dwarfs are starbursting, suggesting that dwarf-dwarf interactions provide an important mode of star formation in the universe. However, the dwarfs involved in interactions still have large gas reservoirs (and thus capacity for future star formation). Our interacting dwarfs tend to be low metallicity and thus offer a unique window into modes of star formation that were important at earlier epochs.

Sizing Up Dwarf Galaxies at $z > 1$: UV Colors, Stellar Masses and Star Formation Rates
Peter Kurczynski, Rutgers University
10:05am Friday

Deep HST imaging allows the detection and study of dwarf galaxies at $z > 1$. Our recent multiwavelength analyses of continuum and Ly-alpha selected galaxies in the Hubble UltraDeep Field (HUDF) and CANDELS fields reveals a diversity of physical properties. We show that these galaxies are on the whole bluer than comparable luminosity galaxies in the local universe, although they are as diverse in their UV colors as local dwarf galaxies (Kurczynski et al. 2014, ApJL 793 5). On the SFR-M* diagram, Ly-alpha selected galaxies fall above the main sequence, implying bursty star formation (Vargas et al 2014, ApJ 783 26). In this presentation, we illustrate that low luminosity continuum selected galaxies appear to lie on the main sequence, suggesting a more quiescent evolution. The systematic study of low luminosity galaxies spanning the epoch of peak cosmic star formation will elucidate the mechanisms of formation and evolution for the bulk of the present day galaxy population.
Quenched void galaxies in the Galaxy and Mass Assembly (GAMA) survey
Samantha Penny ICG, University of Portsmouth
10:30pm Friday

Void galaxies reside in the most under-dense regions of the Universe, and as such, they are ideal the ideal galaxy population in which to examine intrinsic vs. extrinsic effects on evolutionary processes such as star formation and mass assembly. I will discuss the result of a study of void galaxies in the Galaxy and Mass Assembly (GAMA) survey to z = 0.1. While the majority of these void galaxies are blue, star forming objects with (u-r) < 1.9, we identify a number of void galaxies with optical and mid-IR colours consistent with no ongoing star formation. When matched to a randomly drawn sample of non-void galaxies, the void and non-void galaxies exhibit similar properties in terms of optical and mid-IR colour, morphology, and star formation activity, suggesting comparable mass assembly and quenching histories. The passive void galaxies have masses > 10^{10} M_{\odot}, and therefore likely reside in haloes with M_{\text{halo}} > 10^{12} M_{\odot} - the critical halo mass in models at which feedback models can quench star formation. Given their isolation, we suggest the passive void galaxies must have undergone mass quenching, and galaxies in sufficiently large haloes will rarely form stars regardless of environment. Simulations shows that major mergers are rare in void galaxies, and gas accretion must be the dominant mass assembly process for the highest mass void galaxies.

Coffee Break
10:55am-11:25am Friday

Nuclear Star Clusters: an illustration of scale coupling in dwarfs galaxies
Nicolas Guillard, ESO
11:25am Friday

Observations of dwarfs galaxies suggest that Black Holes (BHs) and Nuclear Clusters (NCs) are co-evolving with their hosts. However, their formation and how they are fuelled is still unclear. NCs, unlike BHs, may provide a visible record of the accretion of stars and gas. Therefore, they can be used as probes for the gas and star fueling of the nuclei of dwarfs galaxies. Whether NCs form via accretion of multiple clusters or in-situ star formation, the mass build-up in such regions ultimately depends on both pc-scale (e.g turbulence) and kpc-scale (e.g spirals, bars). Thus, one needs to understand these scaling coupling in order to properly address the physical processes involved in NCs formation. The associated physical processes have so far been studied numerically at resolution from 100 to 50 pc, mostly focusing on the role of bars. The main nuclear structures (e.g., the nuclear disks at the 10-50 pc scale) thus remain unresolved and the fueling processes unclear. From the analysis of simulations of a dwarf galaxy at parsec resolution, I will present the coupling effects between large scale (~ 30 kpc) and small scale (~pc). I will focus on the fueling mechanisms and the formation of nuclear star clusters. I will emphasise the impact of star formation and stellar driven feedback, and finally provide a detailed view of the formation and evolution of nuclear star clusters.
Many views of quenching from SAMI
Scott Croom, University of Sydney
11:50am Friday

While we have a good general picture of the quenching of star formation in galaxies, the specifics are still very much missing. Much of this is due to the many and varied processes at play. In this talk I will tackle some of these issues using new results from the SAMI Galaxy Survey, a multi-object integral field survey of local galaxies which has already targeted over 1000 objects. I will specifically show how the distribution of star formation in galaxies (as traced by Halpha) is modulated by environment and dependent on stellar mass. I will then show the prevalence of AGN and SF winds in galaxies, and discuss their impact on galaxy evolution.

Stellar metallicity gradients as a function of mass, morphology and environment
Nicholas Scott, The University of Sydney
12:15pm Friday

The stellar population of a galaxy constitutes a fossil record of its assembly history. Spatially resolving this record allows us to discriminate between several competing formation scenarios for massive galaxies. In particular, changes in stellar metallicity gradient with radius are thought to be a strong discriminator between in-situ and merger-driven assembly.

The SAMI Galaxy Survey is an integral field spectroscopy study of nearby galaxies that spans a broad range in mass and environment. Using the first 1000 galaxies from this survey we derive spatially resolved stellar population parameters from both absorption line indices and a full spectral fitting technique. This large sample allows us to isolate the effects of mass, environment and morphology on stellar metallicity gradients, and therefore infer the role of in- versus ex-situ assembly across the full breadth of the nearby galaxy population.

Dangerous Liaisons: Asymmetry in Gas Kinematics in the SAMI Galaxy Survey
Jessica Bloom, University of Sydney
12:40pm Friday

Tracing the formation history of galaxies is one of the primary goals of modern astrophysics. The role of mergers in determining the formation history of galaxies is a significant open question, as is the relationship between merger history and galaxy environment. Calculations at low redshifts can be matched with high redshift measurements to put together a picture of how merger rates and influence has changed over cosmic time. Asymmetry in gas kinematics can be used as a tracer of dynamical disturbance in both high and low redshift galaxies. Using the large amount of data provided by the SAMI Galaxy Survey, we are able to make statistically robust statements about the proportion and nature of kinematically disturbed galaxies within the sample. These measurements can be used to answer questions about the formation history of galaxies. We fit the emission line kinematics of SAMI Survey galaxies, and measure deviations from a simple rotating disk model using the quantitative technique of kinemetry (Krajnovic et al., 2007). We are able to show that kinematic analysis is a closer tracer of perturbation than comparable automated methods based on morphology, and provide a perturbed fraction of 21% for our sample. We also see that perturbed galaxies tend to be bluer than normal galaxy, and have higher rates of star formation. Finally, we investigate the relationship between environment and perturbation, in order to understand how dynamical disturbance is affected by environment density.

Lunch
1:05pm-2:30pm Friday
Study of the growth of massive galaxies based on their outer stellar populations  
Emin Karabal, ESO / AIM Saclay  
2:30pm Friday

We are collecting ultra deep multi-band optical images of nearby ETGs obtained with Megacam on the CFHT as part of the Atlas3D, NGVS and MATLAS collaborations. These images reach surface brightness sensitivity as low as 29 mag arcsec$^{-2}$ and reveal fine structures around the galaxies (streams, tails, shells) that are the relics of their collision history. Besides, such images allow us to also study the stellar populations in the very outer halo of galaxies, at 5-10 $R_{eff}$, which also bring key information on the major processes of galaxies growth via minor/major mergers or secular evolution.

My talk will address the mass assembly of galaxies combining information from fine structures (statistics, shapes, etc.) and outer stellar populations (age and metallicity). I will especially focus on the metallicity gradients that are thought to hold information for merger processes.

The masses of galaxy group satellites through weak gravitational lensing with KiDS: Evidence for tidal stripping?  
Cristobal Sifon, Leiden Observatory  
2:55pm Friday

As galaxies enter the dense environments of galaxy groups, they become satellite galaxies and are predicted by numerical simulations to suffer heavily from tidal stripping, losing up to 90% of their mass after a few orbits. In this talk I present the first step towards using observations to test these predictions. We take advantage of the overlap (currently 105 sq. deg.) between deep optical imaging from the Kilo-Degree Survey (KiDS) and redshift measurements from the Galaxy And Mass Assembly (GAMA) survey, a unique spectroscopic survey that is 98% complete to a magnitude of 19.8 in the r-band from which a highly pure galaxy group catalog (the G3C) is available. We use weak gravitational lensing to measure the masses of satellite galaxies from G3C. The high purity of the sample allows for a clean, straightforward interpretation of the signal. We measure the mass in three bins in projected separation from the group center, which we take as a proxy for time since infall. Since the three subsamples have approximately the same stellar mass distributions and owing to the high purity of the sample, we can readily interpret potential differences in lensing mass as being due to tidal stripping. We detect the lensing signal from all three subsamples with high significance and measure a $\sim$2-sigma decrease in total mass between satellites located close to the group virial radius, $r_{200}$, compared to satellites around the group scale radius ($r_{200}/5$). While our measurements are consistent with a tidal stripping scenario, our uncertainties preclude us drawing any firm conclusions at the moment. We forecast that using the full overlap between KiDS and GAMA would allow us to place constraints on tidal stripping scenarios, and use of the full KiDS survey (with a similarly constructed group catalog) to place constraints on the truncation profile of satellite galaxies.
The outer halo regions of massive elliptical galaxies, where formation signatures are long-lasting, provide important clues to galaxy growth. However such regions are traditionally hard to probe in detail. I present results from the SLUGGS survey on the Keck telescope which extends ATLAS3D-like maps of stellar kinematics and metallicities from $\sim 1$ Re to $\sim 3$ Re for nearby massive ellipticals. Including globular clusters as a stellar proxy we have extended this to $\sim 10$ Re.

We find evidence for a transition in halo properties at several effective radii, including the radius that may mark the transition between a dissipative in-situ core and an outer accretion-dominated halo. We find a trend for outer gradients to steepen for lower mass galaxies. Comparison with the latest two-phase galaxy growth simulations indicates that feedback is required to match this trend. Our 2D kinematic maps provide clues to the merger history of individual galaxies. Our data generally support a picture in which early-type galaxy halos grow from the accretion and disruption of satellites (and their globular cluster systems).

Closing Remarks
3:45pm Friday

Coffee Break
4:00pm-4:30pm Friday
6 Posters

The Effects of Environment on the Growth of Galaxies at z=1-2
Rebecca Allen, Swinburne University

There is ongoing debate regarding the extent that environment affects galaxy size growth beyond z > 1. To investigate the possible differences in the growth mechanisms of star-forming and quiescent galaxies as a function of environment at z=2.1, we create a mass-complete sample of 59 cluster galaxies (Spitler et al. 2012) and 478 field galaxies with log(M*/Msun) > 9 using accurate photometric redshifts from the ZFOURGE survey. We compare the mass-size relation of field and cluster galaxies using measured sizes from CANDELS HST/F160W imaging. We find that the sizes and colors for quiescent field and cluster galaxies are consistent. However, massive star-forming cluster galaxies have sizes that are larger than massive star-forming field galaxies. Both field and cluster star-forming galaxies have negative color gradients with cluster galaxies tending to be redder in color. We will also present our current work at z 1 and explore the possible size growth evolution of galaxies in high-density environments.

Insights into bulge evolution during the last ~10 Gyrs.
Josh Argyle, University of St Andrews

Bulges of disc galaxies are theorised to play a pivotal role in the evolution of their hosts. However, the formation of the bulge and its relation to the galaxy size and mass distribution remains poorly understood. The evolution of bulges since z < 2 is thought to be mainly driven by two competitive processes: secular vs. externally triggered events. These leave differing imprints, especially in the morphology and kinematics of the bulge population. We present the results of a study of the structural evolution of disc galaxies with focus on the central regions. Based on high redshift CANDELS (0.5 < z < 2) and local SDSS data (z = 0.02-0.2), we perform bulge-disc decompositions of 300 galaxies with stellar masses > 10^{10} M\odot. Utilising a new adaptive Markov Chain Monte Carlo (MCMC) algorithm with inbuilt diagnostic tests, we achieve fast convergence and parameter estimates. This offers a powerful investigative tool for these high redshift galaxies where the parameter space becomes poorly constrained due to the limited signal-to-noise and resolution. I will present a description and interpretation of the structural evolution of disc galaxies over the past 10 billion years.

Extremely Star-Forming z 0.1 Galaxies as Probes of High Redshift Disk Formation
Robert Bassett, Swinburne University of Technology

I will present results from an ongoing study of extremely gas-rich and turbulent disk galaxies at 0.07 < z < 0.14. These massive (M* > 10^{10} M\odot) disks have strikingly similar properties to clumpy galaxies near the peak of cosmic star formation such as those observed in the SINS survey. Galaxies in our sample, although rare locally, are nearby enough that we can resolve details about their clumps which are inaccessible at high redshifts. Our multiwavelength survey includes IFS data from Keck and Gemini observatories, photometry from the Hubble Space Telescope, and CO observations from the Plateau de Bure interferometer which we combine to better understand the high resolution properties of clumps, including details about dust and gas masses in individual clumps. Aside from representing the best currently known laboratories for performing detailed studies of clumpy star-forming disks, our sample (the so-called DYNAMO survey) also presents a mystery as to how such gas rich disks can exist in the local universe.
The Infrared Spectral Energy Distribution of SpARCS Brightest Cluster Galaxies
Nina Bonaventura, McGill University

Brightest Cluster Galaxies (BCGs), the most massive and luminous galaxies residing at the gravitational centers of galaxy clusters, ought to be ideal laboratories for measuring the complex interplay between the many physical processes occurring in their unique environment and their effects on galaxy formation and growth, such as galaxy infall and merging, cluster cooling flows and competing AGN feedback and gas heating, as well as star formation processes. With this in mind, we present the results of an unprecedented study of the Spitzer/Herschel infrared broadband Spectral Energy Distribution (SED) of this unique class of galaxies, involving the largest sample (485) of optically selected BCGs from similarly massive clusters (\(10^{14}\) Msun) in the Spitzer Adaptation of the Red-Sequence Cluster Survey (SpARCS). We build stacked infrared SEDs in each of six evenly spaced redshift bins throughout the 0.1-to-1.9 redshift range of our sample, to uncover evolutionary trends in BCG activity through cosmic time; as well as separate the BCGs into 24-micron-bright versus 24-micron-faint sub-populations, to check for the expected differences in the level of star formation activity.

Upon fitting the stacked BCG SEDs with a variety of infrared galaxy SED templates from multiple libraries in the literature, we see a picture of a star-forming BCG as opposed to a “red and dead” elliptical BCG, where they appear to retain a pulse of star formation activity down to a lower redshift than expected. The average BCG of the 24-micron-faint population, which outnumbers the 24-micron-bright population by a factor of five, appears purely star-forming in nature with an estimated star-formation rate ranging from tens to hundreds from the low- to high-end of the redshift range of our sample (the 24um flux of the vigorously star-forming, high-redshift “faint” BCGs overlap a deep silicate absorption feature in a best-fit starburst SED). The 24-micron-bright population, on the other hand, consists of a mix of purely star-forming BCGs, pure AGN, as well as a number of candidate AGN/star-forming composite systems, which exhibit a brighter luminosity than the faint population in each redshift bin. Considering the observed evolution of the SED, we support a scenario in which the star-formation activity in the BCGs transitions from vigorous to passive towards lower redshifts, while a small but active subset is dominated by both AGN and star-forming galaxies. An interesting implication from the 24-micron-bright subset is that the AGN feedback occurring within these BCGs is perhaps not powerful-, isotropic-, or efficient- enough to fully suppress the concurrent star-formation activity, as the SEDs retain a dominant star-forming nature formation before, during, and after an apparent peak phase in AGN activity at an average redshift of 0.93.

What Shapes the Local 1.4 GHz Galaxy Luminosity Function?
Nicolas Bonne, Monash University

Modelling luminosity functions of star formation rate proxies in a physically meaningful way is difficult, as star formation does not have a clear correlation with halo mass. Functions are typically fitted empirically, effectively using the relationship between galaxy space densities and star formation rate, which has no real physical significance. We propose a new method for fitting such luminosity functions, which retains physical information relating to the galaxy duty cycle, and will help us better understand how star formation can both enhance and regulate galaxy growth. Using a sample of 6,890 S1.4 < 0.9 mJy NVSS 1.4 GHz continuum fluxes, we calculate local Universe luminosity functions for early-type and late-type galaxies, approximately star forming and AGN populations respectively. To approximate the form of the luminosity functions we first model the star forming galaxy main sequence as star formation rate (and AGN) duty cycles as a function of stellar mass proxy (K-band). We then convolve these models with K-band luminosity functions to produce our final fit. These models provide a good approximation to the data, retaining more information than empirical models, such as the range of galaxy masses associated with any level of star formation rate, and how this varies with star formation. Using this model, we can calculate the local star formation rate density.
Do Brightest Cluster Galaxies and Intra-Cluster Light grow through the same mechanism/s?
Emanuele Contini, Purple Mountain Observatory

I will review the relevant literature where theorists modeled the main mechanism/s responsible for the Intra-Cluster Light (ICL) formation, from the first hydro simulations to the current state-of-art semi-analytic models. The main point of the talk will be the following question: Is the formation of the ICL parallel to the build-up of the Brightest Cluster Galaxy (BCG)?

Studying the Intrinsic Shape of S0 Bulges to Unveil their Formation Process
Luca Costantin, Dipartimento di Astronomia, Universita di Padova

Several scenarios have been proposed for explaining the photometric, kinematic, and dynamical properties of galactic bulges. Studying the intrinsic shape of the bulges provides a essential piece of information for testing the results of numerical simulations of their formation. For the first time we have derived the intrinsic axial ratios of the bulges of a sample of 13 lenticular non barred galaxies without any assumption on their intrinsic shape, analyzing their light distribution. Preliminary results show that the orbits of stars in triaxial bulges are more anisotropic than those in axisymmetric bulges, suggesting a different formation process.

A Signature of Merger Driven Star Formation in Spiral Galaxies
Tim Dolley, Monash University

Local galaxy star formation is thought to be dominated by secular evolution, but star formation triggered by mergers must also contribute. We have measured the clustering of spiral galaxies as a function of specific star formation rate (SSFR), for a morphology selected sample. We find that large scale clustering of spiral galaxies is independent of SSFR, indicating spiral galaxies with high and low SSFRs typically reside within the same mass dark matter halos. On intermediate scales (∼ 500 kpc), spiral galaxies with high SSFRs have a deficiency in satellite companions, but an excess of satellite companions at smaller scales (∼ 50 kpc). This appears to be the signature of recent or ongoing mergers, where the suppressed correlation function at ∼ 500 kpc scales is due to the infall of a satellite companion.
Galaxy types and galaxy growth in the group environment
Michael Drinkwater, University of Queensland

We present a new measurement of the density-morphology relation in low-density environments based on the Galaxy and Mass Assembly (GAMA) survey. We define environment as the total mass of the groups hosting the galaxies. The high spatial completeness of GAMA makes it possible to directly measure the dynamical masses of small groups, unlike previous work. We classify galaxies as spiral or elliptical by a combination of colour and image profile (Sersic index).

We measure the fraction of elliptical galaxies in the GAMA groups across four orders of magnitude in group mass ($10^{11}$ to $10^{15}$ Msun). Remarkably we find the elliptical fraction grows continuously over the whole mass range, not just in the large galaxy clusters (group masses over $10^{14}$ Msun). The variation is strongly driven by the fact that the average galaxy mass also increases strongly with the group mass. When we control for galaxy mass we still find a significant relation: the elliptical fraction increases by 11% ($±2\%$) per decade of group mass. However, the fraction only changes for group masses above a threshold of $10^{12}$ Msun. The ratio is constant in smaller groups. The threshold mass is close to the critical mass above which gas can more easily removed from the host halos of single galaxies. This can explain the change in colour of galaxies but not the mass growth. We are testing the contribution of major mergers in these low-mass environments using new numerical simulations of the GAMA groups.

Properties of high-z emission-line galaxies and escape fraction of Lyman-α photons from star-forming galaxies at $z=2.24$
An Fangxia, Purple Mountain Observatory,

I will introduce our works on probing high-z emission-line galaxies (ELGs) through deep narrow-band surveys. We obtained our deep Near-infrared and optical narrow-band imaging data through CFHT/WIRCam and Magellan/Megacam respectively. We identified the samples of Hα and Lymanα ELGs at $z=2.24$ in the Extended Chandra Deep Field South based on the data from this two narrow-bands. I will present the results from two works of ours: one on the properties of these high-z ELGs, such as stellar mass, extinction, SFR, luminosity function, etc., and the other on the Lyman-α escape fraction of star-forming galaxies at this redshift. Our results suggest that Hα ELGs are representative of star-forming galaxies. And we find that with proper extinction correction our Hα luminosity function mirrors the stellar mass function of star-forming galaxies at the same cosmic epoch. This finding indeed reflects the tight correlation between star formation rate and stellar mass for the star-forming galaxies, i.e., the so-called main sequence. This talk is based on the work The properties of Hα emission-line galaxies at z = 2.24 (2014, ApJ, 784, 152) by An F.X. et al., and our ongoing research.

The Neutral Hydrogen Content of Early-type and Late-type Galaxies
Dane Kleiner, Monash University

The availability of neutral hydrogen in galaxy mergers play an important role in how galaxies build up mass. We have used a spectral stacking technique to measure the neutral hydrogen content of galaxies observed in cosmic web. Our sample has been separated by galaxy morphology and we measure significant ($> 7 \sigma$) detections for both the late and early types. The detection for the late types is unsurprising as these galaxies are traditionally gas rich but we further investigate the reliability of morphological classifications for early types and how gas rich they truly are. We relate these measurements to the galaxies environment and discuss the implications for galaxy growth.
The evolving demographics of the red sequence since $z = 1$
Thomas Melvin, ICG Portsmouth

In the local universe we observe a bimodal galaxy population, with galaxies tending to be either part of the blue cloud or the red sequence. This bimodality is observed to become less distinct at higher redshifts. Here, we combine photometric and spectroscopic data from the Cosmic Evolution Survey (COSMOS) with visual morphological classifications of the images from Galaxy Zoo: Hubble to explore how the demographics of the red sequence have evolved over the last eight billion years (i.e since $z \sim 1$). Over the period of time covered by our sample ($z \sim 0.2-1$), we find that the fraction of all galaxies within the red sequence remains constant, but at a lower fraction than observed at $z = 0$. We also find that the red sequences becomes almost a magnitude redder in rest frame colour over this period. When exploring the morphology of the red sequence, we find that, as the universe ages, the fraction of disk galaxies (barred or unbarred) which are found on the red sequence increases. We propose that the increasing population of disks that are red appear as they move from the blue cloud to the red sequence via slow, secular processes which do not drastically alter their morphologies.

Multicolour evolution of galaxy populations as seen from a hydro-cosmological simulation and a semi-analytical model
Alessio Romeo, PMO-CAS Nanjing

By means of our cosmological-hydrodynamical simulation and semi-analytical model we studied galaxy populations properties in clusters and groups, spanning over 10 different bands from UV to NIR, and their evolution since redshift $z=2$. We compare our results in terms of the RS luminous-to-faint ratio (LFR) with recent observational data reaching beyond $z=1$, finding a very mild evolution of this quantity, especially if measured in terms of stellar mass. We also find that the Butcher-Oemler effect is wavelength-dependent, with the fraction of blue galaxies increasing steeper in optical-optical than in NIR-optical colours. Besides, only when applying a lower limit for sample selection in terms of (either fixed or variable) absolute magnitude, the BO effect can be reproduced, while the blue fraction results much less evolving when selecting samples by stellar mass. As to differences through environments, we find that normal groups and (to less extent) cluster outskirts present the highest values of both blue fraction and LFR at low $z$, while fossil groups and cluster cores the lowest: this separation begins after $z \sim 0.5$, whilst at high $z$ all groups coincide at almost the same conditions.
Galaxy vivisection and the intimate black hole-bulge connection
Giulia Savorgnan, Swinburne University

Galaxies and black holes have grown together in symbiosis through the cosmic ages. A manifestation of their coevolution is the correlation between the black hole mass and several properties of the host bulge. These relations have now advanced beyond simple linear relations, with bends and substructure revealing exciting new clues to the different pathways of galaxy evolution. A careful galaxy decomposition is however required to accurately measure these galaxy/bulge properties.

We have performed state-of-the-art galaxy decompositions for the largest sample of galaxies with directly measured black hole masses. Using 3.6 um Spitzer imagery, which is an excellent tracer of the stellar mass, our decompositions take into account bulges, disks, spiral arms, bars, rings, haloes, extended or unresolved nuclear sources and partially depleted cores. We have additionally used kinematical information to confirm the presence of rotationally supported components in most early-type galaxies, and to identify their extent (intermediate-scale, embedded disks or large-scale disks). We present updates and modifications to several key black hole mass scaling relations, and discuss the important implications for galaxy evolution models.

An adaptive optics view of the morphological evolution of galaxies during $1 < z < 2$.
Sarah Sweet, RSAA ANU

While local galaxies fall into two dominant populations (passive, red, pressure-supported spheroids, and blue, star-forming disks), these familiar Hubble-type classifications do not apply as readily to high-redshift galaxies, the most massive of which are compact and red. Logically, these high-z galaxies likely become the elliptical population at $z=0$, but they must grow by 3-5 times in size in the interim. It is proposed that the size evolution of galaxies either occurs by accretion of smaller galaxies, whereby the compact core remains, or by adiabatic expansion due to mass-loss winds, whereby the entire galaxy expands. The key to distinguishing between these two scenarios is the accurate measurement of the size-mass relation. This requires sufficient resolution to measure effective radii and Sersic indices of the most compact galaxies over a wide field of view, at rest-frame optical wavelengths to avoid bias due to small-scale localised star formation.

In this talk I will describe our project using the Gemini South Adaptive Optics Imager, with its unique capability of diffraction-limited near-infrared wide-field imaging, to image the cores of galaxy clusters over the redshift interval $1 < z < 2$. I will present our results from the first two galaxy clusters, as well as our methodology for processing the complex data from this new instrument (including successful correction for the quasi-static off-axis distortion, varying PSF and image ghosting).
The Growth and Evolution of Milky Way-like Galaxies
Bryan Terrazas, University of Michigan

We use the semi-analytic model developed by Henriques et al. 2014 in order to gain insight on the evolution of Milky Way-mass galaxies. Tracing their growth histories back to z=2, we find there is an enormous diversity of progenitor masses, indicating the existence of a myriad of pathways to the Milky Way’s stellar mass at the present day. Our study focuses on clarifying where this physical scatter in growth histories comes from. Separating those galaxies that are star-forming at the present day from those that become quiescent, we find that quiescent galaxies grow significantly more stellar mass at earlier times. In addition, the halo masses of galaxies that become quiescent are in general significantly larger than those of galaxies that have always been star forming. In fact, in the context of this model, halo mass plays an important role in determining when systems stop growing their stellar mass. Namely, the larger the halo mass, the earlier it stops forming stars, or quenches. The staggered quenching that occurs as a result of halo mass in the context of this model leads to a large range of stellar masses from which galaxies can eventually grow to have masses similar to that of the Milky Way. The quenching of galaxies also seems to depend heavily on black hole mass which grows via radio mode accretion. We analyze the connection between black hole mass and halo mass in the context of this model and relate this to quenching mechanisms. Our results provide a possible explanation for what may cause the diversity of growth histories and how we can understand it in the larger context of galaxy formation and evolution.

Probing Asymmetric Structures In The Outskirts of Galaxies
Zhangzheng Wen, Purple Mountain Observatory

Upcoming large imaging surveys will allow detailed studies of the structure and morphology of galaxies aimed at addressing how galaxies form and evolve. Computational approaches are needed to characterize their morphologies over large samples. We introduce an automatic method to quantify the outer structure of galaxies. The key to our approach is the division of a galaxy image into two sections delineated by the isophote, which encloses half the total brightness of the galaxy. We call the central section the inner half-flux region (IHR) and the outer section the outer half-flux region (OHR). From this division, we derive two parameters: Ao, which measures the asymmetry of the OHR, and Do, which measures the deviation of the intensity weighted centroid of the OHR from that of the IHR relative to the effective radius. We derive the two parameters from HST/ACS z850-band images for a sample of 764 galaxies with z850 < 22 mag and 0.35 < z < 0.9 selected from the GEMS and GOODS-South surveys. We show that the sample galaxies having strong asymmetric structures, particularly tidal tails, are well-separated from those with regular morphologies in the AoOHRDo space. Meanwhile, the widely used CAS and Gini-M20 methods turn out to be insensitive to such morphological features. We stress that the AoOHRDo method is an efficient way to select galaxies with significant asymmetric features like tidal tails and study galaxy mergers in the dynamical phase traced by these delicate features.