Mapping the Pathways of Galaxy Transformation Across Time and Space

Avalon, Catalina Island, California

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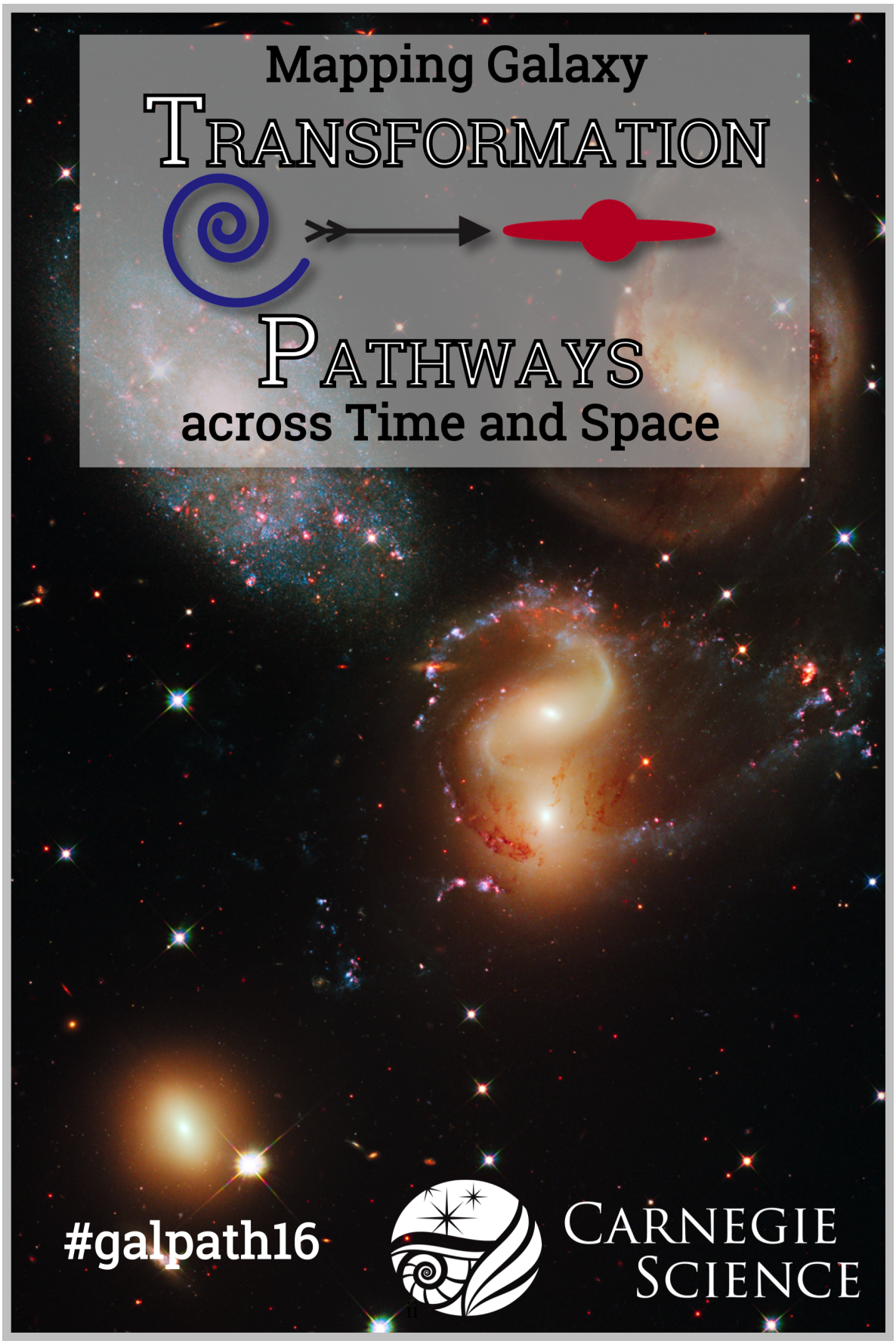
Mapping Galaxy
TRANSFORMATION
PATHWAYS
across Time and Space
#galpath16
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Contents

Session 1

Transitioning Galaxies in Clusters and Beyond

Monday
9:00 - 9:30 am

Bianca Poggianti
INAF-OAPd

I will discuss methods to identify galaxies in transition from being star-forming to being passive, based on both integrated and spatially resolved spectroscopy of galaxies in clusters and other environments at low redshift. I will present results obtained with a large program with MUSE at the VLT, showing the relation between gas removal and star formation activity, and discuss the conclusions that can be obtained from the star formation rate-mass relation and the spectroscopic identification of recently quenched galaxies.

High Central Mass Density: Best Ticket to Cross the Blue to Red Bridge

Monday
10:00 - 10:20 am

David Koo
Univ. of Calif., Santa Cruz

I will report on several studies of field galaxies by our team that continue to favor high stellar mass within the central 1 kpc radius as being the best ticket to cross the bridge from being an active star forming galaxy to a quiescent one. Our studies range from using SDSS for local galaxies to using the rich, deep, multi-wavelength imaging and our Keck spectroscopic data in the CANDELS fields for redshift z $\sim$ 2 "nuggets". After normalizing for the evolution in both the star formation rate versus mass and the central mass density thresholds needed for transformations at different masses, we find a ""universal path"" or bridge that almost all field galaxies seem to take from redshifts z $\sim$ 2 to today, whether by taking slow fading strolls or fast quenching dashes to quiescence.

Monday
10:20 - 10:40 am

The death of galaxies: evolution through the post-starburst phase

Decker French

University of Arizona, Steward Observatory

Post-starburst (or 'E+A') galaxies are in transition between star-forming galaxies and early-types, and represent a clear path for galaxies to transform from star-forming to quiescence. Many show signs of a recent galaxy-galaxy merger and a newly-evolved stellar bulge, and most have LINER-like emission, which may indicate low luminosity AGN activity. Thus, the study of this short-lived phase of galaxy evolution can address the connections among mergers, star formation history, and the evolution of the nucleus as a galaxy evolves onto the red sequence. Surprisingly, we have discovered that many these galaxies, which are not currently forming stars, have significant reservoirs of molecular gas, which may fuel the central, supermassive black hole or later star formation episodes. We have also found that post-starburst galaxies host a disproportionate number of Tidal Disruption Events, in which a star is accreted onto the black hole. The recent starburst in these galaxies allows us to put strong constraints on the details of their recent star formation histories, and to place them on a timeline post-burst. I will discuss these results and other new work detailing how their stellar populations, gas content, and black hole properties evolve.

Monday
10:40 - 11:00 am

Resolving the Star Formation Quenching

Shoubaneh Hemmati

IPAC/Caltech

Internal secular evolution processes are known to be one of the main mechanisms responsible for the evolution of "global" properties of galaxies such as their star formation activity, stellar mass assembly, and morphology. In this talk, I will illustrate the relation between global properties and kpc-scale substructures of galaxies out to z$\sim$2. Using combined high resolution data from the Hubble Space Telescope and long exposure spectroscopic observations with the Keck telescope, I produce 2D maps of physical properties of galaxies such as rest-frame optical color, stellar mass and star formation rate surface density, extinction and age as well as 1D profiles of nebular dust attenuation, and other diagnostic optical line ratios. I will present the resolved main sequence of star formation inside individual galaxies with different global properties and discuss the potential use of this methodology in resolving the challenge of star formation quenching by selecting galaxies at different environments.

To Quench or Not To Quench? How What We Say Affects What We Think about Galaxy Evolution

Monday
11:30 - 12:00 pm

Louis Abramson
UCLA

Is "quenching" the *termination* of star formation or the *compression* of star formation histories (SFHs)? I discuss the deep implications this reframing has for what we see as and how we study core processes shaping galaxy life-cycles. As a lens, I use two outcomes from the IMACS Cluster-Building Survey: our finding that most z∼0.5 post-starbursts are rejuvenated passive galaxies, and a simple model positing that every galaxy has a lognormal SFH whose parameters are set at birth. Both studies reinterpreted key metrics of galaxy evolution typically seen as 'clear-cut' evidence for one-way quenching, causing our focus to shift from from mechanisms that *stop* SF to those that *accelerate* evolution. They led to a paradigm in which the decline in activity of SF galaxies since z∼2; the removal of systems from that population; and the correlations between environment, SFR, and morphology all reflect the same underlying phenomenon: the initial configuration of the matter density field. This "density-driven growth" and "starburst recycling" picture is quite different from the dominant "grow-and-quench" narrative, yet both describe the data well. As such, I contend that ours is a viable alternative framework, but current observations are in fact too un-constraining to confirm any description as "the best." I close by reviewing new HST-derived results that preview the kinds of discriminating data next-generation facilities will provide, enabling definitive tests of evolutionary models and the construction of a unique context in which to set explanations.

A Bayesian's perspective of galaxy growth via bulge evolution

Monday
12:00 - 12:20 pm

Josh Argyle
University of St Andrews

Bulges play a pivotal role in how a galaxy might evolve. However, the exact mechanisms involved in shaping their hosts and even their demographic evolution with cosmic time still remain an unanswered piece in the galaxy formation puzzle. In this talk I will present an innovative study into the stellar-morphological evolution of spheroidal and spheroidal-disc galaxies over the redshift range $0< z < 3$. We have combined a new adaptive MCMC algorithm to decompose galaxy light into different structures and a proper Bayesian model selection method to extract the most likely morphology. I will present the results of our analysis based on a bulge-disc decomposition of ∼800 galaxies with $M^* > 10^{10} M_*$

Monday
12:20 - 12:40 pm

Quasars Probing Galaxies: Gas Accretion in Extended Galactic Disks?

Crystal Martin
UC Santa Barbara

"I will present new Keck LRIS spectroscopy of 50 galaxy – quasar pairs and describe the kinematics of circumgalactic gas in typical, star-forming galaxies at redshift 0.2. We find the Doppler shift of resonance absorption in MgII lies entirely to one side of the galaxy systemic velocity. The sign of the net rotation

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Monday
12:40 - 1:00 pm

The Las Campanas PrISM Survey

Jeffrey Rich
Carnegie Observatories

"The information gained from spatially resolved optical spectroscopy has proven crucial to understanding the complete picture of galaxies and their contents. In order to fully understand the interplay between the processes that govern and regulate star formation and galaxy evolution we are building building a sample of the largest, highest spatial resolution, and widest spectral coverage data cubes ever taken for nearby galaxies: the Las Campanas PrISM Survey.
I will present recent results and ongoing work using our data cubes to map the ionized ISM and its properties at spatial scales of order 10 pc in nearby galaxies such as M83 and NGC 300. The high spatial resolution of our data affords us the opportunity to study the characteristics and total contribution of diffuse ionized gas, a less well-understood component of nearby galaxies, as well as metallicties, star formation rates gas kinematics and more. I will also discuss how resolved spectroscopy can help detect, quantify and distinguish between star formation, shocks, diffuse ionized gas and AGN to help better inform larger, less resolved studies of galaxy properties.

Session 2

Observing the Consequences of Quenching in Simulations

Monday
2:30 - 3:00 pm

Greg Snyder
STScI

I will describe results on mergers, morphology, and quenching using mock data from hydro simulations. From merger models, we created and analyzed thousands of synthetic spectra to reconcile the incidence of poststarburst galaxies with merger rates. Currently, we are conducting mock surveys of the Illustris project to determine how standard feedback models set correlations with galaxy structure, and to learn how mergers would appear in deep HST and JWST surveys. Without simulations and synthetic data, we cannot reliably assign meaning to any given observed property. How should we interpret rare and subtle features? Is a galaxy type rare because it is unimportant or because it is short-lived? To answer such questions, we must measure observability timescales, containing the information needed to convert number densities into physical event rates. This requires creating realistic synthetic data from large simulation suites and determining how these data connect to physical processes.

Galaxy Zoo: Evidence for diverse morphologically dependent quenching histories across the green valley and the role of AGN feedback

Monday
3:00 - 3:20 pm

Rebecca Smethurst
University of Oxford

We present the results of a new Bayesian-MCMC analysis of the star formation histories of over 126,000 galaxies across the colour magnitude diagram showing that diverse, morphologically dependent quenching mechanisms are instrumental in the formation of the present day red sequence. To do this we utilise the classifications from Galaxy Zoo in a novel way, weighting by the vote fraction to include results from all galaxies rather than using a threshold to split our sample into late- and early-type morphology. We show that the rate at which quenching can occur is morphologically dependent in each of the blue cloud, green valley & red sequence, and that the green valley is a transition population for all morphological types, not a "red herring"". We discuss

the nature of the possible quenching mechanisms which give rise to the distribution of quenching parameters, considering the influence of the group and field environment, secular evolution and mergers, both with and without black hole activity. We show that a population of type 2 AGN host galaxies have recently (within 2 Gyr) undergone a rapid ($\tau < 1$ Gyr) drop in their star formation rate. We demonstrate that slower ($\tau >$ 2 Gyr) quenching rates dominate for high stellar mass ($\log10[M^*/M_\odot] > 10.75$) hosts of AGN with both early- and late-type morphology. The diversity of this new method highlights that rapid quenching mechanisms cannot account fully for all the quenching across the current AGN host population.We discuss how these results show that both merger-driven and non-merger processes are contributing to the co-evolution of galaxies and supermassive black holes across the entirety of the colour magnitude diagram.

Monday
3:20 - 3:40 pm

BaLROG - Bars in Low-Redshift Optical Galaxies

Marja Seidel

Carnegie Observatories

The plurality of existing galaxies in today's Universe remains in many facets an enigma in terms of their individual formation and evolutionary histories. While merging processes seem to have been especially dominant in the early Universe, the accelerating expansion of it is drawing galaxies further apart and internal processes due to their own morphology start having a crucial influence. One of the main drivers of this so-called 'secular evolution' are bars. Their significant departure from axisymmetry and the associated torques are responsible for their ability to redistribute angular momentum among the host galaxy as well as drive gas towards the center triggering star formation and/or building up a central mass concentration. We use integral field observations in combination with N-body simulations in order to better understand and quantify their influence in nearby galaxies. While the effect of bars on global galaxy parameters seems to be marginal, they seem to have a crucial influence in certain regions (resonance points), in particular altering the bulge. Our in-depth analyses using kinematics and stellar populations support the longevity of bars, their similarity to the bulge and difference to the disk as a structure rotating as a cylinder within the host galaxy.

The Role of Secular Evolution in Galaxy Transformation

Monday
4:50 - 5:20 pm

Alison Crocker
Reed College

This talk will summarize the roles of the secular evolution processes that are likely involved in galaxy transformation or maintenance of that transformation. Secular processes here are defined to be those which do not involve the external influences of either the environment or mergers and additionally to not require the input of an AGN. I will outline the contributions of violent disk instabilities and bar-mediated gas concentration to spheroid (or pseudo-spheriod) creation, but focus more on the evidence for and theory of morphological quenching. This process is invoked to explain the observed lower star formation efficiencies of cold-gas hosting, bulge-dominated galaxies. If there is time, I will discuss the maintenance role of hot gas halos around massive galaxies and how precipitation from these hot gas halos periodically reinvigorate minor episodes of star formation (as well as AGN activity).

There and back again: pathways to and from the red-sequence for ISM rich ETGs

Monday
5:20 - 5:40 pm

Timothy Davis
Cardiff University

In recent years it has become clear that a large fraction of ""quenched"" galaxies that lie on the optical red sequence have a significant cold ISM, and are forming stars. This begs the question: are these galaxies quenching, and near the end point of galaxy transformation? Or are they being regenerated? Using (sub-)millimetre data and optical integral field spectroscopy (from MUSE, ATLAS3D, H-ATLAS & AlFoCS; the ALMA Fornax Cluster Survey) along with semi-analytic and hydrodynamic simulations I will show that the majority of this population are regenerated red-sequence galaxies, which have begun to transform once more. In clusters, however, slower transformation mechanisms mean we may well be catching some galaxies as they transform for the first time. That star-formation is regenerated in these objects has significant impact on the interpretation of the trajectories of ETGs in the green-valley, and how these vary with galaxy mass.

Session 3

Galaxy Mergers on FIRE

Tuesday
9:00 - 9:20 am

Jorge Moreno

Cal Poly Pomona

Galaxy mergers and interactions are responsible for generating bursts of star formation, for changing galactic morphology in dramatic ways, and for triggering single and dual active galactic nuclei. In this talk, I will unveil the very first results from a novel suite of high-resolution galaxy merger simulations, based on the 'Feedback In Realistic Environments' (FIRE) model. This model treats energy and momentum-driven feedback from young stars and SN explosions explicitly, which acts directly on resolved star-forming clouds within the ISM. Moreover, this framework relies on a new meshless Lagrangian hydro code, GIZMO, which solves many problems associated with older solvers. Our first work focuses on the spatial localization of star formation. In particular, we confirm results from previous work: galaxy-galaxy interactions enhance nuclear star formation, and suppress it at large galacto-centric radii (Moreno et al. 2015). However, two major differences are found. First, star-formation enhancement and suppression are not as dramatic as in older models. Secondly, the interaction-induced nuclear starburst has a larger spatial extent. These differences are a reflection of the fact that, in our new models, non-axisymmetric gravitational torques are not as effective at driving fuel into the central regions as in older sub-grid based models. This suite of merger simulations is ideal for making predictions for, and interpreting results from, observations by new-generation integral field spectroscopic surveys.

Tuesday
9:20 - 9:40 am

Probing Ionization Mechanisms and AGN Activity in Luminous Infrared Galaxies with Near-Infrared Spectroscopy

H.Jacob Borish
University of Virginia

I present an analysis of ionization mechanisms in a sample of 47 luminous infrared galaxies as traced by their near-infrared line emission. These galaxies are hotbeds of extreme merger-driven star formation and are sometimes observed to contain luminous AGN - both phenomenon are obscured by dust within the galaxies, necessitating the need of long-wavelength data to assess the nature of their activity. The TripleSpec spectra are characterized by strong line emission from hydrogen recombination lines, [Fe II] lines, and ro-vibrational lines of molecular hydrogen. The [Fe II]/Pa-beta emission line ratio are roughly correlated with the optical emission line classification, with the HII region-like systems and LINERs having the lowest and highest values, respectively, of the ratio. This result is broadly consistent with shocks being the dominant mechanism driving this ratio. In addition, no evidence of embedded AGN (as traced via broad line regions or emission from coronal lines) in narrow-line LIRGs with HII region-like or LINER spectra were found. This study is part of the Great Observatories All-Sky LIRG Survey (GOALS).

Tuesday
9:40 - 10:00 am

Does AGN and stellar feedback affect the molecular gas in merger remnants?

Junko Ueda
Harvard-Smithsonian Center for Astrophysics

AGN and stellar feedback has been recently considered as an important process in galaxy evolution because galactic winds and outflows driven by AGN and starburst could blow out large amounts of the surrounding gas, quenching star formation. We have conducted HCN (1-0) observations of 16 local merger remnants, which have molecular gas disks detected in the CO, using the Large Millimeter Telescope (LMT). These merger remnants are taken from the sample of our ALMA/SMA study which reveals that nuclear and extended molecular gas disks are common in the final stages of mergers. We find that half of 16 sources have large line widths of the HCN compared to the CO. While the HCN line profiles of local galaxies have the same line widths as the CO line, several galaxies with AGN and active nuclear starburst have large line widths of the HCN. We thus suggest that the large line widths found in our sample may result from galactic winds and outflows driven by AGNs and starbursts. Furthermore, we investigate the relation between the ratio of the line width (FWHM(HCN)/(CO)) and the size of the molecular gas disk. As a result, we find that sources with large FWHM(HCN)/(CO) have compact molecular gas disks. If the large line widths of the HCN result from AGN and stellar feedback, this suggests that the feedback may destroy the molecular gas disks.

Large Scale Outflows and Dense Outflows in low-z ULIRGs

Tuesday
10:00 - 10:20 am

George Privon
Pontificia Universidad Catñlica de Chile

The coalescence stage of disk-disk galaxy mergers is thought to be a critical phase where an buried AGN activates and joins with the starburst to clear gas from the nucleus and quench star formation. The most spectacular example of this stage are the ULIRGs. Outflows are nearly ubiquitous in these systems, but it not yet determined if these winds escape the halo and whether the dense molecular gas goes along for the ride. Do the winds disrupt the densest portions of the molecular ISM or do they merely remove the lower-density molecular and atomic ISM, effectively ""starving"" the starburst. I will show VLT/MUSE observations of the outflowing atomic wind in the dual AGN NGC 6240 and ALMA observations of a dense molecular outflow in the coalesced ULIRG IRAS 13120-5453. These observations provide unique information on the character and possible fate of the winds clearing the nuclear ISM.

The Role of Major Mergers in (obscured) Black Hole Growth and Galaxy Evolution

Tuesday
11:30 - 12:00 pm

Ezequiel Treister
P. Universidad Catolica, Chile

A clear picture is emerging in which rapid supermassive black hole (SMBH) growth episodes (luminous AGN) are directly linked to major galaxy mergers, while the lower luminosity AGN can be triggered by secular processes. In this scenario, the more traditional unification paradigm in which orientation is the main parameter only holds at lower luminosities, while for the more violent accretion events, triggered by major mergers, we find evidence for an evolutionary sequence in which the AGN is first heavily obscured (Compton-thick), to then reveal an unobscured quasar.
In this talk, I will present observational evidence in support of this scenario, both in the local Universe and at high redshifts. In particular, I will discuss the main results from a NuSTAR AO-1 program aimed to obtain high energy observations for a sample of 12 nearby galaxies undergoing major mergers. These data allow us to detect even heavily obscured SMBH growth episodes, including the detection for the first time of a hidden AGN in NGC6286. Then, I will present the first results from our program aimed to obtain optical and near-IR Integral Field Unit (IFU) spectroscopy and ALMA maps for a sample of confirmed nearby dual AGN (separation <10 kpc), including the archetypical galaxy NGC6240. Clear evidence for complex morphologies and kinematics, outflows and feedback effects can be seen in these systems.
The importance of these high-luminosity, merger-triggered, obscured SMBH growth episodes, identified in the IR as ULIRGs, for the cosmic history of SMBH growth and its connection to galaxy evolution will be discussed.

Tuesday
12:00 - 12:20 pm

Clumpy Star-formation in Local Luminous Infrared Galaxies

Kirsten Larson
IPAC/Caltech

Star-formation in high-z galaxies is often found to be concentrated in luminous star-forming clumps much larger than those observed in the local universe. These large clumps of star-formation are thought to be caused by high molecular gas fractions and high turbulence. We present HST narrow-band imaging of Pa-beta and Pa-alpha emission of 50 local Luminous Infrared Galaxies from the Great Observatory All-Sky LIRG Survey (GOALS). LIRGs are often highly disturbed systems undergoing major mergers with molecular gas fractions of ∼10 - 50%. We can therefore study how the size, number and luminosity of the clumpy star-formation varies with MGF and merger stage. These data allow us to study spatially resolved HII regions down to 60pc and directly compare to star-forming clumps found in both local and high-z galaxies. We find star-forming clumps in the local LIRGS of similar sizes to those resolved in local normal galaxies (60 - 400pc radius) but with higher luminosities that fit between those found in normal local galaxies and those at z∼2.

Tuesday
12:20 - 12:40 pm

High-resolution cosmological simulations of major mergers: some merger remnants are star-forming and have stellar discs

Martin Sparre
HITS, Heidelberg Institute for Theoretical Studies

I present a suite of cosmological zoom-in simulations of major mergers run with the moving-mesh code, AREPO. The simulated galaxies have a z=0 mass comparable to the Milky Way, and they are simulated with a 40 times finer mass resolution than the Illustris simulation. I will show how the galaxy morphology of major merger remnants behave: In all the simulations a major merger at z=1 reduces the strength of the disc, but in several cases the merger remnant regrow a new significant disc before z=0. Also, a fraction of the major merger remnants are not quenched, but remains star-forming with blue colours. I will show how the stellar metallicity distribution function in merger remnants at z=0 has a memory of the merger that happened at z=1. This will have direct implications for galactic archaeology studies. This is one of the first studies of major mergers in cosmological simulations, since most of the existing literature about mergers relies on idealised non-cosmological setups.

Rethinking the Narrative of a Micro-Merger: Impacts on the Host Galaxy Morphology

Tuesday
12:40 - 1:00 pm

Rachael Beaton

Carnegie Observatories

In the Lambda-CDM paradigm, Milky Way sized galaxies are assembled via many minor- (1:5 to 1:10 mass ratio) and micro-mergers (less than 1:10 mass ratio) of dwarf satellite companions over cosmic time. Artifacts of such events are preserved by the large dynamical timescales within the stellar halo, where many stellar debris can be found in abundance with the haloes of the Local Group. While these known debris are quite diverse in morphology, they are almost uniformly consistent with being old or ancient events. Understanding the earlier phases of these accretions and the potential impact on the parent galaxy is left to extrapolation from their current fossilized state. In a survey for micro-merger debris within the Local Volume (with D=50 Mpc), I have discovered tidal debris with surviving satellites, whose morphologies defy the 'norm' of the Local Group. Two exciting examples are the bright satellite of NGC 5387, which is currently in undergoing a starburst (Beaton et al. 2014) and IC 2209 (interacting with NGC 2460), whose interaction debris contain a ridge of HII regions (Beaton et al. in prep.). The dynamical morphologies of the stellar tidal debris estimate that these interactions are relatively young, with the debris forming in less than 1 Gyr – suggesting that these mergers could offer unique insight on the early stages of micro-mergers not probed locally. I use N-body modelling to study the later evolution of the accretion event, in particular its impact on the parent galaxy, and global morphology metrics to 'blindly' classify these interacting systems (Beaton et al., submitted). Comparing snapshots from the models to deep imaging of other disturbed systems, I build a more dynamic narrative for events at the micro-merger mass scale and demonstrate, despite intuition, that events at the micro-merger mass scale have the potential to impact the inferred properties of the host galaxy.

Session 4

TBD

Tuesday
2:30 - 3:00 pm

Phil Hopkins
Caltech

Extreme Red Quasars in SDSS3-BOSS

Tuesday
3:20 - 3:40 pm

Fred Hamann
UC Riverside

Dust-reddened quasars are believed to mark an early stage of massive galaxy evolution where declining star formation rates are accompanied by blowouts of gas and dust that provide our first visible views of a luminous central AGN. The recent Baryon Oscillation Spectroscopy Survey (BOSS) of SDSS-III discovered many more faint quasars with higher redshifts and redder colors than any previous large survey. I will describe studies that combine BOSS spectra with SDSS and Wide-Field Infrared Survey Explorer (WISE) photometry of nearly 100,000 z $>$ 2 quasars to identify red quasars and characterize trends in the quasar properties with reddening. We find a number of strong trends consistent with a young evolution stage. For example, red quasars are 5 to 8 times more likely to have all varieties of ""intrinsic"" absorption lines in their spectra, including broad absorption lines (BALs) and their narrower cousins (mini-BALs) that identify strong quasar-driven outflows. Red quasars also tend to have emission line spectra resembling narrow-line Seyfert 1s, which are believed to have high accretion rates (L/Ledd). Perhaps most surprising is a new population of extreme red quasars (ERQs), selected via rest-frame UV to near-IR colors similar to Dust Obscured Galaxies (DOGs), that we find to have uniquely exotic emission line properties such as highly blueshifted CIV emission lines and the broadest and most blueshifted [OIII] lines ever recorded (with FWHMs and blue wings reaching 5000 km/s). These extreme [OIII] lines strongly favor a unique evolution stage involving galaxy-scale blowouts. We now have ongoing ALMA sub-mm observations of several ERQs to measure the star formation rates and search for signs of disturbance/'feedback' in the molecular gas (CO, [CI]) in their host galaxies.

Tuesday
3:20 - 3:40 pm

A Near-Infrared View of Shocks in Nuclear Outflows

Vivian U
UC Riverside

The role of shocks in quenching star formation and subsequently driving galaxy evolution is growing increasingly prominent with the advent of emission line modeling and integral field observations that help to identify and understand these processes. Shocks are particularly important phenomena in galaxy mergers where violent interaction of gas takes place in the interstellar medium of the systems. However, advanced optical tools used in these diagnostics encounter challenges at both physical and technical levels, e.g. shocks and other photoionization processes are difficult to discern using only optical lines, and that the nuclei of these merger systems are often dusty and optically thick. With high-resolution near-infrared integral-field observations taken with OSIRIS on Keck, I will present how we rely on near-infrared diagnostics such as the ro-vibrationally excited H2 and Br gamma lines to identify and characterize shocks associated with nuclear outflows seen in our merger systems. The resulting tools and calibrations will become progressively important for understanding galaxy evolution as we enter the era of JWST and new infrared instruments on 30-meter class telescopes.

Tuesday
4:50 - 5:10 pm

Star Formation Suppression due to AGN Feedback

Lauranne Lanz
Caltech/IPAC

Feedback due to active galactic nuclei is one of the key components of the current paradigm of galaxy evolution; however our understanding of the process remains incomplete. Radio galaxies with strong rotational H2 emission provide an interesting window into the effect of radio jet feedback on their host galaxies, since the large masses of warm (>100 K) H2 cannot solely be heated by star formation, instead requiring jet-driven ISM turbulence to power the molecular emission. I will discuss the insights multiwavelength observations of 22 H2 luminous radio galaxies yield on the impact of AGN jets on the star formation activity in these galaxies.

Star Formation in Luminous Quasars at 2<z<3

Tuesday
5:10 - 5:30 pm

Duncan Farrah
Virginia Tech

We investigate star formation rates in optically selected, luminous type 1 quasars at 2<z<3 using stacked Herschel observations. The star formation rates remain approximately constant with redshift, with a mean rate of 300 $M_{\odot}$/yr. This is consistent with the processes that trigger quasars evolving in a similar way to the processes that trigger star formation, and with the bulk of star formation in quasar hosts at this epoch not being in the 'starburst' mode. We find higher rates of star formation in quasars with higher accretion rates, and propose that we observe such a relation because the free gas fraction is higher at z>2, making the correlation easier to discern, and because that short-term AGN variability introduces scatter that is averaged out in our stacking analyses. We also find higher star formation rates in quasars with higher black hole masses, and argue that this result is at least to some extent independent of the relation with accretion luminosity. The two relations are plausibly driven by the available free gas, and how efficiently this gas is channeled into the nuclear regions, respectively. These relations together could also explain why we see no clear relation between star formation rate and Eddington luminosity. We observe a decline in star formation rate with increasing CIV equivalent width. This decline can be partially explained as a manifestation of the Baldwin effect, but likely has an additional contribution from a scaling with black hole mass. Conversely, we find no systematic relation between star formation rate and the asymmetry of CIV, suggesting that AGN winds do not affect star formation on timescales comparable to the AGN duty cycle.

Detailed visual morphologies of 200,000 galaxies at 0.25 < z < 4 from Galaxy Zoo and Hubble Legacy Imaging

Tuesday
5:30 - 5:50 pm

Brooke Simmons
UC San Diego

From 2010 to 2015, over 150,000 people contributed over 12,000,000 independent visual classifications of approximately 200,000 galaxies imaged using the ACS and WFC3 cameras as part of the AEGIS, CANDELS, COSMOS, GEMS, and GOODS surveys. Here we present the combined, weighted, debiased visual morphological classifications of these galaxies. Measurements include details of clump structures, bar features, spiral arm counts, bulge strength in disks, and merger/tidal features. The classifications agree very well with professional visual classifications. We show first results from the data sets, including basic demographics of the samples, and identify subsamples of spiral, clumpy, and merging galaxies at a range of redshifts. The data releases for the ACS and WFC3 classifications are imminent (expected by late summer 2016, once the papers are accepted); those desiring early access to the data need only ask.

Session 5

From Nuclear Outflows to Galactic Winds

Wednesday
2:30 - 3:00 pm

Anne Medling
Australian National University

The evolution of a galaxy depends heavily on its gas content: gas both forms stars and fuels black hole growth. These processes may be capable of self-regulating, since both star formation and AGN activity can drive outflows that may remove gas from the host galaxys reservoir. Such outflows are challenging to study because of the wide range of scales involved. Distinguishing between launching mechanisms requires high spatial resolution, but such observations usually are too limited in field-of-view to determine what effect an outflow has on galactic scales. I will present some first results from our two-pronged approach, which combines wide-field optical integral field spectroscopy tracing galactic winds on several kpc scales and AO-assisted near-infrared integral field spectroscopy to zoom in on the launch regions of these winds. The combination of these observations is a powerful way to connect the physical mechanisms driving galactic winds to the physical effects these winds can have on their host galaxies.

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

Wednesday
3:00 - 3:20 pm

Dale Kocevski
Colby College

I will summarize the insights gained from the CANDELS and X-UDS surveys regarding the demographics of the AGN host population out to z$\sim$2. In particular, I will focus on 1) the high frequency of disturbed morphologies among heavily obscured, compton-thick AGN at z$\sim$1-2 and 2) the prevalence of luminous AGN in compact, star forming galaxies at z=2.5. The former result suggests that merger-triggered AGN at z$\sim$1 are heavily obscured, which may help explain why it has been so difficult to clearly establish an AGN-merger connection. The latter result suggests SMBH growth, and possibly AGN feedback, was ubiquitous in 'blue-nugget' galaxies at z$\sim$2. Based on their size, stellar mass, and star formation rates, these galaxies appear to be the direct progenitors of the compact 'red nugget' population. Our findings indicate the first generation of quenched

galaxies emerged in the early Universe directly following a phase of rapid SMBH growth. I will discuss what these observations reveal about the connection between AGN activity and the rise of the red sequence at z∼2.

Wednesday
3:30 - 3:40 pm

The Cosmic Evolution of AGN Feedback: Insights from Broad-band Radio Spectral Indices

Kristina Nyland
NRAO

Although our knowledge of the physics of galaxy formation and evolution has made great strides over the past few decades, we still lack a complete understanding of how the first galaxies formed at high redshift, the details of the complex symbiotic relationship between galaxies and their supermassive black holes (SMBHs), and the mechanisms responsible for triggering and halting the vigorous star formation (SF) and nuclear activity in galaxies during the 'peak epoch' of galaxy assembly. While the next generation of radio telescopes are expected to usher in many exciting advancements in this area of research, existing wide-area surveys from telescopes such as the GMRT, JVLA, and ATCA can already provide interesting constraints. Here, I present a preliminary analysis of the 150 to 1400 MHz radio spectral indices of objects identified in the five multiwavelength deep fields that comprise the Spitzer Extragalactic Representative Volume Survey (SERVS). In addition to identifying high-redshift radio galaxies in SERVS, I compare the broad-band radio spectral indices with various host galaxy properties, such as photometric redshift, to investigate implications on the cosmic evolution of AGN feedback.

Wednesday
3:40 - 4:10 pm

The Close AGN Reference Survey

Tanya Urrutia
Leibniz Institut fúr Astrophysik, Potsdam

In galaxy evolution simulations, the AGN phase is thought to be special in transforming a galaxy, especially through the so-called AGN feedback, which shuts down star formation and/or leaves it turned off. Observational evidence for this is much more scarce: while AGN outflows are ubiquitous, their predicted vast effects on the host galaxy is tenuous and confined to a few spectacular examples. In my talk, I will present CARS (www.cars-survey.org), the Close AGN Reference Survey, which studies 35 local, luminous, Type 1 AGN. The backbone of the survey is data from the MUSE 3d spectrograph, which maps out in detail spatial and spectral information about the host galaxy, but much multiwavelength ancillary data exists for these objects. I will show statistically how outflow properties (strength, mass, ionization potential) correlates with certain AGN properties, especially the accretion rate. I will also show some

spectacular examples of the so-called "green wisps" (large AGN-ionized regions in the host galaxy). As the name says, the observations done with CARS will act as a reference point for the higher redshift Universe and make predictions on the peak of AGN activity at z∼2.

Galaxy evolution in dense environments

Wednesday
4:50 - 5:10 pm

Simona Mei

Observatory of Paris/University of Paris Denis Diderot

We believe that elliptical galaxies formed the bulk of their stellar population in dense regions at redshift of z∼2.5-3, and then evolved passively up to the present. Galaxy clusters and proto-clusters are the ideal environments to study the formation and evolution of early-type galaxies, and early probes of cosmology. Clusters at z>1.5 are shown to host the star forming progenitors of their current red sequence early-type population. We will present our recent cluster and protocluster detections in the HST CDF-S, CANDELS and SSDF fields using deep observations with Spitzer, the HST/WFC3 grism spectroscopy and VLT/KMOS IFU spectroscopy. We will discuss our results in terms of galaxy evolution and the formation of the massive early-type progenitors.

Transforming Galaxies in Extreme Environments: the Era of Star Formation and AGN Activity in Massive Clusters at z=1-2

Wednesday
5:10 - 5:30 pm

Stacey Alberts

Steward Observatory, University of Arizona"

It is well established that galaxy properties are connected to their environment, with local massive galaxy clusters representing the extreme, populated primarily by passively evolving early-type galaxies with very little star formation or black hole accretion activity. Cluster assembly models have long predicted that the last major epoch of mass growth and star formation (SF) activity in massive clusters occurred in short bursts at very high redshift (z∼3-5); however, recent studies have begun to reveal that clusters at z=1-2 contain significant SF and AGN activity, on par with or even in excess of lower density environments. This epoch, then, represents an important opportunity to study the effect of environmental mechanisms on the transition of galaxies from blue to 'red and dead'.

In this work, we present a detailed, multi-wavelength study of SF and AGN activity in 11 near-infrared selected, massive (log M > 14 $M_{\odot}$) galaxy clusters at 1<z<1.75. Utilizing optical to far-infrared imaging from Herschel/PACS, we characterize the spectral energy distributions (SEDs) and dust-obscured SF properties of cluster galaxies in relation to their environment. Identification and decomposition of AGN through SED

fitting allows us to include the contribution to cluster SF from AGN hosts and quantify the AGN fraction as a function of cluster-centric radius and redshift. In good agreement with recent studies, we find that cluster galaxies at z>1.4 have field-like SF activity right into the cluster cores, followed by a transition toward significant quenching by z∼1. AGN also show a significant rise in activity in cluster cores, with clusters at z>1-1.5 showing an excess in their AGN fraction over that found in the field. This indicates that environmental triggering of AGN is efficient in massive clusters during this epoch. Lastly, we constrain the timescale of cluster galaxy quenching by comparing Ha from our HST observations, which traces SF on short (∼10 Myr) timescales to our infrared SF, which traces longer timescales (∼100 Myr). We find that the ratio of these tracers is correlated with cluster-centric radius, indicating recent quenching in cluster galaxies. Taken together with other clues from the literature, these results paint a clearer picture of the role of environment in galaxy evolution.

Wednesday
5:30 - 5:50 pm

The Keck OSIRIS Nearby AGN Survey: Spatially Resolved Inflows and Outflows in Seyfert Galaxies

Francisco Muller-Sanchez

University of Colorado at Boulder

"I present the first results from the KONA (Keck OSIRIS Nearby AGN) survey, which uses the integral field unit OSIRIS plus LGS adaptive optics to probe down to scales of 5-30 parsecs in a sample of 40 Seyfert galaxies. In this talk, I will describe recent work showing how AGN are fed and how they influence their host galaxies. We find that AGN-driven outflows of ionized gas are ubiquitous, and that biconical models of radial outflow provide a good fit to the spatially resolved kinematics. Inflows of molecular gas are found in approximately half of the sources, where they occur mostly in nuclear spiral structures or nuclear bars with mass inflow rates of ∼0.1-10 $M_{\odot}$ yr-1. This is of the order of the outflow rates, suggesting that AGN feedback suppresses accretion onto the supermassive black hole (SMBH). Furthermore, the kinetic power of the outflow follows a relationship with the velocity dispersion of the molecular gas in the central 25 pc, but this becomes indiscernible when the large-scale dispersion is considered. This suggests that AGN feedback has a strong impact on the turbulent ISM near the SMBH, but not on the galaxy disk. Finally, our observations provide direct evidence of the ways in which the outflows of ionized gas interact with the circumnuclear ISM, either by creating cavities of molecular gas, or by launching molecular outflows.

Mapping the incidence and distribution of AGN accretion across the galaxy population

Wednesday
5:50 - 6:10 pm

James Aird

University of Cambridge

To understand the role of AGN in the transformation of the galaxy population throughout cosmic time, we must determine how the incidence of AGN and the distribution of their accretion power depends on the physical properties of the galaxies that host them. We combine near-infrared selected samples of galaxies from the CANDELS/3D-HST and UltraVISTA surveys with deep Chandra X-ray data to provide new constraints on the distribution of specific accretion rates (scaled relative to the total host galaxy mass) within both star-forming and quiescent galaxy populations as a function of stellar mass and redshift. Our results reveal a broad underlying distribution of accretion rates (reflecting long-term variability in the level of AGN fuelling) in both galaxy types. The probability of a star-forming galaxy hosting an AGN (above a fixed specific accretion rate) shows a strong stellar mass dependence revealing a higher incidence of AGN in massive host galaxies and undergoes a stellar-mass-dependent evolution with redshift. The probability of a quiescent galaxy hosting an AGN is generally lower but does not depend on stellar mass and evolves differently with redshift. Our results show that the levels of black hole growth are closely linked to the transforming galaxy population and provide vital constraints on any potential impact of AGN on the transformation process.

Session 6

Environment and the Evolution of Dwarf Galaxies

Thursday
9:00 - 9:30 am

Gurtina Besla
University of Arizona

Low mass, dwarf galaxies (M∗ = 1e8 - 5e9 Msun) are typically gas rich, unless found in proximity to a massive host. This has lead to the conclusion that the evolution of dwarfs is dominated solely by their host environment, through processes such as tidal and ram pressure stripping. Turning the argument around, this also implies that dwarfs are ideal probes of the circumgalactic medium (CGM) and dark matter potentials of their hosts. However, dwarf galaxies are often found with companions, invoking an additional environmental pathway for their evolution. Recent results from the TiNy Titans Survey illustrate that dwarf-dwarf galaxy interactionscan be an important mode of gas removal, causing these galaxies to possess large envelopes and streams of gas. Such extended structures can be efficiently stripped upon entering a more massive environment, highlighting an overlooked mode of gas supply to the CGM of galaxies like our Milky Way.

The Preferred Pathway to the Red Sequence

Thursday
9:30 - 9:50 am

Jeremy Tinker
New York University

I combine group catalogs from SDSS data with high-resolution N-body simulations to statistically determine the preferred pathway to the red sequence: group or field processes. In the parlance of halo occupation, these equate to processes that impact satellite and central galaxies. This method quantifies the timescale of the migration to the red sequence. I will show that field processes are the dominant pathway to the z=0 red sequence, and that the migration timescales are substantially different for central and satellite galaxies of the same stellar mass. Additionally, I will present new measurements of the scatter between halo mass and galaxies mass, yielding constraints on the correlation between halo growth and stellar growth as well as the 'duty-cycle' of star formation.

Dissecting z∼1 Galaxy Clusters in Phase-Space: Studying Star Formation from the Outskirts to the Core

Thursday
9:50 - 10:10 am

Allison Noble

University of Toronto

Understanding the influence of environment is a fundamental goal in studies of galaxy formation and evolution. High-redshift galaxy clusters offer ideal laboratories with which to examine environmental effects as infalling galaxies morph from star-forming to red and dead galaxies within the cluster core. In Noble et al. 2013, we presented a novel definition for environment using the phase space of line-of-sight velocity and clustercentric 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 revealed 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 (Noble et al. 2016). With a sample of 120 spectroscopically-confirmed cluster members, we investigate various galaxy properties as a function of phase-space environment for dynamically distinct galaxy populations, namely recent infalls and those that were accreted onto the cluster at an earlier epoch. 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. I will conclude with brand new results from ALMA Cycle 3 observations of some of the first molecular gas detections in the cores of three galaxy clusters at z=1.6.

Effects of Local Envirnonment and Stellar Mass on Galaxy Quenching Out To z ∼ 3

Thursday
10:10 - 10:30 am

Behnam Darvish

California Institute of Technology

We study the effects of local environment and stellar mass on galaxy properties using a mass complete sample of quiescent and star-forming systems in the COSMOS field at $z \lesssim 3$. We show that at $z \lesssim 1$, the median star-formation rate (SFR) and specific SFR (sSFR) of all galaxies depend on environment, but they become independent of environment at $z \gtrsim 1$. However, we find that only for star-forming galaxies, the median SFR and sSFR are similar in different environments, regardless of redshift and stellar mass. We find that the quiescent fraction depends on environment at $z \lesssim 1$, and on stellar mass out to $z \sim 3$. We show that at $z \lesssim 1$, galaxies become quiescent faster in denser environments and that the overall environmental quenching efficiency increases

with cosmic time. Environmental and mass quenching processes depend on each other. At z $\lesssim$ 1, denser environments more efficiently quench galaxies with higher masses ($\log(M/M_\odot) \gtrsim 10.7$), possibly due to a higher merger rate of massive galaxies in denser environments, and that mass quenching is more efficient in denser regions. We show that the overall mass quenching efficiency ($\epsilon_{\rm mass}$) for more massive galaxies ($\log(M/M_\odot) \gtrsim 10.2$) rises with cosmic time until z $\sim$ 1 and flattens out since then. However, for less massive galaxies, the rise in $\epsilon_{\rm mass}$ continues to the present time. Our results suggest that environmental quenching is only relevant at z $\lesssim$ 1, likely a fast process, whereas mass quenching is the dominant mechanism at z $\gtrsim$ 1, with a possible stellar feedback physics.

The evolutionary pathways of dwarf galaxies

Thursday
10:30 - 11:00 am

Federico Lelli

Case Western Reserve University

The mechanisms that transform gas-rich dwarf irregulars (dIs) into gas-poor dwarf ellipticals (dEs) are still unclear. Starburst dwarf galaxies are transition-type, fast-evolving systems, which may hold the key to understand such mechanisms. We study the structure and dynamics of 18 starburst dwarfs at z=0, combining interferometric HI observations with HST imaging of resolved stellar populations. We also consider control samples of non-starbursting dIs in the group/field environment and dEs in the Virgo cluster. We reach the following results. (1) Starburst dwarfs have gas fractions similar to dIs, indicating that stellar feedback did not eject large amounts of gas out of their potential wells. Gas consumption or expulsion are not viable mechanisms for the transformation of gas-rich dwarfs into gas-poor dEs. (2) The inner rotation curves of starburst dwarfs rise more steeply than those of typical dIs, pointing to an unusual concentration of mass (gas, stars, and dark matter). Some "compact" dIs and rotating dEs, however, show similarly steep rotation curves and are potential descendants of starburst dwarfs. (3) Starburst dwarfs have more asymmetric outer HI distributions than dIs, suggesting that starbursts are triggered by interactions/mergers between dwarf galaxies or cold gas accretion from the IGM.

Thursday
11:30 - 12:00 pm

It's Complicated: Galaxy Evolution in Compact Groups

Sarah Gallagher

Western University

Compact groups of galaxies host a handful of galaxies within a few galaxy radii of each other. With low relative velocities and high number densities, galaxies in this environment interact strongly and over extended time periods, and thus dynamical galaxy evolution is enhanced. At the same time, the small membership means that these groups remain imprinted with their early history: their initial relative positions and velocities influence strongly their current properties. These low-mass systems are thus ideally suited to test galaxy evolution in the dense, low-mass environments that were likely building blocks of galaxy clusters and isolated ellipticals. I'll synthesize the results from a mult-wavelength observational and theoretical effort to map the baryons and reconstruct the recent history of local compact groups with the aim of understanding galaxy evolution in this important environment.

Thursday
12:00 - 12:20 pm

Star formation suppression in galaxies in Hickson Compact Groups

Ute Lisenfeld

Universidad Granada (Spain)

Galaxies in Hickson Compact Groups (HCGs) live in an environment where galaxy interactions play an important role. Mid-infrared colours from the Spitzer and WISE are able to classify galaxies in blue, star-forming and red quiescient objects. Galaxies with intermediate colour, populating the so-called "canyon" region are rare.
I will present an analysis of the molecular gas and SF properties of a sample of galaxies in HCG with CO data. We find that the star formation efficiency and also the molecular-to-stellar mass is lower in canyon compared to blue galaxies, indicating that a loss of molecular gas and suppression SF is crucial in the morphological transition.

Galaxy Evolution in Dense Group Environments: Clues from Warm Diffuse Gas

Thursday
12:20 - 12:40 pm

Philip Appleton
Caltech/NASA Herschel Science Center

"Due largely to spectrometers onboard Spitzer and Herschel, our understanding of the energetics of warm diffuse gas in compact groups has provided new insight into large-scale processes shaping gas in dense environments. I will review the progress that has been made in understanding how energy is driven into the ISM of host galaxies through both galaxy-galaxy collisions, and feedback from starburst or AGN-driven winds, using both ground-based IFU and space-based observations. Ranging from turbulent heating of the intra-group medium in Stephans Quintet, to outflows and winds in other systems, I will discuss processes that can change the state of molecular gas in galaxies. How might theses processes suppress star formations, and for how long? Can shocks and turbulence transform galaxies or are they merely tracers of activity? I will discuss the importance of understanding warm molecular and diffuse atomic gas in high redshift systems, and how new opportunities emerge from the capabilities of JWST, WFIRST, ALMA and SPICA. The possibility of detecting turbulent warm molecular gas at very high-z will be reviewed in the context of a possible future NASA far-IR surveyor mission. "

Connecting dusty starburst galaxies and proto galaxy clusters: a case study at z=2

Thursday
12:40 - 1:00 pm

Chao-Ling Hung
University of Texas at Austin

The cores of massive galaxy clusters are dominated by elliptical galaxies with minimal star formation, but the pathways that lead to these massive, quenched galaxies remain unclear. Proto galaxy clusters at z>2 with rich populations of submillimeter galaxies (SMGs) and dusty star-forming galaxies (DSFGs) represent important sites and critical phases where/when the massive cluster galaxies are actively assembling. I present our search of DSFGs within and around a protocluster at z$\sim$2.1 in the COSMOS field. Both color-selected SFGs and DSFGs show significant overdensities around the proto-cluster, and this structure spans across several tens of cMpc, considerably larger than previously observed. The cluster core and the extended DSFG- and SFG-rich structure together demonstrate an active cluster formation phase, in which the cluster is accreting a significant amount of material from large scale structure while the more mature core may begin to virialize. Along with other DSFG-rich protoclsuters and protocluster candidates, I discuss if these intense star formers are triggered concurrently through galaxy interactions and/or enhanced gas supply, and how do these mechanisms may lead to subsequent quenching.

Session 7

The Morphologies of the Most Luminous galaxies in the Universe

Thursday
2:30 - 3:00 pm

Jeyhan Kartaltepe

Rochester Institute of Technology

In the local universe, Ultraluminous Infrared Galaxies (ULIRGs, $L_{IR} > 10^{12}$ $L_{\odot}$) are all interacting and merging systems. To date, studies of ULIRGs at high redshift have found a variety of results due to their varying selection effects and small sample sizes. Some studies have found that mergers still dominate the galaxy morphology while others have found a high fraction of morphologically normal or clumpy star forming disks. Near-infrared imaging is crucial for interpreting galaxy structure at high redshift since it probes the rest frame optical light of a galaxy and thus we can compare directly to studies in the local universe. At high redshift (z$\sim$2), not only are ULIRGs much more common, but many more of the extreme HyLIRGs ($L_{IR} > 10^{13}$ $L_{\odot}$) are detected. We have recently obtained HST WFC3-IR imaging of a sample of high-z HyLIRGs over the wide area COSMOS field in order to study their morphology and determine if they are the analogs of ULIRGs in the local Universe. In this talk, I will present our first results on the merger origin of these extreme systems, and compare them to CANDELS results of LIRGs and ULIRGs at the same redshift, thereby probing a luminosity range of over two orders of magnitude at the peak epoch in star formation activity and spanning a range of parameter space in the SFR-M* plane.

Giant cosmic tsunamis: the impact of galaxy cluster merger shocks on galaxy evolution

Thursday
3:00 - 3:20 pm

Andra Stroe
ESO

The galaxy population in relaxed clusters is dominated by passively evolving ellipticals. However, a large fraction of clusters are undergoing mergers, which in the most extreme cases, give rise to cluster-wide traveling shocks. Is the galaxy population in merging clusters dominated by passive galaxies? How do merger shocks interact with cluster galaxies? Through Halpha, HI and radio mapping of galaxy clusters at low redshift (z$\sim$0.2) we uncover, for the first time, whether shocks inhibit or trigger star formation in cluster galaxies. We find that in young clusters undergoing a merger, the passage of the shock through gas-rich cluster galaxies can compress the gas and lead to vigorous star formation lasting for a few 100 Myr, reversing the typical environmental trends operating in galaxy clusters. The complex interaction between the merger, the shock wave and gas can ultimately accelerate the quenching of gas-rich star-forming galaxies. Shock induced star formation may a fundamental driver in the evolution of proto-clusters and high-redshift clusters, where mergers and shocks were far more common than in the nearby Universe.

The Role of Environment in Transforming Galaxies Across Cosmic Time

Thursday
3:20 - 3:40 pm

Gillian Wilson
University of California Riverside

Despite a dramatic build up in the number of quenched galaxies at z $<$ 2, it is still unclear how this quenching comes about. Potential quenching mechanisms fall into two categories: processes that act on ""centrals"" and those that act on ""satellites"". While both hydrodynamic and semi-analytic models do a good job of predicting the quenched fraction of centrals, they over predict the fraction of quenched satellite galaxies, reflecting our much greater uncertainty about how ""environmental"" quenching occurs.
I will present results from GCLASS, a 25-night Gemini/GMOS spectroscopic follow-up survey of ten massive clusters at z$\sim$1, and explain what we are learning about quenching and stellar mass assembly of galaxies in these, the densest of environments, relative to the field population. In particular, I will discuss evidence for a change in the dominant satellite galaxy quenching mechanism at z=1 relative to the local universe. I will conclude by discussing GOGREEN and DEEPDRILL, two new large surveys approved by Gemini & Spitzer, designed to study the effects of environment at lower stellar mass and at higher redshift, respectively. Collectively, these powerful new surveys are beginning to allow us to place constraints on the location and timescale of quenching and,

in concert with both hydro-simulations and semi-analytic models, identify the complex role of environment in shaping galaxy transformation over cosmic time.

The Latte Project: Simulating Satellite Dwarf Galaxies around a Milky Way-mass Galaxy

Thursday
3:40 - 4:10 pm

Andrew Wetzel

Carnegie Observatories & Caltech

The Latte Project is a new suite of cosmological zoom-in baryonic simulations that model the formation of Milky Way-mass galaxies at parsec-scale resolution, using the FIRE (Feedback in Realistic Environments) model for star formation and stellar feedback. These simulations self-consistently resolve the satellite dwarf galaxy populations that form around the Milky Way-mass host galaxies, including the relevant physics to model their stellar populations. I will discuss the relative impacts of (internal) stellar feedback and (external) environment on the star formation histories, stellar kinematics, and chemical enrichment histories of these simulated dwarf galaxies, including comparisons with the observed dwarf galaxies around the Milky Way and Andromeda.

An emerging consensus on the merger rate of massive galaxies at z=0-3

Thursday
4:50 - 5:10 pm

Allison W. S. Man

European Southern Observatory

At the peak of cosmic star formation history at z$\sim$2, galaxy mergers are typically identified via close pair selections. Searches for satellites are limited to the most massive galaxies due to the NIR survey sensitivity limits. While the LCDM predicts that their merger rate increases monotonically with redshift, almost all observations indicate that the merger rate is nearly constant out to z$\sim$3. We argue that a considerable fraction of mergers are missed in current searches based on optical and NIR data. At z>1, satellites can contain comparable gas and stellar masses. This implies that a population of gas-rich (likely dusty) satellites can be missed in stellar-mass limited searches. I will present how ALMA is used to identify these missing gas-rich satellites around massive galaxies. While this will mitigate the tension between the observed vs LCDM-predicted merger rate of massive galaxies, it may imply that our current constraints on the merger-driven mass and size growth of massive galaxies may be incomplete.

Thursday
5:10 - 5:30 pm

The Evolution of HI in Galaxies as a Function of Environment

Jessica Rosenberg
George Mason

Galaxies in the local universe possess a wide range of properties due, at least in part, to their merger history and environment. I will discuss our use of optical and HI 21 cm data (from SDSS and ALFALFA) to study the gas and stars in galaxies as a way of tracing the impact of pair interactions as well as the group and cluster environment on the gas content of galaxies. We find that interacting pairs show little change in their HI gas content as the interaction progresses while there is evidence for gas depletion towards the center of galaxy groups, and even more significant depletion towards the center of galaxy clusters, likely driven by ram pressure stripping. These results indicate that the group and cluster environments play an crucial role in the evolution of gas in galaxies in the local universe.

Thursday
5:30 - 5:50 pm

The SAMI Galaxy Survey: The impact of the cluster environment on the star formation of infalling galaxies

Matt Owers
Macquarie University and Australian Astronomical Observatory

The star-forming properties of galaxies that reside in the dense cores of galaxy clusters are remarkably different from those in the field; quiescent early-type galaxies are much more prevalent in cluster cores whereas star-forming spirals dominate in the field. These differences must be reconciled with the hierarchical nature of large-scale structure formation, where the cluster galaxy population increases by the accretion of galaxies from lower density environments. The dominant mechanism responsible for transforming infalling galaxies, cluster-related or otherwise, remains elusive. Getting to the heart of this issue requires a robust definition of galaxy environment, along with resolved information on the recent star formation history of the infalling galaxies.
The SAMI Galaxy Survey will provide resolved spectroscopy for around 3600 galaxies. Of those galaxies, 700 have been selected to be members of eight massive clusters of galaxies. A redshift survey conducted on the AAT's AAOmega multi-object spectrograph provided a sample of 3000 confirmed cluster members that have been used to characterize the dynamical properties of each cluster. In particular, the redshift survey has allowed a robust characterization of the projected phase-space (PPS) distribution of the clusters. The position of a galaxy in PPS can be used as a proxy for the time since infall for a galaxy. In this talk, I will present an analysis of the resolved star-forming properties of SAMI cluster galaxies which, based on their position in PPS, are very likely to be encountering the cluster core for the first time. The majority of these galaxies show ongoing star-formation their centers, but show evidence for young (<1Gyr) stellar populations with no ongoing star-formation in the outer parts of the

disk. This indicates that the galaxies are having their star formation quenched from the outside-in, likely due to the effects of ram-pressure stripping as they traverse the clusters.

Session 8

Galaxy transformations at z∼2

Friday
9:00 - 9:30 am

Mariska Kriek
UC Berkeley

In the past years it has become clear that the massive galaxy population at z∼2 was much more diverse than today, ranging from compact quiescent to large star-forming galaxies. The relation between these two populations and their possible evolutionary connection are still poorly understood. If these galaxy types indeed are evolutionary connected, how do the star-forming galaxies quench and shrink into the quiescent galaxies? Or is there a different population of progenitors for the compact quiescent galaxies? New studies based on CANDELS, ALMA, and deep near-infrared spectroscopy with MOSFIRE give new insights into these questions. In this talk I will present several projects that make use of the populations of post-starburst and compact star-forming galaxies for understanding the formation of z∼2 compact quiescent galaxies are their connection to star-forming galaxies at similar redshift.

The mechanisms for quiescent galaxy formation at z<1

Friday
9:30 - 9:50 am

Kate Rowlands
University of St Andrews

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, 2016). It is not well known how much post-starburst galaxies contribute to the build-up of the red sequence at z<1, due to small number statistics in previous redshift surveys, and aperture bias at very low redshifts (e.g. in SDSS). By exploiting the highly complete, wide-area GAMA and VIPERS spectroscopic surveys, we select post-starburst galaxies undergoing rapid quenching (<1 Gyr timescales), green-valley galaxies undergoing slower quenching and red sequence galaxies. We chart the build-up of the red sequence over the last 8 billion years and find that <10% of galaxies on the

red sequence could have gone through a post-starburst phase. The majority of galaxies at low redshift undergo a much slower decline in their star formation before reaching the red sequence. This picture is consistent with the recent detection of significant amounts of residual cold gas in local PSB galaxies (Rowlands et al. 2015, French et al. 2015), indicating that multiple events may be required to transform a low redshift star-forming galaxy into a future quiescent galaxy.

Friday
9:50 - 10:10 am

How to quench massive galaxies

Andreas Faisst
Caltech/IPAC

The time-scale over which quenching of star-formation is happening is closely related to the actual quenching mechanism and therefore offers a tool to understand the physics of the shut-down of star-formation. However, very little is known about these time-scales. We use a sample of 400 very massive (logM $>$ 11.4) galaxies at z $\sim$ 2 in the COSMOS field to investigate their quenching time-scale and possible mechanism using their trajectories in the 3-dimensional phase space spanned by stellar mass, SFR, and galaxy size. In more detail, we predict the size evolution of quenched galaxies from star-forming galaxies assuming two possible mechanisms: the 'waning model' (cut off of gas flow on galaxy leading to its consumption over $>$500 Myrs) and the 'instantaneous-quenching model' (instantaneous gas depletion by a merger-induced star-burst). We find that an 'instantaneous-quenching' model best reproduces the observed size evolution of quiescent galaxies at logM$>$11 and therefore conclude that such massive galaxies have to quench on short time-scales of several 100 Myrs. The high merger rates of such galaxies strengthen this picture of merger-induced star-formation quenching.

Friday
10:10 - 10:30 am

The structures and star formation activities of massive galaxies in cosmological simulations

Robert Feldmann
University of California, Berkeley

The properties of galaxies changed dramatically between z$\sim$2-3 and today. The specific star formation rates of typical star forming galaxies decreased by an order of magnitude and the number of quiescent galaxies grew strongly. In addition, a significant fraction of massive galaxies at early times were highly compact with effective radii of 1 kpc or below, while similarly massive galaxies with such small radii are extremely rare today. I will discuss the transformational processes that affect the star formation and size evolution of massive galaxies with the help of the MassiveFIRE project, a set of state-of-the-art cosmological simulations of massive galaxies and their environments over cosmic time. In particular, I will show that the halo accretion rate is a key parameter

in determining which massive galaxies at z∼1.5-3 become quiescent. Furthermore, I will discuss the compact sizes of massive, quiescent galaxies at early times and the size growth between z∼3 and z=0. If time permits, I will evaluate (based on mock data derived from the simulations) how well future observations with JWST will help constrain global properties of massive galaxies at intermediate redshifts.

Evidence for a Significant Population of Massive Quenched Disks in the Early Universe

Friday
10:30 - 11:00 am

Elizabeth McGrath
Colby College

Using CANDELS, we select a sample of massive ($>10^{10}$ $M_{\odot}$), quiescent galaxies at z>1 to explore the relationship between morphology and star-formation quenching in the early universe. While observations in the local Universe suggest that the mechanism responsible for quenching star formation is linked to the structural transformation from disk to spheroid, we find a significant fraction (∼30%) of disk-dominated galaxies among the quiescent population at high redshift, far in excess of what we find today. The persistence of stellar disks long after star-formation has ceased implies that in at least some cases quenching precedes morphological transformation. We examine formation scenarios for these massive quiescent disks as compared with their quiescent spheroid counterparts, and discuss possible quenching mechanisms.

The gas content of galaxies over cosmic time

Friday
11:30 - 12:00 pm

Gergely Popping
ESO Garching

The star-formation activity of our Universe increased from early epochs (z∼6), peaked around z=2, and then decreased by an order of magnitude until present age. To fully appreciate the physical origin of the star-formation activity of our Universe we need to focus on the gas content of galaxies over cosmic time. The most recent versions of cosmological models of galaxy formation explicitly include the detailed tracking of the atomic and molecular hydrogen content of galaxies and make predictions for the sub-mm lines emission from species such as CO, HCN, and [CII]. New semi-empirical approaches provide data-driven predictions for the atomic and molecular gas content of galaxies. I will discuss the predictions made by these different types of models for the HI and H2 content of galaxies and their sub-mm line emission, and the inferred gas properties of 25000 galaxies at redshfits $0.5 < z < 3$, taken from the CANDELS survey. I will present results such as a weak evolution in the HI content and HI mass function of galaxies, strong evolution in the H2 content of galaxies, weak evolution in the cosmic density of HI, the evolution of atomic and molecular gas in dark matter

haloes, and predictions for CO luminosity functions. I will finish by demonstrating how a comparison between theoretical models of galaxy formation and observed and inferred gas masses can reveal caveats in our understanding of galaxy physics.

Friday
12:00 - 12:20 pm

Structural transformation and quenching in massive post-starburst galaxies

Omar Almaini
University of Nottingham

Despite many years of study, we still do not fully understand why massive galaxies abruptly switch off their star formation in the distant Universe. It is also unclear if the same processes are responsible for the morphological transformation of galaxies, to produce the Hubble Sequence we observe today. The rare class of post-starburst ('E+A') galaxies provide a unique opportunity to study the transition phase, but until recently only a handful had been identified at high redshift (z>1). Using a new PCA technique, we have recently identified over 500 post-starburst galaxies in the UKIDSS UDS field, spanning the redshift range 0.5<z<2.0 (Wild et al. 2016; Maltby et al. 2016). We find that their space density is sufficient to provide a major growth channel for massive quiescent galaxies. We also find that post-starburst galaxies at high redshift (z>1) are surprisingly compact and spheroidal, with a distribution of Sersic indices that are indistinguishable from the old quiescent population. We conclude that the quenching of star formation occurs during (or after) the event that forms the proto-spheroid. Our findings are consistent with a scenario in which compact massive galaxies are formed from extremely gas-rich dissipative collapse, with rapid quenching followed by a gradual growth in size.

Friday
12:20 - 12:40 pm

Modelling dusty galaxies

Anna Sajina
Tufts University

I will present current work on comparing GADGET+Sunrise hydrodynamic simulations with observations of IR-luminous galaxies at z∼0.3-3. I will especially focus on the relative roles of stars and AGN in heating the dust, how this changes throughout a merger stage and as a function of A_V. I will compare the results of the simulations with empirical measurements. I will address the successes and limitations of the current generation of hydrodynamic simulations. Lastly, I discuss a new MCMC-based luminosity function evolution code in development at Tufts and how it combines with the above efforts to constrain the role of AGN and star-formation activity in the IR luminosity function through cosmic time.

How fast can the Universe make a massive quiescent galaxy?

Friday
12:40 - 1:00 pm

Pablo G. Perez-Gonzalez
Universidad Complutense de Madrid

We will discuss our results about the Star Formation Histories (SFHs) of massive (M> 10^{10} $M_{\odot}$) quiescent galaxies (MQGs) at z>1. These SFHs have been inferred from the analysis of rest-frame ultraviolet/optical spectro-photometric data from the SHARDS and Hubble Space Telescope Wide Field Camera 3 (HST/WFC3) G102 and G141 surveys of the GOODS-N field. Taking advantage of the SHARDS data resolution, we are able to break the typical degeneracies inherent to most stellar population studies by measuring UV and optical absorption indices. The population of MQGs at z>1 shows a duality in their properties. Dead galaxy samples at these redshifts are dominated (at the 80-85% level) by systems with relatively young mass-weighted ages, t_M <2 Gyr, and short star formation timescales, 60-200 Myr. The evolution of these so-called mature galaxies from z<1 to z= 0 is consistent with being passive, but accompanied with a stellar mass increase not affecting the mean ages. There is also an older population of 'senior galaxies' (15% of the sample) with t_M=2-4 Gyr, longer star formation timescales, around 400 Myr, and larger masses, $\log(M/M_{\odot})\sim10.8$ (0.3 dex larger than the mature population). The number density of this sub-population of senior galaxies is consistent with that found for massive quiescent galaxies at z∼2, implying that those galaxies did not restart their star formation activity once they were quenched. We find that the derived SFHs for our MQGs are consistent with the slope and the location of the Main Sequence (MS) of star-forming galaxies at z>1.0, when our galaxies were 0.5-1.0 Gyr old. According to the derived SFHs, all of the MQGs experienced a Luminous Infrared Galaxy (LIRG) phase during typically 500 Myr and roughly half of them went through an Ultra Luminous Infrared Galaxy (ULIRG) phase for 100 Myr. Based on average mass-weighted ages for massive galaxies at $z < 1$ we find that that the build-up of the red sequence is continuous down to z∼1, and only below that redshift (in the last 6 Gyr), the evolution of massive galaxies is dominated by quiescence.

Session 9

Revealing the X-ray main sequence of star formation

Friday
2:30 - 3:00 pm

Alison Coil
UC San Diego

We present measurements that reveal an 'X-ray main sequence' of star formation over a wide range of redshifts and stellar masses, providing new, independent constraints on the slope and evolution of the star forming main sequence. Our results are based on large, stellar-mass limited samples of star-forming galaxies selected at near-infrared wavelengths in the CANDELS/3D-HST and UltraVISTA surveys. We use deep Chandra imaging to extract X-ray information for all galaxies in our sample and use an advanced Bayesian technique to recover the intrinsic distribution of luminosities, pushing substantially below the nominal X-ray detection limits. Our distributions exhibit a clear peak at low X-ray luminosities that is associated with star formation. By tracking the luminosity of this peak as a function of stellar mass and redshift we reveal the X-ray main sequence, with a slope of $\sim$0.6, a normalization that evolves strongly with redshift, and no evidence for a turn-over or flattening at high stellar masses. Comparing to tracers of star formation at other wavelengths indicates that X-rays are providing a robust, relatively direct, yet independent tracer of the average star formation rates of galaxies.

JVLA and ALMA Spatially-Resolved Observations of Intensely Star-Forming Regions in Galaxies at z $\sim$ 1-3 in the Hubble Ultra-Deep Field

Friday
3:00 - 3:20 pm

Wiphu Rujopakarn
Kavli IPMU, University of Tokyo

We utilize extremely sensitive blank-field surveys at radio and millimeter bands from the Jansky Very Large Array (JVLA) and Atacama Large Millimeter Array (ALMA) in the 2' x 2' Hubble Ultra-Deep Field to study the distribution of star formation in five galaxies and six X-ray AGN hosts at z = 1-3. The JVLA and ALMA images at 6 cm and 1.3 mm reach sensitivities of 0.33 and 31 uJy/beam rms at 0.3" and 0.4" resolutions, respectively. Together, they reveal a direct and spatially-resolved view of

intensely star-forming regions within each galaxy that is independent of dust extinction and uncontaminated by old stellar populations. We will present the morphology of star formation in relation to old stellar populations, size and SFR surface density, gas fraction, and discuss the implications on outflows and evolution of these intensely star-forming (yet typical, i.e., SFR*) systems at the peak epoch of galaxy evolution.

Friday
3:20 - 3:40 pm

Tracing the Inside-out Growth & Outside-In Quenching of Disks over ∼85% of cosmic time.

David Wilman
USM & MPE

With radial profiles of HAlpha emission from a unique combination of KMOS^{3D} and HAGGIS surveys, I will describe how star formation drives the spatial growth, evolution and quenching of galaxy disks over ∼85% of cosmic time. The 75 night KMOS^{3D} survey on the VLT with up to 20hour on-source in 600+ mass-selected galaxies at z∼0.7-2.8 traces star formation and the kinematics of the ionized gas into the outer disk. Most galaxies at this gas-rich epoch contain turbulent star forming disks which are more extended than their stellar disks, even in galaxies with low SFR for their stellar mass. In the local Universe, in contrast, HAlpha profiles from HAGGIS demonstrate that the star forming disks of most central galaxies are similar in size to their stellar disks, while outside-in removal of star forming gas is common, especially in satellite galaxies of group-mass halos. These also have compact stellar disks and anti-truncated stellar disk profiles, emphasizing the role of gravitational processes. Our combined results suggest that the evolution of disk galaxies is characterized by galaxy-wide, rapid accretion and star formation at z>1 and by the slower, more subtle accumulation of gravitational and stripping effects on an otherwise stable, low mass star forming disk at lower redshifts.

Poster Abstracts

The Shocked POststarburst Galaxy Survey #1

Katey Alatalo
Carnegie Observatories

Modern day galaxies are found to be in a bimodal distribution, both in terms of their morphologies, and in terms of their colors, and these properties are inter-related. In color space, there is a genuine dearth of intermediate colored galaxies, which has been taken to mean that the transition a galaxy undergoes to transform must be rapid. Given that this transformation is largely one-way (at z=0), identifying all initial conditions that catalyze it becomes essential. The Shocked POststarburst Galaxy Survey (http://www.spogs.org) is able to pinpoint transitioning galaxies at an earlier stage of transition than other traditional searches.

UV Colors of Shocked Poststarburst Galaxies #2

Felipe Ardila
Princeton/Carnegie

There exist multiple pathways through which galaxies can transition from blue, gas-rich, star-forming disks to red, gas-poor, quiescent spheroidals. Most post-starburst searches only detect galaxies after they have quenched their star formation and already transformed, thus missing objects with additional mechanisms for ionizing the remaining gas. The Shocked POststarburst Galaxy Survey (SPOGS) aims to identify galaxies in this transitional phase with nebular lines which are excited from shocks rather than star formation processes. We explored the UV properties of these objects with NUV and FUV photometry from archival data of the *Galaxy Evolution Explorer(GALEX)* for 759 of the 1067 objects in SPOGS. The remaining objects were either not within the *GALEX* footprint, or not significantly detected within the data in both bands. Any available *GALEX* images containing the object (across multiple surveys of varying depth)were coadded to obtain the deepest possible intensity map of each object. Photometry was performed using the Source-Extractor Kron (AUTO) aperture setting, and validated with the *GALEX* catalog of discrete sources (GCAT) available in the NASA/IPAC Extragalactic Database (NED). The goal of this project was to obtain UV photometry

for as many SPOGS objects as possible, in order to compare these objects to other post-starburst galaxies in color-mass, color-magnitude, and star-formation rates. This will provide significant insight on this transforming phase of a galaxy's life, and allow us to better understand these SPOGS objects.

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3 Galactic Conformity from z=0.2-1 with PRIMUS

Angela Berti
UC San Diego

We test for galactic conformity from z=0.2-1.0 to a projected distance of 5 Mpc using spectroscopic redshifts from the PRism MUlti-object Survey (PRIMUS). Our sample consists of ∼60,000 galaxies in five separate fields covering a total of ∼5.5 square degrees, which allows us to account for cosmic variance. Dividing our sample into star-forming and quiescent galaxies using a cut in specific star formation rate, we identify star-forming and quiescent "isolated primary" galaxies. We match the redshift and stellar mass distributions of these samples, to control for correlations between quiescent fraction and redshift and stellar mass. We detect a significant conformity signal (>3 sigma) of ∼5% on scales of 0-1 Mpc and a 2.5-sigma signal of ∼1% on scales of 1-3 Mpc. We also test for redshift and stellar mass dependence of the conformity signal within our sample.

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4 The Effect of the Cluster Environment on Galaxy Transformations

Pierluigi Cerulo
Universidad de Concepcion

Clusters of galaxies are the most massive virialised cosmic structures. They host a diversity of environments, from the dense cores to the sparse outskirts, providing observational laboratories for testing the theories of galaxy interactions. Clusters are characterised by a prominent red sequence and an over-abundance of early-type galaxies with respect to the field, indicating that their galaxy members undergo significant transformations from blue, star-forming and spiral-like to red, quiescent and bulge-dominated. I present the results from the study of a sample of 9 clusters at $0.8 < z < 1.5$ from the HAWK-I Cluster Survey (HCS, Lidman et al. 2013). We find that the build-up of the red sequence is accelerated in clusters with respect to the field, suggesting that the mass of the host dark matter halo is a crucial parameter in setting the timescales for star formation quenching. Further, we find that the red sequence in z∼1 clusters is dominated by elliptical galaxies at all luminosities, while in local clusters it becomes dominated by S0 galaxies at magnitudes fainter than M*. This result suggests that faint S0 galaxies are a late addition to the red sequence, resulting from

the transformation of red, passive spiral galaxies. I discuss the implications of these results in the general framework of galaxy and cluster evolution and give an overview of my current and ongoing work on the HCS sample.

Clusters/Protoclusters of Starbursting Galaxies #5

David L Clements

Imperial College London

The combination of Herschel and Planck data allows us to search for groups of far-IR luminous sources over large fractions of the extragalactic sky. This work has uncovered a significant population of what appear to be galaxy clusters/proto-clusters where several member galaxies are undergoing near-simultaneous major bursts of star formation. These far-IR luminous galaxies may be gas and dust rich spiral-type galaxies transforming into the dust and gas poor elliptical galaxies that dominate galaxy clusters today. Observations of these sources are ongoing to confirm their nature, determine their evolutionary status, and to examine the physical processes that might be behind the high star formation rates seen. It is already clear that these objects present challenges for the current generation of galaxy and galaxy cluster formation models, which fail to reproduce this kind of source in the numbers and luminosities seen, but better statistics on this population and a better understanding of the processes driving their activity are needed for progress to be made.

A CONSTANT RATIO BETWEEN BLACK HOLE ACCRETION AND STAR FORMATION IN IR-BRIGHT AGNs #6

Y.Sophia Dai

IPAC/Caltech

We study the relationship between AGN and star formation in a sample of far-infrared(FIR) detected active galactic nuclei (AGNs). We calculated the star formation rate (SFR) from the AGN-removed IR luminosity. We discuss the caveats in SFR estimates for AGN systems, and the binning and selection effects in deriving the AGN-SFR correlation. We confirm that there is a positive correlation between the AGN luminosity and SFR, after removing the redshift effect. We investigate the Eddington ratio and supermassive black hole (SMBH) mass and found no effects on the correlation. We find a constant ratio between the SFR and the black hole accretion rate (BHAR) regardless of redshift or SMBH mass. The flat mass accretion ratio has a value and scatter comparable to the accumulated mass ratios found between SMBH and host stellar mass in the local universe. Our results support the evolution picture where the SMBH andthe host galaxyare growing at a relatively constant rate, possibly from a common gas supply.

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7 Gas Loss By Ram Pressure Stripping and Internal Feedback from Low Mass Milky Way Dwarf Satellites

Andrew Emerick

Columbia University - American Museum of Natural History

The combination of ram pressure stripping, tidal stripping, and internal feedback from massive stars dominates the evolution of infalling dwarf satellites of the Milky Way. In the context of recent observational and theoretical work placing constraints on the quenching timescales of dwarf satellites, we investigate the ability for ram pressure stripping and internal feedback to explain the quenching process in the smallest satellites of the Milky Way using three-dimensional, high resolution, wind tunnel simulations. Using initial conditions appropriate for a dwarf galaxy like Leo T, we investigate whether or not environmental gas stripping and internal feedback together can quench these low mass galaxies on the expected timescales, shorter than 2 Gyr. We find that internal feedback in these low mass galaxies is too infrequent to have a significant effect on the stripping evolution, in contrast to feedback in more massive galaxies. Our results show that ram pressure stripping operates less efficiently than expected on low mass dwarfs, requiring additional physical processes to account for the whole picture of dwarf satellite quenching. I will discuss these results and briefly discuss the possible roles tidal stripping, group pre-processing, and reionization may play in quenching these low mass dwarf galaxies.

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8 The geometry of the AGN obscurer in a hyperluminous quasar

Duncan Farrah

Virginia Tech

We study the geometry of the AGN obscurer and ongoing rates of star formation in IRAS 09104+4109, an obscured hyperluminous quasar at z=0.442, using infrared data from Spitzer & Herschel, X-ray data from Nustar, Suzaku, and Chandra, and an optical spectrum from Palomar. The infrared data can be reproduced by a smooth AGN torus with a viewing angle (from pole-on) of 38 degrees and a half-opening angle of 39 degrees, and a starburst with a star formation rate of 126 Solar masses per year. Combined with previous work, this is consistent with iras having undergone at least two epochs of luminous activity in the last 200Myr: one approximately 150Myr ago, and one that is currently ongoing. The inferred ages of the current starburst, and the radio jets, suggest that the two are not directly associated. The X-ray and infrared data are both consistent with axisymmetric, coaligned, toroidal obscurers in which the line of sight viewing angle is close to, but larger than, the half-opening angle of the torus. This 'skimming' of the edge of the torus is consistent with no broad lines being visible in direct (optical) light. The X-ray data further suggest a photon index of 1.8

and a line-of-sight column density of 5e23cm-2. This argues against a fully reflection-dominated hard X-ray spectrum. Both the X-ray and infrared data are consistent with a bolometric luminosity of 1.3-6.5e13Lsun. Combining constraints from the X-ray, optical and infrared data suggests that the bulk of the infrared and X-ray torii are within a vertical height of 20pc, and a radius of 200pc, of the nucleus.

TCB Flash: Constraining the Timescale for Satellite Quenching in Local Group-like Environments

#9

Sean Fillingham

UC Irvine

Current hydrodynamic and semi-analytic models of galaxy formation fail to reproduce the observed fraction of passive satellite galaxies across a broad range in satellite stellar mass. This discrepancy hinges on a general lack of understanding regarding the physics by which star formation is suppressed, or quenched, in over-dense environments.Comparing detailed observations from the SDSS and the Local Group with subhalo distributions in cosmological N-body simulations, we measure the timescales upon which a typical satellite galaxy quenches after falling into the virial volume of its host system. By constraining this timescale, we are able to infer the physical mechanisms likely acting on these systems and begin to piece together a coherent picture of satellite quenching, spanning more than 5 orders of magnitude in stellar mass. In particular, our results indicate a critical mass scale at which ram pressure stripping likely becomes the dominant quenching mechanism in groups and clusters, including our own Local Group.

Induced star formation in interacting galaxy pairs

#10

Isaura L. Fuentes-Carrera

ESFM, Instituto Politecnico Nacional, MEXICO

"The correlation between enhanced star formation (SF) and external perturbations is not straightforward. Models and observations show a clear SF enhancement and SF efficiency increase as separation between merger nuclei decreases, suggesting that the starburst phase occurs at a late stage of merging and is confined to the central kiloparsec. However, enhanced SF is also seen in early interactions and it does not always come from the central parts but from the outskirts. In this work, we present a 3D kinematical analysis of early interacting galaxies. Using scanning Fabry-Perot interferometry Halpha observations, we derived the extended kinematics of the ionized gas in order to study the contribution of circular and non-circular motions. We searched for any type of perturbation that may be related to enhanced SF in order to characterize the mechanisms involved in the SF processes in this type of systems.

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11 Tracing the role of active nuclei in galaxy transformation: HI absorption surveys out to z = 1

Marcin Glowacki
University of Sydney

Powerful active galactic nuclei (AGN) provide a key mechanism for transforming massive galaxies from gas-rich star-forming systems to passively-evolving red galaxies. In particular, radio jets from an AGN can couple directly to the cold interstellar medium (ISM) of their host galaxy. There is growing evidence (e.g. Morganti et al. 2003) that jet-driven outflows of neutral gas can rapidly deplete or even remove the cold gas reservoir in these galaxies.
When seen in absorption against the continuum emission of radio-loud AGN, the 21-cm line of neutral hydrogen (HI) can provide a powerful probe of these cold gas outflows, but until very recently observational evidence was largely restricted to nearby objects (redshifts of $z < 0.15$). In this talk, I will present some early results from commissioning the new Australian SKA Pathfinder (ASKAP) radio telescope, probing HI absorption across the largely unexplored epoch between $z = 0.4$ and 1. I will discuss how these results inform us on prospects for future large-area HI surveys of the evolving radio AGN population.

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12 MegaMorph and how it can identify key galaxy types

Boris Haeussler
ESO Chile

The build-up of the galaxies that populate the red sequence from the star-forming galaxies in the 'blue cloud' is the key to understanding how those most massive galaxies form. Several processes have been suggested for this transformation and are the main topic of this conference, e.g. major and minor mergers, SF quenching and in-situ star-formation, which can all move and add mass to the red sequence as a whole. Each of these processes leaves a characteristic imprint on the galaxy light and colour profiles. In order to identify their importance, both the identification of the respective samples and the accurate measurement of their properties is vital.
In this talk, I will introduce how GalfitM - a multi-band version of Galfit, developed by the MegaMorph project - can be used for both these purposes by measuring light profiles in multiple bands (or even IFU data) simultaneously and in a consistent manner. I will show that this leads to more secure measurements of galaxy properties - and hence a more secure identification of galaxy populations needed to examine the transformation of galaxies. While I will demonstrate that this new method allows a cleaner separation of bulge- and disk-components in galaxies, I will concentrate on one-component profiles in this talk and how they can be used to identify the key observables in the processes mentioned. Using a sample from the GAMA survey, I will show how galaxy structural

parameters, such as half-light radius and Sersic index, vary from near-UV to optical to near-IR wavelengths. This provides an alternative way of quantifying colour gradients and identifying the radial change of stellar populations in galaxies.

TBD

#13

ChangHoon Hahn
New York University CCPP

The GMRT 150MHz All Sky Survey

#14

Preshanth Jagannathan
NRAO / UCT

We present the 150MHz radio sky survey by the GMRT spanning 3.6pi steradian of sky from -53 dec to +90dec covering 90% of all visible sky. The extracted 5336 image mosaics with a median rms noise of 3mJy and the associated high reliability seven sigma source catalog of 0.623 million sources are available publicly. The processing of this survey utilizing archival data was made possible due to innovative direction-dependent ionospheric phase correction algorithms and, a fully automated parallel calibration and imaging pipeline. At greater depth and higher resolution than NVSS, we hope the surveys acts as an essential low frequency resource in the study of galaxies and AGN.

Spectroscopic Bulge-Disc Decomposition of SDSS-IV/MaNGA Galaxies

#15

Evelyn Johnston
ESO, Chile

One can see an IFU datacube of a galaxy as simply a stack of images at each wavelength step. If the S/N and spatial resolution is sufficiently high, features, such as the bulge, disc, spiral arms etc., can be distinguished in each image. In such cases, it is possible to decompose the datacube of the galaxy wavelength-by-wavelength to spectroscopically separate the light from each component, and thus measure their independent star-formation histories. To boost the amount of information one can extract from the data, the best approach for this decomposition would be to use all the information in the cube simultaneously. Such an approach is now possible with GALFITM, a modified version of Galfit that is able to fit multi-waveband images of galaxies simultaneously to produce one wavelength-dependent model.

This new approach to galaxy fitting has been developed and tested using commissioning data from the SDSS-IV Mapping Nearby Galaxies at APO (MaNGA) survey. We will present an overview of this new technique and along with some preliminary results for the bulge and disc star-formation histories of lenticular galaxies within the MaNGA survey.

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16 Quenching of star formation in massive galaxy clusters -Lynx W caught-in-the-act

Inger Jorgensen
Gemini Observatory

In massive galaxy clusters the interactions between galaxies and cluster gas as the galaxies enter the cluster for the first time may lead to quenching of the star formation. This interaction transforms them into passively evolving bulge-dominated galaxies. We present evidence for a cluster 'caught-in-the-act' at redshift 1.27. The Lynx W cluster contains a significant population of bulge-dominated galaxies with very young stellar populations and/or low-level star formation. The population is present throughout the cluster. We link this population to our larger sample of bulge-dominated galaxies in rich clusters spanning from the present to redshift 1.27. In total, our data currently cover eight clusters at z=0.2-1.27 with deep spectroscopic data and Hubble Space Telescope imaging. We find substantial cluster-to-cluster variation of the galaxy populations, but also the expected signature of passive evolution of bulge-dominated galaxies from z$\sim$1.3 to the present.

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17 Hidden in plain sight: Mass segregation using galaxy analogues in simulations

Gandhali Joshi
McMaster University

We use high resolution DM-only simulations to explore the mass functions and radial distributions of subhalos in group and cluster halos with two popular halo finders: the Amiga Halo Finder (AHF) and ROCKSTAR. There are significant differences in the subhalo radial distributions, due in large part to differing subhalo hierarchies. Instead of looking strictly at subhalo populations, we identify a sample of 'galaxy analogues' and show the radial distribution of these analogues agree well at large halo-centric radii, but still show significant differences at small separations from the host halo centre where phase-space information becomes important for disentangling the analogues from the dense host mass distribution. The extent to which galaxies are segregated by mass within their parent halos is a currently unresolved topic that could shed light on environmentally-driven mechanisms of galaxy evolution. We explore mass segregation

in our parent halo population using the identified galaxy analogues. Like some previous work, we see evidence for mild mass segregation at small radii (within 0.5Rvir) with average galaxy analogue mass decreasing with radius. We also see evidence that beyond a virial radius, the average galaxy analogue mass tends to increase with radius. These mass segregation trends show a further dependence on halo mass with the trends becoming weaker in more massive halos. Our findings suggest that the observed mass segregation trends are likely dominated by the accretion history of the subhalos rather than dynamical friction, particularly in massive clusters. We are currently extending this study with SPH group and cluster simulations.

The Distribution of Active Galactic Nuclei in Massive Galaxy Clusters at z∼1

#18

Wenli Mo

University of Florida

We present an analysis of the distribution of active galactic nuclei (AGN) in ∼2000 galaxy clusters at z∼1 from the Massive and Distant Clusters of WISE Survey (MaDCoWS). At this epoch, MaDCoWS provides the most coverage of the extragalactic sky. We use existing catalogs from literature of AGN selected based on their optical and mid-infrared colors and radio emission. Stacking the radial distribution of AGN in MaDCoWS galaxy clusters, we find a distinct overdensity in quasar excess within 2' of cluster center. For radio AGN, this overdensity is concentrated to within 1' of cluster center. We also investigate the dependence of the cluster AGN distribution on cluster mass and central radio activity, and quantify the fraction of clusters hosting extended radio sources at this epoch.

Physical properties of star-forming and quiescent galaxies at z∼3

#19

Hooshang Nayyeri

UC Irvine

"In this work we investigate the far infrared properties of star-forming and passively evolving systems at z∼3 in the five CANDELS fields as identified from LBG and 4000A/Balmer break selections. We use the Herschel/SPIRE observations in the 250, 350 and 500 microns to construct a stacked far infrared SED of the different populations. This along with the stacked optical and near infrared observations from CANDELS reveal information on the SFR and dust temperatures of these galaxies. This together with the mass and SFR measured for individual sources from SED fitting would help us in better understanding the evolutionary path of each population at z∼3. "

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20 Probing the transformation of galaxies in clusters at high-redshift using dynamical analyses

Lyndsay Old

University of Toronto

Galaxy clusters host the most massive galaxies in the Universe. As such, observations of galaxy clusters deliver not only the properties of galaxies at the time we observe them, but also give us insight into how they form and evolve over cosmic time. Dynamical analyses of high-redshift cluster galaxies provide a way of extracting both the local and global dynamical history of todays massive galaxies. These analyses separate galaxies that reside in dynamically distinct subgroups, which are likely to have been recently accreted and also characterise the history of the galaxys global environment, for example, by deducing whether clusters exhibit signs of a recent merger. To date, dynamical analysis has been generally restricted to clusters at low-redshift due to lack of spectroscopic redshifts for member galaxies. I will present new results on the dynamical analyses of ten galaxy clusters at z$\sim$1, for which there are an unprecedented number of spectra at this epoch. In particular, I will discuss i) the fraction of infalling galaxies that are in sub-groups, ii) how dominant massive red galaxies are in the infalling subgroup population, iii) how properties such as star formation in these infalling subgroups differ from virialised galaxies. I will discuss the implications that these results have on the transformation of galaxies in dense environments and how these results compare to the evolution of cluster galaxies from z$\sim$1 to the current day in cosmological simulations.

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21 Exploring the merger-starburst connection and its impact on the observed bimodality in galaxy properties

Milena Pawlik

University of St Andrews

The observed diversity in galaxy properties as well as the varying frequency of different galaxy types throughout cosmic time point to a complex evolutionary picture with a range of possible pathways: from evolution in isolation, through that affected by the environment, to violent galaxy interactions and mergers. Transformations along the pathways may lead to present-day galaxies having remarkably divergent properties from their initial states, which makes the disentangling of the different effects challenging. The short-lived (post-)starburst (SB/PSB) galaxies, that show evidence of an historical rapid increase and subsequent quenching in star formation, may provide an insight into one of the processes governing galaxy evolution. Theoretical modelling has shown that they could be a result of gas-rich major mergers, and consequently, a transitional population linking the star-forming 'blue-cloud galaxies and the passively evolving spheroids populating the 'red sequence'. The aim of this work is to explore the merger-starburst connection and to learn about the significance of the PSB galaxies in

the formation of the observed bimodality in galaxy properties, through analysis of the morphology and structure of galaxies at different stages of the SB/PSB phase.
I will introduce the shape asymmetry, a new automated measure designed to quantify morphological disturbance in galaxy outskirts (Pawlik et al. 2016), that we combine with pre-existing structural parameters to study the evolution of galaxies throughout the (post-)starburst phase. Our analysis of an evolutionary sample of SB/PSB galaxies (Wild et al. 2010) revealed that ∼50% of galaxies with very recent starbursts (<0.1 Gyr) show morphological features characteristic of a recent merger, and that this fraction declines with the starburst age for the next 0.5 Gyr - a trend resembling that expected for post-mergers with fading tidal features. The lack of significant evolution in their central concentration of light suggests that local SB/PSB galaxies do not attain the highly concentrated structure characteristic of galaxies populating the present-day red sequence during the first 0.6 Gyr after the starburst.
I will finish by presenting our more recent work where we investigate the dependence of the evolutionary pathways of SB/PSB galaxies on their stellar mass and extend to samples of older PSB galaxies (<1.5 Gyr), and I will compare the morphological and structural properties of SB/PSB galaxies to those of post-mergers modelled in hydrodynamical simulations.

Understanding the galaxy transformations leading to dwarf ellipticals

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22

Reynier Peletier

Kapteyn Institute, University of Groningen

I will describe some recent results of the Fornax Deep Survey, a deep multicolour imaging survey using the VST at ESO, together with followup longslit and IFU spectroscopy, about the formation of dwarf galaxies. I will discuss the effect of the cluster environment on the evolution of galaxies by comparing a new catalog of faint galaxy debris around the central Fornax cluster galaxy NGC 1399 with debris in the field (from Duc et al. 2015) and the Virgo cluster. I will also compare in detail dwarf ellipticals in Fornax with dwarf irregulars in the field, by comparing properties such as abundance ratios of various elements, surface brightness profiles in the outer regions, and kinematical support, to answer the question whether and how dwarf ellipticals originate from dwarf irregulars, and what the role of the environment is in this process.

23

TBD

Reynier Peletier
Kapteyn Institute, University of Groningen

24

MHD simulations of ram pressure stripping of a disk galaxy

Mariana Ramos-Martinez
IRyA-UNAM

The removal of the ISM of disk galaxies through ram pressure stripping (RPS) has been extensively studied in numerous simulations. These models show that this process has a significant impact on galaxy evolution (the truncation of the ISM will lead to a decrease in the star formation and the galaxy will become redder). Nevertheless, the role of the magnetic fields (MFs) on the dynamics of the gas in this process has been hardly studied, although the influence of magnetic fields on the large scale disk structure is well established. The presence of MFs produce a less compressible gas, thus increasing the scale height of the gas in the galaxy, that is, gas can be found farther away from the galactic potential well, which may lead to an easier removal of gas. We test this idea by performing a 3D MHD simulation of a disk galaxy that experiences RPS under the wind-tunnel approximation.

26

Nearby velocity-offset AGN: signposts of double supermassive black holes?

Hsin-Yi(Jenny) Shih
Gemini Observatory

Galaxy mergers should result in large numbers of double supermassive black holes (SMBHs), and these objects may play an important role in shaping some of the galaxies that we see today. For example, The low central stellar density of luminous ellipticals is hard to explain unless it is the result of a small-separation black hole pair losing angular momentum to the surrounding stars, ejecting them from the galaxys nucleus (Begelman et al. 1980; Postman et al. 2012). However, few double SMBHs have been detected to date. A recent search for AGN whose emission lines are offset in velocity from the stellar nuclei of their host galaxies has turned up >300 objects that appear to be "offset AGNs" that are in the process of joining the presumed SMBH at the galaxy's center (Comerford & Greene 2014). To confirm whether these objects are genuinely offset AGNs, we observed 7 of the closest offset AGN candidates ($z < 0.03$) with IFU spectroscopy and deep imaging. These data can help us either confirm the offset/double-AGNs or, if they are not double SMBHs, identify the nature of the objects that are confusing this seemingly promising method of finding double SMBHs through kinematics.

The MOSDEF Survey: Dissecting the star-formation rate vs. stellar mass relation at z $\sim$ 2

#27

Irene Shivaei

UC Riverside

We investigate the correlation between stellar mass and star-formation rate (SFR) among star-forming galaxies at the critical epoch around z $\sim$ 2, from the MOSFIRE Deep Evolution Field (MOSDEF) survey. The MOSDEF survey is a multi-year project that uses the near-IR MOSFIRE spectrograph on the Keck telescope to characterize the gaseous and stellar contents of $\sim$ 1500 rest-frame optically selected galaxies at 1.37 $<$ z $<$ 3.80. The SFR-M_* relation is commonly used to distinguish star-forming and quiescent galaxies. Based on a representative sample of 264 galaxies with H-alpha and H-beta spectroscopy, we have estimated robust dust-corrected instantaneous SFRs over a large dynamic range in stellar mass ($\sim$ 10^9 - $10^{11.5}$ $M_\odot$) to quantify the SFR-M* relation. We find that different assumptions for the dust correction, such as using the color excess of the stellar continuum to correct the nebular lines, sample selection biases against red star-forming galaxies, and not accounting for Balmer absorption, can yield steeper slopes of the SFR-M* relation. Moreover, We compare the SFR-M* characteristics based on the SFR(H-alpha) with those of the SFR(UV) derived from the stellar continuum at 1600 A. We argue that in the absence of direct measurements of galaxy-to-galaxy variations in the attenuation curves and the initial mass function, the larger scatter in SFR(H-alpha)-M* relation compared to that of the SFR(UV)-M* relation can not uniquely be attributed to the stochasticity of star formation in high-redshift galaxies. Separately, by incorporating mid- and far-IR data from Spitzer and Herschel, we have a direct probe of dust obscured star forming regions that might be missed by Balmer lines. We investigate panchromatic SEDs of our galaxies that are individually detected in the IR bands, using the extensive photometry from 0.3 - 500 μm, and present the first direct comparison between Balmer line and panchromatic SED-based SFRs for z $\sim$ 2 galaxies.

Star Formation in Interacting vs. Spiral Galaxies in the Local Universe

#27

Beverly Smith

East Tennessee State University

"We have extracted UV/optical/IR fluxes for 'clumps' of star formation in sample of nearby interacting galaxies, derived their star formation rates, and compared with regions in normal spiral galaxies. We have used archival Hubble Space Telescope images to investigate the star cluster population in the most luminous of these clumps. The luminous knots of star formation in nearby interacting galaxies are good local analogs for clumps found in high redshift galaxies."

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29 Sizes and mass profiles of post-starburst galaxies at z∼1.5

Katherine (Wren) Suess
UC Berkeley

Observations over the last decade have revealed that quiescent galaxies were much more compact at earlier epochs. Several mechanisms have been proposed to form these extremely dense galaxies, including compaction via violent disk instabilities or minor merging, gas-rich major mergers, and dissipational collapse formation. Post-starburst galaxies are the optimal test cases for these formation mechanisms, as they are the direct, unpolluted products of the quenching process. Recently quenched post-starburst galaxies at $z > 1$ have been shown to be more compact than starburst or quiescent galaxies at similar redshifts. These studies characterized post-starburst galaxy sizes based on the half-light radius; however, the half-mass radius could differ and is needed to verify the finding that post-starburst galaxies are indeed more compact than their progenitors. We use photometric data from CANDELS to perform pixel-to-pixel spectral energy distribution fitting of 20 post-starburst galaxies at $0.7 \lesssim z < 2$ selected by their dominant A-type star population. This allows us to generate mass profiles and confirm the sizes of post-starburst galaxies. Pixel-to-pixel SED fitting also allows us to investigate galaxy age gradients. Together, the sizes and age gradients allow us to discriminate between the different proposed scenarios for forming compact quiescent galaxies.

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30 The Importance of Black Hole Mass in the Physics Behind Quenching

Bryan Terrazas
University of Michigan

Using the Henriques et al. (2015) semi-analytic model, Terrazas et al. (2016) found that quiescence is primarily a function of black hole mass, where central galaxies become quiescent when heating from their active galactic nuclei becomes sufficient to offset the cooling rate. We present an analysis of observational data of local central galaxies with directly-detected black hole mass measurements in order to test this correlation and determine the main physical drivers of quiescence. We find that the specific star formation rate is a smooth and tight function of the black hole mass-stellar mass ratio, or what we call the black hole prominence, for all galaxies of different morphological types. As a result, partially-quiescent galaxies - which have generally been thought of as transitory stages towards complete quiescence - are found to be stable systems with intermediate black hole prominence. Further, we compare our observational data with four state-of-the-art galaxy formation models. We find that models that balance gas cooling with AGN heating in order to grow the quiescent population show the best agreement with observational trends that relate black hole mass, stellar mass,

and star formation rate. Our results provide strong evidence that the black hole has an increasingly suppressing, smoothly varying effect on the star formation occurring within central galaxies, giving credence to the AGN feedback paradigm.

Resolving distant quasar host galaxies with high angular resolution techniques

#31

Andrey Vayner
"University of California, San Diego

We will present the latest results from an OSIRIS-LGS survey to resolve and study high-redshift (z = 1.4 - 2.5) radio-loud quasar host galaxies. Keck Adaptive Optics (AO) with OSIRIS provides the necessary resolution and contrast to remove the bright-unresolved quasar emission to study the underlying faint host galaxy with unprecedented sensitivity. Thus far, our radio-loud sample consists of eight high-redshift quasar hosts with ionized gas emission resolved at sub-kiloparsec scales, yielding essential constraints on the galaxies dynamics, morphologies, star formation rates, metallicities, and nebular emission diagnostics. We combine OSIRIS and AO observations with multi-wavelength data sets from Atacama Large Millimeter/submillimeter Array, Hubble Space Telescope, and Very Large Array to better understand the multiple phases of the ISM and stellar population properties of the hosts. These quasar hosts show evidence for both concurrent star formation and extended quasar narrow line emission over 1 to 20 kpc. Powerful outflows are observed along the path of the radio jets and lobes, with a suppression of star formation by a factor of 10 in some sources compared to other regions of the host galaxies.

Compact Groups in the Millennium Simulation

#32

Trey Wenger
University of Virginia

The importance of compact groups in galaxy formation, both at the present time and throughout the history of the Universe, remains an open and interesting question. To investigate this question, we developed an algorithm to identify and characterize compact groups in the Millennium Simulation. Using various clustering tools and selection criteria, we select compact groups of galaxies from each redshift snapshot of the simulation between z$\sim$11 and z=0. We find that the fraction of non-dwarf galaxies in compact groups peaks at $\sim$1% near z$\sim$1-2. By tracking individual compact group members through the simulation, we find that compact groups rarely, if ever, dissociate. At z=0, about 5% of galaxies have been members of compact groups at some point in their history. We plan to extend this analysis to include dwarf galaxies using the much finer resolution of the Millennium-II Simulation.

The prevalence of dwarf galaxy compact groups over cosmic time

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33

Christopher Wiens
University of Virginia

"Galaxy interactions are critical to the evolution of the universe, influencing everything from star formation to the structure of the known universe. By studying at galaxy interactions through computer simulations, we are able to observe what would normally take billions of years to progress. 'Compact groups' are extremely dense assemblies of at least 3 galaxies and typically no more than 10 that are interacting gravitationally. These groups yield much information about galaxy interactions and mergers in dense environments but are difficult to observe at high redshifts. Compact groups of only dwarf galaxies probe a regime of galaxy evolution that has been hypothesized to be common in the early universe. Here we investigate the populations of such dwarf galaxy compact groups in numerical simulations. In particular, the Millennium II Simulation is a massive n-body simulation of cold dark matter particles on a time scale equivalent to the known universe. This simulation allows us to study high redshift objects and timescales of billions of years. Our preliminary findings indicate that these dwarf galaxy compact groups do exist in both the Millennium and Millennium II simulations. In both simulations, there is a large number of dwarf compact groups with an evolution track that mirrors more massive compact groups with a peak in groups around a redshift of 2."

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