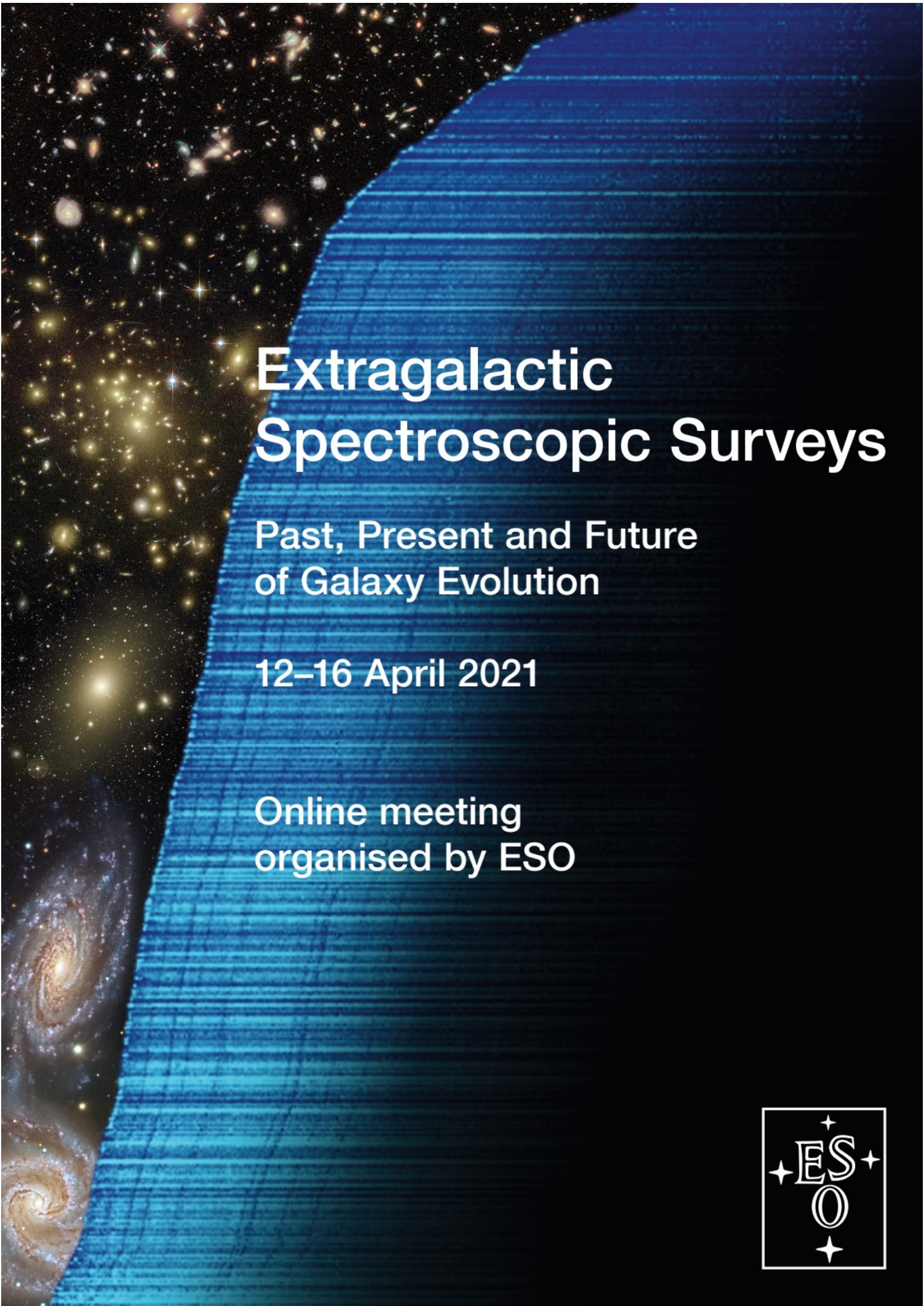

Extragalactic Spectroscopic Surveys

Past, Present and Future of Galaxy Evolution

12–16 April 2021

Online meeting organised by ESO

Session 1: Stellar Populations and Star Formation History

Talks

Invited Talk

Daniel Thomas (University of Portsmouth, UK)

Stellar Populations and Star Formation History

The analysis of stellar populations provides key insight into the formation and evolution of galaxies. Recent large-scale galaxy surveys have taken the field a giant step forward enabling detailed, statistical studies of spatially resolved stellar population properties in galaxies within the multi-dimensional parameter space of galaxy mass, type and environment. I will review recent developments in studies of stellar population and chemical enrichment properties of galaxies across cosmic time.

Arjen van der Wel (Sterrenkundig Observatorium, Belgium)

The LEGA-C Survey of 4000 Galaxies at z~1: Stellar Populations and Stellar Kinematics

LEGA-C is revealing, for the first time, the star-formation history and stellar kinematic properties for the general galaxy population at large lookback time (z=0.6-1). I will present the third and final data release, summarize results so far, and give a preview of what we can expect to see over the next few days in this meeting and over the coming months: how high-quality spectroscopy facilities the transition from a qualitative to a quantitative description of the stellar dynamical and stellar population evolution of galaxies.

Francesco D'Eugenio (Ghent University, Belgium)

LEGA-C: stellar population gradients 7 Gyr ago

The LEGA-C survey is a large deep spectroscopy survey of the Universe at a lookback time of 7 Gyr. We use partially-resolved spatial information to present the first study of spatially-resolved stellar population properties on a statistically significant sample in the distant Universe. We show that i) post-starburst galaxies at z=1 show inverse age gradients, consistent with the effect of a central starburst and ii) star-forming galaxies show strong metallicity gradients, consistent with what is observed in the local Universe.

Tania Barone (Australian National University, Australia)

Stellar Populations and the Mass--Size Plane across 7 Gyr using the LEGA-C and SAMI Surveys

We investigate scaling relations between stellar population and galaxy structural parameters over a 6.7 Gyr lookback time. Specifically, we investigate the change in age and metallicity relations from z[0.60, 0.76] using the LEGA-C Survey, to low redshift using the SAMI Survey. We find that, similarly to their low-redshift counterparts, the metallicity of quiescent galaxies at z[0.60, 0.76] correlates with the gravitational potential, in that galaxies with deeper potential wells are metal enriched. This supports the theory that the relation arises due to the gravitational potential regulating the escape velocity required by metal-rich stellar and supernova ejecta to escape the system and avoid being recycled into later stellar generations. Conversely, we find no correlation between age and surface density in LEGA-C, despite there being a relation at z=0. We robustly explain our results as being a consequence of population evolution with redshift in the mass-size plane.

Anna Gallazzi (Kavli Institute for Cosmology, Firenze, Italy)

Galaxy evolution across environments as probed by the stellar population fossil record

We compare the ages, stellar metallicities and [alpha/Fe] of satellites and centrals in SDSS DR7, as a function of stellar and host halo mass, to gain insight into when and where galaxies quench under the action of environment. We argue that the observed trends in age, metallicity, [alpha/Fe] and quiescent fraction at low masses reveal the action of

satellite-specific environmental effects in a `delayed-then-rapid' fashion. When accounting for the varying quiescent fraction and the epoch of infall, small residual excess in age, metallicity and [alpha/Fe] emerge for ancient infallers satellites in massive halos, compared to equally-massive central galaxies. This result points to the action of environment in the early phases of star formation in galaxies located close to cosmic density peaks. Pushing this kind of studies at intermediate redshift is now within reach thank to the high-quality spectroscopy of large galaxy samples from surveys as LEGA-C, WEAVE-StePs and prospects from 4MOST.

Mario Llerena (Universidad de La Serena, Chile)

Rest-frame UV properties of CIII/λ1909 emitters at z=2-4 with the ultra-deep VANDELS survey

The first 2-3 Gyr of cosmic history are key to understand reionization and how most present-day galaxies form and assemble. According to recent observations, normal galaxies at these early epochs show more extreme stellar and nebular properties than their lower redshift counterparts, but the connection between these properties and the physical mechanisms facilitating galaxy growth and the escape of ionizing photons used for sustaining cosmic reionization still need to be established. In this scenario, CIII]λ1909 emitters have been proved to be relevant to find out these connections because of their properties similar to primaeval galaxies. In this talk, we present the physical properties and chemical abundances of a large sample of CIII] emitters at z=2-4 selected from the unprecedentedly deep VIMOS/VANDELS spectroscopic survey. In particular, we discuss UV emission-line diagnostics and key scaling relations involving stellar metallicities, C/O abundances, and other global properties.

Ignacio Martin Navarro (Instituto de Astrofísica de Canarias, La Laguna, Spain)

IMF variations in the Fornax cluster

The stellar initial mass function (IMF) is a fundamental ingredient in stellar population synthesis models and for decades it was considered to be universal. However, the universality of the IMF has been recently challenged by detailed stellar population modeling of massive early-type galaxies. I this talk I will present our recent efforts within the Fornax3D collaboration to study and characterize spatially resolved IMF variations in the Fornax cluster. I will describe how the use of MUSE IFU data allows for

an unprecedented view of the stellar population properties of nearby galaxies. I will present our sample-wide two-dimensional characterization of the IMF variations, showing for the first time resolved IMF maps for a sample of 23 galaxies. Moreover, I will also show how the combination of detailed stellar population analysis and Schwarzschild dynamical modelling provides insightful information about the origin of the observed IMF variations.

Roberto Maiolino (University of Cambridge, UK)

The JWST Advanced Deep Extragalactic Survey

I will give an overview of JADES, the extensive survey that will be undertaken jointly by the NIRSpec and NIRCam GTO teams.
I will focus primarily on the spectroscopic component of the survey, which will dedicate several hundred hours of multi-object spectroscopic observations to obtain spectra of a few thousand galaxies with unprecedented sensitivity, probing the earliest phases of galaxy formation and their subsequent evolution and transformation across the cosmic epochs. The observations will use low, intermediate and high resolution spectroscopy, therefore enabling us to explore a broad range of diagnostics that will deliver detailed information on the properties galaxies, such as spectroscopic redshfits, star formation rates, stellar populations (stellar masses, ages, star formation histories), ISM ionisation and excitation, chemical enrichment, kinematics, dust attenuation, etc.
I will illustrate the legacy value of the survey and the synergies with observations in other bands.

Pre-recorded talks

ChangHoon Hahn (Princeton University, USA)

The Probabilistic Value-Added Catalog for the DESI Bright Galaxy Survey

Over the next five years, the Bright Galaxy Survey (BGS) of the Dark Energy Spectroscopic Instrument (DESI) will measure the spectra of 10 million galaxies out to z~0.5. The PRObabilistic Value-Added BGS (PROVABGS) will provide posteriors on the physical properties (e.g. M*, SFR, metallicity) for each of these galaxies and produce the most statistically powerful magnitude-limited sample for galaxy studies. In this talk, I will present the target selection and design of the DESI BGS. I will

also present the methods used to construct the PROVABGS, such as neural network emulators for stellar population synthesis, which enables tractable sampling of 10 million posteriors. Lastly, I will discuss the potential of PROVABGS to advance galaxy science.

Christopher Haines (INCT, Universidad de Atacama, Copiapó, Chile)

Tracking the evolution of galaxy populations over the last 8 Gyr with VIPERS

The VIMOS Public Extragalactic Redshift Survey (VIPERS) is an ESO Large Programme that obtained spectra for ~100K galaxies at redshifts 0.5-1.2 across a 24deg2 survey region. This dataset has enabled us to reveal the development of the bimodal galaxy distribution in the D4000-M* plane over the last 8 Gyr, track the evolutions and extents of the red sequence and blue-cloud populations in unprecedented detail, and explore the relationships between star-formation history and galaxy structure. The large volume covered and high sampling rate of VIPERS makes it a unique resource for studying the most massive galaxies (log M*>11) in the Universe, and we highlight the dramatic collapse in the number density of massive star-forming (D4000<1.55) galaxies after z~0.8 and the parallel rise in the numbers of low-density massive passive galaxies.

Adriano Poci (Macquarie University, Marsfield, Australia)

The Assembly Histories of Local Galaxies from IFU Data

The wide-spread implementation of Integral-Field Units on large telescopes has revolutionised galaxy evolution, in particular in the local Universe. I will present the results of an emerging technique for combining all facets of the stellar content of galaxies in remarkable detail in an `orbital-population' model, as constrained directly by the high-quality spectroscopic data. Through the combined consideration of the stellar populations and kinematics, we constrain how these galaxies formed, the major events in their assembly history, as well as accurately measuring their present-day configurations. I will present intrinsic chemical, dynamic, and chemo-dynamic correlations for a handful of local galaxies. I will also preview how this technique can lead to the direct modelling of the observed data-cube itself.

Giustina Vietri (INAF IASF-Milano, Italy)

AGN activity and star formation of optically-selected Type II AGN in VIMOS spectroscopic surveys

Using a large (812) sample of optically-selected Type II AGN at redshift range 0.5<z<0.9 in the VIPERS and VVDS surveys we investigate the correlations between AGN activity and star formation (SF) properties. We find a bimodal distribution of the sample in terms of SFR distance from the main sequence (MS) of normal star forming galaxies: AGN host galaxies with stellar mass <10ˆ10 Msun have similar SFR compared to the normal star-forming MS galaxies, while massive galaxies (>10ˆ10 Msun) exhibit low level of SF activity. For both populations we find a positive correlation between the AGN power, probed by the [OIII] luminosity, and SF MS offset, which could reflect the co-evolutionary path between the AGN and SF, with a common gas supply which both triggers SF and fuels the AGN activity. Moreover, I will discuss the possible effect of AGN feedback on the SF content of luminous and massive host galaxies, as suggested by the presence of outflowing gas traced by the [OIII] emission line.

Evelyn Johnston (Universidad Diego Portales, Chile)

BUDDI-MaNGA: a statistical spectroscopic survey of galaxy bulges and discs

As a galaxy evolves, its morphology typically changes. The processes that trigger these transformations affect their bulge and disc in different ways, leaving characteristic imprints on their stellar populations. Extracting the clean spectra of these components through traditional techniques is tricky due to the superposition of the light from other structures. But, the introduction of IFU surveys of nearby galaxies provides the combined spatial and spectral information for these galaxies. We have developed BUDDI to use this spatial information to cleanly separate the spectra from the bulges and discs, and applied it to the MaNGA DR16 sample of galaxies to extract their independent SFHs. To date, this is by far the largest sample of bulge and disc spectra extracted from IFU datacubes through light profile modelling, and we will use it to study how galaxies evolve and the role of their individual structures. I will present the sample and technique, and will highlight our initial results

Posters

Adrian Bittner (ESO, Garching, Germany)

The stellar population content of bar-built nuclear structures in the MUSE TIMER project

Using IFS observations obtained in the MUSE TIMER survey, we derive stellar population properties in the central regions of 21 local, barred galaxies. As expected in the picture of bar-driven secular evolution, nuclear discs are clearly distinguished by stellar populations that are younger, more metal-rich, and have lower [α/Fe] enhancements. We argue that continuous (stellar) nuclear discs may form from a series of bar-built (gas-rich) nuclear rings that grow in radius, as the bar evolves. In this picture, nuclear rings are simply the star-forming outer edge of nuclear discs. Finally, by combining our results with those from a accompanying kinematic study, we do not find evidence for the presence of large, dispersion-dominated components in the centres of these galaxies. This could be a result of quiet merger histories, despite the large galaxy masses, or perhaps high angular momentum and strong feedback processes preventing the formation of these kinematically hot components.

Adrian Bittner (ESO, Garching, Germany)

The GIST Pipeline: A Multi-Purpose Tool for the Analysis and Visualisation of (Integral-field) Spectroscopic Data

We introduce a convenient, all-in-one framework for the analysis of IFS data. The GIST conducts all steps from read-in and preparation of data, over the analysis, to the production of publication-quality plots. In its basic setup, it extracts stellar kinematics, performs an emission-line analysis and derives stellar population properties from full spectral fitting as well as via the measurement of line-strength indices. To this end, the pipeline uses the well-known pPXF and GandALF routines, while being fully independent of the used instrument and employing an elaborate parallelisation. GIST further features a dedicated visualization routine with a sophisticated graphical user interface. This routine allows easy access of all measurements, spectra, fits, and residuals in fully-interactive plots. The pipeline is already used by numerous surveys, such as TIMER, Fornax3D, PHANGS, and WEAVE.

Giuseppe D'Ago (Pontificia Universidad Católica de Chile, Chile)

The Red Sequence investigated with a novel IFU analysis GUI

In the recent years, MUSE has been reshaping the way we investigate galaxies in the nearby Universe and at low-intermediate redshift. The collection of a significant amount of datasets and the execution of large programmes and IFU surveys urge us to develop and use fast and reliable programming tools and codes in order to exploit the unique treasure of information we can extract from instruments like MUSE, but also user-friendly analysis tools. I will present a highly customisable and flexible GUI, initially designed for MUSE, for performing (really) fast and reliable full-spectrum template fitting on-the-fly directly on the datacube, without the need of difficult intermediate steps and further coding. As a scientific example, I will present my recent results on the investigation of the metallicity gradient in some galaxy clusters by making use of a synergistic approach involving MUSE and HST data.

Justus Neumann (ICG, University of Portsmouth, UK)

The new MaNGA Firefly Catalogue

The MaNGA Firefly Value-Added-Catalogue (VAC) provides measurements of spatially resolved stellar population properties in MaNGA galaxies. It is built upon the MaNGA data analysis pipeline (DAP) and employs the full spectral fitting code FIREFLY to derive parameters such as stellar ages, metallicities, masses, star formation histories and dust attenuation. In addition to Voronoi-binned measurements, it also provides global properties, such as central values and radial gradients. With this poster, I will give an update on the MaNGA Firefly VAC that now doubled in sample size (~10,000 galaxies) as compared to the version published in SDSS DR15. One of the major new additions is the choice to select the results from fits that used either the MILES or the novel MaStar models, the later of which allow to constrain the fit over the whole MaNGA wavelength range.

Mina Pak (Korea Astronomy and Space Science Institute, KASI)

Stellar populations of decomposed bulge and disk for S0 galaxies

We investigate the stellar populations of bulges and disks separately using the CALIFA data. We find a tight correlation in stellar age-metallicity for bulge, whereas that in disk component appears to be a larger scatter

and offset from the bulge component. This implies that the star formation histories of the disks are more complicated than those of bulges. Both the ages of bulges and disks of the high-mass S0s appear to increase with local density. The age difference between bulge and disk (ΔAge) tends to increase with local density, both for the high-mass and low-mass S0s. The high-mass S0s have systematically higher ΔAge than the low-mass S0s at given local density. The results indicate that the stellar mass significantly influences the evolution of S0 galaxies, but the environment also plays an important role in determining the evolution of bulges and disks at a given mass.

Taniya Parikh (Max-Planck-Institut für extraterrestrische Physik, Garching, Germany)

Stellar population parameters using MaNGA and MUSE

The stellar initial mass function (IMF) has implications for a wide range of problems in astrophysics and is one of the largest uncertainties when analysing the integrated light of galaxies. The MaNGA IFU survey provides the opportunity to make precise spatially resolved measurements of stellar population properties in galaxies, owing to its unique combination of spatial resolution, wavelength coverage, and sample size. We measure radial gradients in age, metallicity, abundances of various individual elements, and the low-mass IMF slope from stacked spectra. We derive these parameters by fitting stellar population models to a combination of optical and near-infrared absorption features. We compare local and global trends for early- and late-type galaxies, with an attempt to understand the processes that drive the evolution of these objects. Through MUSE we focus on a galaxy-by-galaxy approach to study detailed spatial variations and also obtain results from full spectrum fitting.

Sebastian Francisco Sanchez (UNAM, Ciudad de Mexico, Mexico)

Pipe3D, a pipeline for IFS galaxy surveys

We present the most recent results based on Pipe3D, a pipeline tool developed to analysis the spatial resolved stellar population and emission line properties. Previous versions of the pipeline was tested with CALIFA, MaNGA, SAMI and MUSE data (AMUSSING++ compilation), using only one SSP-library (GSD156), and a limited set of emission lines (52 galaxies). We introduce a new version of the code fully re-written in Python, that significantly improves the efficiency. In addition we have included different SSP-library analysis and a new set of emission lines (252 in total).

We use this new version to analyze the MPL-10 version of the MaNGA dataset (~9500 galaxies), and we are in the process of reanalyzing the AMUSSING++ compilation (~900 galaxies observed with MUSE).

Thomas Spriggs (University of Hertfordshire, UK)

Fornax3D project: A Census of the PNe population in the early-type galaxies in Fornax.

The study of Planetary Nebulae (PNe) in other galaxies offers a view into the late stages of stellar evolution in galactic environments that are considerably different compared to that of the Milky Way. For instance, the specific number of PNe is thought to depend on the stellar metallicity of their parent population at a given stellar age. Massive early-type galaxies provide a benchmark for studying PNe in a super-Solar metallicity regime for old stellar population, and in this respect, integral field spectroscopy offers a unique way to detect PNe against the bright stellar background their central regions. We use Fornax 3D Project MUSE to explore the PNe population of the brightest early-type galaxies within the Virial radius of the Fornax cluster. We also highlight the improvements that MUSE Adaptive Optics (AO) observations would provide for the detection of distant PNe. Such improvements could be applied to helping constrain a value for the Hubble constant (H0).

Tjitske Starkenburg (CIERA. Northwestern University, Evanston, USA)

Star-forming and quiescent galaxies in synthetic spectroscopic surveys from cosmological simulations

The populations of star-forming, green valley, and quiescent galaxies, whether predicted from simulations or observed, vary depending on how these are defined and on the tracers used to measure star formation rates. We explore star formation and quiescence of galaxies in 6 large-scale cosmological simulations and compare apples-to-apples to observational data. We carefully build synthetic galaxy spectra for all (~3e5) simulated galaxies and (re)measure star formation and quenching indicators. Using this wealth of spectral data, we describe the populations of star-forming and quiescent galaxies in simulations, in synthetic observations, and in observational data, and carefully compare. This allows us to connect the different quenching mechanisms in the simulations to trends in the (mock) observational indicators. Additionally, we combine our observational and theoretical knowledge to provide

comparisons and conversions for a number of observational quenching and quiescence indicators.

Stefano Zibetti (INAF-Osservatorio Astrofisico di Arcetri, Firenze, Italy)

The "local" drivers of the bimodality in galaxy stellar populations

I will present results on the spatially resolved stellar population (SP) properties of nearby galaxies over a broad range of masses and morphology, representative of the local Universe, obtained by joining integral field spectroscopy from CALIFA and broad-band images in a Bayesian framework with a highly complex SP modelling. Local scales have an important role in determining the properties of SPs, which result in local scaling relations linking age and metallicity with stellar mass surface density (Zibetti et al. 2017, 2020, +in prep.). Purely passive and old regions exist at any stellar mass surface density (mu*), while young regions become relatively older at increasing mu* and create a sequence that merges with the sequence of old and passive regions at mu*>5E3 Msun pc-2. Stellar metallicity is shown to follow a universal relation with mu*, but only at stellar masses >3E10 Msun. Total stellar mass, rather than stellar mass density, appears as the main drive r of galaxy bimodality.

Sree Oh (Australian National University, Canberra, Australia)

Kinematics of galaxy bulges, disks, and gases

We investigate the stellar kinematics of the bulge and disk components in 826 SAMI galaxies. The spatially resolved rotation velocity (V) and velocity dispersion (σ) of bulge and disk components have been simultaneously estimated using the penalized pixel fitting (PPXF) method with photometrically defined weights for the two components. The spin parameter λR indicates bulges are pressure-dominated systems and disks are supported by rotation. The two components show Tully-Fisher and Faber-Jackson relations with similar slopes, but different intercepts suggesting that the galaxy stellar mass scales with both V and σ for both bulge and disk components of all galaxy types. Our findings suggest that the relative contributions of the two components explain, at least to first order, the complex kinematic behaviour of galaxies. Looking further ahead, we compare gas and stellar kinematics and discuss dependence of spatial distribution of gas on galaxy type.

Po-Feng Wu (National Astronomical Observatory of Japan, Tokio, Japan)

Resolving post-starburst galaxies with spectroscopical surveys near and far: road to quenching up to z=1

Post-starburst (PSB) galaxies are quiescent galaxies whose star-formation rates had dropped rapidly in the recent past thus good proxies to study quenching. They are traditionally selected by spectra. Therefore, comparing samples across redshifts are complicated by different spectroscopic apertures. I start from PSB galaxies in the MaNGA IFU survey at z=0, using the spectra integrated over the entire IFU. The large aperture mitigates the severe aperture bias with fiber spectra on low-z galaxies. I show that most of the PSB galaxies appear to have a fading compact star-formation event in the central 1 kpc. I then present the sample at z~1 identified by the LEGA-C survey. PSB galaxies at z~1 show overall stronger Balmer absorption at the center. Smaller ones are also bluer. Central compact star formation before quenching can explain these features of PSB galaxies at z=1. I will discuss the mechanisms, possible improvements, and new opportunities.

Session 2: Stellar and Gas Kinematics

Talks

Invited Talk

Federico Lelli (Arcetri Astrophysical Observatory, Italy)

Gas dynamics across cosmic time

The emission lines of cold/warm gas are key tools to trace galaxy dynamics at different cosmic epochs. At z=0, the combination of Hα, CO, and HI observations allowed studying gas dynamics in hundreds of galaxies of different masses and morphologies, from quiescent ellipticals to star-forming dwarf irregulars. Regular rotation and low gas turbulence are the rule at z=0 with the exception of interacting and merging systems. Combined Hα+HI rotation curves extend from the innermost regions of galaxies out to tens of effective radii, probing deep into their dark matter halos. These data revealed surprisingly tight scaling relations between baryons and dark matter, which challenge current models of galaxy formation. At z=1-3, integral-field spectroscopy of Hα and [OIII]-5007 Å lines allowed tracing the inner dynamics of massive galaxies for significant samples: the importance of disk turbulence, the rotation-curve shapes, and the evolution of scaling relations remain debated at this cosmic epoch. Radio and sub-mm interferometry of CO and [CI] lines are also key tools at z=1-3 albeit currently limited to small galaxy samples. At z=4-7, ALMA observations of the [CII]-158 μm line have opened an entirely new window for galaxy dynamics. The study of the high-z Universe is particularly promising to test the predictions of current models of galaxy formation.

Invited Talk

Caroline Foster (University of Sydney, Australia)

Stellar kinematics

Integral field spectroscopic (IFS) surveys have revolutionised our understanding of the stellar dynamics in external galaxies at z~0. Studies of gas-phase dynamics and deep slit-based spectroscopy at high redshift

show that galaxies have experienced significant dynamical evolution since z~1. Theoretical modelling suggests that this dynamical evolution is closely tied to the formation and assembly history of galaxies.
I will give a brief overview of the field of stellar kinematics with a focus on extragalactic systems, including key discoveries from major surveys with spatially resolved stellar kinematics. Finally, I will explore future avenues for progress with current and future facilities/observing campaigns.

Giulia Santucci (University of New South Wales, Australia)

Internal mass distributions and orbital structures of SAMI passive galaxies

Galaxy mergers play an important role in how galaxies evolve over time, however extragalactic astronomers do not yet completely understand the process by which those mergers happen. The merger history of a galaxy is thought to be one of the major factors that determines the internal kinematic structures of galaxies, with galaxies having undergone more mergers predicted to show different properties. Therefore, we expect that the internal kinematic structures of passive galaxies could show different characteristics depending on their merging history. We apply orbit-superposition Schwarzschild models to passive galaxies in the SAMI Galaxy Survey, in order to reconstruct their internal kinematic structure and mass distribution. We find intriguing signs of different orbital structures in galaxies with different kinematic signatures. The future larger surveys that will be enabled by new MOS and IFU facilities will be needed to further explore these intriguing signs in a statistical sample.

Edoardo Iani (Kapteyn Institute - Rijksuniversiteit Groningen, The Netherlands)

Spatially resolving the spectral properties of lensed galaxies at z>3

Despite the progress made with state-of-the-art instrumentation, spatially resolved studies of galaxy spectral properties at redshifts z>3 are still challenging. The typical scale over which intermediate/high-redshift galaxies can be observed is of a few kpc, which is comparable to the size of the entire galaxy. In contrast, lensing fields can offer an excellent solution to circumvent this problem, allowing us to spatially resolve galaxy substructures down to sizes of ~0.1 kpc and at the same time reach faint fluxes in a short amount of observing time. In this talk, I will present the first results of our studies of resolved galaxy spectral properties at z>3,

based on the analysis of VLT/MUSE WFM+AO observations in lensing fields. I will show how the combination of MUSE/AO and HST data provides important information on the star formation process and galaxy ISM dynamics, and discuss the complementarity of our results with future spectroscopic studies with JWST.

Katja Fahrion (ESO, Garching, Germany)

Globular clusters as tracers of galaxy properties

Globular clusters (GCs) are found in all massive galaxies and due to their old ages, they are often regarded as fossil records of galaxy assembly. Photometric surveys of GC systems have shown that many galaxies have bimodal GC colour distributions with a red and blue population that have been interpreted as a metal-rich, in-situ born and a metal-poor, accreted population, linking directly to a two-stage formation of galaxies. However, to effectively use GCs as tracers of galaxy assembly, spectroscopy is required. I will present a novel sample of 720 GCs in 32 galaxies from the Fornax3D project based on MUSE data. With this spectroscopic sample, we establish their value as bright tracers in distant galaxies. Further, we study the relationship between photometric colours and spectroscopic metallicities and derive a non-linear colour-metallicity relation that challenges the simple division of GCs solely based on their colour and has implications for merger histories as traced by Gcs.

Barbara Catinella (ICRAR/University of Western Australia, Australia)

Dynamical scaling relations with radio and integral-field spectroscopy data

Dynamical scaling relations such as the Tully-Fisher relation (TFR) link the baryonic and dark matter content of galaxies, and their slope and scatter encode important information on how galaxies assembled. Traditionally, most TFR work has been based on velocity widths obtained with 21 cm observations, but the advent of large integral-field spectroscopy (IFS) surveys has allowed us to revisit this important relation with new eyes. Interestingly, IFS studies seem to find more scatter at low stellar masses, compared to radio studies, which might be associated to the increasing importance of turbulent motions in these systems. The lack of overlapping samples with both IFS and 21 cm data has prevented a direct comparison until now. We present here the first results of SAMI-HI, a dedicated follow-up of galaxies with SAMI IFS data using the Arecibo radio telescope, and

discuss the potential of the synergy between surveys of cold hydrogen gas and spatially-resolved optical spectroscopy.

Jennifer Hardwick (ICRAR/UWA, Perth, Australia)

The link between angular momentum and star formation cycle in nearby galaxies

Angular momentum (AM) is a fundamental property of galaxies as it is linked to their formation, evolution and morphology. Despite being fundamental, the literature has not currently converged on a solution of how AM is linked to the dark matter halo, how it varies as a function of mass or quantified its effect on morphology. During this talk, I will be explaining how we have been using the xGASS sample to investigate these questions. Given that xGASS is uniformly selected in stellar mass and HI gas fraction it provides a unique opportunity to investigate selection bias generally affecting HI-selected samples. I will present preliminary result on the shape, slope and scatter of mass-size relation, Tully-Fisher Relation, and specific AM – stellar mass relation for xGASS galaxies and discuss how we can combine these scaling relations in order to gain additional insights into the connection between galaxy structure, kinematic and gas content.

Callum Bellhouse (INAF Osservatorio Astronomico di Padova, Italy)

Unwinding the Spiral Arms of Galaxies via Ram-Pressure Stripping

Jellyfish galaxies, which represent the physical manifestation of ram-pressure stripping, have been the subject of many studies as they provide a deep insight into the interplay between environmental and feedback processes and their effects on a galaxy's gas and stellar populations. Here, I present a recent study, as part of the GASP programme, of a newly observed morphological effect of ram-pressure "unwinding" or opening the spiral arms of a galaxy. A sample of 10 unwinding jellyfish galaxies observed with MUSE are compared with simulations to understand the mechanism and the conditions in which such unwinding occurs. Such an effect may be indicative of early stages of ram-pressure stripping, and understanding its origin and prevalence is vital when considering morphological selection of galaxies from imaging data, as the resulting pattern of extended, broadened spiral arms can resemble the disrupted arms of gravitationally disturbed galaxies.

Pre-recorded talks

Anna De Graaff (Leiden University, The Netherlands)

The evolution of the Fundamental Plane to z~1: results from the LEGA-C Survey

The Fundamental Plane (FP), a tight scaling relation between galaxy size, velocity dispersion, and luminosity or stellar mass, provides strong constraints on the formation time and evolution of quiescent galaxies. However, selection biases at high redshift can affect the measured evolution of the FP significantly, and hence the inferred galaxy evolution. The LEGA-C survey has delivered the largest census of galaxy stellar kinematics at z=0.8, comprising a sample of 3000 K-band selected, massive galaxies. Combined with HST imaging, this enables a statistical view of the structural properties of galaxies at z=0.8 and their evolution to the present day. I will discuss the effects of structural and stellar population properties on the FP, and demonstrate that the FP extends to the star-forming population. I will show that, despite strong evolution in the sizes and stellar populations of galaxies, the FP is surprisingly stable to z=1, and discuss the implications for the growth of galaxies.

Ugne Dudzeviciute (Durham University, UK)

Decomposing the rotation curves of star-forming galaxies at high redshift

Galaxy rotation curves provide fundamental measurements of the baryonic and dark matter distributions in galaxies. The kinematic studies of galaxies in the local Universe, showing that the enclosed dynamical mass of galaxies rises far beyond the optical radius, remains one of the cornerstones for the evidence for dark matter. There is less direct evidence for the same dark-matter dominance at high redshift, with recent studies suggesting that dark matter contribution within galaxies may be much lower. To measure the shapes of rotation curves of high-redshift galaxies, we are undertaking the KMOS Ultradeep Rotational Velocity Survey (KURVS) which is deep (~120h per galaxy) study of z~1.5 main-sequence galaxies. These data, which are a factor ~10x deeper than previously undertaken, measure individual Hα rotation curves out to ~15kpc. Here, I will show how we are decomposing the rotation curves in to the speeds of stars, gas and dark matter, and discuss the implications from our study.

Dimitri Gadotti (ESO, Garching, Germany)

The TIMER Survey: constraints on the assembly and evolution of disc galaxies

The TIMER survey with MUSE has mapped the central 6x6 kpc of 21 nearby barred galaxies. The main goals of the survey are: estimating when discs of galaxies settle and secular evolution begins; testing downsizing; and characterising the history of gas accretion. The high signal and spatial resolution of the data allow other unparalleled studies on the formation and evolution of disc galaxies. I will summarise the main properties of the survey and our first publications, leading to new constraints on the nature of inner bars, including the discovery of the first inner bar with a box/peanut, and on the physical processes that govern stellar feedback and its impact on the ISM, with ancillary ALMA data. I will focus though on how the kinematical properties of nuclear discs are fully consistent with the bar-driven secular evolution picture for their formation, and on what can we learn from these results about the nature of the central stellar components of the Milky Way.

Veselina Kalinova (Max Planck Institute for Radioastronomy, Bonn, Germany)

Velocity profiles and star-formation quenching of CALIFA galaxies

We investigate the link between dynamics and star-formation quenching stages of CALIFA nearby galaxies. Combining the results from circular velocity curve (CVC) and an emission-line (EL) classification, our results reveal that the circular velocity profiles of the galaxies, from late- to early-type systems, transit in an evolutionary sequence, and support the working hypothesis that the increasing concentration in the inner part of a galaxy stellar system, along with mergers and secular evolution, produces an active massive nucleus that disperses angular-momentum-rich baryon and quench the star-formation of the galaxies. The proposed Quenching Stages of the galaxies, based on the patterns in the ionised gas distribution of the galaxies, reinforce the inside-out quenching scenario. Further, the Blue cloud galaxies are characterised by slow-rising CVCs, while the Green valley systems have flat ones and the Red sequence galaxies - round-peaked CVC profiles.

Giacomo Venturi (Pontificia Universidad Católica de Chile, Chile)

MAGNUM survey: dissecting galactic outflows in nearby AGN with VLT/MUSE

I will present our results from the MAGNUM survey, which exploits the unique capabilities of the optical/NIR integral field spectrograph MUSE at VLT to study in detail the properties of outflows in nearby Seyferts and their impact on the ISM and star formation in the host (feedback mechanism). MUSE allowed us to map the ionized gas down to ~10 pc in several emission lines revealing ubiquitous kpc-scale outflows, whose properties (e.g. velocity, density, mass rate etc...) were spatially dissected. By matching MUSE with radio data, we detected an intriguing (and possibly common) phenomenon, likely produced by the impact of low-power jets on their host galaxy disks. Finally, we found also evidence of outflow-induced star formation. I will also present preliminary results from a survey of mergers and dual AGN with MUSE Wide- + Narrow-Field, aimed at characterizing outflow acceleration along the whole merger sequence at all spatial scales and the role of mergers in triggering AGN activity.

Posters

Avinash Chaturvedi (ESO)

Exploring kinematical properties of globular cluster systems around Fornax cluster galaxies through VIMOS spectroscopy

The Fornax cluster provides an unparalleled opportunity to investigate the formation and evolution of galaxies in a dense environment in great detail. Using the VLT/VIMOS spectroscopic survey of the Fornax cluster, we confirm the detection of 777 globular clusters (GCs). Combined with previous measurements, this leads to the most extensive catalog of radial velocity measurements of a total of 2341 GCs in Fornax. This VIMOS spectroscopic survey allowed the kinematical characterization of photometrically discovered substructures in the GC distribution. We found that metal-rich (red) GCs are concentrated around the major galaxies, while metal-poor (blue) GCs are kinematically irregular and widely spread throughout the core region of the cluster.

Virginia Cuomo (Universidad de Atacama, Copiapo, Chile)

Bar pattern speeds in CALIFA galaxies: ultrafast bars or too long bars?

More than 10% of the barred galaxies with a direct measurement of bar pattern speed host a bar rotating extremely fast. These bars are generally defined as 'ultrafast'. We selected the ultrafast bars observed in CALIFA and investigated if the bar rotation rates were correctly determined. We tested the measurement of bar pattern speed obtained with the Tremaine-Weinberg method and method proposed by Lee et al. (2020). Most of the galaxies is hosting an inner ring located at the end of the bar and/or strong spiral arms. Our new estimates of bar radius are always shorter with respect to the values used in literature. The corresponding bar rotation rate do not belong to the ultrafast regime, except for one galaxy. The presence of the rings and/or strong spiral arms affected the estimate of the bar radius and of the bar rotation rate. We stressed that a solid estimate of bar radius is missing.

Amelia Fraser-McKelvie (ICRAR/ University of Western Australia, Australia)

A SAMI and MaNGA view on the kinematics of star-forming galaxies

We investigate the physical connection between the growth of dispersion-supported stellar structures (e.g. classical bulges) and position of galaxies on the star forming main sequence (SFMS) at z~0. Combining the might of the SAMI and MaNGA galaxy IFS surveys, we measure the λRe spin parameter for 3781 galaxies with reliable stellar kinematics. After first confirming the importance of PSF corrections for seeing-dominated IFS data, we present the kinematic properties of galaxies above, below, and on the SFMS.

Above log M*~10.5, we find tantalising evidence for an increase in the number of galaxies with dispersion-supported structures, suggesting a connection between bulge growth and the bending of the main sequence. Our results suggest that while a population of galaxies possessing some dispersion-supported structure is already present on the SFMS, further growth would be required after the galaxy has quenched to match the kinematic properties observed in passive galaxies at z~0.

Aishwarya Girdhar (ESO, Garching, Germany)

Multi-wavelength spectroscopy to ascertain quasar feedback

As part of our Quasar Feedback Survey of z<0.2 quasars we are using ESO/VIMOS and ESO/MUSE to spatially-resolve ionised-gas and stellar kinematics in quasar host galaxies. Combined with multi-wavelength information we are assessing: (1) the properties of galactic multiphase outflows driven by jets and/or winds; (2) what impact these have on the star formation (SF) properties of the host galaxies. I will give an overview of our survey, highlighting the crucial role of ESO's spectroscopic instruments. As a showcase, I will present detailed observations of a target. We have used MUSE, to measure gas and the stellar kinematics, and isolated non-gravitational motion caused by the small-scale radio jet that is ploughing into the galaxy disk. We have further analysed the prevalence of the molecular phase of the outflow by using the data from ALMA. By combining the study of the ionised and molecular gas, to the stellar kinematics, we can infer the feedback effects on SF in the host galaxy.

Catalina Mora Urrejola (University of La Serena, Chile)

A tidally induced global corrugation pattern in an external disc galaxy similar to the Milky Way

In this talk I will present evidence of a tidally induced global corrugation pattern in an external disc galaxy similar to the Milky Way. Using Hα Fabry-Perot observations we obtain a 2D line-of-sight velocity (Vlos) field of the low-inclination, late-type galaxy VV304a. The 2D kinematic map reveals a global, coherent and extended perturbation that is likely associated with a recent interaction with the massive companion VV304b. We use multi-band imaging and a suite of test particle and cosmological simulations to quantify the plausible strength of in-plane flows due to non-axisymmetric perturbations, and show that the observed velocity flows are much too large to be driven either by spiral structure nor by a bar. The final Vlos map suggests the presence of a structure in the VV304a disc similar to the Monoceros ring seen in the Milky Way.

Zhu Ling (Shanghai Astronomical Observatory, China)

Uncovering past galaxy mergers via population-dynamics of their stars

I will present advanced dynamical models that can convert the stellar kinematics observed by IFU instruments to phase-space quantities like

energy and angular momentum which remain largely conserved. In addition, these models can include the observed ages and chemical properties of stars which are also conserved. The resulting population-dynamical models allow us then to uncover even those accretion events which are now fully dispersed.
In this talk, I will focus on our recent discovery of an ancient massive merger in the Fornax lenticular galaxy NGC1380 observed by MUSE/VLT. By the end, I aim to have demonstrated that these models provide a unique bridge between the studies of resolved stars in the Milky Way and integrated-light of high(er)-redshift galaxies. Together with direct coupling to state-of-the-art galaxy formation simulations, these population-dynamical models enable us to uncover the hierarchical build-up of galaxies in a cosmological context.

Carter Rhea (L'Université de Montréal, Canada)

Analyzing the Kinematics of SITELLE Spectra using Machine Learning

We describe the first paper in a series of works in which we explore the application of different machine learning algorithms to the spectral analysis of extra galactic emission regions. We discuss the creation of synthetic spectra replicating the primary optical filter of the SITELLE instrument located at the Canada-France-Hawaii Telescope. We employ a convolutional neural network to learn the kinematic parameters, velocity and line broadening, directly from these spectra. Subsequently, we apply our methodology to a field of the nearby galaxy M33 and demonstrate the efficacy of our results in terms of residuals and computational expediency. We develop an open source framework for users to port this methodology to other IFUs, and we discuss future applications of machine learning to spectral analysis.

Wilfried Mercier (IRAP, Toulouse, France)

Morpho-kinematics of galaxies in various environments at $z \sim 0.2 - 1.5$

We present a study of the impact of the environment on the morpho-kinematics properties of intermediate redshift galaxies (z~0.25-1.5) with the use of HST and MUSE data. We use the latest MUSE-GTO observations of 17 different fields in the COSMOS area from the MAGIC survey to build a sample of ~ 600 resolved galaxies, within target groups and in their foreground and background, allowing to probe a variety of environments,

with virial masses in the range 10^9 - 10^14 M_sol. We perform a multi-component decomposition from the HST images, and extract the ionised gas kinematics from the MUSE cubes using the [OII] doublet. Taking into account prior information from the morphological decomposition, we perform a mass modelling in order to extract the galaxies main kinematical parameters such as their circular velocity and baryon fraction. After describing our methodology, I will present our results on various scaling relations such as the TFR and show how these scale with structure properties.

Chaitra Narayan (NCRA-TIFR, Pune, India)

The elusive corrugations - caught in dust

We report the detection of small-scale bending waves, also known as corrugations, in the dust lanes of five nearby edge-on disk galaxies. This phenomenon, where the disc mid-plane bends to become wavy, just as in warps but on a smaller scale, is seen here for the first time, in the dust lanes. We enhance the visibility of these features using unsharp masking, trace the dust mid-plane across the disc, measure the corrugation amplitude by eye and the corrugation wavelength using Fourier analysis. The corrugation amplitude is found to be in the range of 70–300pc and the wavelengths lie between 1 and 5 kpc.

The fact that corrugations are seen in stars, gas (Milky Way, IC 2233 etc) and dust indicate gravitational instability as the likely origin. Corrugations can be, in fact as common as warps but may go undetected because of their small size. We assemble mounting evidence indicating that corrugations in the outskirts of gaseous disks may lead to 'silent' star formation.

Session 3: Environment and Intergalactic Medium

Talks

Invited Talk

Bianca Maria Poggianti (Astronomical Observatory of Padova, Italy)

Galaxy evolution and environment: the cluster view at z < 1

This talk focuses on what we have learned about galaxy evolution from large spectroscopic surveys of galaxy clusters at z<1. Multi-object spectroscopy and integral-field spectroscopy have been at the core of our progress in understanding the physical processes that govern galaxy evolution before and after galaxies become part of a cluster, in their journey through different environments. In addition, the most massive haloes in the universe are the best sites to study those environmental effects (ram pressure stripping, strangulation, harassment) that are most -- but not uniquely -- efficient in clusters. Milestones of cluster spectroscopic surveys include studies of the mass assembly, star formation histories and structure (morphologies and sizes) of galaxies. I will focus on some of the observational highlights, and the outstanding questions.

Invited Talk

Cucciati Olga (INAF, Italy)

Galaxy evolution and environment: the density field up to beyond the cosmic noon

It is known that galaxy evolution is affected by several processes taking place in intermediate and high density environments. The lack of such processes, like e.g. in very low density regions, is also providing us with important pieces of information to be compared with high density regimes. In this respect, the study of the density field is a powerful tool to identify very different environments in one go. With all due caveats, this holds up to the highest redshifts explored, where the density peaks are often associated with the presence of proto-cluster candidates. Large spectroscopic surveys are particularly well suited for this kind of studies,

allowing us to parameterise environment on several scales, from the >10 Mpc of voids to the ~1 Mpc of local density peaks. In this talk, I will show the most recent advances in this field, with a particular focus on z>2, where we possibly witness the onset of the effects of environment on galaxy evolution.

Benoit Epinat (LAM, Marseille, France)

Galaxy evolution in groups at intermediate redshift from the MUSE galaxies Groups In Cosmos survey

MAGIC (Muse gAlaxy Groups In Cosmos) is a 100h MUSE-GTO survey aiming at understanding the impact of environment on galaxy evolution. It targets 15 massive groups at 0.3-z-0.8, identified in the zCOSMOS and VVDS VIMOS surveys, probing spatially resolved properties of galaxies down to low mass (~10^8 Msun) but also the intra-group medium.
After introducing MAGIC, I will present a first analysis of the ionised gas kinematic of galaxies in these groups which shows that the Tully-Fisher relation evolves due to quenching and contraction (Abril-Melgarejo+21). I will explain how MUSE observations led to the first detection of very extended ionised gas nebulae within groups, associated to processes such as tidal interactions, AGN feedback, shocks (Epinat+18) and ram pressure stripping (Boselli+19) at z~0.7. I will conclude by discussing the implications of these results on galaxy evolution, on the quenching of star-formation in dense environments and on the build-up of the Hubble sequence.

Yucheng Guo (The Kavli Institute for Astronomy and Astrophysics, Peking University , China)

Metal Enrichment in the Circumgalactic Medium and Lya Halos around Quasars at z~3

Deep observations have detected extended Lya emission nebulae surrounding tens of quasars at redshift 2–6. However, the metallicity of such extended halos is still poorly understood. We perform a detailed analysis on a large sample of quasars at z~3 based on MUSE-VLT data. We find clear evidence of extended emission of CIV1549, HeII1640 and CIII]1909 out to a radius of ~45 kpc. We infer that the average metallicity of the CGM gas within the central 30–50 kpc is ~0.5 solar, or even higher. We also find evidence of a component of the Lya halos, which has much weaker metal emission lines relative to Lya. We suggest that the high metallicity of the CGM within the central 30–50 kpc is associated with

chemical pre-enrichment by past quasar-driven outflows and that there is a more extended metal-poor component of the CGM that is likely associated with near-pristine gas accreted from the IGM. Our results are in good agreement with the expectations of the FABLE zoom-in cosmological simulations.

Michael Hilker (ESO, Garching, Germany)

Dynamical tracers of galaxy assembly in the core of the Fornax cluster

The Fornax cluster is one of the closest dense environments where early-type galaxy evolution can be studied in great detail. It has been subject to several spectroscopic surveys, dedicated to disentangle the assembly history of its member galaxies and to characterise the properties of small stellar systems. In the core of Fornax, more than 2500 radial velocities of globular clusters (GCs) and ultra-compact dwarf galaxies (UCDs) as well as ~1500 of planetary nebulae (PNe) have been collected from surveys with different instruments (FORS, VIMOS, FLAMES, MUSE). They were used to study the complex kinematic structure in the cluster core. The flat velocity dispersion profile beyond 50 kpc from NGC 1399 can be explained by a superposition of the central galaxy and cluster potentials, with contributions from stellar streams that trace interaction events. I will present recent results on our understanding of the assembly of the Fornax cluster core, based on this large spectroscopic dataset.

Pierluigi Cerulo (Universidad de Concepción, Chile)

The Morphological Transformations of Galaxies as a function of the Environment at z = 0.2 - 0.9

The evolution of galaxies is driven by complex physical mechanisms that may have internal or environmental origin. As time passes galaxies become quiescent and acquire early-type morphologies. We have embarked in a study of morphology and star formation in cluster and field galaxies with the aim of investigating the interplay between star-formation quenching and morphological transformations as a function of environment. In this talk I shall present the results of a study conducted on galaxies in the CLASH and CANDELS surveys at redshifts $0.2 < z < 0.9$. By dividing galaxies into star-forming and quiescent we find that, regardless of the environment, there is an increase in the fraction of quiescent disc galaxies at low redshift, supporting the notion that quenching precedes morphological changes, at least at low stellar

masses. I will discuss the implications of our results in the general context of galaxy evolution, taking into account the biases that may affect structural analyses.

Malgorzata Siudek (IFAE, Barcelona, Spain)

Different evolutionary paths of VIPERS galaxies at z~1

The statistical power of the VIPERS survey which observed ~90,000 galaxies at z>0.5 and the application of unsupervised FEM clustering algorithm allowed us to select 11 galaxy classes at z~1: 3 passive, 3 intermediate, and 5 star-forming. Physical properties - in particular, those which were not used for classification purposes - of all these subtypes differ between each other, and the transition between different subtypes is not smooth. Studies of environmental dependence indicate that the FEM classification may actually reflect different evolutionary paths of different subclasses of passive, star-forming, and intermediate subtypes of galaxies. For instance, the most passive class of red galaxies, residing in dense environments is the most compact and ~20% smaller than other red galaxies of a similar stellar mass. This may indicate that they were formed as a result of a spherical collapse rather than galaxy mergers. In my talk, I discuss the emerging scenarios of galaxy evolution.

James Trussler (University of Cambridge, UK)

The weak imprint of environment on the stellar populations of galaxies

Leveraging on the statistical power of the SDSS, and by separating star-forming, green valley and passive galaxies, I will show that the imprint of environment on the stellar populations of galaxies is much weaker than previously thought. Satellite galaxies are in fact only marginally more metal-rich (<0.03 dex) and older (<0.5 Gyr) than central galaxies of the same stellar mass, with stellar metallicities that show only a weak dependence (<0.05 dex) on the density of the environment within which satellites reside. Thus, while the environment plays a crucial role in the quenching of star formation in galaxies, it only plays a minor role in shaping the properties of star-forming and passive galaxies. Furthermore, by comparing the levels of chemical enrichment in star-forming and passive galaxies, I will show that it is in fact starvation (rather than gas stripping) that becomes progressively more important in quenching star formation in satellites in progressively denser environments.

Pre-recorded talks

Brian Lemaux (UC Davis, California, USA)

The Legacy of VIMOS in Exploring and Defining Proto-cluster Environments at High Redshift

The past decade has been witness to immense progress in the understanding of the early stages of cluster formation. During this time, samples of forming clusters at higher redshift, termed “proto-clusters” have begun to compete with lower-redshift samples both in number and in the homogeneity of the detection methods. I will focus on the legacy of VIMOS in exploring and observationally defining such regions in the universe. These achievements were primarily realized through the lens of large galaxy surveys such as VVDS, zCOSMOS, and VUDS with immense involvement from the PI of VIMOS, the late Prof. Olivier Le Fèvre. I will discuss these observations and the development of the methods for characterizing proto-clusters. Several case studies of a diverse set of massive proto-clusters will be presented and I will discuss the role of Keck/DEIMOS in continuing the legacy of VIMOS. I will finally discuss constraints on relationship of star formation rate and galaxy density at these redshifts.

Matilde Mingozzi (Space Telescope Science Institute, Baltimore, USA)

In/out-flows of cold gas in ram-pressure stripped galaxies

Cold outflows are ubiquitously found in local and distant galaxies, possibly having a profound impact on their host galaxy and environment evolution. Indeed they carry material that would otherwise have been used to form stars from galactic nuclei to the outermost regions of galaxy halos. In this context we analyzed the gas kinematics in the central regions of galaxies characterized by AGN activity taken from the GAs Stripping Phenomena in galaxies with MUSE (GASP) sample, exploiting also the complementary information provided by ALMA. These galaxies are affected by ram pressure stripping that removes gas from galaxies in dense environments. MUSE allows to investigate the atomic gas through the NaID doublet, while ALMA provides information on the molecular gas through the CO. In this talk I will discuss the role of cold gas in/out-flows in these peculiar objects in triggering AGN activity and in channeling cold material in the tails of stripped gas, and their l ink to the ionized phase.

Marina Trevisan (Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil)

The properties and environment of very young galaxies in the local Universe

In the local Universe, there are only a few dwarf star-forming galaxies with very low metal abundances, which many believe to have formed most of their stellar mass during the last few hundred Myr. But little is known of more massive Very Young Galaxies (VYGs). In this work, we study a sample of 207 VYGs that have formed at least 50% of their stellar mass within the last 1 Gyr. We find that VYGs tend to have higher surface brightness and to be more compact, dusty, asymmetric and clumpy than control sample galaxies (CSGs). A subsample with HI detections revealed that VYGs are more gas-rich than CSGs. VYGs tend to reside in the inner parts of low-mass groups and are twice as likely to be interacting with a neighbour galaxy than CSGs. On the other hand, VYGs and CSGs have similar gas metallicities and large-scale environments. Our results suggest that gas-rich interactions and mergers are the main mechanisms responsible for the recent triggering of star formation in VYGs at low redshifts.

Adam Watts (ICRAR/UWA, Perth, Australia)

Gas removal and the global HI asymmetry of galaxies

Observations have revealed that disturbances in the cold neutral atomic hydrogen (HI) in galaxies are commonplace. These disturbances are the imprint of the physical mechanisms that govern galaxy evolution, making it interesting to study what physical information they carry. I will present an analysis of these disturbances, through the measurement of asymmetry, in spatially integrated ('global') HI spectra. Utilising deep HI observations, I find that galaxies with asymmetric HI spectra typically have suppressed HI content. Further, satellite galaxies are more asymmetric than centrals, implying that gas-removal is responsible for their disturbed gas reservoirs. Utilising cosmological simulations I will confirm this interpretation, and show that it is driven by satellites in logMh/Msun > 13 haloes undergoing hydrodynamical gas removal. Last, I will show examples from the simulation that demonstrate the diversity of processes that are responsible for global HI asymmetry in galaxies.

Posters

Lodovico Coccato (ESO, Garching, Germany)

The influence of environment in the formation of lenticular galaxies

Lenticular galaxies (S0s) are believed to form through 2 main pathways: mergers or fading of a spiral progenitor. It is not clear yet what is the dominant scenario, nor what are the parameters and physical conditions that favor one path instead of the other. In a pilot study with 21 galaxies (Coccato et al. 2020), we suggest that environment (field of cluster) plays a role in the formation of S0s: S0s in the field are most likely formed through mergers, whereas S0s in clusters are most likely formed through processes that involve the rapid consumption of gas (e.g. starvation, ram pressure stripping) from a spiral progenitor. In this talk I will review the latest findings on this topic and present the results of a larger survey aimed at determining the role of environment in the formation of S0s.

Luca Cortese (ICRAR/University of Western Australia, Australia)

The role of environment on the star formation quenching of satellite galaxies

One of the key open questions in extragalactic astronomy is what stops star formation in galaxies. At least for satellite galaxies, it is accepted that environment should play an important role. In clusters, we see examples of cold gas being removed from the infalling star-forming disks, but whether stripping is widespread, or quenching is just a consequence of the inability of these galaxies to replenish their cold gas reservoirs, remains unclear. Moreover, whether quenching is accompanied by structural transformation is still a matter of debate. In this talk, I will discuss the current status of environmental studies of satellites in the local Universe, focusing on the evidence for a physical link between stripping and quenching of the star formation, and on the connection between quenching and morphological transformation. I will show how the combination of HI, CO and optical spectroscopic surveys is finally providing us with a coherent picture for the evolution of satellites at $z\sim0$.

Yuchen Ding (Shanghai Astronomical Observatory, China)

Probing environmental quenching in the Fornax cluster through a population-orbit superposition method

Recent observations of gas metallicities in cluster galaxies have provided tentative evidence of slow-then-rapid quenching: when galaxies enter the cluster their external gas supply is cut off, but star formation in a disk continues for another 1-2 Gyr before suddenly quenched (e.g., Maier et al. 2019). Environmental quenching can thus be probed by the age and metallicities of the stars in these 'residual' disks. The problem, however, is to extract the age and metallicity of these particular disk stars from the rest of the galaxy, which are mixed along line-of-sight. We overcome this difficulty by applying the recently developed population-orbit superposition method (Zhu+2020) to each of 23 early-type galaxies in Fornax cluster observed by MUSE/VLT. Our preliminary results suggest that star formation in disks could last for ~2 Gyrs after infall or even continue till today, depending on a galaxy's location in the cluster and its content of gas before falling into the cluster.

Anna Durkalec (National Centre for Nuclear Research, Warsaw, Poland)

Galaxy clustering and its dependencies at high redshift.

Studies of the galaxy clustering at low and intermediate redshifts show that the relation between the luminous structure and underlying dark matter distribution is not only biased but also dependent on properties of galaxies. To understand the origin of this separation the studies need to be conducted on spectroscopic data at higher redshift.

With this aim in mind, we studied the dependence of galaxy clustering on their luminosity and stellar mass in the redshift range between 2 and 3.5 using spectroscopic data from the VIMOS Ultra Deep Survey (VUDS). We measured how the dependence of characteristic dark matter halo masses, large scale bias and halo asymmetry changes with both redshift and galaxy properties. We measured the stellar-to-halo mass ratio (SHMR) which points to a significant model-observation discrepancy for low-mass galaxies at z~3, suggesting a higher than expected star formation efficiency of these galaxies.

Enrichetta Iodice (INAF-Astronomical Observatory of Capodimonte)

The assembly history of the Fornax cluster

The Fornax cluster provides a uniquely compact laboratory in which to study the detailed history of early-type galaxies and the role played by the environment in driving their evolution and their transformation from late-type galaxies. In this contribution I would like to review the complexity of the nearby Fornax cluster as result by combining the high-quality integral-field data obtained with MUSE at ESO-VLT from the Fornax3D project with the deep images from the Fornax Deep Survey (FDS), performed with the ESO VLT Survey Telescope (VST).

Fiorella Lucia Polles (SOFIA/USRA)

Excitation mechanisms in the intracluster filaments surrounding Brightest Cluster Galaxies

The excitation of the filamentary gas structures surrounding giant elliptical galaxies at the center of cool-core clusters, a.k.a BCGs (Brightest Cluster Galaxies), is key to our understanding of AGN feedback, and of the impact of environmental and local effects on star formation. Using the photoionization code Cloudy, we investigated the contribution of the thermal radiation from the cooling flow surrounding BCGs to the excitation of the filaments. We explored the effects of turbulence, and of metallicity, on the optical and infrared lines. Such models of self-irradiated clouds, manage to reproduce simultaneously a large number of optical-to-infrared line ratios when all the gas phases (from ionised to molecular) are modelled self-consistently.

Abhisek Mohapatra (National Institute of Technology, Rourkela, India)

CGM and their connection with the galaxies

In this talk, I will present initial results from the C III CGM survey (CIIICs). We have obtained a sample of metal-enriched cool gas traced by C III absorption at z $\sim$ 0.8-0.9 using HST/COS quasar spectra. Using photoionization models, we infer the number density (nH), C-abundance([C/H]) and line-of-sight thickness (L) of these absorption systems. We systematically search SDSS DR16 catalogue for galaxies associated with these absorbers within an impact parameter of 500 kpc. We find that these metal-enriched gas absorbers reside in group environments with at least two galaxies within the impact parameter of 500 kpc. We estimate various properties (star formation rate, stellar mass,

age, etc.) of these associated galaxies using photometric/spectroscopic observations. We examine the kinematics of the C III absorbers relative to the galaxy systemic velocities and also explore the connection between different galaxy properties with the derived absorber properties.

Ana Lourenco (Universidad de Valparaiso, Chile)

Jellyfish galaxies in violent neighbourhoods

In a hierarchical Universe, galaxy clusters continue to grow with cosmic time, and thus a large number of them are disturbed by accretion of groups or major collisions. Hydrodynamical numerical simulations show that ram pressure stripping can be enhanced during cluster interactions providing an alternative way of forming jellyfish galaxies. In this work, we built a reliable sample of interacting galaxy clusters using different interaction criteria such as the magnitude gap between the two brightest cluster galaxies (BCG), X-ray center and BCG offset, X-ray morphology, and DS substructure analysis. We use X-ray and optical data to investigate the influence of the collisions between clusters on the galaxies' gas stripping, supplying a statistical analysis of the position of the jellyfishes from the WINGS and GASP surveys with respect to cluster substructures. In our preliminary results, we show notorious cases of jellyfishes near discontinuity regions of the intracluster medium.

Benedetta Vulcani (INAF, Padova, Italy)

Resolving the pre-processing of galaxies in groups and filaments with MUSE

Galaxies inhabit a wide range of environments and are affected by different physical processes. Spatially resolved maps combined with the knowledge of the hosting environment are very powerful to classify galaxies by mechanism. I will present some breakthrough results based on the GAs Stripping Phenomena in galaxies with MUSE survey on the effects of the low density environments on galaxy evolution. I will discuss the multitude of mechanisms that can affect galaxies in isolation, groups and filaments, such as starvation, ram pressure stripping, gas accretion, galaxy-galaxy interactions, mergers, and cosmic web stripping. I will also show how filaments can assist gas cooling and increase the star formation in the densest regions in the circumgalactic gas of the galaxies flowing through them through Cosmic Web enhancement. I will probe the power of IFU data in pinning down the acting mechanism.

Adam Watts (ICRAR/UWA, Perth, Australia)

Gas content, star formation, and the global HI asymmetry of galaxies on the star-forming main sequence

Observations have revealed that disturbances in the cold neutral atomic hydrogen (HI) in galaxies are commonplace, even in gas-rich, star-forming galaxies that are free from strong environmental effects. I will present an analysis of these disturbances, though the asymmetry of integrated HI spectra, to determine whether they are associated with a change in the gas or star-formation content of galaxies. I find that, in this regime, there is no evidence for any change in the HI content of galaxies with asymmetric HI spectra. However, there is evidence for a small increase in their star formation-rate, driven by the galaxies with the strongest disturbances in their HI reservoirs.

Session 4: Formation and Interstellar Medium

Talks

Invited Talk

*Guillermo Blanc (*Carnegie Institution for Science, *US)*

New Views into the ISM, Star Formation, and Feedback in the Nearby Universe

Star formation and feedback from massive stars are the main agents driving the evolution of galaxies. These processes control the growth of the stellar component, set the structure, kinematics, and thermodynamics of the ISM, drive the chemical enrichment of galaxies, and regulate the baryon cycle and the star formation efficiency of gas. Systematic multi-wavelength mapping of the cold and ionized ISM of nearby galaxies and the Milky Way has become the benchmark for star formation studies in the local universe. Observations from sub-pc to tens of kpc scales across multiple ISM phases are needed to characterize these processes and their spatial and temporal complexities. I will present the current state of the field in terms of ISM mapping in nearby galaxies and the Milky Way, and the opportunities that new surveys will bring in the coming years.

Invited Talk

Manuel Aravena (Universidad Diego Portales)

ALMA deep field surveys and the ALMA Spectroscopic Survey in the Hubble Ultra Deep Field (ASPECS)

I will briefly review the current efforts to provide dust continuum and molecular line deep field observations with ALMA. In particular, I will show how our ALMA large program ASPECS is providing a more complete picture of the assembly of galaxies. In the deepest continuum imaging obtained for an extragalactic deep field we detect dust emission from ~50 individual galaxies that are found to span a wide range in stellar mass, SFR and HST morphology. ASPECS is finding most of the dust reservoirs in the UDF. A significant fraction of the dust-detected galaxies is also

detected in molecular gas emission which are used to constrain the excitation of the molecular gas component. Our measurements of the cosmic molecular gas density shows an order of magnitude decrease from z=2 to z=0, allowing us to put new constraints on the gas accretion process that is needed to explain the build-up of stellar mass in galaxies through cosmic history.

Ross McLure (University of Edinburgh, UK)

The VANDELS ESO Public Spectroscopic Survey

VANDELS was a uniquely deep spectroscopic survey of high-redshift galaxies in the CANDELS UDS and CDFS fields with the VIMOS spectrograph on the VLT. Using integration times of 20-80 hours, the fundamental aim of the survey was to provide the high-signal-to-noise ratio spectra necessary to measure key physical properties such as stellar population ages, masses, metallicities, and outflow velocities from detailed absorption-line studies. The final VANDELS data release (DR4) features spectra and redshift measurements for 2087 galaxies, pre-selected to belong to three main target categories: (a) bright star-forming galaxies at $2.4 \leq z \leq 5.5$, (b) massive quiescent galaxies at $1.0 \leq z \leq 2.5$, and (c) fainter star-forming galaxies at $3.0 \leq z \leq 7.0$.
In this talk, I will present an overview of the survey and review the science results obtained by the VANDELS team.

Victoria Fawcett (Durham, UK)

An X-shooter insight into dust-reddened quasars

An important fraction of quasars are red at optical wavelengths, indicating (in the vast majority of cases) that the accretion disc is obscured by a column of dust . In recent work by our group, we have shown fundamental differences in the radio properties of SDSS optically selected red quasars, which cannot be explained with a simple viewing angle hypothesis (Klindt et al. 2019, Fawcett et al. 2020, Rosario et al. 2020). In our latest work, we use VLT/X-shooter spectroscopy of a sample of red and typical quasars to gain insight into these differences. We confirm that dust reddening is the main cause of the red colours, and from fitting the [OIII] emission line we find stronger evidence for outflows in red quasars, possibly affecting the host galaxy. We confront our spectra against accretion disc models and confirm that red quasars are powered by standard thin-disc accretion. The lack of any fundamental differences between red and blue quasars in terms of simple accretion properties suggests external processes, such as

outflows, may be key features that distinguish the two populations. Red quasars may therefore represent an important phase in galaxy evolution.

Antonello Calabro (INAF – OAR, Italy)

Probing the relation between UV slope and stellar metallicity at z > 2

The measurement of the stellar metallicity in galaxies is fundamental to understand their evolution across cosmic epochs, but is very difficult as it requires high signal-to-noise spectra. Benefiting from uniquely deep, UV rest-frame spectra of 600 star-forming galaxies at redshifts between 2 and 5.5 from the VANDELS survey, I derive the stellar metallicity from two absorption features at 1501 and 1719 Angstrom, which are metal sensitive features produced in the photosphere of young O-B stars. I will show for this sample the mass-metallicity relation, and a relation between the stellar metallicity and the UV-continuum slope (a proxy for the dust attenuation). The latter sheds light on the joint evolution of metal and dust content in galaxies between 2 and 3 Gyr after the Big Bang, and will allow the characterization of large statistical samples of galaxies at even earlier epochs with next generation telescopes.

Mirko Curti (University of Cambridge, UK)

A KLEVER probe of the ISM in high-z

I will present KLEVER, an ESO Large Programme aimed at investigating dynamics, gas excitation properties and chemical abundances in high redshift galaxies, by means of near-IR spatially resolved spectroscopy. Exploiting KMOS multi-IFU observations in the J,H and K bands we aim to map multiple optical rest-frame emission lines (from [O II]3727 to [S III]9530) in a sample of ~200 galaxies between 1.2 < z < 2.5. The survey targets both gravitationally lensed galaxies in Frontier Fields clusters and non-lensed galaxies in CANDELS.

We investigated the physical drivers responsible for the evolution in the emission line ratios and assess whether the offsets from the local relations correlate with different properties like electron density, ionisation parameter and nitrogen abundance by implementing a novel, machine-learning based approach.

We also derived full metallicity maps, exploiting different calibrators and evaluate presence and evolution of metallicity gradients.

Sara Ellison (University of Victoria, Canada)

Complexity and scatter in kpc-scale star formation scaling relations in ALMaQUEST

The ALMA-MaNGA QUEnching and STar formation (ALMaQUEST) Survey has obtained ALMA CO(1-0) observations of 46 MaNGA selected galaxies in order to map molecular gas and star formation on kpc-scales in the nearby universe. In this talk, I will use ALMaQUEST to demonstrate that the star formation scaling relations show significant galaxy-to-galaxy variation in their shape and normalization, and hence that none of these relations is truly universal. Furthermore, I show that the molecular gas main sequence of recently `retired' galaxy regions is distinct from the star-forming regions, even within a given galaxy, indicating that depletion of the gas reservoir is associated with the quenching process. Finally, I will investigate the relative roles of gas depletion and star formation efficiency in regulating star formation in nearby galaxies.

Ryan Sanders (University of California, Davis, USA)

Galaxy gas-phase metallicities from the epoch of reionization to the present day

Recent large spectroscopic surveys have enabled a detailed understanding of the gas-phase metal abundance of galaxies out to cosmic noon (z=1-3). Gas-phase metallicity is a sensitive probe of the cycle of baryons governing secular galaxy growth. I will discuss best practices for measuring gas-phase metallicities at high redshifts and the latest constraints on direct metallicity calibrations at z~2, with implications for future observations from JWST. Using data from the MOSDEF survey, I will present new measurements of the mass-metallicity relation at z=2.3 and z=3.3. I interpret these results using analytic chemical evolution models, placing constraints on the metal and mass loading of galactic outflows and identifying the relative importance of dilution from gas accretion and metal removal by outflows in setting the form and evolution of the mass-metallicity relation. I will discuss ways to extend gas-phase abundance studies into the epoch of reionization with JWST and ALMA.

Justus Neumann (ICG, University of Portsmouth, UK)

Stellar populations of galaxy bars and the distribution of stellar metallicity in galaxies

Stellar populations (SP) save imprints of the dynamical and chemical evolution of galaxies across cosmic time. Spatially resolved spectroscopic surveys offer the unique opportunity to study global and local drivers of SP in galaxies. In this talk, I will present results from two studies. First, I use an unprecedented sample size of >3 million spatial bins across 8000 galaxies in the MaNGA survey to investigate the distribution of stellar metallicity in nearby galaxies as a function of radius and stellar surface mass density in the global mass-morphology plane. Second, I use MUSE observation with high spatial resolution from the TIMER project to present detailed maps of star formation histories in bars of 9 nearby galaxies. I compare our data to state-of-the-art cosmological zoom-in simulations of barred galaxies and show that our MUSE observations can be explained by the dynamical influence of the bar on SP with different ages and kinematic properties.

Pre-recorded talks

William Cramer (Arizona State University, USA)

Spectacular ram pressure stripping: high resolution studies of the impact on the multiphase ISM

Ram pressure stripping is a key process by which galaxies in clusters evolve, on a base level, stripping away gas and consequently quenching star formation. I will present evidence from recent observations with high resolution instruments, including HST and ALMA, of the direct influence and effects of ram pressure on the dense ISM of two galaxies: D100 in the Coma cluster, and NGC 4402 in the Virgo cluster. The dense ISM is of particular interest because it is the birthplace of star formation. We find direct observational evidence supporting both the compression of molecular gas, possibly triggering a starburst, and of direct stripping of molecular gas via momentum transfer. Our evidence of these effects on the ISM due to RPS allow us to investigate how the ISM in RPS galaxies evolves, and presents a more complex picture than simple quenching. Furthermore, I will present analysis based on HST observations of D100, a galaxy with an extremely long and narrow (60 x 2 kpc) H-alpha tail, of the properties of stars formed in the tail, and the stellar population of the disk of the galaxy, and what it reveals about the evolution of D100 under ram pressure.

Rebecca Davies (Swinburne University of Technology, Australia)

The Connection Between Galaxy Star Formation Rates and HII Region Electron Densities at 0 < z < 2.6

The rapid decline in the average star formation activity of galaxies from z~2.6 to z~0 is accompanied by an order of magnitude decrease in the typical electron densities of HII regions. However, it is unclear what connects the pc-scale properties of the line-emitting gas with the global properties of the host galaxies. I will summarize unique new results from a study of 611 galaxies at 0 < z < 2.6, drawn primarily from the KMOS^3D and SAMI surveys. We measure both the local electron density of the line-emitting gas and the volume-averaged electron density across the star-forming disks at four different redshifts, yielding unique constraints on the volume filling factor and evolving spatial distribution of ionized gas in HII regions. We compare our measurements to quantitative predictions to evaluate whether the electron density evolution is most likely to be driven by changes in the strength of stellar feedback, the molecular cloud density, and/or the hydrostatic equilibrium pressure.

Alex Gurvich (Northwestern University, Chicago, USA)

Feedback regulated star formation in galaxies evolving from bursty clumps to time-steady discs

How star formation rates are regulated in disk galaxies is a key question in galaxy evolution. Feedback regulated models of star formation posit that star forming disks are governed by vertical equilibrium between gravity and pressure from stellar feedback and predict Kennicutt-Schmidt (KS)-like relations. We use the FIRE hydrodynamic cosmological zoom-in simulations, which include multi-channel models for stellar feedback and produce a complex and multiphase ISM, to show that vertical pressure balance in Milky Way-mass star forming disk galaxies leads to time-steady and spatially distributed star formation, reproducing the KS-relation at low redshift. However, the simulations also predict that at high redshift these galaxies have clumpy morphologies and time-variables or "bursty" star formation rates. We discuss the implications of these complex star formation histories on the time-scales probed by commonly used observational star formation rate indicators (FU V and H-alpha).

Sandro Tacchella (Harvard-Smithsonian Center for Astrophysics, Cambridge, USA)

Fast, Slow, Early, Late: Quenching Massive Galaxies at *z* ~ 0.8

We investigate the stellar populations for a sample of 161 massive, mainly quiescent galaxies at $z_{obs} = 0.8$ with deep Keck/DEIMOS rest-frame optical spectroscopy (HALO7D survey). With the fully Bayesian framework Prospector, we simultaneously fit the spectroscopic and photometric data with an advanced physical model (including non-parametric star-formation histories, emission lines, variable dust attenuation law, and dust and AGN emission) together with an uncertainty and outlier model. We show that both spectroscopy and photometry are needed to break the dust-age-metallicity degeneracy. We find a large diversity of star-formation histories: although the most massive ($M_* > 2\times10^{11}$ Msun) galaxies formed the earliest (formation redshift of $z_f \approx 5-10$ with a short starformation timescale of $\tau_{SF} \leq 1$ Gyr), lower-mass galaxies have a wide range of formation redshifts, leading to only a weak trend of z_f with M_*. Interestingly, several low-mass galaxies with have formation redshifts of $z_f \approx 5-8$. Star-forming galaxies evolve about the star-forming main sequence, crossing the ridgeline several times in their past. Quiescent galaxies show a wide range and continuous distribution of quenching timescales ($\tau_{quench} \approx 0-5$ Gyr) with a median of $\tau_{quench} = 1.0+0.8 -0.9$ Gyr and of quenching epochs of $z_{quench} \approx 0.8-5.0$ ($z_{quench} = 1.3^{+0.7}_{-0.4}$). This large diversity of quenching timescales and epochs points toward a combination of internal and external quenching mechanisms. In our sample, rejuvenation and “late bloomers” are uncommon. In summary, our analysis supports the “grow & quench” framework and is consistent with a wide and continuously-populated diversity of quenching timescales.

Jessica Thorne (ICRAR/UWA, Perth, Australia)

Using the SED-fitting code ProSpect to trace star formation over the last 8 billion years

The Deep Extragalactic VIsible Legacy Survey (DEVILS) is a new spectroscopic campaign aimed at bridging the near and distant Universe by producing the highest completeness survey of galaxies at intermediate redshifts. It is at this under-sampled epoch where both galaxies and their host halos undergo significant evolution. With preliminary redshifts from DEVILS and the plethora of auxiliary data in the COSMOS field, we can begin to use DEVILS to understand the evolution of galaxies over the last 8 billion years. Using our new spectral energy distribution fitting code ProSpect, we have measured the star formation histories, stellar masses, and star formation rates for half a million galaxies in the D10-COSMOS field and are using these measurements to trace the evolution of star formation and stellar mass build-up in galaxies.

I will present these preliminary science results from DEVILS and highlight the wealth of information that will come from DEVILS once it is completed.

Posters

Jorge K. Barrera-Ballesteros (Instituto de Astronomia, UNAM, Mexico)

Star Formation is self-regulated at kpc scales

We present the relation between the star formation rate density, Ssfr, and the hydrostatic mid-plane pressure, Phyd, for 4260 star-forming regions of kpc size located in 96 galaxies included in the EDGE-CALIFA survey. We find that these two parameters are tightly correlated, exhibiting a smaller scatter and a stronger correlation in comparison to other star-forming scaling relation. A power-law, with a slightly sub-linear exponent, is a good representation of this relation. Our analysis suggests that the primary channel of self regulation of the Ssfr at kpc scales comes from momentum flux injection to the interstellar medium from supernovae explosions. However, other channels of pressure in disk galaxies may also play a significant role in shaping the Ssfr at local scales. Our results also suggest that Phyd can be consider as the main driver of the star formation at kpc scales, rather than individual components of the baryonic mass.

Guilherme Couto (Universidad de Antofagasta, Chile)

Characterization of mild ionized gas outflows in star-forming galaxies

It is thought that supernova-driven outflows are important in the regulation of mass growth in star forming galaxies, suppressing the conversion of gas into stars. This presentation will show preliminary results of our study of the VALES (Valparaiso ALMA Line Emission Survey) sample, composed of 15 star-forming galaxies, using VLT/MUSE integral field spectroscopy data. I will present ionized gas excitation and kinematics information obtained with our data and how they relate with outflow parameters, illustrating the impact they have in the galaxies. I will also present results obtained with SED fitting using CIGALE code to multiwavelength broad and narrow band fluxes obtained from the GAMA survey. Our main goal is to characterize the weak outflows we observe in this sample, and retrieve crucial evolutionary parameters such as the eta, which relates the mass outflow rate with the star formation rate, in order to compare and fine-tune theoretical models.

Marco Gullieuszik (INAF - Padova Observatory, Italy)

Star Formation in the tails of ram-pressure stripped galaxies from the GASP MUSE Large Programme

GASP (GAs Stripping Phenomena in galaxies with MUSE) is a survey of galaxies at z=~0.05 located in different environments, from the field to clusters. The project aims to clarify how, where and why the gas removal occurs. The MUSE observations revealed ram pressure stripped Hα-emitting extraplanar tails in most of the stripping cluster candidates. All galaxies present bright Hα clumps in their tails as well as interclump regions of more diffuse emission. Using diagnostic BPT diagrams we conclude that in-situ SF is the dominant gas ionization mechanism in all the tails. I will summarize the main results on the star formation process in the tails, and on how the star formation rate depends on the properties of the galaxy and of its environment; I will also present some of the questions our work has opened and that will be addressed by using the GASP MUSE data and its multiwavelength ongoing follow-ups, including an ongoing observing programme with HST.

Gustavo Orellana-González (Universidad Católica de la Santísima Concepción, Chile)

Cosmic evolution of molecular gas mass density from an empirical relation between L_rad and L_co

Historically, GHz radio emission has been used extensively to characterize the star-formation activity in galaxies. In this work, we look for empirical relations amongst the radio luminosity, the infrared luminosity, and the CO-based molecular gas mass. We assemble a sample of 278 nearby galaxies with measurements of radio continuum and total infrared emission and the CO (J = 1-0) emission line. We find a correlation between the radio continuum and the CO emission line (with a scatter of 0.36 dex), in a large sample of different kinds of galaxies. Making use of this correlation, we explore the evolution of the molecular gas mass function and the cosmological molecular gas mass density in six redshift bins up to z = 1.5. These results agree with previous semi-analytic predictions and direct measurements: the cosmic molecular gas density increases up to z=1.5. In addition, we find a single plane across five orders of magnitude for the explored luminosities, with a scatter of 0.27 dex.

Joanna Piotrowska (University of Cambridge, UK)

Physical drivers of quenching in massive centrals – an observational and simulated perspective

Understanding the physics behind galaxy quenching is one of the most important questions in the field of galaxy evolution. We investigate how quenching operates in local, massive, central galaxies by comparing the Universe observed by the Sloan Digital Sky Survey (SDSS) with cosmological simulations – EAGLE, Illustris and TNG. Our machine learning analysis reveals supermassive black hole (SMBH) mass as the most relevant parameter for determining whether a galaxy is star-forming or quenched. We also show that the observed correlations between quiescence and other galactic properties are of secondary importance and stem from their connection with the SMBH mass. We then infer molecular gas content from the reddening of SDSS spectra and compare it with simulations to understand the physical mechanism of SMBH feedback. Our results indicate that SMBH can successfully quench massive centrals by combining preventative heating feedback and turbulence injection into the interstellar medium.

Alberto Saldana-Lopez (Observatory of Geneva, UniGE, Switzerland)

Using LIS UV-lines to select Lyman continuum leaking candidates in the VANDELS survey

Identifying sources with a significant production of continuum photons (\lambda\<912A) escaping from the host galaxy is a hard task at high-z due to the absorption by the neutral IGM. Here, we make use of a sample of 400 galaxies ($3 < z < 5$) within the VANDELS survey to infer their continuum leaking properties through the study of some LIS UV absorption lines. To do that, we first estimate the intrinsic stellar emission and dust attenuation E(B-V) of every galaxy by fitting the spectra to the best mixed-age and mixed-metallicity STARBURST99 models. The -predicted-continuum photon-escape fraction is then obtained by measuring the covering factor of the SiII1260 line and applying the relations proposed in Gazagnes, Chisholm et al. (2018). We found ~40 LyC candidates. We then compare these estimates with f_{esc} constraints from CANDELS and ground-based photometry, and study other LIS lines (CII1334, SiII1527 and AlII1640), in order to understand the role of the ISM in high-z galaxies.

Nofoz Suleiman (Astronomy Department, Eötvös Loránd University, Budapest, Hungary)

The physical and statistical properties of IR-bright Dust-Obscured Galaxies & SED modeling by CIGALE

Systems hosting dust-enshrouded nuclear starbursts and/or an accreting SMBH are particularly complicated to study due to the complex interaction of massive star heating and the AGN, the absorption and release of radiation from dust, and the presence of the old stellar population behind it. The aim of this work is to characterize the physical properties of IR-bright dust-obscured galaxies (DOGs). We examined 30 DOGs at $0.05 \leq z \leq 2$ discovered by combining images of the optical, near-IR, mid-IR, and detected at Herschel SPIRE bands. We have detected a significant AGN contribution to the mid-IR luminosity for 90% of DOGs. Our DOGs contain Type 1, Type 2, and intermediate types of AGN. The other physical parameters, such as stellar mass, SFR, Dust mass & luminosity are studied in detail with other parameters and comparing with other DOGs' samples. Several statistical dimensional reduction techniques are used by R packages software are applied to our sample (e.g PCA) to reduce their dimensions.

Neven Tomicic (INAF- Astronomical Observatory of Padova, Italy)

Characteristics of the diffuse ionized gas in gas-stripped galaxies

The diffuse ionized gas (DIG) is an important component of the interstellar medium (ISM), and it can be affected by many physical processes in galaxies. Measuring its distribution and contribution in gas emission allows us to properly study both its source of ionization and star formation rates (SFR) in galaxies. We measure for the first time the DIG emission fractions in gas-stripped galaxies in local clusters drawn from the GAs Stripping Phenomena in galaxies with MUSE survey (GASP). These galaxies are at different stages of stripping. I will present our current results on variations of the DIG fractions, its characteristics in metallicities, ionisation parameters and BPT features, as well as its potential origins of ionization, across the galaxies of the GASP survey. Furthermore, I will present a comparison of the dense gas and the DIG properties to those of normal galaxies from the same survey.

Eelco van Kampen (ESO, Garching, Germany)

Building samples of distant cluster galaxies with ALMA

Beyond z>1.5, galaxies in and near galaxy clusters are more actively forming stars than their local counterparts, most likely due to higher gas fractions at these earlier epochs. ALMA is and will be instrumental in quantifying this by measuring dust and molecular gas masses of these high-redshift sources. Results from successful ALMA programs targeting distant galaxy clusters show that there is indeed evidence for differences with local cluster galaxies, which will be highlighted.
What is lacking is a large enough statistical sample of such sources, either from targeting specific areas of various clusters, or mapping out a whole cluster up to several times its virial radius and beyond. Strategies for obtaining such large samples of distant cluster galaxies are discussed, with the aim of probing a range of environments. Such strategies include exploitation of the growing ALMA archive.

Anatolii Zadvornyi (Kapteyn Astronomical Institute, Groningen)

Star formation suppression, gas consumption and stripping in cluster satellites

Observations show that satellite galaxies have a peak in quenching timescale at stellar masses M_star = 10^9 M_sun; less and more massive satellite galaxies quench quicker. This trend was investigated using EAGLE simulation particle data. The trend can be qualitatively reproduced. Gas particles of satellites were selected at infall time and their evolution was tracked into the future to find the prevailing mechanism that removes their gas. Low mass satellites have part of their star forming gas mechanically removed by ram pressure stripping, this effect becomes less effective with increasing stellar mass; higher mass satellites are quenched relatively quickly by starvation which also becomes less effective at lower masses. Intermediate mass satellites at M_star = 10^9.75 M_sun are on the intersection where neither of the mechanisms are effective and hence the gas consumption is longer.

Session 5: Instrumentation

Alice Concas (Kavli Institute for Cosmology, Cambridge, UK)

Ionised and neutral gas outflows across cosmic time

Galaxy formation models suggest that massive gas outflows driven by stellar and AGN feedback play a key role in shaping the star formation efficiency and metallicity of galaxies. We study the demographic of gas outflows across cosmic time, using 600k spectra from the SDSS at z=0 and new IFU data at z=2 from the KLEVER survey with VLT/KMOS. We adopt a stacking approach of the [OIII]λ5007, Hα and [NII] emission lines probing ionised gas, and of the NaD absorption doublet probing neutral gas. At z=0, we found that massive gas outflows are not ubiquitous but occur only in AGN and starburst galaxies (SFR>10 $M_{\odot}$/yr) and, when detected, gas outflows have velocities smaller than the galaxy escape velocity, suggesting that the gas will likely fall back into the galaxy. At z=2, we compare the kinematics of [OIII]λ5007 and Hα lines finding clear gas outflows in AGN-dominated massive galaxies, while the incidence of galactic winds remains unclear in purely star-forming ones.

Invited Talk

*Sofia Feltzing (*Lund Observatory, Sweden*)*

Upcoming multi-object spectrographs

The past decade has seen a sharp rise in the number of multi-object spectrographs with larger and larger mulitplex. The next generation of facilities with a larger multiplex and higher spectral resolution includes WEAVE and 4MOST.Different science cases have driven the design of past, present and future multi-object spectrographs. In this talk I will review the Galactic and Extra-Galactic main science drivers for the design of WEAVE and 4MOST. The current status of the two projects will be discussed and their complementary role in particular for Milky Way archeaology will be discussed. Time allowing, I will also contrast these two facilities with other operational and future facilities.

Jenny Greene (Princeton University, USA)

The Prime Focus Spectrograph Galaxy Evolution Survey

The Prime Focus Spectrograph (PFS) will be a massively multiplexed spectrograph with 2400 fibers in a 1.3 deg sq field of view. With wavelength coverage from 0.38-1.26 micron, and 1 Angstrom resolution, PFS is ideally suited to a range of exciting galaxy evolution surveys. I will present the basic survey design for the PFS Galaxy Evolution Survey, a 130 night program for Subaru starting in 2023. This survey will chart the growth of galaxies in the cosmic web from cosmic dawn through the peak epoch of star formation density in the universe. The high multiplexing will allow us to link the anisotropic cosmic web and galaxy physical properties, as well as probe the evolution of the IGM through a tomography survey at redshift two and LAEs to redshift 7. The program will be highly complementary to similar surveys planned with MOONS.

Michele Cirasuolo (ESO, Garching, Germany)

MOONS at the VLT: current status and planning for galactic and extragalactic surveys

MOONS is the new Multi-Object Optical and Near-infrared Spectrograph under construction for the VLT. This remarkable instrument will allow large-scale spectroscopic campaigns needed to study the formation and evolution of stars and galaxies over the entire history of the Universe. I will present the current planning for Galactic and Extragalactic large survey foreseen for MOONS. On a timescale of 5-6 years MOONS will provide radial velocities and detailed chemical abundances for several million stars in the obscured regions of the Bulge and Disk, and beyond our Galaxy; as well as spectra for millions of galaxies from redshift 1 up to 10 with all the key spectral diagnostics and environmental information, comparable to what SDSS has done in the local Universe. This will represent a unique data-mine for both for Galactic and Extragalactic studies for years to come. I will also present the current status of the instrument and possible synergies with the ELT.

Giovanni Cresci (INAF – Arcetri, Italy)

MAVIS: sharper than JWST, deeper than HST

MAVIS (MCAO Assisted Visible Imager and Spectrograph) is a forthcoming instrument for the ESO’s VLT Adaptive Optics Facility, currently starting

Phase B. It is made of two main parts: a Multi-Conjugate Adaptive Optics (MCAO) system, that cancels the image blurring induced by atmospheric turbulence in the visible on a large field, and its post focal instrumentation, a wide field imager and a IFU spectrograph, both covering the visible part of the light spectrum. MAVIS has the potential to be an extremely novel and powerful facility: with an angular resolution of 15 mas (close to 50 times better than the seeing limited conditions) and a powerful and sensitive post-focal instrumentation, MAVIS will be instrumental to bring answers to a number of astrophysical science questions. In particular, thanks to its high sensitivity and unparalleled spatial resolution, it will survey unique details of the dynamics, ISM and stellar populations of high-z galaxies and of early galaxy assembly.

Lidia Tasca (Marseille University, France)

MOSAIC on the ELT: high-multiplex spectroscopy to unravel the physics of stars and galaxies from the dark ages to the present days

The powerful combination of the cutting-edge multi-object spectrograph MOSAIC with the world largest telescope, the ELT, will allow us to probe deeper into the Universe than was possible. MOSAIC is an extremely efficient instrument in providing spectra for the numerous faint sources in the Universe, including the very first galaxies and sources of cosmic reionization. MOSAIC has a high multiplex in the NIR and in the VIS, in addition to multi-Integral Field Units (Multi-IFUs) in NIR. As such it is perfectly suited to carry out an inventory of dark matter (from rotation curves) and baryons in the cool-warm gas phases in galactic haloes at z=3-4. MOSAIC will enable detailed maps of the intergalactic medium at z=3, the evolutionary history of dwarf galaxies during a Hubble time, the chemistry directly measured from stars up to several Mpc. Finally, it will measure all faint features seen in cluster gravitational lenses or in streams surrounding nearby galactic halos.

Pre-recorded talks

William Brandt (Penn State University, USA)

X-ray Survey Follow-Up as a Driver of Extragalactic Spectroscopic Surveys

Cosmic X-ray surveys over the past two decades have played a critical role in transforming our understanding of distant growing supermassive black holes (SMBHs), a central component of galaxies. They also provide unique insights into normal & starburst galaxies, groups & clusters, and transients. Robust exploitation of the many thousands of X-ray sources detected fundamentally requires large-scale spectroscopic follow-up for redshift determination and source characterization. I will describe successes and challenges specific to spectroscopic follow-up of large samples of X-ray survey sources, and how these have advanced our understanding of SMBH demographics, physics, and ecology. I will also highlight future opportunities with, e.g., 4MOST, MOONS, PFS, and new ambitious X-ray surveys. For example, I will discuss the science potential of spectroscopic follow-up of the large XMM-SERVS survey, which is now providing sensitive XMM-Newton coverage of the LSST Deep Drilling Fields.

Mark Dickinson (NSF's NOIRLab, USA)

ATLAS Probe: galaxy evolution & cosmology from spectroscopy of 200M galaxies out to z = 7

Galaxies form and evolve in the context of their local and large-scale environments. Their baryonic content is intimately connected to the properties of their dark matter halos and their location in the "cosmic web". Local spectroscopic surveys measure local environment, clustering (a constraint on dark matter halo masses), and spectral features (measuring physical conditions of gas and stars). Deep "pencil-beam" spectroscopic surveys probe galaxy evolution out to the epoch of reionization, but over limited volumes with limited statistics and spectral information. JWST will provide optical rest frame spectroscopic diagnostics at high redshift, but with limited statistics.

ATLAS (Astrophysics Telescope for Large Area Spectroscopy) is a NASA probe-class space mission concept that will achieve groundbreaking science in galaxy evolution, cosmology, and Galactic and solar system astronomy. ATLAS uses a 1.5m aperture telescope with 0.4 sq. deg field of view and R=1000 slit spectroscopy at 1-4 micron wavelengths to observe up to 6,000 spectra simultaneously. ATLAS surveys would measure redshifts and spectral diagnostics for ~200 million galaxies out to $z < 7$ over ~2000 square degrees.

Benne Holwerda (University of Louisville, USA)

Spectroscopic Surveys and HI in Deep Fields

The MeerKAT (64 x 13.5m dish radio interferometer) is South Africa's precursor instrument for the Square Kilometre Array (SKA), exploring dish design, instrumentation, and the characteristics of a Karoo desert site and is projected to be on sky in 2016. One of two top-priority, Key Projects is a single deep field, integrating for ~5000 hours total with the aim to detect neutral atomic hydrogen through its 21 cm line emission out to redshift unity and beyond. Key for maximizing science with LADUMA is additional spectroscopic information; to identify OH masers, as a prior for HI stacking, and for the star-formation and metallicity indicators. Stacking is especially useful to maximize HI science at high redshift but very large and accurate catalogs of optical redshifts are needed. The LADUMA target field (CDFS) is targeted by DEVILS, WAVES and MOONRISE. I will discuss future science and expected returns.

Alicia Lanz (Australian National University, Canberra, Australia)

The Magellan Infrared Multi-Object Spectrograph Project

The Magellan Infrared Multi-Object Spectrograph (MIRMOS) is a near-infrared (NIR) multi-object spectrograph (MOS) and integral field unit (IFU) instrument concept slated for deployment at the Magellan 6.5-meter telescopes at Las Campanas Observatory. MIRMOS is designed to address frontier scientific questions in extragalactic, cosmological, and exoplanetary science.

I will discuss these scientific questions and the resulting instrument specifications and design, including an instantaneous wavelength range from 0.89-2.4 microns with a spectral resolution R>3,700.

MIRMOS will support multiple observing modes including an IFU with a 26"x20" field of view and a multi-object mode which uses a robotic slit mask to address a 13' x 3' field.

MIRMOS will complement and extend the existing and planned suite of space-based and ground-based infrared spectrographs for the coming decade of scientific exploration.

Tanya Urrutia (Leibniz Institut für Astrophysik, Potsdam, Germany)

The MUSE view in Deep Fields: IFUs as spectroscopic survey instruments

The multiplexing nature of the MUSE instrument has yielded a 1'x1' field of view with 300 pixels on the side; quite large for an integral field spectrograph. Coupled with its enormous sensitivity, this means that MUSE can yield identifiable spectra of approx. 100 galaxies in its FoV in 1 hour observing time without the need for photometric pre-selection. Exploiting the 3D nature of MUSE, we can optimally select galaxies of spectroscopy, hence needing about 1/4th of the time of other slit or fiber spectrograph surveys. Using the MUSE-Wide Survey, a 100 arcmin MUSE view over deep HST fields with 1 hour integration times, I will highlight some of the contributions MUSE can make in galaxy surveys due to its blind nature. As an example, we find an unprecedented density of Lyman Alpha Emitters, allowing us for an unbiased view of their luminosity function, clustering properties and equivalent width distribution.