BACK AT THE EDGE OF THE UNIVERSE

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LATEST RESULTS FROM THE DEEPEST ASTRONOMICAL SURVEYS

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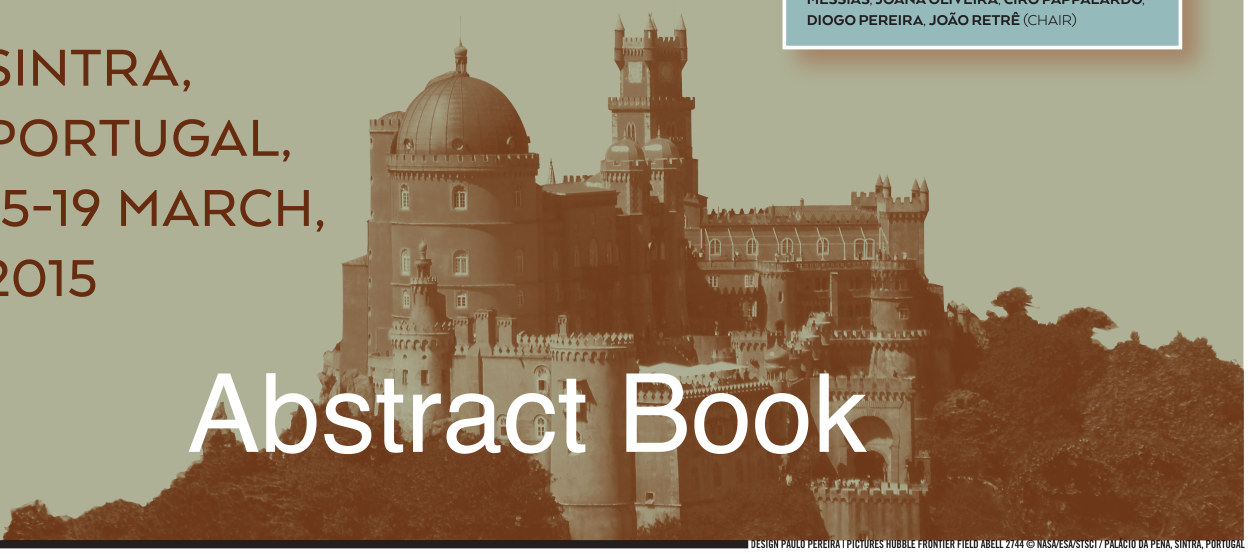
SINTRA, PORTUGAL, 15-19 MARCH, 2015



Abstract Book

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Scientific Rationale for the Conference

Nine years after being “At the Edge of the Universe”, it is time to return to lovely Sintra and discuss, once again, the latest achievements of the deepest observations of the Universe. This time, well into the era of the Deep Fields, we believe we understand a little bit better how galaxies form and how they evolve into the multitude of shapes, sizes, environments and activity they display at later epochs. Making full use of the capabilities of the largest and most powerful ground- and space-based observatories, operating throughout the electromagnetic spectrum, large international teams have extensively studied the most distant reaches of the Universe. Many hours of telescope time and computational effort have been employed in what is one the most pressing issues of modern science, and many findings have driven us ever nearer to understanding the formation and evolution of galaxies.

Where are we now? Have we reached a solid theoretical framework for galaxy formation and evolution? What else do we need in order to find the still elusive first galaxies, hosting the first generation of stars and the very first AGN in the Universe? What can theory tell us about where to look and how to look into this seemingly impenetrable problem? Do we know how galaxies assemble and how feedback processes take place and drive their evolution? How do galaxies depend on, or determine, their environment? How is this work driving the development and fine-tuning of the next generation of telescopes and their respective surveys?

The Institute of Astrophysics and Space Sciences aims at aiding in this effort, hosting once again an international conference aimed at discussing galaxy formation and evolution in the light of the deepest astronomical observations. The focus is on the latest observational results, and on how they shape, and are shaped by, the latest theoretical framework.

Main Topics

- Galaxy formation, the first billion years
- Reionization
- High-redshift star-forming galaxies
- Early AGN activity
- High-z quiescent galaxies
- Environments at high redshifts
- Gas and dust at early epochs
- Feedback processes
- Galaxy mergers and morphological evolution
- Galaxy mass assembly
- Star-formation History
- Extragalactic backgrounds
- The next generation of deep surveys

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Andrea Cimatti (U. Bologna)
Carlos De Breuck (ESO)
Mark Dickinson (NOAO)
James Dunlop (ROE)
Henry Ferguson (STScI)
Mauro Giavalisco (U. Mass.)
Ken Kellermann (NRAO)
Jennifer Lotz (STScI)
Bahram Mobasher (co-chair, U. California)
Ray Norris (CASS)
Laura Pentericci (Obs. Roma)
Piero Rosati (U. Ferrara)
David Sobral (IA/Leiden)
Linda Tacconi (MPE)

LOC

Ana Alves
Marlise Fernandes
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Elvira Leonardo
Silvio Lorenzoni
Katrine Marques
Hugo Martins
Hugo Messias
Joana Oliveira
Ciro Pappalardo
Diogo Pereira
João Retrê (chair)

Day 1

Observations of High Redshift Galaxies

R.J. Bouwens[1]

[1] *Leiden University*

Abstract

Over the last few years, enormous progress has been made in the study of galaxies at very high redshifts, thanks to the extraordinary capabilities of the HST WFC3/IR camera, the Spitzer/IRAC instrument, and both ultra-deep and wide areas programs. Already, more than 800 probable galaxies are known at $z \geq 6$, with >20 credible candidate galaxies at $z \sim$ 9-11. The galaxy with the highest redshift confirmation through spectroscopy is at $z \sim 8$, but new HST-grism programs promise to extend such confirmations to $z \sim 11$. With current samples, early galaxy build-up is increasingly well understood on many different fronts, including UV luminosities, stellar masses, sizes, and UV colors. One potentially surprising development has been the quantification of the fluxes in various key nebular lines in the mid-IR, like Halpha and [OIII], as such lines can be useful for both providing tight constraints on the redshift and constraining the star formation rates in galaxies. In my introductory presentation, I attempt both to set the context and to provide an overview of the exciting work now being done on galaxies in the early universe.

Probing the Epoch of Reionization with the Hubble Frontier Fields Clusters

Hakim Atek[1], Johan Richard[2], Jean-Paul Kneib[1,3] & the CATS team

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Abstract

The identification of the first generation of galaxies and the possible sources of cosmic reionzation is one of the foremost challenges in modern astrophysics. Great progress has been made in characterizing galaxy populations at redshift z=6-7 through photometric observations in blank fields. A complementary approach is to exploit the power of gravitational lensing offered by massive galaxy clusters, which gives access to the faintest sources at high redshift. I will discuss the first results of the Hubble Frontier Fields program that aims at peering deeper into the distant Universe. Using the first HFF clusters A2744 and MACS0416, I will show how combining HST capabilities with gravitational telescopes can be an efficient way to study the faintest galaxy populations ever observed at those redshifts. We can now put constraints on the faint-end slope of the UV luminosity function at $z \sim 7$ down to an absolute magnitude of $M_{UV} = -15.5$, which is about $0.01L^{\star}$, and two magnitudes deeper than the deep blank fields. I will also discuss the implications of the new constraints on the galaxy UV luminosity density on the cosmic reionization.

Probing Galaxy Build-up at the Edge of the Universe: Insights from Ultra-Deep HST and Spitzer Observations

Pascal Oesch[1]

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Abstract

The observational frontier of galaxy build-up now lies at only ∼450 Myr after the Big Bang, at redshifts $z \sim$10-12. This became possible only thanks to the powerful WFC3/IR camera on the HST. In combination with deep data from Spitzer/IRAC we were able to robustly detect rest-frame optical light of a small sample of z∼10 galaxies, allowing us to measure the evolution of the stellar mass density over 96% of cosmic history. However, probing galaxies at these early epochs is challenging even for HST and the sample sizes at these redshifts are still very small. Once observational biases are properly accounted for, the ongoing Hubble Frontier Field program is a prime new dataset to improve upon our current extremely sparse sampling of the UV LF at $z > 8$ and to answer some of the most pressing open questions. For instance, even the evolution of the cosmic star-formation rate density at $z > 8$ is still debated. While our measurements based on blank field data indicate that galaxies with SFR$>$ 0.7 $M_\odot$/yr disappear quickly from the cosmic record between z∼8 and z∼10, the results from the CLASH survey favor a more moderate decline. In this talk I will review the recent progress in studying galaxy build-up out to z∼10 from blank field HST surveys as well as the first completed Frontier Fields and I will provide a future perspective for the JWST era and beyond.

The Brightest Galaxies at Cosmic Dawn

Michele Trenti[1]

[1] *The University of Melbourne*

Abstract

Recent Hubble's near-IR observations transformed our view of early galaxy formation by building reliable samples of galaxies out to redshift $z \sim 8$ ($\sim$ 700 Myr after the Big Bang) and hinting at a dramatic evolution in properties at yet earlier times. From $z \sim 8$ to $z \sim 10$ ($\sim$ 200 Myr) the luminosity density seems to decrease by a factor ten, but bright galaxies may remain relatively common based on a handful of bright ($m < 27$) sources detected in legacy fields (GOODS/CANDELS). I will present our existing observations at z $8 - 10$ and combine them with spectroscopic followup data and with the measurement of the two point correlation function at $z > 7$ to discuss the connection between dark-matter halos, assembly of galaxies, and production of reionizing photons during cosmic dawn. Finally, I will preview the first results from the new extra-large (32 days) Brightest of Reionizing Galaxies (BoRG) HST survey, designed to find the most luminous $z \sim 9 - 10$ sources accessible before the next generation of IR space telescopes.

Lyman-break galaxies in the Epoch of Reionization

Silvio Lorenzoni[1]

[1] *Instituto de Astrofísica e Ciências do Espaço, Universidade de Lisboa, OAL, Tapada da Ajuda, PT1349-018 Lisboa, Portugal*

Abstract

I will present a selection of robust Lyman-break galaxy candidates at redshifts $z \sim 6-10$, within the Epoch of Reionization, based on data from WFC3 on HST, the recent XDF data release and the CANDELS programme in particular. This sample shows significant and rapid evolution of the galaxies' properties and of their luminosity function with redshift. The star formation history in this time frame and its implications for reionization will also be discussed.

Redshift $z \sim 9$ galaxies in the Hubble Frontier Fields and implications for the high-redshift evolution of the UV luminosity density

Derek McLeod[1]

[1] *Institute for Astronomy, University of Edinburgh*

Abstract

The Hubble Frontier Fields (HFF) survey has recently begun to deliver ultra-deep HST imaging of massive low-redshift galaxy clusters. The key science goal of the HFF project is to use the gravitational lensing of the foreground clusters to identify and study faint background galaxies at redshifts $z > 7$. Here we present the results of a recently submitted paper, which uses a photometric redshift analysis to identify a robust sample of $z \sim 9$ galaxies from the first two clusters targeted by the HFF survey. This sample significantly improves on previous determinations of galaxy number densities at $z \sim 9$ and allows us to provide tighter constraints on the decline in star-formation density within the epoch of reionization. We conclude that the new data strengthen the evidence for a smooth decline in the UV luminosity density from $z = 8$ to $z = 9$, contrary to recent reports of a dramatic drop-off at these redshifts. This provides support for the scenario in which early galaxy evolution is sufficiently extended to explain cosmic reionization.

The sizes of $z \sim 6-8$ lensed galaxies from the Hubble Frontier Fields Abell 2744 data

Ryota Kawamata[1], Masafumi Ishigaki[2,3], Kazuhiro Shimasaku[1,4], Masamune Oguri[2,4,5], Masami Ouchi[3,5]

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[4] *Research Center for the Early Universe, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan*
[5] *Kavli Institute for the Physics and Mathematics of the Universe (Kavli IPMU, WPI), The University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba 277-8583, Japan*

Abstract

We investigate sizes of $z \sim 6-8$ dropout galaxies using the complete data of the Abell 2744 cluster and parallel fields in the Hubble Frontier Fields program (HFF; PI: J. Lotz). HFF is a project to conduct deep imaging observations of 6 high-magnification clusters aiming at probing faint high-redshift galaxies behind these clusters. Thanks to strong magnification by cluster lensing combined with very deep exposures, the data enable us to detect $z \sim 6-8$ galaxies as faint (in intrinsic luminosity) as those from the HUDF12 data. By directly fitting light profiles of observed galaxies with lensing-distorted Sérsic profiles on the image plane with the `glafic` software, we accurately measure intrinsic sizes of 31 $z \sim 6-7$ and eight $z \sim 8$ galaxies, including those as faint as $M_{\rm UV} \simeq -17$. We find that half-light radii $r_{\rm e}$ positively correlates with UV luminosity at each redshift, although the correlation is not very tight. Largest ($r_{\rm e} > 0.8$ kpc) galaxies are mostly red in UV color while smallest ($r_{\rm e} < 0.05$ kpc) ones tend to be blue. We also find that galaxies with multiple cores tend to be brighter. Combined with previous results at $2.5 \leq z \leq 12$, our result confirms that the average $r_{\rm e}$ of bright ($(0.3-1)L^{\star}_{z=3}$) galaxies scales as $r_{\rm e} \propto (1+z)^{-m}$ with $m = 1.31 \pm 0.1$. We find that the ratio of $r_{\rm e}$ to virial radius is virtually constant at $3.5 \pm 0.1\%$ over a wide redshift range, where the virial radii of hosting dark matter halos are derived based on the abundance matching. This constant ratio is consistent with the disk formation model by Mo et al. (1998) with $j_{\rm d} \sim m_{\rm d}$, where $j_{\rm d}$ and $m_{\rm d}$ are the fractions of the angular momentum and mass within halos confined in the disks.

Rapid evolution in the bright end of the galaxy luminosity function between $z = 5, 6$ and 7

Rebecca Bowler[1], James Dunlop[1], Ross McLure[1]

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Abstract

At very high redshift ($z > 6$), the shape of the bright-end of the luminosity function (LF), be it plunging exponentially or a more gentle power law decline, depends on the onset of feedback and/or dust obscuration that acts to quench or obscure the most massive galaxies. Unfortunately, the *HST* surveys typically used to select samples of $z = 5$–8 Lyman-break galaxies have insufficient area to well constrain the number densities of the brightest (and rarest) objects, and instead wider-area ground-based surveys are required. We have used the combined $1.7\,\mathrm{deg}^2$ of deep multi-wavelength data in the COSMOS/UltraVISTA and UDS/SXDS surveys, the largest area of appropriate depth near-infrared imaging available to date, to provide the best constraints on the bright-end of the LF at $z = 6$ and 7. The samples includes the brightest known $z \simeq 6$ and $z \simeq 7$ galaxies with $M_{\mathrm{UV}} \sim -23.0$, and SED fitting to the comprehensive multi-wavelength photometry available shows that they are also some of the most massive, with stellar masses of $\log(M/M_{\mathrm{solar}}) = 10.5$. Our determination of the rest-frame UV luminosity function shows a gradual steepening of the bright-end slope from $z = 7$ to $z = 5$, accompanied by brightening of the characteristic magnitude by ~ 0.5 mag. When compared to the underlying dark matter halo mass function, these results are consistent with the onset of mass quenching of the most massive galaxies from z = 7 to z = 5 or the rise of significant dust obscuration in the brightest objects.

Investigating star-forming galaxies in the first billion years with deep spectroscopy

Eros Vanzella[1], et al.

[1] *INAF-Osservatorio Astronomico di Bologna*

Abstract

The investigation of faint luminosity regimes ($L < L^*$) within the first billion years is essential to characterize the early generation of star-forming systems and their role in the cosmic hydrogen reionization. The combination of high-quality ESO archival data and the ongoing ESO VLT/FORS2 large program (P.I. Pentericci) has allowed us to collect the deepest spectroscopic observations of $z > 5$ galaxies in their UV domain. I will present results from 15-30 hours integration (and up to ~50hr for a few cases) on $z > 5$ candidate galaxies lying in the CANDELS fields. Composite spectra of hundreds of hours ($100 - 400hr$) will be presented and linked to the physical properties extracted from their observed spectral energy distribution and colors. For the first time a stacked spectrum of $z \simeq 6$ $non - Ly\alpha$ emitters has been computed. The spectroscopic investigation of even fainter luminosity regimes ($L << L^*$) is severely limited by current facilities. However, a first glance of the properties in the faint luminosity domain, down to a few percent of L^*, is feasible through strong lensing magnification. In this regard, the discovery of sources with $L \sim 0.01 - 0.07L^*$, low stellar mass and steep ultraviolet spectral slope ($\beta_{UV} < -2.5$) at spectroscopic redshift $3.0 - 6.5$ in the CLASH and Frontier Fields galaxy cluster surveys will be also reported and their possible ionizing nature discussed.

Probing the end of the reionization epoch with high redshift galaxies

L.Pentericci[1]

[1] *INAF-Osservatorio Astronomico di Roma*

Abstract

The epoch of re-ionization is a fascinating time in the history of the Universe that is still largely unexplored. Lyman alpha emitting galaxies at high redshift offer a powerful probe of both reionization and of the early phases of galaxy formation. In particular the Lyman alpha emission is an efficient tool for identifying the very first galaxies and provides a robust test of the reionization epoch. I will review the most recent observational results on high redshift galaxies including those coming from our ongoing ESO Large Program and the constrains that we can place on the reionization epoch using the first statistical samples of spectroscopically confirmed z=7 Lyman break galaxies. I will also discuss how future spectroscopic surveys with the E-ELT of very high redshift Lyman break galaxies and Lyman alpha emitters will allow us to explore and characterize the reionization epoch in detail.

VANDELS: A deep VIMOS survey of the CANDELS UDS and CDFS fields

Ross McLure[1]

[1] *Institute for Astronomy, Edinburgh University*

Abstract

VANDELS is a uniquely *deep* VLT public spectroscopic survey of high-redshift galaxies, carefully designed to exploit the multi-wavelength imaging and near-IR grism spectroscopy available in the CANDELS UDS and CDFS fields. VANDELS has been awarded $\simeq 1000$ hours of VLT time, with the fundamental aim of moving beyond redshift acquisition, and obtaining spectra with high enough signal-to-noise to derive metallicities and velocity offsets from absorption and emission lines. Using integration times set to obtain a constant S/N level ($20 < t_{int} < 80$ hours), VANDELS will target: *a)* $2.5 < z < 5.5$ star-forming galaxies with $H_{\rm AB} \leq 24$ ($I_{AB} \leq 25$), *b)* $H_{AB} < 22.5$ passive galaxies at $1.5 < z < 2.5$; *c)* fainter ($H_{AB} \leq 27$) star-forming galaxies at $3.0 < z < 7.0$ and *d)* X-ray/radio selected AGN. Combining ultra-deep VIMOS spectroscopy with the best optical+nearIR+Spitzer imaging, VANDELS will produce a unique legacy dataset, capable of unveiling the physics underpinning high-redshift galaxy evolution. In this talk I will give a brief overview of the VANDELS science goals, and present spectra from the first VANDELS observing runs in Nov/Dec 2014.

First Stars and Black Holes in the Reionization Era

Andrea Ferrara[1]

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Abstract

The phase transition by which the cosmic gas turned again into an ionized state after recombination is dubbed Cosmic Reionization. This process is driven by the first sources of UV light in the universe and therefore can teach us a lot on the formation of the first stars and black holes. I will first discuss the key physical aspects of the formation of these sources from a theoretical point of view. I will then concentrate on the identification of experimental tests of current theories based on recently available and forthcoming data from deep surveys, and outline the potential of complementary strategies, as for example, the Near Infrared Background fluctuations.

Faint Galaxies at $z = 5 - 10$ for UV Luminosity Functions and Cosmic Reionization

Masafumi Ishigaki[1], Ryota Kawamata[1], Masami Ouchi[1], Masamune Oguri[1], Kazuhiro Shimasaku[1], Yoshiaki Ono[1]

[1] *The University of Tokyo*

Abstract

We present the comprehensive analyses of faint dropout galaxies up to $z \sim 10$ with the first full-depth data set of Abell 2744 lensing cluster and parallel fields observed by the Hubble Frontier Fields (HFF) program. We identify 54 dropouts at $z \sim 5 - 10$ in the HFF fields, and enlarge the size of $z \sim 9$ galaxy sample obtained to date. Although the number of highly magnified ($\mu \sim 10$) galaxies is small due to the tiny survey volume of strong lensing, our study reaches the galaxies' intrinsic luminosities comparable to the deepest-field HUDF studies. We derive UV luminosity functions with these faint dropouts, carefully evaluating the combination of observational incompleteness and lensing effects in the image plane by intensive simulations including magnification, distortion, and multiplication of images, with the evaluations of mass model dependences. Our results confirm that the faint-end slope, α, is as steep as -2 at $z \sim 6 - 8$, and strengthen the evidence of the rapid decrease of UV luminosity densities, $\rho_{\rm UV}$, at $z > 8$ from the large $z \sim 9$ sample. We examine whether the rapid $\rho_{\rm UV}$ decrease trend can reconcile with the large Thomson scattering optical depth, $\tau_{\rm e}$, measured by CMB experiments allowing a large space of free parameters such as average ionizing photon escape fraction and stellar-population dependent conversion factor. No parameter set can reproduce both the rapid $\rho_{\rm UV}$ decrease and the large $\tau_{\rm e}$. It is possible that the $\rho_{\rm UV}$ decrease moderates at $z > 11$, that the free parameters significantly evolve towards high-z, or that there exist additional sources of reionization such as X-ray binaries and faint AGNs.

Does reionization cause the rapid drop in galactic Lyα emission at $z \geq 6$?

Andrei Mesinger[1]

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Abstract

The large cross-section of the Lyα line makes it a sensitive probe of the ionization state of the intergalactic medium (IGM). We present the most complete study to date of the IGM Lyα opacity, and its application to the redshift evolution of the 'Lyα fraction', i.e. the fraction of color-selected galaxies with a detectable Lyα emission line. We use a tiered approach, which combines large-scale semi-numeric simulations of reionization with moderate-scale hydrodynamic simulations of the ionized IGM. This allows us to simultaneously account for evolution in both: (i) the opacity from an incomplete (patchy) reionization, parameterized by the filling factor of ionized regions, $Q_{\rm HII}$; and (ii) the opacity from self-shielded systems in the ionized IGM, parameterized by the average photo-ionization rate inside HII regions, Γ. In contrast to recent empirical models, attenuation from patchy reionization has a unimodal distribution along different sightlines, while attenuation from self-shielded systems is more bimodal. We quantify the average IGM transmission in our ($Q_{\rm HII}$, Γ) parameter space, which can easily be used to interpret new data sets. Our new, improved models highly disfavor an evolution in Γ as the sole driver of a large change in IGM opacity. Using current observations, we predict that the Lyα fraction cannot drop by more than a factor of ≈ 2 with IGM attenuation alone, even for HII filling factors as low as $Q_{\rm HII} \geq 0.1$. Larger changes in the Lyα fraction could result from a co-evolution with galaxy properties. Marginalizing over Γ, we find that current observations constrain $Q_{\rm HII}(z \approx 7) \leq 0.6$, at a 68% confidence level (C.L.). However, all of our parameter space is consistent with observations at 95% C.L., highlighting the need for larger observational samples at $z \geq 6$.

Constraints on reionization from a multi-wavelength analysis of $z > 6.5$ galaxies

Marco Castellano[1], Laura Pentericci[1], Eros Vanzella[2], Adriano Fontana[1], Andrea Grazian[1]

[1] *INAF-Osservatorio Astronomico di Roma*
[2] *INAF-Osservatorio Astronomico di Bologna*

Abstract

Our understanding of the epoch of re-ionization has progressed in these last years thanks to IR instruments from space and ground enabling the selection and study of large galaxy samples at z> 6. In particular, the first spectroscopic observations of z∼7 galaxies have shown a marked decrease in the fraction of Lyα emitting galaxies at z>6.5 that can be interpreted as evidence of an increase of the neutral hydrogen fraction in the IGM. Unfortunately, the interpretation of these findings is plagued by our lack of understanding of the physical properties of the sources. Indeed, the measured lack of Lyα emission can be also explained by a combination of factors such as an increase in the escape fraction of inizing photons (f_{esc}), or an higher dust coverage in star-forming regions.

I will present the latest results from our ESO FORS2 large program aimed at constraining the Lyα emission properties of z>6.5 galaxies in the CANDELS fields. I will show that an accurate multi-wavelength analysis of these sources enabled by the deepest IR data available in these fields allows to break the degeneracies among different factors (f_{esc}, dust) explaining their lack of Lyα emission. In particular, I will present constraints on the Ly-continuum escape fraction obtained by measuring mid-infrared colors affected by optical rest-frame emission lines in stacked samples of both photometric and spectroscopic z∼7 galaxies.

Revolutionising our understanding of distant Lyman-α emitters: the evolution of the LF from $z \sim 9$ to $z \sim 2$

Jorryt Matthee[1], David Sobral[1,2,3], et al.

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[3] *Departamento de Física, Faculdade de Ciências, Universidade de Lisboa, Edifício C8, Campo Grande, PT1749-016 Lisbon, Portugal*

Abstract

I will present results from our recent largest narrow-band surveys in order to improve our understanding of the early Universe ($z > 2$) using the Lyα emission line. This talk will focus on the $z = 6.6$ LAE luminosity function (LF; arXiv:1502.07355). To derive this LF, we used a combination of archival narrow-band NB921 data in UDS and new NB921 measurements in SA22 and COSMOS/UltraVISTA, all observed with the Subaru telescope, with a total area of 5 deg2. Lower redshift interlopers were excluded by using broad-band optical and near-infrared photometry and we also excluded three supernovae with data split over multiple epochs. We spectroscopically confirmed the two most luminous Lyα emitters ever found at $z = 6.604$ and 6.541 in the COSMOS field using Keck/DEIMOS and VLT/FORS2, for which I will show the spectra. Combining the UDS and COSMOS samples we find no evolution of the bright end of the Lyα LF between $z = 5.7$ and 6.6, which is supported by spectroscopic follow-up, and conclude that *Himiko*-like sources are not as rare as previously thought, with number densities of $\sim 1.5 \times 10^5$ Mpc^3. Combined with our wide-field SA22 measurements, our results indicate a non-Schechter-like bright end of the LF at $z = 6.6$ and a different evolution of *observed* faint and bright LAEs. This differential evolution was not addressed in previous studies, or discarded as cosmic variance, but we argue instead that it may be an effect of re-ionisation. Using a toy-model, I will show that such differential evolution of the LF is expected, since brighter sources are able to ionise their surroundings earlier, such that Lyα photons are able to escape. Our targets are excellent candidates for detailed follow-up studies and provide the possibility to give a unique view on the earliest stages in the formation of galaxies and re-ionisation process.

The Grism Lens-Amplified Survey from Space (GLASS): Lyα emitters at the epoch of reionization

K. B. Schmidt[1] & the GLASS collaboration

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Abstract

The Grism Lens-Amplified Survey from Space (GLASS) is an ongoing HST slitless grism spectroscopy program. It will observe 10 massive clusters at $z \sim 0.5$ including the 6 Hubble Frontier Fields and 8 CLASH clusters. The final GLASS cluster was observed in January 2015. GLASS was designed to i) explore the gas and galaxies at the epoch of reionization, ii) assess how gas and metals cycle in and out of galaxies, and iii) investigate why galaxy evolution is dependent on environment. The former two take advantage of the lensing magnification of the foreground clusters to reach fainter luminosities and higher spatial resolution than would be possible in blank field observations. The GLASS data contain deep near-infrared (0.8-1.7μm) spatially resolved spectroscopy of roughly 20000 objects at low, intermediate and high redshift, ideal for addressing i)–iii). We will present the first preliminary results from the completed GLASS survey. In particular, we will present the GLASS spectroscopy of hundreds of photometrically selected galaxies at $z > 6$ behind the observed clusters. For several of these sources Lyα has been detected in the GLASS spectra. We will show how this spectroscopic sample can be used to explore the epoch of reionization, and in particular, how it can be used to determine for the first time whether the reionization is 'patchy' or 'smooth' at $z > 7$.

Lyman Continuum Signal from $z \sim 3$ star-forming galaxies and higher redshift implications

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Abstract

The Lyman Continuum (LyC) escaping galaxies is under investigation to understand the physical processes responsible of the re-ionization of the Universe. Current studies are unable to obtain unambiguous LyC detections, even from the faintest star-forming galaxies. One of the reasons is that, to increase the statistics, we usually try to combine star-forming galaxies with different physical properties. In this project we are measuring LyC signal from about 80 spectroscopically confirmed star-forming galaxies at $z \sim 3$, for which multi-wavelength photometry from CANDELS is available. We aim to take advantage of the spectral energy distribution fitting and to stack samples of galaxies with physical properties sensitive to LyC leakage. This stack can enhance the weak LyC signal, instead of dilute it within the average of a large sample of LyC emitters and not emitters. Also, the dedicated-stack results can teach us about the physical properties of the re-ionization sources.

The assembly of massive black holes in the early universe

Marta Volonteri[1]

[1] *Institut d'Astrophysique de Paris*

Abstract

In the past 15 years evidence has been accumulating on a population of bright quasars, powered by massive black holes, already in place when the Universe was less than a billion years old. These rare black holes, with mass estimates of up to a few billion solar masses are likely the "tip of the iceberg", black holes that witnessed a rapid growth. A still elusive population of lower mass black holes, including the initial "seeds", must represent the building blocks of both these high-redshift powerful quasars, as well as the massive black holes we detect today in nearby galaxies, including our own Milky Way. I will discuss theoretical models of the formation and growth of the first black holes, and how they relate to today's black holes.

Illuminating the Dark Ages: Quasars in the Epoch of Reionisation

Bram Venemans[1]

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Abstract

Quasars are the brightest (non-transient) objects observed at the highest redshifts, $z > 7$. Such high redshift quasars are important as detailed analysis of quasar spectra provides unique information about the baryonic and physical condition of the Universe during the epoch of reionisation. Furthermore, the density of high redshift quasars puts powerful constraints on the mechanisms that are required to seed and grow $>10^9$ $M_{\rm sun}$ supermassive black holes less than a Gyr after the Big Bang. Because these quasars are rare, surveys covering large areas on the sky are required to discover such objects. In this talk I will describe the results of our on-going programme aimed at discovering quasars at the highest redshifts ($z > 6.5$) in various large optical and near-infrared surveys. I will present the results of our successful search and of our multi-wavelength follow-up observations, including ALMA observations of dust and gas in the quasar host galaxies. Lastly, I will discuss the implications of our findings for models of massive galaxy and black hole formation at high redshift.

Towards the first generation of Radio Powerful AGN in the Universe

J. Afonso[1,2], J. Casanellas[3], H. Messias[1,2]

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[3] *Max Planck Institut fur Gravitationsphysik (Albert-Einstein-Institut), D-14476 Potsdam, Germany*

Abstract

The existence of powerful AGN has now been established well within the first Gyr of the Universe, through the observations of tens of QSOs up to the currently highest redshift of $z \sim 7$ and theoretical work that shows how such super-massive ($\mathrm{M} \sim 10^9\,\mathrm{M}_\odot$) black holes can exist at such early epochs. In particular, these results imply that radio powerful sources should exist at very high redshifts ($z > 7$), even if all efforts to detect them have so far been unsuccessful. Over the coming years, powerful new facilities like the JVLA, GMRT, LOFAR, and the several upcoming SKA pathfinders experiments (ASKAP, MeerKAT, WSRT-Apertif) will dramatically increase our knowledge of the Radio Universe. Revolutionary deep-wide radio surveys like EMU, WODAN, or LOFAR will cover the sky at extreme depths over unprecedented large areas, and the first radio galaxies of the Universe should be finally identified. In this talk I will discuss our efforts to identify the earliest radio monsters of the Universe, and how the upcoming generation of full-sky deep radio surveys will lead to the discovery of the first radio galaxies, overcoming the limitations found in the deepest radio observations currently available.

Reionization, small-scale structures and radiative feedback

Ilian T. Iliev[1]

[1] *University of Sussex*

Abstract

Simulations of the early structure formation and the Epoch of Reionization have now reached sufficient volume, dynamic range and resolution to make reliable predictions of the fundamental features and observable signatures of these epochs at the full range of relevant scales. I will summarise important recent progress we have made in this area, including performing a series of simulations of early structure formation on all scales from the tiny cosmological minihaloes hosting the very first stars up to very large volumes of hundreds of Mpc, with up $6912^3 = 330$ billion particles, largest by far simulations of this epoch. We have derived a precise high-z halo mass function and scale-dependent halo clustering, directly useful for modelling the LOFAR and SKA sky. These structure formation simulations were used as basis for performing state-of-the-art radiative transfer simulations in volumes of up to $(714Mpc)^3$, comparable to the full volume of the LOFAR EoR experiment, but including all atomically-cooling ionizing sources. I will discuss the best observational signatures, from point of view of the simulations, for using EoR radio observations to understand the nature of the ionizing sources. I will also present the first results from a suite of extremely high resolution, massively parallel radiative hydrodynamics simulations of the reionization with grids up to 4096^3, which were ran on up to 132,000 computing cores and 8,192 GPUs. Our simulations resolve and follow in detail the feedback effects of all star forming objects from the minihaloes hosting the first stars onwards. This allows us to address questions like what was the nature of the first sources, what is the post-reionization abundance and spatial distribution of satellite galaxies and globular clusters, how much such objects contributed to reionization and how radiative feedback influenced later galaxy formation and the intergalactic medium.

Probing the First Black Holes and Clusters with the Murchison Widefield Array

N. Seymour[1], C. Jackson[1]

[1] *ICRAR/Curtin University*

Abstract

Wide area surveys probing virgin parameter space always provide large samples of rare sources with extreme properties. The Murchison Widefield Array (MWA) provides a new deep view of the low frequency, southern radio sky. The GaLactic and Extragalactic All-sky MWA (GLEAM) will provide $3\,\pi$ steradian imaging from 80 to 230 MHz. GLEAM will detect around half a million extra-galactic sources among which will be radio galaxies within the Epoch of Reionisation (the first black holes at $z > 7$) and in $z > 1$ galaxy over-densities (i.e. proto-clusters hosting the most massive galaxies and black holes). I will present the scientific motivation for studying such sources and how they can reveal detailed astrophysics about black hole and galaxy growth in extremes regimes. I will also present the methods required to find and follow-up such rare sources within the large GLEAM dataset and results in this area to date.

Finding early radio galaxies: the IR perspective

Hugo Messias[1], José M. Afonso[1,2]

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[2] *Departamento de Física, Faculdade de Ciências, Universidade de Lisboa, Edifício C8, Campo Grande, PT1749-016 Lisbon, Portugal*

Abstract

Today, it is expected that super-massive black holes and the respective hosts have closely co-evolved throughout cosmic time, based on a variety of evidences, such as the black-hole mass versus stellar dispersion relation (Gültekin et al.2009, McConnel & Ma 2013). Attempting to understand the initial conditions and primeval stages of such co-evolution forces one to search ever deeper into the faint Universe in search for early active galactic nuclei (AGN) sources. Or maybe not.. Given the current depths of radio surveys, one should expect already the detection of the brightest AGN up to redshifts of 7 or beyond. Nevertheless, we do not seem to find them. In fact, these sources may have been detected already, but are extremely difficult to identify. Although the radio spectral range has the advantage of not being affected by dust-extinct (as opposed to UV-to-near-IR high-redshift surveys), generally on its own, it does not provide a way to know how far from us a given source is. This work explores IR-selection criteria of high-redshift sources or optically-faint AGN sources (far-IR risers, Dowell et al.2014, or KI-AGN, Messias et al.2012) cross-matched with existing deep radio-surveys in order to identify early radio galaxies. This presentation will show the first results of this large quest (including HerMES, SERVS, and other wide-field surveys), such as identification strategies, number statistics, photometric analysis, and (on a best-effort basis) distance measurements.

Looking for the sources of Reionization at the Edge of the Universe

A. Grazian[1], E. Giallongo[1], F. Fiore[1]

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Abstract

Establishing the number density of faint AGNs at $z > 4$ is crucial to understand their role as main contributors to the Reionization of the Universe. We have selected 45 faint ($H < 27$) AGN candidates at $z > 4$ in the CANDELS GOODS-South, GOODS-North and HUDF fields thanks to the extensive multi-wavelength and ultra-deep data-sets from Chandra, HST, VLT, LBT and Spitzer. We have adopted a relatively novel selection criterion: AGN candidates with robust photometric redshifts at $z > 4$ are detected in the WFC3 H160-band, which corresponds to the rest frame UV luminosity, and are selected thanks to their unambiguous emission in the ultra-deep X-ray images by Chandra at a level of $L_X > 10^{43-44}$ erg/s. We have derived the UV-luminosity function of AGNs at $z > 4$ at $M_{1450} < -23$, in the luminosity regime typical of the local Seyfert galaxies. The AGN luminosity function shows a steep slope at the faint end. The selected AGN population can produce at z=4-6 a photoionization rate which is consistent with what is required to keep the inter galactic medium highly ionized, as observed in the Lyman-alpha forest of high-z QSOs. This faint AGN population at high-z can thus provide a significant contribution to the Reionization of the Universe.

Day 2

Getting the Science from Next-Generation Deep Surveys

Ray Norris[1]

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Abstract

Deep surveys have two distinct roles: (a) to answer specific science questions, (b) to make unexpected discoveries. While (a) is common to all well-designed projects, (b) is rapidly changing.

Over half the astronomical discoveries in recent years have been unexpected. For example, only 10% of the discoveries from Hubble were listed in its science goals, so that answering the specific science questions would have missed 90% of Hubble's science output. The only Nobel prize resulting from Hubble (Dark Energy) was completely unexpected. But, ironically, our ability to capture unexpected science from next-generation surveys may be diminished by the same technology that enables the deep surveys. While many astronomical discoveries in the past resulted from observing the Universe in a new way, they also relied on human ability to distinguish discoveries from artefacts. Next generation surveys are certainly taking us into new areas of observational phase space, but the instruments are so complex that no individual will truly understand them, and the petabyte databases will prevent any user from sifting through the data. So it will be difficult to discover the unexpected with next generation telescopes. Or can we design algorithms to search for the "unknown unknowns"?

The systematic search for $z \geq 5$ active galactic nuclei in the *Chandra* Deep Field South

Anna K. Weigel[1], Kevin Schawinski[1], Ezequiel Treister[2], C. Megan Urry[3], Michael Koss[1], Benny Trakhtenbrot[1]

[1] *ETH Zurich, Zurich, Switzerland*
[2] *Universidad de Concepción, Concepción, Chile*
[3] *Yale University, New Haven, United States*

Abstract

We investigate early black hole growth through the methodical search for $z \geq 5$ AGN in the *Chandra* Deep Field South. We base our search on the *Chandra* 4-Ms data which at $z \sim 5$ makes us sensitive to luminosities as low as $\sim 10^{42}$ erg s^{-1} ($\sim 10^{43}$ erg s^{-1}) in the soft (hard) band. The deep X-ray data should allow us to detect Compton-thin AGN with $M_{\rm BH} > 10^7 M_\odot$ accreting at Eddington ratios > 0.1. The field contains over 600 $z \sim 5$ Lyman Break Galaxies. These high-redshift galaxies are the progenitors of massive, local galaxies and based on lower redshift relations we would expect ~ 20 of them to host AGN. We combine the *Chandra* data with optical GOODS/ACS and infrared CANDELS/WFC3 and *Spitzer*/IRAC data. After excluding clear low-redshift sources and objects with insufficient filter coverage, our main sample consists of 58 high-redshift candidates. We use a range of redshift estimators including a photo-z code, stacking, colour criteria and the Lyman Break Technique. We also use the X-ray Hardness Ratio as additional information. The final $z \geq 5$ candidates that remain after we combine our redshift tests, are likely to be low-redshift interlopers. We thus conclude that, contrary to our expectation of finding at least a few high-redshift AGN, the field does not contain any convincing $z \geq 5$ AGN candidates. Our results place interesting constraints on early black hole growth and we discuss a range of possible explanations.

Tracing metal enrichement using cosmological explosions

A. Cucchiara[1]

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Abstract

There are more than 60 Gamma-ray bursts (GRB) up to redshift six for which has been possible to measure the neutral hydrogen content along their line of sight using absorption spectroscopic technique. We present the largest sample of GRB-DLAs to date and the metallicity of their hosts in order to understand if this particular subset of hosts can be the key to understand the role of metallicity in GRB formation as well as star-formation rate. We compare this sample with DLAs along quasars and demonstrated that GRB-DLAs live in a metal enriched environment, especially at $z > 4$. We also derive that our metallicity measurements are broadly consistent with a mild metallicity bias for the GRB formation. Forthcoming NIR spectroscopic capabilities at 8-30meter telescopes, JWST, and future planned mission (e.g. SVOM) will enable to study in details the metal contents of the primordial Star-formation sites, beyond what would be possible with large, magnitude limited surveys. Redshift $z > 7$ GRBs will represent the lighthouses of such discoveries, pinpointing the faintest galaxies and sites of the metal enrichments and first ionization after the dark ages.

The most luminous quasars: probing the AGN/galaxy co-evolution at its extreme

E. Piconcelli[1] at al.

[1] *Osservatorio Astronomico di Roma (INAF), Via Frascati 33, Monte Porzio Catone, I-00040, Italy*

Abstract

We have undertaken an extensive multi-wavelength observing program (from mm-wave to hard X-rays) to investigate the role of nuclear activity in SMBH-galaxy self-regulated growth via extended outflows. Specifically, we look into the properties of high-z, WISE-selected, hyper-luminous quasars at $2 < z < 3$ and the impact of AGN-driven feedback on their host galaxies. I will review the most relevant results obtained to date with emphasis on the discovery of [OIII] outflows in high-z, hyper-luminous ($\geq 10^{14}$ $L_{\odot}$), dust-enshrouded quasars and the relation between AGN properties (obscuration, Eddington ratio and luminosity) and large-scale winds.

Beyond the Confusion: Enhancing our View at High Redshift with the Herschel Lensing Survey

Rawle[1], Egami[2], Altieri[1], Boone[3], Clement[4], Combes[5], Dessauges-Zavadsky[6], Pérez-González[7], Richard[4], Schaerer[6], Sklias[6], Valtchanov[1], Walth[2]

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[2] *University of Arizona*
[3] *CNRS, IRAP, Toulouse*
[4] *CRAL, Observatoire de Lyon*
[5] *Observatoire de Paris*
[6] *Observatoire de Genève*
[7] *Universidad Complutense Madrid*

Abstract

For the reddest Herschel bands, the fundamental sensitivity limit was set by source confusion. As a result, even the deepest Herschel surveys can only detect the most intensely star-forming galaxies beyond $z \sim 2$, with 'normal' star formation at this epoch left unexplored. We present multi-wavelength results based on the "Herschel Lensing Survey" (HLS). Efficiently exploiting the gravitational lensing effect of massive foreground clusters, HLS removes the veil of confusion and allows us to probe a large sample of intrinsically faint galaxies at $z > 2$. The survey covers many famous clusters, including all those in CLASH and the Hubble Frontier Fields (HFF), ensuring abundant ancillary imaging from UV–to–mm (e.g. GALEX, HST, Subaru, Spitzer, Scuba–2). Thus we can link Herschel-detected dusty star formation to stellar and gas characteristics, yielding a complete picture of galaxies prior to the peak epoch of star formation.

Here, we discuss recent highlights from HLS. A new sample of well-constrained, strongly-lensed galaxies allows us to examine the star-forming main sequence for low luminosity galaxies (e.g. LIRGs) at $z = 2 - 4$. We compare and contrast their dust characteristics with the deep-field detected HyLIRGs. For a subsample with IRAM PdBI CO line measurements we explore the gas component, finding an increasing molecular gas fraction with decreasing stellar mass (at low star formation rates), as well as evidence for a non-universal dust–to–gas ratio. We also investigate several outstanding sources at very high redshift, including a merging system at $z = 5.2$ with spatially distinct (sub-kpc scale) velocity components observed by SMA and JVLA, and a galaxy at $z = 4.7$ which is quintuply lensed at $>130\times$ magnification. Such examples enable a view of the early Universe in a level of detail only recent achievable for local galaxies.

The promise of Euclid to understand galaxy formation and evolution

Andrea Cimatti[1], on behalf of the Euclid Consortium

[1] *University of Bologna – Department of Physics and Astronomy*

Abstract

Euclid id is a Medium-class ESA mission selected in the context of Cosmic Vision 2015-2025, and with launch in 2020. Euclid is a survey mission based on a 1.2 m diameter telescope designed to address the key questions of modern cosmology, and in particular the dark energy equation of state (Laureijs et al. 2011). Euclid will survey 15,000 square degrees (the Wide Survey) with visible (broad red filter) and near-infrared (Y, J, H bands) imaging to mag(AB)=24.5 and 24.0 in the visible and near-IR respectively, and with near-infrared slitless spectroscopy in the spectral range of about 12 m. A deeper area of 40 square degrees (the Deep Survey) will be also observed in imaging and spectroscopy down to limiting fluxes fainter by about 2 magnitudes. This will provide high-quality images and near-IR photometry of about 2 billion galaxies, and spectroscopic redshifts and spectra for a few tens of million galaxies out to about z=2 (and beyond). Besides cosmology, Euclid will also provide an immense legacy dataset useful to address a wide range of modern astrophysical problems. This talk will focus on the expected role of Euclid in the field of galaxy formation and evolution.

Galaxy formation: Insights from models

Joop Schaye[1]

[1] *Leiden Observatory, Leiden University*

Abstract

Simulations of galaxy formation have become invaluable tools for the interpretation of observations, but their predictive power is often overestimated. I will discuss some of the limitations of the models and present recent results from the EAGLE and Aurora simulation projects.

Galaxy formation in the PLANCK era: Matching the observed evolution of star formation rates, colours and stellar masses across cosmic time

Bruno M. B. Henriques[1], Simon D. M. White[1], Peter A. Thomas[2], Raul Angulo[3], Qi Guo[4], Gerard Lemson[1], Volker Springel[5,6], Roderik Overzier[7]

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[7] *Observatório Nacional/MCTI, Rua José Cristino, 77. CEP 20921-400, São Cristóvão, Rio de Janeiro-RJ, Brazil*

Abstract

I will present results from the recent major release of the Munich galaxy formation model. In addition to the new PLANCK cosmology, significant modifications to the physics were implemented in order to fix major problems identified in previous versions. These include the too early formation of low mass objects and their too passive populations at later times. I will show how the new physics result in a model that is consistent with the observed evolution of the stellar mass functions of all, red and blue galaxies from $z = 3$ to $z = 0$, while matching the evolution of the star formation rate densities and the main sequence of star formation across the entire observable mass range.

I will connect the different evolution of low and high mass galaxies to the efficiency of the star formation quenching processes included in the model such as AGN radio mode feedback and environmental effects across cosmic time. Particular attention will be paid to the processes affecting more massive galaxies and moving them to the passive population as early as $z = 3$. Finally, I will show how the predictions from this new model compare with observations of the early universe (UV luminosity functions and stellar mass functions at $z > 5$), which were never used as constraints.

The first billion years of galaxy formation in cold and warm dark matter cosmologies

Pratika Dayal[1,2]

[1] *Institute for Astronomy, University of Edinburgh, Royal Observatory, Edinburgh, EH9 3HJ, U.K.*
[2] *Institute for Computational Cosmology, University of Durham, South Road, Durham DH1 3LE, U.K.*

Abstract

Over the past few years, instruments such as the Hubble Space Telescope have provided tantalising glimpses of a time when the earliest galaxies were just assembling in an infant Universe. In this talk, I will present a semi-analytic theoretical model that captures the key physics of supernova feedback in ejecting gas from low-mass halos, and tracks the resulting impact on the subsequent growth of more massive systems via halo mergers and gas re-accretion in early galaxies. In addition to successfully explaining a wide rage of observed data sets, our model naturally predicts the evolution of the faint end slope of the luminosity function and yields a census of the cosmic stellar mass density at these early epochs. I will show how this framework will be a powerful testbed for WDM models accessible with the forthcoming James Webb Space Telescope. I will end by showing the implications of early galaxy formation for reionization in both cold and warm Dark Matter cosmologies.

High-redshift galaxies in the Illustris Simulation

Shy Genel[1]

[1] *Columbia University*

Abstract

I will present results from the Illustris simulation, which is a large cosmological hydrodynamical simulation that follows thousands of massive galaxies down to z=0 inside a $100Mpc^3$ volume, resolving $\lesssim kpc$ scales. It is run using the Arepo moving-mesh code, and models cooling, stellar population evolution, and various feedback processes. I will discuss a broad range of observables at $z = 0 - 5$, including galaxy masses, morphologies, sizes, and star-formation activity. I will discuss the evolution of scaling relations such as the star-formation main sequence and the Tully-Fisher relation, as well as how individual galaxies evolve with time on these relations.

Cosmic Reionization On Computers

Nick Gnedin[1]

[1] *Fermilab*

Abstract

Cosmic Reionization On Computers (CROC) is a long-term program of numerical simulations of cosmic reionization. Its goal is to model fully self-consistently (albeit not necessarily from the first principles) all relevant physics, from radiative transfer to gas dynamics and star formation, in simulation volumes of up to 100 comoving Mpc, and with spatial resolution approaching 100 pc in physical units. We describe our numerical method, the design of simulations, the calibration of numerical parameters, and compare simulation results with the observational data.

Galaxy Stellar Mass Assembly at High z

Karina I. Caputi[1]

[1] *Kapteyn Astronomical Institute, University of Groningen, P.O. Box 800, Groningen, The Netherlands*

Abstract

Over the last decade, increasingly ambitious blank galaxy surveys conducted at near- and mid-infrared wavelengths have allowed us to investigate the process of galaxy stellar mass assembly over the first few billion years of cosmic time. In this talk, I will briefly review our progress on this topic and argue that, in spite of the inevitable uncertainties that still exist in high-z galaxy studies, some clear consensus is starting to emerge in the field. I will also discuss the presence of massive galaxies at $z > 5$, whose systematic study is becoming possible only now thanks to the availability of ultra-deep near-infrared data over large areas of the sky, and the plausible tension with galaxy formation models. Finally, I will conclude on how future infrared telescopes, particularly the *James Webb Space Telescope* and *Euclid*, will be crucial to provide a clear picture of galaxy stellar mass assembly since the epoch of reionisation.

Properties of galaxies with $2 < z < 6+$ as seen from the VIMOS Ultra-Deep Survey

Le Fèvre, O.[1], and the VUDS collaboration

[1] *Laboratoire d'Astrophysique de Marseille, France*

Abstract

I will present the general properties of galaxies at $2 < z < 6+$ as seen from the VIMOS Ultra Deep Survey (VUDS). VUDS is an ultra-deep spectroscopic survey of 10000 galaxies selected at $z > 2$ in the COSMOS, ECDFS, and VVDS-02h field covering a total of 1 deg^2, the largest to date. Spectra not only deliver accurate redshifts, but also spectral line and indices in the UV rest-frame, which are used to infer internal physical properties. The average spectral properties and their distribution are computed for the first time with a robust statistical basis up to redshift $z \simeq 6$, in relation to the strong evolution of the mass-SFR relation observed in VUDS. These properties are correlated with local environment, multi-wavelength and morphology properties. Inferences on the galaxy assembly scenario, and on the contribution of major physical processes like merging and accretion will be discussed.

The Progenitors of Today's Ultra-massive Galaxies Across Cosmic Time

Danilo Marchesini[1], Adam Muzzin[2], Mauro Stefanon[3], Marijn Franx[2], Gabriel Brammer[4], Cemile Marsan[1], Benedetta Vulcani[5], J. Fynbo[6], B. Milvang-Jensen[6], J. Dunlop[7], F. Buitrago[7]

[1] *Tufts University*
[2] *Leiden Observatory, Leiden University*
[3] *University of Missouri*
[4] *Space Telescope Science Institute*
[5] *Kavli Institute for the Physics and Mathematics of the Universe, Todai Institutes for Advanced Study, University of Tokyo*
[6] *Dark Cosmology Centre*
[7] *University of Edinburgh, Royal Observatory*

Abstract

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

Evolution of the brightest and most massive galaxies since $z \sim 6$

L. A. M. Tasca[1], and The VUDS collaboration.

[1] *Aix Marseille Université, CNRS, LAM (Laboratoire d'Astrophysique de Marseille) UMR 7326, 13388, Marseille, France*

Abstract

The VIMOS Ultra Deep Survey (VUDS) is a large ESO programme which just completed the observation of ~ 10000 galaxies up to $z \sim 6$ with the VIMOS spectrograph on the VLT. This is the largest and most uniform sample of spectroscopically confirmed high redshift galaxies ever assembled to date.

By studying the spectroscopic and SED–fitting derived properties of these sources we have been able to study the evolution of the star formation rate (SFR) - stellar mass ($M_\star$) relation and specific star formation rate (sSFR) of star forming galaxies (SFGs) since a redshift $z \simeq 5$ (Tasca et al. 2014, submitted). We observe a turn–off in the SFR–$M_\star$ relation at the highest mass end up to a redshift z$\sim$ 3.5, that we interpret as the signature of a strong on–going quenching mechanism and rapid mass growth. We find that the sSFR increases strongly up to $z \sim 2$ and it significantly flattens in $2 < z < 5$.

In addition, by combining VUDS spectroscopy, HST/WCF3 and ACS photometry and multi–wavelength data we are able to probe the evolutionary sequence of the progenitors of massive, compact, quiescent early type galaxies observed at later epochs in a statistically robust context (Tasca et al. in preparation).

New constraints on the abundance of very massive galaxies at $4 < z < 7$ from UltraVISTA and S-COSMOS

Mauro Stefanon[1,2], Danilo Marchesini[3], Adam Muzzin[2], Gabriel Brammer[4], James S. Dunlop[5], Marijin Franx[2], Johan P. U. Fynbo[6], Ivo Labbé[2], Bo Milvang-Jensen[6], Pieter G. van Dokkum[7]

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[7] *Department of Astronomy, Yale University, New Haven, CT 06511, USA*

Abstract

We study the population of massive (i.e., $\log(M_*/M_\odot) > 11$) galaxies at $4 < z < 7$ using a Spitzer IRAC 4.5μm-complete sample obtained complementing the Ks-band selected UltraVISTA catalog with detections in the residual images resulting from the photometry in the IRAC 3.6μm and 4.5μm bands.

We investigate the systematic effects of the bayesian prior, the specific SED template sets, the contamination by nebular emission lines and different star-formation histories in the measurement of photometric redshifts and stellar population parameters. We find that these measurements are mostly affected by the introduction of the bayesian prior, while the other factors introduce small dispersions.

We study the evolution of the stellar mass function (SMF) in three redshift bins, $4 < z < 5$, $5 < z < 6$ and $6 < z < 7$. The SMFs obtained without the introduction of the bayesian prior do not show any evolution from $z \sim 6.5$ to $z \sim 3.5$, suggesting that massive galaxies could already be present when the Universe was ~ 0.9 Gyr old. However, the introduction of the bayesian prior drastically reduced the number of $z > 4$ massive galaxies implying a rapid growth in the first 1.5 Gyr of cosmic history.

The VIMOS Ultra Deep Survey: The UV Luminosity Function up to $z \sim 5$

J. Pforr[1], O. Le Fèvre[1] and the VUDS team

[1] *LAM, Marseille*

Abstract

Luminosity functions describe the number of galaxies at a given luminosity in a certain volume. Tracing the evolution of the luminosity function in the UV with redshift then allows one to understand the evolution of galaxies and their star formation rates and to compute the star formation history of the Universe. Many studies have investigated the UV luminosity function and its evolution with redshift out to very high redshifts relying largely on photometry alone. The very deep rest-frame UV spectroscopy obtained with VUDS for galaxies between redshift 2 and ∼6 in combination with spectroscopy from the VVDS survey and the deep photometric data from Ultra-VISTA and CANDELS allows us for the first time to reach a spectroscopy-based measurement of the rest-frame UV luminosity function out to redshift 5 and to obtain a more robust measurement of the faint end slope of the LF between z∼2 and 4. We will extend this study to put tighter constraints on the cosmic evolution of the dust attenuation and star formation rate density out to z∼5.

The MUSE 3D view of the Hubble Deep Field South

Jarle Brinchmann[1], Roland Bacon[2], MUSE collaboration

[1] *Leiden University*
[2] *CRAL, Lyon*

Abstract

We present the results of an ultra-deep spectroscopic survey of the Hubble Deep Field South using MUSE, the new panoramic integral field spectrograph for VLT. The data cube resulting from the 27 hours of integration covers one arcmin2 field of view at an unprecedented depth with a 5sigma line flux limit of 1.5e-18 cgs, increasing the number of redshifts known in the region by an order of magnitude, up to 189 redshifts with 26 Ly-a emitting galaxies that are not detected in the HST images down to magnitude 29.5. We will describe the overall sample properties and demonstrate the power of 3D spectroscopy to disentangle sources to disentangle sources confused by ground-based image quality. The field of view MUSE also allowed us to detect 19 groups within the field and we will discuss the promise of MUSE for future deep surveys of the Universe. Note: The data cube and associated data products will likely be released to the wider community by the time of the meeting.

The evolution of high redshift massive galaxies in HUGS/CANDELS

A. Fontana[1]

[1] *INAF - Osservatorio di Roma*

Abstract

I will present the latest results on the evolution of high redshift massive galaxies from CANDELS and HUGS. The latter, in particular, is the deepest survey ever conducted in the K band over areas of cosmological interest. Resulting from an ESO Large Program that used more tan 200 hours of exposure time with the IR images Hawk-I at the VLT, it delivers images of suber quality (*seeing* < 0.4) over two of the CANDELS field (UDS and GOODS-S/HUDF), reacing magnitude limits as faint as K=26.5-27. Merging this data set with the rest of the CANDELS dataset we have been able to investigate the evolution of massive galaxies at high redshift. In my talk I will focus in particular of two main results: - the evolution of the Galaxy Mass Function at $z > 4$, and its consistency with the evolution of the star-formation rate as a function of redshift;
- the number density and redshift evolution of passively evolving galaxies at $z > 2$.

The Cosmic History of Star Formation

James S. Dunlop[1]

[1] *Institute for Astronomy, University of Edinburgh.*

Abstract

I will give a brief overview of how recent work at UV, optical, infrared, mm and radio wavelengths have impacted on our current understanding of the cosmic evolution of co-moving star-formation rate density. I will review recent progress at $z \simeq 2-3$, corresponding to the putative peak of star-formation activity, but will focus primarily on new results at the very highest redshifts. I will conclude with a brief discussion of how anticipated new results from deep ALMA imaging have the potential to clarify and complete our understanding of cosmic star-formation history

MUSE integral-field spectroscopy towards the Frontier Fields Cluster Abell S1063

W. Karman[1], K.I. Caputi[1], C. Grillo[2], I. Balestro[3], P. Rosati[4], E. Vanzella[5] , D. Coe[6], L. Christensen[2], A. M. Koekemoer[6], T. Krühler[7], M. Lombardi[8], A. Mercurio[9], M. Nonino[3], A. van der Wel.[10]

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[10] *Max-Planck-Institut für Astronomie, Königstuhl 17, 69117 Heidelberg, Germany*

Abstract

I will present the first observations taken with the newly installed VLT integral field spectrograph Multi Unit Spectroscopic Explorer (MUSE) on one of the Frontier Fields Clusters, Abell S1063. Because of the relatively large field of view of MUSE (1 arcmin^2), MUSE is very good to simultaneously target multiple background galaxies in blank and cluster fields over the full optical spectrum. MUSE has a relatively high spatial (0.2“) and spectral resolution (1.25 Å), preventing source confusion and allowing for detailed spectral line analysis. We have reduced the four hours of data obtained in the Science Verification phase on this cluster, and determined redshifts for 53 galaxies in the field. We confirm the redshift of 5 cluster galaxies, and determine the redshift of 29 other cluster galaxies, and show the distribution of active and passive galaxies in this cluster. Behind the cluster, we find 17 individual galaxies at higher redshift, including three previously unknown Lyman-α emitters at $z > 3$, and 5 multiply lensed galaxies. We find C III], C IV, and He II emission in a multiply lensed galaxy at $z = 3.116$, indicating the presence of an active galactic nucleus. Furthermore, we show the possibilities of MUSE for obtaining detailed velocity maps of cluster members and background galaxies. All of these properties show that with MUSE one can very efficiently observe towards clusters and obtain both a mass model for the cluster and perform a blind search for high redshift galaxies.

Reconstructing the formation of massive galaxies from their SHARDS

Pablo G. Pérez-González[1] and the SHARDS collaboration

[1] *Universidad Complutense de Madrid, UCM, Madrid 28040, Spain*

Abstract

One of the most widely researched topics in Extragalactic Astrophysics in the last decades is how the nearby galaxies morphologically classified as ellipticals formed their stars and assembled. In this context, we now have unequivocal observational evidences about the existence of a numerous population of massive galaxies which not only had assembled a considerable amount of stars ($\sim 10^{11}$ $M_{\odot}$) by z$\sim$2, but were already evolving passively by that time. These galaxies, the likely progenitors of nearby ellipticals, are also quite compact in comparison with local galaxies of the same mass. These results are mainly based on measurements designed to obtain stellar masses and sizes, and our estimations of these parameters are now quite robust. In order to advance in our understanding of the formation of nearby early-type galaxies, now we need a more secure determination of how exactly those high-z massive red galaxies formed and assembled their stellar mass in just 2-3 Gyr (z>2) in a compact structure. In other words, how was their Star Formation History and which are the properties (age, metallicity, dust content) of their stellar populations? And how could they end up with such high masses and small sizes? In this talk, we will present our results about the SFH of massive galaxies at z=1–3 and their structural evolution down to z$\sim$0 based on the deepest spectrophotometric data ever taken. These data were gathered by the Survey for High-z Absorption Red and Dead Sources (SHARDS), a ESO/GTC Large Program aimed at obtaining R$\sim$50 optical spectra of distant galaxies in the GOODS-N field. Our data are ideal to carry out detailed and robust stellar population and environmental studies down to very faint magnitudes (27 AB mag). We will present 2 main results: 1) the precise characterization of the stellar ages, star formation timescales, and the IMF of red and dead galaxies at z>1 and their progenitors at higher redshifts; and 2) the constraints imposed by our data (jointly with those from other large surveys) about the interplay between the SFH, environment, and the structural assembly of massive galaxies at 0<z<3.

The ZFOURGE survey: the evolution of galaxies since redshift $z = 4$

Lee R. Spitler[1,2]

[1] *Macquarie University, Sydney, Australia*
[2] *Australian Astronomical Observatory, Sydney, Australia*

Abstract

I will review results from the ZFOURGE survey, a new imaging campaign to track galaxy evolution over the last 12 billion years. Deep Magellan/FourStar near-infrared imaging taken with medium-bandpass filters allows us to finely sample galaxy spectral energy distributions and derive accurate photometric redshifts and stellar population parameters. Using ultra-deep Ks-band imaging ($25.5 - 26$ AB mag. $5 - \sigma$) in 3 deep fields (COSMOS, UDS, GOODS-S) to select galaxies, we have constructed large stellar mass-limited galaxy samples to redshift $z = 4$. With these catalogs we have: (1) conducted an evolutionary study of the star-forming and quiescent galaxy stellar mass functions to a redshift of $z = 3$, (2) demonstrated the existence of quiescent galaxies out to $z = 4$, (3) performed a general census of the massive galaxy population at $z = 3 - 4$ (4) tracked the evolution of active galactic nuclei host galaxies and (5) discovered one of the most distant galaxy clusters known so far.

Exploring the evolution of the stellar mass function in the redshift range $1 < z < 3$ with UltraVISTA & UDS

Alice Mortlock[1], Ross McLure[1]

[1] *Institute for Astronomy, University of Edinburgh, Royal Observatory, Edinburgh EH9 3HJ*

Abstract

The galaxy stellar-mass function is a key observational tool for improving our understanding of galaxy mass assembly, the physical processes of high-redshift star-formation and differentiating between competing theoretical models of galaxy evolution. Here we report the initial results of a long-term study to measure the evolving galaxy stellar mass function over the redshift interval $2 < z < 8$, spanning the interval from the first galaxies to the peak of cosmic star-formation rate density. By combining the power of deep, wide-area, ground-based near-IR surveys (UKIDSS UDS, ULTRAVISTA & VIDEO) with ultra-deep HST imaging of the HUDF, Frontier Fields and CANDELS, the aim is to accurately measure the evolving stellar mass function over a dynamic range of >1000 in luminosity, using datasets ranging in size from 4 sq. arcmins to 10 square degrees. Here we present the first mass function results from the ULTRAVISTA and UDS fields, which incorporate deconfusion of the deep IRAC SPLASH data using the TPHOT algorithm. We highlight the importance of combining optical, near-IR and mid-IR selection in order to obtain a more complete census of the high-redshift galaxy population.

Combining spectroscopic and photometric data to study how resolved (kpc-scale) substructures in galaxies govern their global physical properties

Shoubaneh Hemmati[1], Bahram Mobasher[1]

[1] *University of California Riverside*

Abstract

This talk is focused on the resolved physics of substructures in galaxies at kpc-scale and their relation with the global properties of the host galaxy using combined high resolution photometric data from the Hubble Space Telescope and very deep long exposure spectroscopic observations with the Keck telescopes. I use the optical and near-infrared data taken as part of the CANDELS project in the GOODS fields to perform pixel-by-pixel analysis of 120 galaxies at intermediate redshifts (out to z$\sim$1.3). The targets are selected to have disk-like morphologies and extended emission in the Keck/DEIMOS spectra. I produce resolved rest-frame (U-V) color, stellar mass and star formation rate surface densities, stellar age and extinction maps and profiles along the galaxies rotation axes. I develop a technique to identify blue and red regions within individual galaxies, using the rest-frame color maps. I quantify the spatial distribution and covering fraction of red and blue regions with respect to both redshift and stellar mass of the host galaxy, finding that the stronger concentration of red regions toward the centers of galaxies is not a significant function of either redshift or stellar mass. I also find that the covering fraction of the blue regions does not evolve strongly with redshift at the redshift range of this study. These findings imply that if the central bulge formation is due to migration of stellar clumps, it should have happened at higher redshifts. I discover that there is a tight correlation between the stellar mass and star formation rate of red and blue regions in galaxies, with the median of blue regions forming a tighter relation with a slope of 1.1 $\pm$ 0.1 and scatter of $\sim$0.2 dex compared to red regions with a slope of 1.3 $\pm$ 0.1 and a scatter of $\sim$ 0.6 dex. The blue regions show higher specific Star Formation Rates (sSFR) than their red counterparts with the sSFR decreasing since z $\sim$ 1, derived primarily by the stellar mass surface densities rather than the SFRs at a giver resolution element. Using the DEIMOS spectra, I model the optical nebular emission lines and construct the optical line ratio profiles diagnostic of gas phase metallicity (R23) and interstellar nebular dust extinction (Hα/Hβ). I find that the nebular dust extinction profile, inferred from Balmer decrement, is in agreement with the average stellar extinction derived from the resolved SED modeling. Using the R23 metallicity profiles I present, for the first time, the mass metallicity relation inside galaxies and its variation as a function of spatial position.

Day 3

The AGN-Galaxy connection out to the highest redshifts

Philip Best[1]

[1] *SUPA, Institute for Astronomy, University of Edinburgh*

Abstract

I will review the connection between the growth of galaxies and the AGN activity associated with the growth of their central black holes. Focussing initially on lower redshifts where our understanding is better, I will discuss the evidence for two fundamentally different modes of AGN activity in the Universe, the nature of the galaxies that host each of these, and the feedback effects of each mode of activity. I will then summarise what is known about each of these different modes of AGN activity out to the highest redshifts.

AGN feedback and outflows : the road to star formation quenching

M. Talia[1,2], A. Cimatti[1,2], M. Brusa[1,2], VUDS and zCOSMOS teams

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[2] *INAF- Osservatorio Astronomico di Bologna, Via Ranzani 1, I-40127, Bologna, Italy*

Abstract

The unique synergy of spectroscopy from large surveys (VUDS, zCOSMOS, public surveys in the GOODS-S), complemented with public HST imaging, Chandra X-ray data, and Spitzer and HERSCHEL infra-red data is exploited to investigate the relationships between galaxies and AGNs at $z \geq 1$.

First exploratory results based on a small sample of galaxies at $1 < z < 3$ with ultradeep spectroscopy from the GMASS survey (Cimatti et al. 2013) showed possible evidence of the feedback processes triggered by AGNs, that are thought to lead to the rapid suppression of the star formation activity in high redshift galaxies. In the colour-mass plane, two parallel trends emerge during the ∼2 Gyr between the average redshifts z∼2.2 and z∼1.3: while the red sequence becomes rapidly more populated by ellipticals, the majority of AGNs disappear from the blue cloud/green valley where they were hosted predominantly by star-forming systems with disk and irregular morphologies. At z∼2.2, the ultraviolet spectra of active galaxies show possible gas outflows with velocities up to about -500 km s^{-1} that are not observed neither in inactive systems at the same redshift, nor at lower redshifts. These outflows indicate the presence of gas that can move faster than the escape velocities of active galaxies. The ejection of part of the inter-stellar medium can lead to a rapid decrease of the star formation in host galaxies and the morphological transformation from disky/irregular to spheroidal galaxies.

In this work we have extended the analysis to a larger sample of galaxies in order to put more stringent constraints on the outflow velocities and gas properties, and study their dependence on galaxy properties such as stellar mass, star-formation rate, and AGN luminosity. I will present the results of our spectroscopic analysis and discuss how they are contributing to uncover the key role played by AGN feedback in galaxy evolution.

A direct measurement of the gas content of a massive elliptical galaxy in the peak era of galaxy assembly

M. T. Sargent[1], E. Daddi[2], M. Onodera[3], F. Bournaud[2], R. Gobat[4]

[1] *Dept. of Physics & Astronomy, U. of Sussex*
[2] *DSM/Irfu/Sérvice d'Astrophysique, CEA Saclay*
[3] *Institut für Astronomie, Dept. für Physik, ETH Zürich*
[4] *Korea Institute for Advanced Study, Seoul*

Abstract

Very little is known about the interstellar medium content and gas reservoirs of distant, passively evolving galaxies compared to the gas and dust in active galaxies which are now being characterised by infrared and sub-mm observatories on a routine basis. Gas fractions $f_{\rm gas} = M_{\rm gas}/(M_{\rm gas} + M_\star)$ in galaxies on the main sequence of star formation have been observed to rise by an order of magnitude out to $z \sim 2$. Does the gas content decrease with cosmic time in a synchronised fashion in both active and passive galaxies, i.e. following an average, 'universal' cosmic decline?
I will present the outcome of the first direct measurement of the molecular gas in passively evolving galaxies at high redshift, obtained through IRAM/PdBI follow-up of the CO(2→1) line toward an $6{\times}10^{11}\,M_\odot$ elliptical galaxy with $z = 1.43$ in the COSMOS field. This observation reveals a gas fraction which is about an order of magnitude lower than the dominant population of star-forming galaxies at this redshift. I will discuss the implication of this finding in the context of the AGN feedback paradigm and models of ISM replenishment through stellar evolution, as well as by comparison to simulations and observations of gravitational/morphological quenching.

The growth of typical star-forming galaxies and their super massive black holes across cosmic time: consequences for AGN feedback/quenching

João Calhau[1,2], David Sobral[1,2,3]

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[3]*Leiden Observatory, Leiden University, P.O. Box 9513, NL-2300 RA Leiden, The Netherlands*

Abstract

Understanding galaxy formation and evolution requires the understanding of both the star formation history (the growth of galaxies) and black hole accretion history (the growth of their black hole), and how they influence each other. Here, we explore a sample of typical Hα-selected star-forming galaxies from the HiZELS survey. We use direct detections but also relying on stacking in the X-rays, far-infrared (FIR) and radio, along with the wealth of multi-wavelength data in COSMOS to study the relative growth between typical galaxies, from z=2.23 to z=0.4, and their black holes. We find that the fraction of AGN increases with Hα luminosity and that the relative black hole to galaxy growth seems to be relatively constant for star forming galaxies since z=2.23. We find a typical fraction of AGN candidates of 20%, although only about 1% were selected through the X-rays. Typical Star Forming galaxies are shown to always be growing their stellar mass much quicker than their black holes (logarithmic ratio of -4) with SFR's of the order of 10 to 100 $M_\odot\,yr^{-1}$ and an AGN accretion rate of the order of 10^{-3} $M_\odot\,yr^{-1}$. Our results may have important consequences for our understanding of how galaxies like our own evolved in the last 11 Gyrs.

The faint radio sky: a tale of three populations

P. Padovani[1], M. Bonzini[1], V. Mainieri[1], N. Miller[2], K. I. Kellermann[3]

[1] *European Southern Observatory, Karl-Schwarzschild-Str. 2, D-85748 Garching bei München, Germany*
[2] *Department of Mathematics and Physical Sciences, Stevenson University, 1525 Greenspring Valley Road, Stevenson, MD 21153-0641, USA*
[3] *National Radio Astronomy Observatory, 520 Edgemont Road, Charlottesville, VA 22903-2475, USA*

Abstract

We present the evolutionary properties and luminosity functions of the radio sources belonging to the Extended *Chandra* Deep Field South (E-CDFS) Very Large Array survey, which reaches a flux density limit at 1.4 GHz of 32.5 μJy at the field centre and redshift $\sim$ 5. Our sample, which includes $\sim$ 700 radio sources, is $\sim$ 3.5 times larger than the CDFS one, on which our recent work was based, and is the deepest radio sample for which such results have ever been obtained. The sub-mJy radio sky turns out to be a complex mix of star-forming galaxies and radio-quiet AGN evolving at a similar, strong rate and declining radio-loud AGN. While the well-known flattening of the radio number counts below 1 mJy is mostly due to star-forming galaxies, these sources and AGN make up an approximately equal fraction of the sub-mJy sky. One of the main messages, especially to non-radio astronomers, is that radio surveys are reaching such faint limits that, while previously they were mainly useful for radio quasars and radio galaxies (i.e., non-thermal sources), they are now detecting mostly star-forming galaxies and radio-quiet AGN, i.e., the bulk of the extragalactic sources studied by infrared, optical, and X-ray surveys.

The e-MERGE Galaxy Evolution Survey

Tom Muxlow[1], Ian Smail[2]

[1] *Jodrell Bank Centre for Astrophysics, University of Manchester, UK*
[2] *Institute for Computational Cosmology, Durham University, UK*

Abstract

The e-MERLIN Galaxy Evolution Survey (e-MERGE) is an ambitious multi-tiered legacy survey to exploit the unique combination of very high sensitivity and spatial resolution to study the formation and evolution of star-forming galaxies and AGN out to redshifts of $z > 5$. These observations will provide a powerful, obscuration-independent tool for measuring the massive star formation and AGN activity in high-redshift galaxies, hence tracing the development of the stellar populations and the black hole growth in the first massive galaxies.

With a resolution of 50-200 mas in C- and L-Bands, corresponding to $< 0.5 - 1.5$kpc at $z > 1$, e-MERLIN gives us our first truly reliable view of the distribution of star-formation within typical galaxies at the epoch where the bulk of the stars in the present-day Universe were being formed. In a previous study (Muxlow et al, 2005) it was shown that high angular resolution imaging of the distant radio source population with MERLIN is able to separate radio emission from AGN and star-forming regions. Thus in the deep e-MERGE Tier 1 observations of a 30 arcminute field centred on GOODS-N, combination EVN+e-MERLIN+JVLA imaging will disentangle the relative contributions of AGN and star-formation - an essential step given the apparently simultaneous growth of the black holes and stellar populations in galaxies. With the central region of the Tier 1 field ultimately reaching sub-μJy noise levels, e-MERGE will image several thousand star-forming galaxies, and statistically characterize the nature of the sub-μJy radio population - which are the target objects for the SKA.

Initial results from e-MERLIN, JVA, and EVN on the e-MERGE Tier 1 region are presented here.

Observational signatures of an evolving interstellar medium in high redshift galaxies

Alexandra Pope[1]

[1] *University of Massachusetts Amherst*

Abstract

The prominent peak in the history of star formation and black hole accretion at $z \sim 1$–3 suggests strong evolution in the mechanisms that grow stars and black holes in galaxies. Multi-wavelength observations of the interstellar medium (ISM) can quantify both the energy balance between star formation and active galactic nuclei (AGN) activity, and constrain the composition and conditions of the gas and dust available to form new stars. In order to measure and understand the evolution of the ISM in high redshift galaxies, we combine diagnostics from mid-IR spectroscopy, far-IR/(sub)mm continuum and CO molecular lines. We present new observations from the Large Millimeter Telescope of the gas and dust in distant galaxies. We quantify the evolution in the ISM with redshift and as an AGN grows more luminous within a star forming galaxy in order to understand what is driving the peak epoch of galaxy evolution.

Understanding relationships between star formation rate, stellar mass and obscuration at high redshift with the SCUBA-2 Cosmology Legacy Survey

Nathan Bourne[1], Jim Dunlop[1], and the S2CLS team

[1] *Institute for Astronomy, University of Edinburgh, the Royal Observatory, Blackford Hill, Edinburgh EH9 3HJ, UK*

Abstract

Our understanding of the history of star formation relies on accurately measuring the star formation rate (SFR) density from low to high redshifts, taking full account of the obscured ultraviolet (UV) light that is reprocessed by dust in the far-infrared (FIR). This is especially important at high redshifts where the obscuration of typical star-forming galaxies can become so great that the UV luminosity of a galaxy is poorly correlated with its total SFR. Yet we have a very limited understanding of obscuration in typical star-forming galaxies at high redshifts. Galaxy samples at $z > 3$ become biased towards either FIR-bright or UV-bright tails of the population, as a result of the photometric selection techniques. We need to bring these two ends of the spectrum together if we are to characterise the relationship between stellar mass and SFR, and understand the evolution of the SFR density. Using the SCUBA-2 Cosmology Legacy Survey we tackle this problem by combining the deepest submm imaging with the latest techniques to break through the confusion limit, and measure the distribution of SFR and obscuration as a function of stellar mass and UV luminosity at high redshifts.

The evolution of the dust and gas content in galaxies

Paola Santini[1]

[1] *INAF Osservatorio Astronomico di Roma*

Abstract

By means of Herschel observations, we have studied the scaling relations in place between gas, dust, stellar mass (M_{star}) and SFR and their evolution from z$\sim$2.5 to the local Universe. The gas mass is estimated from dust mass measurements by adopting assumptions on the dust-to-gas ratio. The inferred relation between SFR and gas mass (integrated Schmidt-Kennicutt relation) for the bulk of the population is in good agreement with previous results based on CO measurements, despite the completely different approaches. This confirms the reliability of this method, applicable to much larger samples of galaxies. In order to resolve the degeneracies associated with the Main Sequence (MS) relation, dust and gas evolution have been investigated by disentangling the effects of M_{star} and SFR. We observe no evolution in the gas fraction (f_{gas}) with redshift once M_{star} and SFR are fixed. We explain these trends by introducing a universal relation between fgas, M_{star} and SFR that does not evolve with redshift, at least out to z$\sim$2.5. Galaxies move across such relation as their gas content evolves across the cosmic epochs. The projection of this 3D fundamental relation onto the M_{star}-SFR plane yields the MS and its evolution with redshift. We observe that the gas fraction of MS galaxies evolves differently depending on their stellar mass, in agreement with a downsizing scenario.

Towards the complete mass function of dusty galaxies

Michal Michalowski[1], James Dunlop[1], Maciej Koprowski[1]

[1] *Institute for Astronomy, University of Edinburgh, Royal Observatory, Edinburgh*

Abstract

The distribution of galaxy masses as a function of redshift provides an important constraint on galaxy evolution models, as it informs us about integrated star-formation in the past. I will present recent result on the stellar mass distribution of dusty galaxies in the distant universe. First, using various SED codes applied to real and simulated submm galaxies, I will show to what extent we can reconstruct their masses from broad-band photometry. Then I will present what we have learnt from stellar masses of submm galaxies found in the SCUBA2 Cosmology Legacy Survey. Due to unprecedented image quality of SCUBA2, the size of the images ($\sim 2\,\mathrm{deg}^2$) and their depth, this sample is unique it terms of completeness, and redshift recovery fraction. Finally, I will discuss the preliminary results on stellar masses of fainter dusty galaxies, discovered in the ALMA Cycle 1 survey of the Hubble Ultra Deep Field.

Evolution of stellar metallicity in high redshift galaxies.

V. Sommariva[1], F. Mannucci[2], G. Cresci[2], A. Cimatti[1], F. Calura[3], M. Castellano[4], et al.

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[2] *INAF Arcetri Firenze, Italy*
[3] *INAF Bologna, Italy*
[4] *INAF Roma, Italy*

Abstract

Metallicity is a fundamental property of galaxies, and it's study can place important constraints on galaxy evolution. In particular, stellar metallicity is a direct measure of the amount of metals present in a galaxy, as a large part of the heavy elements lie in its stars. In spite of its importance, stellar metallicity has been measured only a handful of high-z sources, as high signal to noise and very long exposures are required to measure it from well defined photospheric absorption features in the UV rest frame. Our pilot study of the mass-stellar metallicity relation at $z \sim 3$ (Sommariva et al. 2012) with FORS2 has confirmed the feasibility of such studies at high-z as well as the low metal content derived independently for the gas phase component. But due to the faintness of the targets at $z \sim 3$ only a limited sample has been collected, and the sparse data at lower redshift do not allow yet to study the cosmic evolution of the stellar metallicity. Here I will present the new results coming from MODS and GMASS data observed at $z \sim 2$. The aim of this work is to trace, for the first time, the cosmic evolution of stellar metallicity from $z \sim 2$ to $z \sim 3$, and compare the observational results with the predictions of the theoretical models.

The chemical evolution of galaxies from high to low redshift

Rob Yates[1]

[1] *Max Planck Institut für Extraterrestrische Physik (MPE), Giessenbachstraße 1, 85748, Garching, Germany*

Abstract

In this talk, I will discuss how the chemical evolution of various types of galaxies has proceeded over cosmic time, with a particular emphasis on the insights given by the Munich semi-analytic model (SAM) of galaxy formation. The chemical properties of the gas and stars in galaxies provide crucial information on how these galaxies have evolved in general. We can combine our theoretical knowledge of their varied star formation histories with that of metal production in the hearts of stars and supernovæ to explain the often puzzling chemical compositions observed at both high and low redshift. For example, using the Munich SAM built on the MILLENNIUM simulation of hierarchical dark-matter structure formation, we have found that the chemical properties in a) the ISM of local star-forming galaxies, b) the photospheres of G dwarfs in the solar neighbourhood, and c) the stellar populations in nearby elliptical galaxies can all be *simultaneously* reproduced without requiring a variable IMF or strong, interaction-induced starbursts at high redshift (Yates et al. 2013). I will further present how the iron abundances in the hot gas surrounding galaxy clusters can also be well explained by the same model, given certain considerations regarding the metal enrichment and pristine infall occurring at redshifts above 3 (Yates, Thomas & Henriques, in prep.).

Additionally, I will present the leading theoretical perspective on the evolution of the mass-metallicity relation (MZR) out to high redshift. The shape and evolution of the MZR, as well as of the mass-SFR-metallicity relation (or FMR), is still hotly debated, and no clear consensus has been formed. I will show the latest results on this topic from the new Munich SAM, which includes a detailed galactic chemical enrichment scheme, a sophisticated treatment of H_2 formation, and improved modelling of the cycling of baryonic material throughout galaxies. I will also explain how gradual dilution in quiescent, post-merger systems above redshift 1 drives the positive correlation between SFR and metallicity seen in massive galaxies by redshift 0 (Yates et al. 2012; Yates & Kauffmann 2014). This work will be supplemented by our team's up-coming *observations* of the metal content in the star-forming gas surrounding gamma-ray bursts (GRBs) detected around redshift 2.5. This data will provide a unique insight into the low-mass, high-redshift region of the MZR and FMR, and help us further explain how galactic chemical evolution has proceeded over cosmic time.

Day 4

The MOSDEF Survey: Study of Rest-frame Optical Properties of Galaxies at $1.5 < z < 3.5$

Bahram Mobasher[1]

[1] *Department of Physics & Astronomy, University of California, Riverside, USA*

Abstract

The MOSFIRE Deep Evolution Field (MOSDEF) Survey is designed to exploit new capabilities of the MOSFIRE instrument on the Keck Telescope to study the evolution of rest-frame optical spectra for ∼1500 galaxies in the CANDELS fields, spanning the redshift range $1.5 < z < 3.5$. Despite the critical importance of this cosmic epoch for assembly of galaxies, star formation activities and black hole growth, our knowledge of the spectroscopic properties of galaxies has been very limited. This talk presents the first scientific results from the MOSDEF survey. Using rest-frame optical spectroscopy, we target emission and absorption line features between 3700 Å and 6800 Å, spanning the full diversity of stellar populations and dust extinction over a large dynamic range in stellar mass. We study the evolution of Mass-Metallicity and Mass-Star Formation Rate (SFR) relations with redshift, the BPT diagrams at high redshifts ($z \sim 2.3$) and dust and excitation properties of star-forming galaxies at $z \sim 1.4 - 2.6$. I also study the effect of the outflows on the physical properties of galaxies (mass, metallicity, star formation rate) at the redshifts of the MOSDEF galaxies.

sSFR functions out to $z = 1.4$ combining the COSMOS and GOODS surveys

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Abstract

The mass-SFR relation characterizes how the instantaneous star formation is determined by the galaxy past star formation history. Its evolution is linked to the growth of the dark matter structures. I will present a novel approach to study the mass-SFR relation by measuring the sSFR functions in several stellar mass bins out to $z = 1.4$. I will demonstrate that such approach is necessary to avoid selection effects. We base our analysis on the COSMOS field including the new SPLASH/Spitzer data, MIPS and Herschel data over 2 deg^2. We also combine COSMOS and GOODS data. I will show that the shape of the sSFR function is invariant with time at $z < 1.4$ but depends on the mass, with a broadening of the sSFR function ranging from 0.28 dex at $\mathcal{M} \sim 10^{10}\mathcal{M}_{sun}$ to 0.46 dex at $\mathcal{M} > 10^{11}\mathcal{M}_{sun}$. Such broadening results from an increasing diversity of SFHs as the stellar mass increases. We obtain a new parametrisation of the sSFR evolution as a function of mass and redshift. I will link these results with the evolution to the cosmological accretion rate and the numerous physical processes, as gas exhaustion in hot gas halos or secular evolution, which can gradually reduce the sSFR and increase the SFH diversity.

The nature and evolution of star-forming galaxies over the last 11 Gyrs with a single, homogeneous selection

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Abstract

I will present the results from the deepest and widest narrow-band surveys ever undertaken with the best 4-8 m telescopes (CFHT, UKIRT, Subaru and the VLT); a unique combined effort to select large, robust samples of (mostly) Hα star-forming galaxies at $z = 0.20$, 0.40, 0.8, 0.84, 1.47 and 2.23 (corresponding to look-back times of 2, 4.2, 7.0, 9.2 and 10.6 Gyrs) in a uniform manner over $\sim$2-10 deg^2 in the COSMOS, UDS and SA22 fields. We are able to fully evaluate and overcome cosmic/sample variance with our large, multiple volumes. Our results reveal the exponential decline of the typical star-formation rate of galaxies (SFR*) over the last 11 billion years, and very little evolution in the stellar mass function of star-forming galaxies, with strong implications to the main drivers of galaxy evolution. Our Hα star formation history also implies a stellar mass density growth which is in perfect agreement with independent observations of the stellar mass density growth over the last 11 billion years, finally resolving the worrying disagreement seen in the literature.

I will finish by showing how our large and homogeneously selected samples of Hα emitters across cosmic time are ideal to unveil the evolution (by comparing like with like) of the dynamics (e.g. SINFONI, KMOS), dust (e.g. Herschel, Spitzer, ALMA), clustering, environment, and (resolved) metallicity (e.g. KMOS, FMOS) of typical star-forming galaxies since the peak of the star formation history.

Galaxy formation activity just before its peak epoch explored with [OIII] emitters at $z > 3$

Tomoko Suzuki[1], Tadayuki Kodama[1,2], Ken-ichi Tadaki[3], Masao Hayashi[2], Yusei Koyama[4], Ichi Tanaka[5], Yosuke Minowa[5], Rhythm Shimakawa[1,5], and Moegi Yamamoto[1]

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Abstract

It has been known that galaxy formation activities, such as star formation and AGN growth, are peaked at $2 < z < 3$. In this study, we focus on the epoch slightly beyond this peak, $z > 3$, to know how the galaxy formation is being most activated to come to the peak. At this redshift regime where Hα can no longer be reached by ground based telescopes, the [OIII] nebula emission line turns out to be the most efficient and effective tracer of star-forming galaxies, as it becomes very strong at high redshifts due to much higher excitation states.

We have performed deep narrow-band imaging survey with Subaru/MOIRCS in the SXDF-UDS-CANDELS field as a part of MAHALO-Subaru project, and have constructed coherent samples of ~ 35 [OIII] emitters at $z = 3.17, 3.62$, as well as ~ 100 Hα emitters at $z = 2.19, 2.52$, using two custom-made narrow-band filters in the K-band. Using these unique sample of $z > 3$ [OIII] emitters, we investigate their basic physical quantities, such as stellar mass, star formation rate (SFR) and size with multi wavelength data and HST high resolution images that are all available. The stellar mass and SFR show a clear, tight correlation known as the "star forming main sequence" for star forming galaxies at lower redshifts, with a hint of turning over of its evolution towards higher redshifts. On the other hand, their mass-size relation is almost identical to that of star forming galaxies at $z \sim 2 - 2.5$, indicating that there is no evolution since $z \sim 3.6$ to $z \sim 2$.

Based upon these intriguing results together with their internal structures (e.g. clumpiness and dustiness) obtained from the HST images, we discuss the formation/evolutionary stages of those star forming galaxies at $z > 3$ in comparison with those at $z \sim 2$, and also taking into account any sampling effects.

The MOSDEF Survey: The Star-Forming Main Sequence at $z \sim 2$

Irene Shivaei[1], Naveen Reddy[1], Alice Shapley[2], Mariska Kriek[3], William Freeman[1], Alison Coil[4], Brian Siana[1], Bahram Mobasher[1], Laura de Groot[1], Sedona Price[3], Ryan Sanders[2]

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[3] *University of California, Berkeley*
[4] *University of California, San Diego*

Abstract

We investigate the correlation between the stellar mass and the star-formation rate (SFR) among star-forming galaxies at $z \sim 1.5 - 2.3$ from the MOSFIRE Deep Evolution Field (MOSDEF) survey. The MOSDEF survey is a four-year project that uses the NIR MOSFIRE spectrograph on the 10-m Keck I telescope to characterize the gaseous and stellar contents of ~ 1500 mass-selected galaxies at $1.5 \leq z \leq 3.5$. With a large sample of ~ 250 spectroscopically confirmed galaxies with observed Hα and Hβ lines we calculate dust-corrected instantaneous SFRs. SFRs are also inferred from the UV luminosity and dust-corrected using the UV slope. Comparing the star-forming main sequence based on the two independently estimated SFRs, provides insight into some the main debates on whether the relation and its scatter is affected by the assumed diagnostic of SFR. By using SFR tracers that are sensitive to different timescales, we can assess the degree to which galaxies are smoothly building up their stellar masses during a time when they will be forming most of their mass.

Post-starburst galaxies and the origin of the galaxy bimodality

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Abstract

Despite decades of study, we still do not fully understand why massive galaxies abruptly switch off their star formation in the distant Universe. It is also unclear if the same processes are responsible for the *morphological* transformation of galaxies, to produce the Hubble Sequence we observe today. The rare class of post-starburst ("E+A") galaxies provides a unique opportunity to study the transition phase, but until recently only a handful had been identified at high redshift ($z > 1$). Using a new PCA technique, we have recently identified over 500 post-starburst galaxies in the UKIDSS UDS field. We find that their space density is sufficient to provide a major growth channel for massive quiescent galaxies during this crucial epoch. We also find that post-starburst galaxies are surprisingly compact and spheroidal, with a distribution of Sérsic indices that are indistinguishable from the old quiescent population. We conclude that the morphological transformation of these massive galaxies occurred during the same event that quenched their star formation. Our findings provide strong evidence for the scenario in which a significant fraction of compact spheroids are formed from gas-rich mergers, leading to a major burst of star formation that is subsequently abruptly terminated.

The Nature of [CII] emission in Lensed Dusty Star-forming Galaxies from the SPT survey

Bitten Gullberg[1], Carlos De Breuck[2], Axel Weiß[3], Joaquin Vieira[4] + the SPT SMG collaboration

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[2] *ESO*
[3] *MPIfR*
[4] *University of Illinois*

Abstract

ALMA spectroscopy (cycle 0 and 1) of point sources from the South Pole Telescope survey has uncovered a population of high-redshift ($z = 2 - 5.7$), strongly lensed dusty star-forming galaxies (DSFGs). This has resulted in an unbiased redshift distribution for DSFGs peaking for $z \sim 3.5$, i.e. higher than previously believed of $z \sim 2.5$, and doubled the number of sources at $z > 4$. In this talk I will present the latest result from our fine-structure line survey of 20 DSFGs. Comparing [CII] velocity profiles (APEX and *Herschel)* with CO velocity profiles from ALMA reveals consistent velocity profiles, suggesting little differential lensing between these species. Combining the [CII] detections with low-J CO detections (ATCA), we find [CII]/CO(1–0) luminosity ratios of 5200 ± 1800, and argue that this line ratio is best described by [CII] and CO emitting gas with higher [CII] than CO excitation temperature, high CO optical depth $\tau_{\rm CO(1-0)} \gg 1$, and low to moderate [CII] optical depth $\tau_{\rm [CII]} \lesssim 1$. The geometric structure of photodissociation regions (PDRs) allows for such conditions.

Modelling the SEDs of galaxies at high redshift: recent progress and future challenges

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Abstract

The spectral energy distributions (SEDs) of galaxies contain important signatures of the physical processes that shape their evolution. Multi-wavelength observations spanning the full ultraviolet to radio spectral range are becoming available not only for local galaxies, but also for samples of increasingly high redshift galaxies, thanks to deep observations with e.g. HST, Spitzer, Herschel and ALMA. In order to understand these observations in the context of galaxy evolution theories, we use SED models that translate the observed light into physical properties such as stellar mass, star formation rate, metallicity, and dust content. While these models have been extensively calibrated and applied to local galaxy samples, they are only now starting to be used to understand galaxies in the young Universe. In this talk I will review the main ingredients of spectral energy distribution models and I will describe recent and ongoing developments that are implemented to make the models applicable at high redshifts, in particular in the context of the MAGPHYS code. I will focus on specifically on: (i) recent updates on the spectral evolution of young stellar populations; (ii) self-consistent modelling of the nebular emission of galaxies, and how this affects the broad-band SEDs; (iii) challenges in parameterizing the star formation histories of galaxies, and why they matter; (iv) progress in modelling the contamination by active galactic nuclei (AGN); and (v) how to account for 'cosmological effects' when modelling galaxy SEDs at high redshifts.

The VIMOS Ultra Deep Survey: Lyα Emission and Stellar Populations of Star-Forming Galaxies at $2 < z < 6$

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Abstract

A comprehensive study of star-forming galaxies (SFGs) at $z \sim 2-6$ using ground-based spectroscopy and multi-wavelength photometry is vital for understanding physical processes that govern star formation and galaxy assembly at these cosmic epochs. Until now, such studies were limited by small samples because of the lack of large area, deep spectroscopic observations at high redshifts. The extensive ground-based spectroscopy campaign from the VIMOS Ultra-Deep Survey (VUDS), and the deep multi-wavelength photometry in three very well observed extragalactic fields (ECDFS, COSMOS, VVDS), allow us to investigate physical properties of a large sample ($\sim$8000 galaxies) of spectroscopically confirmed SFGs at $z \sim 2-6$. We will present results from our spectro-photometric studies of Lyα emitters and non-Lyα emitters at $2 < z < 6$, and infer possible correlations between their best-fit SED parameters and rest-frame UV spectral features.

Star-forming galaxy properties at $z \sim 4$ and impact of nebular emission: applying lesson from ~ 2

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Abstract

While main optical and near-IR emission lines are not yet observable at high redshift ($z > 3$), it has been recently shown that nebular emission could affect physical parameter derivation of distant galaxies.

We use a sample of 149 spectroscopically-confirmed UV-selected galaxies at $z \sim 2$ to investigate the relative dust attenuation of the UV continua and the nebular emission in these galaxies. For each galaxy of the sample, at least one optical (rest-frame) emission line has been measured and 41 galaxies have additional observations with Spitzer/MIPS at 24μm. We are able to reproduce all the observed quantities for galaxies with no or little extinction, while for attenuated galaxies we need to apply an extra amount of dust attenuation toward nebular emission in comparison with stellar attenuation. We also find a tight correlation between star formation rate and the amount of extra attenuation which can explain the discrepant results about difference in attenuation between nebular and stellar emission at $z \sim 2$.

Finally, assuming that nebular emission has the same properties (dust attenuation) at $z \sim 4$ than $z \sim 2$, we update the estimation of the impact of nebular emission at $z \sim 4$ using the latest CANDELS data with a large spectroscopic sample (N$\sim$ 200).

A consistent view on normal star-forming galaxies from $z \sim 1.5$ to 8 from multi-wavelength observations and SED modeling

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Abstract

We present new results from a multi-wavelength analysis of normal/typical star-forming (SF) galaxies combining our sample of strongly lensed galaxies at $z \sim 1.5 - 4$ and $z \sim 6 - 7$ (from the Herschel Lensing Survey and others) with a large sample of LBGs from$z \sim 3 - 8$ and a Herschel-selected sample at $z \sim 1.5 - 3$ (primarily from the GOODS fields). The observations include deep ground-based, HST, Spitzer, and Herschel imaging, plus LABOCA/SCUBA2 data, IRAM and ALMA dust continuum observations for some of the objects. We also include CO and [CII] 158 micron line measurements our group and others have recently obtained.

The observed SEDs are modeled with our SED fitting tool including nebular emission for the stellar part, and allowing for energy-conserving global SED fits including also dust emission.

We present direct constraints on dust attenuation from IR and UV measurements, yielding new information on the dependence of attenuation on galaxy mass and on its redshift evolution. Both the empirical data and our modeling shows that the UV attenuation at $z > 3$ may be larger than commonly thought, with implications on the global history of star formation (SFR density) at high redshift.

We also present evidence for variable star formation histories in high-z galaxies and discuss important implications on the specific SFR, its redshift evolution, the SF main sequence at high redshift, and other related issues.

Finally, we also show the empirical behavior of gas, dust, and stellar properties of $z \sim 1.5 - 3$. galaxies of normal/typical SF galaxies at these redshifts, as found from combination of lensed and unlensed galaxy samples, and discuss the consistent picture of high-z star-forming galaxies obtained in this way.

New insights on the evolution of Halpha equivalent width and sSFR up to $z \sim 5$

E. Mármol-Queraltó[1], R.J. McLure[1], F. Cullen[1], et al.

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Abstract

The evolution of the physical properties of galaxies such as the stellar mass and the star formation rate (SFR) have been (and are) extensively analysed using photometric data in a wide range of redshifts. However, these results rely on fitting their spectral energy distributions (SEDs) where rest-frame optical nebular emission lines (e.g., Hα) may contaminate the broad-band fluxes and bias the results inferred. Actually, recent works have shown that the specific SFR seems to evolve far less rapidly than expected in most theoretical models. In addition, it has been claimed that the equivalent width (EW) of Hα evolves rapidly with redshifts, which it is difficult to understand since the Hα EW should be a reasonable proxy for the sSFR.

In this work, we combine the best-available broad-band photometry in CANDELS with new near-infrared spectroscopy taken from the 3D-HST survey for a sample of star-forming galaxies at intermediate redshifts ($z \sim 1.3$) to robustly test a method to infer reliable measurements of Hapha from the flux excess between observations and the SED fitting. Following this method, we revisit the photometric data available for galaxies up to $z \sim 5$ to trace the evolution of the equivalent width of Hα. I will show here that, in contrast with previous works, we find a mild evolution of Hα, much slower than the expected from the extrapolation of observations at lower redshifts. Moreover, we find that certainly the Hα EW follows the evolution of the sSFR. Finally, I will discuss these results and their implications for our understanding of galaxy evolution.

Proto-clusters at high-z: structures and stellar populations

Tadayuki Kodama[1,2], Masao Hayashi[1], Yusei Koyama[3], Ken-ichi Tadaki[4], Ichi Tanaka[5], Rhythm Shimakawa[2,5], Tomoko Suzuki[2,1], and Moegi Yamamoto[2,1]

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Abstract

We have been targeting ∼10 proto-clusters at $1.4 < z < 3.1$ covering the peak epoch of galaxy formation on our Mahalo-Subaru project. We emply unique sets of narrow-band filters on wide field instruments of Subaru (Suprime-Cam at optical and MOIRCS at NIR) to map out line-emitting star-forming galaxies (Hα, [OIII], and [OII] emitters) associated to the proto-clusters. We present that all of our targets show prominent large-scale structures in and around them, indicating that they are still in vigorous assembly phase. Moreover, we show that star formation activity in the cluster cores is very high at $z \sim 2$ involving a significant fraction of dusty star-bursting galaxies, but such strong activities at proto-cluster centers at high redshifts declines sharply as time progresses, and the peak of star formation activity is shifted outwards to surrounding lower density regions. This clearly indicates the "inside-out" formation of galaxy clusters.

Spectroscopic follow-up observations reveal that the proto-cluster galaxies at $z \sim 2$ tend to have much higher ionization states than present-day counterparts, characterized by the presence of strong [OIII] emission lines. Moreover, we find that their gaseous metallicities in dense environment are systematically higher than those in the general fields at $z \sim 2$. This is probably due to some environmental effects on the gas inflow/outflow processes.

Using HST imaging, AO-assisted narrow-band imaging, and ALMA observations, we are now at the stage of resolving internal structures of individual galaxies to know the physical processes of galaxy formaiton in action and their environmental dependence. We will also review these on-going/future projects.

Witnessing the formation of galaxy clusters at redshift $z \sim 3$

Paola Andreani[1], Edwin Retana-Montenegro[2], et al.

[1] *ESO, Germany*
[2] *Leiden Observatory, NL*

ABSTRACT

We discuss the first results drawn from our APEX/LABOCA observations of two high-z candidate protoclusters, discovered in Herschel surveys.

APEX/LABOCA has followed up Herschel sources towards two fields containing an overdensity of objects. Fields have been selected through far-infrared colour criteria suited to pin point high-z sources, very likely physically associated to a lensed source at the same redshift.

APEX/LABOCA, together with Herschel, and near-IR observations are used to confirm the nature of these fields as hosts of a protocluster, which is strengthening the case of gravitational lensing as a tool to find high-z galaxy clusters in the process of formation. We discuss the identification and the nature of these sources, and the challenge that this kind of overdensities poses to current Cosmological models.

The progenitors of early-type galaxies in clusters and proto-clusters

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Abstract

Galaxy clusters and proto-clusters are the ideal environments to study the formation and evolution of early-type galaxies, and early probes of cosmology. Clusters at $z > 1.5$ are shown to host the star forming progenitors of their current red sequence early-type population. The next generation of wide-field infrared space missions, such as WFIRST and Euclid, will permit us to detect and characterize thousands of these massive objects by searching galaxy concentrations in imaging and grism spectroscopy, and study their galaxy proprieties with the next generation integral field units. We will present our recent cluster and protocluster detections in the HST CDF-S, CANDELS and SSDF fields using deep observations with Spitzer, the HST/WFC3 grism spectroscopy and VLT/KMOS IFU spectroscopy. We will discuss our results in terms of galaxy evolution and the formation of the massive early-type progenitors.

Galaxy Clusters around radio-loud AGN and their evolution across cosmic time

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Abstract

Powerful high redshift radio-loud AGN (RLAGN), are known to preferentially lie in overdense fields and are promising beacons for identifying large-scale structure and galaxy (proto)-clusters. However, due to the relatively small number of confirmed high-z clusters, it is still challenging to draw a clear picture of their formation and evolution.

I will present results of our large Spitzer program, CARLA (Clusters Around Radio-Loud AGN), that has targeted 420 RLAGN at $1.3 < z < 3.2$ for a total of more than 400 hours of Spitzer/IRAC time and that for the first time allows to systematically study the fields of a large sample of powerful RLAGN over a wide redshift range. Studying the density of red color-selected sources shows that ∼200 CARLA fields are rich and compact structures with overdensities established within cells of 0.5 Mpc (Wylezalek et al. 2013). The surface density proves that indeed most of the excess sources are associated with the targeted RLAGN. Two CARLA protoclusters have already been spectroscopically confirmed and more observations with KMOS/MUSE/MOSFIRE and HST are currently being analysed (Wylezalek et al. in prep., Noirot et al. in prep.).

This large (proto-)cluster sample also allows us for the first time at these redshifts, to systematically measure the luminosity function of clusters around RLAGN. Our measurements for m^* are consistent with passive evolution models and high formation redshifts ($z_f \sim 3$, Wylezalek et al. 2014). We find a slight trend toward fainter m^* for the richest clusters, implying that the most massive clusters in our sample could contain older stellar populations. The results are consistent with cosmic downsizing, as the clusters studied here were all found in the vicinity of RLAGNs – which have proven to be preferentially located in massive dark matter halos in the richest environments at high redshift – and they may therefore be older and more evolved systems than the general protocluster population.

The Environments of $z = 2.2$ Radio Galaxies as Traced by Hα Emitters

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Abstract

Radio galaxies are the most massive galaxies in the high redshift universe and are known to lie in protocluster environments. Feedback from the central AGN of the radio galaxy may affect the protocluster galaxies, perhaps suppressing star formation within these galaxies. We have studied seven $z = 2.2$ radio galaxies with HAWKI narrow band and broad band imaging in order to map out their environment using Hα emitters and to explore the effect the radio galaxy may be having on these companion galaxies. The results can be compared to the blank field HAE survey HiZELS (Sobral+12 etc.). We find that 60% (or 4 out of the 7) radio galaxy fields are overdense compared to the field, in agreement with Venemans et al. (2007) who used Lyman alpha emitters to map out the environment of radio galaxies. We also find that while the star formation rate (SFR) of the HAEs in the radio galaxy fields is higher the specific SFR is lower than for field galaxies of the same mass. This suggests that the radio galaxy fields have undergone rapid evolution that is now haltering, perhaps because the radio galaxy is heating the surrounding gas, stopping it accreting onto the companion galaxies and fueling their star formation.

Evolution at the edge: cold molecular CO(1-0) gas in the halos of high-z radio galaxies

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Abstract

To understand how hierarchical merging, gas accretion and feedback mechanisms drive early galaxy evolution, it is crucial to study the properties of cold molecular gas −the raw ingredient for star formation− in active galaxies at high redshifts. I will present result from an imaging-survey of cold molecular CO(1-0) gas in proto-cluster radio galaxies at $z \sim 2$, covering many hundreds of hours of observations at the Very Large Array and Australia Telescope Compact Array. We find tantalizing evidence that a large fraction of the CO(1-0) emission in high-z radio galaxies does not follow the bulk of the star formation. Instead, cold molecular gas is often spread on scales of many tens of kpc across the IGM in the halo environment. This may potentially provide direct observational evidence of predicted cold-flow accretion at high-z. In several cases, we find CO(1-0) emission just beyond the brightest edge of the radio source, indicating that jet-induced feedback can also play an important role in the cooling or formation of molecular halo gas. I will discuss how our results may shed a light on how these massive high-z proto-cluster radio galaxies will evolve into present-day giant central-cluster ellipticals. This project also highlights the crucial role of “intermediate-frequency” 20-50 GHz radio receivers in the ALMA/SKA era if we want to fully understand the important role of the cold IGM in the early evolution of the Universe.

Localising the star formation in high redshift radio galaxies

G. Drouart[1]

[1] *Chalmers University of Technology, Onsala Space Observatory*

Abstract

The HeRGÉ (*Herschel* Radio Galaxy Evolution) project consists of a representative sample of 70 powerful radio galaxies (HzRGs) spanning $1<z<5.2$. A combination of *Spitzer*, *Herschel* and submm observations allowed for a characterisation of their IR SED into a AGN and a starburst component. Interestingly, HzRGs simultaneously exhibit properties common to QSOs and SMGs at similar redshift. While the limited resolution of single dish observation does not provide information on the location and the origin of the star formation, UV to submm fitting with advanced models (AGN torus and PÉGASE, a galaxy evolutionary code) indicates that the observed starburst does not take necessarily place into the galaxy. More evidences for this scenario appears thanks to our recent ALMA cycle 2 observations.

Dynamical and structural analysis of a large-scale structure at $z = 0.65$ in CANDELS UDS

Audrey Galametz[1] and the CANDELS Clustering Collaboration

[1] *MPE, Garching*

Abstract

We report the discovery of a large-scale galaxy structure at $z = 0.65$ within the UKIDSS Ultra-Deep Survey. Several galaxy overdensities at $z_{phot} \sim 0.65$ were discovered in the CANDELS UDS field. An extended analysis over the full UKIDSS field of view shows that the structure is composed of a couple of tens galaxy clumps and spreads over more than $10h_{70}^{-1}$ Mpc. We have recently conducted a spectroscopic follow-up of the main knots of the structure and intra-structure filaments using the multi-object spectrograph VIMOS on VLT. We confirm the physical association of at least ten sub-structures. A background extended structure of several clumps at $z = 0.69$ as well as a number of foreground clusters at $z > 0.6$ were also spectroscopically confirmed. Embedded within one of the most observed astronomical wide fields and covered by extensive UV-to-mid-IR imaging, including HST imaging for the 5 Mpc inner part, this structure is one of the most optimal laboratory to investigate the environmental dependence of galaxy properties. We will present the general geometry of the structure, the nature of its different sub-components and the dynamical analysis of the system. We will also present preliminary absorption line measurements derived from the (medium resolution) optical spectroscopy that coupled with structural parameters from the high-resolution HST data permit to investigate the dependence with density of classical scaling relations e.g., between stellar masses, galaxy effective radii and measured velocity dispersion.

Identification of High-z Mergers through Resolved Mass Distributions

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Abstract

The presence of giant star-forming clumps in $z > 1$ disk galaxies strongly limits our ability to visually distinguish between normal galaxies and interacting systems, and thus to characterize the properties and frequency of high redshift mergers. Exploiting deep HUDF/CANDELS observations for a sample of $1.5 < z < 3$ galaxies, in combination with state-of-the-art numerical simulations of high-z mergers and isolated disks, we have found that structural parameters measured on stellar mass maps can offer a robust proxy for the full kinematic information. The morphological classification based on these mass-derived structural indicators results in a high fidelity sample of close-to-coalescence mergers and cannot be reproduced by H-band measurements alone, which are affected by a higher contamination from clumpy disks. I will discuss how the merger rate derived with this novel selection technique compare with other merger rate estimates to $z \leq 3$. Furthermore, combining the morphological classification with UV and Herschel FIR data, I will present the properties of mass-selected mergers in terms of, e.g., their location on the main sequence of star-forming galaxies and the relative importance of bursts occurring in clump sized or centrally concentrated regions with respect to a more diffuse star formation.

Protoclusters at $z \sim 3-6$ Probed by Wide-field Imaging

Jun Toshikawa[1], Nobunari Kashikawa[1], Roderik Overzier[2], Matthew A. Malkan[3], Shogo Ishikawa[1], Masafusa Onoue[1], Tanaka Masayuki[1], Yuu Niino[1]

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[2] *National Observatory of Brazil*
[3] *University of California, Los Angeles*

Abstract

We will present our systematic search for galaxy protoclusters at $z \sim$ 3-6. Protoclusters provide a great deal of information of early stage of cluster formation in large-scale structure and environmental effects on galaxy evolution. We investigated sky distributions of $z \sim$ 3-6 galaxies, selected by the dropout technique, in wide fields of the CFHT Legacy Survey Deep Fields and identified eighteen protocluster candidates. We have carried out follow-up spectroscopies on eight of these candidates (two candidates were observed at each redshift) by using the Subaru, Keck, and Gemini telescopes. We could confirm that some actual clustering structures in narrow redshift range by detecting their Lyα emissions, even at $z \sim 6$. These discoveries were achieved in "random fields"; that is, QSOs or radio galaxies were not used as protocluster probes. Based on these systematic observations, we will discuss structure evolution in protoclusters and possible different properties of protocluster galaxies from field galaxies from $z \sim 6$ to $z \sim 3$ by comparing with theoretical model.

Galaxy correlation functions in the CANDELS fields

Catherine White[1], Harry Ferguson[2]

[1] *Johns Hopkins University*
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Abstract

Galaxy angular clustering statistics contain information about how galaxies populate halos. It has been found that nearby galaxies' clustering is dependent on color: redder galaxies are more strongly clustered than blue galaxies, implying that red galaxies tend to live in denser environments than blue galaxies. Galaxies also tend to be the same color as their neighbors, an effect known as galaxy conformity. We will present the clustering statistics of galaxies in the CANDELS fields at higher redshifts, $2 < z < 6$, specifically auto- and cross-correlations of galaxies in bins of color and luminosity. The presence or absence of the low redshift trends at higher redshift will shed light on how galaxies form and cluster over most of the age of the universe.

Investigating the acceleration of galaxy growth in a $z = 3$ protocluster

Nancy Hine[1], Jim Geach[1], Kirsten Coppin[1], Jason Stevens[1]

[1] *University of Hertfordshire*

Abstract

One route to accelerated galaxy growth in the very densest environments in the Universe at early epochs (protoclusters) is via an earlier onset / higher frequency of major mergers which trigger star formation and black hole growth compared to galaxies in the average density field. If this is the case, one would expect the relative fraction of normal galaxies exhibiting on-going merger and tidal interactions in protocluster regions to be different to that of an identically (mass) selected field population. We have examined the rest-frame UV morphologies of Lyman-break Galaxies (LBGs) in the SSA22 protocluster at $z = 3.1$ compared to LBGs at $z \sim 3$ in the HDF-N. Our results indicate that the merger fraction for the protocluster is significantly larger than that for the field suggesting that dense environments may indeed have higher merger fractions than the field at $z \sim 3$.

The role of the stellar mass and the environment in shaping galaxy properties at different redshifts

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Abstract

Distinguishing the separate contributions of environmental versus in situ processes is critical to understanding galaxy evolution. Observational studies have had increasing success quantifying the role of environment and mass in shaping galaxy properties. I will show how color and morphological fractions depend both on mass and environment and how they evolve with time. I will focus on those galaxies that show signs of an ongoing or recent transformation of their star formation activity and/or morphology, and propose an evolutionary scenario for the different subpopulations.

To understand how mass and environment co-work, it is important to understand how they are related. I will present a detailed analysis of the galaxy stellar mass function, both from an observational and theoretical point of view. The observed galaxy stellar mass function is very similar in the field, groups and clusters and its evolution with time (from $z = 0.6$ to 0) does not depend on environment. Semi-analytic models are not able to fully reproduce the observational results, indicating that the adopted recipes to model the evolution of central and satellite galaxies still have to be better implemented in simulations.

Poster Presentations

The reversal of the star formation - density relation in a high redshift galaxy cluster

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[2] *INAF-Osservatorio Astrofisico di Arcetri, Italy*

Abstract

In the local universe the cores of massive galaxy clusters are typically dominated by red passive galaxies with old stellar populations, and low-level star-forming galaxies are usually located at the cluster outskirts. A 'red sequence' of galaxies is already in place for these clusters up to $z \sim 1.5$, so the peak epoch of mass assembly in high density environments must reside at higher redshifts. We report on Herschel observations of the massive cluster XDCP0044-2033 ($z = 1.58$) that shows a strikingly high amount of star formation in the cluster core (< 250 kpc), of more than 1000 solar masses / year, unprecedented in a galaxy cluster. This brings evidence that we start to see the long sought reversal of the star formation density relation at high redshift in high density environments. I shall discuss the on-going search to detect high-redshift star-forming clusters with Planck/Herschel observations and the longer term prospect of future survey missions, like Euclid.

Giants towards the Edge of the Universe: Mpc-scale radio galaxies at low and high redshift

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Abstract

Giant radio galaxies (GRGs) are those with a projected linear size LLS >1 Mpc/h_{75}, and only about 150 of them are reported in the literature. In recent efforts of our research team we have used automated algorithms as well as visual inspection of large-scale radio surveys like NVSS, WENSS, SUMSS and FIRST, to increase the number of known GRGs. These methods, together with findings of volunteers of the Radio Galaxy Zoo project, have led us to increase the number of known GRGs to over 500.

Here we restrict ourselves to the 193 GRGs with optical spectra of their hosts available in SDSS DR12, and classify these according to their activity type, namely QSOs, Sy1, Sy2, LINER, dwarf AGN, and those without emission lines. We find that GRGs are hosted by galaxies of all these types. We divide the sample in a low- and high-redshift one at their median redshift ($z \sim 0.4$), giving 91 low-z and 102 high-z GRGs. We find a clear difference between the two samples, suggesting a much higher level of activity at z >0.4: the fraction of QSO+Sy1 types is 40% at low z, and 80% at higher z. Likewise, the fraction of dwarf AGN is 30% at low z and only 10% at $z > 0.4$. Since there is no significant trend for the linear sizes of the sources to change with redshift, we conclude that the evolution in spectral activity occurs on a shorter time scale than that of the radio activity. This would be consistent with the view that GRGs grow so large because they have a longer period of radio activity compared to smaller sources, and that the radio activity depends more on the *efficiency* of accretion onto the central black hole rather than on the accretion *rate*.

We classify the radio morphology into Fanaroff-Riley classes FR I and FR II and find that FR I's occur almost exclusively at z <0.4. Contrary to the accepted paradigm, for these low-z GRGs we find no segregation in radio luminosity at all between FR I and II types.

Cosmology using Strong Lensing with H-ATLAS: The first steps towards a 1000-lens sample

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Abstract

Gravitational lensing promises to be an important tool for cosmology. For example, an unbiased sample of 1000 lenses could determine Ω_Λ with an error of 1%, similar to the state-of-the-art Planck and supernova surveys. However, currently the largest sample contains less than 100 lenses. A shallow, 550 square degree, far-infrared survey by Herschel (H-ATLAS) revealed a large number of potentially lensed sources, possibly allowing us to realise an unbiased 1000-lens survey. To test this possibility, we are investigating the brightest, high-redshift H-ATLAS sources, which have luminosities typical of lensed galaxies. We have observed 217 out of 236 sources at 850 μm with the SCUBA-2 instrument on the James Clerk Maxwell Telescope (JCMT). These observations will provide better estimates of photometric redshifts, and in turn, of luminosities. We determine the probability that the sources are lensed by by comparing their luminosities to the expected luminosity functions. We will present the results of this project, and describe our current plans towards a 1000 lens sample, which might provide a low-cost and complementary method to constraining the cosmological parameters.

The low surface brightness haloes of massive galaxies in ultradeep imaging and their relative importance

Fernando Buitrago[1]

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Abstract

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

Emission line galaxies from the SHARDS medium-band ultra deep survey.

Antonio Cava[1] & SHARDS team[2]

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Abstract

SHARDS (Survey for High-z Absorption Red & Dead Sources) is an unbiased ultra-deep spectro-photometric survey with OSIRIS@GTC aimed at selecting and studying massive passively evolving galaxies at z=1.0–2.3 using a set of 25 medium-band optical filters (FWHM 15–17nm, 500–950 nm) in GOODS-N. Nonetheless, the data quality allows a plethora of studies on galaxy populations, including emission lines galaxies and AGN. We exploit the SHARDS dataset to select star forming galaxies through their [OII] line emission and to investigate their physical properties. Equivalent widths, line fluxes, luminosities, star formation rates and extinction properties of this galaxy population are investigated. Special attention is devoted to the study of the attenuation law through the use of multi-wavelength data and comparing UV-/IR-/[OII]-selected samples. The ultra-deep SHARDS data, thanks to their relatively good equivalent spectral resolution (R$\sim$50), demonstrate to be a powerful tool for the detection and study of high-redshift star forming galaxies.

The Co-evolution of QSOs and Galaxies

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[1] *Departamento de Astronomía, Universidad de Guanajuato, Guanajuato, Mexico*

Abstract

Using two large samples of QSOs detected in the mid-infrared (MIR) with WISE, we show that their W2−W3 colors vary with redshift in a way that suggests the following trend of star formation in their host galaxies: from $z = 0$ to $z = 2.7$ star formation increases by a factor of 3, then stays constant up to $z = 4$, and decreases again at higher redshift. This behavior is slightly different from the best fits for the star formation history of field galaxies as deduced from the Optical-UV and IR, but is consistent with was is observed for submillimeter galaxies at high redshift.

Our results form the clearest evidence, so far, that the host galaxies of QSOs form their stars before field galaxies, and is in good agreement with the hierarchical biased structure formation paradigm.

Emission Line Galaxies in CANDELS: Equivalent Width Distributions from Broadband Photometry at $z < 2$

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Abstract

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

Unavoidable uncertainty in the observed luminosity of galaxies at high redshifts

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Abstract

Gravitational lensing modifies properties of the observable galaxies by having impact on their number densities, shapes and brightness. As a result, the observed luminosity function (LF), the main topic of my talk, can be significantly different from the intrinsic one. Since the LF is one of the primary inputs we have from distant populations of bright objects, it is highly important to understand the impact of weak (and strong) gravitational lensing on the LF. In this talk I will elaborate on how to model the effect of weak gravitational lensing statistically, as well as on how do parameters of the observed luminosity function depend on the underlying foreground field of galaxies.

The Extremely Wide-Field gzK Galaxy Survey

Shogo Ishikawa[1,2], Nobunari Kashikawa[1,2], Takashi Hamana[2], Jun Toshikawa[1,2], and Onoue Masafusa[1,2]

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[2] *National Astronomical Observatory of Japan*

Abstract

We present the clustering properties of star-forming galaxies at $z \sim 2$ and discuss the dark halo masses and their evolution from the accurate clustering analysis. By applying the gzK selection method over 5 deg^2 based upon the Subaru and CFHT/UKIRT public archival data, we obtained a large sample of 41,112 star-forming galaxies (sgzKs) at $z \sim 2$ down to $K < 23.0$. We obtained high-quality two-point angular correlation functions (ACFs) and found that clustering strength depends upon a galaxy luminosity, which is consistent with previous studies. Our ACFs show an apparent excess from the power-law at small angular scale, enabling more detailed estimation of dark halo mass by the HOD analysis, which is formulated by 1-halo term and 2-halo term. We derived the stellar-to-halo mass ratio (SHMR), which indicates that star-formation efficiency at $z \sim 2$ drops in massive dark halo compared with the local Universe. Moreover, We discuss the relation between sgzKs and local SDSS galaxies and Lyman break galaxies at $z \sim 4$ by tracing the evolution of the dark halo.

Construction of the Spectral Energy Distribution Model of Galaxies and Application to Observational Data

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Abstract

Heavy elements are formed by nucleosynthesis in the process of steller evolution, and significant fractions of them are emitted to interstellar space as dust grains. Dust grains scatter and absorb the ultraviolet and optical emission from massive stars, and re-emit in the infrared. To understand the intrinsic properties of galaxies, we must take into account both of dust extinction and re-emission. In this study, we constructed a spectral energy distribution (SED) model which is consistent with chemical evolution of galaxies by considering dust extinction and re-emission. By fitting our SED model to observational data, we can estimate star formation rate, metallicity, dust abundance and other important quantities of galaxies. Further, we are able to use this model for data obtained from high-z observations because our SED model is consistent with chemical evolution, in other words, physically more realistic.

Evolution of the Hβ+[OIII] and [OII] Luminosity Functions and the [OII] Star-Formation History of the Universe up to $z \sim 5$ from HiZELS

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Abstract

We unveil the evolution of the Hβ+[OIII] and [OII] luminosity functions and star formation histories from $z \sim 0.8$ to 4.7 using data from HiZELS. This is the first time that the Hβ+[OIII] and [OII] luminosity functions and star formation histories have been studied at these redshifts in a self-consistent analysis. This is also the largest sample of Hβ+[OIII] and [OII] emitters in this redshift range, with a large comoving volume coverage of $\sim 1 \times 10^6$ Mpc^3 in two independent volumes (COSMOS and UDS), greatly reducing the effects of cosmic variance. We find significant evolution in both $L_\star$ and $\phi_\star$ for both emitters. Our predicted [OIII] LFs shows that, in comparison to our Hβ+[OIII] LF and AGN LFs, our Hβ+[OIII] samples are dominated by star-forming, [OIII] emitters. We will also present the cosmic star-formation history based only on [OII] emitters up to $z \sim 5$ (to reduce bias effects from different tracers) and find that the peak of star-formation occurred around $z \sim 3$. For the $z < 2$ measurements, we find that our [OII] star-formation rate densities (SFRDs) are in agreement with Hα and stacked radio studies, suggesting that our sample is representative of a star-forming population. Our star formation history is able to recover the stellar mass density evolution. Interestingly, we also find that the Hβ+[OIII] SFRDs are in agreement with other star-forming results in the literature, suggesting that even our Hβ+[OIII] sample is dominated by star-forming galaxies.

Galaxy morphology at $0.5 < z < 1.0$ with VIPERS

Janusz Krywult[1], Agnieszka Pollo[2]

[1] *Jan Kochanowski University, Poland*
[2] *Jagiellonian University and National Centre for Nuclear Research, Poland*

Abstract

The ongoing VIMOS Public Extragalactic Redshift Survey (VIPERS) enable a detailed analysis of the distribution and physical properties of galaxies in the redshift range $0.5 < z < 1.2$. Based on the first 57,000 VIPERS spectroscopic measurements, photometry and structural parameters of galaxies obtained from the Sersic profile fitting to the CCD images coming from CFHTLS survey we analyse the morphological properties of galaxies. Using multi-band photometry and Sersic parameters galaxies were divided into the early-type, late-type and intermediate population. We analyze and compare each galaxy sample and discuss physical correlation between morphological parameters of galaxies and their colour and other properties like luminosities and stellar masses. In addition we study the redshift evolution of these relation.

First IR-based implications for the dust attenuation and star formation of typical LAEs

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Abstract

Measuring the IR luminosity of galaxies is crucial for reliably deriving their dust attenuation and stellar population. We stack publicly available deep Spitzer/MIPS 24 μm (Magnelli et al. 2011) and Herschel PACS images (Lutz et al. 2011; Elbaz et al. 2011; Magnelli et al. 2013) for 213 $z \simeq 2.18$ Lyα Emitters (LAEs) in the GOODS-South. We obtain a strong upper limit to the IR luminosity of typical high-redshift LAEs and constrain the attenuation curve for the first time. The very low 3σ upper limit $L_{\rm TIR}^{3\sigma} = 1.1 \times 10^{10} L_\odot$, obtained from the MIPS data, implies that LAEs have little contribution to the faint (≥ 100 μJy) number counts of submm galaxies by ALMA (Hatsukade et al. 2013; Ono et al. 2014). This $L_{\rm TIR}^{3\sigma}$ gives $IRX \equiv L_{\rm TIR}/L_{\rm UV} \leq 2.2$, or $A_{1600} \leq 0.9$ mag, indicating that dust attenuation is remarkably small. Indeed, the inferred escape fractions of Lyα, 16–37%, and of UV continuum, $\geq$ 44%, are both significantly higher than the cosmic averages at the same epoch (Hayes et al. 2011; Burgarella et al. 2013). We find that the SMC attenuation curve (Pettini et al. 1998) is consistent with the IRX and the UV slope $\beta = -1.4^{+0.2}_{-0.2}$ of our stacked LAE, while the Meurer's relation predicts a 3.8 times higher IRX at this β. SED fitting using the Calzetti curve (Meurer et al. 1999; Calzetti et al. 2000) also gives a ~ 10 times higher SFR than that calculated from the IR and UV luminosities, $SFR_{\rm tot,IR+UV} = 1.5$–$3.3$ M$_\odot$yr^{-1}. Thus, the SMC curve is preferred. With the stellar mass $6.3^{+0.8}_{-2.0} \times 10^8M_\odot$, our LAEs lie on a lower-mass extrapolation of the star formation main sequence at $z \sim 2$ (Daddi et al. 2007; Rodighiero et al. 2011). It suggests that the majority of $z \sim 2$ LAEs are mildly forming stars with relatively old ages of ~ 200 Myr. Note that adopting the Calzetti curve leads us to conclude that they are in the burst mode similar to brighter LAEs (Hagen et al. 2014; Vargas et al. 2014). Finally we will discuss the possibility of constraining the attenuation curve and star formation mode of luminous LAEs by ALMA.

Some of the details of this work are written in Kusakabe et al. (2014), ApJL, 800, L29

GASiFy: A multiwavelength survey of local galaxies with high sSFR

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Abstract

We are conducting a survey of HI, CO, and optical IFU observations of a large sample of nearby galaxies with high specific star-formation rates (sSFR). Their sSFR are akin to star-forming galaxies commonly surveyed at high redshift and span a wide range of stellar masses, $10^{8-10.7}$ $M_\odot$. The results are fasincating suggesting that these galaxies share many properties with their high redshift bretheren such as high gas fractions, high ISM pressures, and clumpy star formation. The advantage of such a survey of local galaxies is that we can discover some aspects that are unknown about or impossible to study in distant galaxies, such as their HI content. Studies such as this one are important to put surveys of high redshift galaxies into their proper astrophysical context – this is the main point of this presentation.

Probing the spatial distribution of star formation in distant ULIRG with ALMA

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Abstract

Evidence that distant ultra-luminous infrared galaxies (ULIRGs) exhibit a wider range of properties than local ones suggests that the physics involved in these distant highly star-forming systems is not limited to the major merger triggering of compact starbursts as it is locally. The finding of a tight scaling law linking the star-formation rate (SFR) of galaxies to their stellar mass up to z$\sim$3 or more suggests that instead it is extragalactic gas infall that regulates star-formation even in most of these systems. A sample of z$\sim$2 ULIRGs has been selected to be observed during ALMA Cycle 1 (band 7) to probe the projected spatial distribution of star-formation in these galaxies spanning a range of "starburstiness" (excess SFR for their mass at their redshift) and Herschel vs Spitzer color index ($IR8$=$L_{IR}/L_{8\mu m}$) - sensitive to the destructive power of concentrated massive stellar light on PAHs. The goal of this work is not only determine typical sizes, but IR surface brightness, since distant ULIRGs are particularly irregular in shape. This preliminary report will show a comparison of these high-z observations to local ULIRGs, see if they fall on the same relations than those observed for local star-forming galaxies and compare their obscured vs rest-frame UV and optical light to spatially resolve optically thick star-forming regions and better understand the far-IR vs UV relation.

The most luminous, dusty star-forming galaxies at high redshift discovered by Herschel: the ALMA view

Rui Marques-Chaves[1,2], Ismael Perez-Fournon[1,2], Paloma Martinez-Navajas[1,2], Alexander Conley[3], Dominik Riechers[4], Rob Ivison[5], David Clements[6], Helmut Dannerbauer[7], Viktoria Asboth[8], Frank Bertoldi[9], James Bock[10,11], Shane Bussmann[4], Asantha Cooray[12], C. Darren Dowell[10,11], Duncan Farrah[13], Jason Glenn[3], Nicolas Laporte[14], Sebastian Oliver[15], Alain Omont[16], Joaquin Vieira[17], Marco Viero[9], Julie Wardlow[18] and the HerMES collaboration[19]

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[19] *http://hermes.sussex.ac.uk/*

Abstract

Very high redshift galaxies have been discovered by optical and near-infrared deep surveys. However, they are typically not very massive and present star formation rates up to several hundred solar masses per year (Finkelstein et al. 2013, Nature, 502, 524). The Herschel Multi-tiered Extragalactic Survey (HerMES, Oliver et al. 2012, MNRAS, 424, 1614), the largest project that has being carried out with the Herschel Space Observatory, has discovered massive, maximum-starburst galaxies up to a redshift of 6.34 (Riechers et al. 2013, Nature, 496, 329; Dowell et al. 2014, ApJ, 780, 75). The discovery of these dusty star-forming galaxies (DSFGs) at high-z challenges current theoretical models of galaxy formation and have become a critical player in our understandig of cosmic galaxy evolution. We will describe the method we had developed to find these dusty, massive, star forming galaxies at z > 4 based on Herschel/SPIRE colours and present results from multi-wavelength follow-up observations, including recent ALMA cycle 2 spectroscopy.

Star-forming galaxies at the edge of the universe

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Abstract

The most fundamental observational properties that need to be determined to obtain a comprehensive understanding of the physical processes of galaxy formation and evolution are the cosmic star formation history of the Universe and the volume-averaged star formation rate as a function of epoch. However, determining these quantities with high accuracy alone are insufficient for our understanding of galaxy formation and evolution. Which physical mechanisms drive the evolution and how do they depend on environment? Previous studies have made considerable progress in recent years, but even so their measurements are affected by significant scatter and uncertainties due to the use of different star-formation indicators, worsened by small area sampling and the effects of cosmic variance. We aim at overcoming these issues by using wide-feld, sensitive un-biased surveys of star-forming galaxies at a range of redshifts. The High-redshift Emission Line Survey (HiZELS) is a successful panoramic extragalactic survey which uses the narrow-band technique (in the J, H and K bands) to search for emission line galaxies and primarily targets H emitters at $z = 0,84$; $1,47$ and $2,23$. We present preliminary results from the the spectroscopic follow-up of line-emitting galaxies from HiZELS, especially to study the non-H alpha populations, and from a survey of Lyman emitters at $z > 7$ within the Epoch of Reionisation.

Extremely red K-[3.6] galaxies: a candidate passive population at $z \sim 6$

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Abstract

With a combination of ultra deep and wide infrared survey data from the *Spitzer* Extended Deep Survey (SEDS) and the UKIRT Infrared Deep Sky Survey, we selected objects satisfying $K - [3.6] > 1.3$. From spectral energy distribution (SED) fitting, we found our color selection identifies a variety of galaxy types, including (1) post-starburst galaxies at $z \geq 5$, (2) dusty star-forming galaxies at $z < 4$, (3) nebular line emitters at $z > 4$, and (4) Type-2 AGNs. Significant fraction of red $K - [3.6]$ galaxies are identified as AGNs or dust obscured galaxies at $z = 1 - 4$. While we failed to isolate significant fitting solutions individually for the remaining red galaxies, we identified some candidates of passive galaxies at $z \geq 5$ which are characterized by relatively blue $[3.6] - [4.5]$ colors. Stacked SED of the three candidates in the SEDS UDS field is well fit by the post-starburst template with $\mathrm{M}_* = (5.8 \pm 0.8) \times 10^{10}\,\mathrm{M}_\odot$ at $z \sim 6$. The stellar mass density of these post-starburst galaxy candidates, $(8.2 \pm 4.8) \times 10^{-7}\,\mathrm{M}_\odot\,\mathrm{Mpc}^{-3}$, is much lower than that of star-forming galaxies, but the non-zero fraction suggests that initial star-formation and quenching have been completed by $z \sim 6$. We also discuss this observational results with the recent semi-analytic model galaxies.

The evolution of faint radio sources in the XMM-LSS field

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Abstract

One of the primary goals of the SKA continuum surveys is to map the cosmic evolution of star-forming galaxies and AGN out to high redshift. Achieving these goals relies on multi-wavelength complementary datasets to separate the AGN and star-forming galaxy contributions to the faint radio population and to obtain photometric redshift estimates for a large fraction of the detected radio sources. In this talk I will present a multi-wavelength investigation of the evolution of faint radio sources out to z $\sim$2.5. This study combines a 1 square degree VLA radio survey, complete to a depth of 100μJy, with accurate 10 band photometric redshifts from the VIDEO and CFHTLS surveys. The results indicate that the radio population experiences mild positive evolution out to z$\sim$1.2 increasing their space density by a factor of $\sim$3, consistent with results of several previous studies. Beyond z=1.2 there is evidence of a slowing down of this evolution. Star-forming galaxies drive the more rapid evolution at low redshifts, z<1.2, while more slowly evolving AGN populations dominate at higher redshifts resulting in a decline in the evolution of the radio luminosity function at z>1.2

The formation of Passive Disc Galaxies found at redshifts between 1 and 3

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Abstract

How a galaxy becomes passive, but still showing a disc-dominated light profile (aka, Passive Disc Galaxy, PDG), can be explained by different mechanisms, each with strong or weak points (e.g., Bundy et al.2010). By going to early cosmic times, one limits the mechanisms inducing the PDG phase to those which act faster, thus reducing the scenario degeneracy. This work exploits an easy colour selection based on infra-red bands (Ks, $4.5\,\mu$m, $8.0\,\mu$m, $24\,\mu$m), which selects $z > 1$ galaxies with reduced or no dust emission (either heated by star-formation or galactic nuclei activities), candidates for passive or dust-free galaxies. Based on the morphological analysis based on HST-ACS+WFC3 imaging, one can then select disc-dominated sources among the colour-selected sample. The panchromatic data-set available in GOODS-N/S allows one to compare the rest-frame optically bluer and redder selected samples, allowing one to explore the mechanism(s) inducing the PDG phase.

VISTA NB118 narrow-band observations: first results

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Abstract

VISTA has observed 1.8 square degrees of the COSMOS field in four broad band filters (YJHKs) and in a narrow-band filter at 1.19 micron (NB118). The data come from the ongoing UltraVISTA survey and from our GTO programme. The NB118 filter corresponds to Lyman alpha at z=8.8, although such galaxies are only expected to be detected in the full 8 year UltraVISTA data. The filter also selects Halpha at z=0.8, [OIII] and Hbeta at z=1.4, and [OII] at z=2.2, and the current dataset contains several thousands of such emitters. I will report the first results on these narrow band selected emission line galaxies.

Progenitor Study of Milky-Way-Like Galaxies over the Cosmic High Noon

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Abstract

In this study we utilize the *HST*/WFC3 and ACS multi-band imaging data taken in CANDELS and 3D-HST surveys to trace the average properties of the progenitors of the Milky Way (MWs) and massive galaxy (MGs) at $0.5 \leq z \leq 3.0$ based on constant number densities. After careful data reduction and stacking analysis, we conduct the radially resolved SED fitting to see the radial profiles of stellar mass and rest-frame color. We find that MWs evolve the mass profiles in self-similar way, while MGs in inside-out where they obtain $\sim 80\%$ of the total mass at outer (> 2.5 kpc) radii. The radial color profiles show that the quenching depends on the distance from its center, which suggests several quenching mechanisms such as morphological quenching and suppression of gas infall into the center. Further effort is made, based on the derived average profile and its dispersion, to evaluate the morphological varieties and their evolution for the first time. By comparing them with the observed star formation rates and color profiles, the results are consistently explained by the star formation activities and manifestation of the Hubble sequence at $z \sim 1$.

22 square degrees to probe the galaxy stellar mass function and density evolutions since $z = 1.5$

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Abstract

I will present multi-wavelength observations undertaken in the area of the VIPERS survey. They include K band photometry (with WIRCam at CFHT) over 22 deg^2 and deep NUV photometry (GALEX satellite) over 12 deg^2. Combined with the CFHTLS photometry and a large spectroscopic sample ($> 50,000$ redshifts), our photometric redshift catalogue reaches an accuracy of 3-5% out to $z = 1.5$. With $\sim 900,000$ galaxies down to $K \sim 22$ and the large volume explored (reduced cosmic variance), we provide unique constraints on the massive galaxy Stellar Mass Function (SMF) and the stellar mass density evolutions from $z = 0.2$ up to $z = 1.5$. By splitting the sample between star-forming and quiescent galaxies, we explore the different characteristics of the processes involved in the quenching of the star-forming galaxies. Our results confirm a scenario where the galaxy star formation is impeded above a certain mass. We also report a clear excess of low mass passive galaxies at low redshift, which stresses the need of at least one other quenching channel. I will show comparison with recent model predictions and discuss the link between galaxy stellar mass and Dark Matter halo mass.

Properties of Submillimeter Galaxies in a Semi-analytic Model using the "Count Matching" Approach: Application to the ECDF-S

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Abstract

We present a new technique for modeling submillimeter galaxies (SMGs): the "Count Matching" approach. Using lightcones drawn from a semi-analytic model of galaxy formation, we choose physical galaxy properties given by the model as proxies for their submillimeter luminosities, assuming a monotonic relationship. As recent interferometric observations of the Extended Chandra Deep Field South show that the brightest sources detected by single-dish telescopes are comprised by emission from multiple fainter sources, we assign the submillimeter fluxes so that the combined LABOCA plus bright-end ALMA observed number counts for this field are reproduced. After turning the model catalogs given by the proxies into submillimeter maps, we perform a source extraction to include the effects of the observational process on the recovered counts and galaxy properties. We find that for all proxies, there are lines of sight giving counts consistent with those derived from LABOCA observations, even for input sources with randomized positions in the simulated map. Comparing the recovered redshift, stellar mass and host halo mass distributions for model SMGs with observational data, we find that the best among the proposed proxies is that in which the submillimeter luminosity increases monotonically with the product between dust mass and SFR. This proxy naturally reproduces a positive trend between SFR and bolometric IR luminosity. The majority of components of blended sources are spatially unassociated.

Confirming $z \approx 2$ galaxy clusters with HST grism spectroscopy

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Abstract

Galaxy clusters are known to form in the densest regions of the universe. Also, they are the most massive collasped and gravitationally bound structures, being therefore unique laboratories for studying growth of structures over cosmic time. Particularly, among galaxy clusters, the most distant ones are key objects to test different models of structure formation and evolution. Indeed, studying high redshift galaxy clusters and their environments is necessary to reveal how clustured galaxies evolve from young and highly star forming systems to the old and passive structures seen at low redshifts.

Based on the unique Clusters Around Radio-Loud AGN (CARLA; Wylezalek et al., 2013) catalogue in terms of size, depth, and uniformity gathering 420 cluster and proto-cluster candidates obtained from a Spitzer/IRAC survey, I will present the first analyses and results of a Cycle 22 HST follow-up programme targeting the 20 most overdenses CARLA fields. These powerful radio-loud AGN fields had been IRAC-colour-selected to reside at high redshifts in the range $1.3 < z < 3.2$. Newly obtained follow-up data, from WFC3 grism spectroscopy on-board the HST, allow to confirm the redshifts of the sources, and study their galaxy stellar populations, ages, and star formation rate at the time of the clusters' assembly epoch.

The Nature of the MicroJy Radio Source Population

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Abstract

We explore the nature of the microJy radio source population using the deepest ever image obtained at 610 MHz with the GMRT covering 1 deg^2 within the ELAIS N1 field down to a rms noise of 10 μJy and detecting 2800 sources. These observations are complemented by a JVLA 5 GHz image over a smaller area (0.1 deg^2) down to a rms noise of 1 μJy. These data probe the radio source population at flux densities well below the regime dominated by classical radio galaxies and Active Galactic Nuclei. We have matched 85% of the radio population to Spitzer/IRAC and obtained a redshift estimate for 63%. For the sources with redshifts, we have carried out a multi-wavelength study using Optical, Near-Infrared, Spitzer and Herschel data. We use a classification scheme based on X-ray emission, QSO-like SDSS spectroscopy, IRAC colours, and radio-loud AGN flags defined by the logarithmic ratio of the Far-IR to radio flux densities. On the basis of this classification, we find that at least 20% of the sources with redshifts are AGNs while the remaining are adopted as SFGs. We explore the evolution of the Far-IR radio correlation of our SFGs with redshift by binning in radio and infrared luminosities and we find evidence that the median value of the far-IR/radio luminosity decreases with increasing radio luminosity.

Hot-dust (690 K) Luminosity Density and its Evolution in the Last 7.5 Gyr

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Abstract

We study the contribution of hot-dust to the luminosity density of galaxies and its evolution with cosmic time. Using the *Spitzer*-IRAC data over an area of 1.8 deg^2 covered by the COSMOS field, we estimate the contribution from hot-dust at rest-frame 4.2 μm (from $0 < z < 0.2$ up to $0.5 < z < 0.9$). This wavelength corresponds to black-body temperature of $\sim$ 690 K. The contribution due to stellar emission is estimated from the rest-frame 1.6 μm luminosity (assumed to result from stellar emission alone) and subtracted from the mid-infrared luminosity of galaxies to measure hot-dust emission. The results to be presented in this poster are the continuation of the work shown in Messias et al.(2013), and are part of an on-going master-thesis work. The current goals are the identification of possible biases affecting the 2013 work and the direct comparison of the hot-dust component with the cold one observed at longer wavelengths with *Herschel*.

A panchromatic view of the Herschel Virgo Cluster Survey background sources

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Abstract

The evolution of galaxies is set by a complex mechanism of recycling between the stellar and the gaseous components, a process that evolves with time and depends strictly on the reservoir of gas and dust available for the star formation. In order to investigate these processes in nearby Universe, we built a sample of ∼2000 galaxies selected at 250 μm at $z < 0.4$ for which we have robust estimation of flux densities between 60 and 500 μm. We joined to these data photometry estimation obtained with Galex, SDSS, 2MASS, and WISE to have a multi-wavelengths view of each source. We then apply an energy-balanced technique of SED fitting (MAGPHYS) and we estimate different physical parameters, such as star formation, stellar mass, and total IR luminosities. Galaxies at $z \sim 0.1$ have typical Dust Mass of 10^8 $M_{\odot}$, and span a high range of star formation rate, between 0.001 to 50 $M_{\odot} yr^{-1}$. We investigate also the impact of removing different data set from the SED fitting procedure. We found that Mid Infra red wavelengths, i.e. WISE data, have a strong impact in determining the balance between the gas component heated by the interstellar radiation field and the gas component heated in young clouds through star formation.

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

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Abstract

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

Structural Evolution of Hα selected galaxies from HiZELS

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Abstract

Understanding the evolution of galaxies across cosmic time is the cornerstone of modern extragalactic astrophysics and, as new and revolutionary instruments and surveys become available, many questions that have so far been unanswered can finally be tackled.

Using Hα narrow-band imaging over very large areas through the HiZELS survey, we have obtained samples of thousands of galaxies selected in a consistent way since $z \sim 2.5$ until today. A sub-sample is currently being observed with SINFONI and KMOS to provide spatially resolved spectral information of these targets. This allows for the mapping of the galactic properties namely dynamics, star formation and metallicities on a few kilo parsecs scale for hundreds of galaxies.

Here we present the detailed structural analysis of both KMOS followed-up galaxies, but also the more general parent samples and on a local sample observed with CALIFA by running GALFIT (Peng et al., 2002, 2010). We compare their morphological information (size, Sérsic index, ellipticity) with the available Hα maps and explore correlations with related quantities such as SFR, stellar mass and rest-frame colours. We finish by presenting the little evolution in most correlations, apart from those that directly depend on SFR.

Comparison of FIR properties between BAL and non-BAL AGN

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Abstract

Using a sample of 600 quasars detected by the Sloan Digital Sky Survey (SDSS), as well as the Spectral Photometric Imaging Receiver (SPIRE) instrument of *Herschel*, we aim to describe the overall impact of an active nucleus on its host galaxy. We wish to better understand the onset of star formation and active galactic nuclei (AGN) activity, along with how the two phenomena affect one another over the history of the Universe.

To achieve this, we use a spectral energy distribution (SED) fitting technique to quantify the far-infrared emission of our objects, as this wavelength regime probes the cold dust heated by star formation in AGN hosts. As such, we can easily extract the star formation rates (SFRs) of these host galaxies from the output of the SED fit. Our sample includes 51 high-ionization broad absorption line quasars, which we study with particular care to ascertain whether the SFRs in their respective host galaxies deviate from those of the hosts of quasars that do not exhibit broad absorption lines in their spectra.

VIPERS: mass, light and dark energy half a way to the edge of the Universe

Agnieszka Pollo[1,2] for the VIPERS team

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Abstract

Complex relations between the evolution of large scale structure of the Universe, its "dark" content, and galaxies are among today's key cosmological problems. I will present the current status and recent results of the ongoing VIMOS Public Extragalactic Redshift Survey (VIPERS) which allows us for a new insight into studies of the Universe at $z \sim 1$. Thanks to its unsurpassed statistics (it is planned to measure $\sim 100,000$ spectroscopic redshifts at $0.5 < z < 1.2$, and more than a half of this number was already released to the astronomical community), high sampling rate and volume, VIPERS is already becoming comparable to local large galaxy surveys. It will let us trace galaxy clustering with a much higher accuracy than ever before at $z \sim 1$. I will show how, using the VIPERS data, we investigate the evolution of galaxy properties and clustering, between $z \sim 1$ and the present epoch and what are the consequences of its measurement for our understanding of co-evolution of dark matter density field, dark energy and galaxies themselves.

The connexion between galaxy morphology and spectrophotometric properties since $z \sim 6$

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Abstract

The global properties of galaxies show a strong evolution of the star formation rate and stellar mass density at the epoch of galaxy assembly, driven by several competing physical processes (merging, accretion, feedback, environment,...). The morphological properties of galaxies are also strongly evolving over the same timescales. We investigate how the evolution of the morphological properties is connected to the spectrophotometric properties of galaxies since $z \sim 6$.

The spectroscopic data obtained within the VIMOS Ultra Deep Survey, a new unique spectroscopic survey of ∼10000 galaxies between redshifts $z \sim 2$ and $z \sim 6$ conducted at the ESO-VLT (Le Févre et al. 2014), combined with the available Hubble Space Telescope imaging surveys COSMOS (Scoville et al. 2006), GEMS (Giavalisco et al. 2004) and CANDELS (Grogin et al. 2011, Koekemoer et al. 2011) provide a great way of probing galactic evolution across that cosmic epoch.

We make use of a three methods approach to quantify morphological properties by combining visual classification with parametric fitting via GALFIT (Peng et al. 2002, 2010) and with non-parametric quantification - CAS (Conselice 2003), GM_{20} (Lotz et al. 2004), $T\psi\xi$ (adapted from Law et al. 2007), F (adapted from Matsuda et al. 2011) and MID (Newman et al. 2013) - to constrain the evolution of morphological properties of galaxies. The results are then combined with the physical properties of galaxies derived from the VUDS spectra (e.g. EW of lines including Ly-α and CIV, continuum slope β,...) and from the spectral energy distribution derived from multi-wavelength photometry, using the exact knowledge of the spectroscopic redshift.

Integral Field Spectroscopy of the Interacting Radio Galaxy PKS 1934-63

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Abstract

We present new results from VLT MUSE integral field spectroscopy of PKS 1934-63, a young/compact radio-loud AGN with strong [OI]6300 and [OIII] emission and a massive galaxy undergoing a major merger, with extensive star-formation visible in Hα and [NII]6584. We analyze the kinematics and line ratios of the AGN and star-forming components of this double-galaxy system, with MUSE's combination of high spatial and spectral resolution.

The black hole - host galaxy relation for very low-mass quasars

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Abstract

We have investigated the M_{BH} - M_{host} log-linear relation for a sample of 37 quasars with low black hole masses ($10^7 M_\odot < M_{BH} < 10^{8.3} M_\odot$) at $0.5 < z < 1.0$. For 25 quasars, we detected the presence of the host galaxy from deep near-infrared H-band imaging, whereas upper limits for the host galaxy luminosity (mass) were estimated for the 12 unresolved quasars. 75% of quasars were disc dominated. We advocate secular evolution of discs of galaxies being responsible for the relatively strong disc domination.

The Formation and Evolution of the Cosmic Dust

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Abstract

When and how the formation and evolution of galaxies proceeded is one of the most important problems in astrophysics. From the point of view of the chemical evolution of galaxies, galaxies evolve from a state with low abundance of metals and dust grains to a state with high abundance through the star formation in galaxies. Thus, the understanding of dust evolution is crucially importance to understand the formation and evolution of galaxies. However, despite of its importance, most of the previous works have examined the dust evolution by using some oversimplified assumptions. In this work, we explore the evolution of dust contents, in particular, the total dust amount, the grain size distribution, and the extinction curve in galaxies by constructing a novel theoretical model which includes various processes affecting dust properties in a unified framework.

Long GRBs as tools to study galaxy evolution and star formation across the Universe

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Abstract

Gamma-ray bursts (GRBs) allow galaxies to be selected independently of their brightnesses and dust content at any wavelength. The association of Long GRBs (LGRBs) with the death of massive stars, makes this class of GRBs a tool to understand the evolution of star-formation and galaxies, complementary to current galaxy surveys, up to the highest redshifts. However, the progenitor star conditions necessary to produce LGRBs can affect the relation between the LGRB rate and star formation. In order to properly use LGRBs as an independent probe of galaxy and star formation evolution across the Universe, we must use complete samples of GRBs to determine the LGRB rate - SFR efficiency.

I will present the results of our study of the host galaxy properties of the Swift-BAT6 complete sample of LGRBs. Our results show that LGRBs are very powerful in selecting a population of faint low-mass star-forming galaxies, partly below the completeness limits of galaxy surveys. The LGRB rate - SFR efficiency seems to be strongly affected by metallicity, probably due to the conditions necessary for the progenitor star to produce a GRB. Under very basic assumption, we estimate that the LGRB rate can directly trace the SFR starting from $z \sim 4$. The use of the BAT6 complete sample makes these results not affected by possible biases which could have influenced past results based on incomplete samples.

A Dusty, UV-selected galaxy at $z = 7.5$

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Abstract

Candidates for the modest galaxies that formed most of the stars in the early universe, at redshifts $z > 7$, have been found in large numbers with extremely deep restframe-UV imaging. But it has proved difficult for existing NIR spectrographs to characterise them. The detailed properties of these galaxies could be measured from dust and cool gas emission at far-infrared wavelengths if the galaxies have become sufficiently enriched in dust and metals. So far, however, the most distant UV-selected galaxy detected in dust emission is only at $z = 3.2$, and recent results have cast doubt on whether dust and molecules can be found in typical galaxies at this early epoch. Here we report thermal dust emission from an archetypal early universe star-forming galaxy, A1689-zD1. We detect its stellar continuum in spectroscopy and determine its redshift to be $z = 7.5 \pm 0.2$ from a spectroscopic detection of the Lyα break. A1689-zD1 is representative of the star-forming population during reionisation, with a total star-formation rate of about $12\,\mathrm{M}_\odot\,\mathrm{yr}^{-1}$. The galaxy is highly evolved: it has a large stellar mass, and is heavily enriched in dust, with a dust-to-gas ratio close to that of the Milky Way. Dusty, evolved galaxies are thus present among the fainter star-forming population at $z > 7$, in spite of the very short time since they first appeared.

Exploring the faint source population at 15.7 GHz

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Abstract

We investigate the properties of the faint source population at 15.7 GHz, a previously unexplored parameter space. A complete sample of sources with flux densities > 0.5 mJy is selected from the Tenth Cambridge (10C) survey in the Lockman Hole and matched to a range of multi-wavelength data. We find that essentially all (> 97 percent) of the 10C sources are radio galaxies; the populations of starforming galaxies and radio-quiet AGN predicted to be present by recent models, such as the SKADS Simulated Skies, are not found in the 10C sample. The radio galaxies are split into high-excitation and low-excitation radio galaxies (HERGs and LERGs), and we find that the HERGs tend to have flatter spectra, smaller linear sizes, higher flux densities and be at larger redshifts than the LERGs. We use new observations to extend this study to fainter flux densities, and find that the faint, high-frequency sky continues to be dominated by radio galaxies down to 0.1 mJy.

Velocity and mass functions of cosmic structures

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Abstract

It is important to study the relation between the structures consisting of galaxies and dark matter, but it has been a matter of long debate. In order to investigate especially the dynamical aspect of the structure, we use the data provided by the VIMOS Public Extragalactic Redshift Survey (VIPERS) and its mock catalog constructed from N-body simulations. First, we derive galaxy stellar mass using the photometric data and SED fitting and we estimate galaxy stellar mass function at $z = 0.5$ to $z = 1.3$.

Together with this, we also estimate galaxy's line of sight velocity using spectroscopic data and dynamically estimated the velocity dispersion function of clusters. This method was checked by using the mock catalog. Combining these results, we can discuss the relation between dark and luminous structures. In this presentation, we report these results.