Oral Contribution Abstracts

A look at the halo and large-scale environment of high-z quasars with known extended Lyman-alpha emission

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Large samples of high-z (z>~2) quasars have been targeted with sensitive integral-field-unit spectrographs to study their large-scale gas reservoirs, showing extended Lyman-alpha emission with different sizes, morphologies and luminosities at similar quasar luminosities. Here I will present a multiwavelength observational campaign (from rest-frame UV to submm; e.g., MUSE/VLT, HAWK-I/VLT, SCUBA-2/JCMT, ALMA) aimed at assessing the physical properties of a subset of those nebulae and constraining their large scale environments. First, I will report on studies focusing on the brightest and largest Lyman-alpha nebulae known around quasars found at z=2 and 3, which show that these nebulae are associated with massive dark-matter halos (M_DM~10^13 M_solar), at the high-end of halo masses expected for quasars. Secondly, I will present the number counts of dust-obscured galaxies on Mpc-scales around 20 z~2-4 quasars, and discuss trends with respect to their Lyman-alpha nebulae properties. I will conclude by discussing implications of these works.

Multi-scale Modeling of Supermassive Black Hole Evolution and Gravitational Wave Sources

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Supermassive black holes (BHs) play a crucial role in galaxy evolution. In turn, mergers between galaxies can trigger powerful electromagnetic and gravitational-wave (GW) emission from inspiraling BH pairs. I will discuss our recent work using galactic- to cosmological-scale hydrodynamics simulations to improve our understanding of BH formation, dynamics, and fueling throughout cosmic time. This includes studies of active galactic nuclei (AGN) and BH dynamics in merging and isolated galaxies, as well as new models for BH seeding channels at high redshift. I will focus in particular on our recent post-processing analysis of candidate triple BH systems in the Illustris simulations. Our results indicate the existence of a bimodal population of wide-separation versus close triple systems. We also find that the frequency of these events is remarkably insensitive to binary inspiral model parameters. When strongly interacting, these triple systems can

greatly reduce BH merger timescales, and gravitational slingshot ejections can contribute to the population of wandering “kicked” BHs. I will conclude by discussing the implications for GW and multi-messenger observations.

Hydrogen reionisation ends at z=5.3: high-z quasars as a probe of the early IGM

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High-z quasars are our best tool for exploring the high-z inter-galactic medium. Lyman-alpha transmission, measured in the foreground of $z > 5$-7 quasars, provides measurements of the mean IGM optical depth as well as its scatter between different patches of the Universe. To distinguish between models of reionisation and continue developing them, it is crucial to establish how long reionisation-related fluctuations persist in the IGM. We measure Lyman-alpha opacity at $5<z<6$ using a sample of >60 quasar sightlines with SNR>10 per pixel from the XQR-30 sample and archival observations, representing a very significant leap in the quality and quantity of high-z quasar spectroscopy. We also carefully address new systematics, including using new, well-characterised continuum reconstructions. We find great agreement between observations and homogeneous-UVB models at $5.0<z<5.2$, demonstrating that the IGM models and our understanding of uncertainties are robust. Observations significantly deviate from a homogeneous UVB at all redshifts $z >= 5.4$ (>3.5 sigma). Reionisation-related fluctuations, in the UVB and/or temperature of the IGM, must therefore persist until 1.1 Gyr after the Big Bang.

Black-Hole Growth Depends Little Upon 0.1-10 Mpc Cosmic Environment

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We investigate if long-term average SMBH growth depends materially upon host-galaxy local (sub-Mpc) or global (1–10 Mpc) environment. We construct the surface-density field (local environment) and cosmic web (global environment) in the COSMOS field at z = 0.3–3.0. The environments covered range from the field to clusters (M_halo/M_Sun $<$ 10^14), including the environments where 99% of galaxies in the Universe reside. We measure sample-averaged SMBH accretion rate (BHAR) from X-ray observations, and study its dependence upon overdensity and cosmic-web environment at different redshifts while controlling for galaxy stellar mass (M*) with partial-correlation techniques. Our results indicate that BHAR does not significantly depend upon overdensity or cosmic-web environment once M* is controlled, arguing that environment-related physical mechanisms (e.g. tidal interaction and ram-pressure stripping) might not significantly affect long-term SMBH growth. We also discuss prospects for extending this work with the recently completed 13.1 deg^2 XMM-SERVS survey in the LSST Deep-Drilling Fields.

Molecular Outflows in z>6 Unobscured Quasar Hosts - Driven by Star Formation

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Massive quiescent galaxies found at z∼4 are predicted to have already quenched by z∼5. Feedback and outflows associated with a quasar phase are expected to be critical in quenching the most massive galaxies. Observations targeting the molecular outflow phase, which dominates the mass and momentum of outflows and removes the direct fuel for star formation, are however, severely limited in high-z quasar hosts. I will present two new unambiguous ALMA detections of molecular outflows, traced by blue shifted absorption of the OH 119 µm doublet, from a sample of three z>6 infrared luminous quasars: J2310+185514, P183+05 and P183+05. We find no evidence and no requirement for input from the central unobscured quasar to drive the mass outflow rates and energetics of the outflows, which are instead consistent with those found in high-z Dusty Star Forming Galaxies (DSFG). We propose that the molecular outflows are driven by star formation activity and that differences in the spectral properties of the blue-shifted absorption between the quasar and DSFG outflows may be caused by the more compact and/or inclined background dust continuum of the quasar hosts.

Quasar feedback at cosmic noon traced by VLT and ALMA

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Negative feedback from quasars is considered a fundamental physical process in galaxy evolution: it is indeed believed to inhibit the excessive growth of massive galaxies and provide the link between the growth of SMBH and their host galaxies. Recent zoom-in simulations tailored to luminous quasar have shown that direct radiation pressure of the UV, optical and IR photons on the dusty clouds of the ISM can drive massive outflows,

clearing the galactic nucleus within 2 kpc from the SMBH and halting the star formation activity. Here we present deep VLT/SINFONI and ALMA observations of a sample of quasars at z∼2.4 characterized by fast, extended ionized outflows detected through the [OIII]5007 line. The data reveal that the quasar-driven ionized outflows are able to remove gas and dust in the region where outflows are expanding. By mapping the spatially-extended Hα emission, we also note that star formation activity is quenched in the region affected by the outflows. Nonetheless, the ongoing star-formation rate in the rest of the galaxy is still high (100 Msun/yr). These results suggest that the impact of outflows on the galaxy occurs in longer timescales.

Searching for Enhanced Galaxy Evolution in the Environments of z>6 Quasars

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Quasars at very high redshift (z>5) hosting supermassive black holes theoretically should reside in some of the most massive halos in the early Universe, making them a prime target for overdensity searches. Previous studies at z>5 have revealed local overdensities of, e.g., Lya and [CII], while others have found galaxy populations in line with expectations from the field. In a sample of 35 quasars at 6<z<7, we previously used ALMA continuum data to search for an enhancement of DSFGs (which are rare enough that >1 source per pointing would suggest enhanced galaxy evolution) yet our results were consistent with blank field number counts at S > 0.15 mJy. We followed up these fields with HST broadband imaging to search instead for LBGs. Preliminary results show that Lya emission in both quasar fields and the parallel offset fields ~2 Mpc away are consistent with the field-derived z=6 UV luminosity function, except for galaxies brighter than M<-21, where quasar fields show a significant overdensity. With an enhancement of the most massive unobscured galaxies on Mpc scales, this provides tentative evidence of accelerated galaxy evolution near quasar hosts only 1 Gyr after the Big Bang.

Quasar feedback and the origin of extended Lyα glow in z > 6 quasars

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The detection of quasars out to z ~ 7.5 shows that supermassive black holes with masses of ~10^9 M☉ have assembled by the time the Universe was ~680 Myr old. These

observations strenuously test theoretical models of galaxy evolution, which have to explain how such rapid black hole growth comes about. Using state-of-the-art cosmological simulations, I will show that black hole growth to ~10^9 M☉ can occur within rare, massive dark matter haloes tracing extreme overdensities. The rapid black hole growth ignites powerful large-scale outflows which are characterized by a multi-phase structure resembling that of the interstellar medium. I will illustrate the ways in which the quasar hosts and environments are affected by outflows. Finally, I will show that the simulations also account for recent observations of extended Lyα nebulae around $z > 6$ quasars. A close match between theory and observations is only possible if quasar feedback already operates efficiently in these quasars. I will highlight theoretical insights into the nature of Lyα nebulae at $z = 6$, explaining their detailed observational properties, their dominant physical mechanism, and the potential to detect them at $z = 7.5$.

XQR-30: the ultimate XSHOOTER survey of Quasars at the Reionization Epoch

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XQR-30 is a quasar survey based on a 248-hour ESO Large Programme (P.I. V. D’Odorico) carried out with XHSOOTER@VLT. Thirty quasars at redshift z=5.8-6.6 were observed with resolving power of R~8000-9000 and median SNR~40 per pixel (@1285A rest frame), quadrupling the existing sample of quasar spectra at similar resolution and high-SNR. The XQR-30 QSO sample is going to be observed also with the MUSE spectrograph at the VLT and with the ALMA interferometer ([CII] observations are already available for more than half of the sample). The scientific goals of the survey span from the study of the unfolding of the reionization process, early metal enrichment, the nature of the first stars and galaxies, to the environment of quasars and the formation of early super-massive black holes. In this talk, I will describe the characteristics of the survey and briefly review the results obtained up to now, among them: the constraints on the neutral hydrogen fraction up to z~6.5, the chemical properties of the gas associated with the first galaxies, the statistics of the metal absorption lines and the study of the Broad Absorption line QSOs in the sample.

AGN imprints on the IR emission of galaxies at the Epoch of Reionization

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We study the co-evolution of SMBHs with their host galaxies at z~6 by using a suite of cosmological hydro-dynamical simulations, including different feedback prescriptions and radiative transfer calculations through dust. We compare the multi-wavelength (UV to FIR) emission of AGN-host galaxies with normal star-forming galaxies. We find that a large fraction (>50%) of the UV radiation in dusty, faint (MUV~-24) AGN is obscured and re-emitted at rest-frame MIR wavelengths, boosting the MIR-to-FIR flux ratio by a factor ~10-100 with respect to normal star forming galaxies. Our results suggest the possibility to exploit the synergy between JWST and ALMA to unveil faint and/or dust-obscured AGN by measuring their MIR-to-FIR ratio. We also find that AGN radiation effectively heats the dust in their surroundings, producing a clumpy, warm (T>200 K), dust component, but also the diffuse dust on ~kpc scales, which is usually assumed to be heated by stars only. As a consequence, we show that the star formation rate in AGN-hosts inferred by the FIR luminosity via standard SED fitting methods can be overestimated by even two orders of magnitude, depending on the AGN bolometric luminosity.

Building Semi-Analytic Black Hole Seed Models to Analyze Seeding Conditions Using IllustrisTNG

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Because early Universe black holes (BHs) grew to billions of solar masses in size in less than 1 Gyr of cosmic time, BH seeding models face stringent constraints. In order to constrain the parameter space of possible seeding criteria, we use an approach that combines the advantages of a full cosmological simulation with the flexibility of semi-analytic modeling. Using galaxy halo catalogs from the cosmological magneto-hydrodynamical IllustrisTNG simulations, we construct semi-analytic, post-processing models that produce BH formation and merger histories under a wide range of seeding criteria. Specifically, we vary the maximum gas metallicity and the minimum gas and total halo mass for seed formation, and we also consider seeding probabilities less than unity. With this approach, we are able to trace the BH population over cosmic time for many possible seeding scenarios. The results highlight the important interplay between all the physical criteria. Several combinations of the seeding criteria in our TNG models produce BH number densities comparable to observations at z=0. Our work provides an efficient means of comparing BH seeding criteria within a large cosmological simulation.

Tomography of the environment of the COSMOS/AzTEC-3 submillimeter galaxy at z ∼ 5.3 revealed by Lyα and MUSE observations

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Submillimeter galaxies (SMGs) are proposed as the progenitors of massive ellipticals in the local Universe. We study the members of the protocluster around the SMG AzTEC-3 at z = 5.3. We use Lya emission and its synergy with previous CO and [CII] observations. We identified ten Lya emitting sources, including one extended emission embedding AzTEC-3 and a star-forming galaxy located to the North, LBG-3. The extended Lya emission is elongated to the North of LBG-3 and to the South of AzTEC-3, where a faint galaxy is also located. The elongated structures could resemble tidal features due to the interaction of the two galaxies with AzTEC-3. Also, we find a bridge of gas, revealed by the Lya emission between AzTEC-3 and LBG-3. The kinematics of the Lya emission towards another galaxy of the field supports the idea of a merger of its components. Therefore, we find evidence of interaction and mergers around AzTEC-3 that could condition the fate of the protocluster. Given the Lya luminosity of the Lya emission, we estimate a dark matter halo of 10^12 Msun at z = 5.3.This dark matter halo indicates that this region could evolve into Fornax-type cluster at z=0.

A Lya protocluster at redshift 7

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Lyman alpha emitting galaxies (LAEs) are excellent tracers of large scale structures and can be efficiently selected with narrowband technique at very high redshift. Many protoclusters have been discovered with LAEs at redshift up to 6.6. In this talk, I will present a protocluster at redshift 7 discovered by the LAGER (Lyman Alpha Galaxies in the Epoch of Reionization) project. We used the Dark Energy Camera on CTIO Blanco 4m telescope with a custom-made narrowband filter NB964 to search for LAEs at redshift 7. In the LAGER-COSMOS field, we discovered a protocluster with a significant overdensity of 5.1 and mass of 3.7e15 solar masses. It has been spectroscopically confirmed with Magellan Telescope observations. Furthermore, we found its member galaxies are able to provide sufficient ionizing photons to ionized the IGM within the protocluster. Note the average neutral hydrogen fraction of IGM is still 0.2--0.4 at redshift 7. Thus, this protocluster provides a unique natural laboratory to investigate the environment effect on the reionization and the structure assembling in the early universe.

How quasars may shape the co-evolutionary path via "radiative dusty feedback"

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Observations indicate a co-evolutionary sequence, from dust-obscured starbursts to unobscured luminous quasars. Some form of black hole (BH) feedback is required to expel the obscuring gas and dust, but the physical mechanism remains unclear. We suggest BH feedback, driven by radiation pressure on dust, as a promising mechanism for powering galactic outflows. The resulting "radiative dusty feedback" preferentially removes the obscuring dusty gas, and such radiation-driven outflow models may be applied to the different populations of dusty quasars observed around cosmic noon. We show that the central BH spin determines the radiation feedback geometry, and hence the accretion flow pattern, with two distinct trends for high-spin and low-spin objects. This may also have important implications for BH growth in the early Universe, in particular in the dust-rich environment of the first quasar host galaxies. I will discuss how BH radiative dusty feedback may provide a natural physical interpretation for the observed co-evolutionary path.

Small quasar proximity zones reproduced with flickering AGN lightcurves

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Proximity zones are regions of highly ionized gas in the vicinity of quasars, where the excess of ionizing photons from the quasar allows for transmission of the Lyman-alpha forest, even at redshifts where transmission would otherwise be saturated. In recent years, a population of quasars with exceptionally small proximity zones have been observed. These small proximity zones can be reproduced if the quasar has only turned on within the last 100,000 years, but this is hard to reconcile with the past accretion events that must have occurred to grow a 1e9 M_sun black hole by redshift 6. In this talk I will present results from radiative transfer simulations including variable quasar lightcurves and show the effect that this has on the Lyman-alpha forest. Using simple toy lightcurves, I will place constraints on the average length of an accretion event and on the duty cycle of the first quasars. I will also present results showing, for the first time, the time evolution of quasar proximity zones using lightcurves taken from state of the art simulations of accreting black holes in a cosmological environment.

Active Galactic Nuclei in First Light And Reionization Epoch Simulations

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The First Light And Reionization Epoch Simulations (FLARES) is a novel suite of hydrodynamical cosmological zoom simulations formed by re-simulating a range of environments from a large parent volume. This method allows us to simulate much larger effective volumes than possible with traditional periodic box methods. It also makes FLARES ideal for studying massive/rare objects such as Active Galactic Nuclei (AGN) and bright star forming galaxies that might be absent in smaller periodic box simulations. In this talk I will discuss the population of supermassive black holes in FLARES and present the properties of FLARES AGN and their contribution to the light emitted by high redshift galaxies. I will also discuss the AGN contribution to ionizing photon budget during reionization. Using a set of matched simulations, run both with and without AGN, I will also study the impact of these objects on galaxy formation in the early Universe.

Extended emission around the reddest "extremely red quasar": no signs of extreme outflows in the inner circumgalactic medium

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Dusty quasars might be in a young stage of galaxy evolution with prominent quasar feedback. We study a population of luminous, extremely red quasars (ERQs) that has extreme spectral properties related to exceptionally powerful quasar-driven outflows. We present KCWI observations of the reddest known ERQ, at z = 2.3184, with extremely fast [OIII] outflow at 6000 km/s. The Lya halo spans 100 kpc, appears circularly symmetric at <30 kpc from the center and filamentary on larger scales, and has centrally concentrated surface brightness profile. The halo is kinematically quiet. We detect HeII and CIV nebular emissions with kinematics similar to the Lya halo and a narrow component in the [OIII]. Quasar reddening acts as a coronagraph allowing views of the innermost halo. A narrow Lya spike in the quasar spectrum is inner halo emission. The inner region is dominated by past/moderate-speed outflow and the outer region is dominated by inflow. Properties of the halo are within the ranges found in other luminous quasars, and the differences can be explained by the presence of dust and global patchy obscuration. We find no definitive evidence of quasar feedback on circumgalactic scales.

Automated methods to find the most distant quasars

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We develop an automated method to identify high-redshift ($z > 6$) quasars in photometric surveys in the presence of large numbers of contaminants and false positives. Our approach combines i) Bayesian model comparison to compare quasar SEDs to those of contaminating populations such as brown dwarfs, ii) model checking at the pixel level to select only stationary point-sources, and iii) machine learning classifiers to optimise the final classification. We test our algorithms on a cross-matched set of ~4000 visually classified candidates from SDSS and UKIDSS. Our aim is to use these methods on upcoming data-sets from, eg., Euclid and LSST that will enable us to find the first quasars at redshifts of $z > 8$.

Short time variability in IMBHs

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Finding IMBHs is a very difficult task since their luminosity can be comparable to other stellar phenomena at radio, NIR, optical and X-ray wavelengths. Because variability is a ubiquitous property of accreting BHs and its characteristic time scale correlates with mass (with smaller BHs showing faster variability), intranight monitoring of these type of sources can help to constrain the completeness of current searches for dwarf BHs, and potentially the seeds of Super Massive BHs, by finding IMBHs through variability. We have conducted a high cadence nuclear monitoring of a sample of galaxies which host AGN bona-fide dwarf BHs. These observations can probe the ubiquitousness of short-time scale variability and open a new window of opportunity to discover and study these much sought after BH population.

Redshift identification of X-ray selected active galactic nuclei in the J1030 field: searching for large-scale structures and high-redshift sources

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The existence of supermassive black holes (SMBHs) with MBH=1E9 Msun powering luminous quasars at z~6 and beyond, represents a persistent challenge for extragalactic astronomy. Theory strongly argues that these objects must have formed within the most massive dark matter halos (Mhalo ~ 1E12-1E13 Msun) situated in the most overdense regions of the early Universe, where large reservoirs of gas are available for an efficient BH fueling. In the last years, a large multiwavelength campaign has targeted one of these overdense fields, the one centered around the z=6.31 QSO SDSS J1030+0524 (J1030). J1030 is powered by a billion solar mass SMBH and is the first ever z=6 QSO around which a spectroscopically confirmed galaxy overdensity has been detected. In this talk, I will present the first results derived from the spectroscopic and photometric redshift catalog for the Chandra J1030 survey, the fifth deepest X-ray field. I will discuss how we searched for large scale structures in the field, and focus on the properties of the high-redshift subsample.

Detecting High-z Quasar Hosts with JWST

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Studying the host galaxies of high-redshift quasars provides vital insights into the early growth of supermassive black holes and the black hole—galaxy connection. However, observing high-redshift quasar hosts in the rest-frame ultraviolet/optical has eluded even the Hubble Space Telescope, with the bright emission from the quasar completely concealing the underlying host galaxy. The James Webb Space Telescope (JWST) will launch a new era in this field, providing the opportunity to observe the stellar components of these host galaxies for the first time. I will discuss how JWST can be used to detect quasar hosts, showing our detailed predictions for photometric observations using the BlueTides simulation and our plans for our Cycle 1 GTO and GO observations.

Super-Eddington AGN across the cosmic time

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The level of activity in a galaxy evolves with time, likely in an intermittent way. The accretion rate drives many of the properties of the galaxies during their active phase.

This allows us to identify such accretors by the detailed analysis of their UV spectra. In the presented work we selected a sample of high accretor candidates from the SDSS-RM survey at redshift range $1.1<z<4.3$. We performed a careful spectroscopic analysis of their UV spectra based on the AlIII1860 with the objective to study the evolution of the black mass and accretion rates properties along the redshift range and to identify the super-Eddington sources. We demonstrate that AGN with the highest accretion rates shows extreme properties such as denser broad-line region, high metal content, face-on orientation, strong outflows, and signatures of a burst of star formation. Also, since their luminosity per mass converges towards a limit, the super-Eddington AGN can be used as standard candles. The same analysis is currently extended to the recent UV observations from the SDSS-V survey.

(Re)solving Reionization with Lyman-alpha emission

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The Epoch of Reionization was the last major phase transition of the Universe. While the timeline of reionization is increasingly well-constrained, its sources remain elusive. Whether the ionizing photon budget arose from a multitude of ultra-faint galaxies or a rarer set of bright galaxies is a key open question. The key uncertainty is the ionizing photon escape fraction (LyC Fesc), and how this varies among galaxy properties. In my talk I will argue to tackle this problem based on measurements of resolved Lyman-alpha (LyA) emission from the X-SHOOTER LyA survey at z=2 (XLS-z2). I will show observational evidence that the defining traits of LyC leaking galaxies are highly ionising stellar populations, low column density gas and a dust-free, high ionization state ISM. This is evidence that galaxies leak ionising photons (with LyC Fesc 20-50 %) when the hottest stars are still shining. Motivated by these results, I will present a model of a LyA Emitter-dominated emissivity that naturally accounts for the galaxy emissivity over z~2-8 and therefore the strong evolution of the average LyC Fesc of the full galaxy population over this epoch.

Constraining galaxy overdensities around three z~6.5 quasars with ALMA and MUSE

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Most models of SMBH formation suppose or conclude that luminous high-redshift quasars should emerge in the most massive dark matter haloes. As a consequence, z>6.5 quasars should trace massive galaxy overdensities in the early Universe. However, this classic prediction of SMBH formation models has remained difficult to confirm observationally. We have observed promising SCUBA2-detected SMGs in the proximity of 3 z~6.5 quasars with ALMA to confirm their redshift via the [CII] line and test whether they are associated with the quasars. We have also used MUSE to find closer Lyman-alpha emitting companion galaxies around these 3 quasars. We find that the SMGs are not associated with the quasars, whereas MUSE LAEs are highly overdense around the quasars. I will present the updated constraints on the large-scale cross-correlation of z>6 quasars and galaxies, showing a clear overdensity of galaxies on small scales, and highlight a dichotomy between the [CII]- and Lyman-alpha-selected quasar companion galaxies, suggesting quasars might preferentially live in dust-rich environments.

Putting breaks on star formation: evidence for the integrated effect of historic AGN feedback

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Understanding the physical processes responsible for ceasing star formation in galaxies is one of the most important unresolved questions in the field of galaxy evolution. We investigate how star formation is brought to a halt in local, massive, central galaxies by comparing Sloan Digital Sky Survey (SDSS) observations with three state-of-the-art cosmological simulations – EAGLE, Illustris and IllustrisTNG. We address the complex nature of quenching by deploying machine learning techniques to determine which galactic property is the most predictive of quenching. We find that the supermassive black hole mass (MBH) is the most powerful parameter in determining whether a galaxy is star-forming or quenched – a statement which is true for all three implementations of AGN feedback in the simulations. Remarkably, this prediction is precisely confirmed in the SDSS observations, where we infer MBH from a variety of calibrations for ~230 000 local galaxies. We then analyse the molecular gas content in both observed and simulated galaxies to find that a viable AGN feedback model combines turbulence injection and heating to successfully quench star formation in central galaxies.

Black holes fuelled by misaligned gas

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Strongly misaligned or counter-rotating structures, i.e. gas or stars that are significantly misaligned with respect to the main stellar body of the galaxy, are a clear signature of a past external accretion event. This external accretion event provides a fresh supply of gas to the galaxy and may contribute to star formation and black hole fuelling. In this contribution I will present a study of the incidence of AGN activity and star formation in a large sample of galaxies with stellar/gas misalignments. I will show that AGN are enhanced in galaxies with misaligned gas, indicating a possible triggering of black hole fuelling. I will discuss the expected frequency of this fuelling mechanism and the implications for AGN activity in general.

Emission Line Diagnostics with JWST and SDSS to Detect Simultaneous IMBH and Stellar Excitation in z~0 Dwarf Galaxies

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Amidst persistent star formation, dwarf galaxies present an opportunity to reveal active intermediate mass black holes (IMBHs) in the elusive 10^3 – 10^4 M_s range. We introduce photoionization simulations tailored to address key physical uncertainties including mixing thermal and non-thermal radiation fields, complex cloud geometries, and differing AGN SED models. We find that the AGN diagnostics in the optical and mid-IR are often degenerate with respect to the investigated physical uncertainties. In contrast to recent work, we show that [O III]/Hb typically remains bright for dwarf AGN down to 10^3 M_s. These dwarf AGN are predicted to have inconsistent star-forming and Seyfert/LINER classifications according to common optical diagnostics. In the mid-IR, [O IV] 25.9 um and [Ar II] 6.98 um are more robust IMBH tracers than optical diagnostics. Based on these emission lines, we provide mid-IR emission line diagnostic diagrams with demarcations for separating starbursts and AGN with varying AGN fractions. The diagrams are valid over a wide range of physical conditions and therefore will prove useful for future JWST observations of local dwarf AGN in the search for IMBHs.

The properties of void galaxies and their black holes in the EAGLE simulations

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Cosmic voids, defined as underdense regions of the cosmic web, are important because they may serve as laboratories for studying the effects of large-scale environment on the formation and evolution of galaxies and their black holes, as they are expected to be less evolved and retain the memory of the early Universe. Galaxies are expected to evolve primarily through internal processes in cosmic voids, and then their properties would be distinct from galaxies residing in denser environments. In this talk, I will present the results of a systematic examination of the primary properties of central galaxies and their black holes as a function of the void centric distance by using the cosmological hydrodynamic simulation EAGLE in conjunction with the void catalogue built by Paillas et. al. 2017. To understand the differences found, we explore the assembly history of galaxies and discern the possible effects of large-scale environment on galaxies.

Insights into quasar evolution in the first two billion years after the Big Bang

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Luminous high-redshift quasars are signposts of the early growth of supermassive black holes. Understanding their formation, their role in driving galaxy evolution, and their contribution to hydrogen and helium reionization, are the key goals of high-redshift, spectroscopic quasar surveys. In this talk I will present our efforts to constrain the evolution in quasar demographics and their physical properties from redshift z=3 to z=7.5. Starting with a discussion on the evolution of the quasar luminosity function, I will highlight the results of the Extremely Luminous Quasar Survey (2.8<z<5) and our new work on the Pan-STARRS1 distant quasar survey (5.7 < z < 6.2). Based on near-infrared spectra of the 38 quasars from the X-SHOOTER/ALMA sample at z=5.7-7.5, I will complement the constraints on quasar demographics with an analysis of the evolution of their physical properties (accretion properties, signatures of BLR winds, Fe/Mg enrichment) with redshift to provide an overview of quasar evolution in the first two billion years after the Big Bang.

Resolving the sub-pc structure of AGN with GRAVITY

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I will present key results from our VLTI/GRAVITY Large Programme on nearby AGN. GRAVITY, the 4 telescope near-infrared interferometer at the VLT, provides an unprecedented 3 mas imaging angular resolution and 10 µas astrometric accuracy. I will highlight the major breakthroughs where we have: 1) spatially resolved the BLR in

several AGN for the first time, finding the BLR can generally be described as a rotating disk; 2) imaged the hot dust continuum in NGC 1068, finding a ring of emission at the expected dust sublimation radius consistent with a geometricallly thin disk; 3) doubled the sample of AGN with interferometrically measured dust sizes, finding consistency with previous NIR results but with evidence for an evolving structure with AGN luminosity; and 4) independently measured the distance to an AGN by combining GRAVITY and reverberation mapping data. I will give an outlook towards the upgrade to GRAVITY+. With greatly enhanced sensitivity and sky coverage, GRAVITY+ will allow for observations of AGN out to high redshift, enabling studies of SMBH-galaxy coevolution using direct SMBH mass measurements to trace the evolution of the famous local scaling relations.

A MUSE view of the Lyman Alpha emitting gas around a pair of z~3 strongly-lensed star-forming galaxies

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Extended halos of HI Lyman Alpha (Lyα) emission are now ubiquitously found around high-redshift star-forming galaxies and quasars. But our understanding of the nature and powering mechanisms of these halos is still hampered by the complex radiative transfer effects of the Lyα line and limited angular resolution. In this contribution, we present the analysis of a strongly-lensed pair of galaxies at z=2.92 embedded in a Lyα halo. The combination of high-quality MUSE observations with the gravitational lensing effect allowed us to resolve the properties of the gas down to ~1kpc scales. Globally, the system shows a line profile that is markedly asymmetric and redshifted, but its width and peak shift vary significantly across the halo. By modeling the profiles with a collection of galactic wind models, we were able to reconstruct the kinematics and density maps of the halo. The resulting maps show tentative evidence of enhanced Lyα escape in the regions between the two galaxies, possibly a consequence of an ongoing collision. Our results also suggest that most of the emission is explained by resonant scattering, with a minor contribution from in situ star formation in satellites.

Comfortably dusty: reducing the tension between local and high-z galaxies IR observations

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ALMA observations have revealed the presence of large amounts of dust in the first generations of galaxies in the Universe. This surprising finding relies on a hardly testable assumption on these sources dust temperatures, Td, due to the lack of multiple FIR continuum data at z>5. The lack of knowledge on Td casts doubts also on other deduced properties of high-z galaxies, including infrared luminosities and obscured Star Formation Rates. We have developed a new analytical method to constrain Td using a single continuum data by combining it with the CII emission. With our method, one can analyse uniquely the large number of data provided by recent ALMA large programs such as ALPINE and REBELS, quantitatively investigating the cosmic Td evolution at unprecedented high-redshift. We find that Td mildly increases at a higher redshift and we physically motivate this Td(z) trend with the decrease of gas depletion time induced by the higher cosmological accretion rate of early galaxies. A higher Td reduces the tension between local and high-z IRX-β relation, and it alleviates the problem of the uncomfortably large dust masses deduced for some Epoch of Reionization galaxies.

Constraining quasar feedback using quasar emission line spectra: predictions from RHD simulations

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While quasar feedback is a major pillar of modern galaxy evolution theory, the process by which quasar energy couples to the host galaxy's ISM is still unclear. Observational constraints on the mechanics of this coupling can be derived from emission line spectra of illuminated ISM clouds, known as the narrow line region (NLR). I will present novel radiative-hydrodynamic (RHD) simulations of NLR clouds with a spatial resolution of ~0.01 pc, a resolution required to resolve the density structure of the HII surface layer that emits the ionized emission lines. I will demonstrate that both the dynamic behavior of the HII layer and its predicted emission line spectrum depend on the dominant quasar feedback mechanism, implying that observed line spectra can constrain the mechanics of quasar feedback. I will also compare our predictions with observed optical line spectra of quasars, and with UV line spectra observed in a new HST program.

Far-Infrared Properties of Normal Dusty Star-Forming Galaxies across z=0.5-6

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Exploiting gravitational lensing effects produced by massive galaxy clusters, we are able to break through the confusion noise limits in the Herschel PACS/SPIRE bands (100-500 µm) and greatly improve the characterization of the far-infrared properties of normal star-forming galaxies (SFR=10-100 Msun/yr) across z=0.5-6. We deblended Herschel data for 180 continuum sources that were blindly discovered in the 33 lensing cluster fields observed by the ALMA Lensing Cluster Survey (ALCS), a 100-hr ALMA large program, down to a delensed 1.15 mm flux density of ∼0.02 mJy. With the analyses of far-IR continuum, we show that, (1) faint millimeter sources (~0.1mJy) are mostly populated by galaxies at z=1-2, which suggests a decreasing obscured fraction of cosmic star formation at z>4, (2) there is no or weak redshift evolution of dust temperature with L_IR<10^12 L_sun galaxies (i.e., LIRGs) at z=0−2, (3) at L_IR>10^12 L_sun (i.e., ULIRGs), the dust temperatures show no evolution across z=1−4 while being lower than those in the local Universe, and (4) no redshift evolution of gas depletion time scale is found for L_IR-complete sample at z=1-4.

Discovery of a powerful and variable ultra-fast outflow in a z=3.6 quasar

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Broad absorption lines (BALs) probe quasar outflows originating from the inner regions around the black hole, providing us unparalleled insights into the quasar central engines. Such outflows are believed to play a major role in communicating the huge SMBH accretion luminosity to the gas reservoir in the host. Studying the variability of these BALs can help us to understand their structure, temporal evolution, and key physical properties. We have recently discovered a multi-component, ultra-fast (0.12c-0.18c) BAL outflow in an ultra-luminous quasar at z~3.6. This outflow stands out to be persistent over time and exhibits complex variability in each component. This allows us to derive location and kinematics of the outflow. This information has been crucial to constrain its remarkable power (~10% of the quasar bolometric luminosity) and establish the relevant role of BAL outflows in the quasar feedback mechanism.

Spatially Mapping the metal-enriched absorbing CGM of a massive galaxy at z ~ 4.5

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High-redshift radio galaxies (HzRGs) are hosted by some of the most massive galaxies known at any redshift and are unique markers of concomitant powerful AGN activity and extreme starbursts. I will present our spatially resolved spectral analysis of MUSE observations of the kpc-scale Lyman-alpha halo around a massive radio galaxy at z~4.5. We identify and measure the kinematics and column densities of eight HI absorbing systems. The strongest absorber is detected across the extent of the Lya halo. It has a significant column density gradient along the SW-NE direction and a velocity gradient along the radio jet axis. The absorber is also observed in CIV and NV, and very likely represents an outflowing metal-enriched shell driven by a previous AGN/star formation episode and is now caught up by the radio jet leading to jet-gas interactions. These observations suggest that feedback from AGN in most massive galaxies in the early Universe may take an important part in re-distributing material and metals in their environments. This target is one of our MUSE HzRGs sample. I will present the plans for analyzing this sample in which my approved PI JWST (ID1970) program will play a key role.

COSMOS2020: New Insights into Galaxy Assembly and Evolution over the first 10 Billion Years

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The COSMOS field has proved to be one of the cornerstone surveys in extragalactic astronomy. We have built a new photometric redshift catalog COSMOS2020 from the latest ultra-deep imaging from Subaru, VISTA, and Spitzer. We measure 1M sources across the 2deg2 field using both apertures and profile-fitting photometry, pairing each with two SED fitting codes to derive four sets of precise photometric redshifts. We then measure the form and evolution the Galaxy Stellar Mass Function from 0.2<z<7.5 to reveal a strikingly constant rate of mass assembly stretching back into the Epoch of Reionization. We also find new samples of ultra-luminous galaxies at z>7.5 which form the most robust constraints on the UV Luminosity Function at such early times, confirming an excess of luminous sources. Are we witnessing a stage before feedback has suppressed their growth? Such a scenario challenges galaxy formation theory. We will have our answer soon; five of these luminous z~9 galaxies will be followed up with spatially resolved spectroscopy in the Cycle 1 JWST NIRSpec program BEASTS (PI:Weaver) where we will confirm this excess and reveal the mechanisms responsible for their fantastic growth.

The hunt for X-ray luminous quasars at z>5.5 with eROSITA

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At z>5.5, at the end of the epoch of reionization, X-rays in the soft 0.5- 2 keV band probe the hard X-ray restframe emission, thereby offering a less absorption-biased window on the full active galactic nuclei population. Quasars at these high redshifts are however very rare. Optical and near-infrared dropout detected z > 5.5 quasars significantly outnumber X-ray detected ones, which strongly limits our ability to statistically treat accretion processes in the early universe. The eROSITA All-Sky Survey (eRASS) will allow us to produce a complete census the bright end of the X-ray emitting high-redshift quasar population, eventually increasing their known population by a factor of 3 (Wolf et al. 2021). We have developed a selection pipeline, based on a random forest spectral classifier and classical SED fitting, to discover new high-redshift quasars in eRASS. We report first results from this search: the discovery of five rare, extremely X-ray luminous quasars at z>5.5. In addition we will present the eROSITA detection of previously known high-redshift quasars and discuss implications for super-massive space density shortly after reionization.

Black Hole Masses from the OzDES Reverberation Mapping Project

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Accurate mass measurements for supermassive black holes (SMBHs) are critical for understanding their evolution over cosmic time and their co-evolution with their host galaxies. Outside of the local Universe, reverberation mapping (RM) of active galactic nuclei (AGNs) is the most accurate method for measuring SMBH masses. RM measures the time lag between the continuum and broad emission line region (BLR) variability of AGN, which gives the virial mass when combined with the broad line width. I will present the latest results from the Dark Energy Survey (DES) - Australian DES (OzDES) RM project, which monitored 771 AGNs for 6 years with weekly photometry and monthly spectroscopy. Our results include some of the highest-quality Mg II lags and a new relationship between the radius of the Mg II BLR radius and the continuum luminosity (R-L relation). I will also describe our latest results on the C IV R-L relation. Both relations are important because they are widely used to estimate the masses for large numbers of SMBHs from single-epoch spectra, and our measurements provide some of the best data at cosmic noon – the peak of AGN activity.

Enhanced star formation in z~6 quasar companions

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Quasars powered by supermassive black holes at z~6 are predicted to reside in cosmic over-dense regions. However, observations so far could not confirm this expectation due to limited statistics. The picture is further complicated by the possible effects of quasar outflows (i.e. feedback) that could either suppress or stimulate the star formation rate (SFR) of companion galaxies, thus modifying the expected bias. I will quantify feedback effects on the properties and visibility of companions by comparing cosmological zoom-in simulation runs of a quasar in which feedback is either included or turned-off. With respect to the no-feedback case, companions (a) directly impacted by the outflow have their SFR increased by 2-4 times, and (b) tend to be more massive. Both effects shift the [CII] and UV luminosity functions toward brighter magnitudes.
