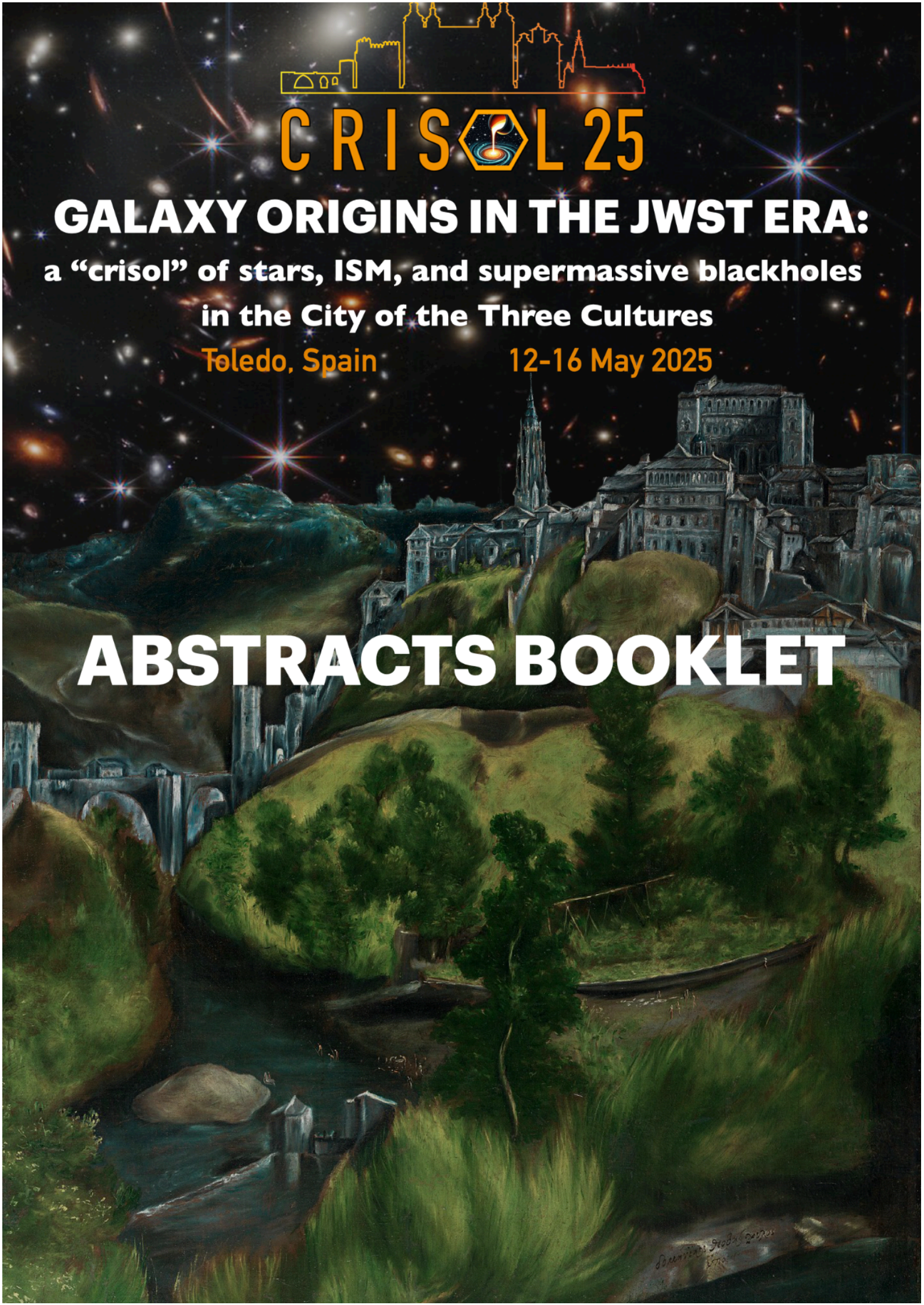
CRISOL 25
GALAXY ORIGINS IN THE JWST ERA:
a "crisol" of stars, ISM, and supermassive blackholes
in the City of the Three Cultures
Toledo, Spain
12-16 May 2025
ABSTRACTS BOOKLET

Monday May 12, 2025

Rachel Somerville & Mark Dickinson - INVITED - The Cosmic Crisol in the JWST era: insights and puzzles from an observational and theoretical perspective

Opening review of what we are learning about the first Gyr of cosmic history (Universe origin, as the title of the conference) from JWST surveys (and from other observatories) at cosmic noon to cosmic dawn. This would be a high level talk with theoretical (given by Rachel) and observational (by Mark) perspectives to set up the stage.

Stefano Carniani – Luminous galaxies in the early Universe

The advent of JWST is a giant leap forward in our understanding of the early Universe and the origin of the first galaxy populations at z>10. One of the most exciting and puzzling results is the discovery of numerous luminous galaxies already in place 500 Myrs after the Big Bang. Such observations have raised several questions about the formation of such bright galaxies. Here we discuss the recent JWST observations of the most distant luminous galaxies spectroscopically confirmed at z~14. These two galaxies have a Muv of -20.81 and -19 and provide a crisp spectroscopic confirmation to the trend that has been inferred several times from photometric samples that the galaxy UV luminosity function evolves slowly, with more luminous galaxies at high redshift than predicted. Thanks to the analysis of the size and the UV slope we conclude that the rest-frame UV emission is dominated by light of the stellar population and does not arise from an AGN. The NIRSpec spectra reveal only a faint CIII] emission line in the brighter galaxy, contrasting with observations of other luminous galaxies at lower redshift. Additionally, the recent detection of [OIII]88μm emission using ALMA suggests these galaxies are not extremely metal-poor. Nevertheless, the weak CIII] emission line raises further questions about its origin. We discuss possible models to explain the lack of strong UV lines and the existence of such large and luminous galaxies so early in cosmic history.

Vasily Kokorev - A Glimpse of the New Redshift Frontier

I will present the discovery of five galaxy candidates at redshifts between z = 15.9 and z = 18.6 in JWST observations from the GLIMPSE survey. These robust sources were identified using a combination of Lyman-break selection and photometric redshift estimates. The ultra-deep NIRCam imaging from GLIMPSE, combined with the strong gravitational lensing of the Abell S1063 cluster, allows us to probe a fainter population MUV= -18 mag for the first time. Together with the scarcity of brighter galaxies at z>15 in public surveys, these findings suggest a steep decline in the bright end of the UV luminosity function at z _ 17. Assuming various star formation histories, these sources are

likely progenitors of the unusually UV-bright galaxies that JWST now routinely uncovers at z = 10 _ 14. Overall, these results indicate that the luminosity distribution of early star-forming galaxies could be shifting towards fainter luminosities, implying that future surveys of Cosmic Dawn will need to explore this faint luminosity regime.

Marco Castellano - How did it all start? Searching for galaxies 100-300 Myr after the Big Bang

The first two years of observations with JWST have unambiguously shown that the density of galaxies beyond z10 remains significantly higher than expected using previous extrapolations, pushing the epoch of first galaxy assembly to even earlier epochs, beyond z15. While this evidence is robustly settled up to z14, the density of galaxies at z15 and beyond remains essentially unknown. At these redshifts, indeed, galaxies become even fainter and detectable only in the reddest JWST bands, making their identification progressively harder. I will report the results of the first comprehensive search of galaxies beyond z15 performed on all the major deep JWST extragalactic surveys - GLASS, CEERS, JADES, PRIMER, NGDEEP. I will describe the selection criteria adopted, the different classes of low-redshift objects that may contaminate the selected samples, and the techniques adopted to minimise their impact. I will show that promising candidates are found at z15-20 and even at z>20, although it becomes increasingly harder to exclude contamination from populations of red objects at lower redshifts. I will present the resulting constraints on the evolution of the LF beyond z15 and how they compare with theoretical models that are already in tension with observed data at 1015 universe in future cycles to thoroughly explore the epoch 100-300 Myr after the Big Bang.

Seiji Fujimoto - A Glimpse of an Ultra-Faint 10^5 Msun PopIII Galaxy Candidate Through Abell S1063

Detecting Population III stars is a holy grail of astrophysics. Simulations predict these stars should be observable even as late as z6. However, they remain an uncharted frontier, even with JWST. We present an unambiguous Pop III galaxy at z=6.5 discovered in the latest deepest NIRCam survey, GLIMPSE. The 9-band NIRCam imaging, including two medium-band filters, reveals the textbook signature of Pop III: strong H-alpha emission (EW ~2500AA) with apparently no detectable metal lines (e.g., [OIII]), accompanied by a Balmer jump indicative of a nascent (<5 Myr) stellar population. No galaxy with similar colors has been found in the entire JWST archive. This discovery was only possible due to the unprecedented depth of the imaging, amplified by ~3x gravitational lensing, unveiling this 10^5 Msun candidate. In this talk, we will also discuss our novel NIRCam-based techniques to efficiently search for Pop III galaxies, their completeness and contamination rates, and the Pop III UV Luminosity Function at z6–7, including the simulation predictions.

Yongda Zhu - Constraining the Topology of Cosmic Reionization Using NIRCam WFSS Observations

The timeline and topology of cosmic reionization are closely linked to the formation and evolution of galaxies in the first billion years after the Big Bang. In my talk, I will address two pressing questions in this field. First, how can we connect JWST observations of galaxies (ionizing photon production) to the intergalactic medium (IGM) constraints (ionizing photon absorption), specifically the relation between IGM opacity and galaxy density? I will present recent JWST WFSS observations of z~6 [OIII] emitters in two highly Lyα-transmissive quasar fields, providing strong constraints on reionization and galaxy evolution models through comparisons with hydrodynamic simulations. Second, what environments lead to more efficient galaxy-driven ionization? I will discuss new results from FRESCO and CONGRESS data, as well as our NIRSpec MSA data, exploring how ionizing photon production efficiency and other ISM properties relate to galaxy overdensity at high z.

Gauri Kotiwale - Metallicity of galaxies at the tail-end of the Epoch of Reionisation

Past studies show that young star-forming galaxies are the primary sources driving the Epoch of Reionisation. Gas-phase metallicities trace massive stars and physical processes such as star formation and feedback, which enrich the interstellar medium (ISM) and reionise the intergalactic medium (IGM) in these galaxies. Thus, studying gas-phase metallicities provides invaluable insights into the chemical enrichment of early galaxies and the reionisation of the Universe. However, accurately estimating the metallicities of high redshift galaxies is still an ongoing challenge.

I will present new results using JWST/NIRCam wide-field slitless spectroscopy and imaging in several fields at $5 < z < 7$ from the EIGER survey, COLA1 survey and the ABELL 2744 lensing cluster field from the ALT survey. To investigate the evolution of the mass-metallicity relation at these redshifts, I stack rest-frame optical spectra of [OIII] emitting galaxies in different stellar mass bins. I will present metallicity estimates for galaxies with stellar masses ranging from 10^7 to 10^{10} M_{sun}. I will also address the issue of degenerate metallicities obtained using various [OIII]5008/H-beta metallicity calibrations and show how we break this degeneracy through the temperature-sensitive [OIII]4363 emission line.

Our large sample of [OIII] emitting galaxies (~700) is obtained with a simple and known selection function, enabling fair comparisons with simulations. Therefore, I will compare our observations to results from cosmological simulations and present statistically robust results which will characterise the ISM of the first galaxies.

Lena Komarova - Evidence for Radiation-Dominated Feedback in Nearby Analogs to Early Starbursts

JWST is revealing metal-poor, high-ionization dwarf starbursts at z > 6, which were likely important agents in the epoch of reionization. Since the IGM is optically thick to Lyman continuum (LyC) at these redshifts, local analogs such as Green Pea galaxies (GPs; z ~ 0.2) can shed light on the conditions and LyC escape mechanisms in these extreme, early objects. We present evidence of radiation-dominated feedback, rather than conventional supernova feedback, in 20 local analogs from the Low-redshift Lyman Continuum Survey (LzLCS) and 6 GPs from the literature. We show that radiation likely drives 300-1000 km/s superwinds in galaxies with high O32 = [O III]λ5007/[O II]λ3726,3729 and low values of 12 + log(O/H). These winds are inferred from broad, power-law wings of [O III]λ5007 emission lines in our Magellan/MIKE, VLT/X-shooter, and WHT/ISIS spectra. The wind properties are linked to young (< 3 Myr) stellar populations and high ionization parameters (O32 > 3.5), and the winds may emerge via the same channels as the ionizing radiation in a picket-fence geometry. We also identify a subset of objects with high-velocity emission-line wings that are Gaussian in form, which are consistent with conventional feedback dominated by SNe.
Our results point to radiation-driven feedback being an important mode of LyC leakage in reionization.

Qiao Duan - Galaxy Mergers in the Epoch of Reionization

Galaxy mergers are fundamental drivers of galaxy formation and evolution. Understanding the evolution of galaxy merger history across cosmic time is essential for unraveling the processes that shape galaxy growth. While extensive studies have focused on mergers at $z < 3$, investigations at $z > 3$ remain limited.
In this work, I present the first comprehensive analysis of galaxy mergers during the epoch of reionization, spanning the redshift range $z = 4.5 - 11.5$. This analysis utilizes data from eight JWST observational fields (CEERS, JADES-GOODS, NEP, NGDEEP, SMACS-0723, MACS-0416, GLASS, and El-Gordo), collectively covering an area of ~190 arcmin^2. Using a statistically robust methodology, I accurately quantify close-pair mergers and derive critical metrics, including galaxy pair fractions, merger rates, and stellar mass accretion rates at $z > 6.5$. For the first time, I demonstrate a remarkably rapid merger rate of approximately six mergers per galaxy per Gyr during $z = 6.5 - 11.5$, highlighting its significant role in driving stellar mass growth in the early Universe.
Additionally, I explore the impact of mergers on star formation and AGN activity. This includes findings of enhanced star formation rates (SFR) in merging galaxies compared to non-mergers and an excess AGN fraction within merger samples.
My work on galaxy mergers has been detailed in two papers within the Galaxy Mergers in the Epoch of Reionization series, both submitted to MNRAS. One of these papers has already received a referee response with minor revisions.

Lola Danhaive - A first look at the ionised gas kinematics of high-redshift galaxies

Studies of gas kinematics at z<4 have built a picture where most star-forming galaxies slowly settle into dynamically cold disks before turning into massive hot quiescent galaxies. Pushing these analyses to higher redshifts is crucial for both understanding the origin of the dynamical populations we see in the local universe and tracing their evolution in cosmic time to uncover the conditions for the formation of the first discs. I will present a first look at ionised gas kinematics at z>5 for a large sample of galaxies, focusing on ~100 Ha emitters from the FRESCO survey. Kinematic properties such as rotational support, intrinsic velocity dispersion, and dynamical mass, are inferred from the NIRCam grism data using a novel tool GEKO combined with imaging from the JADES survey. By comparing to measurements out to cosmic noon, this analysis places additional constraints on the redshift evolution of the velocity dispersion and rotational support, shedding light on the dynamical properties of early galaxies. These measurements provide crucial insights on the physics of galaxy evolution, especially in light of recent observations of dynamically cold disks at high-redshift and the seeming disagreement with many theoretical models. I will discuss relations between kinematics and star formation and highlight factors driving the increased turbulence we observe. The inferred dynamical masses can be used to obtain constraints on the gas and dark matter fractions in these early systems, providing some of the first benchmark values against which to test predictions from cosmological simulations.

Minami Nakane - JWST Measurements of [O/Fe] Ratios and Implications for Chemical Enrichment in Early Galaxies at z~10

In a recent work, a low [O/Fe] ratio in a luminous galaxy of GN-z11 at z =10.6 is reported (Nakane et al. 2024). As origins of such low [O/Fe] at the early epoch after the Big Bang (~430 Myr), the possibility of short delay time of Type-Ia supernovae (SNe Ia) or existence of bright hypernovae (BrHNe)/pair-instability supernovae (PISNe) has been discussed.
To further investigate chemical enrichment of early galaxies with Fe abundances, we construct a larger sample of galaxies at z=9.3-12.3 selected from z>9 galaxies observed by JWST/NIRSpec based on the high signal-to noise ratios of the continuum detections. We present [O/Fe] ratios derived from individual spectra of 6 galaxies including GHZ2 and GN-z11, and composite spectra of 8 galaxies. We fit the prism data with the model spectra consisting of BPASS-stellar and Cloudy-nebular spectra in the rest-frame UV wavelength ranges with Fe absorption lines, carefully masking out the other emission and absorption lines in the same manner as previous studies conducted for lower redshift z~2-6 galaxies with oxygen abundance measurements. We obtain low [O/Fe] ratios for 2 out of 6 individual spectra and composite spectra compared to the Milky Way stars. We discuss the timescale of Fe enrichment and possibility of short delay time or BrHNe/PISNe. The [O/Fe] measurements of GN-z11 and GHZ2 support the connection with globular clusters (GCs) previously suggested by the rich nitrogen abundances.

Rohan Naidu - INVITED - Census of high-z galaxies

Review about the galaxies we are discovering at very high redshift, in the very early stages of cosmic history (the origins, as in the title of the conference). This talk could concentrate on galaxy census and other subtopics of interest.

Callum Witten - An evolved protocluster in the early Universe: the birth of an ionised bubble and the (likely temporary) death of its resident galaxies

Protocluster environments host the most extreme overdensities of galaxies and hence ionising photons in the very early Universe. As such, they naively appear to be incredible engines for the production of early ionised bubbles. However, this conclusion is complicated by the presence of local, dense neutral gas, that facilitates their excessive star formation, and dust produced by their old stellar populations, which leads to the absorption of ionising photons. Therefore, studying these complex structures is crucial in understanding the catalysts of the reionisation process. I will present new JWST/NIRCam, JWST/NIRSpec and VLT/XSHOOTER observations of a z~8 protocluster that reveal evidence of an ionised bubble, dense neutral gas and quenched stellar populations, amongst 16 galaxies within a ~50 pkpc x 50 pkpc region. We model the growth of this ionised bubble and exploit Lya observations to understand that the old stellar populations present in this overdense environment drove the ionised bubble that we show has to be present. Moreover, we utilise recent NIRCam grism spectroscopy of a second z~8 candidate protocluster to spectroscopically confirm 8 galaxies within a similarly small spatial region. These new observations of the rarest, most massive structures in the early Universe reveal them to be incredible powerhouses for the build-up of stellar mass, with abnormally high gas and dust masses, and to be complex mechanisms behind the production of ionised bubbles at the earliest cosmic epochs.

Eiichi Egami - SAPPHIRES: Slitless Areal Pure-Parallel High-Redshift Emission Survey

SAPPHIRES (Slitless Areal Pure-Parallel High-Redshift Emission Survey) is JWST's Cycle-3 large treasury pure-parallel program with a time allocation of 600 hours, exploiting the power of the NIRCam/Grism wide-field slitless spectroscopy (WFSS) mode. At the time of this writing (Nov 2024), the program has already executed ~140 hours of observations. Here, we will present an overview of SAPPHIRES and the results from our early data release (EDR), focusing on one deep parallel field with a total observing time of ~60 hours. Using the two orthogonal-dispersion grisms (R and C) with the F356W and F444W filters covering 3-5 microns, this EDR data set provides the deepest and most complete NIRCam/Grism WFSS data so far over an area of ~15 arcmin^2, which is complemented by deep (5-10 hr) 13-band NIRCam imaging data also obtained by SAPPHIRES. In this presentation, we will present scientific highlights from the analysis of the SAPPHIRES EDR data such as, (1) emission-line galaxies and their clustering at

z~4-9, including broad-line AGN (i.e., Little Red Dots; LRDs), (2) spatially-resolved morphology and kinematics of line-emitting regions, (3) search for low-metallicity Pop-III galaxy candidates, and (4) z>10 galaxy candidates identified in the imaging data. We will also report any additional exciting discoveries that will be made as we obtain more SAPPHIRES data continuously until the time of this conference in May 2025.

Yoshinobu Fudamoto - JWST Wide Field Spectroscopic Study of Galaxy Over-Density at z=8.47

Understanding galaxy formation at redshifts z>6 and its role in cosmic reionization is one of the key goals of current extragalactic astronomy. Dense regions of galaxies are among the primary phenomena contributing to the reionization of the Universe (Tilvi+20), as they can create large ionized bubbles extending approximately a few Mpc, which allow ionizing photons to travel greater distances.Thanks to the unprecedented capability of James Webb Space Telescope (JWST), identification and detailed study of such galaxy over-density in the heart of cosmic reionization finally became within our reach (Morishita+23, Hashimoto+23). As part of a JWST Cycle-3 Treasury imaging and spectroscopic survey, Slitless Areal Pure-Parallel HIgh-Redshift Emission Survey (SAPPHIRES), wide field slitless spectroscopy (WFSS) of NIRCam/Grism survey is covering an unprecedentedly large area. As part of the WFSS survey, around the MACS0416 cluster, we spectroscopically confirmed 7 to 9 galaxies are in the ~ 5 arcmin^2, forming a massive galaxy over-density at z=8.47 through detections of [OIII]λλ5007, 4959 and Hβ emission lines. Interestingly, they are located close to the several already known star-forming galaxies at z=8.31 (MACS0416-Y1, JD1/JD2, Tamura+18, Li+24) forming extended galaxy group (~ 100 cMpc). In this talk, we report the discovery of the highest-redshift galaxy overdensity known to date. We present an analysis of the member galaxies using F356W and F444W spectroscopy, compare them with field galaxies, and discuss their implications for cosmic reionization.

Jorge Zavala - Probing Intense Activity Inside a "Cosmic Crucible" at z=12 with JWST and ALMA

In this talk, we will present recent findings from our JWST and ALMA observations targeting GHZ2/GLASS-z12, a galaxy at z=12.3. These observations provide key insights into the nature and physical conditions of this 'cosmic crucible' through direct detection of spectral features such as H-alpha, [OIII]4959,5007AA, [OIII]88um, and a number of other UV transitions. Our analysis suggests that this galaxy is powered by compact, young star-forming regions that may evolve into dense stellar clusters. We will discuss the supporting evidence for this scenario, as well as the ongoing challenges. While focusing on a single galaxy, this study represents a significant step forward in understanding the nature of the luminous population of z>10 galaxies, and demonstrates the unique capabilities of JWST instruments (including NIRCam, NIRSpec, and MIRI) and their synergy with telescopes like ALMA.

Zhaozhou Li - Formation of galaxies at cosmic dawn by feedback-free starbursts

JWST observations indicate a surprising excess of luminous galaxies at z≳10, consistent with an efficient conversion of accreted gas into stars. This is very different from the suppressed star formation by feedbacks at later times, demanding a potential paradigm shift for early galaxy formation. I will show that the high densities and low metallicities at this epoch guarantee a high star-formation efficiency by feedback-free starbursts (FFBs) in the most massive dark-matter haloes. FFBs are expected in high-z massive halos where the gas density exceeds 1e3 cm^-3, with a free-fall time of ≲1 Myr, below the time required for low-metallicity massive stars to develop winds and supernovae. I will discuss the conditions for FFB and the observable predictions for galaxy mass and luminosity functions, sizes, outflows, dust attenuation, etc. Tentative comparisons to early JWST results at high z seem to indicate qualitative agreement with the FFB predictions.

Javier Álvarez-Márquez - Insights into the starburst nature of GN-z11 galaxy with the JWST MIRI spectroscopy

This talk presents new MIRI/MRS spectroscopic observations of the high-redshift galaxy GN-z11, covering its rest-frame optical spectrum. The [OIII]5008 and Hα emission lines are detected and spectroscopically resolved, with profiles well-modeled by a single, narrow component. The MRS spectrum shows no evidence of a broad Hα line, which would suggest a broad line region typical of a type 1 active galactic nucleus (AGN). Additionally, neither the UV and optical continuum nor the optical emission line luminosities support the presence of an actively accreting black hole.

Our findings suggest that the MRS optical spectrum of GN-z11 is consistent with a massive, compact, low-metallicity starburst galaxy, where any AGN contribution, if present, would be minimal. With its exceptionally high star formation rate and stellar mass surface density, approaching those found in the densest stellar clusters, GN-z11 may be undergoing a feedback-free, highly efficient starburst phase. GN-z11 thus stands as an ideal example for studying the nature of bright galaxies in the early Universe.

This talk will also underscore the pivotal role of MIRI spectroscopy in investigating the large population of bright galaxies identified by JWST in the primordial Universe, emphasizing the need for future MIRI spectroscopic surveys targeting a broader sample of galaxies at z > 10.

Alejandro Crespo Gómez - Digging into the nature of GNz11: rest-frame optical MIRI imaging

The galaxy GN-z11 at z=10.6 is the brightest known galaxy before the main Epoch of Reionization (EoR) and belongs to the class of luminous galaxies in the early Universe. The nature of this galaxy as an extreme young and compact starburst or as a massive super-Eddington accreting black hole is under debate based on existing NIRCam and

NIRSpec data. So far, the knowledge of this galaxy has been limited to its UV emission, which traces a stellar population typically younger than 10 Myr, while the presence of an older stellar population is unclear due to the lack of optical and near-IR observations.

Tuesday May 13, 2025

Anna de Graaff - INVITED - The rapid rise of massive quiescent galaxies in the first 2 Gyr

Review about the quiescent galaxy population at comic noon and the higher redshifts that JWST is probing, with special regard on what these studies are finding about the very early stages of galaxy formation (the origins, as in the title of the conference).

Drew Newman - Dynamical evidence of an overmassive black hole in a quiescent galaxy at z=2

Measuring black hole masses across cosmic time is a key step toward understanding the co-evolution, or lack thereof, between supermassive black holes (SMBHs) and their host galaxies. Resolved stellar kinematics can detect and provide accurate masses of inactive black holes, but applications have been limited to the relatively nearby universe. I will present JWST NIRSpec/IFU observations of a massive, quiescent galaxy (M_* ~ 3 x 10^11 Msol) at z~2 that is gravitationally magnified by a factor of ~25x in its center. We obtain remarkably detailed stellar kinematic maps down to the inner ~90 pc, thereby resolving the SMBH sphere of influence for masses >~ 3 x 10^9 Msol. I will present evidence of a SMBH and estimates of its mass for the first time in such a distant quiescent galaxy. I will discuss novel constraints on the evolution of fundamental black hole scaling relations, implications for the growth and quenching of massive galaxies at early epochs, and connections to local “relic” galaxies and high-redshift black hole populations from JWST.

Marianna Annunziatella - MIDIS: Unveiling the Star Formation History in massive galaxies at 1<z<4.5 with spectro-photometric analysis

Understanding the star formation history (SFH) of galaxies is crucial for unveiling the physical processes driving galaxy evolution. Massive galaxies (M*>10^10 M$_\odot$) are of particular interest as they appear to form rapidly during the early epochs of the Universe. This study presents a spectrophotometric analysis of a sample of massive galaxies within the redshift range 1 < z < 4.5. The sample is drawn from CANDELS data in the GOODS-S field and includes both quiescent and star-forming galaxies. For this study, we use low-resolution spectroscopic data from the NIRISS instrument on JWST, combined with broadband and medium-band photometry from JWST, HST and ground-based telescopes. SFHs are derived using the spectral energy distribution (SED) fitting codes BAGPIPES and Synthesizer, exploring various models, including single and dual stellar populations and non-parametric SFHs. The results reveal early mass assembly in these galaxies, with the formation of 10^8 M$_\odot$ by z ~ 6 and 10^9 M$_\odot$ by z ~ 5.5. Earlier and more rapid mass

assembly is identified when considering non-parametric SFH. This analysis underscores the importance of advanced spectrophotometric fitting technique in enhancing our understanding of the cosmic history of massive galaxy assembly.

Tobias Looser - Galaxy assembly in the first billion years: Mini-quenching and more evidence for bursty SFHs

Directly observing the first quenched galaxies and understanding the mechanisms responsible for their quenching are crucial for constraining galaxy formation models. Before the JWST era, quenched galaxies were identified only up to z < 5, all of them being massive (M⋆ > 10^10 M⊙).
Recently, JWST has pushed this frontier to z ~ 7–8. However, interestingly, not all of these newly discovered quenched systems are massive. The SFHs of these "mini-quenched" galaxies suggest that they quenched recently and rapidly. This is likely driven by internal feedback mechanisms, such as outflows triggered by intense star formation or accreting black holes, which eject the ISM and halt star formation. However, the ISMs of these galaxies will likely be re-accreted leading to rejuvenation, as predicted by simulations postulating bursty SFHs in the first billion years.
Additional recent studies have provided further evidence for bursty SFHs at high-redshift, by analyzing the scatter around the MS and tracing star formation on different timescales.
Building on this foundation, I will present the first results from OASIS (JWST Cycle 3 Program #5997), a deep spectroscopic survey designed to investigate these phenomena. The survey includes a diverse sample of more mini-quenched galaxies, "lulling" galaxies (i.e., those with low specific star formation rates below the MS), rejuvenating galaxies, star-bursting galaxies, and intermediate cases. I will conclude by discussing the quantitative constraints OASIS places on bursty SFHs and exploring the transition from temporary quenching and bursty star formation to permanent quenching and secular evolution at high redshifts.

William Baker - Investigating the abundance and nature of high-z quiescent galaxies

One of the most important findings so far with JWST has been the number of high-redshift quiescent galaxies uncovered. These galaxies are crucial tests of galaxy formation and evolutionary models both in their abundances and implications for galaxy feedback processes. However, large samples of spectroscopically confirmed high-redshift galaxies have yet to be fully-explored. In addition, there are key questions about their stellar populations which can be explored through their star-formation histories. In this talk I will present results from a recent exploration of 18 spectroscopically confirmed massive (central) quiescent galaxies as part of the JADES survey. With deep imaging and spectroscopy from JADES we can probe down to low-mass satellite galaxies (finding two), yet the least massive central in our sample of 18 is at 10^10 solar masses. I will discuss their number densities, adding a spectroscopically corrected estimate to the more common pure photometric samples. I will also compare with the FLAMINGO simulations,

one of the largest simulations to-date in order to probe their abundances whilst being able to account for cosmic variance in the simulations. I will explore their star-formation histories and stellar population properties, determining formation and quenching times with accurate spectrophotometric modelling, how these compare to the age of the universe within the very earliest times, and what this tells us about early galaxy quenching. I will also probe the AGN abundance within these galaxies in the present day and what this means for possible quenching mechanisms.

Darko Donevski - Reconstructing the Histories of Dust-Rich Quiescent Galaxies up to z ~ 3

Recent discoveries of significant dust and cold gas in quiescent galaxies (QGs) at the Cosmic Dawn challenge the conventional view that these objects have negligible ISM relative to their stellar mass. These findings raise key questions, such as how quenched galaxies sustain or replenish their dust content after star formation ceases.
In this talk, I will discuss results from two pioneering studies addressing this question both from an observational and theoretical point of view. We identify a notable fraction of dust-rich QGs in deep JWST fields up to z ~ 3. By modeling their star formation histories, we find diverse formation redshifts, distinct quenching pathways (both slow and fast), and evolving ISM conditions. I will also highlight how cosmological simulations reveal that AGN feedback does not impact dust and cold gas on the same timescales as commonly thought.
I will further elaborate on the main channels for the replenishment of dust in QGs that are identified by linking the observed data with simulations. The main channel for dust re-growth, most active within 200 million years post-quenching, is less dependent on cold gas than expected. I will illustrate the impact of this process through the age-attenuation plane of JWST detected QGs and outline implications for interpreting dusty QGs in the first 3 Gyr of the universe. Finally, I will outline how these insights may significantly affect interpretation of ALMA/JWST results and color-based selection techniques.

Lucie Rowland - REBELS with ALMA & JWST: The build-up of massive galaxies in the early Universe

In this talk, I will present results from a now completed JWST NIRSpec IFU program targeting 12 galaxies selected from the REBELS (Reionisation Era Bright Emission Line Survey) ALMA large program at redshifts of 6.5-8. Thanks to the exceptional sensitivity of the NIRSpec prism, we detect key optical emission lines from [OII] to [SII] for most of the sample, enabling metallicity constraints through multiple calibrations and insights into ionisation properties from traditional BPT diagnostics. A notable result is the discovery of near-solar oxygen abundances in several of these galaxies, challenging conventional models of early chemical enrichment. I will focus on extending the mass-metallicity and fundamental metallicity relations to higher stellar masses, comparing these systems to

typical z~6-8 galaxies observed in other programs, and exploring the implications for the rapid growth and chemical evolution of massive galaxies in the early Universe.
In addition, ALMA [CII] and dust continuum observations of the same galaxies provides critical context, allowing us to link spatially resolved metallicity information to dust properties and gas kinematics. This presentation will complement other talks analysing different aspects of the same dataset, offering a comprehensive view of the processes shaping massive galaxies during the Epoch of Reionisation.

Erica Nelson - Big Bad Bois: Balmer Breaks and Broad Lines in Candidate Massive Galaxies a Billion Years After the Big Bang

One of the most remarkable findings in early JWST data was the existence of a population of ultra-red potentially massive galaxies at z > 7. The best redshift and stellar mass estimates of these objects placed them at z > 7 and log(M∗)> 10, pushing up against the limit of available baryons in a ΛCDM cosmology. However, these estimates were based on photometry alone, making inference of their physical properties uncertain. Here I will present spectroscopy of these fiducially massive early galaxies with JWST NIRSpec. This spectroscopy lays to rest the first-order uncertainties in their interpretation: they are neither low redshift interlopers nor emission line dominated. A number of these objects display evidence of broad lines in their spectra perhaps suggesting the presence of AGN, as has been posited in other populations of “little red dots” at these redshifts. Incredibly, we detect Balmer breaks in the two highest redshift galaxies in our sample, at z ~ 8, the likeliest interpretation of which is the existence of stellar populations older than 100Myr just 650Myr after the Big Bang. Even with spectroscopy, the nature of these objects remains uncertain suggesting a very rapid build-up of the first galaxies, supermassive black holes, or both. With this talk, I hope to open a discussion of what the next key steps are to understanding galaxy and black hole growth in the early universe.

Miroslava Dessauges-Zavadsky - Unveiling the UV-brightest monsters in the distant Universe

We present ALMA dust+CO emission of 12 UV-monsters at z~2.1−3.6 selected for their extreme rest-UV brightness of MUV=−23.4 to −24.7, outshining by 2-3mag the JWST discovered UV-luminous galaxies at 7<z<14, and identified as strong LyC leakers. Characterised by negligible dust attenuations with blue UV slopes (−2.62 to −1.84), very young stellar populations of 10 Myr, and powerful starbursts (sSFR=112 Gyr−1), they lie 1.5dex above the main sequence for their Mstars~(1.5−4.6)×10^9 M⊙. These physical properties unique at cosmic noon very much resemble those of galaxies at the epoch of reionisation! Surprisingly we detect dust continuum for 9 galaxies, yielding high dust masses barely produced by SNe. The CO emission evidences high gas fractions of 82%. The star formation efficiencies reach >40%, with amazingly short gas depletion timescales <13 Myr to 71 Myr. These galaxies are likely caught at the beginning of their mass build-up and undergo very efficient+fast gas conversions into stars that can only result from gas

collapse within short free-fall times. The feedback-free model seems to explain their formation; similarly to what is proposed for the 7<z<14 UV-bright galaxies. To reconcile the co-spatial dust emission with the UV-bright unattenuated emission, we speculate about radiation-driven outflows temporary removing dust at the starburst location and expelling dust at large distances in line with the FIR effective radii (1.7−5 kpc).

Luca Costantin - Revealing the complex morphologies of high-z disk galaxies with JWST

Understanding how galaxies acquire their structure across cosmic time is crucial for unraveling the processes governing the stellar mass buildup in the Universe. In this context, the imaging capability provided by JWST allowed for unprecedented detail in unveiling the complex morphologies of high-z disk galaxies. These observations revealed an unexpected variety of structures, including the presence of barred galaxies at epochs much earlier than previously anticipated.
In this talk, I will explore the latest insights into the complex morphologies of disk galaxies at and beyond cosmic noon. I will highlight the emergence of barred structures at high redshifts and their implications for galaxy formation and evolution. In particular, I will discuss the discovery of ceers-2112, the furthest barred spiral galaxy observed to date, which suggests a more dynamic and diverse picture of disk galaxy evolution than predicted by current cosmological simulations.
Thus, this talk will provide a synthesis of the emerging view of high-z disk galaxies, illustrating how JWST is offering a transformative perspective on the origins and evolution of early galaxies.

Nor Pirzkal - Resolving star formation at Cosmic Noon using WFSS

We present observations of the spatially resolved star formation in galaxies in the Hubble Ultra Deep Field (HUDF) near Cosmic Noon. With the advent of JWST, star forming galaxies at the Cosmic Noon are significantly better resolved than using HST or ground based observations. With a pixel scale of 0.060” per pixel, structure potentially linked to star formation can be seen when these objects are photometrically imaged. Traditionally extracted Wide Field Slitless Spectroscopic spectra of sources where star formation is patchy leads to either emission lines not being detected or an incorrect determination of the observed wavelengths of emission lines in these objects, caused by the offset between the assumed center of the galaxies and the source of the emission lines. Using new techniques, we are able to leverage the spatial resolution of JWST, multiple prisms and orientation on the sky, and the high multiplexing capability of WFSS observations to identify star forming galaxies, determine their accurate redshifts, and create full forward modeled 2D spatially resolved maps of [OII], [OIII], Hb, and Ha emission lines. Here we present results using NGDEEP JWST NIRISS observations of the HDF and the resolved star formation of over 300 galaxies. We show how traditional 1D WFSS data processing can lead to systematic errors in redshift and emission line fluxes, and therefore

significantly affect derived physical parameters such as star formation rates for these objects.

Marc Huertas-Company - The emergence of the Hubble sequence as seen by COSMOS-Web

The first JWST deep surveys have opened a new window into understanding the morphological evolution of galaxies across cosmic time. However, all previous works are based on small-number statistics, preventing accurate probing of the morphological diversity at cosmic dawn. Leveraging the wide area coverage of the COSMOS-Web survey, we quantify for the first time the stellar mass functions of different morphological types from z~7 with unprecedented statistics and establish robust constraints on the epoch of emergence of the Hubble sequence, including dynamically cold disks. In my talk I will discuss the main results of this work: (a) At redshift z>4.5, the massive galaxy population is dominated by disturbed morphologies—even in the optical rest-frame—and very compact objects confirming that a significant fraction of the star formation at cosmic dawn occurs in very dense regions. (b) Galaxies with Hubble-type morphologies—including bulge- and disk-dominated galaxies—rapidly emerge starting from z~4. (c) Massive quenched galaxies are predominantly bulge-dominated from z~4 onward, suggesting that morphological transformations are ubiquitous to quenching mechanisms at the high-mass end. (d) Low-mass quenched galaxies are typically disk-dominated, pointing to different quenching routes in the two ends of the stellar mass spectrum from cosmic dawn. (e) Using stellar bars as a proxy, we speculate that dynamically cold disks might have been common ($>50\%$) among the star-forming population since cosmic noon.

Emma Curtis-Lake - INVITED - Unveiling the physical properties of the earliest galaxies: current mysteries and challenges revealed by JWST Surveys

Review about the galaxies that several teams (JADES, CEERS, MIDIS, NGDEEP, UNCOVER, PRIMER, COSMOSWeb, etc) are discovering at very high redshift, in the very early stages of cosmic history (the origins, as in the title of the conference). It will concentrate on SED modeling and derived physical properties, among other subtopics of interest.

David Puskas - Importance of mergers in driving star formation and black hole activity from Cosmic Noon to Cosmic Dawn

I present the most comprehensive study of major galaxy mergers (stellar mass ratio 1:4) to date, focusing on the poorly understood redshift range of z~3–9. Using NIRCam imaging and NIRSpec spectroscopic data from the JADES GTO program I examine galaxy close

pair fractions, major merger rates, and mass accretion rates to assess the role of mergers in galaxy growth. Close pair fractions are measured using a probabilistic method that incorporates full posterior distributions and uncertainties from photometric redshifts and spectral energy distribution (SED) fitting for a mass-complete sample in the range of log(M/Msol) = 8–10. Galaxies hosting major companions are identified based on projected 5–30 kpc separations and overlapping redshift posteriors. The redshift evolution of close pair fractions rises steeply and turns over at z~6, with a dependence on primary galaxy mass. By assuming merger timescales from simulations, these fractions are converted into major merger rates, which increase and flatten at high z, showing weak stellar mass scaling. Cumulative mass accretion from mergers contributes approximately 16% to total mass growth, consistent with ex-situ mass fractions from our simple numerical model. Additionally, I evaluate the role of mergers in star formation and stellar mass growth by analysing their position relative to the star-forming main sequence, using SED-derived star formation rates and stellar masses. Finally, I assess the AGN fraction within mergers to explore their connection to triggering AGN activity. This study provides critical insights into the hierarchical growth of galaxies during the early universe.

Claudia di Cesare - The burstiness and mass dependence of star formation in low mass galaxies at z~4-5

Observations indicate a tight correlation between the star formation rate (SFR) and the stellar mass (M*) over a range of galaxy masses and redshifts. JWST opened up the possibility to investigate the properties of this relation at high-redshift with unprecedented details, providing information on the efficiency of gas conversion into stars and its associated feedback in the early Universe. In this talk I will present the first results on the SFR - M* relation in the ALT survey using a statistical sample of ~400 Ha selected galaxies with log(M*/Msun) = 6-10 at 4 < z < 5. ALT is a 48 hrs JWST cycle 2 program (3516, PIs: Matthee & Naidu) using NIRCam imaging and grism on a region around the lensing cluster Abell 2744. I will focus on the degeneracy between the inferred slope and the mass-dependent scatter of the main sequence, in particular when forward-modeling selection effects on the observational sample. Then, I will delve into the investigation of the star formation histories (SFH) of galaxies. To do so I employ diverse indicators (Ha and UV luminosity) which are sensitive to changes in the SFR on different timescales, and help us discern between smooth or busty star formation in the early Universe. Throughout the talk, I will point to numerical simulations and models that aid in the interpretation of the observational results.14

Alba Covelo Paz - 3,000 Hα emitters at z~4-7: a new tracer of galaxy build-up in the first ~1.5 Gyr

The first billion years of cosmic history witnessed the formation and build-up of the first galaxies. Simulations show that this is a bursty process, characterized by a stochastic sequence of bursts of star formation followed by more quiescent phases. Measuring the

amplitude and duration of these oscillations on early star formation (i.e., the burstiness) is paramount to constrain our galaxy formation models. Here, we make use of JWST H_ spectroscopic measurements of thousands of galaxies to derive the star-forming main sequence at 4 ~ 3 before JWST, and how we can use it to probe star formation across cosmic time.

Jens Melinder - Old stellar populations and hot gas in the most distant galaxies - JWST/MIRI results from the MIDIS-RED project.

The extremely high redshift galaxies (z>~10) discovered, and spectroscopically confirmed, in the last couple of years with JWST/NIRCAM+NIRSPEC provides clues to how the very first galaxies formed their stars. In this talk I will present new measurements on four of the highest redshift galaxies (at z=9.7-13.4) in HUDF with JWST/MIRI (F560W, F770W, and F1000W) obtained in the MIDIS-RED program. The addition of MIRI data to the existing NIRCAM/NIRSPEC data allow us to probe the rest-frame red optical emission (including optical nebular emission lines and stellar continuum from intermediate age stellar populations). We also obtain star formation histories and various emission line properties for these galaxies from SED fitting and I will discuss how these observations fit into current theories of how the first galaxies formed.

Carlota Prieto Jiménez - Exploring Galaxy Interactions in the Early Universe through Resolved Hα Emission

This presentation focuses on MIRI/JWST medium resolution spectroscopy (MRS) and imaging (MIRIM) of the Lyman-break galaxy B14-65666 and the lensed galaxy MACS1149-JD1, the two only galaxies at redshift above 7 with spatially-resolved Hα emission so far.
B14-65666(z=7.15) and MACS1149-JD1(z=9.11) each consist of two clumps that are kinematically separated as revealed by MIRI. While B14-65666 does not exhibit any signs of active galactic nucleus activity, it is one of the UV-brightest starburst galaxies in the Epoch of Reionization and it is one of the few where dust continua emission at rest-frame 88, 122, and 158 μm emission has been detected. MACS1149-JD1 is a normal star-forming galaxy and the spectroscopy with JWST revealed that it is dust-free with a subsolar metallicity, indicating a relatively young and metal-poor system.
The new MRS data spatially and spectrally resolve the Hα emission in the different galaxy components. The MIRIM F560W observations provide the resolved and integrated rest-frame optical continuum. MIRI data, combined with the multiwavelength ancillary data (NIRCam and ALMA), enable us to calculate physical properties such as Stellar Formation Rate. Additionally, the SED-fitting analysis allows us to study the resolved Hα equivalent width and distinguish between young and mature stellar populations, as well as identify different properties in gas and dust along the clumps. This study will shed light on understanding the role of galaxy interactions and reionization of the Universe.

Matteo Messa - Revealing the parsec-scales details of high-z star-forming systems with JWST

I will present the study of a gravitationally lensed system at z=6.14, behind the cluster MACSJ0416: Initially observed as a wide Ly-alpha arc, the combination of NIRCam imaging and NIRSpec IFU reveals a intensively star-forming system, dominated by ~10 compact clumps, with derived intrinsic sizes on the order of 1-10 pc, and (surface) densities of the order of thousands M*/pc^2, making them ideal candidates of proto-GCs. Many of those stellar clumps show very steep UV slopes (-3<beta<-2.5), hinting at extreme ionisation efficiencies; however, while some of those are surrounded by HII regions with large equivalent widths (EW>2000 A), others show a lack of nebular lines, possibly hinting at young objects deprived of gas or with non-negligible escape fractions. The compact clumps of the system are linked by a low-surface brightness (in UV and Optical) arc where also continuum-dark low-metallicity (down to 1% Solar) emitting regions are found. The entire system spans only few kpc in size and reveals how zooming into pc-scales and allows to uncover the complex sub-structures of high-z star-forming systems. The combination of large magnification factors (given by the lensing) and deep exposures allow to reach faint magnitudes (>31 ABmag), uncovering 5 additional satellite systems, at Mpc distances from the main Lya emitter, and revealing a possible overdensity of galaxies.

Eden Girma - Mind the gap: numerical experiments between kilo-parsec and parsec scale at high-redshift

Recent JWST discoveries at redshifts of 5<z<10 foreground our poor understanding of the nuclear regions shaping galaxy progenitors. We present a new approach to modeling high-redshift galactic nuclei via a suite of magneto-hydrodynamical high-resolution isolated simulations in RAMSES, deliberately focusing on gas-rich reservoirs that comprise the central kilo-parsec of possible high-redshift galaxy systems. Our simulation suite encompasses a large parameter space of observationally-informed initial conditions, self-consistently captures the multi-phase star-forming interstellar medium at an effective resolution of 2 pc, and requires only a fraction of the computational resources generally allocated for galaxy simulations. We present preliminary insights into how large supplies of gas can actually disrupt supermassive black hole (SMBH) accretion and growth, contrary to standard semi-analytical SMBH and circumnuclear disk (CND) co-evolution models. Only systems with gas fractions below 50% evolve into rotation-supported thick turbulent disks where both CNDs form and SMBH seeds can dynamically survive at the system center. As gas fraction increases, subsequent increase in Toomre mass enables the build-up of massive gas clumps that can perturb SMBH trajectories and inhibit the formation of a stable accretion-fueling inner gas disk. We find that systems with the highest gas fractions undergo an extreme burst of star formation, followed by stellar feedback that completely evacuates any remaining gas. This suggests a critical turning point of surface density above which efficient star formation and consequently strong feedback prevents the transport of gas towards the central SMBH.

Wednesday May 14, 2025

Desika Narayanan - INVITED - The formation of cosmic dust in the earliest galaxies

Review about dust from cosmic noon to dawn, focusing on what studies about dust are finding or could find about the very early stages of galaxy formation (the origins, as in the title of the conference).

Rebecca Fisher - Investigating The Dust Attenuation Properties of 12 Massive Galaxies Using REBELS JWST NIRSpec and ALMA Observations

JWST and ALMA have started to reveal the prevalence and properties of dust up to very high redshifts, however, there remain many uncertainties. While some studies have shown consistency with local star-forming galaxies, others suggest an evolving dust attenuation law and the detection of the 2175A bump at very high redshift is unexpected. We present a detailed analysis of dust within 12 massive (log(M*/MSun)=9.1–9.9) galaxies at z=6.5-7.7. Measuring the attenuation curve directly from NIRSpec R100 spectra we see evidence for a dust bump in three galaxies, indicating the presence of small carbonaceous dust grains, implying these must form rapidly. We find shallower attenuation laws at higher A_V and stellar mass, while we find no strong correlation of the slope with M_UV or gas-phase metallicity. Comparing this to empirical models suggests that the most important factor driving the variation in these attenuation curves is the dust-star geometry, not the dust grain properties. Physical properties derived from rest-frame far-infrared observations from the ALMA REBELS large program support this interpretation. Overall, our results show little evolution in dust properties and no significant deviations in the shape of dust attenuation curves compared to the local Universe. Finally, we use the synergy between the spatial resolution of the JWST IFU observations and high-resolution ALMA observations of the FIR dust continuum available for a subset of these sources to investigate their dust properties on spatially resolved scales for the first time.

Denis Burgarella - Forging the First Dust – Transition from Stellar to ISM Grain Growth in the Early Universe

We investigate the coevolution of metals and dust for 173 galaxies at $4.0<z<11.4$ observed with JWST/NIRSpec. We use the code CIGALE that integrates photometric and spectroscopic data. Our analysis reveals a critical transition at Mstar~108.5 $M_\odot$, from galaxies dominated by supernovae and AGB stardust, to those dominated by grain growth. This implies a two-mode building of dust mass, supported by model predictions. The detection of stardust galaxies provides a natural and inherent explanation to the excess of UV-bright galaxies at z>10 by JWST. Besides, we observe that the metallicity of galaxies at $z\gtrsim8$ presents a metal-to-stellar mass ratio larger than a few 10-3, above a floor.

This suggests a very fast rise of metals at high redshift, impacting the tentative detections of population III objects.
Until the conference, two new datasets will be analyzed:
1) the alpine/crystal sample where resolved spectrophotometry will permit to better understand inside the galaxy, region per region.
2) The same method will be applied to the CAPERS dataset, and we will increase the statistics, which allows to identify, and characterize more of these objects. One of the main open questions is whether this galaxy population becomes dominant when getting closer, or above z = 10, and maybe to pop.III.

Anishya Harshan - What made the dust so hot in a z = 8.3 galaxy? Case Study of MACS0416-Y1

Mass assembly of massive galaxies in the early universe is an area of rapid research. MACS0416-Y1 is one such massive galaxy that was known even before the launch of JWST. This galaxy, confirmed to be at z= 8.312, has been well studied using HST imaging and ALMA observations, and this makes Y1 one of the very few galaxies in the epoch of reionization with known dust and gas properties such as dust temperature, dust mass, and gas content. More recently, Y1 was observed as part of the CANUCS JWST survey. The deep rest-frame UV and optical NIRCam imaging and deep NIRSpec spectroscopy allow us to conduct a spatially resolved analysis of Y1. In this talk, I will present the resolved star formation and ISM properties of this z=8, high dust temperature, and high gas mass galaxy, giving insights into the formation and evolution of high mass galaxies during the EoR.

Hiddo Algera - The formation of dust in the early Universe

Dust is a crucial component of the interstellar medium, and fundamentally alters the observable signature of galaxies near and far. Recent ALMA observations have revealed dust to be widespread at z ~ 7, and moreover detected its presence as far back as z = 8.3. In contrast, JWST observations of even more distant galaxies suggest a predominantly blue, dust-poor population at z > 10.
This apparent contradiction raises an important question: how can the earliest galaxies appear dust-poor while galaxies at z ~ 7 are surprisingly dust-rich? In this talk, I will shed light on this puzzle from two different angles: first, I will discuss the status of recent and ongoing deep ALMA searches for dust in JWST-selected galaxies at z ~ 8.5 - 14.2. Following this, I will present a detailed study of the build-up of massive dust reservoirs at z~7, leveraging JWST/NIRSpec IFU observations of 12 ALMA-detected galaxies from the REBELS survey. Through a combined analysis of dust, metals and [CII]-based gas masses, I will present the first statistical constraints on the dust-to-gas and dust-to-metal ratios of galaxies in the early Universe, and thereby shed light on their pathways of dust buildup.

Ambra Nanni - Origins of Carbon Dust in a JWST-Observed Primeval Galaxy at z~6.7

JADES-GS-z6-0, a high-redshift galaxy (z~6.7) recently observed as part of the James Webb Space Telescope (JWST) Advanced Deep Extragalactic Survey (JADES), exhibits a distinct bump in its rest-frame ultraviolet spectrum, at 2175 A, indicative of small hydrocarbon grains, signs of rapid metal and dust enrichment in its interstellar medium (ISM). The main goal of this study is to investigate the conditions under which these carbonaceous grains could originate and whether any commonly proposed dust formation scenarios can be ruled out.
We investigate diverse dust production channels from a possible maximal formation redshift of ~18, permitting dust contributions from asymptotic giant branch (AGB) stars over the longest possible timescale.
Our model successfully reproduces multiple properties observed with JWST, including key spectral features of JADES-GS-z6-0 such as Balmer decrement, UV slope and gas-phase metallicity. This match is obtained by employing a bursty star-formation history, with a significant starburst occurring after ~600 Myr and producing ~30% of stars. Our findings indicate two key pathways for the formation of hydrocarbon grains in JADES-GS-z6-0: (1) efficient dust accretion within the ISM, necessitating a low depletion of metals into dust grains from Type II supernovae (10%), or (2) dust production predominantly via Type II supernovae, requiring a high depletion fraction (90%) without dust accretion in the ISM. We further demonstrate that small hydrocarbon grains are unlikely to originate solely from AGB stars.

Mirko Curti - INVITED - ISM in high redshift galaxies Cosmic Cradles: The ISM and Nebular Properties of Early Galaxies revealed by JWST

Review about the ISM in high redshift galaxies, concentrating on the nebular properties in the very early stages of galaxy formation (the origins, as in the title of the conference) as probed by JWST with different surveys such as JADES, CEERS, UNCOVER, etc.

Souradeep Bhattacharya - Probing chemical enrichment in star-forming galaxies using oxygen and argon abundances

Galactic chemical enrichment mechanisms have primarily been constrained by alpha-enrichment ([α/Fe]) and metallicity ([Fe/H]) measurements from deep absorption-line spectra of individual stars in the Milky Way (MW) and some local group dwarf galaxies. At larger distances out to high-redshifts (z~2), such measurements are only possible from integrated light from galaxies, almost exclusively from massive early-types. For the integrated emission-line spectra of star-forming galaxies (SFGs), we found that the oxygen-to-argon abundance ratio, log(O/Ar), vs Ar abundance, 12+log(Ar/H), is analogous to [α/Fe] vs [Fe/H] for stars. Utilising this diagnostic window, at low redshifts (z<0.3) with Sloan-Digital Sky Survey (SDSS) observations of ~800 SFGs, we observationally show that galaxy chemical enrichment history is driven primarily by the interplay of core-collapse and Type Ia supernovae, and how the impact of prevalent chemical enrichment

mechanisms varies with galaxy mass. With a smaller sample of 17 SFGs at higher redshifts (z~1.3-7.7) with JWST/NIRSPEC and Keck/MOSFIRE, we show that MW-like chemical enrichment processes occur at least out to z~4, beyond which rapid but intermittent star-formation may be at play. This new O & Ar abundance based diagnostic window for emission nebulae will enables us to reveal the unique fingerprints of galaxy chemical enrichment all the way out to cosmic dawn.

Thomas Stanton - Tracing the chemical enrichment pathways of high-redshift star-forming galaxies

By tracing the abundances of heavy elements within the interstellar medium we can constrain the key secular processes regulating the growth of galaxies, namely the history of star formation and the impact of large-scale inflows and outflows of gas. Specific element abundance ratios provide a unique constraint on the rate of enrichment via different physical processes (e.g. CCSNe vs Type Ia SNe), yielding insights into the timescales of star-formation and chemical enrichment. At z>2, most observations are sensitive to only the oxygen abundance, though recent developments in methodology and the advent of high-quality JWST spectroscopy have enabled the measurements of additional elements at these redshifts. In this talk, I will present measurements of O and Fe abundances for 65 star-forming galaxies at $3.0 < z < 3.8$, and demonstrate how we can interpret our results using chemical evolution models to constrain the efficiency of galaxy-scale outflows. I will also present O, Ar and Ne abundances from the JWST EXCELS survey of nine galaxies at $z \approx 4$. These results show clear evidence of O-enhanced non-solar abundance ratios (i.e., O/Fe and O/Ar) as expected for young systems in the early Universe. Finally, I will comment on the implications of non-solar abundance ratios on our understanding and modelling of galaxies in the high-redshift universe, as will be explored with EXCELS and other future JWST surveys.

Giacomo Venturi - Gas-phase metallicity gradients in galaxies at z~6-8

Cosmological simulations have different predictions for the evolution of gas metallicity gradients out to high z. However, until the advent of JWST, metallicity gradients could be probed only up to z~2-4. I will present gas-phase metallicity gradients in three systems at z~6-8, when the Universe was only <1 Gyr old and the galaxy assembly was vigorously taking place. By making use of JWST NIRSpec IFU observations, we mapped the ionised gas in several rest-frame optical emission line diagnostics (e.g. [OII], Hb, [OIII], Ha). We find generally flat radial gradients of gas metallicity, which are consistent with these sources being experiencing galaxy-scale gas mixing, induced by frequent mergers and/or stellar feedback. These results extend out to z~8 the regime in which metallicity gradients are explored, providing a critical reference to inform cosmological simulations and models of galaxy evolution.

Alessandro Marconi - Advanced Metallicity Determination with HOMERUN: New Frontiers in JWST Observations

The power of HOMERUN extends to AGN studies, where we analyze narrow emission lines to derive precise abundances, offering fresh insights into AGN environments. Our modeling of broad-line regions (BLR) challenges previous assumptions, showing more moderate—though still supersolar—abundances. Importantly, HOMERUN's direct determination of BLR sizes revolutionizes our approach to measuring supermassive black hole masses. This advanced modeling capability marks a significant step forward in interpreting spectroscopic data, enhancing our understanding of the complex interplay between star formation, AGN activity, and galaxy evolution across cosmic time.

Bianca Moreschini - Exploring the high-z ISM with HOMERUN

Investigating the physical properties and chemical enrichment of the interstellar medium (ISM) through cosmic time is key to understanding galaxy formation and evolution. The JWST has revolutionised this field by enabling UV/optical spectroscopy at unprecedentedly high redshifts, shedding light on the ionised ISM conditions in early galaxies. I will present the first results from the HOMERUN project, a comprehensive spectral fitting tool designed to extract the wealth of information encoded in JWST/NIRSpec spectra of high-z galaxies (z>5). HOMERUN combines the latest photoionisation models with flexible stellar population synthesis and dust attenuation laws to provide robust constraints on key ISM properties, including metallicity, ionisation parameter, electron density, and dust extinction. I will showcase HOMERUN's capabilities through applications to a sample of z>5 galaxies observed as part of the JADES survey, highlighting new insights into their ISM conditions and chemical enrichment pathways.

Bethan James - Exploring multi-phase chemical mixing in high-z analogues: new insights into nitrogen enrichment

Deciphering the interplay between metallicity, star-formation, and outflowing gas, both spatially within a system and globally with redshift, is of paramount importance for understanding galaxy evolution. As such, the treatment of metals as homogeneous distributions throughout star-forming galaxies (SFGs) is no longer acceptable. Chemical inhomogeneities have been detected in the ionized gas of numerous SFGs, with large implications for the flow of metals within and around galaxies. However, metals exist in *multiple* phases and, at present, the distribution of metals throughout the separate gas phases in SFGs remains unknown. Recent high-z observations have opened up crucial questions concerning mixing timescales and the presence of highly enriched nitrogen - but with only one gas phase, are we seeing the complete picture? In this talk we present new neutral gas abundances from UV spectroscopy from CLASSY, covering 45 high-z galaxy analogues. When combined with ionized gas abundances of spatially-matched optical spectra, this unique dataset provides the largest study of metals between two phases

within SFGs. Determining whether metal abundance offsets exist between the two phases, across a range of HII region properties, enables an exceptionally detailed sampling of chemical mixing scenarios and enrichment mechanisms experienced in SFGs. In particular, we find intriguing results for nitrogen, where elevated levels of nitrogen in the ionized gas are attributable to the speed of outflowing gas. The low metallicities and high SFRs of our sample make our findings applicable to both nearby and high-z SFGs and provides the first observational test of multi-phase abundance patterns.

Beth Westoby - A multi-tracer, kpc-scale view of the gas, dust and stars in z~3 submillimeter galaxies

We present new ALMA high-resolution (~0.25”/2 kpc) CO(5-4) and CO(4-3) observations of four z~3 submillimeter-selected dusty galaxies from the ALMA ALESS survey. These data complement existing [sub]-kpc scale ALMA 870μm continuum imaging and JWST NIRCam and MIRI imaging, allowing us to trace the molecular gas, dust-obscured star formation and existing stellar populations on the same scales. The deep CO data also allows us to spectroscopically confirm that two of the sources lie at the same redshift as their respective nearby companions and are likely interacting, including one pair where one source is optically invisible. We find that the molecular gas imaging broadly follows the dusty star forming structure on kpc-scales, but the reservoirs are significantly more extended than both the 870μm imaging and the stellar mass distributions derived from resolved SED fitting. By modeling the kinematics for the sources with 3D-Barolo, we find that the galaxies are well-fit by rotating disk models and have high ratios of ordered-to-random motion (v/sigma>4). Assuming a constant CO-to-H2 conversion factor and excitation ratio, we find that the star formation efficiency (SFE) is highest in the galaxy centers and decreases towards the outskirts, and that the data are consistent with a fixed SFE per free-fall time. This unique, multi-tracer study demonstrates the power of ALMA and JWST to investigate the interplay between gas, dust and stellar properties on kpc scales in the high-redshift Universe.

Mahmoud Hamed - Revealing the parsec-scales details of high-z star-forming systems with JWST

Despite its low contribution to the total mass of the interstellar medium (ISM), dust plays a crucial role in the evolution of galaxies, and it has the biggest impact on the shape of their total spectral energy distribution (SED). Dust attenuates the stellar light by absorbing the short wavelength photons incoming from the newly-formed stars, and emits them thermally in the infrared (IR). The affluence of multiwavelength detections of millions of galaxies, provided by powerful instruments such as JWST and ALMA, has allowed us to study the cold dust in galaxies over a wide range of redshift.
In this work, we use multiwavelength data at $1 < z < 5$ in order to characterize the dust attenuation of ALMA-detected galaxies. Additionally, we study the role of the gas phase metallicity and galaxy morphology in the attenuation of these galaxies. We find that the

attenuation of stellar light correlates with the relative spatial extension of star-to-dust continua: galaxies with relatively compact stellar emission compared to dust emission prefer a steeper dust attenuation law, while larger stellar emission preferred shallow attenuation curve.
With JWST, we use 2D SED fitting to generalize the role of morphology in dictating the dust attenuation features in star-forming galaxies. We find that dust attenuation varies within the galaxies, and is not universal withing different galaxy parts.
These findings are important in the era of large surveys and of state-of-the-art instruments like JWST, when modeling the spectra of galaxies becomes highly important in deriving their physical properties.

Ivanna Langan - The cold gas of star-forming galaxies at cosmic noon

The baryon cycle of galaxies is driven by the flow of baryons in and out of galaxies. The cold molecular gas of galaxies is one of the most fundamental properties of this baryon cycle, as it is the one that sets star formation, which will subsequently drive the chemical enrichment of galaxies. However, studying the cold molecular of high redshift galaxies can be particularly challenging due to its faint nature. In particular, molecular outflows have a direct impact on the evolution of galaxies as they can deplete the molecular gas reservoir of galaxies and potentially enrich their circumgalactic medium with metals. In this talk, I will present a search for molecular outflows in a sample of main-sequence star-forming galaxies (SFGs) at cosmic noon (z~1), using stacking techniques with ALMA CO observations. I will also show preliminary results on the ALMA Chemical Evolution (ACE) large programme survey, relating for the first time the cold molecular gas and the gas-phase metallicity in a representative sample of SFGs at cosmic noon (z~2). These results are laying the ideal foundation for future JWST follow-ups to complete our baryon cycle understanding with warm dust and gas properties.

Isaac Laseter - Efficient Ionizers with Low H-beta+[OIII] Equivalent Widths: JADES Spectroscopy of a Peculiar High-z Population

The last two decades saw the characterization of extreme emission line galaxies (EELGs) as low mass, efficiently ionizing, young, star-bursting galaxies, and thus are considered important contributors to the EoR and progenitors of present-day galaxies. However, JWST has called into question the assumption that every intense star-forming galaxy at faint MUV and high redshift are EELGs as Endsley et al. (2023) discovered a substantial population of UV faint (MUV ~ -17.5), young (<50Myr) galaxies with EW(H-beta+[OIII]) < 400 Å. We utilize deep spectroscopy from JADES to investigate this peculiar population by characterizing the distribution of ionization efficiencies (xi_ion) in the high-z Universe with nebular equivalent widths (EWs). We measure dissimilar scatter between Balmer and [OIII] EWs with elevated xi_ion, finding an [OIII]-deficient population consistent with EELG H-alpha classifications. We find BPASS+CLOUDY models predict these trends for metallicities lower than 12+log(O/H)<7.7 (Z<10%Z_sol), confirmed via direct O

abundances measured from ~60 novel [OIII]4363 emitters in our sample. We further demonstrate these pristine efficient ionizers are excluded under reasonable H-beta+[OIII] selections because of their low metallicities, whereas Balmer correlation remains. We will discuss our current findings on the conditions contributing to the discrepancies observed and the most extremely metal-poor efficient ionizers in JADES.

Bruno Rodríguez del Pino - Spatially resolved properties of ionized outflows in star-forming galaxies from z = 3 to 9

Galactic outflows are considered to play a critical role in the regulation of the stellar mass growth of galaxies and their metal content. With the arrival of the JWST, the study of galactic outflows can be extended to the very early epochs of galaxy formation and evolution. In particular, the IFS capabilities of the NIRSpec instrument provide a unique opportunity to explore the resolved properties of the outflowing gas in high-redshift galaxies through their optical rest-frame emission, allowing to constrain the impact on the host galaxies. In this work, we study the incidence and properties of galactic outflows in a sample of 15 massive, star-forming galaxies from z~3 to z~9 observed with NIRSpec/JWST as part of the GA-NIFS program. In most of the targets we identify galactic outflows through the [OIII] emission line, which in several cases can be spatially resolved. Using the kinematics and the extension of the outflowing gas we constrain the associated kinematics and evaluate whether the outflow might be suppressing star formation in the host galaxy (negative feedback). We also compare properties such as the extinction and metallicity of the outflowing gas and that in the host galaxy, exploring whether galactic outflows might be redistributing metal-rich gas throughout and outside galaxies. This work provides the first spatially resolved study of galactic outflows in a relatively large sample of galaxies in the first 1-2 Gyrs of the Universe, allowing to constrain the role they played in galaxy evolution at very early epochs.

Ulrich Steinwandel - The role of multiphase galactic outflows in regulating star formation in the era of JWST

Galactic winds are observed to be of multiphase nature and consist out of cold, warm and hot gas that can be traced by HI and CO in the cold, H-alpha in the warm and at the highest gas temperatures via photo-ionized metal species such as MgII or OIII or X-rays. While this presents a challenge for outflow observations due to the fact that we need to use different techniques and instruments, the challenge with respect to the numerical modeling is equally hard due to stringent resolution criteria of feedback processes. I will present a set of high-resolution simulations (sub-parsec) of massive galaxies at high redshift (z=6-10), that are targeted to understand the launching of galactic winds and their interaction with their host systems. The simulations include single star formation, non-equilibrium cooling and chemistry as well as the resolved feedback from supernovae. Consistent with a number of different outflow simulations I find that the warm wind (T ~1e4 K) transports most of the mass while the hot wind carries the majority of the energy budget

(T~5e5 K). I will discuss the results of these simulations in the context of an early phase of a feedback free starburst and a later phase of star formation feedback self-regulation. The presented simulations are an important tool to guide the observations of massive high redshift galaxies by JWST. Furthermore, the presented work can bridge the gap between observations and numerical models by providing predictions from high resolution first principle simulations.

Eleonora Parlanti - Exploring feedback in high-z galaxies through the eyes of ALMA and JWST

JWST and ALMA have revolutionized our ability to study the early stages of galaxy evolution, providing unprecedented insights into feedback processes in the high-redshift Universe. By combining the capabilities of JWST, which allows us for the first time to detect the rest-frame optical emission from galaxies at z > 4, with ALMA's view of cold gas, we can now explore the multiphase gas components of galaxies in extraordinary detail.
I will present two studies leveraging the synergies between JWST and ALMA to investigate the physical properties, kinematics, feedback processes, and interplay of ionized and molecular gas in two high-redshift galaxies. The first work focuses on ALESS073.1, a massive, dusty galaxy at z = 4.8 hosting an AGN. Here, we investigate the AGN-driven ionized outflows and their impact on the host galaxy's kinematics, connecting the dynamics of cold gas observed with ALMA to ionized gas traced by JWST. In the second work, we combine JWST and ALMA data to trace gas kinematics and interstellar medium properties of HZ4, a galaxy at z = 5.5. The JWST data reveal a galaxy merger with extended ionized outflows powered by intense star formation. By analyzing the [OIII] outflow observed with JWST and the [CII] outflow detected with ALMA, we characterize, for the first time, the properties of multiphase outflows at z ~ 5.5.
The synergy between ALMA and JWST allows us to have a comprehensive view of the physical processes driving galaxy evolution in the first billion years of the Universe.

Thursday May 15, 2025

Roberto Maiolino - INVITED - The population of black holes in the early Universe and their interplay with galaxies in the JWST era

Review about what JWST (and complementary observatories) is finding about AGN and their role in the very early stages of galaxy formation (the origins, as in the title of the conference).

Michele Perna - GA-NIFS: A high number of dual AGN at z ~ 3

The JWST/NIRSpec programme 'Galaxy Assembly with NIRSpec IFS' (GA-NIFS) is an ambitious project aimed at characterising the internal structure and close environment of >50 distant galaxies and AGN at z=2-11. I will present an overview of the first results obtained for a GA-NIFS subsample of AGN at 3 < z < 7. In particular, I will discuss our investigation into the environments of these sources highlighting the occurrence of galaxy-AGN and dual AGN systems within the relatively small NIRSpec field-of-view (3"x3"). Notably we discovered a triple AGN and four dual AGN. These findings suggest that multiple AGN may be more common than previously thought based on earlier observational campaigns. Moreover our inferred fraction of dual AGN moderately exceeds predictions from cosmological simulations that mimic our observational criteria. These results provide compelling evidence for the significant role of multiple AGN systems in the early universe and highlight the power of JWST/NIRSpec for uncovering the complexities of galaxy evolution during these crucial epochs.

Alessia Tortosa - The X-rays Strike Back: unlocking the formation of SMBHs in quasars at early cosmic times

The rapid formation of SMBHs with masses >10^9M _sun, powering luminous quasars (QSOs) at the Epoch of Reionization (z=6-7.5) is one of the main open questions about the early (< 1 Gyr) Universe. Shedding light on their nuclear properties is crucial and therefore we tackled this challenge using our ~700 hours XMM-Newton Heritage program on the HYPERION sample of 18 luminous QSOs at z>6 powered by SMBH which experienced the fastest SMBH growth during their assembly. Our systematic investigation of these unprecedented-quality X-ray spectra revealed steeper X-ray spectral slopes compared to similar QSOs at z<6. In this talk we present the discovery of a highly-significant (>3 sigma) correlation between the X-ray continuum slope and the velocity of ionized disk winds. This relation, never reported before in AGN samples, unveils a connection between the properties of the inflowing and outflowing gas in the innermost part of the accretion disk, likely triggered by changes in its physical and geometrical properties. Then, we report a dependence of the X-ray continuum slope on

the SMBH growth rate experienced by the SMBHs powering them. We discuss the implications of our results for the origin and evolution of first luminous QSOs and their SMBHs. Our findings, after 3 years of the HYPERION XMM-Newton Heritage program, stress the importance of investigating AGNs at early cosmic epochs on a sub-parsec scale in the X-rays to understand their formation, evolution and feedback processes.

Cristina Ramos Almeida - JWST MIRI reveals the diversity of nuclear mid-infrared spectra of nearby type-2 quasars

Type-2 quasars (QSO2s) are active galactic nuclei (AGN) seen through a significant amount of dust and gas that obscures the central supermassive black hole and the broad line region. Here we present new mid-infrared spectra of the central kiloparsec of four QSO2s at z_0.1 obtained with MIRI/MRS. They are above the star formation main sequence they have and practically identical optical spectra, but their nuclear mid-infrared spectra are completely different. They show 1) silicate features going from emission (S9.7=0.5) to shallow absorption (S9.7=-0.3); 2) strong, weak and absent polycyclic aromatic hydrocarbon (PAH) emission features, from which we measure a larger contribution of neutral molecules, 3) [NeV]/[NeII] ratios ranging from 0.1-2.1 and [NeIII]/[NeII] from 1-3.5, indicating completely different coronal line and ionizing continuum strengths; and 4) warm molecular gas masses of 1-4_10^7 Msun, with molecular gas excitation due to jet-induced shocks in some cases and to heating and/or turbulence in others. This unprecedented dataset allowed us to begin to explore the role of various AGN and galaxy properties including Eddington ratio, electron density, and jet-ISM interactions on some of the spectral differences listed above, and it provides the high-redshift community with a rich dataset of atomic and molecular emission lines, PAH bands, silicate features and rest-frame ~4-25 micron continua that can used as AGN templates.

Alessandro Trinca - Seeking the rise of the first Massive Black Holes: evidence for an early super-Eddington growth?

The advent of JWST marked a major breakthrough, opening an unprecedented window into the high-redshift Universe and expanding the exploration of Active Galactic Nuclei (AGN) towards more distant and fainter objects. Initial observational campaigns unveiled a nearly ubiquitous population of early AGNs, accounting for up to 10-20% of UV-detected galaxies at 4<z<6. A significant fraction of these AGNs are powered by black holes (BHs) that appear overmassive relative to their host galaxies, with black hole-to-stellar mass ratios orders of magnitude higher than those expected from the local scaling relation.
To investigate this intriguing population of early massive BHs, we employ the Cosmic Archaeology Tool (CAT), a semi-analytical model tailored to reconstruct the evolution of the first galaxies and AGNs. CAT enables us to characterize in detail various pathways for the formation of the first black hole seeds and follow their subsequent growth and co-evolution with the host galaxy in a full cosmological context.

We test different BH accretion scenarios against the AGN population revealed by early JWST observations to assess whether their properties can already shed some light on the nature and early evolution of the first massive BHs. We find that an early BH growth dominated by short phases of efficient super-Eddington accretion, driven by the frequent dynamical interactions of the first galaxies, closely matches the observed AGN population. This scenario explains their overmassiveness and provides a natural mechanism to realign these systems with local scaling relations at later times.

Giovanni Cresci - Bubbles, outflows and lurking BHs: the novel JWST/NIRSpec view of high-z AGN

In this talk I will discuss recent NIRSpec integral field data of an intermediate redshift QSO and of a reionisation epoch galaxy, for which the JWST data provide unprecedented dynamical, morphological and ISM properties details.
Thanks to its existing extensive multi-wavelength coverage and to the massive and extended outflow detected both in the ionised and molecular components, XID2028 at z=1.6 represents a unique test case to study QSO feedback in action at the peak epoch of AGN-galaxy coevolution. NIRSpec is revealing a wealth of details hidden in the previous, seeing limited ground-based data, including evidence of interaction between the QSO-driven radio jet, outflow and the ISM of the galaxy, which is producing an expanding hot bubble from which the fast and extended wind detected in previous observations is emerging.
Himiko is instead one of the most luminous Lyα emitters at z=6.595, showing a peculiar morphology suggesting an ongoing merger surrounded by a Lyα halo extended over 17 kpc. NIRSpec confirms that the source is a metal-poor merger of various sub-structures, and reveals the BLR a lurking Active Nucleus in the central blob.
These observations showcase the new window opened by NIRSpec and JWST on the detailed study of feedback and BH growth at high redshift.

Romain Meyer - Discovery of two z~6.5 post-quasar galaxies in large ionised bubbles

JWST is shining a new light on early supermassive black holes and their co-evolution with their host galaxy. On the one hand, the surprising number of AGN at high-redshift is reawakening the debate surrounding the contribution of AGN to cosmic hydrogen reionisation. On the other hand, JWST is discovering a population of over-massive black holes that could be the progenitors of luminous z>6 quasars and explain the growth of these early giants.
In this talk, I will present the discovery of two overmassive black holes (~1/10 BH-to-stellar mass) with NIRSpec IFU observations of two luminous z~6.5 galaxies. The broad Balmer lines (Ha+Hb) indicate BH masses rivalling that of luminous quasars (>10^8 M_sun). The two host galaxies (COLA1 and NEPLA4) were previously known for displaying double-peaked Lyman-alpha emission, indicating the presence of a large (~Mpc) ionised

bubble around them. The ionised bubble has likely been created by the most recent quasar phase of the AGN, which can thus be constrain to have ended < 1 Myr ago. The galaxies' star-formation history indicates that 90% of the stellar mass formed in a recent <20 Myr burst, providing definitive evidence for early SMBH growing faster than their host galaxy and even delaying their growth. In summary, these are two unique laboratories to study quasar host galaxies at a time when the quasar is inactive, opening new perspectives for early BH-galaxy co-evolution studies, and provide evidence that AGN contribute to reionisation.

Elena Bertola - GA-NIFS: Resolving AGN outflow properties at z3-6 with JWST NIRSpec

A key phase of galaxy evolution is the rapid transition (<2Gyr) from early galaxy assembly at 'cosmic dawn' (i.e., z>6) to the so-called 'cosmic noon' (z~1-3), where the cosmic density of both star formation rate (SFR) and SMBH accretion rate peak. Galaxy growth is thus closely tied to AGN activity, yet little is known about the impact of AGN feedback beyond z~3, especially in the ionized gas phase. This is rapidly changing thanks to the advent of JWST.
The GA-NIFS JWST/NIRSpec GTO program includes the largest sample of AGN at z~3-6 with available rest-frame optical spatially-resolved spectroscopy collected with JWST/NIRSpec/IFU.
I will present our study to characterize AGN outflows in such a sample of z~3-6 AGN selected from COSMOS and GOODS-S to have log(Lx/erg/s)>44. We mapped the ionized emission of AGN (Halpha, [OIII], Hbeta, …) at sub-kpc scales and spectrally isolated the broad components tracing outflows from the gas at rest with the galaxy. We derived outflow properties from spatially-resolved and integrated spectra (e.g., velocity, outflow mass rate) and compared them with those of the galaxy (e.g., Mstar, SFR) and of the AGN (Lbol), retrieved from dedicated SED fitting. Finally, we compared our results with literature AGN from the local Universe to earlier cosmic epochs, spanning a very broad range of AGN luminosity.

Junehyoung Jeon - Physical Pathways for JWST-Observed Supermassive Black Holes in the Early Universe

Observations with the James Webb Space Telescope (JWST) have revealed active galactic nuclei (AGN) powered by supermassive black holes (SMBHs) with estimated masses of 10^7-10^8 Msun at redshifts z~7-9 alongside a larger AGN population than previously expected at earlier times (z~6). Some AGNs reside in overmassive systems with higher AGN to stellar mass ratios than locally. Understanding how massive black holes could form so early in cosmic history and affect their environment to establish the observed relations today are some of the major open questions in astrophysics and cosmology. Several models exist to explain these massive objects, including super-Eddington accretion for the black hole seeds to grow faster than the fiducial

Eddington limit or through direct collapse black holes (DCBHs) that provide massive seeds (~10^5-10^6 Msun), able to reach high masses in the limited time available. We use zoom-in cosmological simulations with the GIZMO code to study the formation and growth of DCBH and find that to create massive AGN in overmassive systems at high redshifts, massive seeds accreting more efficiently than the fiducial Bondi-Hoyle model are needed. However, using the semi-analytical model A-SLOTH (Ancient Stars and Local Observables by Tracing Halos), we further conclude that the observed high-redshift AGN population can be explained by both super-Eddington and DCBH scenarios. We discuss how the assembly history of the first SMBHs could be better constrained with upcoming, ultra-deep JWST surveys.

Tanio Diaz Santos - Powerful nuclear outflows and circumgalactic medium shocks driven by the most luminous quasar in the Universe

In this talk I will present results obtained from JWST observations of the most luminous obscured quasar known, WISEJ W2246-0526 (W2246), with a bolometric luminosity of ~3.5x10^14 L⊙, located at z ~ 4.6. The hot, dust-obscured quasar and its host are surrounded by at least three companion galaxies, which are connected by dusty tidal streamers to the central host, thus suggesting they in the process of being accreted. W2246 was observed by JWST with NIRSpec/IFU covering the entire merger system, targeting H-alpha, [NII], [OIII] and H-beta. We detect ionized gas filaments on 40 kpc scales connecting the entire network of merging galaxies. Surrounding the central dust-obscured quasar, we find regions of low ionization consistent with large-scale shock excitation out to distances nearly eight times the effective stellar radius of the quasar host galaxy. In the nuclear region, we find an ionized outflow driven by the quasar with velocities reaching 13,000 kms−1, one of the fastest discovered to date, with an outflow rate of 2000 M⊙ yr−1 and a kinetic luminosity of 6×10^46 erg s−1, with a coupling efficiency of 5%. Therefore, we find the outflow has sufficient energy to explain the kinetic energy due to the turbulent motion of the gas on galactic and circumgalactic scales, and is likely driving the radiative shocks found on ISM and CGM scales. These results show that powerful quasar outflows are a key mechanism regulating the heating and accretion of gas onto massive galaxies.

Jackie Champagne - Dust attenuation in high redshift galaxies in the era of JWST

Despite its low contribution to the total mass of the interstellar medium (ISM), dust plays a crucial role in the evolution of galaxies, and it has the biggest impact on the shape of their total spectral energy distribution (SED). Dust attenuates the stellar light by absorbing the short wavelength photons incoming from the newly-formed stars, and emits them thermally in the infrared (IR). The affluence of multiwavelength detections of millions of galaxies, provided by powerful instruments such as JWST and ALMA, has allowed us to study the cold dust in galaxies over a wide range of redshift.

In this work, we use multiwavelength data at 1 < z < 5 in order to characterize the dust attenuation of ALMA-detected galaxies. Additionally, we study the role of the gas phase metallicity and galaxy morphology in the attenuation of these galaxies. We find that the attenuation of stellar light correlates with the relative spatial extension of star-to-dust continua: galaxies with relatively compact stellar emission compared to dust emission prefer a steeper dust attenuation law, while larger stellar emission preferred shallow attenuation curve.
With JWST, we use 2D SED fitting to generalize the role of morphology in dictating the dust attenuation features in star-forming galaxies. We find that dust attenuation varies within the galaxies, and is not universal withing different galaxy parts.
These findings are important in the era of large surveys and of state-of-the-art instruments like JWST, when modeling the spectra of galaxies becomes highly important in deriving their physical properties.

Samuel Ward - The role of ISM substructure in shaping multiphase AGN outflows

Active galactic nuclei (AGN) drive powerful, multiphase outflows into their host galaxies which are expected to play a key role in galaxy evolution. However, exactly how small-scale accretion disc winds couple to the ISM to drive these outflows remains an open question. In this talk, I will present our AGN in Clumpy DisCs (ACDC) simulations which feature a physically-motivated AGN wind model embedded in an idealised galaxy disc with a resolved ISM which we manual distribute into a clumpy substructure. We find that the hot AGN wind causes the cold ISM clumps to fragment and become entrained in the outflow as small cloudlets. This leads to an outflow that differs significantly from commonly-considered shell-like morphologies, which has important implications for observational studies seeking to characterise outflows and infer their impact on the hot galaxy. We also find that mixing between the AGN wind and ISM clouds produces X-ray emission that can be detected above the level from star formation with telescopes such as Chandra or AXIS. This could provide a complementary probe for the total volume of gas that the outflow has interacted with.
Aswin Vijayan - Remembrance of AGN models past: Learning the physical conditions
One of the most remarkable results from JWST has been the identification of a substantial population of sources exhibiting strong broad H_ emission, typically interpreted to be low-luminosity broad-line active galactic nuclei (BL AGN). In this talk, I will demonstrate using a large grid of photoionisation models, created with Cloudy, that are representative of narrow and broad line regions of AGN. By combining these models with NIRSpec spectra and X-ray detections (or lack of), I will constrain the parameter space governing the physical conditions of these sources. I will demonstrate that there is a degeneracy between extreme gas or physical conditions and the presence of dust for deviations from case-B recombination values for well observed balmer line ratios. This will also have an effect on the adopted bolometric corrections used for inferring the mass of the supermassive black hole. Using these inferred physical conditions, I will re-interpret the observations and apply the refined models to the FLARES simulations, to reproduce high-redshift observations in this context.

Francesco Salvestrini - A JWST-ALMA synergy to unveil the early co-evolution of galaxies and supermassive black-holes

The coexistence between the outstanding mass growth of the SMBHs powering luminous quasars at the Epoch of Reionization (EoR, z > 6), and the concurrent growth of their host galaxies. The knowledge of how quasar host build up and evolve has been limited to far-IR/sub-mm observations till recently. Now, thanks to the growing number of JWST detections of stellar light arising from the host galaxy of quasars and luminous AGN, we investigate the cycle of star formation in the brightest objects in the first billion years.
Here, we exploit mm observations of dust and gas on a sample of 25 quasars at the EoR, including all known quasars at z>7.
These highly accreting SMBHs are hosted in galaxies with a copious amount of dust (~10^8 Msun), but relatively low (<~10^10 Msun) gas reservoir. The intense star formation activity suggests that these galaxies are undergoing a rapid growth, with efficiencies that are among the highest observed so far.
Thanks to JWST/NIRCAM, we now constrain the role of star (10^10 Msun) in the baryonic cycle, which are driving the dust formation, and gravitational collapse of the molecular gas to form new stars.
This is happening at extreme rates, with low gas fractions (~MH2/M*~0.3-0.01), when compared with those measured in star forming galaxies and AGN at later epochs.
This suggest a tight connection between the high star formation efficiency in the host and the bright quasar phase across a wide range of luminosity.

Alice Young - Revealing supermassive black holes in the early universe using photometric variability

Although supermassive black holes (SMBH) reside in the nuclei of most massive galaxies, the origin of SMBHs in the early universe is one of the remaining questions in modern astrophysics. Possible formation mechanisms include “direct collapse” in metal-free halos as well as supermassive “Population III.1” stars acting as progenitors to produce all SMBH seeds by z>10. In this talk I will present our recent re-imaging survey of the Hubble Ultra Deep Field (HUDF) which is designed to address the abundance of active galactic nuclei (AGNs) at comoving number densities where we can distinguish between these seeding mechanisms. I will detail how we have identified variable AGN using photometry to successfully measure the highest co-moving number density of SMBHs at z~6 to date. Further, JWST has revealed a surprisingly large number of black hole candidates in the early universe that could not be detected with HST. These discoveries, in addition to our result indicating high number densities at early times, highlight the importance of understanding the properties of this previously unknown and unexpected population of black holes. As such, I will describe the use of combined multi-epoch photometry from both HST and JWST to perform SED fitting for our variable sources and present what this has revealed about the properties of our SMBH candidates and their host galaxies. Finally,

I will share how these results can assess the contribution of ionizing photons from AGN towards the reionization of the intergalactic medium at z~6.

Jenny Greene - INVITED - Give me a break: The Ambiguous Nature of Little Red Dots

Review about the hot topic of little red dots, one of the most interesting galaxy populations in the very early stages of cosmic history (the origins, as in the title of the conference).

Friday May 16, 2025

Anthony Taylor - Broad-Line AGN at 3.5 < z < 6: The Black Hole Mass Function and a Connection with Little Red Dots

Observational constraints on the evolution of active galactic nuclei (AGN) are key for constraining the origins and evolution of supermassive black holes (BHs) across cosmic time. In this talk, I present a sample of 50 H-alpha detected broad-line AGN (BLAGN) at redshifts 3.5<z<6.8 using data from the CEERS and RUBIES JWST/NIRSpec Surveys. I compute rest-frame ultraviolet and optical spectral slopes for these objects, and determine that 10 BLAGN in our sample are also little red dots (LRDs). I discuss the overlap and connections between the LRDs and BLAGN. I next construct the BH mass function at 3.5<z<6. This BH mass function shows broad agreement with both recent JWST observations as well as theoretical models, indicating that the observed abundance of BHs in the early universe is not discrepant with physically-motivated predictions. This BH mass function is largely featureless, and resembles a power-law. This may indicate that any signature from black-hole seeding has been lost by redshift z~6. I compute the BLAGN UV luminosity function and find good agreement with JWST-detected BLAGN samples from recent works, finding that BLAGN hosts constitute <10% of the total observed UV luminosity at all but the brightest luminosities. Finally, I discuss future plans to better expand and refine the BH mass function at redshift 3-9 using current, planned, and proposed data from JWST.

Bingjie Wang - Evolved Stellar Populations at z ~ 7 - 8 in Little Red Dots Identified with JWST/NIRSpec

The identification of red, apparently massive galaxies at z > 7 in early JWST photometry suggests a strongly accelerated timeline compared to standard models of galaxy growth. A major uncertainty in the interpretation is whether the red colors are caused by evolved stellar populations, dust, or other effects such as emission lines or active galactic nuclei (AGNs). In this talk, I will present recent JWST/NIRSpec spectroscopy of three massive galaxy candidates from the RUBIES program, revealing prominent Balmer breaks at z = 6.7 - 8.4. The Balmer breaks demonstrate unambiguously that stellar emission dominates at rest 0.4 μm, and require formation histories extending hundreds of millions of years into the past in galaxies only 600 - 800 Myr after the big bang. Confoundingly, some also exhibit broad Balmer emission lines, suggesting that dust-reddened AGNs contribute to, or even dominate, the spectral energy distributions at rest > 0.6 μm. I will show new models to decompose the galaxy and AGN light, and discuss potential origins and evolutionary tracks for these objects, from the cores of massive galaxies to low-mass galaxies with overmassive black holes. Finally, I will outline possible future directions aimed at forming a complete physical picture of these intriguing systems.

Changhao Chen - The Host Galaxy (If Any) of the Little Red Dots

We investigate the host galaxy properties of eight little red dots (LRDs) selected from the JWST UNCOVER survey, applying a new technique (GalfitS) to simultaneously fit the morphology and spectral energy distribution using multi-band NIRCam images covering ~1−4μm. We detect the host galaxy in only one LRD, MSAID38108 at z=4.96, which has a stellar mass of log(M∗/M⊙)=8.66, an effective radius Re=0.66 kpc, and a Sérsic index n=0.71. No host emission centered on the central point source is found in the other seven LRDs. We derive stringent upper limits for the stellar mass of a hypothetical host galaxy by conducting realistic mock simulations that place high-redshift galaxy images under the LRDs. Based on the black hole masses estimated from the broad Hα emission line, the derived stellar mass limits are at least a factor of 10 lower than expected from the z≈0 scaling relation between black hole mass and host galaxy stellar mass. Intriguingly, four of the LRDs (50% of the sample) show extended, off-centered emission, which is particularly prominent in the bluer bands. The asymmetric emission of two sources can be modeled as stellar emission, but the nature of the other two is unclear.

Mitsuru Kokubo - Challenging the AGN scenario for JWST/NIRSpec broad H-alpha emitters/Little Red Dots in light of non-detection of NIRCam photometric variability and X-ray

JWST has uncovered a substantial population of high-z galaxies exhibiting broad Hα emission line with a Full Width at Half Maximum exceeding 1000km/s. This population includes a subset known as 'Little Red Dots', characterized by their compact morphology and extremely red rest-frame optical colors. If all of these broad Hα emitters were attributed to type 1−1.9 AGNs, it would imply a significantly higher number density of low-luminosity AGNs than extrapolated from that of more luminous AGNs. Here, we have examined the rest-frame UV-optical flux variability of five JWST broad Hα emitters using multi-epoch, multi-band JWST/NIRCam imaging data. The rest-frame temporal sampling interval of the NIRCam data (~500days/(1+z)) is comparable to typical variability timescales of AGNs with black hole (BH) masses of M_BH~10^7M_sun; thus, the flux variations should be detectable if AGNs were present. However, no measurable flux variation over the rest-frame wavelength range of ~1500-9000 Angstrom has been detected, placing stringent upper limits on the variability amplitudes. This result, combined with the X-ray faintness confirmed by the ultra-deep Chandra data, indicates that, under the AGN scenario, we need to postulate peculiar Compton-thick broad-line AGNs with either (a) an intrinsically non-variable AGN disk continuum, (b) a host galaxy-dominated continuum, or (c) scattering-dominated AGN emission. Alternatively, (d) they could be non-AGNs where the broad-line emission originates from unusually fast and dense/low-metallicity star-formation-driven outflows.

Alberto Torralba - Dissecting Little Red Dots: Spatially resolved spectroscopy of faint broad-line AGN

Recent JWST observations have revealed a population of red compact objects at z>4. Many of these objects, dubbed “Little Red Dots” (LRDs), exhibit broad components in their Balmer lines (i.e., Hα, Hβ), indicative of AGN activity. However, classical AGN+stellar models struggle to accurately reproduce the SEDs of these objects, leaving the true nature of their emitted light unresolved. One of the most surprising features is that many LRDs show Balmer absorption features, which may indicate the presence of extremely dense neutral gas along the line of sight, though the origin of this gas remains unclear.
In this talk, we present the first results from the JWST Cycle 3 GO program #5664 (PI Matthee), which aims to analyze the spatially resolved emission of five LRDs at z~5.3, selected based on their broad Hα emission, using NIRSpec IFU spectroscopy. Our observations were designed to enable us to disentangle the central point source of these LRDs (primarily attributed to AGN) from their extended emission (associated with the host galaxy). This decomposition facilitates a detailed examination of their SEDs, shedding light on the origin of the UV and optical emission in LRDs. The spatially resolved spectroscopy also allows us to set constraints on the stellar masses of the host galaxies. Through high-resolution grating spectroscopy we can study in detail the Balmer absorptions present in the broad Balmer lines of our objects, and characterize the gas dynamics and prevalence of outflows in the ISM of LRDs.

Raphael Hviding - Unveiling Broadened Emission in LRDs: A Statistical Simultaneous Spectral Analysis with RUBIES NIRSpec

JWST has unveiled a population of compact red sources known as Little Red Dots (LRDs). These objects are distinguished by their pronounced V-shaped continua, strong spectral breaks, and, in many cases, broadened emission lines, though their true nature remains uncertain. Utilizing RUBIES NIRSpec spectroscopy, we have conducted simultaneous G395M and PRISM fitting to explore the kinematics and properties of emission lines within the LRDs. Our methodology employs a Bayesian fitting framework that accounts for correlated parameters and enables a direct assessment of the statistical significance of broadened lines in the spectra. This dual analysis of both broad and narrow emission line features aims to identify the underlying physical mechanisms shaping the LRDs' spectral signatures. Specifically, we examine how key physical parameters—such as break strength and spectral slopes—relate to observed line characteristics like presence, strength, and equivalent width of a broadened line. This study underscores the power of statistical spectral analysis in unraveling the physical processes governing these enigmatic objects. Our approach enhances parameter precision and establishes a robust framework for future studies of LRDs, paving the way to understanding the nature and evolution of these new and exciting galaxies.

Takumi Tanaka - The discovery of dual and offset "little red dots” with a pixel-by-pixel color selection method

Deep IR observations by JWST have discovered a new population of high-redshift, red, and compact objects known as "little red dots" (LRDs). Based on the detection and

analysis of broad emission lines, previous studies have suggested that LRDs may be low-luminosity AGNs hosting overmassive black holes. However, with the lack of detection in X-ray, MIR, and variability, the possibility that LRDs are not AGNs is still left open. In this study, we develop a new selection technique of pixel-by-pixel color selection method and apply this method to JWST/NIRCam imaging data. As a result, we identify LRDs with extended or nearby components overlooked in the typical photometric selection methods, which rely on aperture color and compactness. Among them, we found LRDs that appear to be merging with other LRDs (dual LRDs) or galaxies (offset LRDs). The overabundance of dual LRDs suggests that LRDs have an excess clustering on a small scale. From the high offset AGN fraction in our sample, we , for the first time, propose an evolutionary scenario linking LRDs to the known AGN and galaxy populations at lower redshifts.

Vanessa Brown - Balmer Decrements in Little Red Dots: Investigating High-Redshift AGN Attenuation

The study of active galactic nuclei (AGN) at high redshifts is necessary to complete our understanding of black hole growth in the early universe, including phenomena such as the early emergence of bright quasars. JWST has unveiled a mysterious population of faint, very red and compact objects dubbed “Little Red Dots” (LRDs) at $z > 4$ that have thus far eluded definitive classification, though their broad lines and small sizes suggest at minimum an AGN contribution to their emission. It has been proposed that LRDs are heavily dust-attenuated AGN possibly representing an early, obscured growth phase of the unobscured quasars observed at later times. I will present Balmer decrement measurements of a sample of LRDs and discuss the relationship between the dust attenuation of these objects and their evolutionary stage, by exploring the dependence of attenuation on redshift and black hole mass. With these measurements I will discuss the possible connection between LRDs and the broader population of high-redshift AGN.