Invited Talks

Getting JWST to space, what might we find, and what's next?
John Mather, Goddard Space Flight Center

Building on the inspiring and poetic 1996 HST and Beyond report of the Dressler committee, and with the vigorous support of NASA leadership, the JWST team settled on the four top scientific priorities, documented the instrument and telescope performance requirements to meet scientific objectives, made plans, matured 10 technologies, made international agreements, and chose the instrument teams and contractors. The result is the world's most powerful space telescope, performing better than expectations, with a projected lifetime of 20 years. I will briefly review the history, key technical choices, and celebrate the people who made the observatory real. I will summarize current progress towards the main objectives from cosmology to exoplanets, and speculate about what scientific surprises may be in store. Looking toward NASA's future, I will outline key challenges faced by the JWST, and argue that the recommended Decadal Survey 6 m IROUV telescope and the other Great Observatories might be significantly easier to build than JWST.

The Science Performance of JWST
Jane Rigby, Goddard Space Flight Center

I will present the quantitative science performance of JWST, as measured during the grueling six month commissioning period, which demonstrates that JWST is fully capable of achieving the discoveries for which it was built. Almost across the board, JWST's science performance is better than expected. I will show where the delivered performance differs from pre-launch expectations, to inform development of Cycle 2 proposals. And I will acknowledge the collective efforts of the 600 people who commissioned JWST and the 20,000 people who designed, built, and tested it.

Contributed Talks

Assembly of Galaxies

The EIGER Survey: Characterizing the Early Cosmic Ecosystems with JWST

Rongmon Bordoloi, Daichi Kashino, Jorryt Matthee, Rob Simcoe, Anna-Christina Eilers, Ruari Mackenzie, Simon Lilly

We present the first results from the EIGER survey (Emission-line galaxies and Intergalactic Gas in the Epoch of Reionization), a large JWST/NIRCam imaging and slitless grism spectroscopic campaign around six high redshift quasar fields. This survey will obtain 116 hours of NIRCam slitless grism spectra in 155 square arcmin of extragalactic sky. First results in the field of the z=6.3 hyper-luminous quasar J0100+2802, yield a large sample of 120 spectroscopically confirmed [OIII] emitting galaxies over z = 5.33 − 6.96. These galaxies exhibit very high [OIII] rest frame equivalent widths (~1000 Angstrom), which is rare in the local Universe. The galaxies exhibit typical absolute UV magnitudes of -18 to -22, and stellar masses in the range of 10^7-10^8 Msun and star-formation rates of 1-100 Msun/yr. Three strong galaxy overdensities are detected at z~6.187, z~6.3 and z~6.8 respectively. As we approach the epoch of reionization, the Lya transmission spikes are detected preferentially at characteristic distances of a few cMpc from galaxies. This is interpreted as the result of the competition between the high density of gas in the immediate vicinity of the ionizing sources and the drop off with distance in the intensity of the dominant local ionizing radiation field as the cosmic ionizing background weakens. We find 32 4<z<6.2 galaxies within 300 kpc of the quasar sightline, characterize their circumgalactic medium (CGM) using deep NIR quasar absorption line observations. A large fraction of galaxies where CGM absorption is detected exhibit morphological or spectroscopic signatures of mergers. This suggests that early circumgalactic assembly might be significantly different from what is observed at z~0, with HST/COS surveys of the circumgalactic medium. The early data shows the unprecedented power of JWST, and the full survey promises to provide a high-fidelity view of early galaxy assembly.

Ultra-Diffuse Galaxies Observed in the El-Gordo Cluster with JWST

Timothy Carleton, Rachana Bhatawdekar, Cheng Cheng, Jose Diego, Simon Driver, Brenda Frye, Seth Cohen, Rogier Windhorst, Jioshuo Zhang, the PEARLS team

A full understanding of how unusually large “ultra diffuse galaxies” (UDGs) fit into our conventional understanding of dwarf galaxies remains elusive, despite the large number of objects identified locally. A natural extension of UDG research is the study of UDGs at higher redshift to establish how their properties may evolve over time. However, this has been a challenging task given how severely cosmological surface brightness dimming inhibits our ability to detect low-surface brightness galaxies at high-z. In this analysis, we present the first identification of UDGs beyond z~0.6 with deep near-IR observations of the El-Gordo cluster at z=0.87 as part of the PEARLS GTO program. By stacking 7 NIRCAM filters, we are able to achieve surface density sensitivity of 26.5 mag per sq. arcsec., corresponding to similar stellar surface densities as locally observed UDGs. Structural analysis reveals that they have a similar size distribution as their local counterparts, revealing that a substantial UDG population is in place at z=0.87. However, notable differences between this population and that observed locally do emerge in this analysis, such as the color and axis-ratio distributions, which suggest that the UDG population is bluer and more disky at high-z than at z=0. All this evidence suggests that multiple UDG mechanisms are responsible for UDG formation, and that environmental formation may not as important at high-z.

A surprising abundance of massive quiescent galaxies at 3 < z < 5 in the first data from JWST

Adam Carnall

I will present a new search for the highest-redshift massive quiescent galaxies using some of the first JWST imaging data from the Cosmic Evolution Early Release Science (CEERS) survey. We select massive quiescent galaxies at $3 < z < 5$, finding 3 - 6 times higher number densities than previous studies based on pre-JWST datasets from Hubble and Spitzer. Our total massive galaxy number density is consistent with previous measurements of the galaxy stellar mass function, and we therefore find a passive fraction of more than 50 per cent for galaxies with $\log(M_*/M_\odot) > 10.5$, at $3 < z < 4$, in contrast to previous measurements which placed this figure at less than 10 per cent. This has serious implications for cosmological simulations, which already struggle to reproduce previous estimates of massive quiescent galaxy number densities at these redshifts, suggesting that new quenching physics will be required to explain the early evolution of the most massive galaxies. Our sample includes three robustly identified $z > 4$ massive quiescent galaxies, which, if spectroscopically confirmed, would be the highest-redshift quiescent galaxies known. I will also discuss my upcoming Cycle 1 JWST programme, which will target a massive quiescent galaxy at $z = 4.7$ for deep continuum spectroscopy to measure the star-formation history and stellar metallicity. Results from this programme may be available by the time of this meeting depending on scheduling. Preprint available at https://arxiv.org/abs/2208.00986

GATOS JWST Observations of Local AGN: Polar Dust and Feedback in Multiphase Outflows

Erin K. S. Hicks, D. J. Rosario, M. Pereira-Santaella, M. Leist, C. Packham, J. Álvarez-Márquez, I. Garcia-Bernete, A. Labiano, L. Colina, A. Alonso-Herrero, E. Bellocchi, R. Davies, S. García-Burillo, S. F. Hönig, N. A. Levenson, C. Ramos Almeida, T. Shimizu, M. Stalevski, & GATOS Collaboration

Early JWST results obtained as part of ongoing work within the Galactic Activity, Torus, and Outflow Survey (GATOS) collaboration will be presented. From Cycle 1 MIRI observations (PI: David Rosario; ID: 2064) we have found evidence for AGN-heated dust in a 200-pc scale bicone in the nearby Seyfert 2 AGN NGC 5728. This dust is closely connected with the AGN outflow, suggesting that the dust itself is carried by or coupled with the outflowing gas. This has important implications for the role of AGN feedback in forming and maintaining the obscuring torus in AGN. The AGN-heated dust distribution in additional Seyfert galaxies and the prospects for constraining the nature of the polar dust, its extent, and connection to AGN outflows and inflows with the full eight galaxy sample will be discussed. An investigation of AGN feedback produced by relativistic jets will also be presented based on ERS target NGC 7319, part of the Stephan Quintet. MIRI/MRS observations of NGC 7319 spatially resolve for the first time the interaction of a radio jet with the molecular ISM and show how the shock waves heat, ionize, and enhance the turbulence of the ISM. However, only a small fraction of the jet energy remains in the gas phases detected by JWST, so it is still an open question whether the missing jet energy is deposited in the cold molecular gas or if it is efficiently dissipated, hence limiting the AGN feedback effects. Plans to extend our work to characterize multiphase AGN outflows in a sample of six local Seyfert AGN with anticipated Cycle 1 MIRI/MRS observations (PI: Taro Shimizu; ID: 1670) will be summarized.

The Growth of Galaxy Structure, as Told by Early JWST Imaging

Jeyhan Kartaltepe, the CEERS team

The first images taken with the James Webb Space Telescope (JWST) are unveiling galaxies in the distant universe and enabling detailed studies of their properties. In this talk, I will present some of the first results on how our understanding of the growth of galaxy structure in the universe has changed based on these first images. We have conducted a comprehensive analysis of the evolution of the morphological and structural properties of a large sample of galaxies at z=3-9 using the NIRCam images at 1-5 microns taken as part of the Cosmic Evolution Early Release Science (CEERS) Survey in June 2022. This sample consists of 850 galaxies at z>3 detected in both CANDELS Hubble WFC3 imaging as well as JWST CEERS NIRCam images to enable a comparison of HST and JWST morphologies. Our team conducted a set of visual classifications, with each galaxy in the sample classified by three different individuals. We also measured quantitative parametric and non-parametric morphologies using the publicly available codes Galfit, Galapagos-2/GalfitM, and statmorph across all seven NIRCam filters. Using these measurements, I will present the morphologies of these high redshift galaxies, their structural properties, and the fraction of each type as a function of redshift. I will also compare their morphologies to what we knew based on Hubble imaging, and discuss the implication of these results for galaxy evolution. Finally, I will also highlight what we expect to learn from future JWST observations in CEERS, COSMOS-Web, and other Cycle 1 surveys.

Tracing AGN Feedback on the Star-Forming ISM in NGC 7469 with JWST

Thomas Lai, the GOALS team

AGN feedback plays an important role in regulating star formation activity and nearby interstellar medium (ISM) through outflowing winds and ionizing radiation. This impact from the central supermassive black hole however has not been well studied in the past due to the lack of high spatial resolution in the infrared, which prevents us from taking a close look at the star-forming ISM in the vicinity of an AGN. However, the integral-field observations offered by JWST have opened up an enormous opportunity for studying the starburst-AGN connection in the sub-kpc scale. In this talk, we will present the MIRI IFU observation of a type 1 Seyfert galaxy NGC7469, which hosts both a rapidly accreting black hole and a circumnuclear starburst ring with a radius of 500 pc. Dust and warm molecular gas can be studied on a ~100 pc scale as we take the advantage of the high spatial/spectral resolution of MIRI to isolate the starbursting event surrounding the AGN. We find the starburst ring exhibits prominent Polycyclic Aromatic Hydrocarbon (PAH) emission, with grain sizes and ionization states varying by only ∼30%. A suite of H2 pure rotational lines is also detected throughout the ring, enabling us to estimate the warm molecular gas mass and temperature. Our study demonstrates that with JWST the resolved properties of the near nuclear ISM can be finally studied in detail, in even the dustiest galaxies, on the scales of individual star-forming regions.

Revealing the Hidden Star Formation in VV 114 with JWST

Sean Linden, The Great Observatories All Sky LIRG Survey Team

VV 114 is a striking example of how dust obscuration can hide the true nature of star formation activity in luminous infrared galaxies (LIRGs). VV 114E, a completely dust-enshrouded nucleus, has a 7um-to-UV flux ratio that is 80 times larger than VV 114W, a face-on spiral hosting large numbers of optically-luminous young massive star clusters (YMCs). These differences make VV 114 the most extreme such case among local LIRGs. Here we present JWST NIRCam (F150W, F200W, F356W, F444W) and MIRI (F560W, F770W, F1500W) observations of the obscured energy sources that collectively power this extreme system. We identify 374 compact YMC candidates with NIRCam, finding that 20% of these sources are undetected at optical wavelengths. This ‘hidden’ population of YMCs triples the number of young (1 - 4 Myr), massive (~ 10^6 M_sun), and dusty (Av ~ 5) sources identified in VV 114. Further, we find that VV 114E emits 45% of the 15um light of the entire system, and resolves into NE and SW corea with IR luminosity densities of 2x10^13 L_sun kpc^-2 and 7x10^12 L_sun kpc^-2 respectively; 4-10 times larger than what is observed in Orion. Finally, we find that diffuse, filamentary, polycyclic aromatic hydrocarbon (PAH) emission accounts for half of the total 7.7um light of the system. These studies illustrate the ability of JWST to detect, resolve, and characterize the obscured star-formation activity in the most luminous starburst galaxies in the local Universe.

First High-z Quasar Results from the NIRSpec IFS GTO Program

Madeline Marshall, NIRSpec Galaxy Assembly IFS GTO Team

High-z quasars are some of the most extreme objects in the Universe, and understanding their nature has previously been limited due to the lack of infrared spectral capabilities. Here I present our results from the first two z>6 quasars observed as a part of the NIRSpec Galaxy Assembly IFS GTO program, DELSJ0411-0907 at z=6.82 and VDESJ0020-3653 at z=6.86. We have observed these two quasars with the NIRSpec IFU, obtaining high-resolution spatially resolved spectroscopy from 2.9–5.1 microns, covering their key optical diagnostic lines including Hbeta and Halpha. We have measured reliable black hole masses from these broad lines, giving the first reliable M_BH/M_dyn ratios at high-z, and an improved estimate of their Eddington ratios. We have investigated a wide range of host properties, for example their interstellar medium structure and kinematics, star formation rates, excitation mechanisms, and outflows, giving the first NIR look into the host properties of the earliest quasars. As well as presenting these exciting results, I will also outline our upcoming plans for the full sample of six z>6 quasars.

Unscrambling the Lensed Arcs in SMACS J0723

Massimo Pascale, Brenda Frye, Jose Diego, Lukas Furtak, Adi Zitrin, Tom Broadhurst, Christopher Conselice, Liang Dai, Leonardo Ferreira, Nathan Adams, Patrick Kamieneski, Nicholas Foo, Patrick Kelly, Wenlei Chen, Jeremy Lim, Ashish Meena, Stephen Wilkins, Rachana Bhatawdekar, Rogier Windhorst

The first deep field images from the JWST of the galaxy cluster SMACS J0723 reveal a wealth of new lensed images at uncharted infrared wavelengths, with unprecedented depth and resolution. We securely identify 14 new sets of multiply imaged galaxies totaling 42 images, adding to the five sets of bright and multiply-imaged galaxies already known from Hubble Space Telescope data. We find examples of arcs crossing critical curves, allowing detailed community follow-up, such as JWST spectroscopy for precise redshift determinations, and measurements of the chemical abundances and of the detailed internal gas dynamics of very distant, young galaxies. One such arc contains a pair of compact knots that are magnified by a factor of hundreds, and features a microlensed transient. We construct a parametric strong-lensing model constrained by these multiply-imaged galaxies, allowing for accurate magnification estimates of high-redshift galaxies and mapping of the 2D projected cluster mass distribution. The intracluster light extends beyond the cluster members, exhibiting large-scale features that suggest a significant past dynamical disturbance. This work represents a first taste of the enhanced power JWST will have for lensing-related science.

High-redshift spatially resolved Paschen-alpha detection from the ERS program TEMPLATES

Kedar A Phadke, TEMPLATES team

We present the highest redshift spatially resolved Paschen-alpha detection using MIRI MRS IFU data for gravitationally lensed dusty star forming galaxy at redshift z~4. The data was obtained as a part of the early release science program TEMPLATES (Targeting Extremely Magnified Panchromatic Lensed Arcs And Their Extended Star Formation. PID: 1355). Hydrogen recombination lines, especially the Balmer series, have been used for decades as a proxy for star-formation rate (SFR). However, it is notoriously difficult to correct for dust attenuation especially in dusty star forming galaxies owing to large amounts of dust content in such galaxies. Paschen-alpha on the other hand is much less affected by dust extinction and thus a more robust indicator of the SFR. JWST now brings us the required sensitivity and resolution to observe Paschen-alpha at higher redshifts and in a spatially resolved manner (also thanks to gravitational lensing). The previous highest redshift detection of Paschen-alpha was at redshift z~2.5 in a SMG using a long slit on the Sptizer space telescope. In this study, we will compare Paschen-alpha derived SFR of different star forming clumps to SFR derived from integrated IR luminosity and previous ALMA observations of [CII] 158 microns.

Spatially-resolved ISM properties of high star-forming galaxy at z~3.7 as seen by JWST.

Bruno Rodríguez Del Pino, NIRSpec GTO Galaxy Assembly IFS Team

We present NIRSpec IFS observations of a galaxy at z~3.7 obtained as part of the GTO Galaxy Assembly - IFS Survey. Benefited from the wide wavelength range spanned with the R2700 observations, covering from [OII]3727 to [SII]6731, we obtain spatially-resolved ISM properties such as metallicity gradients with different indicators, electron densities and dust extinction through the Balmer decrement. We apply rest-frame optical emission-line diagnostic diagrams to characterize the excitation mechanisms throughout the galaxy, such as star formation or nuclear activity with different degrees of ionization. From the R100 observations we obtain spatially-resolved star formation histories that, together with the observed distribution of current star formation, allow us to constrain the evolution of mass assembly in this galaxy when the Universe was only 1.7 Gyr old.

Opening an era of quasar host studies at high redshift with JWST

John Silverman

JWST has enabled new capabilities in the infrared for the study of the host galaxies of accreting supermassive black holes due its higher resolving power, greater sensitivity, and image stability. We present results on the hosts of SDSS quasars at $1 < z < 4$ using NIRCAM imaging acquired by the CEERS ERS program. As demonstrated, successful decomposition of the emission of the quasar and its host is achieved based on accurate characterization of the point-spread function based on stars within the JWST FOV and methods (plus tools) developed with past HST/WFC3 observations. As reported in Ding, Silverman & Onoue (2022), we detect the host galaxies of quasars at $z > 3$ for the first time and measure the spatially-resolved properties of the stellar population down to the inner few kpc of a massive face-on spiral host at $z = 1.6$. We find that quasar hosts are disk-like, actively forming stars, and compact but not yet as small as the quiescent population which all indicate ongoing growth of their bulges. These results are just the start of the rich science to come from JWST surveys such as the large COSMOS-Web program and similar efforts at $z \sim 6$.

Resolving The Smallest Dust Grains in the Early Universe

Justin Spilker, TEMPLATES team

Although dust grains constitute only a small fraction of the mass of galaxies, they have a large effect on the detectable properties of galaxies. Polycyclic aromatic hydrocarbons (PAHs) blur the line between small dust grains and large molecules. Their abundance and emission depend on both the grain size distribution and the UV radiation field. JWST promises to revolutionize our understanding of the dust-obscured universe. I will present early results from the TEMPLATES DD-ERS program, revealing the detection and spatially-resolved properties of the 3.3um PAH feature in a 'normal' dust-obscured galaxy at z=4.2. This is the most distant detection of any PAH feature and the first time PAH emission has been spatially resolved outside the local universe. We find large variations in both the PAH equivalent width and the L_PAH/L_IR ratio across the source, implying that the PAH emission is not a perfect tracer of either the underlying 3um stellar continuum or the emission of larger cold dust grains detectable with ALMA. I will discuss some early implications for understanding obscured star formation using PAHs and JWST's contributions to a renaissance in this field not seen since the days of Spitzer.

An intermediate-mass Black Hole at z~5.55 with NIRSpec/IFS

Hannah Uebler, NIRSpec/IFS GTO team

We present first results from the NIRSpec/IFS Galaxy Assembly GTO program on a compact, massive, low-luminosity Seyfert 1.5 AGN at z=5.55, when the Universe was only 1 Gyr old. The R2700 data reveal a variety of spectral features, most prominently Broad Line Regions in the Balmer lines, a high-velocity outflow in the forbidden [O III] doublet, several broad He I lines, and He II (4686). We measure a low central black hole mass, potentially providing constraints on growth channels of present-day supermassive black holes. Despite its clear AGN signature, this galaxy falls within the star-forming region of the classical BPT diagram, highlighting the distinctive physical conditions of the first massive galaxies.

First Look at the Rest-frame Optical Spectra and Quasar Host Galaxies of z > 6.5 Quasars using Early ASPIRE Data

Jinyi Yang

We present first results from the NIRSpec/IFS Galaxy Assembly GTO program on a compact, massive, low-luminosity Seyfert 1.5 AGN at z=5.55, when the Universe was only 1 Gyr old. The R2700 data reveal a variety of spectral features, most prominently Broad Line Regions in the Balmer lines, a high-velocity outflow in the forbidden [O III] doublet, several broad He I lines, and He II (4686). We measure a low central black hole mass, potentially providing constraints on growth channels of present-day supermassive black holes. Despite its clear AGN signature, this galaxy falls within the star-forming region of the classical BPT diagram, highlighting the distinctive physical conditions of the first massive galaxies.

Unveiling Chemical Evolution of C, O and Ne at z > 7 galaxies with JWST/NIRSpec

Karla Ziboney Arellano-Cordova

The observations of the JWST have opened a new window in studying the physical properties and abundance patterns of z > 6 galaxies. It improves our understanding of the different processes driving galaxy formation and evolution. This work analyzes the post-processing rest-frame near-UV and optical spectra of three z > 7 galaxies using observations taken with the Near-Infrared Spectrograph (NIRSpec) on the JWST. Such spectra show strong-nebular lines with significant detection of the [O III] λ4363 emission line, allowing the calculation of the electron temperature and the direct abundance determination for O/H, Ne/O, and C/O. Therefore, we reported the detection of C III] λλ1907,1909 in a z > 8 galaxy, which allows calculating the most distant C/O abundance ratio to date. We analyzed the C/O and Ne/O ratios as a function of metallicity, finding a similar trend as seen in z ~ 0 galaxies. Further, we investigated the redshift evolution of the mass-metallicity relationship (MZR) by comparing our results for z > 7 galaxies with those derived in local star-forming galaxies. In this first look at the evolution of the MZR, we also found a similar trend with respect to z ~ 0 galaxies, suggesting a similar physical process driven by outflows such as metal-enriched gas and inflows of pristine gas. However, large samples of z > 7 galaxies with high signal-to-noise and robust absolute flux calibration are necessary to interpret the chemical abundance patterns and their role in shaping the MZR.

Planetary Systems & Origins of Life

The metallicities and carbon-to-oxygen ratios of giant exoplanets

Jacob Bean, Jonathan Lunine

Atmospheric metallicities and carbon-to-oxygen (C/O) ratios are a highly desired constraint on models of giant planet formation. In contrast to the situation for the solar system planets, these properties are more easily accessible for close-in, transiting planets due to the observability of key molecules like H2O, CO, and CO2. However, transit spectroscopy measurements prior to JWST have generally lacked the wavelength coverage, spectral resolution, and precision to capitalize on this promise.

I will present results from a large JWST GTO program focused on measuring atmospheric metallicities and C/O ratios for a sample of canonical hot Jupiters. Ultra-precise thermal emission spectra have already been obtained for three planets, and a fourth will be observed a month before the conference. Our first result is the inference of a highly metal-enriched atmosphere for HD149026b. This planet is the most metal-rich giant planet known, with an estimated bulk metal fraction of 65% by mass. We find that the atmospheric metallicity for this Saturn-mass planet is highly inconsistent with the prediction of the mass-metallicity relationship defined by the solar system planets. Instead, the data match a new relationship between bulk and atmospheric metallicities that may be more fundamental. We also tightly constrain the C/O ratio for HD149026b to be sub-solar. Our continuing analysis of the data from this program will ultimately sketch the population-wide trends in giant planets that should be explored in more detail in Cycle 2 and beyond.

JWST/NIRSpec Transmission Spectroscopy of the Habitable-Zone Exo-Earth TRAPPIST-1g

Björn Benneke, Caroline Piaulet, Pierre-Alexis Roy, Olivia Lim, Rene Doyon, Louis-Philippe Coulombe, Martin Turbet, Néstor Espinoza, Peter Gao, Nicolas Cowan, Thomas Fauchez, Lisa Kaltenegger, Etienne Artigau, Michael Radica, David Lafreniere, Romain Allart, Charles Cadieux, Jake Taylor, Loic Albert, Jason Rowe, Alexandrine L'Heureux

The newly commissioned James Webb Space Telescope (JWST) offers the first opportunity to characterize the transmission spectrum of rocky habitable-zone exoplanets with sufficient precision to identify the molecular constituents within their secondary atmospheres. The rocky exo-Earth TRAPPIST-1g is particularly well-suited for this kind of first study because the low stellar insolation can allow for habitable conditions on its surface, while the small host star strongly amplifies the observable spectroscopic transit signature compared to planets orbiting sun-like stars. Here, we present the first high-precision JWST transmission spectrum of a habitable-zone exo-Earth, the planet TRAPPIST-1g, covering the full range between 0.6-5.3µm, obtained through two JWST transits observations using the NIRSpec PRISM BOTS mode. The sensitivity of these observations is sufficient to detect secondary terrestrial atmospheres of a wide variety of compositions, with molecular bands of CO2, H2O, CH4, NH3, and SO2 plausibly directly detectable if present. The coverage over the entire NIR up to 5.3µm furthermore allows for detecting molecular absorbers even in the presence of high-altitude Titan-like hazes that become more significant less opaque towards long wavelengths. In this talk, we present the results for TRAPPIST-1g and discuss the prospects for in-depth follow-up campaigns in JWST Cycle II.

PDRs4All : a molecular photoevaporation flow from a young protoplanetary disk as revealed by JWST

Olivier Berné, Els Peeters, Emilie Habart, Alain Abergel, Felipe Alarcón, Edwin A. Bergin, Jeronimo Bernard-Salas, Christiaan Boersma, Emeric Bron, Jan Cami, Amélie Canin, Ryan Chown,Sara Cuadrado, Emmanuel Dartois, Daniel Dicken, Meriem El-Yajouri, Asunción Fuente, Javier R. Goicoechea, Karl D. Gordon,Lina Issa, Christine Joblin, Olga Kannavou, Baria Khan, Ozan Lacinbala, David Languignon, Romane Le Gal, Alexandros Maragkoudakis, Raphael Meshaka, Yoko Okada, Takashi Onaka,Sofia Pasquini, Marc W. Pound, Massimo Robberto,Markus Röllig, Bethany Schefter,Thiébaut Schirmer, Ilane Schroetter, Ameek Sidhu,Thomas Simmer, Benoit Tabone, Alexander G. G. M. Tielens,Boris Trahin, Dries Van De Putte, Sílvia Vicente, Mark G. Wolfire, Marion Zannese, and the PDRs4All Team

The evolution of planet-forming disks around low-mass stars in stellar clusters is believed to be significantly affected by far-UV photons (E<13.6 eV) that heat the gas and lead to mass-loss through photo-evaporation. While far-UV photoevaporation has been recognized as a key mechanism in disk evolution, it has been difficult to directly detect and characterize such flows as it requires a combination of high spatial and spectral resolutions.

In this contribution, we will present observations of the 203-506 protoplanetary disk, located near the Trapezium cluster in Orion, obtained with JWST as part of the Early Release Science program PDRs4All, at an angular resolution of 0.1-0.3'' (40-120 AU). We combine these data with Atacama Large Millimeter Array (ALMA) observations, at a spatial resolution of 0.1'' (40 AU) and a spectral resolution of 0.1 km/s.

The data reveal that the 203-506 disk is enshrouded in an envelope of warm molecular gas that extends out beyond 100 AU from the disk. While this envelope rotates with the disk, the gas also shows clear signs of non-Keplerian motion. The NIRSpec spectrum of this envelope shows hundreds of molecular lines due to H2, CO, CH+, OH, possibly CH and HCO+, the Aromatic Infrared Bands, and a number of yet to be identified lines. Analysis of these spectroscopic data show that the gas is warm (~1000K) and dense (~5x10^5 cm-3), consistent with the envelope being a photo-evaporation flow.

These data allow the first direct characterization of such a flow. In particular, a mass-loss rate of the order of 10^-7 Msun/yr is derived, which is in agreement with 1D dynamical models where small dust grains in the flow provide a large UV opacity. This is compatible with the NIRSpec detection, in the flow, of large amounts of PAH molecules which efficiently absorb UV.

JWST Observations of the Jovian System from Commissioning and ERS data

Imke de Pater, Thierry Fouchet, Michael H. Wong, Patrick Fry, Leigh N. Fletcher, Ricardo Hueso, Henrik Melin, Mark Showalter, Dominique Bockelée-Morvan, Emmanuel Lellouch, Katherine de Kleer, Al Conrad, John Stansberry, Bryan Holler, Pablo Ródriguez-Ovalle, Jake Harkett, Matthew Hedman, Deepashri Thatte, Edward Molter, Joel Sánchez-Bermúdez, Lawrence Sromovsky, Manuel López-Puertas, and the ERS 1373 team

Early Release Science data of the Jovian system (#1373) have been taken in July-August; a second set is expected in Nov-Dec. These observations explore the planet's atmosphere, its major and minor satellites and faint ring system. We will present an overview of the results, which our team will put together during an all-hands meeting on data reduction and analysis Oct. 24-28 in Meudon/France. Some teasers are: i) NIRCam images of Jupiter at 1.64, 2.12 and 3.23 microns, taken 10 hrs apart, are used to derive wind profiles in the haze layer above Jupiter's clouds, and reveal a narrow central jet close to the tropopause at an atmospheric altitude where winds have never been observed before on Jupiter. ii) An intriguing illuminated layer is seen above the dusk terminator in filters sensitive to the upper atmosphere: there is an ongoing debate about the origins of this feature. We will present the latest (likely final) model using H2 quadrupole, H3+, and CH4 emissions to explain this feature. iii) The Great Red Spot (GRS) has been observed with NIRCam, NIRSpec and MIRI (combined ERS/GTO program), probing the GRS from below the cloud layers up into the ionosphere, with structures never seen before. NIRSpec/MIRI auroral data will be taken in December. iv) The rings and small satellites show up clearly in our data and a puzzling wavelength dependence is seen in the rings. A second set of images is expected in November. v) Ganymede has been observed with NIRSpec and MIRI showing leading/trailing hemisphere differences. vi) Io has been observed with NIRISS/AMI when the volcanically active Emakong Patera was exceptionally bright. NIRSpec and MIRI data are expected in December.

Finally, context for these new JWST datasets has been provided by numerous ground-based observatories and HST, from the UV to the mid-infrared.

Discovery of Water in a Main-Belt Comet

Michael S. P. Kelley, Henry H. Hsieh, Dennis Bodewits, Mohammad Saki, Stefanie N. Milam, Heidi B. Hammel

Planetesimal formation produces small bodies with a wide range of properties. These objects serve as material inputs to planets, and comprise the debris disks observed around many stars. Asteroids are small bodies that are thought to have formed near or interior to the water-ice line, whereas comets and other outer disk objects are thought to have formed farther from the proto-Sun. Our present-day assessment of the volatile (i.e., water) content of asteroids mainly relies on laboratory analysis of hydrated minerals in meteorites, and spectroscopy of asteroidal surfaces. In the 3-μm wavelength region, spectra of the surfaces of asteroids show evidence for hydrated minerals, but also the presence of small amounts of water ice on some outer main-belt objects (Rivkin et al. 2022, PSJ 3, 153). The latter hints at the presence of a reservoir of water ice in the inner solar system that has survived for ~4.5 Gyr. Related are a small number of so-called main-belt comets, objects that have orbits indistinguishable from main-belt asteroids, but repeatedly produce cometary comae near perihelion. They present an exciting opportunity to directly probe the water ice content of main-belt asteroids. However, previous attempts to measure any gas within these comets have only returned upper limits. With JWST's NIRSpec instrument, we have obtained the first detection of water vapor in a main-belt comet, and the only such detection in a nominally dynamically asteroidal object since the discovery of water vapor plumes from the dwarf planet Ceres (Küppers et al. 2014, Nature 505, 525). The JWST data also show that 238P lacks a CO2 coma found in classical comets, indicating either that this comet had a formation location distinctly different from other comets, or that any accreted CO2 was lost during the long residence time in the main belt.

The Thermal Emission Phase Curve of the sub-Neptune Exoplanet GJ 1214b with MIRI LRS

Eliza Kempton, Jacob Bean, Michael Zhang, Maria Steinreuck, Isaac Malsky, Michael Roman, Vivien Parmentier, Emily Rauscher, Peter Gao, Anjali Piette, Jake Taylor, Taylor Bell, Sarah Kendrew, Laura Kreidberg, Sebastian Zieba, Elsa Ducrot, Pierre-Olivier Lagage, Qiao Xue, Keivan Stassun, Travis Barman, Tiffany Kataria, Kevin Stevenson, Arjun Savel, Matej Malik, Megan Mansfield

The transiting exoplanet GJ 1214b is an exemplar sub-Neptune that has been observed extensively using transmission spectroscopy (e.g. Bean et al. 2010, Berta et al. 2012, Kreidberg et al. 2014). However, these prior measurements have yielded inconclusive information about the planet's atmospheric state because high-altitude aerosols have prevented the detection of any chemical species. Here we present the results of a full-orbit phase curve of GJ 1214b obtained with the MIRI instrument in July of this year. By measuring the thermal emission from the planet over its entire orbital period, we obtain constraints on the planet's atmospheric composition and aerosol properties that have evaded previous attempts with transmission spectroscopy observations at shorter wavelengths. We readily detect GJ 1214b's secondary eclipse and phase-dependent emission at high confidence. We present the novel insights gleaned into this mysterious planet's atmosphere via our thermal emission measurements at mid-infrared wavelengths and summarize lessons learned for future atmospheric characterization studies of sub-Neptune exoplanets with JWST.

The JWST Early Release Science Program for Direct Observations of Exoplanetary Systems II: A 1 to 20 Micron Spectrum of the Planetary-Mass Companion VHS 1256-1257 b

Brittany E. Miles, High Contrast Imaging of Exoplanets and Exoplanetary Systems with JWST ERS Team

We present the highest fidelity spectrum to date of a planetary-mass object. VHS 1256 b is a <20 MJup widely separated (~8", a = 150 au), young, brown dwarf companion that shares photometric colors and spectroscopic features with the directly imaged exoplanets HR 8799 c, d, and e. As an L-to-T transition object, VHS 1256 b exists along the region of the color-magnitude diagram where substellar atmospheres transition from cloudy to clear. We observed VHS 1256 b with JWST's NIRSpec IFU and MIRI MRS modes for coverage from 1 μm to 20 μm at resolutions of ~1,000 - 3,700. Water, methane, carbon monoxide, carbon dioxide, sodium, and potassium are observed in several portions of the JWST spectrum based on comparisons from template brown dwarf spectra, molecular opacities, and atmospheric models. The spectral shape of VHS 1256 b is influenced by disequilibrium chemistry and clouds. We directly detect silicate clouds, the first such detection reported for a planetary-mass companion.

A unique view of frozen comet Hale-Bopp with JWST

Cyrielle Opitom, Michael S. P. Kelley; Silvia Protopapa; Marco Micheli; Colin Snodgrass; Davide Farnocchia, Adam McKay

Comet C/1995 O1 (Hale-Bopp) was one of the most spectacular comets of the last decades. After passing through perihelion in 1997, the comet is now at 46 au from the Sun. Because Hale-Bopp has one of the largest cometary nuclei known, it is still sufficiently bright to be observed with JWST, providing a unique opportunity to observe the frozen surface of an Oort Cloud comet at distances equivalent to the Kuiper Belt.
Observations performed in 2009 showed that the comet was inactive at 28 au and had a geometric albedo higher than the range observed for other comets (Szabo et al., 2012), hinting that its surface might be covered by ice. The wavelength range of the NIRSpec IFU ideally covers spectral features from water, CO2, and methanol ices, some of the main components of cometary ice, allowing us to assess the surface composition of Hale-Bopp.
Following imaging at 1.8 and 3.6 μm with NIRCam in July 2022 that allowed us to refine the ephemeris and confirmed that the comet appears inactive, comet Hale-Bopp was successfully observed with NIRSpec on 2022 October 6. We will present preliminary results about the surface composition of comet Hale-Bopp from these observations, the most distant of a comet ever performed.

The first mid-infrared Y dwarf spectrum reveals its "cool" molecular features!

Polychronis Patapis, MIRI GTO team

We present the 5-18 micron spectrum of archetypical brown dwarf WISE-J1828, observed with the MIRI Medium Resolution Spectrometer (MRS) on JWST. This is the first mid infrared spectrum of a cold Y-dwarf (T~400 K), where the spectral range covers the peak of its emission. At the resolution of the MRS the spectrum shows beautiful spectral features of various molecules, most notably ammonia. We will discuss the data processing, spectral extraction, and first analysis results of this unique dataset, highlighting the detection of molecular species. The fidelity and richness of the spectrum will establish it as the benchmark for future studies of cool objects, opening a new window towards understanding atmospheric models of brown dwarfs, but also of cool giant exoplanets.

First JWST-MIRI MRS results on the PDS 70 planet-forming disk

Giulia Perotti, MINDS (MIRI Mid-INfrared Disk Survey)

Protoplanetary disks (PPDs) represent the evolutionary link between molecular clouds and planets. Knowledge of their molecular inventory is the key to unveil the chemical trail leading to life, yet too few observational constraints of PPDs exist at infrared wavelengths, especially in the mid-IR. This wavelength regime enables to study the emission of molecular hydrogen, PAH, refractory material, and ultimately absorption of ice species in protoplanetary disks. Compared to previous mid-IR facilities, the JWST MIRI instrument offers unprecedented sensitivity, spatial resolution, and spectral coverage. In this occasion, we will present the first JWST MIRI observations of the planet-forming PDS 70 disk as part of the MIRI Mid-INfrared Disk Survey (MINDS) GTO program (Th. Henning, I. Kamp, co-Is).
We will reveal the chemical composition of the gas and dust forming in this iconic disk at a spectral and spatial resolution it was never observed before in the mid-IR. In particular, we will probe the inner disk composition (< 10 AU) and present JWST MIRI MRS 5-20 micron spectra of the upper disk surface. In tandem with high-resolution ALMA data, we will be able to link the astrochemical processes leading to the inner disk composition with the molecular inventory observed in the outer disk.

A First Look Transmission Spectrum of WASP-96b with NIRISS/SOSS

Michael Radica

The next era of exoplanet atmospheric spectroscopy has well and truly begun. The science operations of JWST are now underway, and promise a deeper-than-ever look into the atmospheric dynamics and composition of exoplanet atmospheres; ranging from hot-Jupiters to potential Earth-twins. The JWST Early Release Observations represent some of the very first images and spectra from this revolutionary observatory. Here, we present a transmission spectrum of the hot Jupiter WASP-96b, with hitherto unprecedented wavelength coverage (0.6 — 2.8μm) and spectral resolution (R~800), taken with the NIRISS/SOSS mode as the exoplanet atmosphere component of the Early Release Observations program. We describe constraints on atomic and molecular detections obtained from forward model grids, as well as suites of full Bayesian retrievals — and discuss their implications for the metallicity and carbon-to-oxygen ratio of WASP-96b's atmosphere. We also present a first look into the dynamics of the atmosphere of this giant planet from preliminary comparisons with general circulation models (GCMs). Finally, we suggest specific strategies for future exoplanet observations with the SOSS mode, which is the only of JWST's instrument modes specifically designed for spectroscopy of exoplanet atmospheres.

Planet-Forming Disks in Extreme Radiation Environments

Maria Claudia Ramirez-Tannus, A. Bik, R. Waters, F. Backs, J. Bouwman, W. Brandner, M. Chevance, A. de Koter, A. Derkink, E.D. Feigelson, S.T. Geen, K.V. Getman, Th.K. Henning, I. Kamp, L. Kaper, D. Kruijssen, M.A. Kuhn, S. Longmore, A.F. McLeod, J. Poorta, M.S. Povich, T. Preibisch, V. Roccatagliata, E. Sabbi, H. Sana, S.E. van Terwisga, R. Waters, A. Winter, E. Zari

Our knowledge about the formation history of planetary systems is obtained by comparing the demographics of proto-planetary disks with the exoplanetary system population. Most of the disks that have been characterized to date are located in nearby low-mass star forming regions. However, it is well known that most stars form in denser environments and therefore, it is questionable that the well-studied population of planet forming disks is representative of those in which most exoplanets were assembled. To date, direct characterization of disks affected by external photo-evaporation has been limited to a few, nearby examples, in particular the famous `proplyds' in the ONC. While this region has proven important to understand the physical processes that affect externally irradiated PPDs, it has the disadvantage that a single O star dominates the UV flux. Therefore, the FUV exposure history of ONC disks is uncertain because it depends on the age the O star, the orbits of the low-mass stars, and the dynamical history of the region.

Due to their large distances and high stellar densities, so far it has been impossible to study the physical and chemical properties of proto-planetary disks in other massive star-forming regions. With the advent of JWST, for the first time we have been able to obtain spectra of strongly irradiated proto-planetary disks in the massive star forming region NGC6357. We will present the first results on irradiated disk structure, chemistry and dust mineralogy and the comparison with what it known from similar disks in nearby, less extreme, regions. Additionally, we will present a serendipitous discovery of a sample of proplyds based on the MIRI simultaneous imaging of the cluster. These objects are exposed to a much more extreme radiation field than the proplyds found in Orion opening a new parameter space in studying the evolution of these objects.

Unveiling the ringed centaur (10199) Chariklo from JWST through a stellar occultation

Pablo Santos-Sanz, Altair R. Gomes Júnior (Federal University of Uberlândia, Brazil), Bruno E. Morgado (Valongo Observatory/UFRJ, Brazil), John Stansberry (STScI, USA), Bryan Holler (STScI, USA), Heidi B. Hammel (AURA, USA), Jose L. Ortiz (IAA-CSIC, Spain), Bruno Sicardy (Sorbonne Univ. & Obs. de Paris, France), Nicolás Morales (IAA-CSIC, Spain), Josselin Desmars (IPSA/IMCCE, France), Noemi Pinilla-Alonso (FSI/UCF, USA), Richard G. French (Dept. of Astronomy, Wellesley College, USA), Zhong-Yi Lin (IANCU, Taiwan), Estela Fernandez-Valenzuela (FSI/UCF, USA), Mónica Vara-Lubiano (IAA-CSIC, Spain), Mike Kretlow (IAA-CSIC, Spain), Damya Souami (Obs. de la Côte d'Azur, France), Felipe Braga-Ribas (UTFPR/DAFIS, Brazil), Julio Camargo (Obs. Nacional/LineA, Brazil), Gustavo Benedetti-Rossi (São Paulo State Univ./LineA, Brazil), Flavia L. Rommel (Obs. Nacional/LineA, Brazil), Rene Duffard (IAA-CSIC, Spain), Marcelo Assafin (Univ. Federal do Rio de Janeiro/LineA, Brazil), Rodrigo Leiva (IAA-CSIC, Spain).

We present the results of a stellar occultation by the centaur (10199) Chariklo detected from JWST/NIRCam within Heidi Hammel's GTO program ID 1271: ToO TNOs: 'Unveiling the Kuiper belt by stellar occultations' (PI: P. Santos-Sanz). This is the first stellar occultation observed from JWST and is a successful proof of concept of the feasibility of JWST to characterize solar system objects through this powerful technique. We will present the challenging tasks performed to predict stellar occultations visible from JWST and the instrumental setup used to observe this occultation. Finally, we will present preliminary results of the successful stellar occultation produced by the centaur Chariklo on October 18, 2022, which shows us in-depth details of Chariklo's rings and will serve to search for more material.

First Results from the JWST Transiting Exoplanet Community ERS Program

Kevin Stevenson, JWST Transiting Exoplanet Community ERS Team

Within the first few months, JWST has already transformed our understanding of exoplanets and their atmospheres. This has been made possible by providing access to a broad range of infrared wavelengths at unprecedented precisions. The JWST Transiting Exoplanet Community ERS Program (GO-1366) is exercising the time-series modes of all four JWST instruments and investigating the full suite of characterization geometries (transits, eclipses, and phase curves). The goal is to provide a compelling set of representative datasets that will accelerate the acquisition and diffusion of technical expertise and enable immediate scientific breakthroughs. For this presentation, I will share exciting and unexpected first results from this program, focusing on the detection of previously-unresolved molecules, new evidence for disequilibrium chemistry, and implications for planet formation. I will also discuss the performance of each instrument mode and set expectations for time-series observations in future cycles.

Astrobiology with JWST: Searching for life and habitability in our Solar System

Geronimo Villanueva, Mars and Ocean Worlds GTO teams

JWST will open a new era in the astrobiological exploration of our Solar System. Recently and using orbiters and ground-based observatories we established that Mars lost an ocean's worth of water, while the Curiosity rover has recently detected organics on the Martian surface and in the atmosphere. Organic rich oceans have been suggested to exist under the surface of Europa, Enceladus. If these planets/moons had a rich chemical and diverse past, how much of these volatiles were lost to space, and how much are currently available for life? Are there sub-surface habitable niches connecting now with the atmosphere?

Sensitive infrared spectroscopy is one of the most powerful methods to address fundamental questions of planetary evolution and habitability, by permitting to probe water, other key volatile species and also importantly organic compounds. Telluric extinction and background-noise limit our sensitivity to measure these species from ground, while orbiters and previous observatories generally do not have the wavelength range, coverage or sensitivity to deeply probe these species. With the recent arrival of the James Webb Space Telescope (JWST) to the L2 point, a new window now opens for the exploration of the solar system and beyond at infrared wavelengths.

In this presentation, I will present our JWST latest results as obtained with the Mars GTO and Ocean Worlds (Europa / Enceladus) GTO programs. These observations demonstrate the unique capabilities of this new observatory for fundamental Solar System research, and set the foundation for future dedicated measurements of astrobiologically relevant species and processes.

Kuiper Belt Science with JWST

Ian Wong, John Stansberry, Bryan Holler, Noemí Pinilla-Alonso, Silvia Protopapa, Rosario Brunetto, Joshua Emery, Estela Fernández-Valenzuela, Will Grundy, Dean Hines, Ana Carolina Souza-Feliciano, Heidi Hammel, Stefanie Milam, Dale Cruikshank

Beyond Neptune lies a diverse population of icy bodies collectively known as the Kuiper Belt. These bodies are remnants from the earliest epochs of planetesimal formation and display a wide range of chemical and physical properties that can inform on their origin and evolution. For decades, the vast distances of Kuiper Belt objects (KBOs) have made spectroscopic study of their surfaces extremely challenging. Now, the advanced capabilities of JWST are revolutionizing our understanding of these enigmatic objects. With its continuous wavelength coverage of the near-infrared region (0.6 to 5 micron), NIRSpec offers an exquisite view of the detailed molecular composition of KBO surfaces.

As part of Cycle 1 Guaranteed Time Observation Program 1191 (PI: John Stansberry), JWST has carried out NIRSpec IFU observations of almost a dozen KBOs. These targets include the Pluto–Charon binary system, the dwarf planets Eris and 2002 MS4, and members of the Haumea collisional family. Together, the spectra span a broad range of representative surface types attested throughout the Kuiper Belt. We have combined a suite of independent data processing methodologies with preliminary compositional model retrievals to study the surface properties of the observed KBOs. Our analysis has uncovered a slew of previously undetected molecular absorptions, yielding unprecedented constraints on ice composition and new insights into the formation and subsequent evolution of these objects. We also compare our results with previous ground- and space-based spectra, as well as spatially resolved spectroscopy from the 2015 New Horizons flyby of the Pluto–Charon system. These early observations demonstrate the immense leap in knowledge that JWST will bring to the study of the outer Solar System.

Star Formation and Stellar Populations

Photometry and astrometry with JWST: first scientific results in the field of resolved stars.

Nardiello Domenico, Luigi Bedin, Massimo Griggio, Michele Scalco

In July 2022, JWST has become fully operational, and first data from ERS and Calibration programs became publicly available. These data are mandatory to build the tools for precision point-source photometry and astrometry in crowded environments (and not only). In this talk, our first, independent, data reduction of NIRCam imaging of the metal-poor globular cluster M 92 and of the Large Magellanic Cloud (LMC) field, and the scientific goals we have achieved will be presented. The effective point spread functions and geometric distortion solutions we derived have allowed us to obtain the following first scientific results with JWST in the field of resolved stellar populations:

(i) first JWST color-magnitude diagrams of a globular cluster (down to ~0.1 Msun) and of the LMC stars;
(ii) first detection of white dwarfs in M92 in near-infrared bands;
(iii) detection of multiple populations in the main sequence of M92;
(iv) measurement of LMC internal proper motions.

A preview of the ongoing and future works will be finally illustrated.

Stellar Populations in the Globular Star Cluster 47 Tucanae

Matteo Correnti, A. Boley, A. Burgasser, I. Caiazzo, A. Dieball, R. Gerasimov, J. Heyl, H. Richer, A. Schiebelbein, P-E. Tremblay

We have observed four JWST fields with NIRCam in the very wide filters F150W2 and F322W2 near the core of the globular star cluster 47 Tucanae. The exposure time in each field was about 5 hours. These fields largely overlap with observations that were obtained as much as 12 years ago with HST, so that we additionally have up to 4 HST magnitudes together with proper motions for many of the stars. This allows us to unambiguously identify in the JWST images the cluster white dwarfs, the lower main sequence stars, cluster stars fainter than the end of the hydrogen-burning main sequence, stars belonging to the SMC and background galaxies. In this talk we present some very preliminary results from this program; our goal is to observe for the first time the cooling brown dwarf sequence and to hunt for ancient planetary systems around white dwarfs, as well as understand the atmospheric properties of cool white dwarfs.

On the origin of a kiloparsec size superbubble in the JWST/MIRI images of the "phantom galaxy" NGC628

Divakara Mayya, Jairo Alzate, Luis Lomeli, Javier Zaragoza-Cardiel, Mauricio Gomez

NGC628 is the first nearby galaxy for which JWST data became available to the public. The most striking characteristic of the publicly released MIRI image is the presence of a large number of "holes" in an otherwise bright mid-infrared (MIR) emitting disk. This porous structure has given it a popular nickname "phantom galaxy". The "holes", which are commonly traced in the HI maps, are expanding bubbles or superbubbles most often created by the mechanical power output by the massive stars in young star clusters. However, few cases exist where the stellar population that was responsible for the creation of the bubble was identified. We here analyze the largest of the bubbles in the MIRI image of NGC628, measuring 1.3 kpc in diameter to understand the origin of such large bubbles. We combined the JWST NIRCam and MIRI dataset with archival images from the HST, ALMA, VLA and MUSE, to identify the resolved population that might be responsible for the creation of the bubble, and to map the multiphase morphology and kinematics of the gas in the shell surrounding the bubble. The bubble is dominated by the molecular gas and is expanding at 30 km/s velocity. We find conclusive evidence for the presence of a resolved stellar population younger than 50 Myr inside the bubble, whose collective mechanical power output is sufficient to explain the presently observed radius, velocity and the shell mass. We also find that although the shell is detected in CO, HI and Halpha, the bubble to shell intensity contrast is maximum in the F770W image, making the MIRI images excellent places for studying the population of bubbles. In the contribution, I will discuss the implications of this work in understanding the morphology of MIRI images of nearby galaxies.

Deep diving off the 'Cosmic Cliffs': previously hidden outflows in NGC 3324 revealed by JWST

Megan Reiter, Jon A. Morse, Nathan Smith, Thomas J. Haworth, Michael A. Kuhn, and Pamela D. Klaassen

We present a detailed analysis of the protostellar outflow activity in the high-mass star-forming region NGC 3324, as revealed by the Early Release Observations from JWST. Emission from numerous outflows is revealed in narrow-band images of hydrogen Paschen-alpha and molecular hydrogen (H2). We report the discovery of 24 previously unknown outflows based on their H2 emission. We find three candidate driving sources for these H2 flows in published catalogs of young stellar objects (YSOs) and we identify 15 IR point sources in the new JWST images as potential driving protostars. We also identify several Herbig-Haro (HH) objects in Paschen-alpha images from JWST; most are confirmed as jets based on their proper motions measured in a comparison with previous Hubble Space Telescope (HST) H-alpha images. This confirmed all previous HST-identified HH jets and candidate jets, and revealed 7 new HH objects. The unprecedented capabilities of JWST allow the direct comparison of atomic and molecular outflow components at comparable angular resolution. Future observations will allow quantitative analysis of the excitation, mass-loss rates, and velocities of these new flows. As a relatively modest region of massive star formation (larger than Orion but smaller than starburst clusters), NGC 3324 offers a preview of what star formation studies with JWST may provide.

PHANGS-JWST First Results: Tracing PAHs Throughout the ISM

Jessica Sutter, Karin Sandstrom, Jérémy Chastenet, and the PHANGS Team

We present early science results from JWST NIRCam and MIRI observations of NGC628, NGC1365, NGC7496, and IC 5332 from the Physics at High Resolution in Nearby Galaxies (PHANGS) sample. This initial set of galaxies includes a grand design spiral (NGC628), two barred galaxies which host AGN (NGC1365, 7496), and a lower metallicity environment (IC5332). The NIRCam F335W and MIRI F770W and F1130W bands are ideally positioned to map emission from polycyclic aromatic hydrocarbons (PAHs) at 3.3μm, 7.7μm, and 11.3μm in nearby galaxies at spatial resolutions of 5-40 pc. This provides a previously unattainable view of the emission from these small dust grains, which play a large role in both the thermal regulation and ionization balance in the ISM. These new maps allow us to trace the spatial distribution of the PAHs, which we find widely distributed throughout each galaxy. We assess a novel method for combining the NIRCam F300W, F360W, and F335W bands to isolate 3.3μm PAH feature. As the 3.3μm feature is characteristic of small, neutral PAHs, while the 7.7μm complex traces a charged PAH population, and the 11.3μm feature is primarily associated with PAHs which are both larger and neutral, we can use the proportional strength of these three features to determine how the PAHs vary across different galactic environments. We find evidence of PAH destruction in HII regions and a correlation between the size of the PAH grains and the fraction of H2 to total gas mass. Understanding the properties of the PAHs from these early JWST results will lay the groundwork for further studies of the complex interplay between the dust, gas, and stars that drives galaxy evolution.

JWST/MIRI Observations of a Class 0 Protostar IRAS 15398-3359: Organic Chemistry from Ice to Gas

Yao-Lun Yang, CORINOS

In recent years, the increasing detection of complex organic molecules (COMs) in Class 0/I protostars highlights the extensive chemical evolution at the onset of star formation. However, the formation pathways of COMs and whether most protostars undergo similar chemical evolution remain open questions with little observational constraints. Most COMs form in the ice mantles covering dust grains. While ALMA provides sub-100 au resolution for studying gaseous COMs in nearby embedded protostars, measurements of the chemical composition in ices had been limited by low-resolution and limited sensitivity until JWST, which can probe ices at a spatial scale comparable to that by ALMA with unprecedented sensitivity. In this talk, I will present the JWST/MIRI observations of a Class 0 protostar, IRAS 15398-3359, from the CORINOS program and discuss the prospect of ice identification and modeling in the JWST era. The MIRI spectrum robustly characterizes the shape of ice features, including the fine details of broad absorption features. Besides the common ice species, which are definitively identified, the spectrum shows potential evidence of organic ice species, such as ethanol and acetaldehyde. The well-calibrated spectrum also provides strong constraints on ice modeling and enables direct comparison with synthetic spectra from radiative transfer calculation. Moreover, line and continuum emission in our MIRI observations gives us the most crisp view of the outflows and jets in mid-IR. The ionized lines, such as [Fe II] and [Ne II], trace collimated bipolar jets, while the H2 lines come from the shocked gas in the wide-angle outflow cavity. I will also discuss the potential of a holistic view of COM chemistry learned from both JWST and ALMA observations. The JWST observations of IRAS 15398-3359 show striking details on the ice absorption as well as the protostellar structure, demonstrating the prospect of understanding organic chemical evolution from protostars to planets.

Stellar Physics & Stellar Life Cycle

A Mid-Infrared spectrum and models of the type Ia Supernovae 2021aefx: the thermonuclear explosion of a near Chandrasekhar mass Carbon-Oxygen White Dwarf

Chris Ashall

Although they have long been used as the most accurate extra-galactic distant indicators in the universe, determining the progenitor scenario and/or explosion mechanism(s) of type Ia Supernovae (SNe Ia) has long eluded the astrophysical community. Many of the "smoking gun" observations for distinguishing between these scenarios are located in the virtually unexplored Mid-InfraRed (MIR) wavelengths. In this talk I will present a MIRI spectrum of the normal SN Ia 2021aefx at 340 days past explosion (proposal ID: 2114; PI: Ashall). This is one of the first-ever spectra of a SN observed with JWST. At these late phases, the ejecta is optically thin and the high-density central layers of the explosion are visible. This groundbreaking spectrum shows lines of Argon, radioactive Cobolt, and stable Nickel. Some of the spectral lines include [Ni II] 6.66μm, [Ni III] 7.35, 11.00μm and [Ni IV] 8.41μm. These lines are indicative of high-density burning. Synthetic spectra were produced from a variety of explosion models in order to extract the physical conditions in the ejecta. It was found that SN 2021aefx is consistent with the delayed-detonation model of a near Chandrasekhar mass White Dwarf. This model has a central density in the range of 1–3x10^9 g cm-3, and comes from an Helium accretor. Alternatively, a sub-Chandrasekhar mass explosion with an ejecta mass of 1.2M⊙ may explain the observed spectra, however, the absolute luminosity of this model is inconsistent with the light curve brightness. Finally, I will mention how future Cycle1 observations (proposal ID:2112; PI: Ashall) of core-collapse SNe will allow us to determine the conditions for molecular formation as the precursors for cosmic dust.

Demystifying Unusual Infrared Transients with JWST Spectroscopy

Jacob Jencson, Ryan Lau, Michael Ressler, Mansi Kasliwal, Ori Fox, Matthew Hankins, Kishalay De

In its final years, the Spitzer Space Telescope expanded our view of the dynamic infrared (IR) sky by revealing entirely new and emerging classes of transients. All-sky monitoring by the reactivated NEOWISE mission is continuing this exploration, particularly in the densely obscured Galactic plane. These transients are diverse and populate the luminosity “gap” between classical novae and the much more luminous supernovae. A class of events discovered by Spitzer, dubbed SPRITEs (eSPecially Red Intermediate-luminosity Transient Events), are so red that any associated optical emission is very faint or completely absent. A leading hypothesis for the origin of some SPRITEs is a common-envelope ejection or stellar merger with rapid obscuration by dust formation, but direct confirmation of this idea has proved elusive. In our Galactic backyard, the detection and characterization of mergers in the lowest mass binaries and even star-planet systems has been inhibited by their faint luminosities compounded by high levels of extinction. The key to unraveling the nature of these events is mid-IR spectroscopy, now available with the successful launch of JWST and start of science operations in 2022. We will present the first results from a JWST Cycle 1 GTO program to obtain NIRSpec and MIRI spectra (3-12 micron) of three events (PID 1240; PI M. Ressler). The first two targets, including an extragalactic SPRITE in IC 342 and a Galactic NEOWISE transient believed to be the first example of the merger of a star and a planetary mass companion, were successfully observed in Sept. 2022. Modeling of the spectra to determine the mass and chemical composition of their dusty outflows and constrain the properties of their remnants provides vital new clues to confirm their origins.

Nested Dust Shells around the Wolf-Rayet Binary WR 140 observed with JWST

Ryan Lau, WR DustERS Team

Massive colliding-wind binaries that host a Wolf-Rayet (WR) star present a potentially important source of dust and chemical enrichment in the interstellar medium (ISM). However, the chemical composition and survival of dust formed from such systems is not well understood. The carbon-rich WR (WC) binary WR 140 presents an ideal astrophysical laboratory for investigating these questions given its well-defined orbital period and predictable dust-formation episodes every 7.93 years around periastron passage. In this talk, I will present observations from our Early Release Science program (ERS1349) with the James Webb Space Telescope (JWST) Mid-Infrared Instrument (MIRI) Medium-Resolution Spectrometer (MRS) and Imager that reveal the spectral and spatial signatures of nested circumstellar dust shells around WR 140. MIRI MRS spectroscopy of the second dust shell and Imager detections of over 17 shells formed throughout the past ~130 years confirm the survival of carbonaceous dust grains from WR 140 that are likely carriers of "unidentified infrared" (UIR)-band features at 6.4 and 7.7 μm. The observations indicate that dust-forming WC binaries can enrich the ISM with organic compounds and carbonaceous dust.

The ring and ejecta of the iconic SN1987A revealed by the MIRI/MRS

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The iconic supernova (SN) 1987A in the Large Magellanic Cloud (LMC) has provided us a unique opportunity to study the mechanics of a SN explosion and now to witness the birth of a SN remnant (SNR). Our JWST Cycle 1 observations (PID 1232) of SN 1987A, obtained on July 16th 2022 - 35 years after the initial explosion - have delivered superb quality data from the MIRI/MRS IFU, spatially resolving both the ring and inner ejecta of this nearby SN. The spectra are rich in both line and dust continuum emission, found both in the ejecta and the ring. Low ionisation ionic lines and molecular hydrogen emission are detected from the ejecta, whilst high ionisation emission is present in the ring and the outer environments. In particular, the resolved lines in the mid-IR allow us to gain new insights into the physics of the explosion and its aftermath.

The binary and the disk: the beauty is found within NGC3132 with JWST

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The planetary nebula (PN) NGC 3132 is a striking example of the dramatic but poorly understood, mass-loss phenomena that (1-8) Msun stars undergo during their death throes as they evolve into white dwarfs (WDs). From an analysis of JWST multiwavelength (0.9 − 18 micron) imaging of NGC 3132, we report the discovery of an extended dust cloud around the WD central star (CS) of NGC 3132, seen most prominently in the 18 micron image, with a surface-brightness limited radial extent of >~2 arcsec. We show that the A2V star located 1.7 to CS's North-East (and 0.75 kpc from Earth) is gravitationally-bound to the latter, by the detection of relative orbital angular motion of 0.24(+/-0.045) deg between these stars over ~20 yr. Using aperture photometry of the CS extracted from the JWST images, together with published optical photometry and an archival UV spectrum, we have constructed the spectral- energy distribution (SED) of the CS and its extended emission over the (0.091-18 micron) range. We find that fitting the SED of the CS and the radial intensity distributions at 7.7, 12.8 and 18 micron with thermal emission from dust requires a cloud that extends to a radius of >~1785 au, with a mass of ~ 0.013 Mearth, and grains that are 70% silicate and 30% amorphous carbon. We propose plausible origins of the dust cloud and an evolutionary scenario in which a system of three stars – the CS, a close low-mass companion, and a more distant A2V star – forms a stable hierarchical triple system on the main-sequence but becomes dynamically unstable later, resulting in the spectacular mass-ejections that form the current, multipolar PN.

JWST imaging and spectroscopy of the Ring Nebula
Roger Wesson, The JWST Ring Nebula Team

The iconic Ring Nebula is a bright and relatively nearby (780pc) example of a planetary nebula, the end stage of stellar evolution for low to intermediate mass stars. It presents an astrophysical laboratory with a single very hot (125,000K) source of ionising radiation and a well-defined geometry, in which the physics of dense clumps in an energetic irradiated environment can be studied.

We present images and spectra of the nebula obtained with JWST. NIRCAM and MIRI images provide detailed maps of the ionised, neutral and molecular components of the nebula. The bright ring contains numerous high-density clumps which provide an environment suitable for molecule formation and survival. Two regions of the nebula have been observed with MRS and NIRSPEC - one containing an individual clump within the harsher environment of the ionised region, and another in the main ring, further from the central star. The spectra contain numerous ionised and molecular lines, and reveal differences in the physical conditions between the two regions, with the inner region being more highly ionised.

The End of the Dark Ages

The UNCOVER Treasury Program: An Ultradeep Early JWST Community Deep Field
Rachel Bezanson, UNCOVER

The James Webb Space Telescope (JWST) was built to reveal the earliest moments of cosmic history and the faintest objects driving reionization. This goal drove the design of the Ultradeep NIRSpec and NIRCam ObserVations before the Epoch of Reionization (UNCOVER) Cycle 1 Treasury program. The UNCOVER survey includes a first epoch of ultradeep imaging (~30AB without lensing, and down to ~32AB with extreme magnification) covering ~24 sq. arcmin on and around the well-studied Abell 2744 galaxy cluster at z=0.308, expected in late October/early November 2022. Within Cycle 1 (July 2023), the program will follow-up ~500 background JWST-identified galaxies with extremely deep (up to ~20 hours, to ~29_{AB}) low-resolution spectroscopy with the NIRSpec/PRISM. These high S/N continuum spectra will yield secure redshifts for nearly all targets but will also uncover the physical nature of these galaxies. Our program also includes NIRISS and NIRCam parallel imaging to expand the deep imaging footprint to ~45 sq. arcmin. In this talk, we will present our first results, highlighting unparalleled resolved and ultradeep 2-4 micron imaging of known and previously unknown objects in the field. We will also give an overview of public data releases including early imaging mosaics and photometric catalogs.

JWST Imaging of Lensed High-Redshift Galaxies the Earendel Star System

Dan Coe, Cosmic Spring JWST

The combined powers of JWST plus gravitational lensing are revealing incredibly detailed information down to parsec scales for galaxies observed in the first billion years at $z > 6$. I will present results from two JWST programs I am leading: GO 2282 and 1433, that have already obtained public NIRCam imaging of lensing clusters WHL0137 and MACS0647, with NIRSpec MSA spectroscopy planned for December and January. JWST has spatially resolved the z~11 galaxy MACS0647-JD into two stellar components with different colors and revealed a third companion likely to merge with them. We have measured the colors of the lensed z~6 star Earendel, seeing hints of multiple hot stars. We have observed intensely ionizing young massive clusters of stars and older bound globular cluster progenitors with parsec-scale resolution in the z=6 Sunrise Arc. We have also discovered new candidates out to z~13, all with estimates of ages and stellar masses, and upcoming NIRSpec spectroscopy to confirm them and constrain their metallicities and ionization strengths. You may find our public data products, analysis tools, publications and more at our website cosmic-spring.github.io.

First results from the JADES NIRCam and NIRSpec survey

Emma Curtis-Lake, JADES

JADES (JWST Advanced Deep Extragalactic Survey) is the largest coordinated imaging and spectroscopic survey to be undertaken in the first two years of the telescope. With DEEP NIRCam imaging and spectroscopy taken over GOODS-S in October this year, the survey will be well underway. In this talk I will present first results, from ultra-high redshift candidates and spectroscopic follow-up, to dust, gas and stellar properties of galaxies from cosmic noon to within the Epoch of Reionization.

The Cosmic Evolution Early Release Science Survey

Steven Finkelstein,The CEERS team

The James Webb Space Telescope (JWST) is now revolutionizing our understanding of galaxy formation and evolution in the early universe. I will present early results from the Cosmic Evolution Early Release Science Survey (CEERS), which is one of 13 Early Release Science programs, spanning all areas of astronomy with the data public immediately. This program targets the high-redshift universe with many observational modes, including 100 arcmin^2 of deep (m~29) NIRCam 1-5um imaging, with a primary goal of making an early glimpse into galaxy evolution at z > 10. In parallel to this NIRCam mosaic, CEERS will obtain >1000 slit spectra (1-5um at R~100 and R~1000) with NIRSpec, six pointings with MIRI covering 5-21um, and four pointings with the NIRCam grism. I will highlight results from CEERS (not covered in other talks) on the earliest galaxies to form in the early universe, early massive galaxies, dusty star-forming galaxies, and other exciting results. I will also briefly advertise NGDEEP: The Next Generation Deep Extragalactic Exploratory Public survey, a 125 hr Cycle 1 program. NGDEEP includes an ultra-deep NIRCam imaging pointing, reaching m~31, with ultra-deep NIRISS slitless spectroscopy in parallel. By placing the NIRCam pointing on the HUDF Parallel field (the location of the deepest HST I-band imaging), the NIRISS portion falls on the HUDF proper. The scientific focus of NGDEEP is to study feedback in low-mass galaxies across cosmic time, via the faint-end slope of the UV luminosity function at z=10-14, and via the shape of the low-mass-end of the mass-metallicity relationship at z~1-3. CEERS and NGDEEP are both public surveys, and both teams are committed to rapid release of reduced data products and catalogs.

First Light With JWST - Unveiling Galaxy Populations and Their Properties at Cosmic Dawn

Guido Roberts-Borsani,

The emergence of the first galaxies ~13.6 billion years ago had a profound effect on the Universe, beginning its last major phase-transition, the Epoch of Reionization. Finding and characterizing such early objects has thus far proved challenging, however, owing to their rarity and apparent faintness. The arrival of JWST's unprecedented infrared capabilities thus opens a new window with which to study early galaxy evolution.

As such, in this talk I will summarize the GLASS-JWST ERS survey and describe the first $z>8$ results from spectro-photometric analyses using NIRISS and NIRCam over the Abell 2744 galaxy cluster. Among these, we showcase the power of JWST to peer deep into Reionization, when most intergalactic hydrogen is neutral, by spectroscopically confirming two lensed galaxies via their Lyman Breaks with NIRISS, placing them at redshifts of $z\sim8$. The absence of strong emission line indicators (e.g., Lyα, NV, HeII), blue UV slopes (< -1.7) and moderate absolute magnitudes ($M_{UV}\sim -20$ AB) suggest these objects are young, dust-poor, and representative of a general $z\sim8$ population that has thus far been missed.

Extending to higher redshifts, we further report the surprising discovery of two unusually luminous ($M_{UV}\sim -21$) galaxy candidates at $z>10$, via dropout and photo-z analyses of multi-band NIRCam imaging in blank, parallel fields. The discovery challenges the expected number density of bright galaxies in such volumes. Exploiting the JWST-ALMA synergy, we spectroscopically verify the most distant NIRCam candidate via its [OIII] 88 micron emission with ALMA, revealing a 5.5σ emission line at $z=12.117$ and a dust- and metal-poor system in the early universe. The observations confirm a new population of early galaxies that would have hitherto been missed by HST and ground-based observations. First results from imminent NIRSpec spectroscopy of those same objects will also be shown.

A SPectroscopic survey of biased halos In the Reionization Era (ASPIRE): The Discovery of Multiple Megaparsec-scale Galaxy Overdensities in the Epoch of Reionization

Feige Wang

Distant quasars, the most luminous objects in the early universe, are believed to be powered by accreting supermassive black holes (SMBHs) and hosted by massive galaxies. The discovery of quasars in the Epoch of Reionization (EoR), powered by billion-solar-mass black holes, challenges our understanding of SMBH formation. An assortment of cosmological simulation models are able to produce these massive SMBHs starting with massive seed black holes, growing from the most biased dark matter halos and situated in the most overdone regions of the early Universe. However, the large-scale environment and the host dark matter halo of these earliest quasars are still largely unknown in the observational perspective. To this end, we designed the JWST ASPIRE program which will provide a galaxy redshift survey along the line-of-sight of 25 reionization-era quasars with 62 hours NIRCam WFSS and imaging observations. In this talk, I will present the early JWST observations from our ASPIRE program. From preliminary analyses, we found that several quasars inhabit galaxy overdensities as traced by [OIII] emitters. These galaxy overdensities show filamentary structures and span over megaparsecs. These structures are among the most overdense large-scale structures known in the EoR and could evolve into massive clusters known in the local Universe. These discoveries from the early ASPIRE observations demonstrate the unparalleled redshift survey capability of NIRCam WFSS and the promising discovery potential of ASPIRE.

First Results on the Earliest Galaxies from the JADES/NIRCam Program

Brant Robertson

The JWST Advanced Deep Extragalactic Survey (JADES) is a collaboration of the NIRCam and NIRSpec GTO teams pooling over 750 hours of JWST time to conduct an ambitious study of galaxy evolution in the Great Observatories Origins Deep Survey GOODS-S and GOODS-N fields. Here, we report on exciting first results from the JADES/NIRCam observations about discoveries in the distant ($z>10$) universe that provide new insight into the process of early galaxy formation and cosmic reionization. We discuss how our new constraints on star formation and galaxy growth at the very earliest times will revise our picture for how the first galaxies form and evolve.

Instrumentation

NIRSpec Status, Operations, and Performance

Charles R Proffitt, The STScI NIRSpec Instrument Team

The Near Infrared Spectrograph (NIRSpec) on the James Webb Space Telescope covers the 0.6 - 5.3 microns wavelength range using fixed slit, bright-object time series, integral field unit, and multi-object spectroscopic modes, obtaining data with R = 100, 1000, or 2700. We report here on the current status of NIRSpec operations, performance, calibration, and pipeline data reduction, emphasizing issues that impact planning and interpretation of NIRSpec data by the observing community.

Items of particular note:

(1) The status of the absolute flux calibration, including changes from pre-launch expectations, quality of the absolute calibration, repeatability, and the state of the cross calibration between different NIRSpec modes and other JWST instruments.

(2) Issues affecting MOS planning, such as the evolution of MSA "shorts" and other changes in shutter operability, as well the process of using NIRCAM pre-imaging or other catalogs as inputs to the planning process.

(3) Accuracy of the astrometry and target acquisition, and common issues that can cause target acquisitions and the subsequent observations to fail.

(4) Status of the pipeline data reduction, including a review of known issues and plans for addressing them.

An overview of NIRCam's performance from commissioning and early Cycle 1 calibration

Mario Gennaro, The STScI NIRCam Instrument Team

NIRCam is a workhorse instrument on board of JWST, being responsible for both the wavefront sensing measurements that allow us to align the primary mirror as well as delivering science in 5 different modes: imaging, wide field slitless spectroscopy, time series imaging, time series spectroscopy and coronagraphy.

On behalf of the entire NIRCam team, I will report on the current state of the instrument, describe the challenges faced during commissioning, the performance in each mode as well as the current calibration plan status.

The Status and Performance of NIRISS

Paul Goudfrooij, The STScI NIRISS Team

We summarize the status and performance of NIRISS and its observing modes: Aperture Mask Interferometry, Imaging, Single-Object Slitless Spectroscopy, and Wide Field Slitless Spectroscopy. We compare each mode with similar modes on other JWST instruments, and present instrumental features that can affect observation planning or the interpretation of NIRISS data. Finally, we highlight relevant changes for Cycle 2 operations of NIRISS.

JWST Pipeline and Calibration: Intro and Status

Karl Gordon, STScI Calibration Team

The JWST pipeline was designed and built taking advantage of the commonalities between the science instruments to incorporate the best data reduction algorithms and minimize duplication of code. An overview of the pipeline will be given followed by examples of improvements made based on in-flight data. The performance of the pipeline relies on both the quality of the algorithms and the calibration reference files (e.g., flat fields). An introduction to the calibration program for each instrument will be given, with more detail on the integrated across instruments flux calibration program.