June 15, 2017

We received observing proposals from the 20 Guaranteed Time Observers (GTOs) for JWST time in Cycle 1, detailing a total of over 2100 observations on numerous investigations. As many studies are co-operative efforts involving several GTOs, we summarize below the submissions by science topic rather than summarizing submissions from each GTO. An accompanying workbook details the observation specifications, by observation ID, for each instrument. Look there for specific details on each observation. Following each summary below is a list of the observation IDs that contribute to the science effort.

Observations of Solar System Objects

Large Asteroids

Recent work has shown that asteroids over 200 km in diameter are intact remnants of earliest Solar System history, and that these objects had dynamic histories with ongoing processes. JWST observations of the three largest low-albedo asteroids will extend measurements of Ceres far beyond the wavelengths measureable by the Dawn mission, and provide unique measurements of Pallas and Hygiea that are unavailable from other platforms. Observation IDs: HAMMEL_0001-0003, HAMMEL_0006, HAMMEL_0015-0017, HAMMEL_0021, and HAMMEL_0024-0027.

Trojan Asteroids

The Trojan asteroids are key to understanding early solar system dynamics and planetary migration. They are thought to be organic-rich, but their distances and low albedos make observations difficult. These targeted binary asteroids observations will improve knowledge on their densities, which will be combined with the compositional data gained from spectroscopy. One of the targets is a planned destination for NASA's Lucy mission in 2033. HAMMEL_0004-0005, HAMMEL_0009-0014.

Near-Earth Objects

Near-Earth Objects (NEOs) are of interest to varied communities for diverse reasons, including scientific significance, impact hazard mitigation, NASA's human exploration program, and the emerging field of private asteroid mining. Though several recent missions have visited NEOs, most have had limited spectral capabilities. These observations will be on several NEOs of particular interest, which in the process will test JWST's tracking limits. HAMMEL_0007-0008, HAMMEL_0018-0020, HAMMEL_0022-0023.

Jupiter

Jupiter's extended disk and brightness present an extreme test of JWST capabilities. We will use MIRI/MRS spatio-spectral imaging to create a 3-point mosaic of the Great Red Spot (GRS) and its environs in the 6-11 μm range to determine the 3-

dimensional temperature, composition, and aerosol distribution. We will explore moist convective activity surrounding the GRS via ammonia, phosphine, and condensed ices detectable in this spectral range. We will also search spectra for chemical products that may be unique to the GRS region as a by-product of the production of the poorly understood red chromophores. We will use methane emission to study stratospheric effects of the underlying GRS and moist-convective plumes. HAMMEL_0613-0616.

Saturn

Cassini's long-term exploration of Saturn's seasonal atmosphere concludes in 2017 at northern summer solstice, shortly before JWST's launch. We propose observations that establish a baseline for continuing time-domain observations of the planet, rings and satellites: spectra of faint targets in the Saturn system using JWST's unprecedented sensitivity; cross-calibration of JWST instruments with the instruments on board the Cassini spacecraft; and a test of procedures for JWST observations of faint targets near bright objects. Observations include a reconnaissance of the Saturn system with NIRCam, NIRSpec, and MIRI. A mosaic of Saturn's north polar region using MIRI spectro-spatial imaging (5-16 μm) will explore the continued evolution of the polar temperatures, aerosols and composition, including (i) the expected growth of a wide, hot summer vortex in the stratosphere; (ii) variability within the polar cyclones associated with ammonia, phosphine and aerosols; and (iii) identification of any unique polar chemicals/haze species inaccessible to Cassini in the 5.5-7.5 μm region. Deep spectra of selected small moons of Saturn (Epimetheus, Pandora, Pallene, and Telesto) with NIRSpec will test the capacity of JWST to take deep spectra of faint targets near a bright planet. Spectra of Saturn's main rings with MIRI will test the capacity of JWST to take spatially resolved thermal spectra of icy ring systems and will fill a wavelength gap between Cassini VIMS and CIRS. HAMMEL_0301-0304, HAMMEL_0312, HAMMEL_0314, HAMMEL_0318-0319, HAMMEL_0330, HAMMEL_0617-0620, HAMMEL_0341.

Uranus

We will investigate the influence of Uranus' extreme seasonal tilt on the circulation and chemistry of this ice giant. Spatially-resolved global spectroscopic maps will reveal contrasts in atmospheric temperatures and chemical tracers (e.g., the myriad hydrocarbons produced via methane photochemistry), as well as a full chemical inventory of this ice giant. MIRI observations will be executed near-simultaneously with NIRSpec observations of uranian H3+, allowing us to understand the coupling between the upper, middle, and lower atmospheric regimes for the first time. HAMMEL_0601-0608.

Neptune

We propose to explore the middle atmospheric circulation of this archetypal ice giant world using spatially-resolved global maps of atmospheric temperatures and tracers of dynamics and chemistry (e.g., hydrocarbon species). With simultaneous multi-wavelength (5-29 μm) spectral imaging, we will: (i) reveal the unusual environmental conditions within Neptune's summer south polar vortex; (ii) search for evidence of vertical coupling between tropospheric storm systems/wind fields and stratospheric dynamics; and (iii) search for evidence of tropical vertical oscillation patterns. JWST results for Neptune and Uranus will be inter-compared to understand the similarities and differences between the two ice giants. HAMMEL_0609-0612.

Europa and Enceladus

We will measure and characterize the active zones and plumes on the two active moons, Europa and Enceladus. NIRSpec will probe the near-IR fluorescence emissions (of water, methane and of several other organics), while we will probe the strong (and high contrast) water emissions in the 6-7 microns with MIRI. Molecular maps obtained via IFU will be combined with high-resolution images sampling with NIRCam. Several NIRCam filters will allow us to probe the continuum emission and the strong ice surface feature at 3 microns. HAMMEL-0101-0102, HAMMEL_0401-0410.

Titan

We focus the extremely broad capability of the combined JWST instrument suite to advance our understanding of Titan's gases, hazes, condensates (clouds) and surface composition. NIRSpec's high-resolution spectral imaging (R~2700) at near-IR wavelengths (0.6- 5.0 micron) in IFU mode will yield information on all of these scientific areas. The spatial resolution and multiple filter capability of JWST NIRCam will reveal the distribution of haze and clouds in the atmosphere occurring during southern winter/northern summer. MIRI will be used to measure Titan's stratosphere to attempt new gas detections, and to measure isotopic ratios with unprecedented sensitivity. We will obtain a full-range (4.9-28.8 micron), high resolution spectral-image with MIRI in MRS mode to measure temperatures, abundances of trace gases, isotopic ratios and haze signatures. This combined suite of observations in the 2019-2020 timeframe will follow directly after Cassini (end of mission in 2017) and expand on Cassini's science return. These observations will provide a valuable input to dynamical models, and also serve as a baseline JWST measurement that may be repeated later in the mission as Titan's south pole emerges into summer (Titan is known to be highly variable with season). HAMMEL_0103-0137.

Comet 260P and ToO for a New Dynamic Comet

Our comet observations are designed to survey JWST's spectral mapping modes with a high-priority Jupiter-family comet, 260P, and conduct a Target of Opportunity (ToO) spectral survey of a TBD newly-discovered comet to determine the composition of volatiles not accessible from the ground and to complement ground-based surveys. Comets and asteroids delivered pre-biotic materials to the terrestrial planet zone, providing potential catalysts for life. The abundances and spatial distributions of gas and dust in the inner coma of comets provides insight into the composition and evolution of the nucleus, which in turn provides insight into the materials delivered to the early inner Solar System. We will spectrally map gas (H_2O, CO_2, CO, CH_4, CH_3OH, and others) and dust (silicates and carbonaceous materials) in the inner 1000 km of a moderately bright comet. Key motivations driving this project are: test the heterogeneity of a short-period comet's coma and to determine if gas coma heterogeneity is linked to dust coma heterogeneity; demonstrate the new capabilities of JWST for the study of cometary composition; and provide baseline observations for future cometary science investigations. Mapping gas species in the near-infrared with JWST can provide data heretofore only delivered by in-situ spacecraft missions to 9P/Tempel 1, 67P/Churyumov-Gerasimenko, and 103P/Hartley 2. Beyond the capabilities of those missions, JWST can also map dust composition, providing a near-simultaneous census of the dominant components of a comet nucleus and coma. HAMMEL_0201-0208, HINES_5000

Trans-Neptunian and Kuiper Belt Objects

A number of trans-Neptunian and Kuiper Belt objects will be studied by a number of Guaranteed Time Observers using NIRSpec and MIRI. We plan to exploit JWST's exquisite sensitivity in the 1-5 micron region to study the largest trans-Neptunian Objects and Kuiper Belt objects via reflectance spectroscopy. The composition of even the largest of these bodies is poorly constrained. We propose to use NIRSpec's IFU to obtain the first high-SNR, $R > 100$ spectra for a sample of these objects. MIRI spectra will also be obtained on some targets. These data can be expected to reveal the presence of previously unseen molecular ices, constrain their physical state (crystalline phase, solution with other species, temperature, grain-size), identify new organic species, and constrain isotopic ratios for some elements (H, O, C, N). MIRI MRS and Imaging data will also be used to study temperature variations on several targets, and will be interpreted in the context of existing Herschel and/or Spitzer thermal data. The targets represent a large fraction of the diversity of the Kuiper Belt in terms of collisional history (Pluto and Haumea underwent catastrophic impacts), effects of planetary migration (resonant, classical, Centaur and scattered objects), multiplicity (several host at least one moon), albedo, and major species composition (H_2O, CH_4, NH_3, CO). These objects represent the end-state of accretion and subsequent processing in the Kuiper Belt. This initial reconnaissance of their surface compositions will inform our understanding of the long history of processes in the outermost regions of the Sun's proto-planetary disk. One ToO observation of a stellar occultation by a TBD TNO is proposed. If the occultation is observed, it will provide significant constraints on size and albedo of the object, as well as sensitivity to the presence of an atmosphere or rings (even small bodies are known to have rings; e.g., Chariklo).

Targets: Pluto, Charon, Triton, Haumea, Makemake, Varuna, Eris, Sedna, Quaoar, 2002 TX300, 2005 RR43, 2003 OP32, 1995 SM55, 1999 KR16, 2002 AW197, 2005 UQ513, 2004 PT107, 2007 OR10, Salacia, 2002 MS4, 2003 AZ84, Orcus, Bienor, 2001 SQ73, Encheclus, 2008 FC76, Pholous, 2002 KY14.

FERRUIT_7000, FERRUIT_7010, HAMMEL_1000, HAMMEL_2000, HAMMEL_3000-3001, HAMMEL_4000-4001, HAMMEL_5000, HAMMEL_6000, HAMMEL_7000, HINES_1000, HINES_1001, HINES_2000, HINES_2001, HINES_3000, HINES_3001, HINES_4000, MRIEKE_6500-6505, MRIEKE_6550-6565, LUNINE_1000-1001, LUNINE_2000, LUNINE_3000, LUNINE_4000, LUNINE_5000, LUNINE_6000, LUNINE_7000, LUNINE_8000, LUNINE_9000, LUNINE_10000, WRIGHT_2001.

Extra-solar planets

Transiting exoplanet characterization

HD189733b, HD209458b, WASP-77Ab, and HD149026b. The goal is to derive metallicities and elemental abundance ratios (e.g., C/O) from measured molecular abundances in hot Jupiters. We will make observations of transits of a selected set of hot Jupiters. We selected as a straw-man target list objects that will give the best signal-to-noise over a range of masses. We focus on emission spectroscopy (secondary transits) because this has little intrinsic degeneracy and is feasible for warm to hot giant planets. Transmission is effective for measuring relative abundances, and thus can give good constraints on C/O. With the presence of clouds the determination of absolute abundances, and thus metallicities, because problematic. Observing secondary transits (emission spectra) substantially ameliorates this problem. We focus on NIRCam observations because this instrument has the brightest bright star limits, best spatial pixel sampling, no slit, and good wavelength coverage for capturing the main molecular carriers of C and O. These objects span the range of masses from 0.3 to 2 M_Jup and irradiation temperatures from 1400 to 2000 K. LUNINE_0001-0007,

WASP-17b. We will construct both transmission and emission spectra of this planet over the entire 0.6-14 micron wavelength range using three transit observations (when the planet passes in front of host star) and three eclipse observations (when planet passes behind host star). Both the transmission and emission spectra will be obtained using a combination of NIRISS SOSS, NIRSpec SLIT1600 G395H, and MIRI LRS Slitless modes. MOUNTAIN_1101-1106

HAT-P-26b. We will construct a transmission spectrum of this planet spanning 0.6-14 microns (NIRISS SOSS+ NIRSpec SLIT1600 G395H+MIRI LRS Slitless) and emission spectrum spanning 2.8-14 microns (NIRSpec SLIT1600 G395H+MIRI LRS Slitless). Our program does not explicitly include transmission observations of HAT-P- 26b with MIRI LRS. MOUNTAIN_1107-1110

GJ 3053b, WASP-43b, WASP-107b, and WASP-52b. JWST will revolutionize the study of exoplanet atmospheres by virtue of broader wavelength coverage, higher spectral resolution, better sensitivity, and longer uninterrupted observing time than existing facilities. In this program, we will demonstrate the capabilities of JWST/NIRSpec for exoplanet characterization. We will use high-spectral resolution to penetrate clouds on a super-Earth (GJ 3053b) and observe a hot Jupiter (WASP-43b) over a full orbit. In addition, we will obtain spectra for two giant planets (WASP-107b, transit, high spectral resolution; WASP-52b, eclipse, low spectral resolution). FERRUIT_5000-5003

TRAPPIST-1e. We will probe this planet in transmission using the NIRSpec Prism mode, which provides low-resolution spectra in the 0.6-5.3 micron range. Probing the atmospheres of small exoplanets require multiple transit/eclipse observations to build sufficient precision to detect atmospheric features. Here we plan for five transit observations of this target with the NIRSpec Prism. The orbital period of TRAPPIST-1e is ~6 days, so ample observing opportunities will exist for this planet. MOUNTAIN_1111-1115

HD131399. Direct coronagraphic imaging of a young Jupiter in a complex triple star system. HD131399 is a young triple star system in which the central star has a 4 Jupiter mass planet at about 82 astronomical units (AU) away, and the other two stars have orbits with semi-major axes of 350 AU. Because the system is only 16 million years old, the planet is warm and hence directly visible. This gives us an unprecedented opportunity to study a warm young Jupiter over the wide wavelength range available to JWST. However, the presence of the binary in orbit around the central star complicates the observation and requires careful use of the coronagraphic system in NIRCam. NIRCam's medium passband filters, F300M, F335M, F410M, F430M, and F460M will be used to characterize exoplanet atmospheres, with the wedge and round coronagraph. The filter suite can measure the continuum, CH_4, CO and CO_2. Two wide filters, F322W and F444W, will be used in a search for fainter companions approaching Saturnian masses. The F444W-F322W color can be used to reject background stars. LUNINE_0008-0021

NEAT: NIRISS Exploration of the Atmospheric Diversity of Transiting Exoplanets. We will use NIRISS SOSS to acquire transit and eclipse observations of a sample of 13 exoplanets that span the full available range of equilibrium temperatures (300-3000 K) and masses (1 MEarth-10 MJup) for planets amenable to atmospheric characterization. Our observations will measure the abundance of the molecules and aerosols present in the exoplanets' atmosphere and determine the vertical temperature structure of the hottest targets. These results will allow us to address fundamental issues such as the formation process and formation location of these close-in planets, the presence and characteristics of particulate clouds, and non-equilibrium chemistry effects that might be at play in their atmosphere. Four of our targets are rocky and for these we intend to place some of the first constraints on the mean molecular weight – and hence bulk composition – of their atmospheres. In particular, we will observe multiple transits of the potentially habitable earth-like planets TRAPPIST-1 f & g in June and July 2019, aiming to make the first detection of the atmosphere of a habitable planet; we are committed to publishing these important results and releasing these data quickly, within a few months of the observations. Finally, for one target, WASP-121b, we will acquire observations continuously throughout a full orbital period to constrain its temperature-pressure profile as a function of longitude and study how heat is absorbed and redistributed in its atmosphere.

Targets: HD-209458b, HAT-P-1b, WASP-69b, WASP-80, WASP-107b, GJ-436b, GJ-3470b, TRAPPIST-1f, TRAPPIST-1g, GJ-1132b, LHS-1140b, K2-18b, WASP-121b.

DOYON_1001-1002, DOYON_1010, DOYON_1020-1021, DOYON_1030-1031, DOYON_1040, DOYON_1100, DOYON_1110, DOYON_1120, DOYON_1130, DOYON_1200-1203, DOYON_1301-1304, DOYON_1310-1312, DOYON_1320-1323, DOYON_1400-1401, DOYON_1600

Coronagraphy of Exoplanets

NIRCam Coronagraphic Imaging of Young Planets: This program will observe young, nearby planetary systems with the possibility of imaging multiple planets in a system (similar to HR8799). JWST and NIRCam have a sensitivity advantage over the ground in the 3-5 micron regime with both NIRCam and MIRI having substantial sensitivity advantages. Our coronagraphy program uses the LW arm of NIRCam, and uses the M filters to characterize exoplanet atmospheres and W filters along with MIRI photometry to measure the effective temperature and luminosity of the exoplanets. Systems known to have at least one planet will be studied with the goals of learning more about the architecture of planetary systems, and more about the exoplanet themselves. NIRCam's medium passband filters, F250M, F300M, F335M, F410M, F430M, and F460M will be used to characterize exoplanet atmospheres. This filter suite can measure the continuum, CH_4, CO and CO_2. Two wide filters, F356W and F444W will be used in a search for fainter companions approaching Saturnian masses. The F444W-F356W color can be used to reject background stars.

Targets: HR8799bc, HD 950856b, 51 Eri b, 2MASS 1207, Vega, Fomalhaut, beta Leo, eps Eri, HD 106906

MRIEKE_3500-3561

Characterizing known exoplanets at small angular separations with NIRCam: The NIRCam coronagraph occulting masks are optimized for inner working angles > 4-6 lambda/D, which is > 0.5-0.75 arcseconds at 4 microns. However, many of the exoplanets that have been directly imaged thus far with AO instruments are at smaller angular separations, and would elude observation with those standard modes for NIRCam coronagraphy. By instead positioning the target star behind the narrow end of the MASKLWB occulting wedge (a nonstandard mode but one which is possible via an already-existing pointing override available as an engineering option in APT) and using careful PSF subtraction, we can push the inner working angle in to 0.29 arcsec (~ 2 lambda/D at 4 microns), and thereby enable characterization of critical exoplanet targets, albeit at some cost in contrast. We will observe the inner two planets of the HR 8799 system (d and e) and 51 Eridani b in six medium band filters from 2.5 to 4.6 microns, all using the narrow end of the MASKLWB coronagraph occulter. Careful PSF calibration and subtraction will be used to compensate for the increased speckle halo from the smaller occulter width. In addition to its direct science results, this program will pioneer and assess performance in this new small-angle observing mode to allow it to be offered to the community in future cycles (similar to the successful introduction of the HST STIS BAR5 coronagraph mode which uses a similarly narrow occulter). MOUNTAIN_2121-2126

MIRI Coronagraphic Imaging of Exoplanets: MIRI will provide pioneering mid-infrared (> 5 μm) coronagraphic imaging observations of exoplanets, as ground-based mid-IR observations lack the needed coronagraphic sensitivity, while *Spitzer* lacked the angular resolution to resolve exoplanets. Our main exoplanet aim is thus to carry out multi-wavelength coronagraphic observations of three exoplanets/near-exoplanets — 51 Eri b, HR8799 e, and κ And b — with the four MIRI coronagraphs. (We call κ And b a "near-exoplanet" here because it falls near the planet/brown dwarf transition). These observations will allow us to probe the overall atmospheric temperatures from continuum measurements, as well as the composition and temperature structures of exoplanet atmospheres. The MIRI coronagraphs are sensitive to the NH3 molecule, which is expected to be present in Jovian-type atmospheres. The wavelengths of our observations are thus the three four-quadrant phase mask (FQPM) coronagraph wavelengths of 10.65, 11.4, and 15.5 μm, which will enable 1) the detection of the NH3 line at 10.65 μm, 2) an off-line continuum measurement at 11.4 μm to calibrate the depth of the NH3 line, and 3) a more distant continuum point at 15.5 μm to determine the mid-IR continuum temperature, which traces the atmospheric temperature and cloud structure. We also include long-wavelength Lyot mask observations (23 μm) to image disk emission. RESSLER_6001-6022

Architecture of Directly-imaged Extrasolar Planetary Systems

The Aperture Masking Interferometry mode of JWST/NIRISS offers a rare opportunity to probe extrasolar planetary systems with separations from less than 0.1" to 0.4" in the thermal infrared. On the one hand, AO-fed instruments from the ground mostly operate in the near infrared, and offer deep contrast down to 0.2" at best. On the other hand, thermal infrared is a regime in which the spectral energy distribution of young planets peaks, making AMI observations sensitive to planets with masses down to 4 M_{Jup} around young and nearby stars. Therefore, AMI is an ideal mode that is complementary to ground based direct imaging to probe small angular separations to study the inner part of planetary systems. A complete knowledge of the architecture of extrasolar systems will provide an important observational test to overcome the main limitations of directly imaged planets. Dynamical studies of multiple systems or systems with planets and disks give independent mass estimates that can be confronted with the model-dependent masses of these planets based on uncalibrated evolutionary tracks.

Targets: HD 93649, HD 95086, HD 115600, HR 8799.

DOYON_4000-4005

Direct Spectroscopy of Non-transiting Exoplanets

Direct spectroscopy of non-transiting exoplanets provides complementary information on the physics of exoplanets that cannot be probed by transit or eclipse observations. Due to observational limitations these spatially resolved exoplanets tend to be young, quite massive, and distant from their host stars. Detailed studies of their spectra, in particular metallicity, C/O ratio, and isotopic composition can constrain their formation mechanism and distinguish between a star-like disk instability mechanism or the core accretion mechanism favored for Jupiter-mass planets. 2M1207A/b (TWA 27) will be observed, along with a nearby reference star of similar spectral type and brightness, with the NIRSpec IFU using the high-spectral resolution gratings covering 1 to 5.2 microns. The NIRSpec IFU will be used to obtain spectra of HR8799 b, c, and d, 2MASS J22362452+4751425 b, GU Psc b, and HD106906b, using the G395M grating (R=1000), and F290LP filter to extend the spectroscopy into the 3–5 μm range. FERRUIT_5501-5502, MRIEKE_5000-5010

Transit Spectroscopy of Planets

We are conducting a combined NIRCam and MIRI GTO program to observe the l = 2.4 – 12 μm spectra of a set of transiting planets that are less massive and cooler than ones spectrally characterized so far (with HST and Spitzer). These planets fall mostly in the range $700\text{ K} \le T_{eq} \le 1000\text{ K}$ with masses $19M_{Å} \le M_p < 200M_{Å}$. We seek to obtain transmission and emission spectra (both for at least one planet) to probe a wide range of atmospheric pressures (altitudes) and surface regions. Simulations of these spectra and information retrievals show that we can measure mixing rations of dominant molecular species, measure metallicities, determine pressure-temperature profiles, and perhaps detect new species not seen before in exoplanets (NH_3). These precision measurements should reveal compositions, equilibrium and non-equilibrium chemistries and probe cloud properties. The location and processes of planet formation will also be illuminated and constrained by measuring compositions and comparisons to host stars. We will use the state-of-the-art CHIMERA modeling and retrieval framework to derive physical and chemical properties from the exoplanet spectra. The NIRCam observations are listed here, and some of the MIRI observations listed in the Greene MIRI GTO program are charged to NIRCam. Targets: WASP-80b, HAT-P-19, GJ 436 b, HAT-P-26b, TRAPPIST-1 b, WASP-107b. These TRAPPIST-1 observations and spectroscopic observations of WASP-107b are being done in collaboration with the European MIRI GTO team (Wright PI). GREENE_0001-0011, MRIEKE_5500-5516

Exoplanets and Brown Dwarfs

The program deals with the characterization of the atmosphere of a set of exoplanets and brown dwarfs. Indeed, to answer questions such as: What is the origin of the observed exoplanet diversity? How and where did exoplanets form? What are they made of? Do they have an atmosphere? Are the atmospheric composition and temperature indicative of an environment that could host life? And ultimately: Are there any signatures of life in the exoplanet spectra? We have to go beyond the sole detection and characterization of exoplanets in terms of basic parameters, e.g. radius, mass and orbital dynamics, and get crucial information by characterizing their atmospheres using spectroscopic observations over a broad wavelength range from visible to mid-Infrared. We will observe three transiting exoplanets: a gaseous giant (HAT-P-12 b), one with a mass intermediate between icy giants and gaseous giants (WASP-107 b) and a rocky Earth mass planet (Trappist1 b), and thirteen exoplanets/low mass companions detected by direct imaging. The disk around some of the star/exoplanet systems (HR8799, HD95046, HD106906) will be studied. Imaging observations at long wavelengths could lead to the discovery of low mass companions. The link between exoplanets and brown dwarfs will be made by the observations of seven brown dwarfs. All the observing modes of MIRI will be used. WRIGHT_0001-0050

Survey of Nearby Young M Stars

The population of giant planets on wide orbits orbiting low-mass M dwarf stars (≤ 0.6 M_{Sun}, Teff ≤ 3900 K) is poorly understood. Radial velocity and microlensing surveys provide population constraints and occurrence rate estimates within 10 AU, but current ground based imaging struggles to probe below 1 M_{Jup} at larger separations. In the vicinity of these intrinsically faint stars, where the contrast requirements are less severe, survey simulations reveal that NIRCam 3-5 µm coronagraphic imaging greatly outperforms current ground based capabilities and peaks for young M dwarfs within ~25 pc. Using the latest contrast curves that predict ~10^{-5} contrast at 1" separations, NIRCam imaging is sensitive to ~1 M_{Sat} planets and can push into the ice-giant mass regime (~1 M_{Nep}) around the most favorable targets.

Thus, NIRCam coronagraphic imaging can probe a new planet parameter space around M dwarfs, reaching significantly lower-mass planets at ^{3}10 AU. An attractive NIRCam program is to perform deep, dual band imaging on a sample of the closest youngest M dwarfs. Such observations will provide the first observational limits on the presence of sub-Jupiter mass planets in the outskirts of these stellar systems. Scientific goals of these observations include placing constraints on the peak in the planet surface density distribution, providing deep direct imaging constraints on the microlensing short timescale event population, and probing the separation of the primordial CO ice line, the hypothesized venue for ice-giant formation. To achieve these goals, we will select targets from a prioritized candidate target list. Our small survey will use the MASK430R coronagraph with both the F444W and F322W2 filters. Although we sacrifice some inner working angle with the longer wavelength mask, we are already relatively insensitive at sub-arcsecond separations and this approach saves about an hour of overhead time per target. We plan to integrate for a total of 1 hr in F444W and 30 min in F322W2 spread over 2 roll angles separated by 10^o. This observing strategy allows for color-based rejection of background contaminants and PSF subtraction. We also plan to use target stars as PSF references during image post processing.

Targets: BD+01-2447, LP944-20, AP_Col, Fomalhaut_C, AU_Mic, G7-34, 2MJ0443+0002, 2MJ0944-1220, 2MJ2351+2344, HIP17695, TYC5899-26-1

MRIEKE_4500-4543

Brown Dwarfs

Brown Dwarfs, Circumstellar Disks, and Free-Floating Planetary Mass Objects in Orion

The origin of the stellar initial mass function (IMF) remains a mystery, despite many years of observational and theoretical work. One key issue is how far into the planetary-mass regime 'free-floating objects' can be found, and whether there is a cut-off in the IMF at the very lowest masses, deep into the brown dwarf regime. Embedded clusters in star-forming regions provide an excellent opportunity to search for such objects, as they are relatively warm and luminous when young. Models predict a minimum mass cut-off at a few M_{Jup}, and while ground- and space-based optical and near-infrared observations do show some objects at those limits, it is almost impossible to go any deeper in search of a cut-off without space-based thermal-IR imaging to catch cool (< 1000K) objects at $\sim 1 M_{Jup}$ and below (assuming a 1Myr age for the cluster).

Thus we will carry out a NIRCam survey in Cycle 1 for the very lowest-mass brown dwarf and planetary-mass objects in the inner regions of the Orion Nebula Cluster (a 5 x 2 position mosaic covering approximately 10.5 arcmin x 5.5 arcmin), where the density of cluster members is greatest and the background molecular cloud extinction (and thus shielding from field stars) is highest. This will involve a set of 9 medium- and wide-band filters spanning the whole NIRCam wavelength range, optimised to detect cool objects and to provide selection criteria based on their age, surface gravity, etc. to eliminate field star contaminants, also accounting for dust extinction in the region and infrared excess emission due to circumstellar disks. Candidate very low-mass brown dwarfs will be selected based on the NIRCam photometry and followed-up with NIRSpec multi-object spectroscopy as part of our Cycle 2 GTO program. MCCAUGHREAN_0101-0105, MCCAUGHREAN_1101-1105

Y Dwarf Observations with JWST

The nature of the coolest brown dwarfs - their formation, their atmospheres, including their composition, temperature, pressure structures, and the nature of any clouds that may be present is of particular interest for a number of reasons. Since they form where the Initial Mass Function is rolling off they provide important information about the star formation process. The fact that they appear to have different binarity fractions compared to higher mass stars also indicates that their formation process is different. Objects with masses in the range 5-10 M_{Jup} represent evolutionary end-state analogues for the exoplanets found in a younger, higher-temperature state orbiting nearby stars. Anchoring the model atmospheres for low mass objects will increase our understanding of these objects and perhaps lead to predictions of observable differences (e.g. metallicity) between objects formed via cloud fragmentation (low mass end of star formation) vs. those formed via accretion within a proto-planetary disk. This program will take JWST observations of a selection of the nearest and coldest brown dwarfs. Depending on the object, various combinations of the NIRCam, NIRSpec, and MIRI instruments will be used. MRIEKE_6001-6025, MRIEKE_6100-6106, MRIEKE_6201-6205

The Substellar Companion of GJ 758

The brown dwarf orbiting GJ 758 is one of the coldest sub-stellar mass companions imaged to date. Ground based near-IR photometry and spectroscopy have confirmed an effective temperature of ~700K, and identified a methane-rich atmosphere. Multi-epoch coronagraphic imaging indicates an almost edge-on and eccentric orbit, with the companion moving towards the star at a projected ~100 mas/year. While cooling-track-derived masses place this object above the purported deuterium-burning limit, it is an important benchmark since its orbit is favorable for the future determination of its dynamical mass using astrometry or radial velocity. A thorough characterization of its atmospheric properties will provide a key reference point to compare to field substellar objects of similar temperatures. Moreover understanding its composition will answer fundamental questions regarding the formation of such rare objects (using "metallicity" as a proxy). We will use the MIRI coronagraphs to obtain 10.65, 11, and 15-micron photometry of this sub-stellar companion. This will allow us to probe the ammonia abundance, and compare the properties of this cool bound substellar companion to the atmospheres observed for isolated field brown dwarfs. MOUNTAIN_2130-2135

Probing the cloud properties of SIMP0136+0933

SIMP0136 is one of the nearest isolated brown dwarfs to the Sun; this early-T dwarf lies in the temperature range where dust-bearing clouds, more typical of L dwarfs, sink below the photosphere. The inhomogeneous cloud coverage on its surface leads to rotation-induced variability at the 2-7% level over its 2.4 h rotation. Furthermore, the evolution of cloud patterns leads to a modulation of the light-curve over timescales of a few days. We propose GTO observations to obtain time-resolved SOSS spectroscopy of this benchmark variable brown dwarf over a complete rotation. This observation will detect variability at the 10-70-sigma level per spectral channel over the entire SOSS wavelength domain. By probing different heights in the atmosphere, variability of different chemical species will trace the vertical extent of dust- clouds and upwelling processes in ultra-cool atmospheres. This work will have a strong bearing on the study of hot exoplanets; at a temperature of ~1200 K, SIMP0136 is similar to numerous hot Jupiters. Proper description of dust behavior is key in understanding transit spectroscopy data as dust clouds can readily mask the lower layers of an otherwise clear atmosphere. DOYON_5000

High-Angular Resolution Observations of Ultracool Brown Dwarfs

The ultracool dwarfs of the Y spectral type discovered with WISE are not only very cool (250- 600 K), they are likely of very low masses (5-30 M_{Jup}) for only the least massive brown dwarfs can cool down to such temperatures within the thin disk lifetime. This is why, by clustering at the low-end of the initial mass function, the population of known Y dwarfs (~25) probably constitute the extreme product of turbulent cloud core fragmentation. Although, it may also be that the lowest-mass Y dwarfs belong to an entirely different population of ejected planets whose existence is supported by gravitational lensing studies. However, contrary to ejected planets which are not expected to come as binaries, objects formed through core fragmentation can be produced as binary systems. Any companion found around a Y dwarf would therefore push further down the limits at which the core fragmentation scenario can form objects. This short program will use NIRISS Imaging and the kernel phase technique to search for companions around 2 Y dwarfs (W0855 and W1828) with contrasts of about 3 mag at the peak of the SED in the F480M filter. At the Y dwarfs distances (<10 pc) and the separations probed by NIRISS (0.1- 0.3 arcsec), a significant fraction of the orbit could be traced within the lifetime of JWST and masses of Y dwarfs directly measured for the first time. DOYON_7000-7001

HD 19467 B

Unlike most imaged companions for which masses are highly uncertain, the brown dwarf HD 19467 B has a mass constrained by radial velocity changes induced in its host star, and over the next few years radial velocities and astrometry will yield a direct dynamical mass measurement. Meanwhile its age and metallicity are constrained from other studies of the sun-like host star. It is a critical benchmark object for studies of substellar object evolutionary and atmosphere models, and is a high priority target for mid-infrared characterization with JWST. Its apparent angular separation, 1.6 arcseconds, and relative contrast make this a feasible target for spectroscopy using the NIRSpec IFU plus PSF subtraction. We will obtain R~2700 spectroscopy across the 3 – 5 micron region where the brown dwarf's thermal emission peaks. This will be a joint study in direct collaboration with the NIRCam team, who will be obtaining coronagraphy of HD 19467 B in multiple bands. The combined program will allow for valuable cross-checks of the two techniques, and comparison with available AO high contrast spectroscopy at shorter wavelength. This program will yield insights into the atmosphere of what is likely to become one of the most comprehensively studied substellar companions, and will help pioneer methods for studies of close companions with the NIRSpec IFU. MOUNTAIN_2140-2142

The NIRISS Survey for Young Brown Dwarfs and Rogue Planets in NGC 1333

How far down in mass the stellar initial mass function (IMF) extends is a fundamental, unresolved question in astrophysics. The shape of the IMF at the lowest masses will not only establish the boundary between objects that form `like stars' and those that form `like planets', but also distinguish among competing theoretical models for the origin of brown dwarfs. Thanks to extensive surveys by us and others, the IMF is now reasonably well characterized in several nearby star-forming regions down to about 10 Jupiter masses, but not below. While these surveys suggest that free-floating planetary-mass objects are relatively scarce, recent microlensing studies claim they may be twice as common as stars. The stark contrast between the two results could be reconciled if there is a large population of hitherto undetected 1-5 Jupiter mass objects in star forming regions, possibly formed in protostellar disks and subsequently ejected. Here we propose to use NIRISS in the WFSS mode to survey a nearby young cluster to unprecedented depth, in order to (1) establish firmly the shape of the IMF below the Deuterium-burning limit, (2) investigate the fragmentation limit for 'star-like' formation, and (3) quantify the population of isolated planetary-mass objects. Our proposed observations of NGC 1333 will not only identify and confirm objects down to 1-2 Jupiter masses, but also provide a first estimate of their temperature, and thus mass. DOYON_3000-3003, DOYON_3020-3023.

The Physics of Brown Dwarfs

Brown dwarfs represent a sizeable fraction of the stellar content of the Galaxy and their masses populate the transition between the stellar and planetary mass regime. There is not an accepted explanation on how they form, making them a key element in understanding the origin of stellar masses and their distribution. As brown dwarfs evolve and cool down, their atmospheres resemble those of gas giant extrasolar planets, providing easier targets to observe and investigate the physical and chemical processes in low-temperature atmospheres. The new observational frontier is therefore the discovery and spectral characterization of the coldest and least massive brown dwarfs to test formation theories and advance the physics of cool atmospheres. This is the main driver behind this NIRSpec/JWST proposal, which we have divided into two complementary programs. In the first program, we propose to obtain low and medium resolution near-IR spectra of known and candidate brown dwarfs in two nearby star-forming clusters that are representative of different star formation environments. We will use these data to (i) search for brown dwarfs down to the mass of Jupiter to improve constraints on the minimum mass of the IMF and (ii) search for spectroscopic signatures of formation mechanism (e.g., like a star via cloud core collapse vs. like a planet within a disk). In the second program, we will perform near-IR spectroscopy on the coldest known brown dwarf (250 K), which is also the Sun's 4th closest neighbor, to test model atmospheres at very low temperatures.

The program observations will be carried out as follows:

- Low and medium resolution MOS/NIRSpec observations in the Orion Nebula Cluster, including NIRCam parallel observations
- NIRCam pre-imaging followed by low and medium resolution MOS/NIRSpec observations in the IC 348 cluster, including NIRCam parallel observations
- Low and medium resolution slit observations of WISE 0855−0714

FERRUIT_6500, FERRUIT_6600-6603, FERRUIT_6650-6652, FERRUIT_6660-6662, FERRUIT_6670-6672, FERRUIT_6680-6682, FERRUIT_6700-6702, FERRUIT_6850-6852, FERRUIT_6860-6862, FERRUIT_6800-6801

Protostars, Protostellar Disks, and Young Stellar Objects

HH211 and HH212

We will carry out NIRCam imaging of the young HH211 protostellar outflow in 7 narrow-band filters (F164N, F187N, F212N, F323N, F405N, F466N, F470N to isolate specific molecular and atomic emission lines) and 6 medium- and wide-band filters over a field of ~ 2.2 arcmin x 4.4 arcmin. Also included is NIRSpec IFU (G325H & G395H gratings) imaging spectroscopy of the brightest (SE) bowshock in the outflow. The MIRI team will obtain complementary mid-infrared medium-resolution imaging spectroscopy of the blue-shifted lobe of the HH211 flow.

By examining spectra at different positions along the outflow, density, ionization fraction, temperature, dust content, etc., can be determined as a function of distance from the source, offering a chance to study how the outflow gas interacts with the surrounding medium on larger scales. This will allow us to make the direct connection with the traditional optical/near-IR diagnostics and study the bow-shocks at the tip of the outflow lobes where the jet directly impacts the surrounding cloud and which are known to be very rich spectroscopically. The aim is a comprehensive study of the physical conditions throughout this prototypical deeply-embedded young outflow driven by a Class 0 object, including the density, ionisation fraction, temperature, dust content, etc. This will make it possible to understand the energetics of the flow and its interaction with the ambient molecular cloud on both the large and small scales. The outflow is compact, with an estimated age of only a few thousand years. Substantial existing additional near-IR, mid-IR, and millimetre data will be analysed as part of this study. MCCAUGHREAN_0401-0409, MCCAUGHREAN_0501, WRIGHT_4035-4036

LMC-N79: Study of Most Massive Young Stellar Object Star Formation Region

Observations of galaxies across cosmic time show that the star formation rate peaked at a redshift of ~1.5, meaning star formation in the Universe occurred predominantly at lower than solar metallicity for which an active burst mode may be more prevalent. However, the overwhelming majority of observational studies have been conducted on solar metallicity Milky Way star formation regions. The question is: Are there substantial differences in the star formation process at lower metallicity? Studies of star forming clouds in reduced metallicity galaxies have been inhibited by the lack of observatories with sufficient resolution and sensitivity. With JWST, we will be able to study star formation in the Magellanic Clouds like we can in the Milky Way with Spitzer. Our *Spitzer* SAGE and *Herschel* HERITAGE surveys of the LMC and SMC have revealed where to point JWST to study active star formation from the discovery of thousands of young stellar objects. In the LMC, we have selected the target N79 for a comprehensive imaging and spectroscopic study with

NIRCam, MIRI Imager, and MIRI MRS spectroscopy. This region contains the most massive young stellar object in the LMC and the surrounding region has a very high density of massive young stellar objects. We have ALMA observations of the molecular gas immediately surrounding the most massive YSO.

From the MIRI and NIRCam imaging study we plan to characterize the spectral energy distributions of over 1000 YSOs and pre-main sequence stars to understand the evolution of the circumstellar disks and envelopes of forming stars over a wide range in mass (1 to 50+ M_{Sun}) and evolutionary stage (0 to III). In particular, the greater clarity of JWST will enable us to detect for the first time the planet-forming dust disks around these solar-mass stars at the distance of the LMC and allow us to address questions such as: can planet formation occur at low metallicity when dust disk masses may be smaller than Galactic counterparts? The MIRI imaging of the PAH bands will also probe the PAH physics of the gaseous regions.

We will take MIRI MRS spectra of 5 regions (using the MIRI Imager simultaneously) to characterize the circumstellar and interstellar environment of select massive star formation regions from the most (silicate in absorption and ice features) to least embedded (optically detected protoclusters). Full spectral coverage with MIRI MRS will provide a wealth of information on the physical conditions of the ionized gas (atomic lines), and molecular gas (H2 lines) and the nature of the dust (PAHs, ice features) of the YSOs at lower metallicities. The ionized atomic line emissions will provide excitation of the YSO and also the surrounding ISM. Molecular hydrogen quadrapole vibrational and rotational lines trace the highly excited molecular gas in the region. The spectral resolution is high enough to detect ionized or molecular jets of gas at velocities >100 km s^{-1} allowing us to constrain outflow velocities. MEIXNER_7544-7567, MEIXNER_0025-0033,

Young Stellar Objects

Proto-stellar jets arising from young stellar objects (YSOs) have been studied in exquisite detail over the past 50 years. We understand in depth their emission mechanism, their interaction with the Interstellar medium and the role that they play in the formation of low/intermediate mass proto-stars. We do have reasonable models of the launching mechanisms that are "propelling" these highly collimated outflows, however the observational evidence to test the models is quite scarce, due in grand part that the star formation process takes place at high optical depths (>30mag), and we have lacked the of the sub-arcsecond angular resolution that is needed at wavelengths longer than 5 microns (Something that interferometric observatories like ALMA are currently addressing). A second issue has been 'saturation', since most of the sources driving the jets can be quite bright at infrared wavelengths, and studying the morphology & physics of the emitting central region (few AUs) has been extremely challenging. I believe that understanding observationally the collimation of proto-stellar jets, in the frame of physics of the formation of low mass, is one of the "final frontiers" to be reached in this field.

Thanks to the *Spitzer* Space Telescope, we have been able to identify young stellar systems at an evolutionary stage and environment such that one can glimpse their source at mid-IR wavelengths, at indeed very reasonable IR surface brightness that a superb telescope as JWST can observe them with their "spatial spectrometers" (IFUs), as is the case of MIRI with the Medium Resolution Spectrometer. NORIEGA_0001-0003

YSO Imaging and Spectroscopy

The dense circumstellar envelopes that surround accretion disks and nascent stellar photospheres hide key details of how protostars accrete in-falling matter. Measuring the effective temperatures, surface gravities, and photospheric luminosities of the youngest protostars is a precise and promising way to determine how they assemble their mass over time. Radii of proto- stellar photospheres follow directly from these measurements, and the evolution of these values can be established by observing several objects of different ages. Keplerian motions in the circumstellar disks of Class 0 protostars are now being detected with mm interferometers providing central object masses. The combination of kinematic information and photospheric data together will reveal how these objects evolve in mass, radius, and effective temperature over time, illuminating how they accrete matter from massive envelopes to circumstellar disks to the stars themselves.

The imaging portion of this program concentrates on young objects with disks that show asymmetries, gaps, or perturbations that are potentially indicative of an exoplanet in formation. Imaging candidates have been selected according to a priority scheme, where targets with spirals launched by predicted protoplanets with r > 0.5” are Priority 1 targets, and targets with substructure in sub-mm and scattered light at r > 0.5” are Priority 2 targets. MRIEKE_2500-2516

Protoplanetary Disks

The study of protoplanetary disks has become increasingly important with the Kepler satellite finding that exoplanets are ubiquitous around stars in our galaxy and the discovery of enormous diversity in planetary system architectures and planet properties. High-resolution near-IR and ALMA images show increasing evidence for ongoing planet formation in young disks. We propose here to use JWST to (1) investigate the chemical inventory in the terrestrial planet forming zone, (2) to follow the gas evolution into the disk dispersal stage, and to (3) study the structure of protoplanetary and debris disks in the thermal mid-IR. We propose to observe on the order of 50 targets (Herbig Ae stars, T Tauri stars, brown dwarfs and young debris disks) using MIRI/MRS spectroscopy aiming at high S/N spectra covering the complete MIRI wavelength range. For a handful of selected targets we will also pursue NIRSpec IFU high-resolution spectroscopy (2.9-5 mm). We will search for signposts of planet formation in thermal emission of micron-sized dust – information complementary to near-IR scattered light emission from small dust grains and emission from large dust in the submillimeter wavelength domain. Besides MIRI IFU data on all targets, we will study the spatial structure of outer disks around the signature objects for planet formation, TW Hydrae and HD135344B using the MIRI coronagraph at 15.5 mm. WRIGHT_5001-5070

Protostars

The embedded protostellar phase of star formation, which occurs for a few times 10^5 years after collapse of the parent cloud, is a critical period in the evolution of a young star: during this phase the final mass of the star, the initial chemical composition (ices, gases) of the disk, its size and mass, and thus its ability to form planets, are determined. At the same time, jets and winds from the star-disk system drive outflows that disperse the natal envelope. Many physical processes occur simultaneously in the immediate surroundings of the protostar: infall of the collapsing envelope onto the disk and accretion onto the star, outflows sweeping up and shocking material, and UV photons heating, dissociating and ionizing the gas. Because of the large extinction, these processes can only be investigated using mid-IR to mm wavelengths. Both the physics and chemistry of the protostellar structure (star-disk-envelope-jet) can be probed through unique mid-IR diagnostic features, namely narrow gaseous atomic (e.g., [S I], [Ne II], [Ne III], [Fe I], [Fe II], HI) and molecular (e.g., H_2, HD, OH, H_2O, CO_2, CH_4, C_2H_2, HCN) lines, as well as broad bands of ices (simple and more complex species), PAHs and silicates.
WRIGHT_4001-4037

Protostellar Binaries in Perseus

Recent millimeter surveys of young, "Class 0", protostars reveal that nearly 2/3 are binary/multiple systems. This high observed-multiplicity frequency suggests that most stars are born as binaries or multiples. The formation of multiple systems is thought to arise from three mechanisms: 1) turbulent fragmentation of the parent molecular cloud; 2) thermal fragmentation of a strongly perturbed, rotating, and in-falling core; and 3) fragmentation of a gravitationally unstable circumstellar disk. Processes 1 and 2 will lead to systems with separations of hundreds to thousands of AU, while the third will produce separations of hundreds of AU or less.

We will observe a small sample of protostellar binaries (Class 0 and I young stellar objects) in the Perseus star-forming region with MIRI to gain new insights into the formation and composition of these youngest stellar systems. The sources we have chosen are known binaries (or triples) with separations from 0.5" to 3.2" so that they are resolvable by the MIRI MRS yet still fit within a single MRS field-of-view. A spectacular example is the ALMA image of L1448 IRS3B. While we are unlikely to resolve the closer pair (at a separation of 0.27" or 61 AU), we will be able to separate them from the third member, 0.8" (183 AU) away, and perhaps obtain information on the dust spirals intertwined in the system. The spatial scale also bridges the transition between the first two formation process and the third, which is of order 1–2'' at the 230 pc distance to Perseus. RESSLER_1001-1011

Extinction Mapping of Pre-stellar Cores

We are interested in the evolution of ice mantles on dust grains during the process of molecular core collapse and early protostellar evolution. We have selected a quiescent molecular core (B68), a collapsing core (LDN694-2), and a protostellar core (B335) as our targets. All the objects are situated in front of dense backgrounds of stars, making transmission spectroscopy of ice features feasible.

The NIRCam wide field slitless spectroscopy (WFSS) mode using the grism in NIRCam's long wavelength channel will be used to obtain spectra of background stars behind the target molecular cores. We will obtain grism spectra through the F277W, F356W, F410M, F430M, F460M, and F480M filters to cover the absorption features of H_2O, CH_3OH, CO_2, XCN, and CO ices. We will obtain a few hundred spectra per target core, allowing us to map the spatial distribution of these ices. Our dataset will be the basis for detailed comparisons with theoretical and laboratory models of ice mantle formation and grain surface chemistry. We will also obtain direct images in the F356W and F444W filters as part of our setup and parallel imaging observations with the short wavelength channel of NIRCAM in the F070W, F090W, F115W, F150W, F182M, and F210M filters to study the continuum extinction. MRIEKE_1000-1011, MRIEKE_1100-1111, MRIEKE_1200-1211

Debris Disks and Photodissociation Regions

Absorption Line Spectroscopy of the Edge-on Debris Disk Around HD 32297:

The nearby star HD 32297 (located at 112 pc) possesses a prominent edge-on debris disk that has been beautifully imaged in scattered light using HST STIS. The disk exhibits morphological signatures of interacting with the local ISM, with both sides of the disk being swept back, consistent with Ram pressure interaction with ISM gas. It also possesses a radial asymmetry with the disk detected up to ~680 AU and ~340 AU on the SE and NW sides, respectively. A planetary mass companion may be required to explain this asymmetry. Visual absorption line spectroscopy has detected the presence of a large column of Na I D gas along the line-of-sight, a factor of a few larger than detected toward Beta Pictoris. *Herschel* PACS emission line spectroscopy has detected the presence of CII+ that may be the product of collisional destruction of icy parent bodies. We plan to obtain NIRSpec Fixed Slit (R~2700) spectra at 1-5 mm toward the central star to search for gas-phase absorption features due to circumstellar CO and water. We plan to place our observations into context with NIRCam coronagraphic observations of the disk obtained in a suite of medium band filters (F182M, F210M, F250M, F300M, and F335M) to search for signatures of frozen methane, water, and CO_2 in a collaborative program with the NIRCam GTO team's Scattered Light Debris Disk program. CHEN_0003

NIRISS AMI Observations of Transition Disk Systems

We aim to observe planets in formation around young stars using NIRISS AMI at thermal infrared wavelengths. We focus on Transition Disk systems, in which the natal protoplanetary disk around the young star shows evidence of disruption and gap formation. Such a scenario is expected when a forming planet is dynamically clearing its local environment. We aim to show that planet formation is ubiquitous in Transition Disk systems and that it is responsible for carving the observed large inner cavities. Each detected, and categorized, planet will provide a unique proving ground for theorists modeling disk and planet evolution, disk dispersal, and planet migration. DOYON_6000-6043

The NIRCam Scattered Light Debris Disks GTO Program

The NIRCam Scattered Light Debris Disks GTO program will observe five debris disks using multiple filters, covering a wavelength range of 1.82 - 5 μm, with the goals of determining the material composition of the systems and the spatial locations of various materials. Disk asymmetries and morphologies will be indicative of planets in the systems, while imaging with the F444W wide filter may reveal actual planets. Furthermore, with modeling, we will also study the variations in the grain size distribution as a function of location and the dynamical effects of planets in the systems. We limited our source sample to systems that have been spatially well resolved at optical wavelengths with HST and have high-scattered light flux density ratios and surface brightness. Our targets for the program are: HD 181327, HD 107146, HD 10647, HD 61005, and HD 32297.

In the colder zones of debris systems methane, water, and CO_2 are all frozen solid. Methane, with a melting point of 90 K has a distinct location where it will melt, slightly closer in. Nitrogen (N_2) and carbon monoxide (CO) are even more curious; with a boiling point of 77-82 K and a melting point of 63-68 K, their presence will be strongly segregated in the outer disk regions. Another common group of materials in the outer parts of the solar system are tholins, which are various types of heteropolymer molecules, formed from organic molecules such as methane and N_2 via UV radiation. Tholins are also readily detected in the outer parts of the solar system and are therefore likely to be detected in debris disk systems as well. Importantly, the reflectance of the ices differs from each other at various wavelengths, enabling a compositional study with multi-wavelength NIRCam observations. MRIEKE_4000-4039

Photodissociation Regions—The Horsehead and NGC7023

Photodissociation regions (PDRs) are predominantly neutral regions of the ISM in which the heating and chemistry are mainly regulated by far ultraviolet photons. They are extended regions at the interface between bright stars and molecular clouds, and contain dense structures and clumps immersed in a more diffuse medium which are subjected to photo-evaporation, which brings fresh matter into the diffuse hotter zone. The interaction of stellar radiation with in situ material includes: (1) the disruption of grain mantles/clusters formed in shielded dense regions or coagulated grains, (2) ionization and dissociation of the gas and (3) gas and dust heating. Studies of nearby PDRs have shown that these processes are strongly stratified and active on angular scales that can be as small as ~ 1" (0.002 pc/400 au at a distance of 400 pc), indicating that the physical conditions vary dramatically on small spatial-scales in PDRs (variations in gas temperature from ~ 100 – 1000 K to ~ 10 – 30 K and in gas density from ~ 10^2 - 10^3 to ~ 10^4 - 10^6 cm^{-3}). Nearby PDRs are therefore unique targets to study rapid variations in the dust and gas components as a function of the excitation and physical conditions. We propose to combine imaging and spectroscopy of two emblematic PDRs, the Horsehead and NGC7023, with MIRI, NIRCam and NIRSpec. These two nearby PDRs have different excitation conditions, with simple geometries, and are ideal to take full advantages of the high spatial resolution provided by JWST.

NIRCam will be used to map the PDRs in the F212N (H_2 1-0 S(1)) and F335M (PAHs) filters. Other NIRCam filters will map the continuum and extended red emission. The 9 filters of the MIRI imager will map the aromatic features and the continuum. Spectral mapping will be performed with the IFU of MIRI and NIRSpec at high spectral resolution along 1D scans perpendicular to the interfaces, in order to study the continuum emission, the spectral features and the main H_2 and ionized lines. Fainter lines are also expected. MRIEKE_3000-3033, MRIEKE_3100-3109

Debris Disks with MIRI

We will use JWST to probe the three nearest prominent debris disks in detail: e Eridani, Fomalhaut, and Vega. This program will both test the analogies with the Solar System and develop conceptual templates for interpretation of more distant systems where we can only achieve much poorer physical resolution. We will coordinate with the NIRCam team to obtain images searching for massive planets around the same stars. JWST is capable of resolving the emission of asteroid-belt analog regions around these stars. So far, the existence of such structures can only be inferred indirectly, but from analysis of spectral energy distributions, there appears to be a disk component in this region around many stars. There are two main possibilities for its origin, consistent with models for the production of zodiacal dust in the Solar System: 1) evaporation of comets at the current-day ice line of the systems; or 2) accumulation of planetesimals in the protoplanetary disk ice lines, leading to fossil planetesimal belts. As a test of these alternatives, we will use MIRI coronagraphic observations at 15.5 μm to test for the existence of asteroid-belt-analogs and if they exist, to determine where they lie.

MIRI imaging at 23 (coronagraphy) and 25.5 μm (conventional imaging) will detect the outer belts of these systems at angular resolutions comparable to the best images available with ALMA. The first wavelength will be optimal for any structures affected by scattered light from the star, while the second will include the full extent of the outer rings. When combined with ALMA data, the JWST observations will document the production of small grains that contribute to the halo of debris disks around luminous stars. Because these grains reach super-thermal temperatures, it should be possible to trace them from the parent body rings outward for a significant distance. The very high angular resolution with MIRI will also be ideal to search for structures at the inner edges of cold outer debris rings, structures indicative of the influence of massive planets, or the effects of other snow lines (or both). GRIEKE_2001-2027

Extreme Debris Disks

"Extreme debris disks" refers to a class of the planetary debris disks with excesses at 24 mm by at least a factor of four over the photospheric outputs of their stars. Some extreme debris disks are known to have variable emission over timescales of order 1 year and shorter, even a month or less. In general, these systems have strong mineralogical features in their mid-infrared spectra, indicative of very finely divided dust that must be generated continuously to replace that lost by stellar radiation pressure. It is difficult to explain the very rapid variability of these sources and the transient dust lifetimes without invoking condensation of finely divided grains from silica gas. In fact, a sub-class of extreme debris systems shows solid state features in mid-infrared spectra showing the presence of fine silica (not silicate) dust, evidence for condensation from the gas, and perhaps even for the silica gas itself. Such gas is expected to be a product of high-speed collisions between relatively large planetesimals. Where multi-epoch spectra are available, they usually do not show variability in the spectral features despite the dramatic photometric variations, but high signal to noise spectra are needed to probe this question by comparison with the archival Spitzer IRS spectra. In addition, the improved spectral resolution of the new observations will aid in diagnosing the mineralogy of the dust. The goal of our program is to obtain high signal to noise MIRI spectra of seven selected objects showing signs of extreme collisions that may trace the progress of terrestrial planet building. GRIEKE_3001-3021

Imaging Beta Pictoris' Prototypical Debris Disk

The famous debris disk around Beta Pic was the first circumstellar disk to be spatially resolved. Each successive generation of observations since then has delivered new insights into its complex structure, the physical composition of its constituent dust particles, and the physical processes that shape the disk. As one of the brightest and largest disks on the sky it remains a compelling target for detailed investigations at unprecedented sensitivities with JWST. We will observe Beta Pictoris using both the NIRCam and MIRI coronagraphs to cover the wavelength range 1.8 – 23 microns. NIRCam's F182M, F210M, F250M, F300M, F335M and F444W filters are sensitive to the presence of water and CO ices and organic tholins to allow characterization of disk composition and spatial variations. MIRI 15 and 23 micron coronagraphy will probe the warm inner asteroid belt analogue and the cooler outer main disk, respectively. These observations are coordinated with other GTO programs to ensure rich and consistent data sets across many disks: The 1.8-5 micron observations using NIRCam will be taken with the same set of filters and coronagraph masks as the NIRCam GTO team's Scattered Light Debris Disks program is using for several other disks, and our MIRI observation strategy matches that of the MIRI GTO Archetypal Debris Disk program. In addition to revealing the disk in detail, our deep NIRCam F444W observations will achieve extraordinarily low detection limits to search for unknown wide-separation planetary companions, reaching well below the mass of Saturn.

High contrast imaging has revealed the presence of a ~10 M_{Jup} planet with an orbital semi-major axis ~10 AU. ALMA CO J=1-0 observations have revealed offset emission that may be generated by collisional destruction of CO rich cometary bodies, trapped into a mean motion resonance with a second undetected planet. Multi-wavelength imaging observations have revealed a spectacular edge-on disk extending up to ~1400 AU away from the star in scattered light and thermal emission. We plan to obtain a MIRI MRS mosaic at ~5-28 mm of the inner ~15" of the Beta Pic disk to map the shapes of the 10 and 20 mm silicate emission features as a function of position from the central star. *Herschel* PACS mapping of the 69 mm Forsterite feature indicates that (1) the silicates have an Iron fraction ($Mg_{2-2x}Fe_{2x}SiO_4$, x~0.29) consistent with asteroids that (2) have been processed at high temperatures even at large distances from the star. By contrast, higher spatial resolution Subaru mid-infrared COMICS spectra indicate the silicates are Mg-rich with the crystalline component centered on the star and small grains located at 6.4, 16, and 30 AU from the star. MOUNTAIN_2101-2106, MOUNTAIN_2110-2115, CHEN_0001-0002

Star Clusters, Star Formation Regions, Planetary Nebulae, and Galactic Transients

Dynamics of the Galactic Center Star Cluster

We will observe the Galactic Center, to study the orbits of stars around the supermassive black hole and the structure of the nuclear star cluster. For all PM observations, data from the NIRCam SWC and LWC will be combined to create color-magnitude diagrams, which will be used to help identify and reject fore- and back-ground objects. In each channel we will use filters on the blue end of the spectrum, to obtain the highest spatial resolution. Additional targets for PM studies will be observed in GTO Cycles 2 and 3. MOUNTAIN_3121, MOUNTAIN_3171

Embedded Cluster Survey

We will observe one carefully selected embedded young cluster from among nearby star forming regions within 1 kpc to probe the IMF down to the lowest masses where compact objects can collapse from the ISM. Estimates for this range from < 3 M_{Jup} to > 10 M_{Jup} overlapping the range of planetary masses. Observations such as these will place powerful constraints on very low mass end of the IMF putting theories to the test. We will obtain multi-band imaging of the cluster NGC 2024 well-matched to the NIRCam field of view to disentangle intrinsic color, extinction, and the presence (or absence) of circumstellar disks enabling construction of monochromatic luminosity functions corrected for reddening and free (to a large extent) from disk excess in order to estimate stellar mass distributions to < 2 M_{Jup}.

This program will also identify giant planets ejected through dynamical interactions as well as very low mass brown dwarfs for characterization through follow-up spectroscopy with NIRSpec. Comparing observed C/O ratios based on spectral retrieval applied to the characterization spectra could enable us to distinguish some objects as ejected planets compared to those formed directly from the ISM. MRIEKE_2000-2003

Massive Star Formation

A thorough understanding of massive star formation forms the base for our picture of galaxy evolution, feedback, elemental abundances, the initial mass function, and many other topics. Observationally, massive star formation is a knotty problem because it happens quickly in regions with enormous amounts of overlying extinction. JWST, with its spectacular thermal-IR sensitivity and high spatial resolution can significantly improve our understanding of the early stages of high-mass star formation by providing a new view of massive clouds on the cusp of forming massive stars, by finding and studying the intermediate mass stars that form first in these clouds, and perhaps by finding the very first indications of the massive stars themselves.

By studying the properties of these clouds, we can test alternative ideas for the formation of massive stars: competitive accretion as the overall cloud undergoes global collapse or enhanced accretion rates in individual collapsing clumps. The proposed work will provide an independent way of studying the structure of IRDCs on small spatial scales, uncover any embedded population of lower mass stars forming before massive stars form, trace and measure the mass of structures above the theoretical threshold column densities for massive star formation, and together with millimeter and mid-IR data, examine the freeze-out of molecules in cold, dense environments. The objective is to characterize the size distribution of the cores in the cloud that could give rise to stars.

Our targets will include 3 Infrared Dark Clouds in the 4-kpc ring where most Galactic star formation occurs. By choosing sources at low galactic latitude and within 20 degrees of the Galactic Center, we will have a sample that is close enough to give our measurements an optimal linear scale and has a dense field of galactic background stars. We will use existing maps based on extinction of the 8 mm background to choose cloud segments for single-pointing observations with NIRCam. With 1-hour exposures in the F444W and 3F56W filters, galactic structure models show that we can detect enough stars to use stellar colors to map the reddening at ~3 arc second resolution to column densities of ~0.5 g cm^{-2}. MRIEKE_1500-1507

Star Formation in the Extreme Outer Galaxy

The extreme outer Galaxy (EOG), which we define as the region with a Galacto-centric radius (R_g) of ≥18 kpc, has a very different environment from the solar neighborhood, since it has a much lower gas density, lower metallicity (~ 1 dex), and little perturbation from the spiral arms. The environment is similar to that

found in nearby dwarf galaxies, damped Lyman-α systems, and the early stage of the formation of the Galactic disk. Because of its relative proximity, compared to nearby dwarf galaxies, such as the LMC and SMC (about 10 kpc vs. 50 kpc), the EOG serves as an ideal “laboratory” to study the details of the star formation process in such environments.
In near-infrared (NIR) surveys of the EOG, we have found active star formation occurring in Digel Cloud 1 (DC1) and Cloud 2 (DC2), which are two of the most distant known regions with a $R_g > 20$ kpc. Based on the position of the star-forming clusters with respect to local CO, MIR, H I, and radio continuum peaks and ridges, we have suggested that the DC1 clusters may have been triggered by high-velocity cloud accretion onto the Galactic disk, while the DC2 clusters may have been triggered by a supernova event. For the two clusters in DC2, we found that the initial mass function (IMF) is consistent with that in the solar neighborhood in terms of the high-mass slope and IMF peak. However, we also found that the fraction of stars with a K-band excess (which originates from the inner circumstellar dust disk at radii of $r \le 0.1$ AU) is significantly lower than that in the solar neighborhood, suggesting a metallicity dependence of disk lifetimes. We propose parallel MIRI/NIRCAM imaging ($\lambda = 1.15$–21 μm) of DC1 and DC2. We expect to detect sources down to 8 M_J and to distinguish whether stars down to 0.5 $M_{\odot}$ still have disks. The sensitivity and spatial resolution of JWST will enable us to study star- and planet-forming processes in the EOG at the same depth as the solar neighborhood for the first time. Specifically, we will use the NIR and MIR data to classify the evolutionary stages of YSOs (Class 0–III) and reveal their spatial distribution.
RESSLER_2001-2024

Investigating Dusty Disks in Evolved Stars

We propose to investigate the mysterious mid-infrared dust excesses that have been found around post-AGB stars that are the end products of low and intermediate mass stars (1–8 $M_{\odot}$). These dust excesses are believed to be produced by a dusty disk around the star. The presence of such dusty disks during these late evolutionary stages is unexpected. To understand the mechanisms that can produce such disks, it is important to characterize the disk structure, mass, temperature, and composition.

Disks around White Dwarfs: The search for planets or planetary systems around stars other than our Sun is one of the most exciting quests in recent times. Two types of dust disks have been discovered around white dwarfs (WDs): the first are large dust disks around the hot WDs at the centers of planetary nebulae (PNe), that extend to radial distances of 10–100 AU. The second type are small disks of material that orbit “naked” or cool WDs and exhibit 10 μm silicate emission features. The limited angular resolution of *Spitzer* makes removal of nebular contamination uncertain in the case of the hot WDs (and no spectra are available), and in the cool WD case, the spectra are of low S/N. JWST will allow us to address both issues, even for a small sample of sources.

Young disks resulting from common-envelope ejection in Red Giants: The evolution of very luminous ($L \sim 6000$ $L_{\odot}$) AGB stars is controlled by heavy mass-loss via dusty winds, thus mid-IR excesses are to be expected. However, a class of lower luminosity post-RGB stars ($L< 1000$ $L_{\odot}$) that also exhibit dust excesses have recently been identified in the LMC and SMC using *Spitzer* photometry. For these stars, strong interactions with a compact binary companion during the RGB phase is believed to remove most of the primary's stellar envelope, but with a significant fraction of the ejecta still residing in a disk.

We propose to use JWST/MIRI to obtain high S/N spectra of a small sample of post-RGB stars in the LMC and SMC that will enable us to characterize the properties of the disks and their dust composition. RESSLER_4001-4006

Exozodiacal Disks: A Theatre for Planetary Gravitational Shadow Plays

We will target the known dusty debris system η Crv. The extreme levels of calibration stability offered by the NIRISS-AMI platform will allow the first spatially resolved imaging campaign of the innermost regions. This provides a unique window at solar system scales, and with sufficient contrast reach in the thermal IR to reveal the detailed structure of the disk. Both global properties such as the dust radial and vertical distribution, as well as asymmetric perturbations will be explored. One mechanism for the latter is the presence of gravitating bodies within the circumstellar environment, giving this program the potential to detect unseen companions by their gravitational wakes. DOYON_9000-9004

Sparse Spectral Mapping of NGC 1514

Observations of the planetary nebula (PN) now known as NGC 1514 convinced William Herschel that not all nebulous sources he observed could be resolved into clusters of stars as he had thought; some were indeed surrounded by a "shining fluid". In modern terms, NGC 1514 is a moderately high excitation PN in Taurus, whose central source has recently been proven to be a binary star with a 9.1 yr period the longest period measured spectroscopically for any PN, which only adds to the mystery of the evolutionary status of the pair. The overall appearance of the nebula at visible wavelengths is that of a round, lumpy, double-shelled PN composed of numerous small bubbles. However, *WISE* showed that the PN is also surrounded by two large axisymmetric rings. While other planetary and symbiotic nebulae have similar looking structures at visible wavelengths (*e. g.* MyCn 18 and Hen 2-104), NGC 1514 is unique in that the rings are brightly visible only in the mid-infrared, and a survey of 257 other PN in the *WISE* image catalog showed no other sources with a similar infrared ring structure. Because of the large spatial extent of the nebula, ~ 3 arcminutes in diameter, we will obtain MIRI MRS spectra at 7 locations on the nebula itself, chosen to sample important: on the central source, on two of the brighter bubbles in the inner shell, on the equatorial plane, and on several locations around the rings. Additionally, we will measure two positions on the background to the south of the nebula. Furthermore, despite the offset between the MIRI imager and the MRS fields-of-view, we can take advantage of the nebula's size to perform simultaneous imaging that will cover a significant fraction of the nebula. These images will give us more than 15 times the spatial resolution of WISE. The imaging data will allow better understanding of the relationship between the rings and the inner and outer shells. In addition, the imaging will enable determination of the precise location of the MRS data in relation to the larger scale nebular features. RESSLER_3001-3009

SN 1987A: The Formation and Evolution of Dust in a Supernova

From Supernova to Supernova Remnant, SN 1987A, has given us a unique opportunity to study the mechanics of a supernova explosion and now to witness the birth of a supernova remnant. We want to understand how massive stars age and explode, how their ejecta form dust and molecules and how the blast wave from their violent explosion affects their surroundings. JWST MIRI imaging, MRS spectroscopy and NIRSpec IFU spectroscopy will provide key emission line diagnostics and dust feature and continuum measurements of SN 1987A. The central stellar ejecta of SN 1987A is surrounded by a ring of progenitor gas and dust that is being shocked by the blast wave of the explosion. A large quantity (0.4-0.7 M_{Sun}) of dust in the stellar ejecta has an unknown composition and our MIRI observations may provide the first constraints through the imaging and MRS spectroscopy. Both the MRS and NIRSpec IFU spectroscopy will measure key shocked line diagnostics that will constrain the shock physics as well as the elemental abundances in both the ring and the stellar ejecta. The environment of SN1987A has significant star formation, which has been studied using HST imaging during parallel HST imaging spectroscopic observations of SN 1987A. This star formation will be studied using parallel fields when SN 1987A is the prime target.

MIRI filter imaging at F560W, F1000W, F1800W and F2550W, together with MRS IFU and NIRSpec IFU imaging spectroscopy of the ring and ejecta will be obtained to measure the line and continuum. The goals are a) to study the evolution of the interaction of the blast wave with the 2 arcsec diameter equatorial ring and beyond; b) to determine the nature of the ring's hot dust component discovered by *Spitzer*; c) to search for and confirm mid-IR emission from the 0.5 M_{Sun} of ejecta dust that was discovered at far-IR wavelengths by *Herschel*; d) to study the evolution of the dust and molecules in the ejecta; e) to look for a remnant neutron star. We anticipate running the MIRI imager simultaneously with the MRS. We will take all these measurements back-to-back in time to ensure the measurements are from the same epoch of this time evolving object. These observations will include MRS running simultaneously with MIRI imaging when either the MRS is prime or the MIRI imager is prime. When the MIRI imager is prime, the MRS will be located off SN 1987A and provide a critical background measurement of both the telescope emission background and the ISM background. When MRS is prime, we propose MIRI simultaneous imaging in the 5.6, 7.7 and 25 micron filters to measure the dust emission from young stellar objects (YSO) and the surrounding interstellar medium (ISM). This characterization of the star formation in the region adjacent to SN1987A is relevant to the overall program to study the low metallicity star formation regions in the LMC and SMC. We anticipate a Cycle 2 joint measurement effort of the MIRI and NIRSpec IFU spectroscopy to capture the time evolution. MEIXNER_0041, MEIXNER_7513-7519, WRIGHT_8013-8020

De-Mystifying SPRITEs with JWST

The dynamic infrared (IR) sky is now being explored by the *Spitzer Space Telescope*. Just by searching 200 nearby galaxies, the Spitzer Infrared Intensive Transient Survey (SPIRITS) has found 37 unusual infrared transients, with no optical counterparts whatsoever, dubbed SPRITEs (eSPecially Red Intermediate Luminosity Red Transients). With infrared luminosities between novae and supernovae, SPRITEs are found to occur in grand spiral galaxies. These transients cannot be classical novae as their infrared luminosities are much higher than Eddington. SPRITEs may represent diverse physical origins including (i) the birth of massive binaries that drive shocks in their molecular cloud, (ii) stellar mergers with dusty winds, (iii) 8–10 $M_\odot$ stars experiencing e-capture induced collapse in their cores or (iv) birth of stellar mass black holes. SPIRITS reveals that the infrared sky is not only as dynamic as the optical sky; it also provides access to unique and complementary signatures of stellar astrophysics.

The key to disentangling the various possible physical origins of the new discoveries and deciphering the astrophysics and astrochemistry is IR spectroscopy. Due to the sensitivity limitations imposed by Earth's atmosphere, SPRITEs have been too faint to detect from ground-based IR observatories. We therefore require the unprecedented IR sensitivity of MIRI and NIRSPEC on JWST to obtain the first IR spectra and detections at $\lambda > 4.5$ μm of these mysterious transients. In addition to detecting diagnostic IR emission and absorption lines, the spectra would reveal: i) the composition of the emitting dust (e.g., silicate or carbonaceous grains), ii) the total emitting dust mass, and thus the overall mass of the circumstellar medium, and iii) the integrated IR luminosity, and thus the luminosity of the heating source. RESSLER_5001-5018

Targeted Galaxies

NGC 1068 as Proving Ground for NIRISS AMI

Ground-based imaging of the Narrow Line Region (NLR) of the nearby Seyfert 2 Active Galactic Nucleus (AGN), NGC 1068, reveals substantial near-IR emission aligned along the axis of a biconical outflow. Clear evidence of dust emission at temperatures ~700K imply a heating mechanism acting locally, at distances of ~few 10s pc away from the AGN central engine. At larger distances, the near-IR emission is roughly coincident with [OIII] emission observed from HST, and radio emission possibly due to a jet. Thus it has been suggested that a sheath of interacting material around the jet may be providing heating via photoionization. The highest angular resolution near-IR images, however, show a possible arc of emission, probably in the plane orthogonal to the jet, extremely close to the central point source. This is exactly the region where material inflowing from galactic scales may be redirected into an outflow by AGN feedback mechanisms. If real, the arc must be produced by mechanisms operating at the poorly- understood interface between the inflowing reservoir of material supplying the torus and central engine. Only NIRISS AMI observations can unambiguously detect or rule out the presence of the arc structure; we propose observations in F380M, F430M and F480M filters, yielding 65-70mas resolution across a sub-arcsecond field of view. We expect to measure the temperatures of a variety of clouds in the field, including the arc, with some objects as bright as L=7.7. The processes governing this region are critically responsible for the balance between inflowing material from the galaxy, outflowing material due to AGN feedback, and accretion onto the black hole itself. DOYON_8000-8011

Dust in Backlit Galaxies, VV191 and SDSS J133642.56+620337.3

NIRCam imaging will be obtained for two local spiral galaxies backlit by large galaxies at significantly greater redshift, to retrieve both spatial and wavelength dependent variations in dust attenuation. In one case, favorable geometry should allow a test of how closely the 3.3-micron PAH feature tracks extinction by the overall grain population. These two occulting-galaxy pairs will trace dust attenuation in a very direct way, independent of our knowledge of the "vertical" distributions of stars and dust in their disks. At each wavelength, estimates of the galaxy structure from symmetry (and errors based on departures from symmetry) give the dust attenuation point-by-point. Our targets are taken from the HST STARSMOG survey, with redshift differences guaranteeing that the pair members are not interacting with each other and that corrections for scattering are negligible. These results will provide the effective attenuation law deep into a spiral disk, a measure of how the scale heights of stars and dust differ, and most immediately the radial distribution of attenuation across the NIRCam bands. The targeted systems are VV191 and SDSS J133642.56+620337.3 (=MCG+10-19-097). Each fits within a single NIRCam module. WINDHORST_34110, WINDHORST_34111, WINDHORST_35110, WINDHORST_35111

Internal Dynamics of Milky Way Dwarf Spheroidal Galaxies

We will observe five fields in the nearest classical Milky Way dwarf spheroidal galaxies Draco and Sculptor, to study the internal PM dynamics of their stars. This will determine whether their dark halos have central cores or cusps, which provides an important constraint on the properties of dark matter and cosmological models of galaxy formation. PMs will be determined either from comparison to existing HST data, or from comparison to similar JWST observations to be obtained in GTO Cycles 2 and 3, or to be requested in future JWST GO cycles. MOUNTAIN3101-3105, MOUNTAIN_3151-3155

Dynamics of the Andromeda Galaxy Satellite System

We will observe four dwarf spheroidal companions of the Andromeda Galaxy M31, to determine their bulk PMs. The targets, And I, III, XIV, and XVII, are believed to be members of a satellite plane. Their PMs will resolve whether this plane is a physical structure, which would have important cosmological implications, or merely a chance superposition. PMs will be determined either from comparison to existing

HST data, or from comparison to similar JWST observations to be obtained in GTO Cycles 2 and 3, or to be requested in future JWST GO cycles. MOUNTAIN_3111-3114, MOUNTAIN_3161-3164

Ram Pressure Stripping in ESO 137-001

Once thought to be rare, the number of known ram pressure stripping (RPS) events has been steadily rising, observed as truncated or disturbed gaseous disks or one-sided tails in the X-ray through the radio. These events hold key information regarding the relation between galaxy transformation and environment. We propose MIRI MRS observations of ESO 137-001, a well-studied local galaxy (z=0.01625) with a spectacular double ram pressure stripped tail. At both high spectral (R~2700) and spatial (~0.1 arcsec) resolution over 5-28.8μm, we will detect multiple transitions of rotational H_2 lines as well as a suite of fine structure lines at high significance. From these observables, we will deduce the kinematics and the temperature/density structure of warm and hot gas components in the tail on sub-kpc scales as well as the excitation mechanism(s) responsible. This information will reveal how the (star forming) interstellar medium of the host galaxy responds to strong RPS and how the stripped gas subsequently interactions with the intra-cluster medium. Notably, the detailed state of the H_2 will identify the spatial extent of shocked gas and constrain cooling mechanisms and timescale for molecular gas, informing as to whether star-forming regions in the tail were formed *in situ* or from molecular gas stripped directly from the galactic disk. Flux measurements in the MIRI bandpass will also yield star formation rates. FRIEDMAN_001

The possibility that the apparent association between the most luminous AGNs and global star formation is just a result of a common dependence on galaxy mass indicates that the peaks of star formation and black hole accretion are well separated in time. This leaves the possibility that nascent AGNs are just starting to emit in the cores of the most dramatic star forming galaxies, as predicted by some theoretical simulations; the period as a merger is being completed should be when the AGN is accreting most rapidly and is bright. To probe this possibility requires observational indicators of nascent AGN that are robust against extinction and cannot be confused by star formation. One possibility is to look in the very hard X-ray range. An alternative is the mid-infrared fine structure lines. These lines are at wavelengths of very low interstellar absorption; in addition, they originate in the narrow line region of an AGN, which is extended and hence the lines have many more lines of sight through which they can escape from the galaxy than do hard X-rays, which originate right from the central engine. The [NeVI] line at 7.65 mm has unique advantages, such as very high ionization potential and high critical density. A single MIRI MRS grating setting can measure this line, CO absorptions from red giants and supergiants, the 7.7 and 11.3 micron aromatic features, and [NeII] (some of these lines just over a limited range of redshift). This capability will allow us to make an efficient survey for nascent AGN in five nearby ULIRGs where the evidence for AGNs is weak or contradictory. Targets: IRAS F12112+0305, IRAS F14378-3651, Apr 220, IRAS 17208-0014, IRAS F23365+3604, HD 104181, HD 131120, HD 140572, HD 157856, HD 221756

GRIEKE_5001-5010

I Zw18: Dust Life Cycle at Very Low Metallicity

JWST MIRI and NIRCam will be used to study the life cycle of dust in I Zw18, in a manner comparable to Spitzer studies of the life cycle of dust in the Large and Small Magellanic clouds. With the spatial resolution and sensitivity afforded by JWST, we will be able to study individual objects in the galaxy I Zw18 that has an extremely low metallicity ([Fe/H] = - 1.9) and has been the subject of an HST study that detects both post-main sequence and young stars. Conditions in this galaxy are thought to be similar to high redshift galaxies and our study will shed light on the dust life cycle in the early universe. With NIRCam and MIRI, we will be able to study dusty objects, which were not seen by HST. Of particular interest are dust producers. Unlike our galaxy where low- and intermediate mass stars provide substantial dust via mass loss during the asymptotic giant branch (AGB), high redshift galaxies with known large dust content do not have time for stars with masses below 5 solar masses to evolve onto the AGB and produce dust. Recent works show that supernova can produce substantial amount of dust but it is not clear if that will survive the passages of shocks. Hence studies of intermediate-mass and high mass stars towards the end of their evolution may be keys to understanding dust formation in galaxies. The detection of the massive young stellar objects in I Zw18 will provide insight into the formation of massive stars at low metallicity. Together with the star formation history determinations from HST and the dust mass measurements from the Spitzer Space Telescope and the Herschel Space Observatory, we will be able to construct a dust evolution model of this important galaxy. MEIXNER_7501-7504, MEIXNER_7509-7510, MEIXNER_0001-0002, MEIXNER_0005-0008, WRIGHT_1001-1006

NGC 6822: Dust Life Cycle Study of a Nearby Low Metallicity Galaxy

JWST MIRI and NIRCam will be used to study the life cycle of dust in NGC 6822, in a manner comparable to Spitzer studies of the life cycle of dust in the Large and Small Magellanic clouds, and 1 Zw 18. With the spatial resolution and sensitivity afforded by JWST, we will be able to study individual objects in the galaxy NGC 6822 which has a metallicity ([Fe/H] = -1.2) comparable to that of the SMC. NGC 6822 has been the subject of an HST and ALMA study that detects both post-main sequence and young stars. Conditions in this galaxy are thought to be similar to galaxies at the peak star formation epoch in the Universe and our study will shed light on the dust life cycle in the early universe. With NIRCam and MIRI, we will be able to study dusty objects, which were not detected by HST. Of particular interest are dust producers. Unlike our galaxy where low- and intermediate mass stars provide substantial dust via mass loss during the asymptotic giant branch (AGB), high redshift galaxies with known large dust content do not have time for stars with masses below 5 solar masses to evolve onto the AGB and produce dust. Recent works show that supernova can produce substantial amount of dust but it is not clear if that will survive the passages of shocks. Hence studies of intermediate-mass and high mass stars towards the end of their evolution may be key to understanding dust formation in galaxies. NGC 6822 has the brightest HII regions in the nearby universe. The detection of the massive young stellar objects in NGC 6822 will provide insight into the formation of massive stars at low metallicity. Together with the star formation history determinations from HST and the dust mass measurements from the Herschel Space Observatory, we will be able to construct a dust evolution model of this important galaxy. MEIXNER_0003-0004, MEIXNER_0009-0012, MEIXNER_7505-7508, MEIXNER_7511-7512

NGC 346: Star Formation at Low Metallicity in the Small Magellanic Cloud

Observations of galaxies across cosmic time show that the star formation rate peaked at a redshift of ~1.5, meaning star formation in the Universe occurred predominantly at lower than solar metallicity for which an active burst mode may be more prevalent. However, the overwhelming majority of observational studies have been conducted on solar metallicity Milky Way star formation regions. The question is: Are there substantial differences in the star formation process at lower metallicity? Studies of star forming clouds in reduced metallicity galaxies have been inhibited by the lack of observatories with sufficient resolution and sensitivity. With JWST, we will be able to study star formation in the Magellanic Clouds like we can in the Milky Way with Spitzer. Our *Spitzer* SAGE and *Herschel* HERITAGE surveys of the LMC and SMC have revealed where to point JWST to study active star formation from the discovery of thousands of young stellar objects. In the SMC, we have selected the target NGC 346 for a comprehensive imaging and spectroscopic study with NIRCam, MIRI Imager, MIRI MRS spectroscopy and NIRSpec MSA spectroscopy. This target has prior HST images in which thousands of pre-main sequence stars were identified, Spitzer IRS spectral studies of the region and also young stellar objects in the region, and planned ALMA observations of the molecular.

From the MIRI and NIRCam imaging study we plan to characterize the spectral energy distributions of over 1000 YSOs and pre main sequence stars to understand the evolution of the circumstellar disks and envelopes of forming stars over a wide range in mass (1 to 50+ M_{Sun}) and evolutionary stage (0 to III). In particular, the greater clarity of JWST will enable us to detect for the first time the planet-forming dust disks around these solar-mass stars at the distance of the SMC and allow us to address questions such as: can planet formation occur at low metallicity when dust disk masses may be smaller than Galactic counterparts? The MIRI imaging of the PAH bands will also probe the PAH physics of the gaseous regions.

From the MIRI spectroscopic study, we will characterize the circumstellar and interstellar environment of select massive star formation regions from the most (silicate in absorption and ice features) to least embedded (optically detected protoclusters). The NIRSpec MSA measurements will target both the pre-main sequence stars detected by Hα with HST and embedded targets detected as highly reddened or with water ice by the NIRCam and MIRI imaging study. Full spectral coverage of both instruments will provide a wealth of information on the physical conditions of the ionized gas (atomic lines), and molecular gas (H2 lines) and the nature of the dust (PAHs, ice features) of the planet-forming YSOs at lower metallicities. The ionized atomic line emissions will provide excitation of the YSO and also the surrounding ISM. Molecular hydrogen quadrapole vibrational and rotational lines trace the highly excited molecular gas in the region. The spectral resolution is high enough to detect ionized or molecular jets of gas at velocities >100 km s^{-1} allowing us to constrain outflow velocities. MEIXNER_7521-7543, MEIXNER_0013-0024, MEIXNER_0034-0036, FERRUIT_6351-6353, FERRUIT_6361-6363, FERRUIT_6301, FERRUIT_6302

Spectroscopy of Nearby Galaxies

The nuclei of galaxies and their immediate vicinity are unique laboratories for a number of complex physical processes. Observing a small number of selected nearby galactic nuclei with the integral field units (IFUs) of both MIRI and NIRSpec (jointly with the NIRSpec GTO team) will allow us to study them in unprecedented detail over the entire near- and mid-infrared spectral range (0.7 – 28μm). The unrivaled sensitivity and continuous wavelength coverage offered by the combination of JWST and MIRI+NIRSpec will provide access to a multitude of diagnostic spectral features. Mapping these over the central few hundred pc with the unique spatial resolution of JWST (~0.1", i.e. a few pc for nearby galaxies) will break new ground even for these already well-studied objects.

We propose to observe six nearby galactic nuclei that are selected to represent archetypical examples for various classes of nuclear environments. The specific science goals therefore differ from target to target, but can be broadly summarized as follows:

- Identify any hidden active galaxy nucleus activity in heavily obscured nuclei through the presence and distribution of IR coronal lines;
- Map the kinematics of stars and different gas phases in the central few hundred pc in order to establish their dynamical status, and to constrain the nuclear mass concentration;
- Identify embedded star clusters and determine their ages and masses;
- Constrain the 2-dimensional star formation history via spatial variations in the stellar populations;
- Trace spatial variations in the amount of dust extinction, and the present-day star formation rate and efficiency;
- Map the ionization structure of the interstellar medium to identify the various physical processes at work, and to quantify their relative importance.

Targets: ARP 220, NGC 4654, NGC 6240, Mrk 231, Cen A, Sag A*

WRIGHT_7500-7510, FERRUIT_4500, FERRUIT_4510, FERRUIT_4511, FERRUIT_4520, FERRUIT_4530, FERRUIT_4531, FERRUIT_4540, FERRUIT_4550.

Star Formation in the Local Group

This sub-program will showcase the multi-object spectroscopy capabilities of NIRSpec for stellar studies. We will obtain medium- and high-resolution spectroscopy of hundreds of known pre-main sequence (PMS) stars of different ages, hosted in massive starburst clusters located in different environments (metallicity) in the Local Group. The target clusters are NGC 3603 in the Galaxy, 30 Dor in the Large Magellanic Cloud, and NGC 346 in the Small Magellanic Cloud. These PMS stars have been identified photometrically as objects with strong Hα excess emission and equivalent width exceeding 10 Å, and as such appear to be actively accreting from a circumstellar disc. While for many of these objects comparison with isochrones suggests young ages of the order of a few Myr, a large number of them appear older than 20 Myr, suggesting that in these environments accretion onto PMS stars lasts longer than in small nearby Galactic star forming regions. These NIRSpec observations will allow us to obtain accurate accretion luminosities, mass accretion rates, and in-falling gas kinematics for all these stars from the analysis of several Hydrogen recombination lines (Paα, Brβ, Brγ). The ultimate scientific goal of this project is to understand the very nature of the mass accretion process, and how it depends on the mass, age, and metallicity of the individual objects. This study is unique since existing spectroscopy of PMS stars is so far limited to the solar neighborhood and no information exists for starburst clusters or for non-solar metallicity. Coordinated NIRCam parallel observations in the periphery of the same star-forming regions will support the primary science program: by revealing many more PMS stars of lower mass, they will considerably extend both the number of targets and the parameter space in this investigation. FERRUIT_6101, FERRUIT_6201, FERRUIT_6301-6302, FERRUIT_6151-6153, FERRUIT_6251-6253, FERRUIT_6351-6353, FERRUIT_6361-6363

Clusters of Galaxies

Massive Galaxy Clusters

We will obtain multiband NIRCam images (0.8–5.0 μm) of 7 massive galaxy clusters used as gravitational lenses to study and discover some of the most distant galaxies known in the first billion years of cosmic time. They will also be used to study time-variable objects in or behind these clusters, including possible cluster caustic crossings of background objects. The selected clusters are MACS0416, MACS1149, Abell-2744, El Gordo, PLCK-G165.7+67, CLG-J1212+2733, and GAMA-100033. Some of these clusters were selected from the Hubble Frontier Field program (HFF), while others were selected through X-rays, Sunyaev-Zel'dovich decrements, Light Traces Mass (LTM) techniques, or through far-infrared colors. Additional time-domain science critical for our science goals also needs to be obtained in the NIRCam F090W, F115W, and F150W filters of the HFF clusters, *and* through NIRISS F090W, F115W, and F150W *coordinated parallel imaging* of the HFF-parallel fields, each of which have been previously covered by HST ACS or WFC3/IR in the similar filters of F850LP, F105W/F125W and/or F160W. This will provide substantial additional epochs in these near-IR filters for time-domain studies including the search for AGNs, lensed caustic-crossing stars, and supernovae.

STIAVELLI_0001-0010, WINDHORST_21110-21115, WINDHORST_21210-21214, WINDHORST_211310-21314, WINDHORST_22110-22113, WINDHORST_23110-23113, WINDHORST_24110-24113, WINDHORST_25110-25113, WINDHORST_26110-26112, WINDHORST_27110-27122, WINDHORST_21120-21125, WINDHORST_21220-21224, WINDHORST_211320-21324, WINDHORST_22120-22123, WINDHORST_23120-23123, WINDHORST_24120-24123, WINDHORST_25120-25123, WINDHORST_26120-26122, WINDHORST_27120-27122

Canadian NIRISS Unbiased Cluster Survey (CANUCS)

CANUCS is a JWST spectroscopy and imaging survey of massive galaxy cluster and parallel fields using the NIRISS low-resolution grisms, NIRCam imaging and NIRSpec multi-object spectroscopy. The primary goal is to understand the evolution of low mass galaxies across cosmic time. The resolved emission line maps and line ratios for many galaxies, some at resolution of 100pc, will enable determining the spatial distribution of star formation, dust and metals. Other science goals include the detection and characterization of galaxies within the reionization epoch, using multiply-imaged lensed galaxies to constrain cluster mass distributions and dark matter substructure, and understanding star-formation suppression and morphological transformation in the most massive galaxy clusters.

The CANUCS program has five distinct observations per target field:

1. *NIRISS Wide-Field Slitless Spectroscopy (WFSS) on the cluster field***.** This will provide 1 to 2.3 micron low-resolution spectroscopy for every object in the field, with two orthogonal orientation grisms to mitigate the effects of confusion. The resulting redshifts, emission line fluxes and maps and continuum spectroscopy will enable a wide range of science projects.
2. *NIRCam Imaging on the cluster field.* There will be NIRCam imaging with one NIRCam module centred on the NIRISS field. The primary goal of the NIRCam imaging is photometry and morphology of galaxies at 0.8 to 5.0 microns to sample a wider wavelength range than with NIRISS to better sample both young and old stellar populations.
3. *NIRSpec Multi-Object R=100 Spectroscopy on the cluster field*. We will follow up the cluster field NIRCam and NIRISS observations with two NIRSpec Micro Shutter Array configurations to target galaxies for which NIRISS does not yield redshifts due to either contamination or a redshift with no emission lines in the NIRISS wavelength range ($5 < z < 7.3$). We will prioritize very high-redshift and multiply-imaged galaxies, some of which are already known based on existing imaging.
4. *NIRISS WFSS on a parallel field.* These NIRISS grism observations will be shallower than those on the cluster field, but will survey a larger volume due

to lower gravitational lensing magnification in the parallel field. The science goals are similar to the NIRISS WFSS on the cluster field, providing a wider range of luminosity at a given redshift.

5. *NIRCam Imaging on a parallel field.* The two science goals for these data are: 1) Determine the distance-dependent properties of galaxies at 3 to 8 arcminutes (1.0 to 2.5 Mpc) from the cores to infall regions of massive strong-lensing clusters. 2) Extend the NIRISS study of extreme emission line galaxies up to z = 8 by using medium-width bands that can be dominated by strong emission lines.

Targets: Abell 370, MACSJ0416.1-2403, MACSJ0417.5-1154, MACSJ1149.6+2223, MACSJ1423.8+2404

DOYON_2000-2016, DOYON_2020-2037, DOYON_2050, DOYON_2100-2116, DOYON_2120-2137, DOYON_2150, DOYON_2200-2216, DOYON_2224-2237, DOYON_2250, DOYON_2300-2316, DOYON_2320-2337, DOYON_2350, DOYON_2400-2416, DOYON_2420-2437, DOYON_2450.

High-redshift Quasars and Galaxy Assembly

NIRCam Observations of z>6 Quasars

We propose to obtain deep NIRCAM LW grism slitless spectroscopy in F356W (with a corresponding direct image) and deep NIRCAM SW direct images in F115W and F200W of roughly 4x4 arcmin^2 mosaicked fields that are centered on a sample of six z > 6 luminous quasars. The F356 R~1000 slitless spectroscopy will yield a complete census of emission line selected galaxies at 5.3 < z < 7.0 for [OIII]4959,5007+Hb (the [OIII] doublet giving an unambiguous line identification) and 3.7 < z < 5.1 for Ha. We expect to measure redshifts down to $AB_{3.5} \sim 26.5$ which will yield an average of at least 20 and 100 detected galaxies per field in these two redshift intervals. The broad-band images that will be obtained with the spectroscopy will provide characterization of these galaxies in terms of their masses and star-formation rates, being largely equivalent to the popular BZK diagnostic at z~2. LILLY_0001-0012

NIRSpec IFU Observations of six z~6 QSOs, their Host Galaxies, and one z=7.51 AGN

We will use the NIRSpec IFU with the R≃100 prism in the PRISM/CLEAR position to get the full spectrum from the restframe Lyα to the restframe Hα wavelength range. The science goals are to: 1) verify the spectra of the neighboring galaxies are also at z≃6, and not in the foreground; and 2) selectively bin along the spectral axis to make line-free continuum images for structural studies (e.g., restframe UV or optical structure). We will use NIRSpec IFU observations of one of the highest redshift AGN candidates FIGS1292. This is a spectroscopically confirmed galaxy at z≃7.51, and currently the most-distant AGN candidate based on a weak *N-V* 1240 line detection in deep G102 WFC3 grism measurements. Based on WFC3 broadband imaging,

there is a possible offset between the Lyα emission line region and the continuum light. We will use NIRSPEC IFU observations to confirm both the offset of the Lyα line from the center, and the presence of *N-V* line, which is a signature of an AGN. If confirmed, this will be the most-distant AGN discovered to date, providing direct observational evidence of the "primitive" super-massive black holes.
WINDHORST_31110, WINDHORST_31111, WINDHORST_32110, WINDHORST_32111, WINDHORST_33110

NIRSpec IFU and NIRCam Observations of Five z > 5 Quasar Host Galaxies

This program will address whether the stars in high-redshift (z > 5) quasar host galaxies have formed along with their super massive black holes or if the stellar populations of the host galaxies are lagging behind the black holes in mass assembly. If the star formation has been rapid enough to support the Magorrian relation, the M/L of the stellar population should be small, and spectroscopy of the integrated quasar/host light with JWST could detect prominent absorption features associated with the stars, e.g., the Balmer break. Another possibility is that the high resolution, PSF stability, and good sensitivity at wavelengths past 2.5 mm will allow detection of the host galaxies as extended halos around the quasars. We will observe five of these sources with the NIRSpec IFU and at R = 1000 to identify absorption features in their spectra. To complement these observations, we will also image with NIRCam in two bands in the 4 mm region and one at 2 mm to identify any extent due to the quasar host galaxies. The longer wavelength should have the most favorable contrast of host galaxy to quasar, assuming that the stellar population has evolved to include red giants/supergiants (as would be expected). The shorter wavelength provides a test of the spectral cubes we will generate from the IFU data. By combining these results, we should be able to estimate stellar masses of the quasar host galaxies and to put rudimentary constraints on their stellar populations.
GRIEKE_1001-1030

Lensed Quasars

The interaction of host spheroid and central black hole will be studied by obtaining NIRCam images and NIRSpec IFU data cubes on 4 multiply imaged QSOs and on their lens galaxies. The main purpose of these observations is to take advantage of the gravitational stretching of the host galaxy to effectively obtain spatially resolved spectroscopic data at higher rest frame angular resolution than otherwise possible. We will also obtain spatially resolved data on the lens galaxy. The spectroscopic data will allow us to determine abundances, abundance ratios, and kinematical information. Targets: SDSSJ1206-4332, WFI 2033-4723, HE 0435-1223, PG 1115+080

STIAVELLI_0011-0022

NIRSpec Galaxy Assembly IFS Survey

The goal of the present IFS observations is to characterize the internal structure of distant galaxies and, therefore, to investigate the primary physical processes driving galaxy evolution across cosmic time. The main specific objectives are: to trace the distribution of star formation, to map the resolved properties of the stellar populations, to trace the gas kinematics (i.e. velocity fields, velocity dispersion) and, hence, determine dynamical masses and also identify non-virial motions (outflow and inflows), to map metallicity gradients and dust extinction. These quantities will be mapped for the brightest and most extended star forming galaxies and AGN/QSO hosts up to z ~7, and beyond. The various sub-samples are drawn from previous optical, near-IR, and sub-mm and mm surveys, and include the following groups:

- The brightest and most extended UV/Opt selected star-forming galaxies with 2 < z < 6: This group includes Lyman Break Galaxies (LBGs) and, in general, galaxies selected from their SEDs in the rest-frame ultraviolet and visible wavelengths. Therefore, they represent a population of galaxies characterized by unobscured star formation. The sample includes 28 targets of this type covering the redshift range 2 < z < 6.
- Luminous sub- millimeter galaxies at z > 4: Two of the selected targets are luminous, dusty, starburst galaxies representative of those discovered and characterized by Spitzer, Herschel and ALMA. These objects are extremely luminous, implying SFRs of the order of 1000 Msun/yr, though most of their star formation is obscured.
- Lyman Alpha Emitters (LAE) at the epoch of reionization: These objects have been proposed to be potentially associated with the formation of Population III stars and with primeval direct-collapse Black Holes, providing the key to understand early galaxy formation, as well the re-ionization of the Universe. The sample includes five of these targets with 6.6 < z < 8.68.
- AGNs and the brightest and most distant QSO hosts: The primary goal is investigating the physics of AGN-driven outflows, as well as the effects onto their host galaxies. These observations will also enable us to investigate more broadly the properties of high-z AGN host galaxies. The sample includes fifteen X-ray selected AGNs with 1.5 < z< 4.7, and some of the most luminous and distant QSOs.

These observations will be carried out with the one or two high-resolution spectral configurations that best cover the main optical emission lines at the redshift of the object. A subset of targets, for which the continuum could be detected at low resolution, will be also observed with the prism (R100) over the 0.6-5.3 micron spectral range. FERRUIT_3000-3056

Cosmic Re-ionization and Metal enrichment from Quasar Spectroscopy

Cosmic re-ionization is one of the key frontiers in astrophysics. The re-ionization process informs on the properties of the ionizing sources in the early epoch of galaxy formation. We will carry out 'blue extended' F070LP/G140H (0.7 to 1.8 microns) R = 2700 NIRSpec fixed-slit spectroscopy of the four most distant quasars known at z > 6.7. These spectra will be free from the atmospheric absorption and sky emission that hampers ground-based observations. The quasar spectra will be used to determine the Lyα absorption properties of the IGM, and hence the hydrogen neutral fraction, by making a range of measurements: IGM mean optical depth, Lyα damping wing, peaks and dark gaps, ionized near-zone size. The same observations will also discover many absorption lines of metals such as oxygen, carbon, silicon, etc. in the IGM. These lines will be used to determine chemical abundances, enrichment and ionization histories and constrain feedback models. The micro-shutter array will be used simultaneously to target galaxies at the quasar redshift or in the foreground to trace the large-scale galaxy distribution. FERRUIT_4000-4004, FERRUIT_4100-4104.

Protogalaxies

We will observe the high redshift radio galaxy TN J1338-1942 that is embedded in a rich proto- cluster at $z \simeq 4.11$. At $z \simeq 4.11$, the NIRCam F182M and F210M filters almost perfectly bracket the Balmer and 4000Å breaks, yielding stellar population ages for > 30 spectroscopically confirmed (Lyα) galaxies at $z \simeq 4.11$. WINDHORST_36110, WINDHORST_36111

Deep Fields

JWST NEP Time-Domain Community Field

The JWST North Ecliptic Pole (NEP) Time-Domain Field (TDF) is located within JWST's northern Continuous Viewing Zone (CVZ), will span ∼14' in diameter as covered with NIRCam (∼10' with coordinated parallel NIRISS slitless G150 grism coverage), and will be roughly circular in shape. It is sampled in this GTO program at 4 distinct orientations with NIRCam –the JWST "windmill". This is the *only* region in the sky where JWST can observe a clean extragalactic deep survey field (free of bright foreground stars and with low Galactic fore- ground extinction A_V) at *arbitrary cadence* or at *arbitrary orientation*. The SEP has no such clean field, because it is largely covered by the LMC. The JWST NEP TDF was selected from an analysis of WISE, 2MASS, and SDSS object counts and of Galactic foreground extinction, and is devoid of objects brighter than m_{AB} = 16 mag that would saturate NIRCam. We have deep (m_{AB} > 26 mag) wide-field (∼23'×25') LBT Ugrz images of this field and its surroundings. Our science requires the time-domain windmill to be completed in Cycle 1.

The availability of a clean JWST TDF is critical, since it enables the community to do a wide range of new and exciting time-domain science, including high redshift transient searches and monitoring (e.g., supernovae; SNe), variability studies from weak AGN to brown dwarf atmospheres, as well as parallaxes for extreme scattered Kuiper Belt and Oort Cloud Objects, and proper motions of nearby Galactic brown dwarfs, low-mass stars, and ultracool white dwarfs. Our goal is to cover a large area with both the NIRCam primary imaging and coordinated NIRISS parallel grism spectroscopy, in addition to creating JWST's most efficient time-domain field over the life-time of the JWST mission. We welcome and encourage follow-up through ERS or GO programs of the initial GTO observations to realize its potential as a JWST time-domain *community field*.

HAMMEL_6001-6011, WINDHORST_11110-11115, WINDHORST_11210-11215, WINDHORST_11310-11315, WINDHORST_11410-11415, WINDHORST_11120-11125, WINDHORST_11220-11225, WINDHORST_11320-11325, WINDHORST_11420-11425

Spitzer/IRAC Dark Field

We will obtain shallow JWST imaging in the reddest NIRCam filters of the Spitzer/IRAC Dark Field (IDF) that has been well studied in the time-domain for the last 14 years to AB < 22 mag. This field can be used to study star-formation in very dusty environments, hidden AGN, and other highly dust-obscured variable objects, such as SNe hidden in ULIRGs, providing JWST's exquisite resolution to the wide wavelength coverage and long time baseline of the data in their field to aid interpretation of the variable objects detected therein.

WINDHORST_12110-12111, WINDHORST_13110-13113,

GOODS-S and HUDF

We plan a MIRI multi-band survey in the GOODS-S/HUDF region, covering about 30 square arcmin and using all the broad MIRI imaging bands. Selected galaxies from this survey will be observed with NIRSpec at R = 1000 and from 1 to 5.2 mm. We will model the photometry to separate AGNs from star forming galaxies. We expect to find 30 - 40 AGN of known types and detected at 10:1 signal to noise or higher at 21 mm. We will additionally identify any previously unknown obscured AGNs, and with the deep X-ray, optical and radio data in the same field should obtain a complete sample of these objects. This same survey will provide high quality measurements of some 2000 star forming galaxies. We will compare star formation rates determined from X-rays, hydrogen recombination lines, UV, radio, and mid-infrared to calibrate these indicators at z = 2. We will also use the spectra with NIRSpec to estimate metallicities and study the dependence of the aromatic bands and other properties of the galaxies on this parameter. Together these measurements will let us determine accurate SFR densities, luminosity functions, and other parameters relevant to galaxy evolution. GRIEKE_4001-4011

MIRI HUDF Deep Imaging Survey

Since the very beginning of the JWST project, one of the top priority scientific themes has been 'Galaxy formation and evolution in the early Universe'. One of the fundamental questions to solve in this context is how the Epoch of Reionization (EoR) developed from $z \sim 1100$ to $z \sim 6$ and what kind sources are responsible for the emission of the necessary ionizing photons. Most likely, the main contributors to the reionization are intrinsically faint star forming galaxies, so faint that they have been below the detection limits of previous instruments.

With unique sensitivity above 5 μm, MIRI will play an important role in studying the different phases of EoR and the earliest phases in galaxy formation. With MIRI photometry, it will be possible for the first time to get: 1) an unbiased estimate of the total stellar masses in objects with $z > 4$; 2) determine masses and ages of the young and old stellar populations in objects with z>8.5, exploiting clean measurements of the Balmer Break, and thus providing robust estimations of the Star Formation History for sources in the EoR; 3) with the 5.6 μm filter, MIRI will be the only instrument onboard JWST which will be able to study the Hα emission line for sources with z ~ 7.5 and the Hβ + [OIII] lines for sources with z ~ 10. Our approach to a photometric and statistical study of galaxy evolution using MIRI is two fold: this deep imaging study at a single pointing on the HUDF using the 5.6μm filter and deep 10μm images of the cosmological fields of the galaxies selected for study in the high redshift spectroscopy part of our GTO program.

This 5.6μm imaging survey in the HUDF will allow us to extend the Galaxy Stellar Mass Function (GSMF) by another order of magnitude in stellar mass compared to current work, down to completeness limits of $3x10^8$ M_{Sun} at z = 3, and ~10^9 M_{Sun} at z = 6 - 7, and find several tens of smaller mass galaxies at these redshifts. Moreover, it will allow us for the first time to meaningfully constrain the GSMF for 7<z<10. MIRI deep observations will have a unique role for tracing the rest-frame optical and near-IR light of galaxies at 7<z< 10 and thus constrain galaxy formation models. At z=10, the role of the MIRI photometry becomes crucial, as at these redshifts no NIRCam filter can trace the galaxy light beyond the 4000 Å break. At the spatial resolution of the MIRI imager, most forming galaxies at z>6 and well into the reionization epoch will be resolved, or, if unresolved, tight upper limits on their sizes will be placed. MIRI will investigate the location of the bulk of stars formed from the initial star formation episode. The survey will also play an important role in selecting obscured AGNs. WRIGHT_9001, WRIGHT_9012-9013, WRIGHT_9022-9030

NIRCam-NIRSpec galaxy assembly imaging and spectroscopy in CANDELS

The NIRCam and NIRSpec GTO teams will conduct an ambitious galaxy assembly survey to study the formation and evolution of galaxies from z ≥ 12 to z ~ 2 and below.

The first part of the program is a two-tier survey ('deep' and 'medium'), which combines NIRSpec, NIRCam, and MIRI data, alongside the deepest data from HST, Chandra, ALMA, and JVLA, to produce an unprecedented view of high-redshift galaxies. The program is a collaboration of the NIRSpec and NIRCam GTO teams, and it combines imaging and spectroscopy as well as full use of coordinated parallel observations to get the best out of all three JWST instruments. Indeed, to pursue a detailed understanding of galaxy evolution, the combination of imaging and spectroscopy is critical. By bringing these data sets together on a single field, we will carry out systematic investigations far beyond the sum of the parts.

Each of the two tiers includes at least 9 bands of NIRCam imaging as well as spectroscopy from 0.7–5.2μm at resolutions R = 100–2700. This is complemented by deep MIRI parallel pointings at 7.7 and 12.8 μm.

The Deep survey will cover 46 arcmin2, centered on the HUDF/GOODS-S, with NIRCam imaging to a limit of AB=29.8 (10-σ point source) and a peak exposure time of 120 ksec in F115W. We will conduct two NIRSpec pointings with total integration of 200 ksec each, with an emphasis on z>6 galaxies; the first will be centered on the HUDF and will use pre-flight targets, the second will be based on the NIRCam imaging.

The Medium survey will cover another 190 arcmin2, in both GOODS-S and GOODS-N, with NIRCam imaging to a limit of AB=28.8 (10-σ point source) and with MIRI imaging of 14 arcmin2, reaching AB=26.7 in F770W in 8 arcmin2. We will conduct 12 NIRSpec pointings (43 ksec each, total over the gratings) targeted from JWST imaging, and 12 NIRSpec pointings (13 ksec each) targeted from pre-flight imaging, notably CANDELS. These will provide over 5000 spectra of faint galaxies, including many on the deeper imaging.

The second part of the program is a WIDE MOS survey. This fast tiling of the sky opens up an observational discovery space that is unattainable by any other observing facility. Trying to strike a good balance between exposure time and overheads, the WIDE MOS survey will cover 35 pointings (~270 arcmin2), with the low resolution CLEAR/PRISM configuration (~2.7 ks = 50 min integration) and two of the high-resolution configurations, F170LP/G235H and F290LP/G395H (~1.8 ks = 30 min integrations each). The source selection strategy of the survey relies exclusively on existing photometry making target selection straightforward.

This program will provide continuum spectra for all sources in the targeted CANDELS fields with m_{F160W} < 24.0 mag (AB) and z_{phot} > 1.5 (at R100 ~50 objects per field of view); emission line spectra (at R=100 and R2700 ~250 objects per field of view) for all objects with SED-expected Hα-emission lines fluxes $f_{H\alpha}$ > 10-17 ergs/s/cm2 (corresponding to star formation rates of 6 Msun/yr at z~3). The main science drivers are: 1) a survey of 1-5μm stellar continua at 10x higher resolution than photometry affords, constraining and calibrating SFR's and stellar population ages, 2) a comprehensive 1-5 μm survey of emission lines, to characterize the emission line properties (SFR, excitation and possibly [Fe/H]) of galaxies (mostly at z>4), and 3) to systematically explore the population incidence of ionized gas outflows and kinematics of galaxies over a large range of properties and redshifts. This survey is also an excellent (and possibly rapid) legacy data set for follow-up by the GTO team and the community.

FERRUIT_0100-0106, FERRUIT_0600-0606, FERRUIT_1050-1058, FERRUIT_1060-1068, FERRUIT_1070-1078, FERRUIT_1080-1088, FERRUIT_1090-1098, FERRUIT_1100-1108, FERRUIT_1110-1118, FERRUIT_1120-1128, FERRUIT_1130-1138, FERRUIT_1140-1148, FERRUIT_1150-1158, FERRUIT_1160-1168, FERRUIT_0001, FERRUIT_0500, FERRUIT_1000-1011, FERRUIT_2000-2034, MRIEKE_0001-0144, MRIEKE_0301-0348, MRIEKE_0441-0535

Spectroscopy of High Redshift objects in the early universe

MIRI, with its spectral coverage from 5 to 28 mm and sensitivity, is the only instrument onboard JWST that is able to detect the Ha emission line in galaxies and QSOs at redshifts above 6.7. This is a key diagnostic line to establish the instantaneous star formation, and the ionizing continuum escape fractions for sources during the Epoch of Reionization (EoR) of the universe. The combination of spectral coverage and sub-arcsec integral field spectroscopy (IFS), also makes MIRI a unique instrument to peer into the dust-enshrouded phase of IR-luminous star-forming galaxies (DSFG) at high redshifts. MIRI will provide the first direct sub-arcsec view ever at the (rest-frame) near-infrared light distribution of the evolved stellar population, ionized and hot molecular gas phase in z~2-6 massive DSFGs, and therefore will investigate the physical processes of the obscured star formation and black hole growth in massive star-forming galaxies (SFR of 100 Msun/yr, or above) in the early universe. The MIRI-EC team plans, in coordination with the NIRSpec team, integral field spectroscopic observations of a small sample of prototypical high-z objects, including spectroscopically confirmed Lya emitters (LAE) at redshifts between 7 and 9, most distant QSO known, and luminous Dusty Star Forming Galaxies at redshifts 4 to 6. Simultaneous MIRI images of the host galaxies surrounding fields with the MIRI imager (MIRIM) and F1000W filter will provide the deepest sub-arcsec images (AB ~ 25-25.5) ever taken of cosmological fields at 10 microns over areas of 2.3 arcmin^2, giving the opportunity of detecting very red sources in the early universe, i.e. candidates to AGNs, evolved stellar populations and dusty star-forming galaxies. This imaging complements the GTO MIRI imaging in the HUDF. The programme is coordinated with the NIRSpec team.

WRIGHT_0101-0102, WRIGHT_0201-0204, WRIGHT_0301-0308, WRIGHT_0401-0403, WRIGHT_0501-0502, WRIGHT_0601-0602