JWST

The telescope operates from 0.6 to 25um, is diffraction limited beyond 1.6um.

Imaging and spectroscopic instruments, pixel scales matched to wavelength.

Include slit and integral field spectrographs, coronagraphs, sparse aperture masks capability

Launched on Christmas Day 2021, and now making Early Science, Guaranteed Time and Cycle 1 observations

Launch was near perfect, so minimal fuel was needed to place satellite into L2 orbit.

Anticipated lifetime is 10+ years and up to 20 years, but this may not be the limit on lifetime….

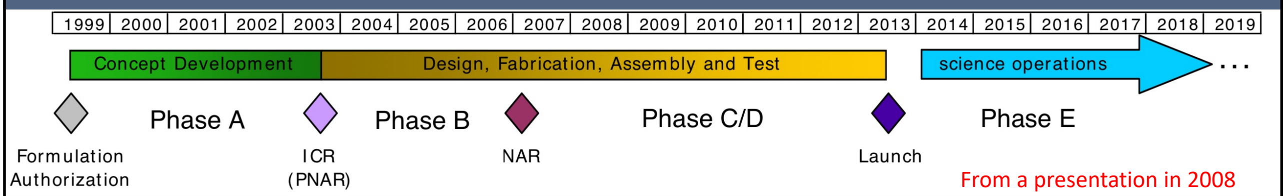
Calibration and full understanding of system is ongoing.

Data reduction pipelines are being updated to deal with data obtained and measured backgrounds.

1

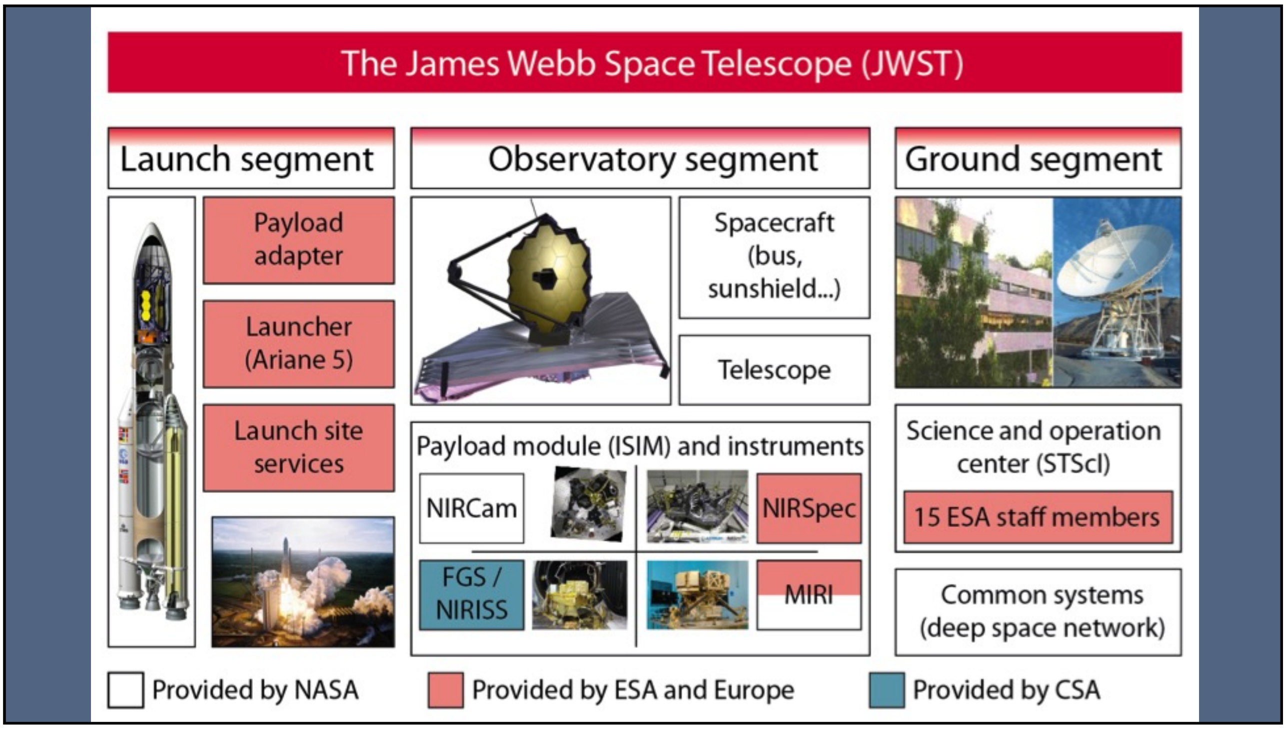
The most ambitious and complex mission

- Conceived in the days when NASA would do things:
- 1990s Better, Faster, Cheaper → Next Generation Space Telescope
- More detailed design increased the budget and timescale
- 2002 NGST renamed JWST and moved to Phase B



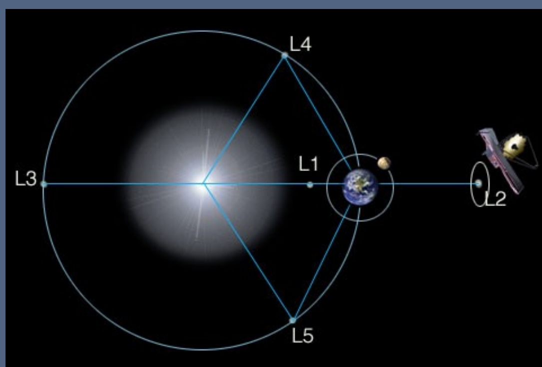
The 2010 Casani review found that the budget was 'badly flawed'
Launch date no sooner than September 2015, and cost of $6.5B

2



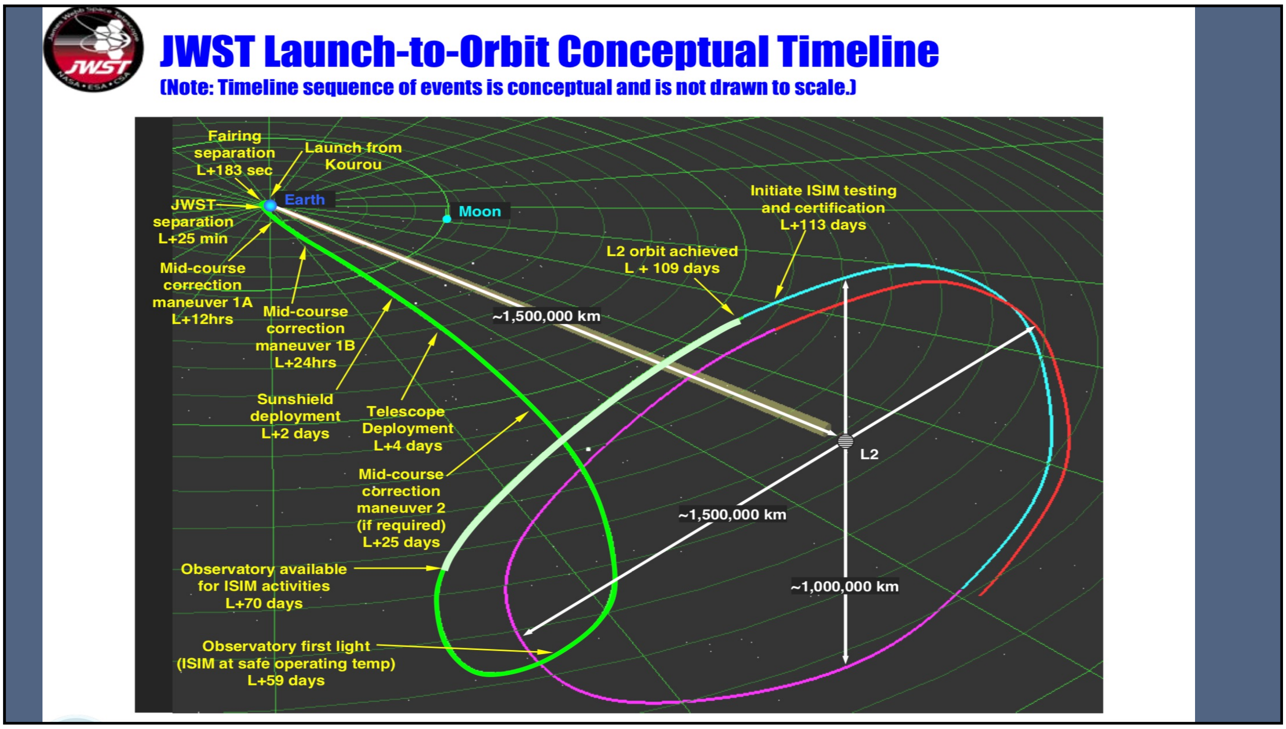
3

JWST   L2 orbit

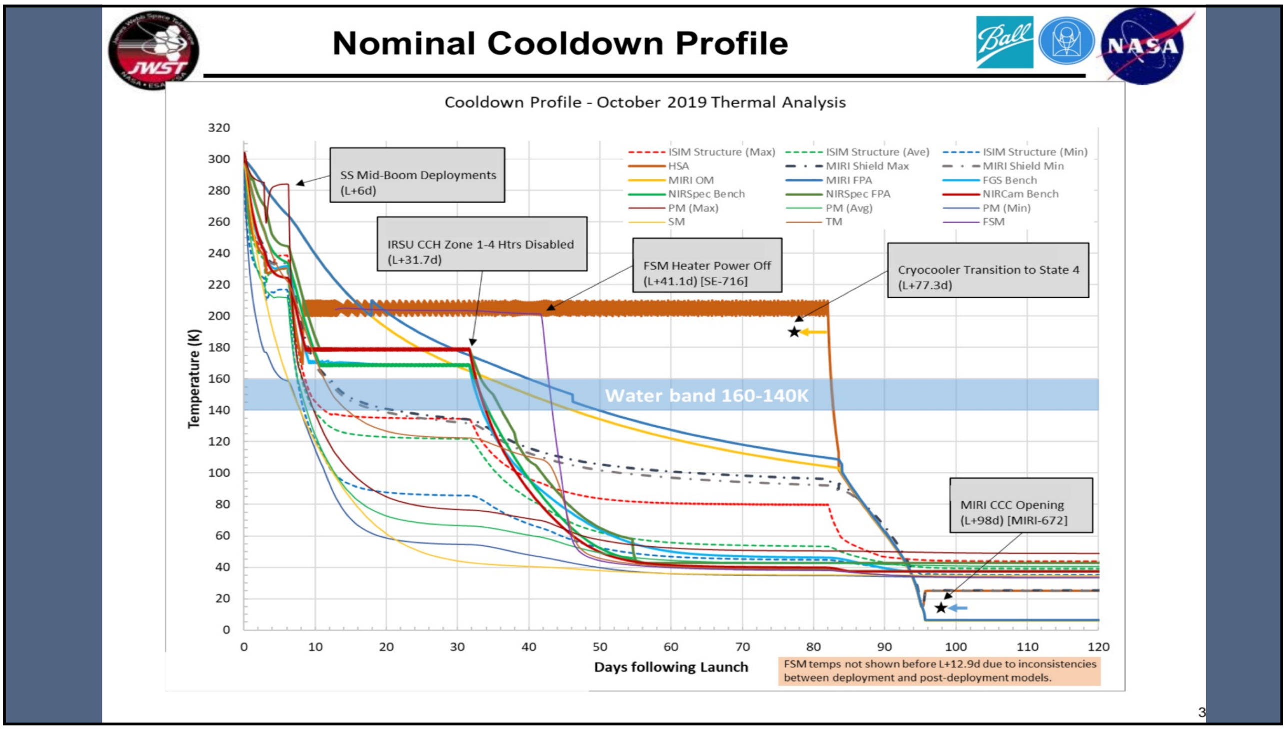


JWST circles around the 2nd Lagrangian point, 1.5 million km distant, keeping out of the Earth and moon shadow for thermal stability and allowing continuous observing and communication with Earth
The sunshade shields thermal emission from Sun, Earth, Moon

4


JWST Launch-to-Orbit Conceptual Timeline
(Note: Timeline sequence of events is conceptual and is not drawn to scale.)
Fairing separation L+183 sec
Launch from Kourou
Earth
Moon
JWST separation L+25 min
Mid-course correction maneuver 1A L+12hrs
Mid-course correction maneuver 1B L+24hrs
Sunshield deployment L+2 days
Telescope Deployment L+4 days
Mid-course correction maneuver 2 (if required) L+25 days
Observatory available for ISIM activities L+70 days
Observatory first light (ISIM at safe operating temp) L+59 days
~1,500,000 km
L2 orbit achieved L + 109 days
Initiate ISIM testing and certification L+113 days
L2
~1,500,000 km
~1,000,000 km

5


Nominal Cooldown Profile
Cooldown Profile - October 2019 Thermal Analysis
ISIM Structure (Max)
ISIM Structure (Ave)
ISIM Structure (Min)
HSA
MIRI Shield Max
MIRI Shield Min
MIRI OM
MIRI FPA
FGS Bench
NIRSpec Bench
NIRSpec FPA
NIRCam Bench
PM (Max)
PM (Avg)
PM (Min)
SM
TM
FSM
SS Mid-Boom Deployments (L+6d)
IRSU CCH Zone 1-4 Htrs Disabled (L+31.7d)
FSM Heater Power Off (L+41.1d) [SE-716]
Cryocooler Transition to State 4 (L+77.3d)
Water band 160-140K
MIRI CCC Opening (L+98d) [MIRI-672]
Temperature (K)
Days following Launch
FSM temps not shown before L+12.9d due to inconsistencies between deployment and post-deployment models.
3

6

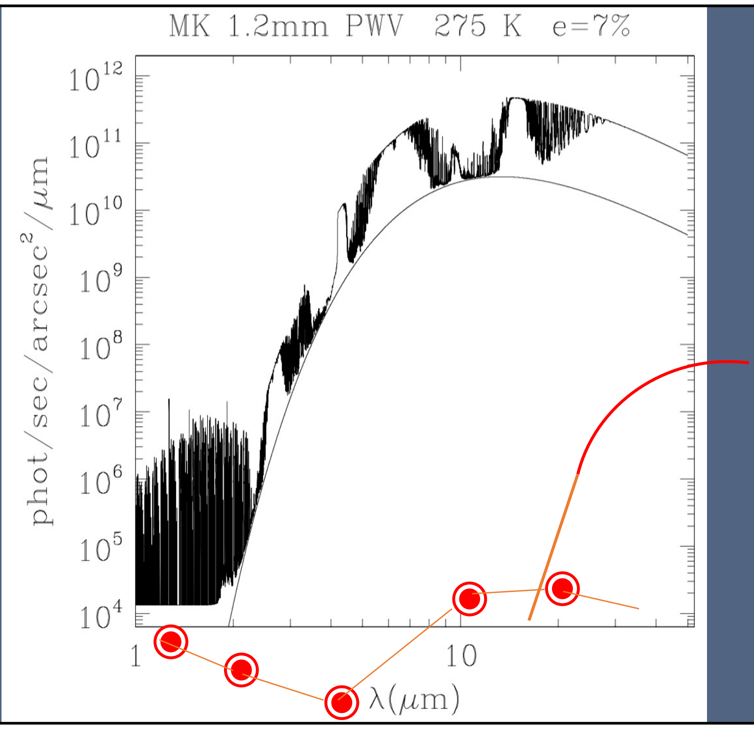
IR Background

JWST is passively cooled with a predicted equilibrium temperature <50K, depending on spacecraft attitude.

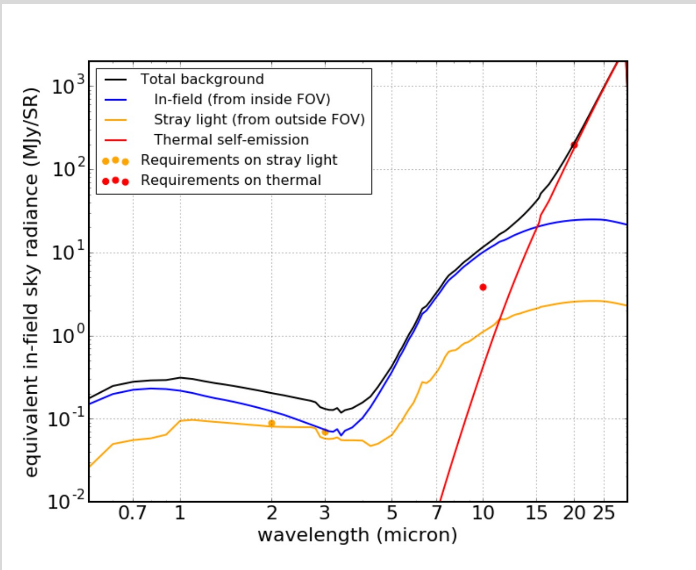
The secondary has less thermal load and has T<30K, but M1 mirror segments are warmer.

With T(eff)~40K, the peak of the thermal emission is 7x longer than a terrestrial telescope with much less power (~T^4).

The photon background from the ZL at L2 is indicated by ◉



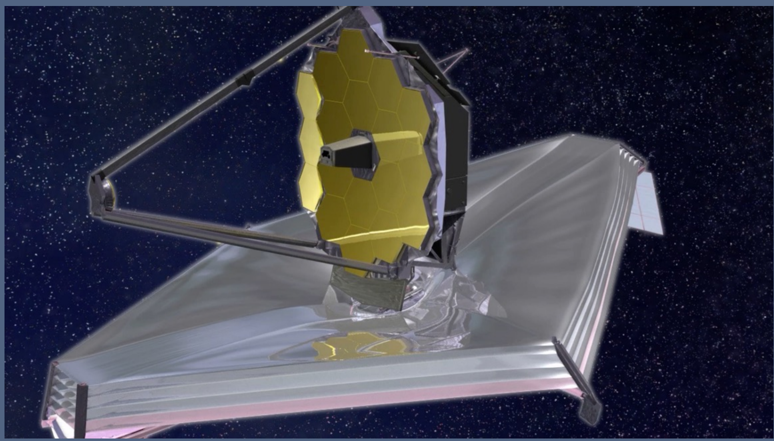
7



This example is for the benchmark pointing (ecliptic Long, Lat = 266.3°, −50.0°, RA, Dec (J2000) =$17^h26^m44^s$ −73°19′56″), chosen to have a zodiacal emission that is 20% higher than the celestial minimum, and to be a stressing case for stray light. In this example, in-field emission from the zodiacal cloud and the Milky Way (blue curve) dominates the background for most wavelengths below 15 μm. At longer wavelengths, thermal emission from JWST itself (red curve) is the dominant source of background. Stray light (yellow curve) results from zodiacal and Milky Way emission scattered into the field of view, and is a significant fraction of the total background, particularly at 1 to 4 μm. The sum of all these emission components is the total background (black curve).

8

JWST Deployment



9

James Webb Space Telescope

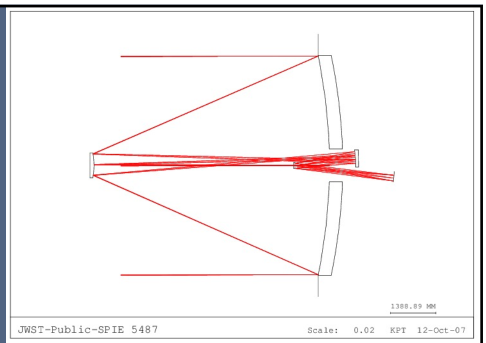
6.5m diameter telescope: M1 has 18 hexagonal beryllium segments folded into rocket nosecone

Optical surface polish 14nm RMS

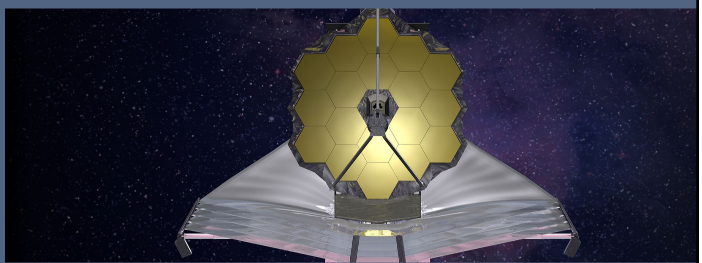
L2 orbit where telescope cools radiatively to 40K, protected by a large sunshield

Secondary mirror supported by a tripod on struts

Three mirror anastigmat (TMA) design, f/16.7, 29.4 m^2 collecting area



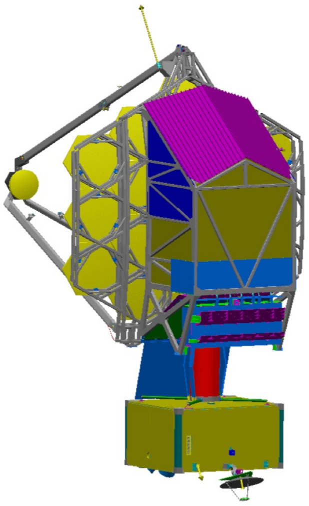
Elliptical **f/1.2 Primary Mirror**
Hyperbolic **Secondary Mirror creates f/9 intermediate image**
Elliptical **Tertiary Mirror images pupil at**
Flat **Fine Steering Mirror which sends beam to instruments**



10

The science payload is integrated to avoid duplication of common science instrument systems

ISIM is:
- **The JWST Science Instruments**
- **Associated Infrastructure: Structure, C&DH, & FSW**



Region 1
Science Instrument Optics Assemblies
- ***Near Infrared Camera (NIRCam)***
- ***Near Infrared Spectrograph (NIRSpec)***
- ***Mid Infrared Instrument (MIRI)***
- ***Fine Guidance Sensor and Tunable Filter (FGS/TF)***

Optical Bench Structure
Radiators and support structure (NGST-supplied)

Region 2
Focal Plane Electronics (FPE)
Instrument Control Electronics (ICE, MCE)
ISIM Remote Services Unit (IRSU)

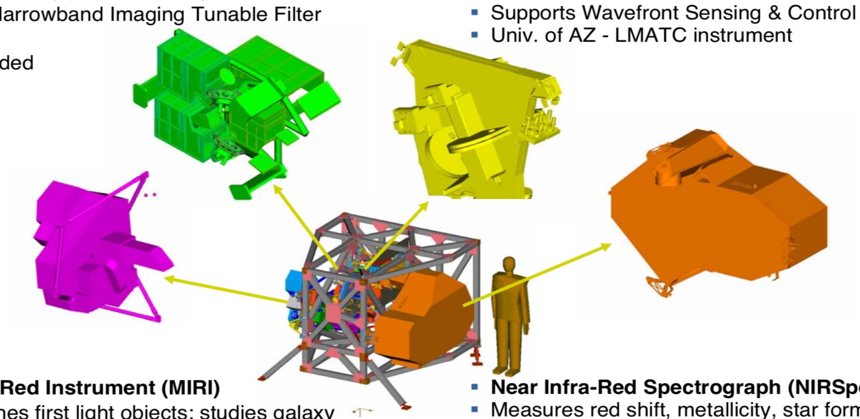
Region 3
ISIM Command & Data Handling (ICDH) Electronics
MIRI Cryocooler Electronics

11

Instrument Overview

- **Fine Guidance Sensor (FGS)**
- Ensures guide star availability with >95% probability at any point in the sky
- Includes Narrowband Imaging Tunable Filter Module
- CSA provided

- **Near Infra-Red Camera (NIRCam)**
- Detects first light galaxies and observes galaxy assembly sequence
- 0.6 to 5 microns
- Supports Wavefront Sensing & Control
- Univ. of AZ - LMATC instrument



- **Mid-Infra-Red Instrument (MIRI)**
- Distinguishes first light objects; studies galaxy evolution; explores protostars & their environs
- Imaging and spectroscopy capability
- 5 to 27 microns
- Cooled to 7K by Cyro-cooler
- Combined ESA/JPL contributions

- **Near Infra-Red Spectrograph (NIRSpec)**
- Measures red shift, metallicity, star formation rate in first light galaxies
- 0.6 to 5 microns
- Simultaneous spectra of >100 objects
- Resolving powers of ~100 and ~1000
- ESA provided with NASA Detectors & Micro shutter

12

JWST Constraints

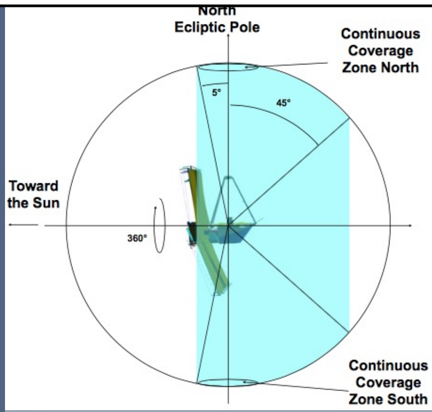
Orbit at L2, provides thermal stability

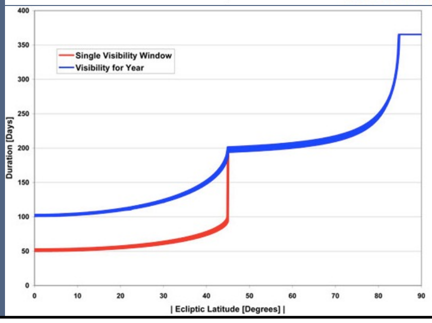
The sunshield provides at least 39% sky coverage

'Field of Regard' is the observable cone allowed by the requirement to keep the telescope in shade. It is an annulus with rotational symmetry about the L2-Sun axis, 50° wide

The telescope has full sky coverage over a sidereal year

Maximum object observability is near the ecliptic poles

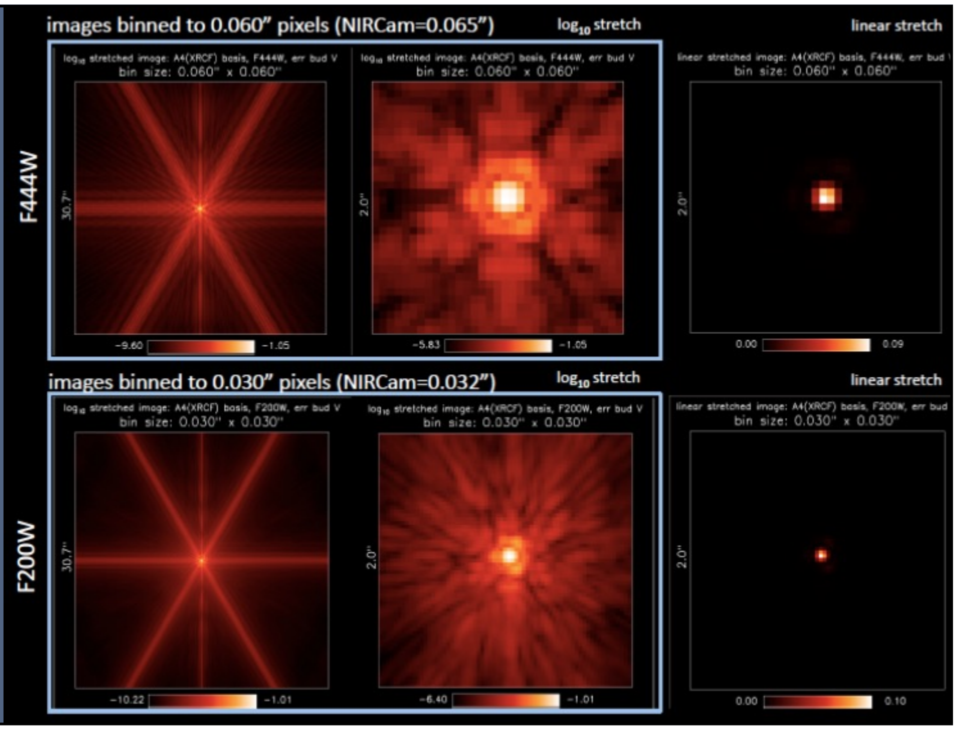




13

These simulated, pre-launch images show diffraction spikes from secondary support struts and print through from hexagonal segment gaps and phase shifts

In-flight performance generally exceeds expectations



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NIRCAM U Arizona + Lockheed Martin

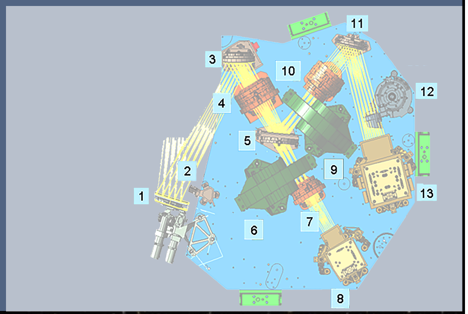
Near Infrared Camera (NIRCam)

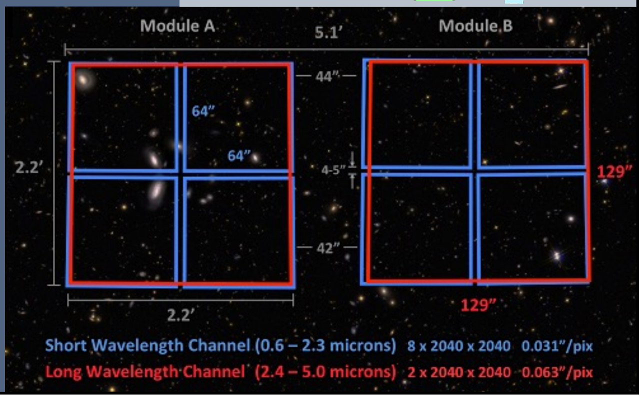
At a Glance:

	Short Wavelength Channel	Long Wavelength Channel
Wavelength Range	0.6 – 2.3 µm	2.4 – 5.0 µm
Nyquist Wavelength	2.0 µm	4.0 µm
Fields of View *	2 × 2.2' × 2.2' (with 4-5" gaps)	2 × 2.2' × 2.2'
Imaging Pixels	8 × 2040 × 2040 pixels	2 × 2040 × 2040 pixels
Pixel Scale	0.032" / pixel	0.065" / pixel
Grism Slitless Spectroscopy	(wavefront sensing across mirror edges)	R = 1400 – 1800
Coronagraphy occulters + Lyot stops	round: 2.1 µm bar: 1.8 – 2.2 µm	round: 3.35, 4.3 µm bar: 2.8 – 5.0 µm

* Two modules image adjacent fields in both channels simultaneously.

Teledyne HgCdTe H2RG detectors
Full frames are read out non-destructively every 10.74 seconds
Smallest subarray 64×64 read out in 49 ms (shortest exposure time)



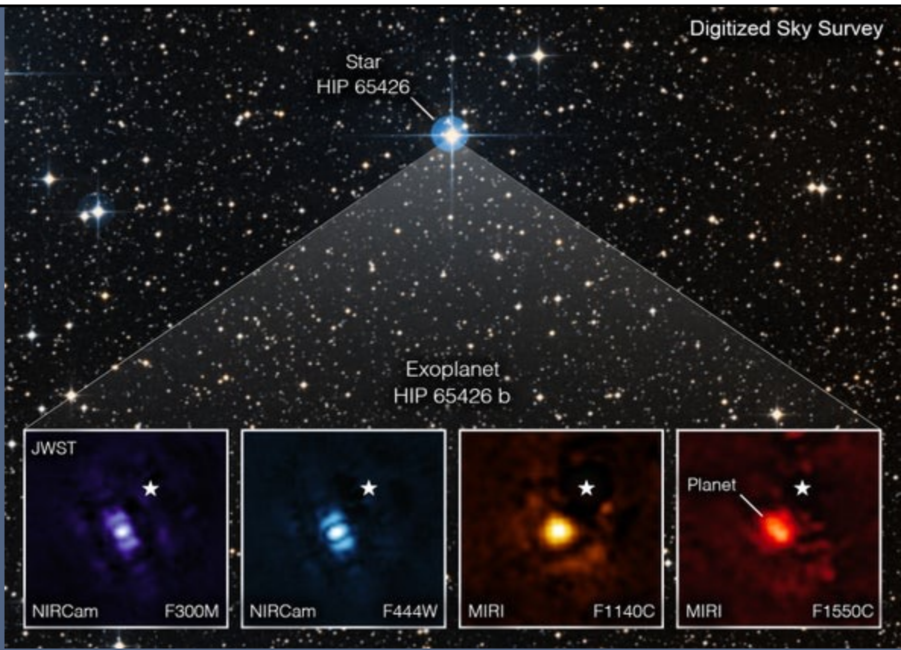


http://ircamera.as.arizona.edu/nircam/in_instrument_overview.php#

15

Image produced from HST (blue) and JWST of a foreground spiral overlapping a background galaxy

16



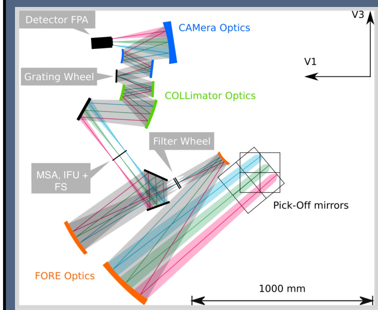
NIRCAM and MIRI coronagraphic images of HIP 65426 b   L-R filters: 3.0, 4.4, 11.4, 14.4 um

The position of the host star, suppressed by coronagraphs is indicated by * The planet separation is ~100AU

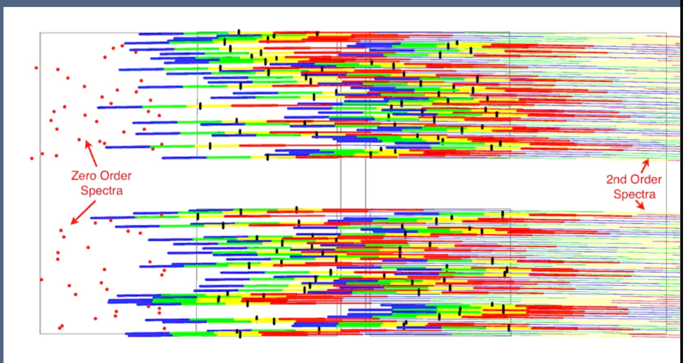
17

NIRSPEC   Near – IR spectrograph offering:

- 0.6µm < λ <5.3µm
- R ~ 100, 1000, 2700
- Micro Shutter Assembly multi-object spectroscopy over 3 arcmin field
  - Up to 100 objects measured simultaneously via 250,000 microshutter mirrors
- Slit spectroscopy fixed slit widths
  - 0.2, 0.4 1.6 arcsec
- Integral Field spectroscopy
  - 3 x 3 arc sec fov, 0.1 arcsec sampling
- with 3 settings for complete coverage



A detailed schematic of NIRSpec's optical path, drawn to scale, with the major optical elements and their positions labeled. The aperture plane is shown as "MSA, IFU + FS". Arrows show the direction of the V1 and V3 coordinate axes.



This figure shows the R~1000 spectra with an arbitrary configuration of open MSA shutters. In the R~1000 and R~2700 modes, the NIRSpec science spectra are produced in the first order of the gratings. For some of these spectra, orders other than the nominal fall onto the detector, as illustrated in the figure above. The second order simply overlaps with the red extension of the science spectrum (which is always present because of the long-pass filters). However, because of its brightness, the undispersed, "white light", zeroth order can potentially compromise the quality of some science data, as seen on the left-hand side of the figure.

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NIRSPEC transit spectroscopy of WASP39B

E.M. Ahrer et al 2022

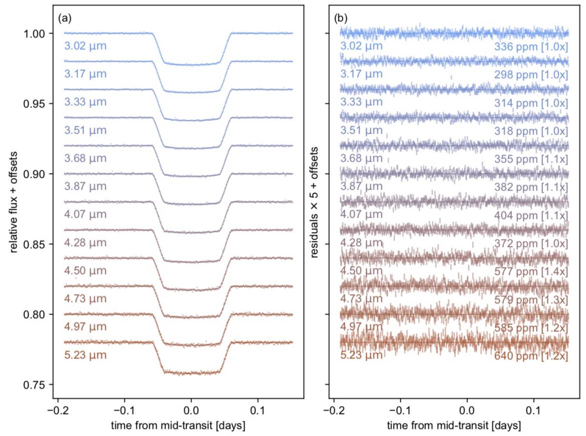

Figure 1: JWST NIRSpec time-series data for WASP-39b. a) Spectroscopic light curves for WASP-39b's transit with a spectral resolving power of 20 and a time cadence of 1 minute (data are binned and offset vertically for display purposes only). An exoplanet light curve model was fitted to the data using a quadratic limb darkening law with an exponential ramp and a quadratic function of time removed. b) Residuals of the binned light curve after subtracting the transit model scaled up by a factor of five to show the structure. The RMS of the residuals are given in units of ppm. The numbers in brackets are the ratio of the RMS to the predicted photon-limited noise.

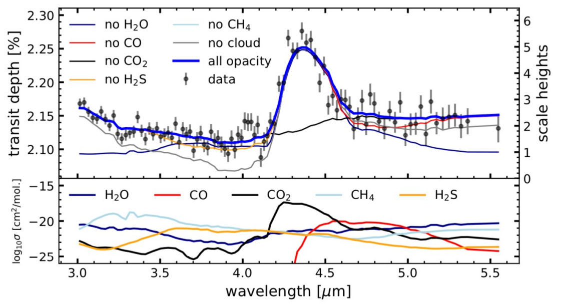

Figure 3: Interpretation of WASP-39b's transmission spectrum. The top panel shows a comparison of the FIREFLy reduction to the best-fit ScCHIMERA theoretical model binned to the resolution of the data (blue curve, see Methods). The key parameters of the model are 10x solar metallicity, carbon-to-oxygen ratio of 0.35, and cloud opacity of 7x10^{-3} cm^2/g. The impact of the opacity sources expected from thermochemical equilibrium over the full bandpass are indicated by removing the opacity contribution from individual gasses one at a time. As in Figure 2, the axis on the right shows equivalent scale heights in WASP-39b's atmosphere. The bottom panel shows the molecular absorption cross-sections for each gas in the best-fit model. The model is well matched to the data (χ^2/N_{data}=1.3), suggesting that our assumptions broadly capture the important physics and chemistry in WASP-39b's atmosphere. However, there is a feature near 4.0 μm that cannot be reproduced by the models used here. The strong CO_2 absorption (4.1 - 4.6 μm) and the apparent lack of methane (3.0 - 3.5 μm) is what drives the solution to an elevated atmospheric metal enrichment, ruling out previous low metallicity estimates[29-31]. The other

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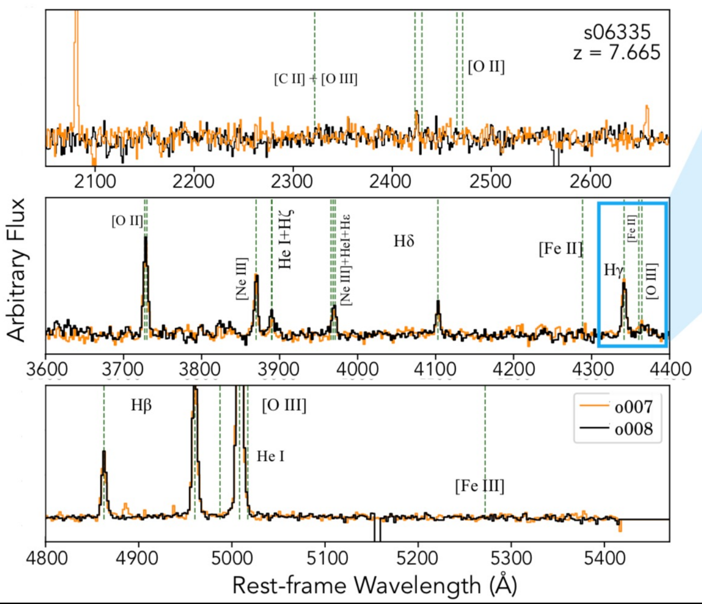
NIRSPEC spectra of lensed galaxies

K.Z. ARELLANO-CÓRDOVA et al 2022

- MSA spectra of galaxies in the SMACS J0723.3-732 cluster field
- Z ~ 7-8
- Spectra from 1.7-5um
- Estimates of :
  - Redshift
  - Extinction,
  - Abundances C,O,Ne
  - Nebular properties Te, ne
- Calibrations ongoing



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MIRI Mid-Infrared Imager/Spectrometer

Imaging: 74 x 113 arcsec fov

- sampled at 0.11 arc sec/pixel
- 5-28um with 9 broad band filters
- Quadrant Phase and Lyot Coronagraphs at 10 - 23 um

Spectroscopy :

Low resolution (R~100) at 5-12um, slit or slitless

Medium Resolution (R ~2000- 3000)

- Covered by 4 IFUs with 3 grating settings for complete coverage
- Currently paused pending investigation of an ‘anomaly’

Garcia Bernete et al 2022

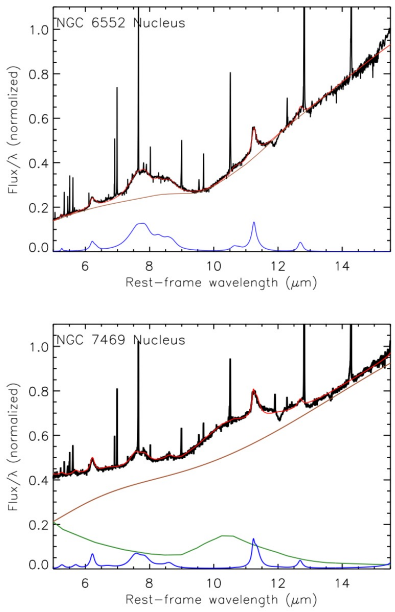

Fig. C.1. Mid-IR spectral modelling of the nuclear regions of NGC 6552 (top panel) and NGC 7469 (bottom panel) using PAHFIT. The JWST/MRS rest-frame spectra and model fits correspond to the solid black and red lines. We show the continuum (solid brown lines) and the fitted PAH features (solid blue lines). The silicate feature in emission (solid green line) is included for the fit of NGC 7469.

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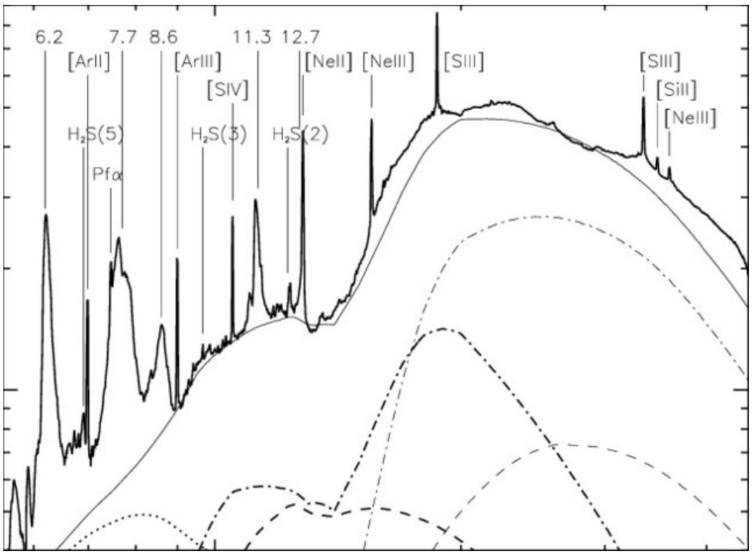


Figure

Caption

Fig. 4. SWS spectrum in the Orion nebula at the position shown in Fig. 2. A fit to the spectrum (see Sect. 3 for details) is shown which uses amorphous astronomical silicate (130 K: bold dashed-dotted, and 80 K: light dashed-dotted), amorphous carbon (155 K: bold dashed, and 85 K: light dashed), and amorphous carbon VSGs (300 K: dotted). The total calculated spectrum is given by the thin solid line. The identification of the strongest spectral features is indicated.

22

Early Science Release observations

Galaxy Gluster SMACS 0723-73, z=0.39

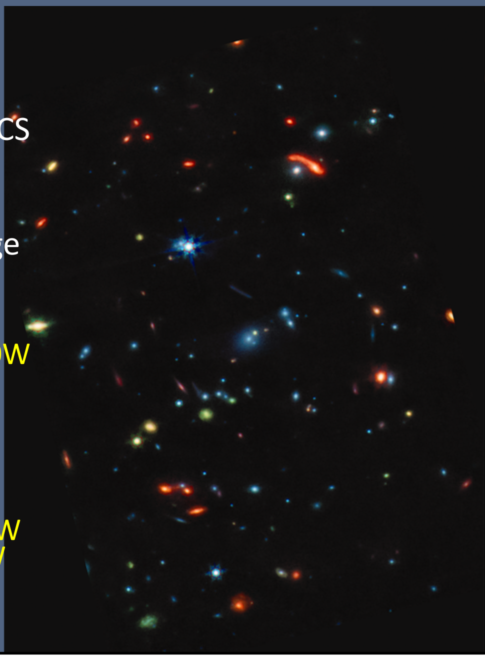
Left: MIRI image

Right: NIRCAM image

Filters:

MIRI:
Red: F1280W + F1800W
Green: F1130W
Blue: F770W

NIRCam:
Red: F444W
Orange: F356W
Green: F200W +F277W
Blue: F090W + F150W



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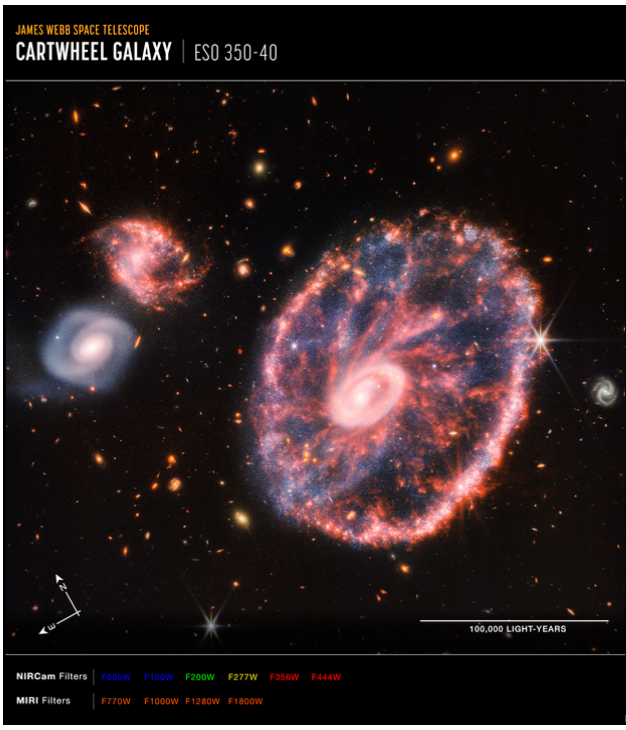

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MIRI Image of Wolf-Rayet 140.
17 concentric dust shells imaged at 7.7, 15, 21 um.

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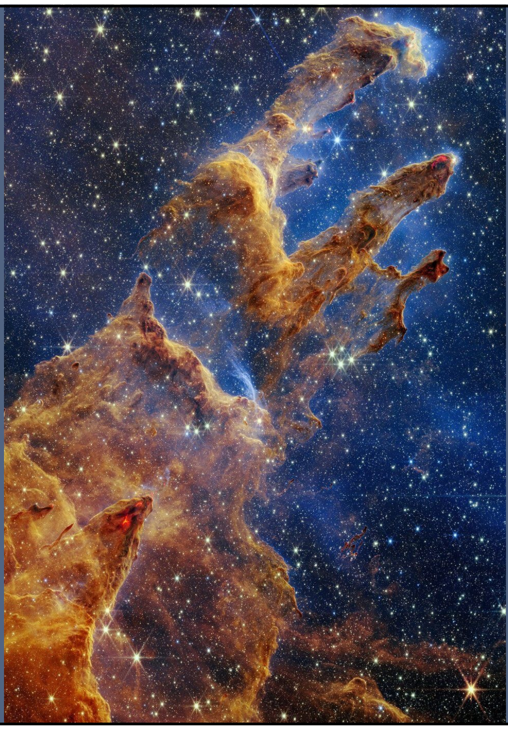

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Near-IR Imager and Slitless Spectrometer NIRISS

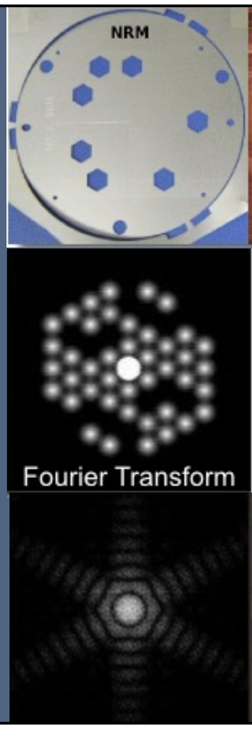
2k HgCdTe detector providing:

- 0.8 – 5um imaging over 133 x 133 arcsec field and 0.8 – 2.2um low resolution (R~ 150) slitless spectrometer with grisms or single object.

Highest resolution imaging will be obtained with the Aperture Masking Interferometer (AMI).

Non Redundant Masks in the telescope pupil plane combine to provide spatial resolution of ~0.5 λ/D at 3 -5 μm.

- Particularly useful for exploration of the inner regions of stars inside the coronagraph working limit with a 5 arcsec field.



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JWST commissioning and first science from a UK perspective

Credit: NASA, ESA, CSA, and STScI

Start Date
Fri, 11/11/2022 - 10:30
End Date
Fri, 11/11/2022 - 15:35

09
NOV

Time
6:00pm

shot

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