Overview of JWST and its GTO programs on star and planet formation

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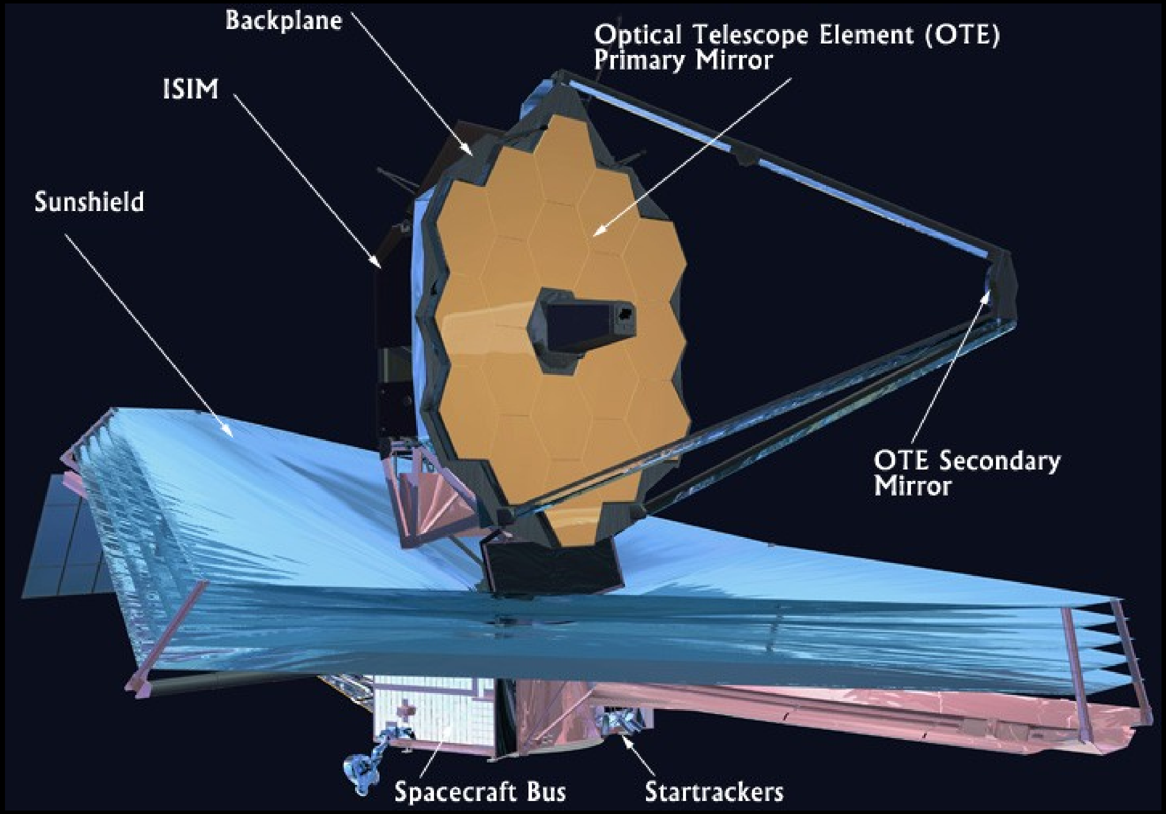
European Research Council
Established by the European Commission

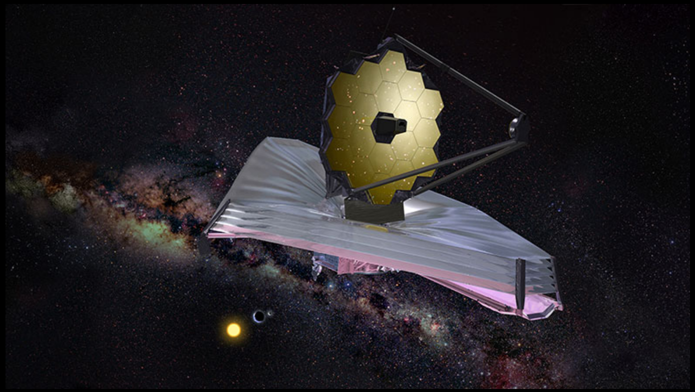
JWST at a Glance

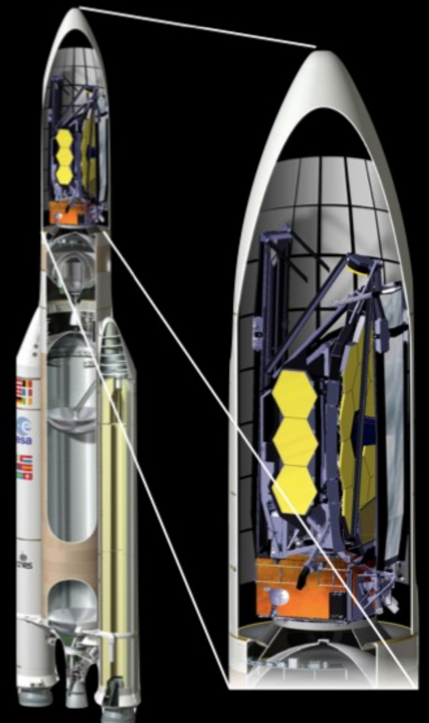


- Largest space telescope ever built
- 6.5m Diameter Segmented Primary Mirror
- Infrared Optimized Telescope (0.6 – 28 μm)
- 4 Instruments (NIRCam, NIRSpec, NIRISS, MIRI)
- Passively Cooled to ~ 40K (NIRCam, NIRSpec, NIRISS)
- MIRI Cooled to 7K

The JWST Mission

- JWST is a collaboration between NASA, ESA and CSA
  - Europe is guaranteed a minimum of 15% of the observing time
- Mission Lead: Goddard Space Flight Center
- Operations: Space Telescope Science Institute
- Launch May 2020 (?)
- Will be placed in an L2 orbit
- Mission Lifetime ~ 10 years

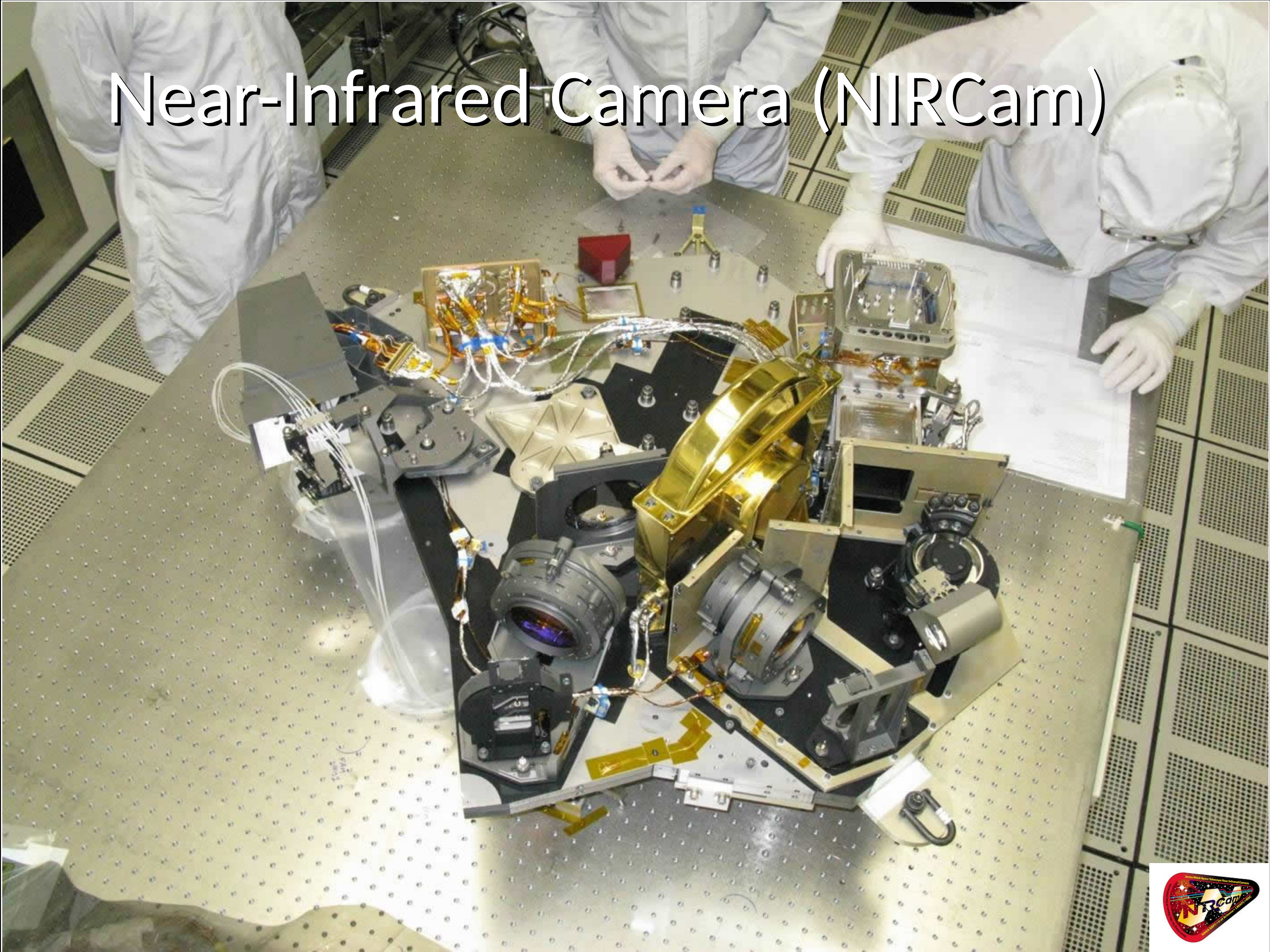




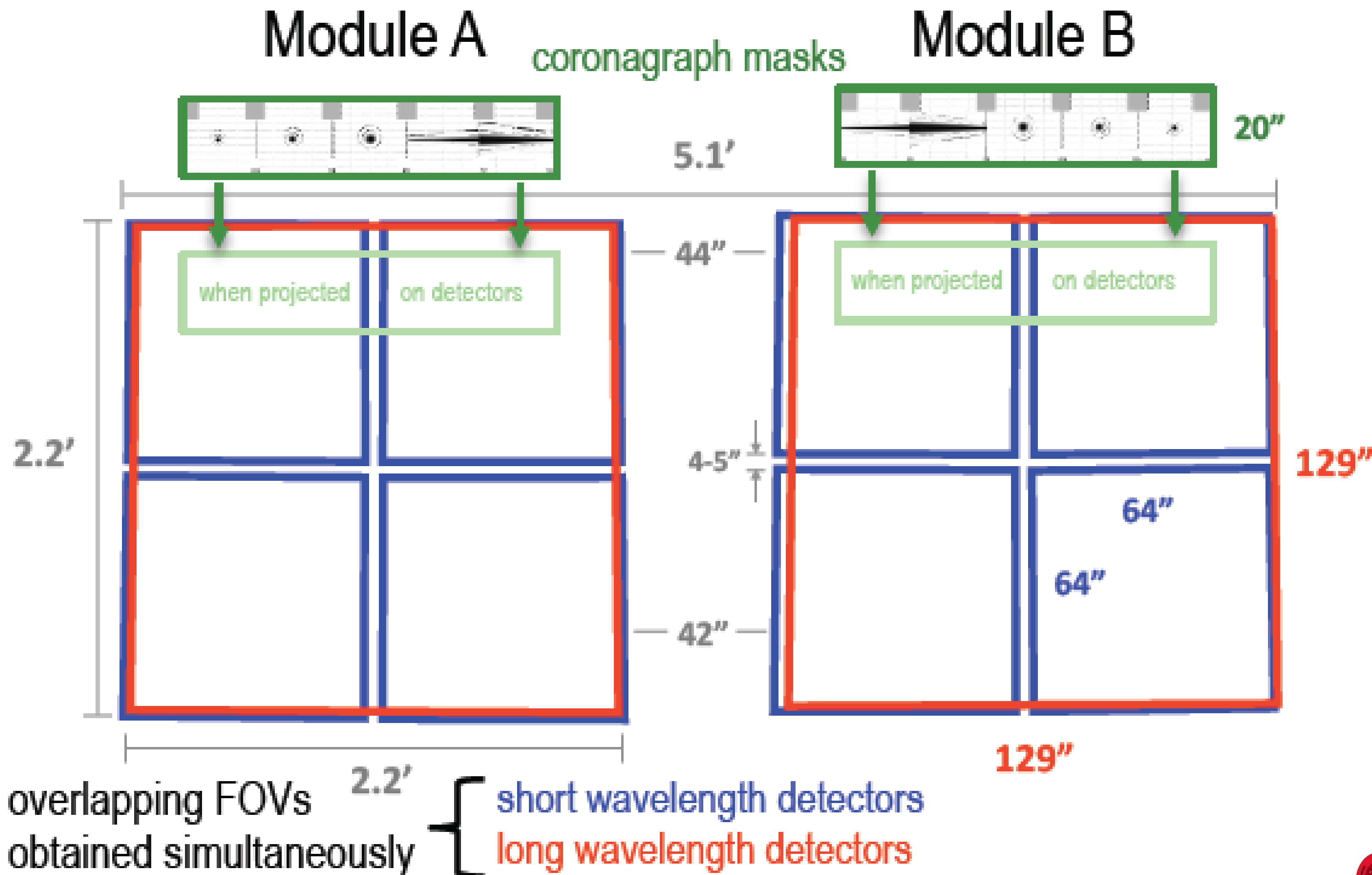
Ariane V

JWST Life-size Model in the Royal Hospital Kilmainham, Dublin

Near-Infrared Camera (NIRCam)



NIRCam Field of View



At a Glance:

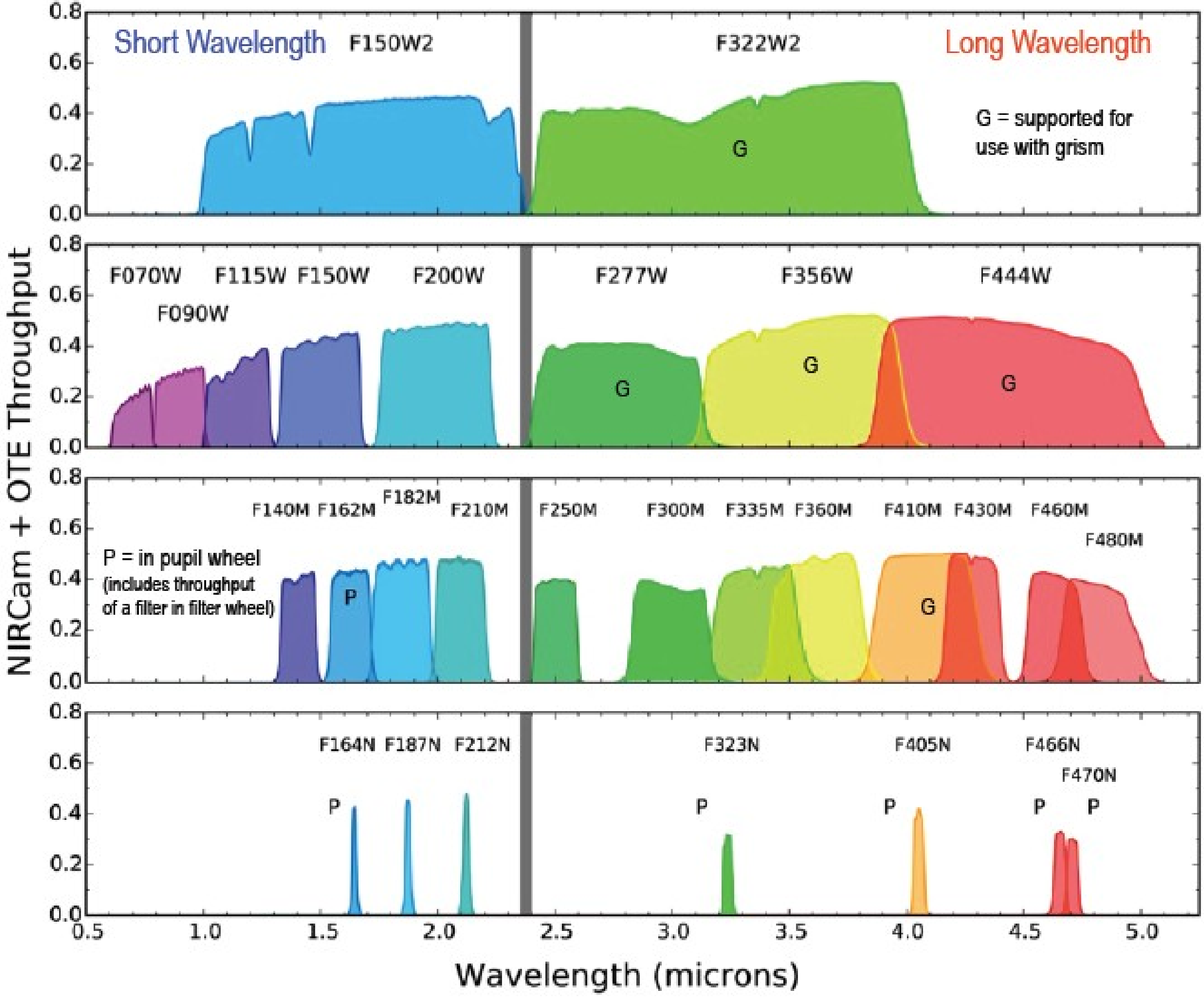
	Short Wavelength Channel	Long Wavelength Channel
Wavelength Range	0.6 – 2.3 µm	2.4 – 5.0 µm
Nyquist Wavelength	2.0 µm	4.0 µm
Fields of View *	2 × 2.2' × 2.2' (with 4-5" gaps)	2 × 2.2' × 2.2'
Imaging Pixels	8 × 2040 × 2040 pixels	2 × 2040 × 2040 pixels
Pixel Scale	0.032" / pixel	0.065" / pixel
Grism Slitless 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

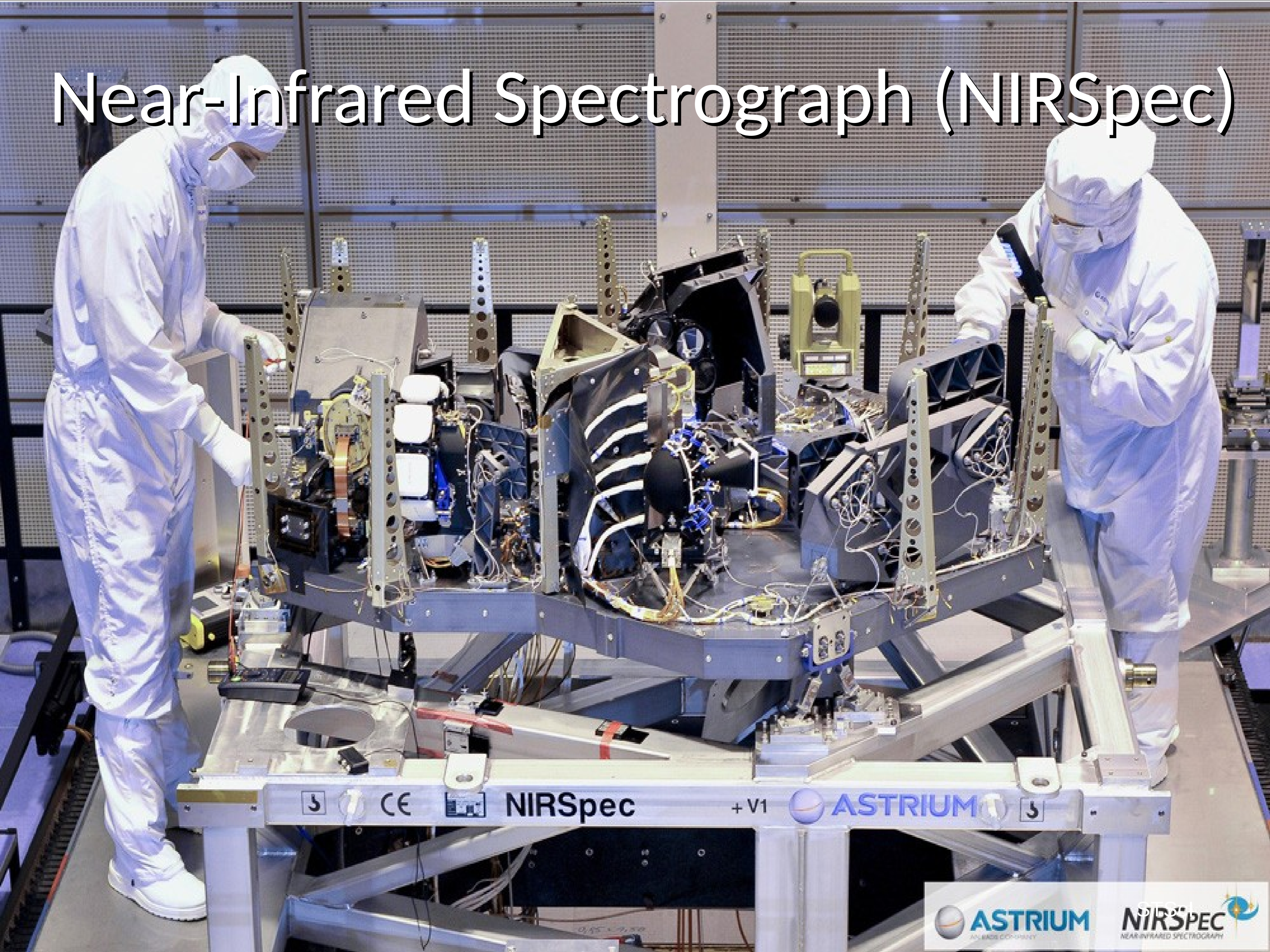
Full frames are read out non-destructively every 10.74 seconds

Smallest subarray 64×64 read out in 49 ms (shortest exposure time)

NIRCam Filters preliminary JWST OTE × NIRCam optics × dichroic × filter(s) × detector QE



Near-Infrared Spectrograph (NIRSpec)

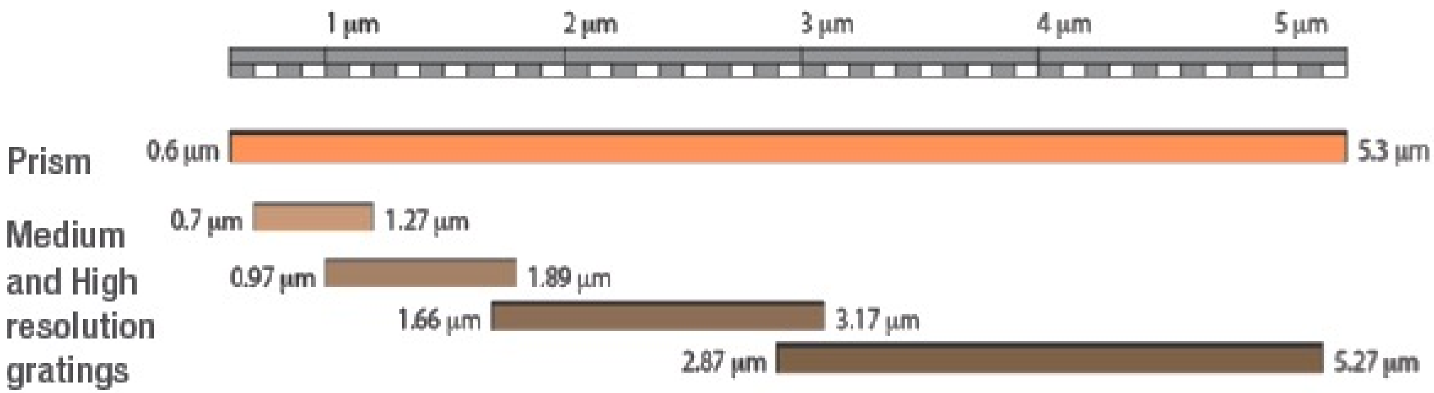


Near Infrared Spectrograph (NIRSpec)

At a glance:

NIRSpec Modes: multi-object, integral-field and slit single object and time series spectroscopy

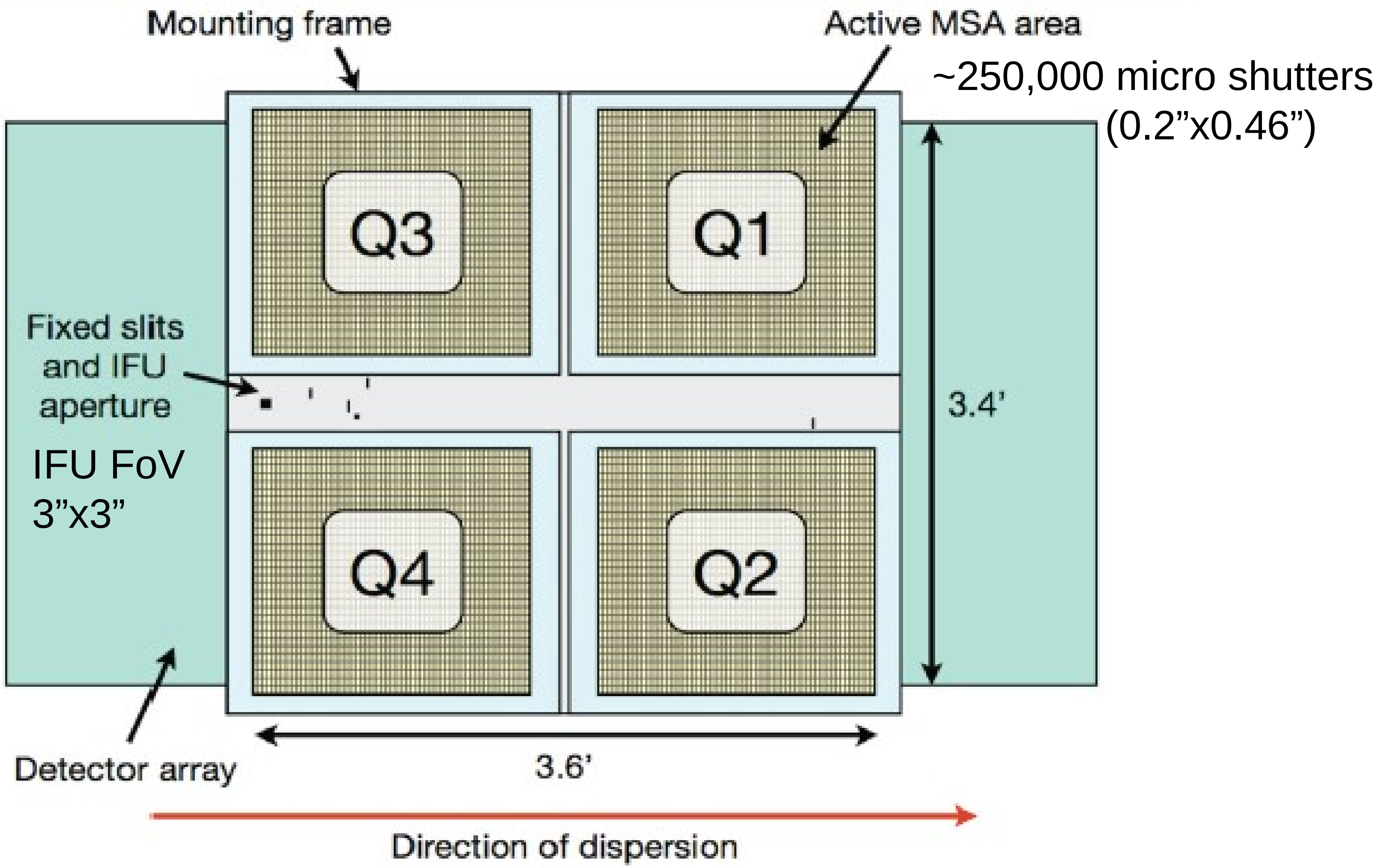
- Detectors: Two HAWAII 2RG infrared detectors with 0.1 arcsec/pixel
- Three Spectral resolutions: ~100, ~1000, ~2700
- Wavelength coverage: 0.6 to 5.3 micron



Field of View

IFU FoV:
3”x3”

Fixed slits
FoV:
0.2” x 3.2”,
0.4” x 3.65”,
1.6” x 1.6”



The NIRSpec focal plane and apertures. The Micro-shutter Assembly (MSA) has four quadrants of micro-shutters to create the slits for NIRSpec MOS.

Near-Infrared Imager & Slitless Spectrograph (NIRISS)

The Near-Infrared Imager and Slit-less Spectrograph (NIRISS)

At a glance:	
Detector	Teledyne HAWAII-2RG; HgCdTe with 5.2μm cutoff; 2048 × 2048 pixels
Field of View	2.2′ × 2.2′
Plate scale	0.065 arcsec / pixel
Pupil Wheel	"Blue" filters; Grism GR700XD; Aperture Mask NRM
Filter Wheel	"Red" filters; Grisms GR150C,R

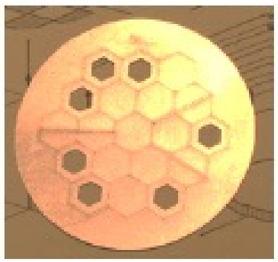
Wavelength range: 0.6-5 μm

Imaging/Aperture Masking Interferometry (AMI)/ Single Object Slit-less Spectroscopy/Wide Field Slit-less Spectroscopy

Aperture Masking Interferometry

Non-Redundant Mask (NRM)
+ Medium-Band “Red” Filters.

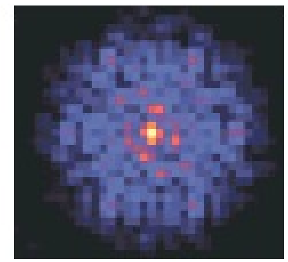
7-hole aperture mask with 21 distinct (“non-redundant”) separations (“baselines”)



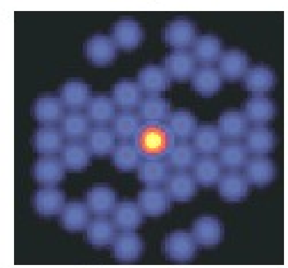
Mask

Michelson:

$\delta\theta = 0.5\ \lambda / D$



NRM PSF
(Interferogram)



Fourier
Transform

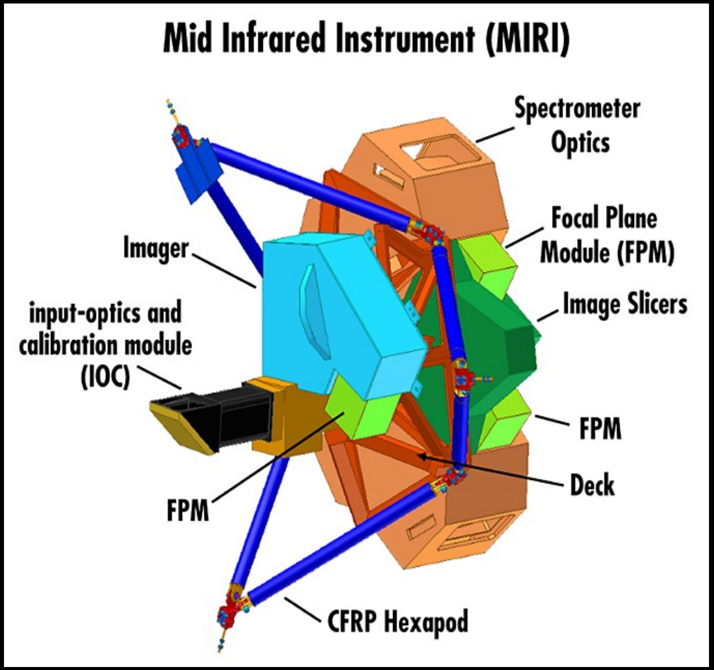
NIRISS AMI enables exoplanet detection at 3.8, 4.3, and 4.8 μm around stars as bright as M’~4, reaching 10^{-4} contrast at separations of 70–400 milli-arcseconds. It provides lower contrast at 2.8 μm with the F277W filter.

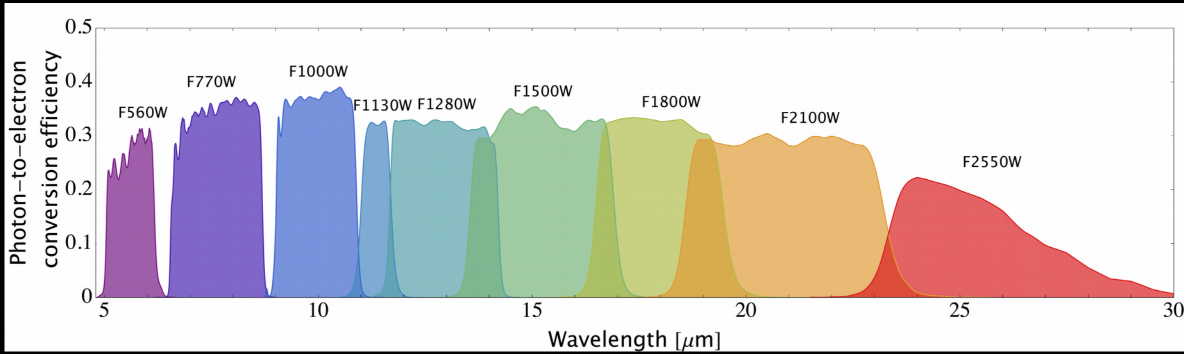
Image reconstruction is also enabled.

Mid-Infrared Instrument (MIRI)

MIRI Details

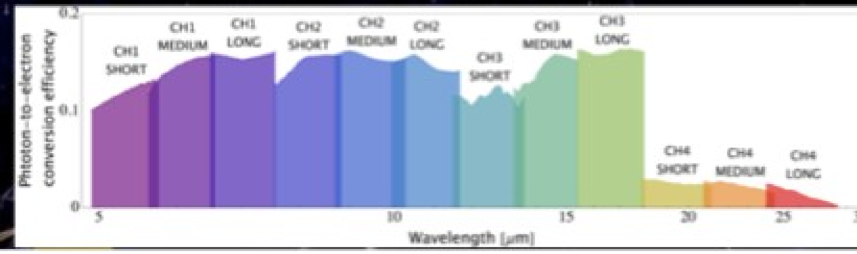
- Imaging (74''x113'') with 9 wavebands from 5 to 28 μm
- Coronagraphic Imaging at 10.65, 11.4, 15.5 and 23 μm (24''x24'')
- Diffraction Limited at 7 microns (pixel ~ 0.11'')
- MR Spectroscopy (R~3000) using 4 IFUs: entire spectrum from 4.9 to 28.8 μm
- LR Spectroscopy (R~100) 5-10 μm (0.5''x4.7'' or slitless)

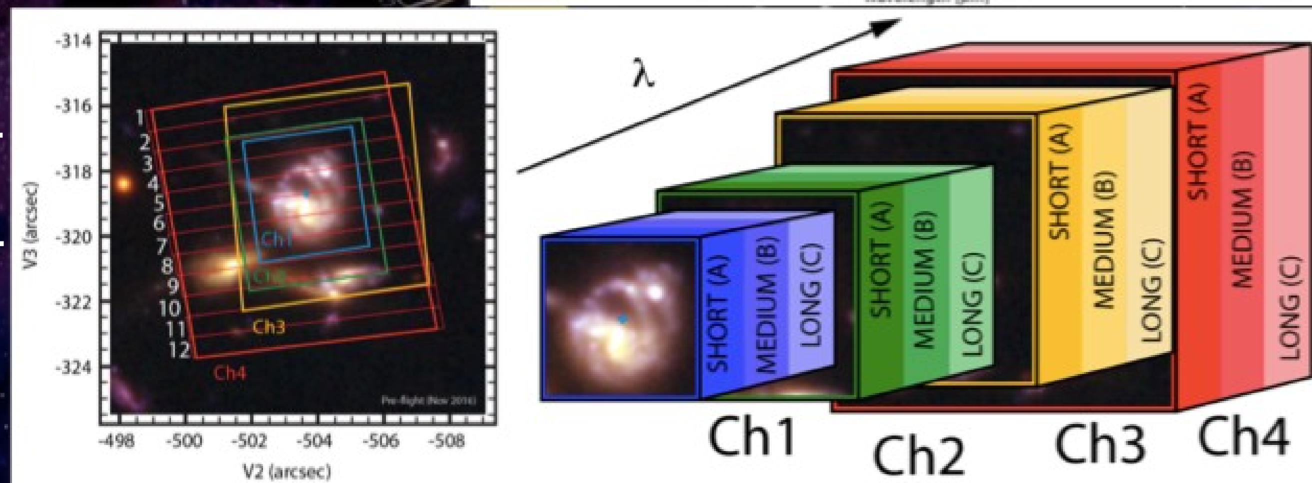


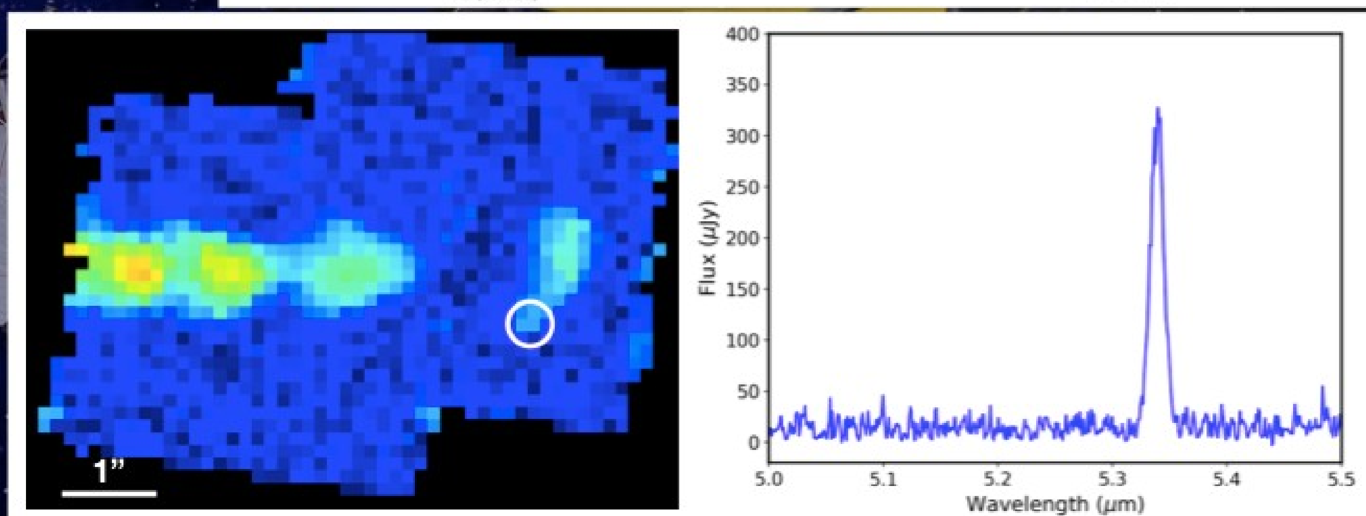


MIRI MRS (IFU)

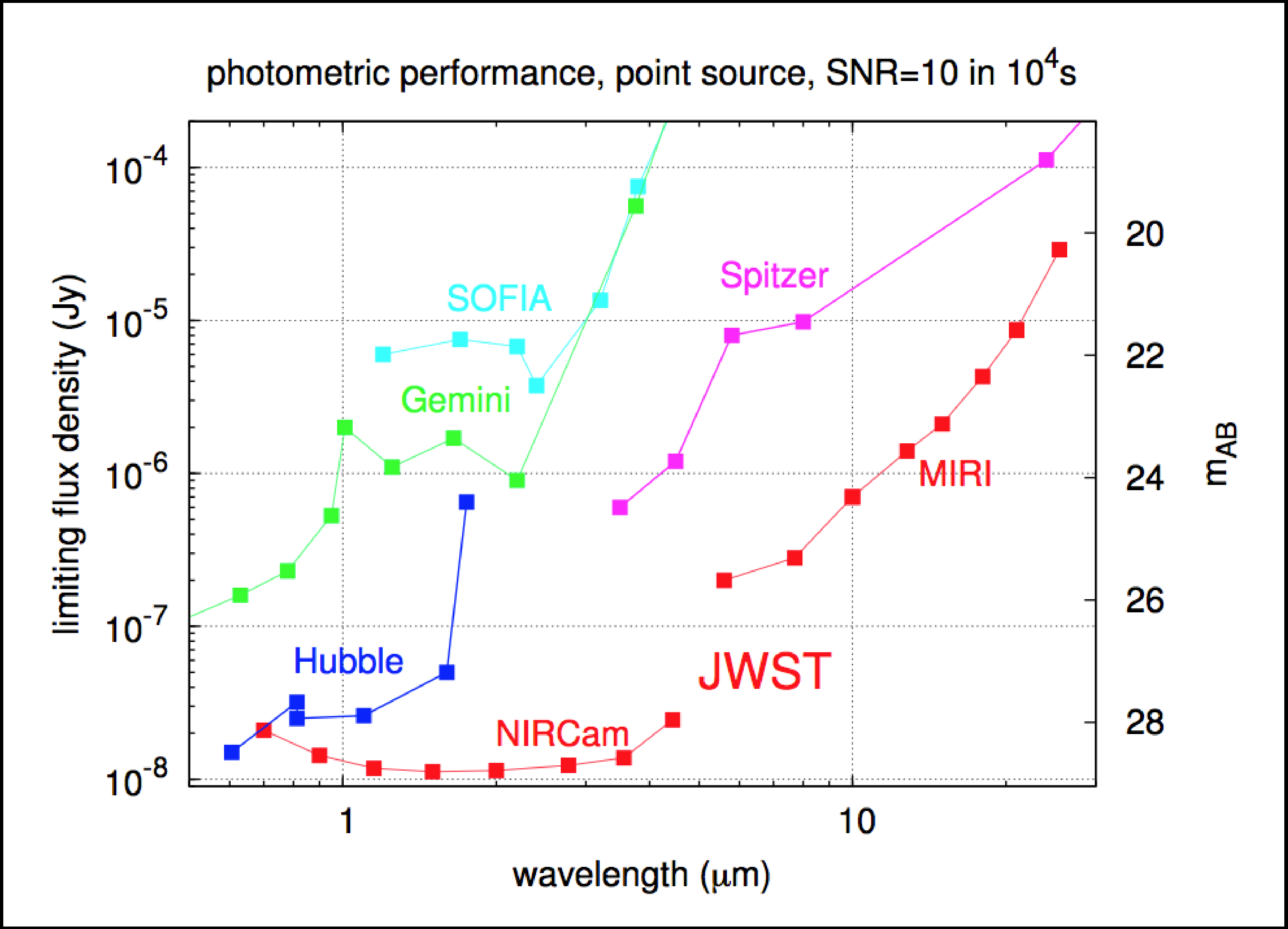
IFU FoV:
from
3.3”x3.7” Ch1
to
7.3”x7.9” Ch4

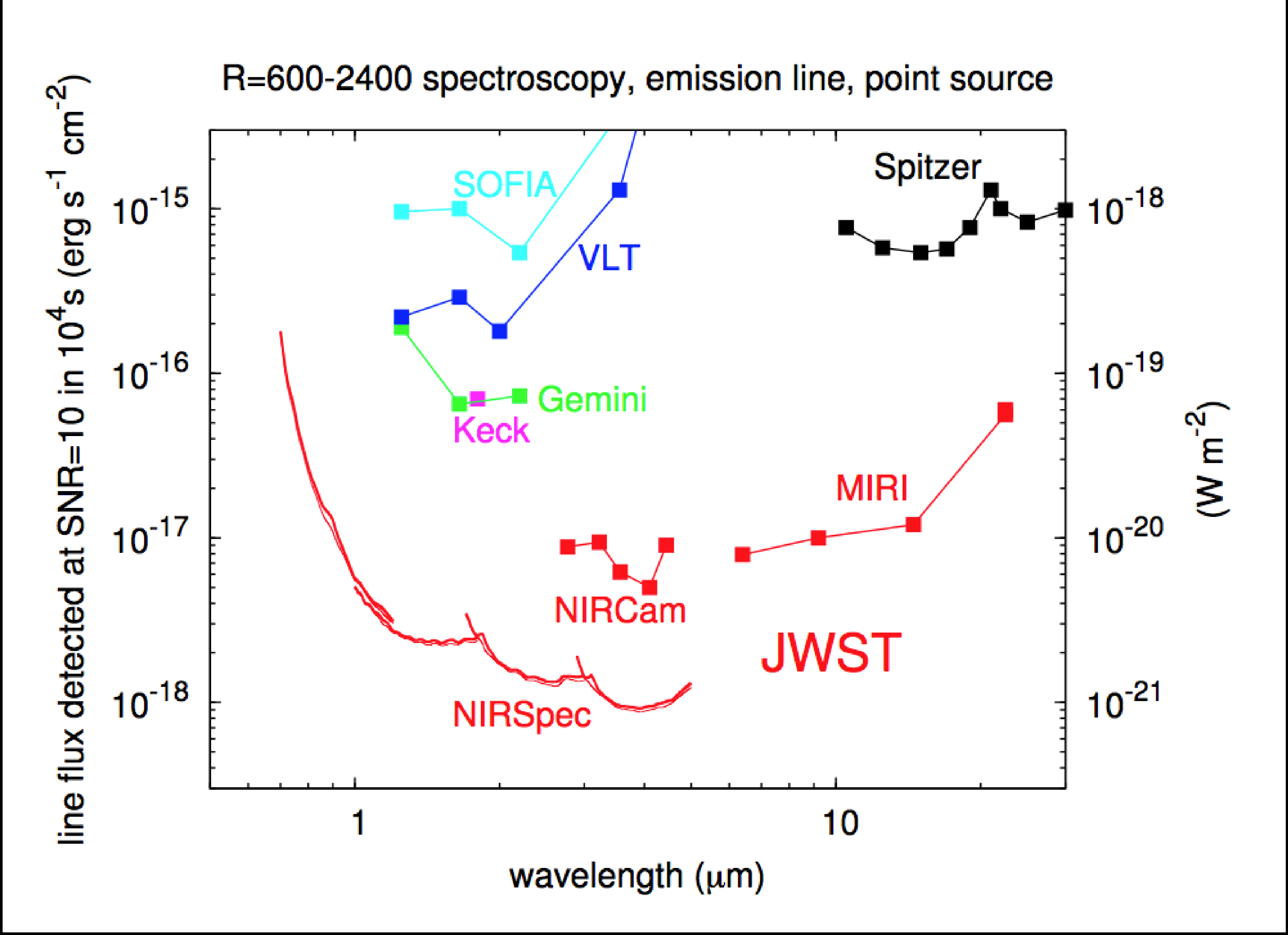






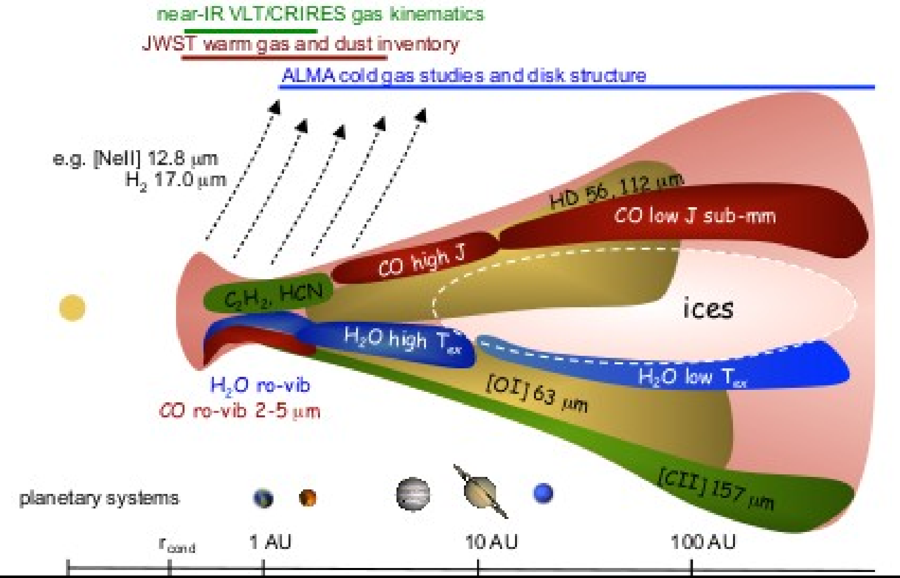
JWST Performance

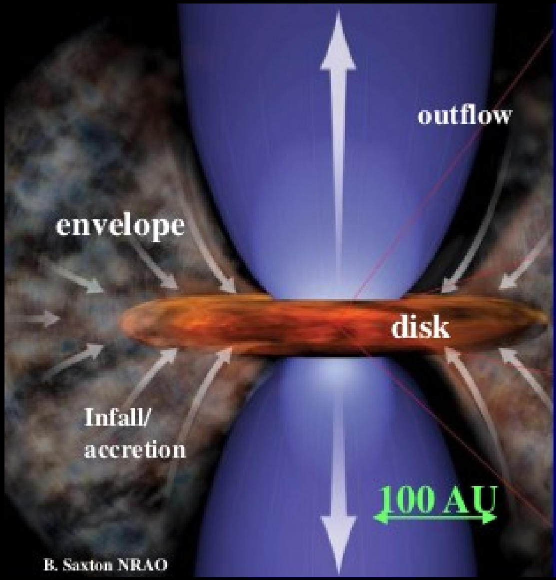



R=600-2400 spectroscopy, emission line, point source
line flux detected at SNR=10 in 10^4s (erg s^{-1} cm^{-2})
(W m^{-2})
wavelength (μm)
10^{-15}
10^{-16}
10^{-17}
10^{-18}
10^{-18}
10^{-19}
10^{-20}
10^{-21}
1
10
SOFIA
VLT
Spitzer
Gemini
Keck
MIRI
NIRCam
JWST
NIRSpec

MIRI EC GTO Programs on Protoplanetary Disks, Protostars and jets

- Protoplanetary disks (GTO 1284). P.I.: Th. Henning (MPIA), 111.4 hrs. ~60 targets (Herbig Ae stars, T Tauri stars, brown dwarfs and young debris disks). MIRI/IFU+NIRSpec (few targets)
- Protostars (GTO 1282). P.I.: E. Van Dishoeck (U. Leiden), 39 hrs. 30 targets (26 low-mass and 4 high-mass embedded YSOs). MIRI/IFU + NIRSpec on 4 targets (T. Greene program)
- Jets (GTO 1257). P.I.: T. Ray (DIAS), 22.8 hrs. HH211. MIRI/IFU + NIRSpec + NIRCam

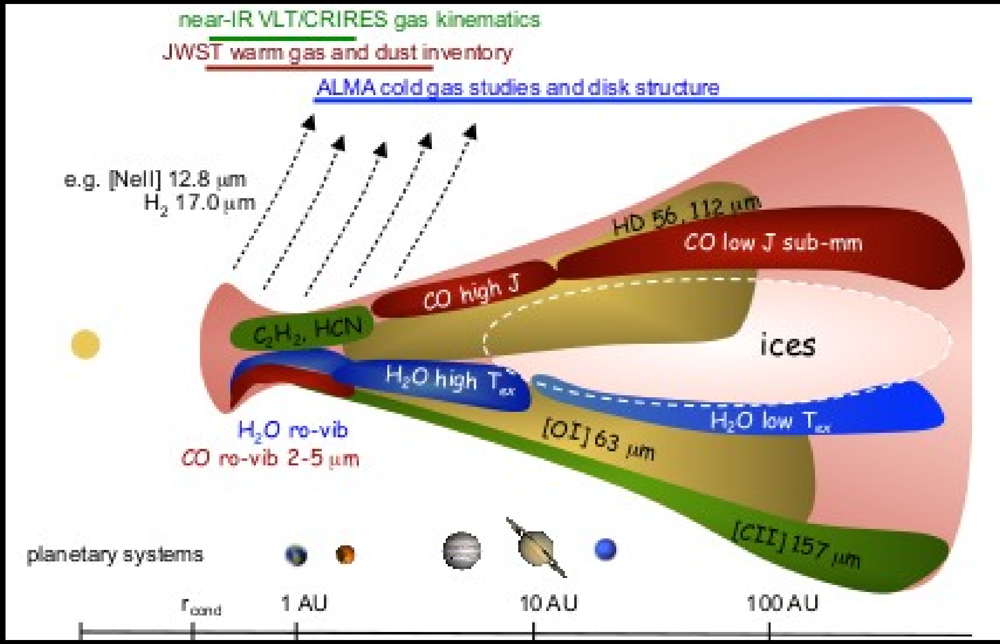


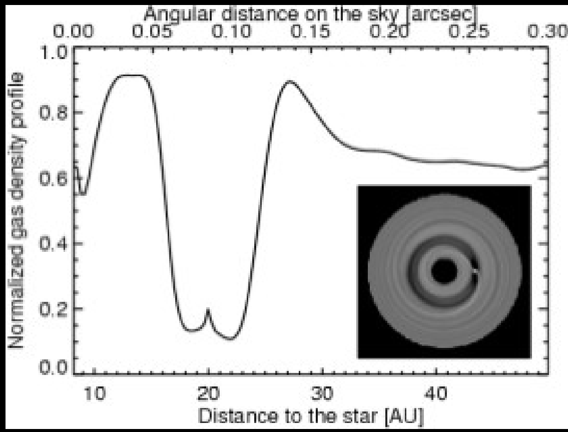


GTO program on Protoplanetary Disks

Aims:

- Investigate the chemical inventory in the terrestrial planet forming zone
- Follow the gas evolution into the disk dispersal stage
- Study the structure and evolution of protoplanetary and debris disks in the thermal mid-IR.
- Planet formation and presence of protoplanets.

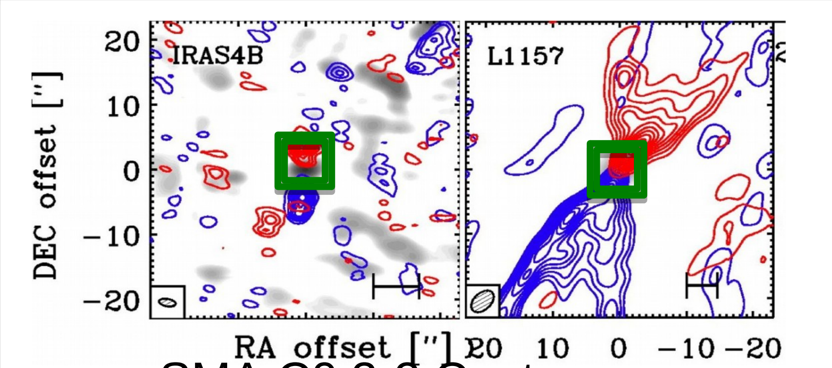




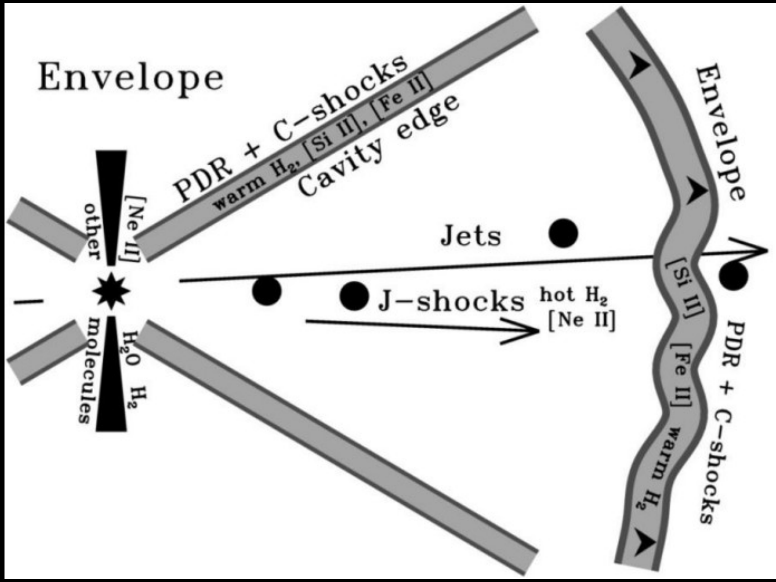
GTO program on Protostars

Aims/Key questions:

- Main characteristics of Class 0/I protostars (accretion and ejection rates, etc..).
- Disks: Origin and location of chemical complexity. Composition and processing of ices. Gas/ice ratios.
- Protostar feedback on surroundings. Physics of jet/wind – envelope interaction (accretion on disk?).
- How do these characteristics change from low- to high-mass stars and with evolutionary stage?



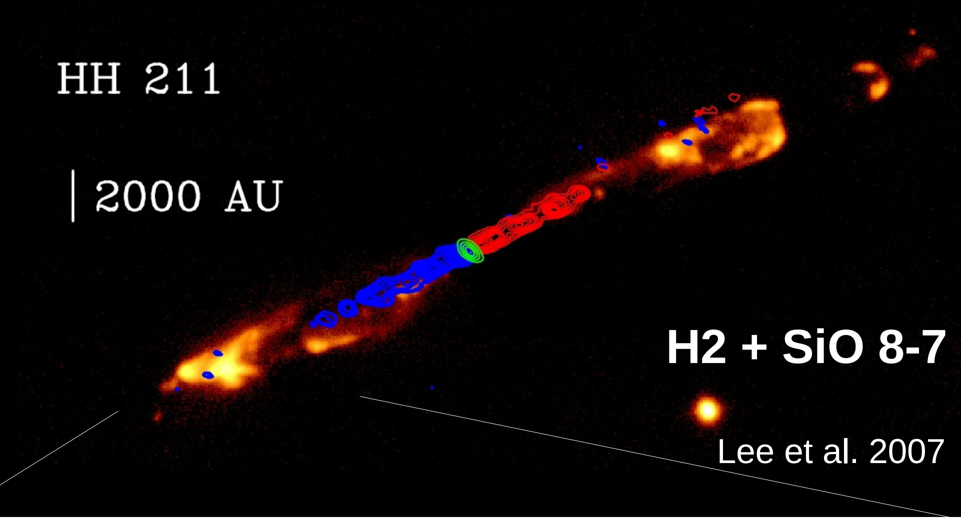
SMA C0 3-2 Contours (Jorgensen et al. 2007)

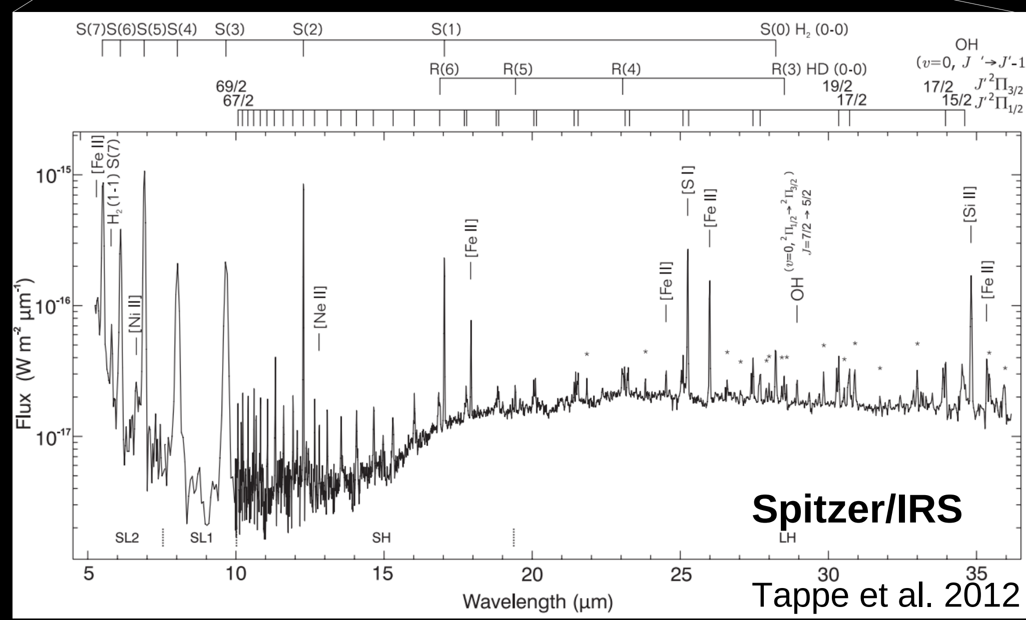


GTO program on Jets (HH 211 map)

Aims/Key questions:

- Do shock properties vary with distance from protostar? Role of UV?
- Is dust launched inside Class 0 jets?
- Is dust destroyed by shocks?
- Shock modelling along the whole flow in the MIR/FIR (+ NIR for the blue-shifted BS)





Other GTO Programs I

- Apart from our 3 GTO programs there are other 4 on Debris Disks, 1 on prestellar cores and 4 on YSOs and 2 on Protostellar Jets + 1 Cycle 0 (Ice Age) (E. Palumbo talk)

YSOs:

- YSO Imaging. P.I.: J. Leisenring (U. Arizona). 19 hrs, NIRCam (4 targets, disks & protoplanets).
- Protostar (YSO) Spectroscopy. P.I.: T. Greene (NASA). 19.1 hrs NIRSpec/IFU (5 YSOs).
- LMC-N79: Study of Most Massive Young Stellar Object Star Forming Region. P.I.: M. Meixter (Johns Hopkins U.). 13.6 hrs, MIRI/IFU, Imager, NIRCam.

Other GTO Programs II

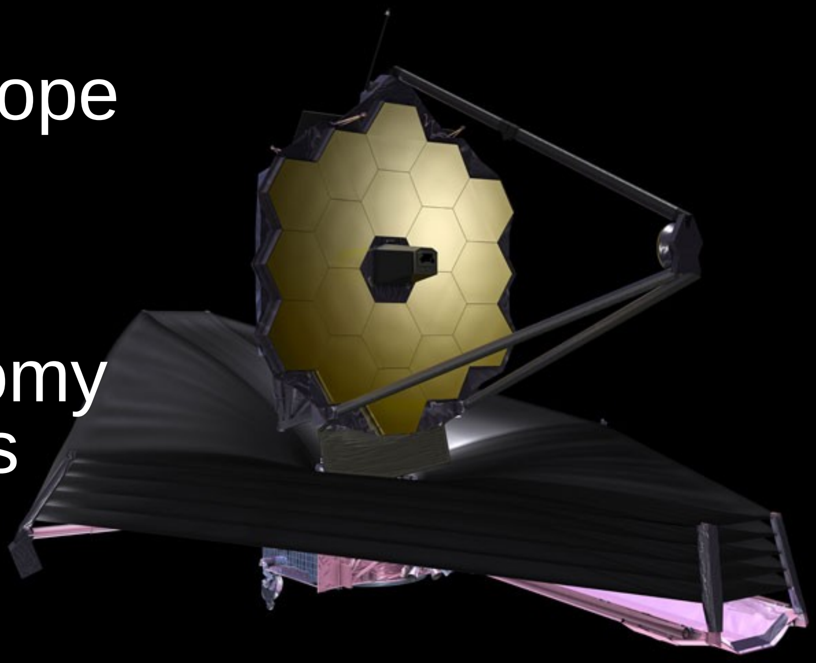
- Protostellar Binaries in Perseus. P.I.: M. Ressler (JPL). 12 hrs, MIRI/IFU (11 targets in Per.)

Protostellar Jets:

- Structure, Excitation, and Proper Motions in HH212 Jet. P.I.: M. Mc Caughrean (ESA). 6.2 hrs, NIRCam.
- Collimation Zone in Protostellar Jets (HH111, HH110). P.I.: A. Noriega-Crespo (STSI). 10 hrs MIRI/IFU & Imager.

Conclusions

- JWST is on schedule for a 2020 launch
  - All instruments are now integrated with the telescope



- JWST will dominate astronomy in the next decade due to its unique capabilities!

- Start thinking about your science cases for Cycle 1!