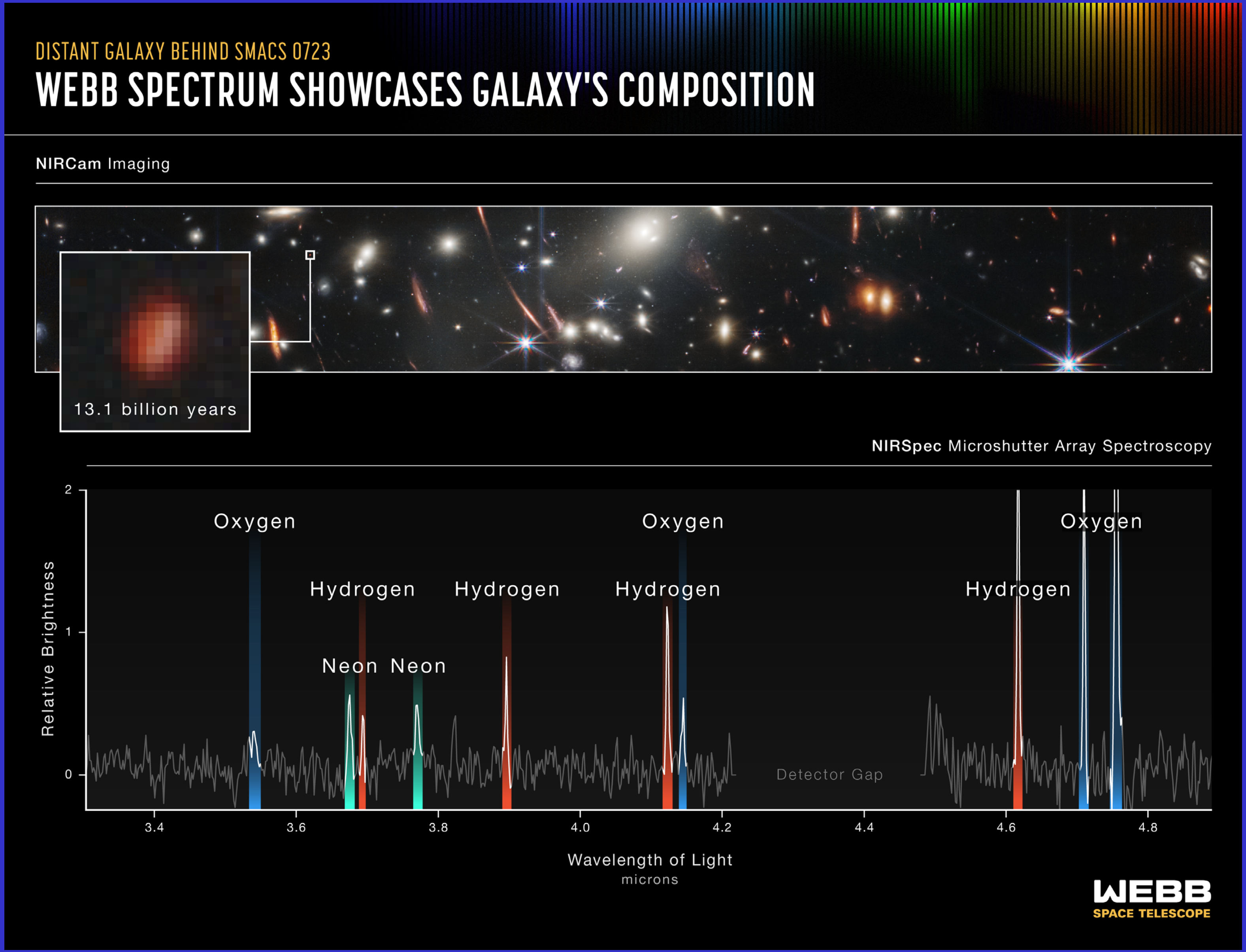
JWST – Exploring the Infrared Universe

Thomas Henning – MPI for Astronomy (Heidelberg)

JWST/NIRCam image of the galaxy cluster SMACS 0723

JWST –Light from the Beginning of the Universe

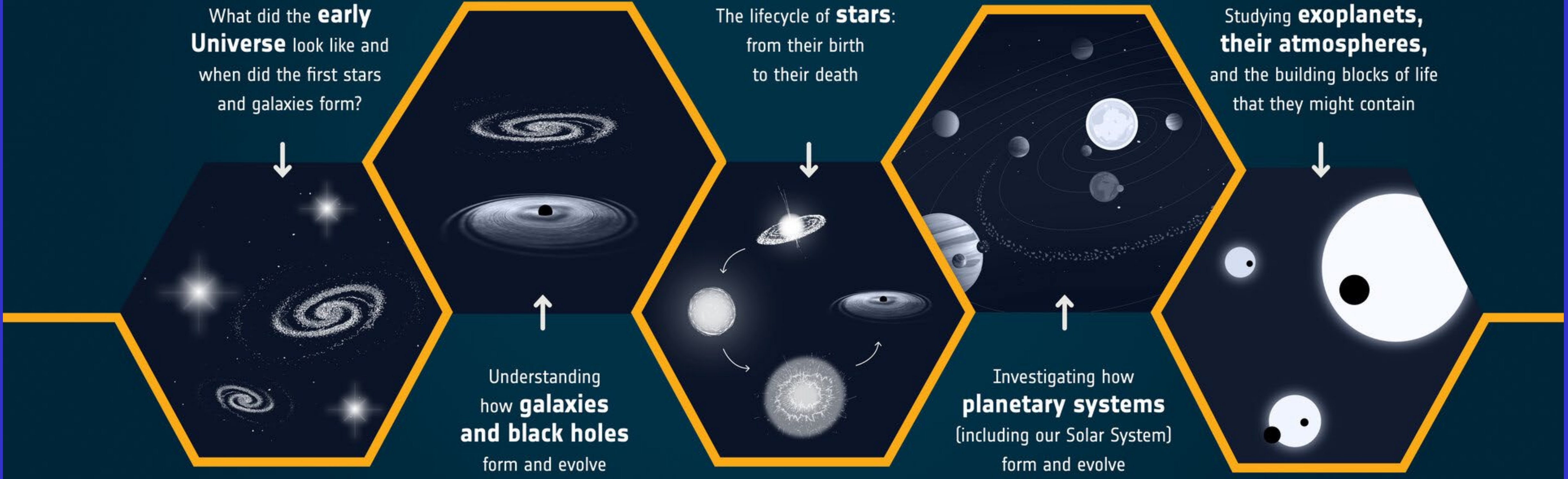


Webbs Journey into Space – 25/12/2021

JWST 1:1 Model in Front of the Deutsche Museum

WEBB SCIENCE

Webb is designed to answer outstanding questions about the Universe and to make breakthrough discoveries in all fields of astronomy.

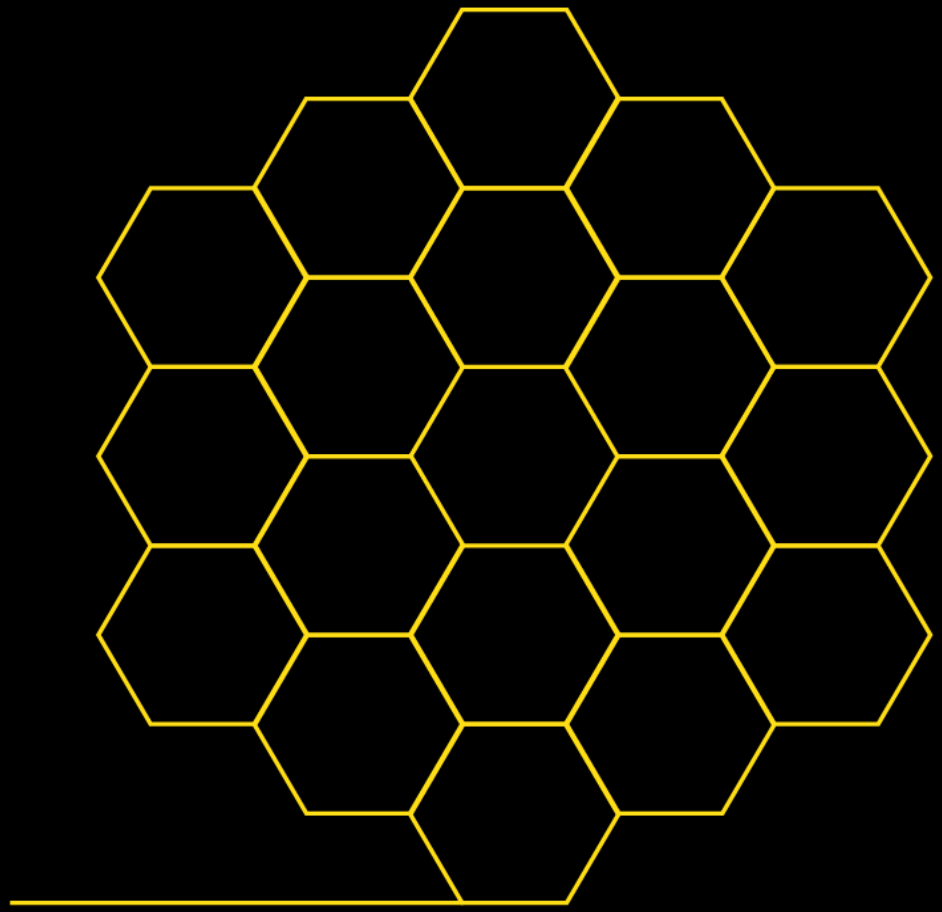


25 %

25 %

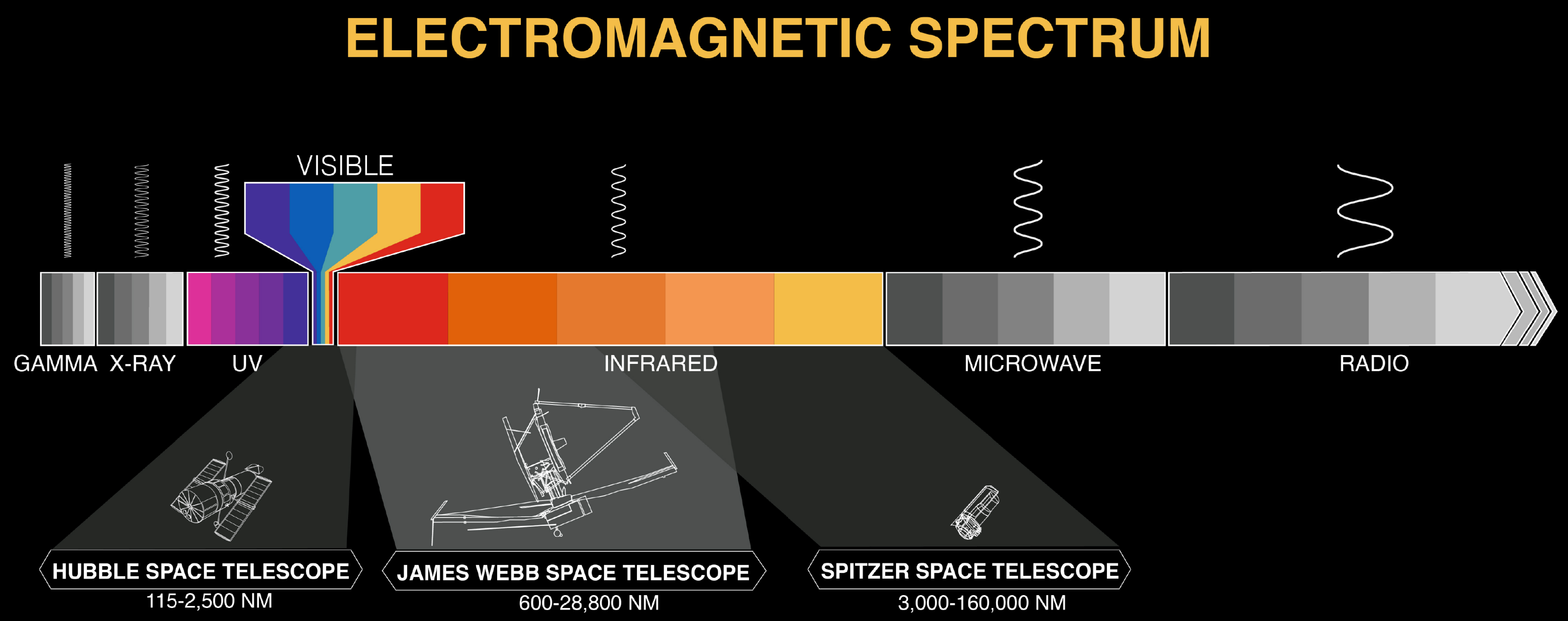
Capturing Faint, Infrared Light

Hubble's PRIMARY MIRROR

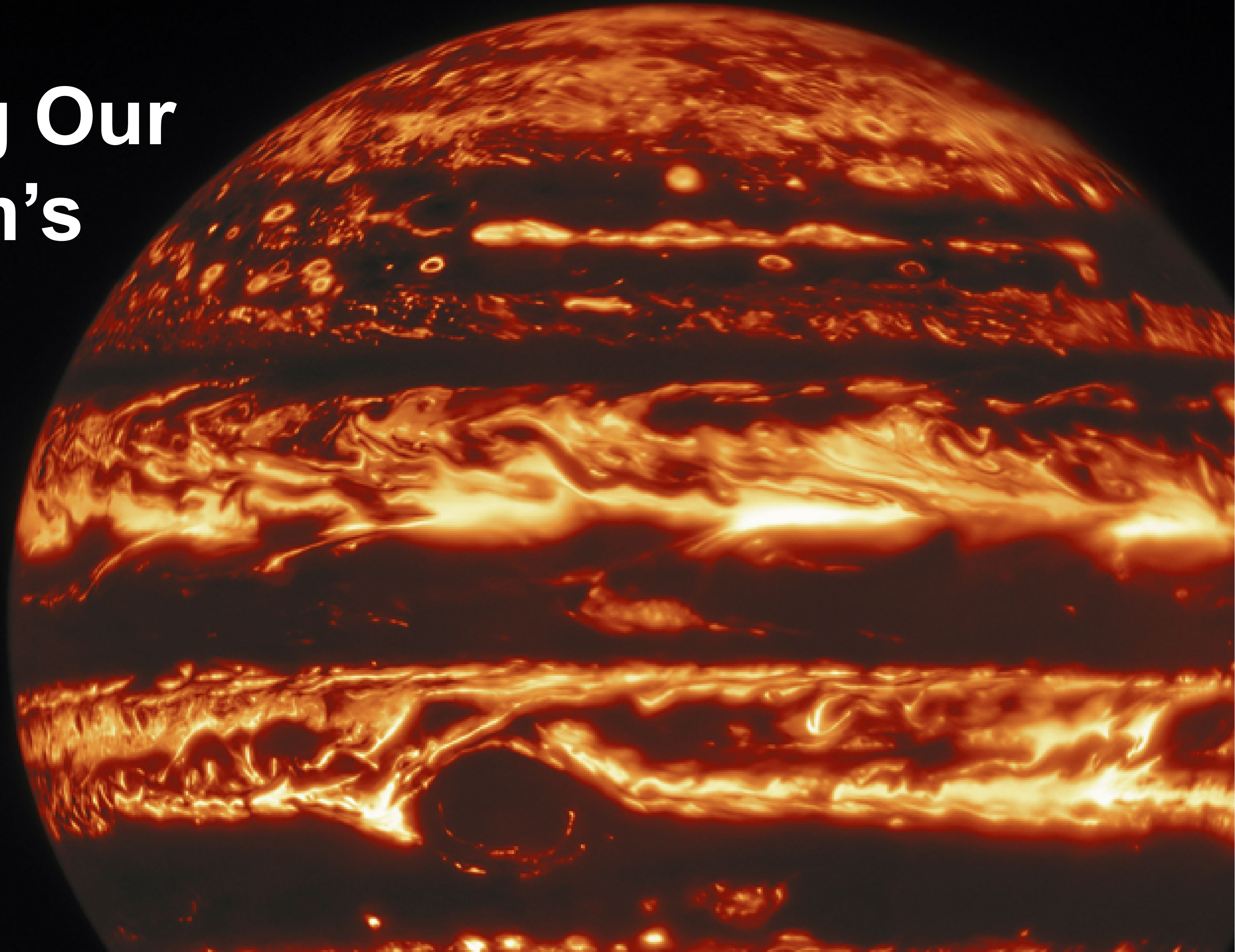


Webb's PRIMARY MIRROR

Webb's Specialization in Infrared Light

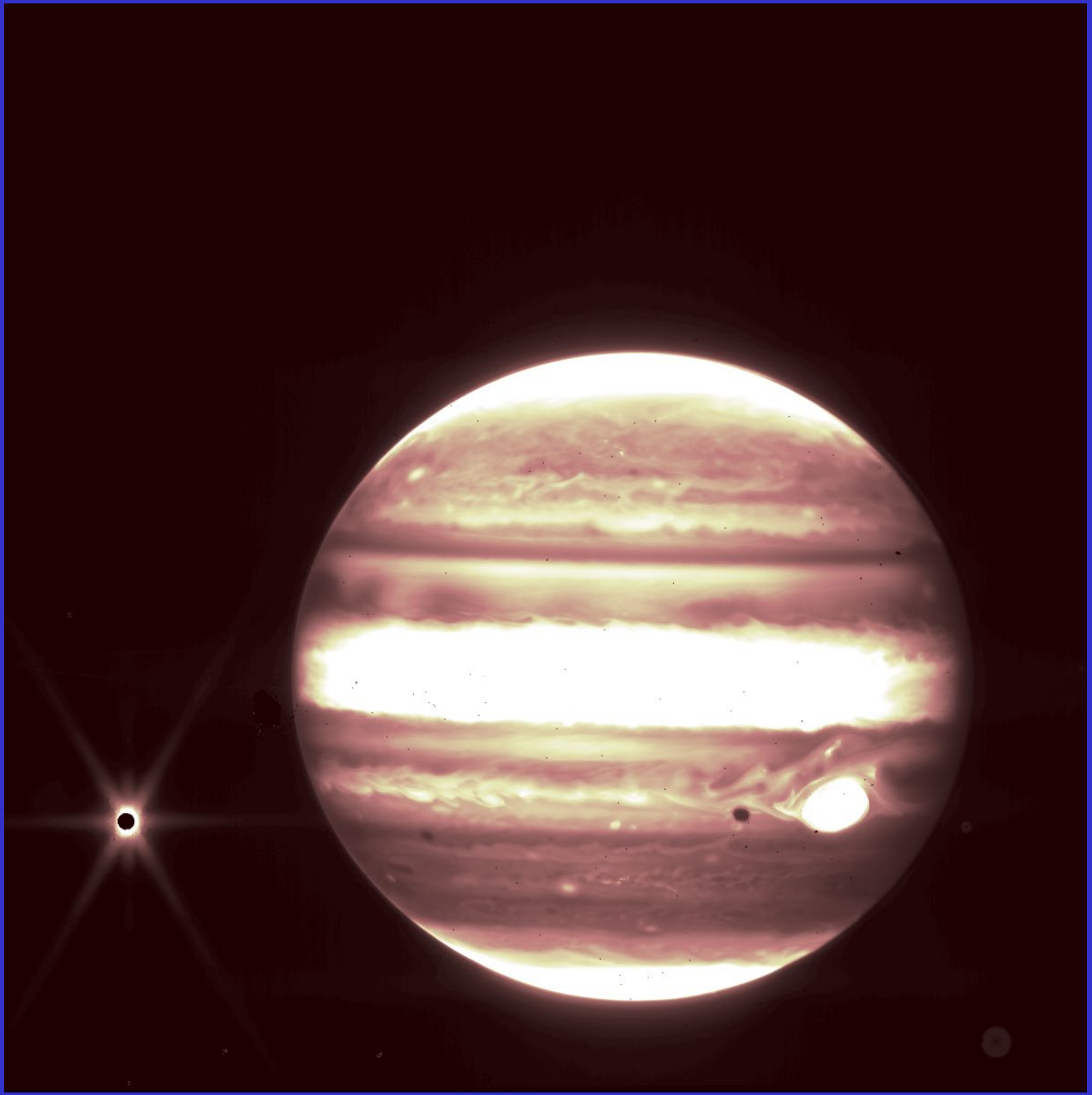


Reexamining Our Solar System's Planets

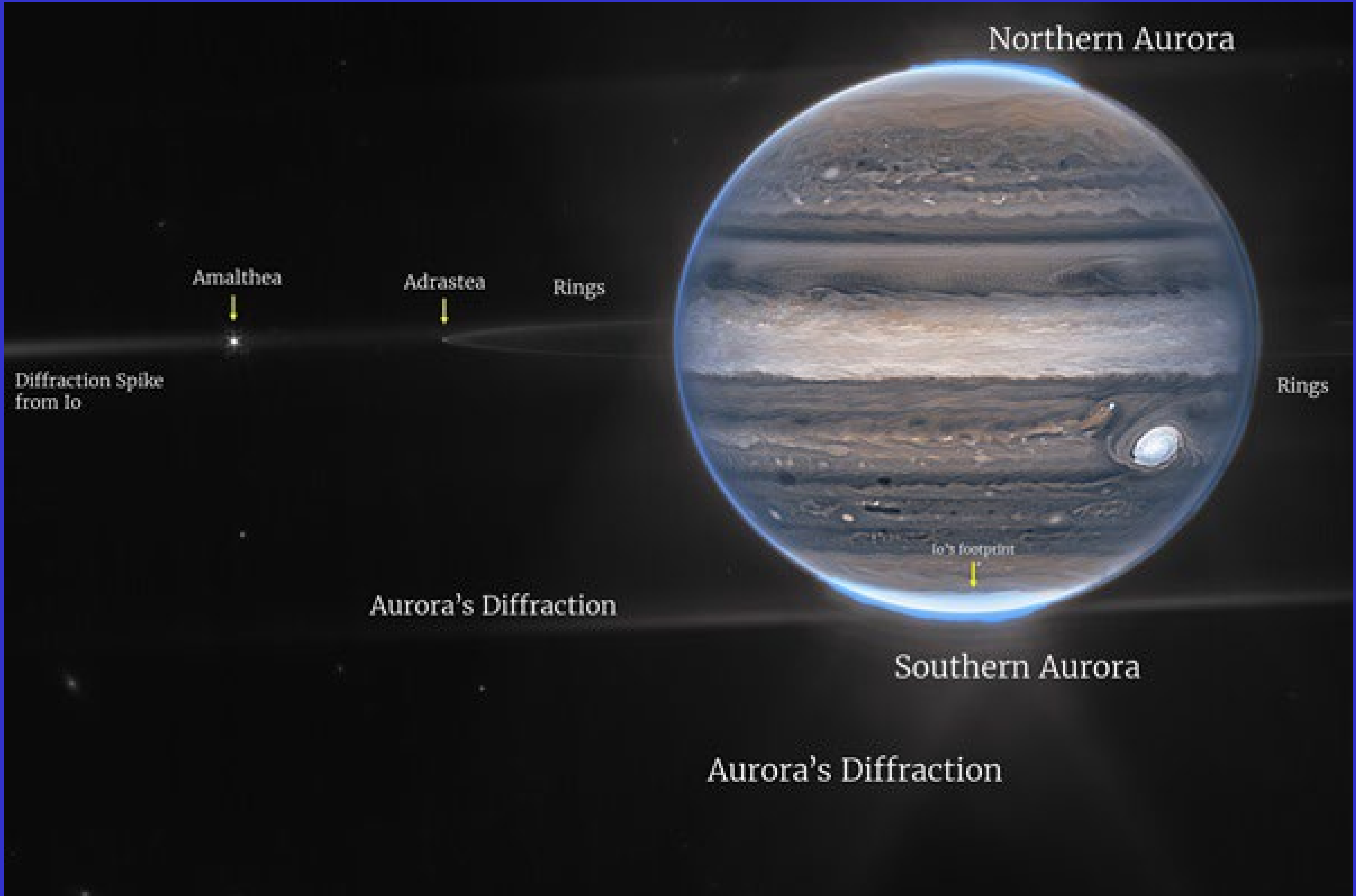


Jupiter in Near-Infrared Light (Gemini North)

NIRCam Image of Jupiter and Europa ($\lambda = 2.12\ \mu m$)



Jupiter – Rings, Satellites, and Aurora with NIRCAM

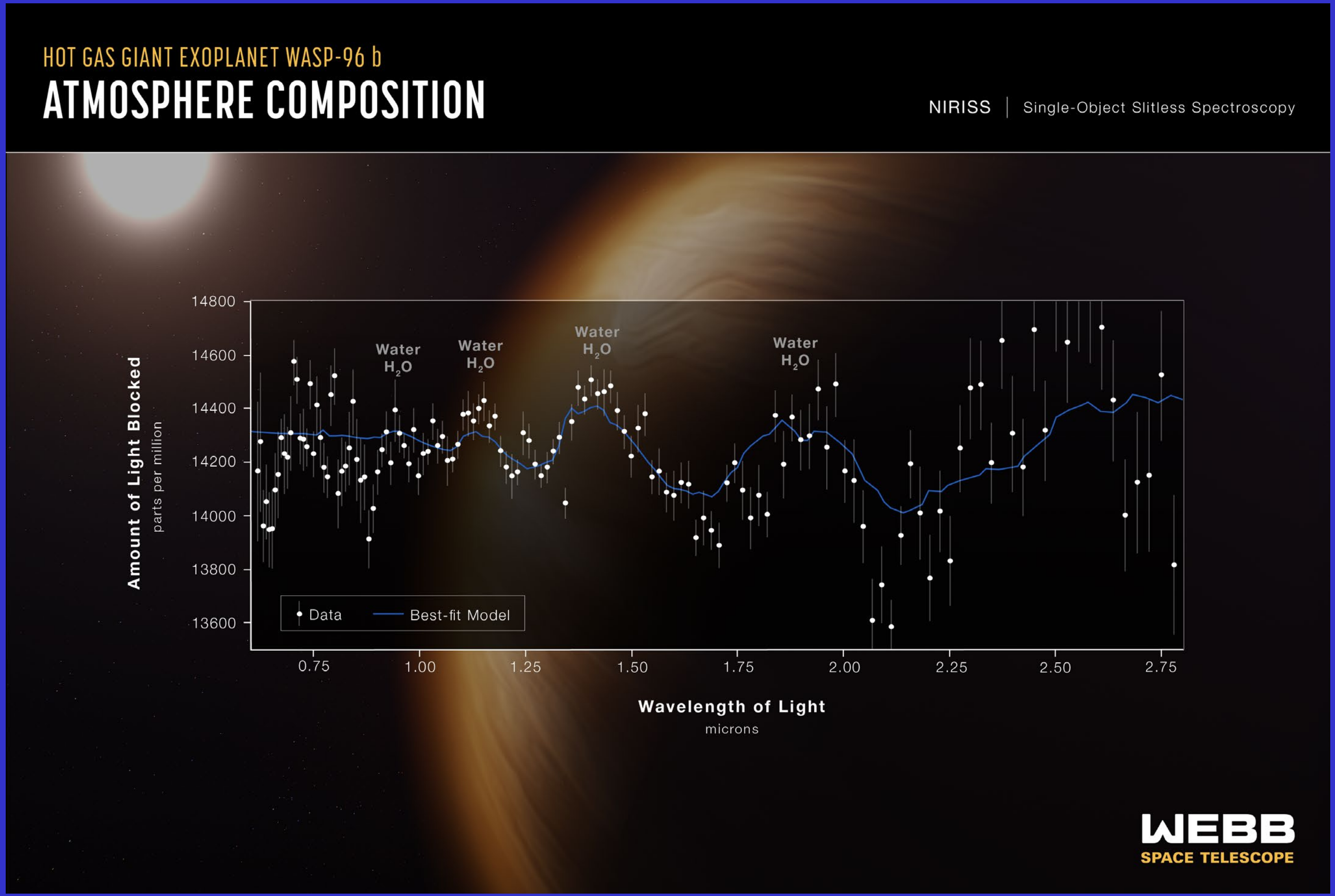


Why Study Infrared Light?

JWST – Uncovering the Infrared Universe

- High-redshift objects emit in the infrared
- Observations can peer through dusty regions
- Cold dusty objects visible in the infrared
- Molecular emission bands in the infrared

WASP-96 b

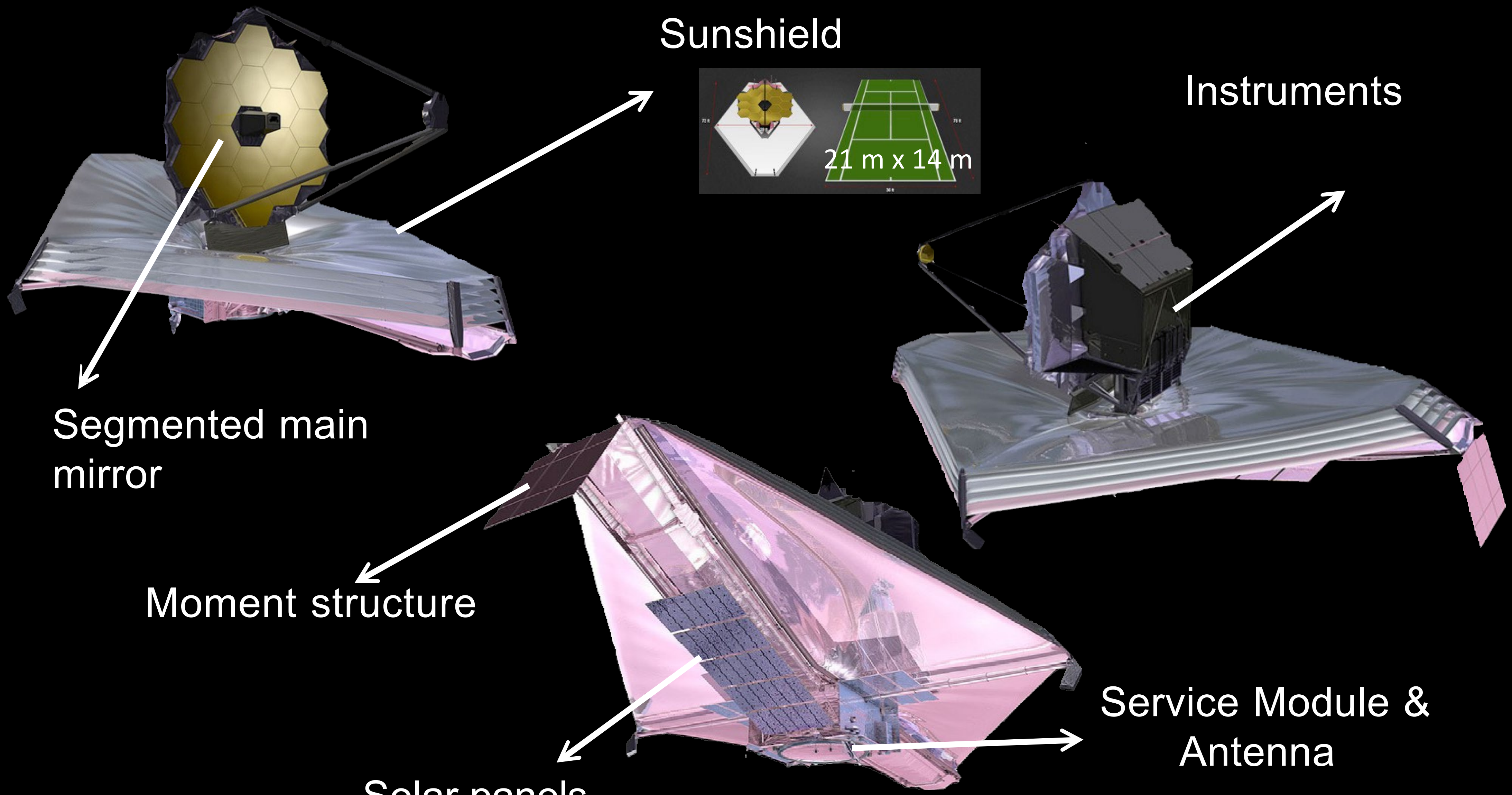


JWST: Ready for Launch!

JWST Spacecraft/Sunshield (left) and Telescope/Instruments in cleanroom

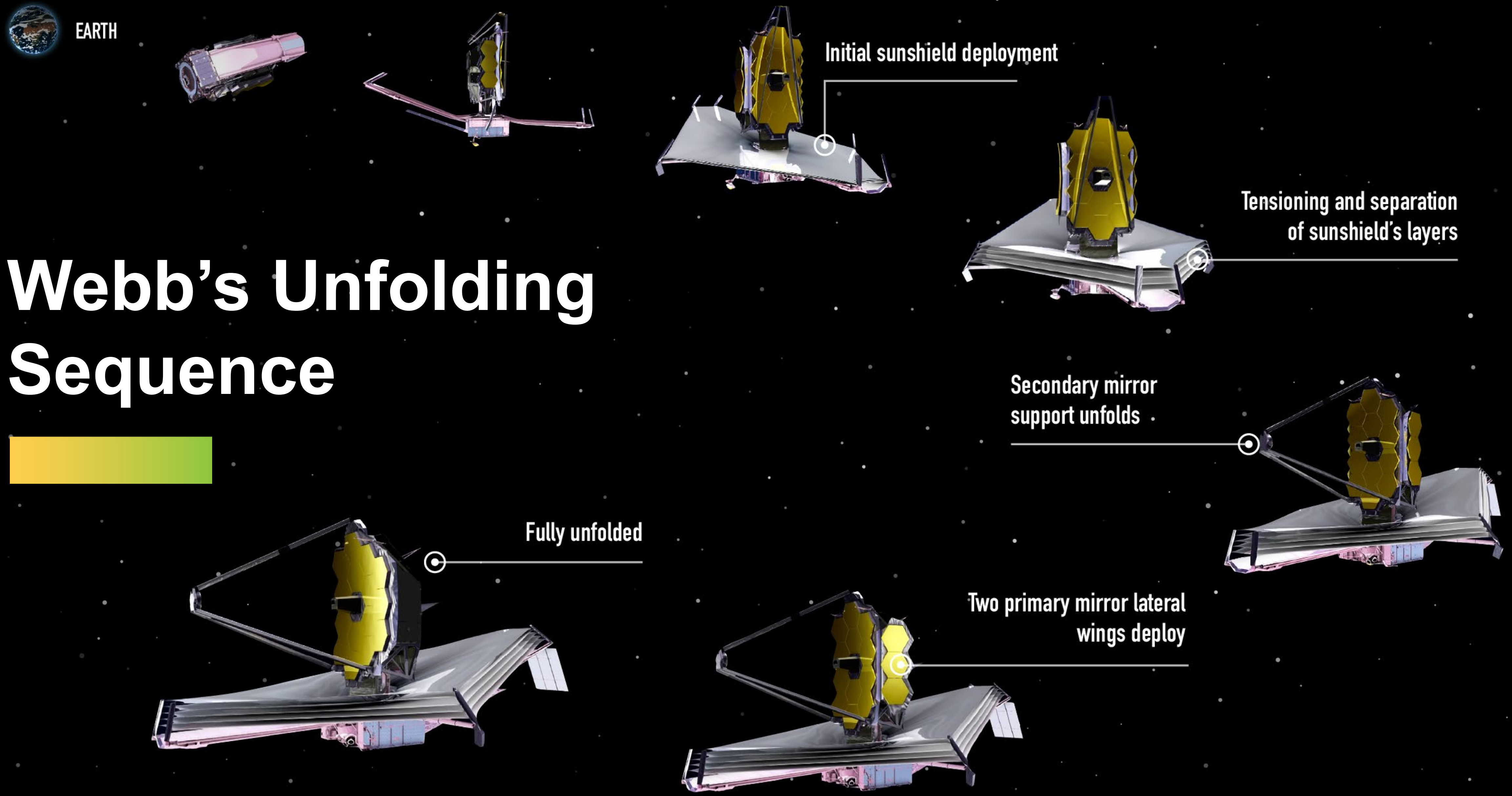
- December 2017: Telescope & Instrument Tests Complete
- January 2018: Integration of Service Module & Sunshield
- May 2019: Service Module & Sun shield complete
- October 2020: Vibration Test of Satellite Complete
- Spring/Summer 2021: Final Integration & Transport to Kourou
- Juli 2021: Launch Readiness Review Completed
- Launch in December 2021
- Data delivery started in July 2022

JWST Structure

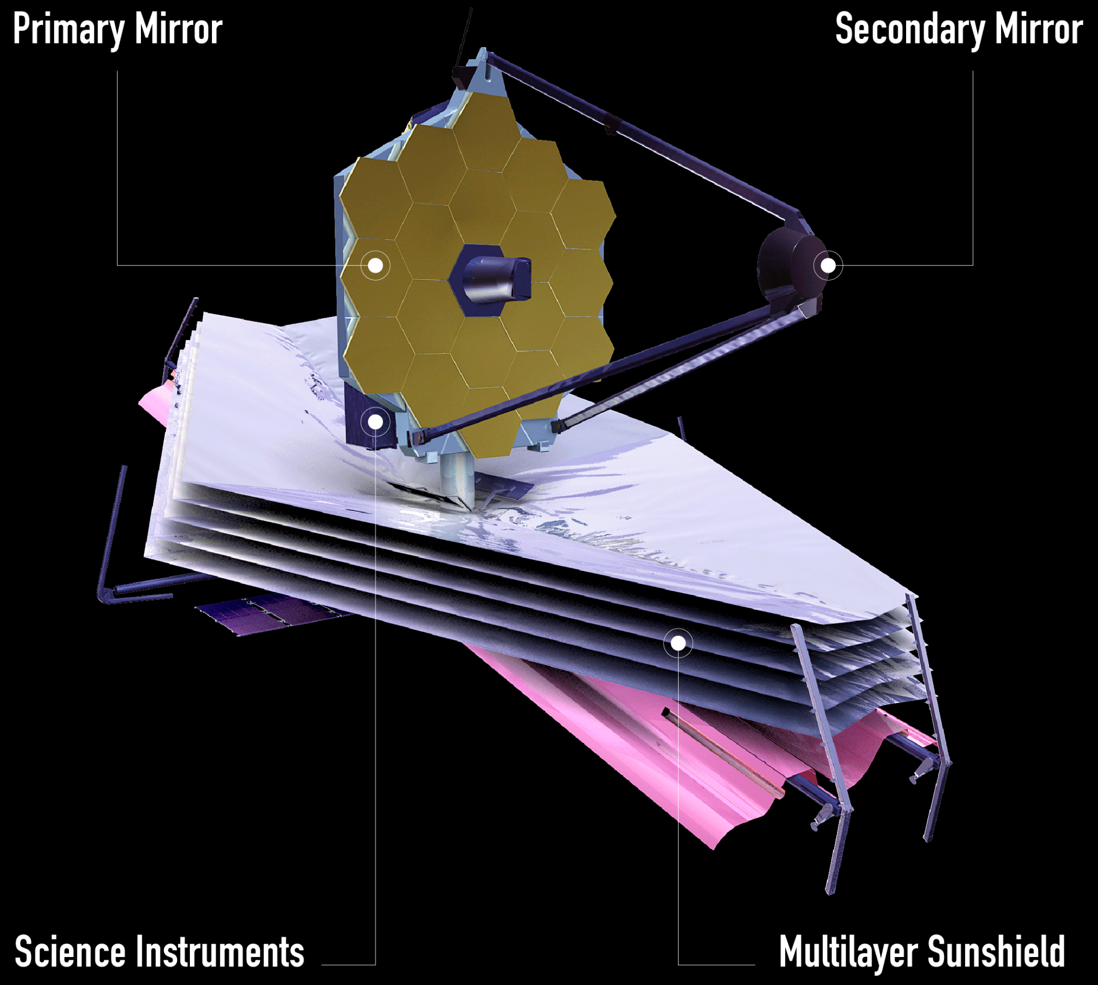


Webb's Journey Begins

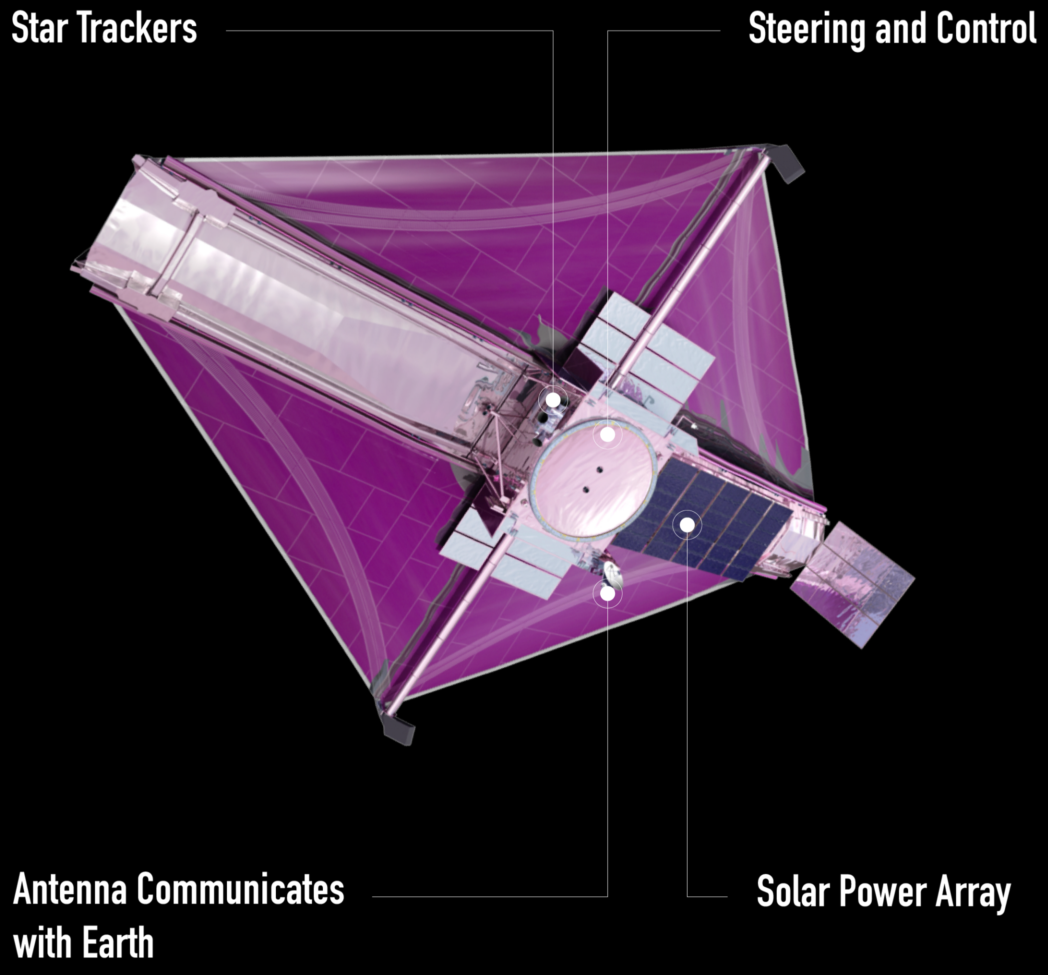
Webb's Unfolding Sequence

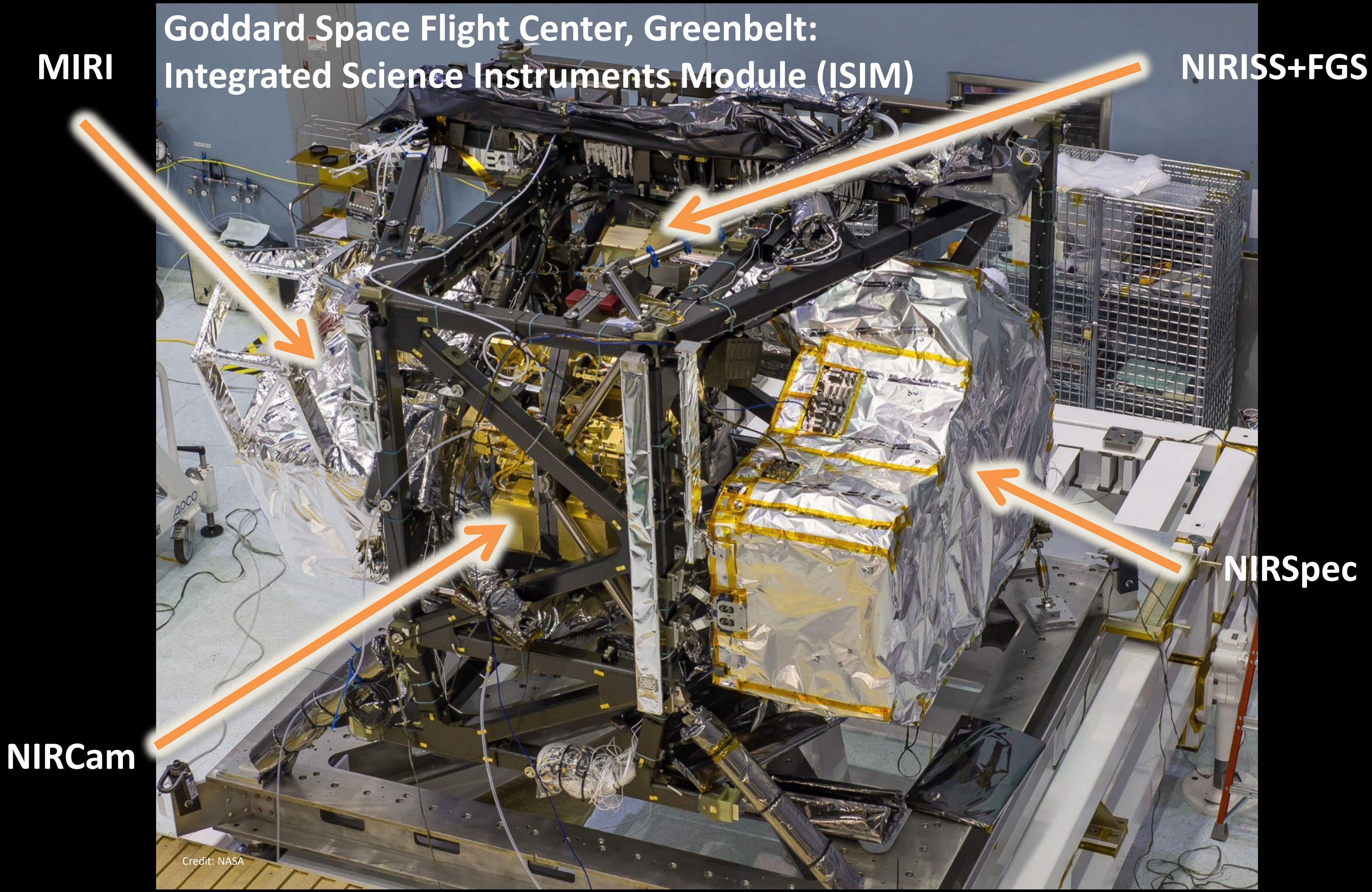


Observing Side

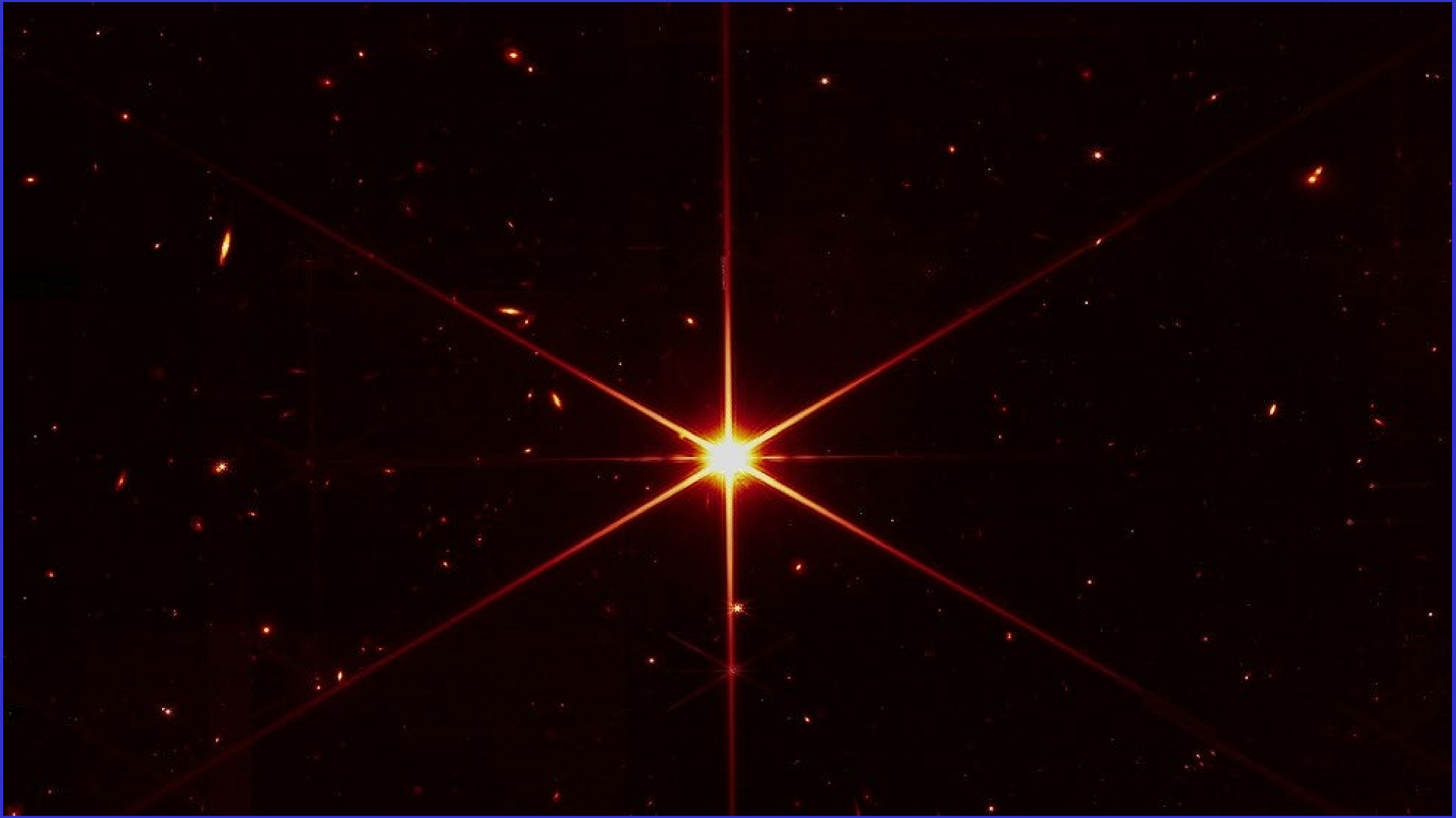


Sun-Facing Side

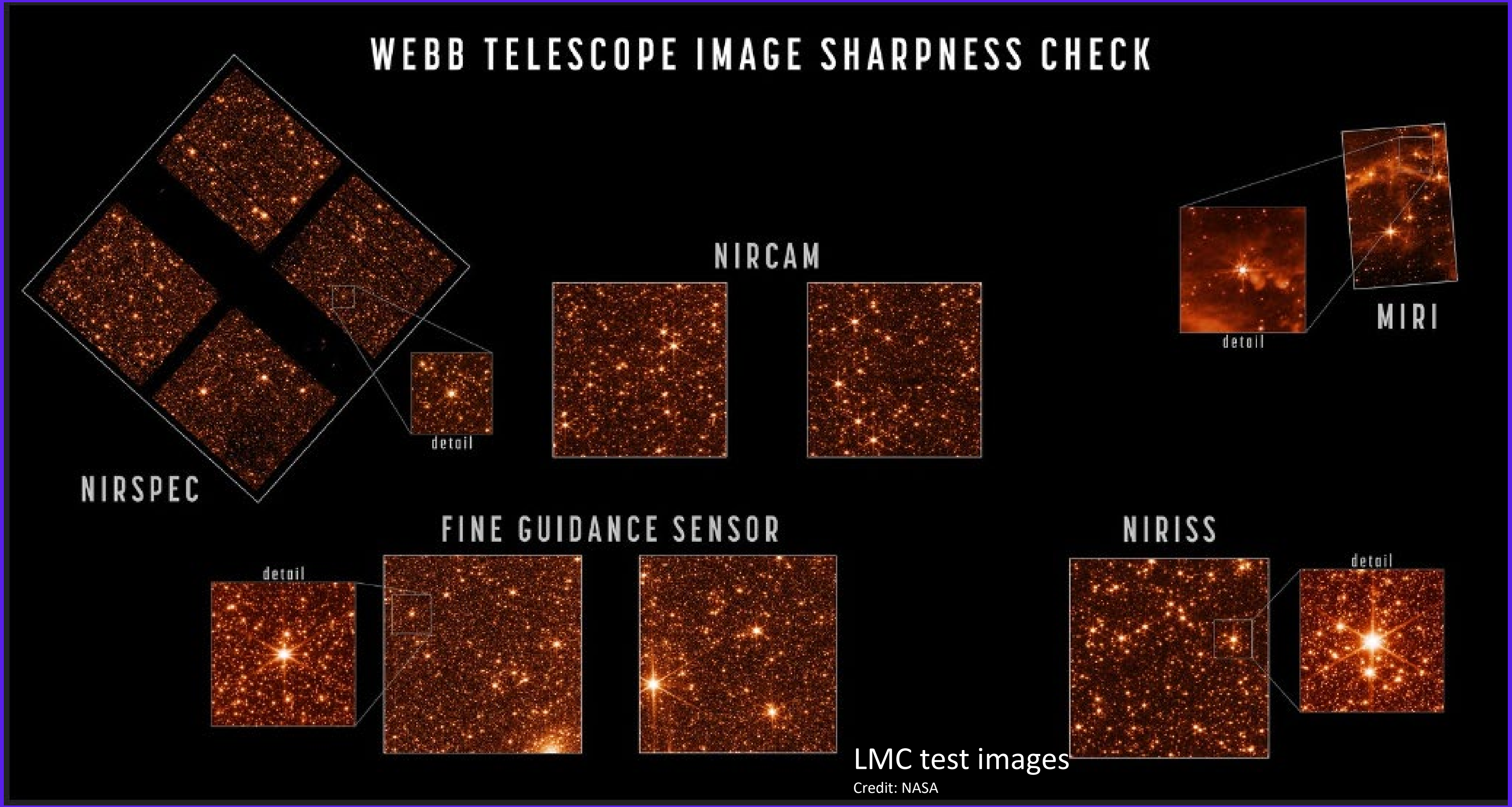



Goddard Space Flight Center, Greenbelt:
Integrated Science Instruments Module (ISIM)
MIRI
NIRISS+FGS
NIRSpec
NIRCam
Credit: NASA

JWST – 18 Segments Work Together!



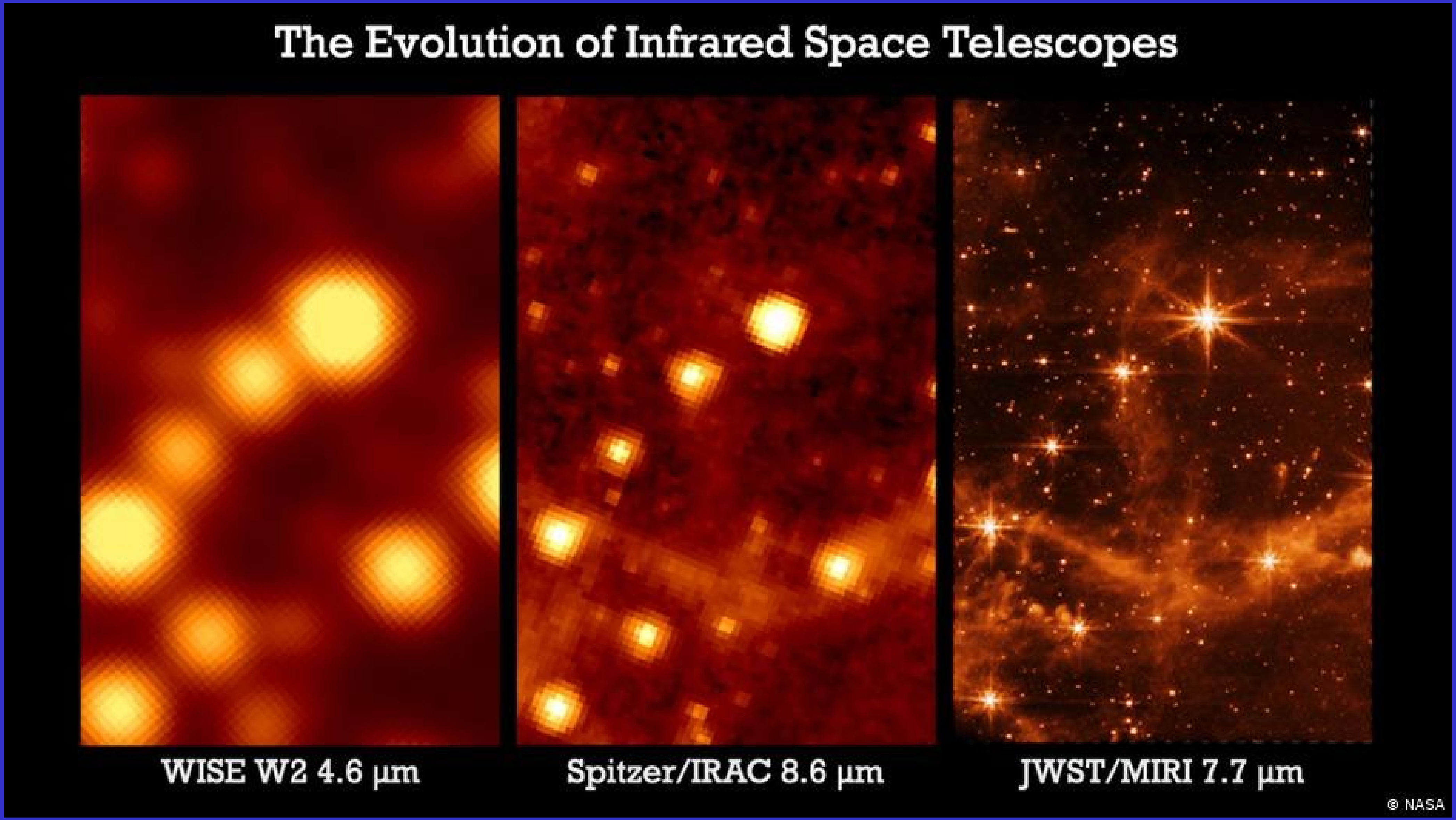
April 28, 2022: JWST ready to go!



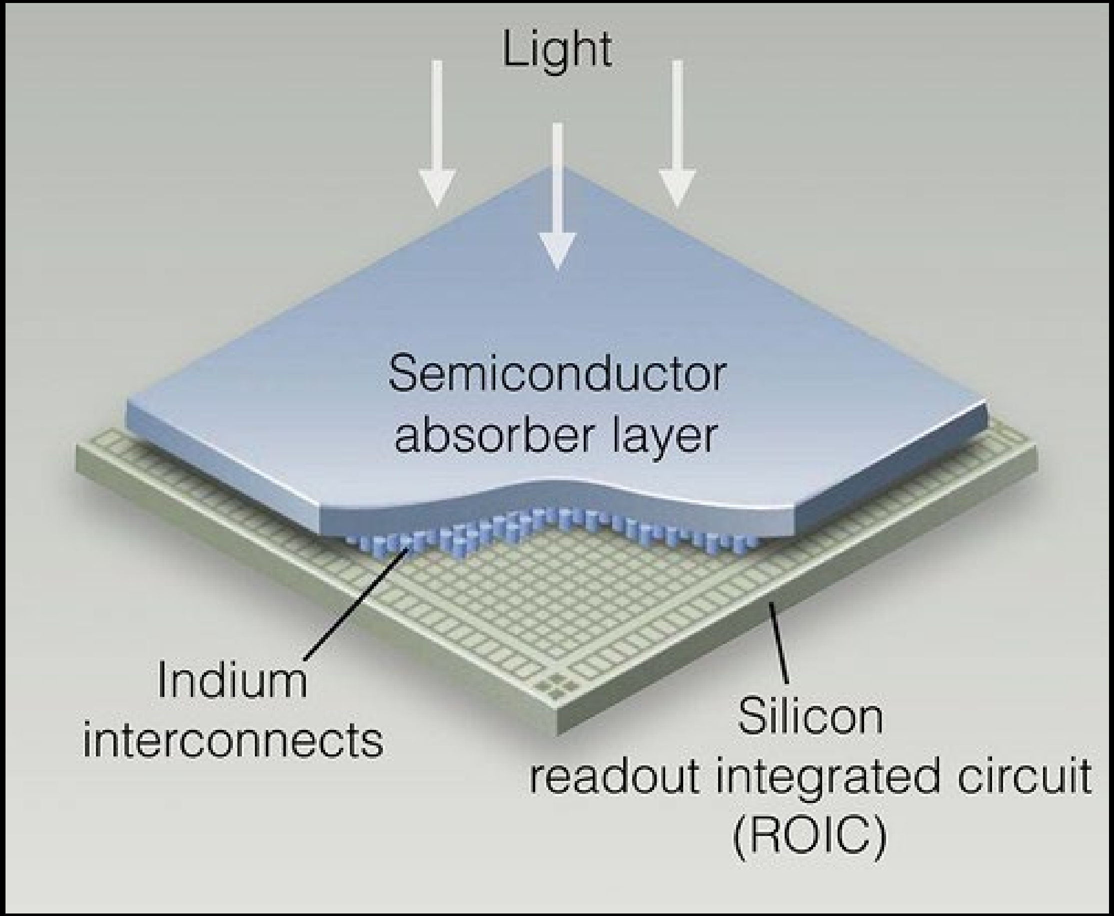
LMC test images

Credit: NASA

JWST – The Most Powerful Infrared Space Telescope



JWST Detectors



Large, high performance IR arrays

Three Key Technologies

1. Growth and processing of the HgCdTe detector layer
2. Design and fabrication of the CMOS readout integrated circuit (ROIC)
3. Hybridization of the detector layer to the CMOS ROIC

Review: Rieke (2007)

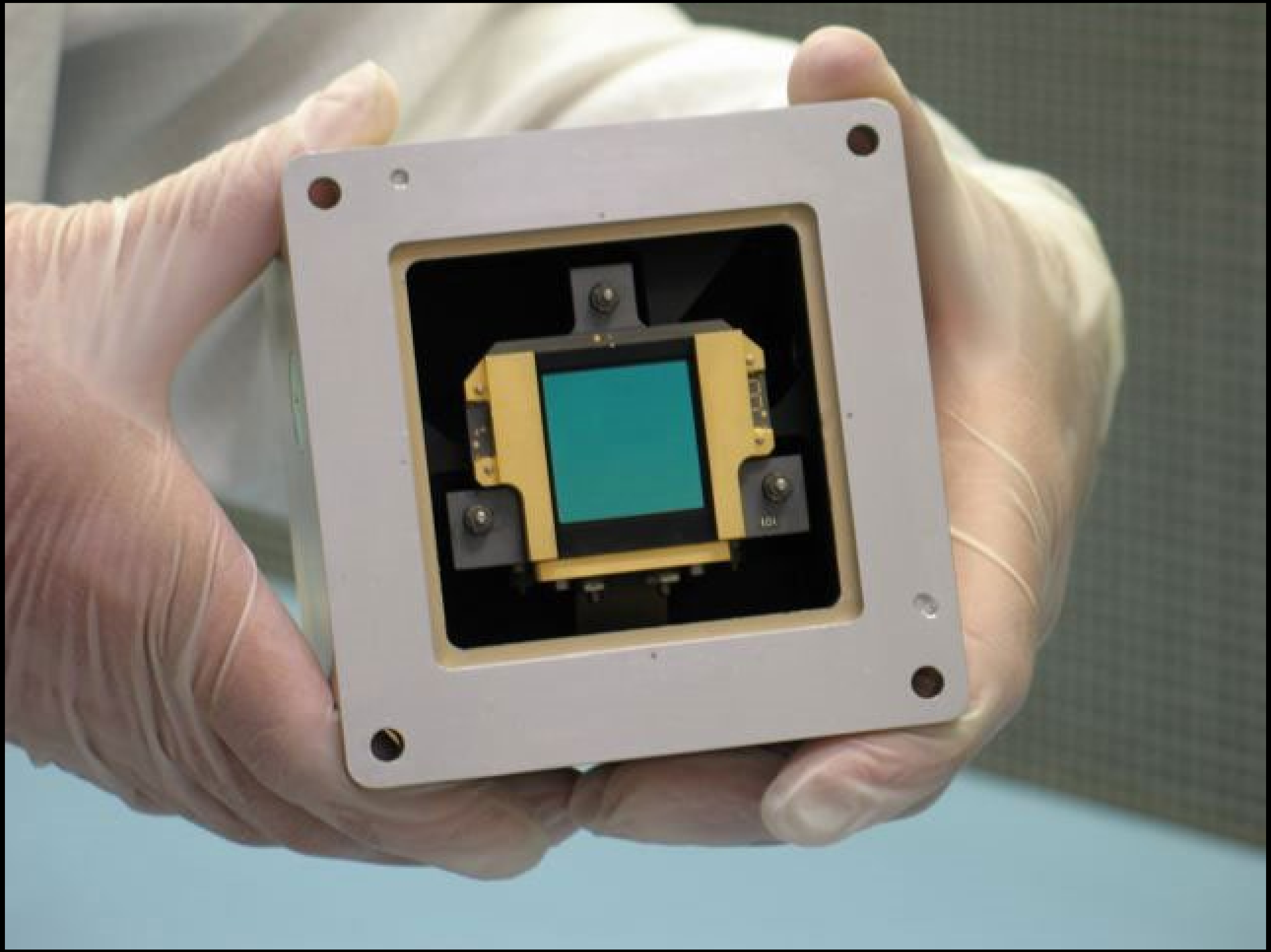
Wavelength range from 0.6 to 28 microns

JWST Detectors

Table 1. JWST Instruments and their Detectors

Instrument	Mercury-cadmium-telluride H2RG		Arsenic doped silicon
	0.6 - 2.5 μm	0.6 - 5 μm	5 - 28 μm
NIRCam	8	2	
NIRSpec		2	
FGS/NIRISS		3	
MIRI			3

JWST-MIRI Detector



Arsenic doped silicon (Si:As) from Raytheon (1024x1024 pixels)

Hardware Contribution - Max Planck Institute for Astronomy

Development, Test and Qualification of MIRI Mechanisms

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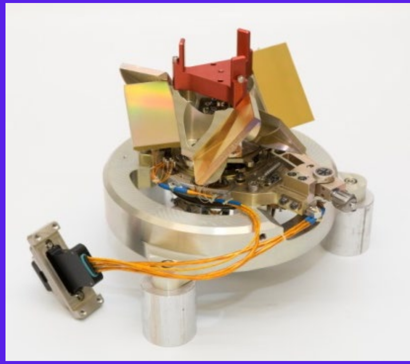
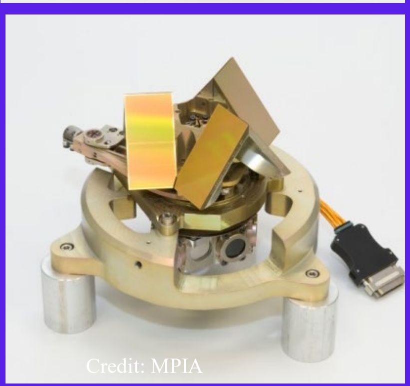
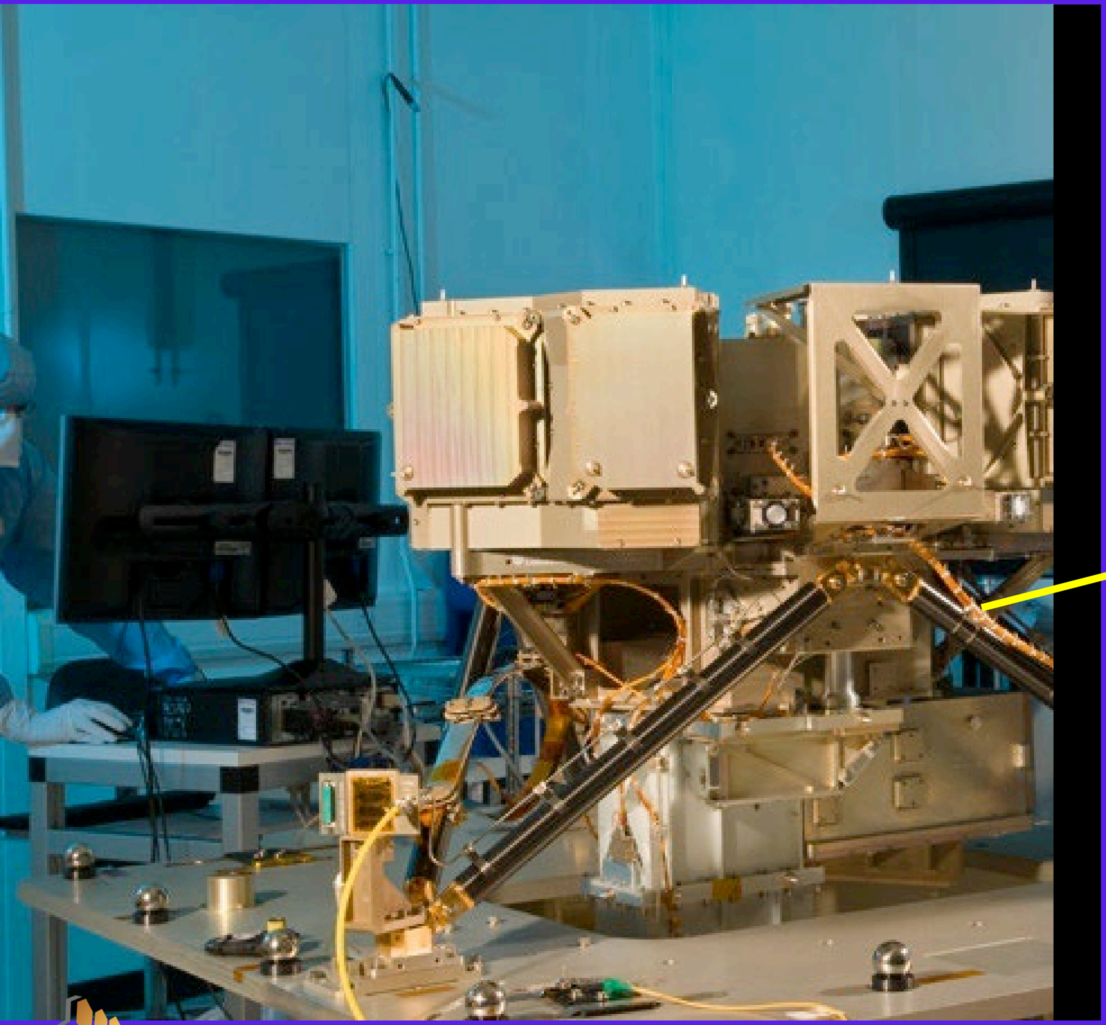


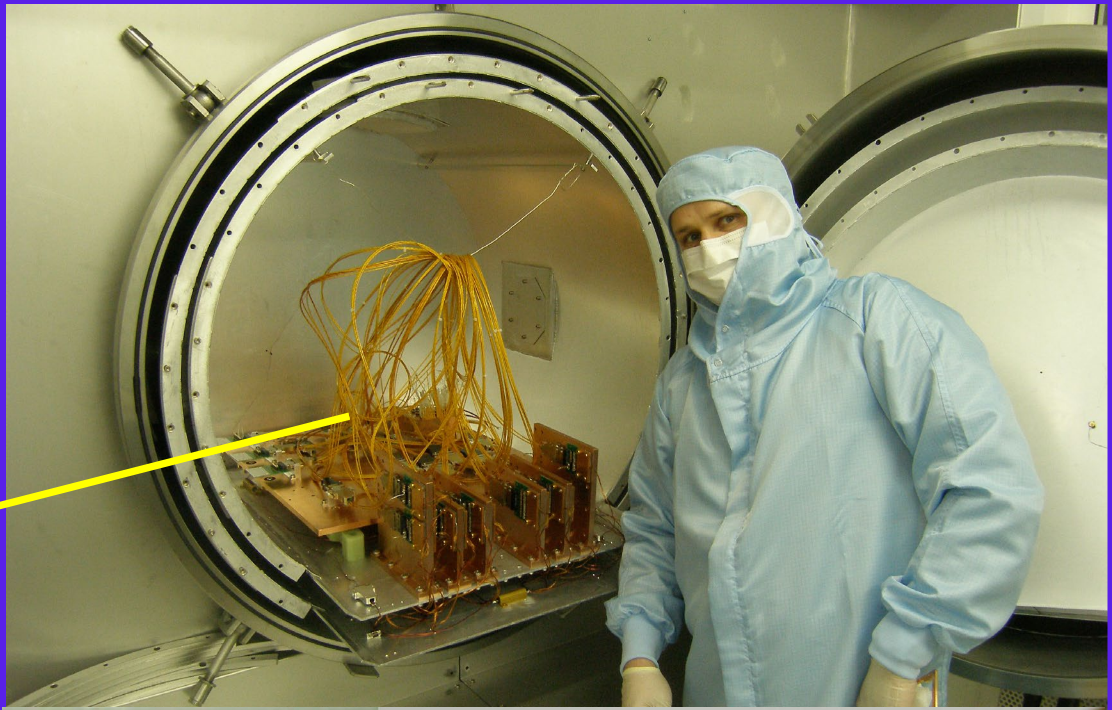


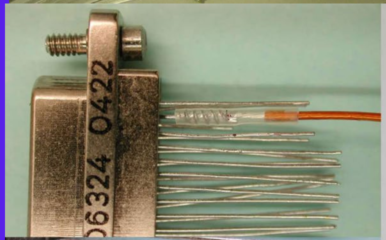
22 scientific institutes contributed to MIRI from 2003-2010

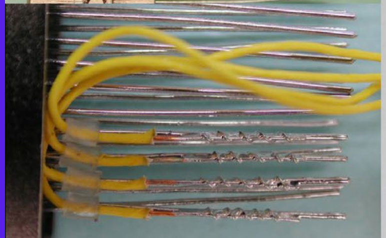
Swiss Hardware for MIRI (PSI/ETH): Cryoharness (and contamination control cover)

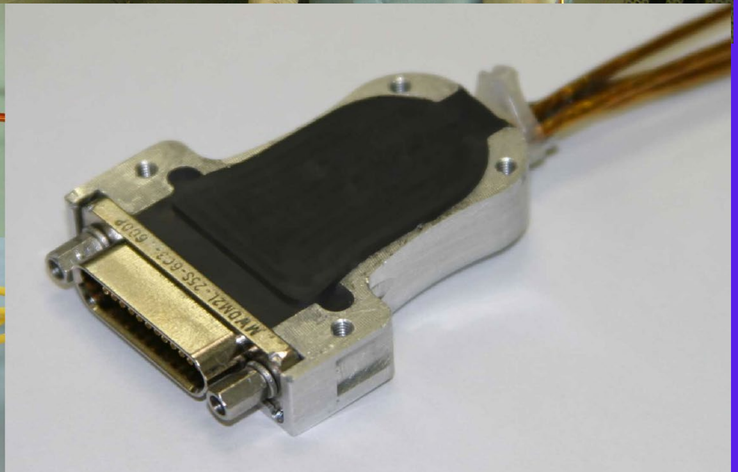


Cryocables from Syderal in PSI test chamber



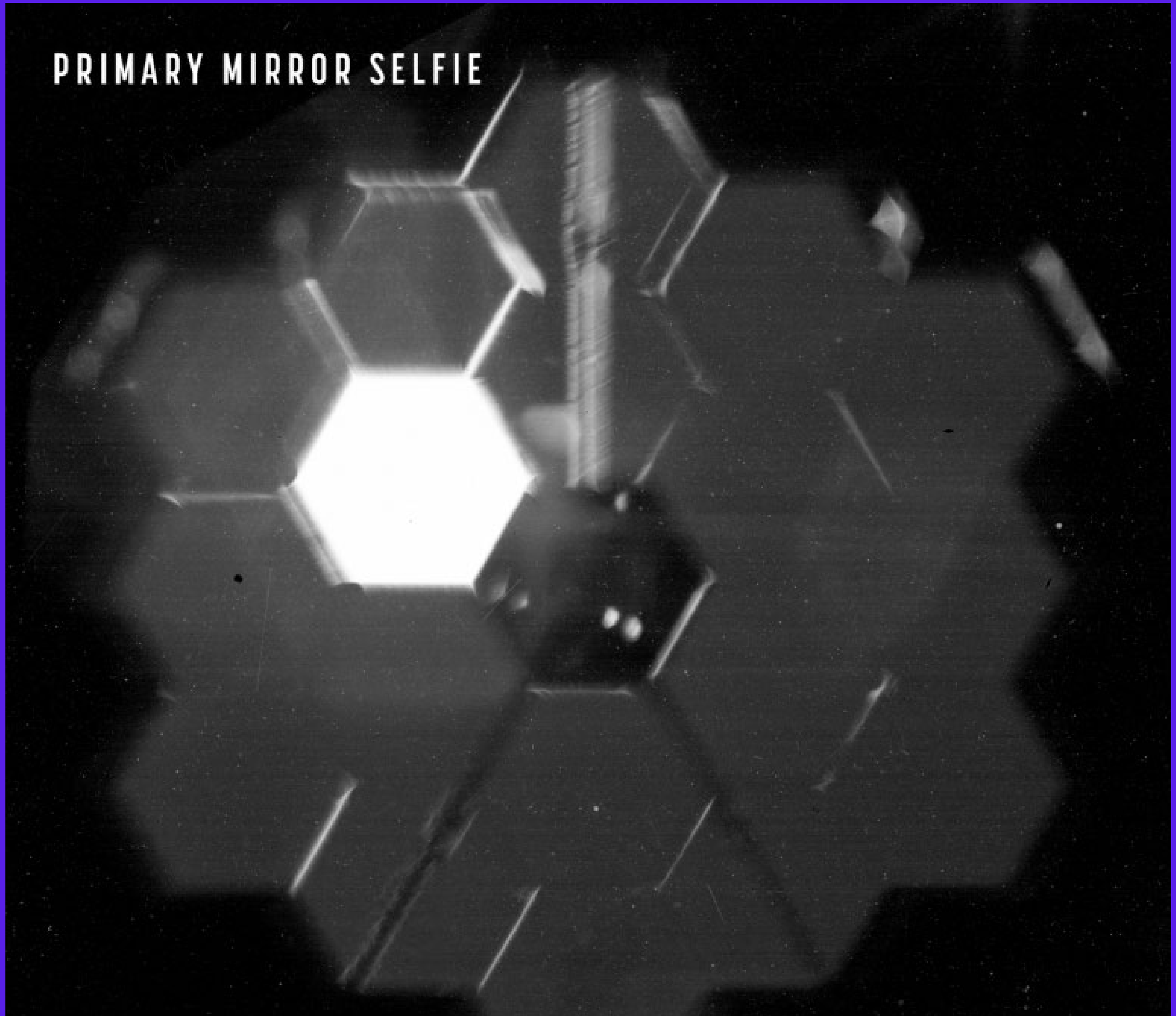






WEBB SPACE TELESCOPE

JWST Selfie



NIRCam: JWST main mirror selfie
Credit: NASA

Stephans Quintet (It‘s a wonderful life …)

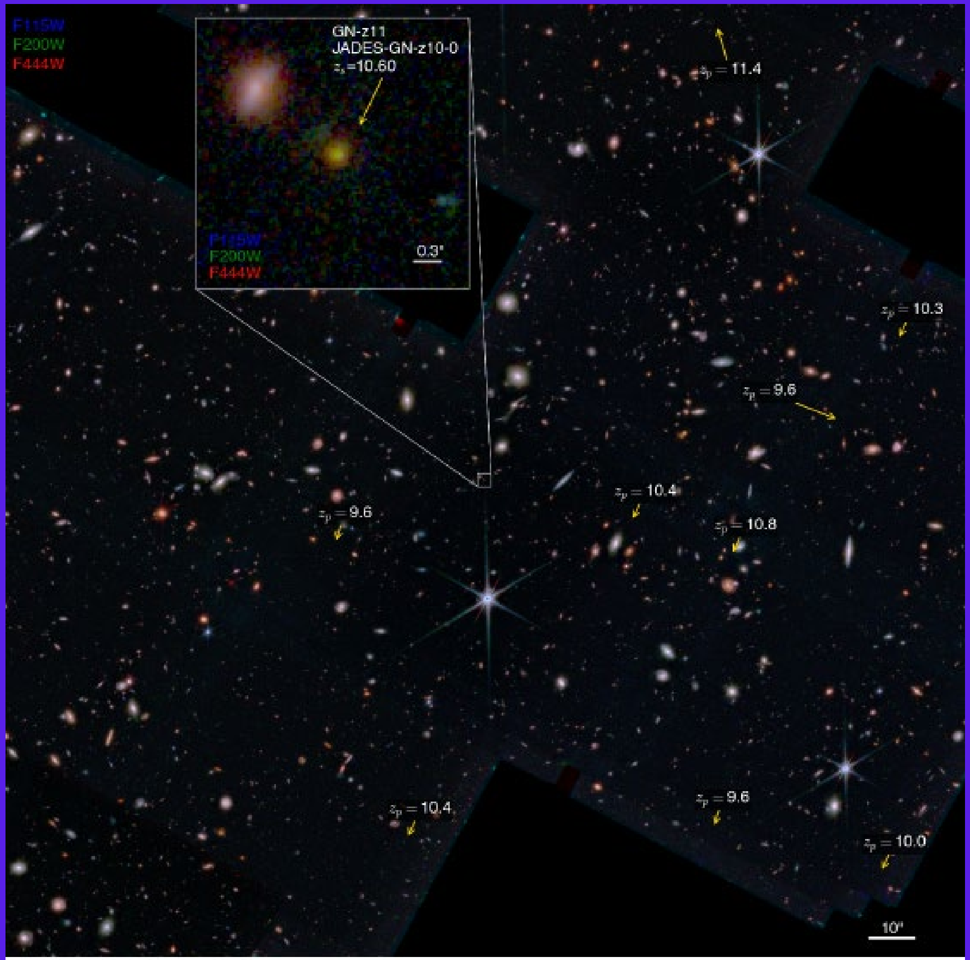
NIRCAM + MIRI
1000 images
150 Million pixels
1/5 moon diameter

The High-redshift Universe – A Goldrush …

Z > 10: Less than 450 Mill. Years after big bang
4 galaxies between z=10.3 and 13.2 spectroscopically confirmed (Curtis-Lake et al. 2023):
Metal-poor, 10^7-10^8 M_{sun} , young stellar ages

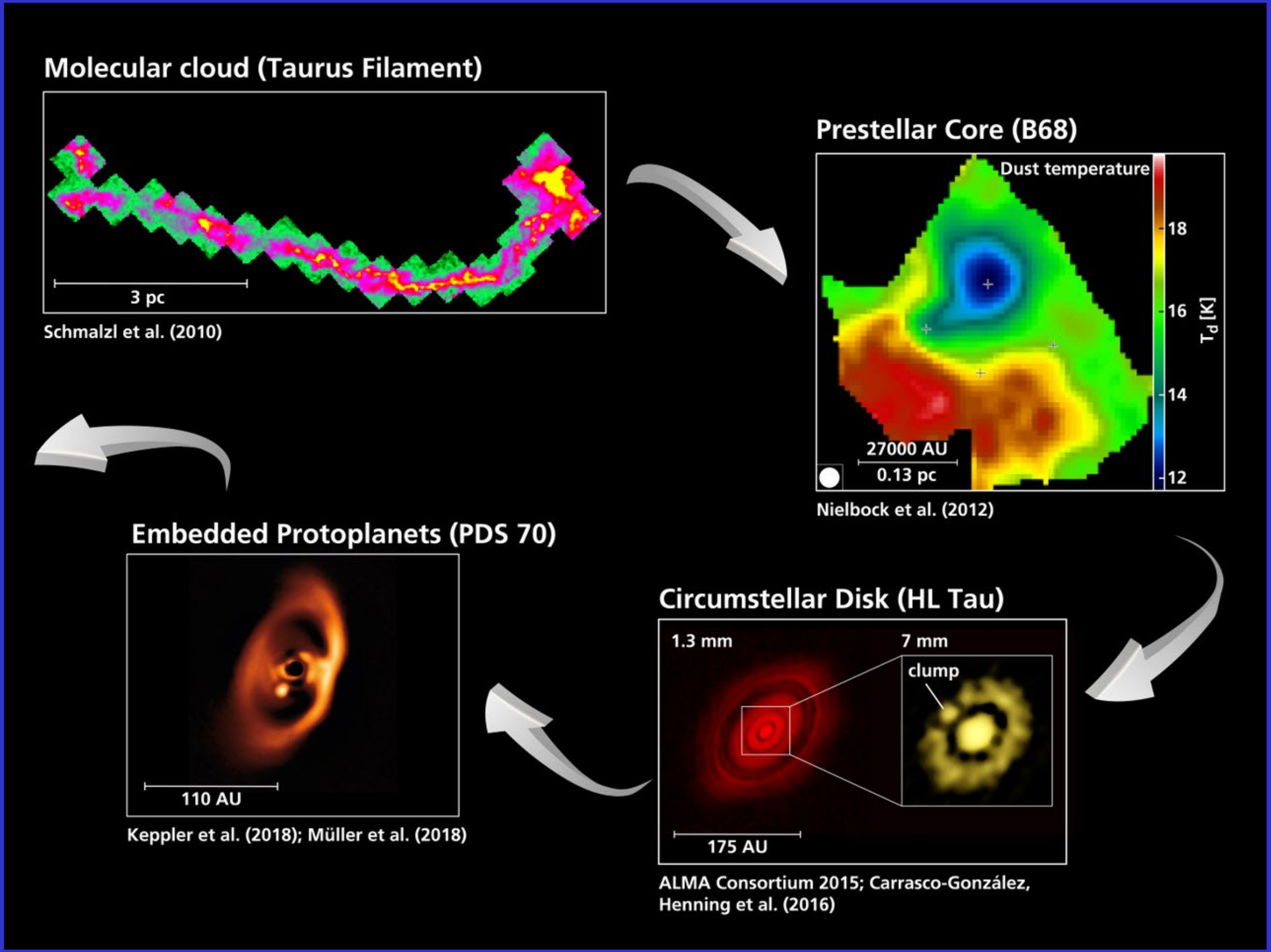
GN – z11
Z=10.6 (Bunker et al. 2023)

10^9 solar masses,
SFR = 20 M_{sun}/yr
Young stellar age= 20 Myr

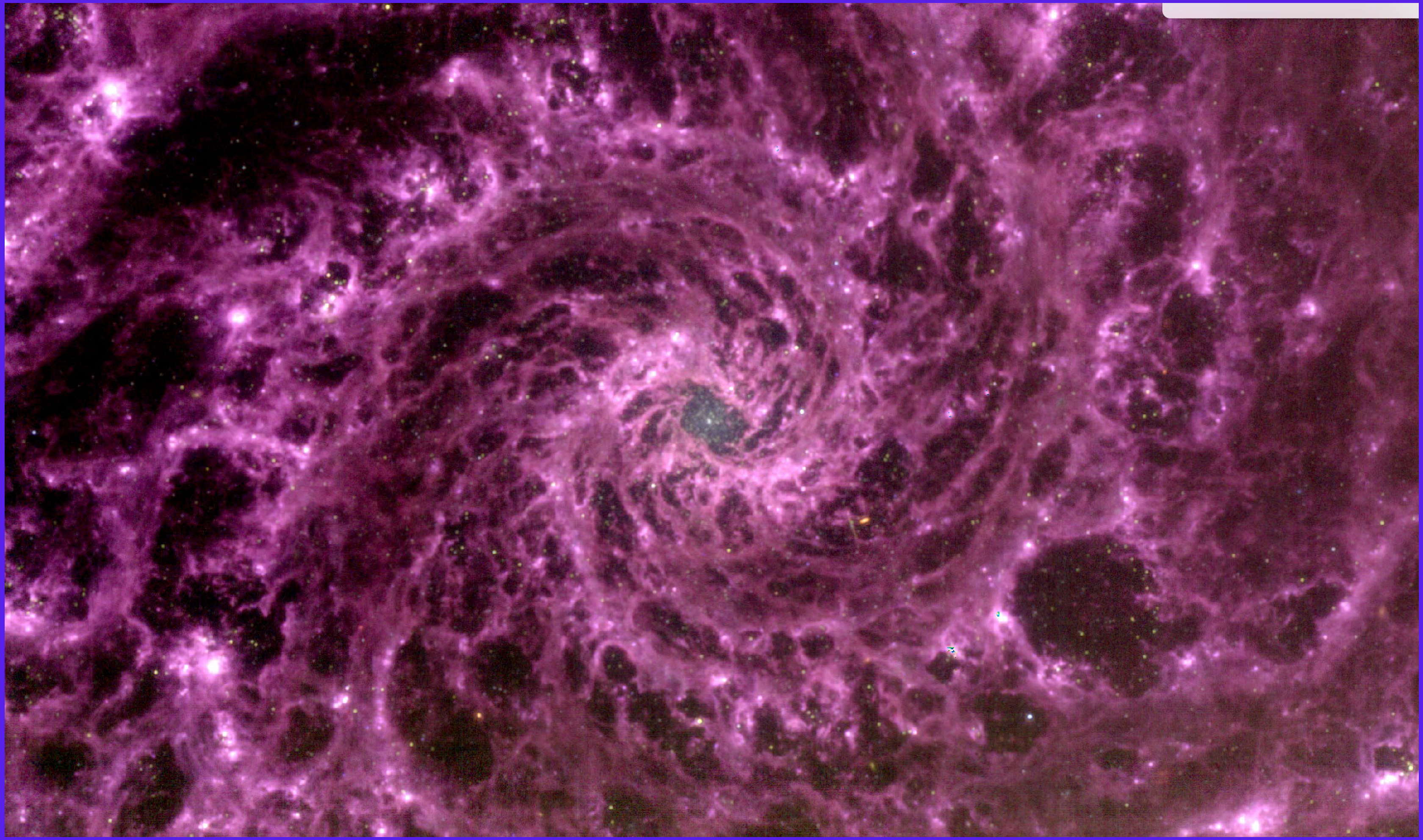


JWST Advanced Deep Extragalatic Survey (JADES):NIRCAM
Taccella et al. (2023)

From Atomic and Molecular Clouds to Planets

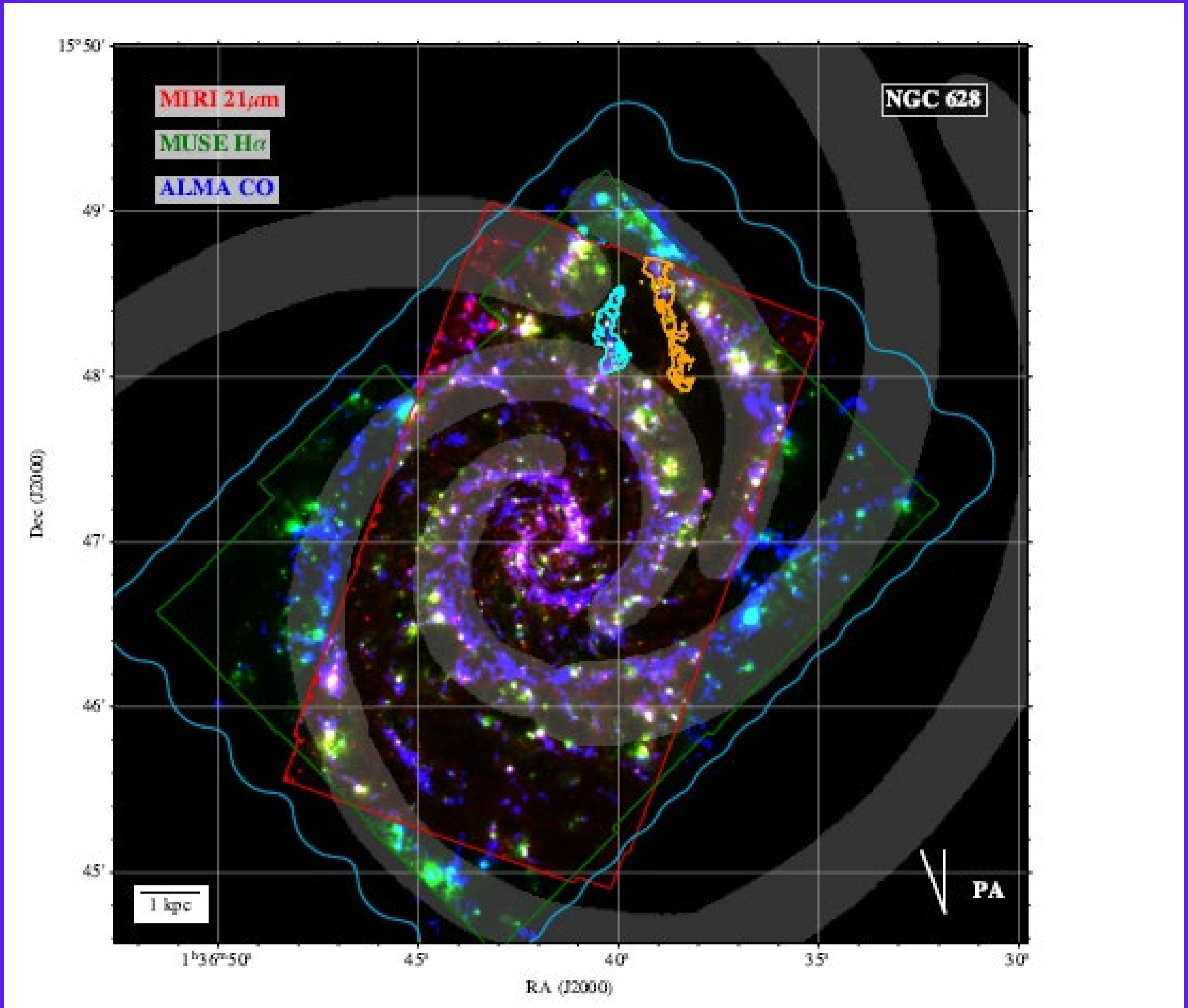


MIRI Image of the Grand Design Spiral Galaxy M 74



Bubbles and Hierachical Structure of Filaments

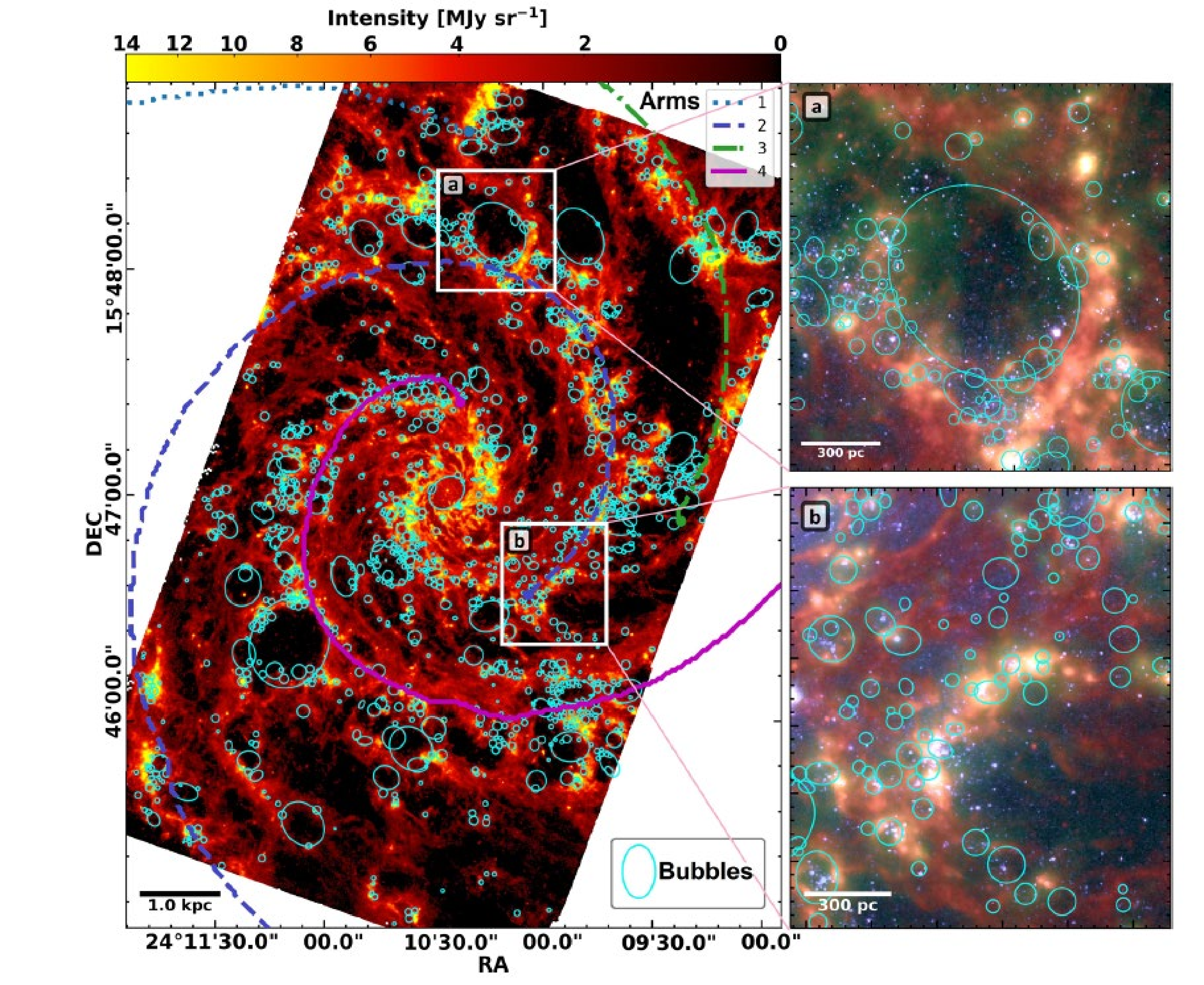
Star Formation in NGC 628



Williams et al. (2022)

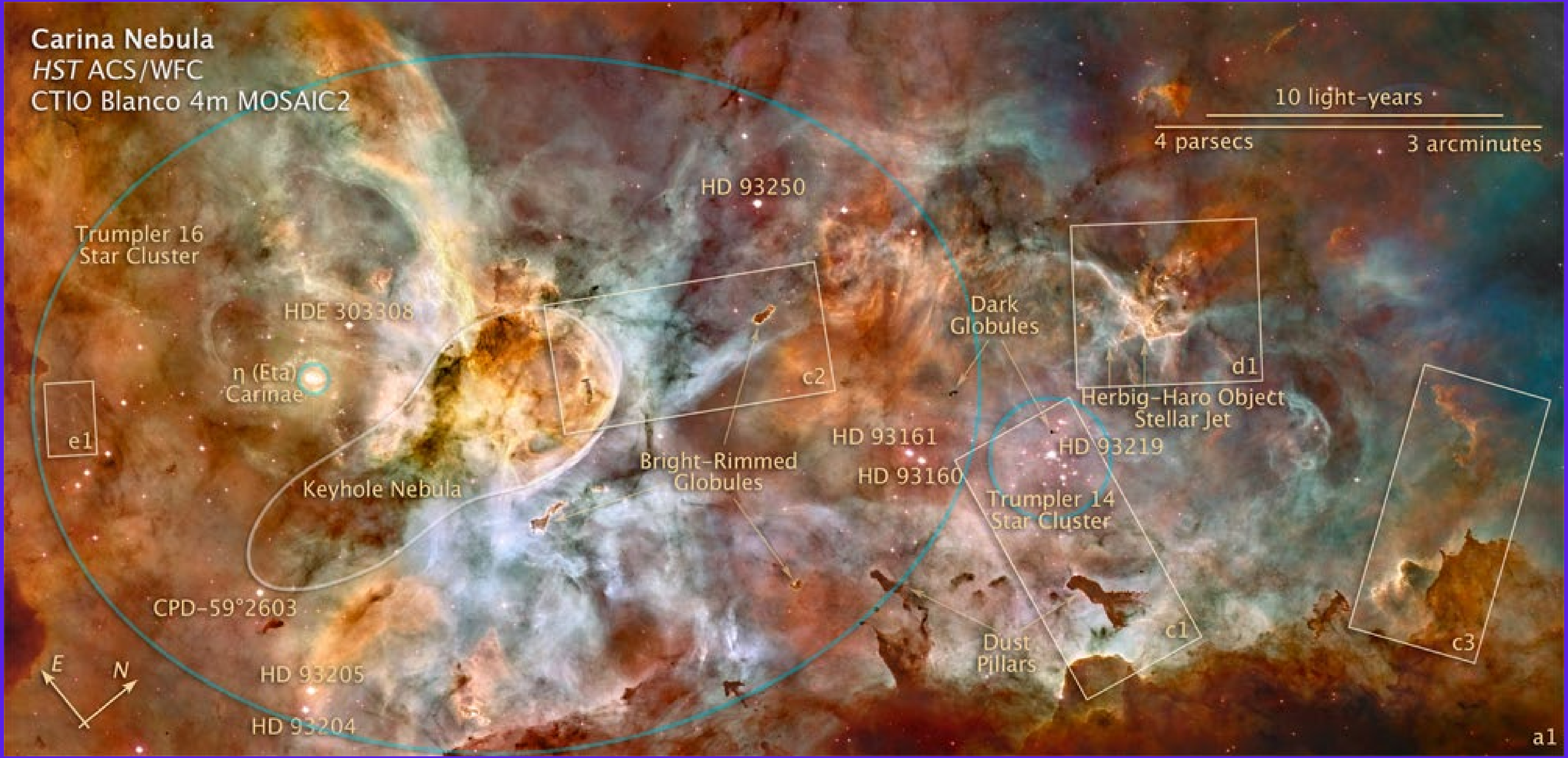
Star Formation in NGC 628

1700 bubbles – feedback



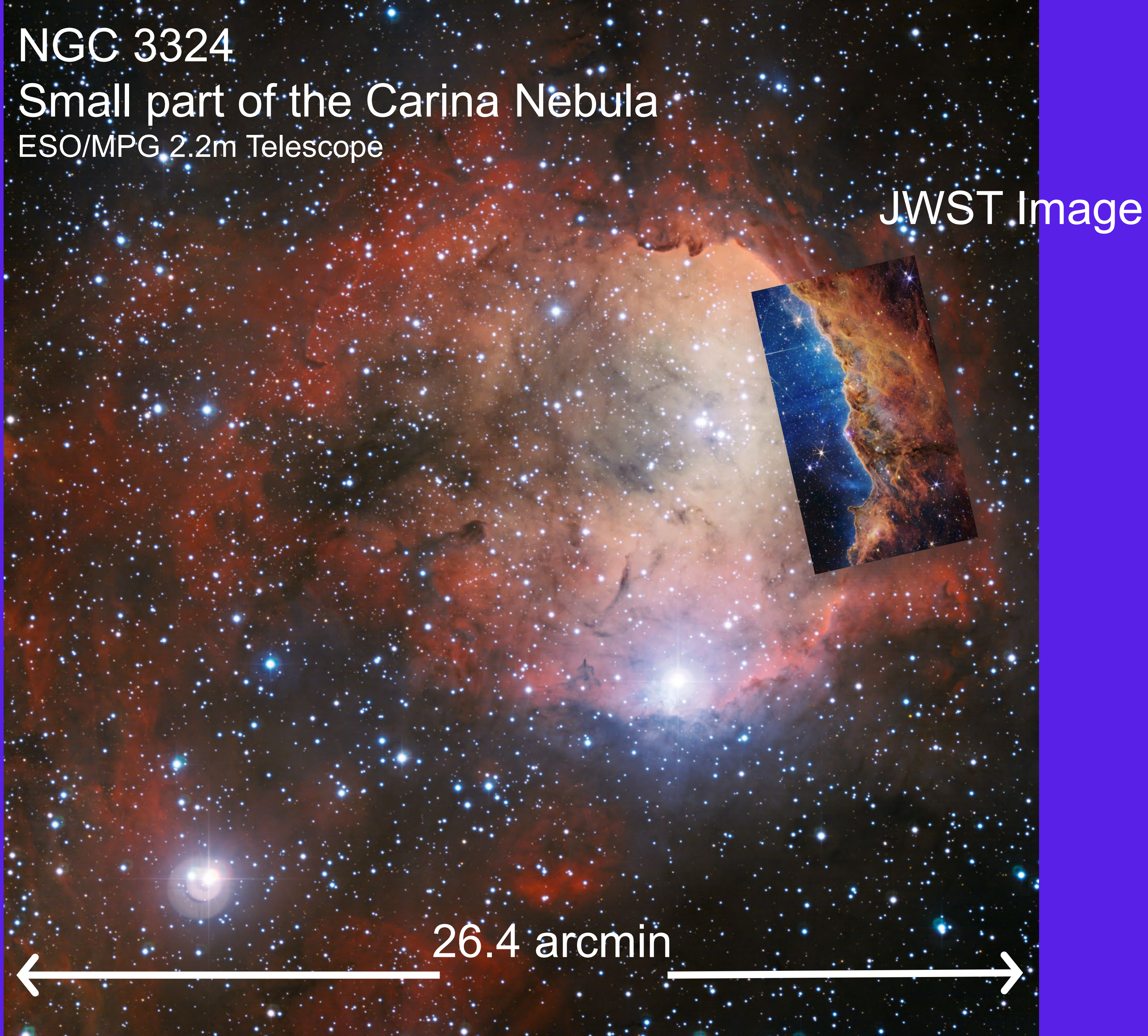
Watkins et al. (2023), PHANGS

Star Formation in the Carina Nebula



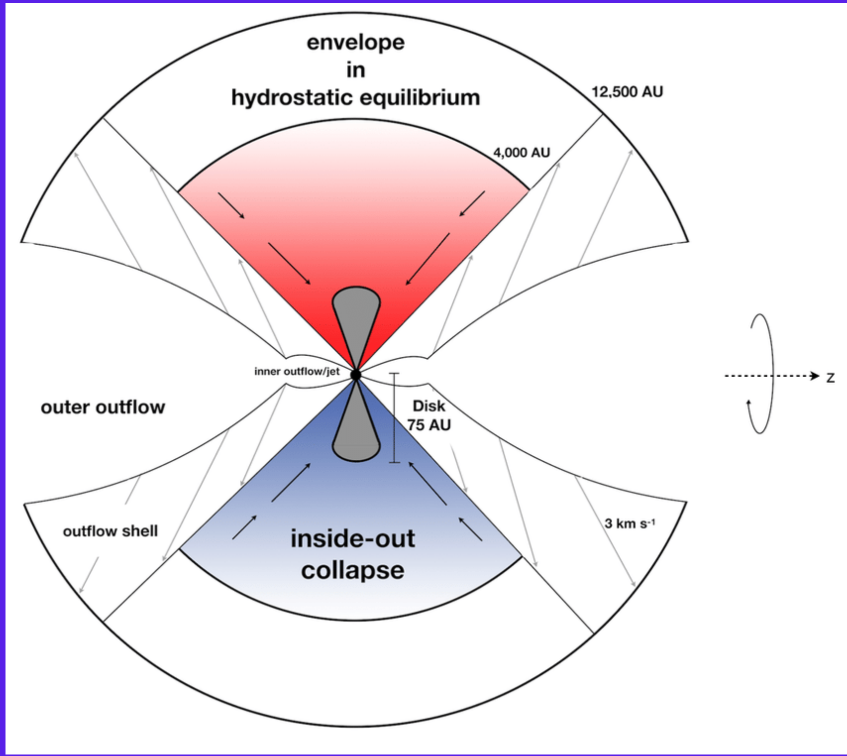
Star Formation in the Carina Nebula

WFI at MPG/ESO
Telescope – La Silla


NGC 3324
Small part of the Carina Nebula
ESO/MPG 2.2m Telescope
JWST Image
26.4 arcmin

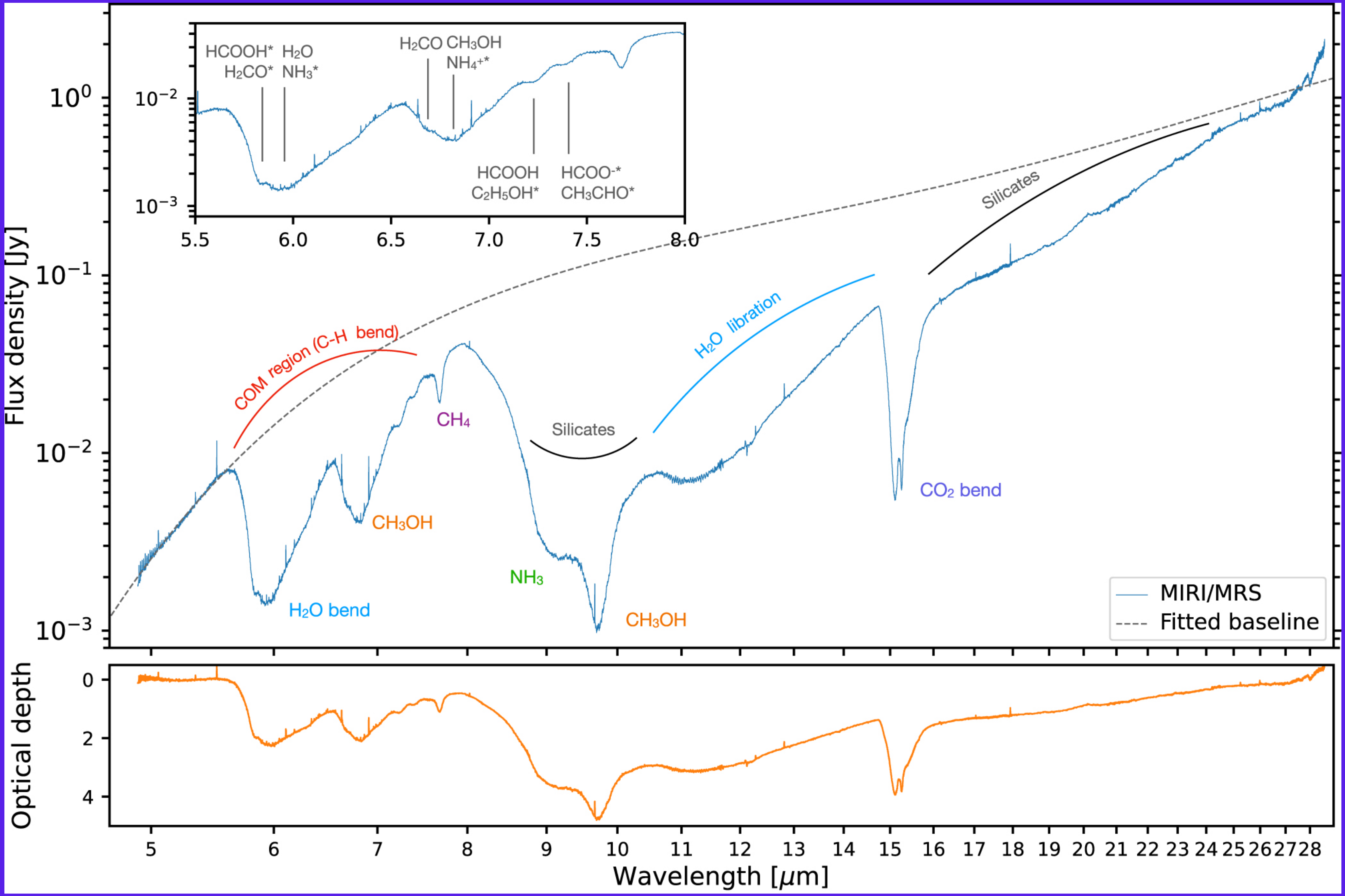
Star Formation in the Carina Nebula

NIRCAM Image of the Protostar L 1527 in Taurus



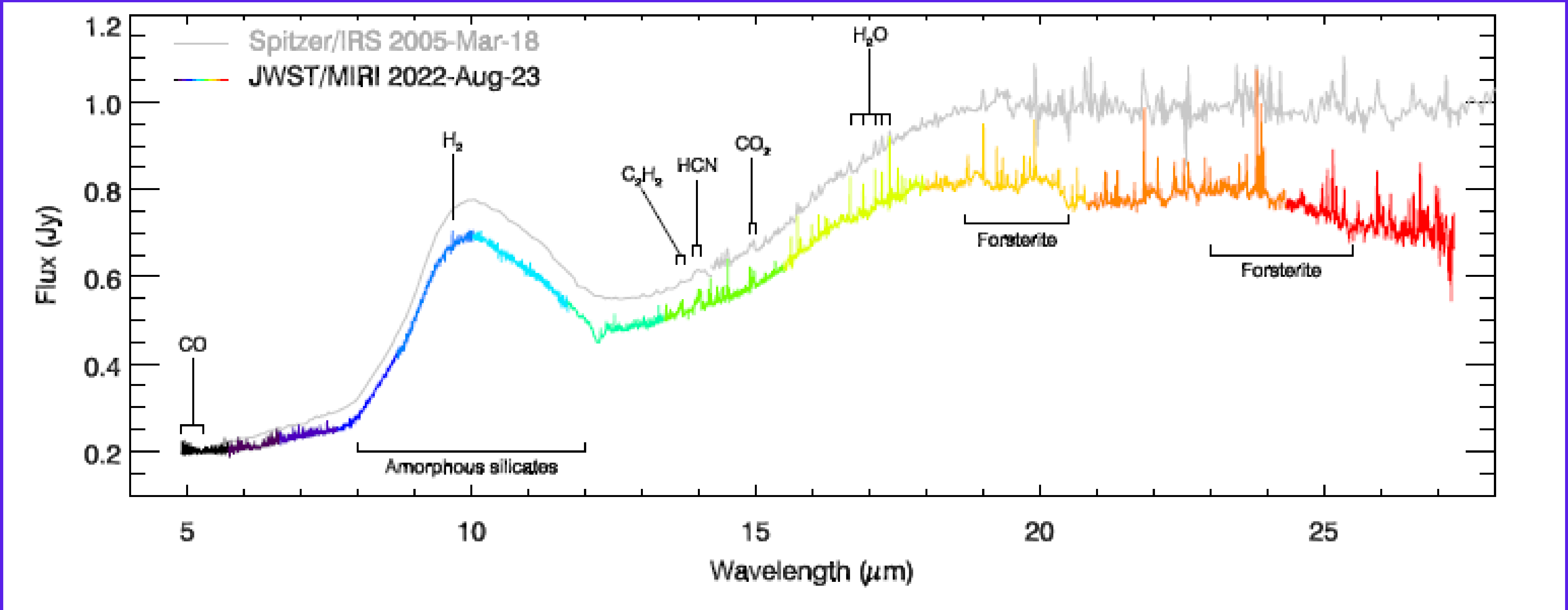
Lizxandra-Flores et al. (2021): ALMA

MIRI Spectrum of the Class 0 Object IRAS 15398-3359



Yang et al. (2022)

MIRI Spectrum of the Disk around the Eruptive Star EX Lupi

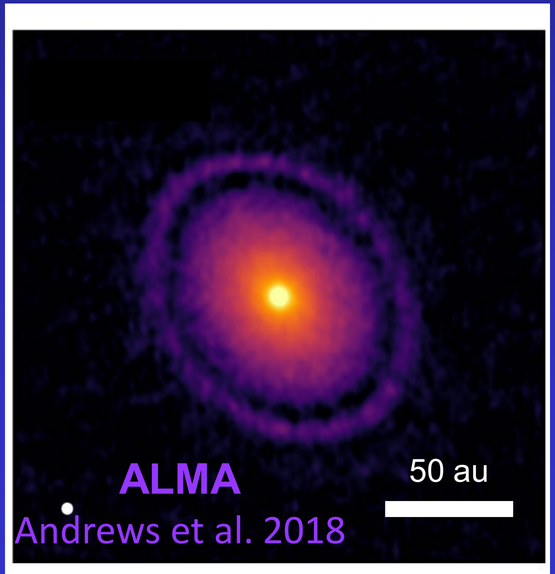


Kospal et al. (2023)

Early MINDS Results

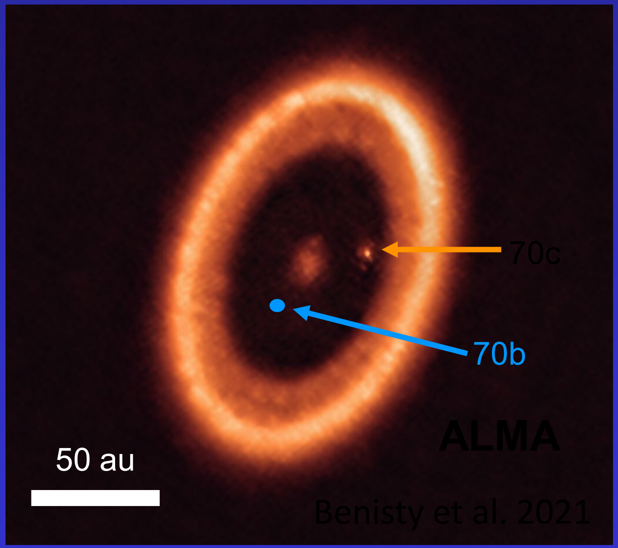
A First Look at the Striking Diversity of Inner Disks

GW Lup
Full disk



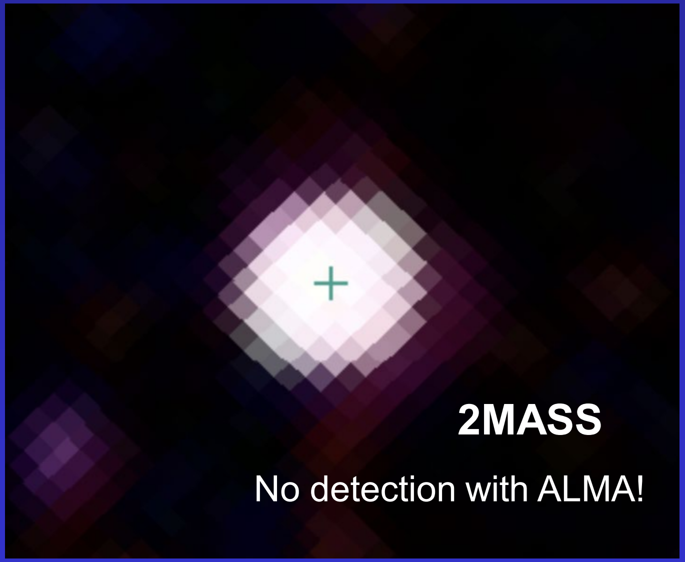
Grant et al. 2023

PDS 70
Transition disk



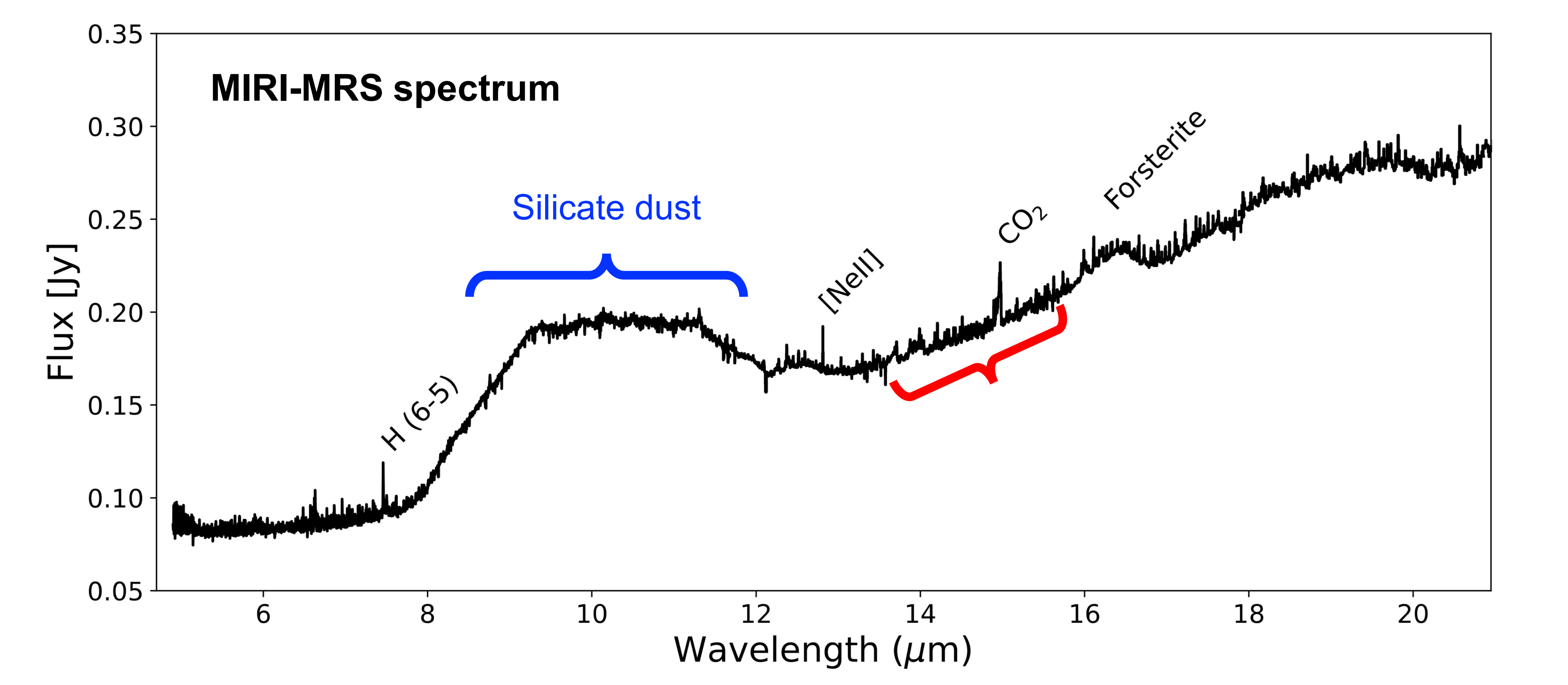
Perotti et al. 2023

J160532
“Young TRAPPIST1"



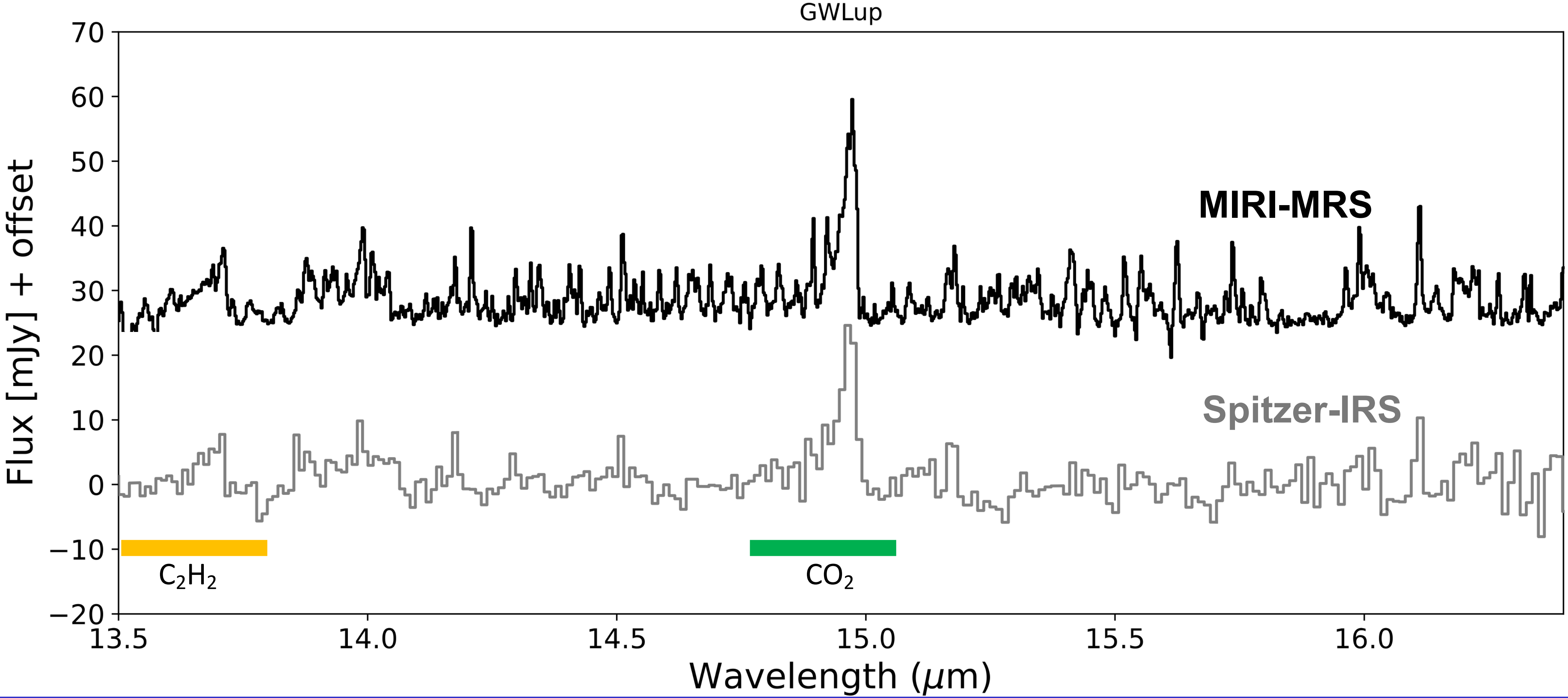
Tabone et al. 2023

GW Lup – A Disk around a T Tauri Star



Grant et al. (2023)

The GW Lup Disk



Credit: S. Grant

Fitting procedure with slab models

Fit one species

Subtract emission

Repeat for the next molecule

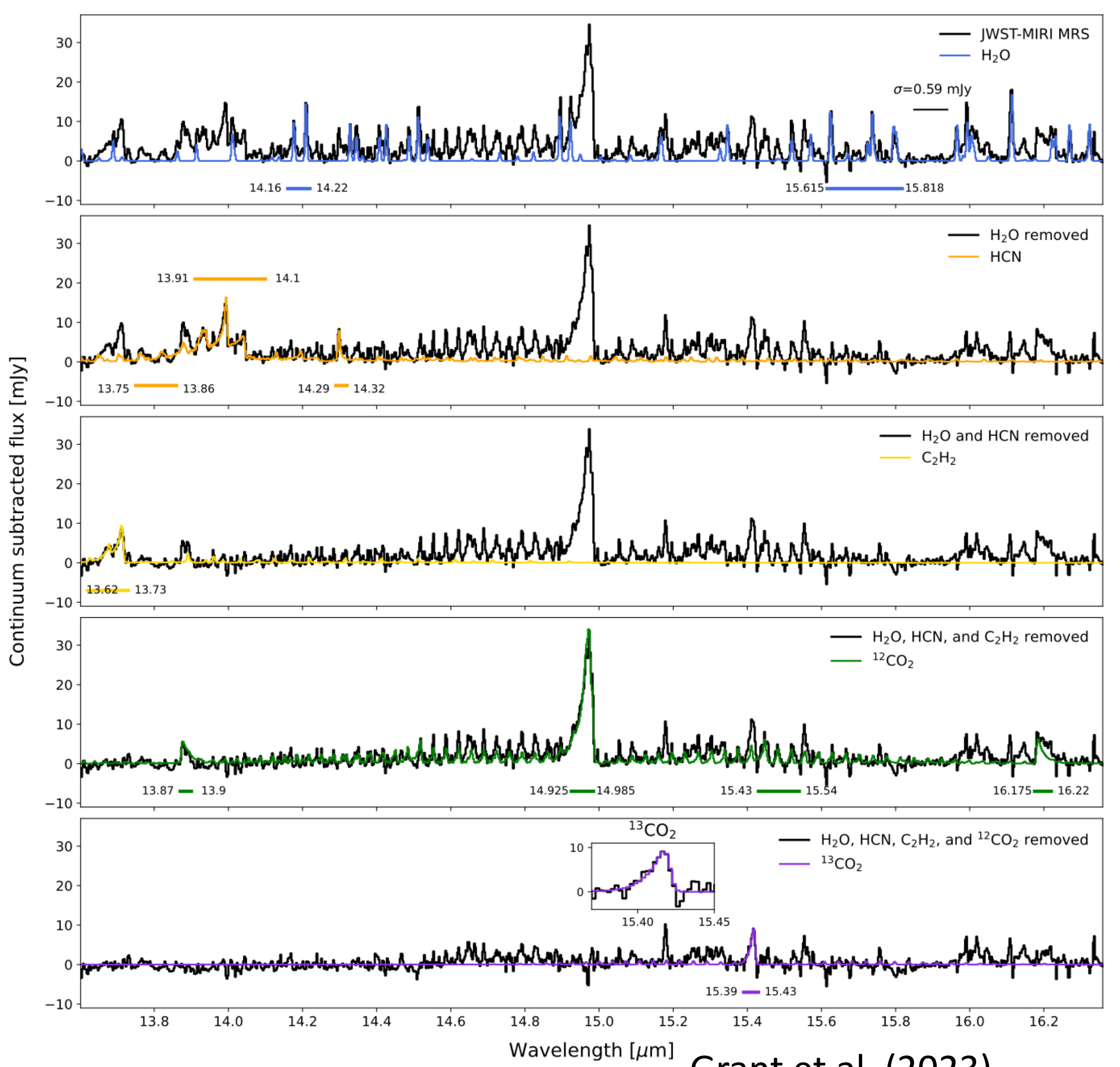
H_2O

HCN

C_2H_2

12CO2

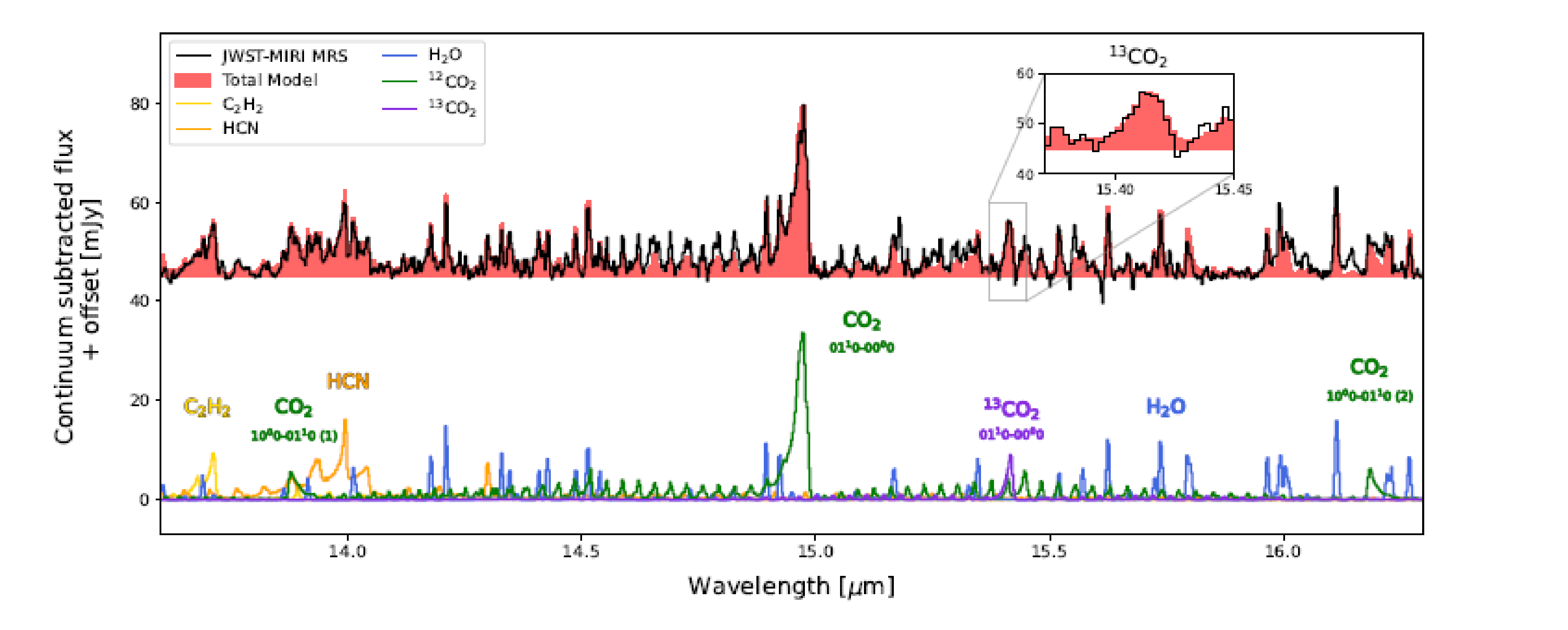
13CO2



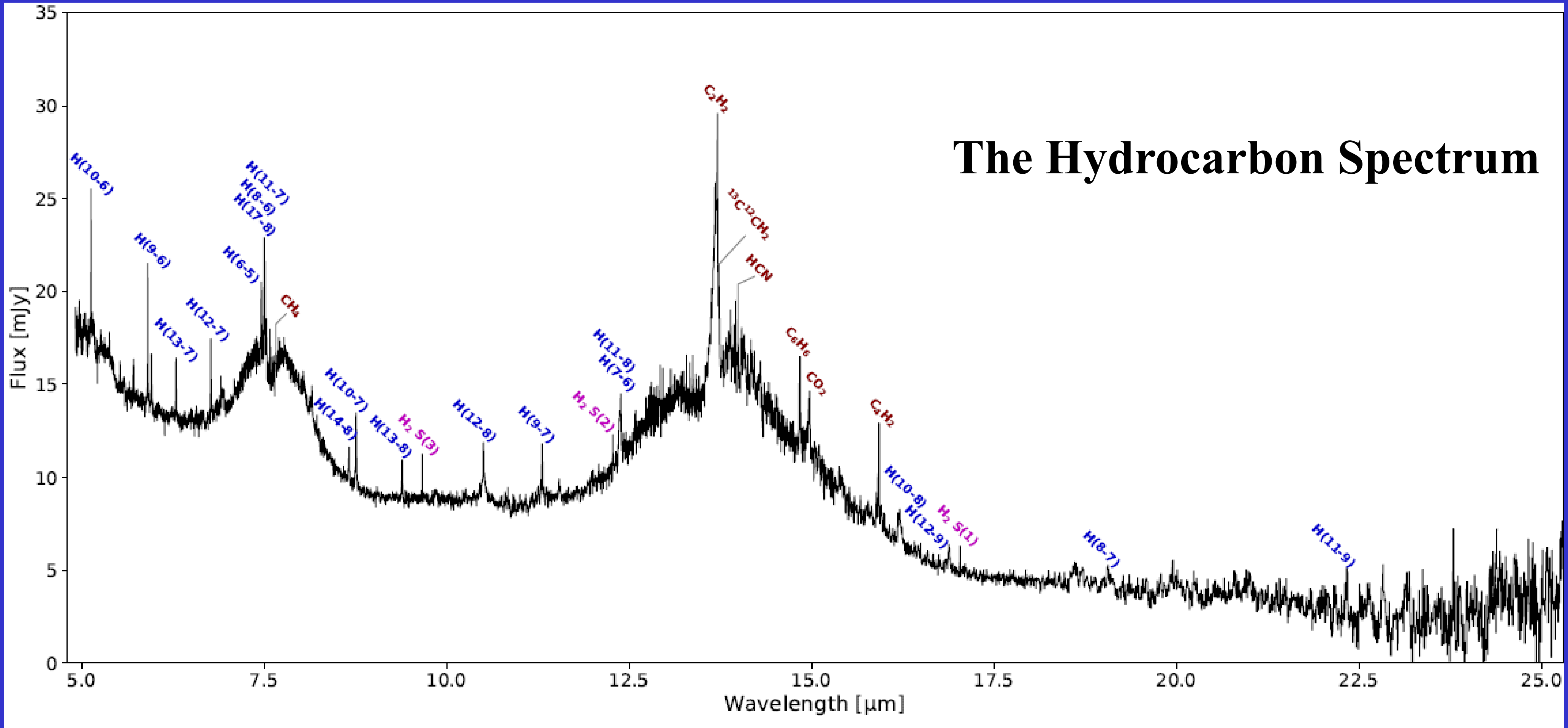
Grant et al. (2023)

Credit: S. Grant

CO_2 and $^{13}CO_2$ Detection



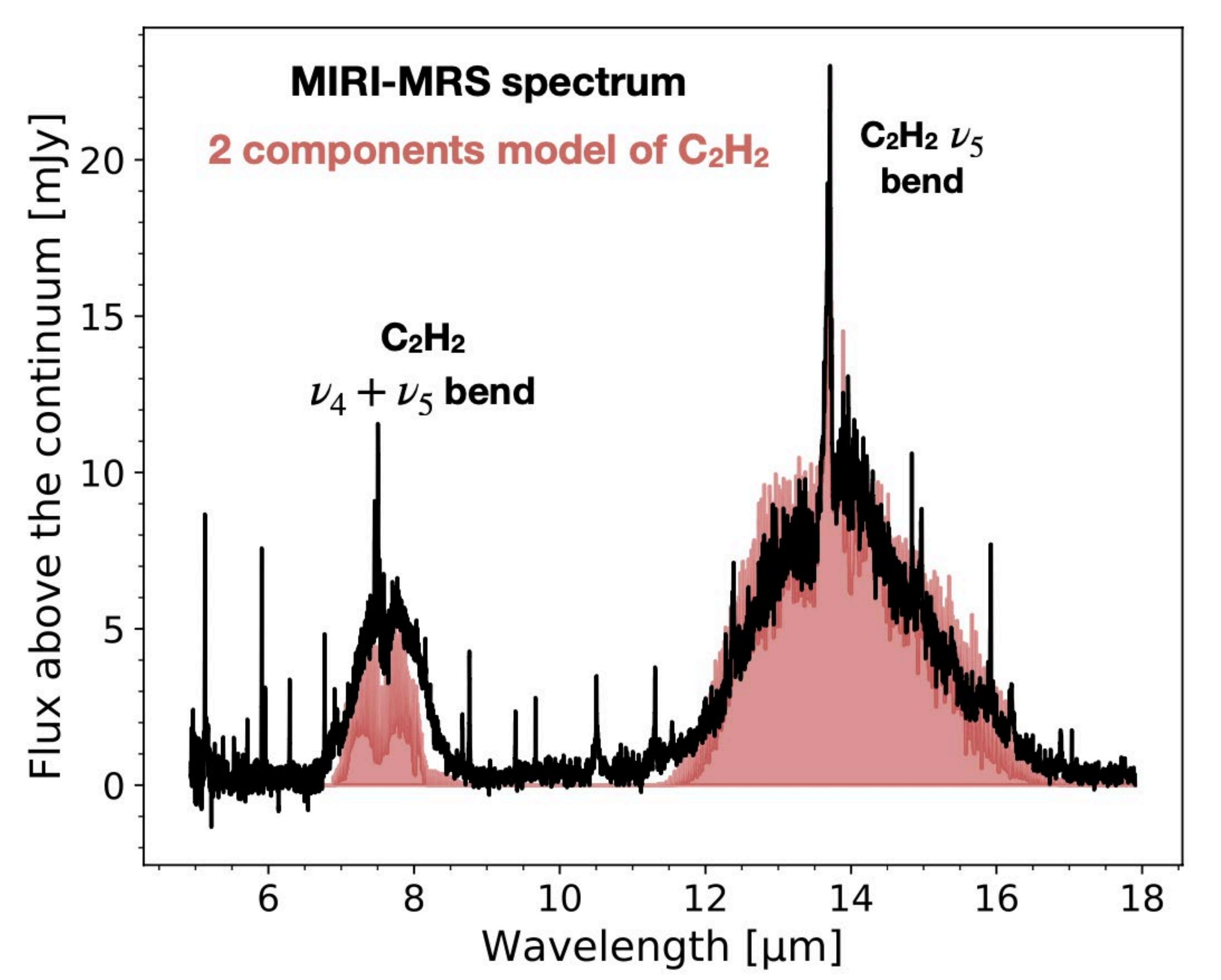
JWST Disk Spectrum around M4 Star



Tabone et al. (2023, Nature Astronomy)

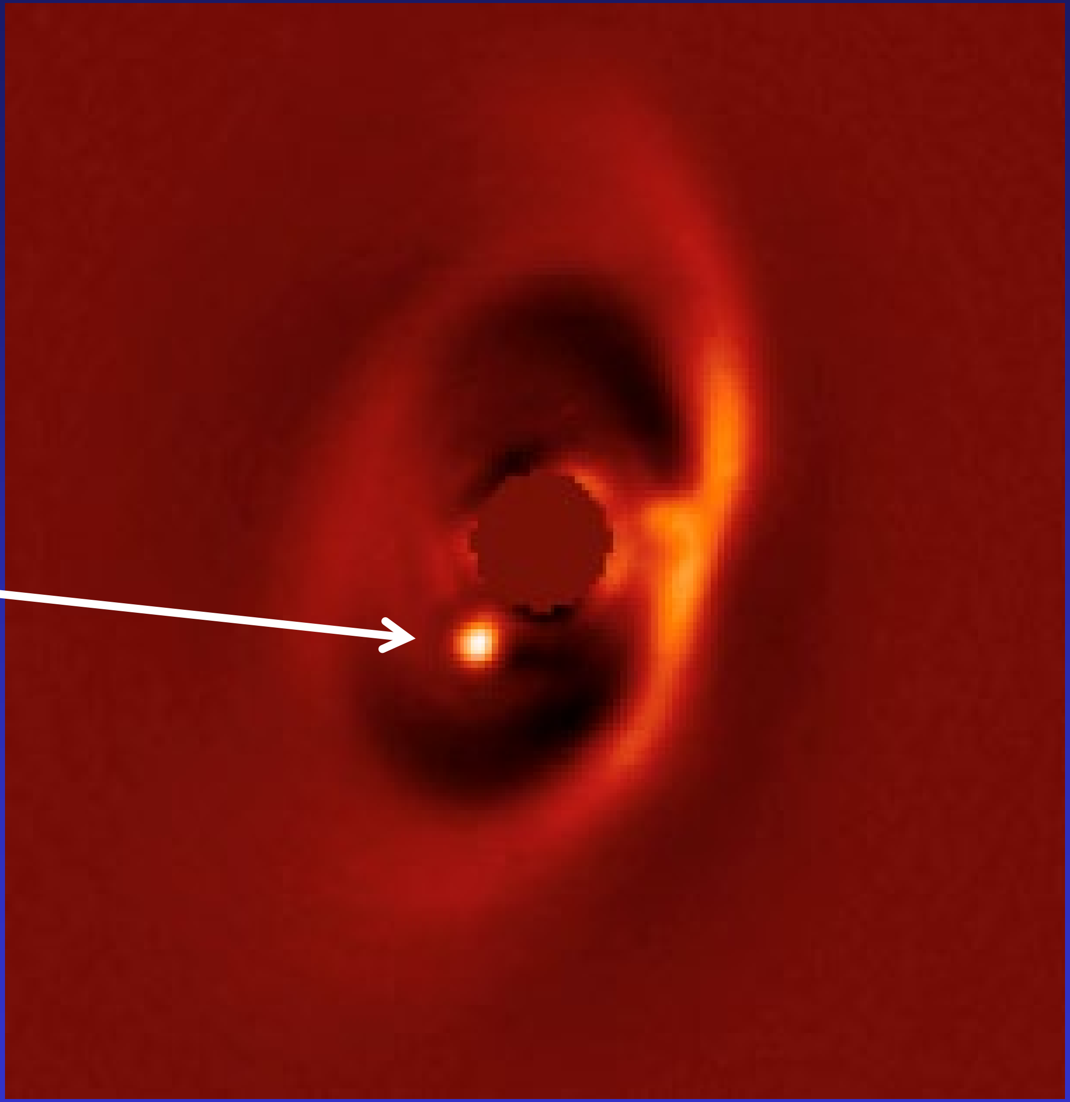
Booming hydrocarbons in J160532 disk

- Bumps produced by very optically thick ($N \sim 10^{21}$ cm^{-2}) C_2H_2 within 0.04au
- Lack of a silicate feature => dust settled and likely optically thin



Discovery of PDS 70b

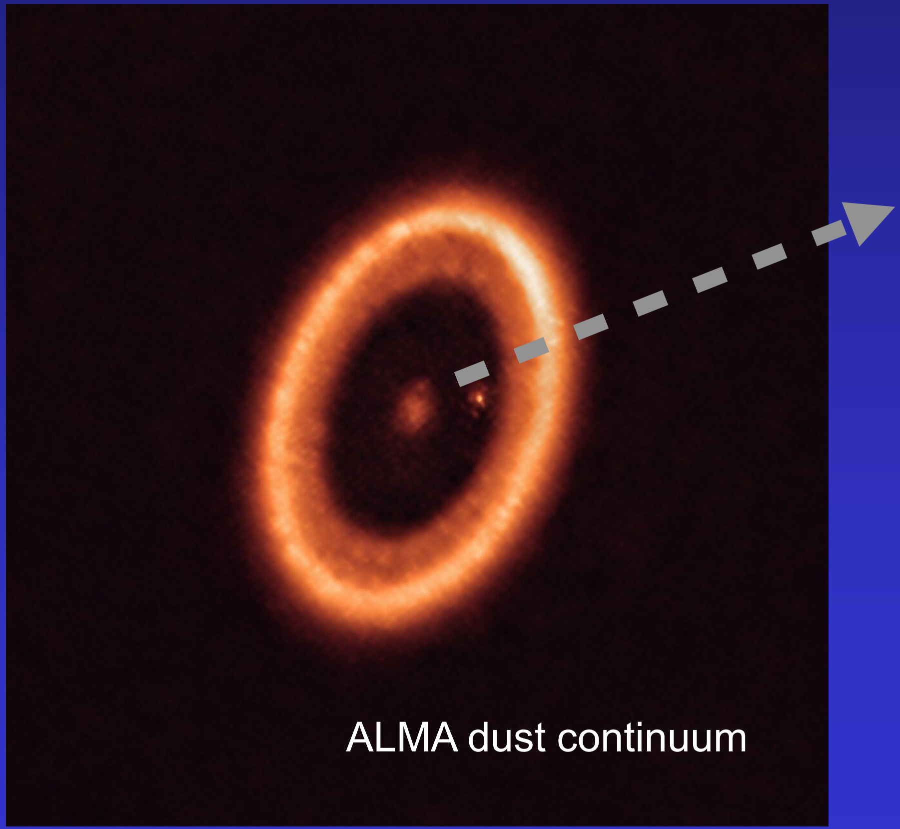
Giant
Planet
at 22 au

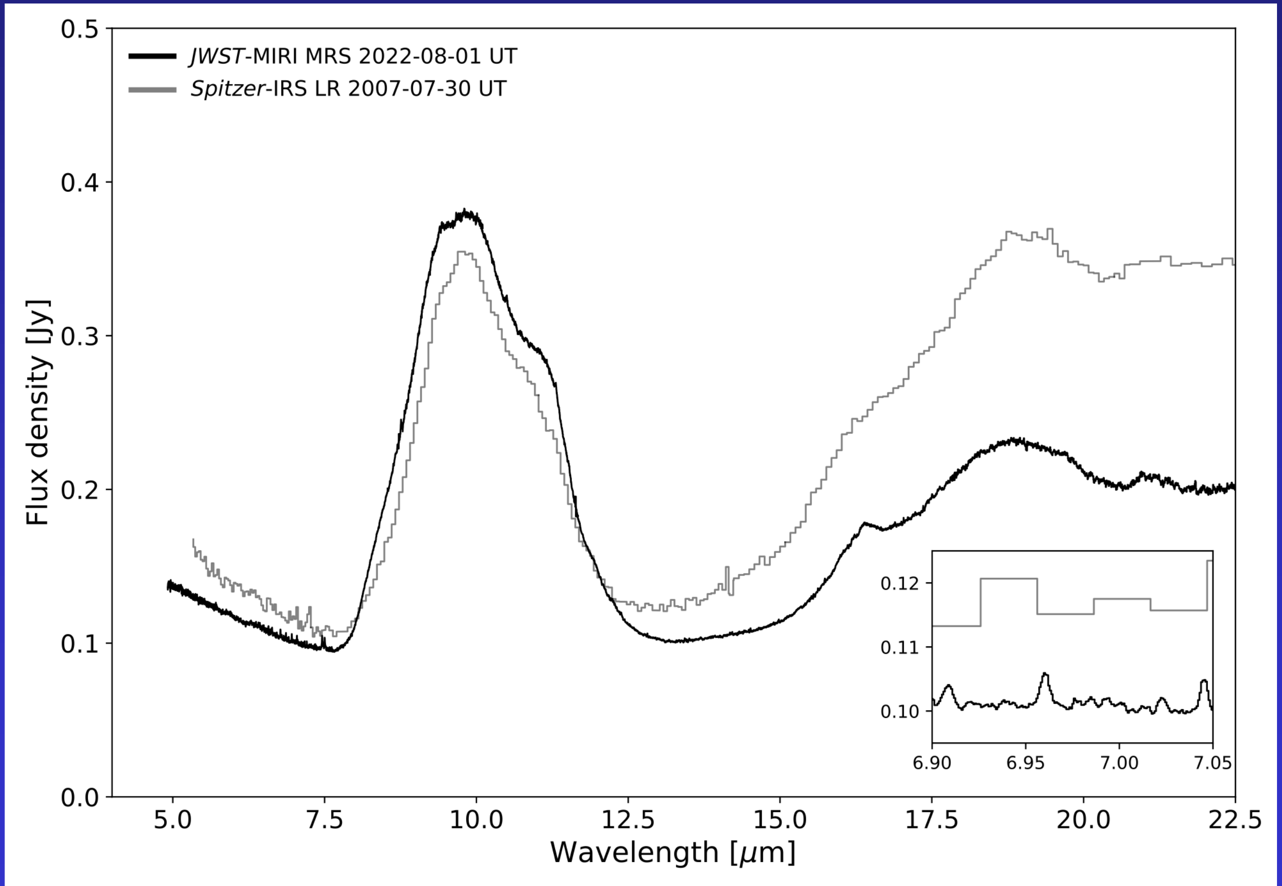


Keppler, Benisty, Müller, Henning et al. (2018)
Müller, Keppler, Henning et al. (2018)

PDS70 : Probing the Inner Region of a Planet-forming Disk

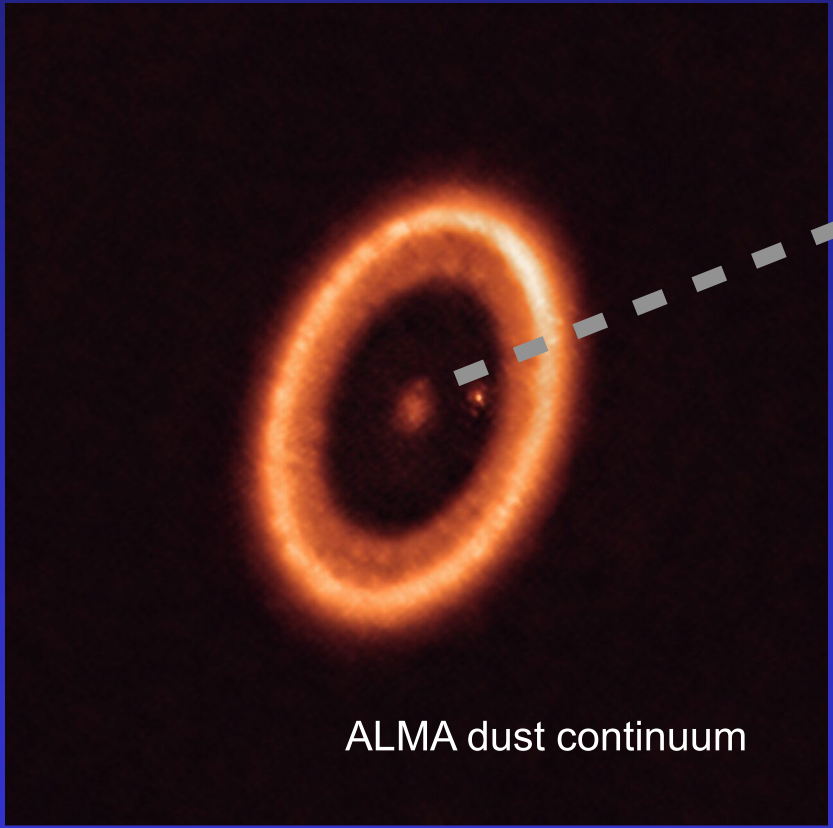
Variability in the IR continuum, likely due to inner disk warp
Detection of reservoir of warm H_2O (T~500 K) from the inner 0.06 au

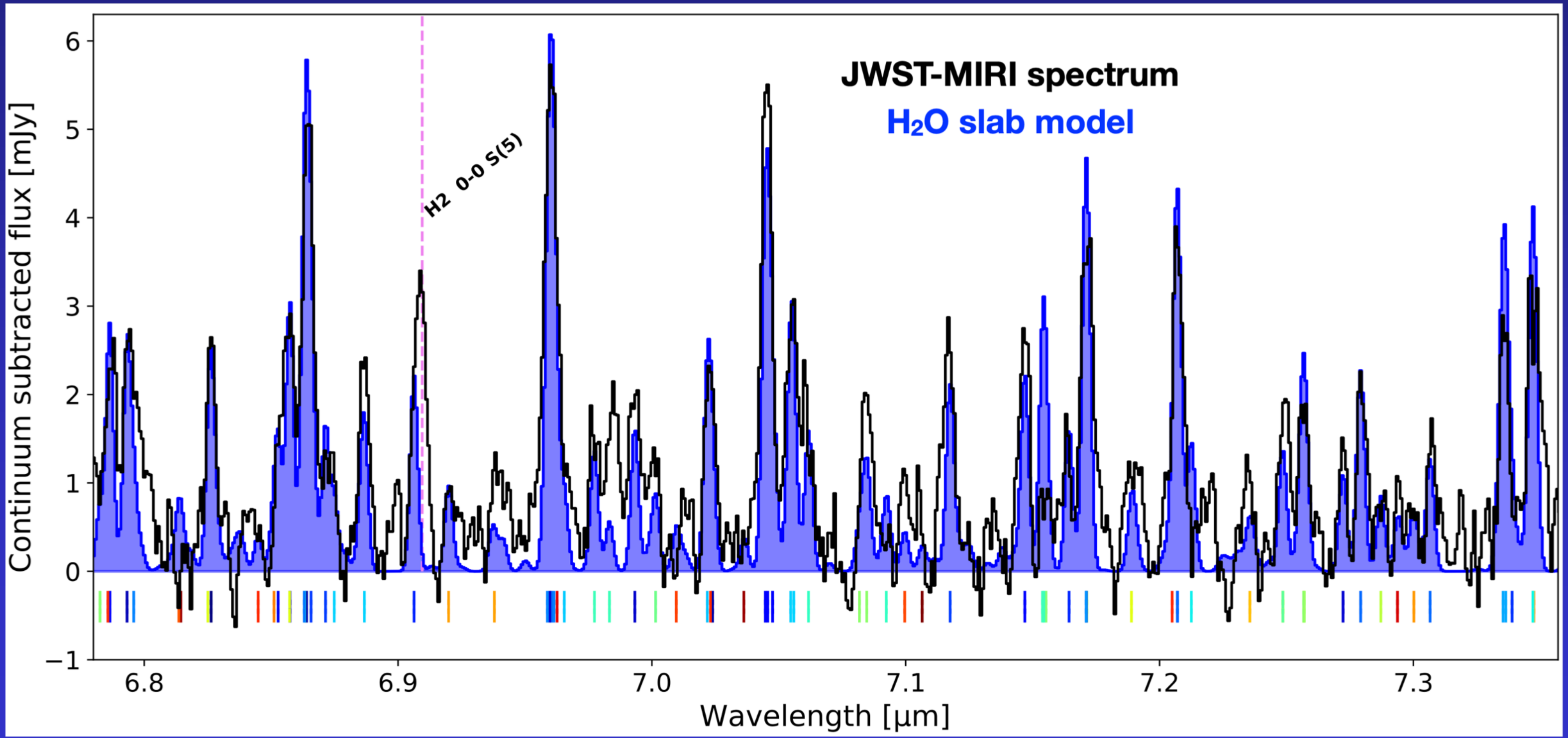




PDS70 : Probing inner disk in a planet-forming disk

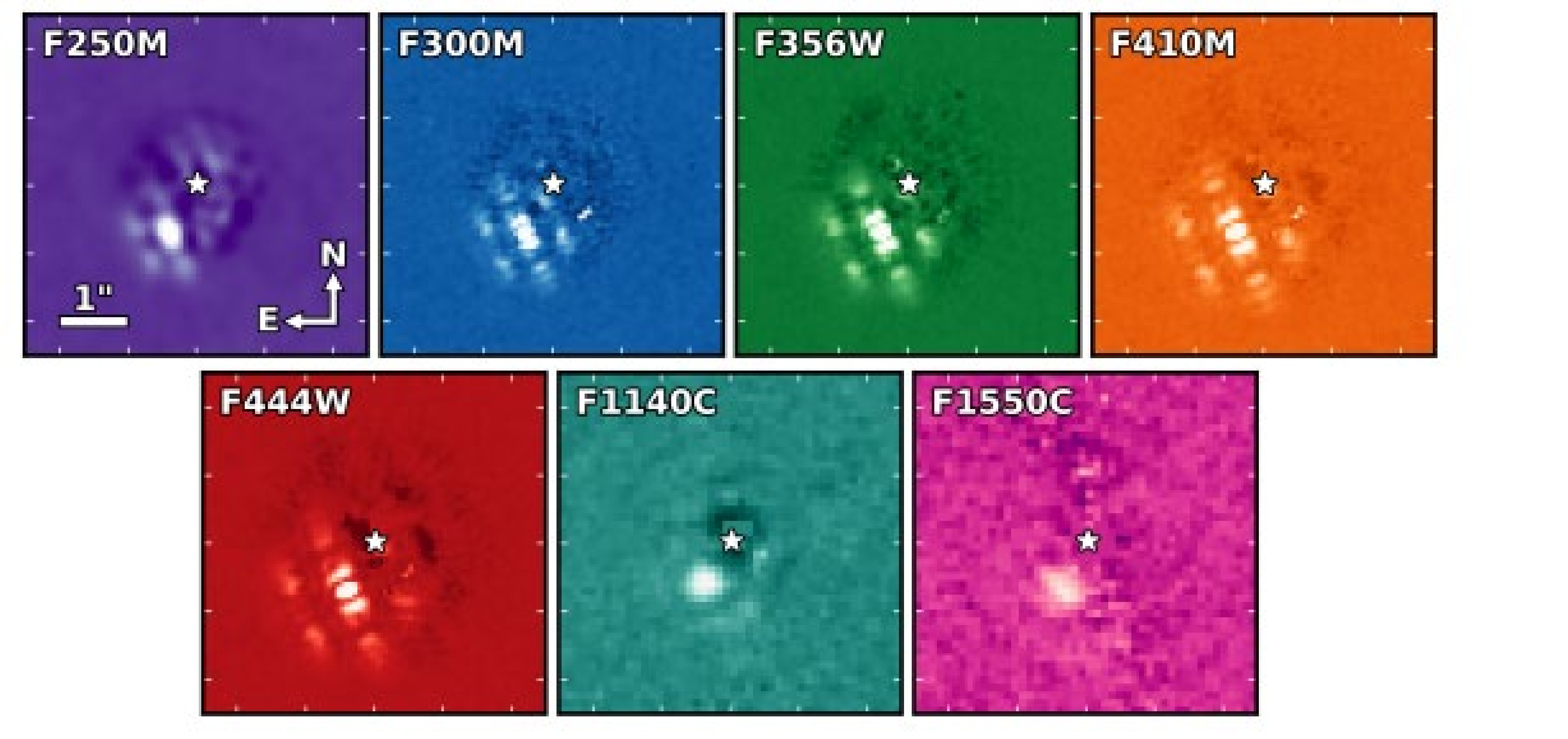
Gas giants in the outer disk affect inner disk dynamics. but do not full block material inflow





Perotti, Henning et al. submitted

First JWST Images of an Exoplanet

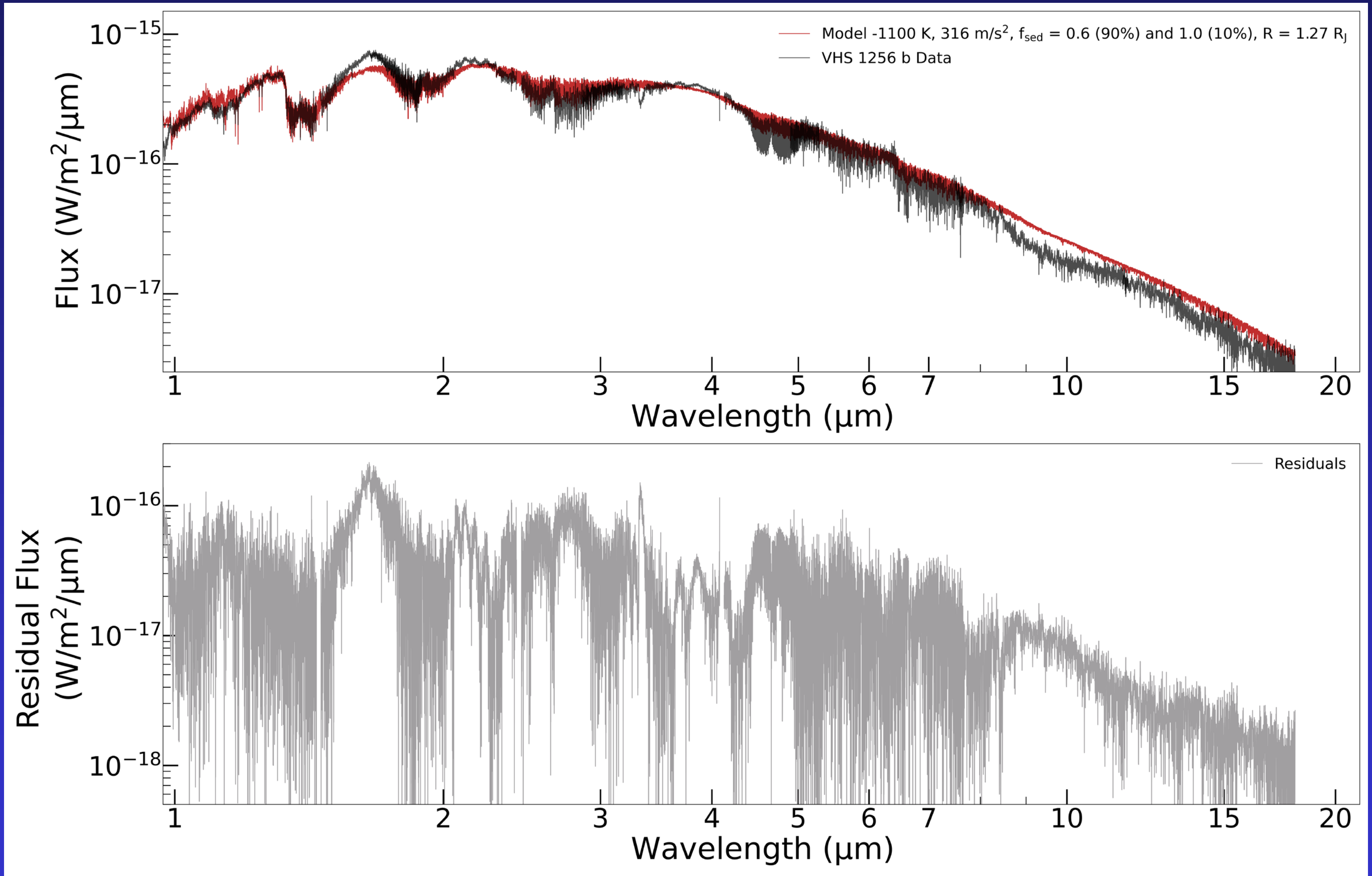


HIP 65426	
F250M	2.523
F300M	3.067
F356W	3.580
F410M	4.084
F444W	4.397
F1140C	11.307
F1550C	15.514

M = 7.1 Mjup

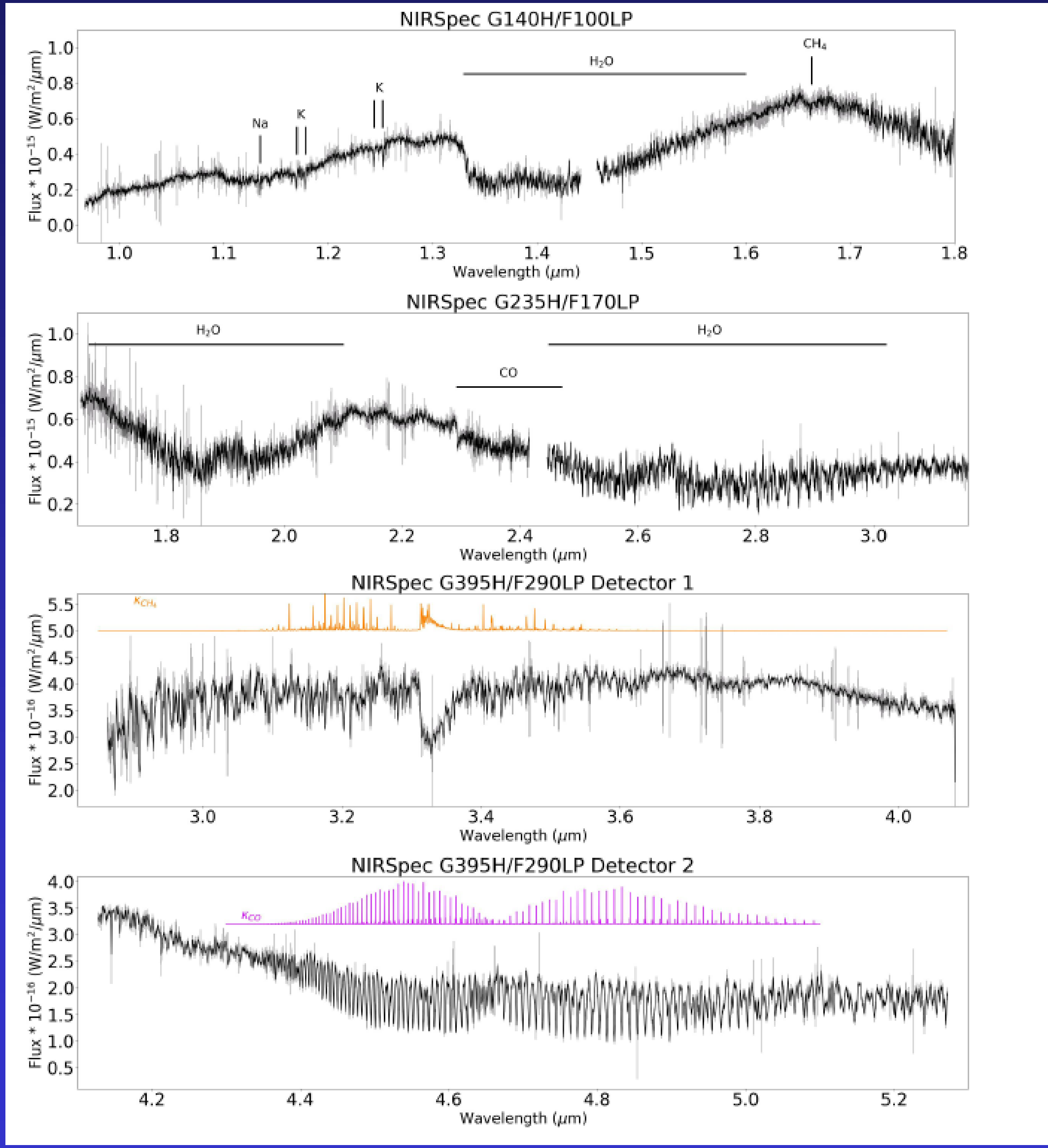
Carter et al. (2022)

First Complete IR Spectrum of Planetary-Mass Object

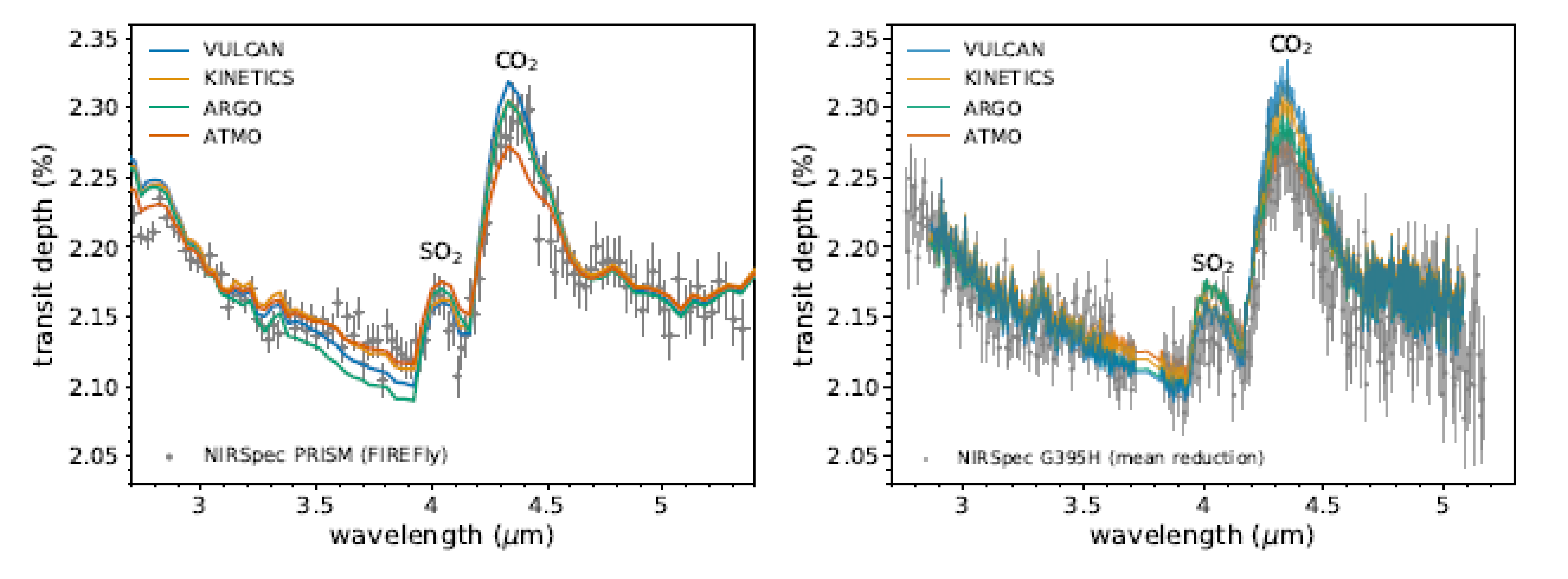


Miles et al. (2022): VHS 1256-1257b

First Complete IR Spectrum of Planetary-Mass Object



Evidence for Photochemistry



$$
\begin{aligned}
H_2O &\xrightarrow{h\nu} OH + H \\
H_2O + H &\longrightarrow OH + H_2 \\
H_2S + H &\longrightarrow SH + H_2 \\
SH + H &\longrightarrow S + H_2 \\
S + OH &\longrightarrow SO + H \\
SO + OH &\longrightarrow SO_2 + H \\
\hline
\text{net}: H_2S + 2\,H_2O &\longrightarrow SO_2 + 3\,H_2
\end{aligned}
$$

WASP-39 b

Tsai et al. (2022)

Webb's Exciting Discoveries