# Science lessons from JWST, for HWO


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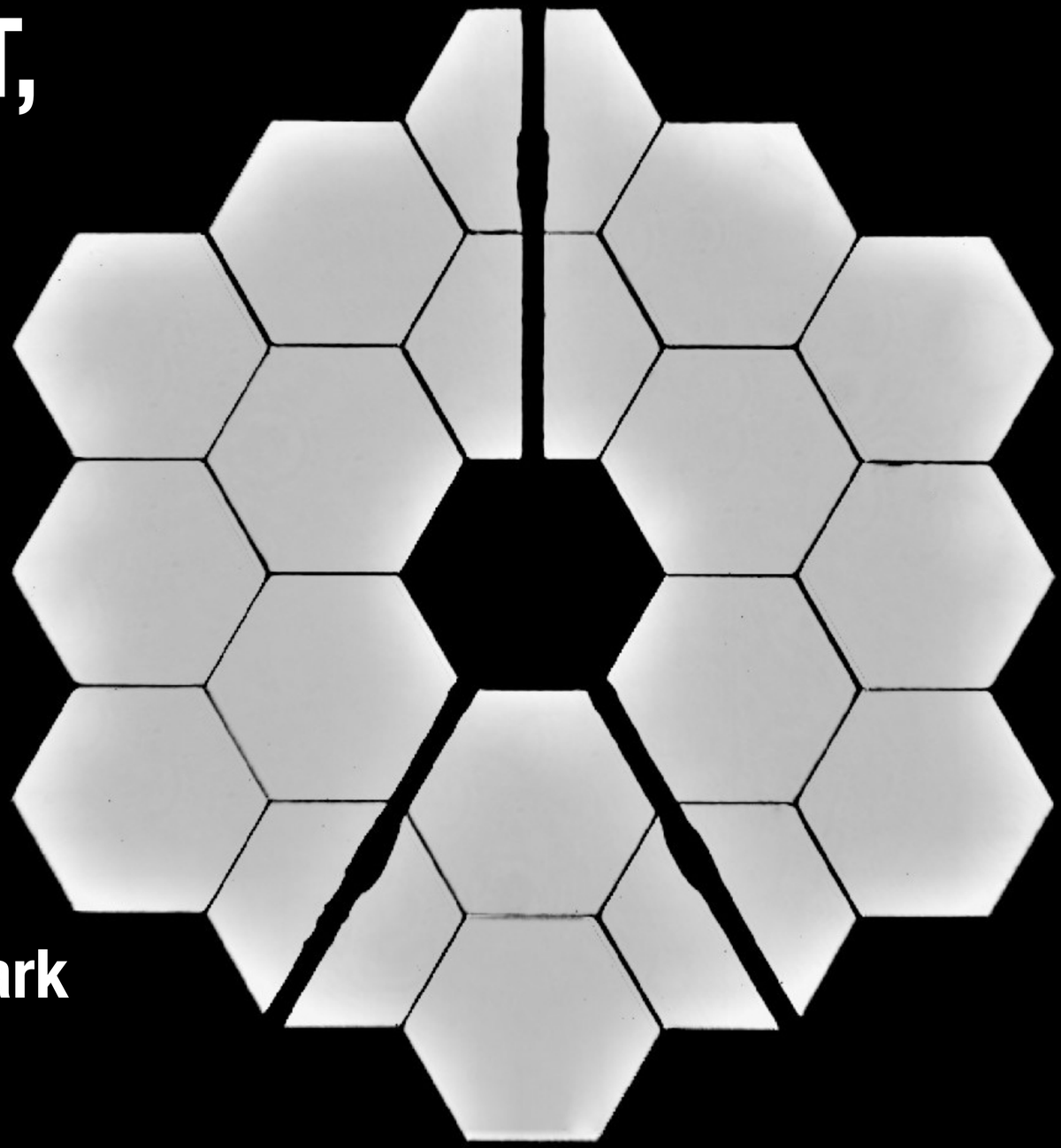
**with ideas from Mike McElwain & Chris Stark**



JWST selfie taken by NIRCam, released 3/16/2022

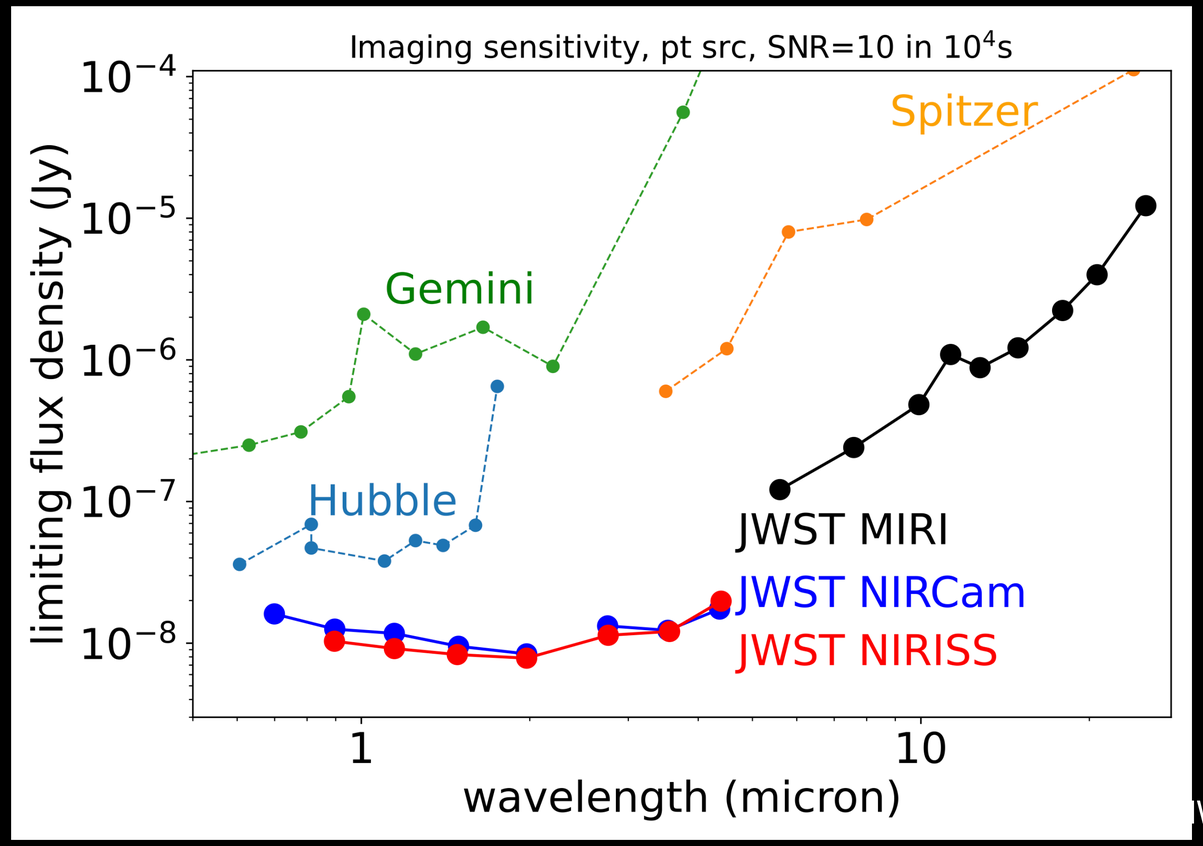
# The “JWST proves key technology” slide that every astronomer needs

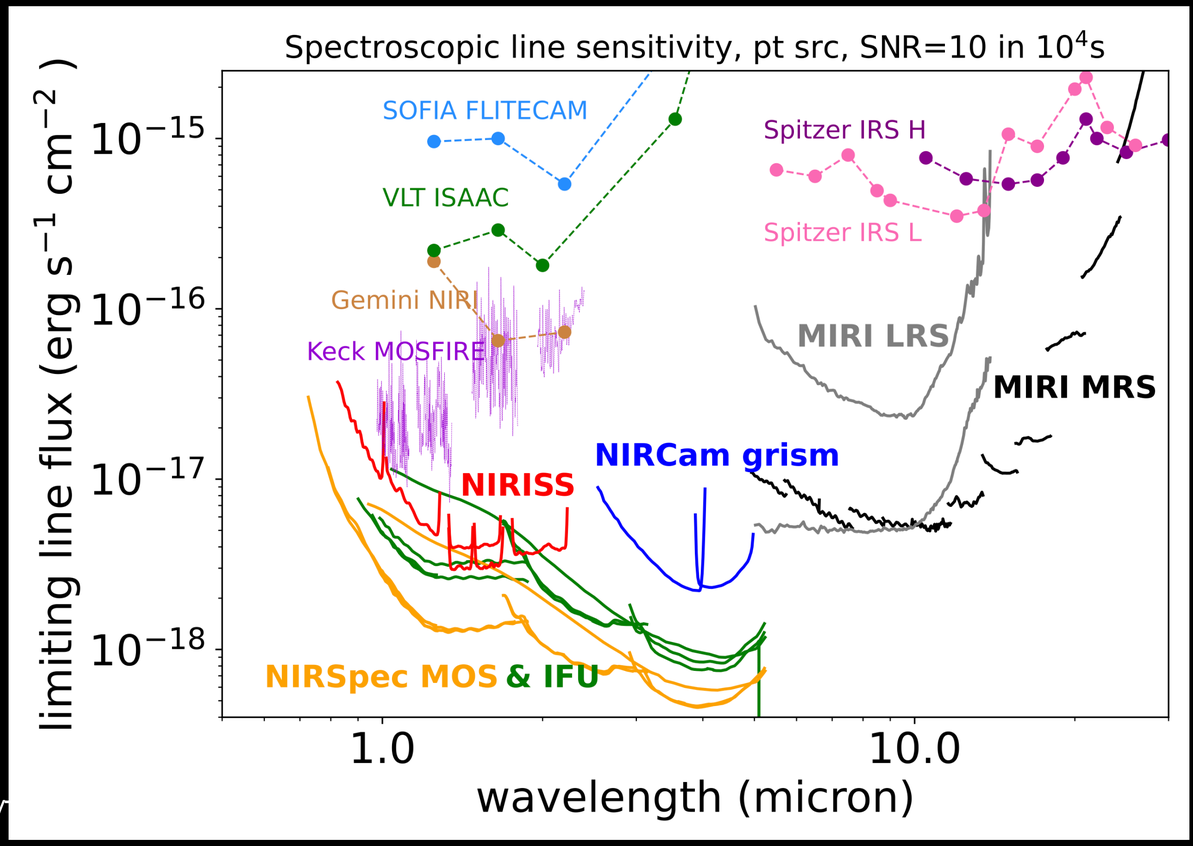
- We can deploy telescopes in space. All 50 JWST deployments worked, involving 178 release mechanisms.
- We can build telescopes bigger than rockets. We crammed JWST’s D=6.5m mirror and its 21x14m sunshield into a 5.4m rocket fairing, then deployed it in the dark on the way to L2.
- We can align segmented telescopes in space. JWST deployed at mm accuracy, then used wavefront sensing and control to align to tens of nm, and sense to even greater precision.
- We can build telescopes that cannot be fully tested on the ground. Computer modeling, with key tests that validate those models, accurately predicted the on-orbit performance.

# Science requirements

- Pick bold science requirements that uniquely require space. JWST's transformative science capabilities (100x more sensitive) were not eclipsed by other facilities, even though the JWST science requirements were written 17 years before launch.

Figures from Rigby, Perrin, McElwain et al. 2023, (PASP, 2023)



# Science requirements

- A carefully constructed, representative, small suite of science requirements (37 for JWST) is something you can build to, and can produce a telescope capable of far more.


Gardner, Mather, Clampin et al. 2006, Space Science Reviews, 123, 485

JWST Science Requirements Document JWST-RQMT-002558 Revision E

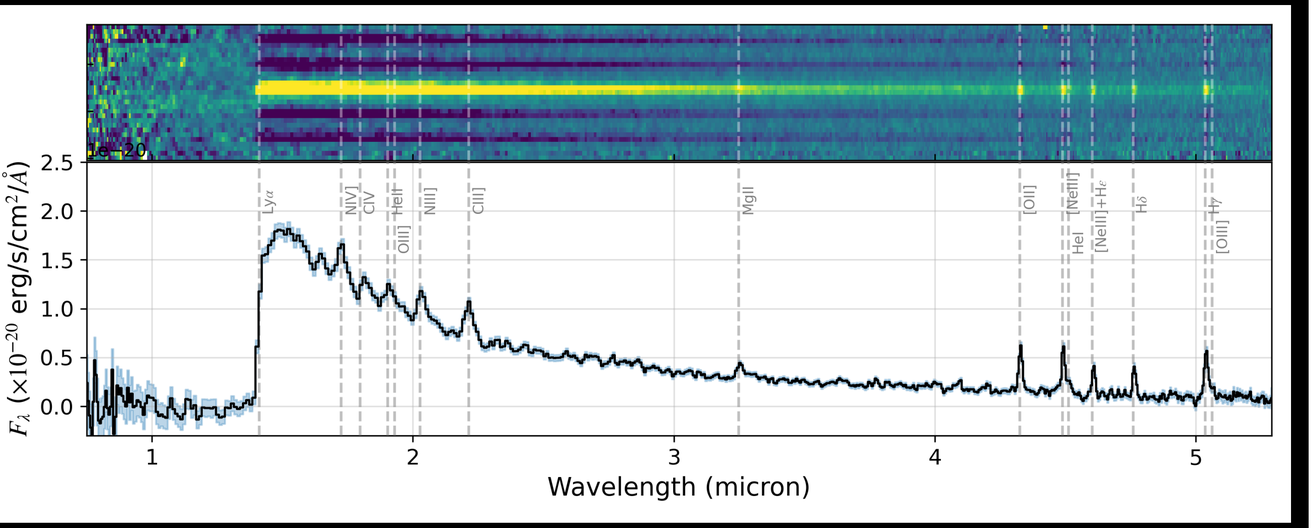
**APPENDIX B: SCIENCE TO MISSION REQUIREMENT TRACEABILITY SUMMARY**

| SR No. | Science Requirement | MRD | Program Plan | ISIM |
|---|---|---|---|---|
| SR-1 | JWST shall be capable of making astronomical observations at wavelengths from 0.6 to 27 mircrometers | MR-107 | L1-1<br>L1-2<br>L1-3 | ISIM-152 |
| SR-2 | JWST shall provide imagery with spectral resolution in the range 3 < R < 200, including broadband (3 < R < 7) imaging with a minimum of 16 discrete filter bandpasses, continuously distributed over a wavelength range 0.6 to 27 micrometers. | MR-185 | L1-1<br>L1-2<br>L1-3<br>L1-17<br>L1-18<br>L1-20 | ISIM-252 |
| SR-3 | JWST shall have coronagraphic imaging capability over the wavelength ranges 2 to 27 micrometers and sparse aperture interferometry between 3.8 and 4.8 micrometers. | | L1-3 | ISIM-852 |
| SR-4 | JWST shall provide spectroscopy with spectral resolution in the range 25<R<5000 over a wavelength range 0.6 to 27 micrometers | MR-186 | L1-19<br>L1-20 | ISIM-253 |
| SR-5 | JWST shall have a near-infrared camera (NIRCam) capable of operating over the wavelength range 0.6 to 5 micrometers and producing images with spectral resolution less than 100. | MR-51<br>MR-185 | L1-17<br>L1-18 | ISIM-153<br>ISIM-152 |
| SR-6 | JWST shall have a near-infrared spectrograph (NIRSpec) operating over the wavelength range 0.6 to 5 micrometers and producing spectra with spectral resolutions of approximately 100 and 1000. | MR-51<br>MR-186 | L1-19 | ISIM-450<br>ISIM-253 |
| SR-7 | NIRSpec shall be capable of obtaining simultaneous spectra of more than 100 objects. | MR-44<br>MR-102 | L1-2 | ISIM-916<br>ISIM-463 |
| SR-8 | JWST shall have a mid-infrared instrument (MIRI) capable of operating over the wavelengths range 5 to 27 micrometers and producing both images with spectral resolution less than 100, and spectra with spectral resolution R ~ 2000. | MR-186<br>MR-185 | L1-20 | ISIM-152 |
| SR-9 | JWST shall have a near-infrared imager and slitless spectrograph (NIRISS) capable of providing low (R ~ 150) and medium (R ~ 500) resolution slitless spectroscopy. As a goal, NIRISS may provide a broad-band (R ~ 4) imaging capability similar to NIRCam between 0.9 and 4.8 μm. | MR-185<br>MR-186 | L1-1<br>L1-3 | ISIM-252<br>ISIM-586 |

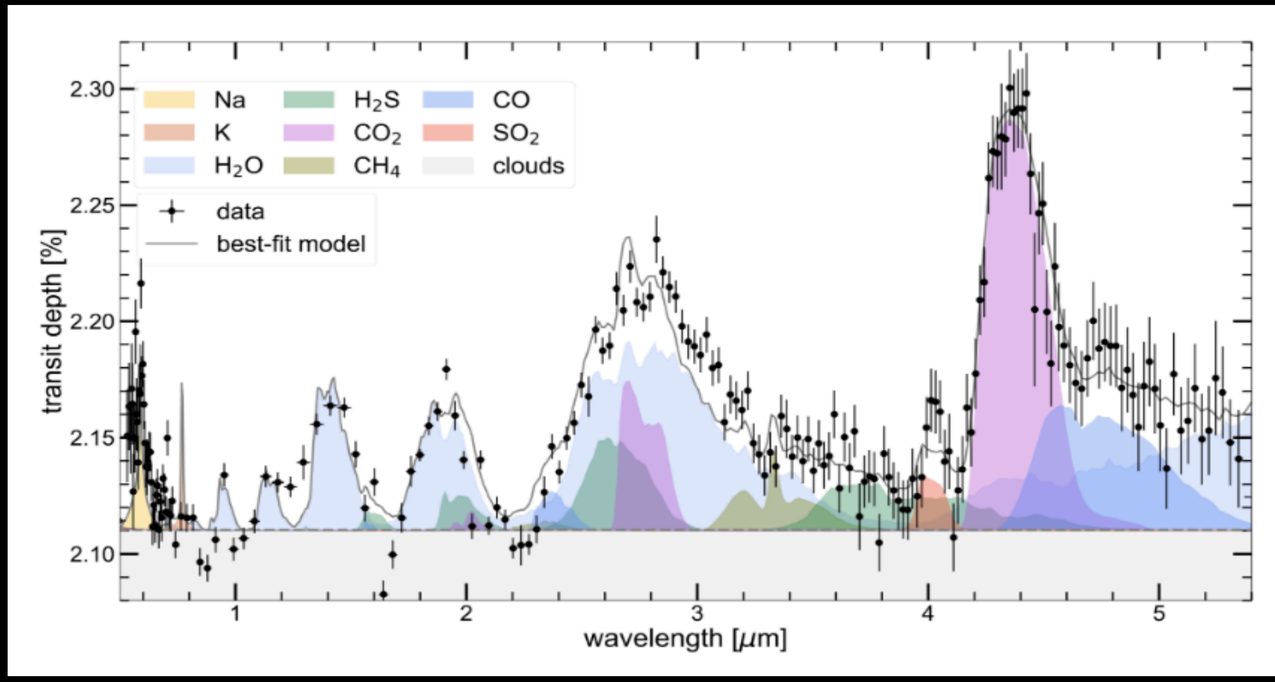
Science traceability matrix for JWST, p1 of 3

# Science requirements

- There is so much payoff if scientific capabilities (not necessarily requirements!) are flexible, and can respond to scientific progress.



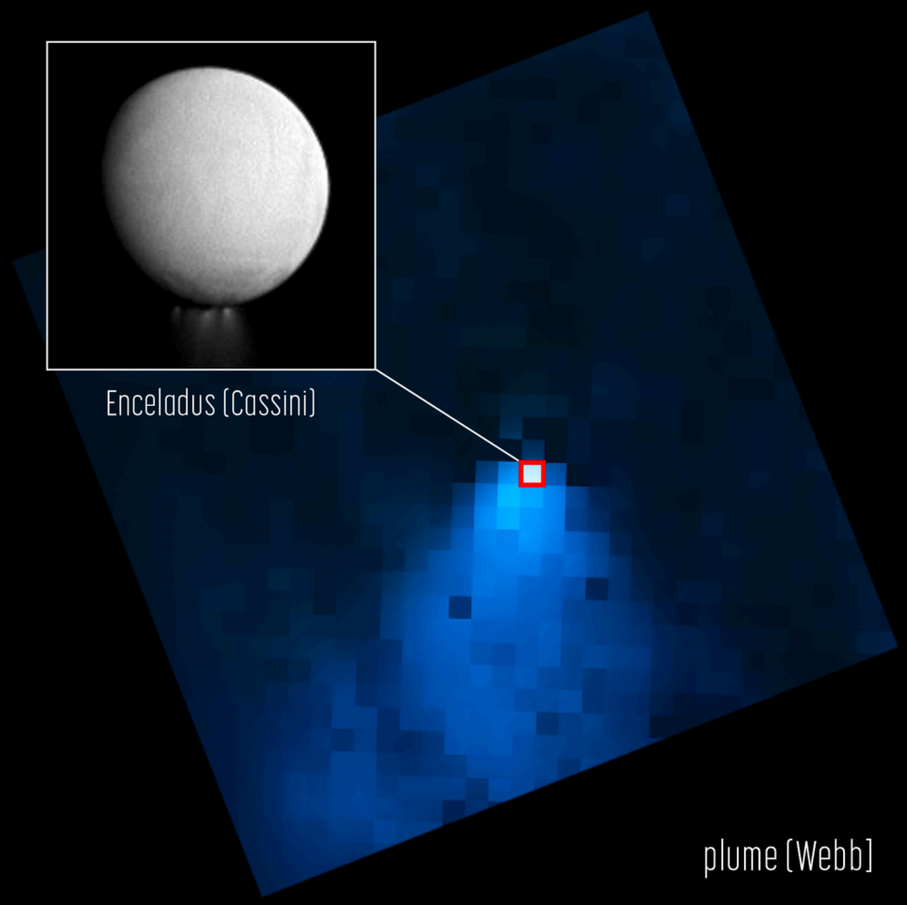

JWST NIRSpec prism mode spectrum of galaxy GN-z11 at z=10.60, Bunker et al. (2023), from the JADES GTO program



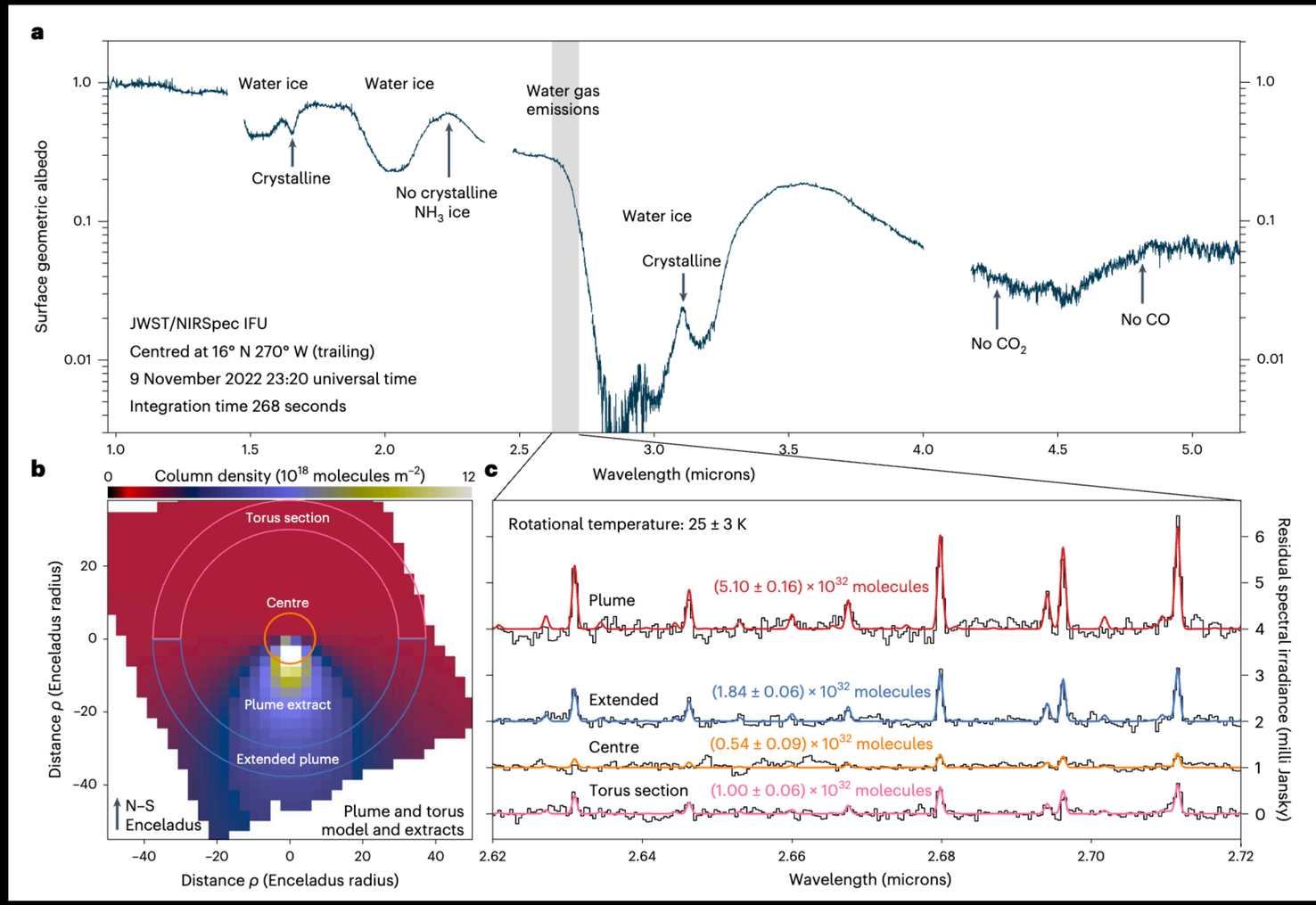

NIRSpec prism mode transit spectrum of WASP-39b, Rustamkulov et al. (2023), from the Transiting Exoplanet Community Early Release Science Program

# Science requirements

- Plan to study the solar system.




Enceladus seen by JWST NIRSpec (Villanueva et al. 2023)




Enceladus seen by JWST NIRSpec (Villanueva et al. 2023)

It helps to be able to drop the mic.

Christopher Jackson as General George Washington,
from the Broadway musical Hamilton
image credit: TheaterMania

# Don’t forget about General Astrophysics

**“It’s all about the people.”**

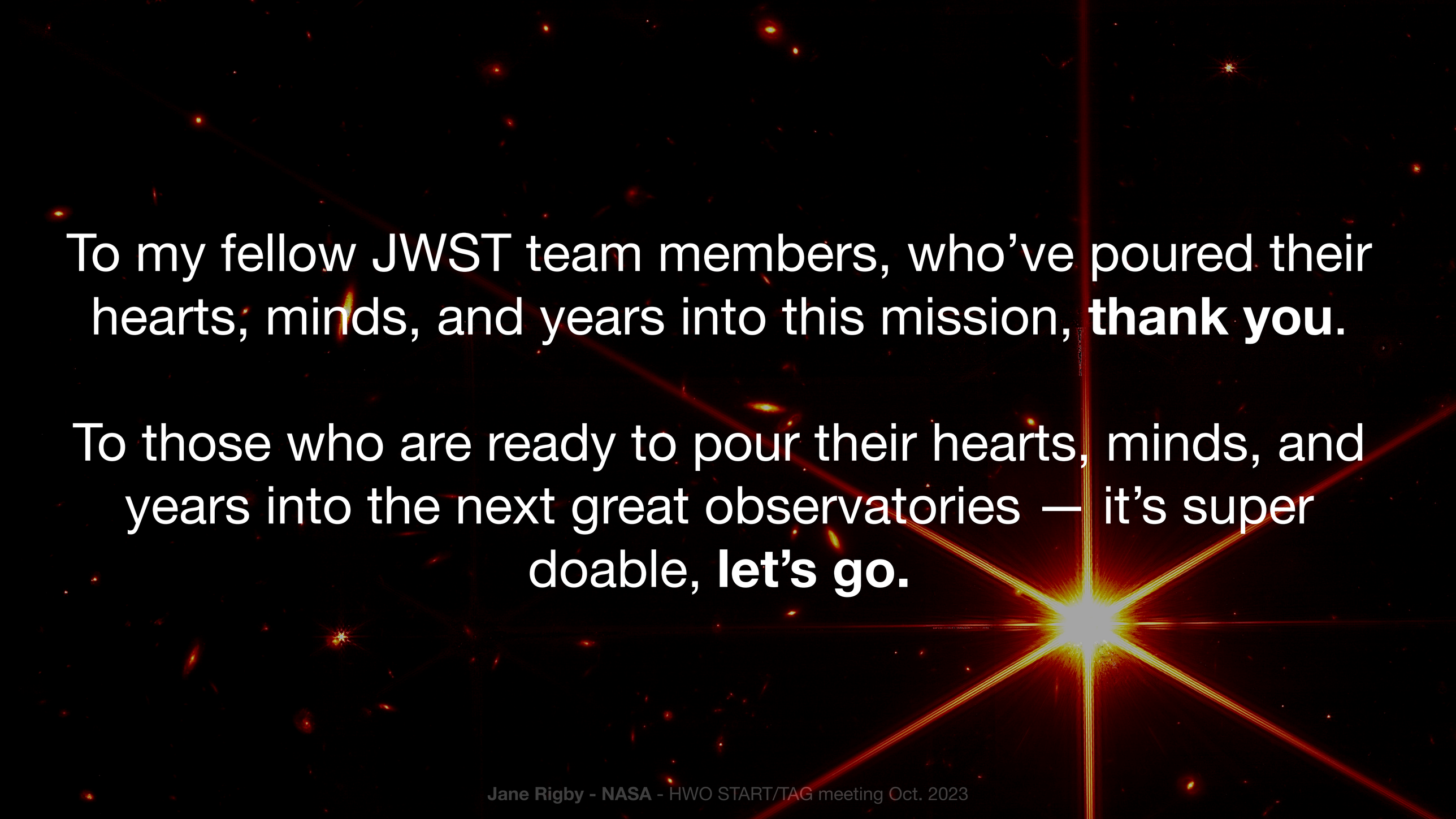
- JWST Project Manager Bill Ochs

**“The pursuit of science, and scientific excellence, is inseparable from the humans who animate it.”**

- Astro2020, Panel on the State of the Profession and Societal Impacts

# “It’s all about the people.” - JWST Project Manager Bill Ochs

- Need support of the science community, the public, and appropriators.
- International partnerships are worthwhile. For JWST they invigorated the science and broadened the usability of the observatory. Also make a mission harder to cancel.
- Over the long haul of a flagship, need to plan for succession and sustainability of personnel.
- We must be realistic about cost. *(Figure out what I can say, that won’t get me in too much trouble).*
- Policies around observing time and funding affect the state of the profession. Policies should be good for all of: the science, the profession and its practitioners, and equity and inclusion. (credit: Chris Stark)


To my fellow JWST team members, who've poured their hearts, minds, and years into this mission, **thank you.**

To those who are ready to pour their hearts, minds, and years into the next great observatories — it's super doable, **let's go.**