The James Webb Space Telescope (JWST)

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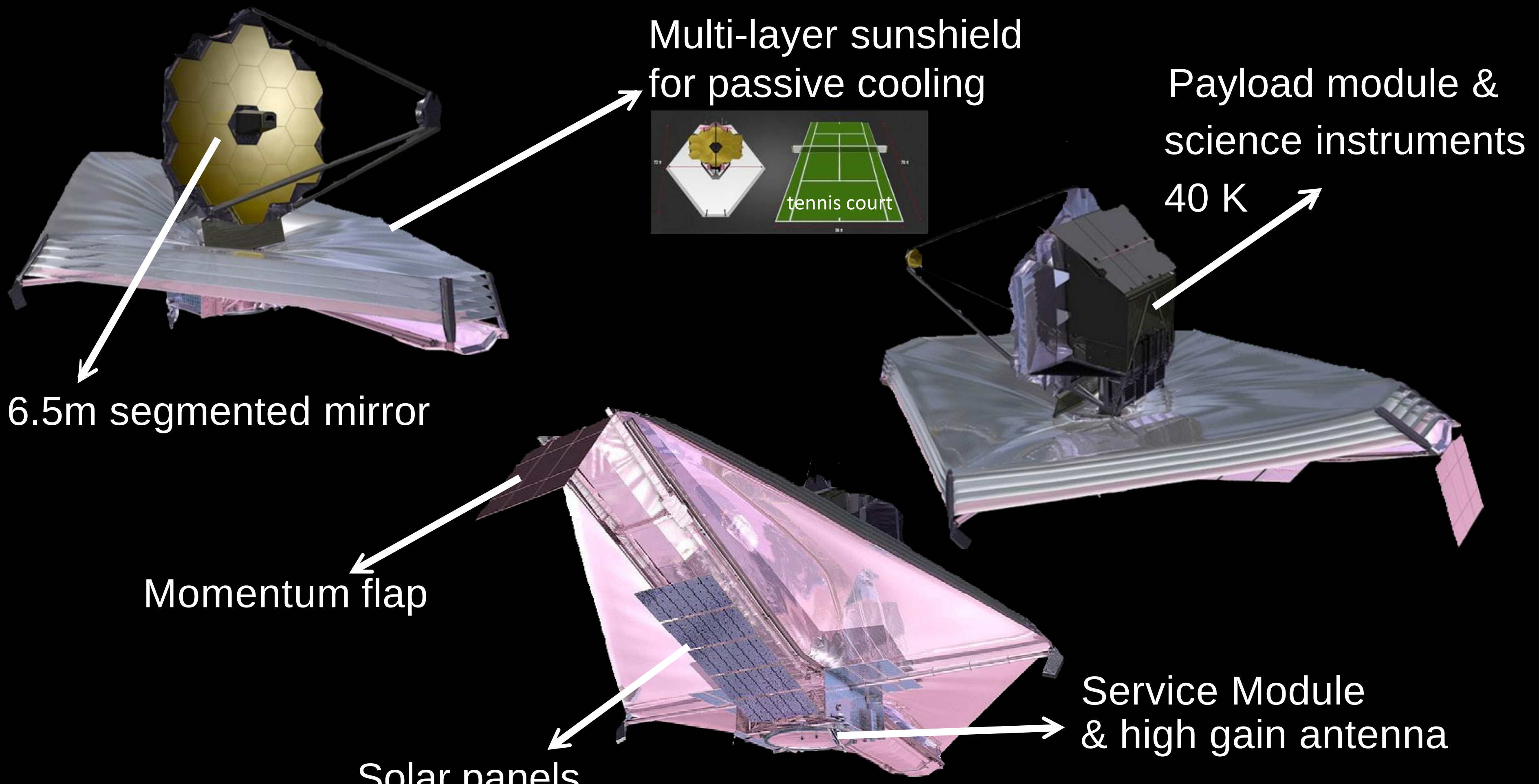
JWST 1 : 1 model

JWST = 6.5 m Infrared Telescope at L2



Multi-layer sunshield
for passive cooling

Payload module &
science instruments
40 K

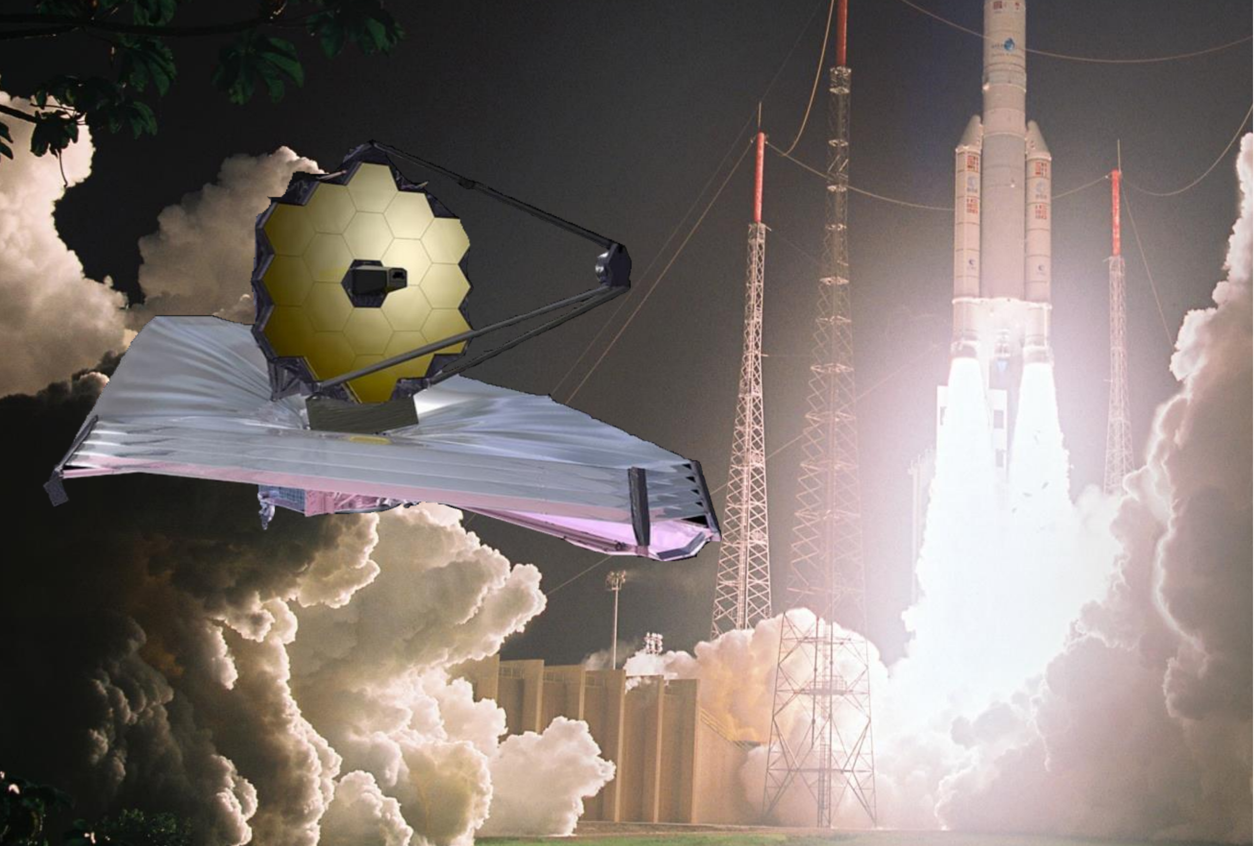
6.5m segmented mirror

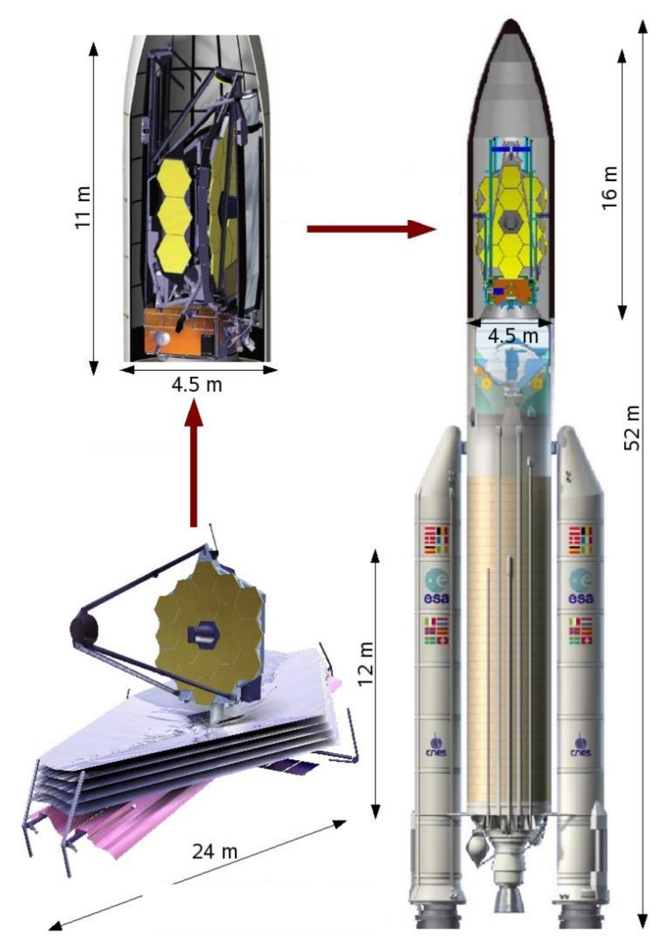
Momentum flap

Solar panels

Service Module
& high gain antenna

- Launch with an Ariane 5 from Kourou, French Guiana
- 6200 kg total weight
- Cryogenic, highly complex payload, warm start



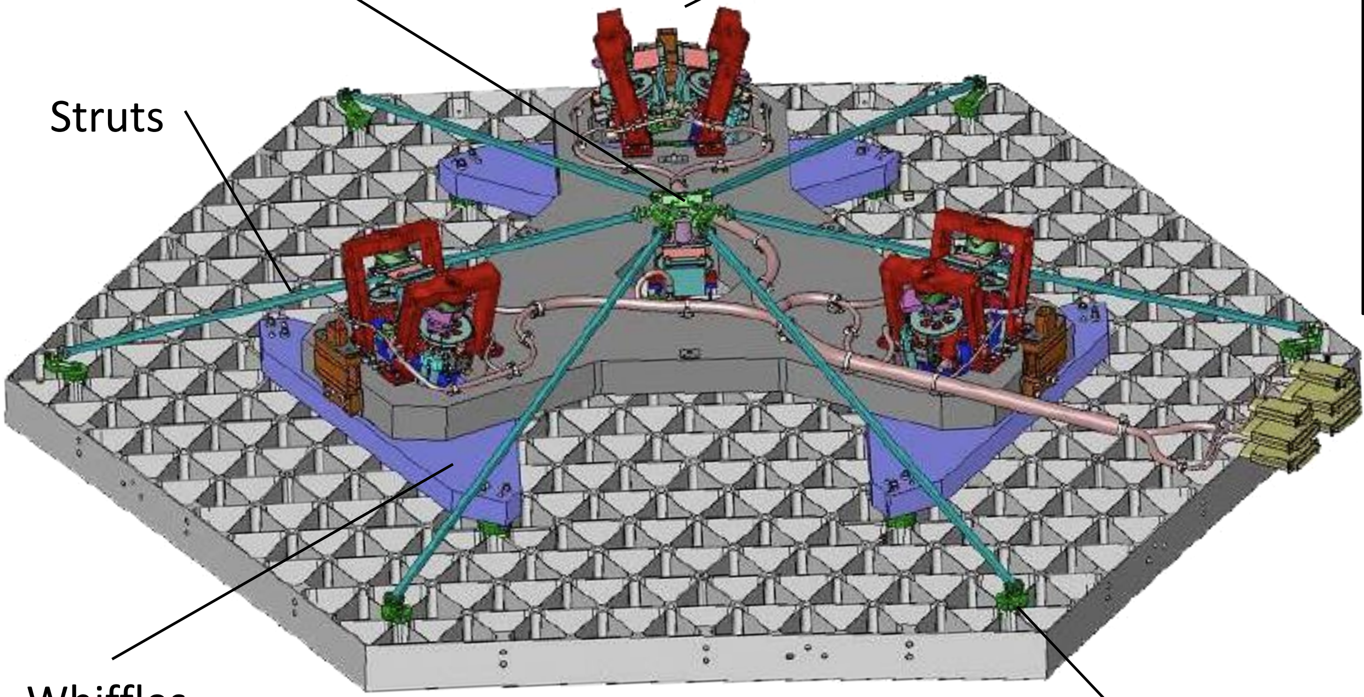


Total time: 30 yr after the vision, > 20 yr technical development

Total cost: 10 Billion $

Primary Mirror Segment Assembly

→ 126 mechanisms only for the mirror support !



Radius of curvature actuator

6 DOF Hexapod actuators

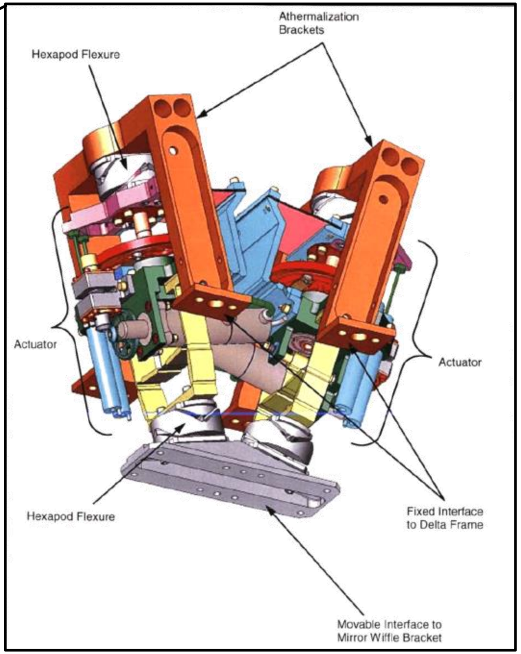
Struts

Electrical connectors

Whiffles

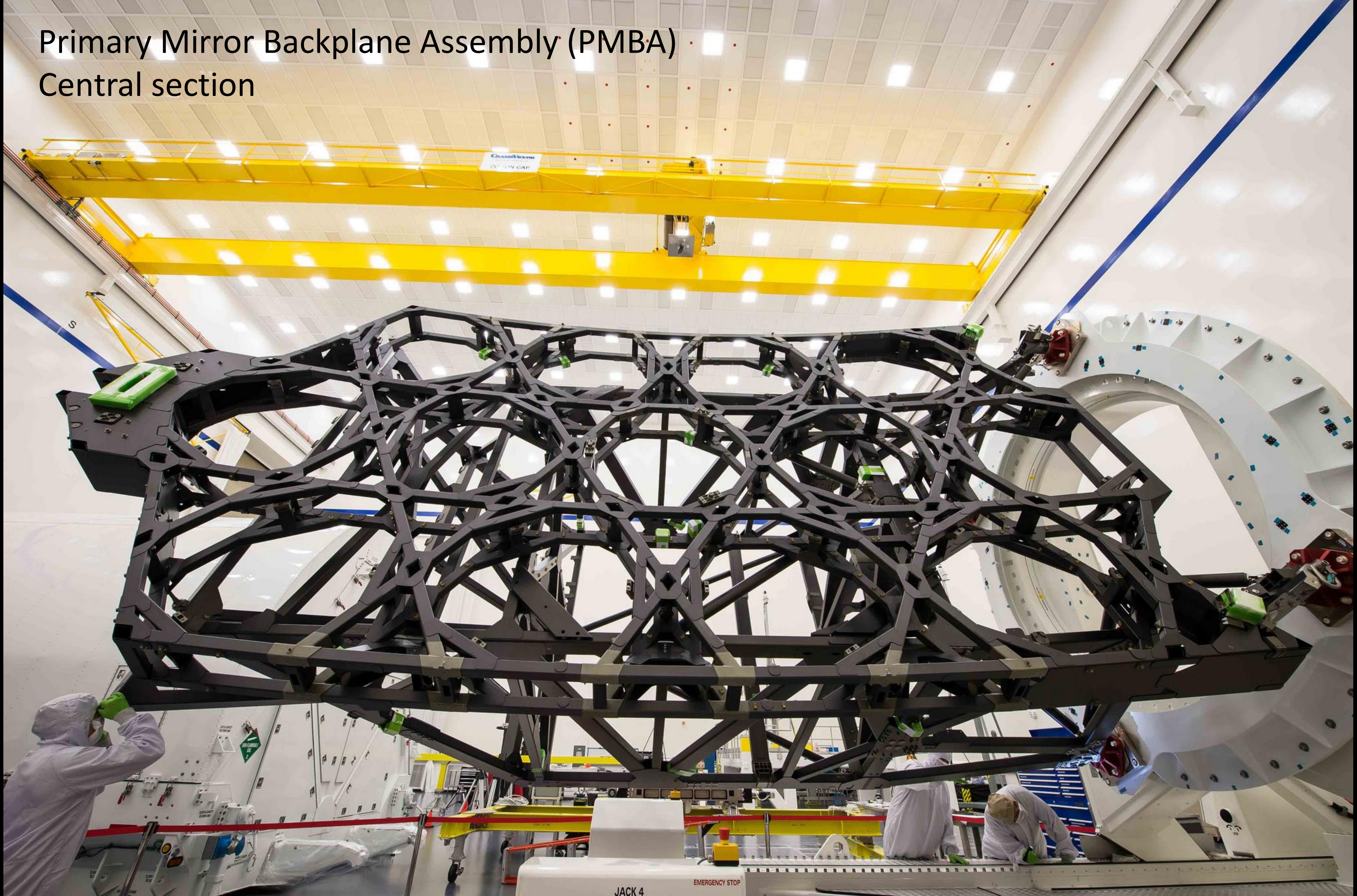
Mirror Substrate

Flexures



1.32 m mirror segment
20.8 kg weight
Berrylium, gold coated
20 nm rms surface accuracy

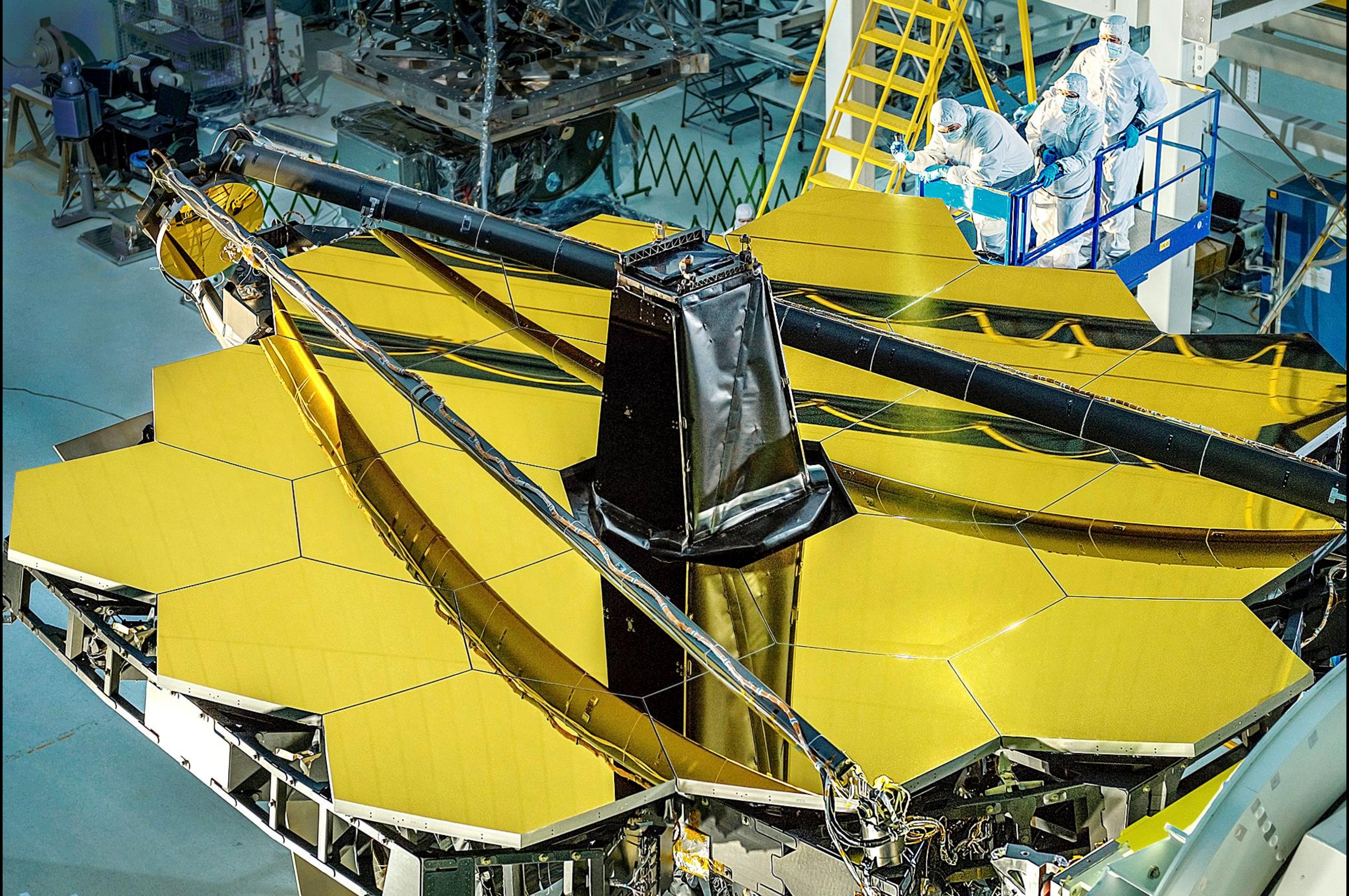
Primary Mirror Backplane Assembly (PMBA)
Central section



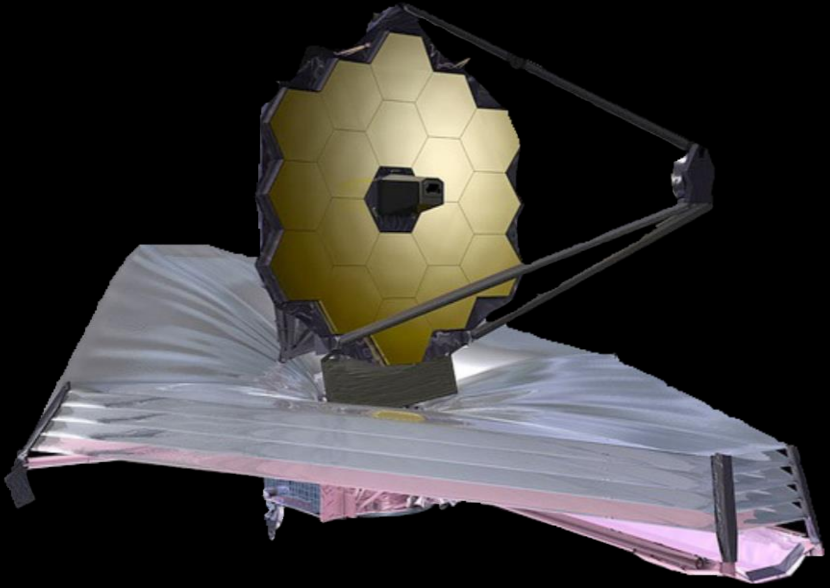
Robot-assisted Integration of primary mirror assembly


NORTH
MV224
20
28

Covers removal

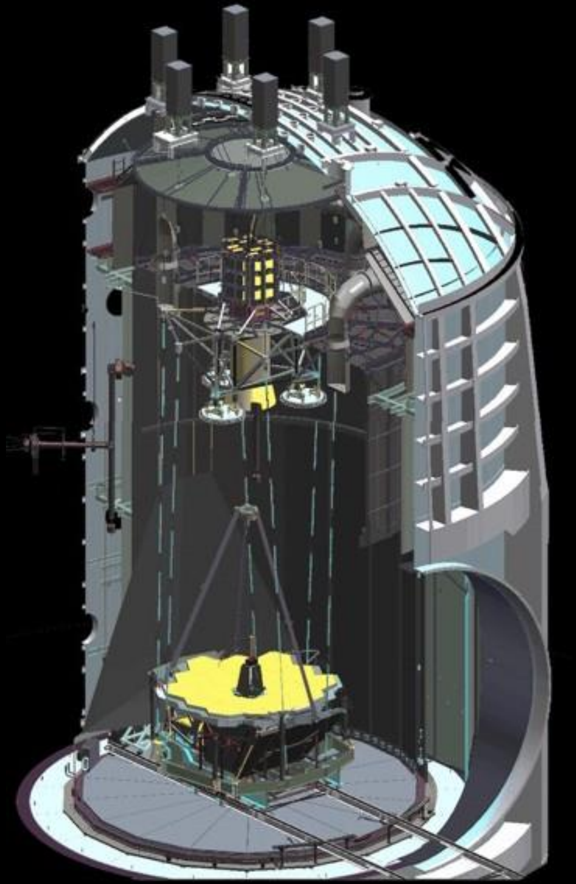


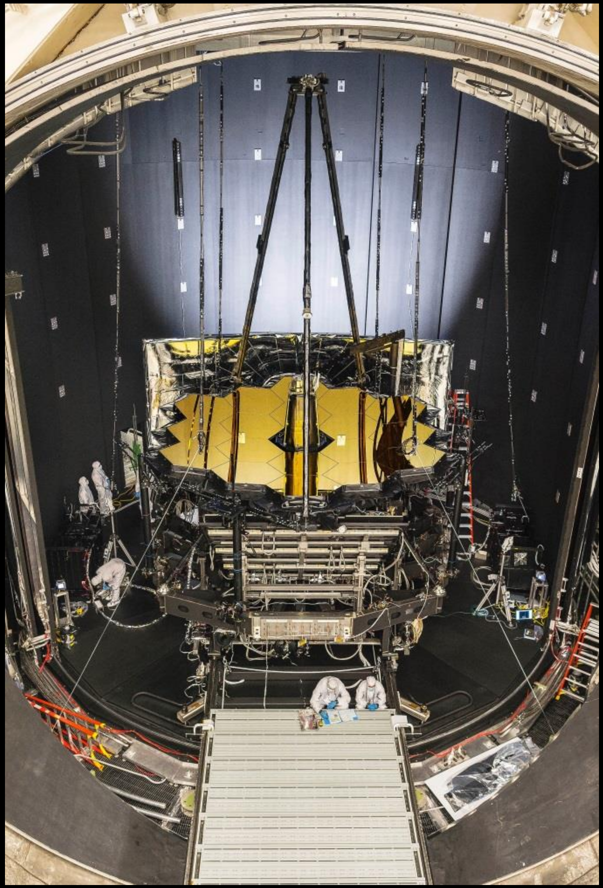
JWST Observatory Status



- NASA press release on 28 September 2017:
  - Launch will be between March and June 2019 (shift from October 2018); reason: integration of various spacecraft elements is taking longer than expected but no technical concerns
- Telescope and science instruments are currently at NASA’s Johnson Space Center (JSC), Houston, Texas in a big cryo-chamber
- Spacecraft bus and sunshield are currently integrated and tested at Northrop Grumman, Redondo Beach, California

Final cryotests of telescope and science instruments in Johnson Space Center Chamber-A





Thermal-vacuum chamber
17 m x 24 m
40 K temperature for JWST

Tests campaign
10 July – October 2017
warm-up since 27 Sept 2017

Test objectives:
Optical Workmanship
Optical Alignment
Thermal balance
Operational Interfaces

Chamber-A, 50 years ago…

JWST Observatory: next steps

- Fall 2017: transport from JSC to Northrop Grumman, Redondo Beach, California
- 2018: Integration of telescope and instruments to spacecraft and sunshield
- 2018: full observatory-level testing

- Early spring 2019: transport to Launch site Kourou, French Guiana
- Launch between May and June 2019

- 6 month commissioning (incl. flight to L2)
- Fall 2019: start of normal science operations

jwst

The James Webb Space Telescope (JWST)

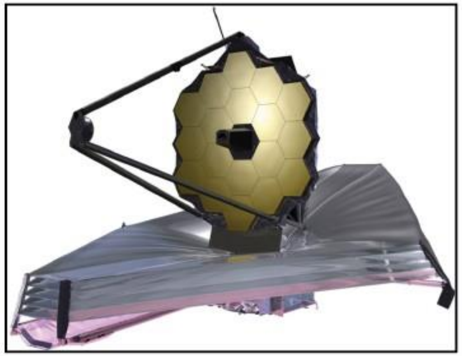
Launch segment

Payload adapter

Launcher (Ariane 5)

Launch site services

Observatory segment



Spacecraft (bus, sunshield...)

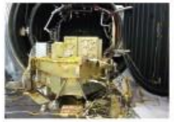
Telescope

Payload module (ISIM) and instruments

NIRCam

NIRSpec

FGS / NIRISS



MIRI

Ground segment

Science and operation center (STScI)

15 ESA staff members

Common systems (deep space network)

⬜ Provided by NASA 🟥 Provided by ESA and Europe 🟦 Provided by CSA

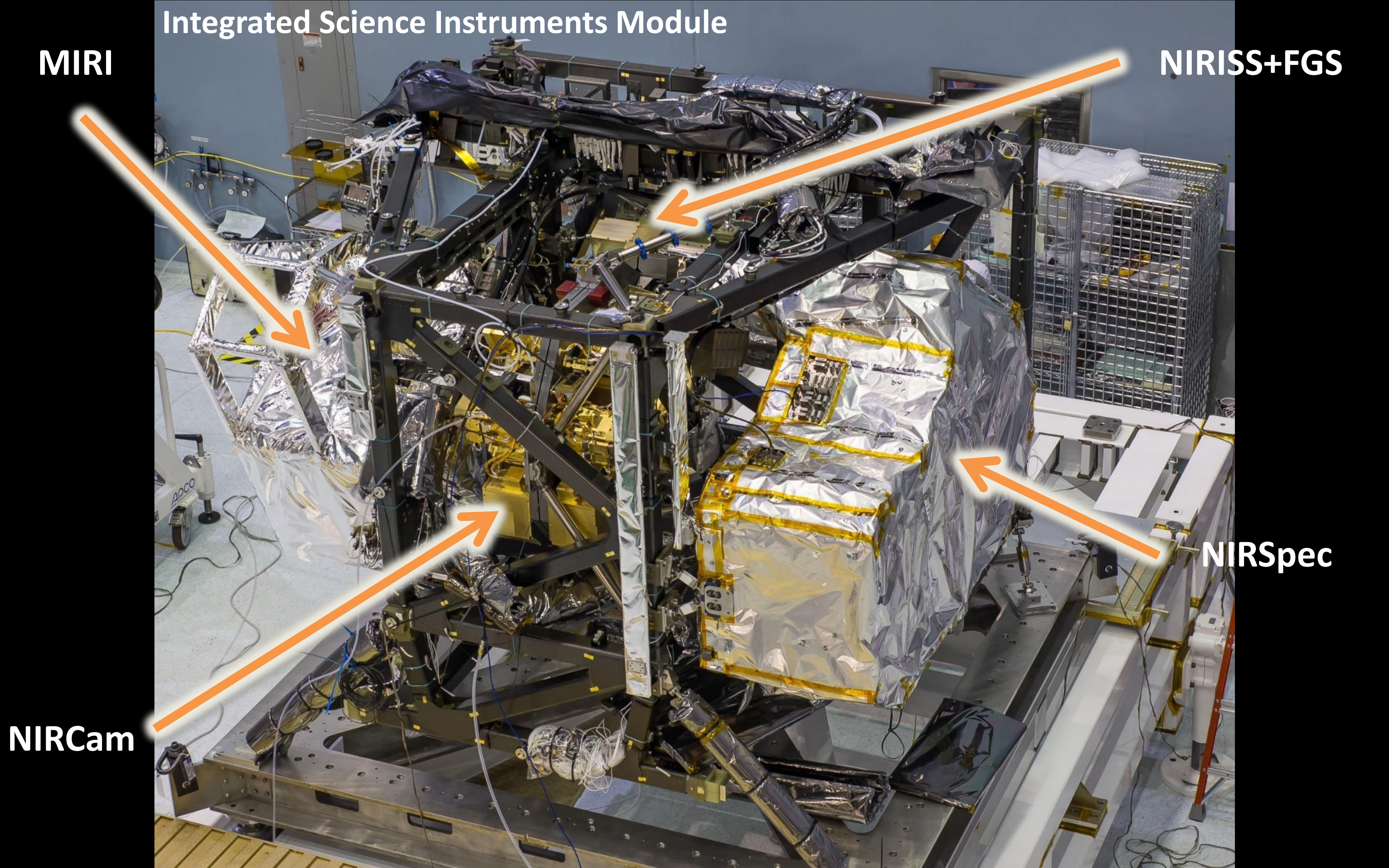
The need for a large, IR optimized space telescope

- High sensitivity (limited only by the natural photon background)
- Spectroscopy to $m_{AB}(2\mu m)$ ~ 30 mag , Imaging to $m_{AB}(2\mu m)$ ~ 32 mag
- Sub-arcsecond spatial resolution (diffraction limited > 2 µm)

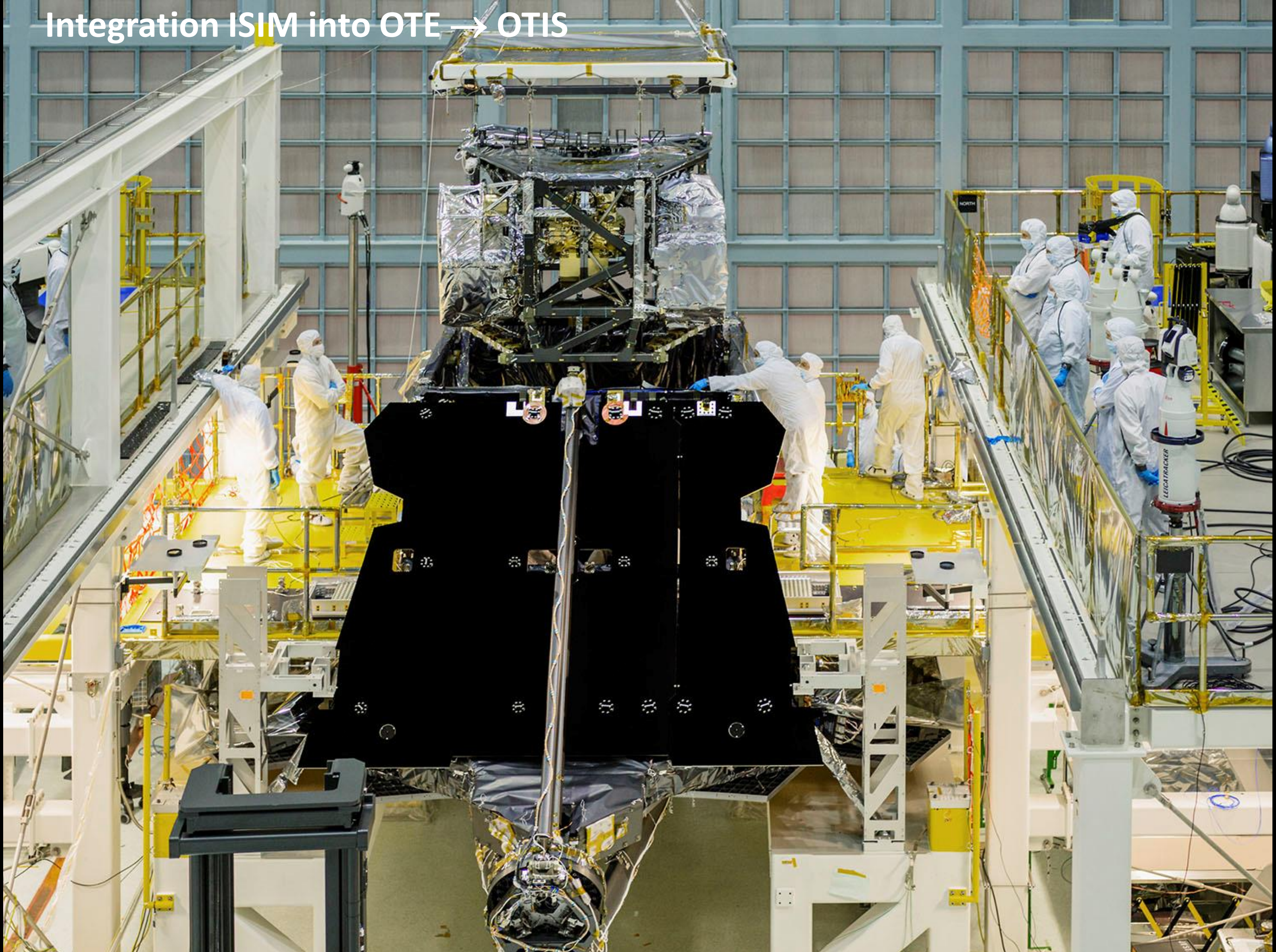
- Highly capable instruments cover 0.6 to 28.5 µm
- Broad, medium, narrow band imaging; MOS and IFUs
- ~ 10 square arcmin field of view
- Spectroscopy R ~ 100, R ~ 1000, R ~ 3000 with complete coverage
- Coronagraphy, exoplanet transit modes

- Full-sky coverage each year, 10-year lifetime

Integrated Science Instruments Module



Integration ISIM into OTE → OTIS

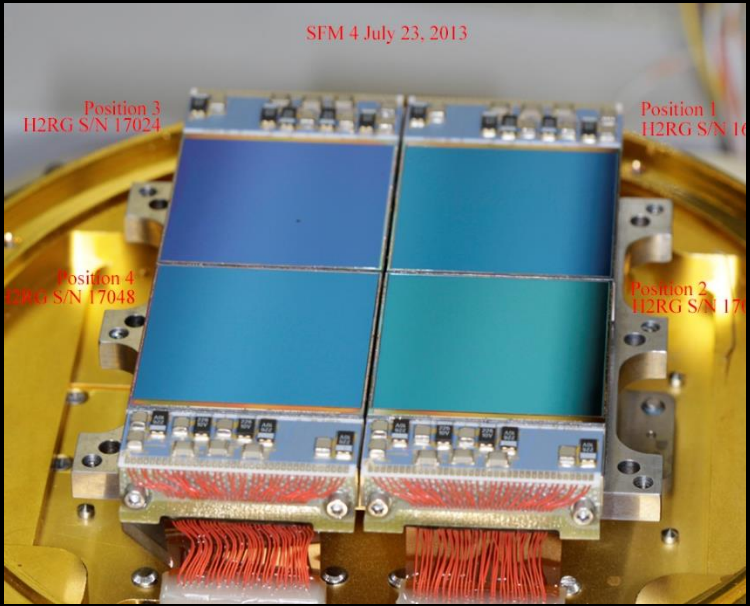


Near Infrared Camera (NIRCam)

NIRCam Capabilities

2 channel imager from $\lambda = 0.6$ to 5.0 microns, get $\lambda < 2.5$ & $\lambda > 2.5$ micron simultaneously
Nyquist sampling of diffraction limit at 2 microns (0.032”/pixel) and 4 microns (0.065”/pixel)
2.2’ x 4.4’ wide field of view
Short and long wavelength coronagraphy
Slitless spectroscopy for $\lambda = 2.4 – 5.0$ micron

Built by Univ. of Arizona and Lockheed-Martin



Short wavelength FPA

Near Infrared Imager and Slitless Spectrograph

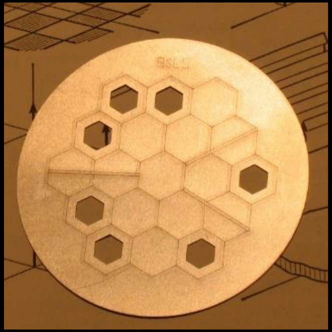
NIRISS Capabilities

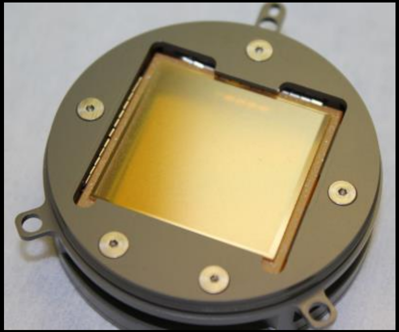
Imaging - λ = 0.9 to 5.0 microns over a 2.2’ x 2.2’ field of view with 0.065” pixels

Wide Field Slitless Spectroscopy - λ = 1.0 to 2.5 microns at R ~ 150

Single Object Slitless Spectroscopy - λ = 0.6 to 2.5 microns at R ~ 700

Aperture Mask Interferometry - λ = 3.8 to 4.8 microns, enabled by non-redundant mask


NIRISS Aperture Mask


Defocusing R~150 grism

Built by CSA and COMDEV

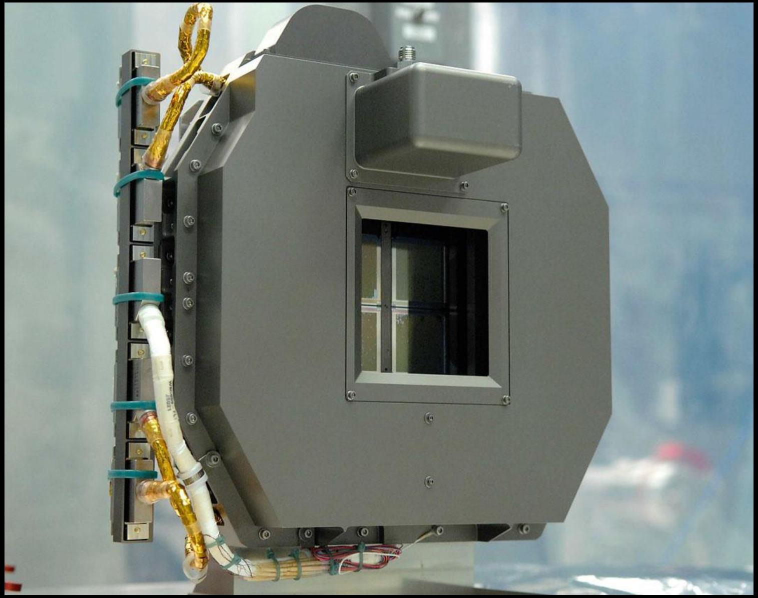
Near Infrared Spectrograph (NIRSpec)

NIRSpec Capabilities

Near Infrared wavelength coverage of λ = 0.6 to 5.0 microns Three different spectral resolutions of R = 100, 1000, and 2700

Modes: **Single Slit Spectroscopy** (slits with 0.4” x 3.8”, 0.2” x 3.3”, 1.6” x 1.6”)
Integral Field Unit (3.0” x 3.0”)
Multi Object Spectroscopy (3.4’ x 3.4’ with 250,000 - 0.2” x 0.5” microshutters)

Built by ESA and Airbus



Microshutter Array

Mid Infrared Instrument (MIRI)

MIRI Capabilities

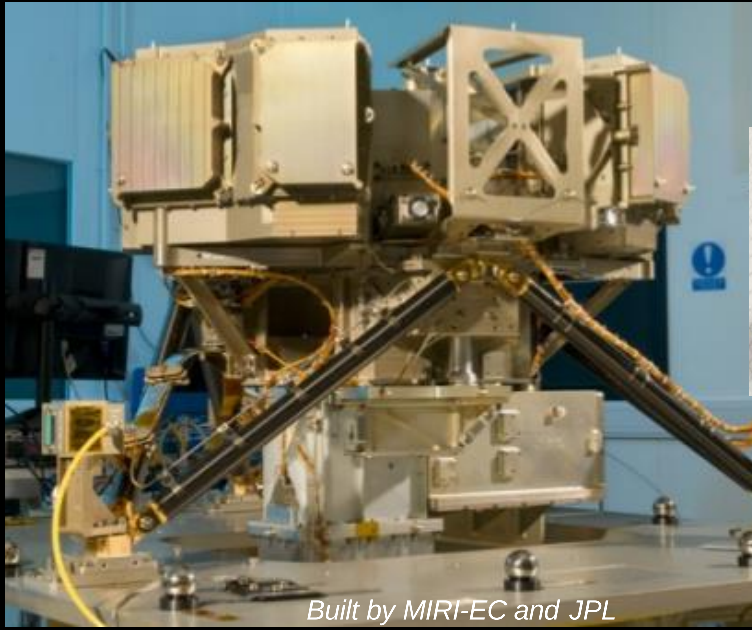
High resolution imager with sensitivity from λ = 5 to 28.5 microns, 10 broad-band filters

λ = 5.0 to 28.3 microns with 0.11” pixels, 1.23’ x 1.88’ field of view

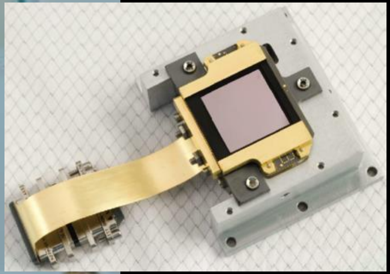
Coronagraphy at 10.65, 11.4, 15.5, and 23 microns (24” to 30” field of view)

Integral Field Unit with R = 2200 to 3500, at 4 wavelengths (3” to 7” field of view)

Single Slit Spectroscopy from 5.0 to ~14 microns in 0.6 x 5.5” slit (R ~ 100 at 7.5 microns)



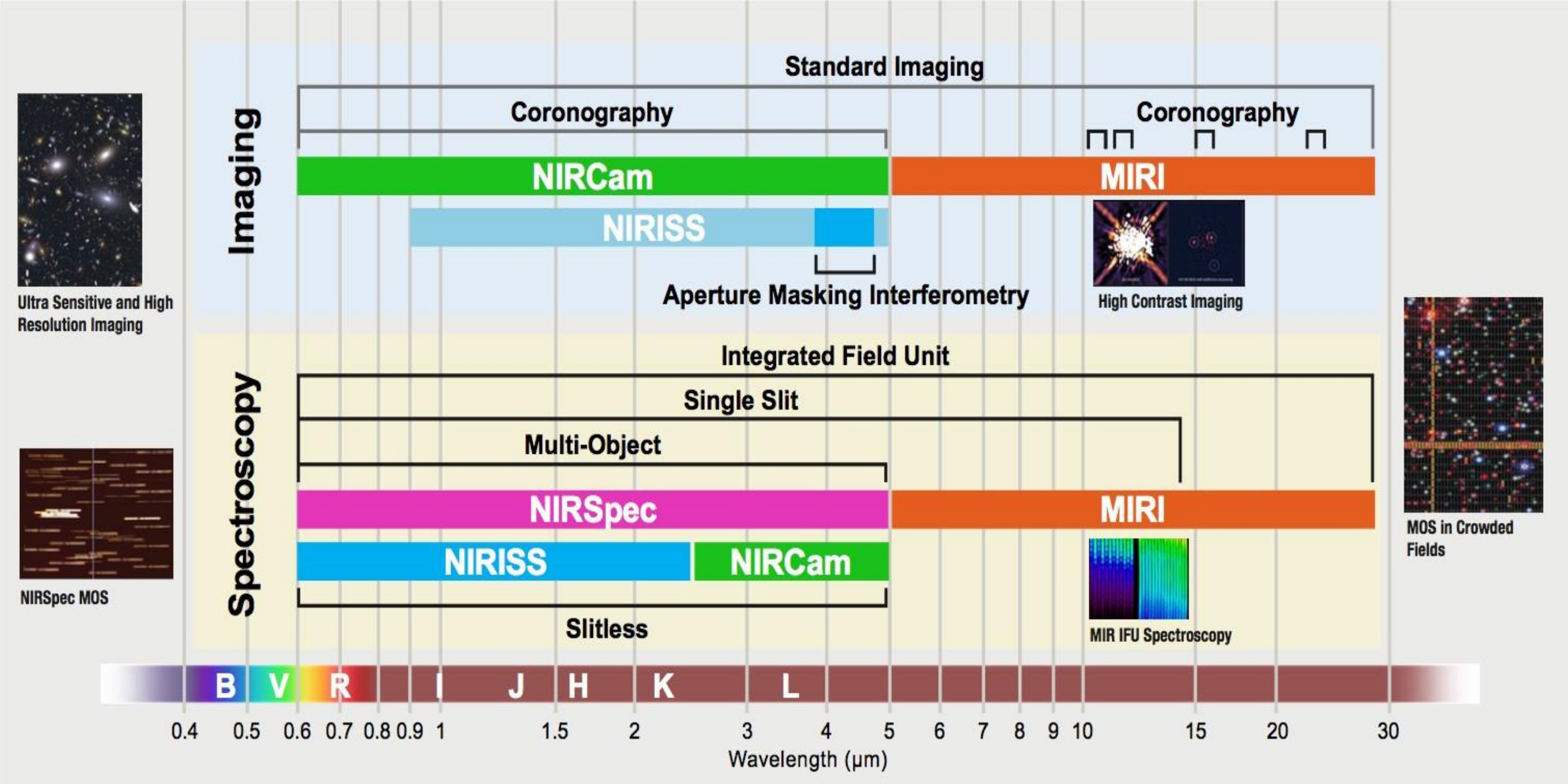
Built by MIRI-EC and JPL



1kx1k Si:As array

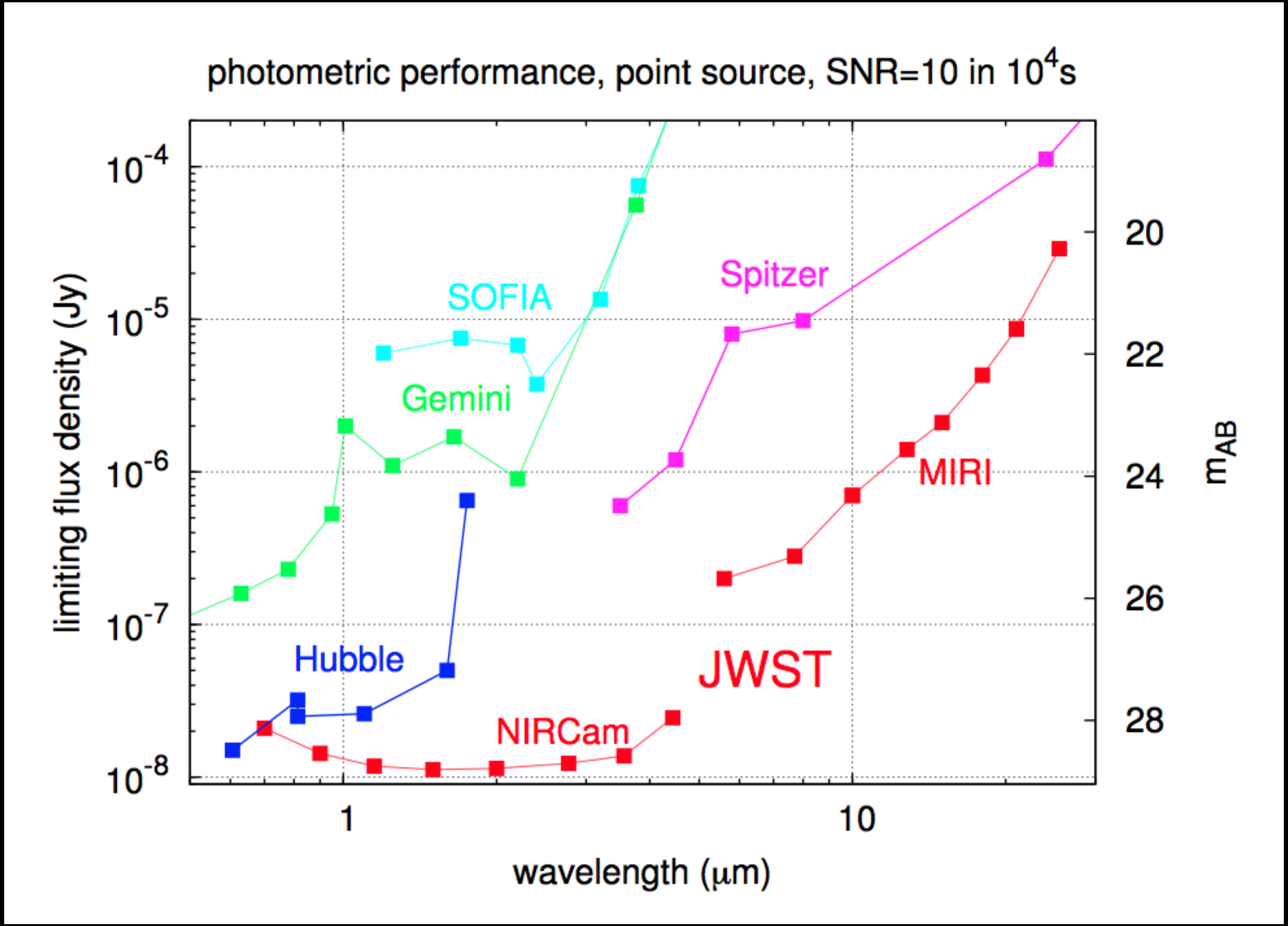
Filter Wheel built by MPIA and Zeiss

Summary JWST observing modes

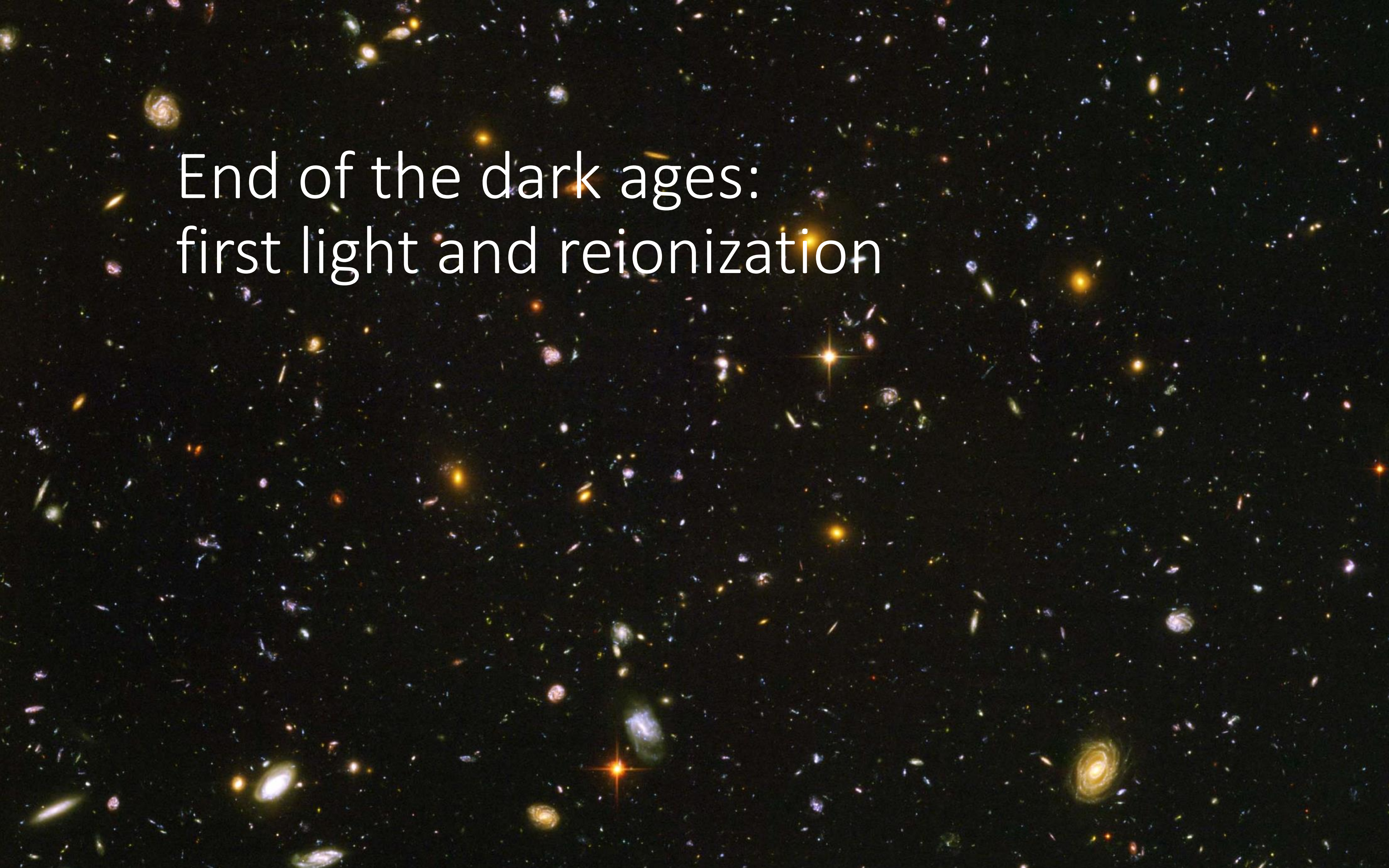


credit STScI

JWST: highest sensitivity with continuous wavelength coverage



End of the dark ages:
first light and reionization



See the first galaxies!

- The first galaxies are small and faint
- Their light is redshifted into infrared
- They are made of low-metallicity, massive stars
  - Supernovae
  - Gamma-Ray-Bursts


Hubble Ultra Deep Field

- Observations:
  - Ultra-deep NIR field
  - Follow-up Spectroscopy MIR

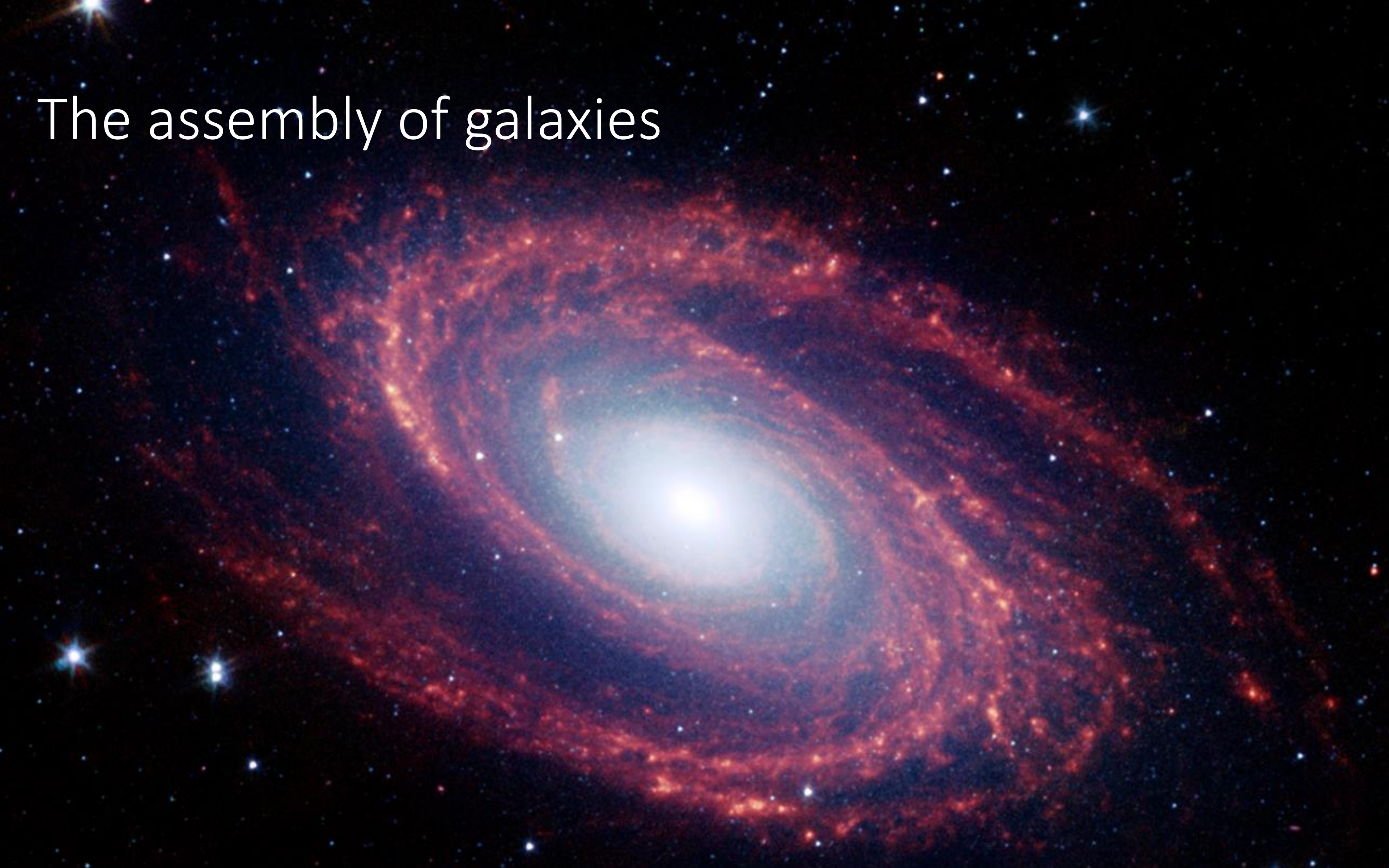
When and how did reionization occur?

- Reionization happened at z>6
- WMAP says maybe twice?
- Probably galaxies, maybe quasar contribution

Observations:

- Spectra of most distant quasars
- Spectra of faint galaxies

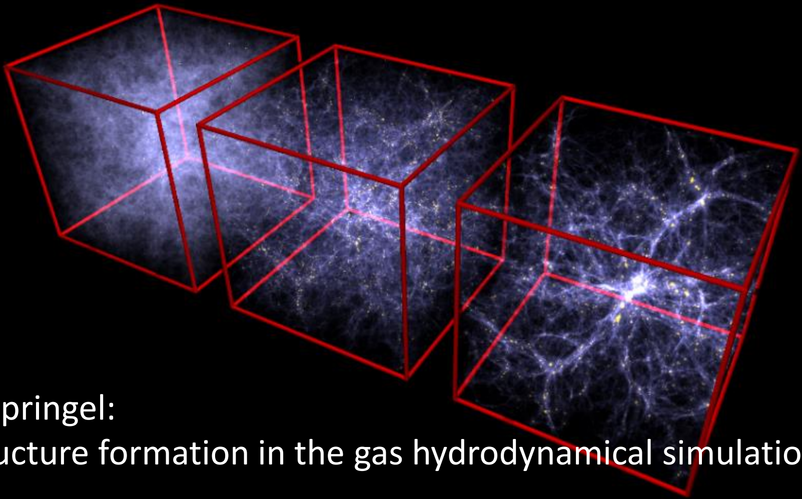
The assembly of galaxies



Galaxy **assembly and evolution**

- Galaxy assembly is a process of hierarchical merging
- Components of galaxies have variety of ages & compositions

Observations:
- NIRCam imaging
- Spectra of 1000s of galaxies



V. Springel:
Structure formation in the gas hydrodynamical simulation

What are the physical processes that determine galaxy properties? What about starbursts and black holes?

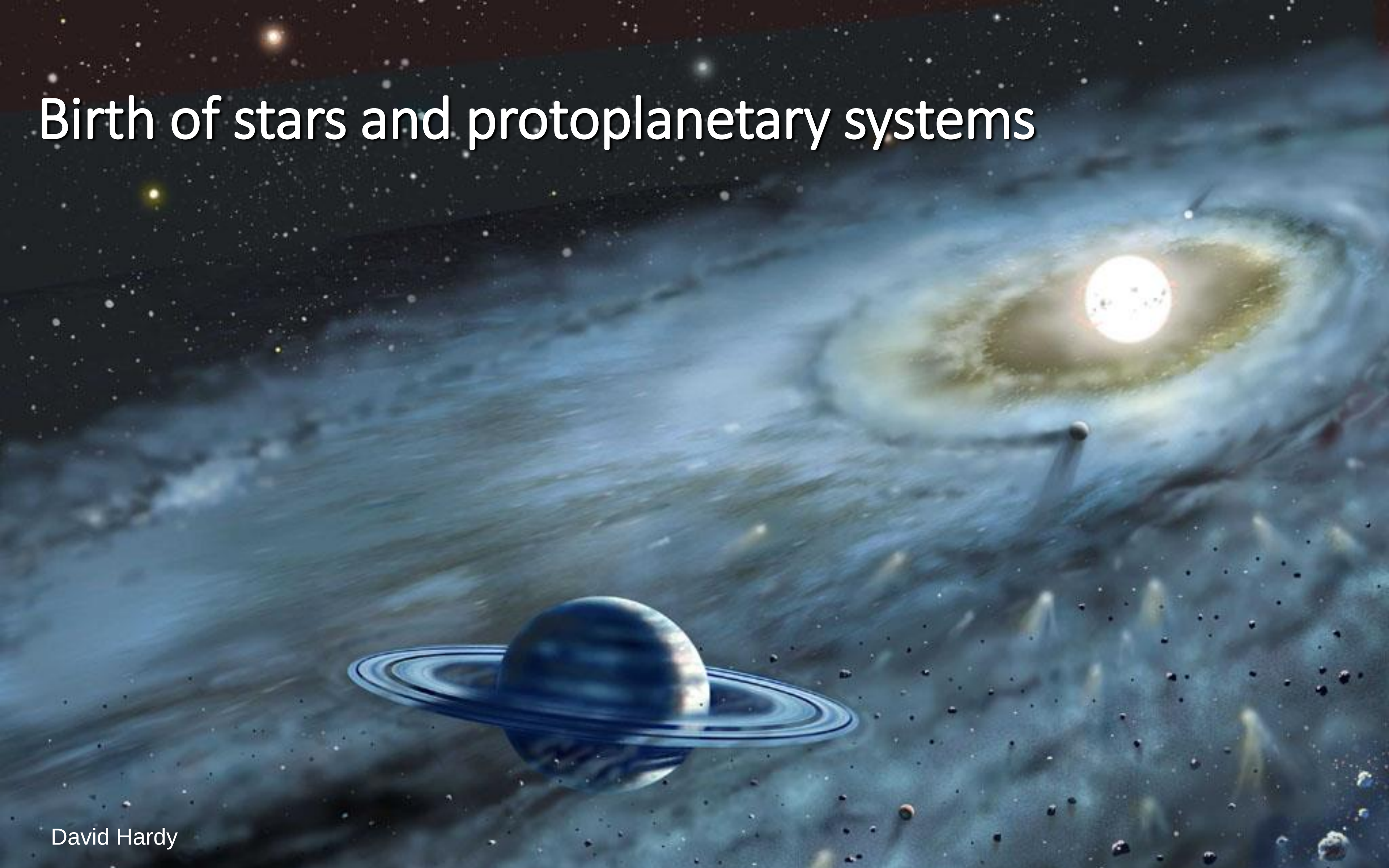
HST + radio image of active galaxy

- Global scaling relations between luminosity, size, kinematics and metallicity.
- Tight correlation between mass of central black holes and surrounding galaxy

Observations:

- MIR spectroscopy
- Velocity dispersion
- MIR emission lines

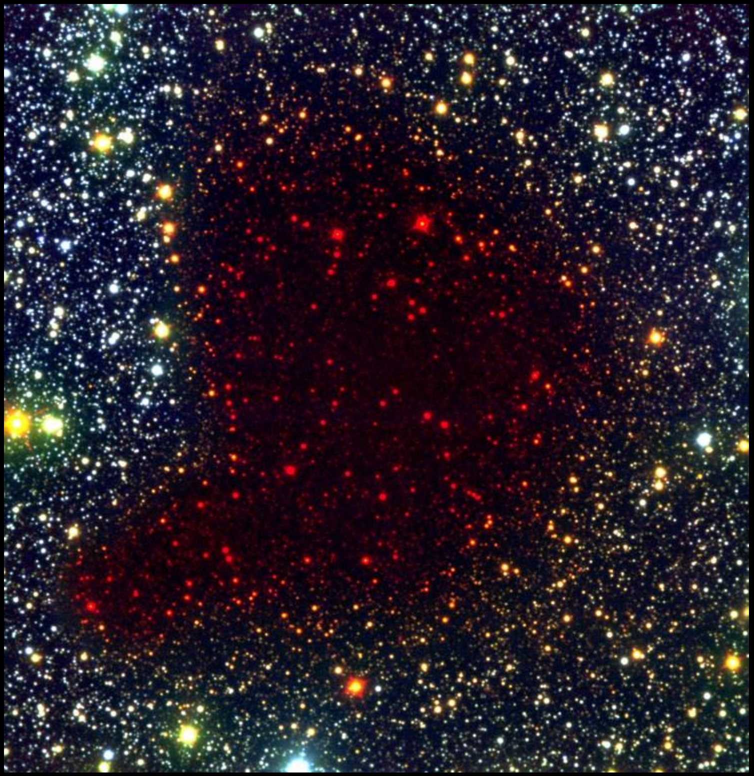
Birth of stars and protoplanetary systems



David Hardy

How do proto-stellar clouds collapse?

- Stars form in small regions collapsing gravitationally within larger molecular clouds.
- We can see through thick, dusty clouds in the infrared.
- Protostars begin to shine within the clouds, revealing temperature and density structure.
- Observations:
  - Deep NIR and MIR imaging of dark clouds and proto-stars



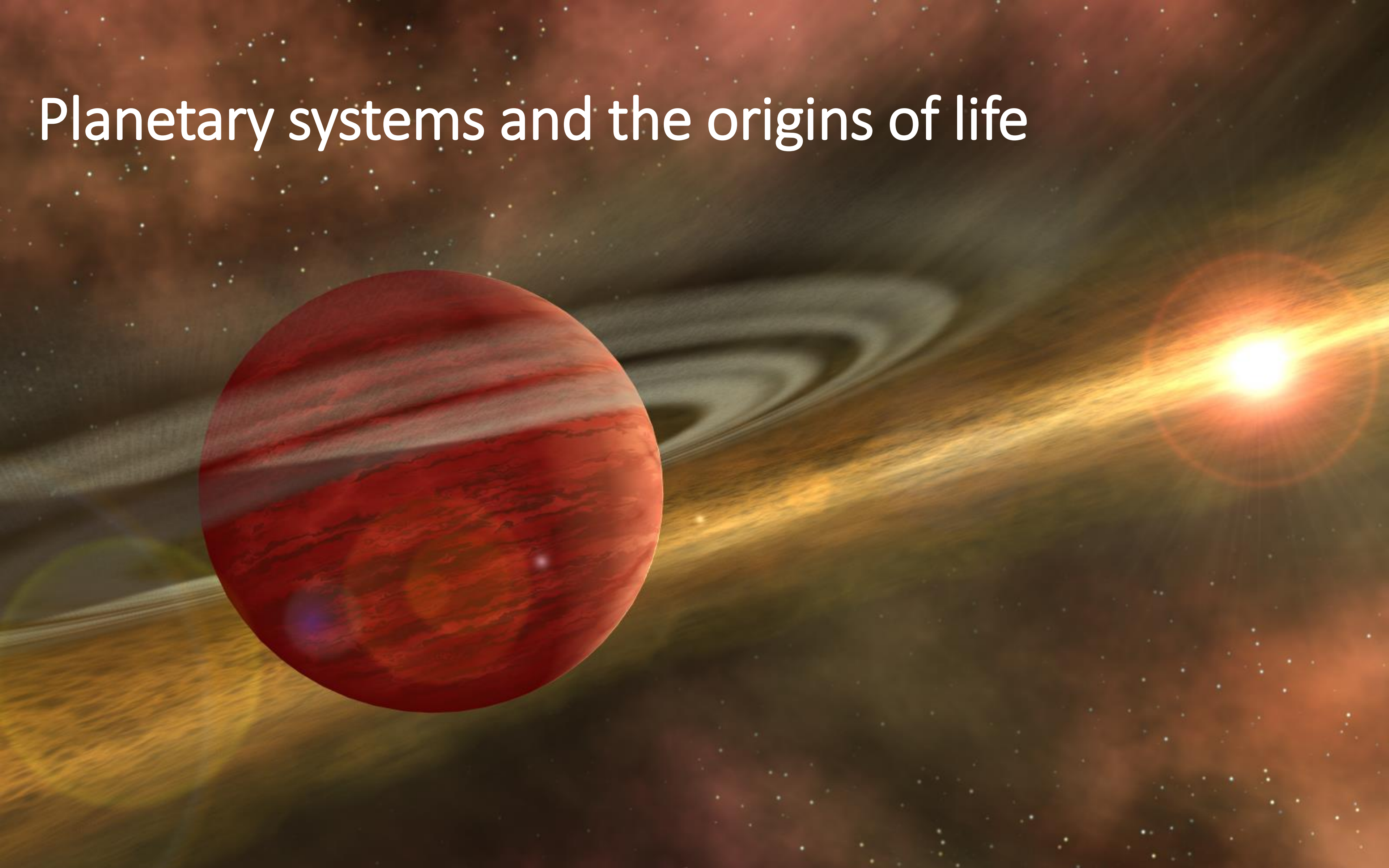
Barnard 68 in infrared

How does environment affect star-formation and vice-versa?
What is the sub-stellar initial mass function?

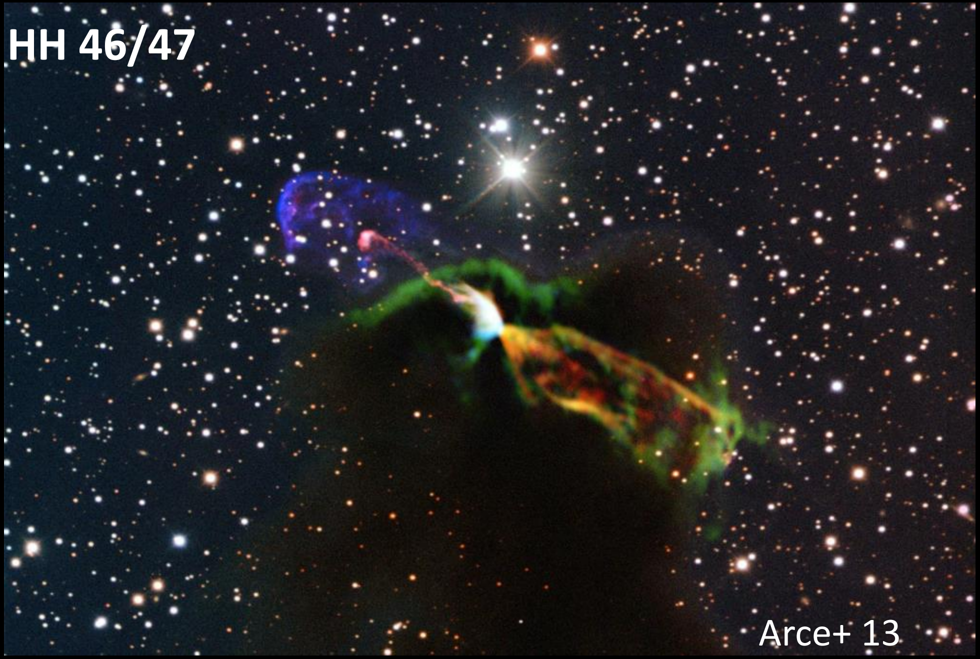
- Massive stars produce winds and radiation
  - Either disrupt star formation, or causes it.
- The boundary between the smallest brown dwarf stars and planets is unknown
  - Different processes? Or continuum?
- Observations:
  - Survey dark clouds and star-forming regions

The Eagle Nebula
as seen in the infrared

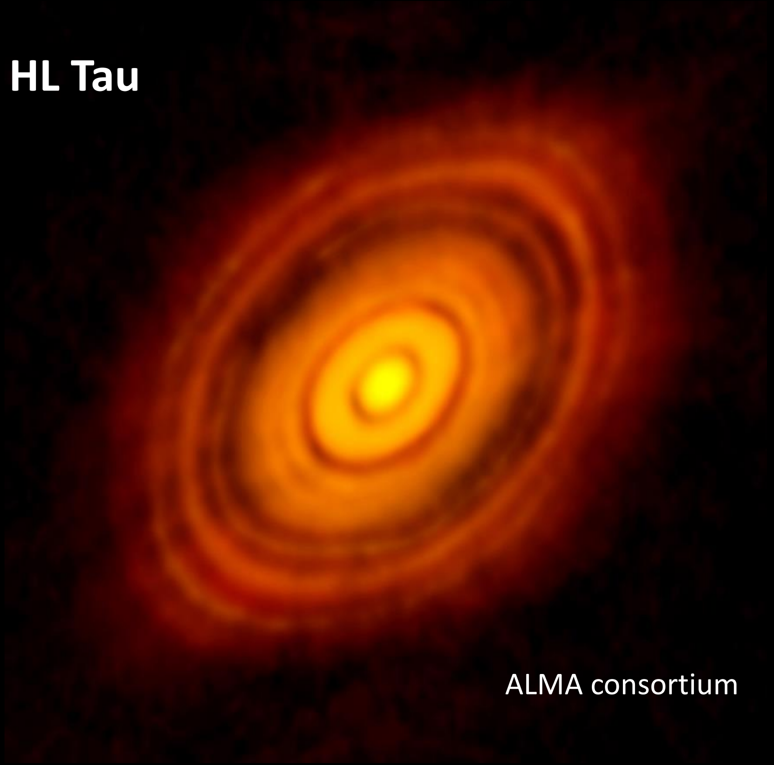
Planetary systems and the origins of life



Deeper insight in the formation of stars and planets



Arce+ 13



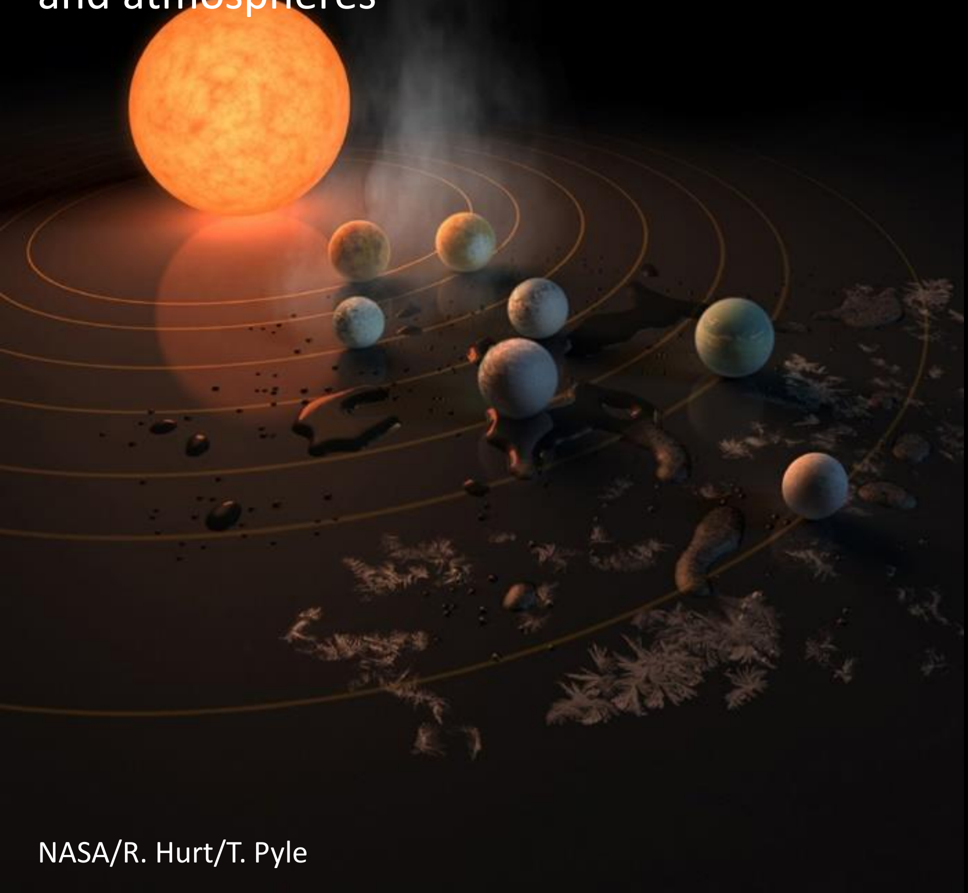
ALMA consortium

- Physical conditions in the gas disk, flaring, winds
- Relation of the ALMA disk structures (gaps, spirals, clumps) with forming planets

Observations: high-performance mid IR spectroscopy / coronagraphy

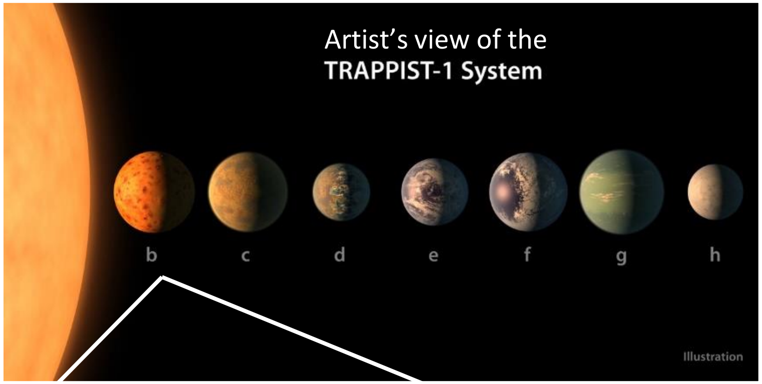
The exoplanet revolution

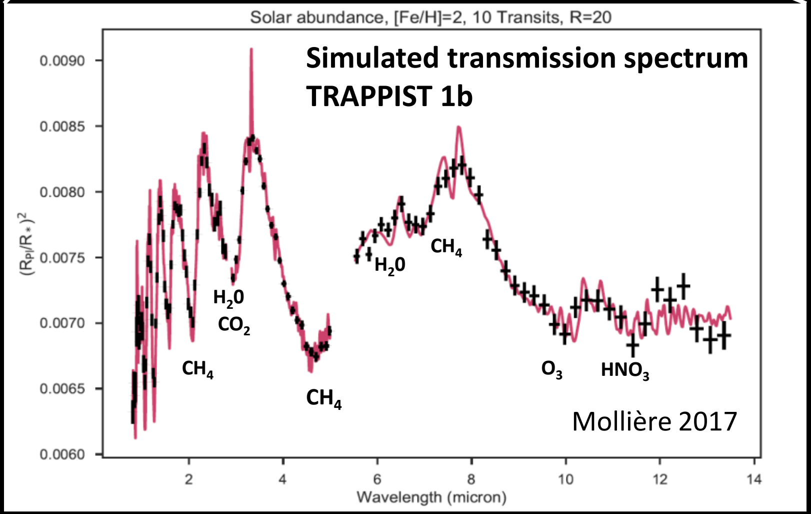
Since 1995 nearly 3000 exoplanet discoveries.
Next step is the characterization of their interiors and atmospheres



NASA/R. Hurt/T. Pyle

Observations:
high-performance MIR spectroscopy



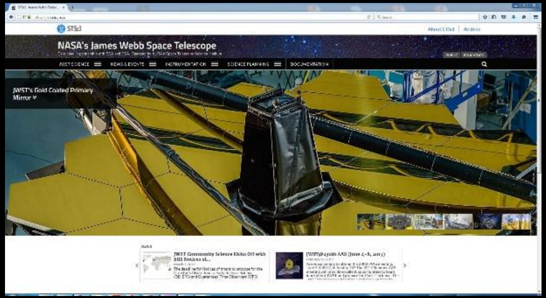


Mollière 2017

JWST will be launched between March and June 2019.
It will revolutionize our view of the infrared universe !

For more information follow JWST at

https://jwst.stsci.edu/



http://sci.esa.int/jwst/

https://jwst.nasa.gov/