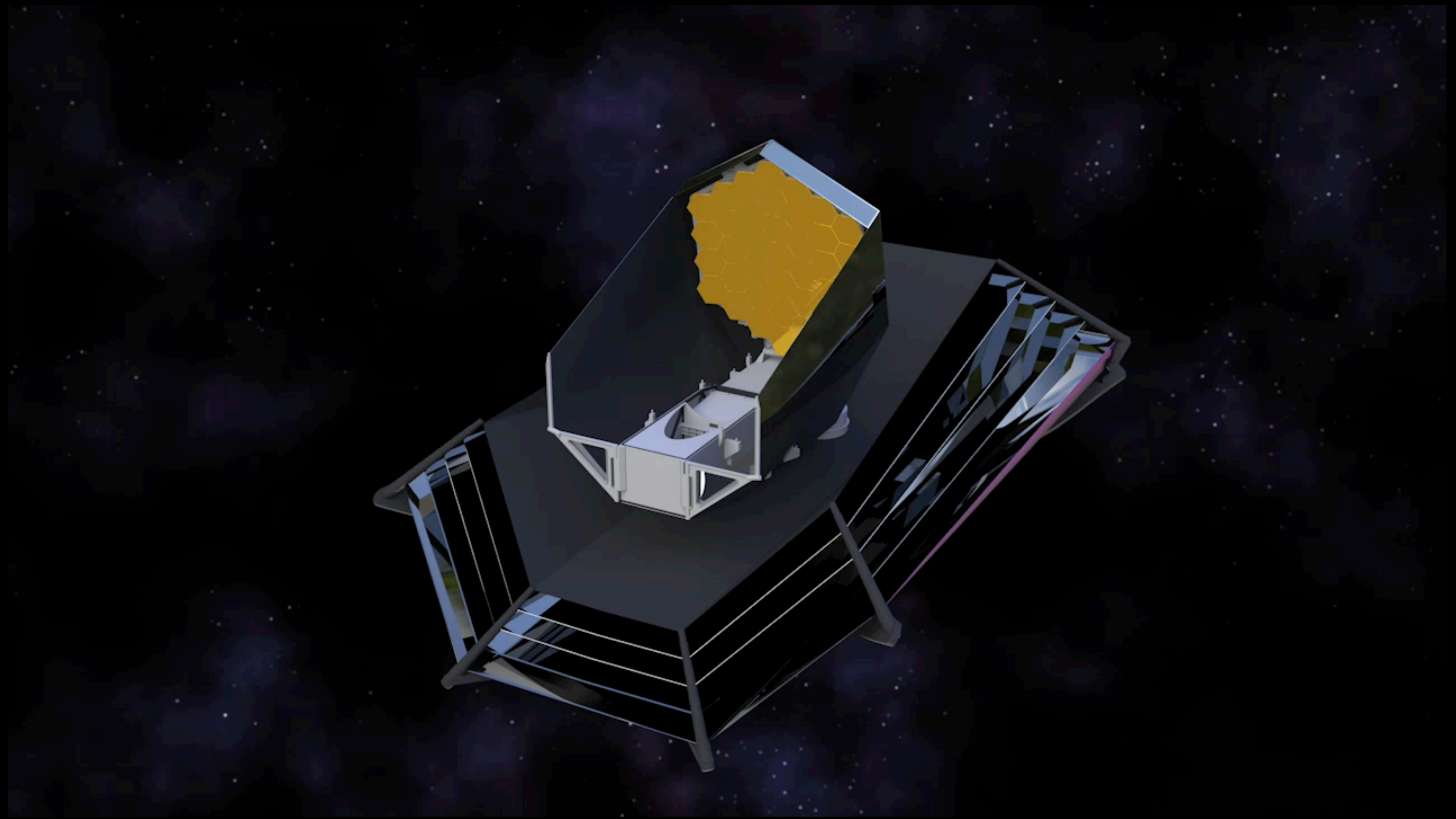
ORIGINS
Space Telescope



A Cooray for the OST STDT

http://origins.ipac.caltech.edu @NASAOriginsTele

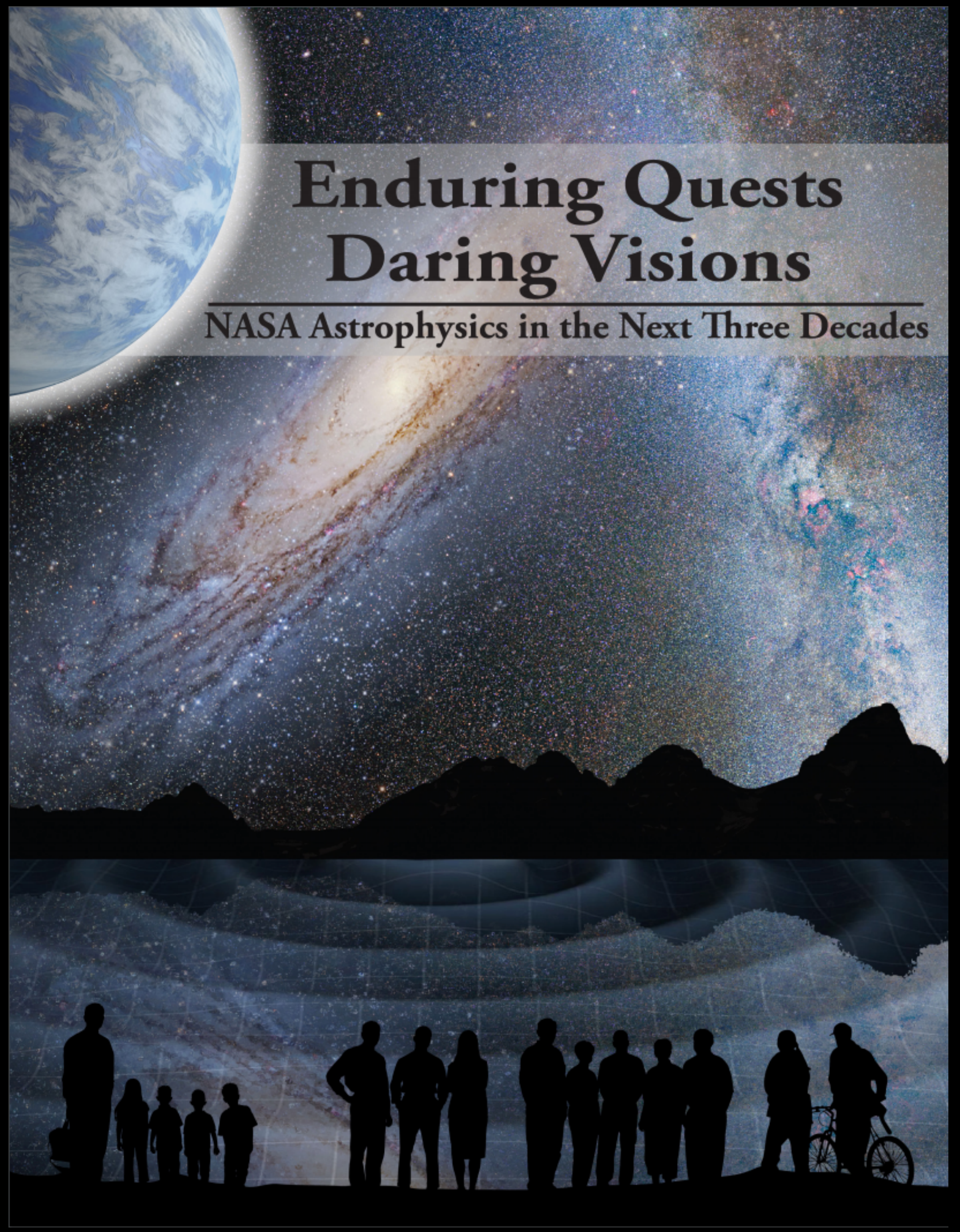
ORIGINS
Space Telescope

From first stars to life

NASA flagship class mission concept for the 2020 Decadal review.

Comes from the NASA Astrophysics Roadmap.

- **5µm** – 600 µm (diffraction limit around 30 µm)
- 4.5K actively-cooled large aperture operating at L2
- factor of 10,000 improvement in sensitivity over previous (driven primarily by cooling not aperture size).
- ultra-sensitive detector arrays => new spectroscopic capabilities
- exoplanet studies via a coronagraph and transit spectroscopy
- modular instrument suite with robotic serviceability
- Mission aimed at mid 2030s: post JWST, concurrent with WFIRST, Athena, LISA, and 25m-35m ground-based optical/IR facilities.
- Science goals and measurement requirements in 2030+



Enduring Quests
Daring Visions
NASA Astrophysics in the Next Three Decades

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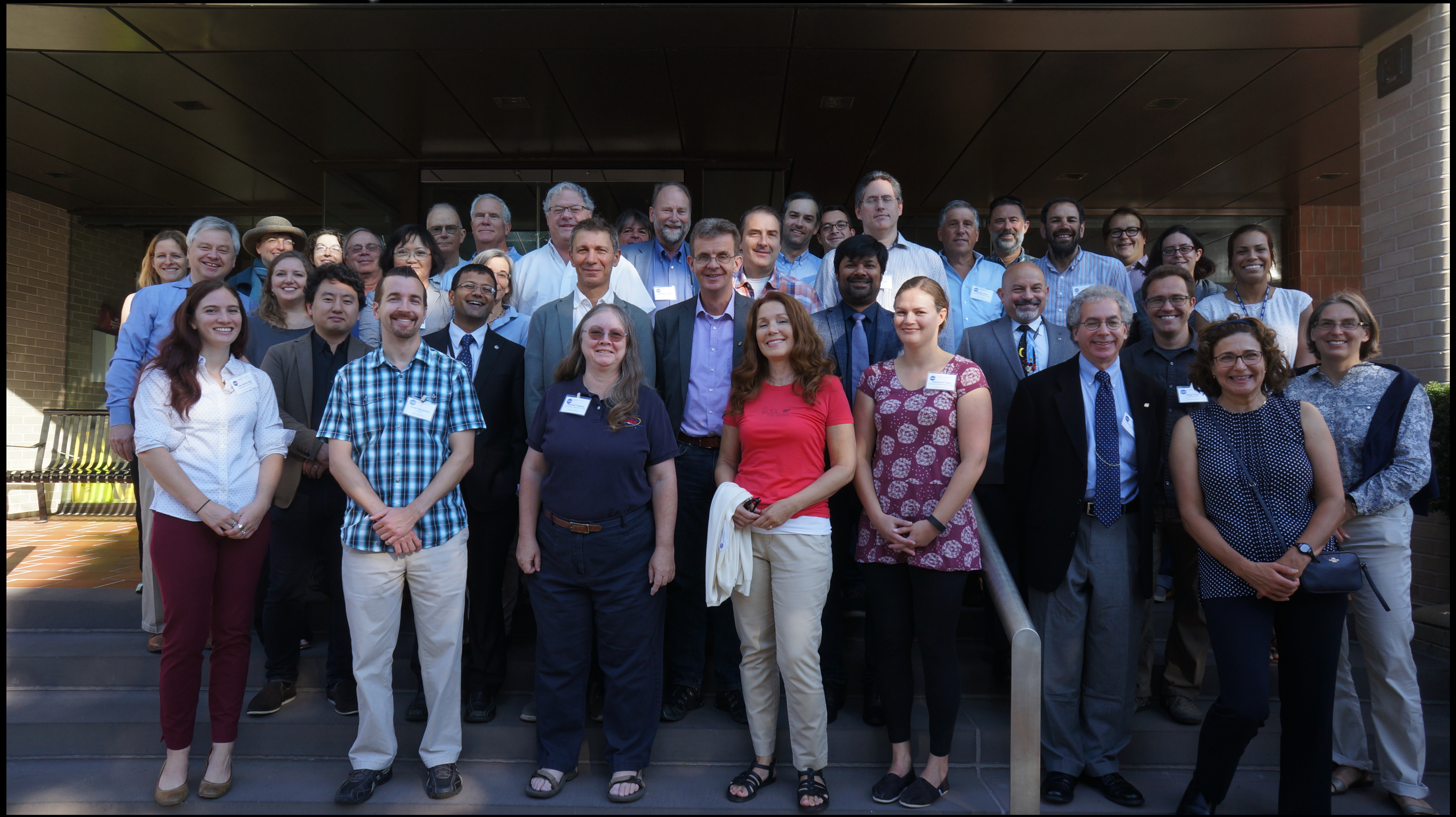

Study Team

- **Community Chairs: A. R. Cooray, UCI*;* M. Meixner, *STSCI/JHU***
- **Study Scientist:** D. Leisawitz, *GSFC*
- **Deputy Study Scientist:** J. Staguhn, *GSFC/JHU*
- **Study Manager:** R. Carter, *GSFC*
- **NASA HQ Program Scientists:** K. Sheth, D. Benford

- **NASA Appointed Members:** L. Armus, IPAC; C. Battersby, UConn; J. Bauer, UMD; E. Bergin, Michigan; M. Bradford JPL; K. Ennico-Smith, Ames; J. Fortney, UCSC; T. Kataria, JPL; G. Melnick, CfA; S. Milam, GSFC; D. Narayanan, UFlorida; D. Padgett, JPL; K. Pontopiddan, STSCI; A. Pope, UMass; T. Roellig, Ames; K. Sandstrom, UCSD; K. Stevenson, STScI; K. Y. L. Su, Arizona; J. Vieira, UIUC; E. Wright, UCLA; J. Zmuidzinas, Caltech
- **Ex-officio representatives:** S. Neff & E. Smith, NASA Cosmic Origins Program Office; S. Alato, SNSB; D. Burgarella, LAM, France; D. Scott, CSA; M. Gerin, CNES; I. Sakon, JAXA; F. Helmich, SRON; R. Vavrek, ESA; K. Menten, DLR; YS Song, KASI; S. Carey, IPAC; S. Wiedner, CNRS.
- **NASA Study Center (Goddard Space Flight Center) Team:** C. Wu (Mission Systems Engr), E. Amatucci (Instrument Systems Engr), M. DiPirro (Chief Technologist), J. Staguhn (Instrument Scientist)
- **Study Advisory Board:** J. Arenberg,Northrup Grumman; J. Carlstrom, Chicago, H. Ferguson, STScI, T. Greene, Ames; G. Helou, IPAC; L. Kaltenegger, Cornell; C. Lawrence, JPL; S. Lipscy, Ball; J. Mather, GSFC; H. Moseley, GSFC; G. Rieke, Arizona; M. Rieke, Arizona; J. Turner, UCLA; M. Urry, Yale.

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From first stars to life

- *Are we alone?* **OST question: How common are life bearing planets?** With sensitive mid-infrared transit spectroscopy, OST will measure biosignatures, including ozone, carbon-dioxide, water, and methane in the atmospheres of Earth-sized habitable exoplanets.

- *How did we get here?* **OST question: How do the conditions for habitability develop during the process of planet formation?** With the sensitive and high-resolution far-IR spectroscopy OST will map the water trail in our Galaxy.

- *How does the Universe work?* **OST question: How do galaxies form stars, make metals, and grow their central supermassive blackholes from reionization to today?** OST will spectroscopically 3D map wide extragalactic fields to measure simultaneously properties of growing super-massive blackholes and their galaxy hosts across cosmic time.

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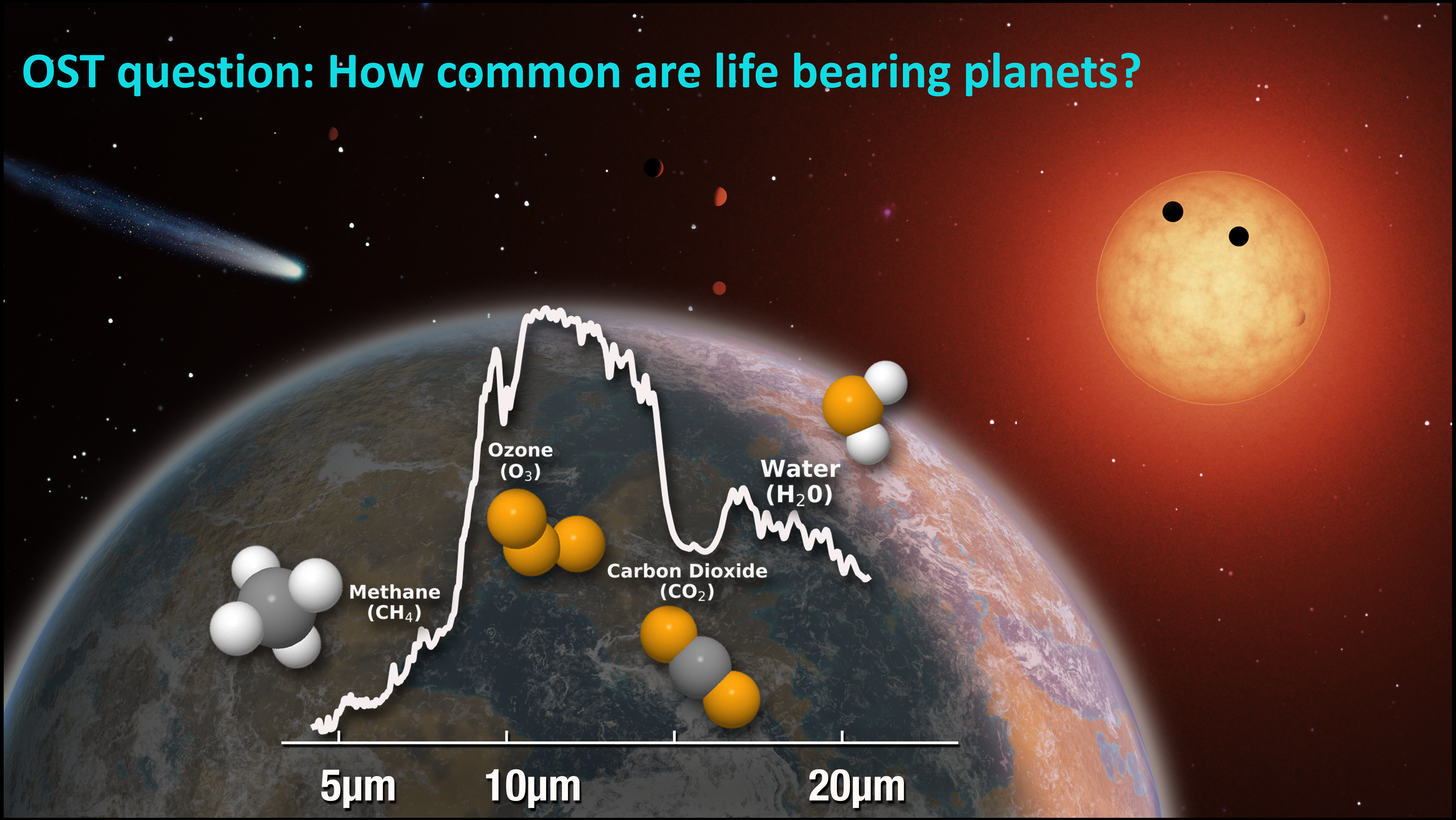
From first stars to life

Are we alone?

- OST question: How common are life bearing planets?



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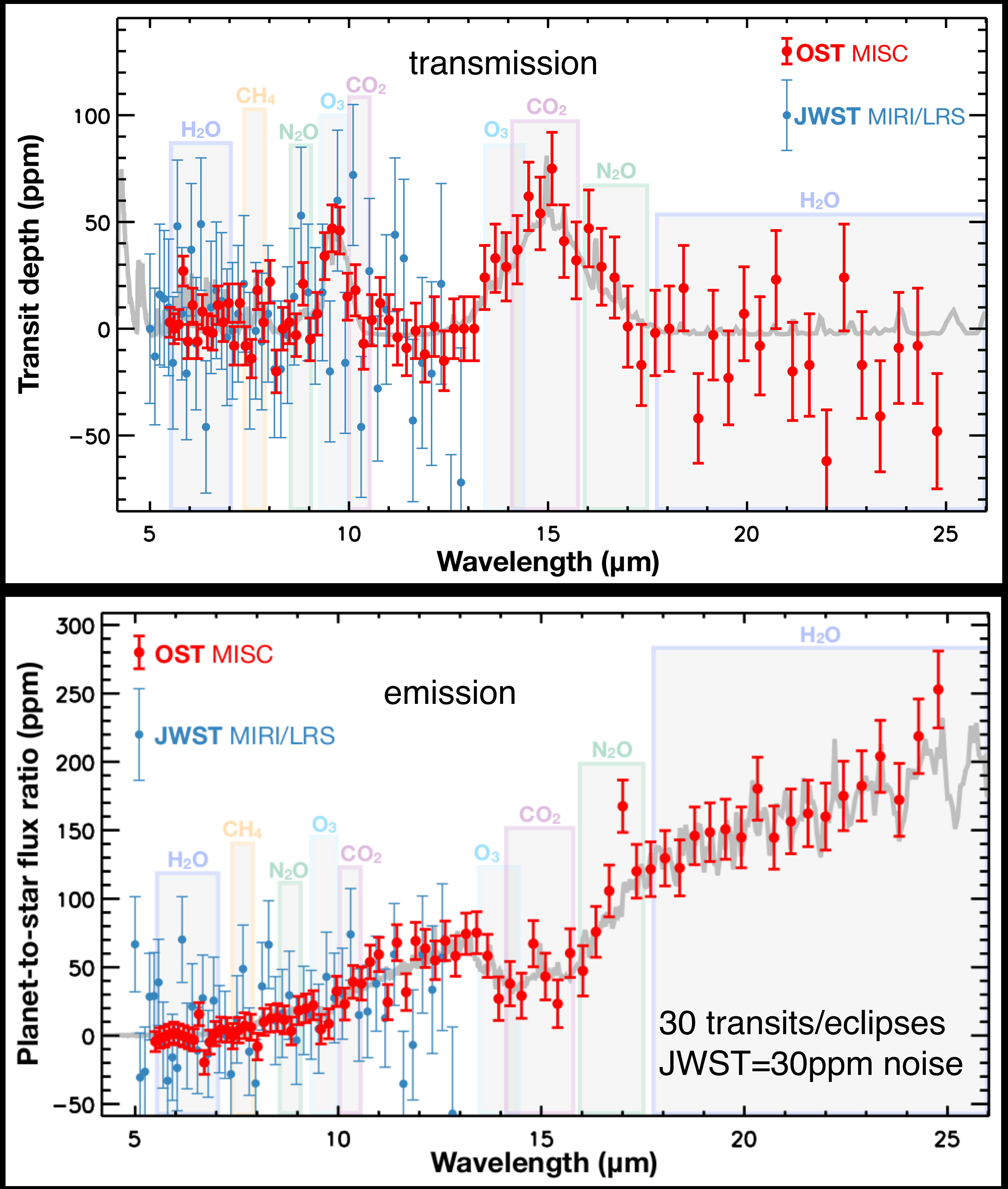
From first stars to life

To detect biosignatures:

- Spectral resolving power (λ/Δλ) of 100-300
- Noise floors < 5 ppm (requirement)
  - (M3V@20 pc – 2 hr at 7 µm)
- Key spectral signatures of Earth-size planets that Origins will detect:
  - H_2O, CO_2, O_3, N_2O, CH_4
  - bio-signatures: O_3 or N_2O plus CH_4
  - bio-indicators: H_2O, CO_2

Origins Space Telescope will have mid-IR capability down to 5 µm; noise floor will be due to mid-IR detector stability.

TRAPPIST-1e simulation



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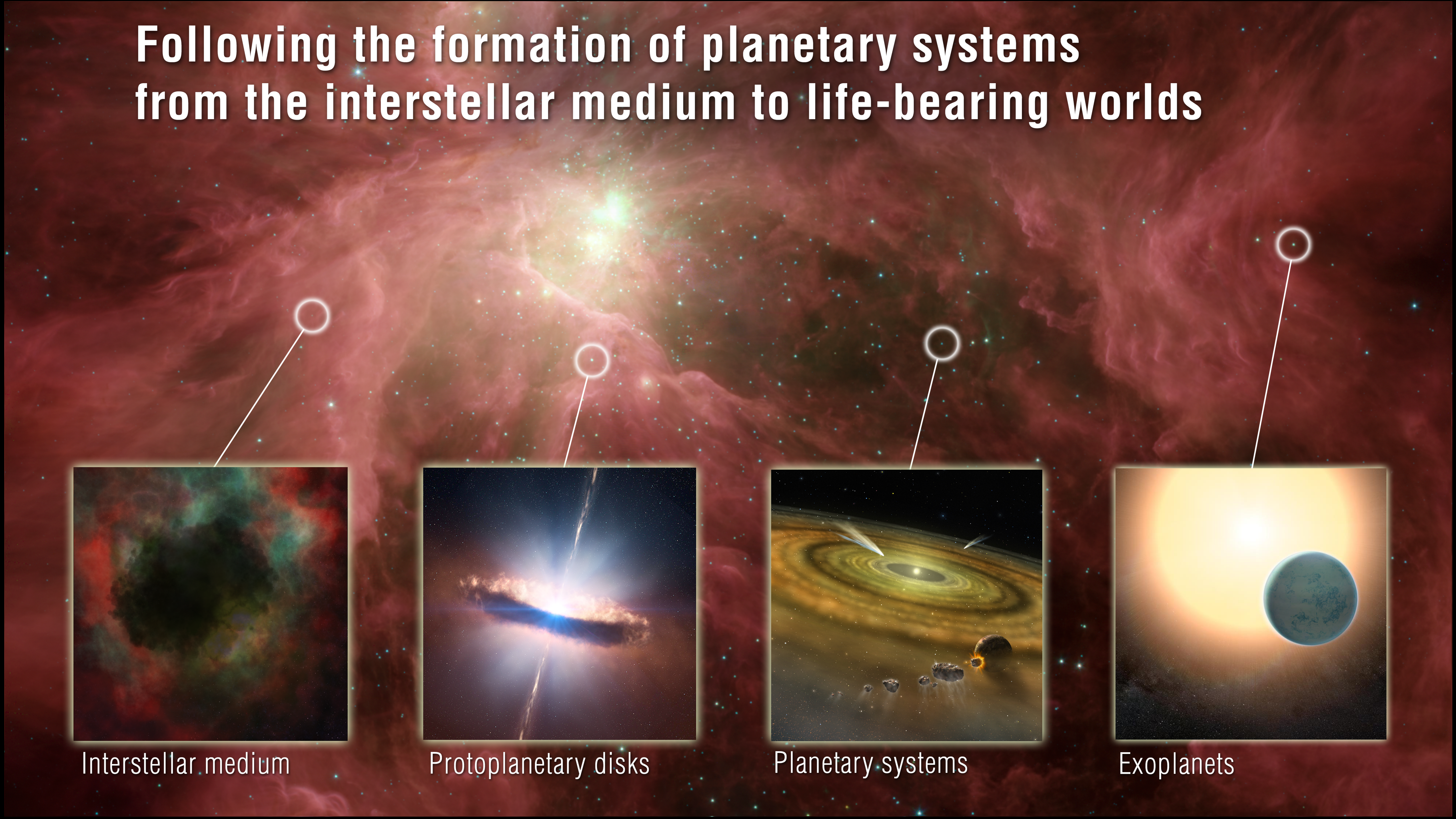
From first stars to life

How did we get here?

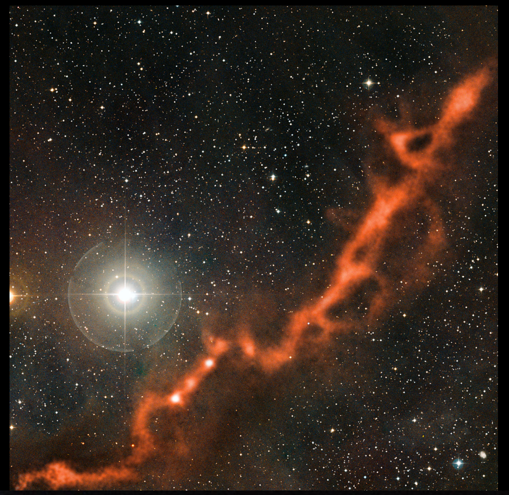


Following the formation of planetary systems
from the interstellar medium to life-bearing worlds

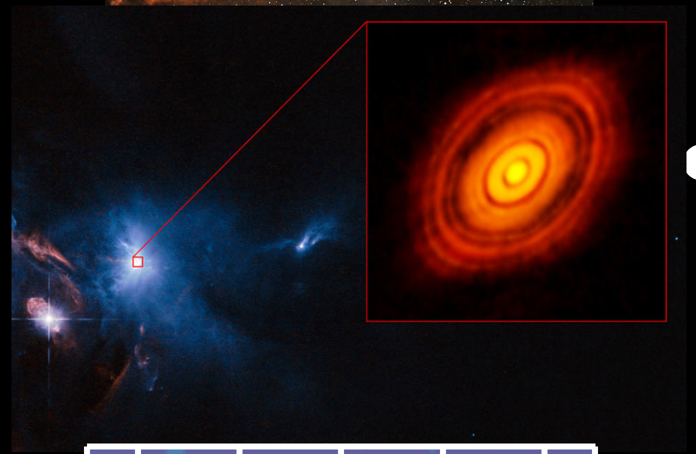
ORIGINS Space Telescope

From first stars to life

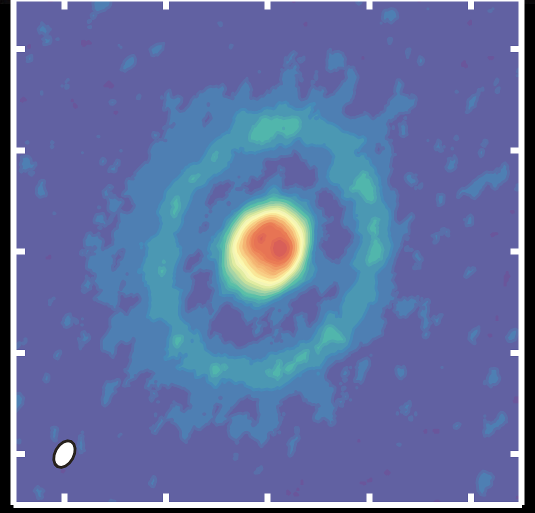
How did we Get Here? The Water Trail



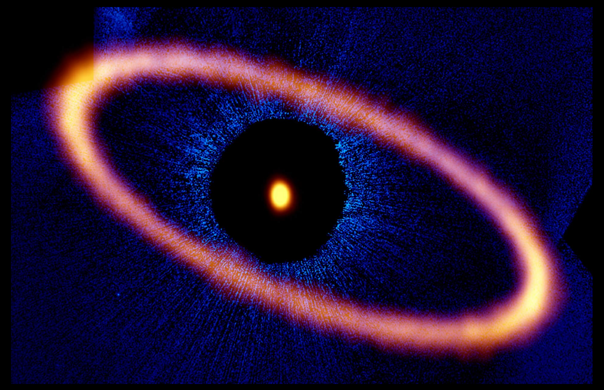
- Water's birth in star-less cores: tracing water vapor in the beginnings of star formation



- Supply to a young disk in protostars: follow water during collapse and the early stages of disk formation.



- Early planet formation in protoplanetary disks: survey water and HD in > 1000 disks, all disks out to 500 pc - trace snowline and water/ice content



- Late planet formation in debris disks: OST can detect water and O I from evaporating planetesimals and determine whether disks are primordial or secondary.

- Supply of life's ingredients to terrestrial worlds: detect water D/H in > 100 comets!

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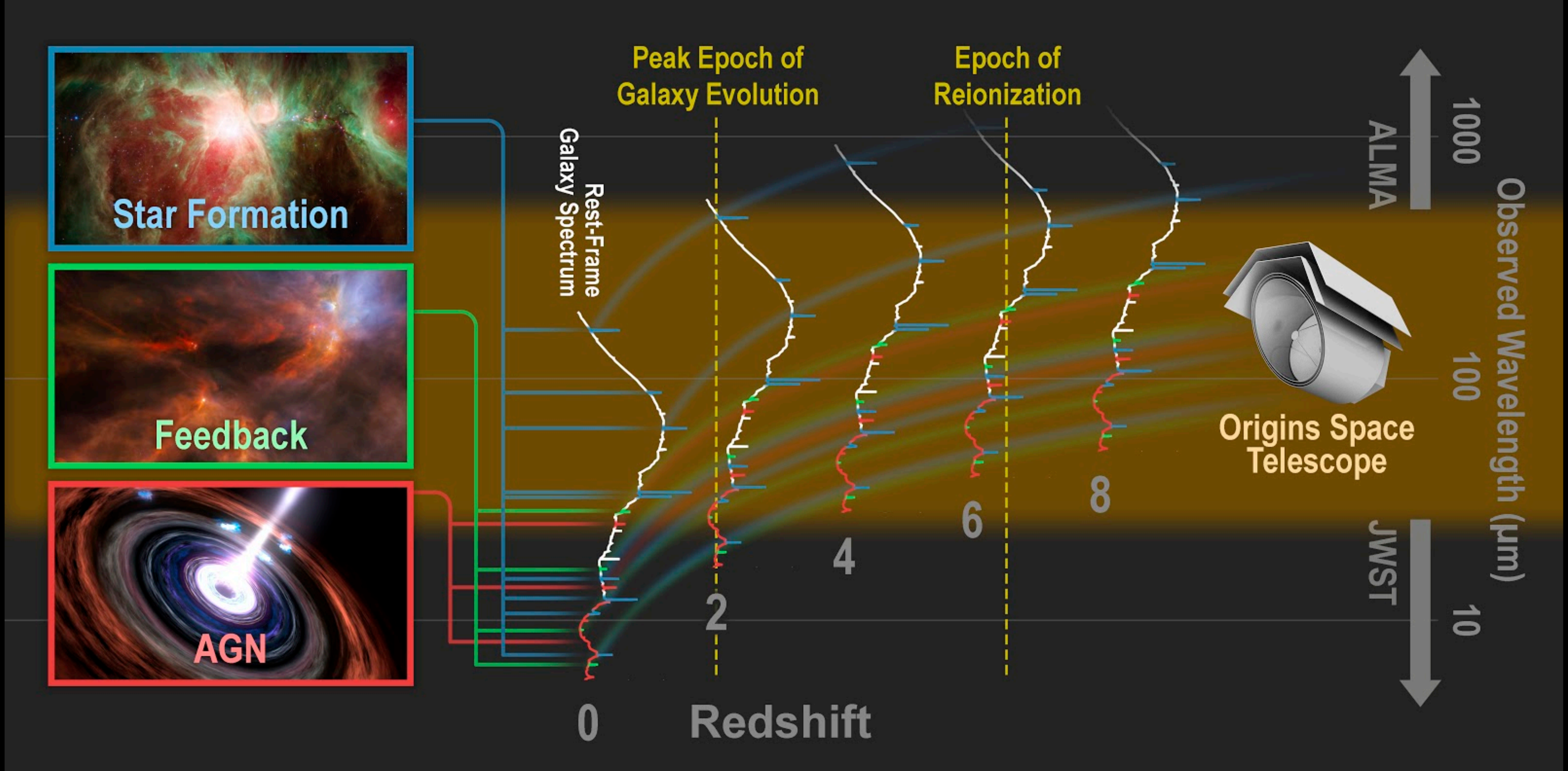
How does the Universe work?



Infrared is rich in key spectral lines!

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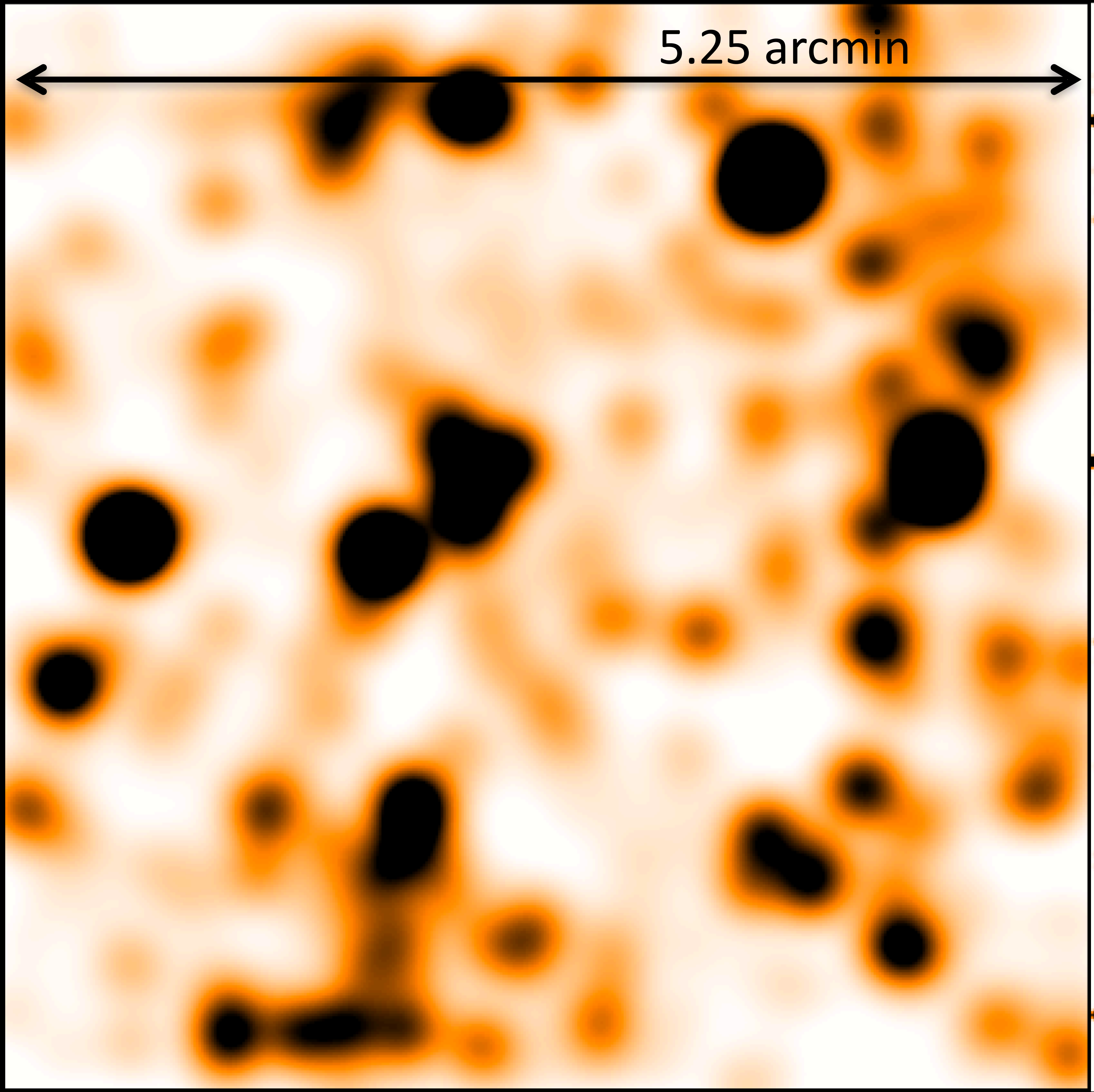
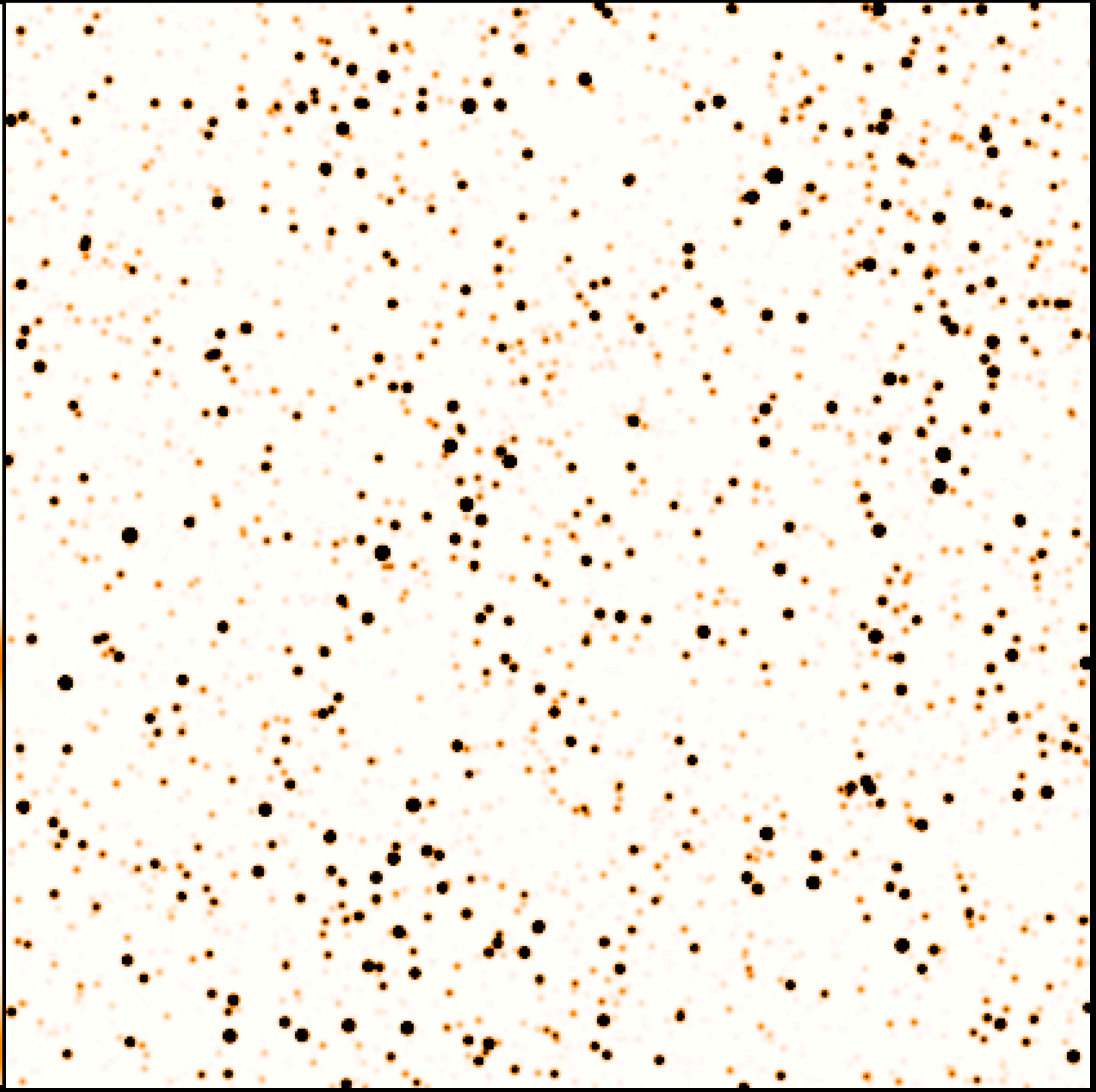
From first stars to life



Spitzer/MIPS



Origins Space Telescope (9m)

From first stars to life

GO Sciences: examples

- **Time-domain sciences**: fast-scanning (100 arcsec/second) allows **follow-up of LISA error boxes!**
- **Direct coronagraphic imaging** of true Jupiters and Saturns
- **Methane sources** on Mars, map out methane distribution. Also **temporal monitoring** of Titan atmosphere.
- **KBO survey to study the albedo distribution** by mapping 100 sq. degrees 2-4 times in parallel with LSST or its successor in 2030s.
- **Image cold dust in exo-zodi/exo-KBO clouds** in TESS, Ariel and other targets.
- Map **crystalline water ice** via the 43 micron emission feature in proto-stellar outflows.
- **Polarization mapping** of the Milky-Way to connect magnetic fields and Galactic star-formation.
- Determine the **cosmic-ray flux in Milky-Way** and other near-by galaxies.
- Spectral line and continuum mapping of local volume galaxies to **study feedback processes**; see bubbles, outflows and fountains in lines such as CII, NII.
- Find **first AGN**; first dust sources.
- Dusty star-formation in **large-scale structure**, clustering measurements. Resolve **Cosmic Infrared Background**.

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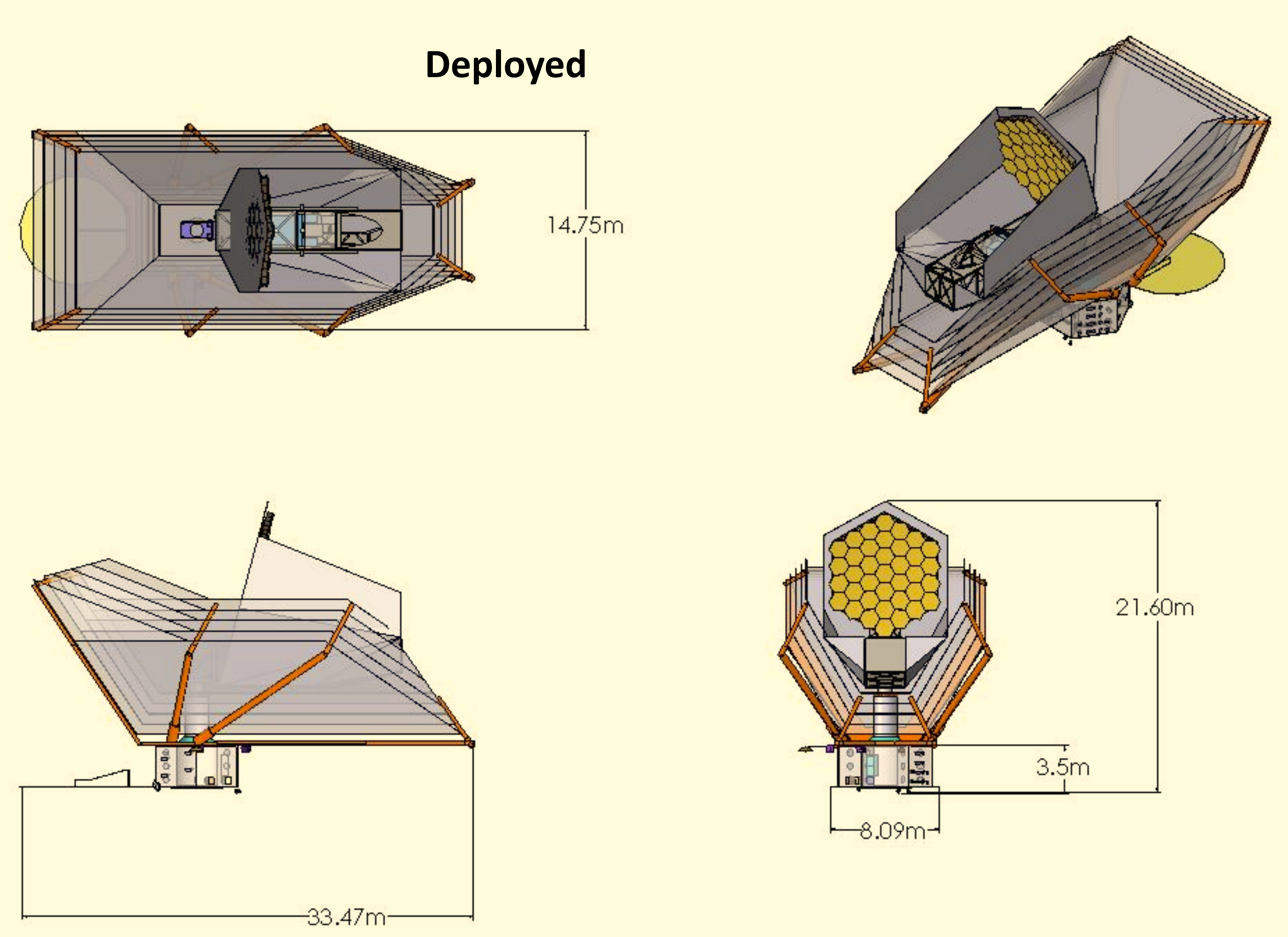
From first stars to life
Concept 1 Highlights

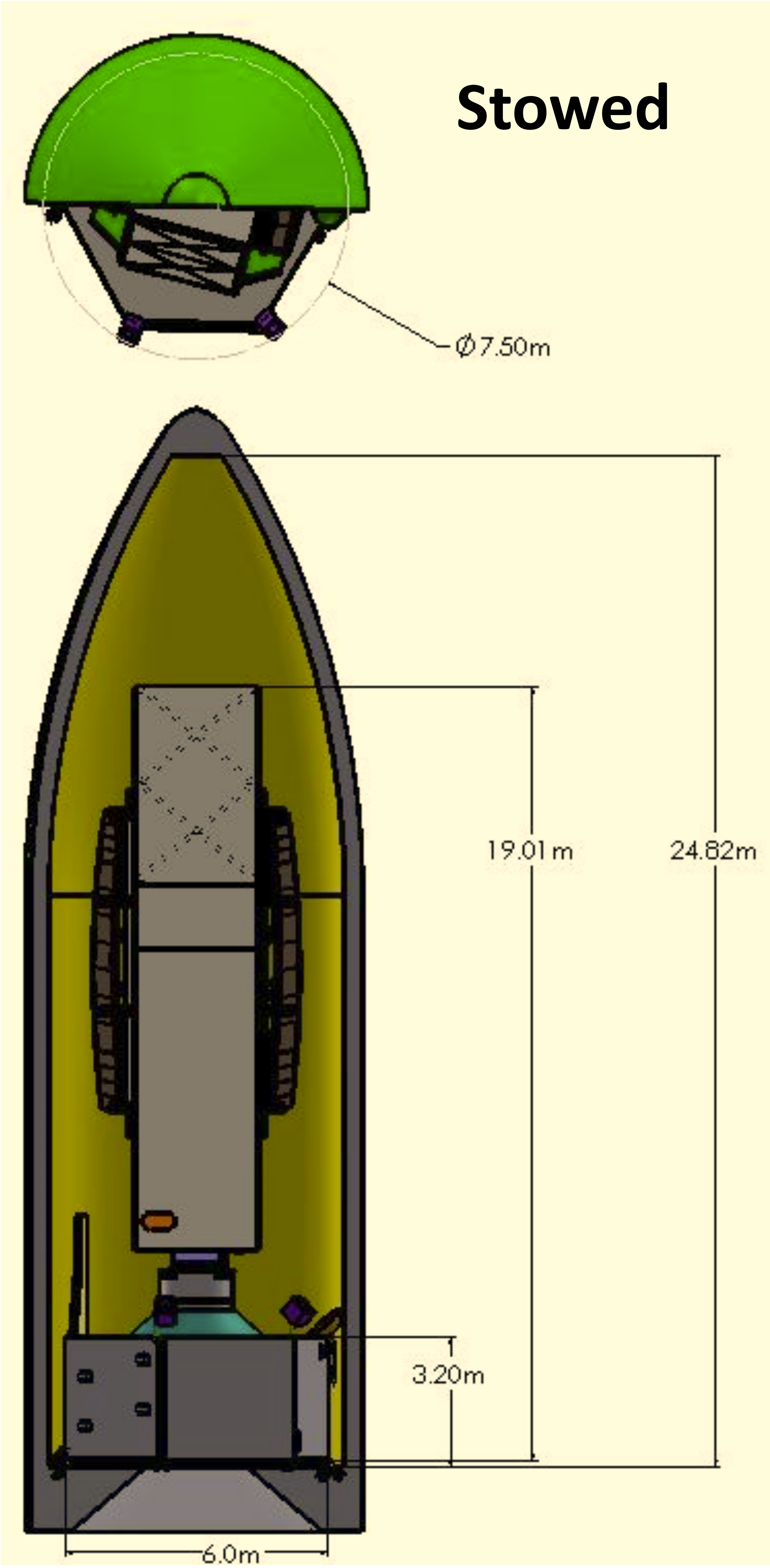
- **Telescope type**: three mirror anastigmat (TMA); unobstructed primary mirror
- **Primary mirror**: 9.1 meters in diameter; 37 hexagonal segments
- **Five instruments housed in an Instrument Accommodation Module (IAM)**
    - Medium Resolution Survey Spectrometer (MRSS) – JPL
    - Hi Res (Far-IR) Spectrometer (HRS) – GSFC
    - Heterodyne Instrument (HERO) – CNES
    - FIR Imager/ Polarimeter (FIP) – GSFC
    - MID-IR Imager Spectrometer/ Coronagraph (MISC) – ARC/JAXA
- **Instrument Wavelength Coverage:** 5 to 600 µm
- **MISC serves as guider for the spacecraft attitude control system**
- **Telescope and instrument operating temperature:** ~4.5 K
- **Cryocoolers used for cooling,** not expendable cryogen
- **Instrument warm electronics housed in the spacecraft bus (270 K)**

ORIGINS Space Telescope

From first stars to life

Concept 1 configuration





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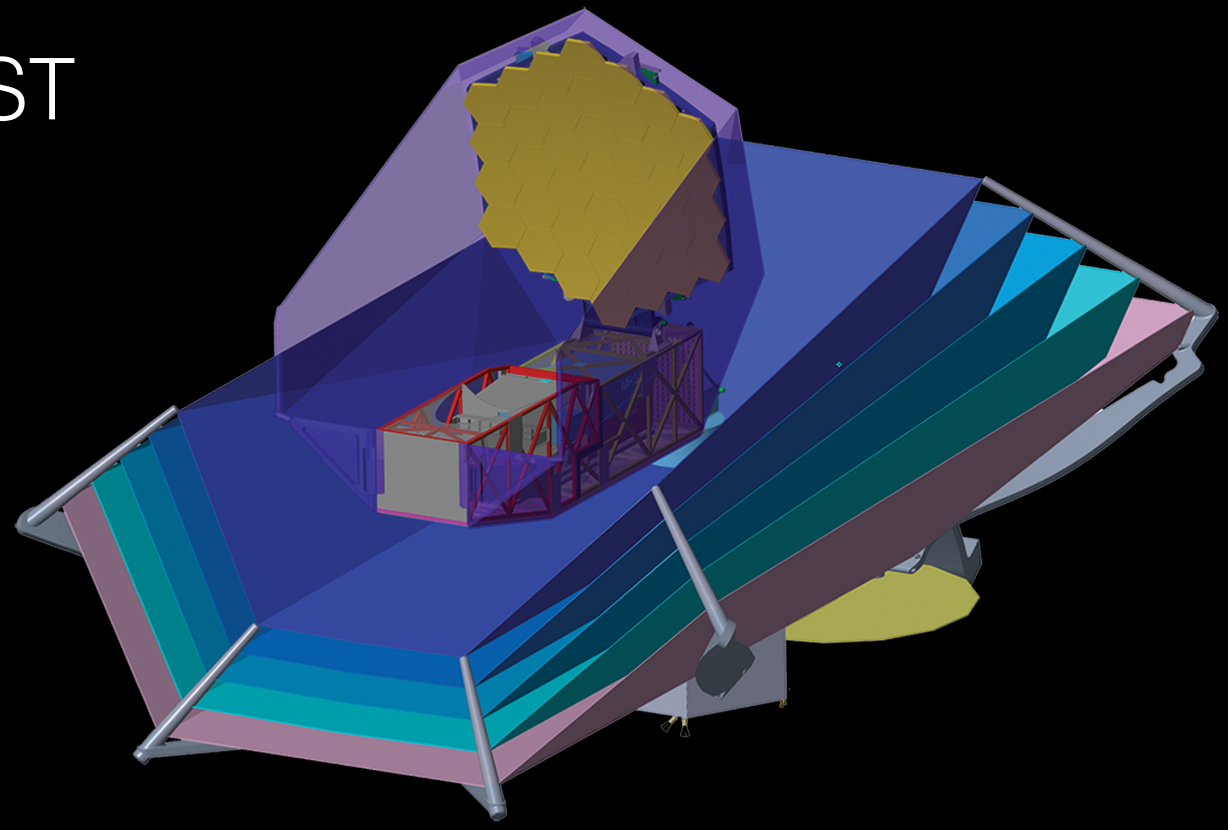
Concept 1 Requirements

- **Mission Life**: 5 Years with 10-year consumables (Once a decade serviceability extends life-time > 30 years).
- **Launch Vehicle**: SLS Block 2, 8.4m x 27.4m fairing
- **LRR**: September 1, 2035
- **OST Observatory Size**:
  - 14.75 x 21.6 x 33.5 m (deployed), 19L x 7.5D m (stowed)
- **Mission Orbit**: Sun-Earth L2 (Sun, Earth, Moon avoidance, No eclipses)
- **Service plan**: Earth-Moon L1, robotic/human
- **Pointing Control** – 44 mas; **Pointing Knowledge** – 30 mas; **Jitter** – 22 mas
- **Folded/scooped sunshade to minimize size** (size fixed for this study)
- **IAM** is to be on-orbit serviceable (underside)
- **Science Observation**: > 70% efficiency
- **Field-of-Regard** (FOR): -5°- +45° Pitch off Sun Line, 360° Yaw about Sun Line, ±5° Roll about Line of Sight (LOS)
- **Communication**: 2 optical terminals, 1 S-band OMNI Pair, 1 S-band HGA
- **Observatory Mass**: ~30000 kg (CBE)
- **Observatory Power**: ~7500 W (CBE)
- **Peak Data Rate**: ~350 Mbit/sec

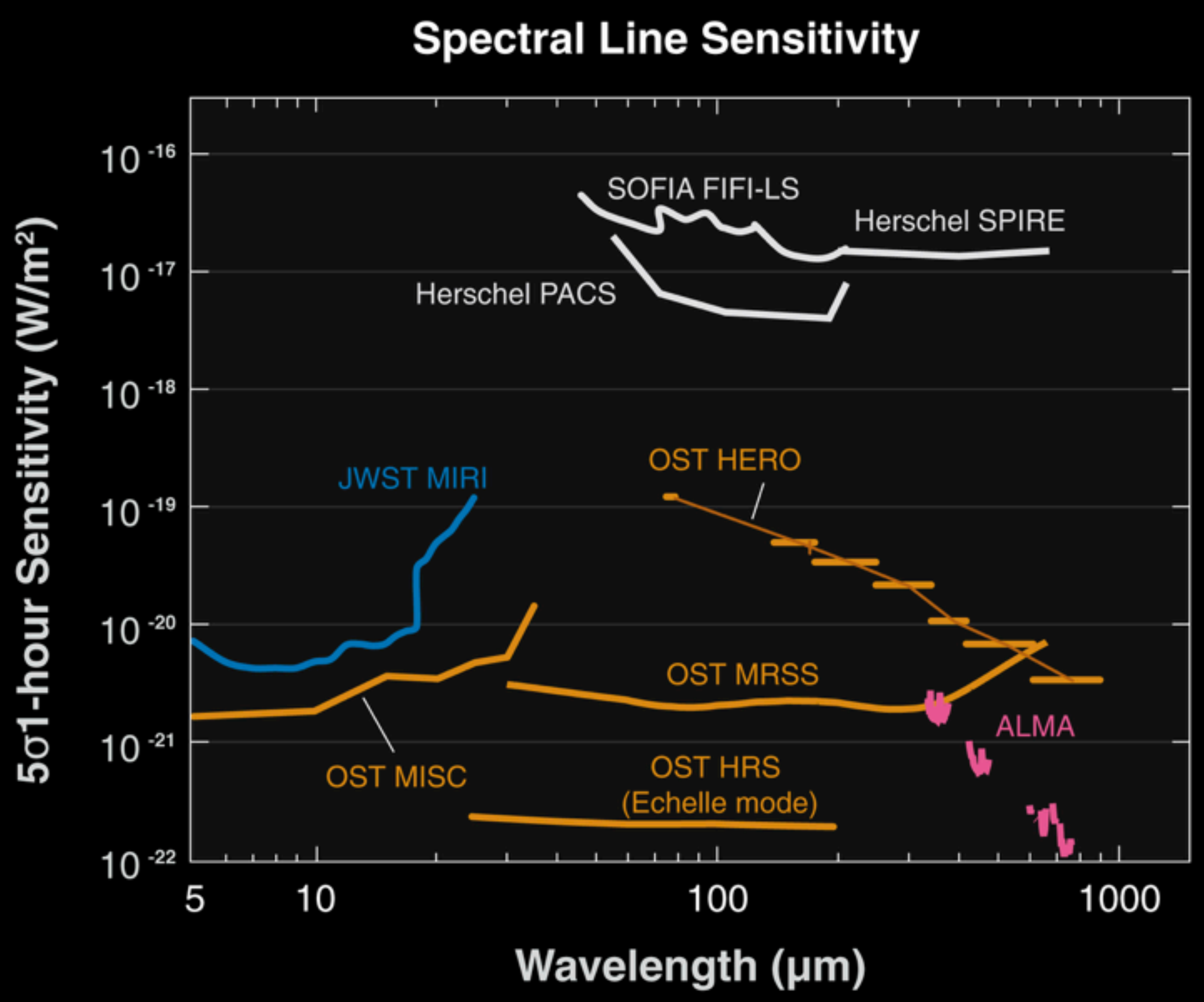


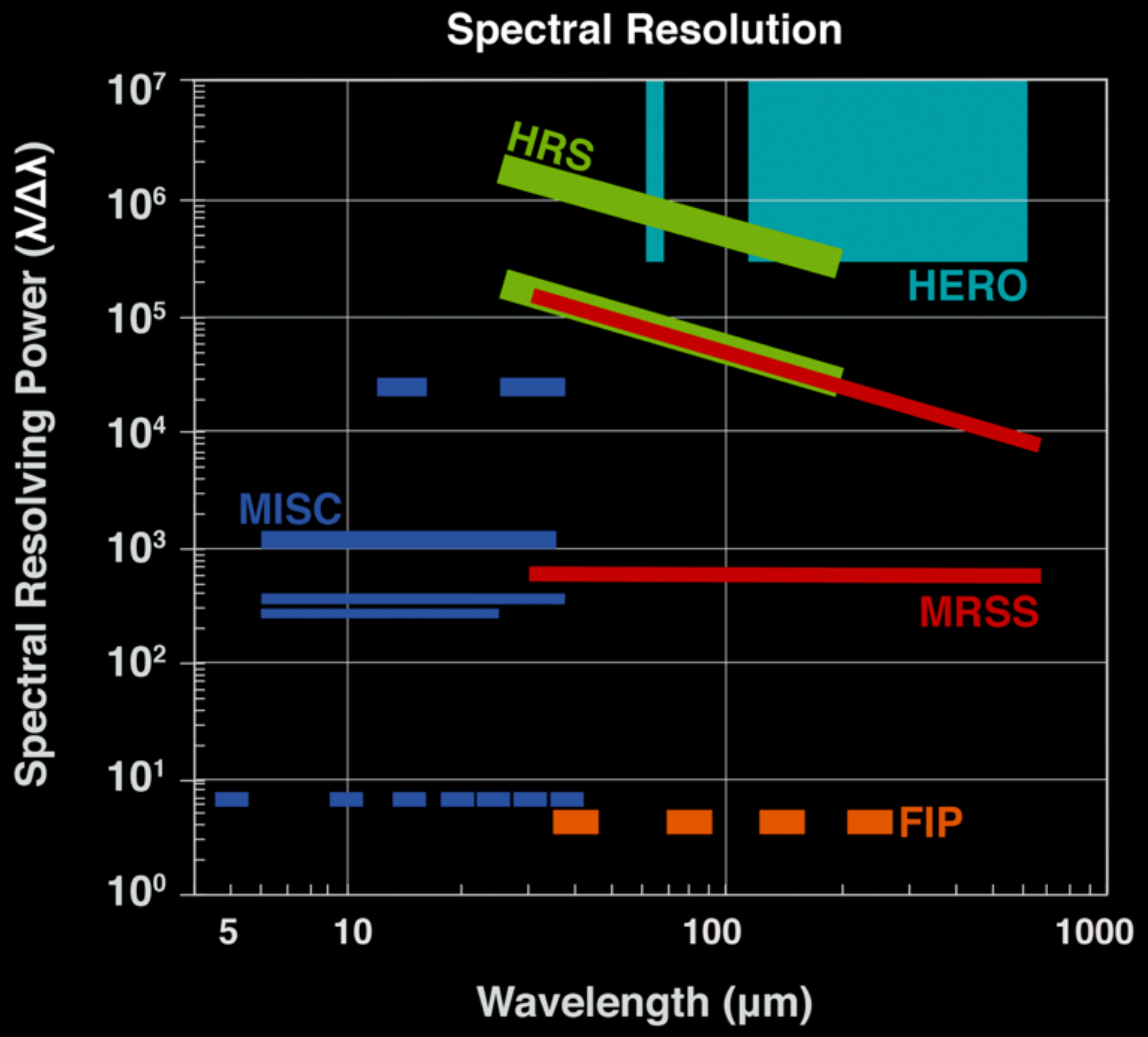
Instrument Specifications

Instrument	Wavelength Coverage	Spectral Resolving Power (λ/Δλ)	Number of spatial pixels or sky beams	Typical Required Sensitivity (1-hr)	Other
Mid-Infrared coronagraph/ imager/IFU	6 to 40 μm	imager: R~10; IFU R>3000	~10^7	photometric: 1 μJy @10 μm	coronagraph 10^{-5}-10^{-6} IWA=2λ/D
Imager + Polarimeter	40, 80, 120, 240 μm	R~3	~100,000	1 μJy - 100 μJy (confusion limit)	polarimetry
Mid-Res Spectrometer	50 to 600 μm	low-res~500 high-res~1x10^5	100 per channel	10^{-21} W/m^2 5σ (any spectral line across full band)	full-band instantaneous with 6 channels
High-Res Spectrometer	35 to 250 μm	low-res~10^4 high-res~few 10^5	10	few 10^{-22} W/m^2 (for a single spectral line)	photon-counting; full band requires scanning
High-Res Heterodyne Spectrometer	63 to 66 μm and 111 to 641 μm	up to ~10^7	10-100	2 mK in 0.2 km/s @ 1 THz	polarization sensitive, near quantum limit

ORIGINS Space Telescope

From first stars to life





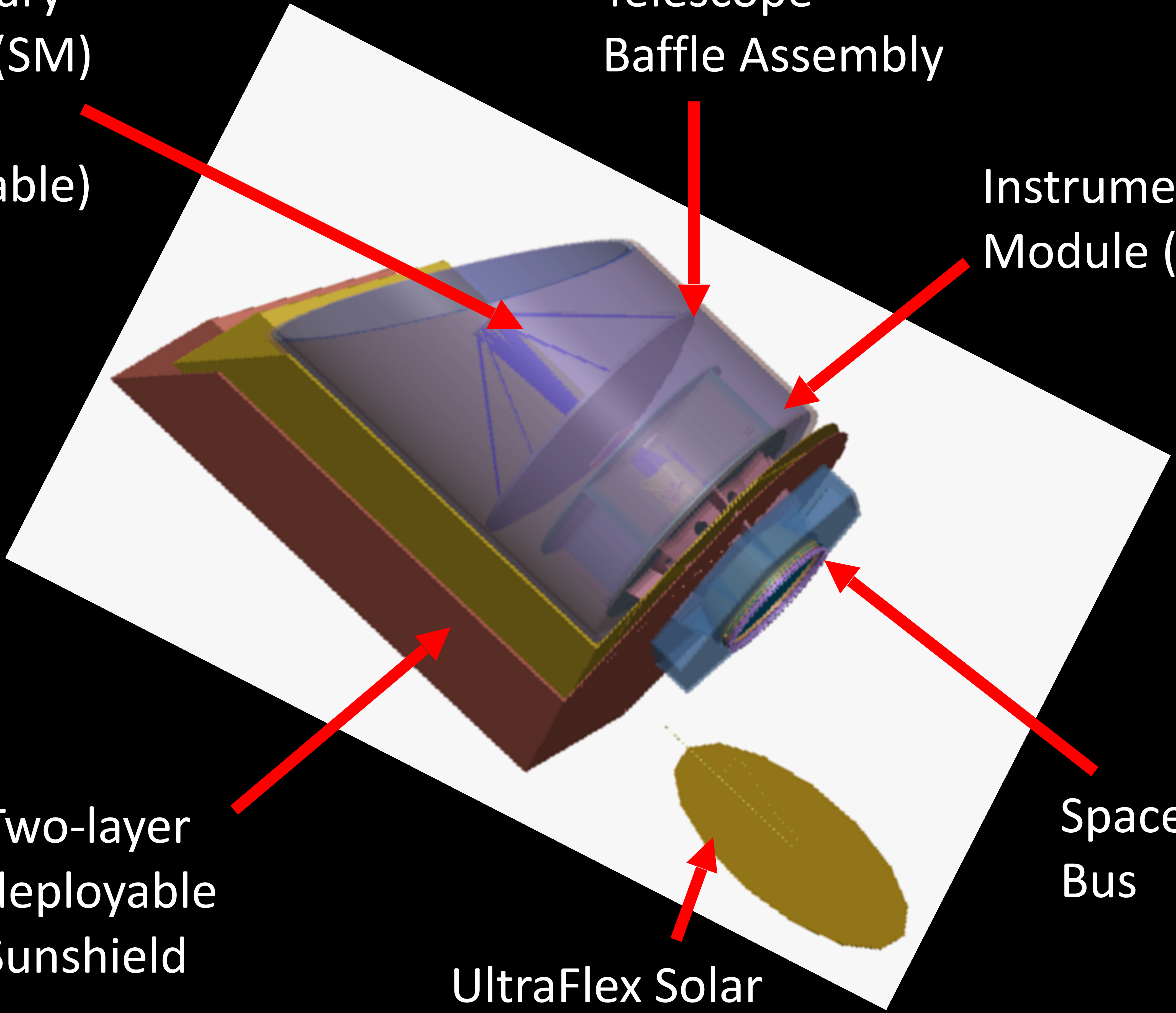
A factor of 10,000 (!) improvement in sensitivity. An immense discovery potential. Origins Space Telescope will not be extending what we know already.

It will be a true revolution in astronomy.

OST Concept 2 Design

  - Spitzer-like configuration
  - No on-orbit deployments, other than sun-shade and solar array.
  - Lower complexity and mass relative to both JWST and Concept 1
  - On-Axis Telescope
  - Telescope and instrument module cooled and maintained at 4-4.5 Kelvin
- Instrument Module accommodates 4 instruments (scaled down from Concept 1)
  - OST Survey Spectrometer (OSS): JPL
  - Far-IR Imaging Polarimeter (FIP): GSFC
  - Mid-IR Imager Spectrometer Coronagraph (MISC): JAXA
  - Heterodyne Receiver (HERO): CNES
- Design to total mass 5,000 kg, including 30% contingency
  - Total flight system mass ~3,850 kg allowed

OST Concept 2 Configuration



Secondary Mirror (SM) (non-deployable)

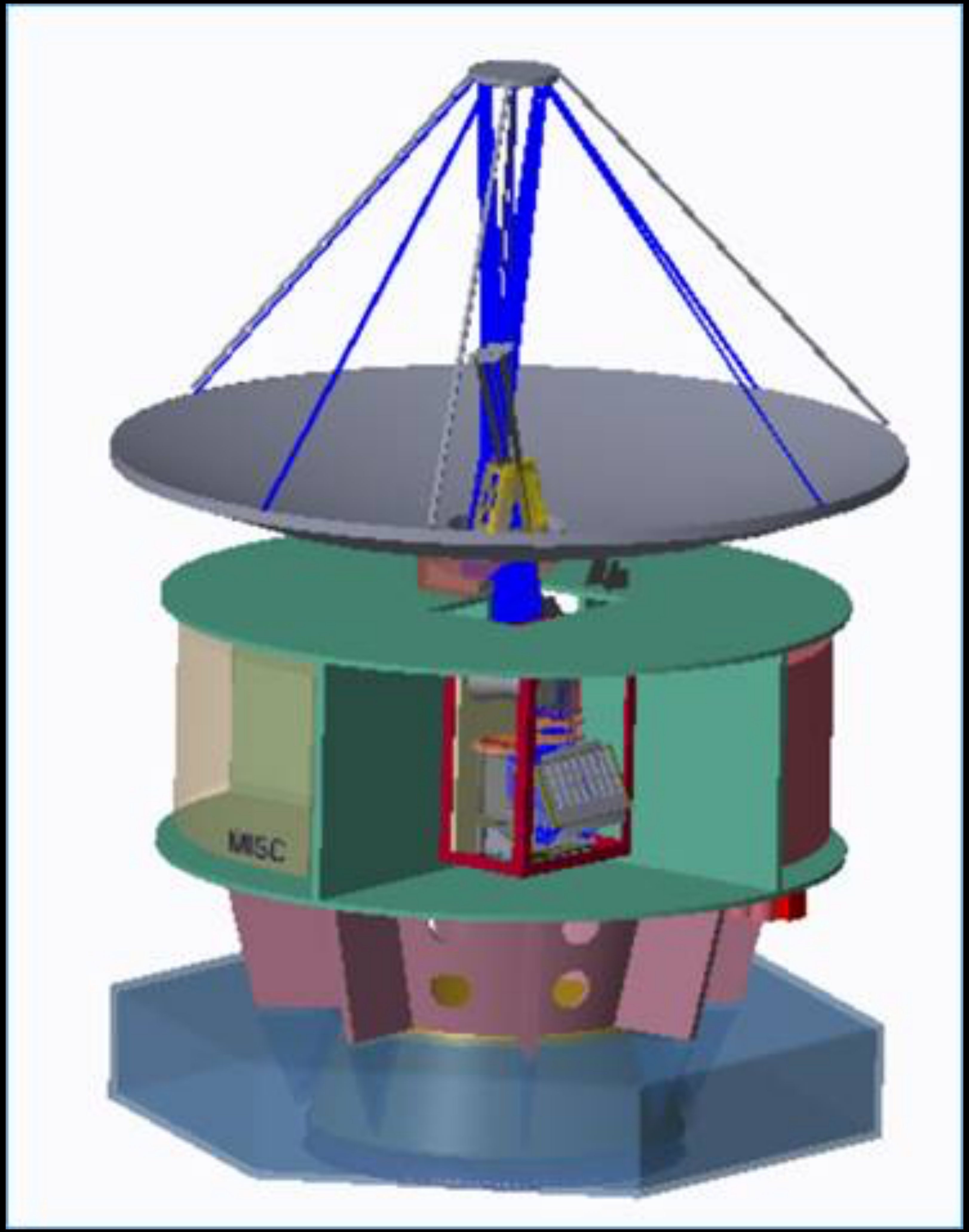
Telescope Baffle Assembly

Instrument Module (IM)

Two-layer deployable Sunshield

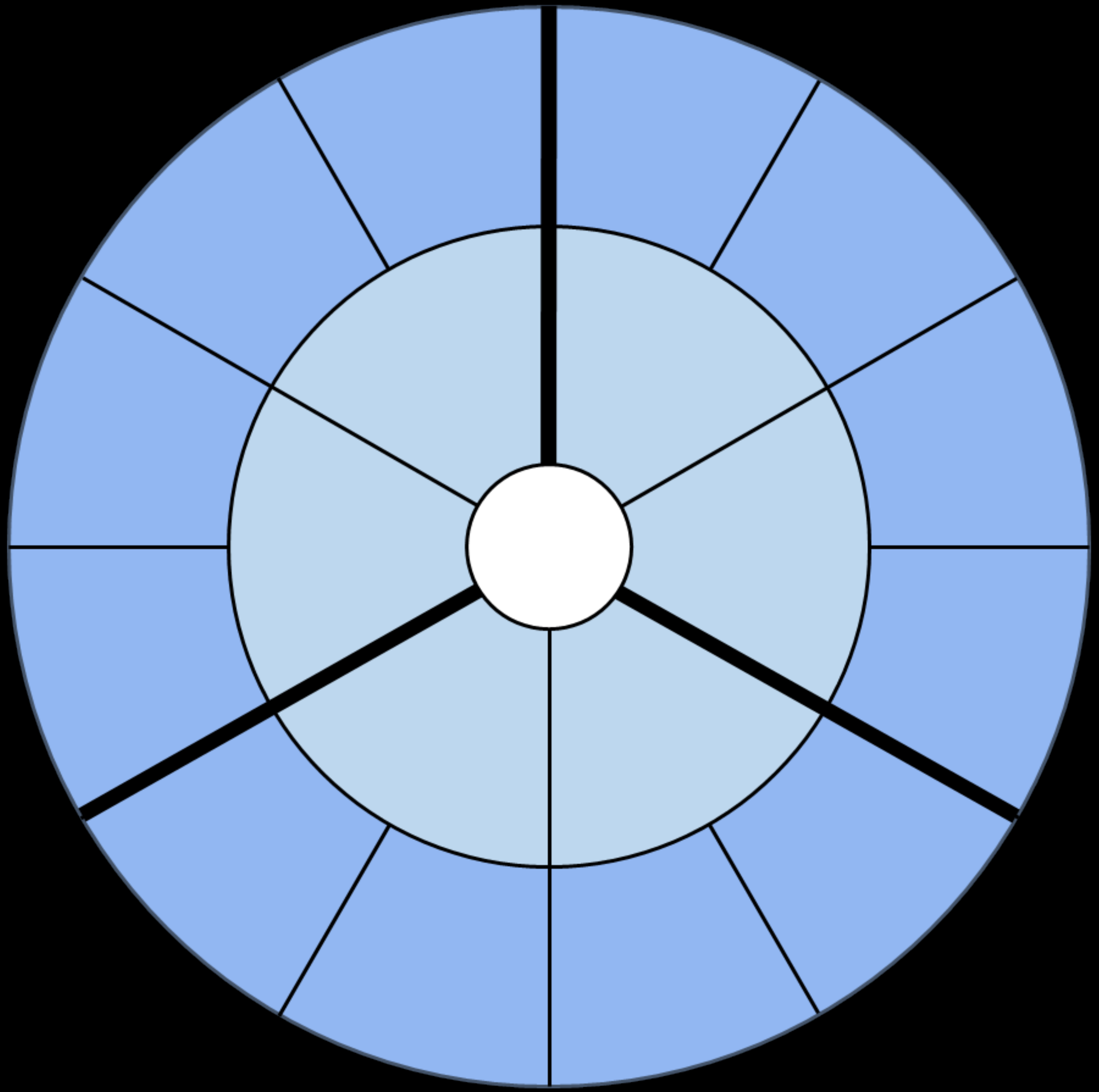
UltraFlex Solar Array

Spacecraft Bus



OST Concept 2 Collecting Area

- Goal: match JWST collecting area
  - ~25m^2
- Current design:
  - On-axis, three-mirror anastigmat (TMA)
  - **5.9m diameter** circle
  - 0.9m diameter hole
  - Assume 5% areal loss due to secondary supports/segment gaps



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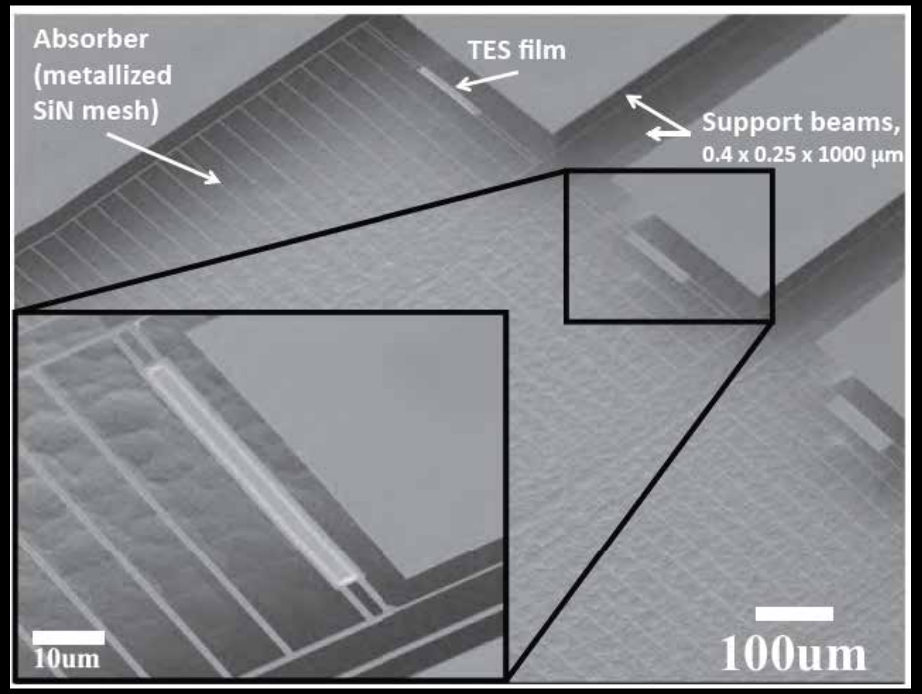
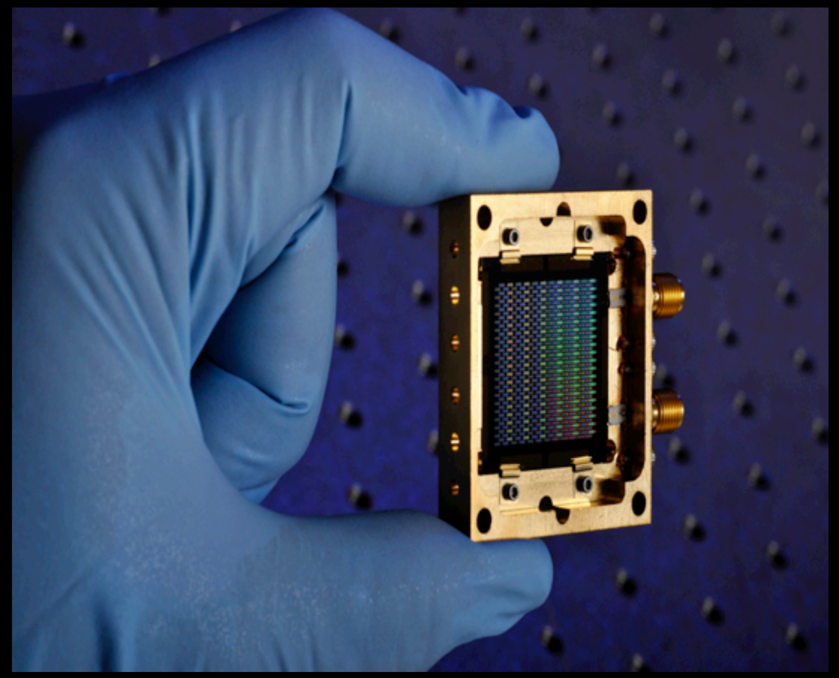
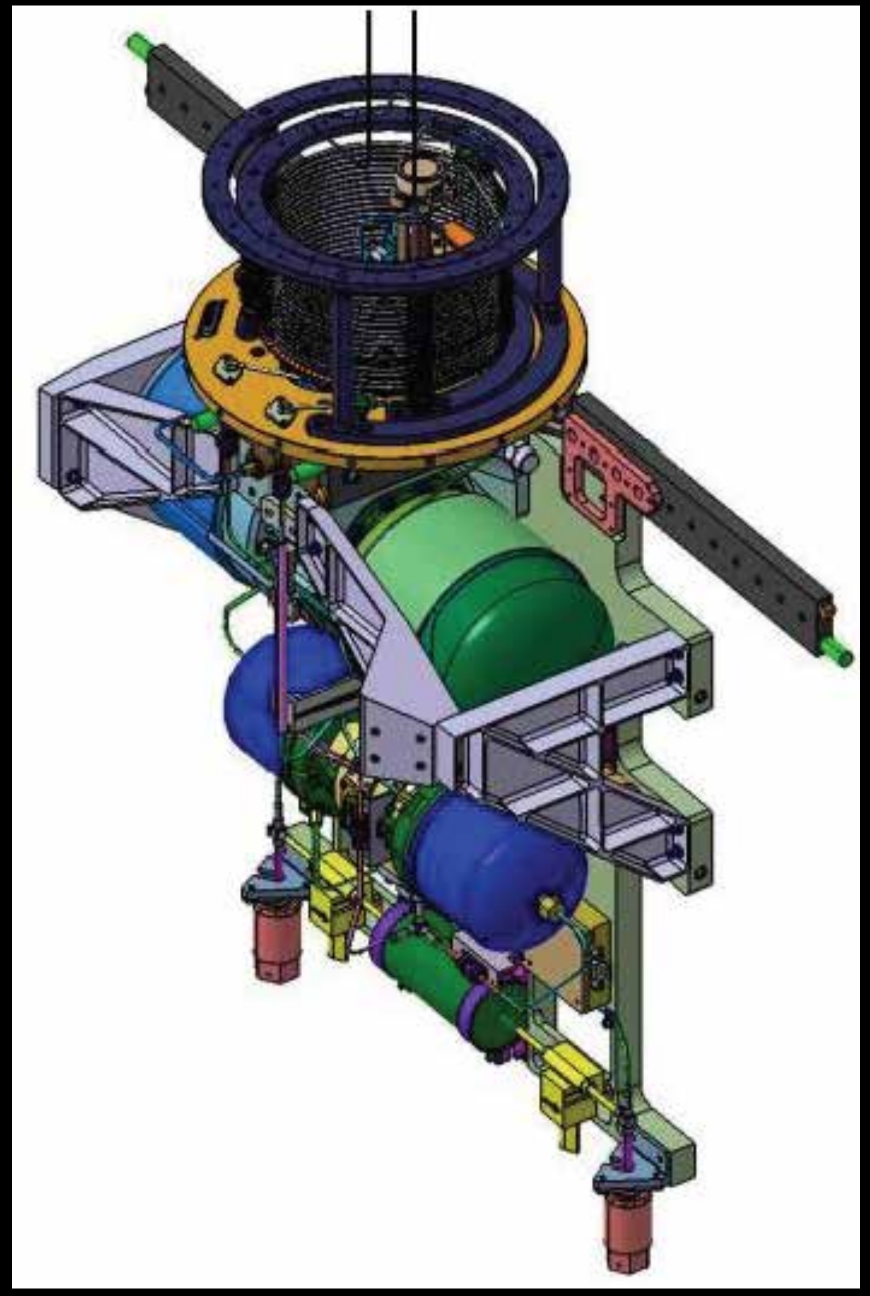
From first stars to life

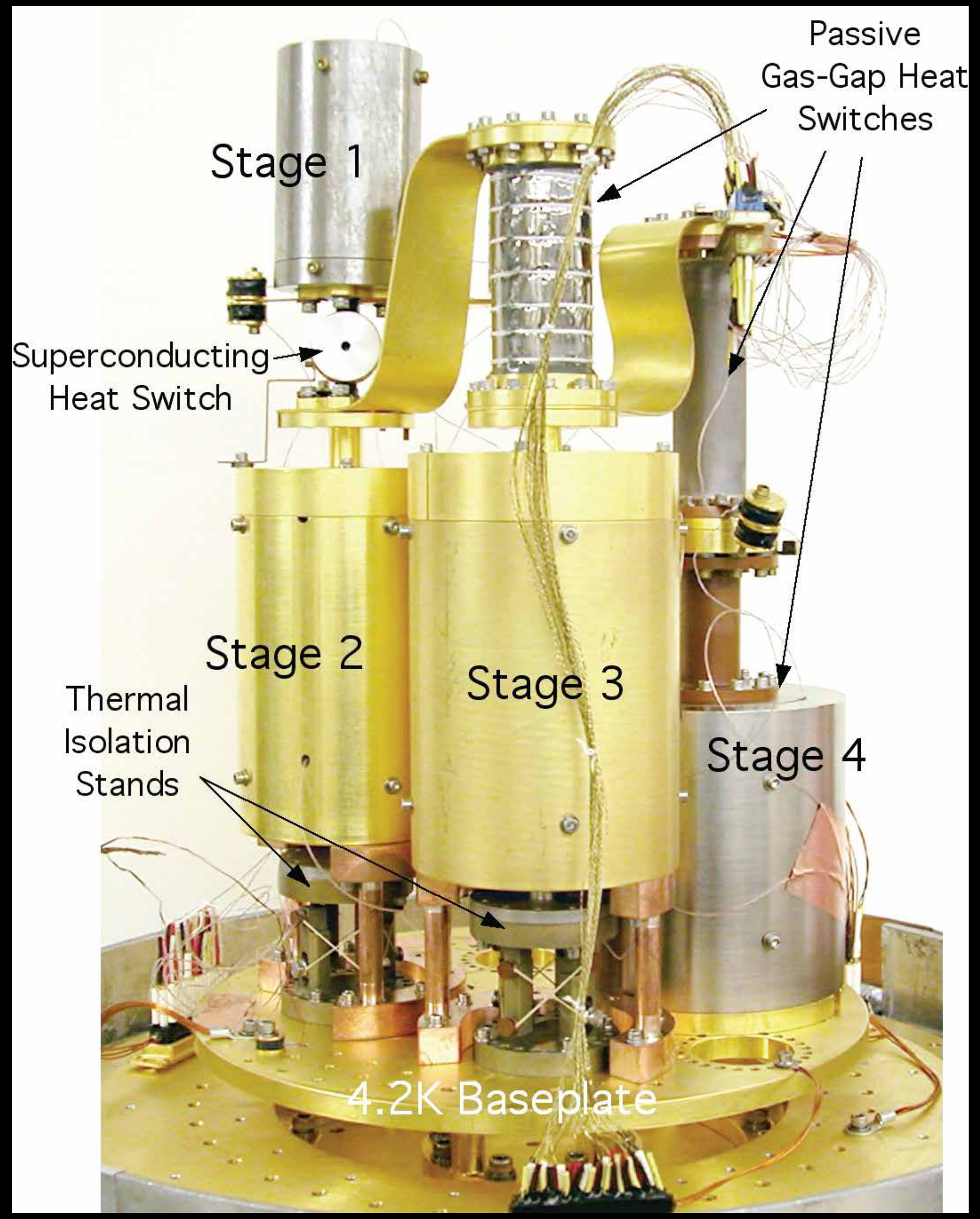
Technology Gaps

- Large-format, high-sensitivity **far-IR direct detectors, multiplexers, and readout electronics**
- Compact Far-IR spectrometers
- Heterodyne focal plane arrays
- Sub-Kelvin cooling
- Large cryogenic optics and actuators
- 4.5 K cryocoolers
- Ultra-stable Mid-IR detectors and coronagraphy









ORIGINS Space Telescope

From first stars to life

Where we are:

- **Concept 1 study complete - STDT delivered interim report to NASA last week**

- **STDT completed Concept 2 definition**
  - Engineering design study has started
    - Spitzer-like configurations under study, 5.9m with a non-deployable mirrors
  - Instrument requirements and performances in iterations with the STDT

- **Concept 2 criteria**: 5000 kg weight limit (with 30% mass contingency) and fit into a 7m-diameter fairing for the launch vehicle.

Concept 2 will be "simpler" than Concept 1, while still being efficient, capable, less complex and preserving the immense gain in sensitivity and greatly expanding discovery space.