ORIGINS Space Telescope

Origins Space Telescope and the Search for Life

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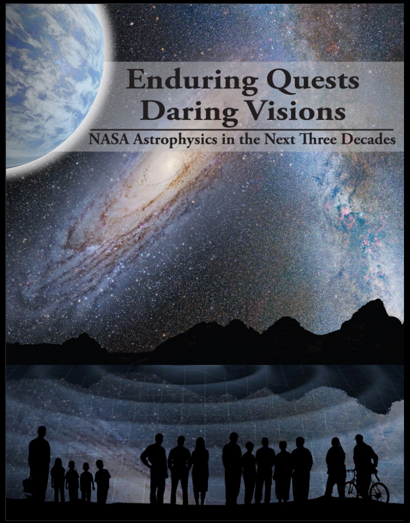
on behalf of the

Origins STDT members, Solar System SWG, and Exoplanets SWG

Giant Planet Systems Panel – April 16, 2021

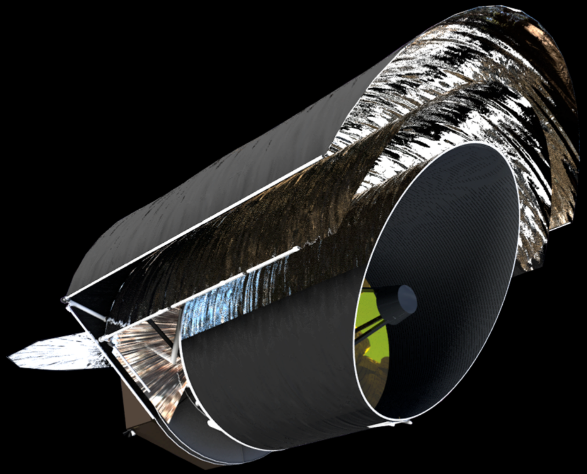
origins.ipac.caltech.edu

From the community, by the community, for the community.



Through the Astrophysics Roadmap, the community expressed interest in a "Far-IR Surveyor" mission.

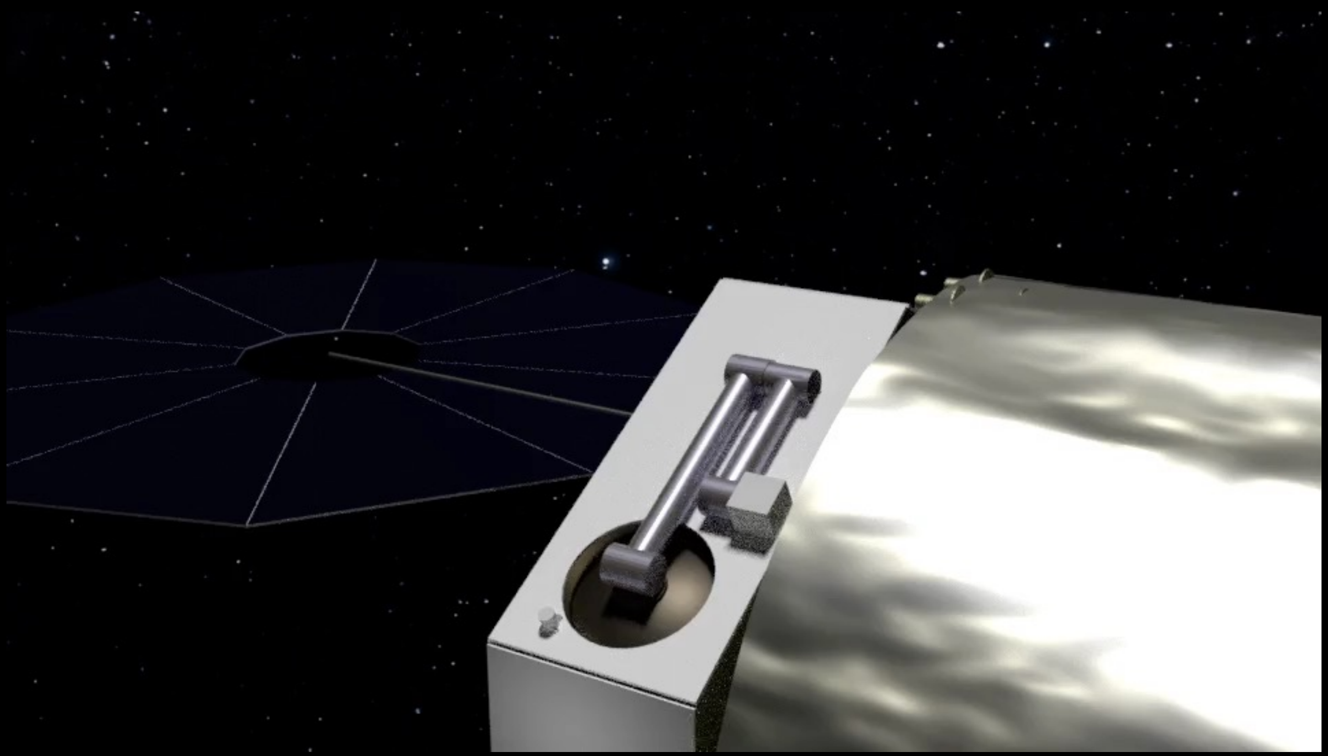
The OST Science and Technology Definition Team has worked with >100 scientists and engineers around the world to design the mission that people want.



Guest Observers will use OST to answer mission-driving science questions and make unexpected, transformative discoveries.

Introduction to *Origins Space Telescope*

- 5.9m non-deployed aperture
  - Same collecting area as *JWST*
- Cooled to 4.5 K
- 1000x more sensitive than *Herschel*
- Wavelength range: 2.8 – 588 μm
  - >2 orders of magnitude
- Scan speed: <60”/sec
- Launch Year: 2035
- Launch Vehicle: SLS or Space-X BFR
- Orbits: Sun-Earth L2
- 5-year primary mission
  - 10 year propellant lifetime
  - Serviceable



SCIENCE DRIVERS FOR MISSION DESIGN

HOW DOES THE UNIVERSE WORK?

How do galaxies form stars, make metals, and grow their central supermassive black holes from reionization to today?

Using sensitive spectroscopic capabilities of a cold telescope in the infrared, Origins will measure properties of star-formation and growing black holes in galaxies across all epochs in the Universe.

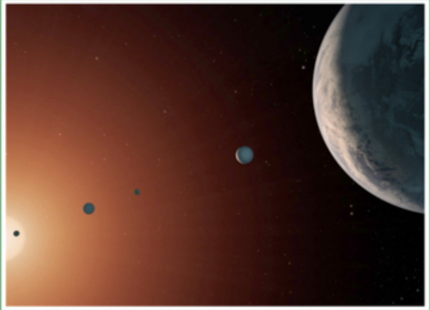
HOW DID WE GET HERE?

How do the conditions for habitability develop during the process of planet formation?

With sensitive and high-resolution far-IR spectroscopy Origins will illuminate the path of water and its abundance to determine the availability of water for habitable planets.

ARE WE ALONE?

Do planets orbiting M-dwarf stars support life?



By obtaining precise mid-infrared transmission and emission spectra, Origins will assess the habitability of nearby exoplanets and search for signs of life.

Origins Guest Observer Program

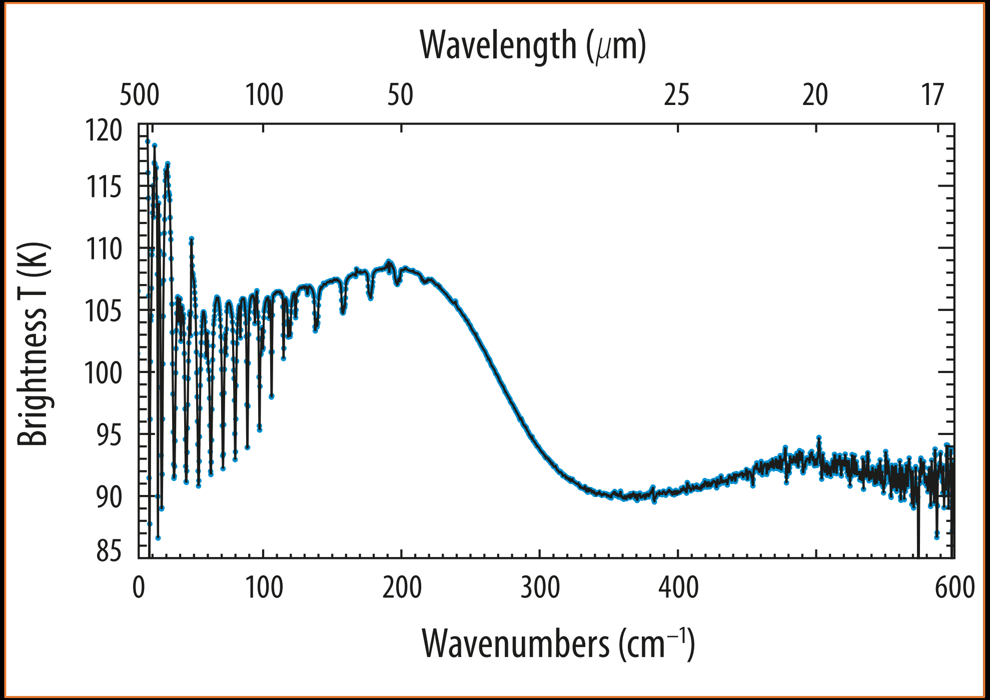
- *Origins* is a general purpose observatory
- Primary mission (5 years)
  - 40% of time for mission-design science objectives
  - 60% of time for General Observer (GO) programs
- Extended mission (5+ years)
  - 100% of time for GO programs

Origins Meets Many Solar System Science Needs

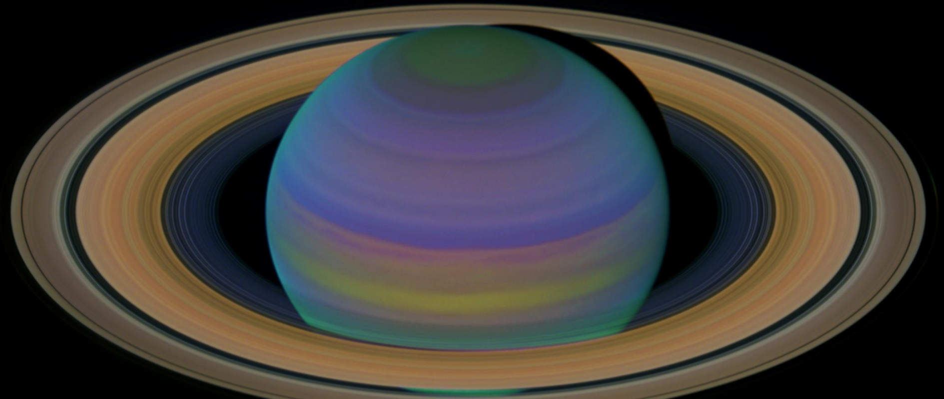
Solar System Science Needs	Origins Performance
Temporal Coverage: Regular, repetitive observations rather than snapshots	Time-series observations (2.8 – 20 μm); Can routinely observe targets every 6 months over duration of the mission
Tracking: Observations of moving targets	Max scan rate = 60”/s, sufficient to track giant planets, comets, and other small bodies
Spatial Resolution: Combine global context with close-in studies; some Solar System objects are extended (Jupiter is 45” diameter)	Large FOVs • 2.7’ x 1.4” to 14’ x 20” (R~300, 25-588 μm) • 3.6’ x 2.5’ (Imaging, 50 μm, 2”/pix) • 13.5’ x 9’ (Imaging, 250 μm, 2”/pix) Mosaicing built into observing strategy
Sensitivity: Improved SNR enables detections of fainter emissions, minor species, isotopologues, etc.	Over 3 orders of magnitude more sensitive than previous far-infrared space observatories
Dynamic Range: Solar system objects range from bright (Jupiter ~1000 Jy, Uranus ~300 Jy at 100 μm) to faint (TNOs)	Instrument modes can utilize neutral density filters, alternative readout schemes
Permit comparative studies: Ability to apply same observing techniques to multiple targets	Field of Regard >40% of sky at any time; 4π steradian over lifetime of mission; 25% larger than JWST

Giant Planet Comparative Planetology

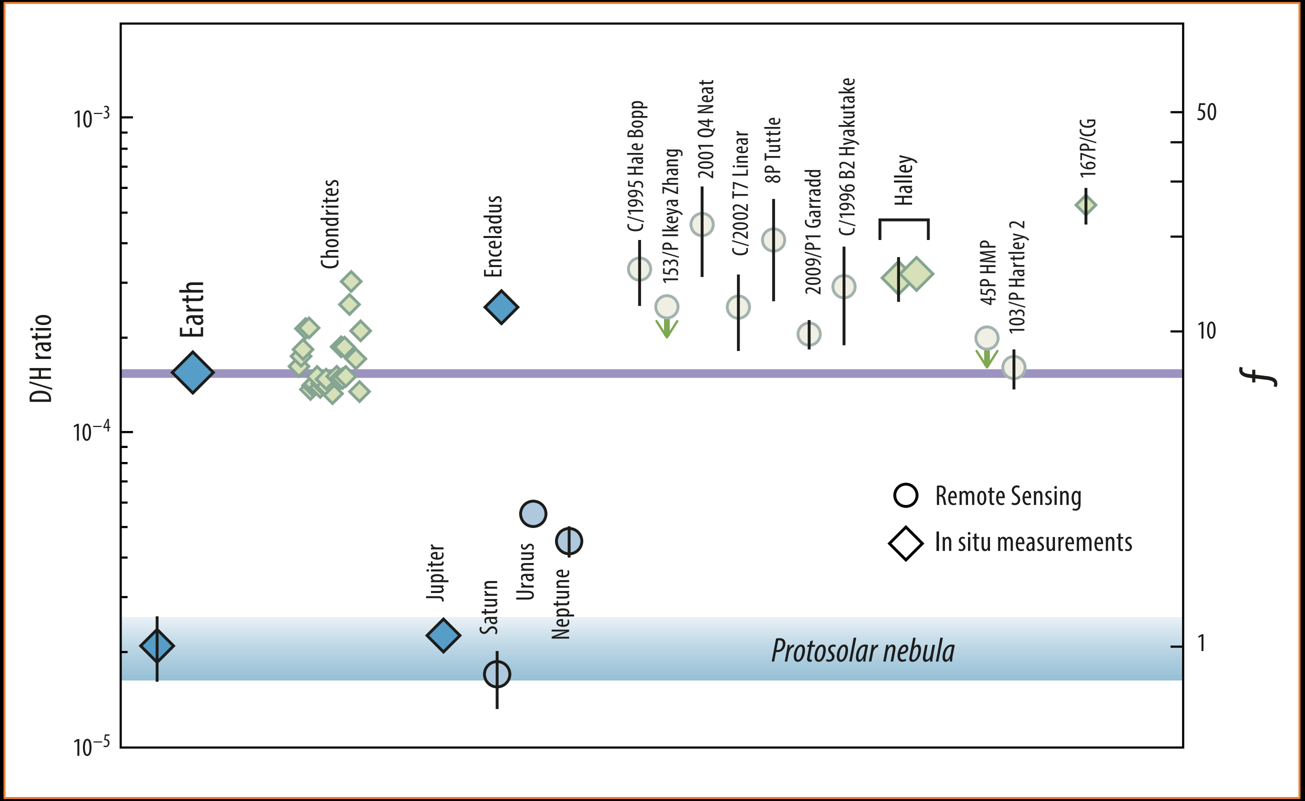
- Temporal and spatial mapping of 4 giant planets
- Goal: Enhance knowledge of thermal history, cloud formation, circulation, variability
  - Direct application to exoplanet studies
- Low-Res: 25 – 588 µm simultaneous @ R~300
- High-Res: 25 – 588 µm @ R~43,000
- UH-Res: 100 – 200 µm @ R~325,000
- *Origins* probes bulk of radiated internal energy



Infrared Cassini spectra of Saturn showing rotational lines and smooth collision-induced continuum that allows temperature (from collision-induced H_2-He opacity), windshear, and aerosol structure determination (Fletcher et al., 2015).



Comet Survey Probing Origins of Earth's Ocean

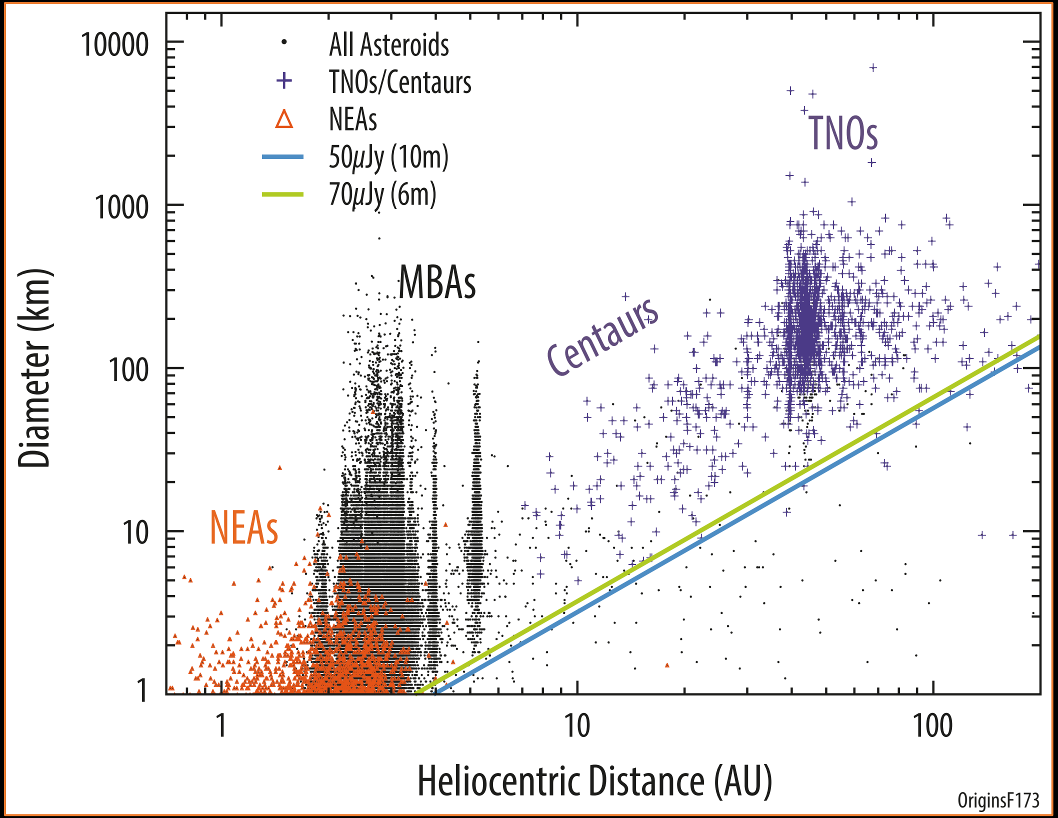


Current D/H measurements in water and H_2 in the Solar System (Altwegg et al., 2015). D/H ratios are shown on left. Enrichment factor, shown on right, $f = [D/H]_{object}/[D/H]_{PSN}$ normalizes the D/H ratio to its protosolar nebula value in H_2.

- Can we determine the origin of water (Earth's Oceans) from isotopic evidence in small bodies?
- Measure HDO in 100s of comets to form an unbiased survey
  - Oort Cloud & Jupiter family
- *Origins* will study comets with production rates 100x less than that measured by *Herschel*
- Measure accurate C, H, O, N isotopic ratios and abundances of trace gases
- Constrain models and inform origin and evolution of solar system

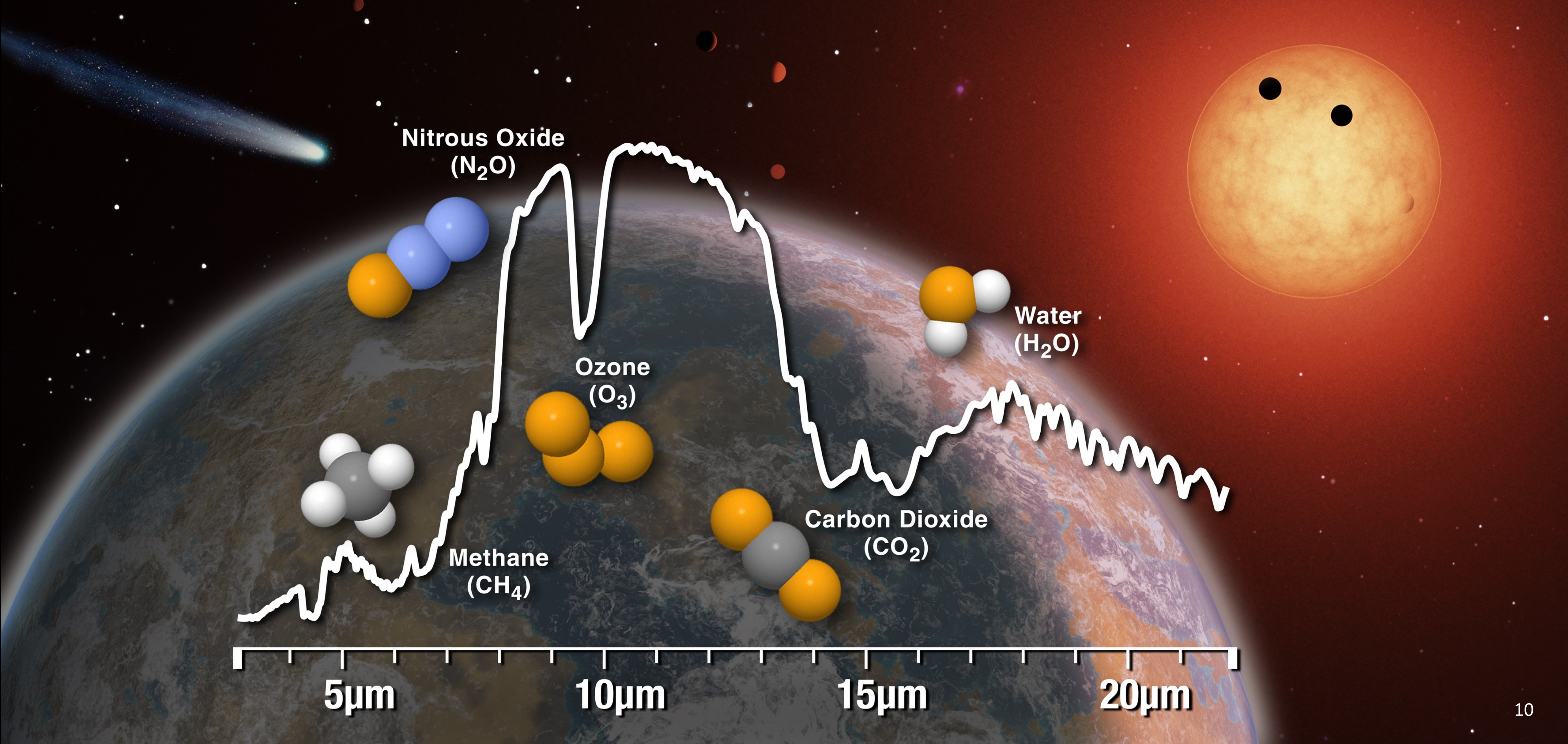
Survey of Small Bodies in Outer Solar System

- Goal: Constrain fundamental models of Solar System formation and evolution
- Measure sizes and constrain thermal properties of distant small bodies
    - Detect 1000s of new objects
    - Few 10s of km in diameter
    - Search for Planet IX
- FIP pointed imaging mode
    - 50 µm (3.6’ x 2.5’ FoV)
    - 250 µm (13.5’ x 9’ FoV)
- Repeated every 6 months
- No survey of this scale has been done before



Diameter vs. heliocentric distance of known small bodies in the Solar System. The lines show the diameters corresponding to continuum flux limits needed to measure these bodies at 100 µm for a 6m (cyan line) and 10m (green line) telescope. Origins enables detection of a size range for such small bodies below that capable by the next generation of ground-based surveys.

Do planets orbiting M dwarf stars support life?



M Dwarfs are Compelling Planet-Hosting Stars

M dwarfs are common

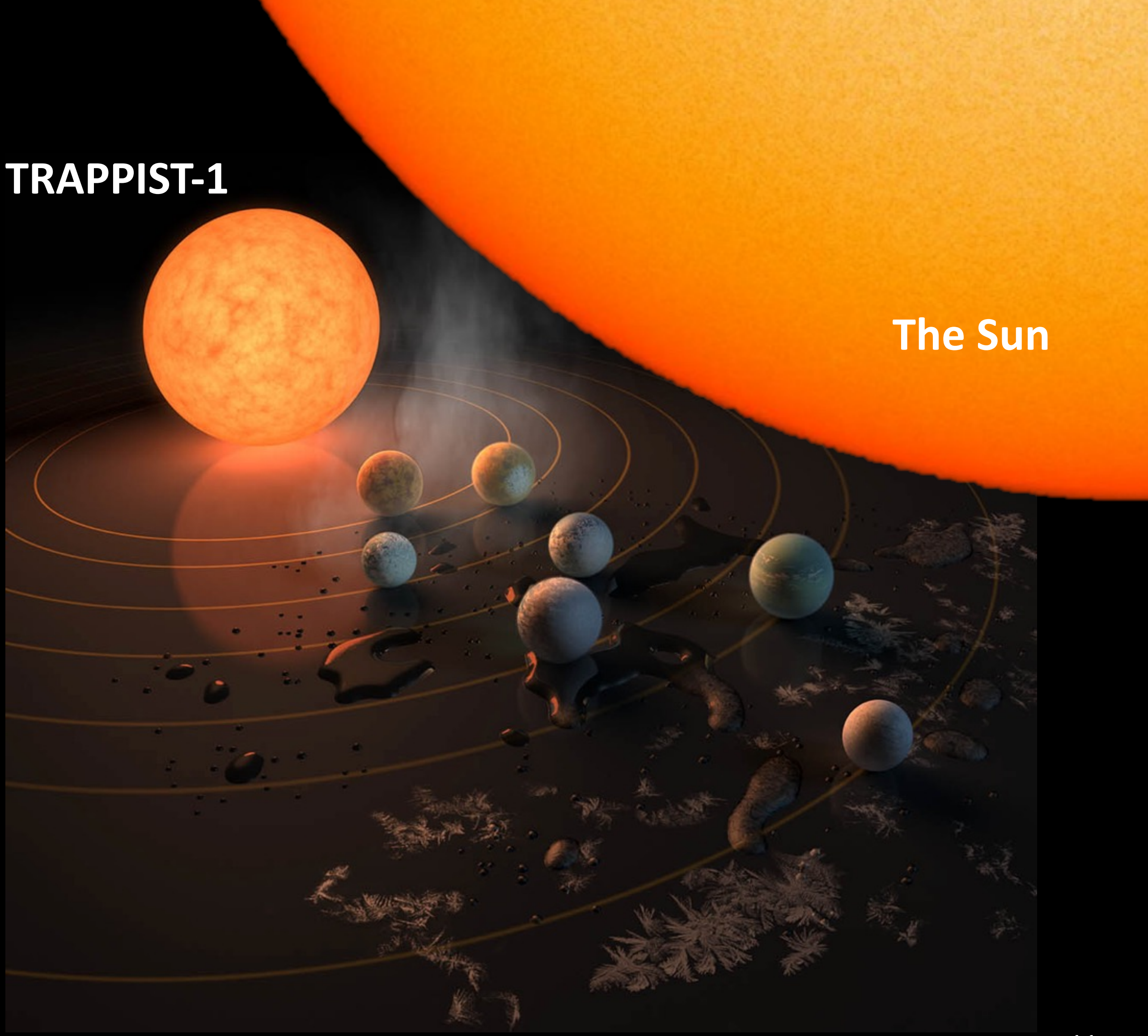
- 75% of stars within 15 pc are M dwarfs

Rocky planets are common around M dwarfs

- 100s known terrestrial planets
- Four HZ planets are already known (TRAPPIST-1d,e,f and LHS-1140b)

Advantages of small (rocky) planets transiting M-dwarf stars

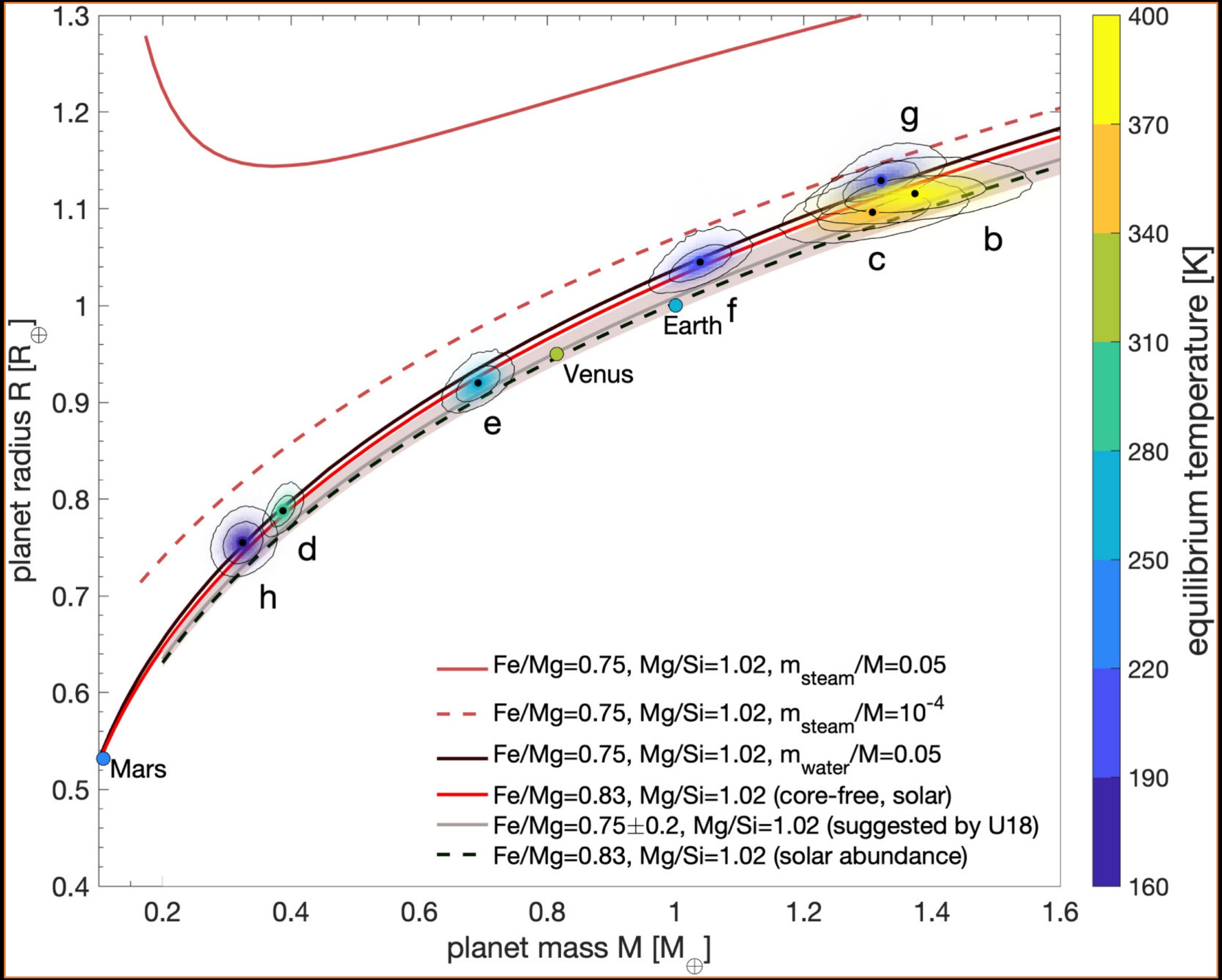
- Larger transit depths
- Closer habitable zones (5 – 100 days)
- Increased transit probability in HZ



Credit: NASA/JPL-Caltech

Advantages of the Transit Technique

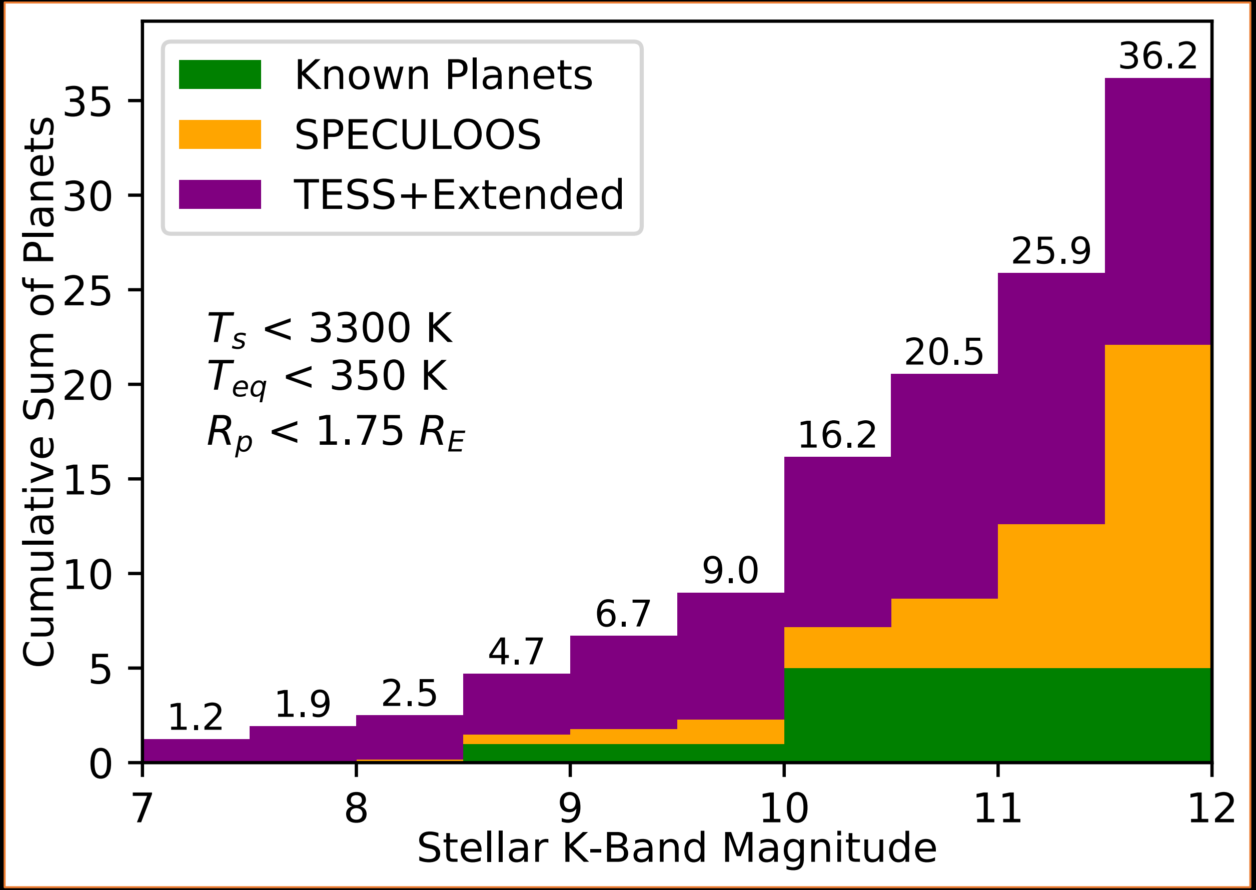
- Precisely determined masses and radii
- Known bulk densities for before atmospheric characterization
- Target planets known to be predominantly rocky



Agol et al. (2020)

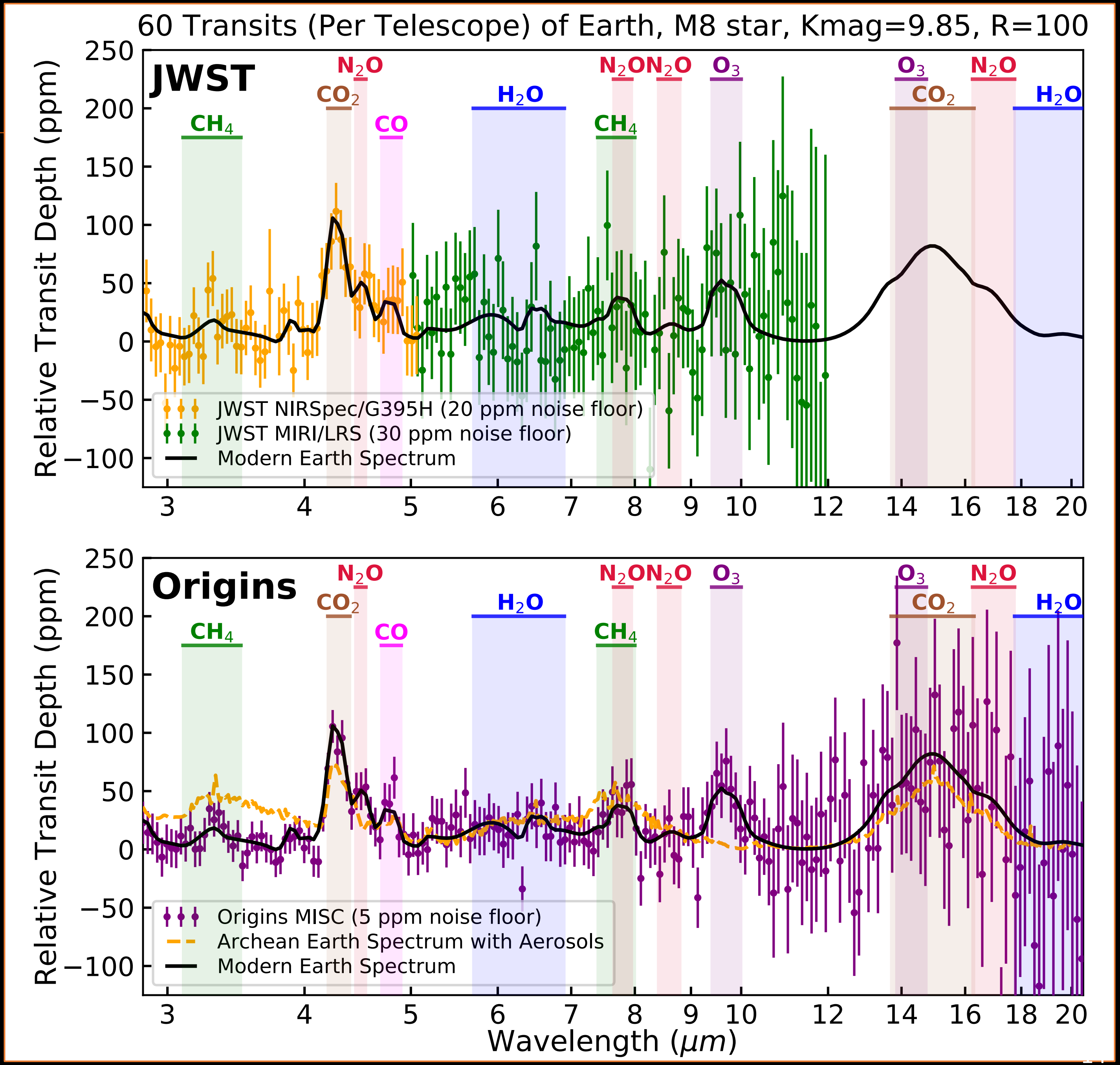
Expected Yields of Transiting Temperate M-Dwarf Planets

- TESS is expected to discover **43±7** temperate, terrestrial exoplanets (Barclay et al. 2018)
- SPECULOOS is expected to identify **14±5** temperate, terrestrial planets orbiting late M to early L dwarfs (Delrez et al., 2018)
- Target stars as faint as K=11.5



Comparison Between *Origins* and *JWST*

- Larger field of regard
  - More transits per year
- Simultaneous, broad wavelength coverage
  - 3 – 20 μm
  - Key spectral signatures
  - H_2O, CO_2, O_3, CH_4, N_2O, etc.
- Instrument designed specifically for high-precision time-series observations
  - Higher throughput
  - Lower noise floor



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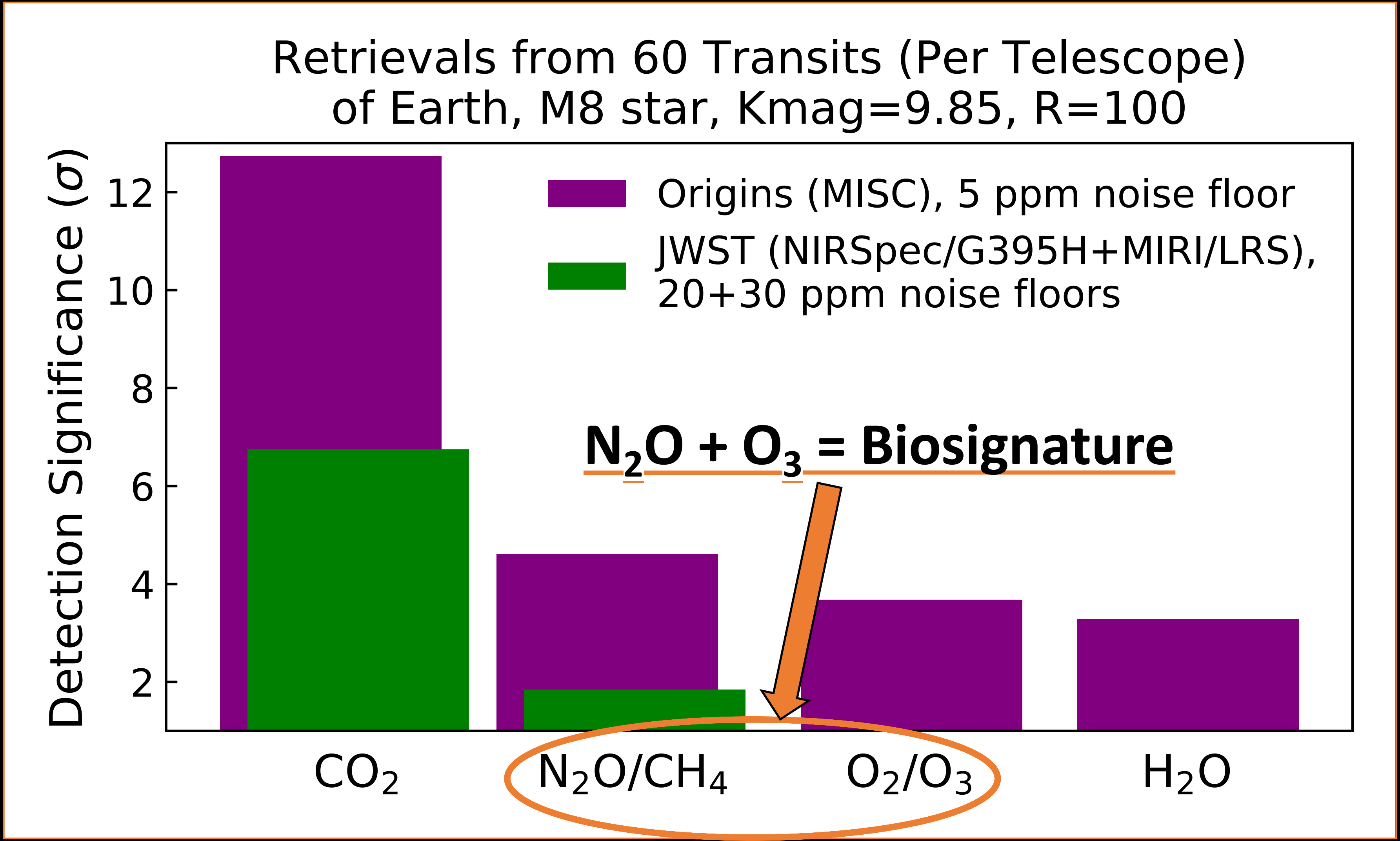

ORIGINS
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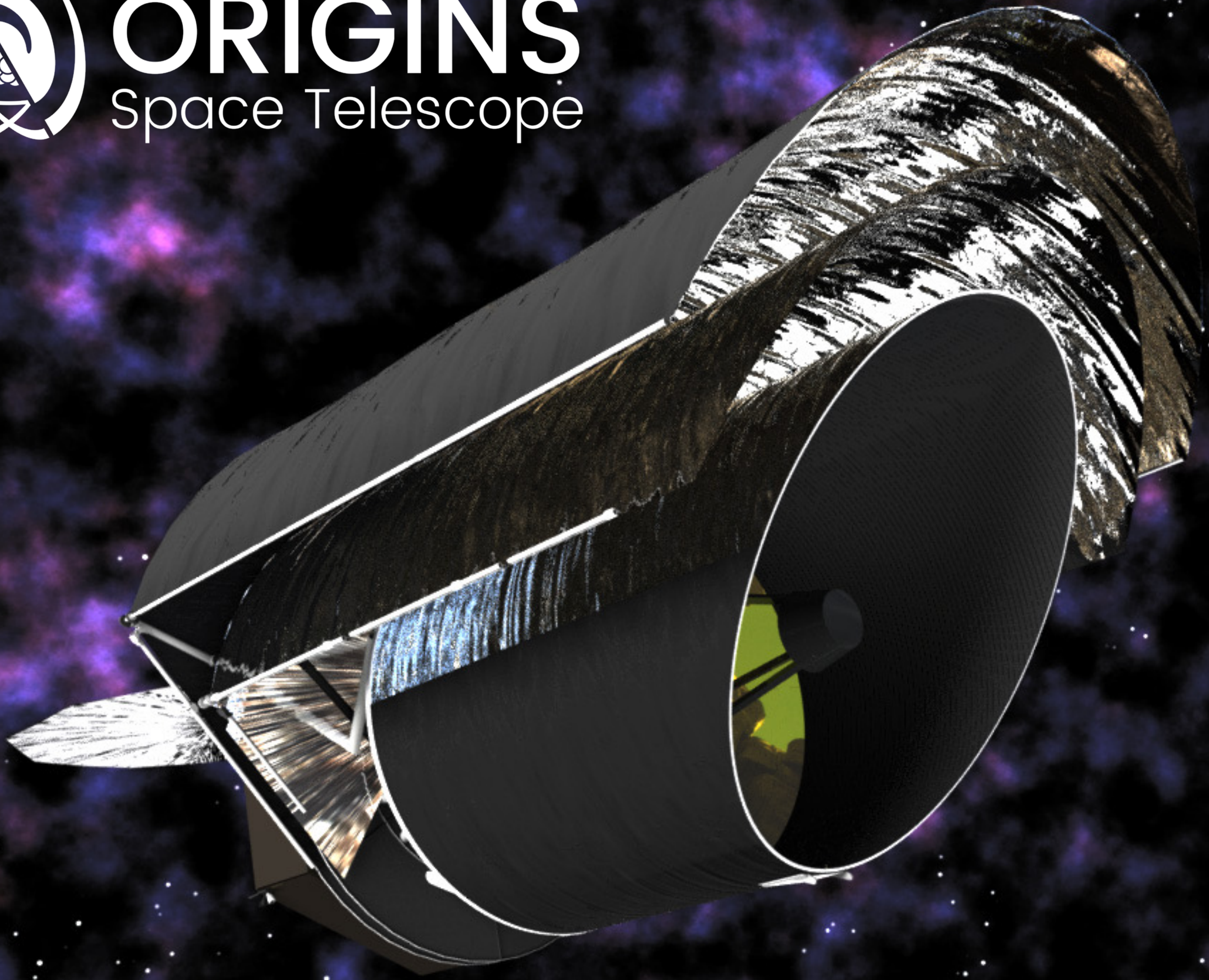

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Conclusions

- *Origins* is a general purpose observatory with a strong GO program (60%)
- Several compelling Solar System science cases
    - Comparative planetology
    - Comet survey, Earth's ocean
    - Small bodies survey
- *Origins* will assess the habitability of nearby M-dwarf planets and search for signs of life