ORIGINS Space Telescope

From the first stars to life

National Aeronautics and Space Administration

Origins Space Telescope: Tracing the Signatures of Life and the ingredients for habitable Worlds

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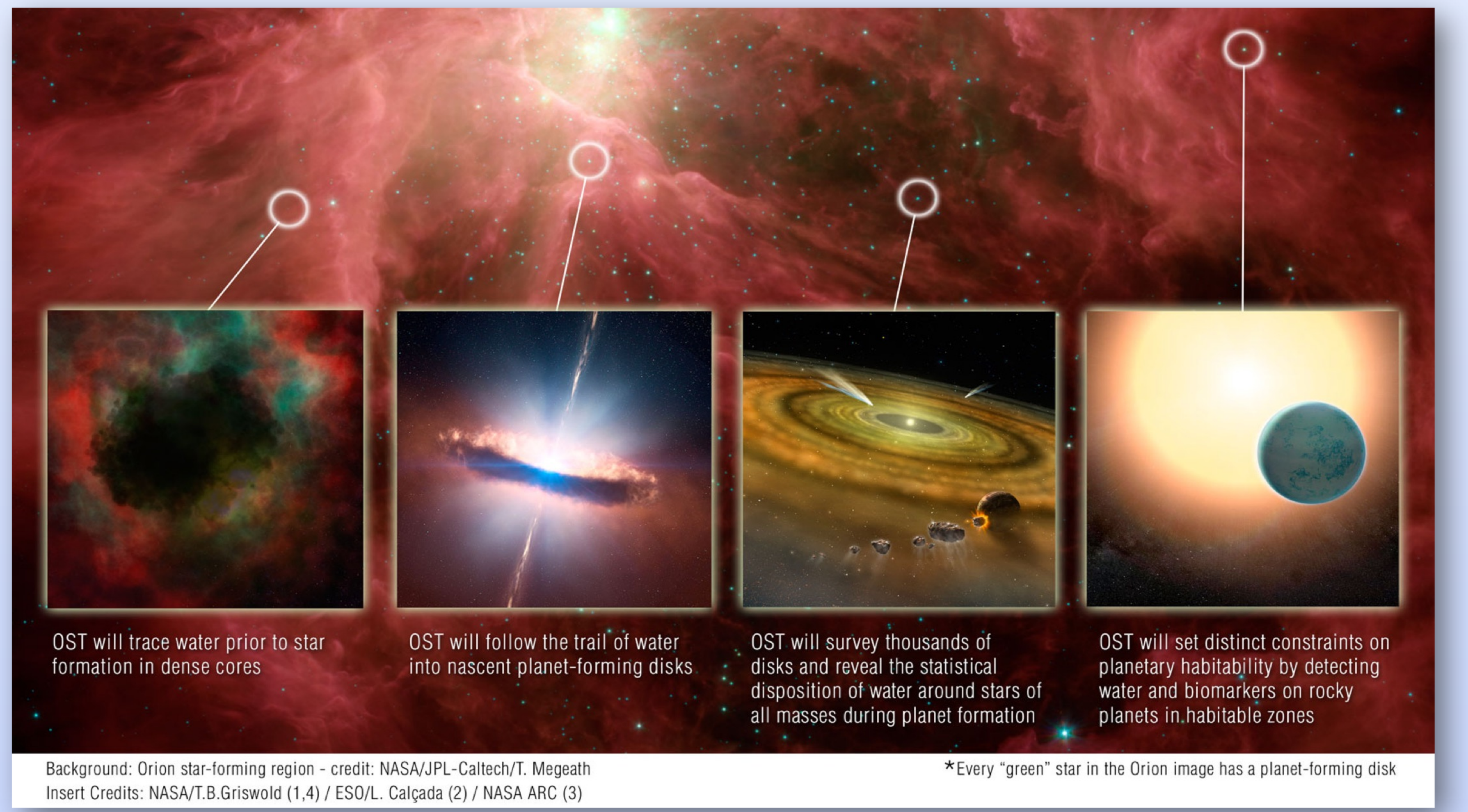
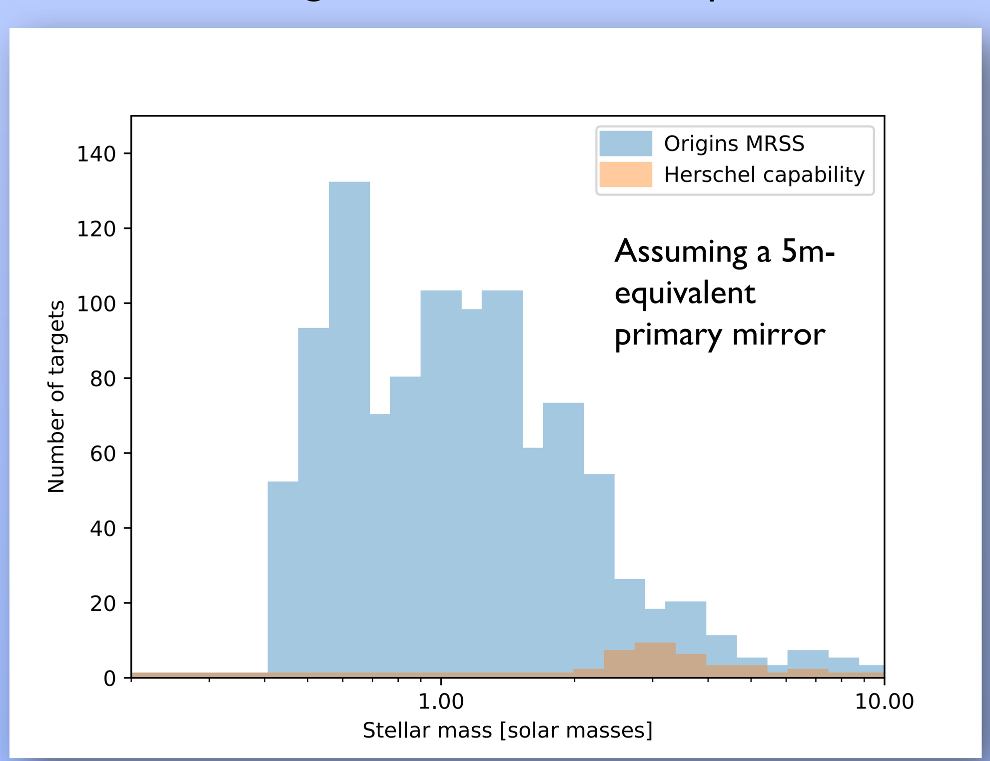


A census of water vapor in planet-forming disks

Are planet-forming disks universally able to seed their planets with water and other volatile species? While we know that many disks have abundant water, a full census will place the Solar Nebula into a broad Galactic context.

Using sensitive, high-resolution, far-infrared spectroscopy, the Origins Space Telescope (OST) will create a comprehensive Galactic census of the water content in up to 1000 planet-forming disks around young stars of all masses, and at disk radii of 1-100 AU. This will reveal whether water is universally abundant and available as an ingredient for habitable planets.

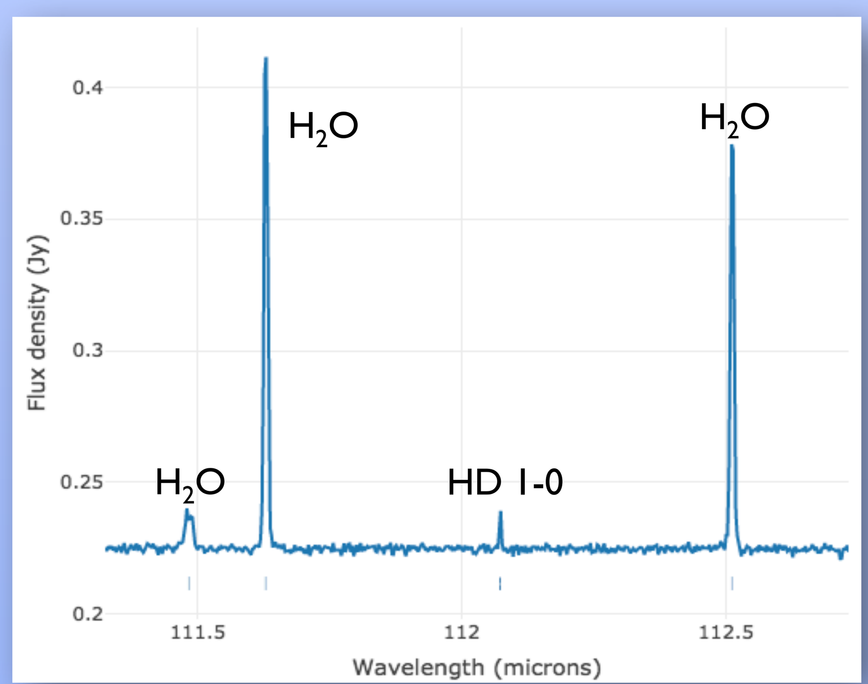


Distribution of pre-main sequence stellar masses in Orion for which OST can measure HD disk masses. The distribution is compared to what Herschel would have been able to do in the same time (1000 hours). The line fluxes are based on models and Herschel detections, but scaled by luminosity and distance to match observed infrared photometry (Megeath et al. 2012). Line sensitivities in the range 10^{-20}-10^{-21} W/m^2 will allow for complete water inventories of disks out to 500 pc.

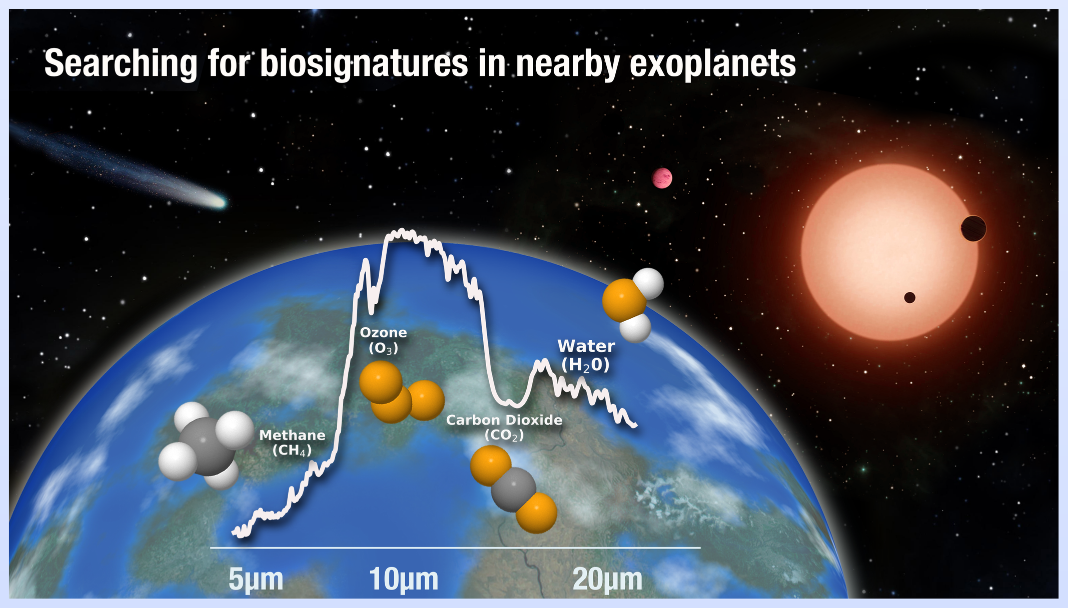
Measuring disk gas masses

What is the planet-forming disk gas mass? Previous estimates of disk masses use the thermal continuum emission of the dust grains or rotational lines of CO as indirect, and highly uncertain, tracers. The Herschel Space Observatory demonstrated that the fundamental rotation transition of HD at 112 μm can be used as a direct tracer of disk mass, but only had the sensitivity to do so for 3 massive disks.

A survey of HD emission with the Origins Space Telescope can expand measurements of accurate disk masses many-fold, up to 1000 disks across their evolutionary tracks around stars of all masses. This will determine the disk gas lifetimes as well as the efficiency with which disks convert their masses into planetary systems.



Simulated OST-MRSS (Medium-Resolution Survey Spectrometer) spectrum of a typical protoplanetary disk in a spectral region around the HD 1-0 line. MRSS will obtain a high resolution spectrum of the full 30-650 micron range in only 2 settings. The high resolving power (R=25,000-10^6) of OST instruments will resolve the velocity structure of all molecular lines, which is critical for measuring their spatial distribution in disks.



Relative intensity of emission as a function of mid-infrared wavelength for an Earth-like planet.

Measuring global thermal structure of rocky planets

Potentially habitable planets have blackbodies that peak in the mid-IR - the wavelengths over which OST can probe. Due to the low estimated noise-floor of OST-MISC (<5 ppm), observations will be sensitive enough to measure phase-resolved thermal emission of rocky planets. Because these measurements are conducted spectroscopically, rocky planet atmospheres can be constrained in both longitude and altitude, providing a heretofore unseen look at the global thermal structure of potentially habitable planets. Measuring the temperatures of rocky planets will allow for a direct determination of habitability. Temperatures are also a critical input to atmospheric models, allowing for higher precision in retrieved abundance profiles.

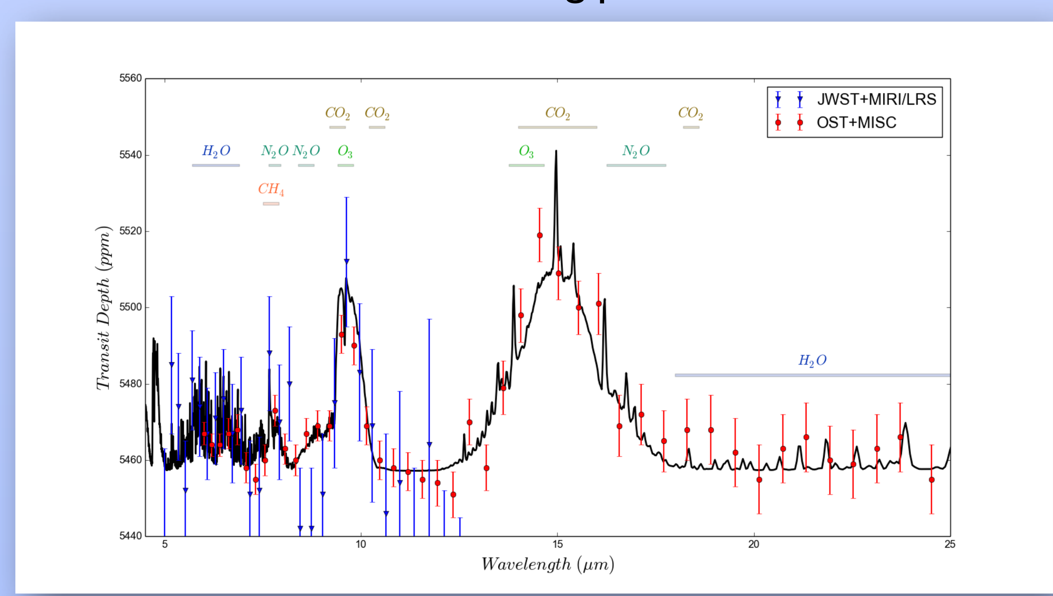
Direct imaging of Jupiter analogs

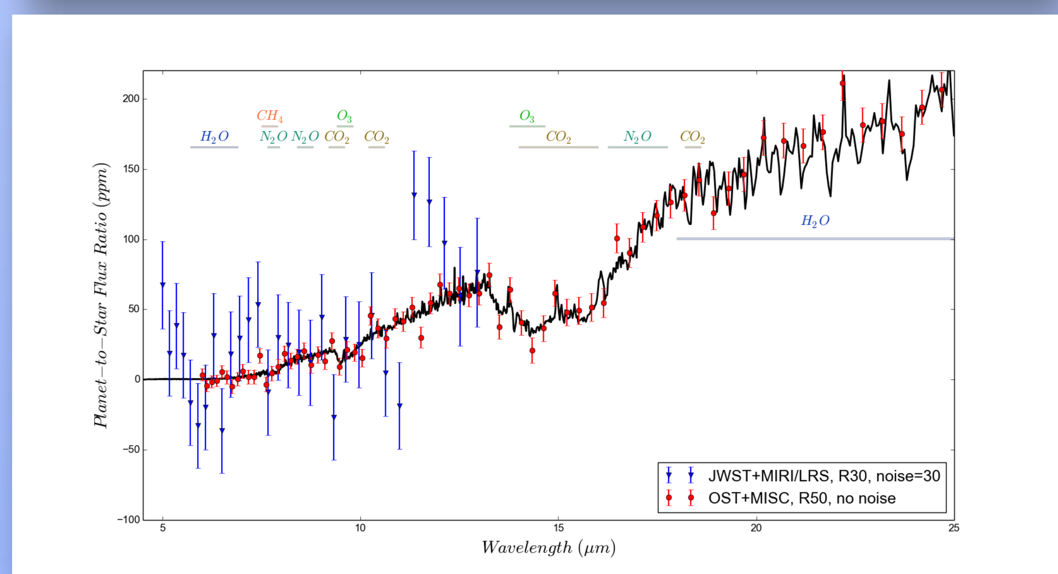
With contrast ratios of 10^{-6}, OST will be able to directly image and characterize the atmospheres of true exoplanet analogs of Jupiter and Saturn (i.e. cool giant planets in orbits beyond 5 AU), critical for understanding the origin and evolution of exoplanetary systems like our own. Molecules such as carbon dioxide and nitrogen-bearing species including ammonia (NH_3) are unique to the mid-infrared and their features are less blended, allowing for more quantitative characterization. OST will also be capable of imaging young gas giants and ice giants, including those at habitable temperatures (~300 Kelvin).

Detecting biosignatures of potentially habitable planets

Habitability is typically defined as the ability of a planet to sustain liquid water on its surface, which is a function of orbital distance and atmospheric composition. Spectroscopic characterization of terrestrial planetary atmospheres will provide constraints for climate models to assess habitability. This remote characterization may also provide evidence of spectroscopic biosignatures.

OST will expand upon the legacy of exoplanet science with Hubble, Spitzer and the upcoming James Webb Space Telescope (JWST) by conducting transmission and emission (dayside and phase-resolved) spectroscopy of exoplanets, including more than a dozen Earth-sized exoplanets transiting in the habitable zones of M-dwarf stars. By leveraging mass, radius and density measurements of this population of planets, OST can pre-select those that are definitively rocky to search for biosignatures by revealing a combined presence of the bio-indicators ozone (O_3), nitrous oxide (N_2O) and methane (CH_4). Using the same techniques, OST will also provide exquisite spectra of more massive exoplanets and use phase curves to characterize non-transiting planets on close orbits.





Simulated OST-MISC (Mid-Infrared Imager Spectrometer Coronagraph) transit spectra and emission (bottom) spectra of a TRAPPIST-1e (0.92 R_E, 250 K) with simulated JWST (blue) and OST (red) data. These spectra assume a conservative noise floor of 30 ppm for JWST and no noise floor for OST, anticipating increased stability of mid-infrared detectors.

The **Origins Space Telescope** is the mission concept for the **Far Infrared Surveyor**, a study in development by NASA in preparation for the *2020 Astronomy and Astrophysics Decadal Survey*.

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Secret OST Word: BIOSIGNATURE