



Jet Propulsion Laboratory
California Institute of Technology

Cool Planets, New Science

Exoplanet Science Enabled by Starshades

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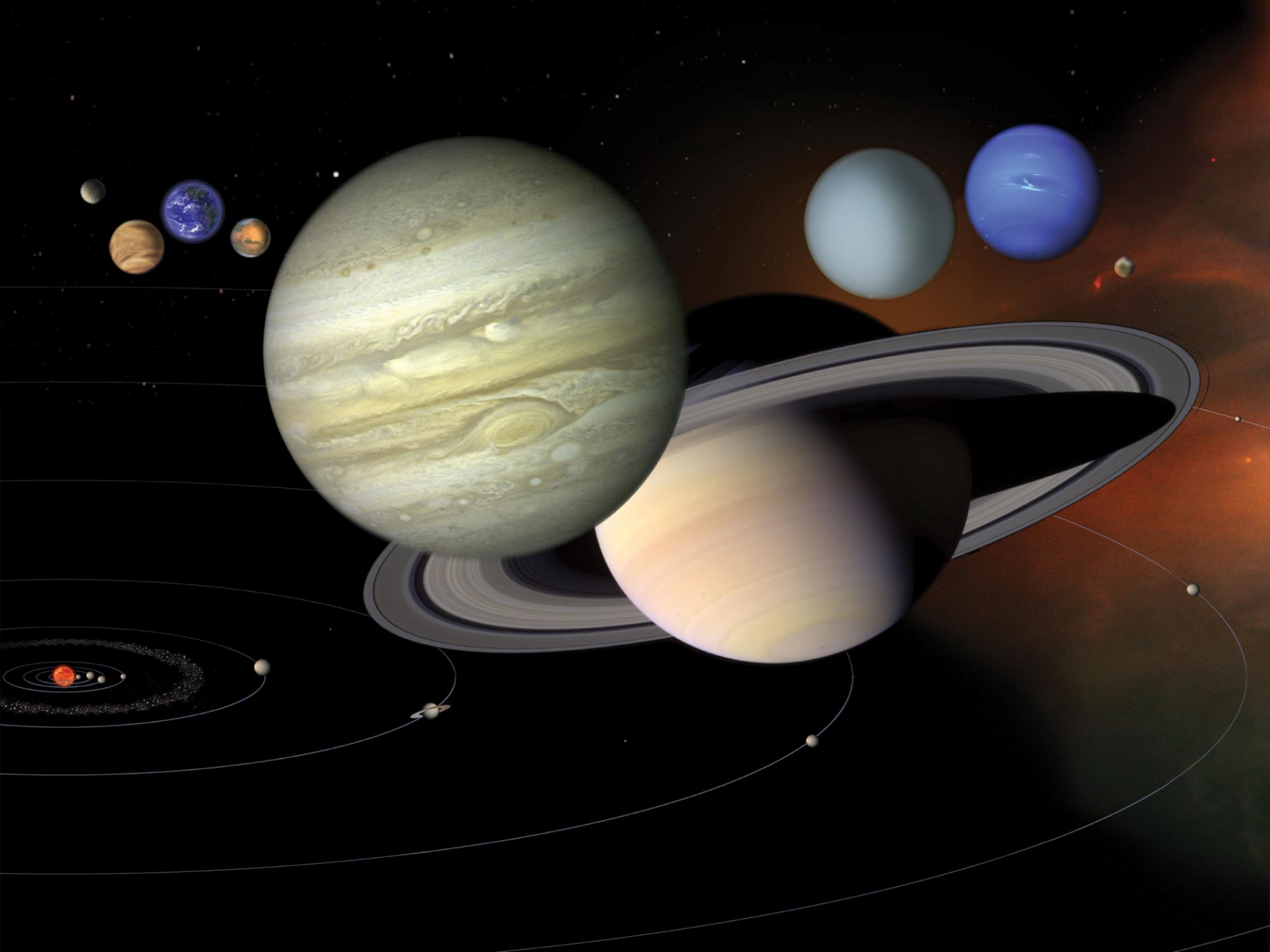
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Starshade Technology Workshop

December 1, 2016

Pasadena CA

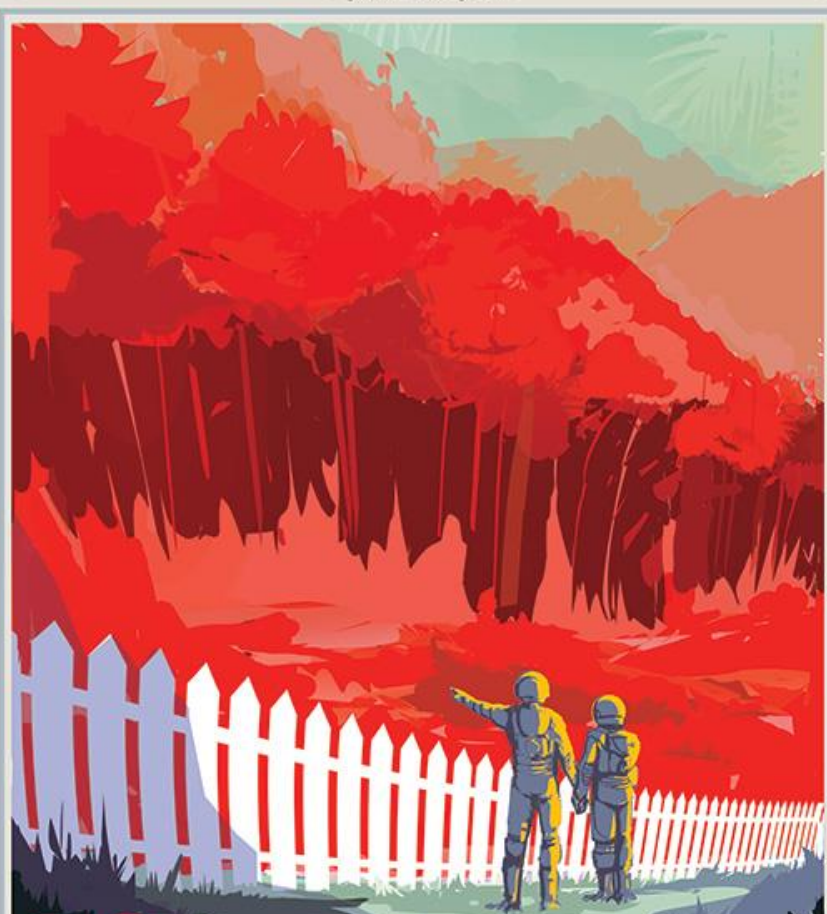




EXPERIENCE THE GRAVITY OF
HD 40307g A SUPER
 EARTH

Twice as big in volume as the Earth, HD 40307g straddles the line between "Super-Earth" and "mini-Neptune" and scientists aren't sure if it has a rocky surface or one that's buried beneath thick layers of gas and ice. One thing is certain, though: at eight times the Earth's mass, its gravitational pull is much, much stronger.

The *Rover Bureau* Series is a product of NASA's Exploration Program Office (explore.jpl.nasa.gov) located at NASA's Jet Propulsion Laboratory (jpl.nasa.gov)



Kepler-186f

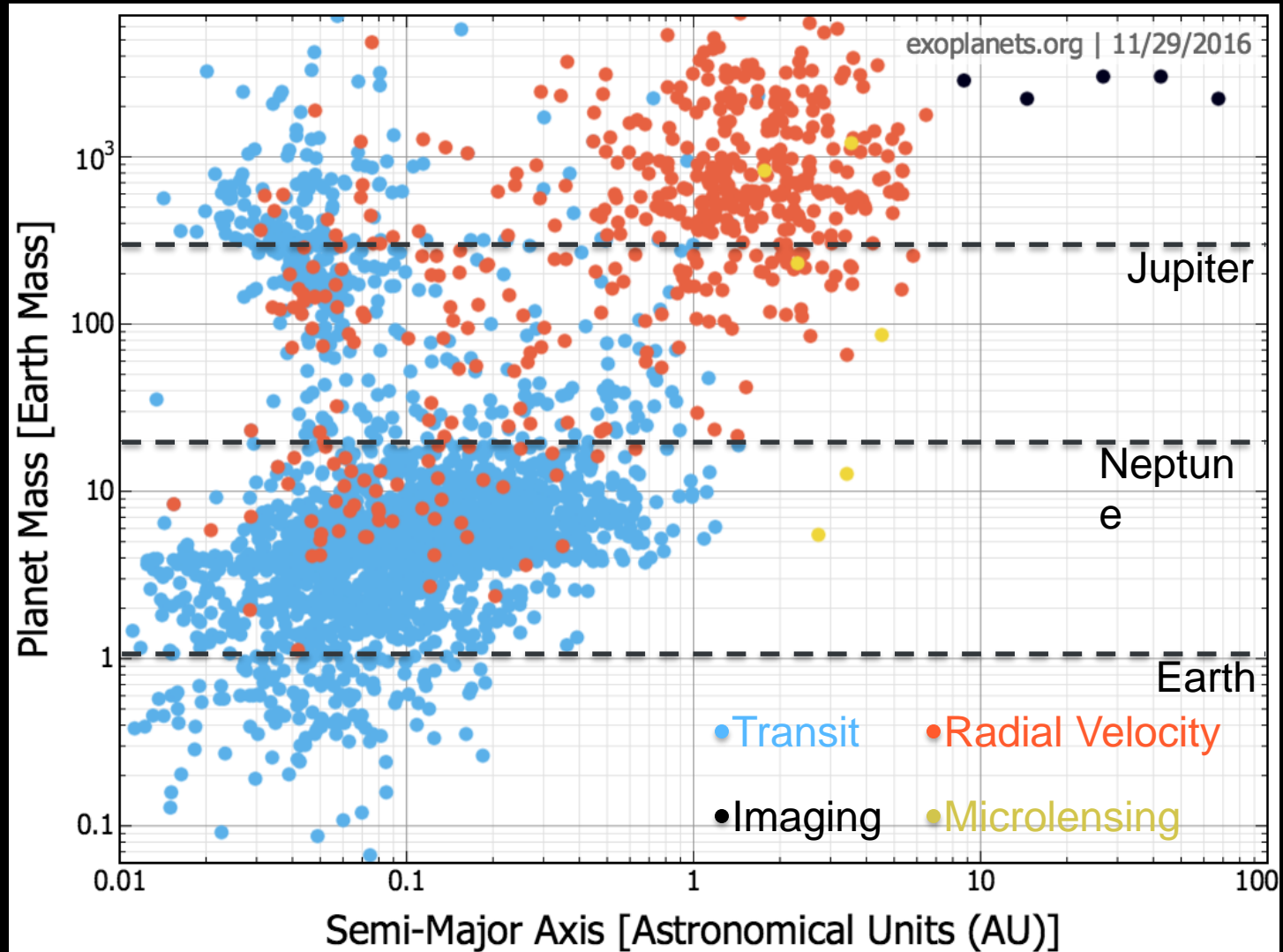
WHERE THE GRASS IS ALWAYS REDDER ON THE OTHER SIDE

Kepler-186f is the first Earth-size planet discovered in the potentially habitable zone¹ around another star, where liquid water could exist on the planet's surface. Its star is much cooler and redder than our Sun. If plant life does exist on a planet like Kepler-186f, its photosynthesis could have been influenced by the star's red-wavelength photons, making for a color palette that's very different than the greens on Earth. This discovery was made by Kepler, NASA's planet-hunting space telescope.

NASA's Exploration Program Office (explore.jpl.nasa.gov) located at NASA's Jet Propulsion Laboratory (jpl.nasa.gov)

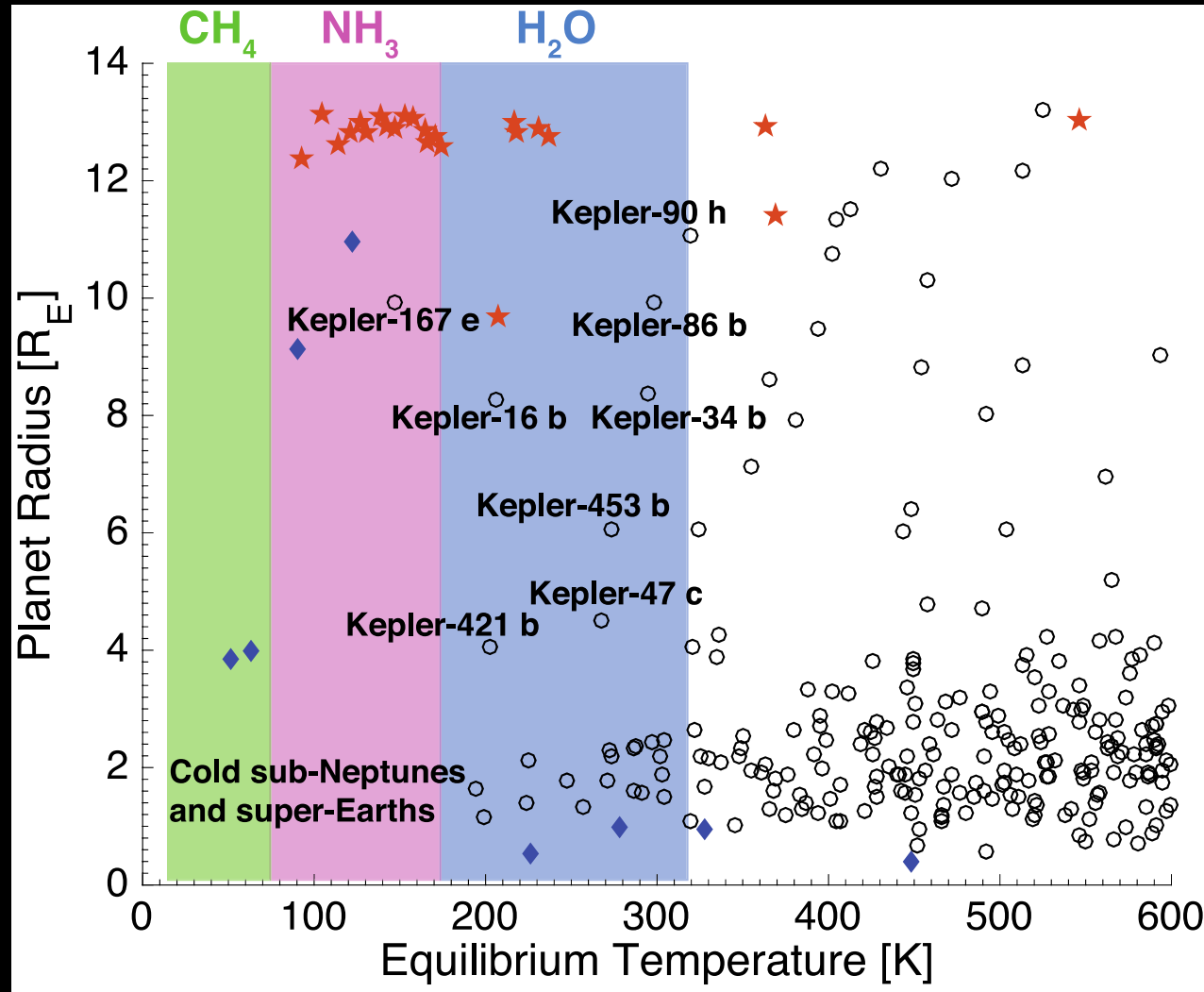
Exoplanet Demography

Commonality of Small Exoplanets



Exoplanet Demography

Wide-Separation Exoplanets



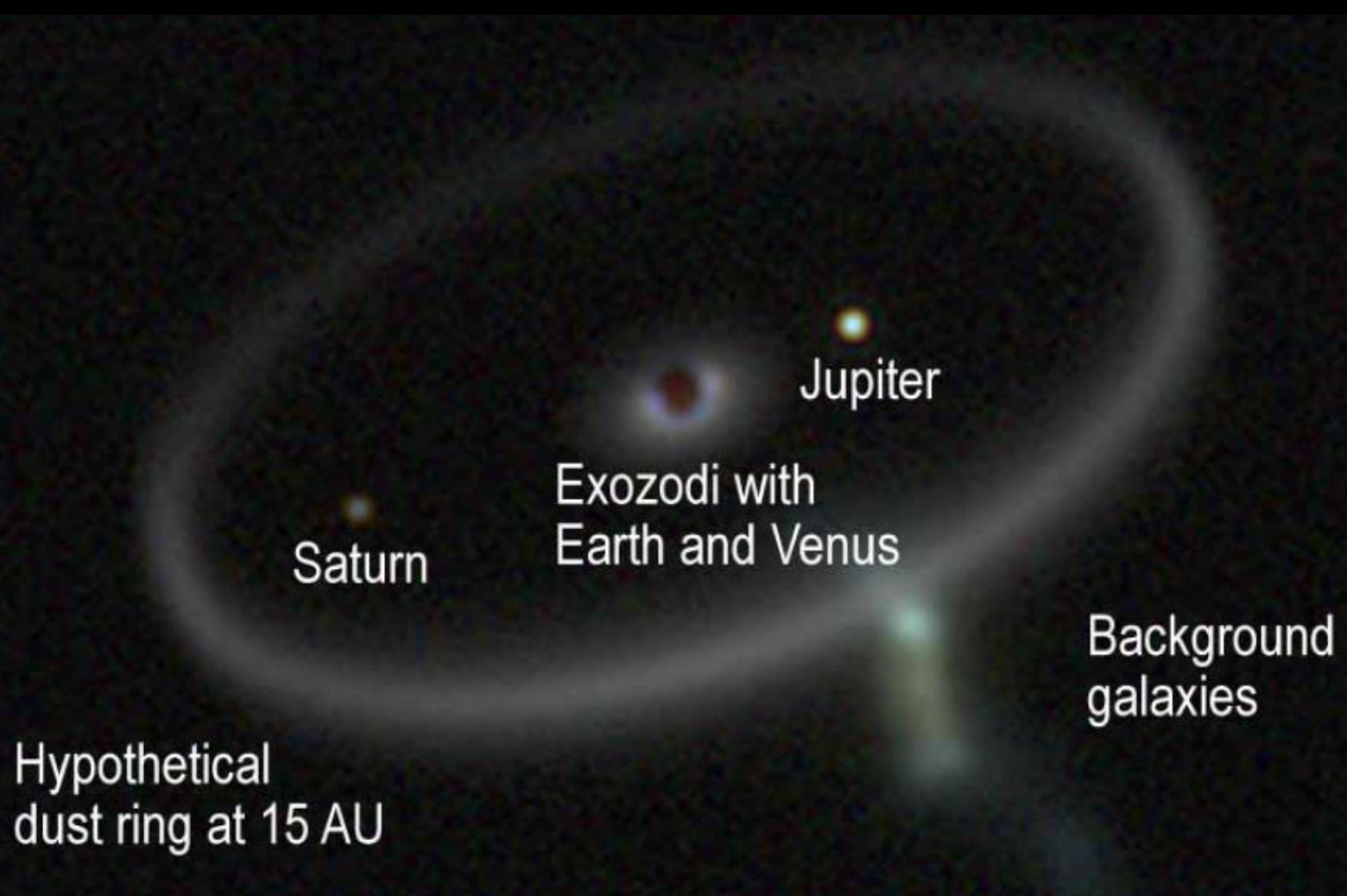
★ Giant exoplanets found by RV surveys

○ Transiting exoplanets found by *Kepler*

◆ Planets in the Solar System

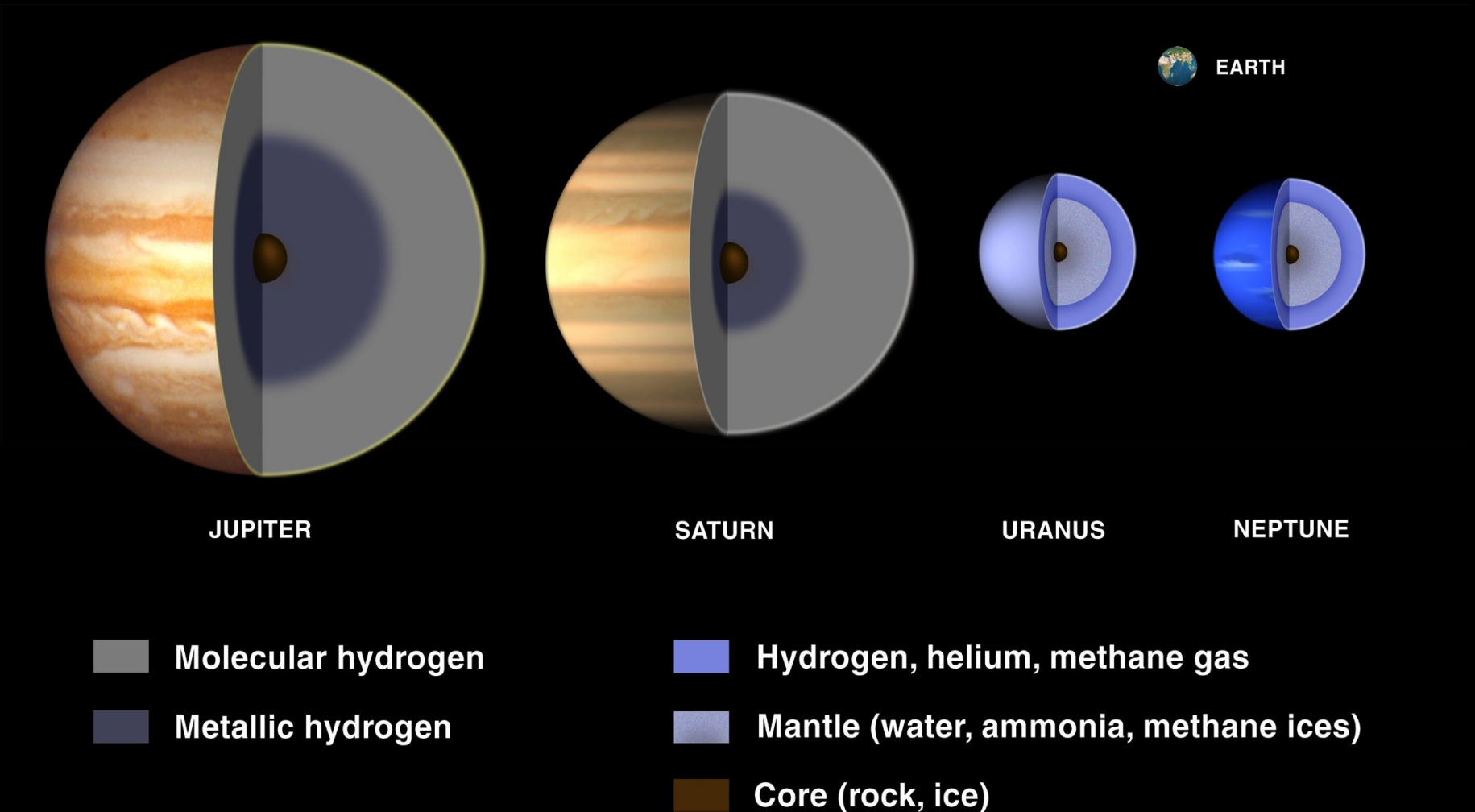
Image of a Solar System

Starshade Rendezvous Mission simulated image of a nearby star



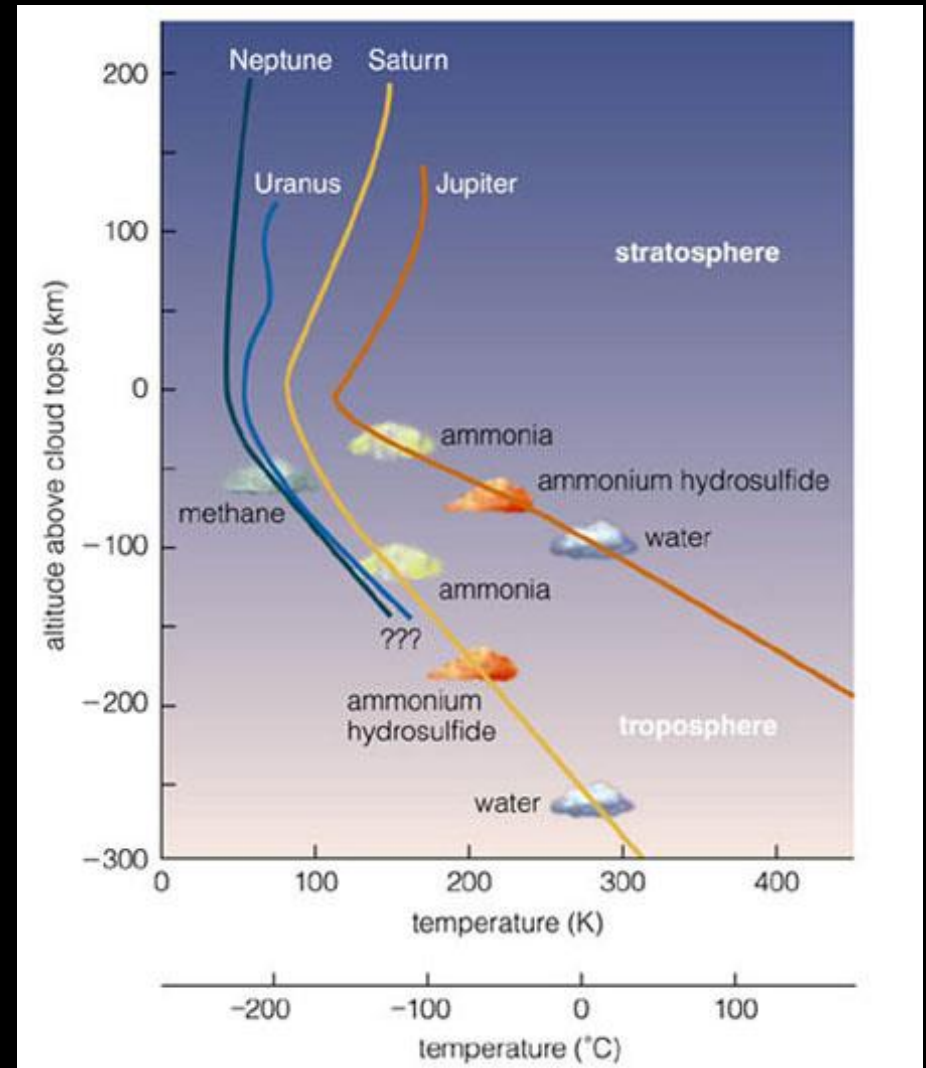
Characterizing Giant Exoplanets

Solar-System Analogs



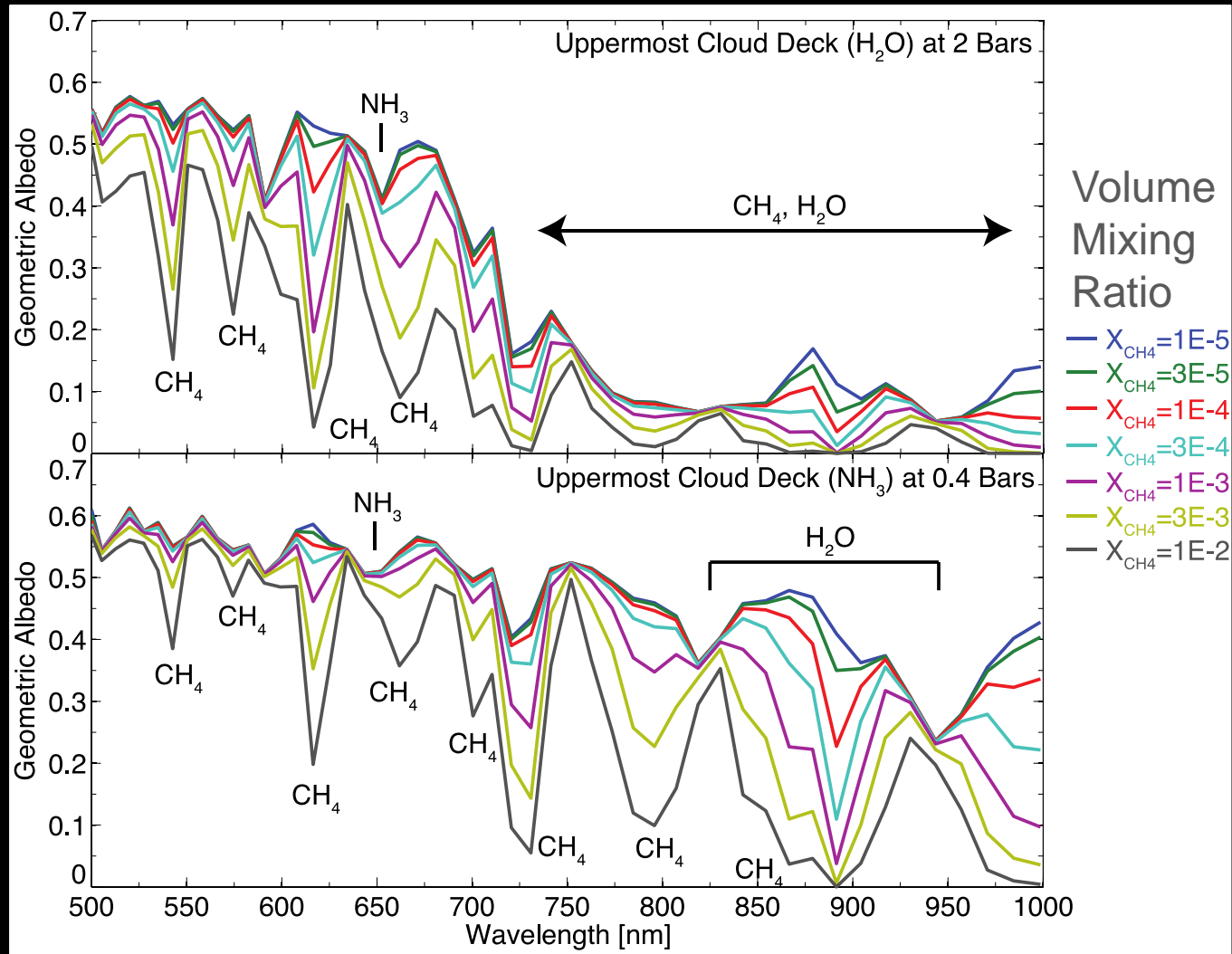
Characterizing Giant Exoplanets

- Abundances of C, N, O
- Convection and advection
- Thermal evolution
- Role of photochemistry
- Comparative planetology



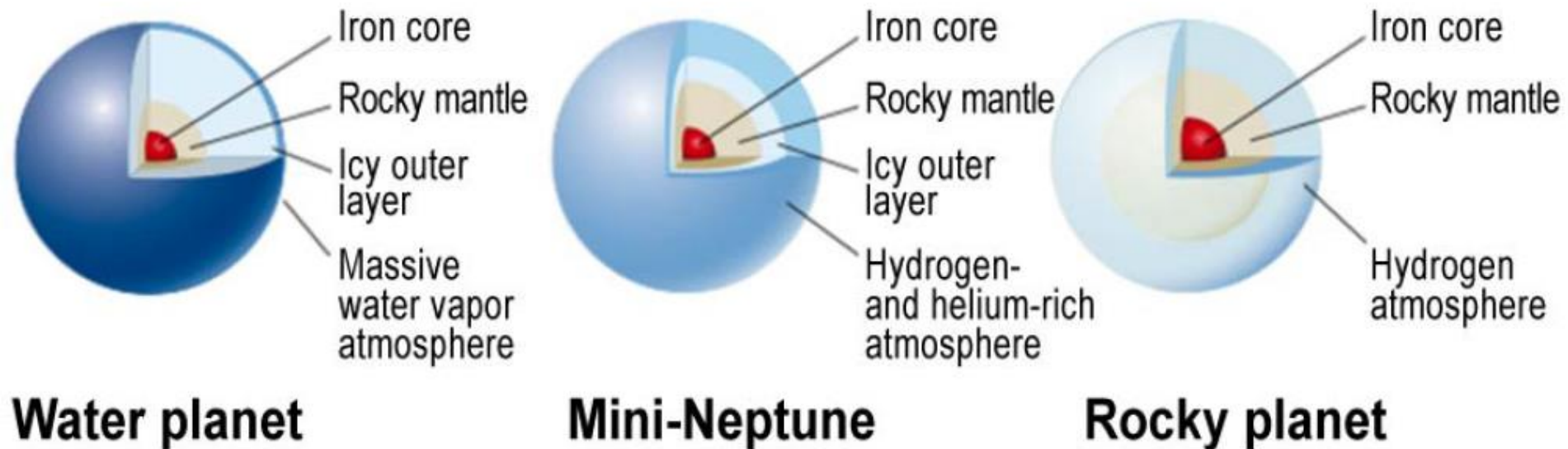
Characterizing Giant Exoplanets

Cloud and Gas Abundance



Measuring Spectra of Sub-Neptunes and Super Earths

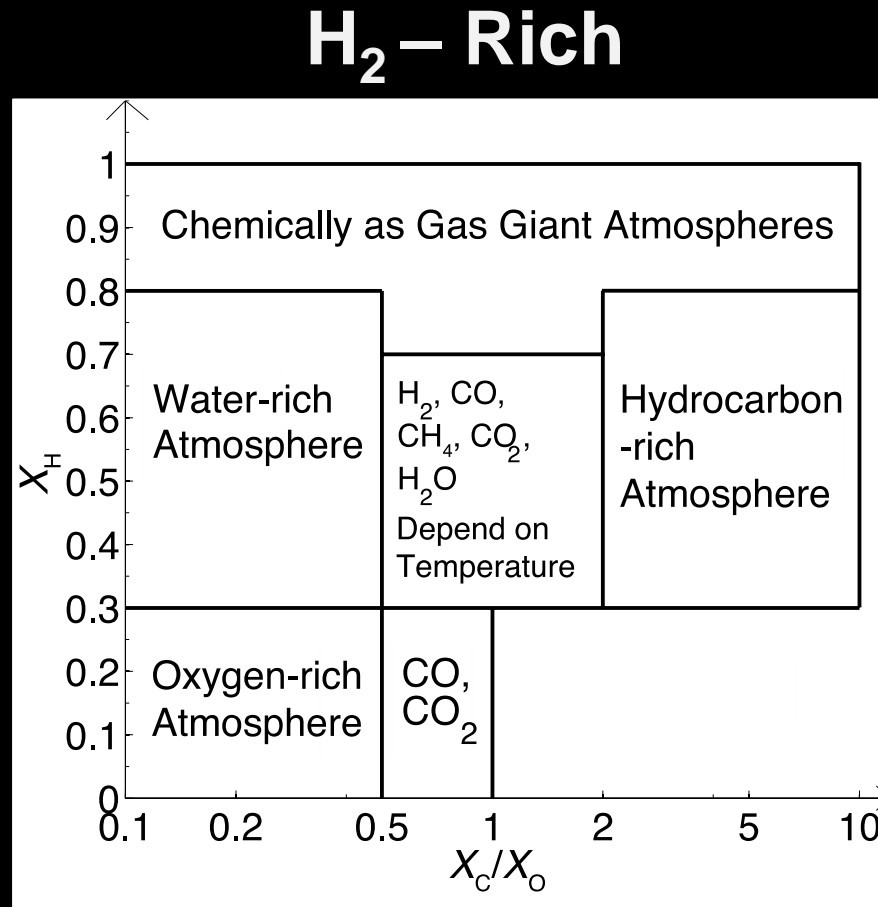
- Is there a surface?
 - Cloud, liquid, or solid
- What is the composition of the atmosphere?
 - H₂-dominated or non-H₂-dominated
- What are the formation and evolution pathways?



Measuring Spectra of Sub-Neptunes and Super Earths

Diversity of Atmospheres

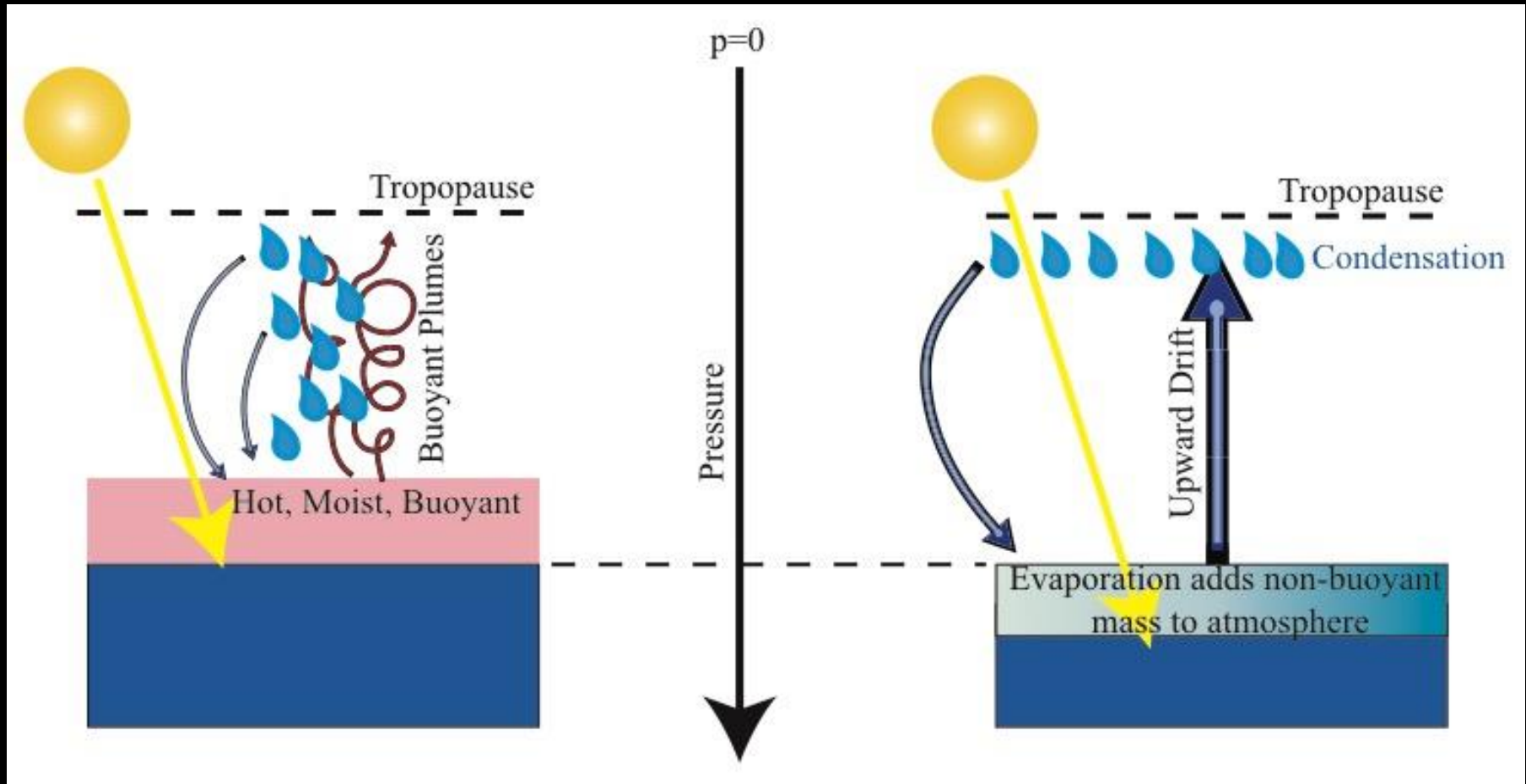
**Carbon
– Poor**



**Carbon
– Rich**

Measuring Spectra of Sub-Neptunes and Super Earths

Condensible-Rich Atmospheres

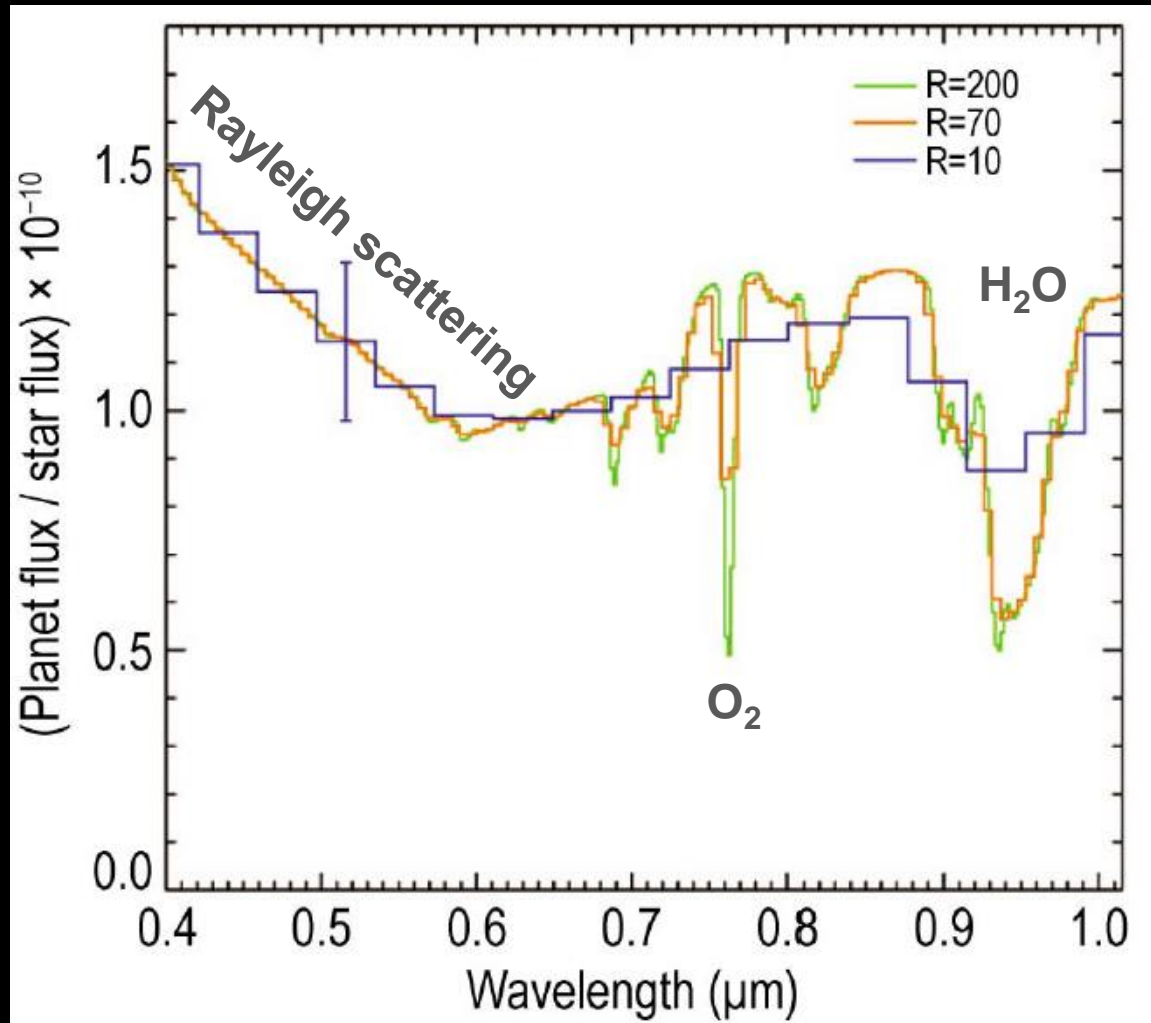


Detecting Earths



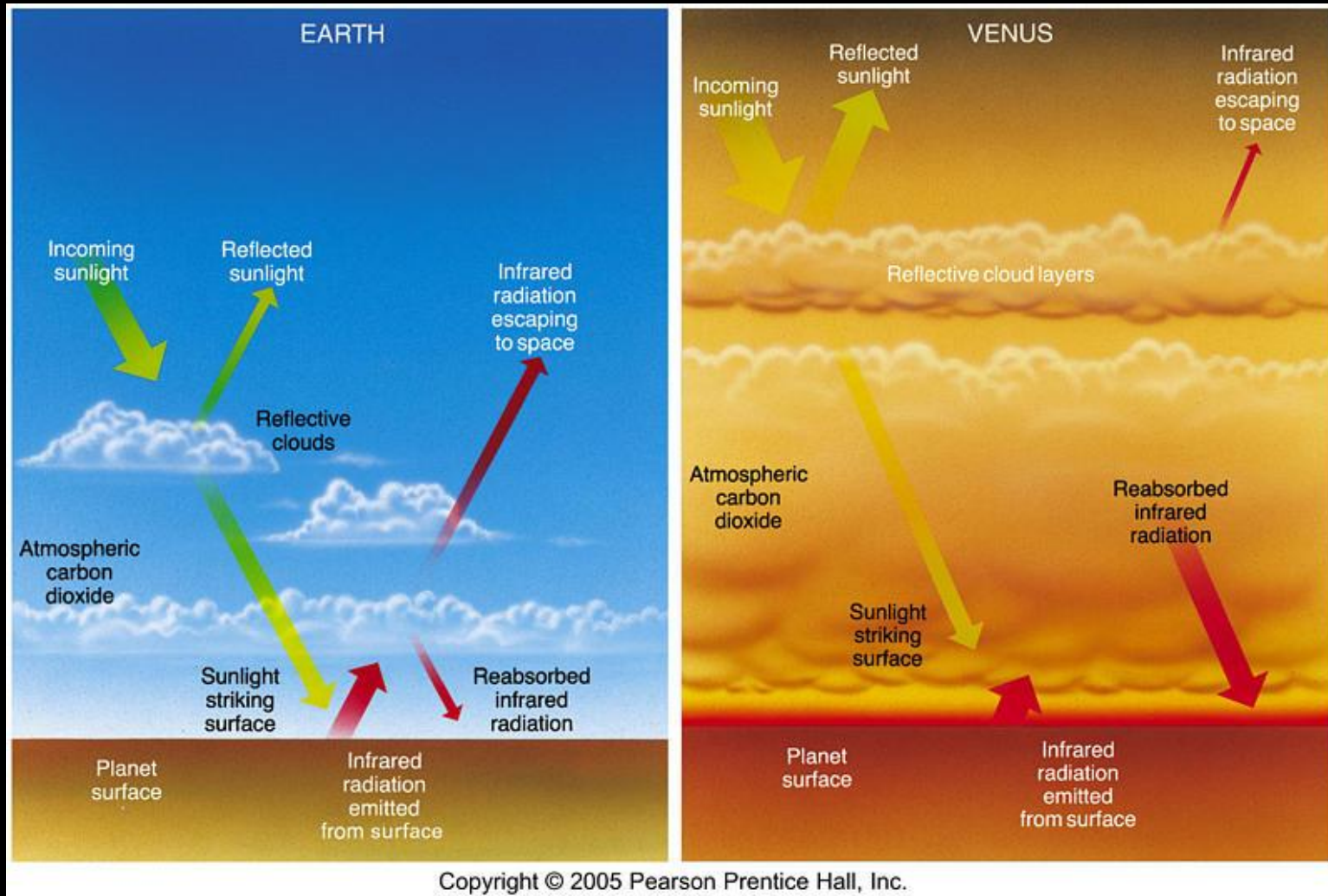
Detecting Earths

Water and Oxygen



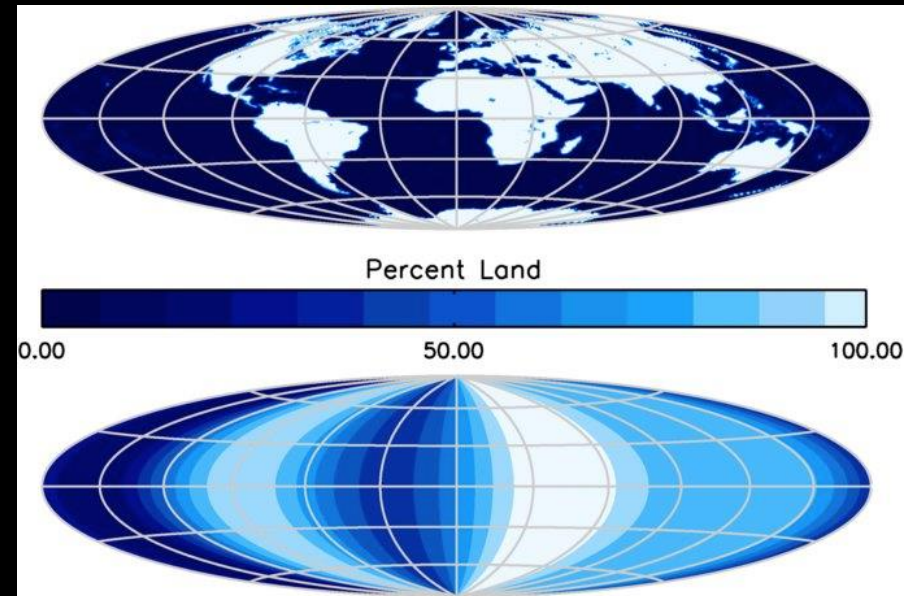
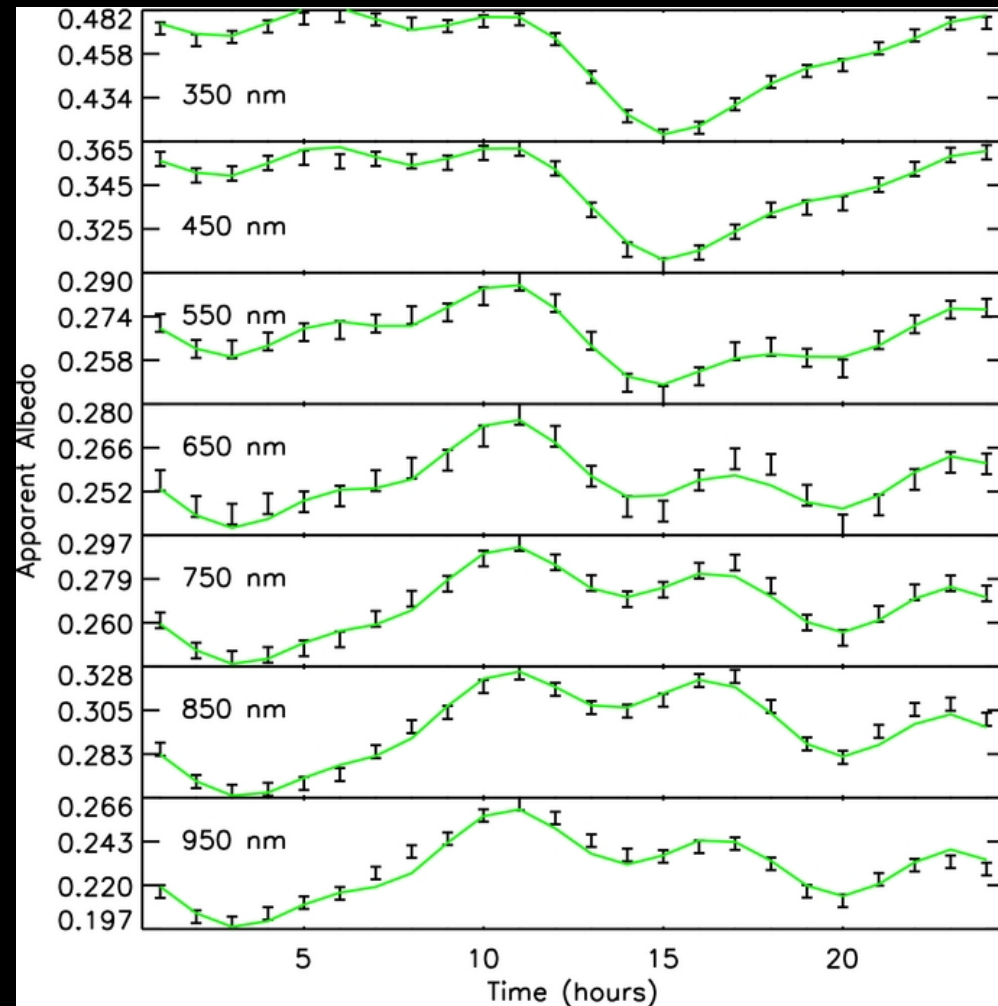
Detecting Earths

Earth vs. Venus



Detecting Earths

Land and Sea





Artist's concept



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