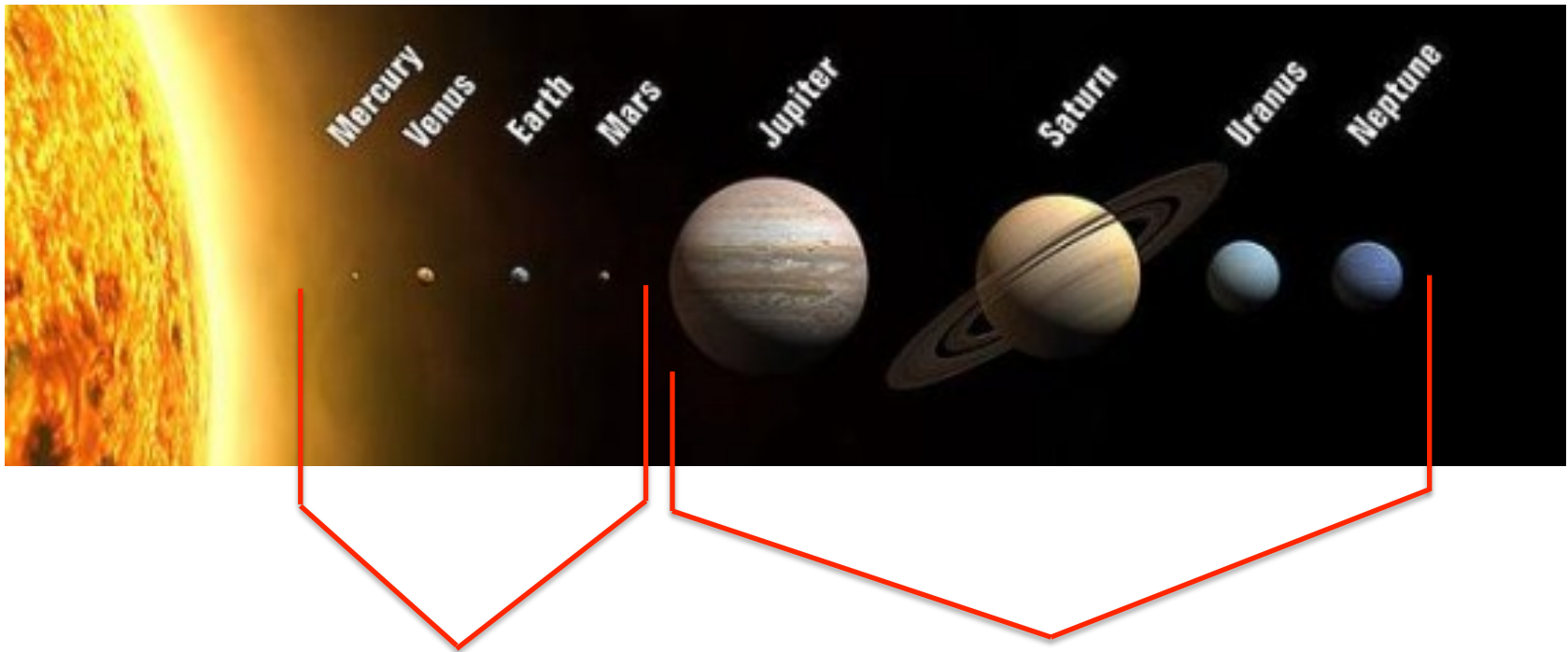


The background of the slide is a deep black space filled with numerous small, white stars. A large, bright orange and yellow celestial body, possibly a gas giant or a nebula, dominates the upper half of the frame. It has a glowing, textured surface with swirling patterns. The title text is overlaid on this celestial body.

A Tour of Distant Worlds

Laura Kreidberg
University of Chicago

Our Solar System



Four terrestrial planets

Four gas/ice giants

- Formed 4.6 billion years ago from a cloud of gas/dust
- 3 trillion miles across

Solar System Discovery and Exploration

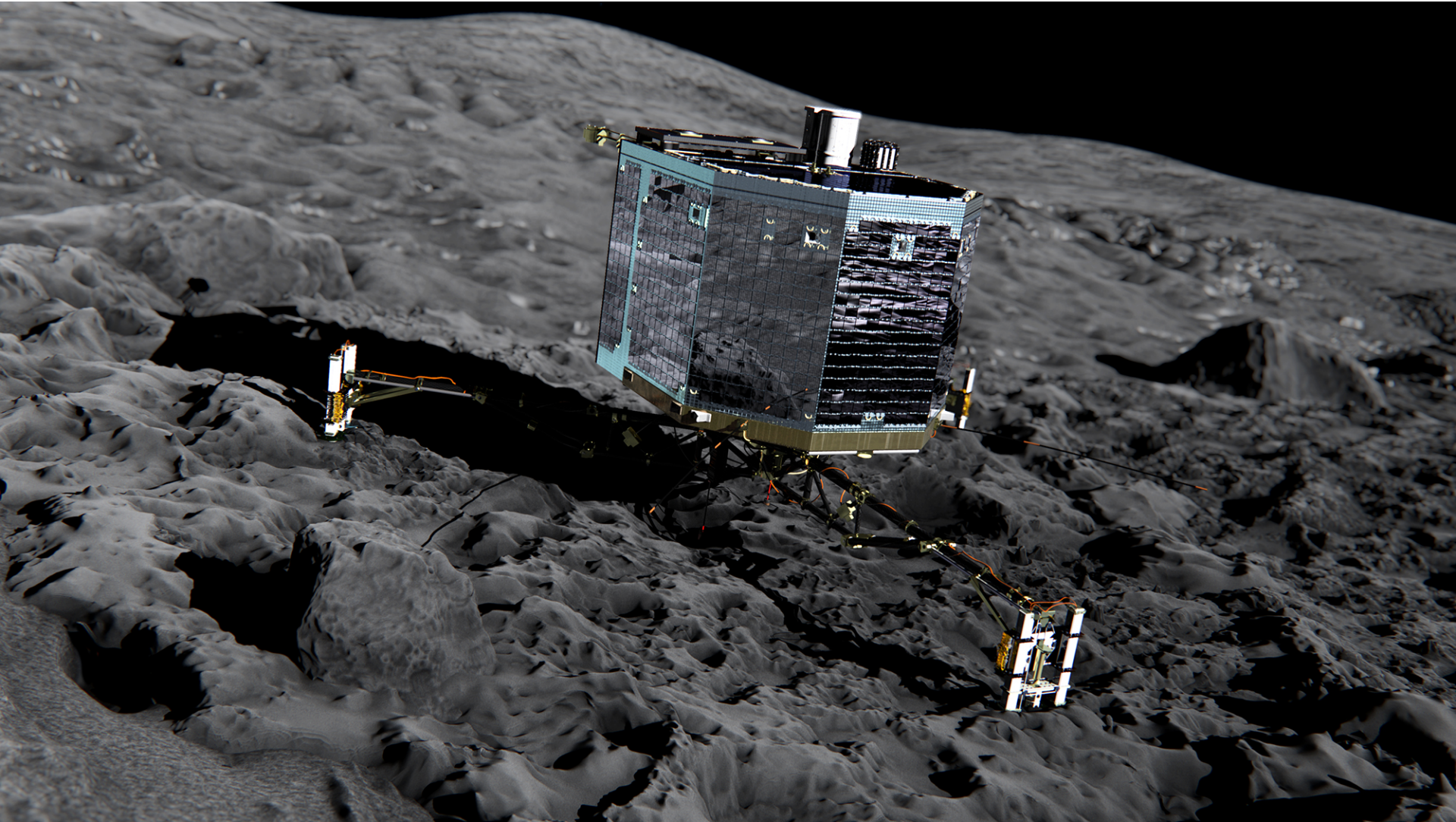
- Mercury, Venus, Mars, Jupiter and Saturn identified by ancient Babylonian astronomers
- Neptune, Uranus, Pluto found between 1781 and 1930
- Spacecraft and rovers sent to planets starting in 1960s

Surface of Mars
Curiosity Rover, 2012

First picture of Jupiter
Pioneer 10, 1973



Solar System exploration continues today



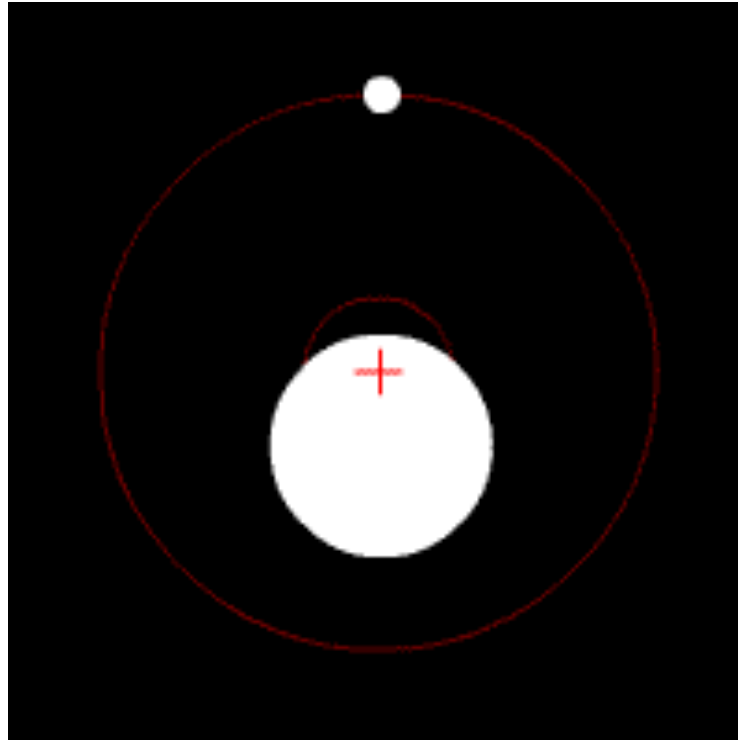
2014: Philae lands on a comet

There are 300 billion stars in the Milky Way –
How many of them host **planets**?



"Milky Way Night
Sky Black Rock
Desert NV"
- Steve Jurvetson

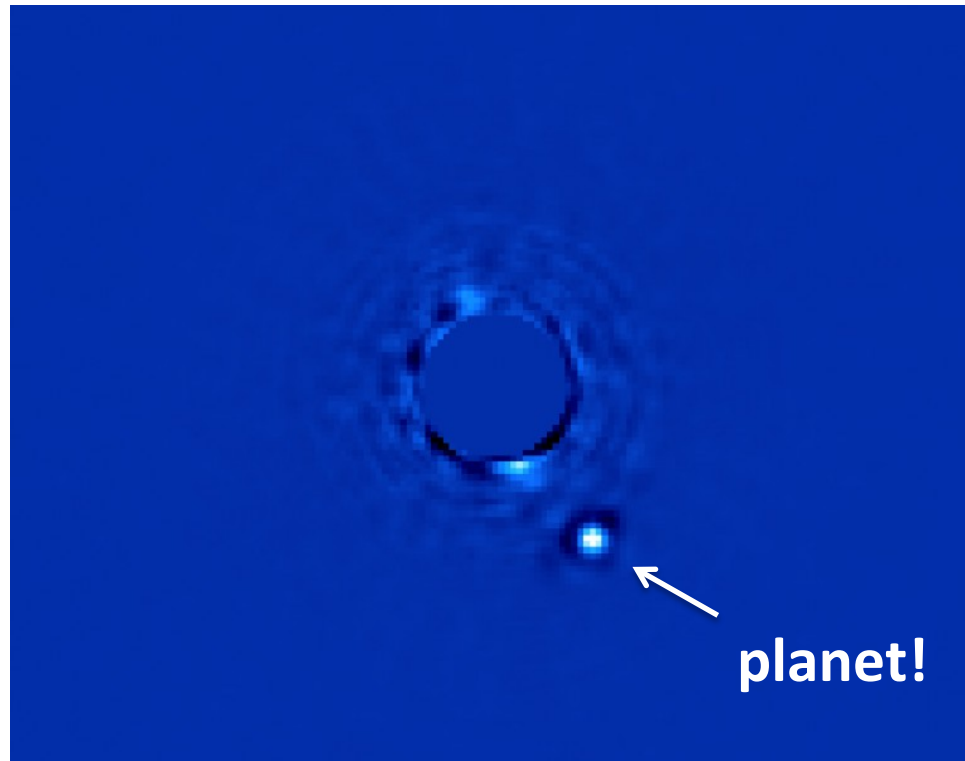
How Do We Discover Exoplanets?



I. Radial velocity technique

- planet's gravity tugs on the star as it orbits
- star appears bluer as it moves toward us and redder as it moves away

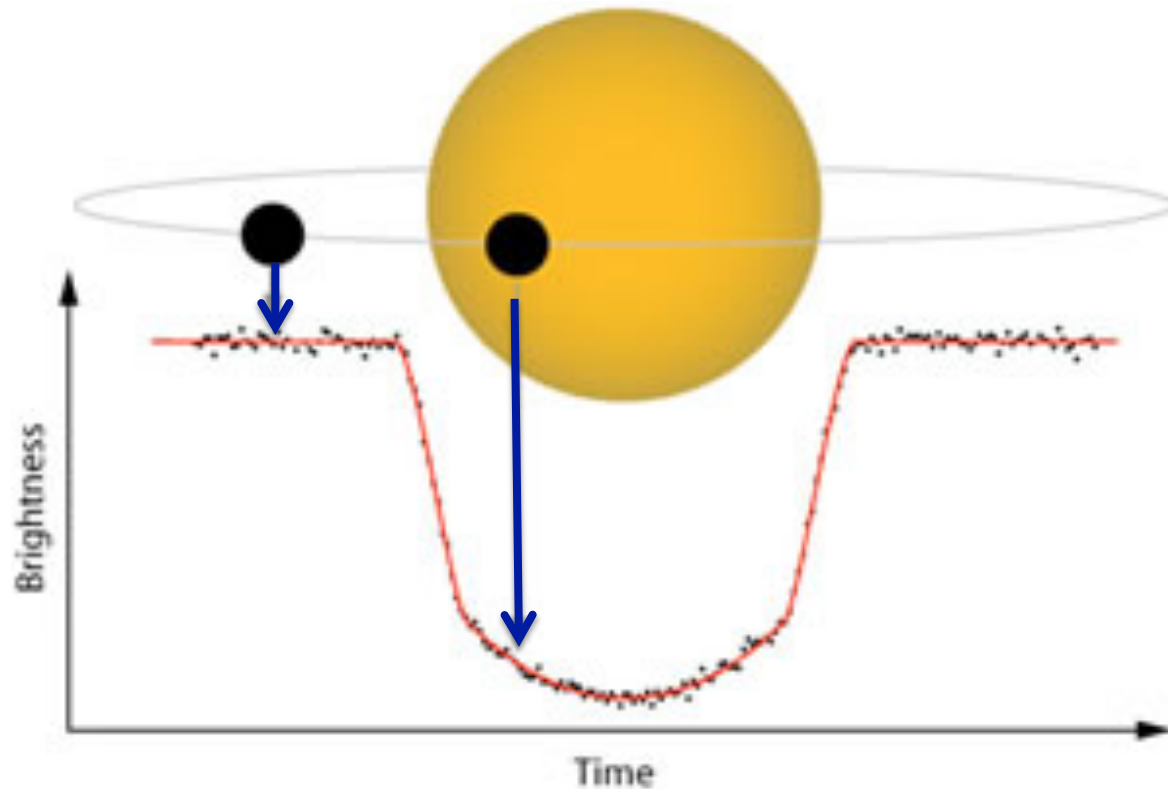
How Do We Discover Exoplanets?



II. Direct imaging

block out light from the star to take a picture of the planet

How Do We Discover Exoplanets?

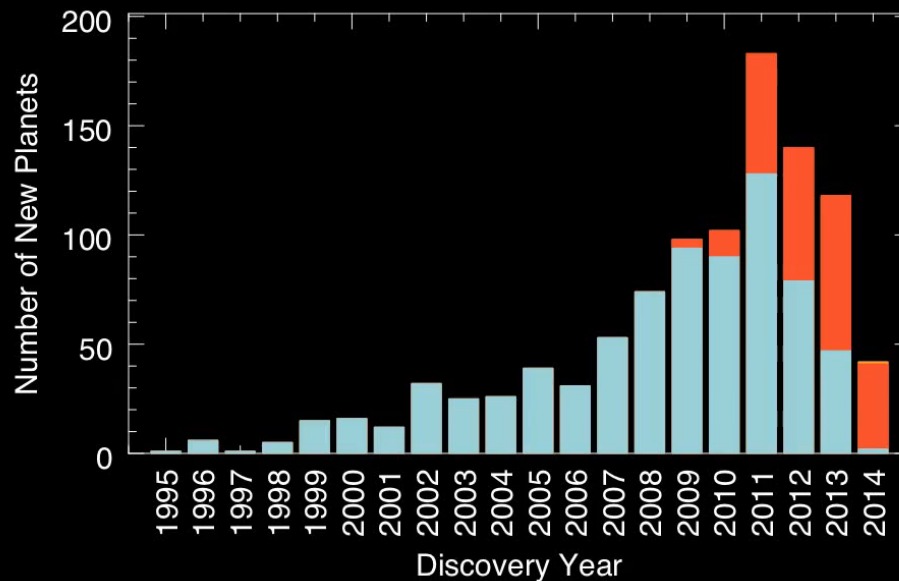


III. Transit technique

planet blocks stellar light as it periodically passes in front of the star

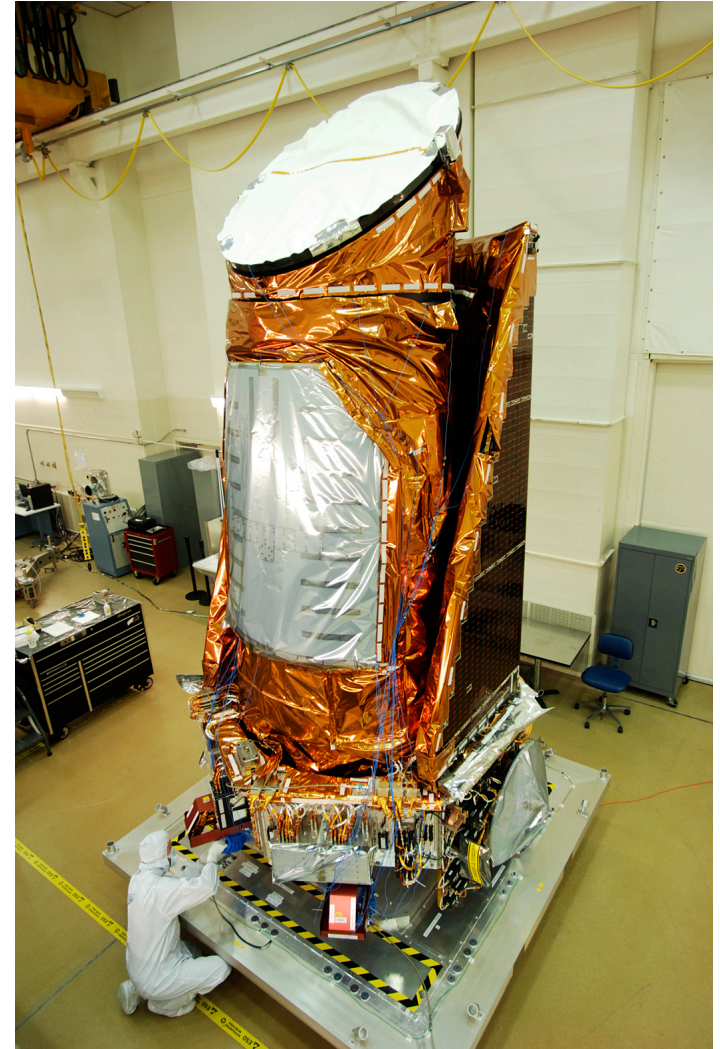
Planets are Everywhere

- First planet discovery in 1995: a hot Jupiter orbiting 51 Pegasi
- Now over 1000 confirmed exoplanet detections
- More than 50% of stars host at least one planet!

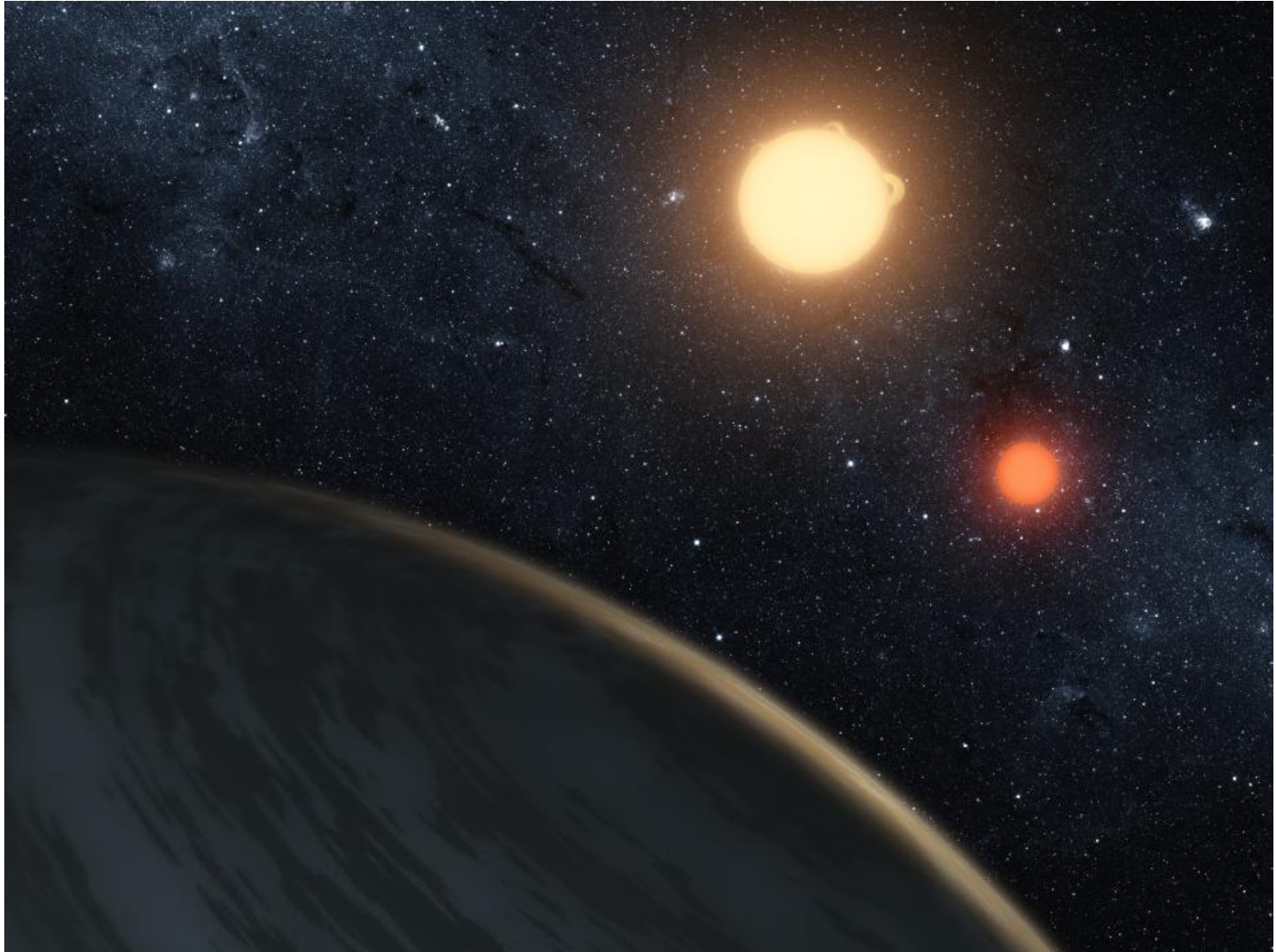


A New Era in Exoplanet Science: The Kepler Space Telescope

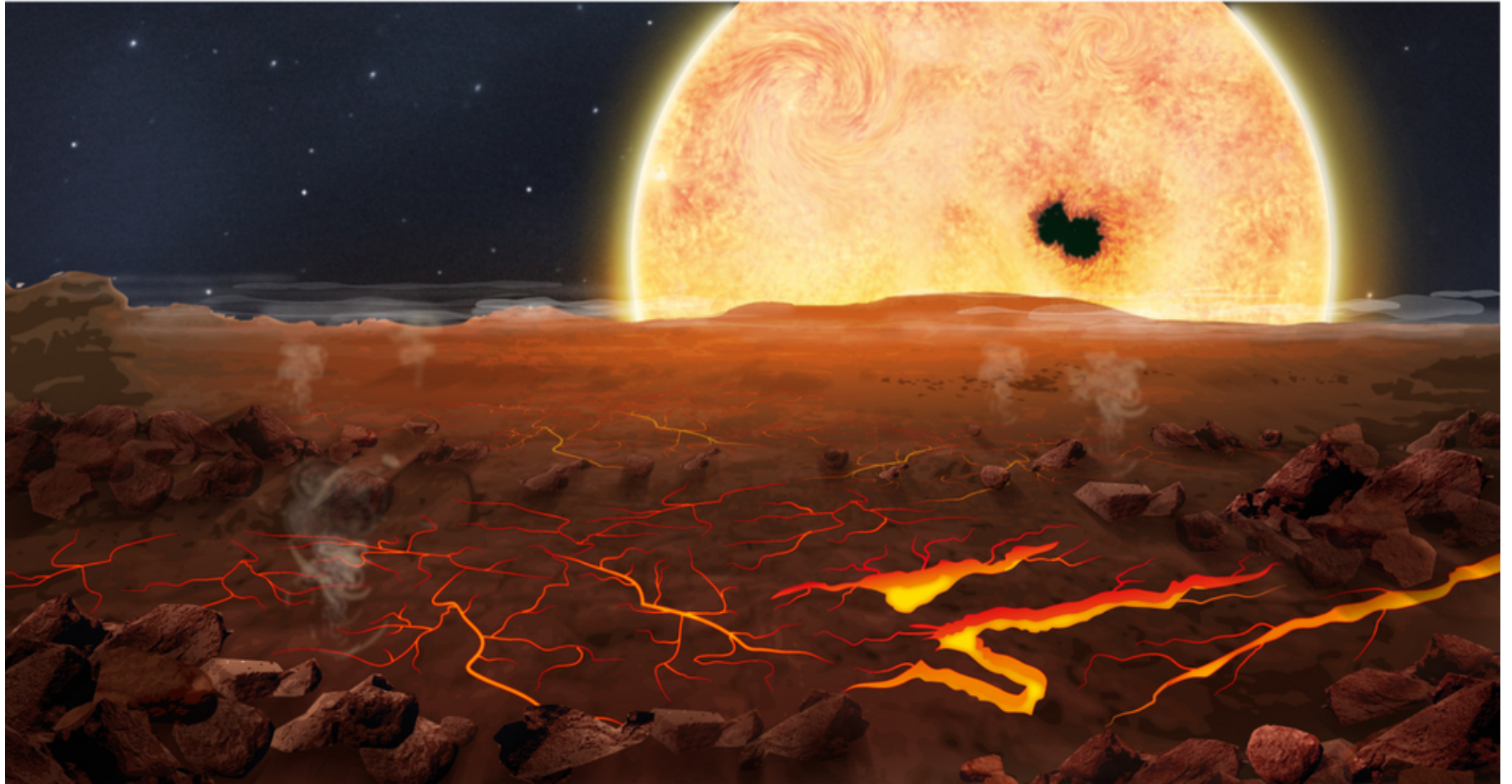
- Kepler is NASA's first dedicated exoplanet mission
- Fixed field of view
- Monitors 150,000 stars for transiting planets



Highlights: Kepler 16, a circumbinary planet

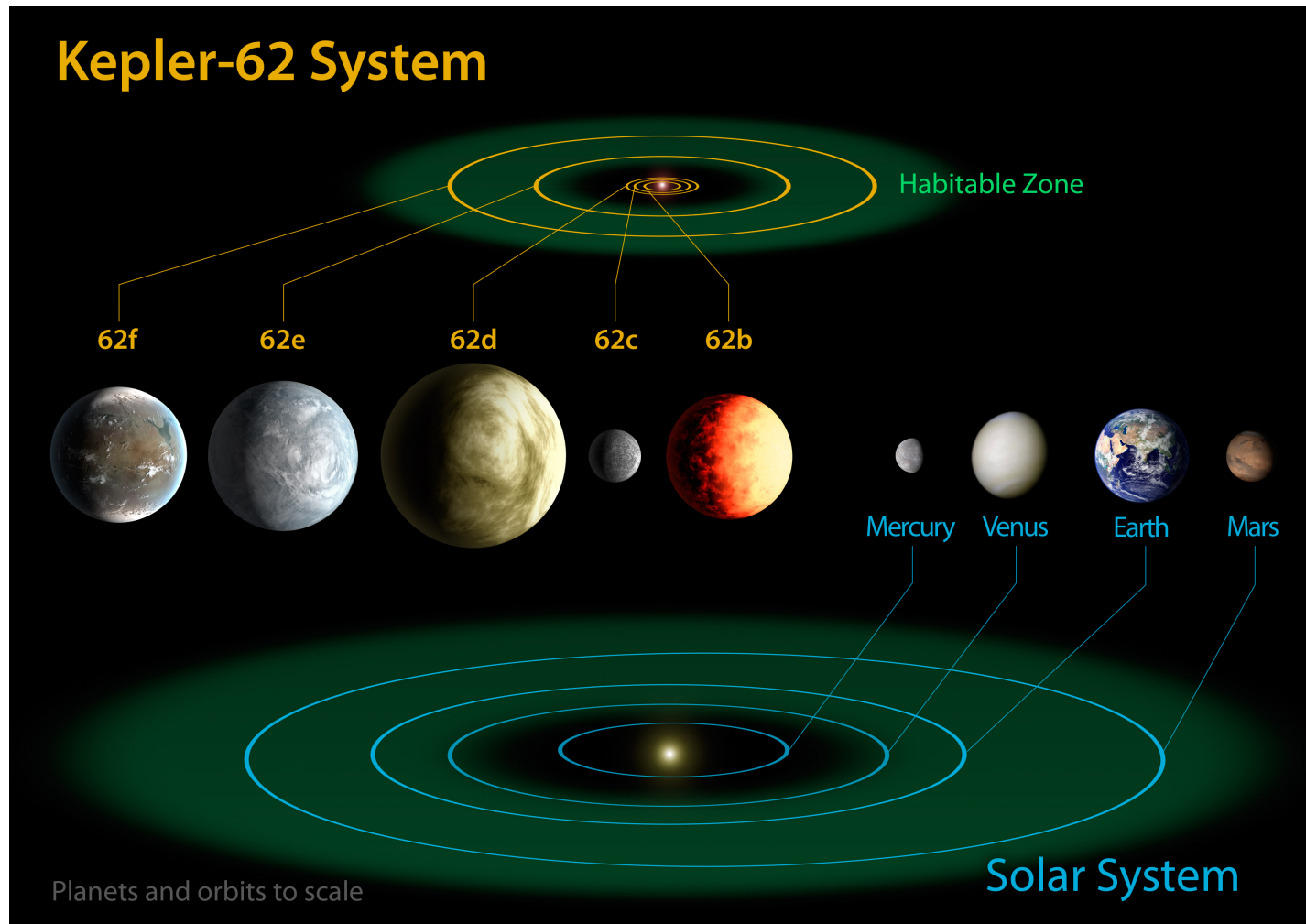


Highlights: Kepler 78, a lava world



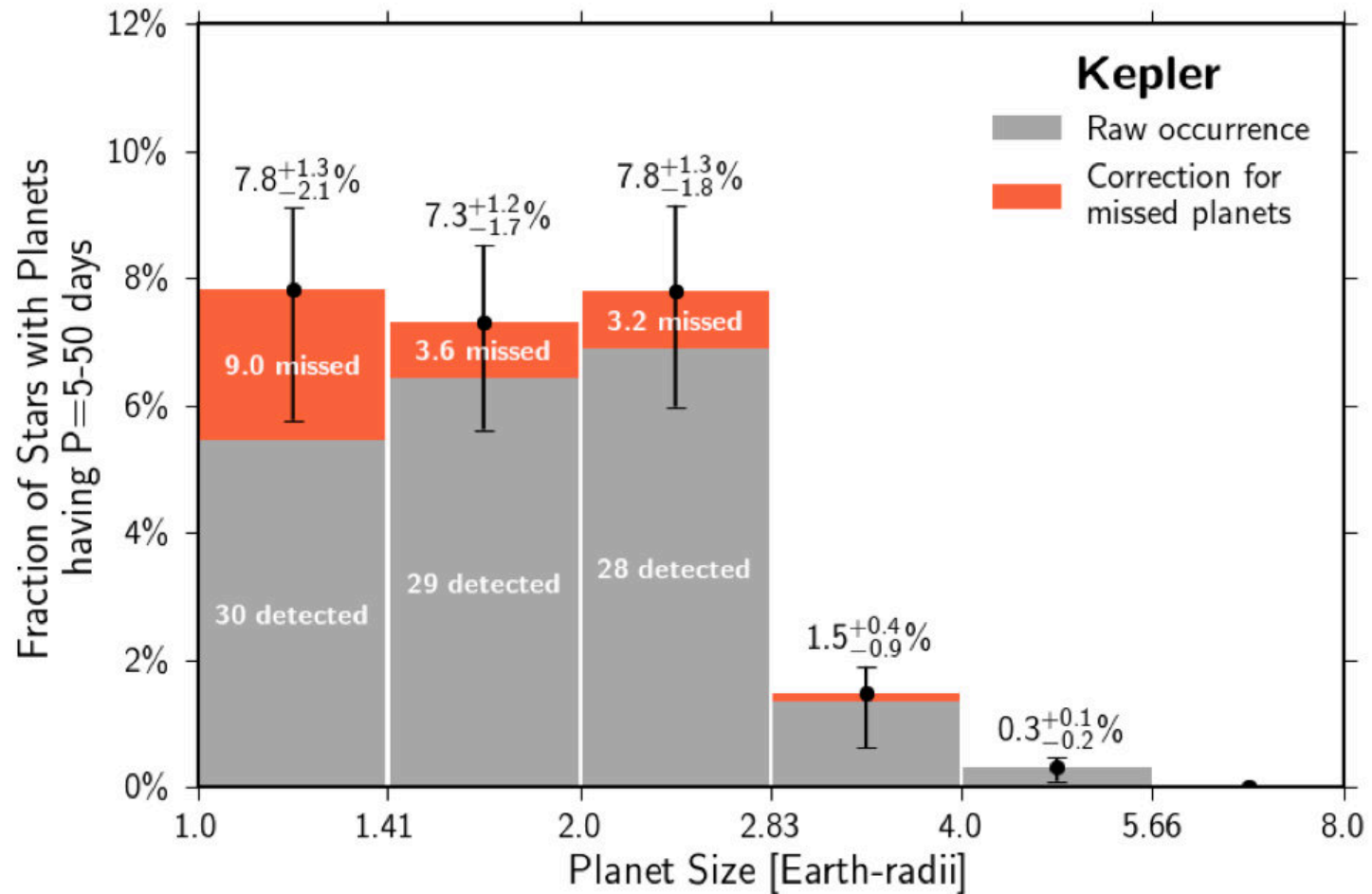
Orbital period = 8.5 hours; temperature > 3,500 degrees Fahrenheit

Highlights: Kepler 62, a 5-planet system



Two planets likely terrestrial and in the habitable zone!

Planet Occurrence Rates from Kepler



Small, Earth-like planets are the most common!

**now that we know planets are everywhere,
what is the next step?**

Part I: Study the Exoplanet Atmospheres

We want to learn what they're made of, how they formed, what they're like, and whether any host life!

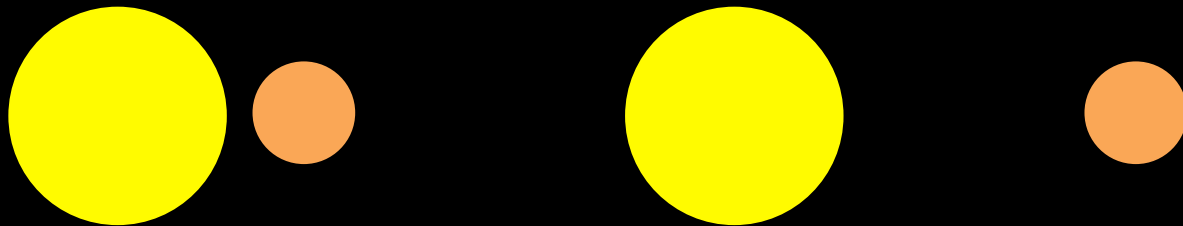
(this is where I come in!)

Me on an observing run in Chile, October 2013



Exoplanet atmosphere characterization 101:

$$(\text{star} + \text{planet}) - \text{star} = \text{planet}$$

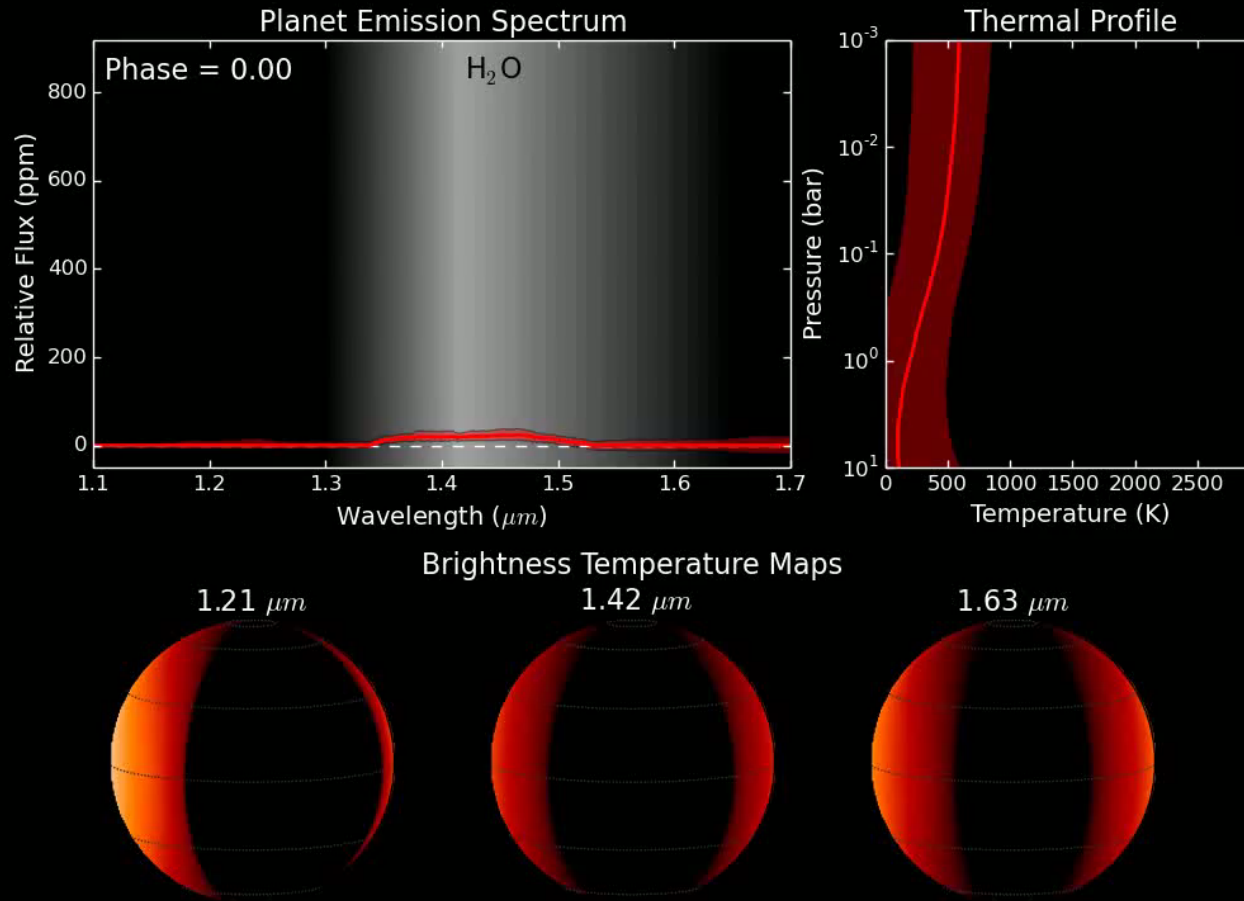


Discovery Highlight #1:

We used a record amount of Hubble observation time (4 days!) to detect clouds in the atmosphere of a super-Earth, GJ 1214b



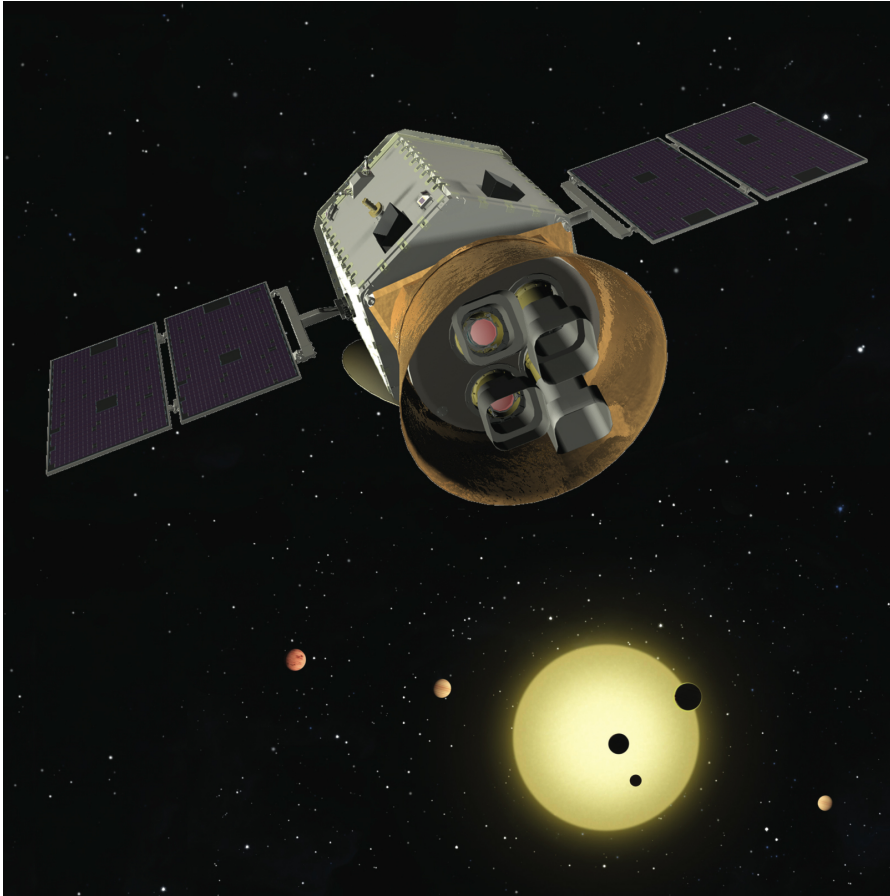
Discovery Highlight #2:



K. B. Stevenson (2014)

A weather map for the hot Jupiter WASP-43b

Part II: Discover the Nearest Planets

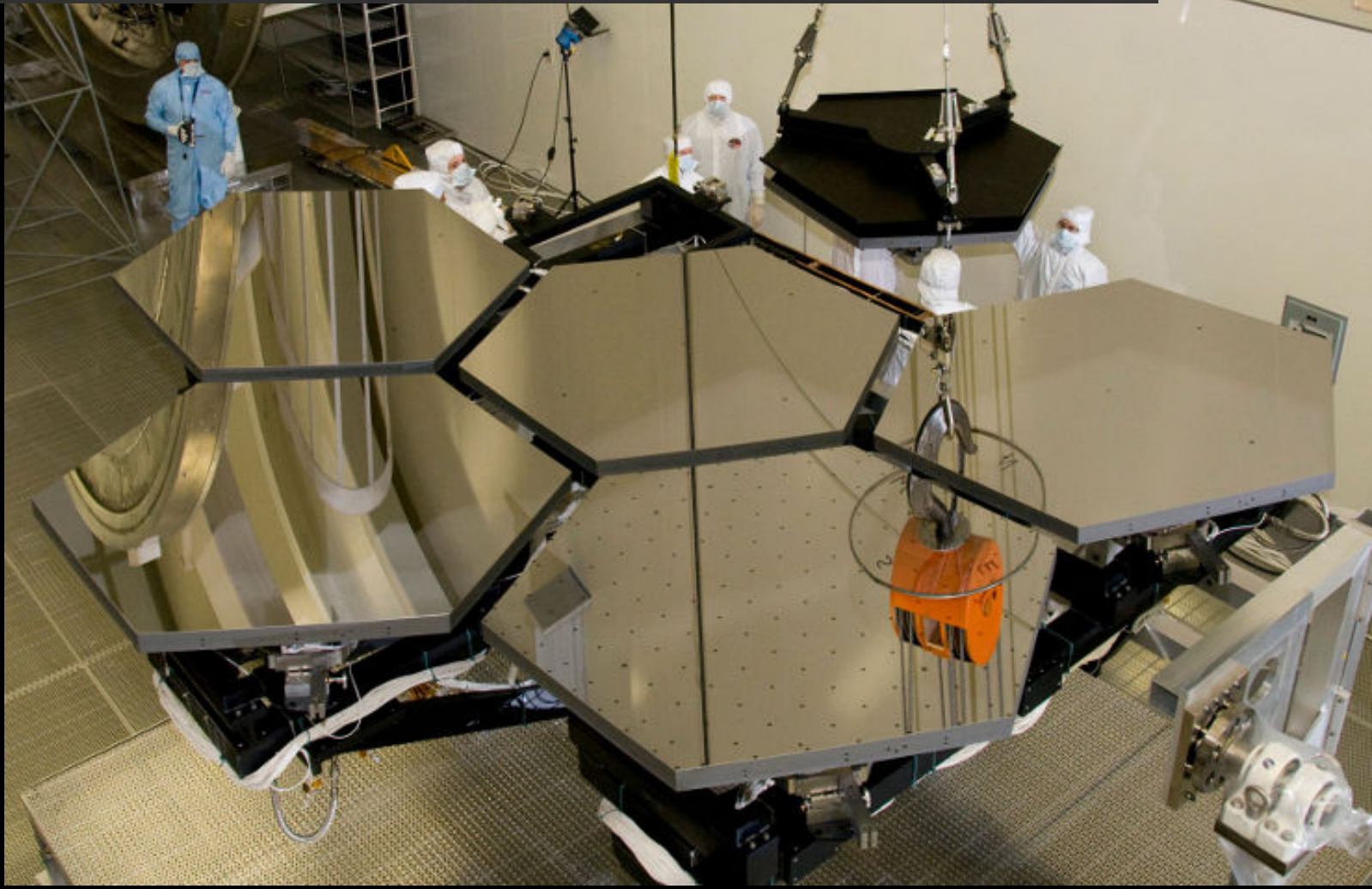


NASA's TESS mission, scheduled for launch in 2017, will search 200,000 **nearby** stars

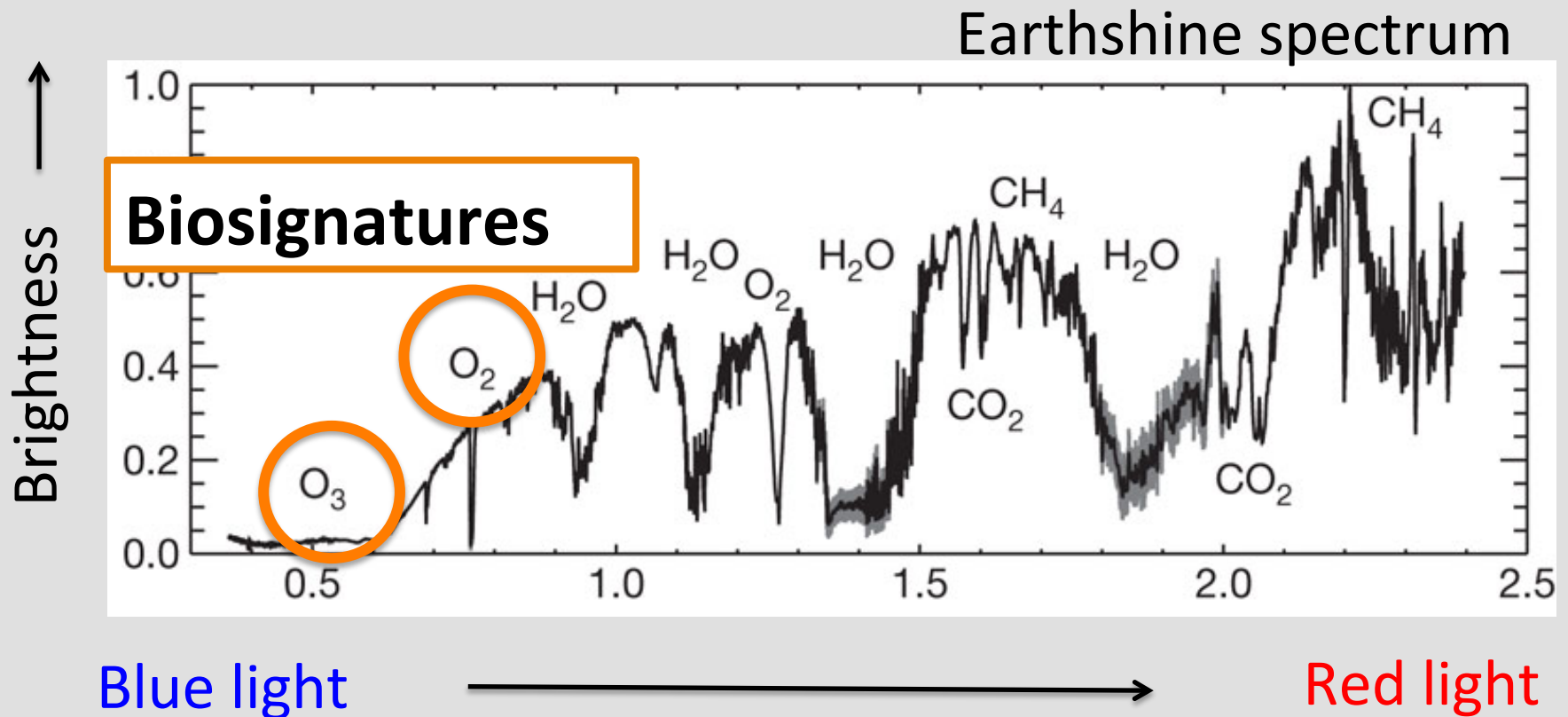
Predicted planet yield: 500 Earths and super-Earths

20 rocky habitable-zone planets

Part III: Launch the James Webb Space Telescope, Hubble's successor



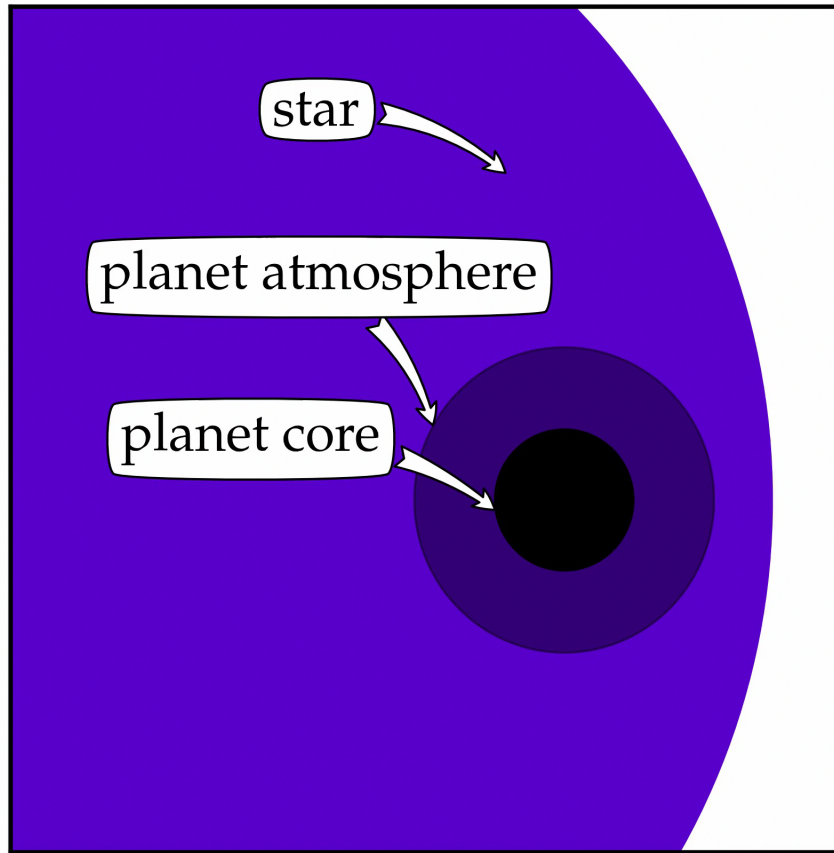
James Webb will detect biosignatures on Earth-like planets



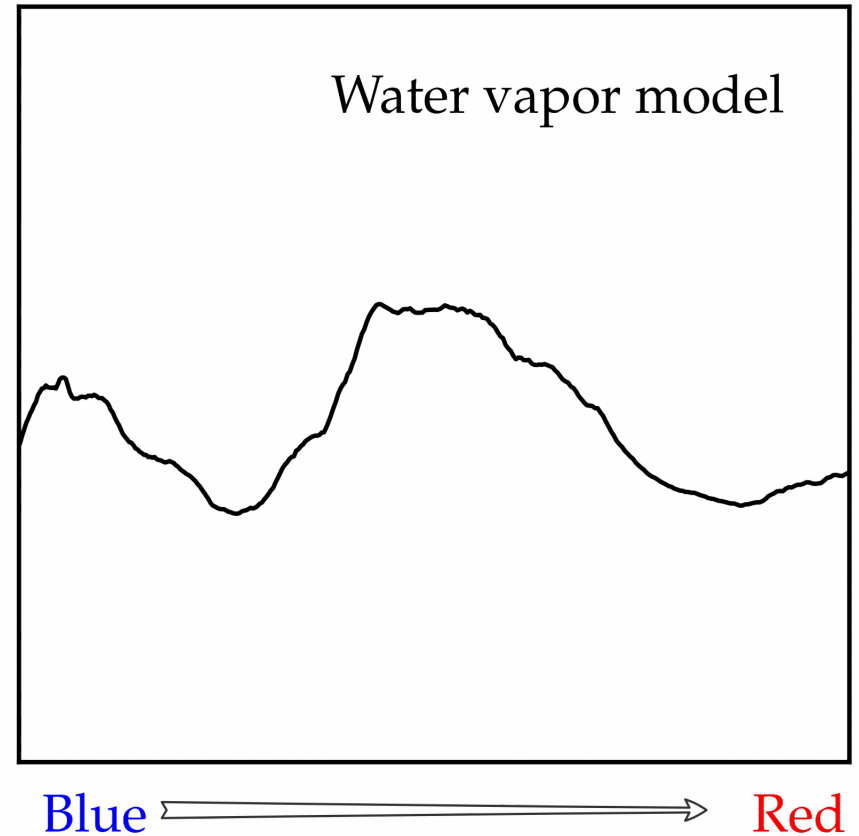


Extra Slides

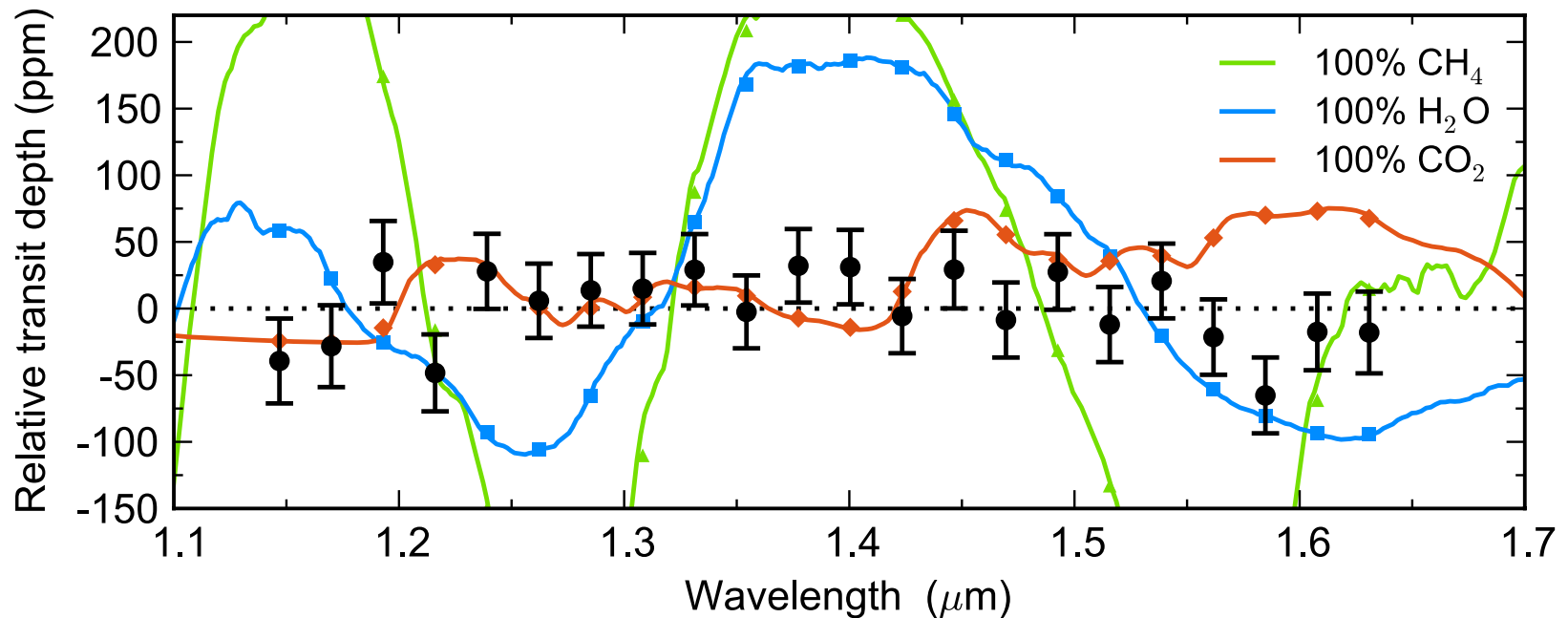
How to See an Exoplanet Atmosphere: Transmission Spectroscopy



Fraction of starlight blocked \uparrow



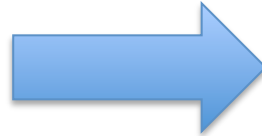
The Cutting Edge of Transmission Spectroscopy: Clouds in the Atmosphere of the Super-Earth GJ 1214b



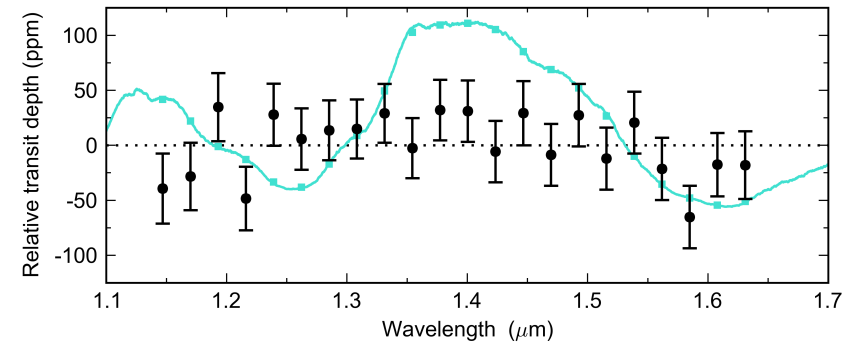
- There must be clouds in the planet's atmosphere to explain the data
- This definitive result was enabled by a high precision measurement using data from a record 3 days of Hubble Space Telescope time

The Future: Towards Earth-Like Exoplanets

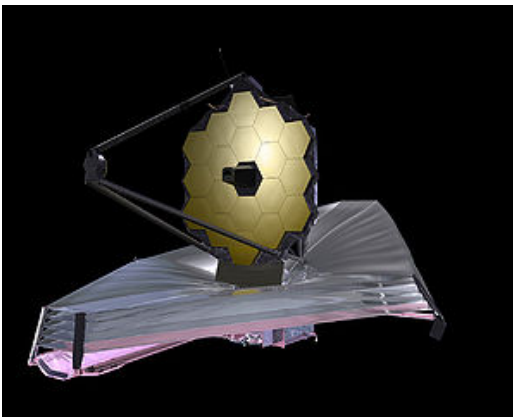
Hubble Space Telescope



GJ 1214b



James Webb Space Telescope



Earth 2.0

