Title: Exoplanets and the Search for Habitable Worlds

Date: Jan 26, 2011 07:00 PM

URL: http://www.pirsa.org/11010116

Abstract: For thousands of years people have wondered, "Are we alone?" Out of the 500 planets so far known to orbit nearby stars, about 100 transit their host stars, that is, the planet goes in front of its star as seen from Earth. The transiting planets are "goldmines" for astronomers, because the planetary sizes, masses, and atmospheres can be routinely measured. NASA's Kepler Space Telescope is further revolutionizing transiting exoplanet studies with its unprecedented photometric precision. Dr. Seager will share her unique insights as a member of the Kepler Science Team including a discussion of recent Kepler announcements. She will also share information on the pioneering technology development that will fuel the search for life on other worlds.

Exoplanets and the Search for Habitable Worlds

Professor Sara Seager
Massachusetts Institute of Technology

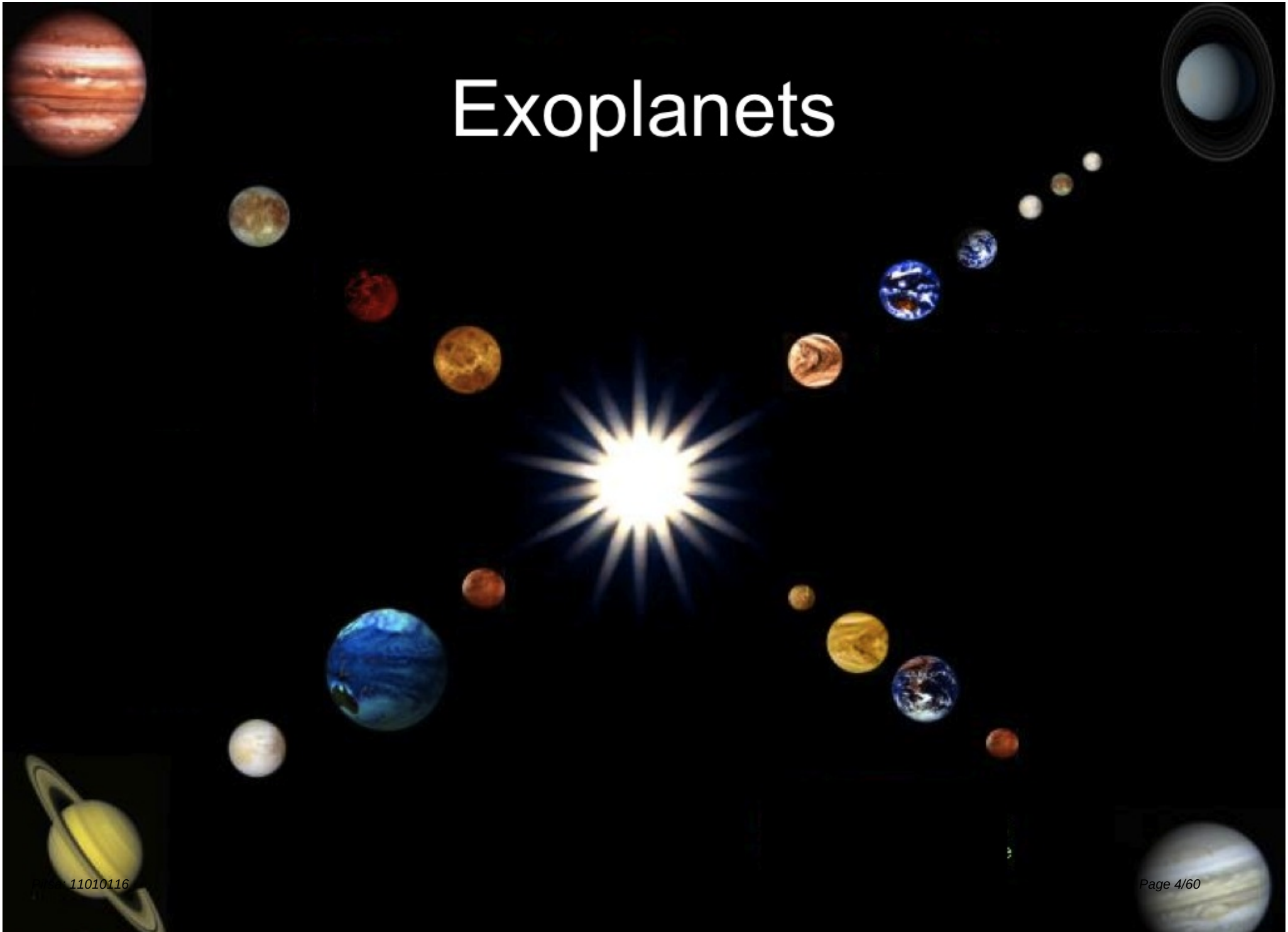
We want to be able to take our children, grandchildren, nieces, and nephews to a dark site and point to a sun-like star and tell them, “That star has a planet like Earth”.

Do you recognize this planet?

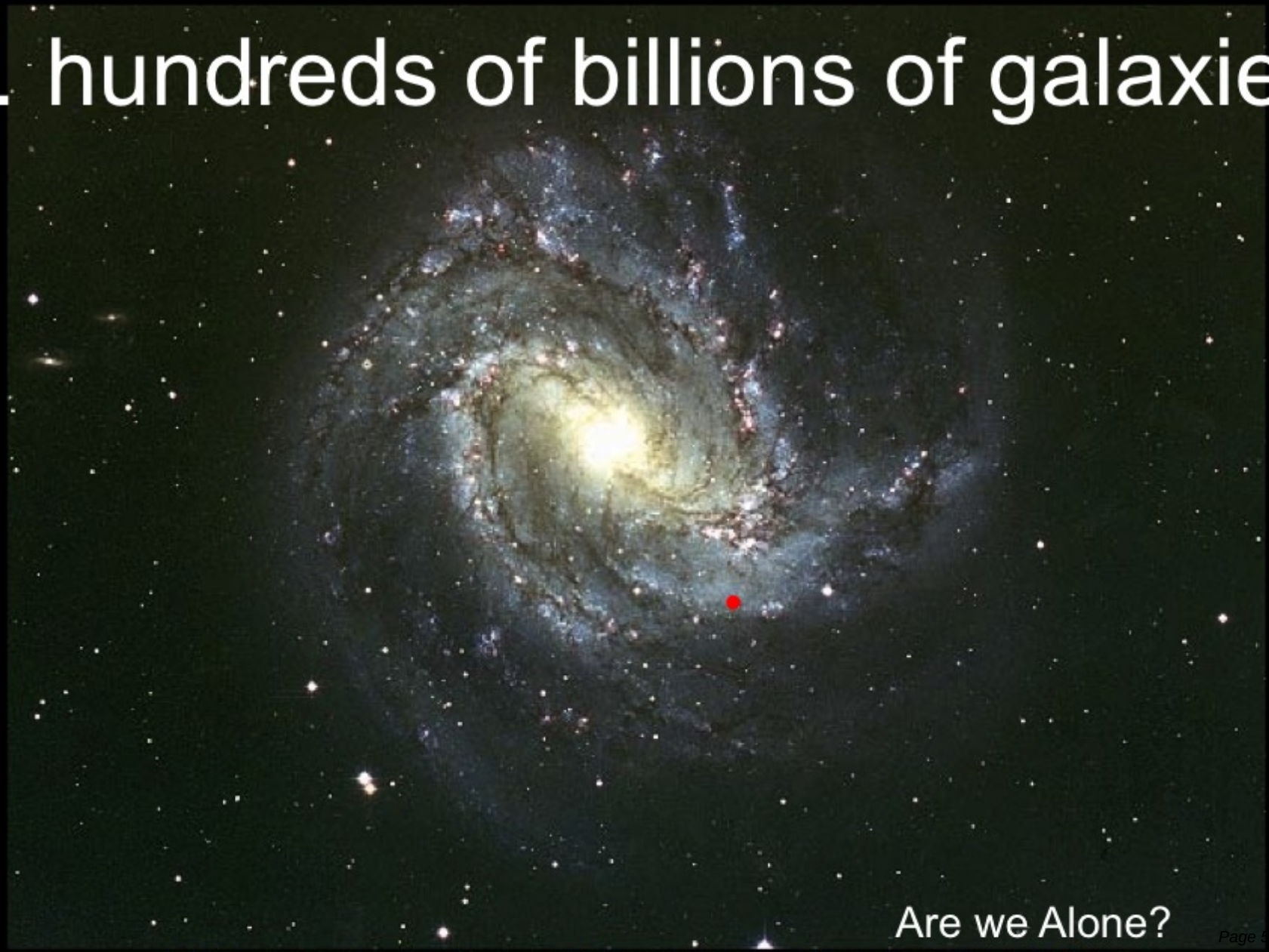
Sara Seager

Massachusetts Institute of Technology

Exoplanets



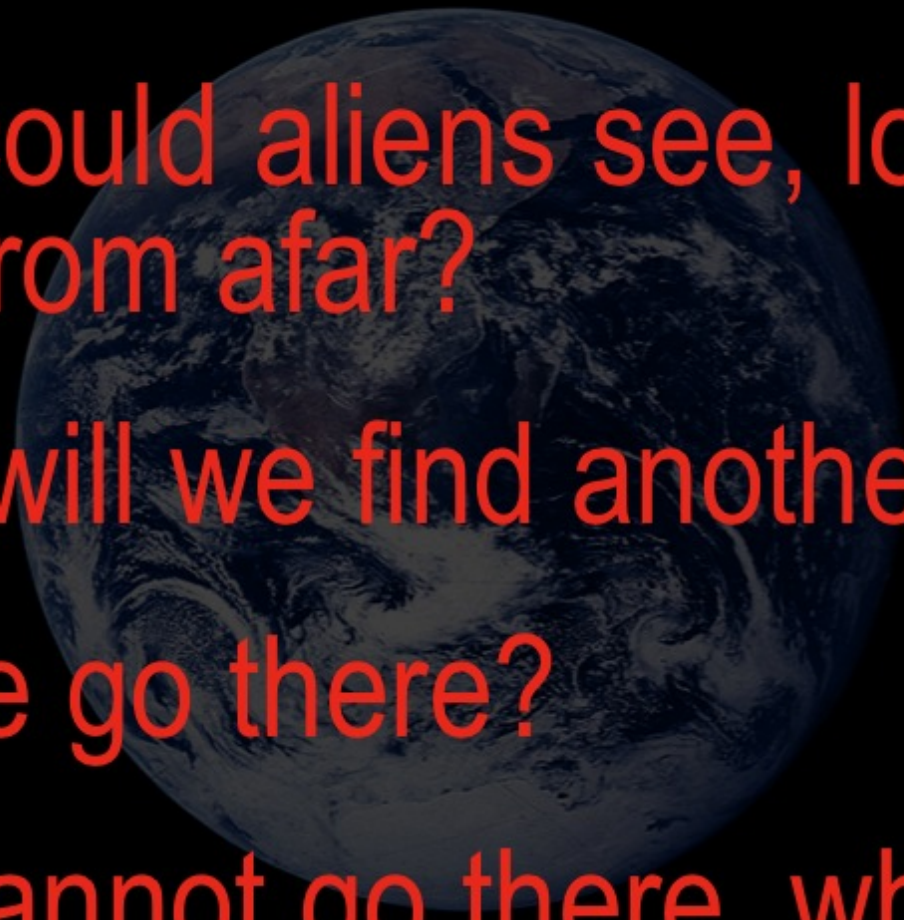
Hundreds of billions of stars …
… hundreds of billions of galaxies



Are we Alone?

M83 © Anglo-Australian Observatory Photo by David Malin

The Questions



What could aliens see, looking at Earth from afar?

When will we find another Earth?

Can we go there?

If we cannot go there, why look?

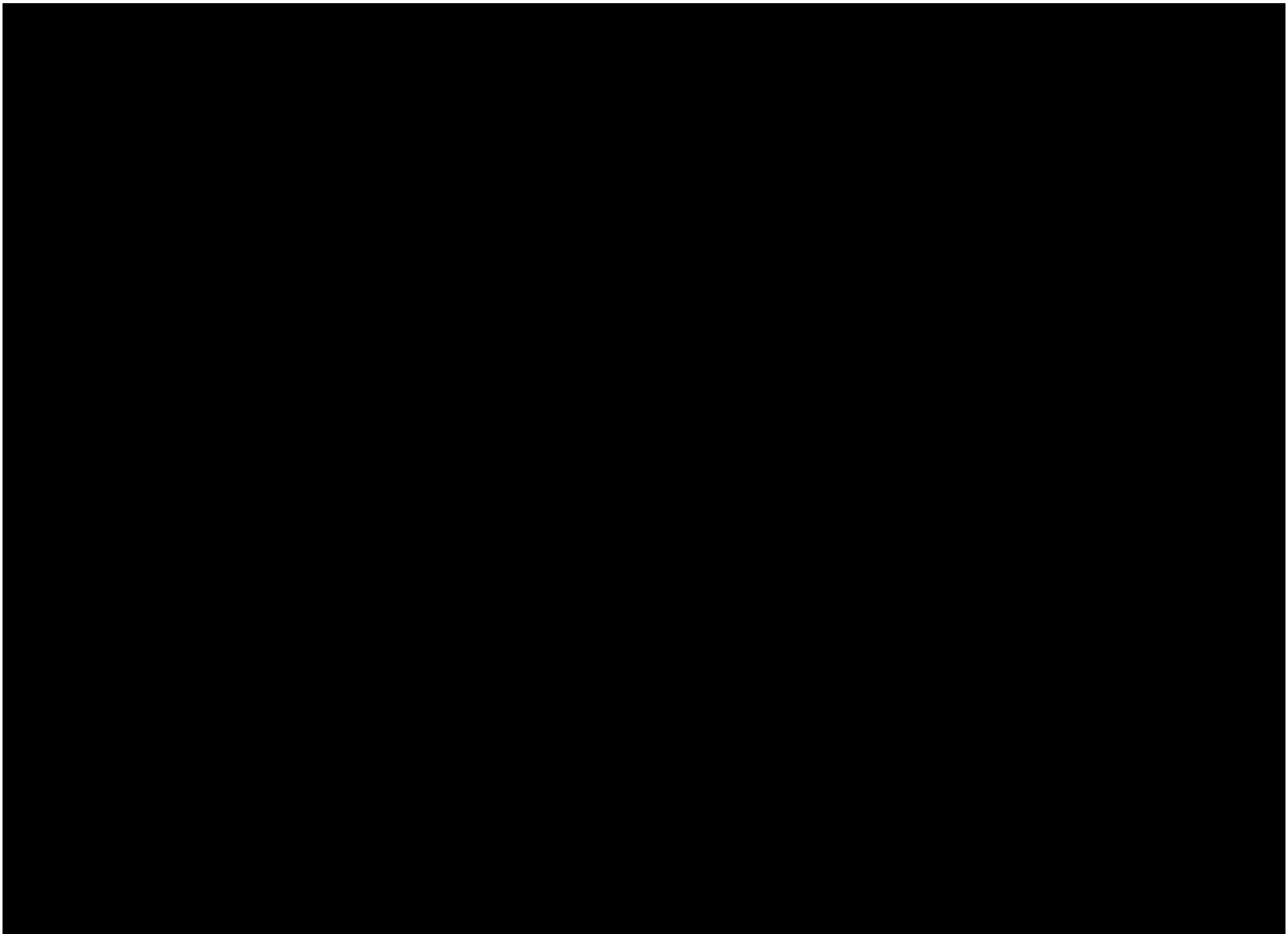
What could aliens see, looking at Earth from afar?

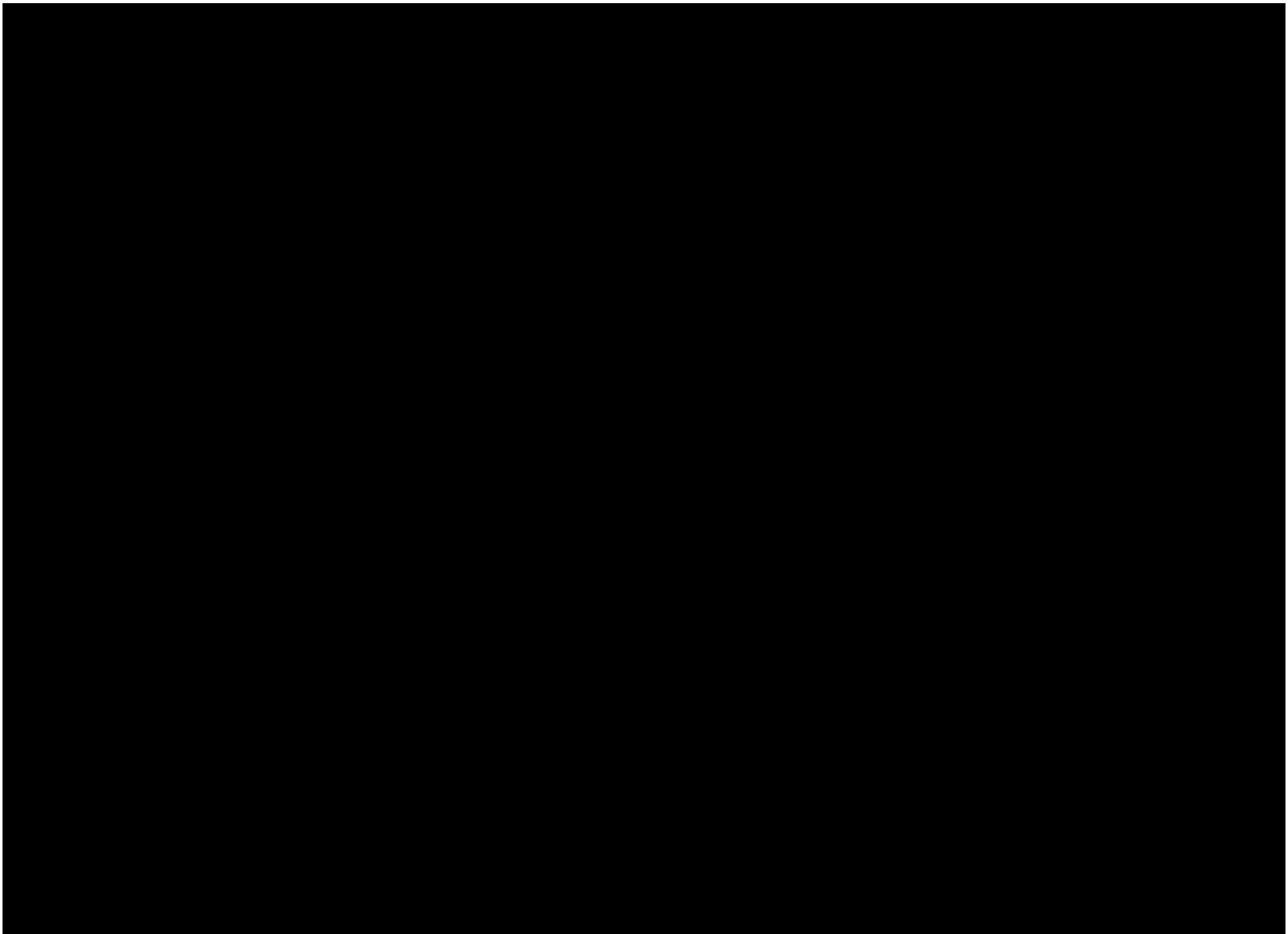
NASA/EPOXI PI: M. A’Hearn Deputy PI: D. Deming

EPOCh + DIXI + = EPOXI

Don Lindler/GSFC

http://www.nasa.gov/topics/solarsystem/features/epoxi_transit.html





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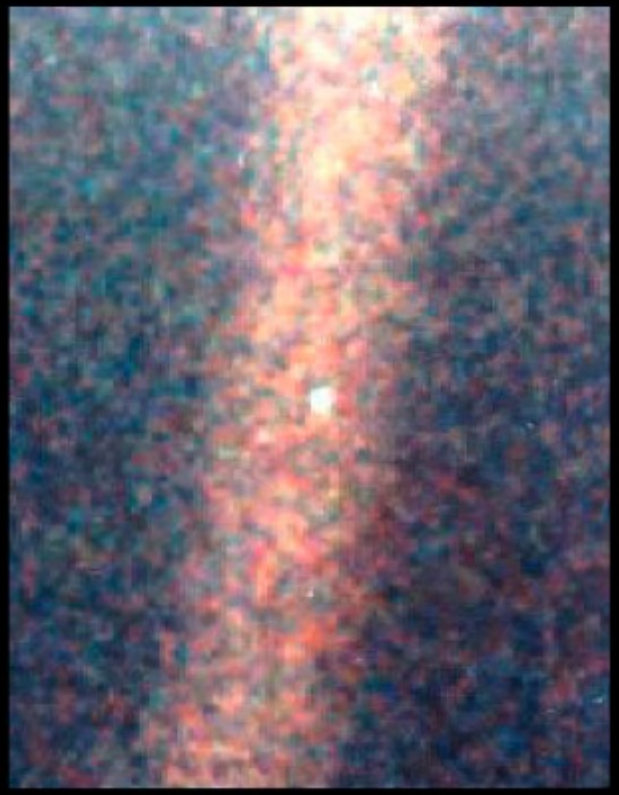
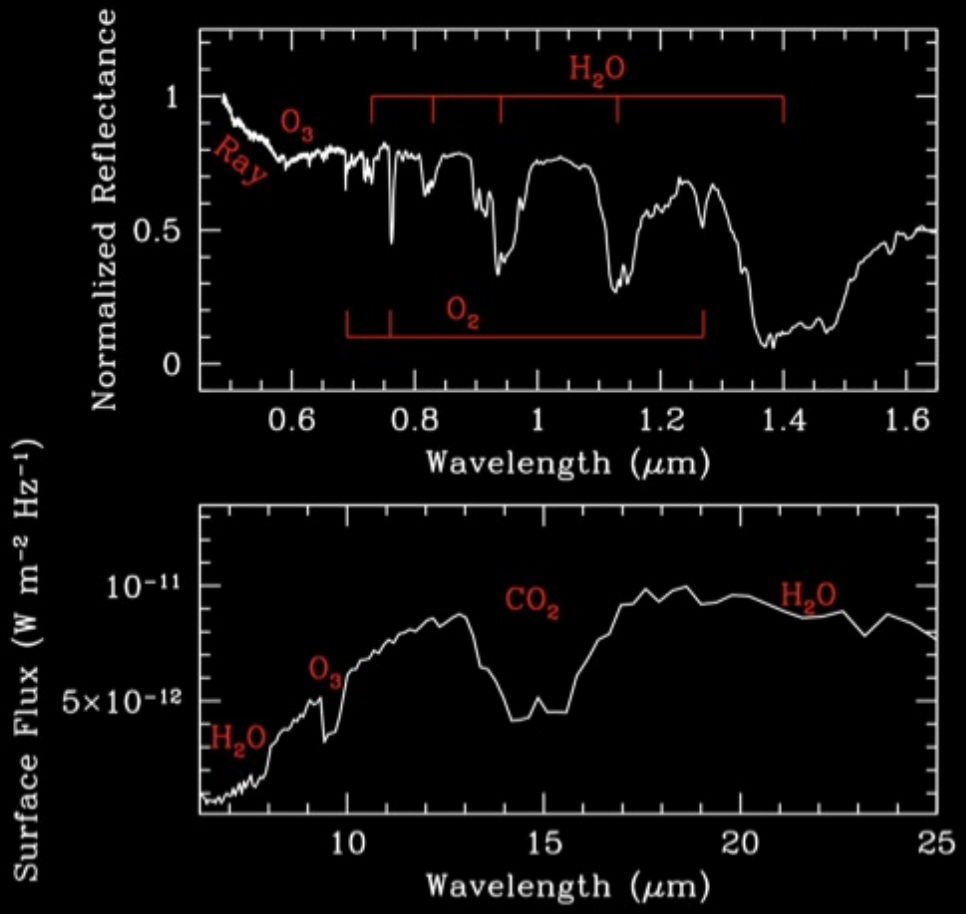
http://www.nasa.gov/topics/solarsystem/features/epoxi_transit.html

A Pale Blue Dot



We Aim to Measure Spectra

Earth's Spectrum



Turnbull et al. 2007

What would aliens see, looking at Earth from afar?

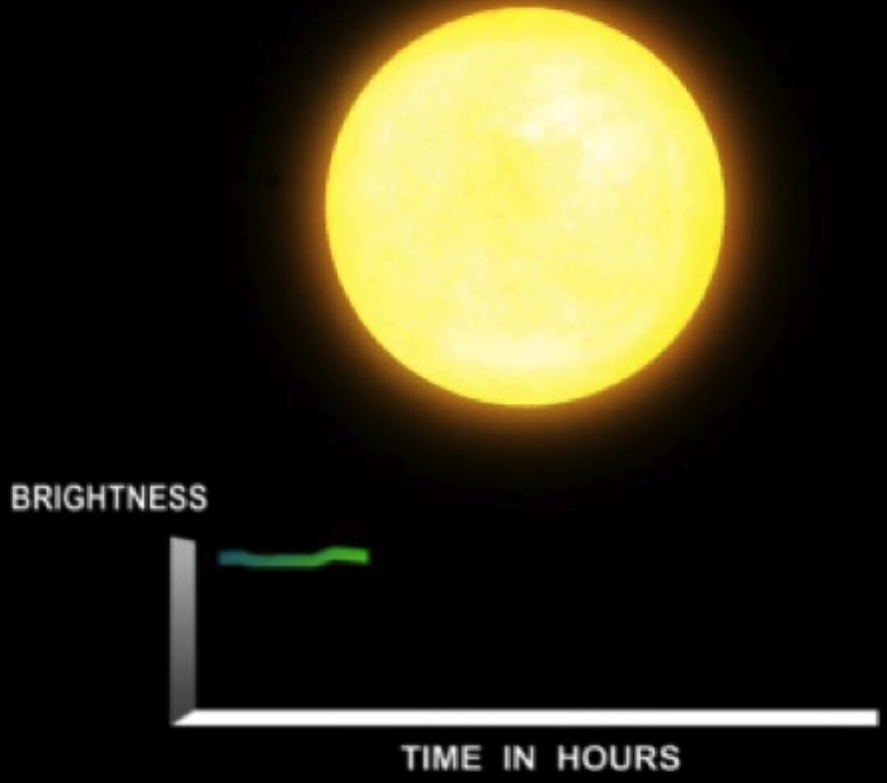
- A pale blue dot with brightness that varies with time
- An atmosphere that has water vapor, oxygen, ozone, and carbon dioxide


I WANT TO
BELIEVE

When will we find another Earth?


Search
for other earths
Direct imaging: 10^{-10}
Transiting Earth: 10^{-4}
Transiting super Earth around a small star: 10^{-3}
© National Geographic used with permission

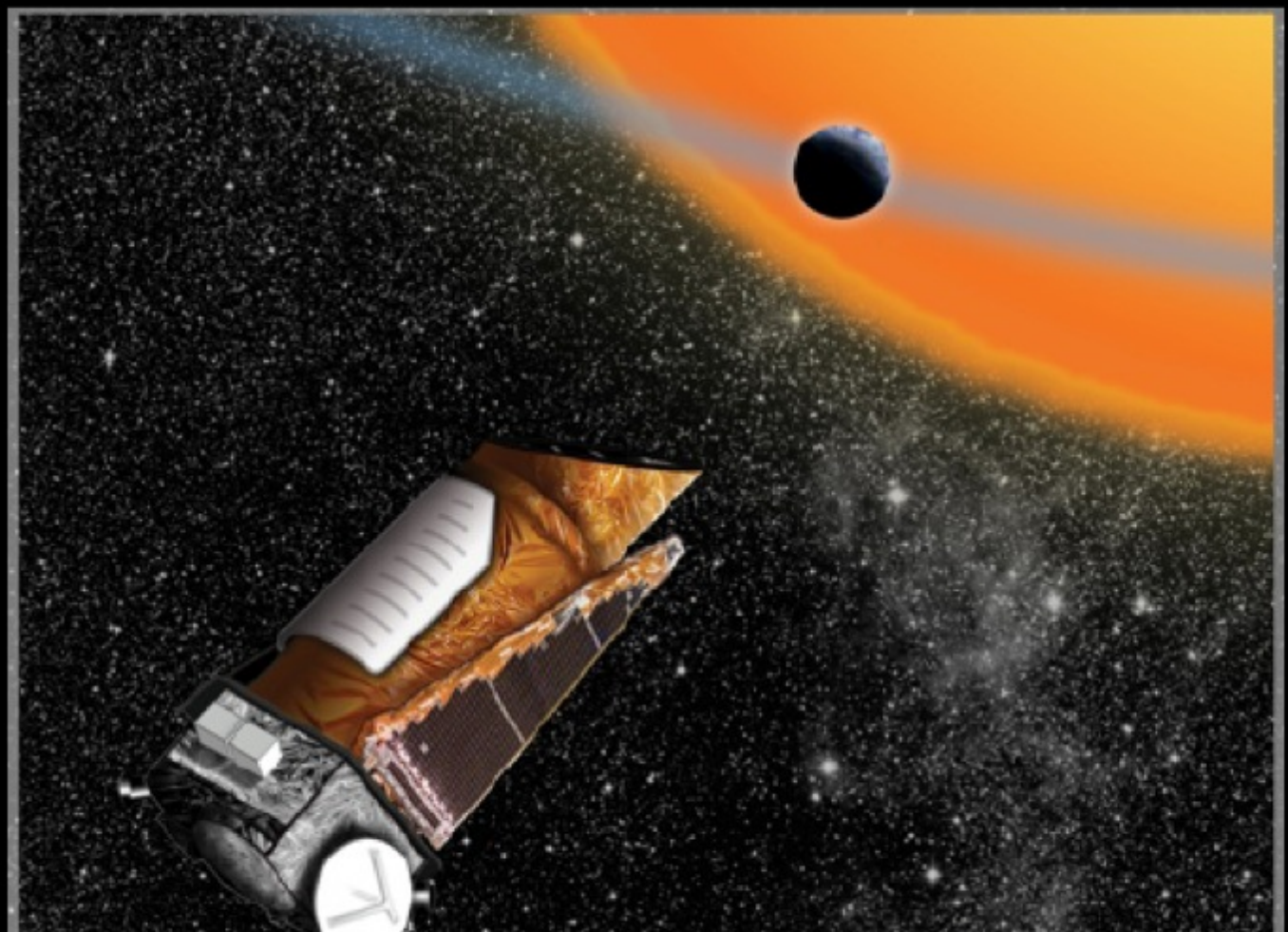
Transiting Planets

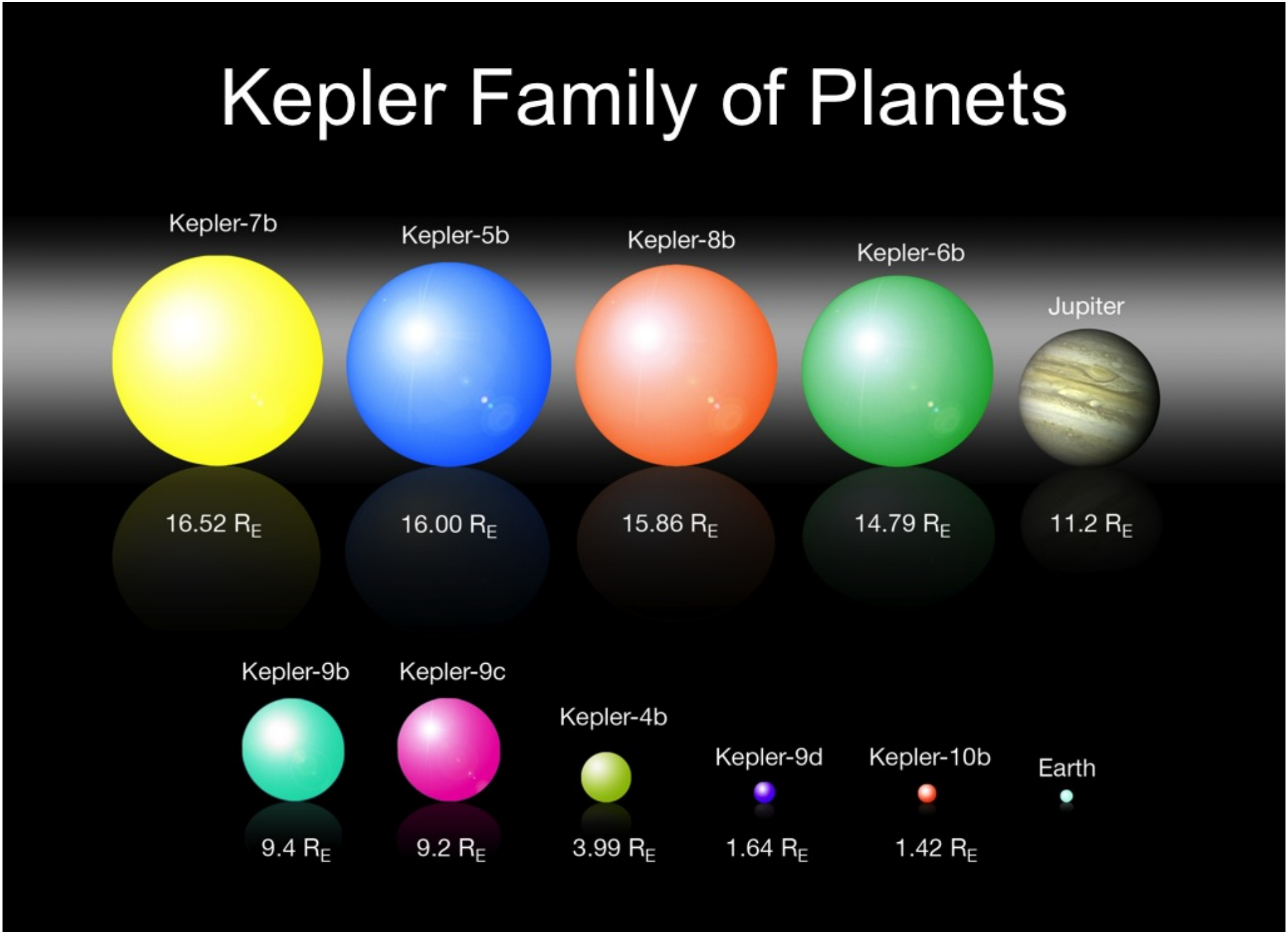


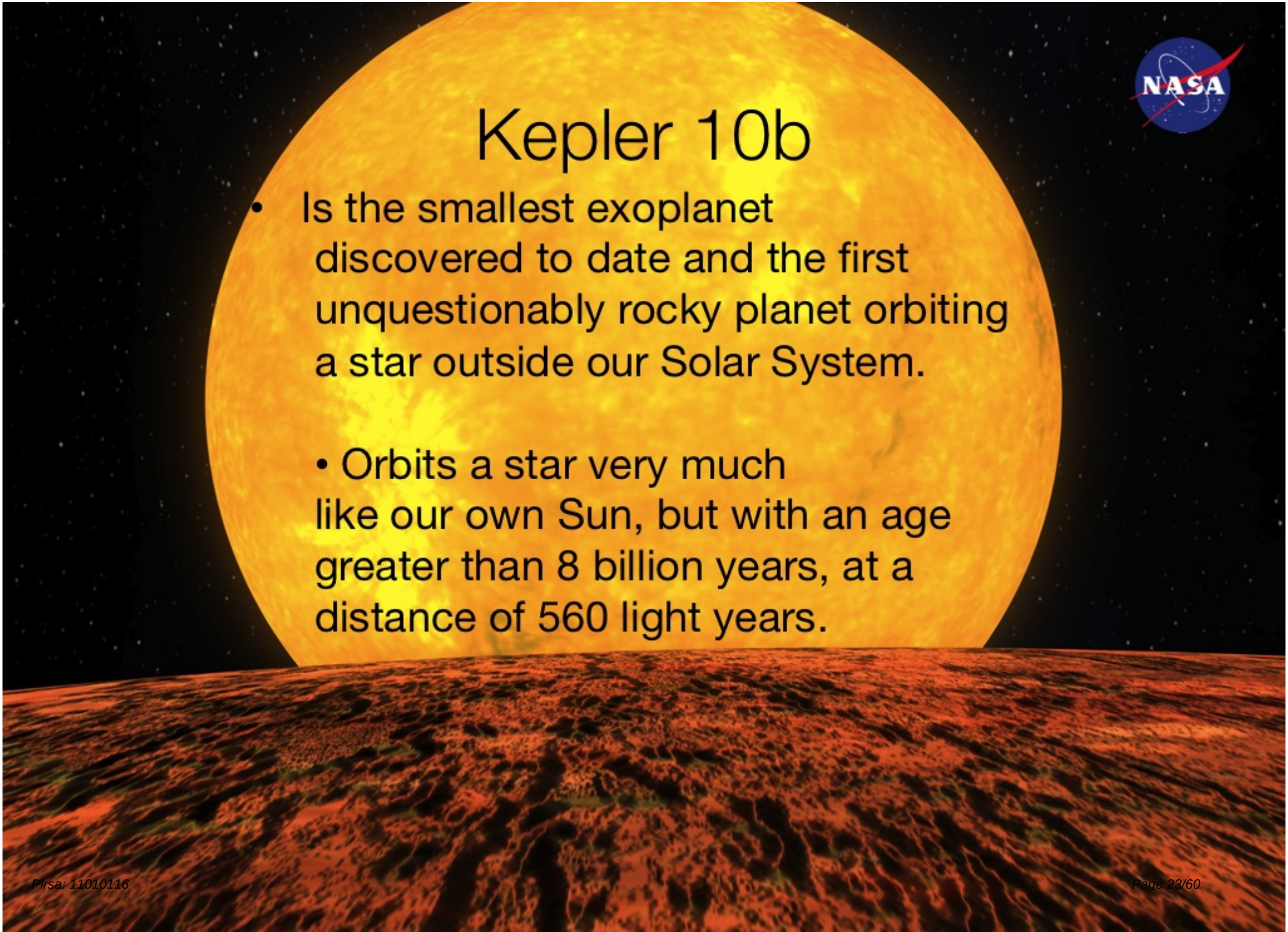
Animation credit: NASA

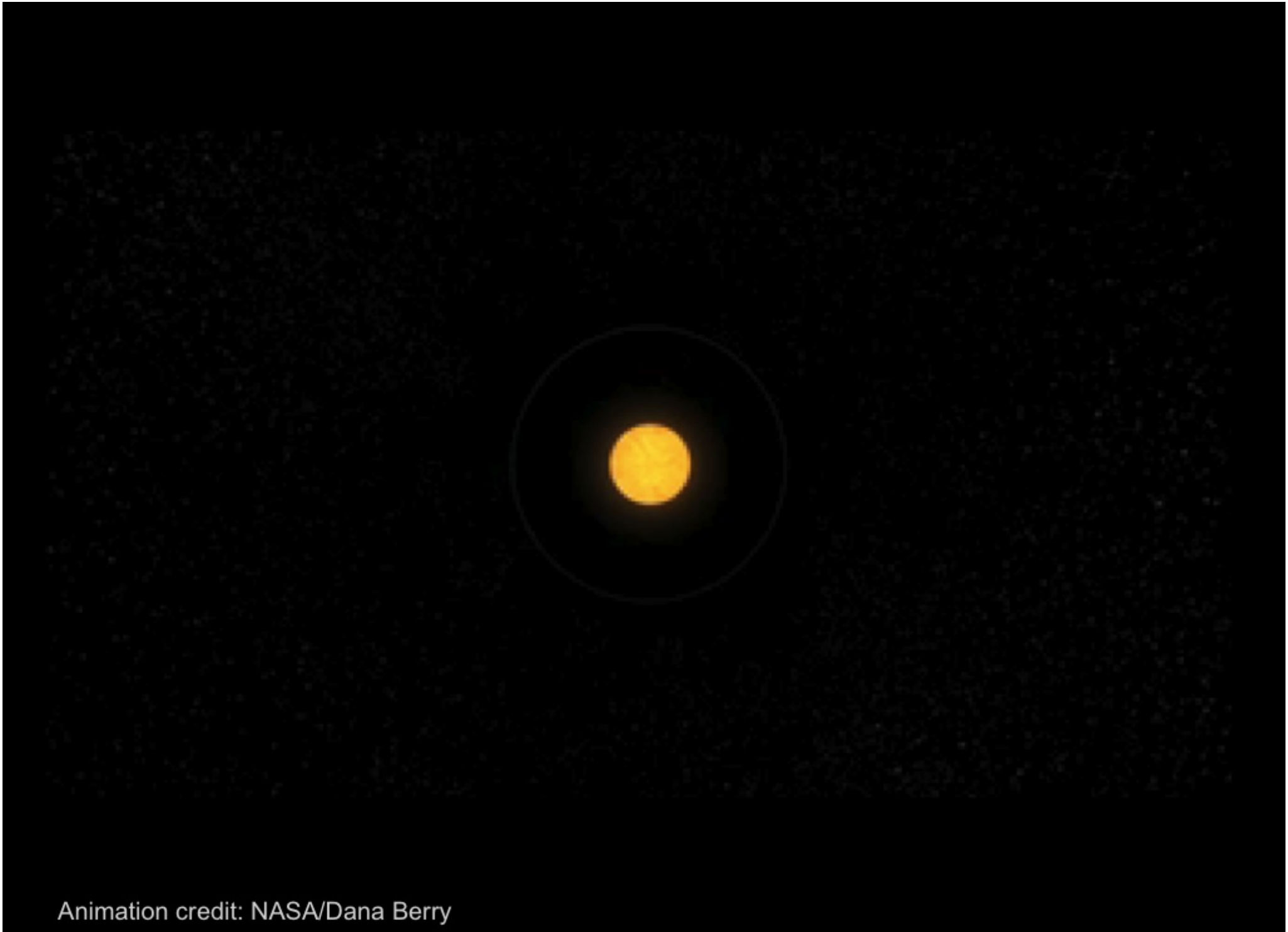
March 6, 2009

NASA's Kepler Space Telescope will determine the frequency of Earth-size planets in or near the habitable zone of Sun-like stars

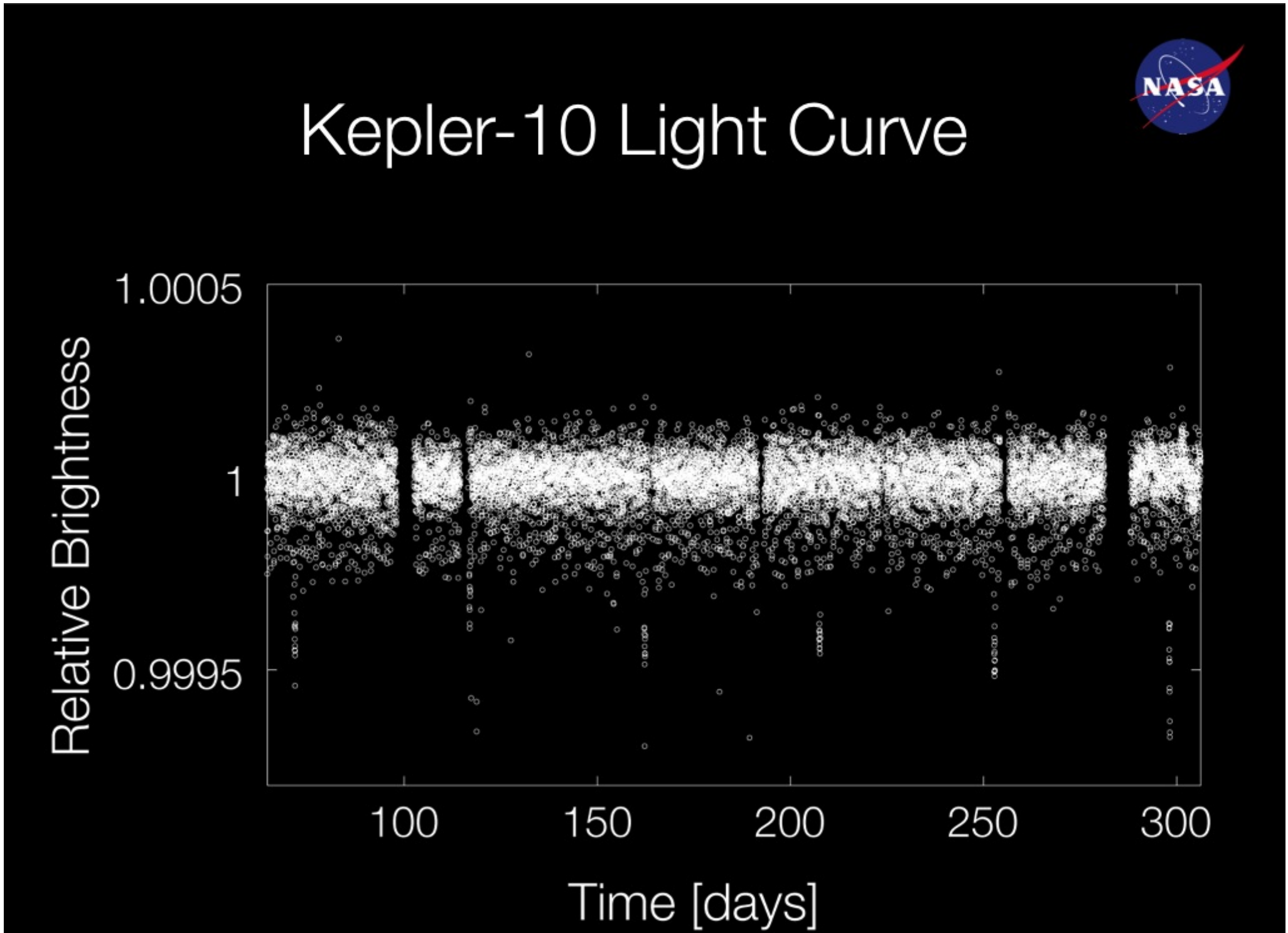


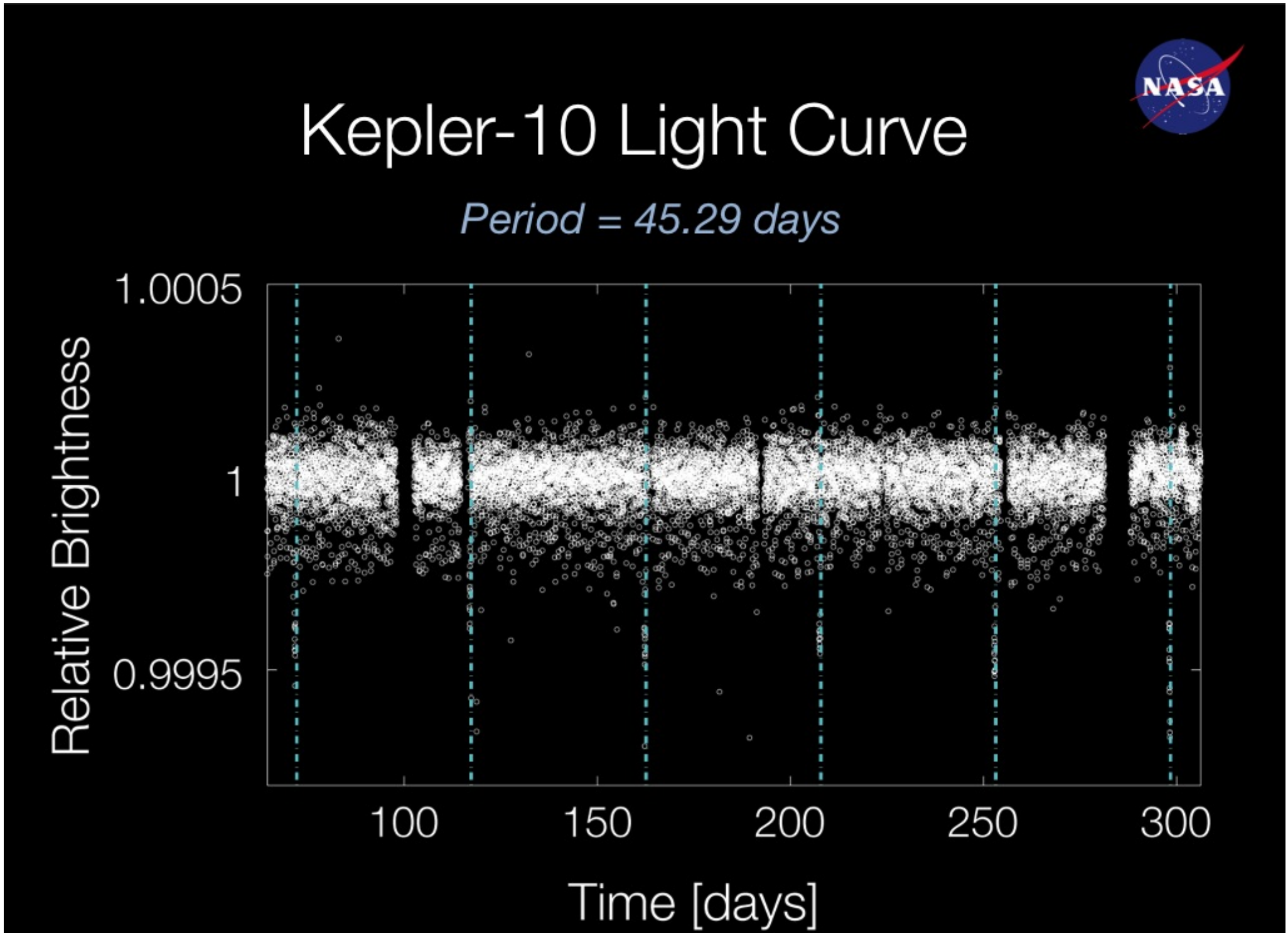

Kepler Family of Planets
Kepler-7b
16.52 R_E
Kepler-5b
16.00 R_E
Kepler-8b
15.86 R_E
Kepler-6b
14.79 R_E
Jupiter
11.2 R_E
Kepler-9b
9.4 R_E
Kepler-9c
9.2 R_E
Kepler-4b
3.99 R_E
Kepler-9d
1.64 R_E
Kepler-10b
1.42 R_E
Earth

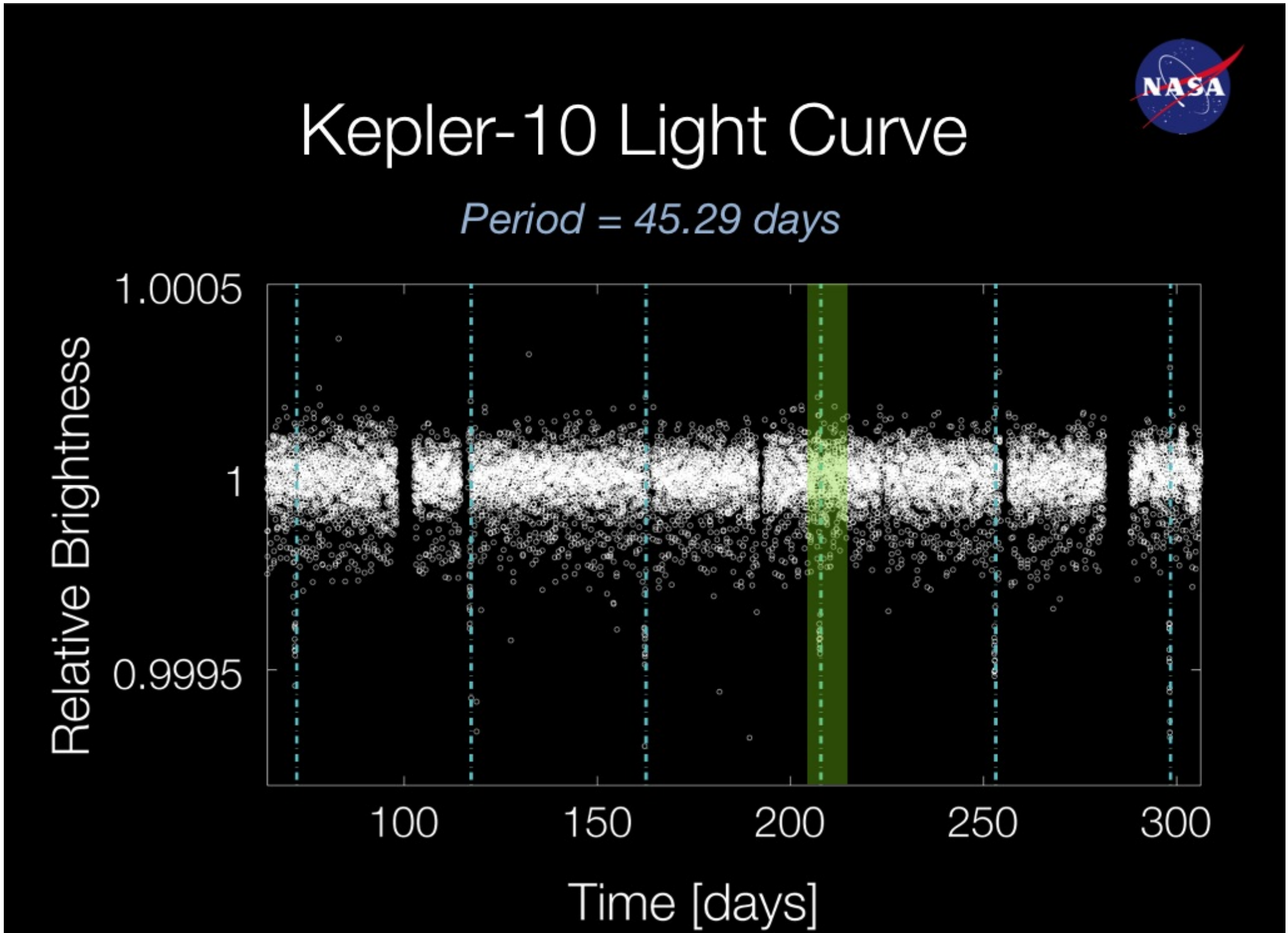

Kepler 10b
• Is the smallest exoplanet discovered to date and the first unquestionably rocky planet orbiting a star outside our Solar System.
• Orbits a star very much like our own Sun, but with an age greater than 8 billion years, at a distance of 560 light years.

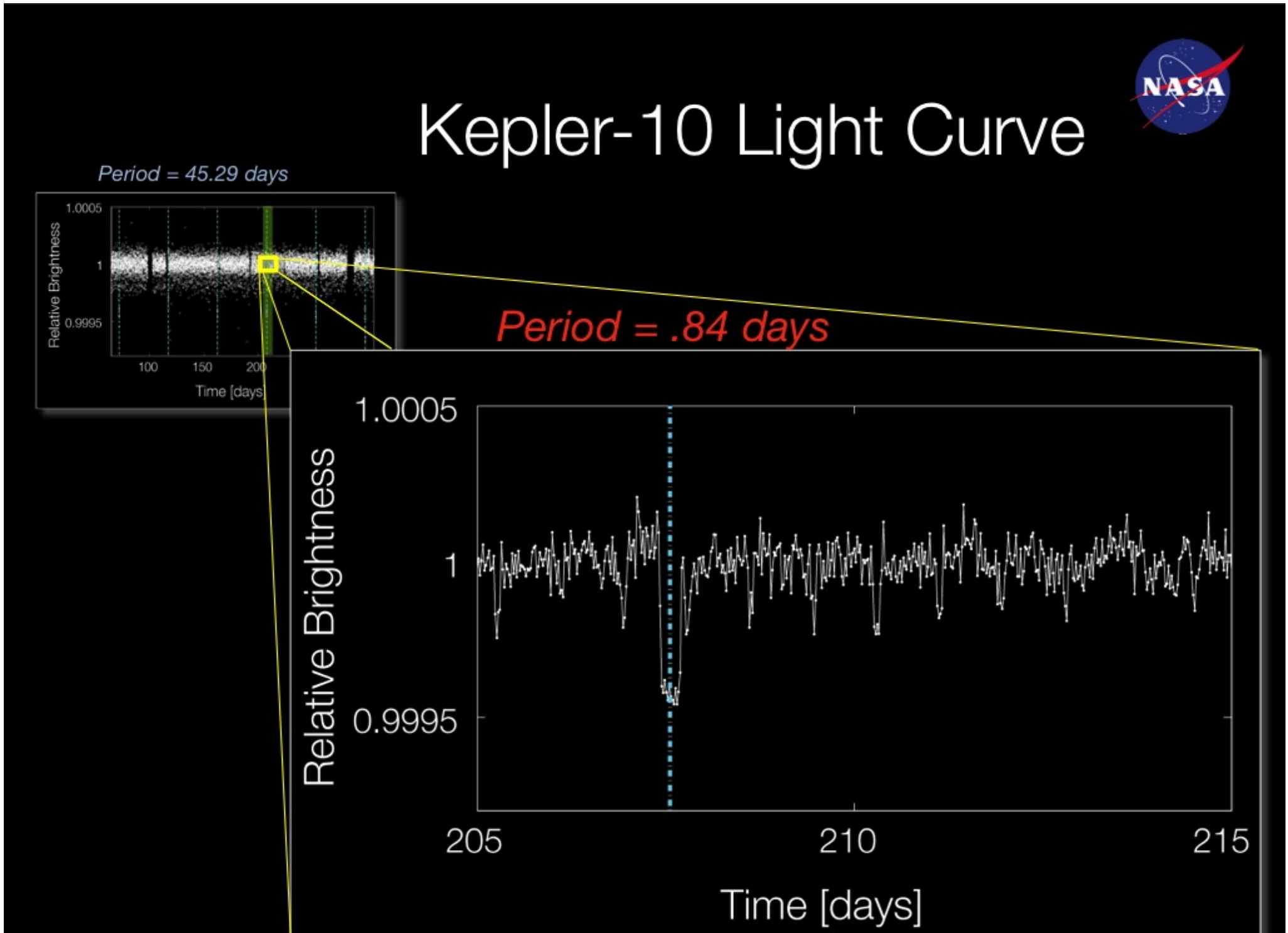


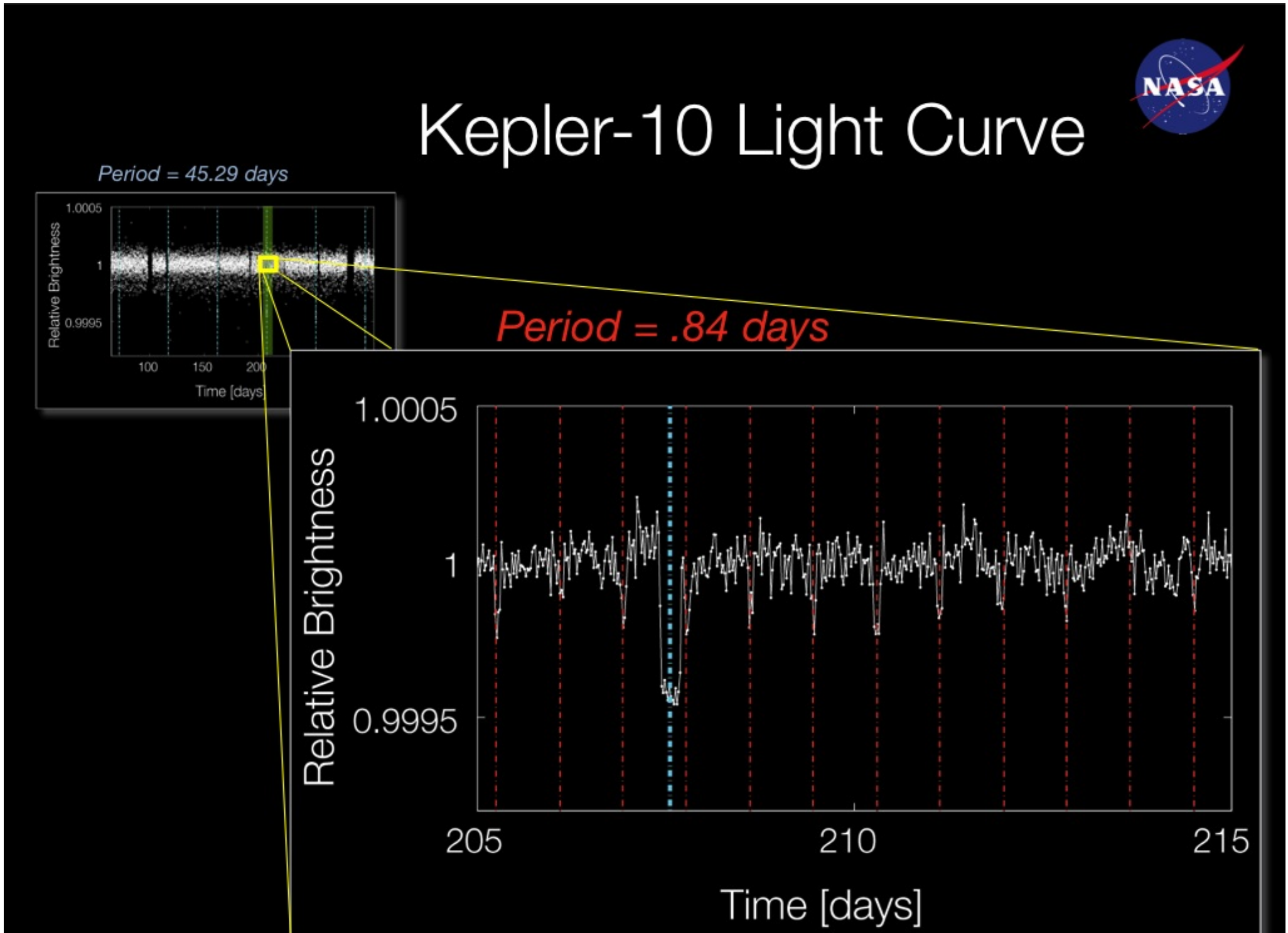
Animation credit: NASA/Dana Berry


Kepler-10 Light Curve
NASA
1.0005
1
0.9995
Relative Brightness
100
150
200
250
300
Time [days]

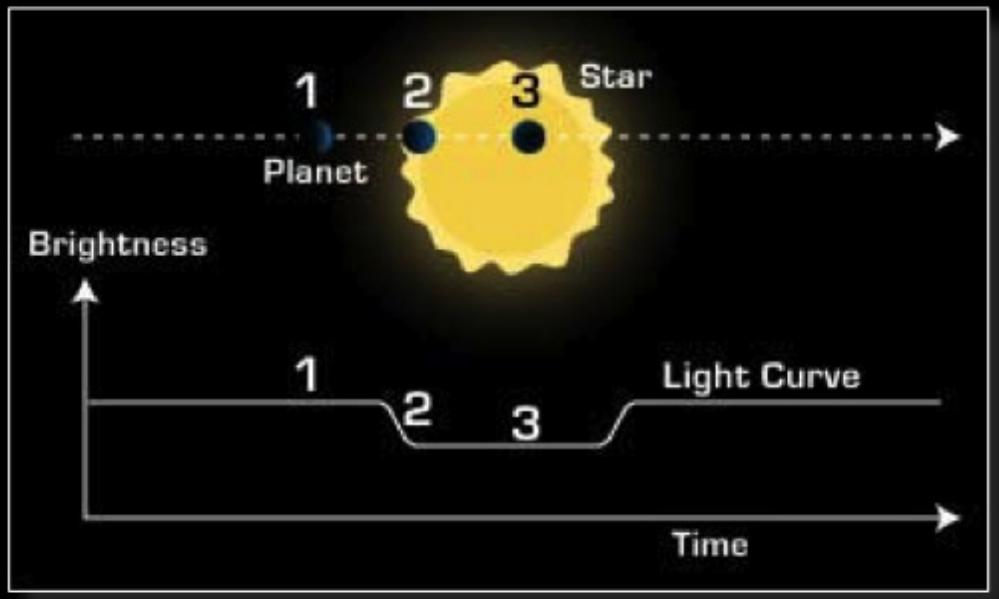

Kepler-10 Light Curve
Period = 45.29 days
1.0005
1
0.9995
Relative Brightness
100
150
200
250
300
Time [days]

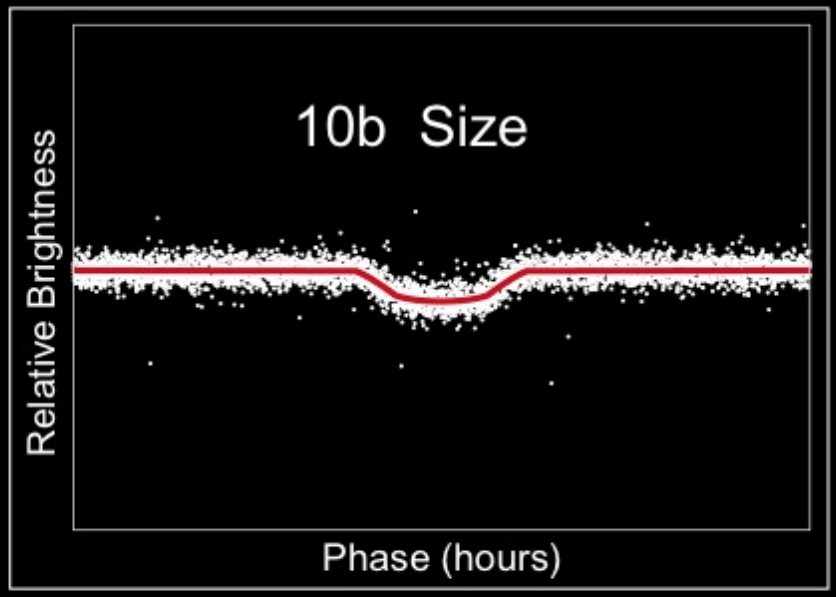

Kepler-10 Light Curve
Period = 45.29 days
1.0005
1
0.9995
Relative Brightness
100
150
200
250
300
Time [days]


Kepler-10 Light Curve
Period = 45.29 days
1.0005
1
0.9995
Relative Brightness
100
150
200
Time [days]
Period = .84 days
1.0005
1
0.9995
Relative Brightness
205
210
215
Time [days]


Kepler-10 Light Curve
NASA
Period = 45.29 days
1.0005
1
0.9995
Relative Brightness
100
150
200
Time [days]
Period = .84 days
1.0005
1
0.9995
Relative Brightness
205
210
215
Time [days]

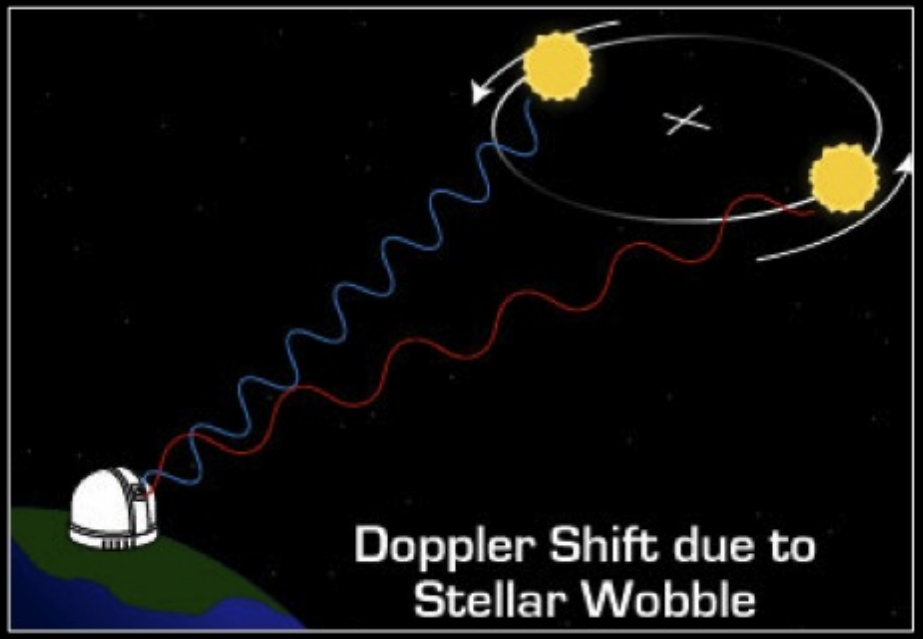
Transit Yields Planet Radius

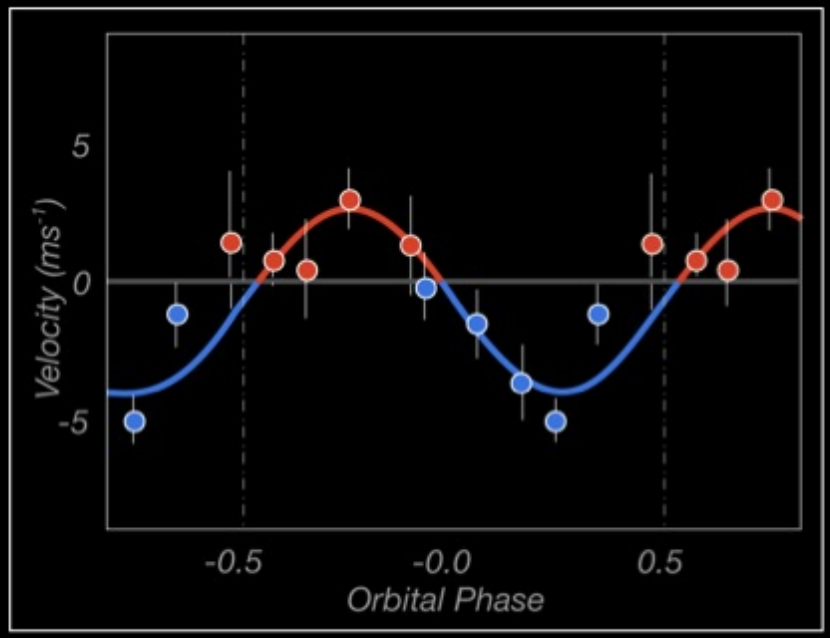




Radius = 1.4 $R_{\oplus}$

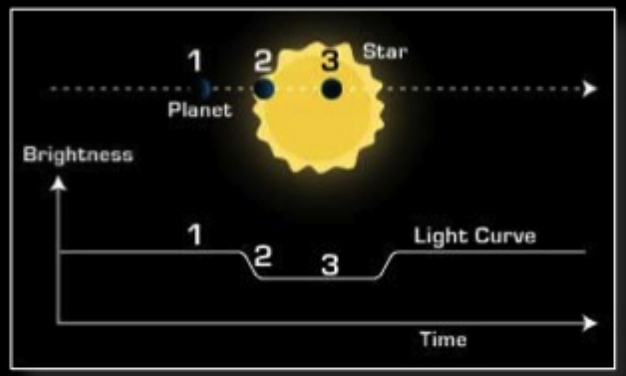
Doppler Measurements Yield Planet Mass





Mass = 4.6 $M_{\oplus}$

Transit and Doppler Measurements Yield Density



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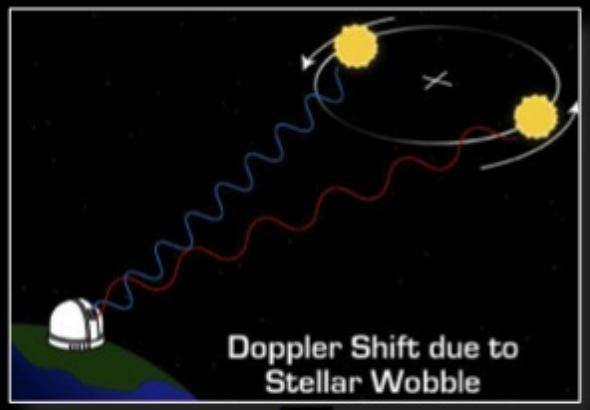
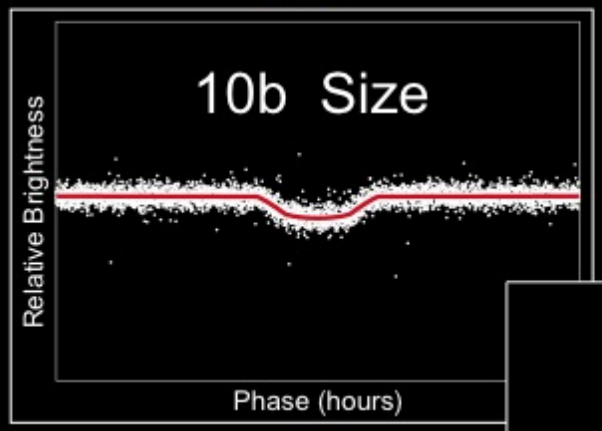
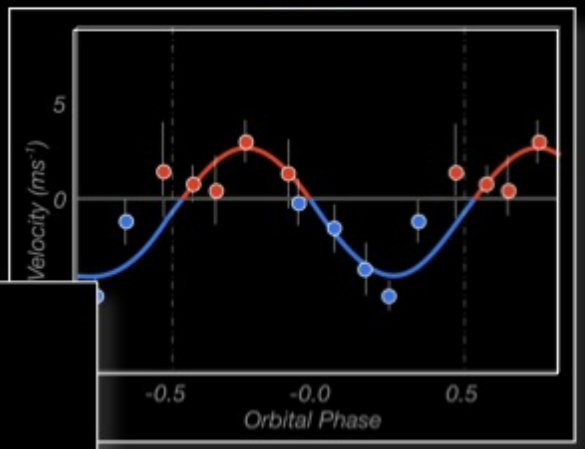


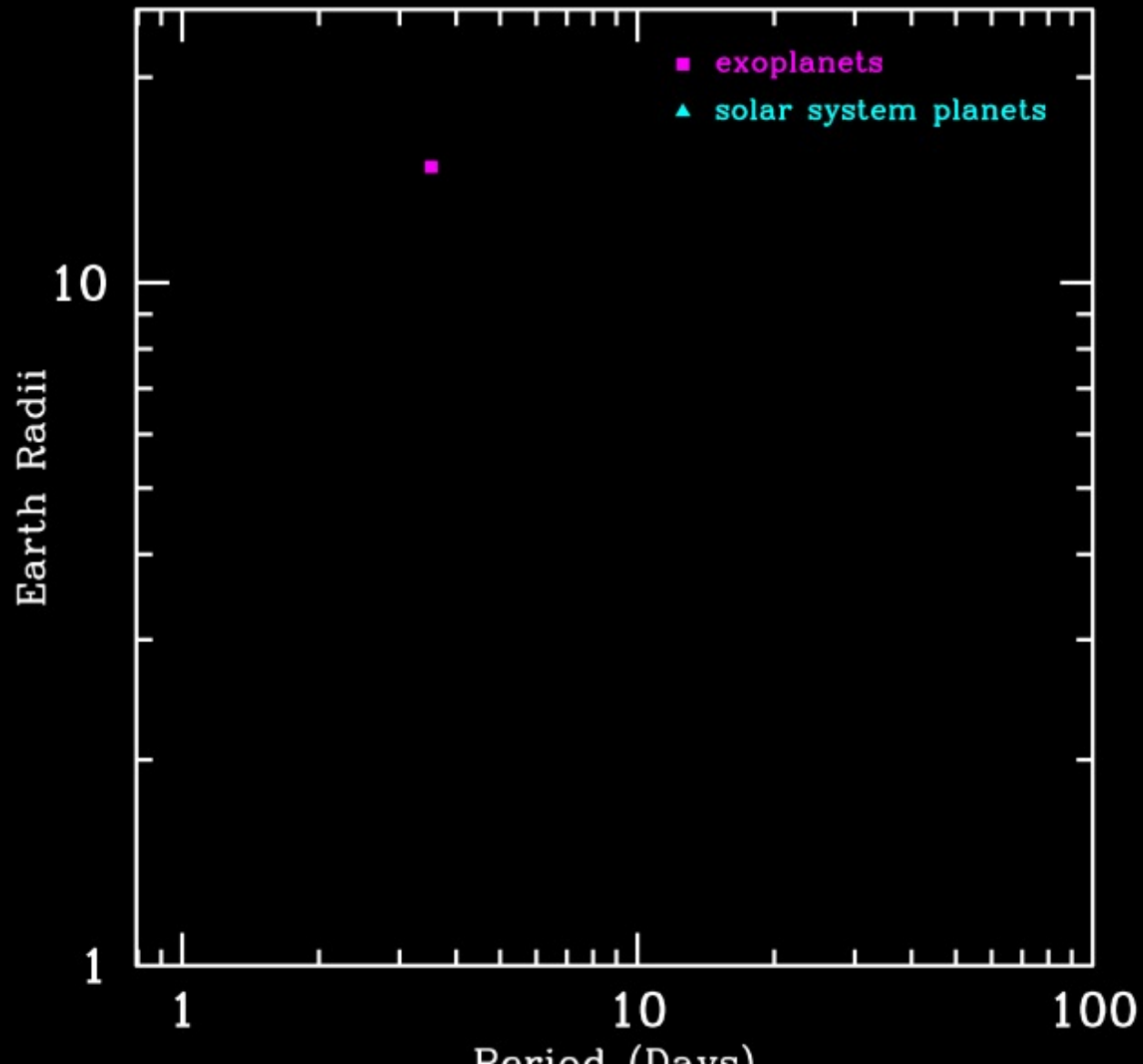




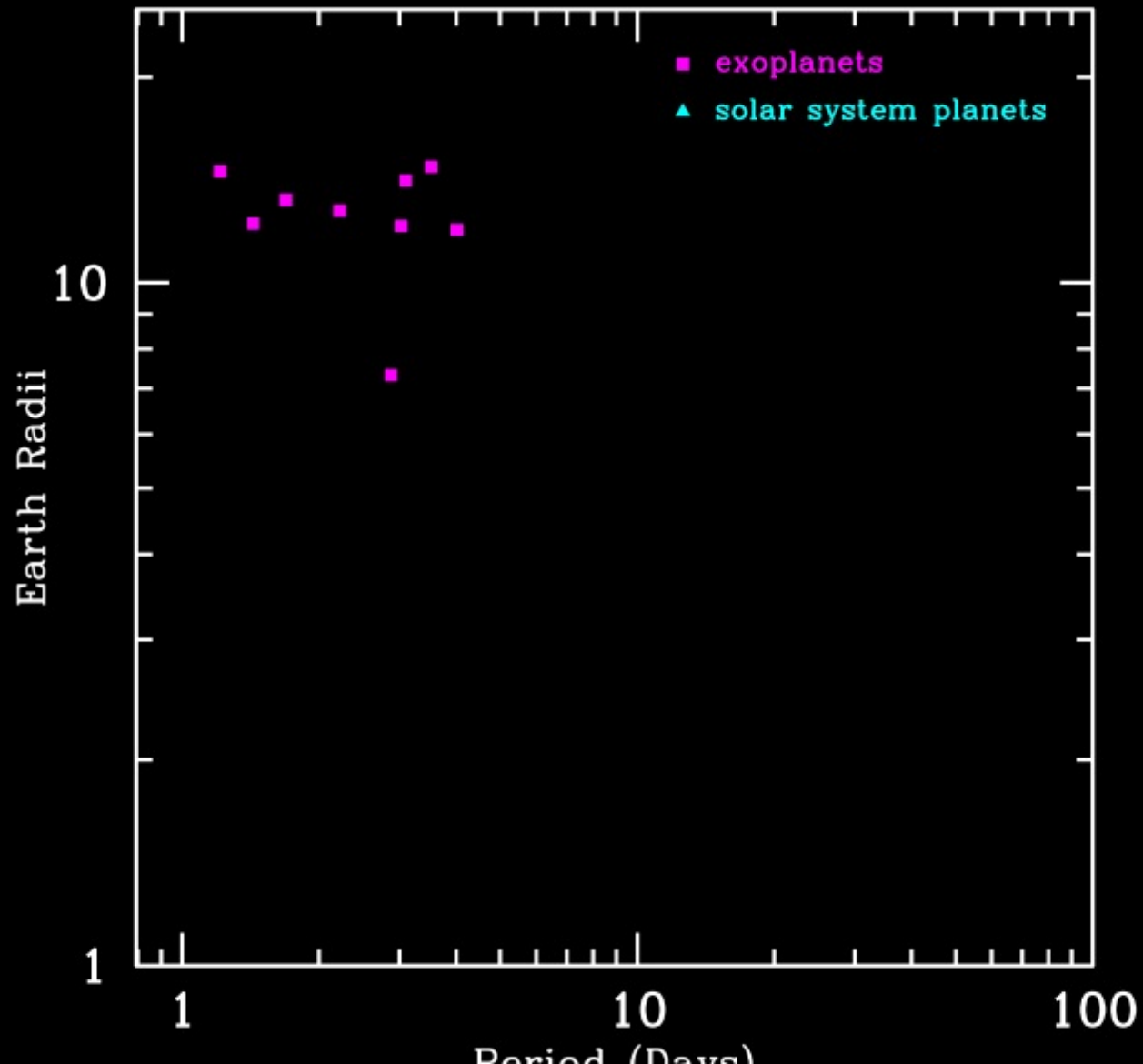
Density

$$\frac{\text{Mass}}{\text{Volume}} = 8.8\ \text{g/cm}^3$$

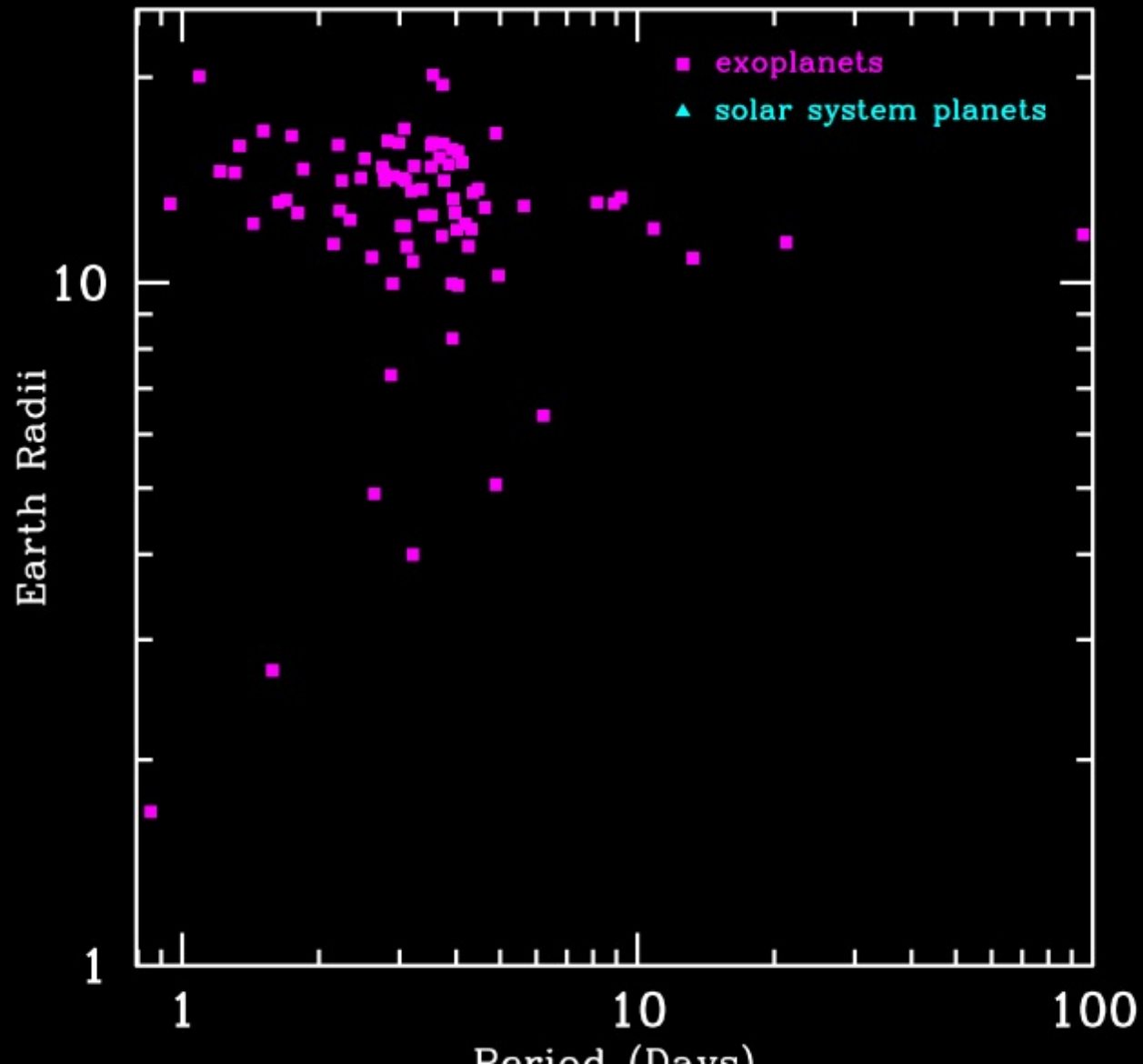
Transiting Planets 2000



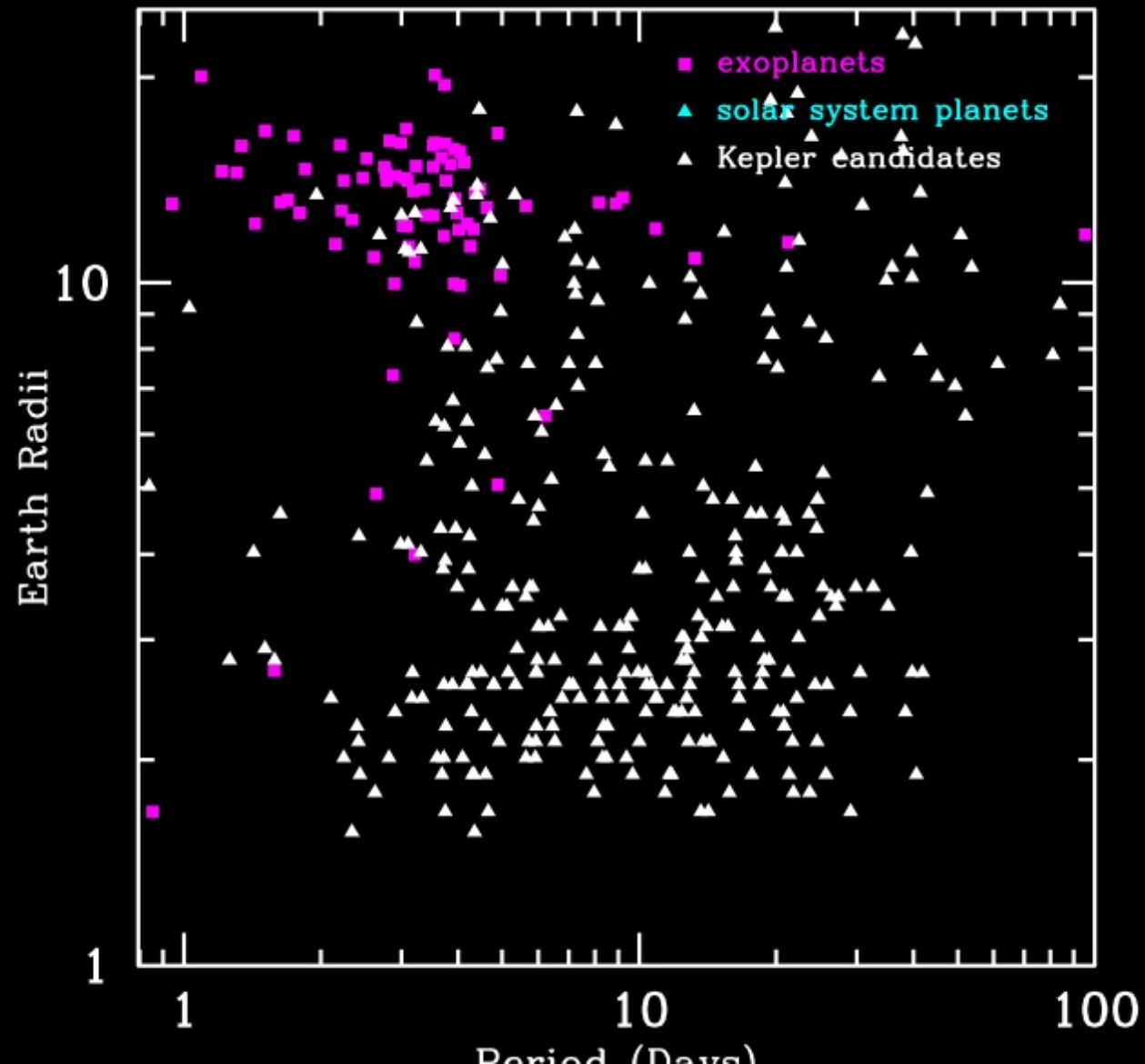
Transiting Planets 2005



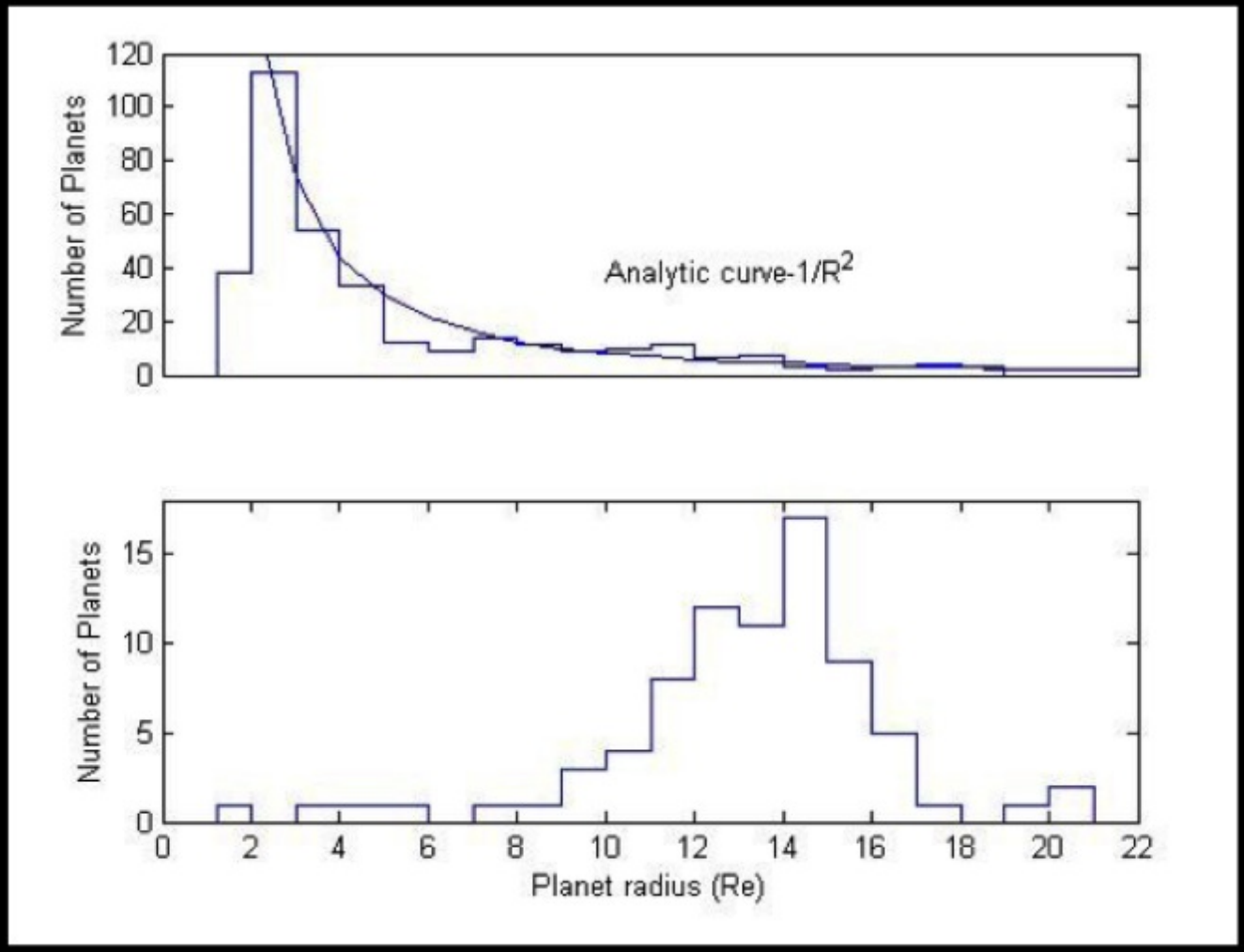
Transiting Planets June 14 2010



Transiting Planet Candidates
June 15 2010



Number of Planet Candidates



Big planets are easier to detect than smaller planets

Kepler has shonw that Neptune size planets are commonest

Borucki et al. 2010

Kepler Summary

- 10 stars with planets so far
- First rocky planet – a hot super Earth
- Kepler will change exoplanet science from individual objects to statistics
- Neptunes are common!
- Next week Feb. 1 data release

On track for the frequency of Earths before 2014

When will we find another Earth (in an Earth-like orbit)?

- Earth-size planet frequency < 3 years
- An Earth mass planet—if we are really lucky—within 4 years by the Doppler (wobble) method

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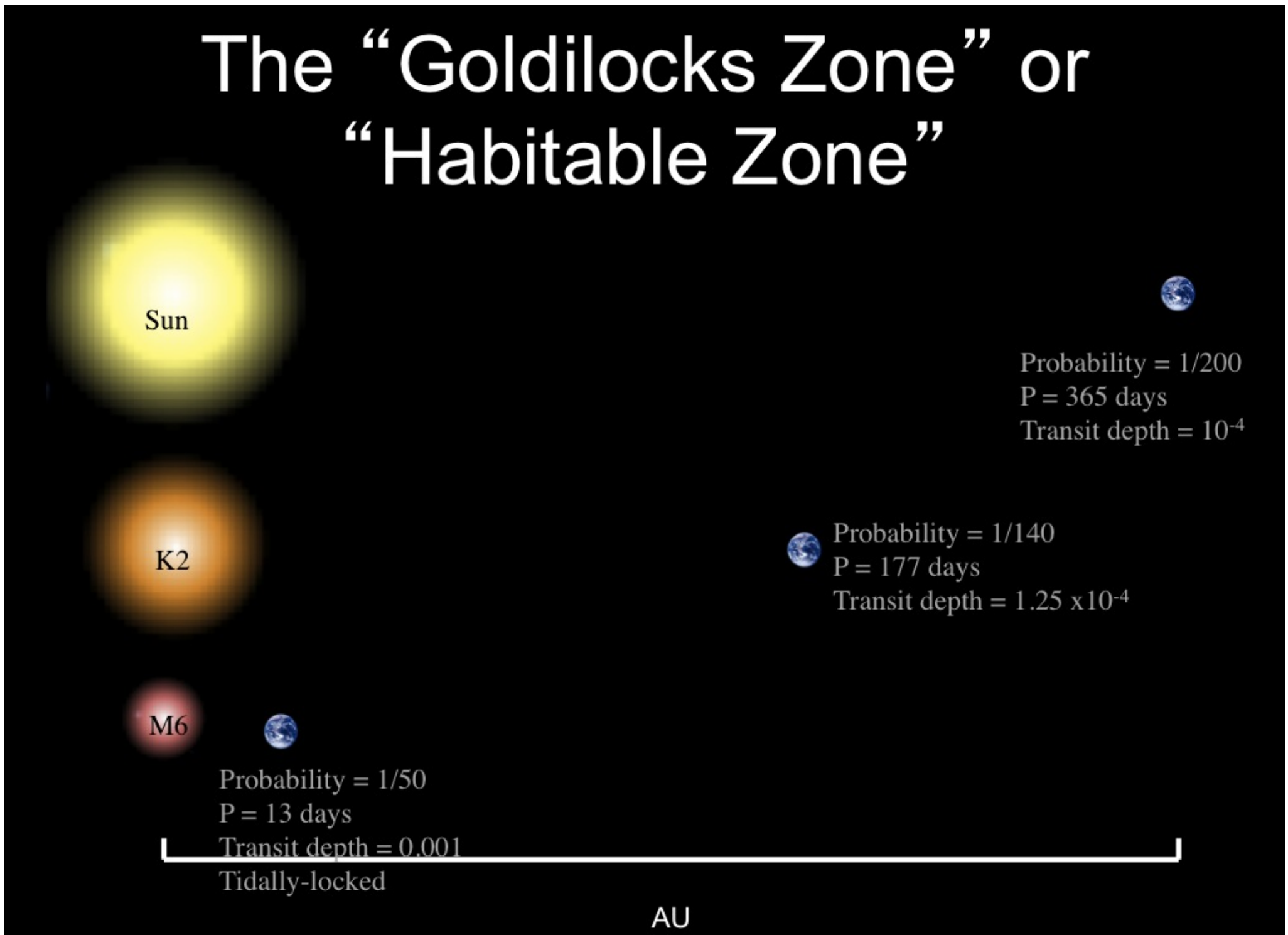
- Direct imaging spectrum within 15 to 25 years

When will we find another Earth? Part II

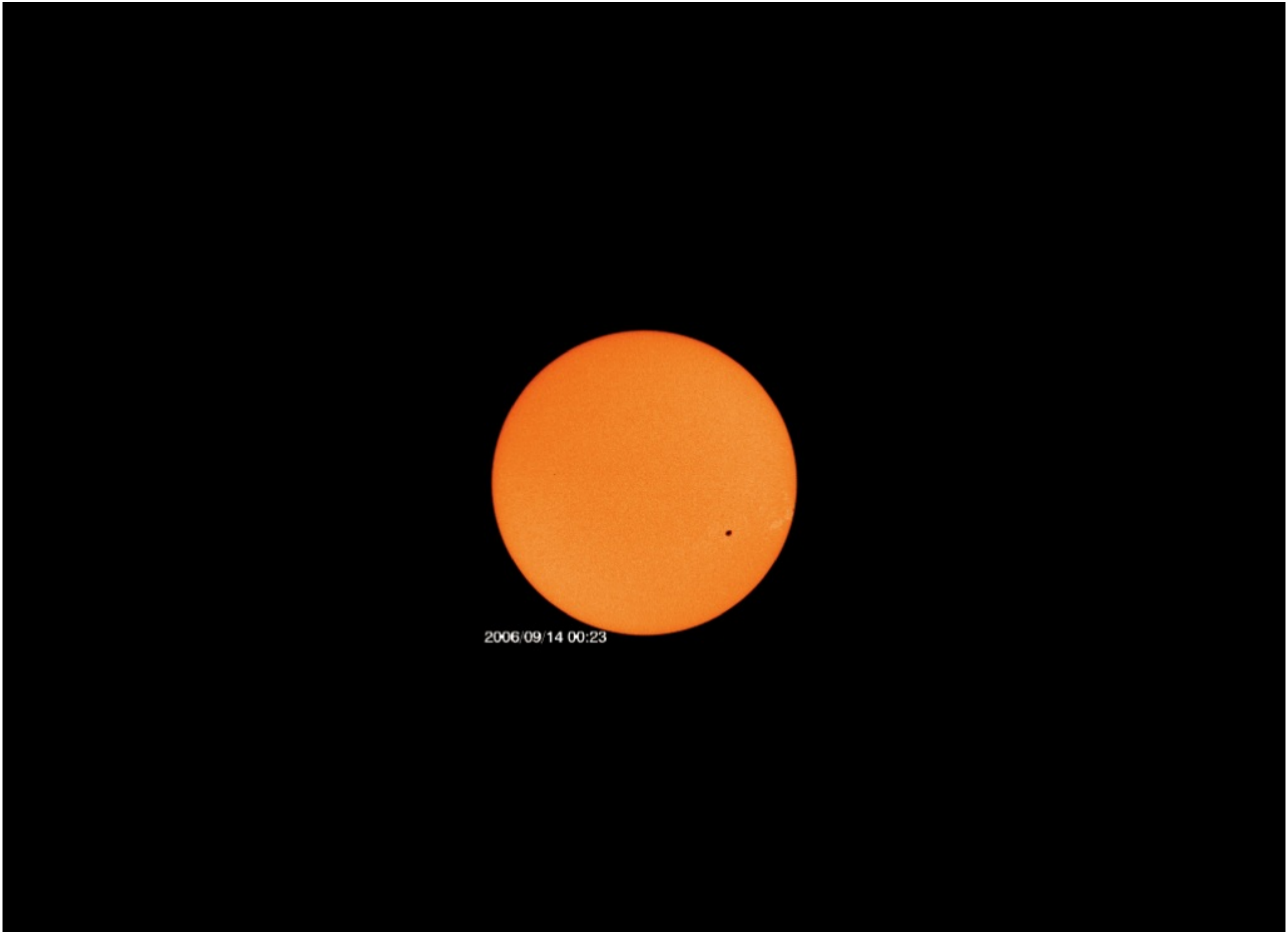
The "Goldilocks Zone" or "Habitable Zone"



When will we find another Earth? Part II

A big Earth transiting a small star:
within one to three years

Can we go there?


2006/09/14 00:23

Alpha Centauri is 4.22 light years away.

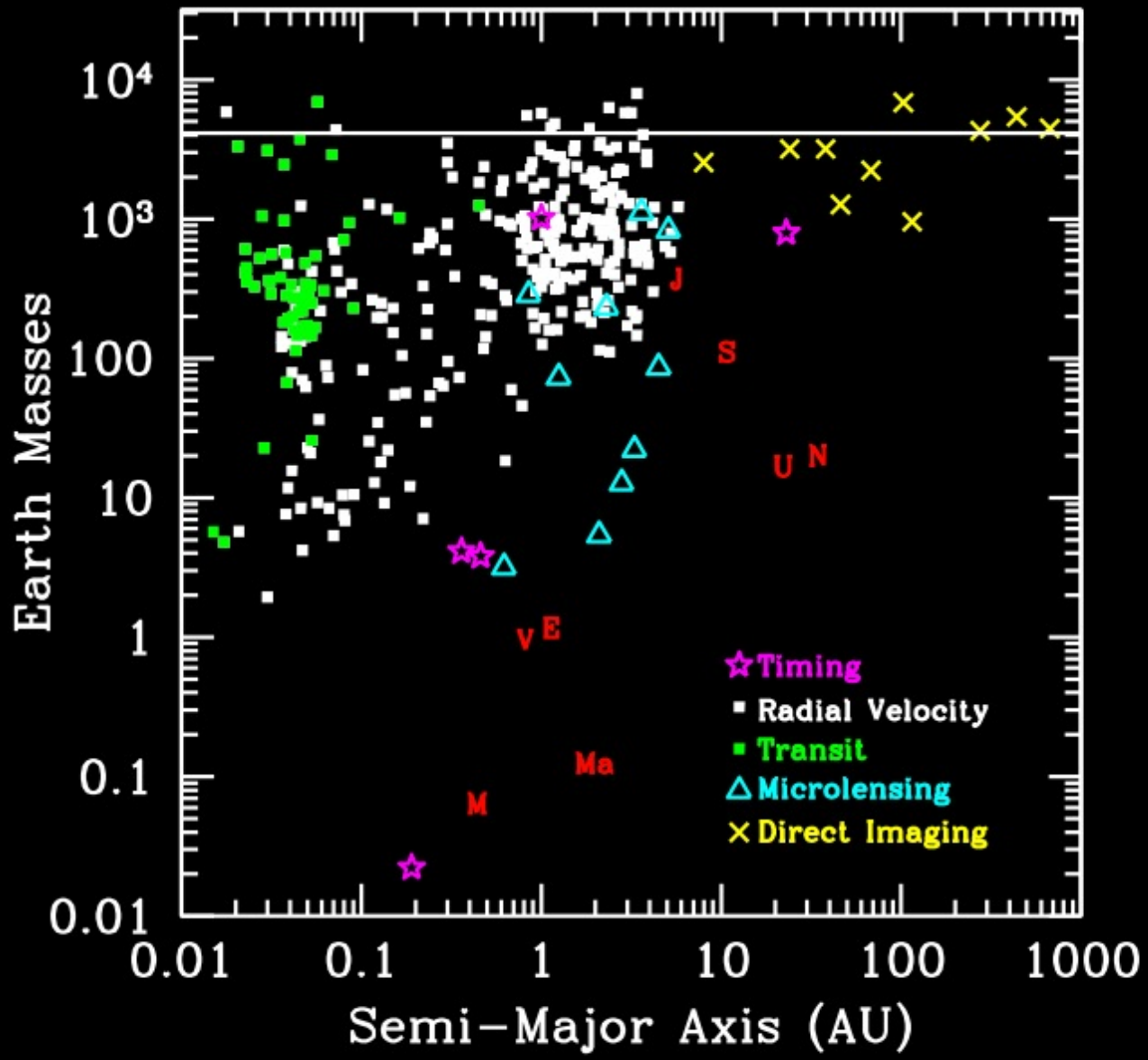
Voyager I would take over 70,000 years to reach the nearest star

Can we go there?

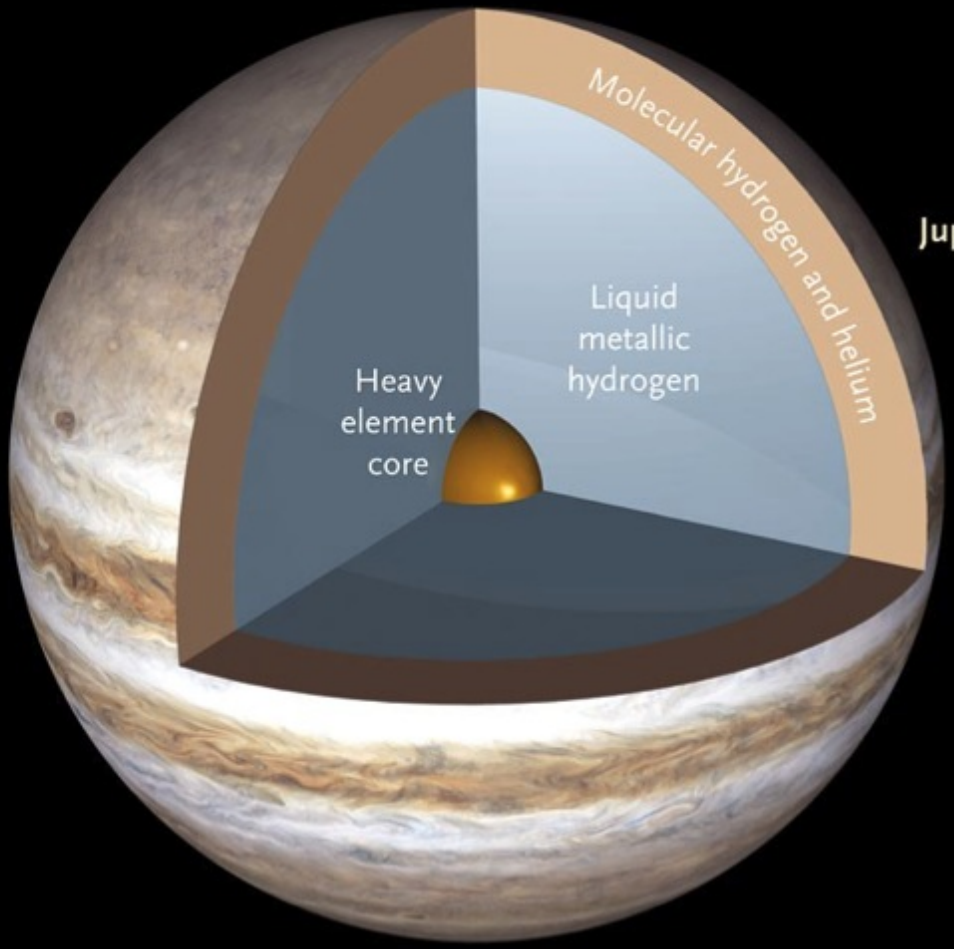
Not for now!

If we cannot go there, why look?

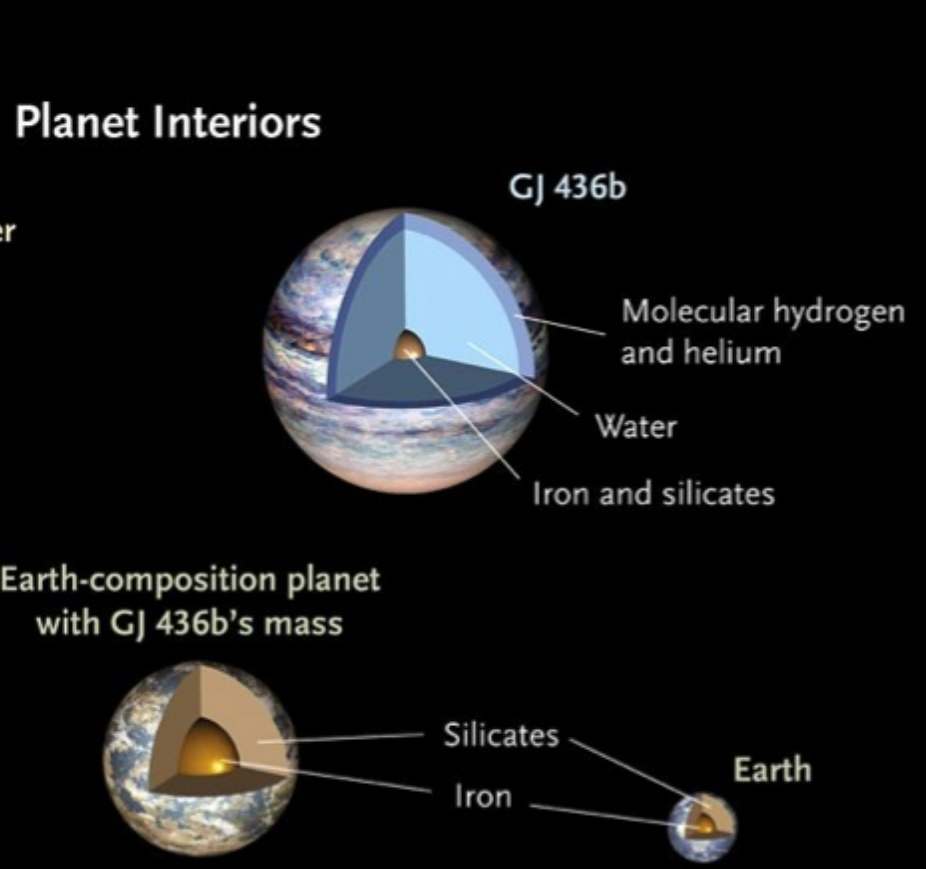
Known Planets



Planet Interiors

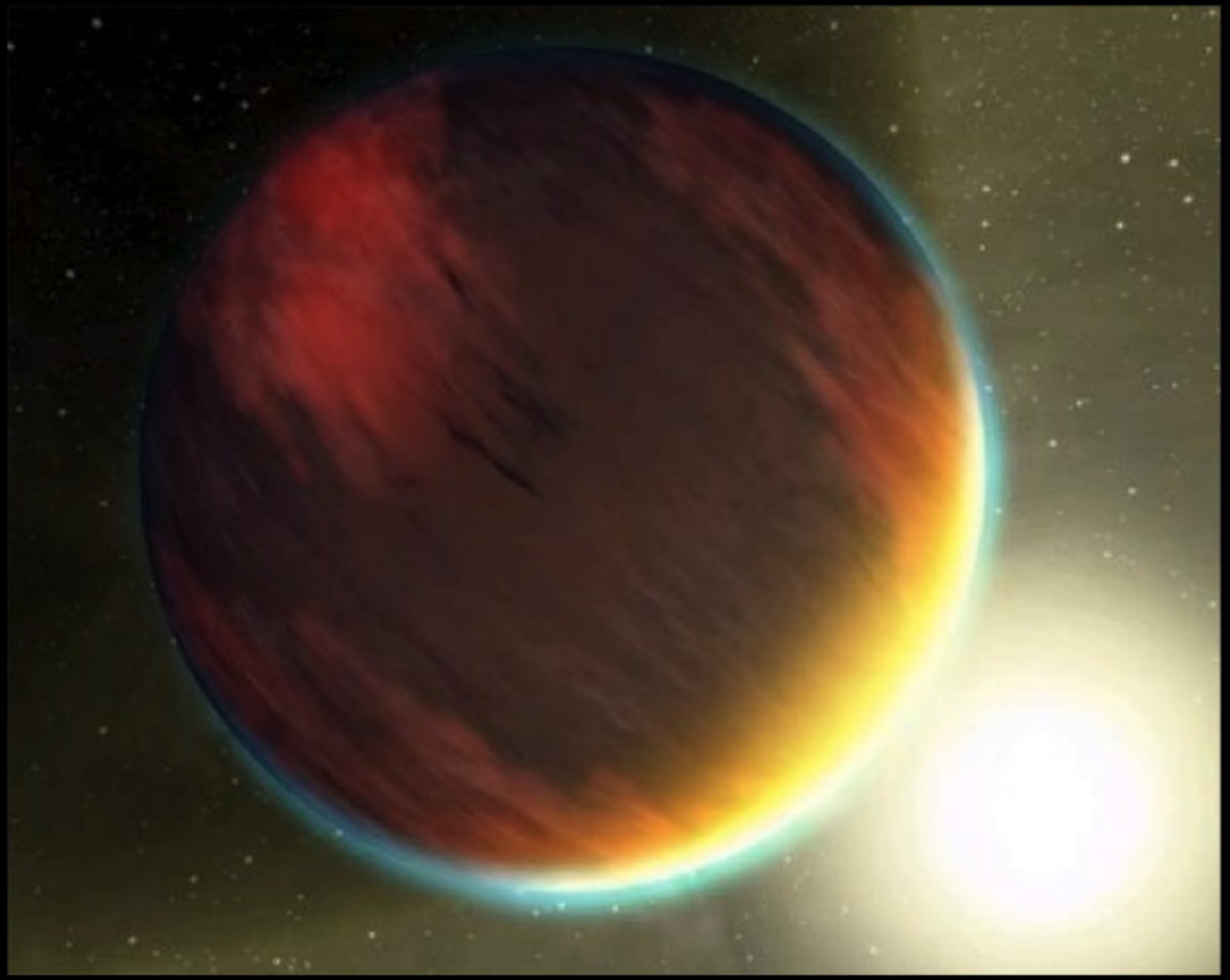


Jupiter

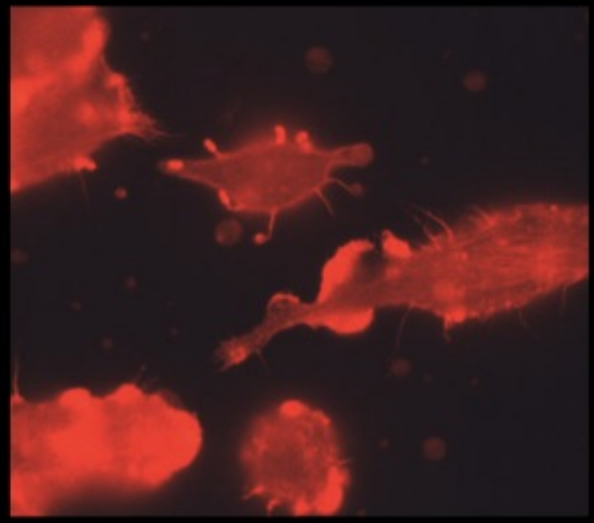


Casey Reid

Planet Atmospheres



Biosignature Gases

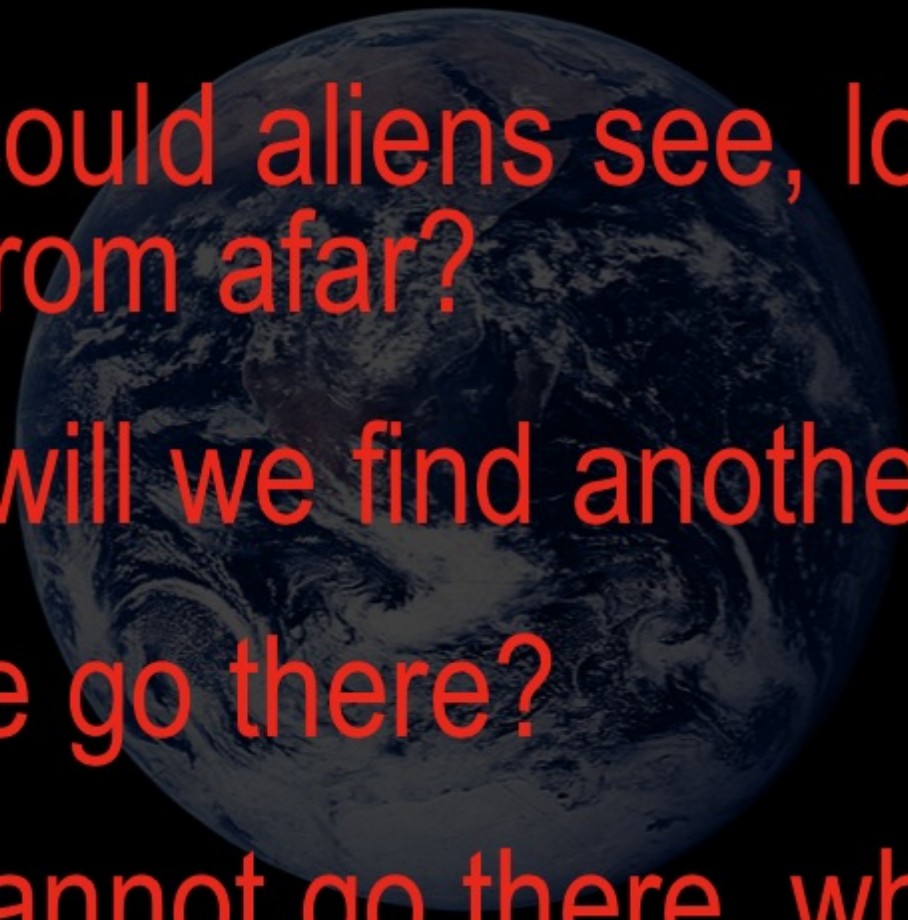



LIFE IN THE EXTREMES
HALOPHILES
LIFE IN THE EXTREMES
PSYCHROPHILES
LIFE IN THE EXTREMES
ACIDOPHILES
LIFE IN THE EXTREMES
RADIORESISTANT MICROBES
LIFE IN THE EXTREMES
BAROPHILES
LIFE IN THE EXTREMES
ALKALIPHILES
LIFE IN THE EXTREMES
XEROPHILES
LIFE IN THE EXTREMES
THERMOPHILES
LIFE IN THE EXTREMES
ENDOLITHS

If we cannot go there, why look?

Remote sensing of interiors, atmospheres, and biosignatures

Summary



What could aliens see, looking at Earth from afar?

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Can we go there?

If we cannot go there, why look?


SETI
No alien civilization appears to be continuously broadcasting a powerful “beacon” signal from a planet circling any of the nearest 1,000 or so Sunlike stars, at least in the frequency bands searched to date.

Gliese 581 Planetary System

Gliese 581 is a red dwarf star located 20.3 light years from Earth in the constellation Libra. It has a mass of one third of the Sun and at least six planets. The fourth planet from the star, Gliese 581g, is the first Earth-like planet detected around a star.

WIRED SCIENCE

NEWS FOR YOUR NEURONS

PREVIOUS POST NEXT POST

New Study Finds No Sign of 'First Habitable Exoplanet'

By Lisa Grossman ✉ January 18, 2011 | 2:54 pm | Categories: Astronomy, Space

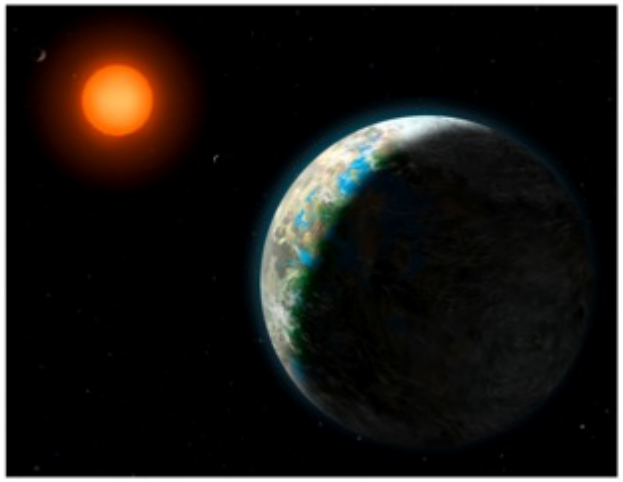


Image: Lynette Cook

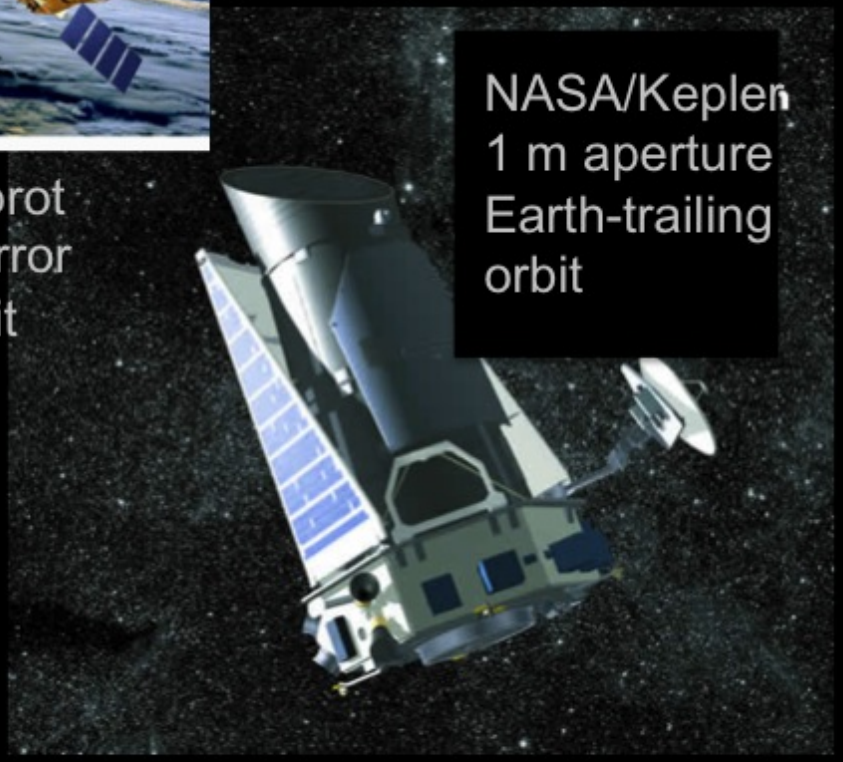
"For the time being, the world does not have data that's good enough to claim the planet," Philip Gregory of UBC

"With the data we have, the most likely explanation is that this planet is still there," Anglada-Escudé said.

"I'm not going to admit that it's a dead planet yet," said exoplanet expert Sara Seager of MIT. "No one will be able to sort this out today … it will take some time."

Transit Survey Telescopes

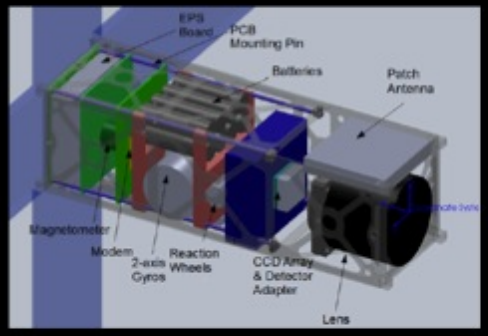
CNES/Corot
30 cm mirror
Polar orbit



NASA/Kepler
1 m aperture
Earth-trailing orbit

TESS concept
6 lenses on the same platform

Plato science payload
Under study by ESO



ExoplanetSat concept
A triple CubeSat constellation of