Exoplanets

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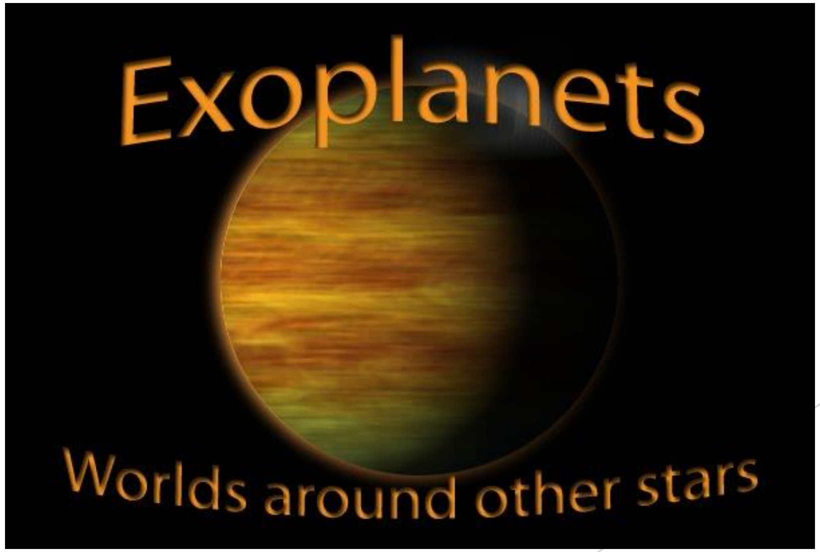
How to detect exoplanets

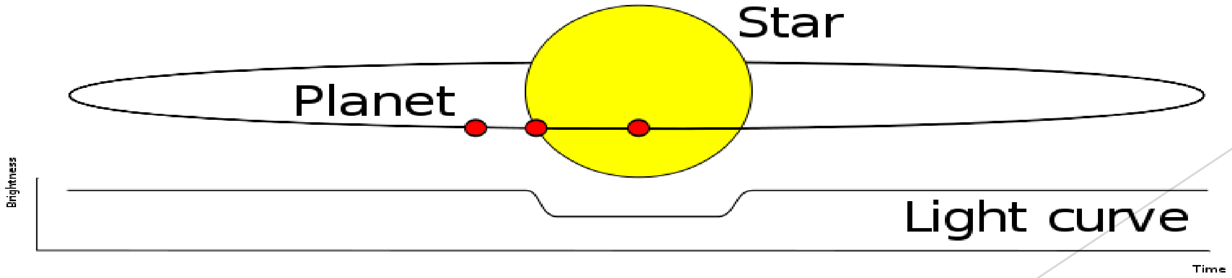
Exoplanets:

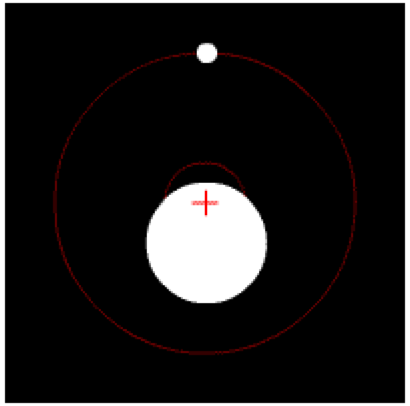
An **exoplanet** or **extrasolar planet** is a planet outside the Solar System.



Transit Method:

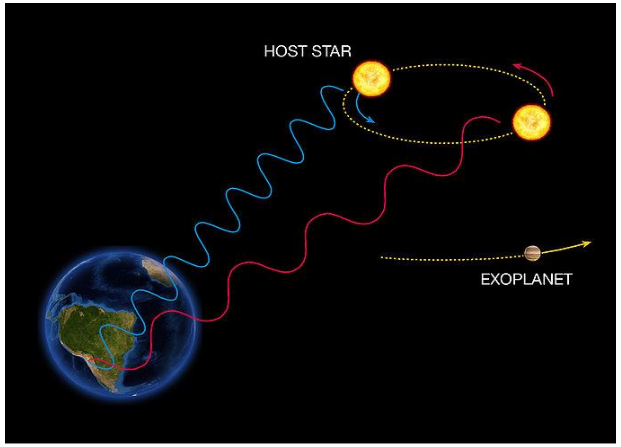
When a planet crosses in front of its star as viewed by an observer, the event is called a transit. Transits by terrestrial planets produce a small change in a star's brightness of about 1/10,000 (100 parts per million, ppm), lasting for 2 to 16 hours. This change must be absolutely periodic if it is caused by a planet. In addition, all transits produced by the same planet must be of the same change in brightness and last the same amount of time, thus providing a highly repeatable signal and robust detection method.





Astrometry:

Astrometry is the area of study that focuses on precise measurements of the positions and movements of stars and other celestial bodies, as well as explaining these movements.
In this method, the gravitational pull of a planet causes a star to change its orbit over time. Careful analysis of the changes in a star's orbit can provide an indication that there exists a massive exoplanet in orbit around the star. The astrometry technique has benefits over other exoplanet search techniques because it can locate planets that orbit far out from the star



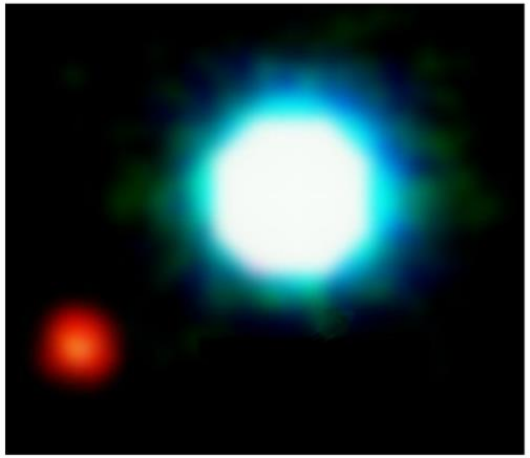
The Radial Velocity Method

ESO Press Photo 22e/07 (25 April 2007)

Radial Velocity method:

The radial velocity method to detect exoplanet is based on the detection of variations in the velocity of the central star, due to the changing direction of the gravitational pull from an (unseen) exoplanet as it orbits the star. When the star moves towards us, its spectrum is blue shifted, while it is red shifted when it moves away from us. By regularly looking at the spectrum of a star - and so, measuring its velocity - one can see if it moves periodically due to the influence of a companion.

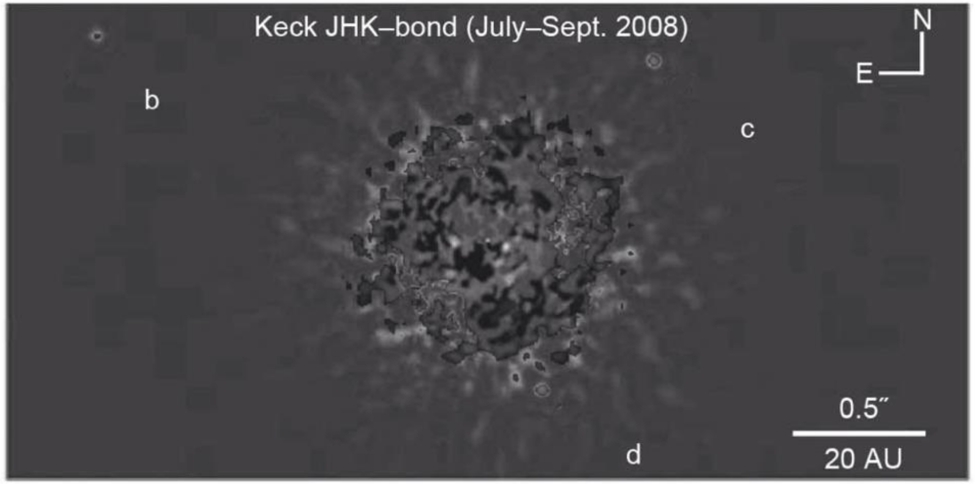
Direct Imaging



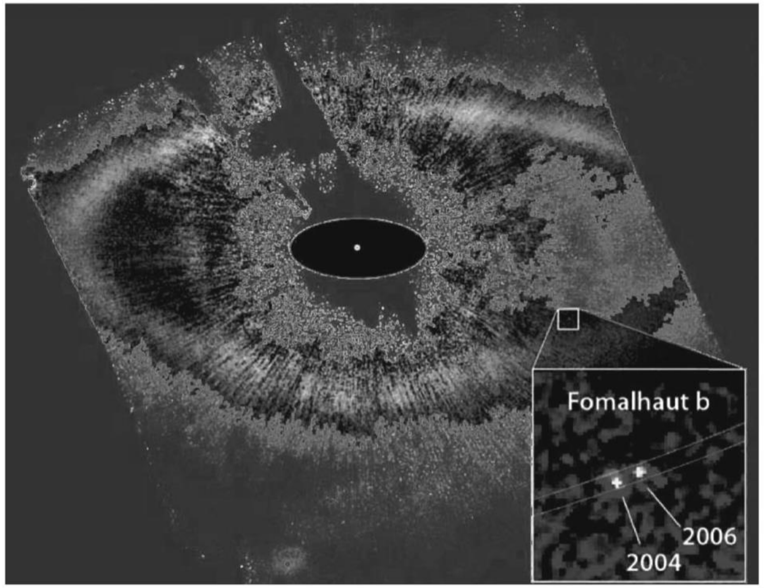
NaCo, VLT, ESO

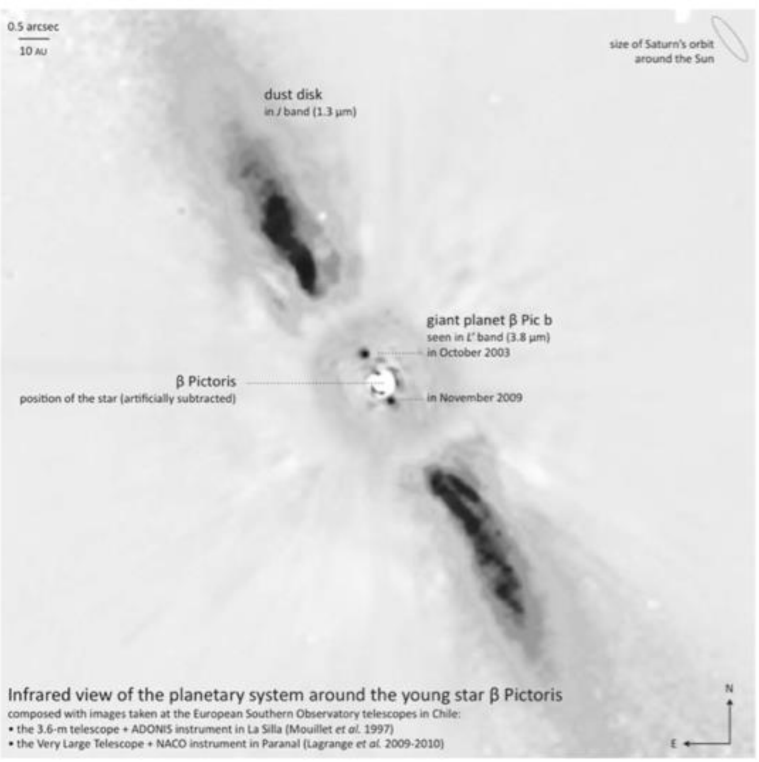
First Image of an Exoplanet?

In July 2004 a group of astronomers led by Gael Chauvin took this image of a planetary-mass object in orbit around brown dwarf 2M1207.



Keck JHK–bond (July–Sept. 2008)

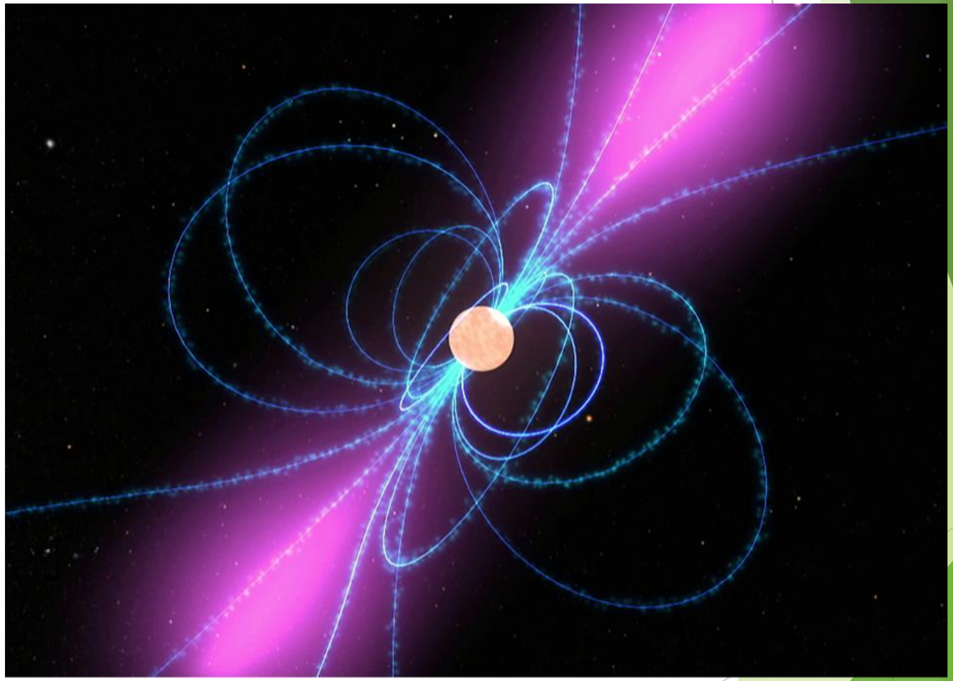




Infrared view of the planetary system around the young star β Pictoris
composed with images taken at the European Southern Observatory telescopes in Chile:
- the 3.6-m telescope + ADONIS instrument in La Silla (Mouillet *et al.* 1997)
- the Very Large Telescope + NACO instrument in Paranal (Lagrange *et al.* 2009-2010)

Pulsar Timing

- Pulsars are neutron stars for which the magnetic and spin axes are misaligned. as pulsars rotate, flashes of radio waves are emitted like a lighthouse which reaches the Earth at regular intervals. These radio flashes can be detected and timed. The intervals between pulses are so regular that they are more accurate than an atomic clock. A planet orbiting this pulsar will cause very slight variations in the timing of these flashes which we can use to detect it. The very first exoplanet orbiting around Pulsar PSR B1257+12 was found using this technique in 1992.



Artist's impression of a pulsar showing magnetic field lines and jets of radiation

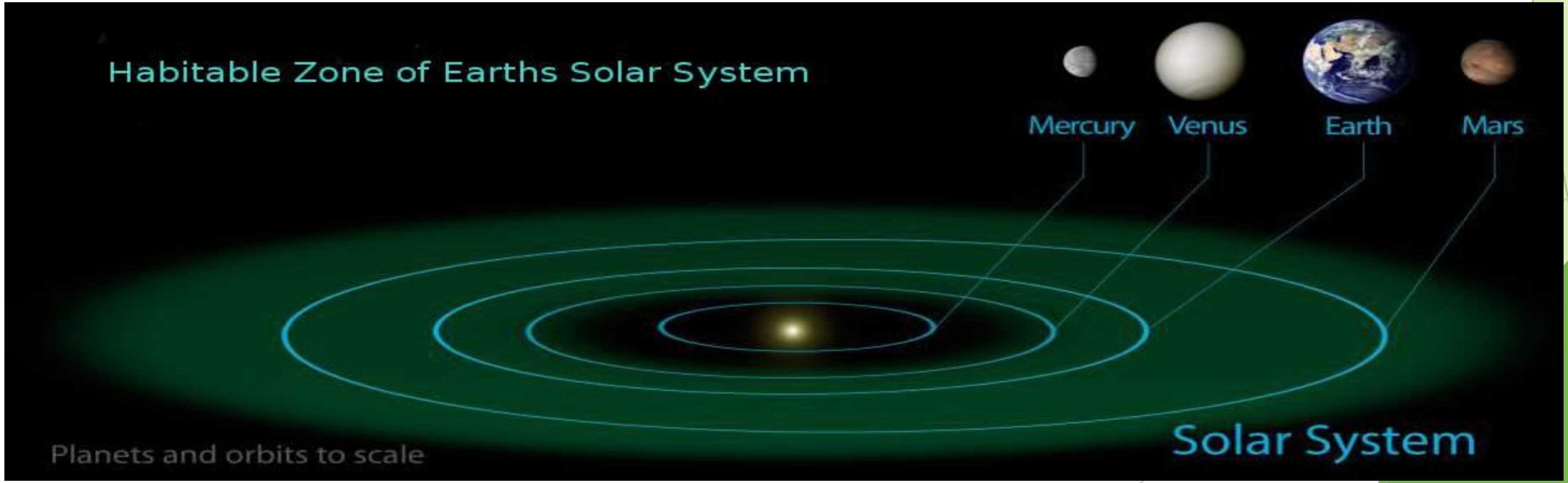
Habitability

Habitability

Liquid water is one of the most important factors for a planet to sustain life. Water can exist as a liquid at atmospheric pressure between 0-100C however it can also exist as a liquid at lower temperatures if there is a higher pressure.

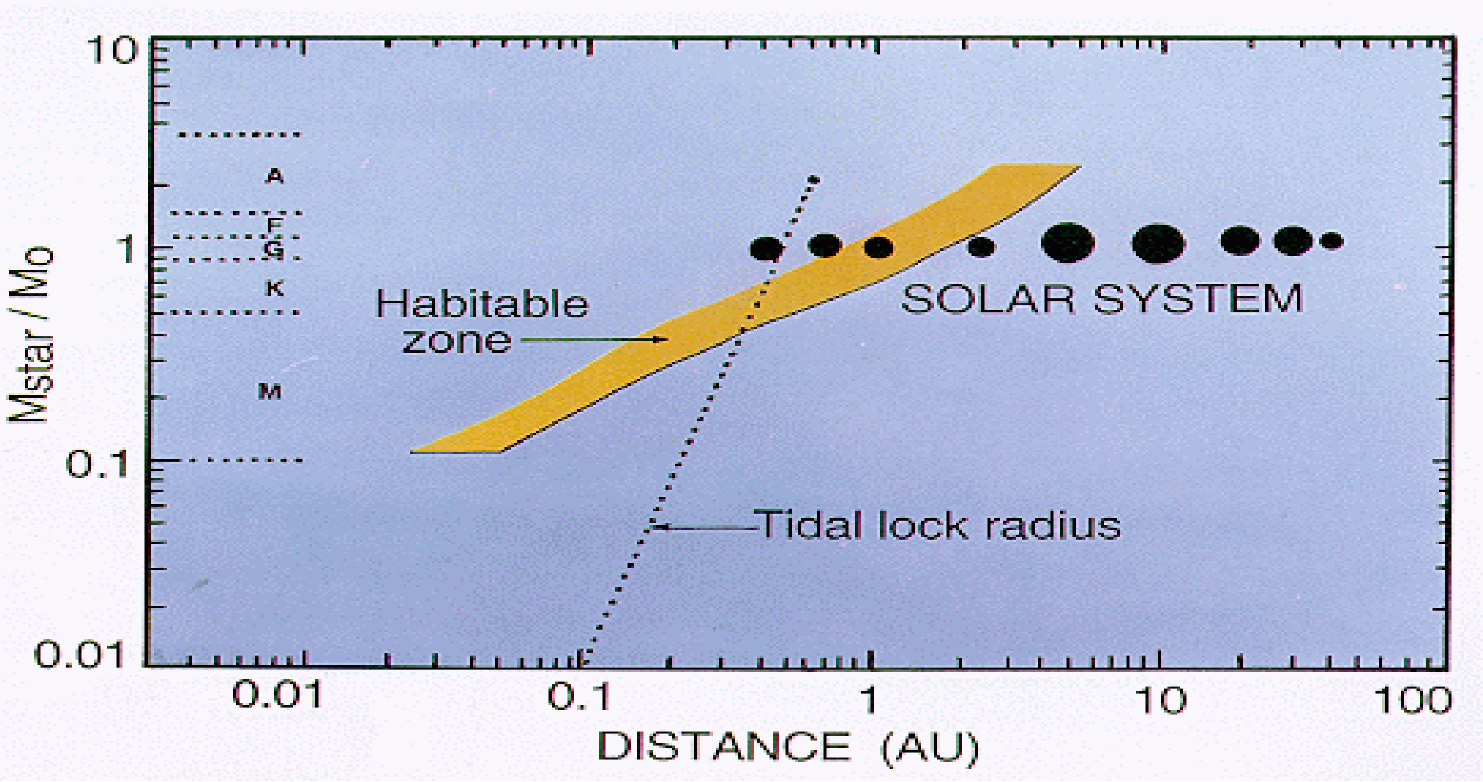
For every star there is an area around the star where with enough atmospheric pressure liquid water can exist, this is called the habitable zone.

In our solar system this ranges from 0.75AU-3AU.



Habitable Zone

For other stars the size and distance of this habitable zone depends on the nature of the star.

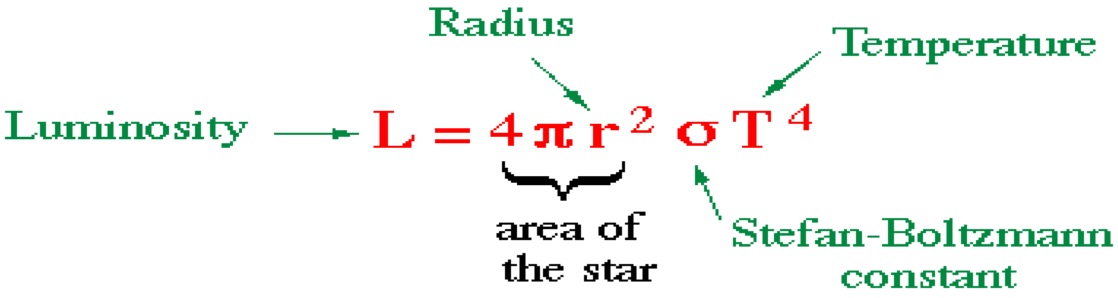


In general an high mass, Luminous star would have a wider habitable zone which is located further from the star and low mass stars with smaller luminosities have the opposite.

For example if a star had a luminosity 1/10 of that of our sun, the earth would need to be in a orbit similar to mercury’s to remain at the same temperature.

Calculating habitable zone

To find the habitable zone around a star, first the two radii of the habitable zone around the sun need to be known which can be found from:



Radius

Temperature

Luminosity

$$L = \underbrace{4\pi r^2}_{\text{area of the star}} \sigma T^4$$

Stefan-Boltzmann constant

By comparing the luminosity of the sun and the luminosity of the star the two radii of the habitable zone of the star can be calculated with:

$$\frac{L_{sun}}{L_{star}} = \frac{{r_{sun}}^2}{{r_{star}}^2}$$

Other factors

- If the planet has a large eccentricity on its orbit where is only spends a small amount of time in the habitable zone, and there would be a large temperature fluctuation which living organisms can only stand so much of.

- Whether the planet is rotating at a suitable speed or has an axial tilt.

- Also some of the larger moons around planets could be considered for life as tidal forces from the planet may heat them.

- Some planets may be frozen on the surface however below the surface may be warmer so there may be liquid water.

- Whether the planet is large enough to retain its atmosphere

- So far there have been approximately 3800 exoplanets that have been found with only around 67 that are potentially habitable.

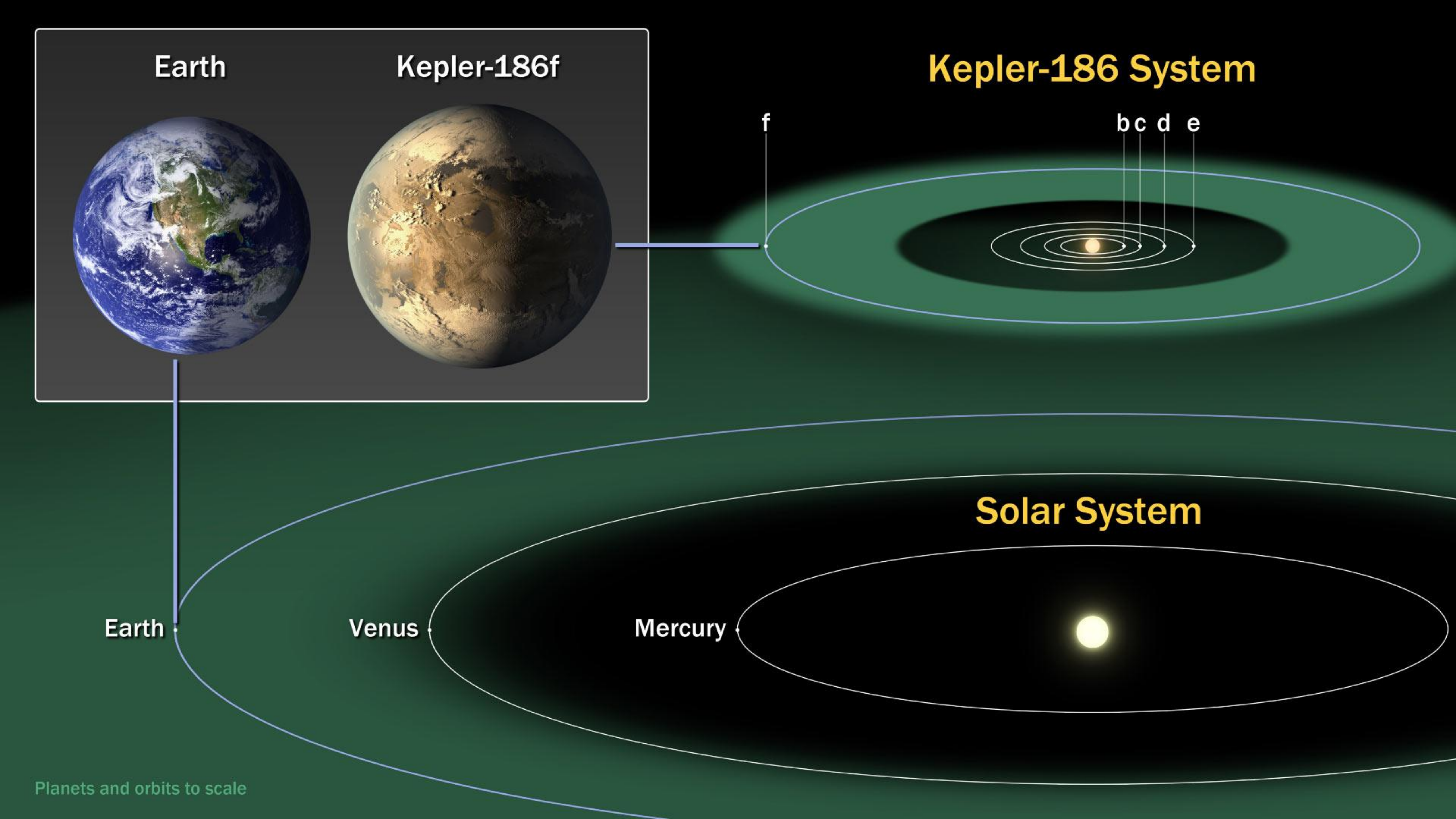
Examples of exoplanets

Kepler-186f

Kepler-186f is a Earth shaped planet orbiting a red dwarf star in the Cygnus constellation approximately 500ly away form our own solar system.

It is one of the most Erath like planets discovered to date and is located with the habitable zone of it’s parent star.

It has a 130 day year and shares its parent star with 4 other rocky planets


Earth
Kepler-186f
Kepler-186 System
f
b
c
d
e
Solar System
Earth
Venus
Mercury
Planets and orbits to scale

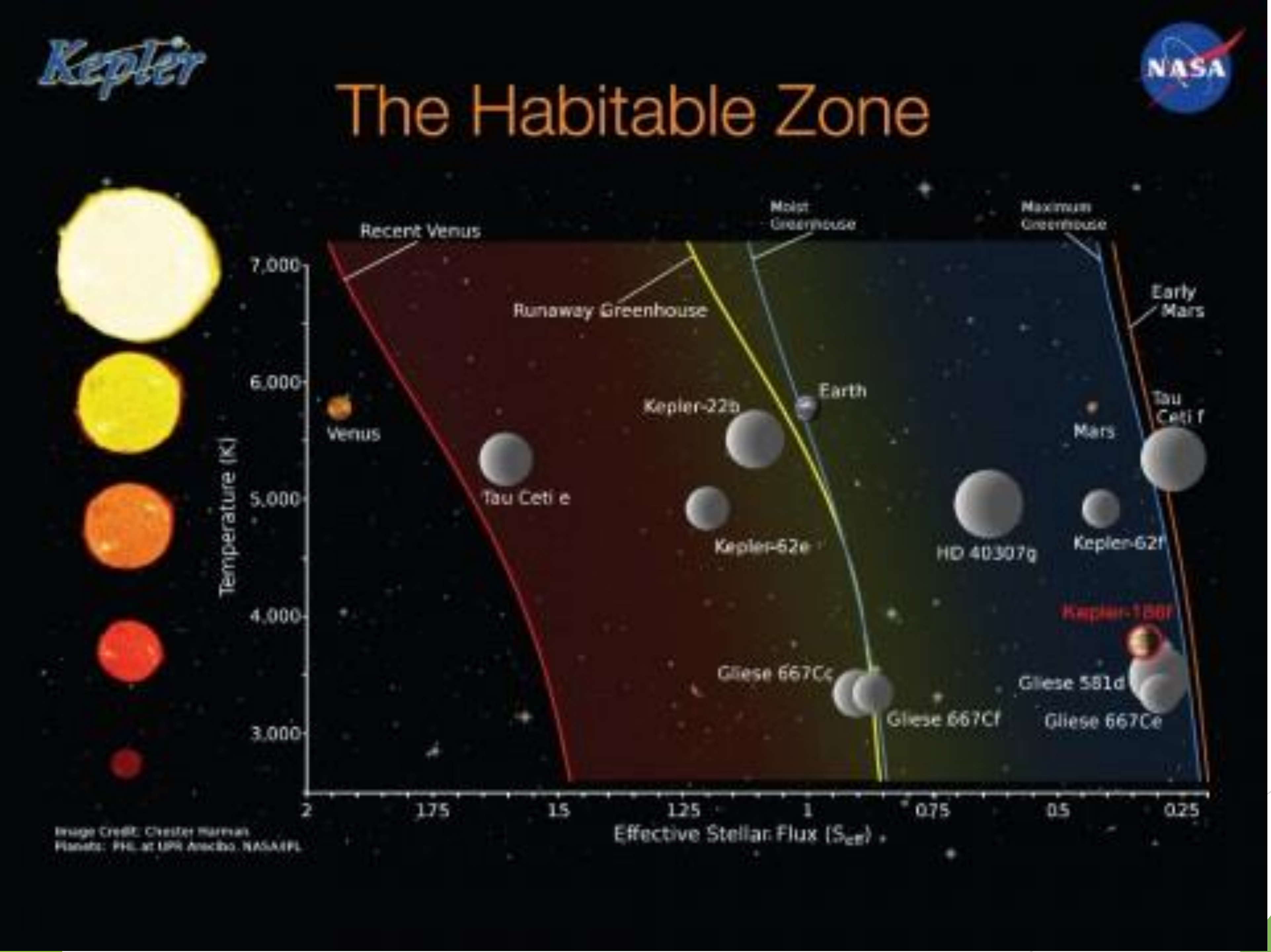
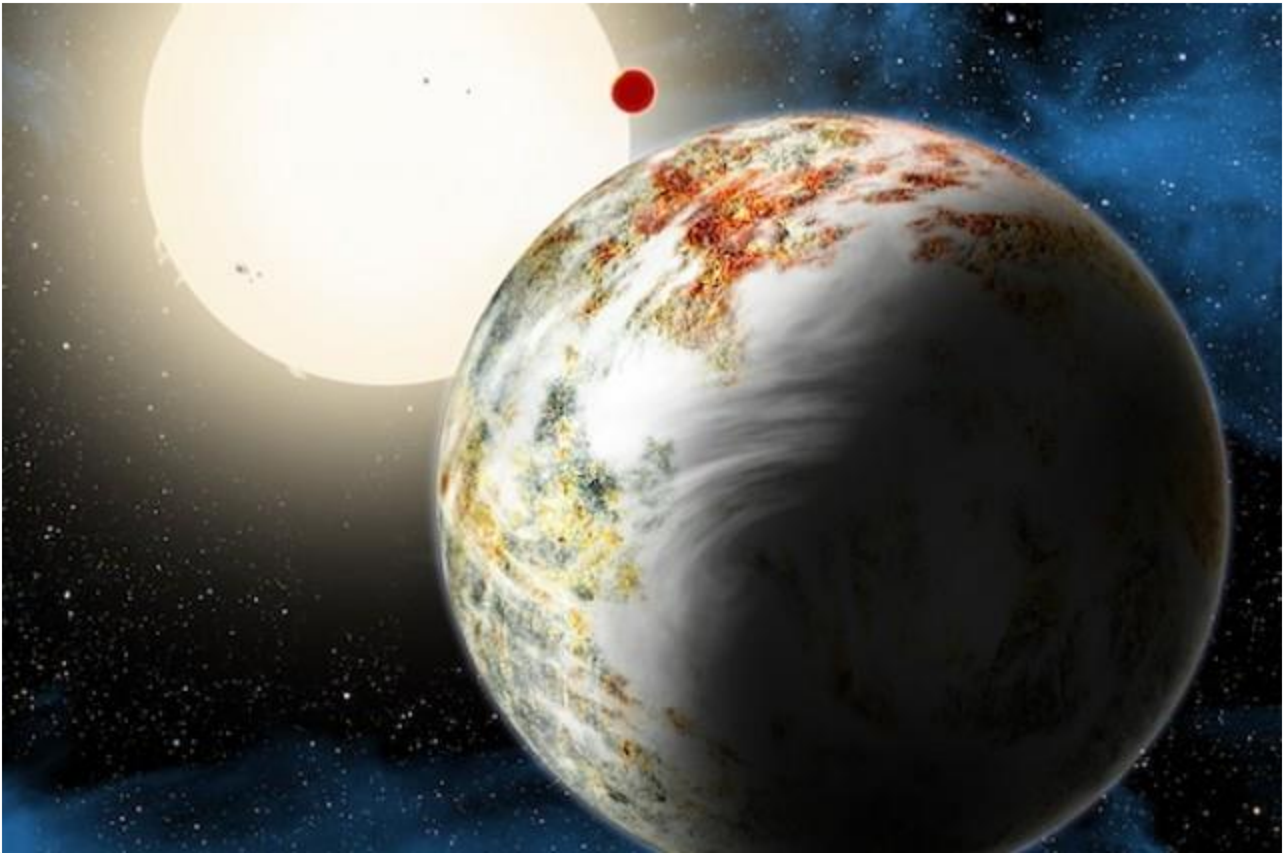


Image Credit: Chester Harman
Planets: PHL at UPR Arecibo, NASA/JPL

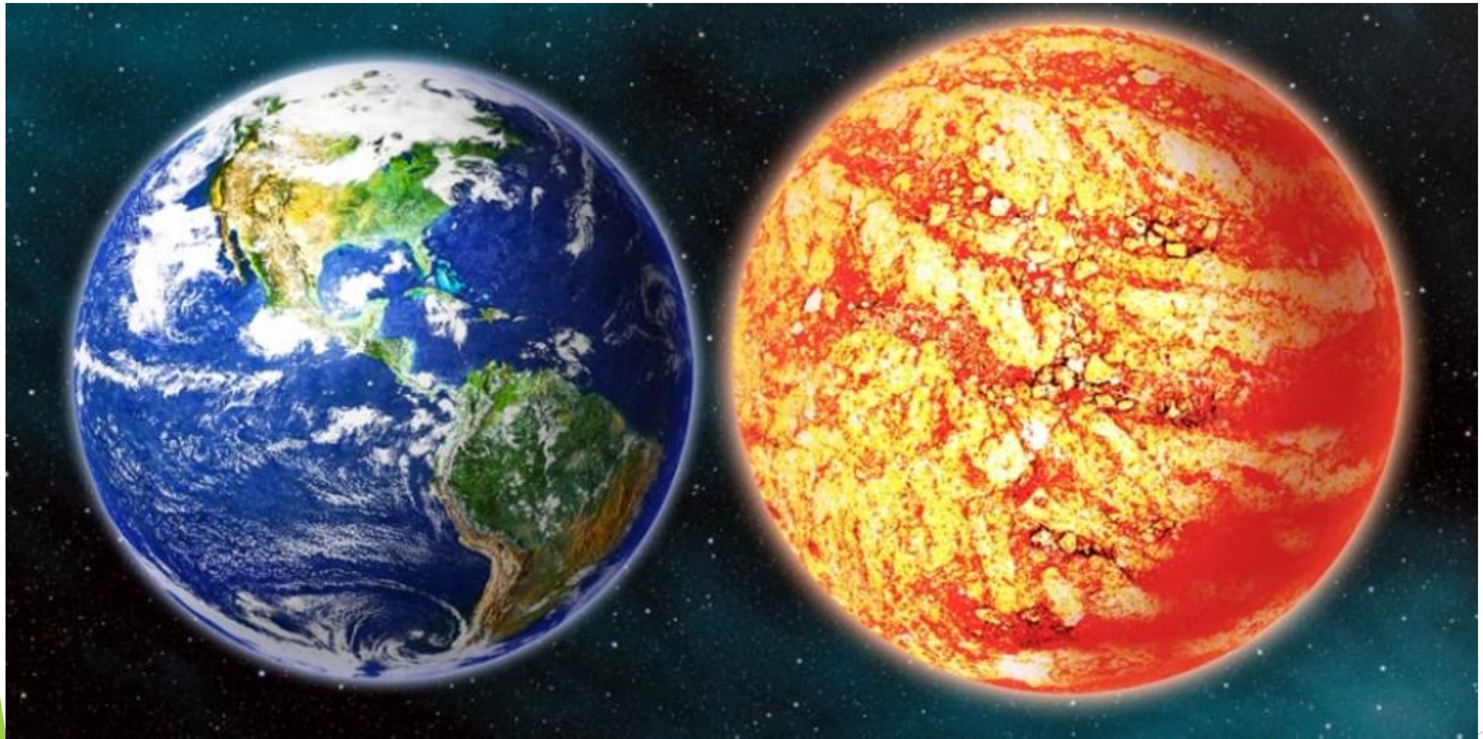
Kepler-10c

Part of a group of planets known as “Super Earths” or “Mega-eraths”. These are rocky planets that orbit their parent stars in the habitable zone which are much larger than Earth. This one, nic-named “The Godzilla planet”, is particularly interesting as it is that larges one so far measuring at 17 times as massive as the Earth.



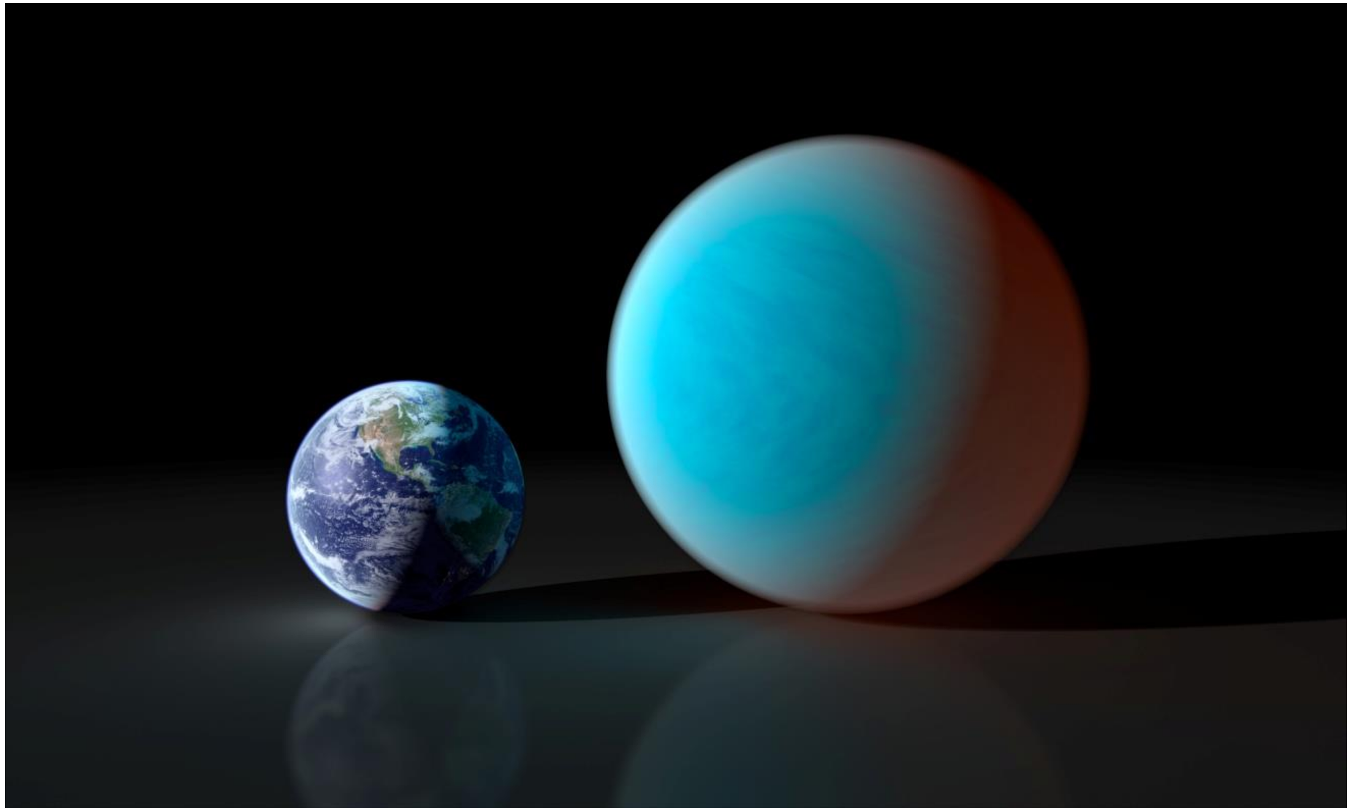
Kepler-78b

Also known as “The impossible planet” because it should not exist.
This planet orbits its parent star very closely; approximately 40 times closer than mercury orbits our sun. At this distant the planet would have had to form inside it’s parent star.



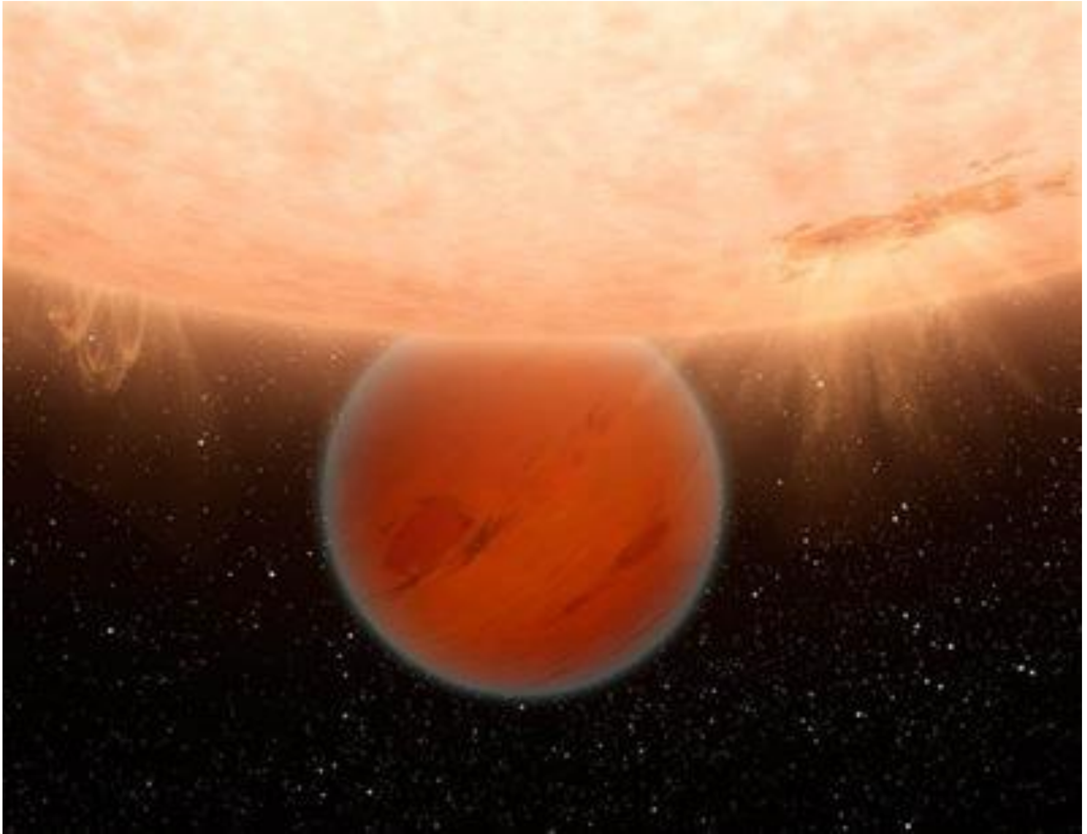
55 Cancri e

The diamond planet. Orbiting a carbon rich star it was found that this planet was also very carbon rich. Given it’s size and heat the carbon in this planet would have been crushed into a diamond state.



Gliese 436 b

Planet made of burning ice. The surface is far too hot for ice to exist but the immense pressure of the material below the surface in a state that is denser than both water and ice.



The End