

The Search For Life



- PART 2

Where is Everyone?

- ▶ Fermi posed a good question. If we are not alone in the universe, surely we would have been contacted by now. So where is everyone?

What is Life?

What is Life?

- ▶ Perhaps the 'Search For Life' should be less about trying to find 'Little Green Men' and more about looking for simpler forms of life.

Bacteria

- ▶ Bacteria were amongst the first lifeforms to inhabit the Earth.
- ▶ Bacteria inhabit soil, water, acidic hot springs, radioactive waste, and the deep portions of Earth's crust.
- ▶ Bacteria also live in symbiotic and parasitic relationships with plants and animals.



The Tardigrade

- ▶ Tardigrades, also known as water bears, or moss piglets, are able to survive for up to 30 years without food or water.
- ▶ They can endure temperature extremes from -253°C to 151°C , as well as exposure to x-rays, and the vacuum conditions of deep space.
- ▶ In 2007, it was taken into space on a Russian low-orbit spacecraft and in 2011 to the ISS. Some now call them space bears.
- ▶ This tiny creature is most likely to survive long after man has disappeared from the Earth.



Where Can Life Exist?

Where Can Life Exist?

▶ Deep Ocean Vents

- ▶ Found at depths of 3000-5000 meters, they are teeming with life where no sunlight penetrates & high temperatures ($>400^{\circ}\text{C}$) and pressures exist.
- ▶ At the bottom of the food chain are microbes that get their energy from chemicals in the vents, usually hydrogen sulfide. Hundreds of other species have been discovered that live only in these vents, including various tube worms, barnacles, mussels and shrimp.



Where Can Life Exist?

- ▶ Under Antarctic Ice
 - ▶ Iron-rich water oozing from under Taylor Glacier is just the mouth of a system of briny aquifers that sits more than 200 meters below ground.
 - ▶ With high levels of salt preventing the water from freezing, the organisms here feed on the iron-rich rock beneath the glacier in spite of the extreme cold, and lack of oxygen.



Blood Falls, Antarctica

Where Can Life Exist?

10

▶ Acidic Hot Springs

- ▶ Observations of bacteria-like organisms in hot springs were made early in the 1900s. They belong to a group of organisms called *archaea* that look like bacteria, but have features of both prokaryote (non-nucleated cells, such as bacteria) and eukaryote (nucleated cells, such as found in animal and plant life).
- ▶ Certain microorganisms called extremophiles have evolved to live in extreme conditions such as very high temperatures (some to over 115 °C {235 °F} and acidity pH <3.0).
- ▶ However, these conditions are deadly for humans, and the water can cause fatal burns and break down human flesh and bone.
- ▶ In 2016, a tourist fell into a hot spring in Yellowstone National Park and was dissolved!

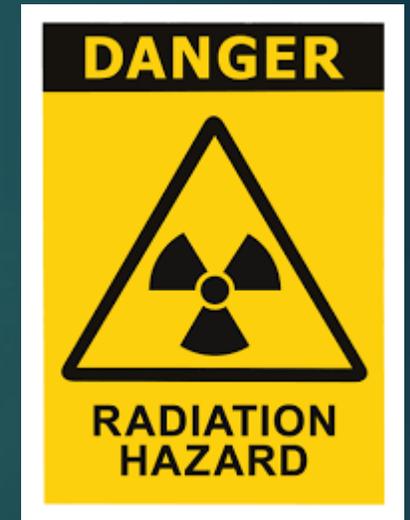


Where Can Life Exist?

11

▶ Under Extreme Radiation

- ▶ *Deinococcus radiodurans*, is a bacterium discovered in the 1950's while a scientist was experimenting with using gamma radiation to sterilize meat. *D. radiodurans* always managed to survive.
- ▶ *D. radiodurans* can tolerate 1,500 kilorads without experiencing mutation.
 - ▶ A rad is a unit of absorbed ionizing radiation dose.
 - ▶ That's about 3,000 times what humans can withstand.



So What Do We Need For Life?

12

- ▶ Water
 - ▶ Preferably liquid.
- ▶ Heat
 - ▶ Well actually energy, lots of energy.
- ▶ Some basic chemicals:
 - ▶ Oxygen, Hydrogen, Carbon, Nitrogen.
- ▶ Time
 - ▶ A lot of it if we want intelligent life!

The Search for Water

The Search for Water

- ▶ Years ago we thought that Earth was special because it was the only place that had liquid water.
- ▶ We knew that water ice existed on comets and some planets and moons within the Solar System.
- ▶ With recent space probes, evidence of liquid water has been popping up all over the Solar System.

Europa

15

- ▶ The surface of Europa, the smallest of Jupiter's Galilean moons, is frozen, covered with a layer of ice, but scientists think there is an ocean of liquid water beneath the surface.
- ▶ Researchers using the Hubble Space Telescope spotted a possible water plume jetting from Europa's south polar region in 2012.



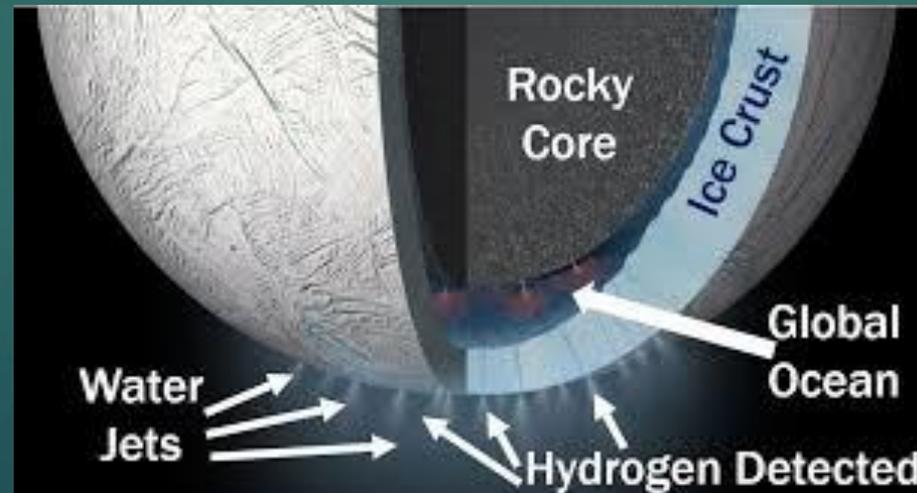
Ganymede

- ▶ This moon of Jupiter likely has a salty ocean underneath its icy surface, making it a potential location for life.
- ▶ The European Space Agency plans a mission to Jupiter's icy moons (JUICE) that in 2030, is planned to arrive and put special emphasis on observing Ganymede.



Enceladus

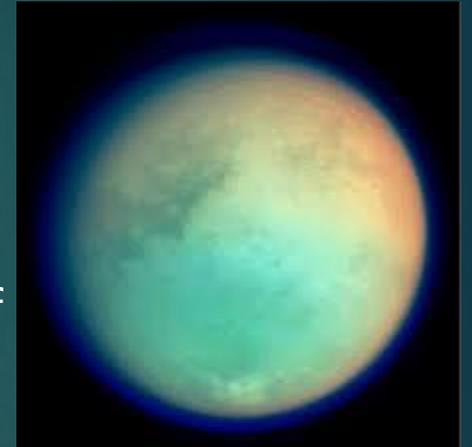
- ▶ In 2014, NASA reported that the Cassini spacecraft had discovered evidence of large underground oceans of liquid water on Saturn's sixth largest moon.



Titan

18

- ▶ Titan, Saturn's largest moon, has clouds, rain, rivers, lakes and seas of liquid hydrocarbons like methane and ethane.
- ▶ Titan's atmosphere is made mostly of nitrogen, like Earth's, but with a surface pressure 50 percent higher than Earth's.
- ▶ The largest seas are hundreds of feet deep and hundreds of miles wide. Beneath Titan's thick crust of water ice is more liquid, an ocean primarily of water rather than methane.
- ▶ Titan's subsurface water could be a place to harbor life as we know it, while its surface lakes and seas of liquid hydrocarbons could conceivably harbor life that uses different chemistry.
- ▶ That is, life as we don't yet know it.



Pluto

- ▶ Pluto's surface is thought to be made up of water, nitrogen and methane ices, long frozen in the cold of outer space.
- ▶ Recent analysis of pictures from the New Horizon space mission, shows it has mountains hundreds of meters high and a vast heart-shaped plain. It also has giant tectonic features, faults hundreds of kilometers long and as deep as 4 kilometers.
- ▶ It was those tectonic features that got scientists thinking that a subsurface ocean of liquid water was a real possibility for Pluto.



Mars

20

- ▶ From early on, man has thought that Mars was a lush planet with rivers, lakes, oceans and canals.
- ▶ We now know it to be a dry and barren land.
- ▶ However, water ice has been detected all over the planet, from the frozen poles to hideaways in deep craters protected from the Sun's rays.
- ▶ Being in the habitable zone around our Sun, Mars holds perhaps the best location to find life, possibly locked in the Martian soil or thriving in deep underground aquifers.



The Goldilocks Zone

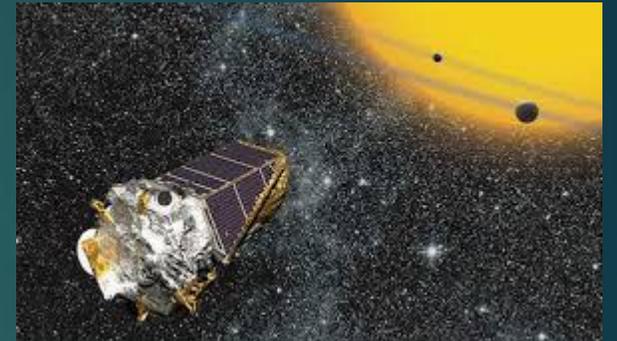
- ▶ When Kepler first discovered evidence of exoplanets orbiting distant stars, scientists considered the zone around the star where liquid water could exist as the most likely place for Earth-like exoplanets and possibly life.
- ▶ A temperature that is not too hot and not too cold but just right!
- ▶ Given what we are learning about our own Solar System, we may have to rethink that idea and consider the possibility of distant moons orbiting exoplanets further out.

The Tools

Kepler

23

- ▶ Although severely compromised and having its mission scaled back, Kepler continues to provide mountains of data that will take many years to analyze.
- ▶ It is likely that its fuel will be spent by late this year or early next.
- ▶ In spite of its mechanical failure, it has given scientists much to ponder and certainly shown us that planets, possibly similar to our own, are not so uncommon in the cosmos.

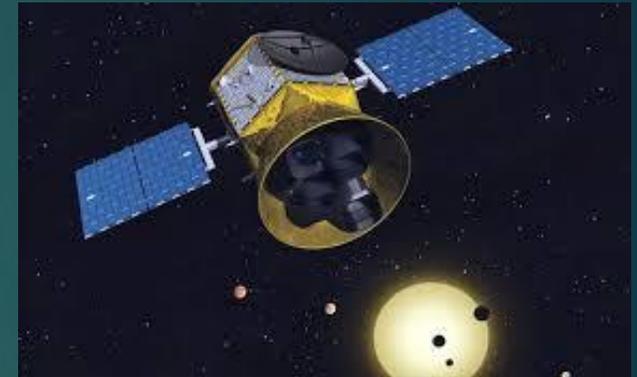


Transiting Exoplanet Survey Satellite

- TESS

24

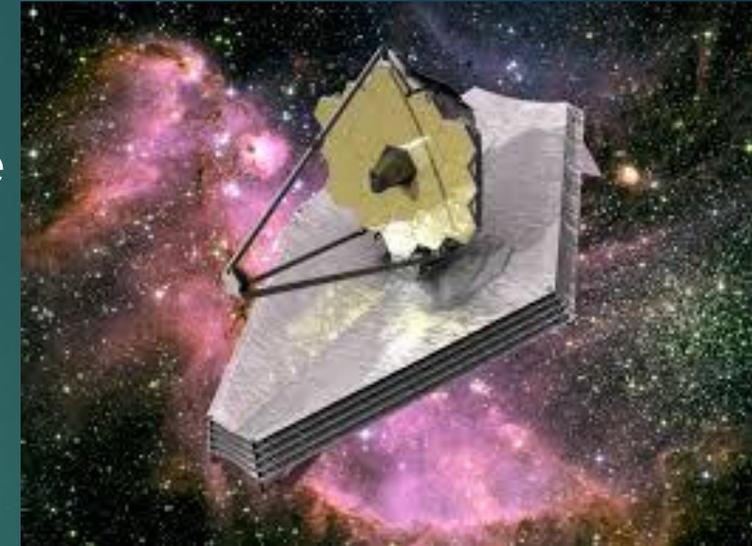
- ▶ On April 18, the Transiting Exoplanet Survey Satellite (TESS) launched from Cape Canaveral. NASA's latest exoplanet hunter will investigate nearer, brighter stars than Kepler.
- ▶ The stars TESS will examine will be bright enough and close enough to allow detailed follow-up studies with large ground telescopes, the Hubble Space Telescope and the upcoming James Webb Space Telescope.



James Webb Space Telescope

25

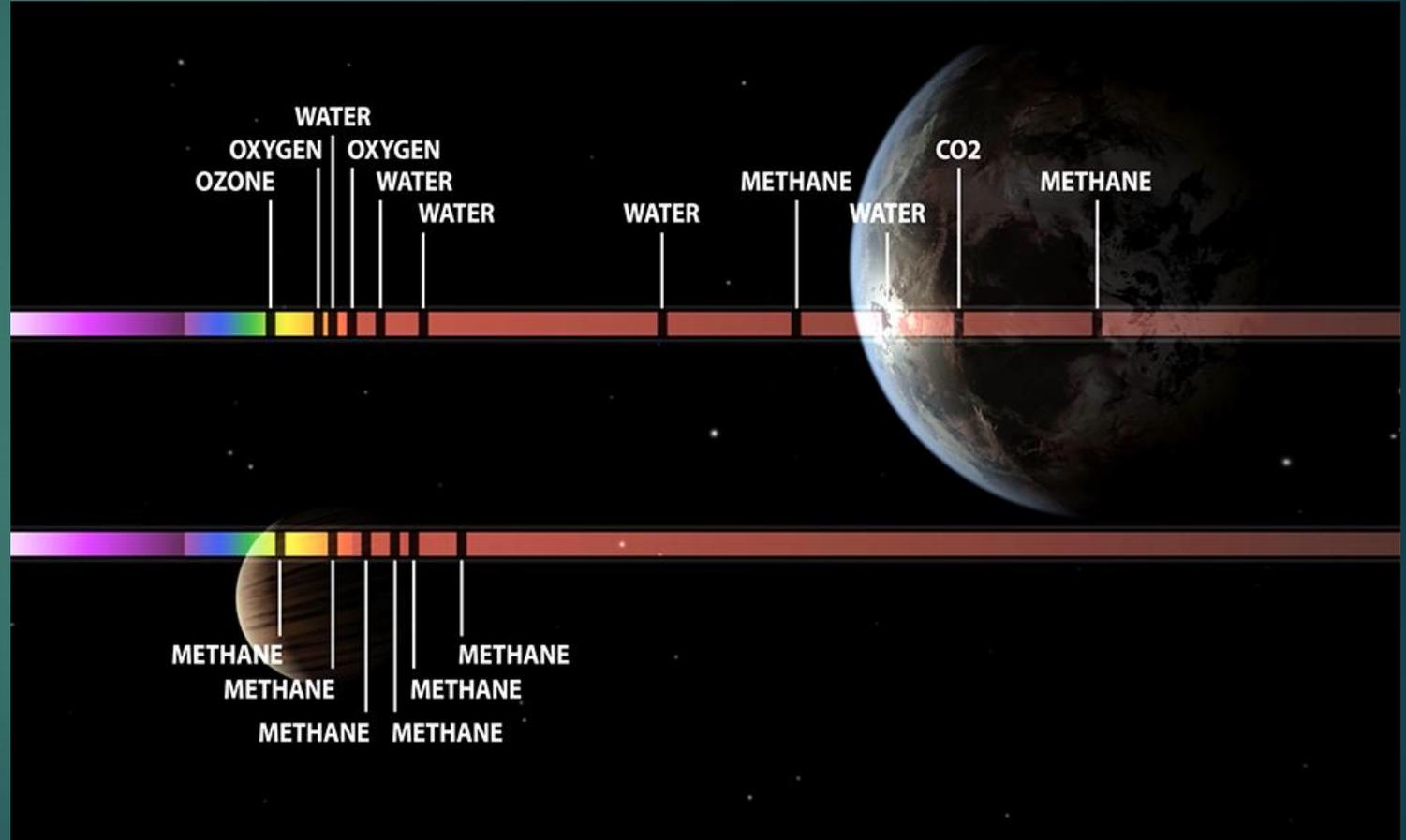
- ▶ NASA's James Webb Space Telescope, scheduled for launch in 2020, will probe the cosmos to uncover the history of the universe from the Big Bang to alien planet formation and beyond.
- ▶ It will focus on four main areas:
 - ▶ first light in the universe,
 - ▶ assembly of galaxies in the early universe,
 - ▶ birth of stars and protoplanetary systems,
 - ▶ and exoplanets (including the origins of life by examining the chemical makeup of their atmospheres).



Spectrophotometry

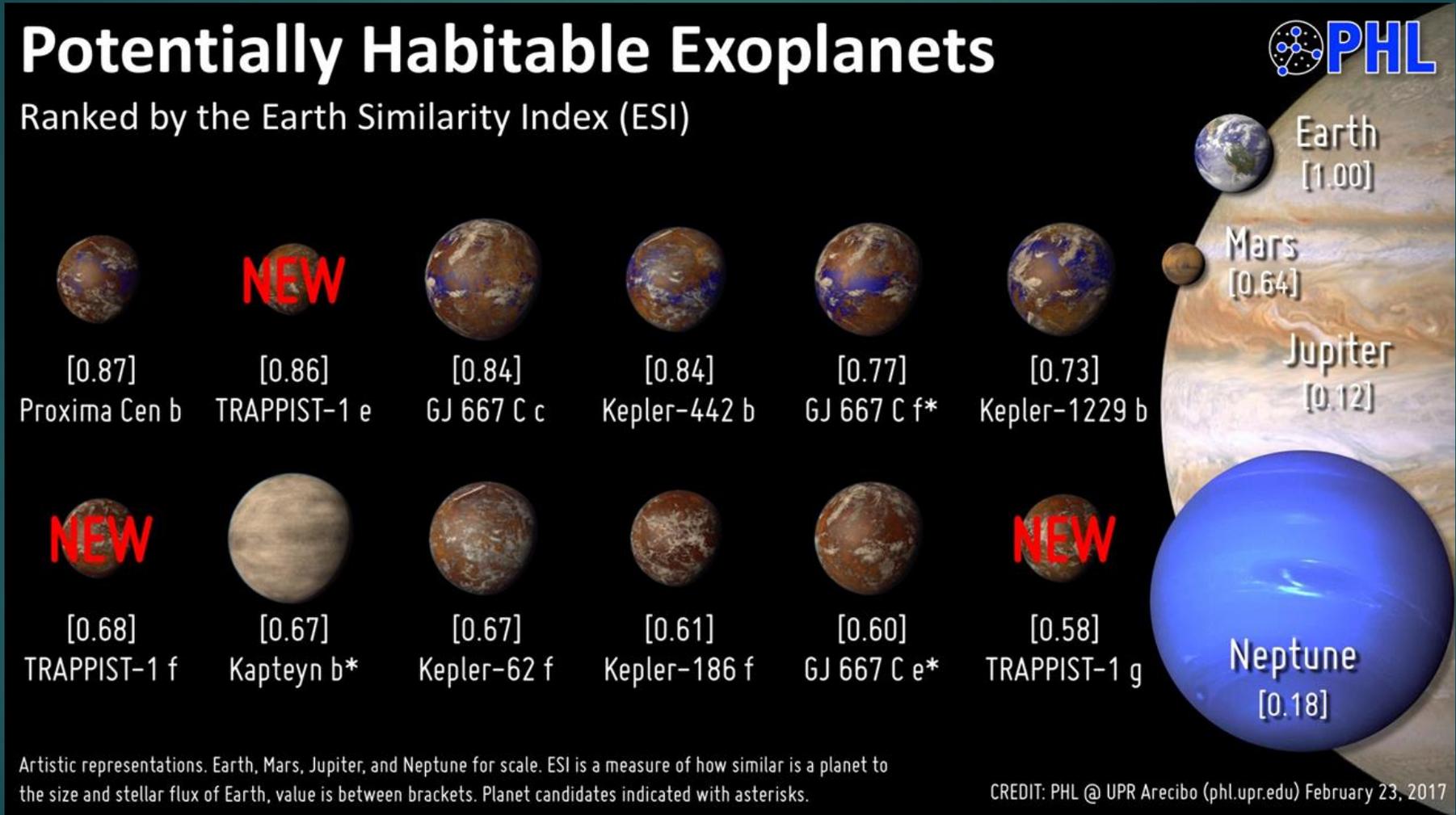
26

- ▶ Light from exoplanets, if passed through a prism, can be spread out into a rainbow of colours.
- ▶ Different colours correspond to different wavelengths of light.
- ▶ Missing colours show up as black lines, indicating specific gases are present, because each gas absorbs light in a specific wavelength (or colour).



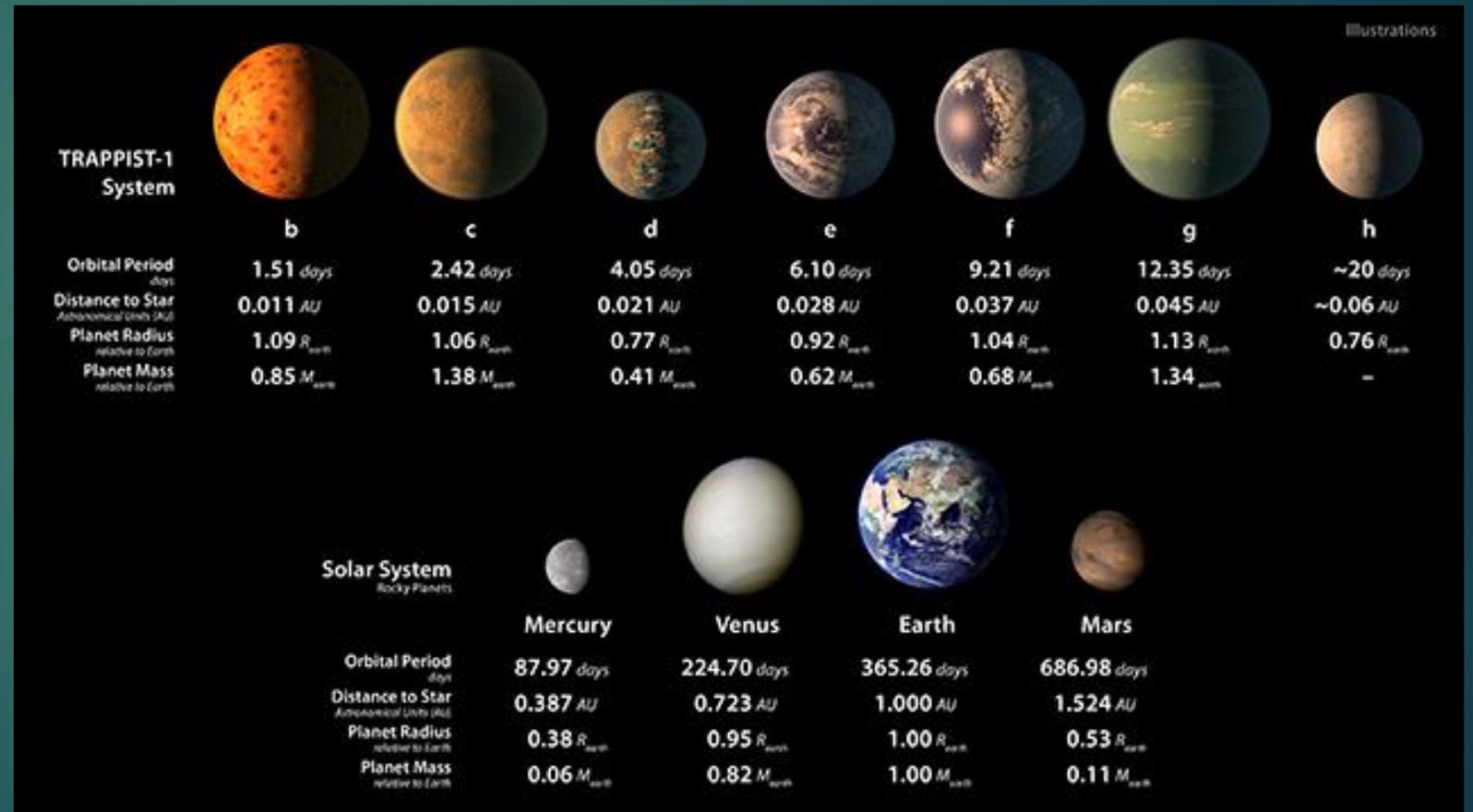
Exoplanets of Interest

Potentially Habitable Exoplanets



The TRAPPIST-1 System

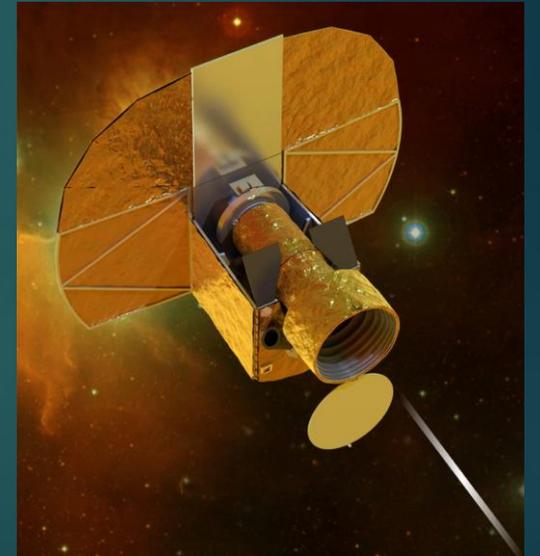
▶ TRAPPIST-1 is a small, red dwarf star some 39 light-years away in the constellation Aquarius



The Future...

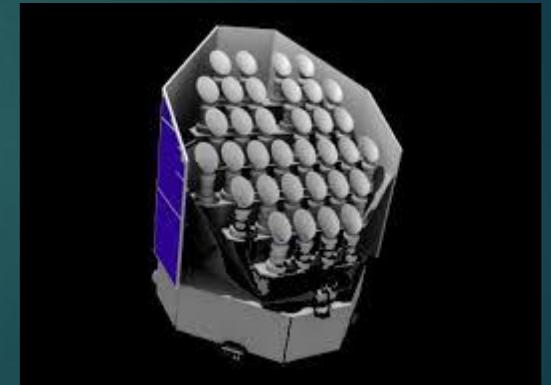
The Future...

- ▶ The European CHaracterising ExOPlanets Satellite (CHEOPS), is expected to be ready for launch by the end of 2018.
- ▶ The mission is designed to calculate the diameters of planets accurately, particularly those planets that fall between super-Earth and Neptune masses.



The Future...

- ▶ The Extremely Large Telescope (ELT), currently under construction in northern Chile, is a reflecting telescope with a segmented primary mirror 39.3 meters (130 feet) in diameter should see first light around 2024.
- ▶ The European Space Agency's PLATO (PLAnetary Transits and Oscillations of stars) is expected to launch in 2026. This optical space telescope will further augment the data from Kepler and Webb. Its mission is to search for earth-like planets in the habitable zone around sun-like stars where water can exist in liquid state.



“ The universe is a pretty big place. If it's just us, seems like an awful waste of space. ”

— CARL SAGAN

Some Resources

- ▶ The Planetary Habitability Laboratory (PHL)
 - ▶ <http://phl.upr.edu/home>
- ▶ Space.com
 - ▶ <https://www.space.com/>
- ▶ NASA
 - ▶ <https://www.nasa.gov/>