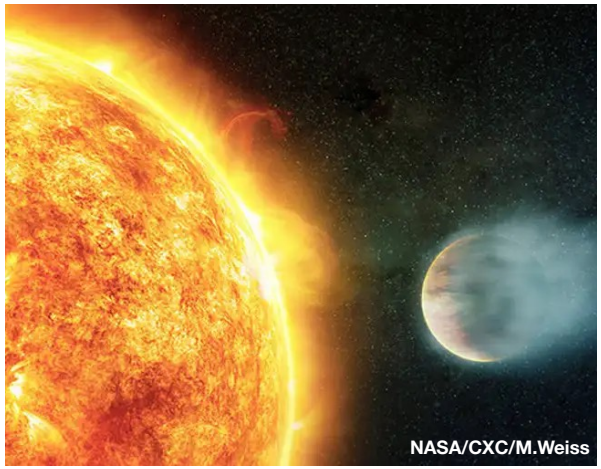

Out of this world

The more planets we discover, the more we realize that there is no such thing as a "normal" solar system. Here are some cool planets that are unlike anything in our solar system:

• The planet Kepler-16b orbits *two* stars. If we could travel there, we would see two "suns" in the sky, just like on Tatooine in *Star Wars*.

• Many stars have massive "Hot Jupiters" around them (pictured above) which orbit very close to their star. WASP-12b is a planet which orbits so close to its star that the star's gravity is literally tearing it apart! KELT-11b is "puffed up" planet with the density of styrofoam.

• Intense heat from stars can evaporate planets! The Neptune-sized GJ 3470b is bombarded by so much radiation from its star that astronomers estimate it has lost 1/3rd of its mass in its life. KIC 1520b is a rocky planet with a surface temperature so high (3300 °F) that metal and rock evaporate, possibly leaving behind a comet-like tail behind the planet.

What's going on at Northwestern?

Taking pictures of other worlds

Professor Jason Wang's group uses the largest telescopes in the world to see the faint light of exoplanets to learn about planets' compositions and evolutions.

How do orbits evolve?

Professors Fred Rasio and Yoram Lithwick use computer simulations and theoretical models to explain why some planets have "weird" orbits.

State-of-the-art infrared cameras

Professor Melville Ulmer's research group is developing new infrared cameras which can be used to take pictures of exoplanets.

The birth of planets

Professor Yoram Lithwick's group uses computer simulations and theoretical models to understand how disks of gas and dust around young stars produce the planets we see today.

Learn more…

There are many great videos, websites, and books which can help you learn more about exoplanets. Here are a few:

- **Crash Course Astronomy: Exoplanets**
  https://youtu.be/7ATtD8x7vV0
- **NASA exoplanet exploration hub**
  https://exoplanets.nasa.gov/
- **TESS Exoplanet Mission**
  https://science.nasa.gov/mission/tess/
- **Exoplanets encyclopedia**
  https://exoplanet.eu/

Exoplanets

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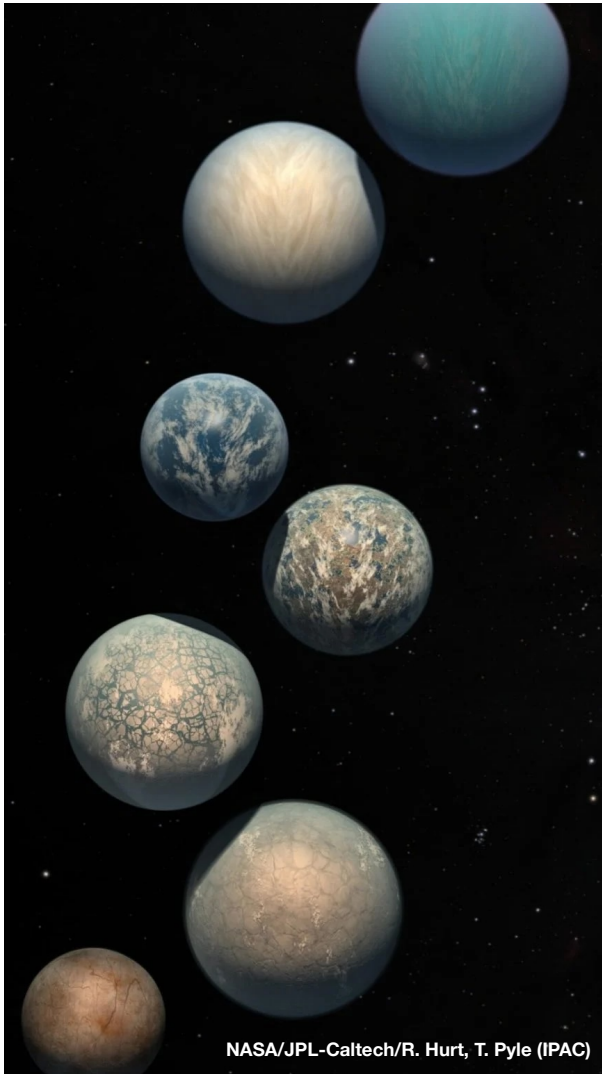
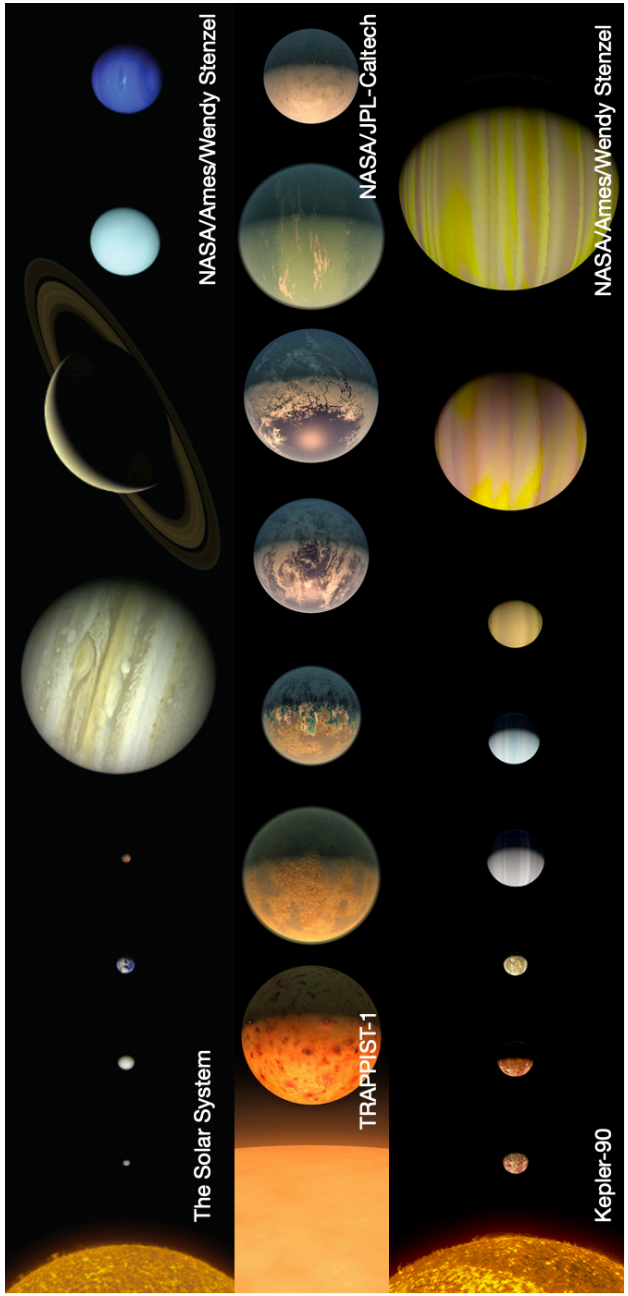


Our solar system is just one of many.



Every star likely hosts one or more planets

Until 1995, the only planets orbiting a living star that we knew about were the Earth and its neighbors in our solar system. In 1995, astronomers discovered the first large planet like Jupiter orbiting around the nearby star 51 Pegasi. In the years since that discovery, astronomers have discovered thousands of planets. We have come to realize that the night sky is full of *solar systems*, not just stars.

The search for life

Many scientists are driven by the age-old question of, "are we alone in the universe?" While astronomers have not yet found life on any planet other than Earth, many planets have been found that may have the potential to host life. These planets are in the "habitable zones" of their solar systems. This means that these planets are the right temperature to possibly have liquid water because they are neither too far away from (too cold) nor too close to (too hot) their host stars. In fact, some solar systems (like TRAPPIST-1) have multiple Earth-sized planets in the habitable zone!

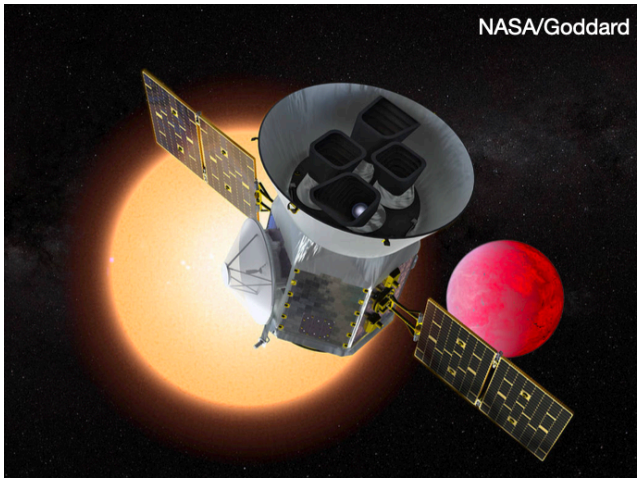
Other ways to find planets

Direct Imaging Only a few planets have had pictures of them taken by telescopes because of how dim they are compared to the stars they orbit. To combat this, astronomers are developing "star-shades" which block the light from a planet's host star to make it easier to take a picture of a planet.

Astrometry & Radial Velocity While orbiting, if it is large enough, a planet's gravity can tug on its host star making it appear to "wiggle" in the night sky.

Gravitational Microlensing Einstein theorized that gravity bends light. As it orbits, a planet can very slightly bend the starlight of its host star.

After discovering a planet, the next thing that astronomers do is *characterize* it. Some questions like "how big is a planet?" or "how far away from its star is a planet?" are easy for astronomers to answer, allowing us to build "maps" of planetary systems like the ones pictured on the left. Astronomers are now using state-of-the-art telescopes to try to understand what exoplanets are made of, and whether or not they resemble the Earth.



Transits & Space Telescopes

Exoplanets are hard to find because they are very dim compared to their host stars and very far away. Most known planets have been discovered through the transit method. When a planet "transits" between us and its star it blocks some of the star's light, and we see the star get dimmer! Telescopes stare at stars for a very long time (months or even years!), waiting to catch a planet in the act of dimming its star. From 2009-2013, NASA's *Kepler* space telescope stared at just *one small patch* of sky and discovered more than 2,000 planets. NASA's new TESS satellite (above) launched in 2018 and is working now to create a map of planets over the whole night sky.