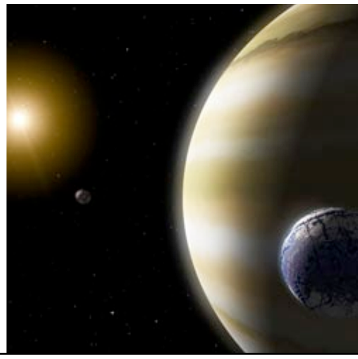


Artist Conception Courtesy NASA/JPL-Caltech

Artist's conception of an extrasolar gas giant. planet

In this Exploration, find out:

- How and when were the outermost planets in our own solar system discovered?
- What are the problems in hunting for other (extrasolar) planets?
- How can astronomers find a planet without really "seeing it"?

Planet Hunting 1: Finding Planets

The Discovery of Planets in Our Own Solar System:

Civilizations across the globe have known of Mercury, Venus, Mars, Jupiter, and Saturn since ancient times. The two outermost planets, and the dwarf planets, were all discovered in the past few centuries, and with the aid of telescopes. Before Uranus was discovered, astronomers didn't expect to find any planets other than the five visible with the unaided eye and the Earth. *Why are Uranus and Neptune harder to see from the Earth than the other five planets? Why wasn't Pluto discovered until the 20th century?*

Comparing the sizes and distances of the planets will help you answer these questions. The diameters and average distances from the Sun for the planets in our solar system are given in Table 1. An easy way to compare average distances between the planets is to look at them in terms of the Earth-Sun distance, which is called an **Astronomical Unit**. The symbol for an Astronomical Unit is **AU**.

Discovery of Uranus

Uranus was discovered in 1781 by musician and amateur astronomer William Herschel. Uranus was the first planet not known about by ancient people all over the world.

While observing the constellation of Gemini with a homemade telescope, Herschel discovered a unique object that didn't act like a star or a comet. After carefully recording his observations over several years, Hershel was able to show that he had found a new planet!

Uranus was named after the Greek god of the sky.

For Tables 1 and 2 complete the last columns with distances in AU using the given distance from the Sun in kilometers for each planet or dwarf planet.

Table 1: Planets in Our Solar System

Planet	Date Discovered	Diameter	Distance from Sun	Distance from Sun in AU
Mercury	Ancient Times	4,878 km	58 million km	
Venus	Ancient Times	12,104 km	108 million km	
Earth	-----	12,756 km	150 million km	1.0
Mars	Ancient Times	6,794 km	228 million km	
Jupiter	Ancient Times	142,796 km	778 million km	
Saturn	Ancient Times	120,660 km	1,427 million km	
Uranus	1781	51,118 km	2,871 million km	
Neptune	1846	54,523 km	4,497 million km	

Table 2: Dwarf Planets in Our Solar System

Planet	Date Discovered	Diameter	Distance from Sun	Distance from Sun in AU
Ceres	1801	950 km	441 million km	
Pluto	1930	2,300 km	5,913 million km	
Eris	2003	2,400 km	10,150 million km	

What about planets orbiting other stars?

Planets orbiting other stars (**extrasolar planets**) are much harder to find than planets in our own solar system. The first such planet orbiting another normal main sequence star or giant star wasn't discovered until 1995!

The Search for Planets Around Other Stars:

The Problem of Distance

- What star is closest to the Sun, and at a real distance of 40,000 billion km?

- How far away would it be on a model with a 1:10 billion scale? *(Hint: think about the Stellar Distances activity.)*

- How many AU away from the Sun is Alpha Centauri?

- What object can be used to represent the Earth on a model with a scale factor of 1:10 billion? *(Hint: Think about the Scale Model Solar System activity.)*

Now, imagine standing on a scale model on a 1:10 billion scale that includes both the solar system and the Alpha Centauri star system.

- If you were to stand at the model of Alpha Centauri and look back at the model Sun and planets, how hard would it be to see the Earth?

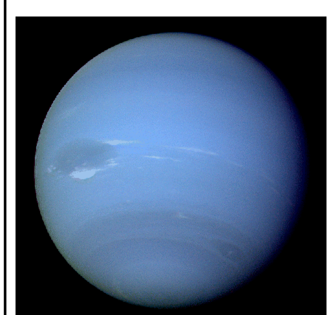
The vast distances between the stars, and the relatively insignificant sizes of planets, present a major problem in the search for extrasolar planets. *However, size and distance are not the only difficulties astronomers face when they look for planets around other stars.*

The Discovery of Neptune and the Power of Math!

Astronomer's began the hunt for Neptune because Uranus' orbit, its path around the Sun, was not shaped as expected. Uranus seemed to have gravity from an unseen planet tugging on it.

Astronomers John Coach Adams and Urbain-Jean-Joseph Le Verrier both made their own mathematical predictions for where this unseen planet would be in the sky.

Neptune was found on September 23, 1846 by Johann Gottfried Galle and his assistant, Louis d'Arrest, based on the mathematical predictions!



(Image Credit: NASA/JPL-Caltech, Voyager)

Neptune is named for the Roman god of the Sea.

Discovery of Pluto

In 1915, American Percival Lowell predicted a ninth planet, based on the differences between calculated and observed orbits of Neptune and other planets. Although these calculations turned out to be wrong, without them Pluto might not have been discovered until much later!

Astronomer Clyde Tombaugh, at the Lowell Observatory in Flagstaff, Arizona, began an exhaustive search for "Planet X". In 1930, 84 years after Neptune's discovery, Tombaugh discovered Pluto.

Pluto was named in a contest for school children across the country.

Due to Pluto's size and orbit in a part of the solar system known as the Kuiper Belt, it is now considered a dwarf planet.

The Problem of Brightness:

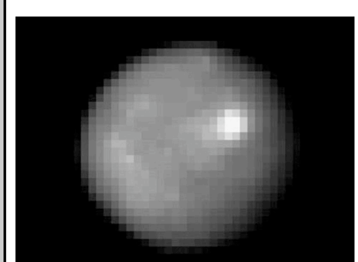
Stars are incredibly bright. The brightness of stars is the only reason we can see any stars other than the Sun without the aid of telescopes. *Our own star puts out as much light as four trillion trillion hundred-Watt light bulbs!* Stars are much larger than planets, but their larger size pales in comparison with the distances between them. Even with the best telescopes, most stars are visible as nothing more than points of light. Two exceptions are the Sun, and the red supergiant Betelgeuse.

Unlike stars, planets are visible only because of the light they reflect from their star. Because stars are so bright, and planets are so dim, planets can easily be lost in the glare of their star.

Summarizing the Problem:

Actually seeing a planet around another star is an extremely hard problem. The size of even the largest planets is almost nothing compared with the vast distances between stars. Stars are very bright and planets are relatively dim. However, despite the difficulties involved, astronomers from all around the world have been willing to tackle the problem and have come up with some very clever ways to find extrasolar planets. Most of the techniques astronomers are using to hunt for new planets involve indirect evidence; they are looking for the tiny effects that a planet has on the star it orbits.

Did you know? *Ceres, the largest object in the asteroid belt, was briefly classified as a planet after its discovery in 1801.*



(Image credit: NASA/HST, ESA, J. Parker (SwRI) et al.)

Finding a Planet without "Seeing" it:

Astronomers have come up with ways of finding extrasolar planets by using the light of the stars planets orbit instead of using the light reflected by the planets.

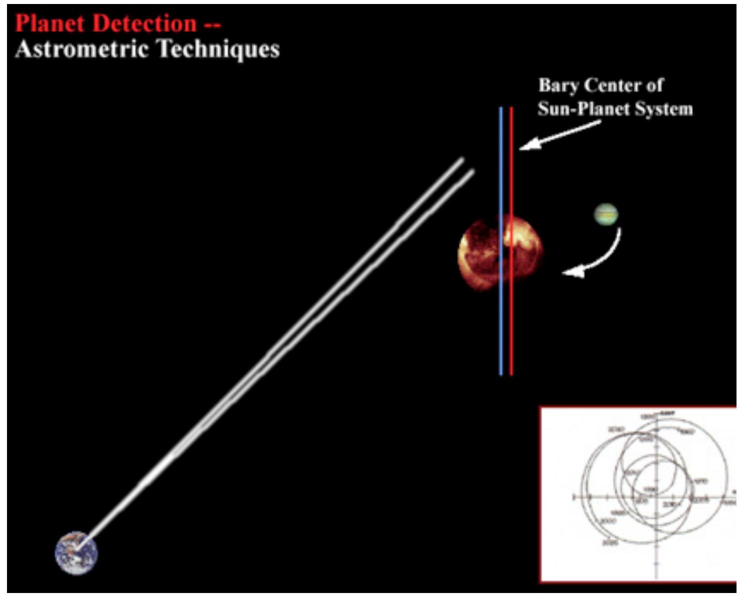
A Matter of Gravity:

Planets have mass and therefore also have gravity that pulls on the matter around them, just as the Earth's gravity pulls on us. Stars, however, have much more mass than planets do. The ability of a planet's gravity to move a star is extremely small in comparison with the star's ability to move the planet. As a planet orbits its star, it causes the star to move with it or "wobble" by a very slight amount. Astronomers can detect the wobble of a star caused by a planet in two different ways. They can look at extremely small changes in the position of a star in the sky with very sensitive instruments in a technique called **Astrometry**.

Using another method, called a **Radial Velocity Search** or **Doppler Spectroscopy**, astronomers look for a slight shift in the color of the star. If a star is pulled away from us it will look redder, and if it is pulled toward us it will look more blue. This is called *Doppler shift*.

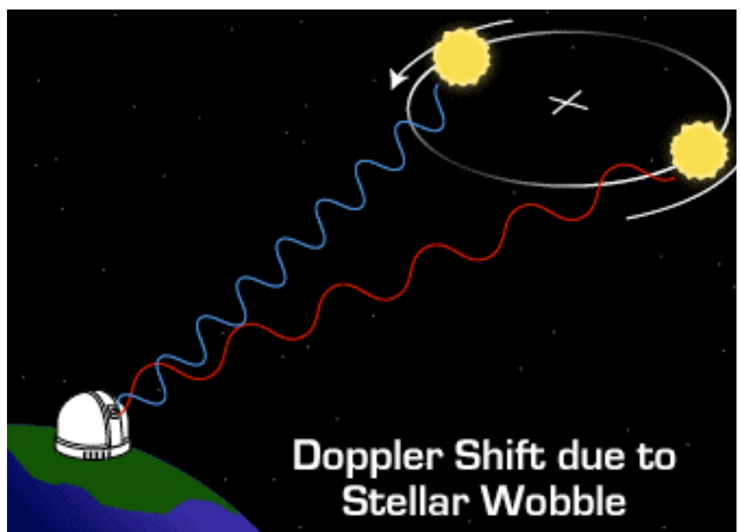
Methods of Detecting Extrasolar Planets

Astrometry



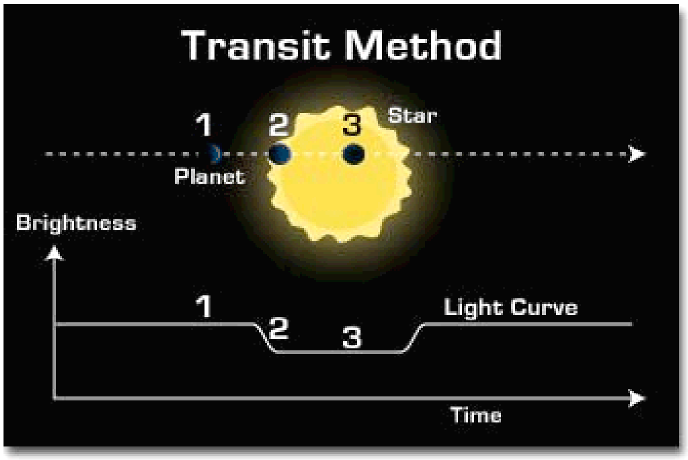
(Image Courtesy NASA/JPL-Caltech)

Radial Velocity Search



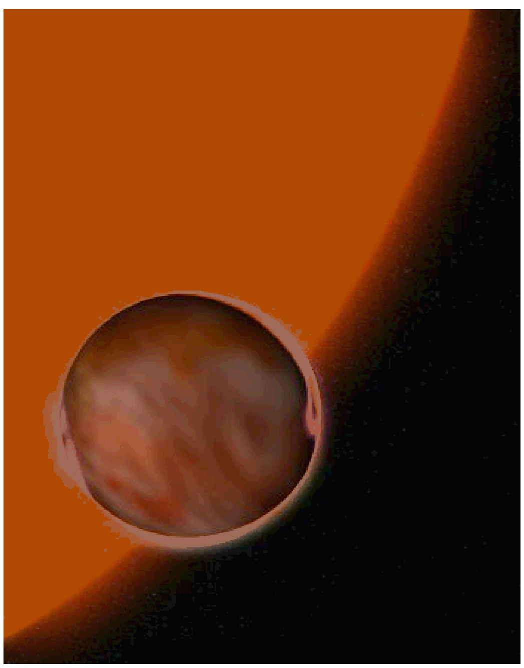
(Image Courtesy NASA/JPL-Caltech)

Transit Method



(Image courtesy: NASA/JPL-Caltech)

Orbiting the sun-like star, X0-1, a planet has been discovered with the transit method by a team of amateur astronomers. Planet X0-1b has 0.9 times the mass of Jupiter and an orbit period of 4 days. During the transit it eclipses about 2% of the stars brightness. It is located in the constellation of Corona Borealis. It is located 600 light-years away from us.



(Artist Conception Courtesy: NASAESA/STScI)

Blocking the Light:

Sometimes astronomers may be fortunate enough to see a planet pass between the Earth and the star the other planet orbits. When our moon passes between the Earth and the Sun, and the Earth, Moon, and Sun are lined up just right, we see a solar eclipse. The Moon is able to block out most of the Sun's light because it is so close to us. Even though the Sun is much bigger than the Moon, the Moon is so close that it and the Sun appear to be about the same size in our sky. When Mercury or Venus passes directly between the Earth and the Sun, we call this event a **transit** rather than an eclipse. This is because such a small percentage of the Sun's light is blocked out by Mercury or Venus. Transits by extrasolar planets also block out a small amount of their star's light. Astronomers can find planets using the **Transit Method** by carefully measuring the light we receive from a star.