Lesson Plan
Exploring the TRAPPIST-1 Planetary System

Time Required
Approximately
60 minutes

Vocabulary
Astronomical Unit
Exobiologist
Exoplanet
Habitable Zone
Light-year
Red Dwarf

SkyGuide Lesson

Teachable Moments -> Exploring the TRAPPIST-1 Planetary System

Guiding Question

What are exoplanets and how is the TRAPPIST-1 discovery significant?

Key Concepts

- An exoplanet is a planet that orbits a star outside of our own solar system.
- Exoplanets are common around other stars and have been discovered by a variety of methods.
- The habitable zone is a region in space around a star that could conceivably support life.
- Earth-Sized planets can be found around red dwarf stars.

Standards Connection

NGSS

Disciplinary Core Idea: Earth's Place in the Universe and Crosscutting Concepts—Patterns Scale, Portion, and Quantity; and Systems and System Models.

Grades 5 – 12
Space Systems

Grades 9 – 12
Space Systems

NSES

General
• Abilities necessary to do scientific inquiry
• Understanding about science and technology
Science as a human endeavor
• Motions and forces

Grades 6 – 8
• Transfer of energy
Earth in the solar system

Grades 9 – 12
• Origin and evolution of the Earth system

Introducing the Lesson

Until recently, our solar system was the only planetary system humans knew. It was even thought by some that our solar system was unique in the universe. This changed in the early 1990s, when astronomers began to discover the first exoplanets, worlds orbiting other stars. Since the first discovery, astronomers have found thousands of exoplanets. Astronomers now believe that planetary systems are plentiful throughout the universe. Science fiction has become science fact!

Humanity is new to hunting planets outside our solar system and astronomers have only recently been able to detect these planets. The problem is that a planet is much fainter than its parent star—less than a billionth as bright. Even the largest and brightest of these exoplanets gets lost in the glare of its star.

Luckily, there are indirect ways of detecting exoplanets by measuring the effects a planet has on its star. One is to detect the gravitational tug of a planet as it orbits its parent star, which makes the star sway back and forth. Another method is to detect the dimming that occurs when a planet passes between a star and an observer back on Earth.

Since planets don't emit their own light, it's hard to detect them optically. Missions, such as Kepler, use advanced technologies to detect Earth-sized planets directly. Perhaps one day we will be able to see the surface of a world orbiting a distant star!

Most of the exoplanets discovered so far have masses equal to or greater than Jupiter—the largest planet in our solar system. Some of these other solar systems have been found to contain two or more planets. More recently, we've began to detect Earth-sized planets using better tools and techniques.

Exoplanets have held several surprises for astronomers who study our own solar system. Many of the gas giant planets discovered orbit very close to their stars—many even closer than Mercury orbits the sun! This was contrary to existing models, which held that gas giants could never form that close to a star—only smaller rocky worlds were thought to survive there.

The orbits of some of these new worlds are greatly elongated, far from the nearly circular orbits of the gas giants of our solar system. Discoveries such as these have changed and continue to change the way we think solar systems form.

Why do astronomers search for exoplanets? One of the most important goals of the search for exoplanets is finding another world capable of supporting life. Allowing us to finally answer one of the greatest questions in the universe - are we alone?

The TRAPPIST-1 system is a significant discovery for a number of reasons:

- The largest batch of Earth-sized rocky planets discovered around a single star.
- Three of the planets are within the habitable zone of the star - the distance from a star that's not too hot or too cold – where water, if present, could exist in a liquid state on a planet's surface.
- Never before have so many planets been detected within the habitable zone of a single star.
- It is possible that liquid water might exist on all 7 planets if the atmospheres of these worlds have the right conditions.
- The distance to the system is only 39.5 light-years – putting future study of the planets' atmospheric compositions within reach of the next generation of telescopes.
- Proved that dim red dwarf stars are also viable hosts for Earth-like planets. This is particularly exciting because red dwarf stars like TRAPPIST-1 far outnumber stars like our Sun in our galaxy.

Leading The Lesson: Discussion Questions

Prior to having students go through the Starry Night lesson, it is important to introduce them to the concept of exoplanets and engage them in a discussion of the exciting scientific endeavor of exoplanet exploration. The discussion questions below, elicit student participation, activate students prior knowledge, and build curiosity about stars, exoplanets, and the potential of alien life on other worlds.

Discussion Questions

A. What is a star? What is a planet? What is an exoplanet?

A star is a large luminous ball of gas that creates and emits its own radiation due to thermonuclear fusion of hydrogen into helium at its core. The nearest star to Earth is the Sun. A planet is an astronomical body orbiting a star and is massive enough to be rounded by its own gravity but not massive enough to cause thermonuclear fusion at its core. An exoplanet is a planet that orbits a star outside of our solar system.

B. Why do astronomers search for exoplanets?

One of the most important goals of the search for exoplanets is finding another world capable of supporting life. If the conditions are right for life, then perhaps biology took place and life (perhaps even intelligent life) are present on these distant worlds.

C. Does each star have exoplanets? Are exoplanets rare or common? How many do you think have been discovered?

Planets are more common than stars, and most stars will have one or more exoplanets orbiting around them. As our ability to detect exoplanets has improved, we have discovered that exoplanets are very common. Initially, most exoplanet discoveries were of planets much larger than Earth, but we are now finding many Earth-sized planets - the biggest discovery being the seven Earth-sized worlds of the TRAPPIST-1 system. As of March 2017, over 3.500 exoplanets have been confirmed.

D. What is a light-year?

A light-year is the distance light travels in one year.
One light-year is approximately 9,460,536,000,000 kilometers (5,878,505,000,000 miles).

E. The closest exoplanet is 4 light-years away. Could we travel to another exoplanet within our lifetime?

With today's technology, it is not possible to travel to another star system within a human lifetime. The Spaceshuttle for example, could travel at 17,500 mph (28,160 km/h). At those speeds, it would cover 153, 300, 000 miles (247,000, 000 km) in 1 year and take about 150,000 years to travel 4 light-years to the nearest exoplanet - Proxima Centauri b.

F. What keeps planets in orbit around their star? What force do planets and stars exert on each other?

The planets are held in their orbits by the Sun's gravity. The strength of gravity's pull is related to the distance from a massive object (in this case, the Sun). The closer to the Sun a planet is, the more strongly it feels the pull of the Sun's gravity, and the faster it moves in its orbit. The more distant a planet is from the Sun, the weaker is the pull of the Sun's gravity, and the more slowly the planet moves.

Sir Isaac Newton described it this way: the force of attraction, F, between two bodies is proportional to the product of their masses, m_1 and m_2, and inversely proportional to the square of their distance apart, d. Mathematically, Newton's Law of Universal Gravitation is written like this:

$$F = G\, m_1 m_2 / d^2$$

where **G** is the gravitational constant.

G. How do you think astronomers are able to detect exoplanets around other stars?

Answers from students will vary.

H. If a planet moves in front of its star (a transit), what do you think will happen to the amount of light reaching you?

The amount of light reaching you would diminish for the duration of the transit. The effect is similar to moving a coin in front of a flashlight.

I. Many of the exoplanets that astronomers have discovered are very large and very close to their parent star. Why do you think that is? Why is it harder to find smaller planets?

Transit Photometry - measuring the dimming of a star's light when its planets pass between us and the star; and Radial Velocity and Stellar Astrometry - two methods that detect the subtle motions of stars caused by orbiting planets tugging on them gravitationally; are some of the most effective methods to detect exoplanets.

It is easier to detect larger planets passing in front of a star and detect the gravitational pull of larger planets on their host star. It is also easier to detect planets if they are orbiting closer to their parent star, as these planets block more light, complete their orbits faster, reflect more light, and can have a greater measurable gravitational effect on their parent star.

J. What makes Earth special compared to other known planets?

Earth is the only known planet in the universe to harbor life.

K. Do you think some exoplanets could support alien life or be habitable by humans? What kinds of criteria should we consider when looking for an exoplanet that might have life?

Our galaxy, the Milky Way, contains up to 400 billion stars. Exoplanets outnumber stars in our galaxy. To date we have also detected many Earth-sized planets at the right distance from their stars to maintain liquid water on their surface. The odds are that a great number of exoplanets in our galaxy alone will be capable of supporting life and be habitable by humans. Odds are also that alien life might be present on some of these worlds.

New tools are being developed that will allow astronomers to look for the telltale signs of life on exoplanets. It will soon be possible to directly detect an analyze the atmosphere of nearby exoplanets. Scientists will be looking for the presence of atmospheric oxygen - a marker that could indicate biological activity.

L. Do you think we'll keep finding more exoplanets?

Yes. Scientists are developing new tools and techniques to detect exoplanets. New space observatories are also being launched in the next few years that will detect even more Earth-sized exoplanets. Hunting for exoplanets is still in its infancy.

M. All exoplanets discovered so far can be found within our own galaxy, the Milky Way. Do you think other galaxies might also have planets?

Yes. Other galaxies are formed much the same way as our own galaxy, the Milky Way. It is safe to conclude that planets also form around stars in other galaxies.

Extension Activities

Activity One: Have your students draw their own exoplanet star system. Have them include details such as the distance to the planets, planet sizes (gas giants, rocky worlds etc), star type (bluer stars are hotter, while redder stars are cooler), planet age, and which ones might be able to support life.

Activity Two: Have students draw and/or write about what it might be like to live on the surface of a TRAPPIST-1 exoplanet.

Vocabulary Link

Astronomical Unit: The average distance from the Earth to the sun, or 149,597,870 kilometers (92,955,807 miles). Abbreviated AU.

Exobiologist: Study the branch of biology that deals with the search for extraterrestrial life and the effects of extraterrestrial surroundings on living organisms. Also called astrobiology.

Exoplanet: a planet that orbits a star outside our solar system.

Habitable Zone: The region in space around a star that might potentially support life; surface temperatures of planets in the habitable zone allow for the existence of liquid water.

Light-Year: The distance light travels in one year. One light-year is approximately 9,460,536,000,000 kilometers (5,878,505,000,000 miles).

Red Dwarf: A small and relatively cool star on the main sequence.

Evidence of Learning

Upon completion of this lesson, you should have evidence that students can:

- Explain what an exoplanet is.
- Understand some of the methods to detect planets outside our solar system.
- Recognize the vast distance between the stars.
- Understand the importance of exoplanet research.

Additional Resources

SkyGuide->Teachable Moments->Exoplanets: Worlds Outside Our Solar System

NASA Exoplanet Archive - http://exoplanetarchive.ipac.caltech.edu