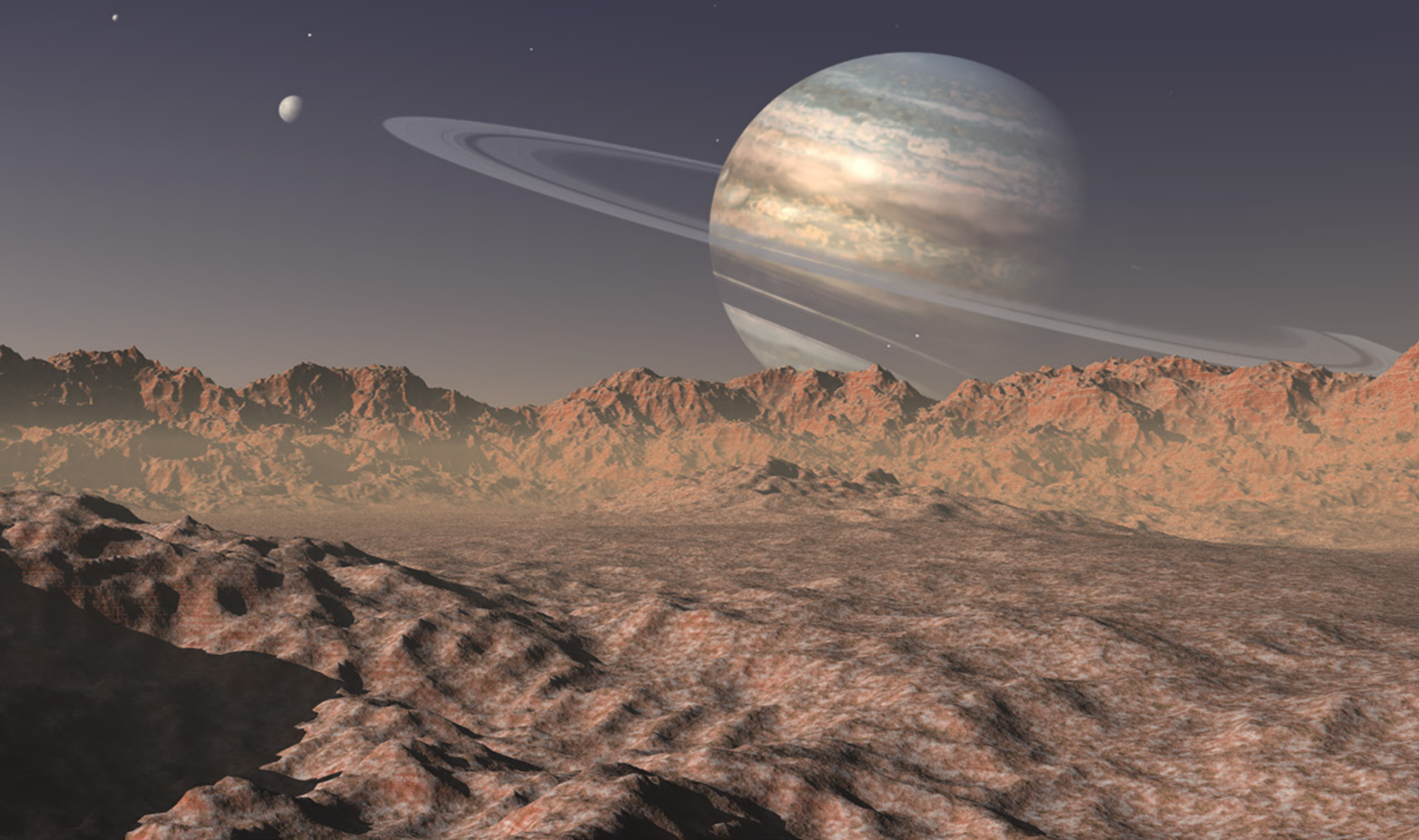
GRIFFITH OBSERVATORY ONLINE SCHOOL PROGRAM

MODULE 4: EXOPLANETS ARE EVERYWHERE

TEACHER GUIDE



Dear Teacher,

Welcome to Griffith Observatory's Online School Program teacher resources!

It is our mission to inspire everyone to observe, ponder, and understand the sky. With this program, we intend to be your partner in education, providing you access to experts and unique activities that bring science to life in your classroom.

Our Fifth-grade Online School Program modules are

- Entirely free to participate
- Aligned with current fifth-grade education Next Generation Science Standards (NGSS)
- Interactive and presented live by Griffith Observatory's knowledgeable staff
- Intended to inspire students' curiosity for space exploration and S.T.E.M. (Science, Technology, Engineering, and Mathematics) subjects and to expose them to the latest astronomical science and technology

If we learn how to observe and do so carefully, we are rewarded with profound discoveries about the universe and ourselves. This is the unifying theme of our Online School Program modules and what we hope your students will take away from the program.

Thank you for teaching the next generation of critical thinkers and observers!

GRIFFITH OBSERVATORY® REC & PARKS LA GRIFFITH OBSERVATORY FOUNDATION

Griffith Observatory Online School Program

Overview

Griffith Observatory's online school program is a live, interactive, virtual school program for fifth-grade students. The program offers live and prepared elements that feature Griffith Observatory's knowledgeable Museum Guides and Telescope Demonstrators. Like the in-person school program, this online program is offered to interested schools on a first-come, first-served basis, and we encourage participation by schools in communities that have limited access to special science-outreach initiatives. The online program enables students to have a meaningful, virtual Observatory experience without transportation and geographic barriers to participation. The operation of both programs is funded by Griffith Observatory and Griffith Observatory Foundation.

Griffith Observatory's online school program is hosted entirely through Zoom, is delivered live from Griffith Observatory, and meets current fifth-grade standards (NGSS 2015).

Structure

The program is a series of modules that each address a different aspect of observation. Each module contains live, recorded, and animated elements, lasts about 30 minutes, and is followed immediately with a question-and-answer session. The modules are intended to be experienced in order, though not necessarily within a particular time-frame.

Goals

The modules are designed to accomplish three goals:

- inspire students to be observers
- encourage students to appreciate their place in and relationship to the universe
- expose students to the latest astronomical science and technology

The Modules

MODULE 1: EVERYONE IS AN OBSERVER

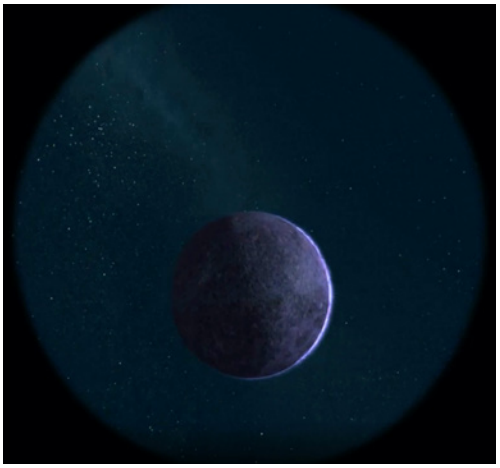
"Everyone Is an Observer" examines the observational skills everyone uses to navigate life. Through virtual daytime and night observation with Griffith Observatory's historic coelostat and Zeiss telescope, participants learn how astronomers observe, use scientific instruments, and record data to expand their knowledge of the universe. How has systematic observation changed our understanding of objects in space, and how have our findings helped us understand Earth's relationship to them?

MODULE 2: CLUES FROM COMETS

"Clues from Comets" investigates the process of using observations to understand cause-and-effect relationships between events, exemplified by our understanding of comets over time. Presented live from Griffith Observatory's Leonard Nimoy Event Horizon theater, the program guides students through centuries of records kept on the appearances of comets as people gradually learned about their nature. Midway into the presentation, participants witness the manufacture of a life-ingredient-bearing comet from household supplies. Finally, participants embark on a journey to a real comet in space fashioned from actual photographs from the *Rosetta* mission. What can comets tell us about the solar system and about ourselves?

MODULE 3: THE SEARCH FOR WATER

"The Search for Water" emphasizes that liquid water is essential for life, looks inward at our own planet with thriving life forms, and then outward for other water-lush worlds. Griffith Observatory's *Our Earth*, *Our Moon*, *Elements*, and *Solar System Worlds* exhibits are explored to identify conditions and materials present on our world versus others. The unique properties of water are examined with a variety of demonstrations, and the resilience of life is explored with footage from Earth's extreme places. Students are then guided through the solar system in search of environments that sustain liquid water. The program includes animated elements from Griffith Observatory's planetarium show *Water Is Life* that have been converted to 2-D and enhanced for on-line learning.



MODULE 4: EXOPLANETS ARE EVERYWHERE

“Exoplanets Are Everywhere” outlines the structure of our solar system and shows how a planet’s distance from its star, among other circumstances, is essential for making it a habitat for life. Students encounter exoplanet discoveries and what they mean. In this exhibit-based experience with interactive components, participants visit simulated alien worlds and solar systems in search of habitable planets. Students will visit The Gunther Depths of Space, experience the solar system models, see the current exoplanet count, take a tour of The Big Picture, see *Our Sun Is a Star*, and get acquainted with modern exoplanet-hunting technology.

MODULE 5: EARTH IS OUR HOME

“Earth Is Our Home” guides participants on an immersive, 13.8 billion-year journey through Griffith Observatory’s *Cosmic Connection* timeline. Environmental change can be caused by cosmic events or by living things. When ecosystems change, life also changes. Real-life stories demonstrate that studying Earth from an astronomical perspective sheds light on how people are changing Earth’s ecosystems. Two core messages are emphasized: The evolution of Earth and life are intertwined, and observation and scientific thinking are key for protecting Earth’s resources and environment.

Program Rundown

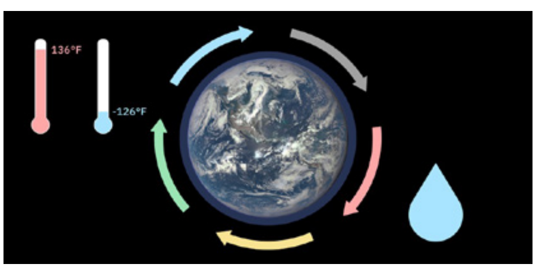
Module 4 Strategies

- Emphasize that the Earth's special relationship with the Sun allows Earth to host the special conditions needed for life by comparing and contrasting other solar system relationships.
- Elicit comprehension and excitement that solar systems are common and that many millions of potentially habitable planets exist by introducing exoplanet-finding technologies.
- Use our exhibits and astronomical art to model complex relationships within solar systems and illustrate how these relationships affect a planet's surface conditions.
- Supplement live and recorded content with documents and materials for the classroom and at home, to be used before and after participating in the module.

Module 4 Breakdown

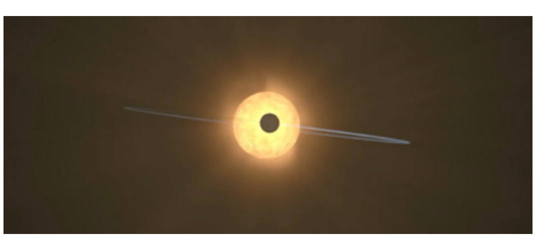
PRE-PROGRAM WAITING ROOM
When logged on early, you encounter a waiting room animation indicating that the program has not yet begun.

ARRIVAL TO GRIFFITH OBSERVATORY ANIMATION
An animation designed and produced by Griffith Observatory's Satellite Studio brings you from the far reaches of the universe to Griffith Observatory.



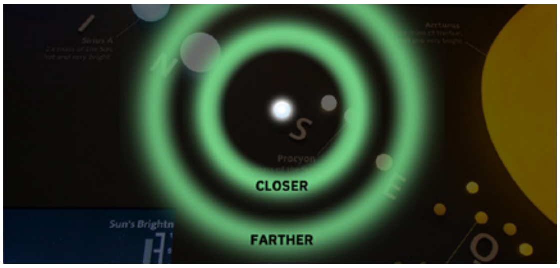
LIVE INTRODUCTION TO YOUR MUSEUM GUIDE
A Museum Guide joins you live from Griffith Observatory's Gunther Depths of Space. The Guide acknowledges our shared survival trait, curiosity, and shares a poll to encourage thought about whether other Earth-like worlds could exist. We learn why the surface conditions on Earth support life and why those of other planets in our solar system don't.

SOLAR SYSTEM AND HABITABLE ZONE INTRODUCTION
The Museum Guide directs us up to the front lawn of Griffith Observatory, where a 3-D model depicts a scale model of our solar system. Students see why certain planets have the surface conditions previously mentioned: Much of it has to do with each planet's relationship with its star. We are introduced to habitable zones, or "Goldilocks" zones.



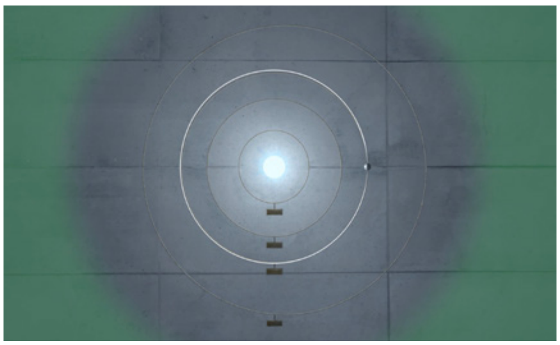
EXOPLANET INTRODUCTION & DISCOVERY METHODS
Our attention is directed outward toward a sky filled with stars and other galaxies. "Exoplanets" are introduced, and different methods for finding them are explained with the help of animations. The goals, challenges, and outcomes of exoplanet-hunting missions are shared.

Program Rundown continued



STAR COMPARISONS AND CRITICAL-THINKING POLL

We visit the *Our Sun Is a Star* exhibit in the Ahmanson Hall of the Sky to learn that stars vary in brightness and in temperature, and so not all suns are the same. The Museum Guide challenges students to think about where some stars' habitable zones are, based on what they have learned thus far.



ASSESSING THE POSSIBILITY OF HABITABLE WORLDS

Visualizations from the front lawn 3-D model and artist conceptions provide a more descriptive look into how solar-system relationships affect exoplanets at surface-level. Atmosphere is introduced as a factor that also affects whether an exoplanet could be a habitable place. Participants learn the current exoplanet count and discover the breadth of possible worlds at the *Other Worlds, Other Stars* exhibit in The Gunther Depths of Space.

CONCLUSION

We look toward a bright future of exoplanet news with an introduction to the new *James Webb Space Telescope*. The students embark on a journey to possible exoplanets and land on them. The landscapes, artist conceptions by renowned astronomical artist Chris Butler, are informed by actual exoplanet research. The live Museum Guide returns with some hopeful remarks about the future of exoplanet research and a reflection that we may not be the only life out there.

QUESTION-AND-ANSWER SESSION

We transition to a question-and-answer session with the live Museum Guide. The Guide answers questions about science from students.

2015 Next Generation Science Standards Reflected in the Program

Module 4: Exoplanets Are Everywhere

GRADE	STANDARD	NGSS DESCRIPTION	HOW THE STANDARD IS ADDRESSED
3-5	Principle I (CA)	The continuation and health of individual human lives and of human communities and societies depend on the health of the natural systems that provide essential goods and ecosystem services.	We identify why Earth is a hospitable place for life compared to the other planets in our solar system and how our relationship with the Sun plays a large role.
5	5-ESS1-1 ESS1.A	The Sun is a star that appears larger and brighter than other stars because it is closer. Stars range greatly in their distance from Earth.	We repeatedly show models that demonstrate how a planet's distance from its star, coupled with the star's brightness, influences a planet's surface conditions. We discuss why living things on Earth rely on our closest star specifically and compare our sun to other stars.
5	5-PS3-1	Use models to describe that energy in animals' food (used for body repair, growth, motion, and to maintain body warmth) was once energy from the Sun.	We discuss the role that the Sun's energy plays in sustaining life on Earth and why it is important that Earth receives just the right amount of this energy.
3-5	3-5-CCC-5 (5-PS3-1)	Energy can be transferred in various ways and between objects.	We explain that the specific amount of solar energy transfered to Earth's water allows that water to exist naturally in three states: Solid, liquid, or gas.
3-5	3-5-CCC-3 (5-PS1-1)	Natural objects exist from the very small to the immensely large.	The immense differences in scale between the Earth, the Sun, other stars, and solar systems are frequently discussed. Materials included in this guide develop the concept of scale in our solar system and beyond.
5	5-ESS2-1	Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact.	We explain that a planet's atmosphere has an influence on its various surface conditions, including its temperatures, whether it has an ocean, and whether it can support life as we know it.
3-5	3-5-CCC-2 (5-PS2-1)	Cause and effect relationships are routinely identified and used to explain change.	We show that if a planet is going around a star and happens to pass in front of it, a tiny amount of the star's light is blocked. These changes may be observed and are evidence that an exoplanet is orbiting the star.

Standards continued

GRADE	STANDARD	NGSS DESCRIPTION	HOW THE STANDARD IS ADDRESSED
3-5	3-5-CCC-1 (5-PS1-2)	Scientific knowledge assumes an order and consistency in natural systems.	Multiple orbital animations provide visual evidence that solar systems have natural order. Students learn that by observing certain data about stars, habitable zone locations may be accurately predicted.
3-5	3-5-ETS1-1	Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.	The objectives, challenges, outcomes of exoplanet-finding missions such as *Kepler* and *TESS* are explored.
3	3-PS2-1	Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.	We demonstrate that as an exoplanet orbits its star, its gravity puts a small tug on the star. This makes the star “dance.” We relate this complex concept to a familiar activity: Holding hands and spinning.
5	5-PS2-1 PS2-B	The gravitational force of Earth acting on an object near Earth’s surface pulls that object toward the planet’s center.	We show how the gravity of stars and planets tug each other into predictable orbits within their solar systems.
3	3-PS2-2	Make observations and/or measurements of an object’s motion to provide evidence that a pattern can be used to predict future motion.	One way to find exoplanets is observing subtle patterns in the motion of a star.

Connecting to the Program

Overview

This section contains all of the information you and your students will need in order to join your online school program webinar session and ensure a successful virtual visit to Griffith Observatory. It is essential that you read and follow these instructions carefully.

Within 24 hours of completing the registration process for our program, you should have received a confirmation email from online.sp@griffithmedia.org. The message includes a **Zoom webinar link**, the **date and time** of your session, and other important information and links. You are responsible for forwarding the necessary information, according to the instructions in the message, to your students and all included teachers. Shortly before your scheduled Griffith Observatory Online School Program webinar session, you will receive a reminder message.

What You Need to Know

- Please be as punctual as possible. Your session includes a window for arrivals before the actual program begins, but the program will begin regardless of whether every registered classroom shows up or not.
- A Griffith Observatory staff member will be in the Zoom room to assist you if needed, relay some reminders, and will then act as your main point of contact for any questions you may have during the program. Use the chat feature to message the "Host and Panelists."
- The school program now uses Zoom's "webinar" model. Teachers and students are encouraged enter the webinar all at once. Although you will be muted with your video turned off, you may still use the chat function to message Griffith Observatory staff.
- Students that join the webinar from their individual devices are also not able to unmute themselves or share their video streams. They may not chat with each other. They may, however, use the chat feature to ask for help and use the Q&A feature to submit astronomical questions to staff. Questions submitted in the Q&A feature are not visible to everyone unless a staff member chooses to answer it live.
- You may also choose to project the program to your class. Note: This means you will need to answer the interactive polls and ask questions for the Q&A on behalf of your class.
- In the unlikely event that the Griffith Observatory video stream drops out of the webinar, please instruct your students to wait patiently and remain in the call.

Essential Information for Students

It is your responsibility to make sure your students receive and understand the following information. You may easily copy it and paste it into a message to your students. Make sure you insert your class's registered session **time**, **date**, and unique **Zoom webinar link** into the **orange** areas below. This information may be found in your confirmation email.

Dear Students,

Your class's Griffith Observatory Online School Program webinar time:
[**INSERT YOUR REGISTERED WEBINAR TIME AND DATE**]

Please log on at the time of your scheduled session. Make sure you set your "Zoom name" to contain your first and last name.

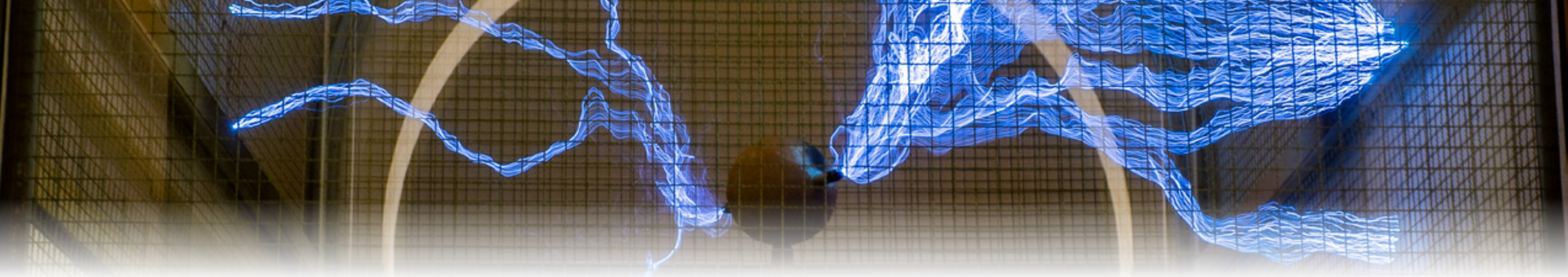
Once you enter the webinar, you will be muted with your video off. You will see a video of Griffith Observatory against a sky that cycles between day and night, and you will hear music. If you do not see the video or hear the music, use this time to work with a grown-up to check your internet connection and sound. You may also use Zoom's chat feature to ask one of the Griffith Observatory hosts for help. Once everything is working perfectly, pay attention to the instructions, and have a great online visit to Griffith Observatory!

Click the link below or copy and paste it into an Internet browser to join the meeting.

YOUR CLASS'S ZOOM WEBINAR LINK:
[**INSERT YOUR GRIFFITH OBSERVATORY ZOOM WEBINAR LINK**]

THIS WEBINAR LINK IS YOURS AND YOURS ONLY. DO NOT SHARE IT WITH ANYONE NOT PART OF YOUR CLASS.

Before the program, please make sure you have reviewed your **Student Guide**.



Frequently Asked Questions

How safe are the online school program's meeting rooms?
Your meeting room has a unique **Zoom webinar link** that will only be issued to the teacher/adult contact(s) you indicated during the registration process and to other teachers and students that have registered for that particular session. The email message with the Zoom webinar link also contains necessary information to relay to your students. This information includes a prohibition on sharing the Zoom webinar link, as keeping the webinar session link private guarantees security. At the beginning of the program, staff will state that any inappropriate, rude, or harassing language or spam sent to staff in the chat or Q&A is not tolerated and may result in being dropped from the Zoom session.

Do my students and I need to download the Zoom app to view the program?
No. You may click the Zoom webinar link or copy and paste it into an internet browser. If you do not have the Zoom app, your browser will present you with an option to "join from your browser." If you do have the Zoom app, you will be redirected to the webinar in your Zoom app after searching the link in your internet browser.

Can I access my registration form to make changes?
There is a link in your confirmation email to make any registration corrections or to reschedule.

What happens if a participant has poor connection, loses connection, or needs help?
Students will be told early in the Zoom webinar what they should do if they need help or if a connection issue occurs. They may use Zoom's chat feature to talk to Griffith Observatory staff members to report or receive help with technical issues. If a participant's call fails, the participant will be able to use the same Zoom webinar link to rejoin the session.

May I or my students record the program?
No. Like the Observatory's in-person school program, the live webinar is designed and intended to be experienced in the moment. We also need to safeguard the program content, quality, and integrity. In the future, we may consider producing recorded versions of the program, but they would be optimized for that format (vs. a live program.)

Contact

For any concerns or questions, contact online.sp@griffithmedia.org.

Pre-program Materials

To get the most out of Module 4: Exoplanets Are Everywhere, explore the following materials before your visit.

Module 4 Glossary

The glossary identifies and defines important words that are useful for students before they attend “Exoplanets Are Everywhere” and explore the following materials.

Listen to the Module 4 Glossary

This helps students become familiar with the terms we shall use in the program. This is recommended as an accessibility resource for students with physical and/or language-related challenges. The audio file includes pronunciations and definitions of important terms used in our program (same as in the Glossary above).

Lesson Plan: Choose Your Own Exoplanet Adventure

This highly interactive two-part lesson plan encourages students to think about the habitability of different environments and the diversity of life.

Make a Solar System Model

This is a resource designed to help students understand the concept of “scale” in our solar system. It features different ways for learners to visualize and reflect upon the size of each planet and how far they are from each other.

Make an Extrasolar Planetary System Model

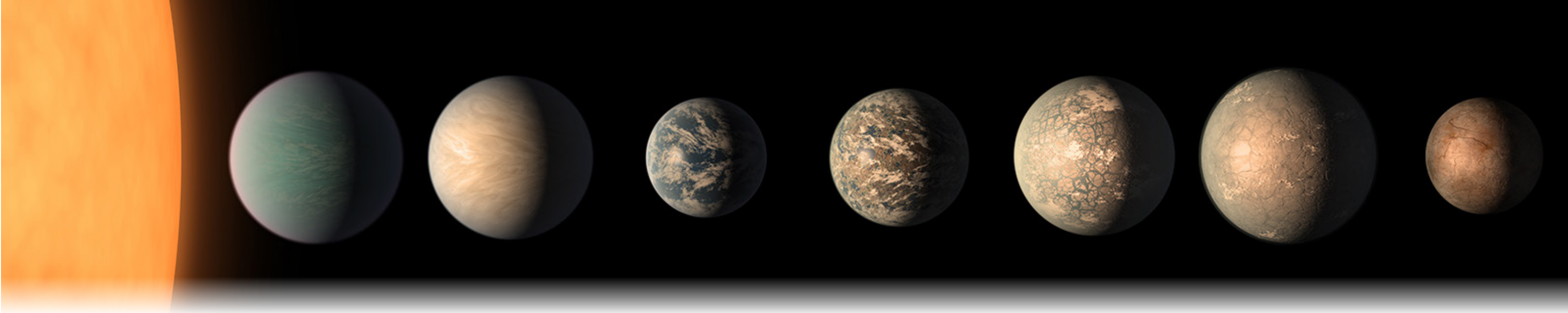
This resource is a supplement to *Make a Solar System Model* that is intended to help students understand how different other stars and solar systems are from each other.

Reality vs. Fiction of Worlds Beyond

In this compare-and-contrast exercise, students encounter imaginative predictions created in the past about worlds beyond Earth and compare them to actual scientific imagery. They are instructed to note similarities & differences.

Zodiac Constellation Activity Chart

This chart is a hybrid between a game and a functioning observing tool. Students complete the chart by engaging in a familiar activity and then use it outside to reveal the unseen sky.



Glossary

MODULE 4: EXOPLANETS ARE EVERYWHERE

astronomy – the study of space and everything in it, including, but not limited to, stars, planets, galaxies, nebulae, black holes, supernovae, asteroids, comets, and the search for life beyond Earth.

atmosphere – the layer of gas that surrounds Earth. It is often called air. Other planets, and some of their larger moons, also have atmospheres.

atom – a basic unit of matter. An atom has a nucleus containing protons and neutrons and a cloud of electrons surrounding the nucleus.

calculate – to determine something with arithmetic.

carbon dioxide – a compound made of the elements carbon and oxygen. It represents a small fraction of Earth's atmosphere. The atmosphere of Mars is mostly carbon dioxide.

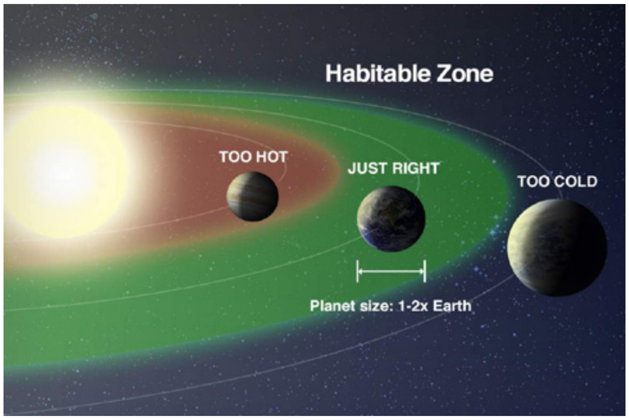
exomoon – a moon that orbits an exoplanet.

exoplanet – a planet that does not orbit our Sun. Most known exoplanets orbit other stars, but some, known as rogue planets, do not orbit any star.

galaxy – a massive collection of stars, gas, dust, and other celestial objects bound together into a single system by gravity. A galaxy may contain from ten million stars to one trillion stars. The Sun and Earth are in the Milky Way Galaxy.

Goldilocks zone – a less technical term for *habitable zone* that comes from the children's story "Goldilocks and the Three Bears." It refers to the porridge that is not too hot, not too cold, but just right. See "habitable zone."

habitable zone – a zone around a star in which temperature conditions are just right for liquid water to exist on an orbiting object's surface.



Hubble Space Telescope **–** a large telescope that orbits the Earth. It takes pictures and makes observations, and astronomers study those pictures and observations to learn about distant objects in space.

James Webb Space Telescope **–** a space-based telescope that was launched on December 25, 2021. It is the largest, most powerful space telescope ever built.

Kepler Space Telescope **–** a space-based telescope, no longer operational, that looked for and discovered 2,662 exoplanets over its lifetime.

light-year – the distance that a beam of light can travel through space in one Earth year. It is approximately 6 trillion miles.

nebulae – plural form of *nebula.* Known as "star nurseries," nebulae are made of large clouds of interstellar gas and dust. They look similar to clouds when viewed from far away. Over time, stars and planets can form within some nebulae.


THE LAGOON NEBULA (M8)

observatory – a place for observing and studying astronomical objects and events.

orbit – a path followed by an object under the influence of gravity from another body. The Earth orbits the Sun. The Moon and the International Space Station orbit the Earth.

planet – A planet is an object that (a) orbits the Sun, (b) is big enough to have enough gravity to be spherical in shape, and (c) has cleared away any objects of a similar size near its orbit. There are eight planets in our solar system: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune.

solar system – a system of planets, moons, asteroids, comets, and other small objects that orbit a star. The Sun is the star in our solar system.

spacecraft – a vehicle or machine that can carry people, instruments, or cargo beyond Earth's atmosphere into space and back home again or to some other destination.

star – a celestial body of hot, dense gas that generates light and other energy and is held together by its own gravity. The Sun is a star, and while stars look like tiny pinpoints of light to us, many are larger than the Sun. They look tiny because they are so far away.

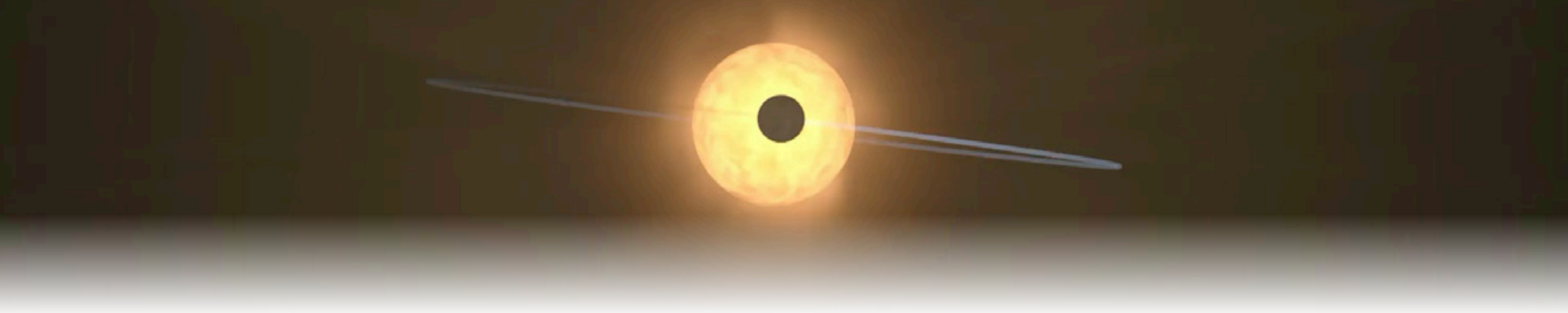
telescope – an instrument that uses lenses and/or mirrors to gather and focus light for observation. In astronomy, telescopes allow the viewer to study distant objects in detail by making them appear larger, brighter, and sharper than what is seen with the unaided eye. There are two primary types of optical telescopes: Reflecting telescopes, which use mirrors, and refracting telescopes, which use lenses.

***TESS* –** The *Transiting Exoplanet Survey Satellite* is a space-based telescope that searches for exoplanets.

universe – all of space and time and all of its contents, including the solar system and all stars and galaxies.

visible light spectrum – the band of colors which the eye can see. They include red, orange, yellow, green, blue, indigo, and violet.

water vapor – the gaseous form of water.



Lesson Plan: Choose Your Own Exoplanet Adventure

LESSON OBJECTIVE

Encourage students to think about the habitability of different environments and the diversity of life.

FIFTH–GRADE NGSS STANDARDS ADDRESSED

5-PS2-1: The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center.

5-LS2-1: Organisms can survive only in environments in which their particular needs are met.

5-ESS1-1: Differences in apparent brightness of the Sun compared to other stars is due to their relative distance from Earth.

5-ESS1-2: Represent data in graphical displays to reveal patterns.

5-ESS2-1: How the geosphere, biosphere, hydrosphere, and/or atmosphere interact.

5-ESS2-2: Role and availability of surface water in Earth's surface processes.

DURATION: 30 minutes

MATERIALS NEEDED

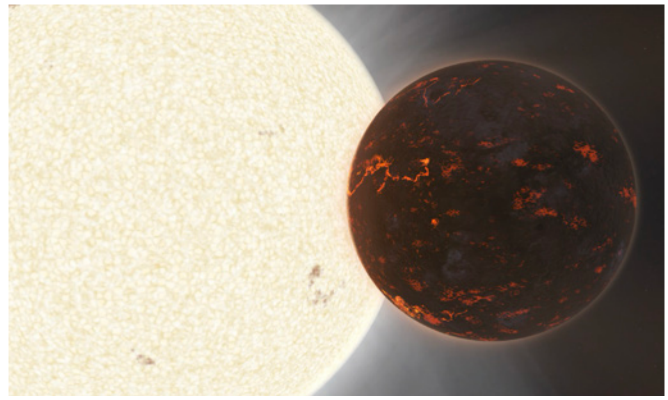
- a one-foot string attached to a foam ball that is a few inches wide
- a two-foot string attached to a foam ball that is a few inches wide
- stopwatch
- two flashlights or other portable light sources
- large images of different types of planets
- a pair of funky, cool sunglasses

ACTIVITY LESSON PLAN PART 1: DETECTING EXOPLANETS

1. Start the session with a quick introduction to exoplanets. Exoplanets are planets that orbit around the stars seen in the night sky. Ask students how people might discover exoplanets.

LESSON PLAN CONTINUED...

2. Pick two volunteers (A and B) and give each a flashlight. Have them shine the flashlights toward the class. Ask the class to think of these lights as stars. Discuss how we could see a planet going around a star if we are not able to travel to it. Move the styrofoam balls between a flashlight and the students to demonstrate how to find exoplanets by seeing when they block the light from their star.



3. Give volunteer A the shorter string with the attached ball and give volunteer B the longer string with the attached ball. Ask volunteer A to hold the flashlight in one hand just above his or her head and use the other hand to swing the ball around just above the flashlight. Have the class count out loud with you how many times it goes around within 10 seconds (about 20 times).
4. Ask volunteer B to hold the flashlight in one hand just above his or her head and use the other hand to swing the ball around just above the flashlight. Have the class count out loud with you how many times it goes around within 10 seconds (about 15 times).
5. They will notice that the ball on the short string swung around more quickly than the ball on the longer string. Describe how the string acts like the force of gravity pulling planets towards their stars (ball towards hand). Planets close to their stars orbit quickly. Planets far from their stars orbit more slowly.
6. Describe how the distance is related to the relative temperatures of the planets. Use our solar system as an example (Mercury and Venus are hot, Earth is warm, and Mars through Neptune are cold.). How would this affect the water and environments on those planets?
7. Ask the students which planet they would want to visit and what five items they would bring. Do they think alien life might be on the planet? What adaptations would they need? What adaptations could have made Earth's lifeforms fit for our environment and proximity to the Sun? What happens to environments when the temperature heats up or cools down?

ACTIVITY LESSON PLAN PART 2: STORY MODE

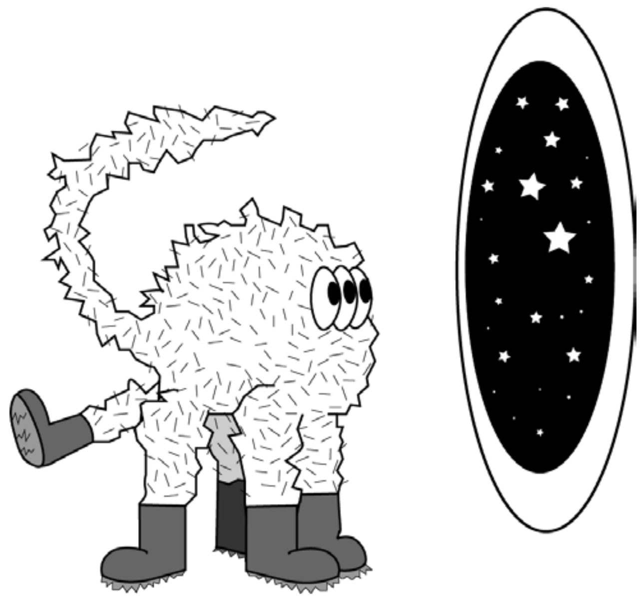
Present a hypothetical scenario: An alien crash-lands through your window.

Q: Raise your hand: How would you help the alien?

It's important to make observations about our new friend before determining what it needs. Ask students to close their eyes and picture the alien covered in thick fur and wearing heavy fur boots. The alien has eyes the size of your whole head. Tell the class to open their eyes.

Q: What do these observations tell us about the possible home of our new friend?
(A: Its home is cold and dark.)

Tell the students once again to close their eyes. While their eyes are closed, grab your two flashlights and turn them on. Tell them that the alien is now frantically pointing at the window.



Q: Should we look where it is pointing? (Yes.)

You follow the alien to the window and see that it's pointing at two stars that are close to each other. Tell the class to open their eyes. They see your two flashlight "stars." Call up your two volunteers again and have them point the flashlights at the class just as before.

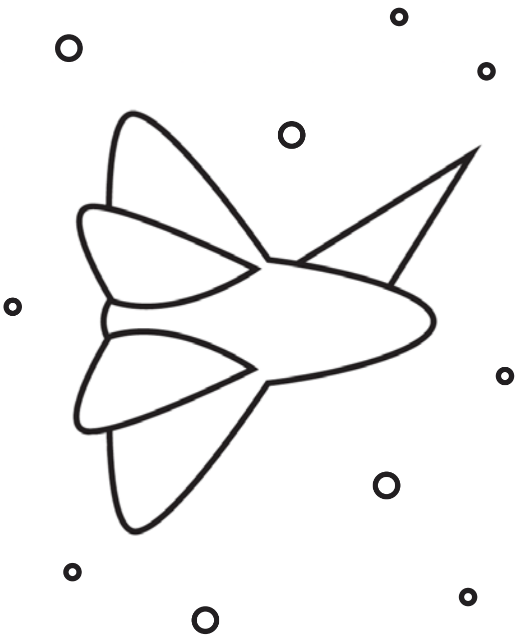
Q: Do we think the alien lives on a star or should we keep looking? (We keep looking.) Is the alien from a planet around one of those stars?

The alien hands you a pair of fancy futuristic-looking telescope glasses. (Put on your sunglasses to demonstrate.) After looking and looking, we eventually see two planets crossing in front of the stars.

LESSON PLAN CONTINUED...

Ask your volunteers once again to hold the flashlight in one hand just above their heads, and to swing their planet-balls around just above the flashlight. Remind the class that one planet (with the shorter string) is orbiting closer to its star and that the other planet (with the longer string) is orbiting farther away from its star.

Q: Our alien friend must be from one of those planets. Which one? Remember our observations about the alien's boots and fur. Would it be from a hot planet or cold planet? (A: Cold.)



Q: How do we know which planet is colder? (A: A colder planet is farther from its star.)

Q: How can we tell which planet is farther away from its star? We can't actually see real exoplanets as easily as we can see these planet-balls. If the classroom lights were off, for instance, you would only be able to see the variation in light that happens when the planet-ball swings in front of the flashlight-star. When looking for exoplanets in space, our only clues are these variations in starlight.

NASA determines how far an exoplanet is from its star by monitoring the rate that a planet passes in front of its star. Inform the students that when they counted how many times the two planet-balls passed in front of their flash-light stars within 10-second periods, that is exactly what scientists do (within much longer time periods).

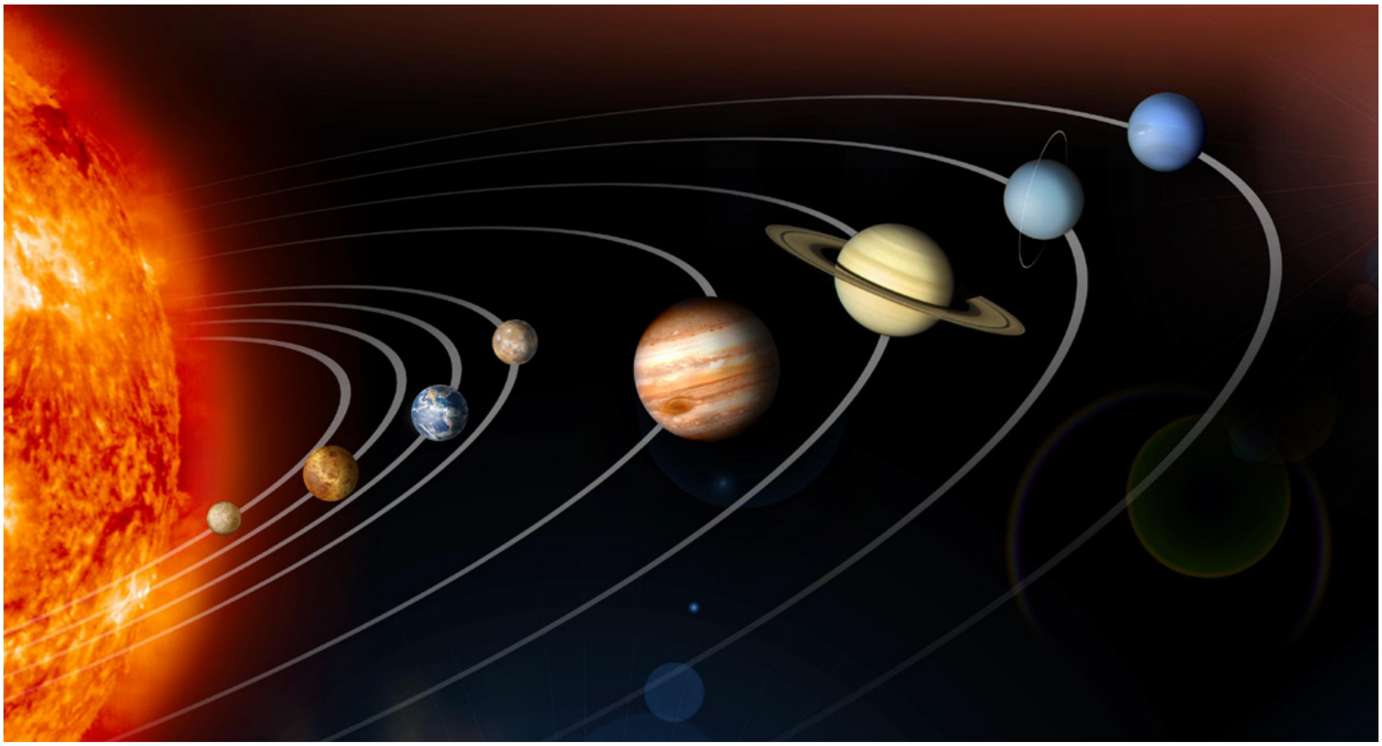
Q: Would the planet that orbits faster or slower be the more likely to be an icy planet?

Q: Which planet do we choose to visit to help bring our alien friend home?

Q: What do we pack for ourselves if we want to step outside the spaceship to explore our alien friend's home?

Make a Solar System Model

We often see our solar system in artists' images such as the one below. The Sun and the planets are pretty, but they are not placed at the correct distances from the Sun and are not the correct sizes relative to one another. You may make your own model to demonstrate how far the planets are from the Sun and from one another. Here are websites that show you how.



EXPLORATORIUM: BUILD A SOLAR SYSTEM

First, you have to calculate the distances between each planet. This is a useful calculator from the Exploratorium (See link below.).

Enter a diameter for the Sun, hit the "Calculate" button, and then see how large all the planets should be and how far you should place them from the Sun.

Careful, though! If you make the Sun one foot (12 inches) wide, you must put the Earth 107 feet away! Try 10mm (1cm) for the Sun.

This web page may help you understand how big space is, and you may use it to build your own solar system model.

https://exploratorium.edu/explore/solar-system/activity/build-model

MAKE A SOLAR SYSTEM MODEL CONTINUED...

At Griffith Observatory, in The Gunther Depths of Space exhibit area, we have models that show the sizes of the planets relative to one another. They are not the right distances apart, however. Can you use the calculator on the previous page to estimate how far the planets, at this scale, should be from one another? In this model, the Sun (represented by the Leonard Nimoy Event Horizon theater on the left) is 62 feet across (744 inches).

REFLECTION: At this scale, how far away would dwarf planet Pluto be from the Sun? *Hint: It's the distance from Griffith Observatory all the way to Laguna Beach!*

BUILD IT THE NASA WAY

Here is a solar system-building project from the people at NASA and JPL. They put astronauts on the Moon! For this project you may use almost any kind of craft materials you like.

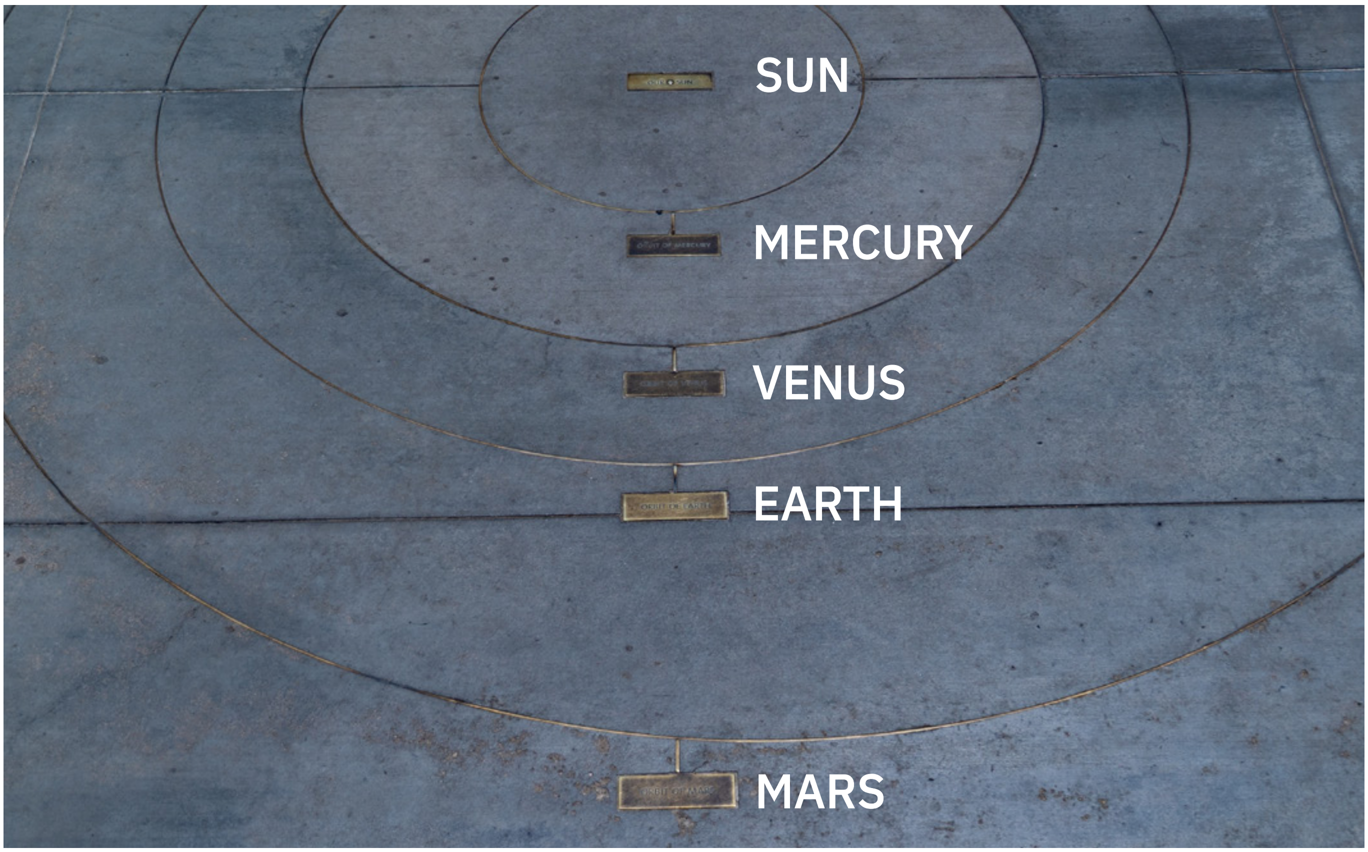
https://www.jpl.nasa.gov/edu/resources/project/make-a-scale-solar-system/

At that same website, there is also a video that explains how far away the solar system's planets really are from one another.

MAKE A SOLAR SYSTEM MODEL CONTINUED...

GRIFFITH OBSERVATORY'S SOLAR SYSTEM MODEL

At Griffith Observatory there is a model of the solar system on the ground between the Observatory stairs and the lawn. It shows the relative distances from the Sun to each planet. Earth is about four feet from the Sun in this model, and Pluto is about 158 feet away! This is a portion of the model that includes the Sun, Mercury, Venus, Earth, and Mars:



Astronomers measure the distances from the Sun to the planets by comparing those distances to the Earth-Sun distance. The Earth is about 93 million miles from the Sun. We call that distance one "astronomical unit," or "AU." To the right are the average distances to all the other planets plus Pluto, measured in AUs.

Mercury	0.4 AU
Venus	0.7 AU
Earth	1.0 AU
Mars	1.5 AU
Jupiter	5.2 AU
Saturn	9.6 AU
Uranus	19.2 AU
Neptune	30.0 AU
Pluto	39.5 AU

REFLECTION: A pretend comet is 186 million miles away from the Sun. How many AUs is that?

SOLAR SYSTEM MODEL PROJECTS

PROJECT A: Here's one way to make your own solar system model: You will need ten objects. You may use any objects you'd like to represent the planets and the Sun: Pennies, pebbles, rocks, balls, dolls–whatever you have. You will also need a ruler or measuring tape and a large open space to place your Sun and planets.

Put your Sun object on the ground. Then measure four inches away from the Sun, and place your Mercury there. Then measure another three inches out from Mercury and place your Venus there. Do the same with all the other planets by adding inches according to the chart below. Each inch represents 9.3 million miles (0.1 AU).

PLANET	ADD INCHES	TOTAL	PLANET	ADD INCHES	TOTAL
Mercury	4	4	Saturn	44	96
Venus	3	7	Uranus	96	192
Earth	3	10	Neptune	108	300
Mars	5	15	Pluto	95	395
Jupiter	37	52			

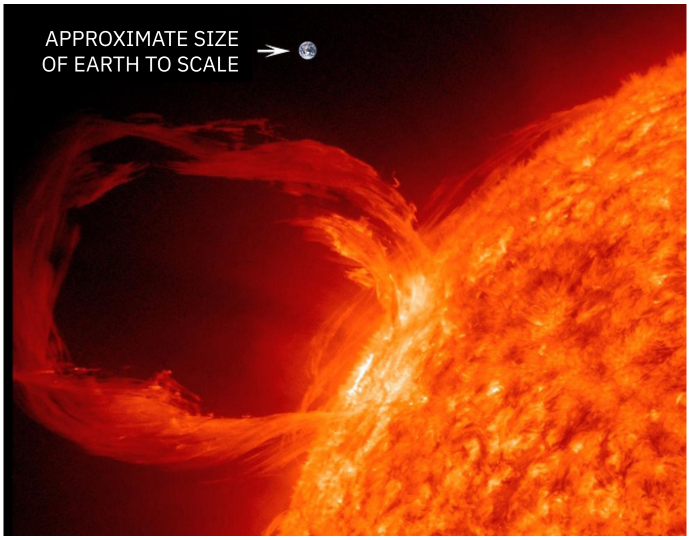
Note: Pluto ends up about 33 feet from the Sun!

After you complete **PROJECT A**, see our *Make an Extrasolar System Model* worksheet to make an extrasolar system model and compare it to this one!

PROJECT B: Another way to do this requires adult supervision and a big space, such as a park, beach, schoolyard, or baseball field. Find a landmark at which to start, such as a tree, person, or home plate. That landmark is the position of the Sun. Take four steps away from the landmark and look back at it. That's the distance to Mercury. Then take three more steps away from the Sun, and you are at Venus's distance. Take three more to get to Earth, then five more to get to Mars, then 37 more to get to Jupiter, then 44 more to get to Saturn, 96 more to get to Uranus, 108 more to get to Neptune, and finally, 95 more steps to arrive at Pluto. At each planet's spot, note how far away the tree looks. It should be pretty tiny at Pluto!

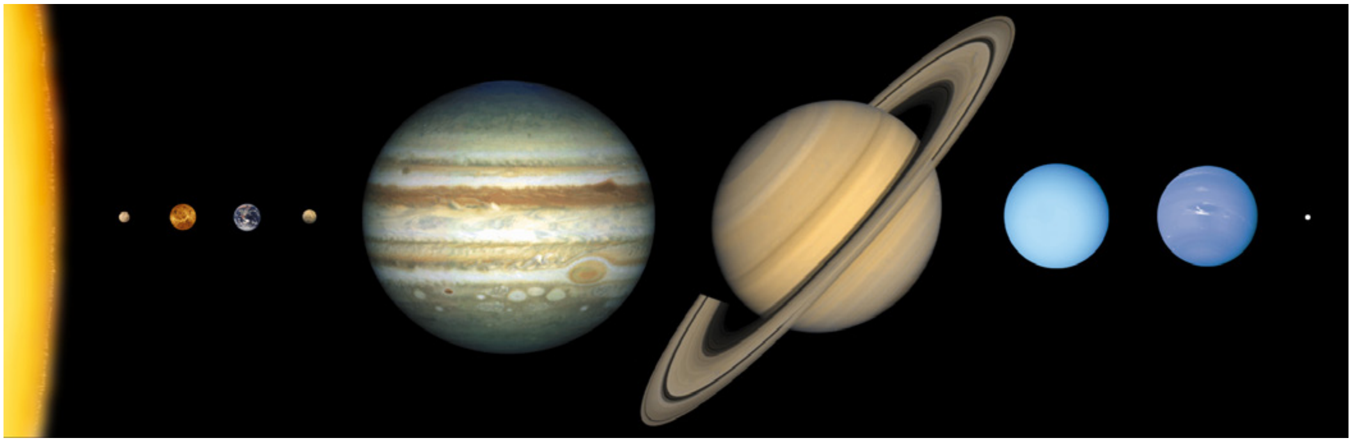
PROJECT C: You may also try this with nine of your friends. Have one friend be the Sun, and have each friend take the number of steps away to stop and stand as each of the planets. If you have a camera, take a picture at each planet distance, or if you have ten people to mark the Sun-to-planet distances, take a picture of your friend-model! Now we should talk about the sizes of the planets and the Sun...

HOW BIG ARE THE PLANETS?

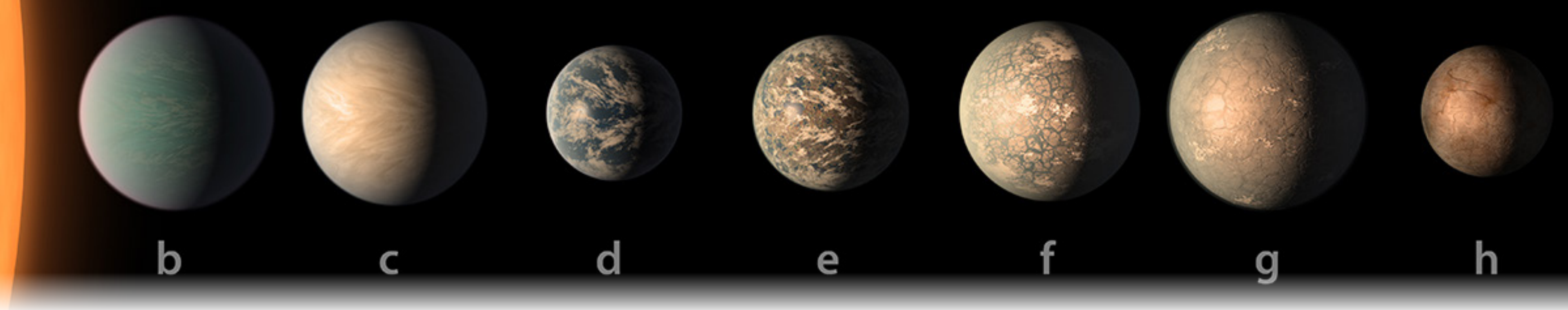


How large is each planet compared to the Sun? We can use diameter (a straight line that passes from one side to the other) as our unit of measurement. For instance, the diameter of the Sun is about 864,000 miles, while Earth is only 8,000 miles across, as you can see in this size comparison image. Earth isn't really this close to the Sun!

The image below illustrates a portion of the Sun with all eight planets in order of their distances from it: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. Even dwarf planet Pluto is pictured; it's the tiny little dot at the far right. As you have learned, these are not the correct distances between the objects, but the relative sizes are correct. Note how enormous the Sun is compared to Earth and the other planets. If you don't count Saturn's rings, Jupiter has the largest diameter of all the planets.



REFLECTION: Did you know that light takes time to travel? Light travels faster than anything we know, at 186,000 miles *per second*. Because the Moon is about 238,900 miles away from us, it takes about 1.3 seconds for the light reflected off of the Moon to reach us (238,900 / 186,000 = 1.3). When we look at the Moon, we are seeing back in time 1.3 seconds! The Sun is about 93,000,000 miles away from Earth. How many seconds does it take for its light to reach Earth?



Make an Extrasolar Planetary System Model

Now that you made a model of our solar system with *Make a Solar System Model*, let's make a model of a solar system beyond ours!

The TRAPPIST-1 extrasolar planetary system is 41 light-years away from us (about 241 trillion miles). It has seven near-Earth-size rocky planets, three of which are in the habitable zone. Its sun, TRAPPIST-1 a, is only 12 percent the size of our sun.

The TRAPPIST-1 extrasolar planetary system is also *much* smaller than our solar system. If you did **PROJECT A** from *Make a Solar System Model*, this next project is a great way to put the size of the TRAPPIST-1 system into perspective! You will need a regular 8.5-in. x 11-in. piece of paper, a drawing tool, and a ruler or tape measure.

Make a dot close to the edge of your paper to represent star TRAPPIST-1 a. Then measure 1.2 inches away from the star, and make a dot that represents planet TRAPPIST-1 b. Then measure another 0.4 inch out from TRAPPIST-1 b, and make a dot that represents TRAPPIST-1 c. Do the same with all the other planets. Add inches according to the chart below. Each inch represents 9.3 million miles (0.1 AU).

PLANET	ADD INCHES	TOTAL
TRAPPIST-1 b	1.2	1.2
TRAPPIST-1 c	0.4	1.6
TRAPPIST-1 d	0.6	2.2
TRAPPIST-1 e	0.7	2.9
TRAPPIST-1 f	0.9	3.8
TRAPPIST-1 g	0.9	4.7
TRAPPIST-1 h	1.5	6.2

Yes, the TRAPPIST-1 extrasolar planetary system is *that* compact compared to ours. Still, three planets are within its habitable zone because the star is much cooler and dimmer than our sun. The planets must be much closer in order to receive heat.

Imagine yourself on one of these planets and looking up... the other planets would look large in the sky.

To learn more about the TRAPPIST-1 extrasolar system, visit:
https://eyes.nasa.gov/apps/exo/#/system/TRAPPIST-1/

Reality vs. Fiction of Worlds Beyond

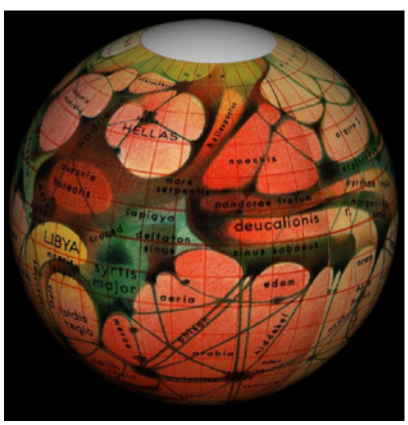
A COMPARE-AND-CONTRAST EXERCISE

Over the years, as people attempted to understand the sky, they told stories and imagined what otherworldly places are like. Some people used observational evidence to describe these places. Some based their predictions on cultural beliefs. Others illustrated dramatic, terrifying, or beautiful worlds simply because they hoped these things could be possible beyond Earth.

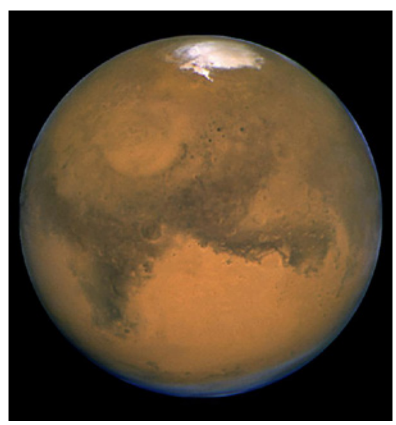
Let's take a look at what people predicted other worlds are like and compare these images to pictures taken by spacecraft. How right *were* we?

MARS

Our planetary neighbor has been the subject of many wild ideas. Before satellites and rovers provided true images of the landscape, many people believed that "canals" are on the surface of Mars. This idea began with observations by an Italian astronomer, Giovanni Schiaparelli. In 1877 he believed he saw a system of straight lines on the surface of Mars, which he called *canali*.



1894 map of Mars by Eugene Antoniadi and Lowell Hess



1999 *Hubble Space Telescope* image of Mars, upside-down

Compare and contrast this drawn map of Mars (left) with a photographic image of Mars (right). What is similar and what is different?

____

____

____

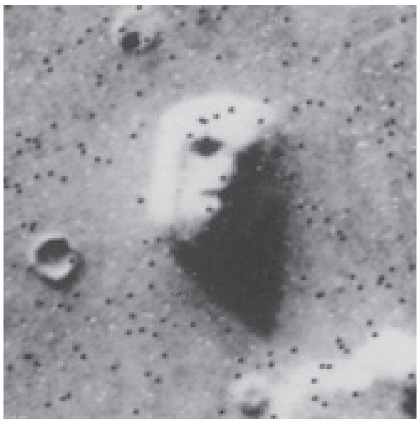
____

____

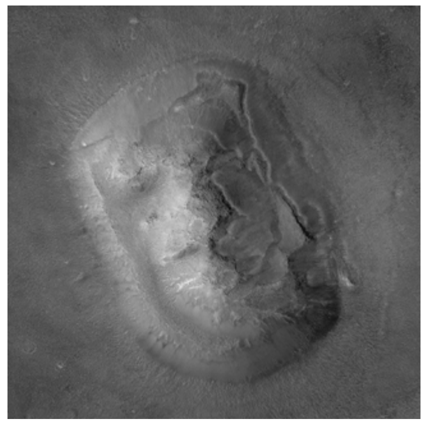
REALITY VS. FICTION OF WORLDS BEYOND CONTINUED...

Even after we were able to capture actual images of Mars, our imaginations still ran wild. Many people believed that the "Face on Mars," a rock formation photographed by the *Viking 1* and *2* missions in the late 1970s, was evidence of an ancient civilization.

We finally obtained better pictures of the same feature in 1998, when *Mars Global Surveyor* and other Mars missions saw that the "face" is just a trick of the light when viewed under certain conditions and from a certain angle.



1976 picture of the "Face on Mars" by the orbiting *Viking 1* spacecraft



1998 image by *Mars Global Surveyor*

What new details are present in the right picture that are not present in the left picture?

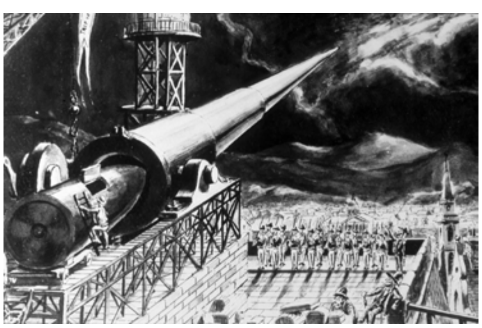
___

___

___

THE MOON

In Georges Méliès's 1902 film *Le Voyage dans la Lune* ("A Trip to the Moon"), Méliès imagined that we would shoot a bullet-like spacecraft into the Moon with a large cannon and that once on the Moon, the voyagers would walk around freely without any protection and would also run into a society of aliens.



a still from the 1902 film *Le Voyage dans la Lune*

1973 The *Saturn V* rocket blasting off from Cape Canaveral

REALITY VS. FICTION OF WORLDS BEYOND CONTINUED...

Why do you think we use rockets instead of canons to launch into space?

____

____

THE NIGHT SKY

Ancient people from around the world filled the sky with stories. The Greeks populated the sky with gods. The Chumash of southern California thought that the Sun is a god who carries a torch from east to west. People who lived during the Tang dynasty (A.D. 618-907) in China thought that Mercury, Venus, Mars, Jupiter, and Saturn are deities associated with five primary elements: Wood, fire, earth, water, and metal.

Painting derived from a Tang dynasty composition of the five planet deities

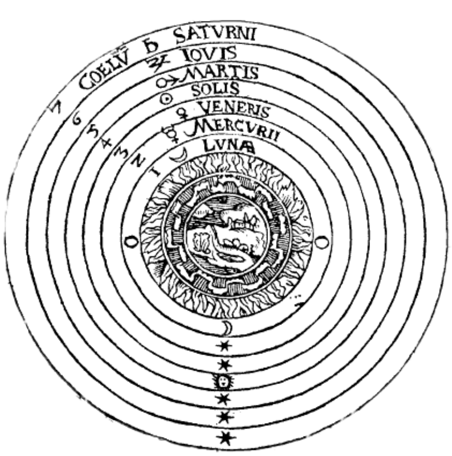
Why do you think many cultures thought that planets, stars, and constellations are different gods, animals, objects, or people?

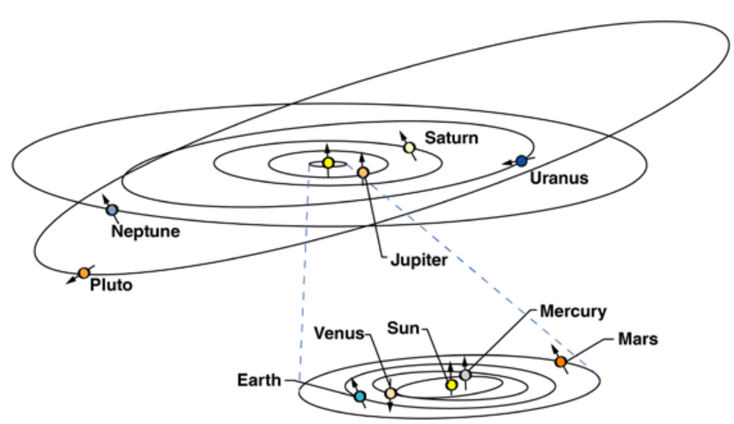
____

____

____

Pictured below to the left is an illustration by Peter Apian, a sixteenth century German astronomer who thought, as others did during his time, that the heavens rotate around Earth. From the second century to the seventeenth century, this idea was mostly unchallenged.





REALITY VS. FICTION OF WORLDS BEYOND CONTINUED...

Can you explain some reasons why the model on the right is more correct than the one on the left?

____

____

____

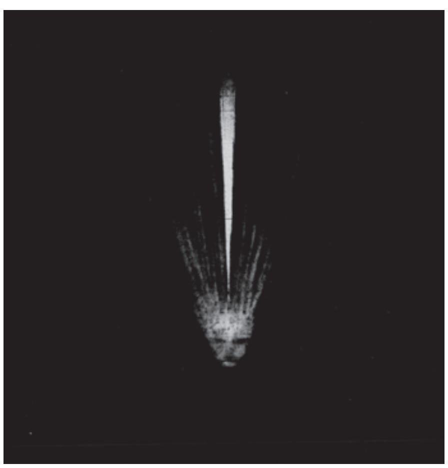
____

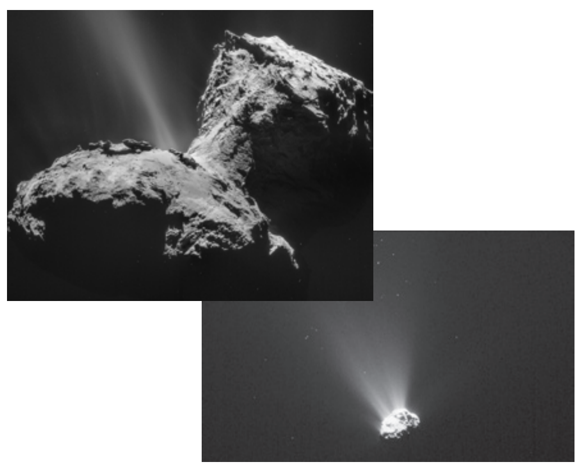
____

COMETS

Comets were objects of mystery and terror to many cultures before modern astronomy revealed their true nature. The illustration on the lower left, from 1942, shows a comet that was said to have "stampeded the terrified citizens and to have caused numerous deaths." (Don't worry. It definitely didn't.) The pictures below on the right show comet 67P/Churyumov–Gerasimenko. The images were taken by the *Rosetta* spacecraft in 2015.

1942 illustration of a 1528 comet over Paris





2015 photos of comet 67p by the *Rosetta* spacecraft

What is similar between the illustration on the left and the photographs on the right, and what new details can we observe in the photographs on the right?

____

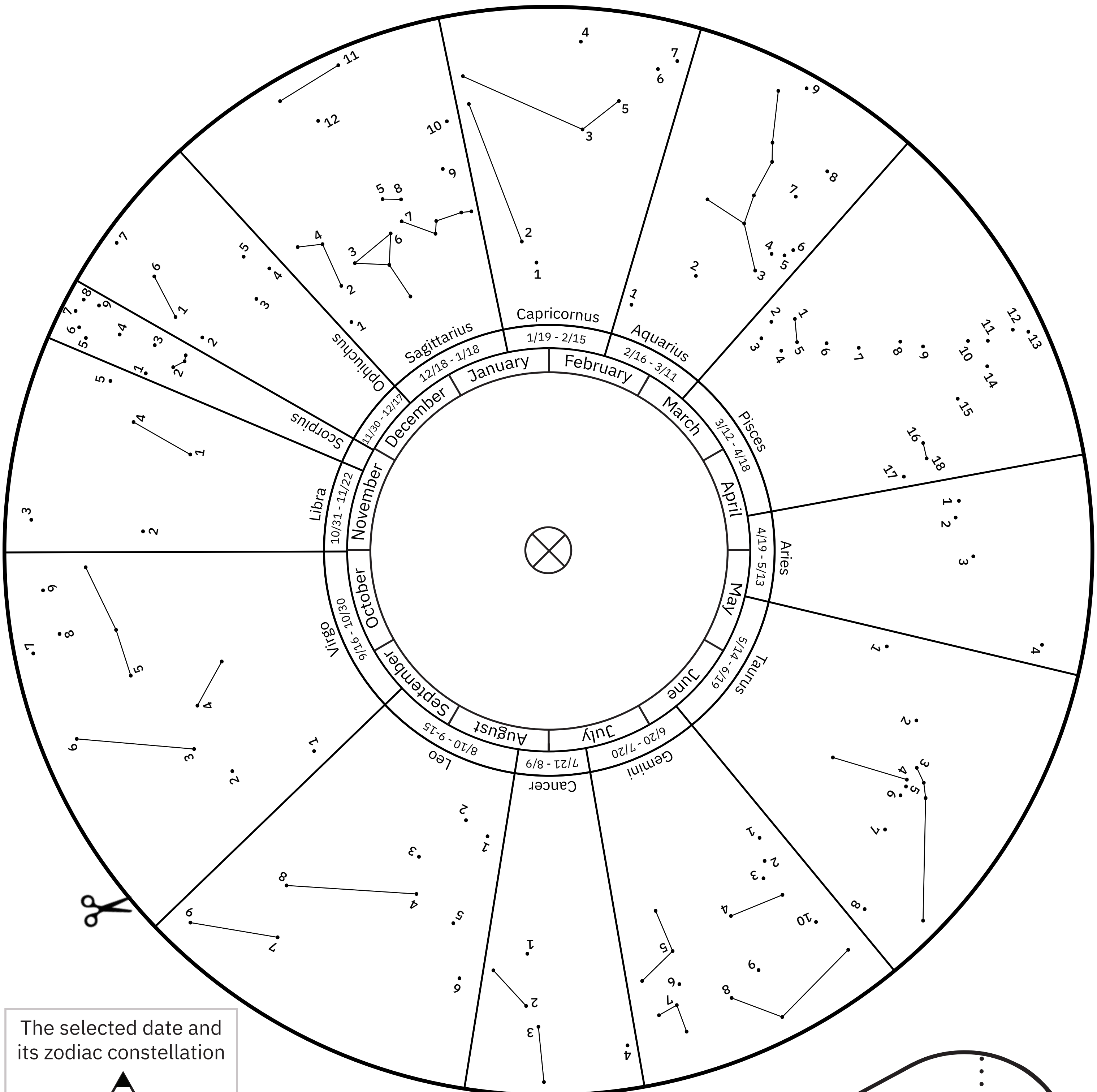
____

____

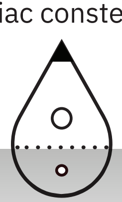
____

Zodiac Constellation Activity Chart

The signs of the zodiac come from the constellations through which the Sun passes during the year. Each day, the Sun is in front of a particular zodiac constellation that is always present but invisible to our view because the Sun is so bright. Complete the constellation connect-the-dots. Then cut out the dial and pin it with a paper fastener to the ⊗ on the chart. Reveal the unseen sky today!

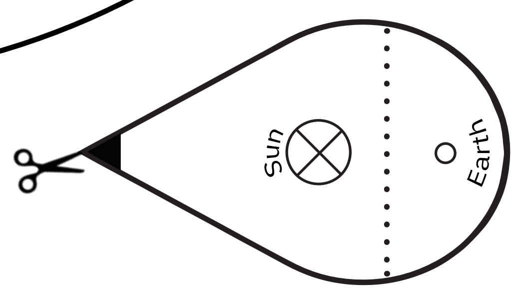


The selected date and its zodiac constellation



The constellations that may be seen in the night sky on that date

This chart may seem unusual; you may find that your zodiac sign is different than what you've been told. This is not an astrological chart. It's an *astronomical* chart. It shows exactly what is observed in the sky. It shows your zodiac constellation. For more info, see **bit.ly/3GvXYky**.



(Sun and Earth not to scale)

Post-program Materials

We hope you and your class enjoyed Module 4: Exoplanets Are Everywhere of Griffith Observatory's Online School Program. To continue your and your students' lifelong journey as observers, here are some activities and resources.

Module 4 Crossword and Grading Version

This worksheet reinforces the new terms students learn in "Exoplanets Are Everywhere" and in the attached materials.

Goldilocks Zone Cut-outs

This tactile astronomy-craft helps students visualize solar system relationships and exercises observational skills. Reflections follow to ensure comprehension.

Make Your Own Exoplanet and Extraterrestrial Life

This activity guides students through the creation of an original exoplanet and an alien lifeform. Students engage in creative and critical thinking to provide adaptations to their species so that it may survive in the environment they created.

The Edible Solar System and Grading Version

This word-deduction puzzle relates the relative sizes of familiar foods to the relative sizes of the planets in our solar system.

Coloring the Cosmos

We have provided three coloring-book-style activities for students. Two are in the style of "exoplanet travel posters" and feature artistic interpretations of scientific findings regarding exoplanets HD 189733 b and KOI-55 b.

Exoplanet Websites

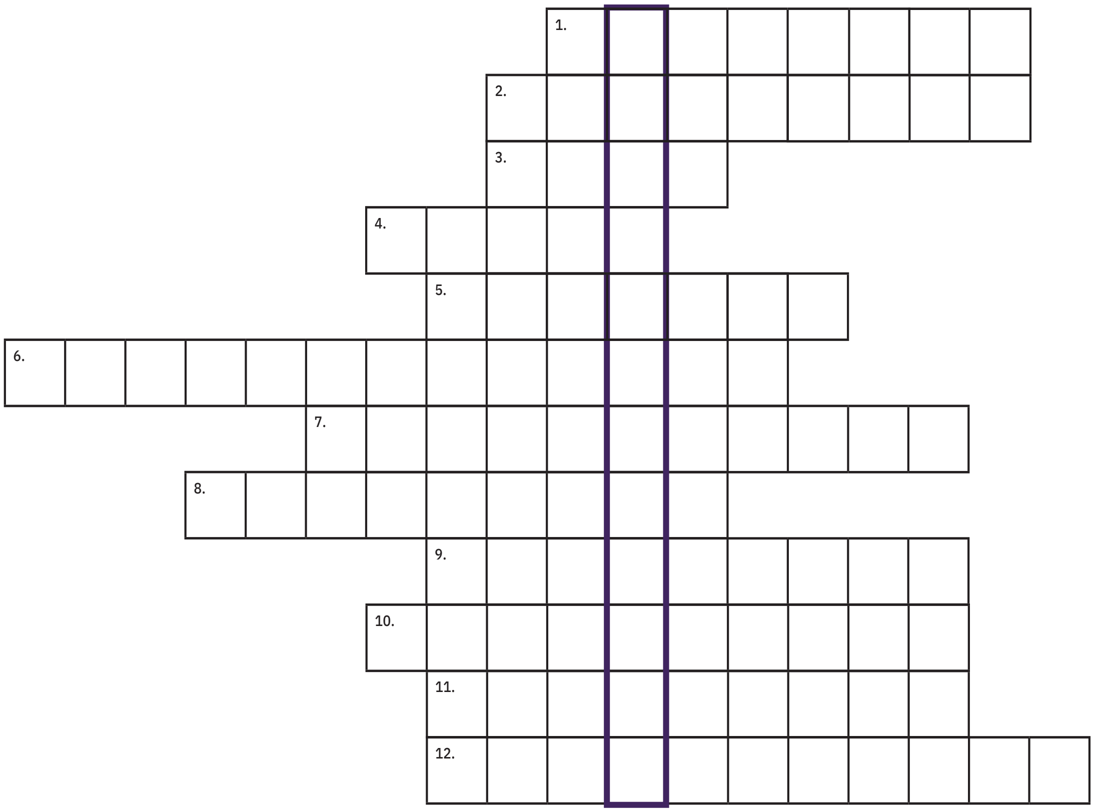
This resource lists and summarizes some extra websites and citizen science projects that involve exoplanets and are way too cool to miss.

Internet Resources

The Internet may be helpful. This variety of websites will help students expand their astronomical knowledge and have fun doing it.

Module 4 Crossword

Solve the crossword to discover the hidden word.



Why did the restaurant on Mercury get poor reviews?

There was ________________________________!

[HIDDEN WORD]

1. all of space, time, and everything in it
2. a planet that orbits another star
3. a celestial body of gas held together by gravity that generates light and energy
4. a regular, repeating path that one object takes around another object in space
5. a moon that orbits a planet outside of our solar system
6. the area around a star where it is not too hot and not too cold for liquid water to exist on the surface, also known as the “Goldilocks zone”
7. a star and all the objects that are bound to it by gravity
8. an instrument designed to make distant objects appear nearer
9. a unit of distance that is equal to the distance that light travels in one year
10. a vehicle or machine designed to fly in outer space
11. the study of space and everything in it
12. a place for observing that houses a telescope and/or other scientific equipment

Module 4 Crossword

Solve the crossword to discover the hidden word.

1.										U	N	I	V	E	R	S	E	
2.									E	X	O	P	L	A	N	E	T	
3.									S	T	A	R						
4.							O	R	B	I	T							
5.								E	X	O	M	O	O	N				
6.	H	A	B	I	T	A	B	L	E	Z	O	N	E					
7.						S	O	L	A	R	S	Y	S	T	E	M		
8.				T	E	L	E	S	C	O	P	E						
9.								L	I	G	H	T	Y	E	A	R		
10.							S	P	A	C	E	C	R	A	F	T		
11.								A	S	T	R	O	N	O	M	Y		
12.								O	B	S	E	R	V	A	T	O	R	Y

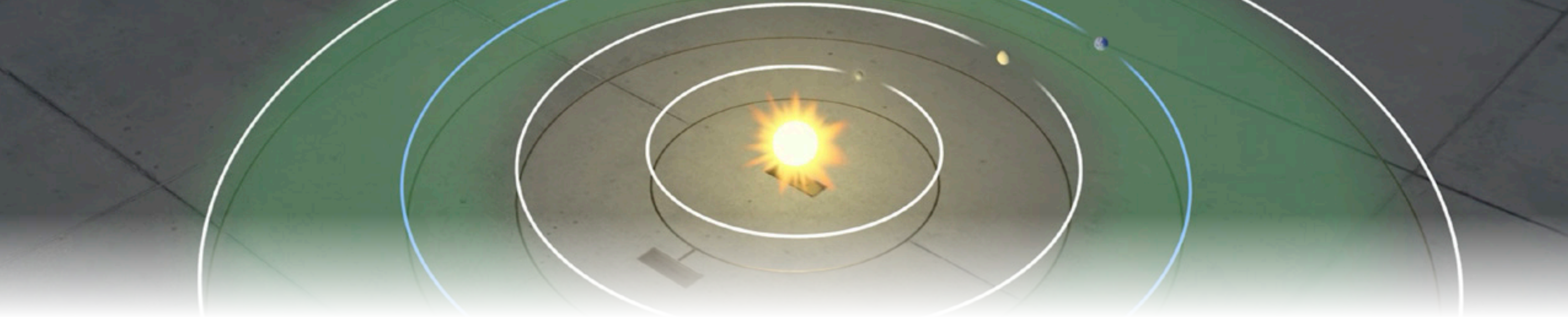
Why did the restaurant on Mercury get poor reviews?

There was NO ATMOSPHERE!

[HIDDEN WORD]

1. all of space, time, and everything in it
2. a planet that orbits another star
3. a celestial body of gas held together by gravity that generates light and energy
4. a regular, repeating path that one object takes around another object in space
5. a moon that orbits a planet outside of our solar system
6. the area around a star where it is not too hot and not too cold for liquid water to exist on the surface, also known as the “Goldilocks zone”
7. a star and all the objects that are bound to it by gravity
8. an instrument designed to make distant objects appear nearer
9. a unit of distance that is equal to the distance that light travels in one year
10. a vehicle or machine designed to fly in outer space
11. the study of space and everything in it
12. a place for observing that houses a telescope and/or other scientific equipment

GRADING VERSION



Goldilocks Zone Cut-outs

WHAT IS A GOLDILOCKS ZONE?

A Goldilocks zone is the habitable area around a star where it is not too hot and not too cold for liquid water to exist on the surface of surrounding planets.

WHY GOLDILOCKS ZONES MATTER: If Earth were where Pluto is, the Sun would be barely visible (about the size of a pea) and Earth's ocean and much of its atmosphere would freeze. If Earth took Mercury's place, it would be too close to the Sun, and its water would form a steamy atmosphere and quickly boil off. Earth's location relative to the Sun is just right for water to remain a liquid. This is why our distance from the Sun is called the habitable zone, or the Goldilocks zone. Rocky exoplanets found in the habitable zones of their stars are more likely to have liquid water on their surfaces. Life on Earth started in water, and water is a necessary ingredient for life as we know it.

DIRECTIONS

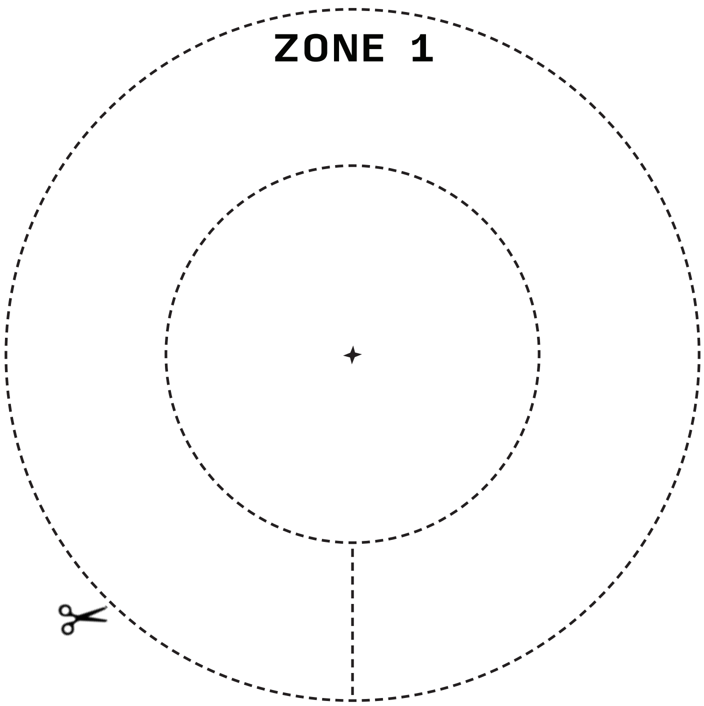
Can you find out which exoplanets could be habitable? The next two pages contain Goldilocks "zones" and "solar systems" that represent actual solar systems that astronomers are studying. Cut out the Goldilocks zones on the "Zones" page. Then place them on top of the solar systems on the "Solar Systems" page using this key:

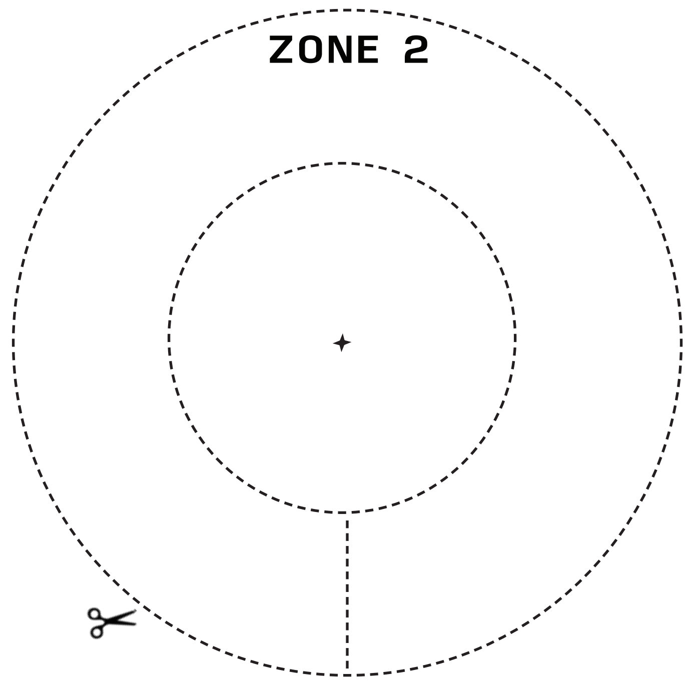
Zone 1 – Solar System 1
Zone 2 – Solar System 2
Zone 3 – Solar System 3
Zone 4 – Solar System 4

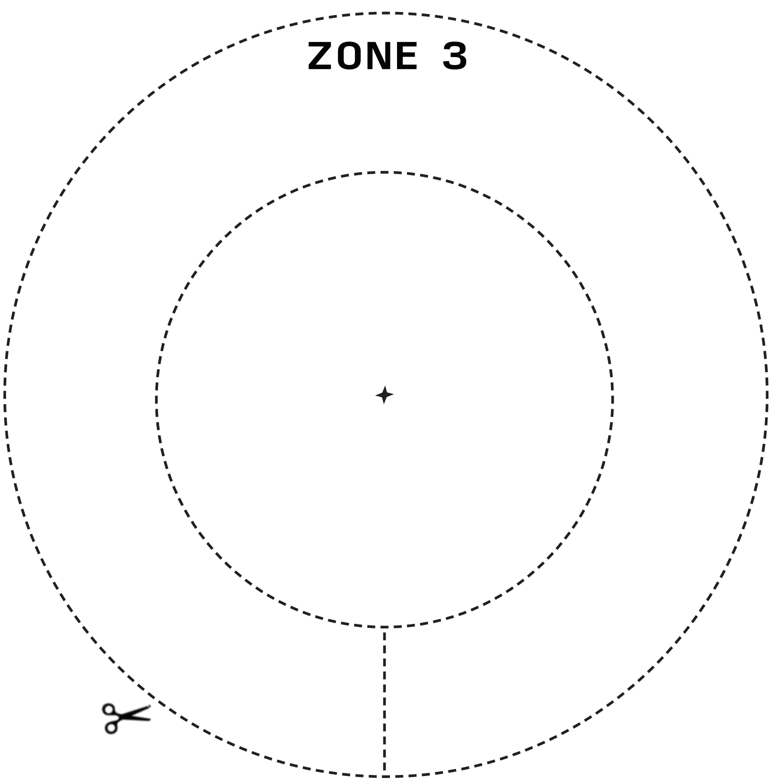
Make sure to place the zones on top of the solar systems so that the stars (✦) are exactly in the center of the zones. A ruler may help you measure equal distances between one inner-side of the zone to the other. Once you've matched up the Goldilocks zones to their corresponding solar systems, go to the "Reflections" pages and answer the questions!

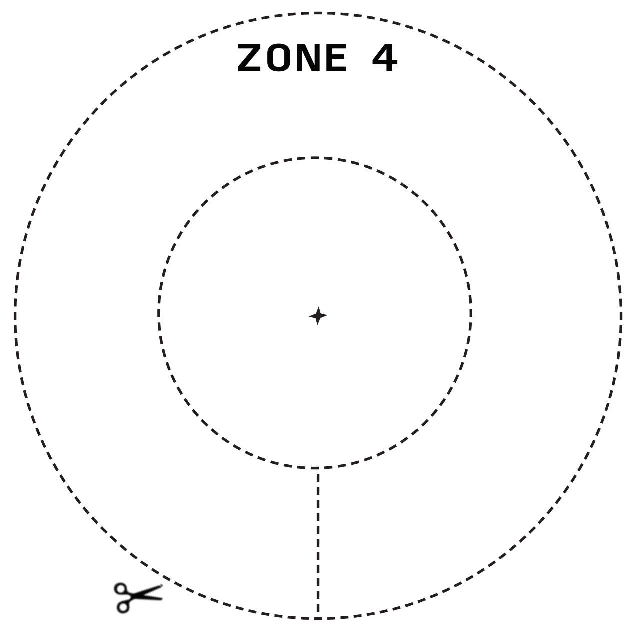
Zones

Cut along the dotted lines to free the Goldilocks zones from the page.





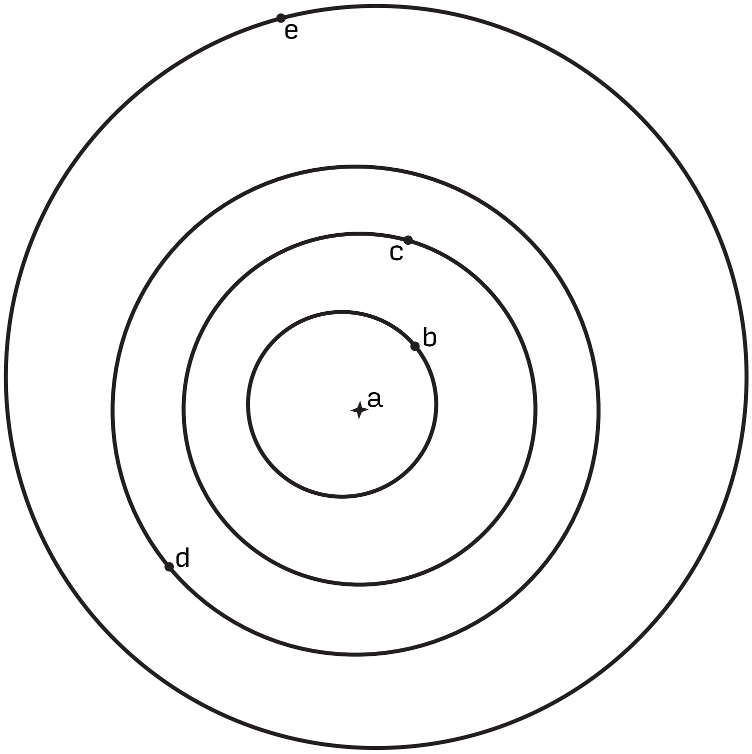




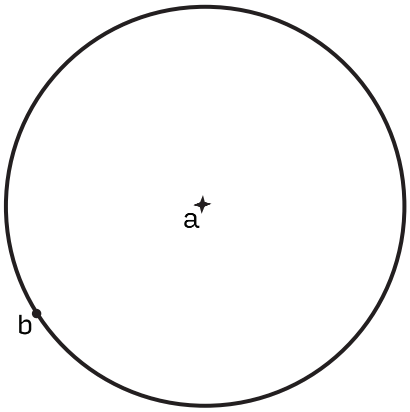
Solar Systems

Place the zones on top of their solar systems so that the stars are exactly in the center.

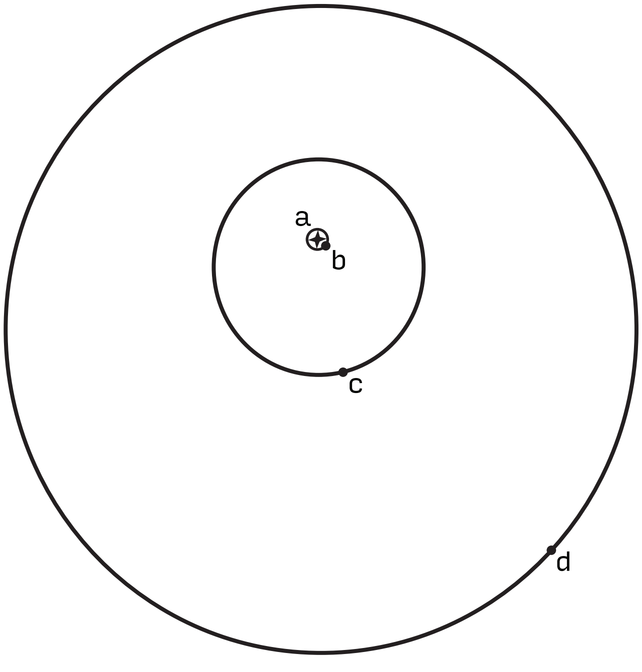
SOLAR SYSTEM 1



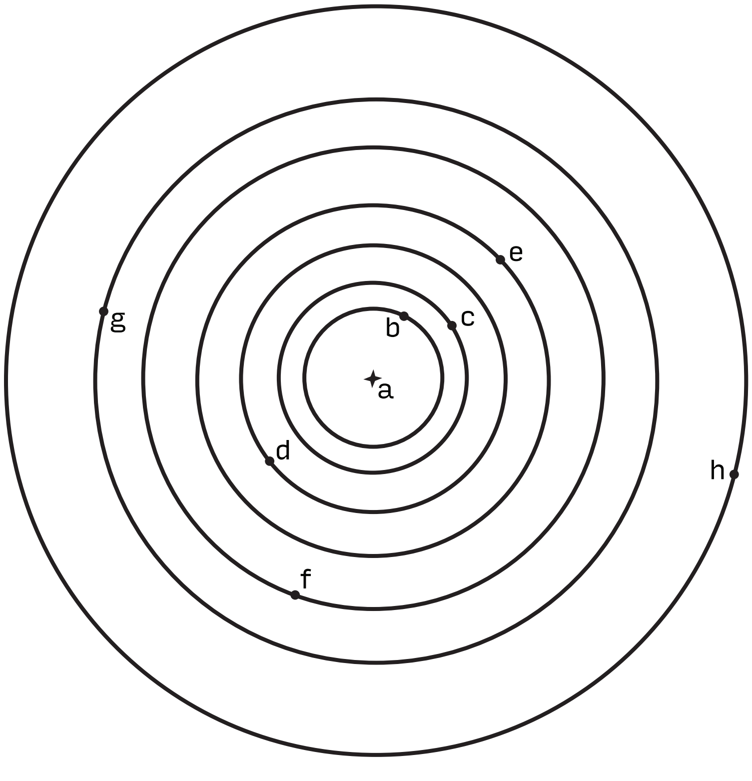
SOLAR SYSTEM 2



SOLAR SYSTEM 3



SOLAR SYSTEM 4



Reflections Part 1

SOLAR SYSTEM 1

Solar System 1 represents *our* solar system, with Sun "a" marked in the center.

Which planet of our solar system completely falls within the Goldilocks zone?

- ○ planet b
- ○ planet c
- ○ planet d
- ○ planet e

What is that planet called? ____________________

Do you think planet b, which is the closest planet to the Sun outside the Goldilocks zone, is hotter or colder than planet d?

- ○ hotter
- ○ colder

Do you think the planets on the far side outside the Goldilocks zone are hotter or colder than planet d?

- ○ hotter
- ○ colder

SOLAR SYSTEM 2

Solar System 2 represents the Proxima Centauri solar system.

Does planet b fall within the Goldilocks zone of star Proxima Centauri a?

- ○ yes
- ○ no
- ○ partially

Star Proxima Centauri a has another exoplanet orbiting on the far side outside the Goldilocks zone, so far away it could not be pictured. Do you think it would be hotter or colder than planet b?

- ○ hotter
- ○ colder

SOLAR SYSTEM 3

Solar System 3 represents the upsilon andromedae solar system.

Which planet is captured in upsilon andromedae a's Goldilocks zone?

- ○ planet b
- ○ planet c
- ○ planet d

What's unusual about planet d? ____

Reflections Part 2

SOLAR SYSTEM 3 CONTINUED...

What do you think the temperatures are like on planets b and c in Solar System 3?
○ too hot ○ too cold ○ just right

SOLAR SYSTEM 4

Solar System 4 represents the TRAPPIST 1 solar system.

Which planet (or planets) orbit in star TRAPPIST 1 a's Goldilocks zone?
○planet b ○planet c ○planet d ○planet e ○planet f ○planet g ○planet h

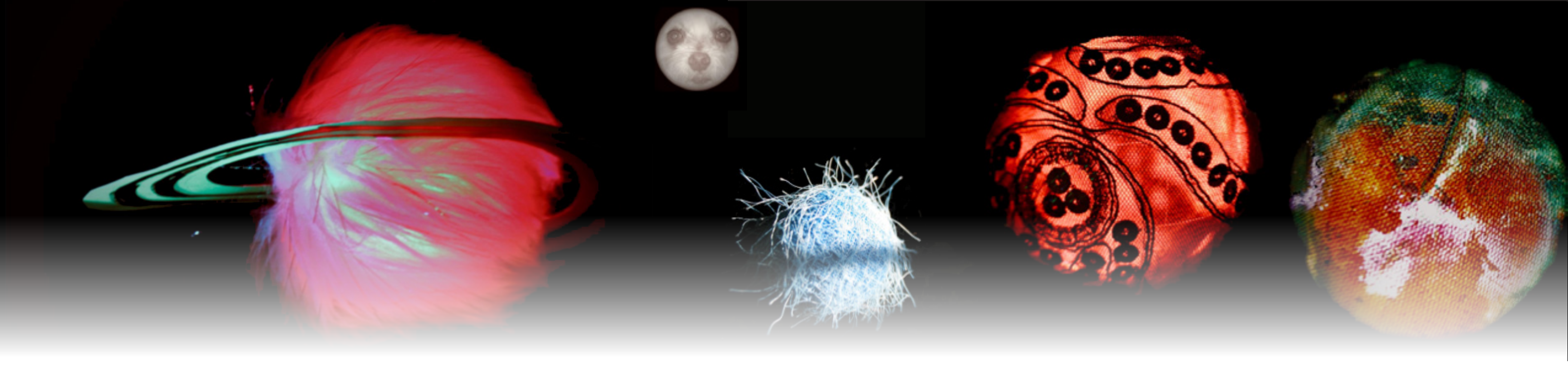
Do you find anything usual about the above answer, compared to the other zones in other solar systems? ______________________________

Which planet do you think has the best chance for liquid water?
○planet b ○planet c ○planet d ○planet e ○planet f ○planet g ○planet h

Conclusion

From these four examples, it's interesting to see how unique each solar system's Goldilocks zone is compared to the planets that orbit the star. Try mixing the zones to other solar systems and see how they don't match up. Planets too close to their star, outside the Goldilocks zone, will burn up or be too hot. Planets too far from their star, outside the Goldilocks zone, will freeze. The universe has so many possibilities for planets with liquid water and the possibility of life.

FUN FACT: The four solar systems are actually *not* to scale with each other. For instance, our Sun is *much* larger, hotter, and brighter than star TRAPPIST 1 a, and so this means the two solar systems' Goldilocks zones are very far away from each other. Exoplanets in the TRAPPIST 1 system must be much closer to its star in order to be inside the zone. Compare other solar systems with ours by visiting https://eyes.nasa.gov/apps/exo/#/. Search for a star, view its system, and then click "COMPARE TO OUR SOLAR SYSTEM."

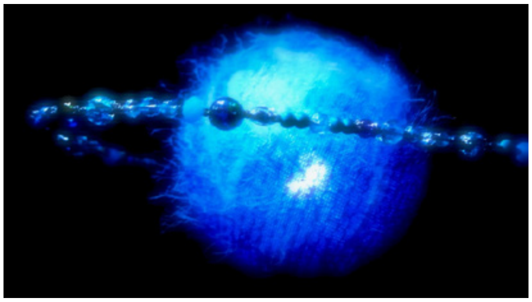


Make Your Own Exoplanet & Extraterrestrial Life

Earth has many environments and different features. There are deep oceans, arctic areas, mountains, forests, deserts, hot springs, and caves, and we have found life in all of these places. The universe is filled with planets that have landscapes ranging from pleasant and familiar to harsh and unfamiliar. We know that organisms may survive only in environments in which their particular needs are met, but we also know that life is diverse and resilient. In this activity, create your own exoplanet by picking characteristics from each category. Later, you will create an alien life form that could potentially survive on the exoplanet you created.

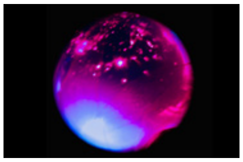
MAIN CLIMATE (SELECT ONE)

- Desert – *hot, very little water, mainly parched sand*
- Ocean – *mainly water with only a few land masses*
- Forest – *CO_2-rich environment that allows tree growth*
- Polar – *cold, with most of the elements frozen*



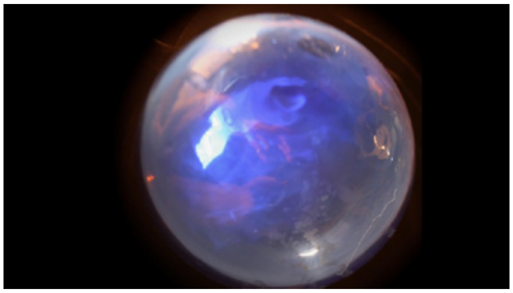
GRAVITY (SELECT ONE)

- Low – *everything weighs less, so less muscle mass is needed*
- Earth-like – *things fall normally*
- High – *creatures need more muscle mass*



LIGHT / ENERGY FROM STAR (SELECT ONE)

- Low – *creatures need a different energy source or a clever way to conserve/maximize sunlight*
- Earth-like – *creatures don't need special adaptations unless light does not reach their habitat*
- High – *creatures need an adaptation that helps them survive radiation*



EXTRA MODIFIERS

- Liquid atmosphere
- Helium atmosphere
- Stinky sulfur seas
- Active undersea volcanoes
- Active land volcanoes
- Frequent dust storms
- Strong winds
- Hot rains
- ____________________

MAKE YOUR OWN EXOPLANET & EXTRATERRESTRIAL LIFE CONTINUED...

Describe your planet using the characteristics you picked. You may be as descriptive as you like. Write about what it would be like to live on your world. Details are encouraged describing what vegetation (if any) would look like or if the seas would cover the planet, and so forth. Have fun with this; explain your planet.

Draw your planet. You may choose to draw what it looks like from space, and/or what its landscapes look like up close.

Name your exoplanet: ______________________________

MAKE YOUR OWN EXOPLANET & EXTRATERRESTRIAL LIFE CONTINUED...

What kind of life form would be able to exist on your exoplanet? Choose some different characteristics below that can help your creature survive depending on the planet environment characteristics you picked.

HABITAT

- Surface
- Underground
- Shallow-water or swamp
- Deep-sea
- Air/sky
- Cave
- ________________

EXTREMITIES // How many? ____

- Wings – *allows for flying*
- Legs or arms with joints – *may run or climb*
- Fins – *provides thrust, steering, and balance in water*
- Hooves – *supports weight, provides traction*
- Claws – *allows protection, digging, and climbing*
- Flowers/fruits/branches/twigs
- Tail(s) – *provides balance, supports communication*
- Tentacles – *flexible, allows for grasping and sensing*
- ________________

TOPICAL

- Fur – *protects from cold*
- Scales – *improves speed, protects, and/or reduces water loss*
- Bio-luminescence – *produces light to communicate*
- Slime – *improves grip*
- Feathers – *allows for flying, protects from cold*
- Tough shell/exoskeleton – *protects from a harsh environment*
- Plant-matter – *feeds on air and sunlight, responds slowly*
- Fluorescence – *protects against radiation, glows*
- Skin – *regulates body temperature in a variety of climates*

EXTRA FEATURES / ABILITIES

- Antennae – *senses touch, air motion, heat, vibration (sound), smell, and taste*
- Blubber – *stores energy, insulates heat, improves buoyancy*
- Echolocation – *may detect objects in their environment by sensing echoes*
- Metal features – *makes stronger and more durable*
- Compressible lungs – *may survive in extreme pressures*
- Chemo-synthetic – *gets energy from chemical reactions instead of sunlight*
- Super-smell – *may detect objects/creatures in their environment by smell*
- ________________

SIZE

- Giant
- Medium
- Small
- Microscopic

MUSCLE

- Bulky
- Lean
- Frail

EYESIGHT

- Super
- Average
- Weak/none
- Night-vision
- Infrared

MAKE YOUR OWN EXOPLANET & EXTRATERRESTRIAL LIFE CONTINUED...

Describe your alien life form. Explain why your creature would be able to survive on the exoplanet you made.

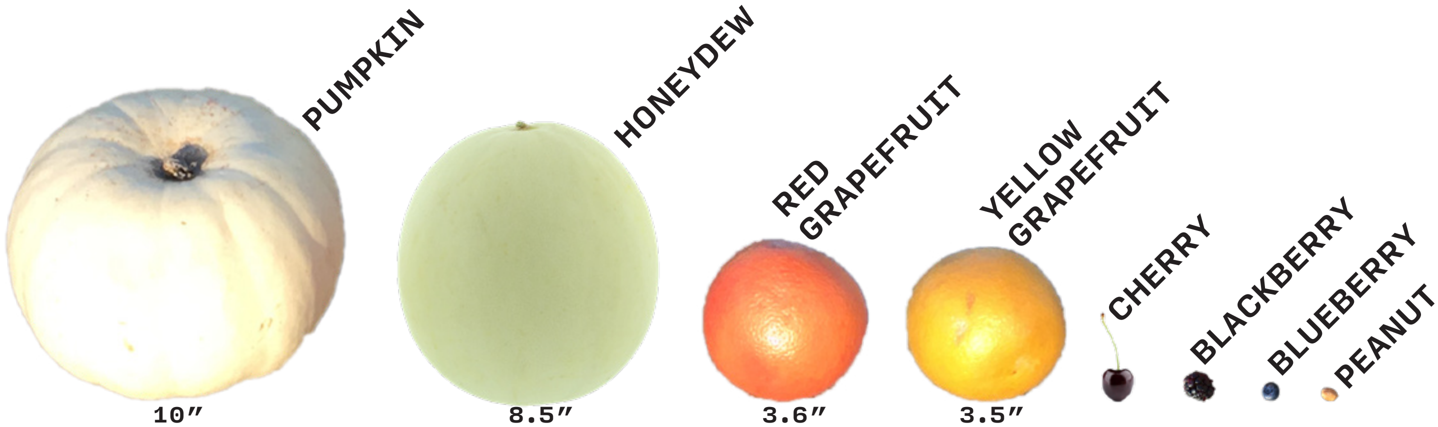
Draw what your life form would look like using the characteristics you chose.

Name your species:

The Edible Solar System

A BRAIN–BUSTER GAME

The edible objects pictured below, arranged from largest to smallest, are scaled-down representations of the sizes of each planet in our solar system. Solve the word deduction game to figure out which edible object represents the size of each planet in our solar system. This may help: Write the planet names on small pieces of paper that you can re-arrange.



- Saturn is bigger than Earth, but smaller than Jupiter.
- Neptune is bigger than Mars, Earth, Venus, and Mercury, combined!
- Uranus is slightly bigger than Neptune.
- Venus is bigger than Mars, but slightly smaller than Earth.
- Uranus is smaller than Saturn.
- Mercury is the smallest of all.

WORKSPACE

PUMPKIN = ______

HONEYDEW = ______

RED GRAPEFRUIT = ______

YELLOW GRAPEFRUIT = ______

CHERRY = ______

BLACKBERRY = ______

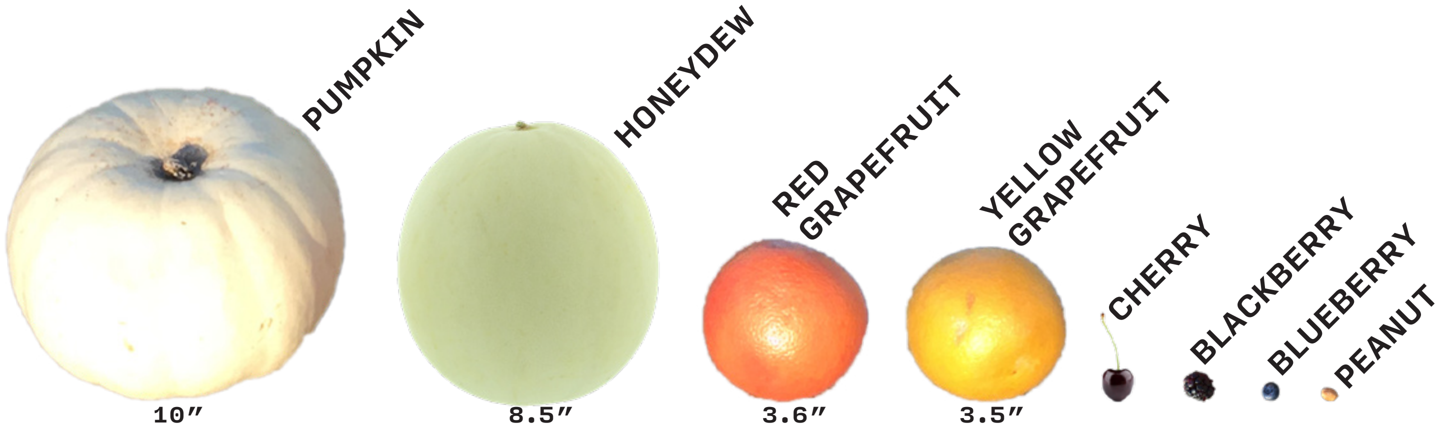
BLUEBERRY = ______

PEANUT = ______

The Edible Solar System

A BRAIN–BUSTER GAME – TEACHER VERSION

The edible objects pictured below, arranged from largest to smallest, are scaled-down representations of the sizes of each planet in our solar system. Solve the word deduction game to figure out which edible object represents the size of each planet in our solar system. This may help: Write the planet names on small pieces of paper that you can re-arrange.



- Saturn is bigger than Earth, but smaller than Jupiter.
- Neptune is bigger than Mars, Earth, Venus, and Mercury, combined!
- Uranus is slightly bigger than Neptune.
- Venus is bigger than Mars, but slightly smaller than Earth.
- Uranus is smaller than Saturn.
- Mercury is the smallest of all.

PUMPKIN = JUPITER

HONEYDEW = SATURN

RED GRAPEFRUIT = URANUS

YELLOW GRAPEFRUIT = NEPTUNE

CHERRY = EARTH

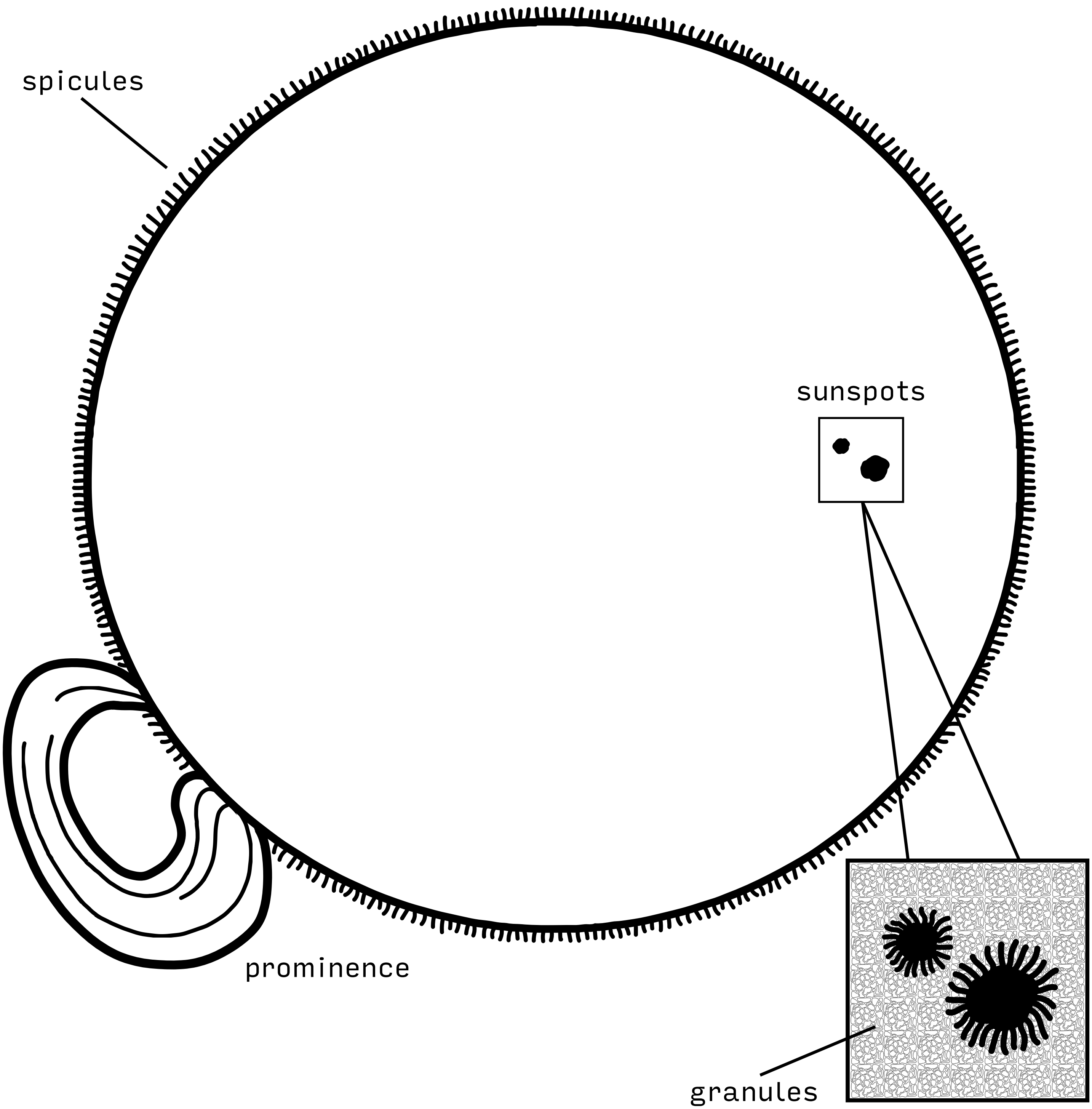
BLACKBERRY = VENUS

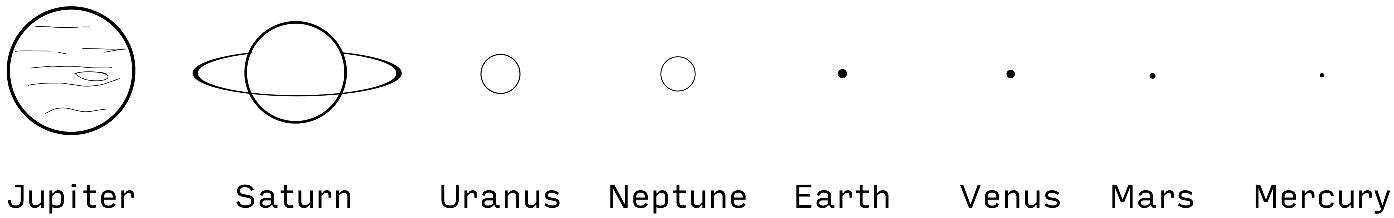
BLUEBERRY = MARS

PEANUT = MERCURY

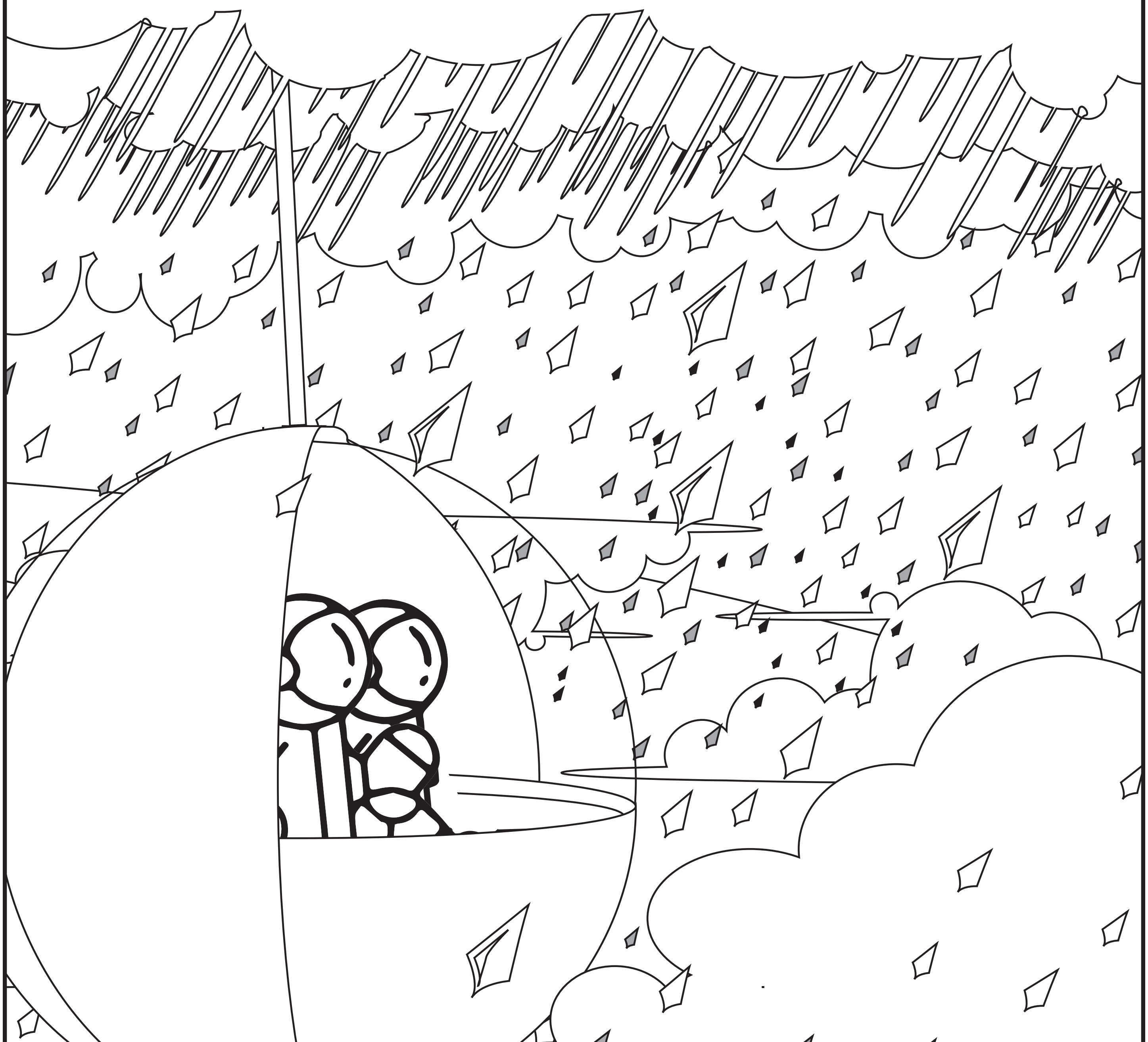
Teacher note: Sizes in this worksheet refer to the body (spherical part) of the planet and don't take into account the size of a planet's rings.

The Sun



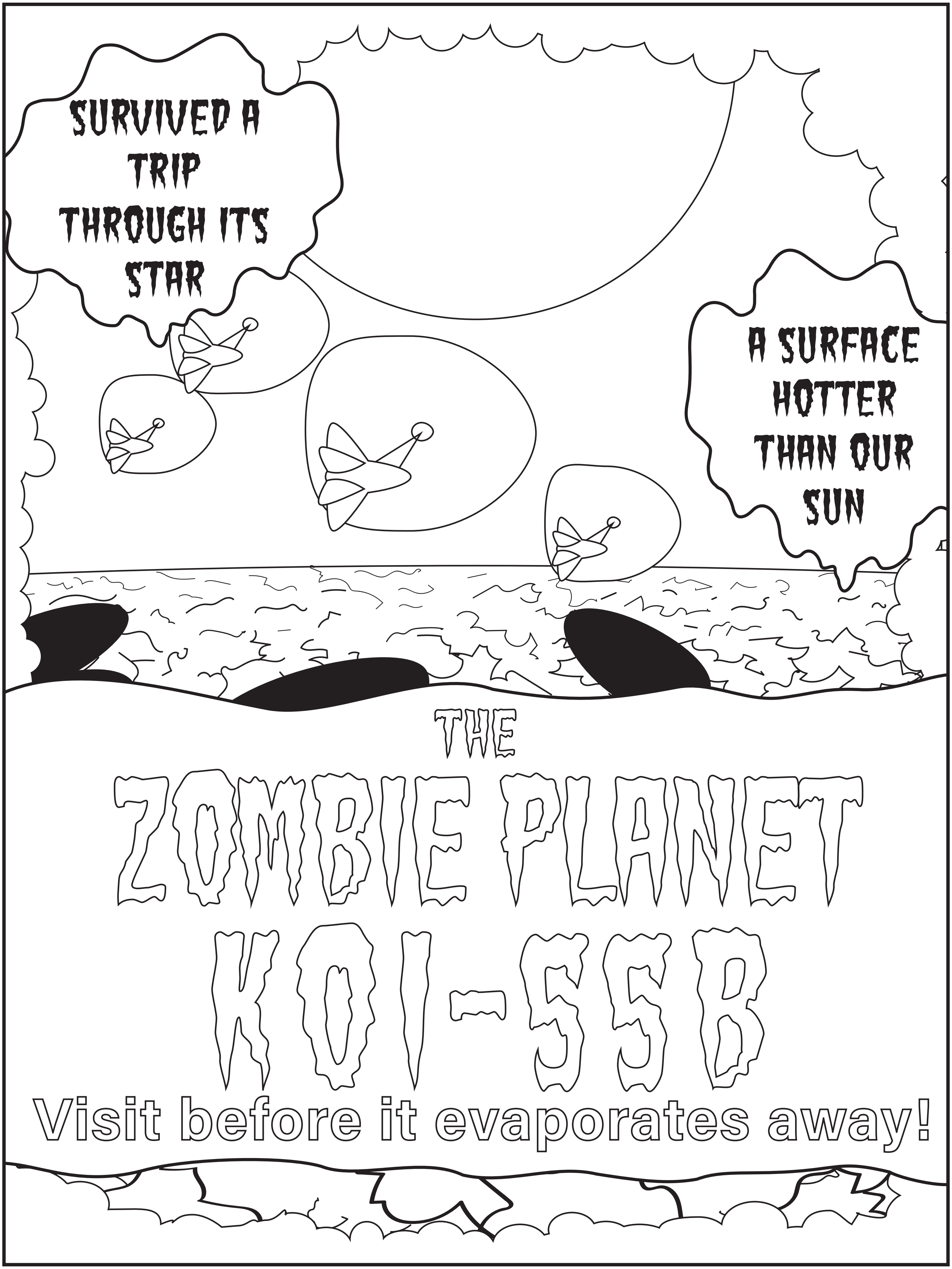


By Sarah Vincent

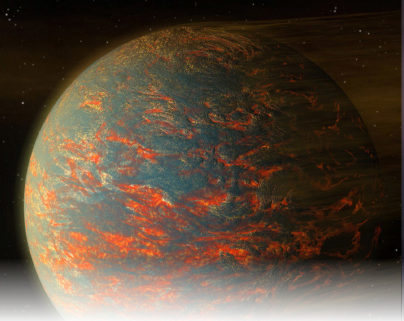
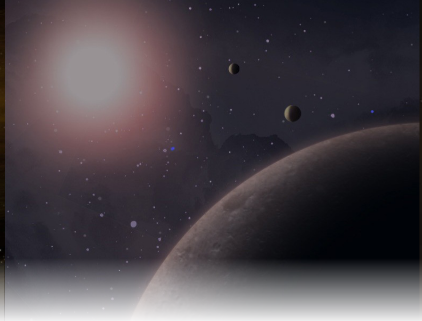
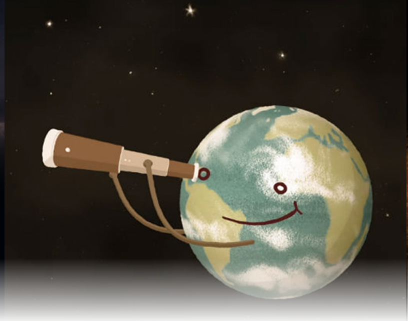
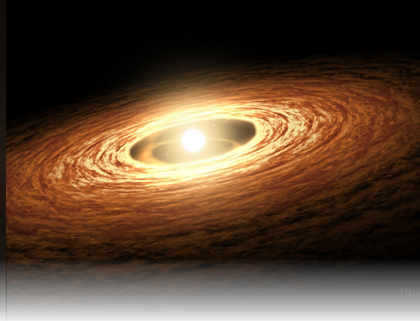


Experience the MOLTEN GLASS RAIN on HD 189733 b

By Brendan Fay



By Brendan Fay

Exoplanet Websites

NASA SPACE PLACE EXOPLANET PORTAL

This is a great place to start if you're new to exoplanets. The NASA Space Place site in general has informative articles, activities, and interactive web games about the Earth, Sun, solar system, universe, and the latest science and tech.

https://spaceplace.nasa.gov/all-about-exoplanets/en

EYES ON EXOPLANETS

"Eyes on Exoplanets" is a scientifically accurate 3D universe that allows you to zoom in on more than 1,000 exoplanets and their solar systems. The program is updated daily with the latest finds from NASA's *Kepler* mission and from ground-based observatories around the world as they hunt for planets like our own.

https://eyes.nasa.gov/apps/exo

NASA EXOPLANET EXPLORATION PORTAL

This site is your gateway to explore NASA's exoplanet news and content. There are videos, pictures, articles, posters, timelines, and activities that involve exoplanets, stars, space telescopes, the search for life, and the latest discoveries.

https://science.nasa.gov/exoplanets

NASA CITIZEN SCIENCE – EXOPLANET EXPLORATION

You can help make actual scientific discoveries with data from NASA! Through collaborations with NASA scientists, you can search for undiscovered worlds in our galaxy. If a project you're interested in is on pause, check back later; they are typically updated with new data regularly.

https://exoplanets.nasa.gov/citizen-science

Internet Resources

Not all websites are equally accurate. The world wide web, while convenient, can frequently provide incorrect and incomplete information. Below is a list of some of the best space science websites recommended by Griffith Observatory educators.

GRIFFITH OBSERVATORY

The most-visited public observatory in the world.

https://griffithobservatory.org

ASTRONOMY CLUBS

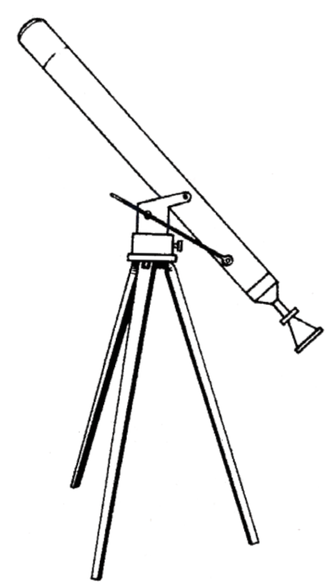
Find an astronomy club near you! Amateur (and some professional) astronomers are happy to share their telescopes, their enthusiasm, and their knowledge. A list of local clubs and more information may be found on our website:

https://obs.la/astronomyresources

CITIZEN SCIENCE PROJECTS

You may make a real contribution to astronomy by participating in these scientific projects.

Help scientists with their research into stars, Mars, Earth, galaxies, astronautics, the Sun, and black holes! Multiple projects are listed at this website:
https://science.nasa.gov/citizen-science



Another useful site that lists multiple Citizen Science projects:
https://zooniverse.org

NASA WEBSITES FOR SPACE FANS

Check out games and projects for budding space scientists:
https://spaceplace.nasa.gov/menu/play

Explore space with NASA's remarkable app, "NASA's Eyes:"
https://science.nasa.gov/eyes

Visit websites dedicated to learning for grades 5 through 8:
https://nasa.gov/learning-resources/for-students-grades-5-8

Watch NASA's live and original programming for free:
https://plus.nasa.gov

GRIFFITH OBSERVATORY

INTERNET RESOURCES CONTINUED...

RESOURCES FOR TEACHERS

Free lesson plans and activities for K-12 from Jet Propulsion Laboratory:
https://jpl.nasa.gov/edu/

Find Next Gen STEM learning opportunities for students in multiple settings:
https://nasa.gov/learning-resources/for-educators

Search NASA's educational activities and resources by subject, type, and grade level:
https://science.nasa.gov/learn/catalog

YOUTUBE CHANNELS

Griffith Observatory

European Space Agency

PBS Space Time

MORE WEB LINKS

California Science Center: Astronomy education programs, workshops, lesson plans, and resources. https://californiasciencecenter.org

The Lunar and Planetary Institute: Astronomy education programs, workshops, and resources. https://lpi.usra.edu/education

StarDate: The public education and outreach arm of the McDonald Observatory, Texas.
https://stardate.org

WorldWide Telescope: This website turns your computer into a telescope and brings together data and imagery from telescopes around the world.
https://worldwidetelescope.org

Astronomical Society of the Pacific: Organization of professional and amateur astronomers with astronomy education conferences, education programs, and resources, including professional development opportunities for teachers. https://astrosociety.org

Planetary Society: Open membership organization that sponsors planetary events and programs. Its "Space for Kids" page lists many at-home activities.
https://planetary.org/kids

Exploratorium: A resource for at-home experimentation and projects.
https://exploratorium.edu/explore

GRIFFITH OBSERVATORY®

Acknowledgments

Griffith Observatory is owned and operated as a public service by the City of Los Angeles, Department of Recreation and Parks. The work of the Department is overseen by the Board of Recreation and Park Commissioners, appointed by the Mayor of Los Angeles with confirmation by the Los Angeles City Council.

The Griffith Observatory Online School Program is made possible by Griffith Observatory Foundation. The primary role of the Foundation is supporting and promoting Griffith Observatory in its mission to inspire everyone to observe, ponder, and understand the sky.

Foundation donors, members, and supporters are a network of passionate people who believe in the value of free public astronomy. You can support Griffith Observatory's programs by donating to Griffith Observatory Foundation by visiting www.GriffithObservatoryFoundation.org

Staff Acknowledgments

We thank Griffith Observatory's full-time and part-time staff for important contributions and continual feedback essential in shaping the program. Staff acknowledgments for the production of Module 4, in alphabetical order:

Nelson Aguilera
Allan Ault
Hayley Bricker
Matthew Burlando
Chris Butler
Alex Carr
Victor Clarke
Ian Crovella
Don Dixon
Jarred Donkersley
April Eden
Brendan Fay
Eric Gabaldon
Bill Grueneberg
Dr. E.C. Krupp
Randy Lowry
David Maddox
Bill McCall
Kaitlynn McGuire
Mark Pine
Troy Powers
Dr. David Reitzel
Ella Ritts
Wayne Roche
Benjamin Roudenis
Patrick So
Jay Taylor
Sarah Vincent
Wayne Woodson

Special thanks to Griffith Observatory Foundation's staff and supporting members who make this program possible.

Additional Media Credits

We thank the following individuals and organizations for the use of their imagery and footage to supplement our educational program.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)
J. Bell – Donald R. Pettit – SkyWorks Digital – Northrop Grumman

NASA JET PROPULSION LABORATORY & CALTECH
Steve Golden

SPACE TELESCOPE SCIENCE INSTITUTION (STScI)
Frank Summers – Mark Malanoski

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA)

UNITED STATES AIR FORCE

JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY

SOUTHWEST RESEARCH INSTITUTE

ARIZONA STATE UNIVERSITY & CARNEGIE INSTITUTION OF WASHINGTON

MALIN SPACE SCIENCE SYSTEMS

CALTECH, PALOMAR OBSERVATORY, & YALE UNIVERSITY
S. Cianciulli – C. Donalek – M. Graham – A. Bauer – M. Bogosavlijevic – R. Williams – S. G. Djorgovski (team leader) – A. Drake – R. Bogosavlijevic – C. Baltay – L. Maxfield – A. Mahabal – D. Rabinowitz

NASA/ESA HUBBLE SPACE TELESCOPE
H. Bond (STScI) – M. Barstow (University of Leicester)

EUROPEAN SOUTHERN OBSERVATORY (ESO)
ALMA (ESO/NAOJ/NRAO) – E. O'Gorman – P. Kervella – VLTI – L. Calçada

MIKULSKI ARCHIVE FOR SPACE TELESCOPES (MAST)

NASA KEPLER MISSION
Dana Berry

NATIONAL RADIO ASTRONOMY OBSERVATORY

NASA GODDARD
NASA's Goddard Space Flight Center Conceptual Image Lab – Walt Feimer (KBRwyle) – Aaron E. Lepsch (ADNET) – Scott Wiessinger (USRA)

LAURIE HATCH

LUIS QUINTERO