JUST RIGHT:
SEARCHING FOR THE GOLDILOCKS PLANET

Exoplanets & Extraterrestrials Activity

"But could there be life that's different from life on Earth? We don't know if other kinds of life are possible or where to look for them." –**Just Right**: **Searching for the Goldilocks Planet**

Exoplanets & Extraterrestrials Activity

In this hands-on activity, you can invite one group of readers to imagine exoplanets, and another group of readers to imagine life (that is like or unlike life on Earth). Could the imagined life and the imagined exoplanet be "just right" for each other? Is there a Goldilocks exoplanet for the life (or extraterrestrials) your readers have envisioned? Is there life that is compatible with the exoplanets your readers have envisioned?

Just Right Conditions

After a reading of **Just Right: Searching for the Goldilocks Planet** by Curtis Manley and illustrated by Jessica Lanan (Roaring Brook Press), revisit what makes Earth and life here compatible:

Habitable Zone (Depicted on Spread 5)
"Earth orbits in our solar system's "habitable zone," where a planet can have liquid water on its surface because its distance from the Sun keeps the planet's temperature just right: not too hot (so all the water doesn't evaporate) and not too cold (so all the water doesn't freeze)."
—**Just Right: Searching for the Goldilocks Planet**

Molten Core & Magnetic Field (Depicted on Spread 6)
"Earth is big enough that part of its core is still molten, swirling with so much iron that it creates a magnetic field strong enough to protect our atmosphere from the solar wind."
—**Just Right: Searching for the Goldilocks Planet**

Atmosphere (Depicted on Spread 6)
"Earth's atmosphere is thick enough that it keeps our oceans from drying up, and its oxygen lets us breathe."
—**Just Right: Searching for the Goldilocks Planet**

Revisit Jessica Lanan's depictions of Goldilocks conditions on Spread 4 to discuss the various options or to reinforce the "just right"-ness of the Earth. If you have the time, consider watching the 5 minute NOVA video *The Goldilocks Zone* from PBS Learning Media.

Other Exoplanets, Other Life

"We can only look for what we do know— life that's like the life on Earth."
—**Just Right: Searching for the Goldilocks Planet**

On Spread 7, author Curtis Manley explains that because we know no other form of life, we use life on Earth as the basis to search for the "just right" or Goldilocks exoplanets. Curtis Manley then asks the reader:

"But could there be life that's different from life on Earth? We don't know if other kinds of life are possible or where to look for them." —**Just Right: Searching for the Goldilocks Planet**

At this point, your readers' imagination and curiosity about astronomy may be equally sparked. You might reinforce that by rereading Spread 14:

"So far they've found no proof of life elsewhere. So far we still seem to be alone in the universe. But as telescopes get bigger and better, and as we watch more and more stars, the chances of finding life improve. What might that life be like?" —**Just Right: Searching for the Goldilocks Planet**

You could follow that up with the question, "and what might the exoplanet that hosts that life be like?"

Exoplanets and Extraterrestrials

Consider dividing your readers into two teams - Exoplanets and Extraterrestrials (or Life). Within those teams, consider partnering 2-3 readers into groups that will work together. Each Exoplanets group will build one planet and each Extraterrestrials group will build one life form / type of life.

Ground Rules for Life

Because you will eventually ask the Exoplanets and Extraterrestrials to make a Goldilocks match, set some ground rules for comparison. (These questions are included in an enclosed worksheet.) For example:

Exoplanets

- Is your exoplanet hot or cold? The average temperature on my planet is _________.
  Note: The average temperature on Earth is 57°F (14°C).
- Do you have water on your planet? Does your magnetic field protect it from evaporating?
- Does your atmosphere have oxygen? Carbon dioxide?
- What food does your planet offer for life to eat?
- Describe your planet. You might include the presence or absence of continents, oceans, ice caps, forests, grasslands, deserts, or anything else you can imagine.

Extraterrestrials

- Do you like hot or cold? My perfect temperature is _________.
- Do you need water to survive?
- What do you breathe? Oxygen, carbon dioxide, or something else?
- What do you like to eat?
- Describe yourself and other life. You might include what you look like and why, how you raise your young, what your perfect environment is like, or anything else you can imagine.

Ground Rules for Life (cont.)

The answers to these or other ground rules questions will help readers create a visual representation of their exoplanet or extraterrestrial.

Building Life

Consider gathering art supplies for readers to use to turn themselves into their imagined exoplanets or extraterrestrials. Good bases for their creations might be a 12" circle of recycled cardboard or large paper plates for the exoplanets and a paper plate mask or headband base for the extraterrestrials.

Other supplies could include markers, glue sticks, pipe cleaners, collage materials, and/or objects from the recycling bin.

Finding Goldilocks

Once your readers have transformed themselves, invite your exoplanets to gather. Arrange them so they have good space around them. Here is some sample dialogue:

"May I have all the exoplanets gather over here? This is your solar system. I am your star, your sun. Please arrange yourself so you are orbiting around me."

Once your planets are in position, invite your extraterrestrials forward.

"Extraterrestrials will be coming to our solar system looking for their Goldilocks planet. They are looking for an exoplanet that is compatible with their life or their needs for temperature, water, oxygen, and food. Please come forward, extraterrestrials seeking a home."

Invite them to interact.

"Extraterrestrials and exoplanets, please have a conversation about temperatures, water, oxygen, and food. This conversation must happen on the move. The exoplanets orbit me and the extraterrestrials orbit the planets. Your goal is to make a match. Exoplanets, you want to be inhabited by life, you want to welcome extraterrestrials. Extraterrestrials, you need to make your home on an exoplanet. If you agree that you are a match and can co-exist, shout 'Goldilocks!'"

The interactivity of their conversations can vary. Here are some engagement variations:

Interview Checklist: Create and print a checklist that the extraterrestrial groups use to "interview" the exoplanet groups about what the exoplanet does and does not offer. This provides some structure, but might be less imaginative or collaborative.

Finding Goldilocks (cont.)

Just Right Tags: Make "too hot, " "too cold," "too dry," "no oxygen," "no food," etc. stickers or signs that can be clipped to planets with clothespins or paper clips. As the extraterrestrials and exoplanets are attempting to match, have the extraterrestrials tag the planet designating their reasons for not matching. Once all the parties have been matched (or cannot match), compare whether a planet with stickers designating it as "unmatchable" for one extraterrestrial may still have found a match with another extraterrestrial. This could spark additional discussion about the idea of "life as we know it" and planetary needs following the completion of matching. This is higher thinking, but might engage learners beyond finding their own matches. Be aware of readers' personal space. Many readers will not want the physical contact of having something stuck to them.

Once all of your readers have a chance to make a match, reassure the unmatched that,

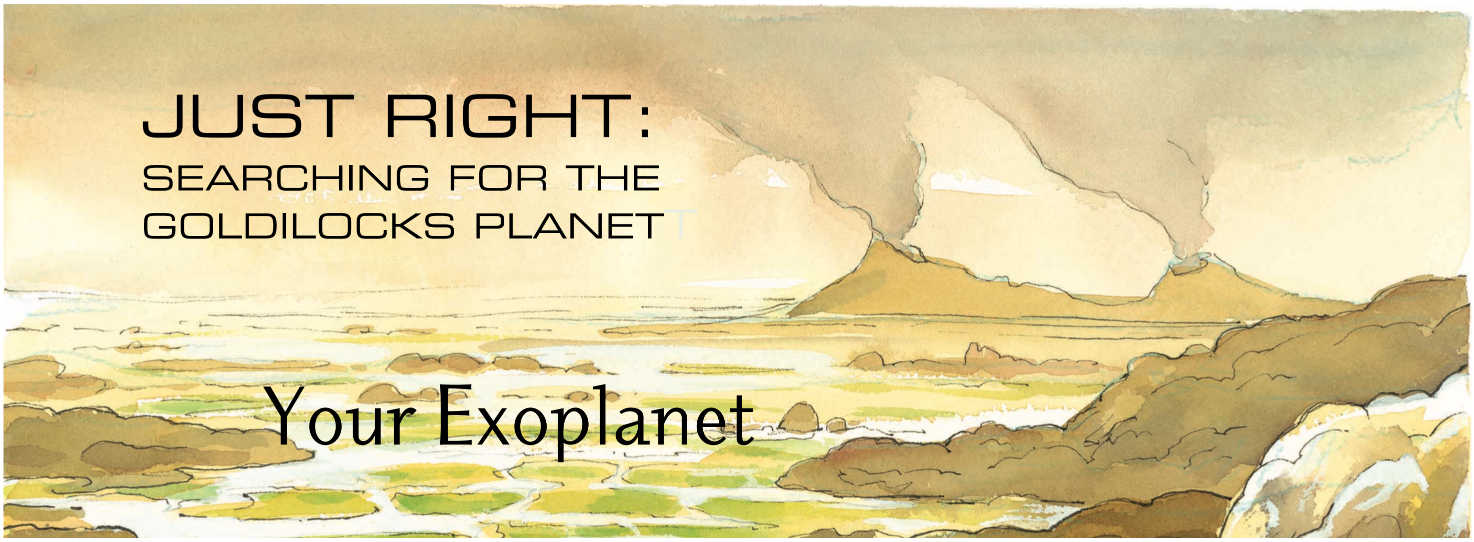
"Extraterrestrials, your Goldilocks planet may not be found today. There are trillions of stars like me in our universe. Exoplanets, you might not have found life to live on you today, but there may be life out there that we cannot even imagine."

Close with Imagination & Inquiry

Remind readers what the book **Just Right** says, "Or maybe it's like nothing we can even imagine."

Consider making this quote into laminated medallions, pins, or stickers for your readers and point them to a display of astronomy books and your copy of **Just Right: Searching for the Goldilocks Planet** to check out.

Activity created for **Just Right: Searching for the Goldilocks Planet** by Curtis Manley and illustrated by Jessica Lanan (Roaring Brook Press) and envisioned by librarians Suzanne Costner and Jennifer Beach. Image © Jessica Lanan.



Your Exoplanet

"The universe is a pretty big place. If it's just us, seems like an awful waste of space." —Carl Sagan

What are the components of your exoplanet?

Is your exoplanet hot or cold? The average temperature on my planet is

_______________________. Note: The average temperature on Earth is 57°F (14°C).

Do you have water on your planet? Does your magnetic field protect it from evaporating?

Does your atmosphere have oxygen? Carbon dioxide?

What food does your planet offer for life to eat?

Describe your planet. You might include the presence or absence of continents, oceans, ice caps, forests, grasslands, deserts, or anything else you can imagine.

Your Extraterrestrial

"The universe is a pretty big place. If it's just us, seems like an awful waste of space." –Carl Sagan

What are the elements of your extraterrestrial?

Do you like hot or cold? My perfect temperature is __________________.
Note: The average temperature on Earth is 57°F (14°C).

Do you need water to survive?

What do you breathe? Oxygen, carbon dioxide, or something else?

What do you like to eat?

Describe yourself as an extraterrestrial. You might include what you look like and why, what your perfect environment is like, how you raise your young, or anything else you can imagine.

Activity created for **Just Right: Searching for the Goldilocks Planet** by Curtis Manley and illustrated by Jessica Lanan (Roaring Brook Press) and envisioned by librarians Suzanne Costner and Jennifer Beach.

Book Quote for Medallions, Pins or Stickers

Consider printing these quotes and making them into medallions, pins, or stickers for your readers.

Activity created for **Just Right: Searching for the Goldilocks Planet** by Curtis Manley and illustrated by Jessica Lanan (Roaring Brook Press) and envisioned by librarians Suzanne Costner and Jennifer Beach. Image © Jessica Lanan.

JUST RIGHT:
SEARCHING FOR THE GOLDILOCKS PLANET

Just Right Temperature Activity

"Earth orbits in our solar system's "habitable zone," where a planet can have liquid water on its surface because its distance from the Sun keeps the planet's temperature just right: not too hot (so all the water doesn't evaporate) and not too cold (so all the water doesn't freeze)."
—**Just Right: Searching for the Goldilocks Planet**

Just Right for Liquid Water & Life

Like Goldilocks' porridge, there is a "just right" temperature for life as we know it. Life here on Earth depends on liquid water. Although we have water in the solid form of ice and the gaseous form of water vapor, plants and animals need liquid water to survive. Except for Earth, the surfaces of all the other planets, dwarf planets, and moons in our solar system are either so cold that any water is trapped in a frozen form, or so hot that the water probably boiled off as vapor long ago. Some planets may even have both situations depending on their temperature extremes. But that doesn't mean that scientists believe that Earth is the only possible place life might exist in the solar system. Liquid water probably exists underground on Mars, and some moons of Jupiter and Saturn are known to have oceans hidden under their frozen surfaces. That is why NASA is sending special missions to look for evidence of life in those places.

Observing Water in Solid and Vapor Forms

Here are some ideas to invite your students to observe the behavior of water at different temperatures with ice cubes and steam. Look for sample observation sheets on the following pages.

Note: At sea level on Earth, the boiling point of water is 212° F (100° C) and the freezing point is 32° F (0° C).

Ice: Place small amounts of ice in bowls in various locations to see how exposure to sunlight, or variations in temperature, affect the melting rate. Or you may wish to place a bowl of ice with each group of students and let them observe and time how long it takes for the ice to begin melting, or to melt completely (depending on the length of time available for the lesson).

Steam: For safety reasons, creating steam needs to be done carefully. It is possible to bring in a crock pot and turn the temperature up to create water hot enough to reach a gentle boil and form steam (especially if you leave the lid on, then raise it to let a cloud of steam escape). Students will need to be seated far enough away that the heat will not harm them and that they will not be able to knock the pot over. Or you could use an electric tea kettle and have students watch for the steam to escape the spout on the kettle.

Observing Water in Solid and Vapor Forms (cont.)

Additional Observations: Use lettuce leaves to demonstrate the reaction of plants to water in a variety of temperatures - frozen, room temperature, or boiling - and record the results on the condition of the leaves.

Plant & Planet Predictions

If plants here on Earth are not able to survive when exposed to the extremes of water temperatures, can students predict how they would react to the even greater temperature ranges, and therefore the possible water temperatures, found on other planets? Record their predictions on a class discussion chart or K-W-L chart.

Temperatures in Our Solar System:
Mercury -279° F (-173° C) to 801° F (427° C)

Venus 864° F (462° C)

Earth -126° F (-88° C) to 136° F (58° C)

Mars -243° F (-153° C) to 70° F (20° C)

Jupiter -258° F (-161° C) in the clouds to 43,000° F (24,000° C) in the core

Saturn -288° F (-177.8° C) in the clouds to 21,092° F (11,700° C) in the core

Uranus -371° F (-224° C) in the clouds to 9,000° F (4,982° C) in the core

Neptune -392° F (-236° C) in the clouds to 12, 632° F (7,000° C) in the core

Explore
"NASA: Solar System Temperatures" at https://solarsystem.nasa.gov/resources/681/solar-system-temperatures/

"NASA: Planet Compare" at https://solarsystem.nasa.gov/planet-compare/

Just Right Temperature Observations & Predictions

Name: ________________________________ **Date:** _______________

Just Right on Ice

Enter your observations about water in its solid form below. Note the location of where your ice cubes were placed - near a sunlit window, outdoors in full sun, outdoors in shade, etc. Where possible, note the temperature.

What is the condition of the ice cubes when first displayed?

What is the condition after 3 minutes?

What do you predict the condition would be after several hours?

Activity created for **Just Right: Searching for the Goldilocks Planet** by Curtis Manley and illustrated by Jessica Lanan (Roaring Brook Press) and envisioned by librarians Suzanne Costner and Jennifer Beach. Image © Jessica Lanan.

Just Right Temperature Observations & Predictions

Just Right Way to Water Plants

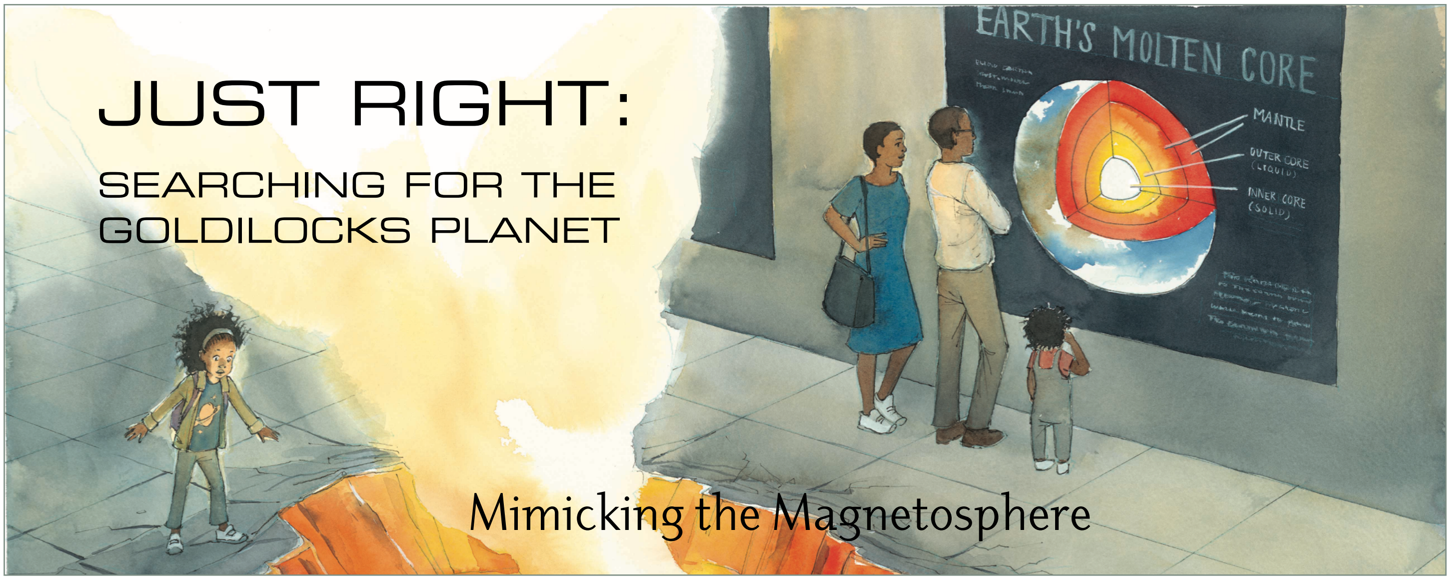
Expose three pieces of similar-sized lettuce to various forms of water. Record what you observe about the lettuce leaves before, during, and after the ice, water, or boiling water (hot enough to produce steam) is applied.

	Water	Ice	Boiling Water
Before			
During			
After			

Just Right Predictions

What do you predict the results would be if plants were exposed to those temperatures on other planets? What if humans were exposed to those conditions? What sort of life forms do you predict might survive in extreme heat or cold?

Activity created for **Just Right: Searching for the Goldilocks Planet** by Curtis Manley and illustrated by Jessica Lanan (Roaring Brook Press) and envisioned by librarians Suzanne Costner and Jennifer Beach.



JUST RIGHT:

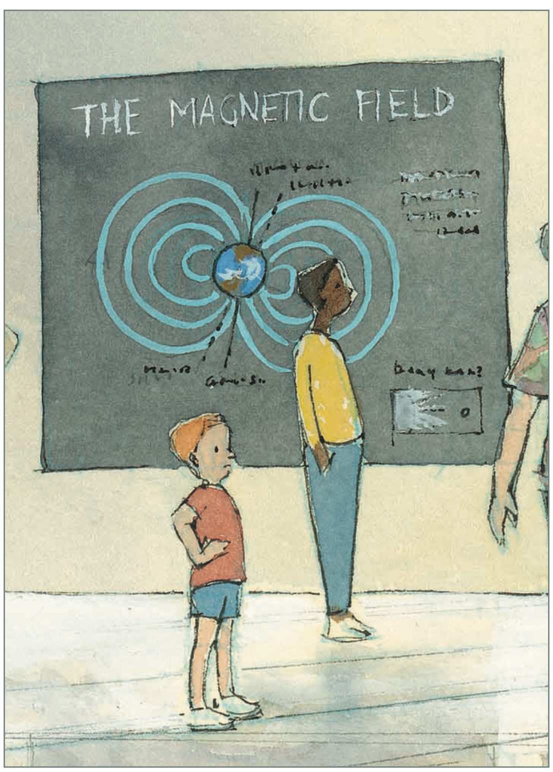
SEARCHING FOR THE GOLDILOCKS PLANET

Mimicking the Magnetosphere

"Earth is big enough that part of its core is still molten, swirling with so much iron that it creates a magnetic field strong enough to protect our atmosphere from the solar wind."
–**Just Right: Searching for the Goldilocks Planet**

Magnetosphere

One of the features that enables the Earth to support life is the protection of the magnetic field around the planet. Like a bubble or a force field around the world, the magnetosphere deflects most solar particles and keeps the solar wind from stripping away the ozone layer and the atmosphere. In turn, the ozone layer protects us from harmful ultraviolet radiation. Without the ozone layer, the radiation would be deadly. And without the atmosphere, we would not be able to breathe and the oceans would evaporate.



What does this field look like and where does it come from? Just like other magnetic fields, the magnetosphere is not visible to the naked eye. It is generated by the molten iron deep within the Earth's outer core. That liquid iron flows around and around the inner core and generates electrical charges, which produce a magnetic field.

Diagrams of the magnetosphere show how the field extends in front of and behind the Earth, with the North and South magnetic poles seeming to act as anchors for the donut-shaped fields of protection.

Explore "NASA Earth's Magnetosphere" at https://www.nasa.gov/mission_pages/sunearth/multimedia/magnetosphere.html

"Our home—the planet Earth—has everything 'just right' for us."
–**Just Right: Searching for the Goldilocks Planet**

Demonstrating Magnetic Fields

To demonstrate a magnetic field, consider using a bar magnet and iron filings. You will need to find a way to contain the filings so they do not scatter loosely, but still allow students to see them react to the magnet. Options for this include:

• Use the lid of a clear lunch or takeout container. Sprinkle the iron filings on whichever side of the lid has a raised edge; this will help contain the filings. Place the magnet under the lid. You may even wish to tape the magnet to the underside of the lid so that you can lift the lid to let students view it from the side or underneath.

• If you would like to have groups of students do this activity on their own, you may provide each group with a bar magnet and a zip-sealed baggie of filings. Have them lay the magnet on the table, then spread the baggie across the top of the magnet.

• Place a cow magnet inside an empty soda bottle (clear, not tinted). Then sprinkle the filings inside the bottle. They will cluster around the magnet creating a 3-D visual representation of the magnetic field.

• You may purchase magnetic field viewing cards that can be held up to a magnet to reveal its poles and the field around it. They are less messy than loose iron filings, since they use a magnetically sensitive film set into a plastic card.

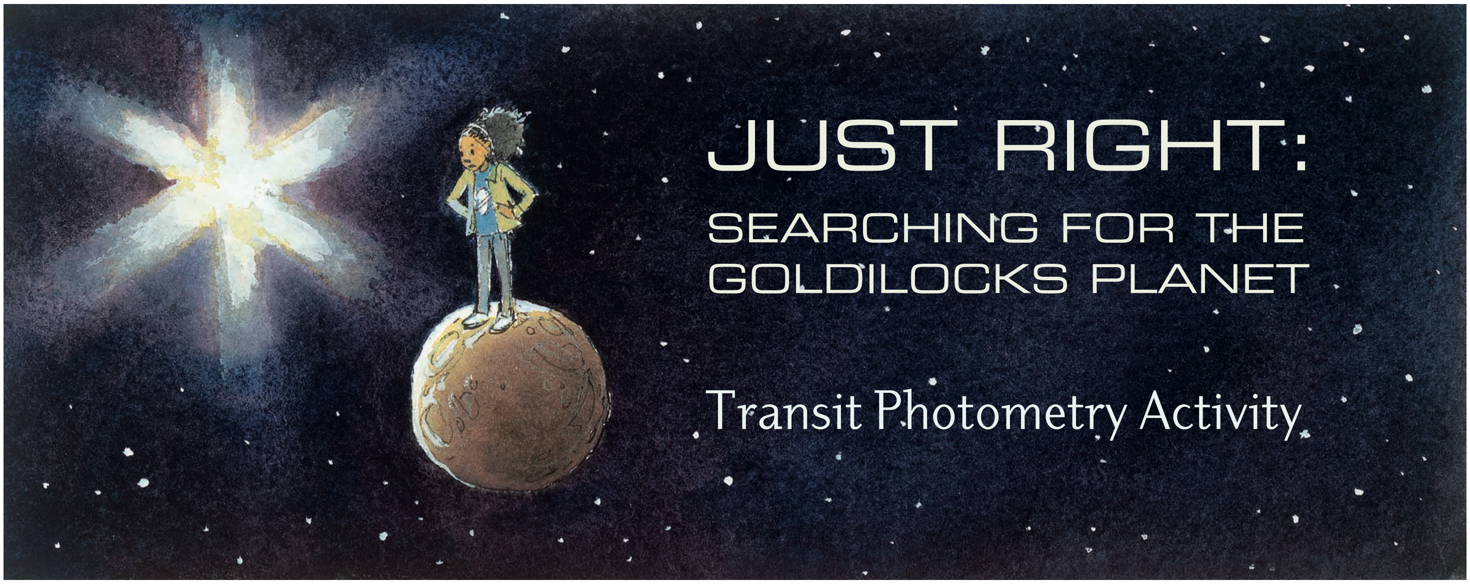
• Science supply businesses also sell premade viewing kits such as a clear plastic cube or cylinder with a magnet suspended in the center and the filings around it, or a clear plastic sealed case with the filings in it that you can use with your own magnet.

Discussing Magnetic Fields

However you choose to stage your demonstration, discuss with students what they observe about the way the filings arrange themselves in relation to the poles. Can they see how the field seems to come out from one pole and curve around to the other pole?

Now look back at the diagram of the magnetosphere around the Earth. Then lead them to predict how that would also mimic the field between the North and South Poles of the Earth. (Do they see the same pattern there?)

The magnetosphere protects us, but what about planets that have no magnetic field? If the planet does not have a metal core capable of producing a magnetic field, then could life exist on that planet's surface?



"The universe is a pretty big place. If it's just us, seems like an awful waste of space." –Carl Sagan

Understanding Transit Photometry

People have always wondered what is out there beyond Earth and its neighborhood. Over the centuries storytellers have woven incredible tales about life on other planets and beings living among the stars, while scientists have created bigger and better instruments for peering out into space and making new discoveries.

One way that astronomers can detect planets in our galaxy is to watch the stars closely. If they see a star dim and then brighten again, an orbiting planet has passed in front of the star and blocked some of the star's light. This dimming and brightening can be detected when the observer, the planet, and the star are lined up perfectly. (That takes some luck, but it does happen.) This method is called **transit photometry**.

Explore "NASA Searching for Shadows" at https://exoplanets.nasa.gov/alien-worlds/ways-to-find-a-planet/#/2 for a more detailed explanation.

Demonstrating Transit Photometry

Obviously we can't practice transit photometry ourselves by going outside and watching for something to pass in front of the sun (our closest star). Staring at the sun would harm our eyes and we wouldn't be able to see anything - not a good idea.

What we can do is simulate what is happening around that distant star as those astronomers study their instruments. **Explore** "Table-top Models to simulate what the Kepler Mission does"at https://www.nasa.gov/kepler/education/models to see a selection of models that can be purchased or built from various materials in your classroom or maker space.

This model can be done easily with household items.

- Place a table lamp (minus its shade) on a table or stool to situate the bulb at eye level. This lamp will be the star.
- Then use a small ball (foam or clay) as an exoplanet. You may wish to suspend it from fishing line or place it on the tip of a small dowel or wooden skewer so that it can be passed around the lamp.
- As your "exoplanet" crosses in front of the bulb, its shape will block a small portion of the light. This demonstrates the event that makes the transit method of identifying exoplanets possible.

Activity created for **Just Right: Searching for the Goldilocks Planet** by Curtis Manley and illustrated by Jessica Lanan (Roaring Brook Press) and envisioned by librarians Suzanne Costner and Jennifer Beach.

"Some stars seem to wave at us—wobbling slightly one way and then the other—as if trying to get our attention. Waving tells us that an orbiting planet is tugging the star around and around with its gravity, like a puppy on a leash running circles around you. This is the radial velocity method of finding exoplanets."
—Just Right: Searching for the Goldilocks Planet

Gravity & Student Wobble

The radial velocity method of detecting exoplanets is based on the way a star's planet(s) affect the star's movements. A star and its planet(s) orbit around their common center of gravity, which is not located in the very center of the star—and so the star seems to wobble as the planet(s) go around it. Sometimes people refer to this method as looking for a "gravity wobble" in the star's movements. Author Curtis Manley helps readers visualize this by describing radial velocity as being "like a puppy on a leash running circles around you." You could also liken it to an adult twirling a child. The child spins free with their feet off the ground, but their weight pulls on the adult so that the adult must constantly shuffle his/her feet to try and stay in position.

You can physically demonstrate radial velocity by having two students hold hands and then spin together. They will be rotating around a common center of gravity as they twirl. Mark that center between them with a colored object that is easy for the other students to observe. (Perhaps the gym teacher can loan a rubber base from a ball game.) Ask the pair to try and keep the marker between them as they spin. When they twirl, they will also be pulling each other slightly off balance. This is what happens as a planet orbits around a star. They influence each other and the planet causes a slight wobble in the star. It is best to do this outside on a soft, grassy area in case anyone becomes a little dizzy.

Walking & Watching the Wobble

Astronomers looking at distant stars may not even realize a star has a "wobble" until they are able to take detailed measurements of its movements. Let's return to the puppy on a leash example. Have you ever seen someone in the distance who seemed to be walking a bit off balance? Then, when the person drew closer, you could see that this person was actually walking their dog. The dog pulling at the leash was affecting the way the person moved, but without more observation, the reason for the "off-balance" style of walking was not obvious.

You can physically demonstrate this concept with a hula hoop with a 5-foot rope tied to one side. Have one student put the hula hoop around their waist. Have another student hold the free end of the rope and run around the first student. What do the two observe? What do your other students observe?

Explore "NASA: Watching for Wobble" at https://exoplanets.nasa.gov/alien-worlds/ways-to-find-a-planet/#/