National Aeronautics and Space Administration

NASA Helio-Club

Session 1
Heliophysics 101

NASA Heliophysics Education Activation Team

Session 1: Heliophysics 101

Find all resources for this session in the Session 1 Folder. Make a copy of the folder to edit documents.

Table of Contents

Time

120 minutes for the full progression of activities
-or- three **25- minute** activities that stand alone

Learning Goal

To introduce fundamental ideas about the Sun and the solar system, including exploring ways to model the heliosphere.

Full Session Overview

This session starts with a Know, Want-to-know, Learned (KWL) strategy for finding out what learners already know about the Sun. Start by engaging learners with a 2-minute video from NASA's Space Place: *Where does the Sun's energy come from?* This video gives learners a quick overview of the big ideas about the Sun and some of the topics that they will be exploring throughout the club sessions. After learners get a wider view of the solar system from the video, which introduces the *heliosphere*, they model structures of the heliosphere using a NASA visualization and a kitchen sink (Activity 1). Next, learners explore two NASA missions that study the boundary of the heliosphere, including Voyager and the Interstellar Boundary Explorer (IBEX). Learners will imagine they sent their return address on the Golden Record and how to write a postcard from space (Activity 2). The session ends with a simple scale model of the size and distance of the Sun-Earth system. Use the KWL to assess knowledge gains.

- **Prior Knowledge:** What do you already know about the Sun? KWL (15 minutes)
- **Engage:** Introduction to Heliophysics (15 minutes)
- **Explore: Activity 1:** Modeling the Heliosphere (25 minutes)
- **Explain**: **Activity 2:** Cosmic Return Address (25 minutes)
- **Extend: Activity 3:** Earth-Sun Scale Model (25 minutes)
- **Evaluate:** KWL (15 minutes)

Materials

NASA Helio-Club Youth Guide (optional) includes all handouts for all six sessions.
Quantities are per learner.

Basics

- ☐ Writing tools (pens or pencils)
- ☐ Art supplies (markers or crayons)
- ☐ (1) pair of scissors
- ☐ (1) roll of tape

Prior Knowledge/Evaluate

- ☐ (1) Handout_KWL_Session 1

Engage

- ☐ (1) Handout_The Sun's Energy Graphic PDF
  or find the digital version here NASA Space Place: Where does the Sun's energy come from?

Explore: Activity 1

- ☐ (1) Handout_The Heliosphere Graphic PDF (needs to be printed in color and laminated)

Explain: Activity 2

- ☐ (1) 5" x 7" index card
- ☐ (1) postage stamp (optional)

Extend: Activity 3

- ☐ (1) measuring tape
- ☐ (1) Handout_Sun-Earth Day Model PDF

Digital Resources

- Educator Resource: Educator Background Information
- Educator Resource: Slides_Session1
- Video: Engage: NASA Space Place: Where Does the Sun's Energy Come From?
- Video: Activity 1: Modeling the Heliosphere
- Webpage: Activity 1: NASA IBEX Mission
- Webpage: Activity 2: NASA/JPL Voyager Mission
- Webpage: Activity 2: Voyager Mission: The Golden Record

Learning Objectives: At the end of the session, learners will be able to…

1. Identify the Sun as a star.
2. Distinguish between a star and a planet.
3. Describe the main features of the heliosphere.
4. Model the scale of the Sun-Earth system.

Key Vocabulary

- **Golden Record** – a gold-plated copper phonograph record, carried aboard the Voyager spacecraft, containing sounds and images selected to portray the diversity of life and culture on Earth, much like a time capsule, intended to communicate a story of our world to extraterrestrials
- **Heliophysics** – the science of understanding the Sun and its interactions with Earth and the solar system, including space weather
- **Heliosphere** – the region around the Sun, sort of like a bubble in space that is inflated by the Sun's constantly outflowing material and the solar wind
- **Heliopause** – the outermost part of the heliosphere; the boundary between the solar and interstellar winds is the heliopause, where the pressures of the two winds are in balance
- **Interstellar Space** – the space between the stars in a galaxy
- **Nuclear Fusion** – a process in which two nuclei join to form a heavier nucleus
- **Plasma** – the most abundant state of matter, very different from solids, liquids, and gases. Plasmas are so incredibly hot that the electrons leave their atoms, making it essentially a gas of charged particles
- **Solar Wind** – a gusty stream of plasma flowing outward from the Sun in all directions, all the time, carrying the Sun's magnetic field out into space
- **Termination Shock** – the point where the solar wind begins to interact with the local interstellar medium and slows down

Review the Educator Background Information **for more information on major concepts.**

Next Generation Science Standards (NGSS) Connections

MS-ESS1-3. Space Systems: **Analyze and interpret data to determine scale properties of objects in the solar system.** In Activity 2 and Activity 3, learners explore the size and scale of the Sun and the heliosphere.

MS-PS2-5. Forces and Interactions: **Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.** In Activity 1, learners explore the influence of the Sun on space.

MS-PS1-4. Structures and Properties of Matter: **Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.** In Activity 1, learners explore how plasma creates the solar wind.

Targeted STEM Skills

Asking questions: Learners ask questions using a KWL.

Making predictions: Activity 1: Learners make predictions about a model of the heliosphere.

Planning and carrying out investigations [MS-PS2-5]: Activity 1: Learners carry out an investigation into the structure of the heliosphere.

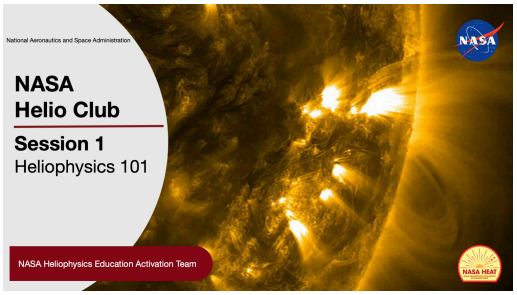
Developing and using models [MS-PS1-4]: Activity 1: Learners use a model to explore how the solar wind defines the boundary of the heliosphere.

Analyzing, organizing, and interpreting data [MS-ESS1-3]: Activity 3: Learners interpret data about the scale of the Sun-Earth system.

Steps: Full Session

**Italics indicate recommended scripts to use with students.*

Use the accompanying slides to help keep learners engaged.



- ➢ **Prior Knowledge:** What do you already know about the Sun? KWL (15 minutes)
- ➢ **Engage:** Introduction to Heliophysics (15 minutes)
- ➢ **Explore: Activity 1:** Modeling the Heliosphere (25 minutes)
- ➢ **Explain**: **Activity 2:** Cosmic Return Address (25 minutes)
- ➢ **Extend: Activity 3:** Earth-Sun Scale Model (25 minutes)
- ➢ **Evaluate:** What did you learn about the Sun? KWL (15 minutes)

Prior Knowledge: What do you already know about the Sun?

Overview (15 Minutes)

A KWL chart is an effective way to assess learners' prior knowledge, identify misconceptions, and measure growth. Use the guiding questions provided in the chart below to focus learners on the content that is explored in this session.

As students share their ideas and predictions, don't give them the answers just yet; rather, encourage them to investigate their questions throughout the session.

If you don't use the Youth Guide, have learners use a notebook to record their observations, draw diagrams, and collect data.

Materials

- Handout_KWL_Session 1

Instructions

A. **Direct learners to page 5** in the NASA Helio Club Youth Guide, or print the Handout_KWL_Session 1

B. Have learners complete the **Know [K] Column** and the **Wonder [W] Column** of the KWL chart. Instruct them to leave the Learn [L] Column blank until the end of the session. [Slide 4]

KWL

[K] – What do you already know?	[W] – What do you wonder about?	[L] – What did you learn?
What do you already know about the Sun? • *What is it?* • *What is it made of?* • *How big is it?* • *How does it make energy?*	*Record questions you have about the Sun in this column.*	*Record what you learned about the Sun in this column.*

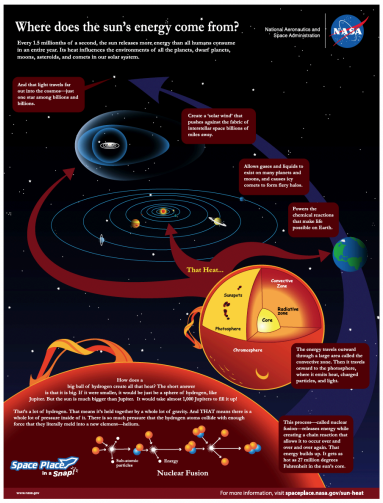
Engage: What is heliophysics?

Overview (15 Minutes)

This introduction activity is intended to build a foundation of knowledge about the Sun.

Begin by defining the word **heliophysics**. Then have learners watch a short video, which provides some basic facts about the Sun. Use the video to answer the questions from the KWL and to introduce two more terms: **solar wind** and **interstellar space**.

These terms are important for learners to know as they begin to learn more about how NASA studies the Sun.



Credit: NASA Space Place

Materials

- Handout_The Sun's Energy Graphic PDF

Instructions

A. **Direct learners to page 6** of the NASA Helio Club Youth Guide, or print the Handout_The Sun's Energy Graphic PDF. This graphic outlines the key points from the video.

B. **Provide Context:** ***Heliophysics*** *is the study of the Sun and its influence on the solar system. There are a lot of very interesting heliophysics topics that NASA studies.* [Slide 5]

C. **Watch:** NASA Space Place: Where does the Sun's energy come from? This short video about the Sun from NASA Space Place provides a brief overview of the heliophysics concepts that we will be exploring throughout the club sessions. [Slide 6]

D. **Revisit:** After learners are finished watching the video, have them take a closer look at the graphic (page 6) to review some of the key points from the video. Have learners use the graphic to help answer the questions in the KWL chart.

- *What is the Sun?*
- *Why isn't it a planet, like Jupiter, for example?*
- *How big is the Sun?*
- *How does it make energy?*

Create a 'solar wind' that pushes against the fabric of interstellar space billions of miles away.	**E. Hypothesize**: **Direct learners to the box on the page 6 graphic that says,** "*Create a 'solar wind' that pushes against the fabric of interstellar space billions of miles away.*" [Slide 7] Ask students: ○ *Have you heard of **solar wind**?* ○ *What about **interstellar space**?* Allow time for learners to share their answers.

Major Concepts

- ★ The Sun is a star. The Sun is much, much bigger than a planet: 1,000 Jupiters can fit into the Sun.
- ★ The Sun is so big and has so much gravity and pressure that it can create energy.
- ★ The Sun makes energy in its core through the **nuclear fusion** of hydrogen into helium. **Nuclear fusion** releases a lot of energy.
- ★ The Sun is made of a super-heated, ionized gas called **plasma**. Plasma is the most abundant state of matter, very different from solids, liquids, and gases. Plasmas are so incredibly hot that the electrons leave their atoms, making plasma gases of charged ions and electrons.
- ★ The Sun releases heat, light, and charged particles. These charged particles make up the **solar wind**.
- ★ **Solar wind** is created by the intense super-heated **plasma** of the Sun, which flows outward in all directions, pushing against the material that is in between the stars, creating a sort of bubble that surrounds our solar system. We call this bubble the **heliosphere**.
- ★ The space between stars is called **interstellar space**. This kind of space turns out to be a little different from the space inside the boundary of the Sun's influence.

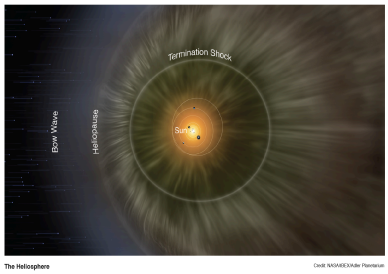
Explore: Modeling the Heliosphere

Overview of Activity 1 (25 Minutes)

This hands-on activity uses the kitchen sink to model the properties of the boundary of the ***heliosphere*** and takes learners through the scientific processes used in investigations: Making observations, using models, and communicating results.

Emphasize to learners that the image on the handout is not a picture NASA took, but rather an illustration based on real data collected by NASA missions.

Scientists routinely use models to better understand phenomena. Colors can be added to these types of models to help us visualize what is going on.



Heliosphere Handout
Credit: NASA / IBEX

Materials

- Waterproof Handout_The Heliosphere Graphic PDF

Instructions

A. **Direct learners** to the Handout_The Heliosphere Graphic PDF, which is the same image on **page 7** of the NASA Helio Club Youth Guide.

B. **Provide Context:** The ***heliosphere*** *has different parts, depending on how it interacts with the boundary of* ***interstellar space***. *We know this from NASA missions like* ***Voyager*** *and* ***IBEX****, which have measured this boundary.*

C. **Examine:** *This visualization was created from a 3D model of the* ***heliosphere*** *using actual data collected by the* ***IBEX*** *mission. Colors are meant to enhance features and show structure.* [Slide 8]

The ***solar wind*** *is represented by the greenish, wavy lines coming out from the Sun.*

The ***heliopause*** *is the outermost boundary of the* ***heliosphere****. Beyond the heliopause is* ***interstellar space****.*

The ***termination shock*** *is the innermost boundary of the* ***heliosphere****, where the* ***solar wind*** *begins to interact with* ***interstellar space****. The* ***termination shock*** *is still inside the* ***heliosphere****.*

The ***heliosphere*** *creates a* ***bow wave*** *because the Sun is moving through* ***interstellar space*** *as it orbits the center of the Milky Way galaxy. It is just like how a bow wave is created as a boat moves through the water.*

Encourage learners to record observations and draw diagrams, like real scientists and engineers do, in the NASA Helio Club Youth Guide. **Educator Background Information:** In anticipation of questions on exactly what interstellar space is made of, you can tell learners that: *Interstellar space is the space between the stars in our Milky Way and contains a cold gas of mostly hydrogen atoms mixed together with a hot gas consisting of plasma.*	*Take a few minutes to examine the **heliosphere** handout and make some observations.* ● *What do you notice about the boundary?* ● *What shape is it?* **D. Model:** *We are going to use this waterproof image and the kitchen sink to model parts of the **heliosphere**.* Take learners through the directions. If you laminated the handout, instruct learners to skip the instructions for wrapping the handout in plastic wrap. Instruct learners to go to the sink and experiment. [Slide 9] You can show learners the Modeling the Heliosphere Video to help them construct the model. [Slide 10] **C. Sharing Results:** ○ *Record your results. Include drawings and diagrams and note any modifications you made in order to perfect the model, perhaps adjusting the water pressure or the position of the image, for example.* ○ *How does this model help us learn about the properties (characteristics) of the **solar wind** and the **heliosphere** boundary?* ○ *Why would a soap bubble not be an appropriate model for the **heliosphere**?* Allow time for learners to share their answers.

Activity 1 Major Concepts

- ★ The **heliosphere** is the region of space influenced by the **solar wind,** and it extends far beyond Pluto. Very far! For perspective, Earth is 1 astronomical unit (AU) from the Sun. Pluto is, on average, approximately 40 AU from the Sun; the boundary of the heliosphere (the heliopause) is approximately 122 AU from the Sun. (1 AU is approximately 93,000,000 miles)
- ★ The **heliopause** is the outermost boundary of the heliosphere.
- ★ The **termination shock** is the innermost boundary of the heliosphere, where the **solar wind** begins to interact with **interstellar space**. The termination shock is still inside the heliosphere.
- ★ The flowing water on the image is a good model for the boundary of the heliosphere because the boundary ebbs and flows with solar activity.
- ★ The shape of the heliosphere is not round, however, because the Sun is traveling through space, orbiting around the center of the Milky Way galaxy, it creates a **bow wave** through interstellar space as it travels.
- ★ NASA missions are interested in studying this boundary because the Sun is the only star that we know of that hosts a planet with life. We can learn about other stars from studying our own star and its influence on space.

Featured NASA Missions: The Interstellar Boundary Explorer (IBEX) is an Earth-orbiting mission that has special telescopes that look out toward the edge of the solar system, mapping the boundary of our solar system. The twin Voyager spacecraft (Voyager 1 and Voyager 2) was launched from Earth in 1977. Voyager 1 reached the termination shock of the heliosphere in 2004 and crossed the heliopause in 2012. It was the first human-made object to enter interstellar space.

Explain: Cosmic Return Address

Overview of Activity 2 (25 Minutes)

In this activity, learners will apply their knowledge of the structure of the heliosphere to create a "cosmic return address."

Learners are challenged to identify the details needed to find a location on Earth, i.e., house number, street name, city, state, and country, and apply that pattern to receiving mail from a location beyond Earth.

In the previous activities, learners were introduced to the heliosphere as a more accurate model of the solar system. Learners may or may not be familiar with the structure of the universe outside of the heliosphere. This would be an opportunity to discuss how the Sun, our star, is located in the Milky Way galaxy, and how galaxies contain billions of stars. There are billions of galaxies in the universe.

Materials

- 5" x 7" index card
- Writing tools
- Art supplies
- Postage stamp (optional)

Instructions

A. **Give Context:** *Have you heard of the **Golden Record?*** [Slide 12]

*The **Golden Record**, a kind of time capsule, is aboard both **Voyager 1 and 2** and is intended to communicate a story of our world to extraterrestrials. The **Voyager** message is carried by a 12-inch gold-plated phonograph record containing sounds and images selected to portray the diversity of life and culture on Earth.*

*Imagine that an extraterrestrial actually found the **Golden Record**! How would they find their way back to Earth for a friendly visit?*

*NASA put some directions to Earth on the **Golden Record,** so our new alien friends can find their way! What do you think these directions would look like?*

B. **Identify:** *Here on Earth, we use addresses to find locations. What is your address (or school address)? What are the key components to an address on Earth?* [Slides 13-18]

Have learners begin to construct their address. Because many young people don't write letters, you may need to guide them through this. Give them a hint: an address goes from smallest (the person) to the biggest (the country).

	C. **Predict:** *What information would you need to add to your address if your new friends came from outside of the* ***heliosphere****? What about from outside of our galaxy?* [Slide 19] Have learners add to their address, after the country. Use questions to probe learners for ideas about the additional information required to receive a "postcard from space." ● Planet: Earth ● Planetary System: Solar System ● Solar System Boundary: Heliosphere ● Galaxy: Milky Way **D.** **Create:** *We don't have any extra records made of gold for you to encode your address on, but we do have postcards! Your challenge is to write your own "golden-record type message" welcoming extraterrestrials to Earth, providing your return address, so they can find your exact location on Earth.* [Slides 20-23] Use the postcard template below to guide learners on how to make a postcard. [Slide 24] ● Have learners write their chosen address (home, school, library, etc.) on the 5" x 7" index card. ● Have learners write a message to an extraterrestrial. What are the best parts of Earth they would want to share with a visitor? ● Have learners decorate the other side of the postcard with directions to Earth. Now that they have a better understanding of what is outside the solar system, could they draw a map for the extraterrestrials to follow?

	E. **Send!** (optional): Provide learners with a stamp and have them mail the postcard to themselves to see if the address really works! The post office will deliver it as long as it has the essential "Earth-based" information, including city, state, and ZIP code.

Activity 2 Major Concepts

- ★ The **Golden Record**, a kind of time capsule, is aboard both **Voyager 1 and 2** and is intended to communicate a story of our world to extraterrestrials.
- ★ The Sun is just one of billions of stars in the Milky Way galaxy.
- ★ There are billions of galaxies in the universe.

*This activity has been adapted from the NASA IBEX mission's Postcards from Space.

Postcard Template

Back

Greetings! [Message] ***Sincerely,*** ***The Earthlings***	***PLACE STAMP HERE*** **Learner Name:** _____ **House #, Street:** _____ **City, State, ZIP Code:** _____ **Country:** _____ **Planet:** _____ **Planetary System:** _____ **Solar System Boundary:** _____ **Galaxy:** _____

Front

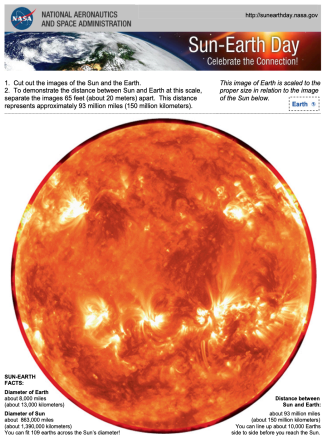
[Image]

Extend: Sun-Earth Scale Model

Overview of Activity 3 (25 Minutes)

In this activity, learners will use a scale model to observe how big the Sun is compared to Earth and the distance between them.

Emphasize to learners that different types of models help scientists learn different kinds of information. The model of the heliosphere in the sink was not to scale, but helps scientists visualize how the boundary of the heliosphere behaves. The Sun-Earth system model is to scale, and helps scientists learn about the sizes and distances of objects relative to one another.



Materials

- Handout_Sun-Earth Day Model PDF
- Measuring tape
- Scissors

C. **Provide Context:** *To give you a better idea of how big the Sun is compared to the Earth, and the distance between them, we can create a scale model.* [Slide 24]

D. **Model: Direct learners to page 9** of their NASA Helio Club Youth Guide, or use the Handout_Sun-Earth Day Model PDF.

Have learners cut out the Sun and the Earth. To demonstrate the distance between Sun and Earth at this scale, separate the images 65 feet (about 20 meters) apart. This distance represents approximately 93 million miles (150 million kilometers).

E. **Reflect**: Ask students the following questions. [Slide 25]

- *What is a scale model?*
- *Why do both size and distance matter when making a model to scale?*
- *Was the model of the heliosphere in the sink a scale model? Why or why not?*
- *Do both scale and not-to-scale models serve a purpose? Explain.*
- *Is there anything that surprised you about the sizes and distance between the Sun and Earth?*

F. **Communicate Results:** Allow time for learners to share their answers.

Activity 3 Major Concepts

- ★ The Earth is approximately 93 million miles from the Sun.
- ★ The Sun is approximately 109 times wider than Earth.
- ★ Models are a representation of a real phenomenon that is difficult to observe directly, because of its size, for example. Using models of the heliosphere can help us visualize something very big.
- ★ Both to-scale and not-to-scale models help scientists in different ways.

Evaluate: What did you learn about the Sun?

Overview of Activity (15 Minutes)

At the end of the session, learners complete the KWL chart, adding what they learned to the [Learn] column.

Encourage learners to look through Session 1 in the NASA Helio Club Youth Guide, and to review the activities and the observations they recorded during the activities, to help them summarize what they learned during the session.

Materials

- Handout_KWL_Session 1

Instructions

A. **Direct learners to page 5** in their NASA Helio Club Youth Guide, or print the Handout_KWL_Session 1

B. Have learners complete the **Learn Column [L]** of the KWL chart.

Emphasize to learners that they should also be correcting any misconceptions they had prior to the session, from the Know [K] column, and answering any questions from the Wonder[W] column, if they are able to.

Session 1 Major Concepts

- ★ The Sun is a star and is the largest object in the solar system; 1.3 million Earths can fit into the Sun.
- ★ The Sun is just one of billions of stars in the Milky Way galaxy; there are billions of galaxies in the universe.
- ★ The Sun is so big and has so much gravity and pressure, it can create energy. The Sun makes energy in its core through the nuclear fusion of hydrogen into helium. **Nuclear fusion** releases a lot of energy.
- ★ The Sun is made of a super-heated, ionized gas called **plasma**. Plasma is the most abundant state of matter, very different from solids, liquids, and gases. Plasmas are so incredibly hot that the electrons leave their atoms, making plasma gases of charged ions and electrons.
- ★ The Sun releases heat, light, and charged particles. These charged particles make up the **solar wind**.
- ★ **Solar wind** is created by the intense super-heated **plasma** of the Sun, which flows outward in all directions, pushing against the material that is in between the stars, creating a sort of bubble that surrounds our solar system. We call this bubble the **heliosphere**.
- ★ The **heliosphere** is the region of space influenced by the **solar wind,** and it extends far beyond Pluto.
- ★ The space between stars is called **interstellar space**. This kind of space turns out to be a little different from the space inside the boundary of the Sun's influence, the **heliosphere**.

References

NASA. (2021, February 26). *NASA IBEX.* Retrieved on June 4, 2023, from https://science.nasa.gov/mission/ibex/

NASA. *Postcards from Space!* Retrieved on June 4, 2023, from http://ibex.swri.edu/planetaria/Postcards_from_Space.pdf

NASA/IBEX/Adler Planetarium. *The Heliosphere.* Retrieved on June 4, 2023, from https://ibex.princeton.edu/sites/g/files/toruqf1596/files/ibex-the_heliosphere_lithograph.pdf

NASA/JPL. *Voyager.* Retrieved on June 4, 2023, from https://voyager.jpl.nasa.gov/

NASA/JPL. *The Golden Record***.** Retrieved on June 4, 2023, from https://voyager.jpl.nasa.gov/golden-record/

NASA Space Place. (2022, August 29). *Where does the Sun's energy come from?* Retrieved on June 4, 2023, from https://spaceplace.nasa.gov/sun-heat/en/

NASA Sun Earth Day. *Scale Model of Sun and Earth.* Retrieved on June 4, 2023, from https://sunearthday.nasa.gov/2007/materials/solar_pizza.pdf

This product was developed by the NASA Heliophysics Education Activation Team (NASA HEAT), part of NASA's Science Activation portfolio. Publication number NP-2023-6-077-GSFC.