National Aeronautics and Space Administration

NASA Helio Club

Youth Guide

NASA Heliophysics Education Activation Team

Welcome to NASA Helio Club!

Get ready to heat up the fun with NASA as you launch into an exploration of our very own star, the Sun!

Heliophysics is the study of the Sun and its influence on the Solar System.

[Helio = Sun]

[Physics = how things work]

There are billions of stars in the Milky Way Galaxy, which is where our Solar System is located. There are billions of galaxies in the known universe. That is a whole lot of stars!

There are many stars in our galaxy that are just like ours. There are some stars that are smaller than the Sun and some stars that can be 100 times bigger than the Sun. The Sun is a very special star because it allows for the existence of life on planet Earth. Without the Sun, life on Earth would not be possible.

Through this 6-session club, you will learn more about how scientists study the Sun, why studying the Sun is so important, how the Sun makes something called space weather, and ways that you can safely observe the Sun.

Session 1 – Heliophysics 101
Session 2 – Observing the Sun
Session 3 – Parker Solar Probe Engineering Challenge
Session 4 – Predicting Space Weather
Session 5 – Aurora: The Beauty of Space Weather
Session 6 – Beyond the Heliosphere

Use the note pages in this guide to record observations and data, just like NASA scientists do!

Materials Checklist

Basics

- ❑ writing tools (pens or pencils)
- ❑ art supplies (markers or crayons)
- ❑ (1) pair of scissors
- ❑ (1) roll of tape

Session 1

- ❑ (1) Waterproof Heliosphere Handout
- ❑ (1) measuring tape
- ❑ (1) 5 x 7 index card
- ❑ (2) postal stamps (optional)

Session 2

- ❑ (1) pair of solar eclipse glasses
- ❑ (1) paper clip, any size
- ❑ (1) 5” x 5” piece of aluminum foil
- ❑ (2) 8.5” x 11” blank cardstock
- ❑ (10-15) UV beads
- ❑ (1) invisible ink pen
- ❑ (1) UV light
- ❑ (1) medium binder clip
- ❑ string

Session 3

- ❑ 4 small, equally sized books or other objects to serve as corner supports for the Plexiglas baseboard (learner provides)
- ❑ steel ball bearings (2-3 of varying size, recommended ¼”, ⅜”, ½”)
- ❑ round magnets (2-3 of varying size, recommended 8-15mm)
- ❑ aluminum foil (1 sheet ~10”x10”)
- ❑ Chalk, white, yellow, or orange
- ❑ scissors
- ❑ (1) 8”x 8” aluminum pan
- ❑ (1) piece of 8.5” x 11” Plexiglass
- ❑ (1) dry erase marker
- ❑ (1) 5 x 7 index card
- ❑ (4) 16 oz plastic cups
- ❑ (4) 3 oz cups (“dixie cups”)
- ❑ (1) 16 oz Styrofoam cup or (2) 8oz (to shred)
- ❑ (10) cotton balls
- ❑ (1) plastic spoon
- ❑ (1) piece of black construction paper

Session 4

- ❑ (1) plotting compass
- ❑ (1) large bar magnet
- ❑ (1) case of iron filings

Session 5

- ❑ (1) paper towel tube or the Spectroscope Template on page 63
- ❑ (1) diffraction grating
- ❑ aluminum foil (1 sheet, ~10”x10”)
- ❑ sting (~1 yard)
- ❑ pony beads: 2 red, 2 purple, 4 green, 1 “O” letter bead, 1 “N” letter bead

Session 6

- ❑ (1) ping pong ball
- ❑ (1) tennis ball

Session 1

Materials

- ❑ (1) waterproof Heliosphere Handout
- ❑ (1) measuring tape
- ❑ (1) 5 x 7 index card

Basics:

- writing tools (pens or pencils)
- art supplies (markers or crayons)
- (1) pair of scissors
- (1) roll of tape

Vocabulary

Golden Record- a gold-plated copper phonograph record, carried aboard the Voyager mission, containing sounds and images selected to portray the diversity of life and culture on Earth. It is a kind of 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

Heliosphere- the Sun's constantly outflowing material, the solar wind, inflates a bubble in space called the heliosphere

Heliopause- the outermost part of the heliosphere; the boundary between solar wind and interstellar wind is the heliopause, where the pressure of the two winds are in balance

Interstellar space- the space between the stars in a galaxy

Plasma - a state of matter much like solid, liquid and gas. 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 material that flows from the Sun in all directions, all the time, carrying the Sun's magnetic field out into space

Termination Shock- the innermost part of the heliosphere

Digital Resources

Video: NASA Space Place: Where does the Sun's energy come from?
https://spaceplace.nasa.gov/sun-heat/en/

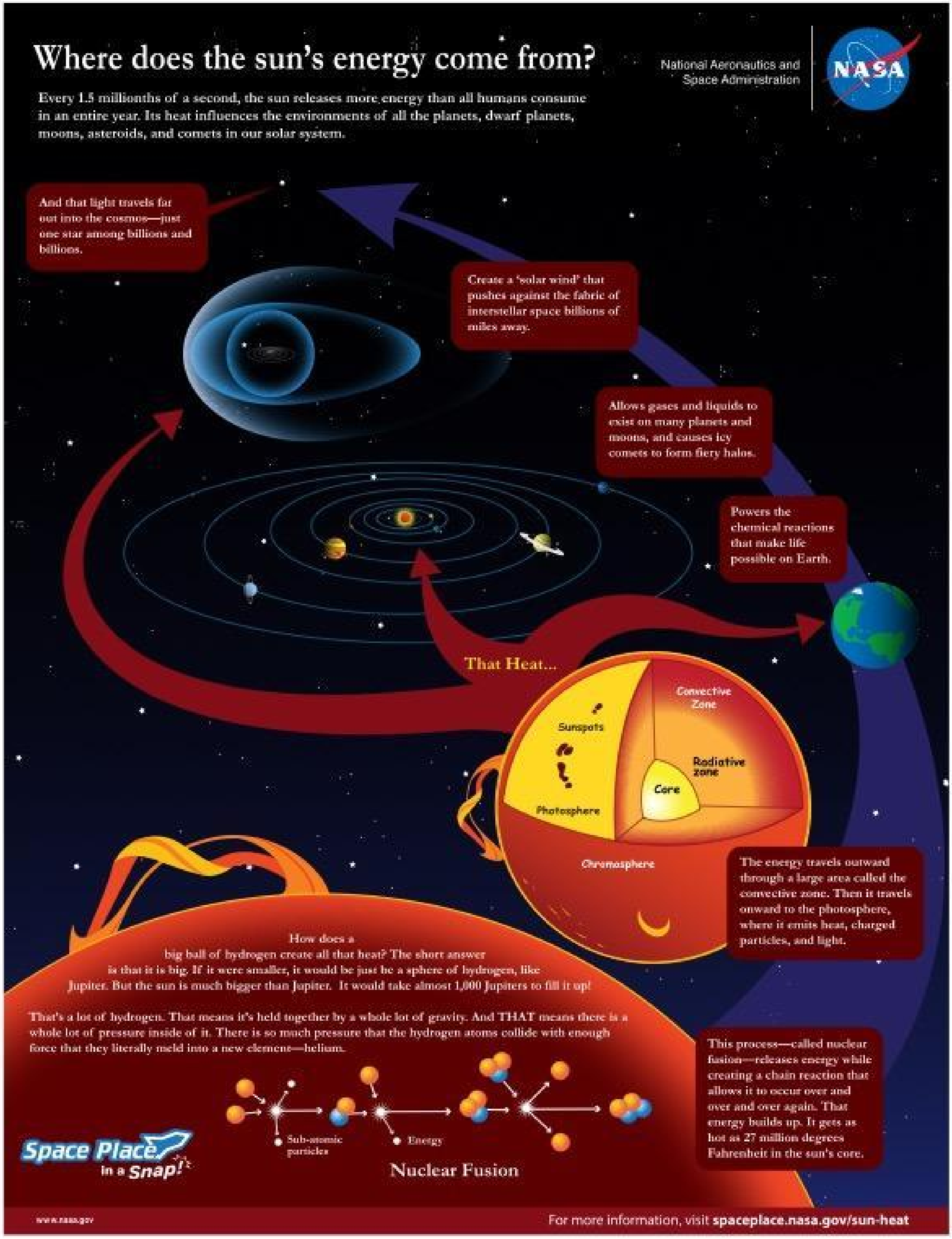
Webpage: NASA IBEX Mission Homepage
https://www.nasa.gov/mission_pages/ibex/index.html

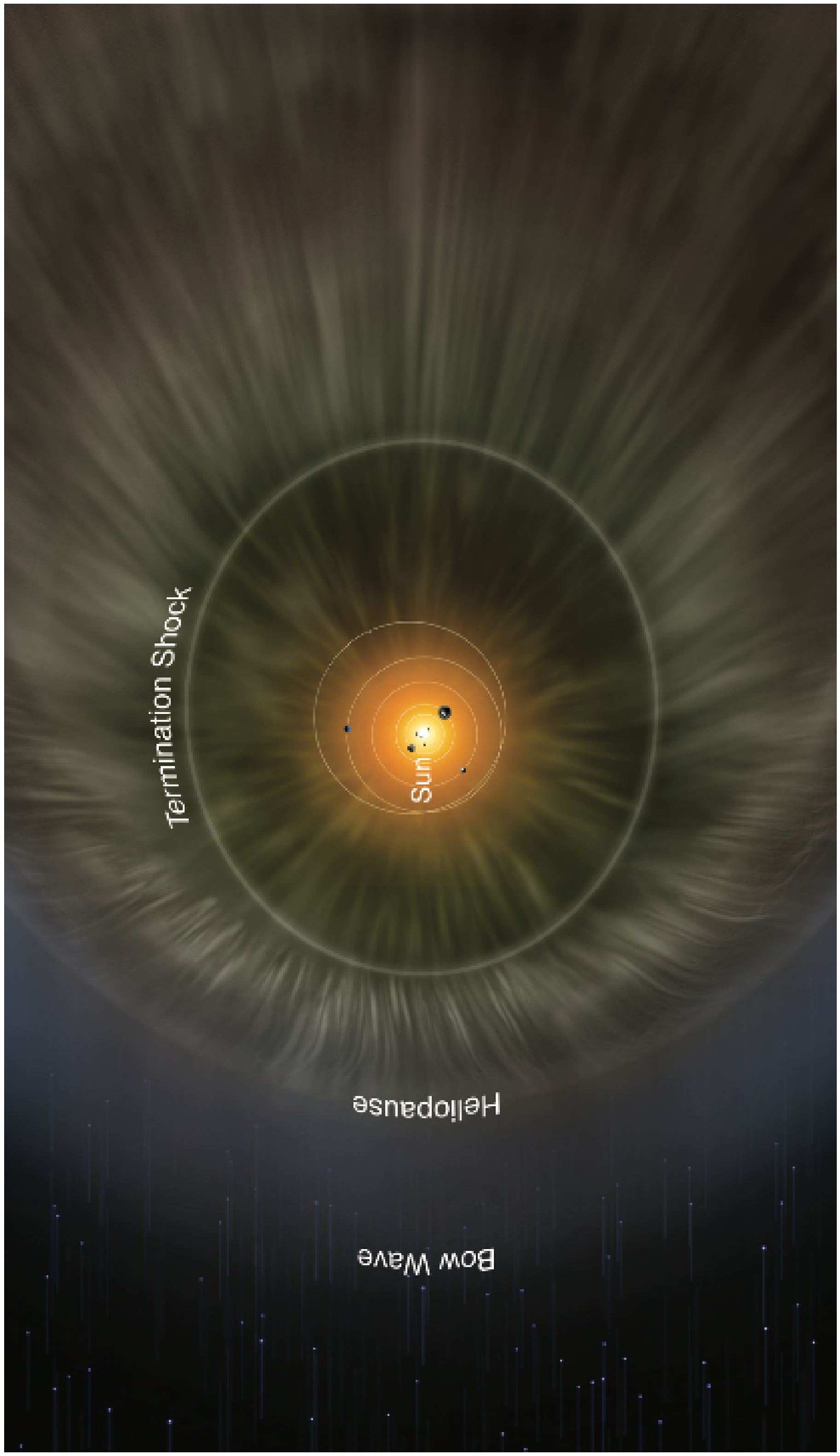
Webpage: NASA/JPL Voyager Mission Homepage
https://voyager.jpl.nasa.gov

Webpage: Voyager Mission: The Golden Record
https://voyager.jpl.nasa.gov/golden-record/

Session 1: 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.**


Where does the sun's energy come from?
Every 1.5 millionths of a second, the sun releases more energy than all humans consume in an entire year. Its heat influences the environments of all the planets, dwarf planets, moons, asteroids, and comets in our solar system.
National Aeronautics and Space Administration
NASA
And that light travels far out into the cosmos—just one star among billions and billions.
Create a 'solar wind' that pushes against the fabric of interstellar space billions of miles away.
Allows gases and liquids to exist on many planets and moons, and causes icy comets to form fiery halos.
Powers the chemical reactions that make life possible on Earth.
That Heat...
Convective Zone
Sunspots
Radiative zone
Core
Photosphere
Chromosphere
The energy travels outward through a large area called the convective zone. Then it travels onward to the photosphere, where it emits heat, charged particles, and light.
How does a big ball of hydrogen create all that heat? The short answer is that it is big. If it were smaller, it would be just be a sphere of hydrogen, like Jupiter. But the sun is much bigger than Jupiter. It would take almost 1,000 Jupiters to fill it up!
That's a lot of hydrogen. That means it's held together by a whole lot of gravity. And THAT means there is a whole lot of pressure inside of it. There is so much pressure that the hydrogen atoms collide with enough force that they literally meld into a new element—helium.
This process—called nuclear fusion—releases energy while creating a chain reaction that allows it to occur over and over and over again. That energy builds up. It gets as hot as 27 million degrees Fahrenheit in the sun's core.
Sub-atomic particles
Energy
Nuclear Fusion
Space Place in a Snap!
www.nasa.gov
For more information, visit spaceplace.nasa.gov/sun-heat



Credit: NASA/IBEX/Adler Planetarium

National Aeronautics and Space Administration

The Heliosphere

www.nasa.gov

The Heliosphere

What do we mean when we say something has an edge or a boundary? Some things, like a table or a soccer field, have clear edges and boundaries. Other objects, like cities and towns, have boundaries that aren't as easy to see. It is hard to say where they end and something else begins. The Solar System is more like a city than a table or soccer field.

You could say that the Solar System extends as far as the influence of the Sun. That could mean the influence of the Sun's light, or the influence of the Sun's gravity, or the influence of the Sun's magnetic field and solar wind.

Could the reach of the Sun's light be a good way to decide how far the Solar System extends? The light from the Sun gets fainter as you move farther away, but there is no boundary where the light stops or where it suddenly gets weaker. How about gravity? Just like light, the influence of the Sun's gravity extends without limit, although it gets weaker farther away from the Sun. There is not a boundary at which it stops. Astronomers are still discovering objects in the outer Solar System beyond Pluto.

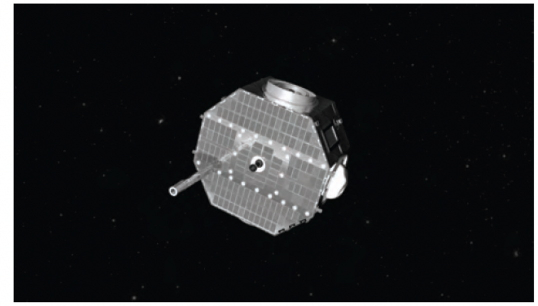
The solar wind is different from light or gravity. As it streams away from the Sun, it races out toward the space between the stars. We think of this space as "empty" but it contains traces of gas and dust, called the Interstellar Medium. The solar wind blows against this material and clears out a bubble-like region in this gas. This is not a bubble like a soap bubble, but more like a cloud of foggy breath that you breathe into chilly winter air.

The entire area, or bubble, inside the boundary of the Solar System is called the heliosphere. The place where the solar wind slows down and begins to interact with the interstellar medium is called the heliosheath. The heliosheath has a few parts: the termination shock (the innermost part of the boundary), the heliopause (the outermost part of the boundary), and the part in-between the inner and outer boundary.

The termination shock is more than twice as far away as the orbit of Pluto. The distances were measured in two places by NASA's Voyager spacecraft and found to be 94 and 84 times the distance between the Earth and the Sun.

NASA's Interstellar Boundary Explorer (IBEX) mission is making maps of the entire Solar System boundary.

To learn more, play games, and sign up for mission updates, visit http://ibex.swri.edu



Credit: NASA/Goddard Space Flight Center Conceptual Image Lab

For you to try: Model the heliosphere using your kitchen sink

Materials

- Picture of the heliosphere (front of this lithograph)
- A sheet of cardboard*
- Clear plastic wrap*
- A sink with running water

* This activity works better if you place the picture of the heliosphere under a sheet of plexiglass or laminate it instead of wrapping it in plastic wrap.

Place the picture of the heliosphere on top of the cardboard. Carefully wrap the plastic wrap around the picture and cardboard, like wrapping a present. Try not to have any wrinkles or bubbles. Make sure the entire picture is covered so no water can get in.

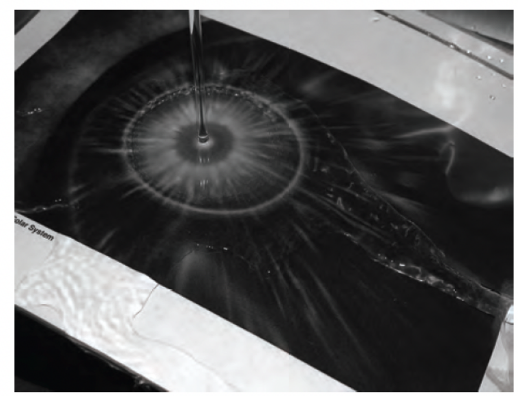
Turn on the faucet and adjust the stream of water so that it is about the thickness of a pencil.

Place the plastic wrapped picture of the heliosphere under the stream of water. Move the picture so that the water hits at the location of the Sun. Tip the image so that the water flows toward the right side of the picture.

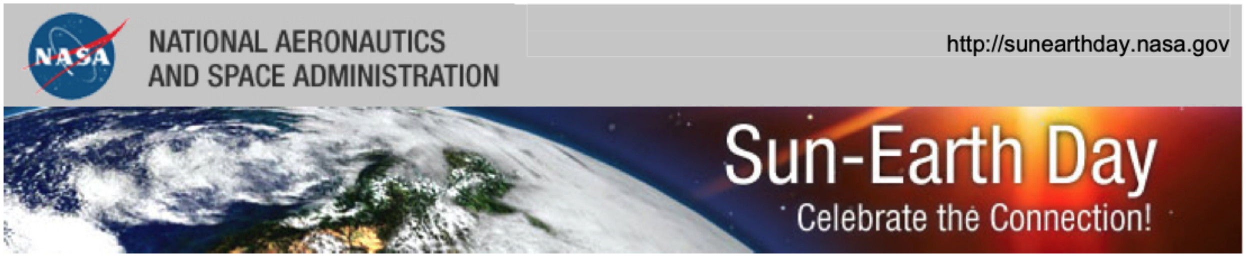
Watch the stream of water flow quickly away from where it hits the paper. This represents the solar wind streaming away from the Sun.

Look for the round edge where the water slows down and looks bumpy. This represents the termination shock.

Adjust the position of the picture up and down, or the amount of water coming out of the faucet, so that the water model matches up with the diagram of the solar wind and the termination shock on the picture.



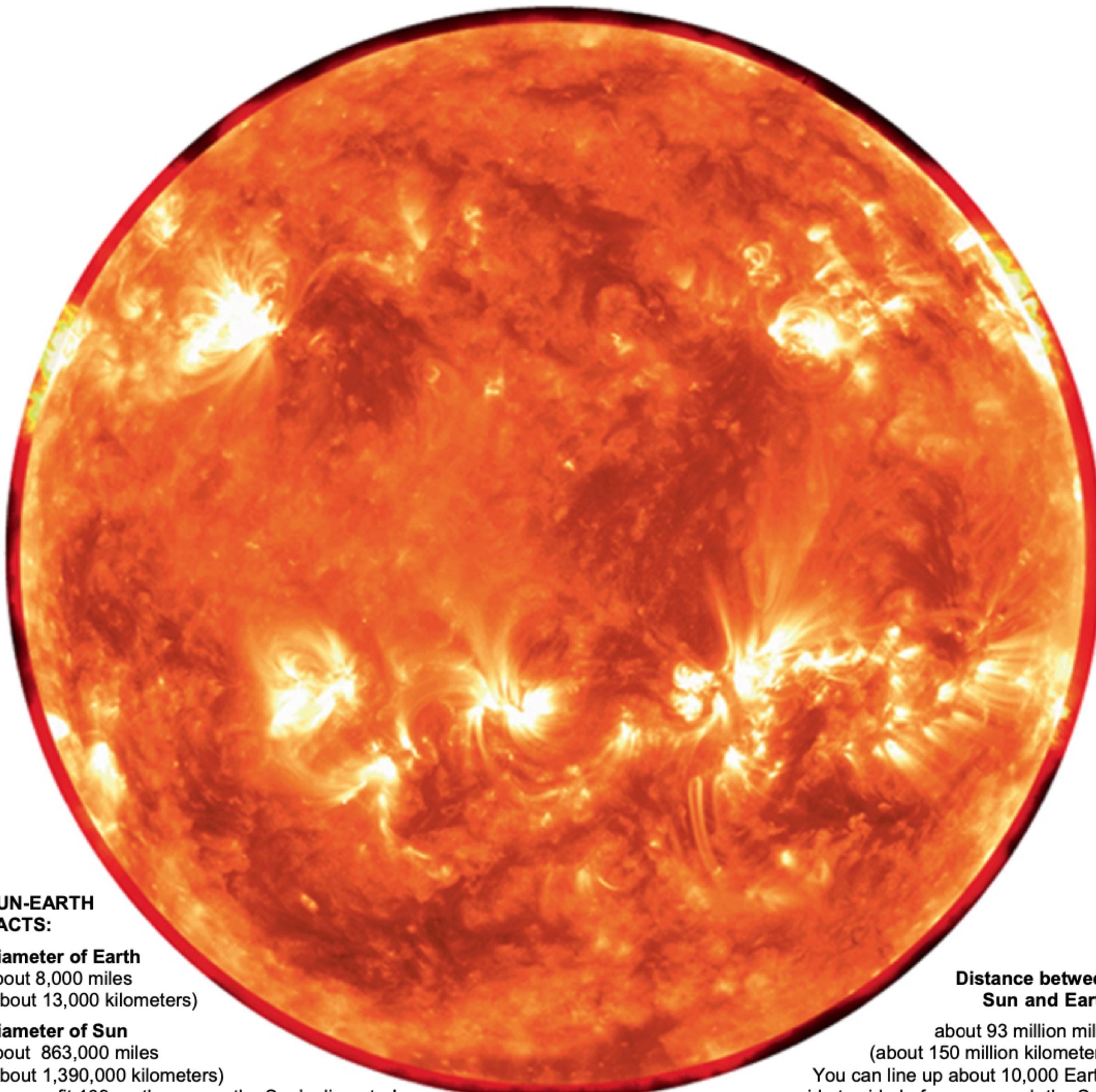
Credit: NASA/IBEX/Adler Planetarium



1. Cut out the images of the Sun and the Earth.
2. 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).

This image of Earth is scaled to the proper size in relation to the image of the Sun below.

Earth



SUN-EARTH FACTS:

Diameter of Earth
about 8,000 miles
(about 13,000 kilometers)

Diameter of Sun
about 863,000 miles
(about 1,390,000 kilometers)
You can fit 109 earths across the Sun's diameter!

Distance between Sun and Earth:
about 93 million miles
(about 150 million kilometers)
You can line up about 10,000 Earths side to side before you reach the Sun.

Intentionally left blank

Session 1: Notes

Session 2

Materials

- ❑ (1) pair of solar eclipse glasses
- ❑ (1) paper clip, any size
- ❑ (1) 5” x 5” piece of aluminum foil
- ❑ (2) 8.5” x 11” blank cardstock
- ❑ (10-15) UV beads
- ❑ (1) invisible ink pen
- ❑ (1) UV light
- ❑ (1) medium binder clip
- ❑ string

Basics:

- writing tools (pens or pencils)
- art supplies (markers or crayons)
- (1) pair of scissors
- (1) roll of tape

Vocabulary

Blackbody Radiation – refers to the spectrum of light emitted by any heated object; common examples include the heating element of a toaster and the filament of a light bulb

Composite Image – the fusing of several images together taken in an overlapping sequence

Corona – the upper atmosphere of the Sun

Coronagraph – a specialized instrument designed to block out the light of the main body of the Sun so that scientists can view the corona

Electromagnetic (EM) Spectrum – comprising all frequencies of electromagnetic radiation that propagate energy and travel through space in the form of waves

Frequency – the number of waves that pass a fixed point in a given amount of time

Infrared Light – a form of electromagnetic radiation invisible to the human eye with wavelengths longer than visible light

Nebulae – enormous clouds of dust and gas occupying the space between the stars **(Stellar Nebulae)** are where a sufficient mass of that gas and dust begin to collapse under its own gravitational attraction – as the cloud collapses, the material at the center begins to heat up and a star is born.

Pinhole Projector – a convenient method for safely viewing the Sun by passing sunlight through a small opening (for example, a hole punched in an index card) and projecting an image of the Sun onto a nearby surface (for example, another card, a wall, or the ground)

Radio Waves – a form of electromagnetic radiation invisible to the human eye with wavelengths longer than infrared light

Solar Eclipse Glasses – a solar viewing tool that protects your eyes from harmful light from the Sun

Solar Flare – energetic bursts of light triggered by the release of magnetic energy on the Sun

Sunspots – cooler regions on the Sun’s visible surface caused by a concentration of magnetic field lines

Telescope – a tool that astronomers use to see faraway objects. Most telescopes, and all large telescopes, work by using curved mirrors to gather and focus light from the night sky

Ultraviolet (UV) Light – a form of electromagnetic radiation invisible to the human eye with wavelengths shorter than visible light

UV-reactive Beads – beads that turn colors in the presence of ultraviolet radiation

Visible Light – a form of electromagnetic radiation that is visible to the human eye

Wavelength – the distance over which a wave repeats itself

X-rays – a form of electromagnetic radiation invisible to the human eye with wavelengths shorter than ultraviolet light

Session 2

Digital Resources

Video: How to Read a NASA STEREO Image
https://www.nasa.gov/feature/goddard/2016/how-to-read-a-stereo-image

Webpage: NASA Hubble Space Telescope Homepage
https://www.nasa.gov/mission_pages/hubble/main/index.html

Webpage: Explore Light with the Hubble Space Telescope
https://www.nasa.gov/content/explore-light

Webpage: NASA SDO Mission Homepage
https://sdo.gsfc.nasa.gov/

Webpage: The Sun Now
https://sdo.gsfc.nasa.gov/

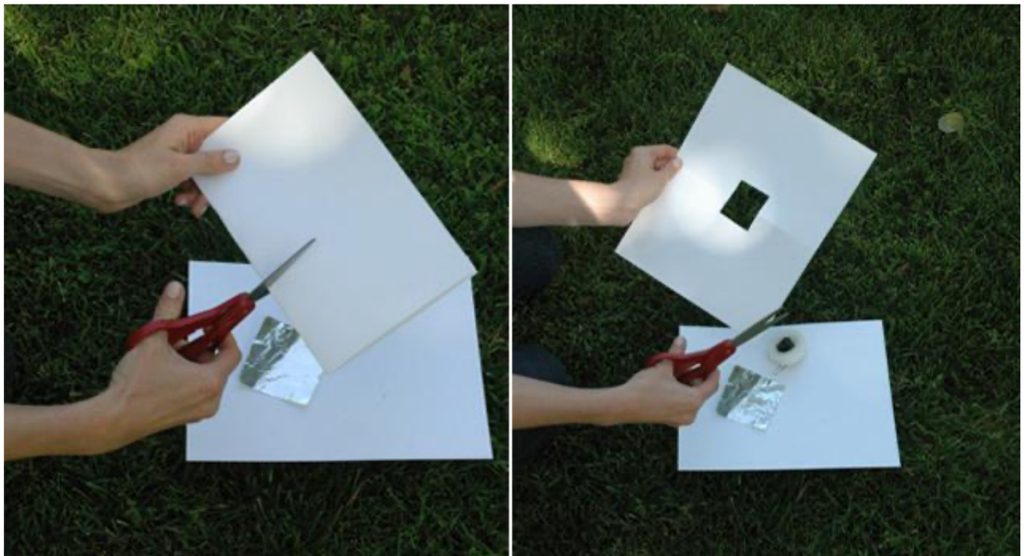
Webpage: NASA STEREO Mission Homepage
https://www.nasa.gov/mission_pages/stereo/main/index.html

Session 2: KWL

K - what do you already know?	W- what do you wonder about?	L- what did you learn?
What do you already know about observing the Sun? Which methods do you know are safe for observing the Sun? When you think of the Sun, what color do you think it is? Can humans see all the different kinds of light that the Sun emits?	**Record questions you have about observing the Sun in this column.**	**Record what you learned about observing the Sun in this column.**

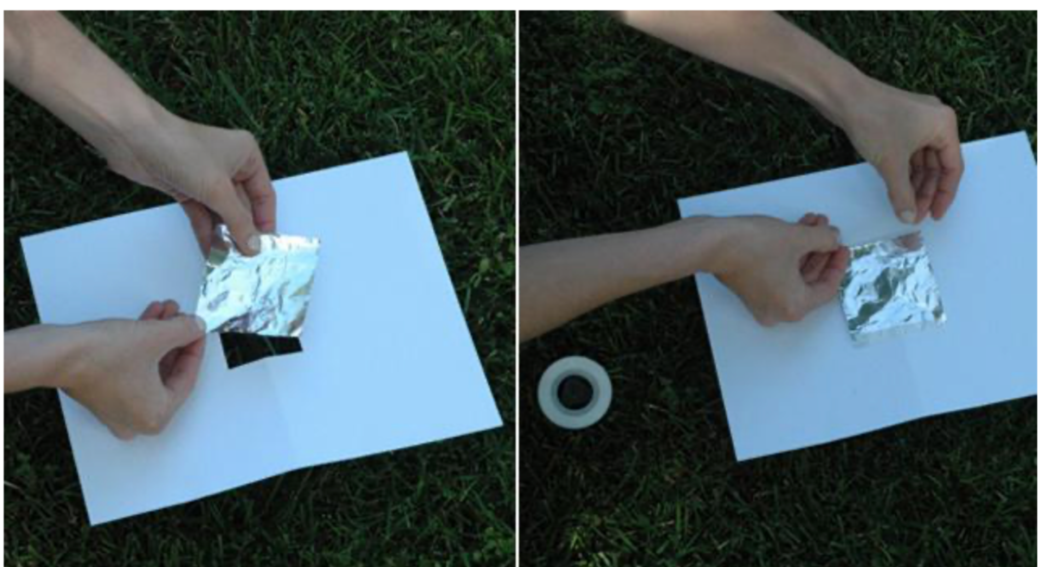
NEVER LOOK DIRECTLY AT THE SUN WITHOUT SAFETY EQUIPMENT

Build a Pinhole Projector



1. Cut a square hole

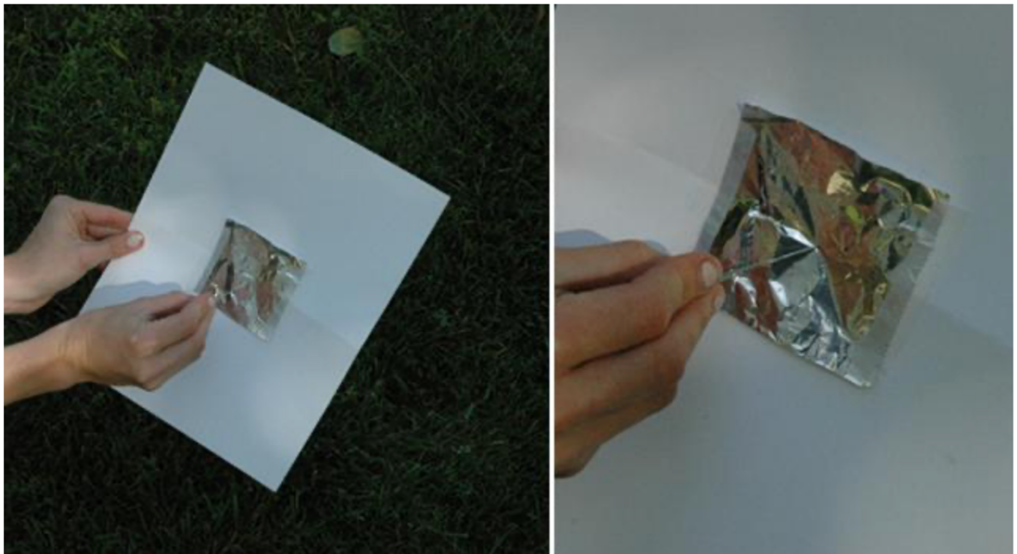
Cut a square hole into the middle of one of your pieces of card stock.



2. Tape foil over the hole

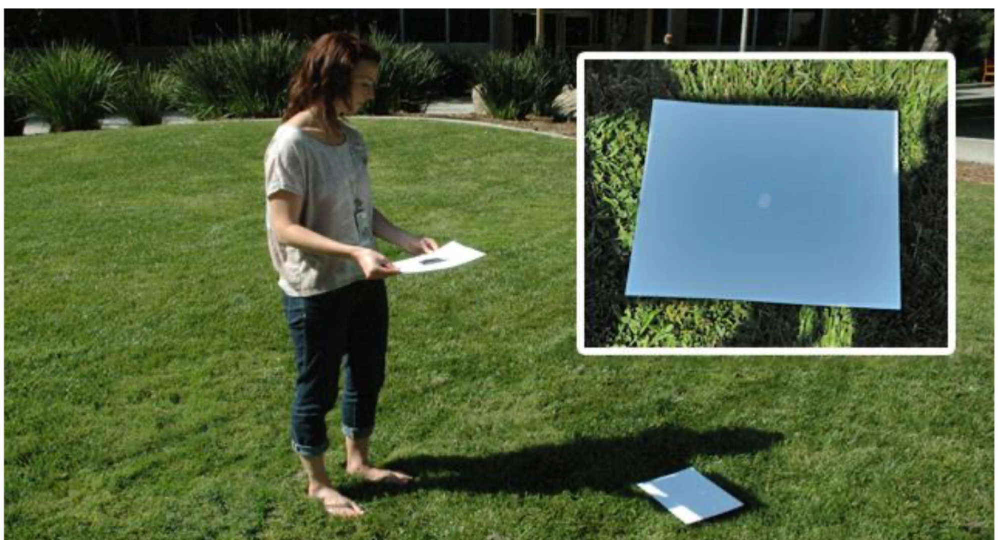
Tape a piece of aluminum foil over the hole.

Credit: NASA Jet Propulsion Laboratory/ California University of Technology



3. Poke a hole in the foil

Use your pin or paper clip to poke a small hole in the aluminum foil.

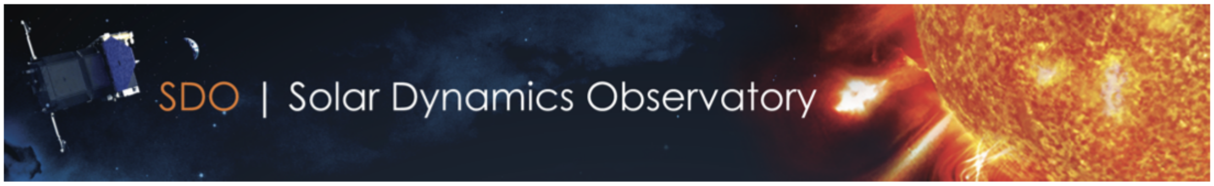


4. Try it out

Place your second piece of card stock on the ground and hold the piece with aluminum foil above it (foil facing up). Stand with the sun behind you and view the projected image on the card stock below! The farther away you hold your camera, the bigger your projected image will be.

To make your projection a bit more defined, try putting the bottom piece of card stock in a shadowed area while you hold the other piece in the sunlight.

Credit: NASA Jet Propulsion Laboratory/ California University of Technology



Solar Observations

Name: ____________________
Date: ____________________
Time: ____________________

Conditions Outside: (Circle all that apply)

Clear

Haze: Heavy Medium Light

Clouds: Heavy Medium Light Drifting Intermediate

Wind: Yes/No

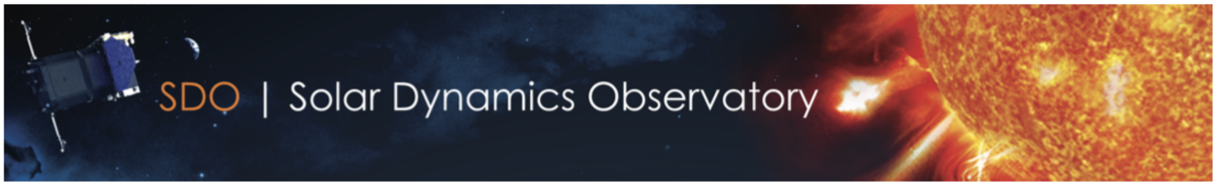
Instruments used in observations:

____

____

Solar Disk

NEVER LOOK DIRECTLY AT THE SUN WITHOUT SAFETY EQUIPMENT



Solar Observations

Name: ____________________
Date: ____________________
Time: ____________________

Conditions Outside: (Circle all that apply)

Clear

Haze: Heavy Medium Light

Clouds: Heavy Medium Light Drifting Intermediate

Wind: Yes/No

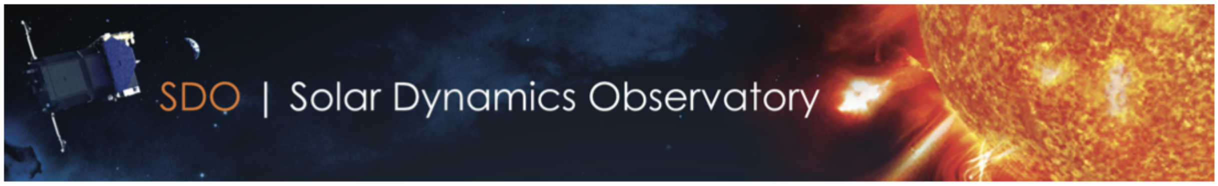
Instruments used in observations:

____

____

Solar Disk

NEVER LOOK DIRECTLY AT THE SUN WITHOUT SAFETY EQUIPMENT



Solar Observations

Name: ______________________
Date: ______________________
Time: ______________________

Conditions Outside: (Circle all that apply)

Clear

Haze: Heavy Medium Light

Clouds: Heavy Medium Light Drifting Intermediate

Wind: Yes/No

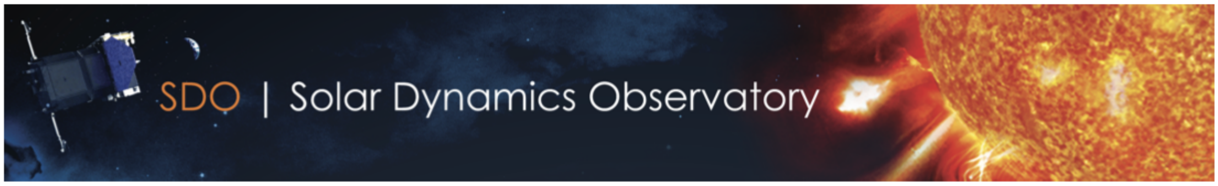
Instruments used in observations:

____

____

Solar Disk

NEVER LOOK DIRECTLY AT THE SUN WITHOUT SAFETY EQUIPMENT



Solar Observations

Name: ____________________

Date: ____________________

Time: ____________________

Conditions Outside: (Circle all that apply)

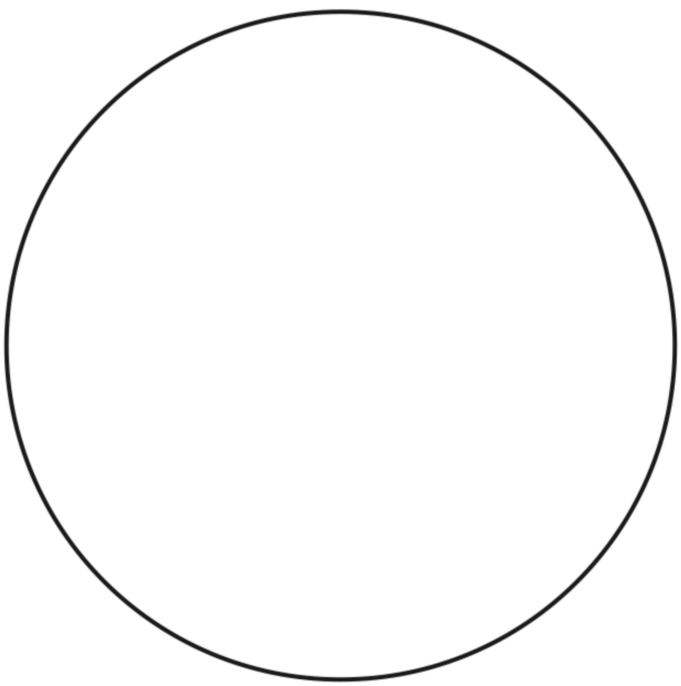
Clear

Haze:	Heavy	Medium	Light		
Clouds:	Heavy	Medium	Light	Drifting	Intermediate
Wind:	Yes/No				

Instruments used in observations:

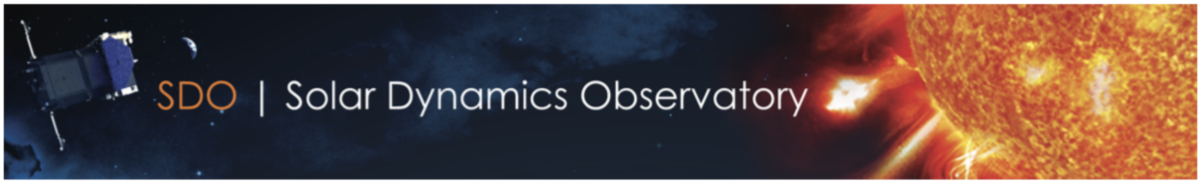
____

____



Solar Disk

NEVER LOOK DIRECTLY AT THE SUN WITHOUT SAFETY EQUIPMENT



Solar Observations

Name: ____________________
Date: ____________________
Time: ____________________

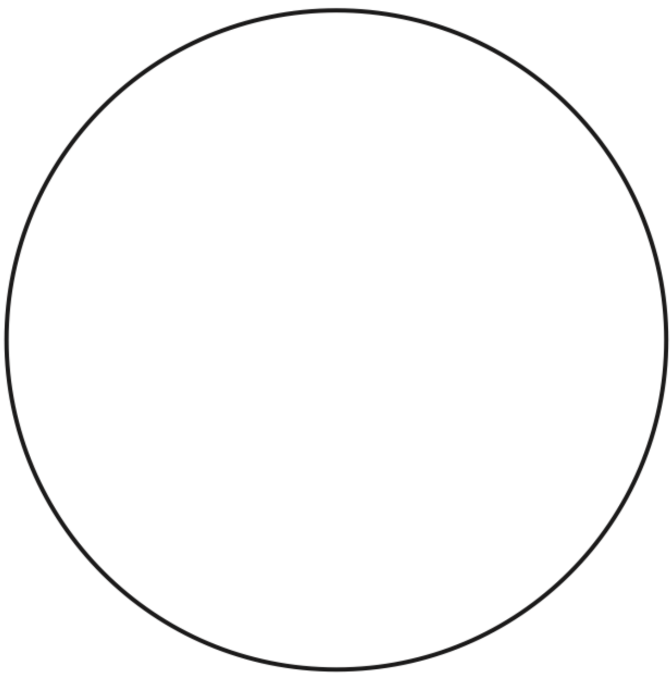
Conditions Outside: (Circle all that apply)

Clear					
Haze:	Heavy	Medium	Light		
Clouds:	Heavy	Medium	Light	Drifting	Intermediate
Wind:	Yes/No				

Instruments used in observations:

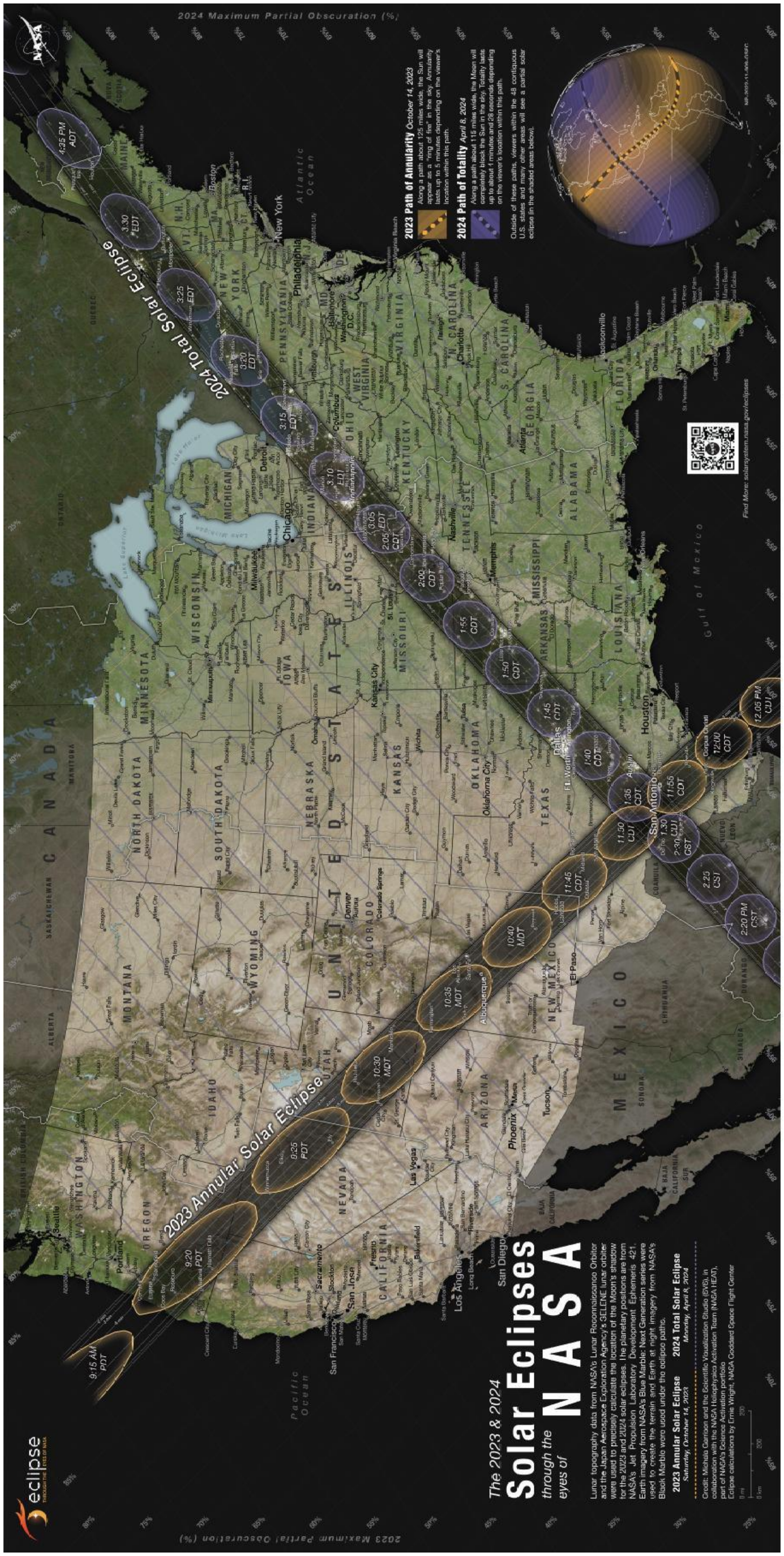
____

____



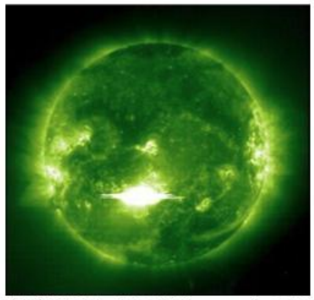
Solar Disk

NEVER LOOK DIRECTLY AT THE SUN WITHOUT SAFETY EQUIPMENT

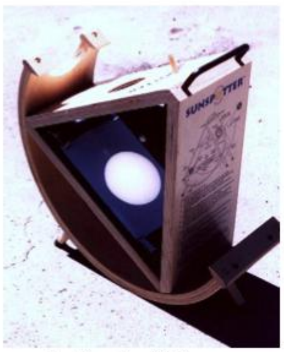

The 2023 & 2024
Solar Eclipses
through the eyes of
NASA
2024 Total Solar Eclipse
2023 Annular Solar Eclipse
2023 Path of Annularity October 14, 2023
2024 Path of Totality April 8, 2024
2023 Maximum Partial Obscuration (%)
2024 Maximum Partial Obscuration (%)

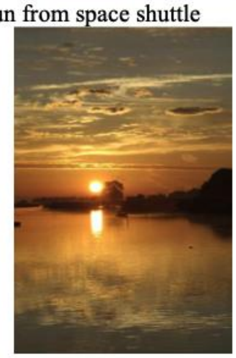
Sample data for investigating the color of the Sun


Sunrise


ESA/NASA SOHO image in EUV

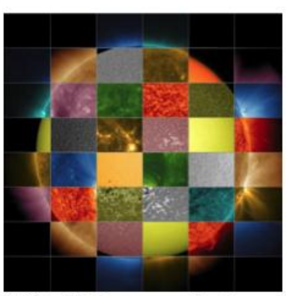

Sun from space shuttle

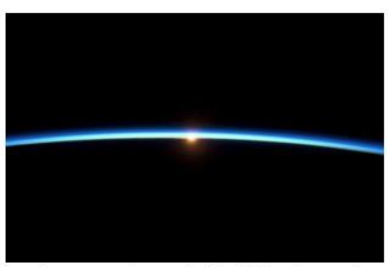

SunSpotter™ image


Sunset


Sunset

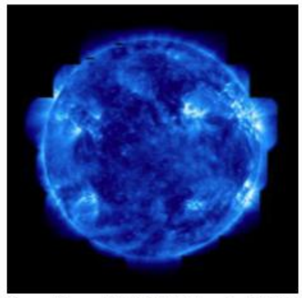

Analemma


NASA SDO composite images


Sunrise seen through Earth's atmosphere


Total solar eclipse

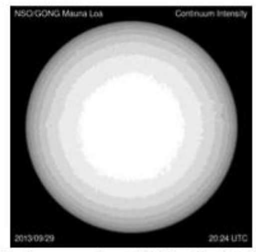
Sun from space



Sun from SDO/AIA, in EUV

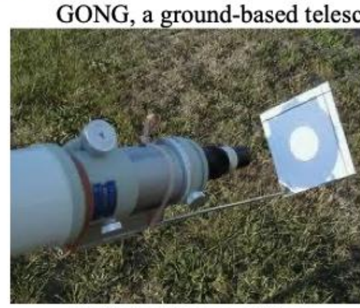
Annular eclipse through a filter

Sun at mid-day



Solar image in visible light from GONG, a ground-based telescope

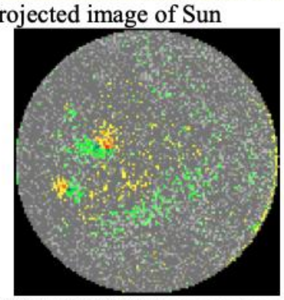
The Green Flash



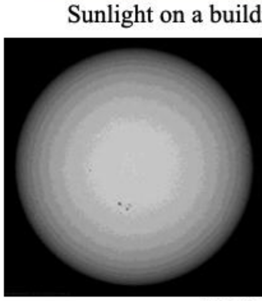
Projected image of Sun

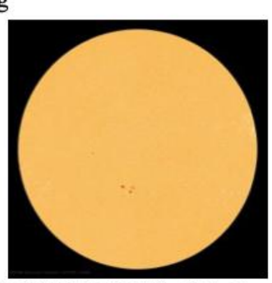
Sunlight on a building

Composite solar image taken in EUV from SDO/AIA

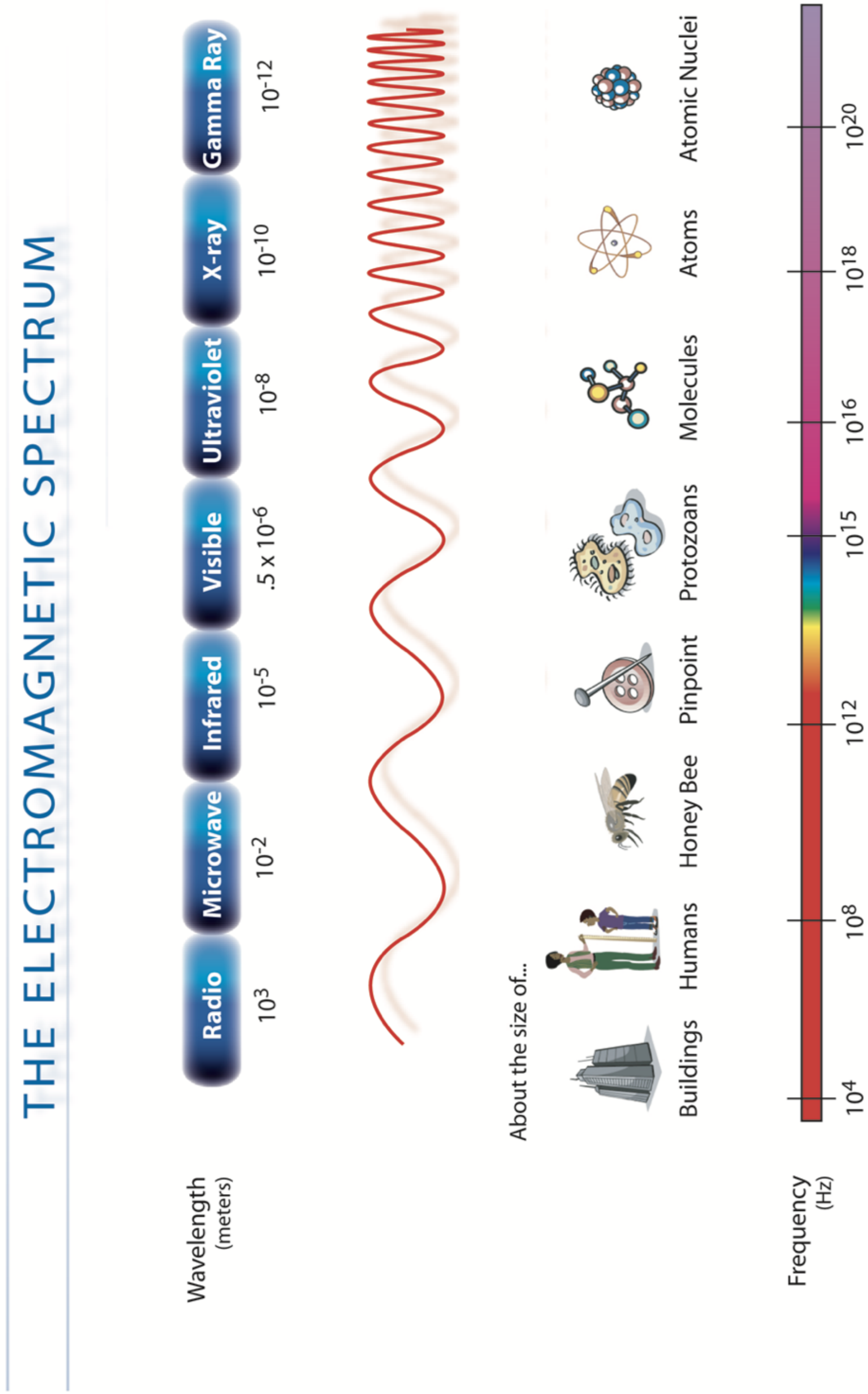


NASA SDO/HMI magnetogram (colorized)





NASA SDO/HMI Visible light images (all)

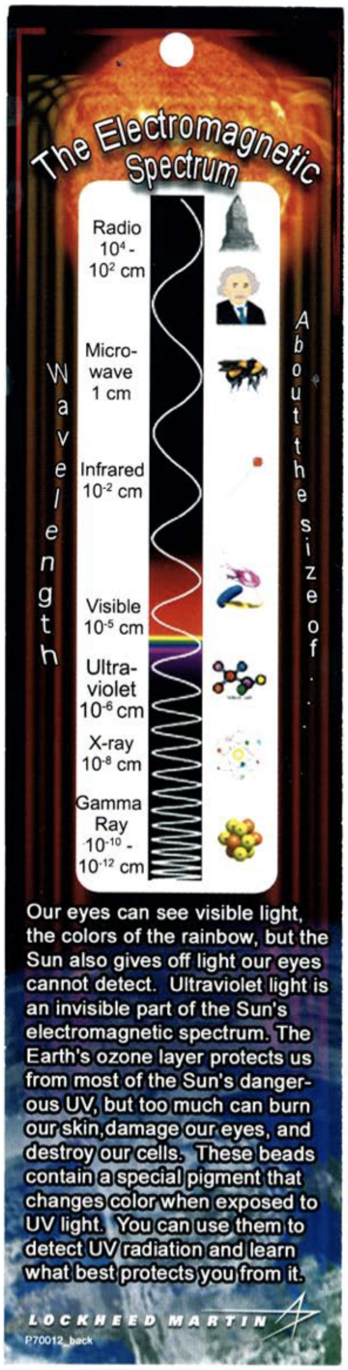

THE ELECTROMAGNETIC SPECTRUM
Wavelength (meters)
Radio
Microwave
Infrared
Visible
Ultraviolet
X-ray
Gamma Ray
10^{3}
10^{-2}
10^{-5}
$.5 \times 10^{-6}$
10^{-8}
10^{-10}
10^{-12}
About the size of...
Buildings
Humans
Honey Bee
Pinpoint
Protozoans
Molecules
Atoms
Atomic Nuclei
Frequency (Hz)
10^{4}
10^{8}
10^{12}
10^{15}
10^{16}
10^{18}
10^{20}

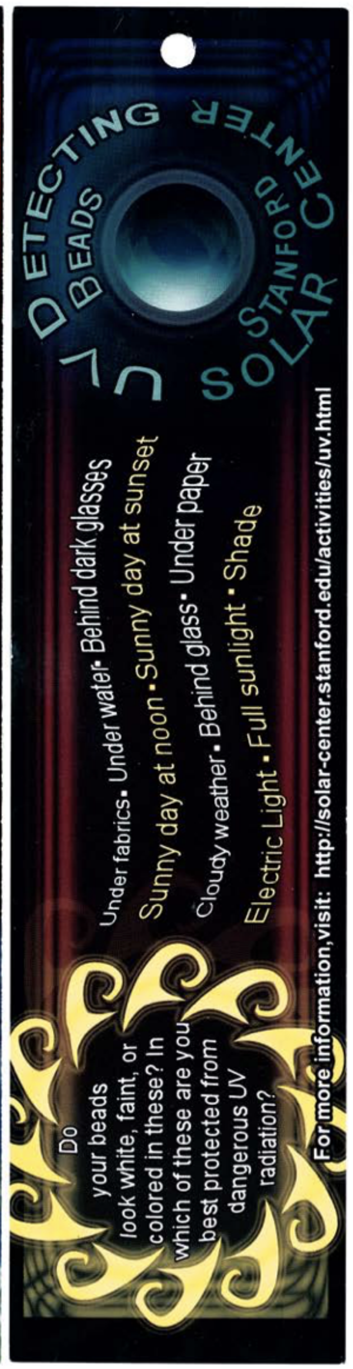
You be the scientist!

UV Bead Worksheet

	Your prediction (Do you think the beads will be white, faint, or colored?)	**Actual Color of Beads** (white, faint, or colored)	**Safe from UV?**	**Notes**
Under water				
In sunlight				
In shadow				
Using sunscreen				
Cloudy sky *(i.e. no direct sunlight)*				
Behind paper				
Behind sun glasses				
Behind eye glasses				
Under cloth				
Inside plastic orange medication bottle				
Behind window glass				
Behind car windshield				
Under brim of cap				
Behind plastic				
Sun at mid-day				
Sun at sunset/sunrise				
UV (black) light				
Fluorescent light				
Incandescent light				
LED light				

UV Bead Bookmarks



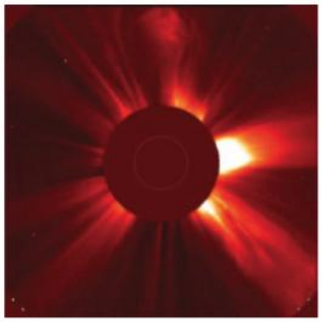


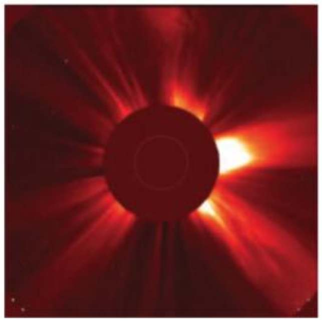
Stanford and Lockheed Martin Solar and Astrophysics Lab developed these bookmarks to support this lesson. The bookmarks briefly explain the electromagnetic spectrum and UV light.

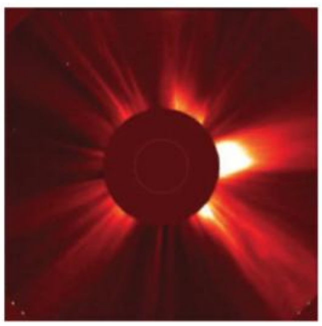
To assemble bookmarks:

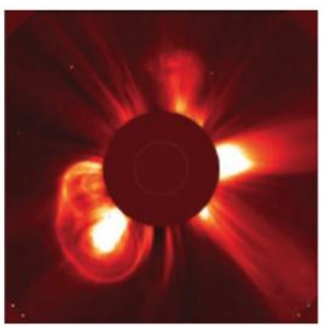
- Make copies of the patterns here.
- Have students cut them out and fold in half lengthwise.
- Cut a piece of cardstock the same size as the bookmark, fold the bookmark around the cardstock, and glue.
- Punch a hole in the top.

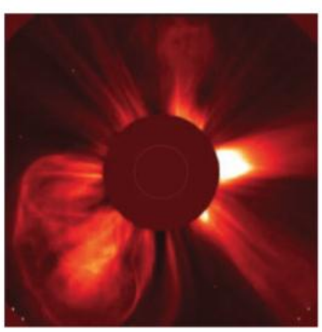
Intentionally left blank

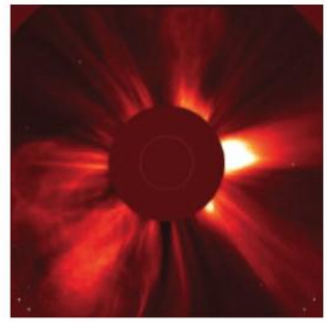

1

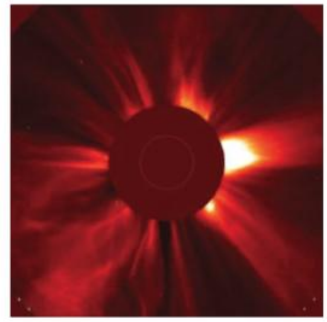

2

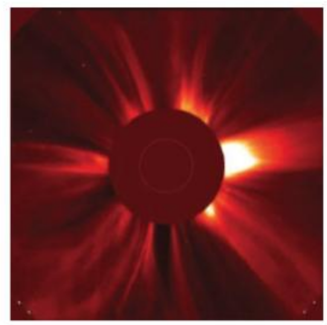

3

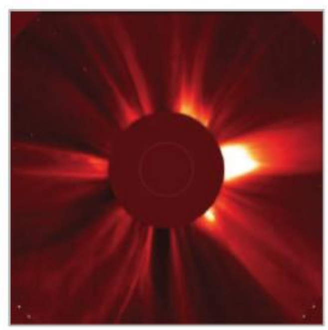

4

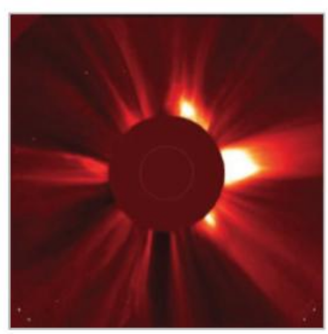

5


6

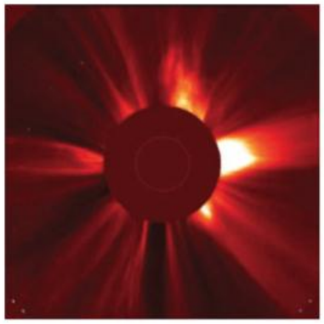

7

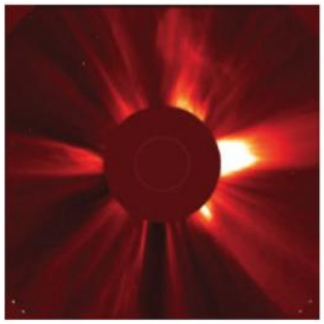

8

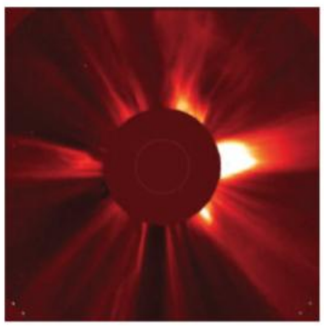

9

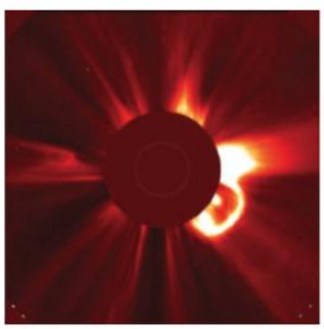

10

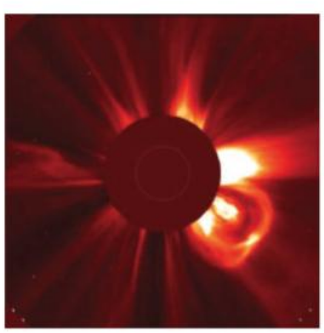
Intentionally left blank

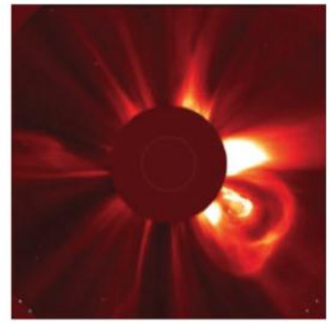

11

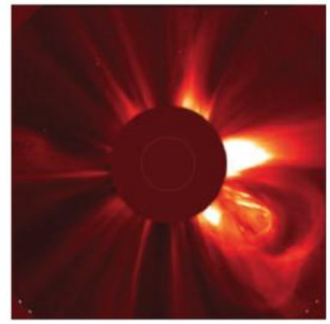

12

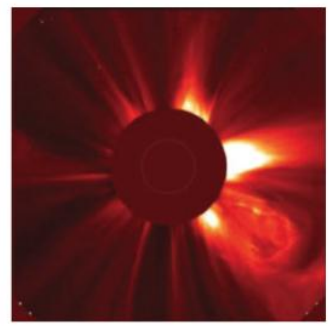

13

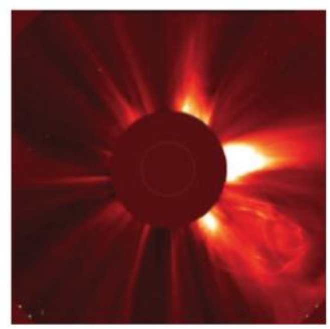

14

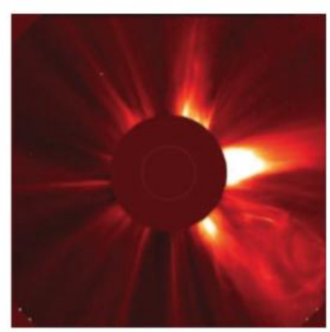

15


16

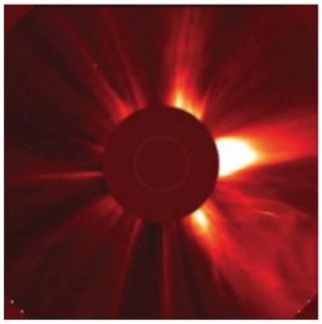

17


18

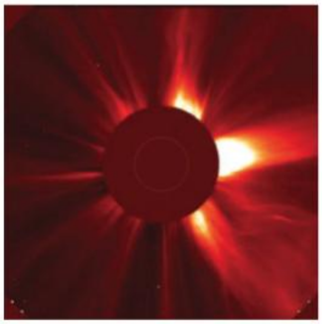

19


20

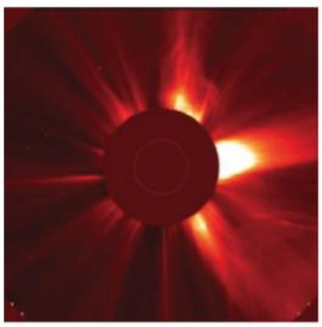
Intentionally left blank



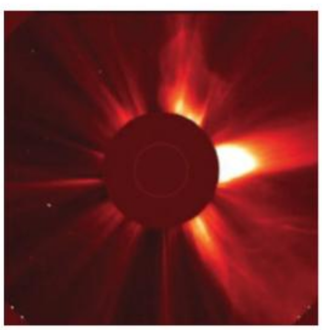
21



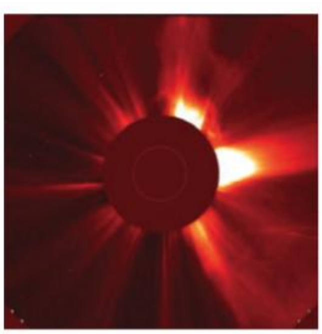
22



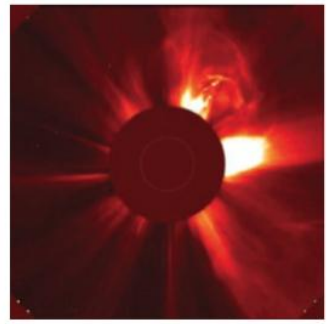
23



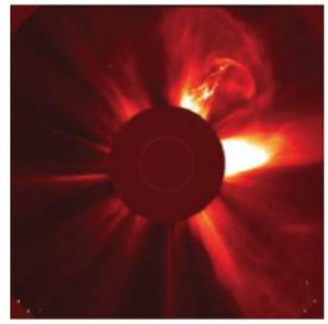
24



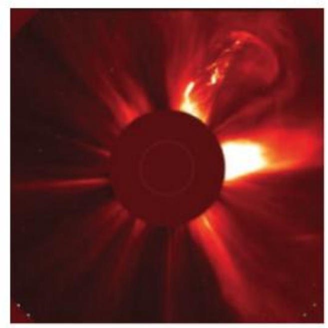
25



26



27



28

29

Images courtesy of SOHO/LASCO C2 consortium. SOHO is a project of international cooperation between ESA and and NASA.

The following animation was taken by the SOHO satellite during November 22 - 28, 2000. The red circle in the middle covers the bright Sun so that the area surrounding is easier to see. The light-red ring in the middle of the circle indicates the size of the Sun.

30

Intentionally left blank

Session 2: Notes

Session 3

Materials

- ❑ (1) dry erase marker
- ❑ (1) piece of transparent Plexiglas (8.5" x 11")
- ❑ (2-3) strong round magnets of various sizes
- ❑ (2-3) steel ball bearings of various sizes
- ❑ (4) small, equally sized books or other objects to serve as corner supports for the Plexiglas baseboard (learner provides)
- ❑ (1) Index Card
- ❑ Spoon
- ❑ Aluminum baking pan
- ❑ (4) larger clear plastic cups (~16 oz)
- ❑ (4) smaller cups (~3 oz)
- ❑ (1) Styrofoam cup (8-16 oz) (tear apart)
- ❑ (1) 10" x 10" piece of aluminum foil (tear apart)
- ❑ (~10) cotton balls (tear apart)
- ❑ White, yellow, or orange chalk
- ❑ (1) piece of black construction paper
- ❑ (1) piece of cardstock
- ❑ (1) ruler

Basics:

- ❑ writing tools (pens or pencils)
- ❑ art supplies (markers or crayons)
- ❑ (1) pair of scissors
- ❑ (1) roll of tape

Vocabulary

Chromosphere- lies just atop the photosphere; in the lower chromosphere, solar material moves as a typical gas or fluid; in the upper chromosphere and above, magnetic forces dominate the motion

Convective Zone- the outermost layer of the solar interior, where hot material rises to the surface of the star, carrying, or convecting, heat with it, where the material cools by giving off sunlight, then sinks down, where it picks up more heat

Corona- the Sun's upper atmosphere; It is filled with plasma, whose movements are governed by the tangle of magnetic fields surrounding the Sun

Gravity Assist- a flyby technique that can add or subtract momentum to increase or decrease the energy of a spacecraft's orbit

Photosphere- often called the "surface" of the Sun, the photosphere is actually the first layer of the solar atmosphere

Radiative Zone- the layer just outside the Sun's core, where the light is passed from atom to atom

Solar Eclipse - when the Sun's light is blocked out by the Moon which occurs when the Moon is between the Sun and the Earth and lined up at just the right angle; there are different types of solar eclipses:

- **Total Solar Eclipse –** a total solar eclipse happens when the Moon passes between the Sun and Earth, completely blocking (100%) the face of the Sun, revealing the Sun's corona. The sky will darken, as if it were dawn or dusk.
- **Partial Solar Eclipse –** experienced when the Sun, Moon, and Earth are not exactly lined up and the Moon only partially blocks out light from the main body of the Sun
- **Annular solar eclipse –** occurs when the Moon is farther away from Earth in its orbit, only blocking 90% of the Sun's disk.
- **Hybrid solar eclipse –** this type of solar eclipse occurs when a total turns annular or the other way around

Solar Eclipse Glasses – a solar viewing tool that protects your eyes from harmful light from the Sun

Sun's Core- the central region of the Sun where nuclear reactions consume hydrogen to form helium

Session 3

Digital Resources

Video: NASA on YouTube: "Parker Solar Probe—Mission Overview"

Video: NASA on YouTube: "How will the Parker Solar Probe get to the Sun?"

Video: NASA on YouTube: "Parker Solar Probe- Orbit and Timeline"

Video: NASA on YouTube: "Why won't it melt? How NASA's Parker Solar Probe Will Survive the Sun"

Video: NASA (JHU APL) on YouTube: Parker Solar Probe's Instruments: WISPR

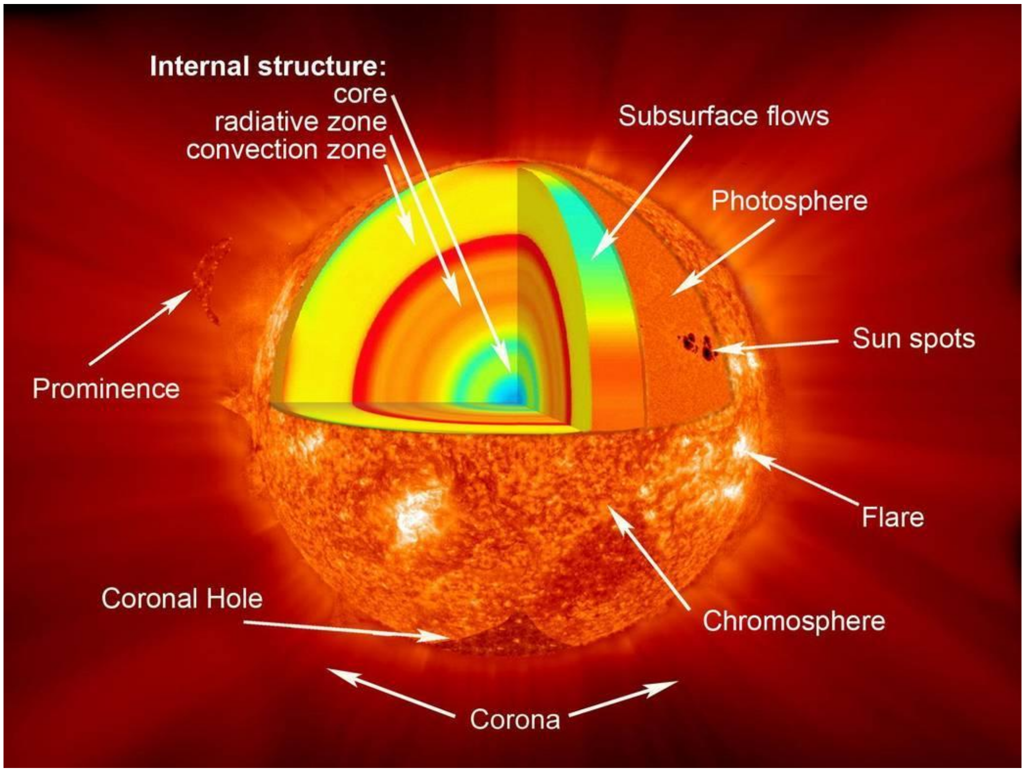
Webpage: NASA Parker Solar Probe Mission Homepage
https://www.nasa.gov/content/goddard/parker-solar-probe-humanity-s-first-visit-to-a-star

Webpage: NASA Eclipse Homepage
https://solarsystem.nasa.gov/eclipses/future-eclipses/eclipse-2024/

Session 3: 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 challenges of studying the Sun? • Why is it challenging to study the Sun?	**Record questions you have about the challenges of studying the Sun in this column.**	**Record what you learned about the challenges of studying the Sun in this column.**

Structure of the Sun



Credit: NASA/Goddard

The Sun and its atmosphere consist of several zones or layers. From the inside out, the solar interior consists of:

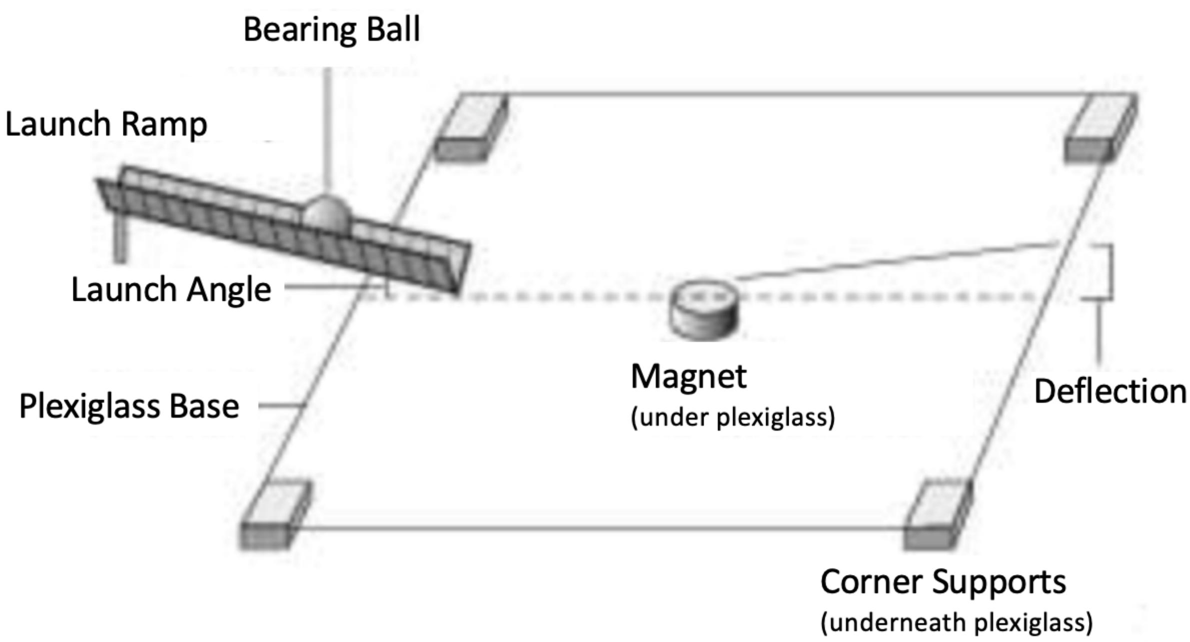
- **Core** - the central region where nuclear reactions consume hydrogen to form helium. These reactions release the energy that ultimately leaves the surface as visible light.
- **Radiative Zone** - extends outward from the outer edge of the core to base of the convection zone, characterized by the method of energy transport - radiation
- **Convection Zone** - the outermost layer of the solar interior extending from a depth of about 200,000 km to the visible surface where its motion is seen as granules

The solar atmosphere is made up of:

- **Photosphere** -the visible surface of the Sun
- **Chromosphere** - an irregular layer above the photosphere where the temperature rises from 6000°C to about 20,000°C
- **Transition Region** - a thin and very irregular layer of the Sun's atmosphere that separates the hot corona from the much cooler chromosphere
- **Corona** - the Sun's outer atmosphere
- Beyond the corona is the **solar wind**, which is an outward flow of coronal gas. The Sun's magnetic fields rise through the convection zone and erupt through the photosphere into the chromosphere and corona. The eruptions lead to solar activity, which includes such phenomena as sunspots, flares, prominences, and coronal mass ejections.

Explore: Engineering Challenge 1: Speed

Gravity Assist/ Slingshot Model



The magnet is the planet.
The ball bearing is the spacecraft.

Part A. Experimental Set-up

1. Find some equally sized books or other objects to create the corner supports for the plexiglass base.
2. Using the dry erase marker, draw a line down the middle of the underside of the plexiglass and tape the magnet to the middle of the plexiglass, under the line.
3. Assemble a launch ramp by folding an index card in half. The angle of the launch ramp represents the energy in which the spacecraft is launched.

Part B. Experiment

4. **Make a prediction:** what will happen to the ball when it approaches the magnet?
5. Use the ramp to launch the ball (spacecraft) toward the magnet (planet). This may take a few times to practice and to determine the proper launch angle of the ramp.

6. Trace the path the ball took on the plexiglass, using a dry erase marker. Record your observations; note the size of the magnet you used, the size of the ball, and how high your ramp was.
    - Experiment with different sized balls (spacecraft) and different sized magnets (planets), marking the path of the ball for each trial.
    - Experiment with different angles of the launch ramp.

    You may want to organize your data in a table. For example:

Trial	Size of Magnet	Size of Ball Bearing	Height of Ramp	How did the ball behave?
1				
2				
3				
4				
5				
6				

Part C. Conclusions

7. Use claim, evidence, reasoning to summarize your results.
    a. How did the size of the magnet (planet) affect the speed and deflection of the ball (spacecraft)?
    b. How did the size of the ball (spacecraft) affect the speed and deflection of the ball (spacecraft)?
    c. How did the launch angle affect the speed and deflection of the ball (spacecraft)?

Credit: teachengineering.com

Explore: Engineering Challenge 2: Heat

Insulation

Part A. Experimental Set-up: Insulating the Cups

(1) Put each insulation material (foil, Styrofoam, cotton, air) at the bottom of the plastic cups (each material goes in a separate cup). Just fill to about an inch. You will need to tear up the aluminum foil, Styrofoam cups and cotton balls into small pieces.

(2) Place the small (3 oz) cup inside the plastic cup and fill all the spaces around the little cup with the insulating material. Again, the cup filled with air is already done!



Credit: teachengineering.com

Part B. Experiment: Which cup will freeze first?

(3) Fill each small (3 oz) cup with 3 spoonfuls of water.

(4) Put the cups in the freezer for 15 minutes.

(5) **Make a prediction:** Which cup will freeze first?

(6) After 15 minutes in the freezer, take the cups out and record your observations. Which cups are starting to freeze? Do some cups have more ice than others?

(7) Put the cups back in the freezer. After another 15 minutes in the freezer, take the cups out and record your observations.

Part C. Experiment: Which cup will melt first?

(8) Remove the cups from the freezer and place them in an aluminum tray.

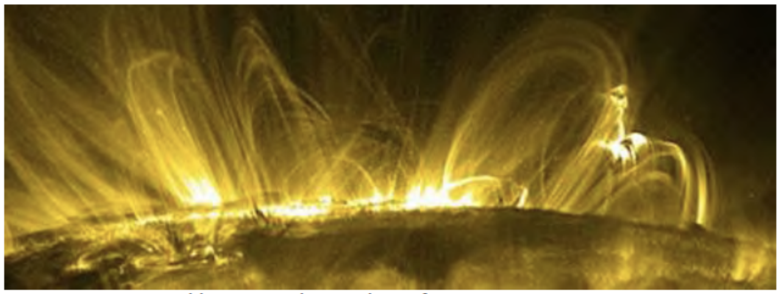
(9) Pour hot water into the tray.

(10) **Make a prediction:** Which cup will melt first?

(11) Record your observations.

The Sun's Atmosphere

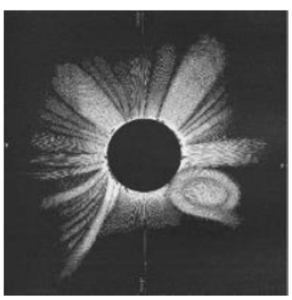
The Sun's *corona* (Latin for "crown") is the outermost part of its atmosphere. It is a jacket of extremely hot gases that reaches far into space. The magnetic energy and heat on the surface of the Sun makes it an incredibly active place. From the corona comes the solar wind that travels through our solar system.



Coronal loops on the Sun's surface. *Image: NASA/TRACE.*

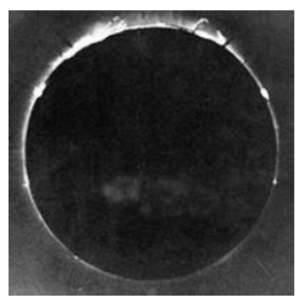
We usually cannot see the Sun's corona because it is hidden by the bright light of the Sun's surface. However, the corona can be seen during a total solar eclipse, when the Moon casts a shadow on Earth and blocks the Sun's light. For hundreds of years, astronomers have sketched what they observed during solar eclipses. The first photographs of eclipses were taken around 1860.

Image: NASA.



Left: Sketch of 1860 total solar eclipse showing a coronal mass ejection. *Image: G. Temple/NASA.*

Right: First photograph of a solar eclipse, in 1860. *Image: C. Young/NASA.*



Today, scientists use special telescopes to observe the corona. They are studying why the corona is so hot, how features such as how coronal streamers and loops are formed, and how the corona interacts with the Sun's magnetic fields.

Discover more about the Sun's corona:

spaceplace.nasa.gov/sun-corona/en/

UNIVERSITY OF ALASKA MUSEUM OF THE NORTH

UAMN Virtual Early Explorers: Sun

Eclipse Chalk Art

Create chalk art and discover the Sun's corona!

Materials Needed:

Cardstock or thin cardboard, black construction paper, chalk, scissors, pencil, round object for tracing. *Optional:* Tissues.

Instructions:

Step 1: Trace and cut out a cardstock or thin cardboard circle, about 4 inches (10 cm) in diameter.

Step 2: Color the circle heavily with chalk. Make thick lines with lots of chalk. If available, use multiple colors such as white, yellow, and orange.

Step 3: Place the circle in the center of the black paper, chalk side up.

Step 4: With your fingers or a tissue, smudge the chalk from the circle outward on the black paper to create rays all around the Sun. And more chalk if needed.

Hint: Help your child by holding the circle in place so it doesn't move around.

Step 5: Remove the circle to reveal the solar eclipse!

During an eclipse, the Sun's corona ("crown"), the outermost part of its atmosphere, is visible!

Activity adapted from NASA Eclipse Activity Guide.

UNIVERSITY OF ALASKA MUSEUM OF THE NORTH

Session 3: Notes

Session 4

Materials

- ❑ (1) compass
- ❑ (1) bar magnet
- ❑ (1) case of iron filings
- ❑ (5) pennies
- ❑ (8) pieces of spaghetti

Basics:

- writing tools (pens or pencils)
- art supplies (markers or crayons)
- (1) pair of scissors
- (1) roll of tape

Vocabulary

Coronal Mass Ejection (CME) - large clouds of solar plasma and embedded magnetic fields released into space after a solar eruption

Dayside Magnetopause - the location in space where Earth's magnetic field balances the pressure of the solar wind. It is located at the edge of the **magnetosphere**

IMF - the interplanetary magnetic field (IMF) is the term for the solar magnetic field carried by the **solar wind** among the planets of the Solar System

Kp Index – a 9-point scale that tells scientists how disturbed Earth's magnetic field is based on an average of magnetic observations from around the world, measured every hours

Magnetism – a physical phenomenon produced by the motion of electric charge, resulting in attractive and repulsive forces between objects

Magnetic Field – a region of influence in the space around the magnet

Magnetic Reconnection – process in which magnetic field lines come together and explosively realign, often sending the particles in the area flying off near the speed of light

Magnetosphere – a region around the planet created by Earth's internal magnetism tha plays a crucial role in our planet's habitability

Magnetotail - the extreme extension of a **magnetosphere**, on the side of a planet opposite the Sun, caused by the **solar wind**

Photosphere – often called the "surface" of the Sun, the photosphere is the first layer c the solar atmosphere

Plasma – a state of matter much like solid, liquid, and gas. Plasmas are so incredibly hot that the electrons leave their atoms, making it essentially a gas of charged particles While uncommon on Earth, 99% of the matter we can see in the universe is made of plasma.

Solar Cycles, Solar Maximum, Solar Minimum – the cycle that the Sun's magnetic field goes through approximately every 11 years when the north and south poles of the Sun flip. The beginning of a solar cycle is a **solar minimum**, or when the Sun has the least sunspots. Over time, solar activity—and the number of sunspots—increases. The middle of the solar cycle is the **solar maximum**, or when the Sun has the most sunspots.
As the cycle ends, it fades back to the solar minimum and then a new cycle begins.

Solar Flares – energetic bursts of light and particles triggered by the release of magnet energy on the Sun

Solar Wind – a gusty stream of material that flows from the Sun in all directions, all the time, carrying the Sun's magnetic field out into space

Space Weather – describes the impact of the solar wind on Earth's systems and technologies in orbit and on Earth

Sunspots – cooler regions on the Sun's visible surface caused by a concentration of magnetic field lines

Session 4

Digital Resources

Video: NASA on YouTube: “The Difference Between CMEs and Solar Flares”

Video: NASA on YouTube: “The Solar Cycle as Seen from Space”

Video: NASA on YouTube: “NASA Science Casts: Earth’s Magnetosphere”

Video: NASA on YouTube: “NASA/ How will the 4 MMS Spacecraft launch and deploy?”

Webpage: NOAA Solar Cycle Sunspot Progression Graph
https://www.swpc.noaa.gov/products/solar-cycle-progression

Webpage: NOAA Kp Index
https://www.swpc.noaa.gov/products/planetary-k-index

Webpage: NASA Solar Dynamics Observatory (SDO) Mission Homepage
https://www.nasa.gov/mission_pages/sdo/main/index.html

Webpage: NASA Solar and Heliospheric Observatory (SOHO) Mission Homepage
https://www.nasa.gov/mission_pages/soho/index.html

Webpage: NASA Magnetosphere Multiscale (MMS) Mission Homepage
https://www.nasa.gov/mission_pages/mms/index.html

Webpage: NASA Themis and Artemis Missions Homepage
https://www.nasa.gov/themis-and-artemis

Webpage: NASA Artemis Mission Homepage
https://www.nasa.gov/artemisprogram

Session 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 space weather? What is it? What causes it? Is it similar to weather on Earth?	**Record questions you have about space weather in this column.**	**Record what you learned about space weather in this column.**

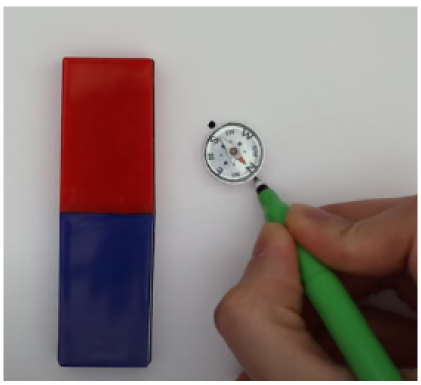
Modeling Magnetic Fields

1. Trace one of the bar magnets on a piece of paper.
   *If you have a gyrocompass, you must orient the magnet to magnetic North.

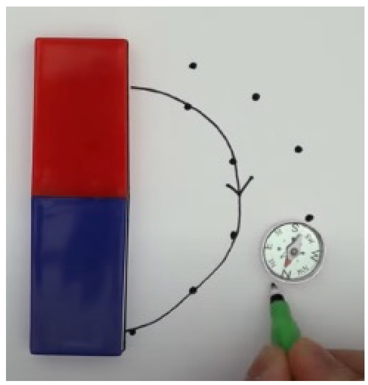
2. Start by placing the compass next to the magnet, near one of the magnet's poles.

3. On the paper, mark where the needle is pointing with a dot.

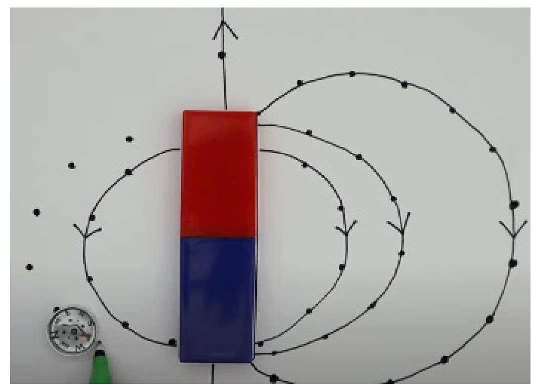
4. Move the compass so that the back of the needle lines up with the dot. Repeat step 3, mark where the needle is pointing with a dot.



Step 4



Step 6

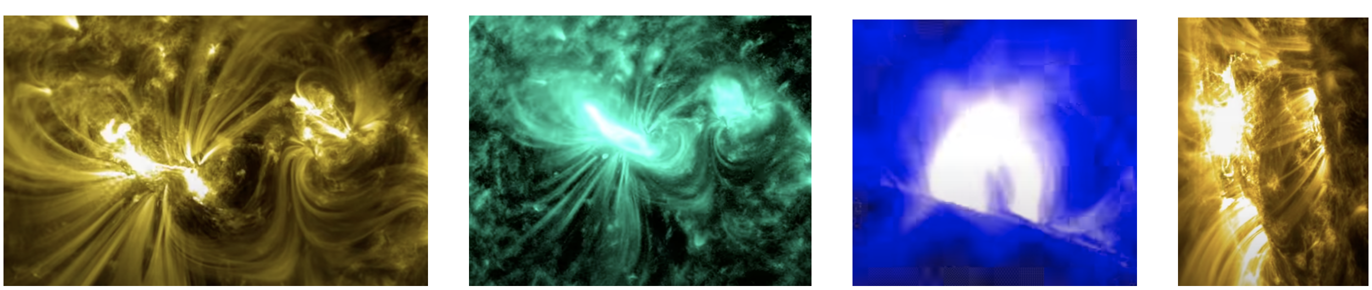


Step 7 Credit: VT Physics

5. Repeat step 4 until your compass is touching the magnet at the opposite poles. Connect the dots.

6. Repeat steps 2-5, starting at different points near the pole of the magnet, tracing the magnetic field lines.

7. Repeat steps 2-6 on the other side of the magnet.

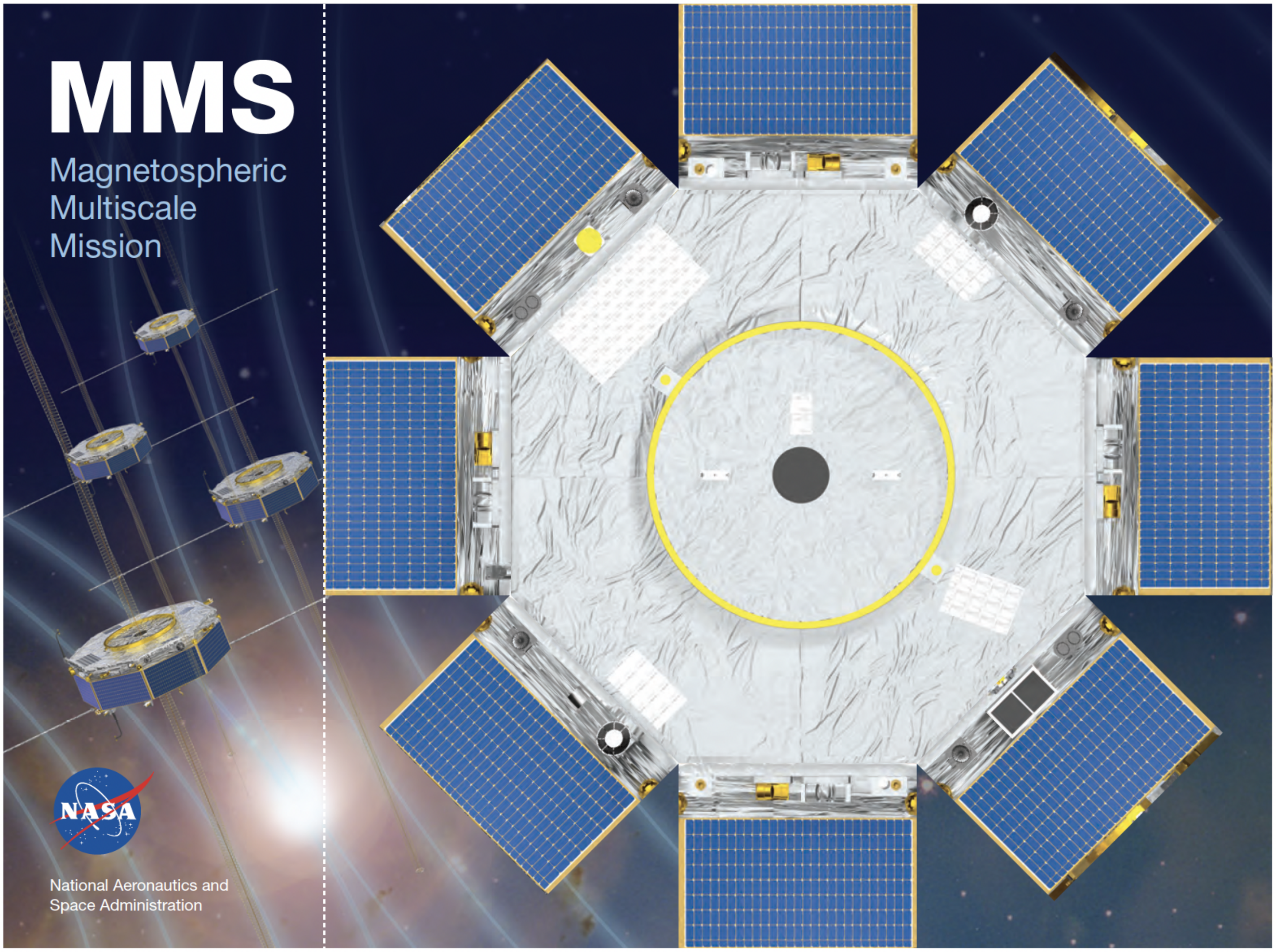


Magnetic field lines seen in solar Flares and CMES.

NOAA Sunspot Data 1986-present

Sunspot Data 1986-present									
Solar Cycle	Year in Cycle	Year	Peak Sunspot #	Point in Cycle	Solar Cycle	Year in Cycle	Year	Peak Sunspot #	Point in Cycle
22	**1**	**1986**	**15**	**min**	**24**	**1**	**2008**	**7**	**min**
	2	1987	61			2	2009	13	
	3	1988	176			3	2010	93	
	4	**1989**	**212**	**max**		4	2011	93	
	5	1990	192			5	2012	98	
	6	1991	204			6	2013	108	
	7	1992	161			**7**	**2014**	**116**	**max**
	8	1993	102			8	2015	89	
	9	1994	53			9	2016	55	
	10	1995	36			10	2017	28	
23	**1**	**1996**	**13**	**min**		11	2018	14	
	2	1997	52		**25**	**1**	**2019**	**5**	**min**
	3	1998	102			2	2020	15	
	4	1999	164			3	2021	56	
	5	2000	175			4	2022	101	

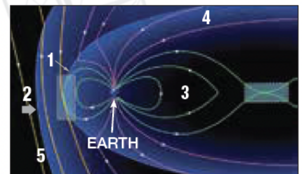
	6	200 1	180	**max**	Predicted	5	202 3	93	
	7	200 2	179		Predicted	6	202 4	112	
	8	200	129		**Predicted**	**7**	**202**	115	**max**



Intentionally Left Blank

MMS

The MMS mission is composed of four identical instrumented spacecraft that will use the Earth's magnetic field as a laboratory in which to study a fundamental plasma process known as reconnection. *Scan the codes to learn more.*



MMS will use a two-phase orbit strategy to explore two different regions where magnetic reconnection often occurs, one on the day side and the other on the night side of Earth. *(Refer to the colored boxes in the image above.)*

KEY: 1: Dayside Magnetopause 2: Solar Wind 3: Plasmasheet 4: Magnetotail 5: IMF

Scan the code or visit mms.gsfc.nasa.gov to learn more.

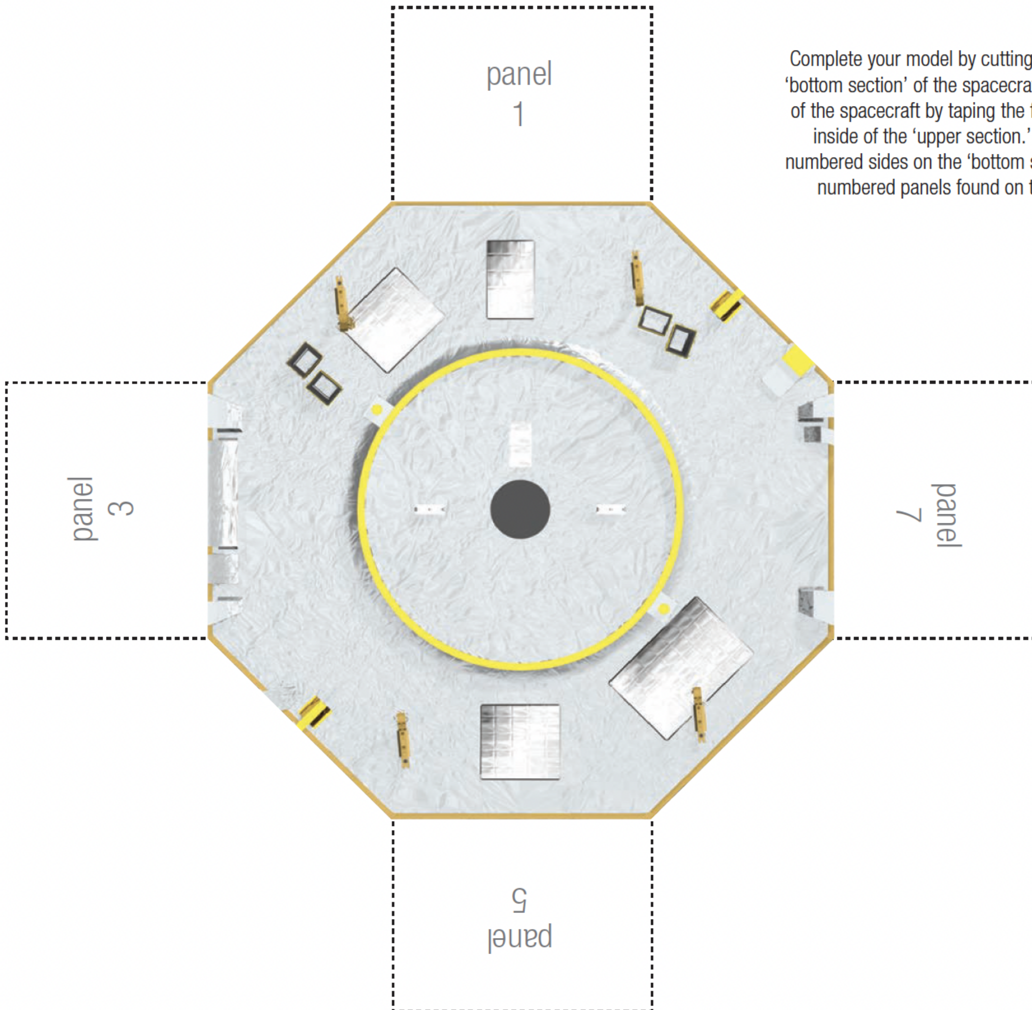
- MMS Updates
- Science Information
- Spacecraft Information
- Images, Videos and Vodcasts
- Educational Activities and Lessons

www.nasa.gov

NP-2012-8-326-GSFC

Intentionally Left Blank

Complete your model by cutting out and attaching this 'bottom section' of the spacecraft to the 'upper section' of the spacecraft by taping the four 'panel' tabs to the inside of the 'upper section.' Make sure that the numbered sides on the 'bottom section' match with the numbered panels found on the 'upper section.'



Intentionally Left Blank

Session 4: Notes

Session 5

Materials

- ❑ (1) paper towel tube or Spectroscope Template
- ❑ (1) diffraction grating
- ❑ yarn (~1 yard)
- ❑ aluminum foil (1 sheet, ~10”x10”)
- ❑ pony beads (2) red (4) green (2) purple
- ❑ letter beads (1) “O” bead (1) “N” bead
- ❑ (1) piece of black construction paper
- ❑ chalk: green, red, purple

Basics:

- ❑ writing tools (pens or pencils)
- ❑ art supplies (markers or crayons)
- ❑ (1) pair of scissors
- ❑ (1) roll of tape

Vocabulary

Airglow- diffuse bands of light that stretch 50 to 400 miles into our atmosphere typically occurring when molecules (mostly nitrogen and oxygen) are energized by ultraviolet (UV) radiation from sunlight

Atmosphere- the layer of gasses surrounding a planet

Aurora- (aurora borealis and aurora australis) often called the northern lights and southern lights, are light displays, more commonly seen at high latitudes, provoked by energy from the Sun and fueled by electrically charged particles trapped in Earth’s magnetic field

Coronal Mass Ejection (CME)- large clouds of solar plasma and embedded magnetic fields released into space after a solar eruption

Electromagnetic (EM) Spectrum- comprised of all frequencies of electromagnetic radiation that propagate energy and travel through space in the form of waves

Geomagnetic Storm- a major disturbance of Earth's magnetosphere that occurs when variations in the solar wind produces major changes in the currents, plasmas, and fields in Earth’s magnetosphere

Infrared Light- a form of electromagnetic radiation invisible to the human eye with wavelengths longer than visible light

Ionosphere- the part of Earth’s atmosphere that is right at the edge of space

Ionization- the process in which an electron is given enough energy to break away from an atom

Kp Index- a 9-point scale that tells scientists how disturbed the Earth's magnetic field is based on an average of magnetic observations from around the world, measured every 3 hours

Light Pollution- a constant nighttime presence of light, emanating from artificial sources and obscuring views of the shared night sky

Magnetic Field- a force between electric currents; two parallel currents in the same direction attract, in opposite directions repel

Magnetosphere- a region around the planet created by Earth's internal magnetism that plays a crucial role in our planet's habitability

Solar Flare- energetic bursts of light and particles triggered by the release of magnetic energy on the Sun

Solar Wind- a gusty stream of material that flows from the Sun in all directions, all the time, carrying the Sun’s magnetic field out into space

Space Weather- describes the impact of the solar wind on Earth’s systems and technologies in orbit and on Earth

Spectroscope- a tool that separates light into its component colors (or wavelengths) to reveal information about the chemical content, temperature and motion of planets, comets, stars, interstellar gas and galaxies

Session 5

Ultraviolet (UV) Light- a form of electromagnetic radiation invisible to the human eye with wavelengths shorter than visible light

Digital Resources

Video: NASA on YouTube: "What is an Aurora?"

Video: NASA on YouTube: "Meet ICON: NASA's Airglow Explorer Mission"

Webpage: NASA Aurora Image Gallery
https://www.nasa.gov/mission_pages/sunearth/aurora-image-gallery/index.html

Webpage: NASA Space Place: What is an Aurora?
https://spaceplace.nasa.gov/aurora/

Webpage: NASA ICON Mission Homepage
https://www.nasa.gov/content/icon-mission-overview

Webpage: NOAA: 30 Minute Aurora Forecast
https://www.swpc.noaa.gov/products/aurora-30-minute-forecast

Webpage: NASA International Space Station Mission Homepage
https://www.nasa.gov/mission_pages/station/main/index.html

Session 5: 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 Aurora Borealis, also known as the Northern Lights? What is it? What causes it? Where does it occur?	**Record questions you have about the Aurora Borealis in this column.**	**Record what you learned about the Aurora Borealis in this column.**

UAMN Virtual Family Day: Amazing Earth

What's in the Atmosphere?

Earth's atmosphere is a jacket of gases that surround our planet. It keeps us warm, gives us oxygen to breathe, protects us from the sun's radiation, and helps to form weather patterns. It makes life on Earth possible.

The atmosphere has six layers, which extend from the ground to outer space.

The **exosphere** is the very edge of our atmosphere. It's about 10,000 km (6,200 miles) thick, almost as wide as Earth itself. The exosphere has some gases, but they are very spread out, and it's very cold.

The **thermosphere** is 513 km (319 miles) thick. It can be very hot in this layer. The thermosphere is home to the International Space Station, and many satellites.

The **mesosphere** is 35 km (22 miles) thick. The air is very thin, so you wouldn't be able to breathe here. Most meteors burn up in the mesosphere.

The **stratosphere** is 35 km (22 miles) thick. Weather balloons fly in this layer. It is home to the ozone layer, which helps protect us from the sun's ultraviolet radiation.

The **troposphere** is the innermost layer, 8 to 14 km (5 to 9 miles) thick. It is where weather happens. This layer has the air we breathe, clouds in the sky, and airplanes flying.

The **ionosphere** overlaps with other layers. It grows and shrinks depending on the energy it absorbs from the sun. In this layer, charged particles are affected by the magnetic fields of Earth and the sun. It is where the aurora happens.

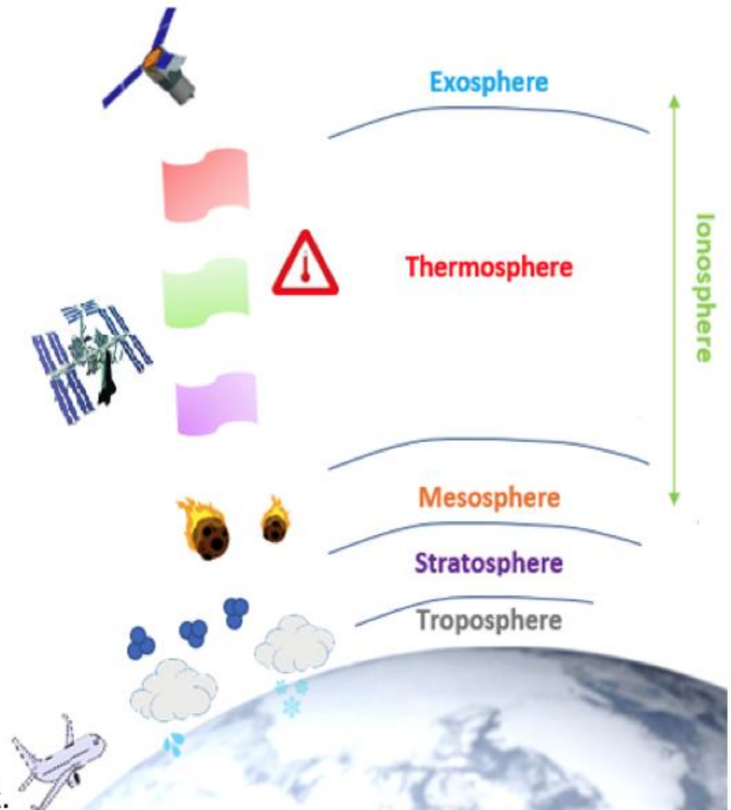
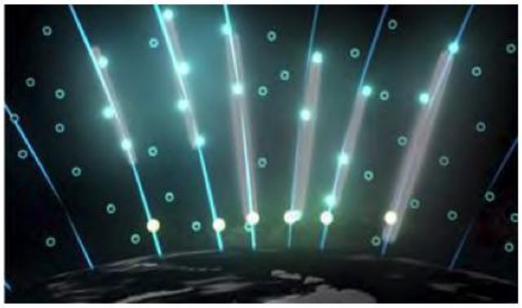


Diagram by Elisabeth Padilla.

Discover more about the atmosphere at
spaceplace.nasa.gov/atmosphere

UNIVERSITY OF ALASKA MUSEUM OF THE NORTH

Aurora Colors



culturalconnections.gi.alaska.edu

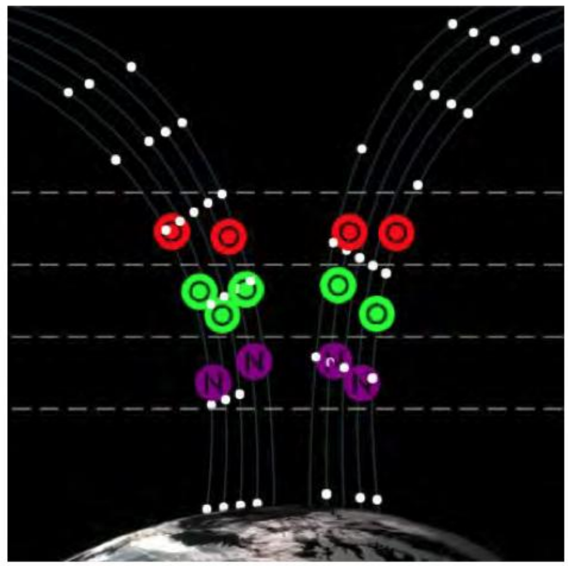
The Sun emits a constant stream of particles, called the solar wind. Some of these particles get caught in Earth's magnetic field and move toward the poles. When the particles enter the atmosphere, they crash into gases. This excites the gases in the atmosphere, and they give off light like a neon sign.

Different gases in Earth's atmosphere create different colors of the aurora:

Red light is caused by energized oxygen high in the atmosphere.

Green, the most common light, is caused by energized oxygen in the middle of the atmosphere.

Purple light, which can appear white or light blue to human eyes, is caused by energized nitrogen lower in the atmosphere.



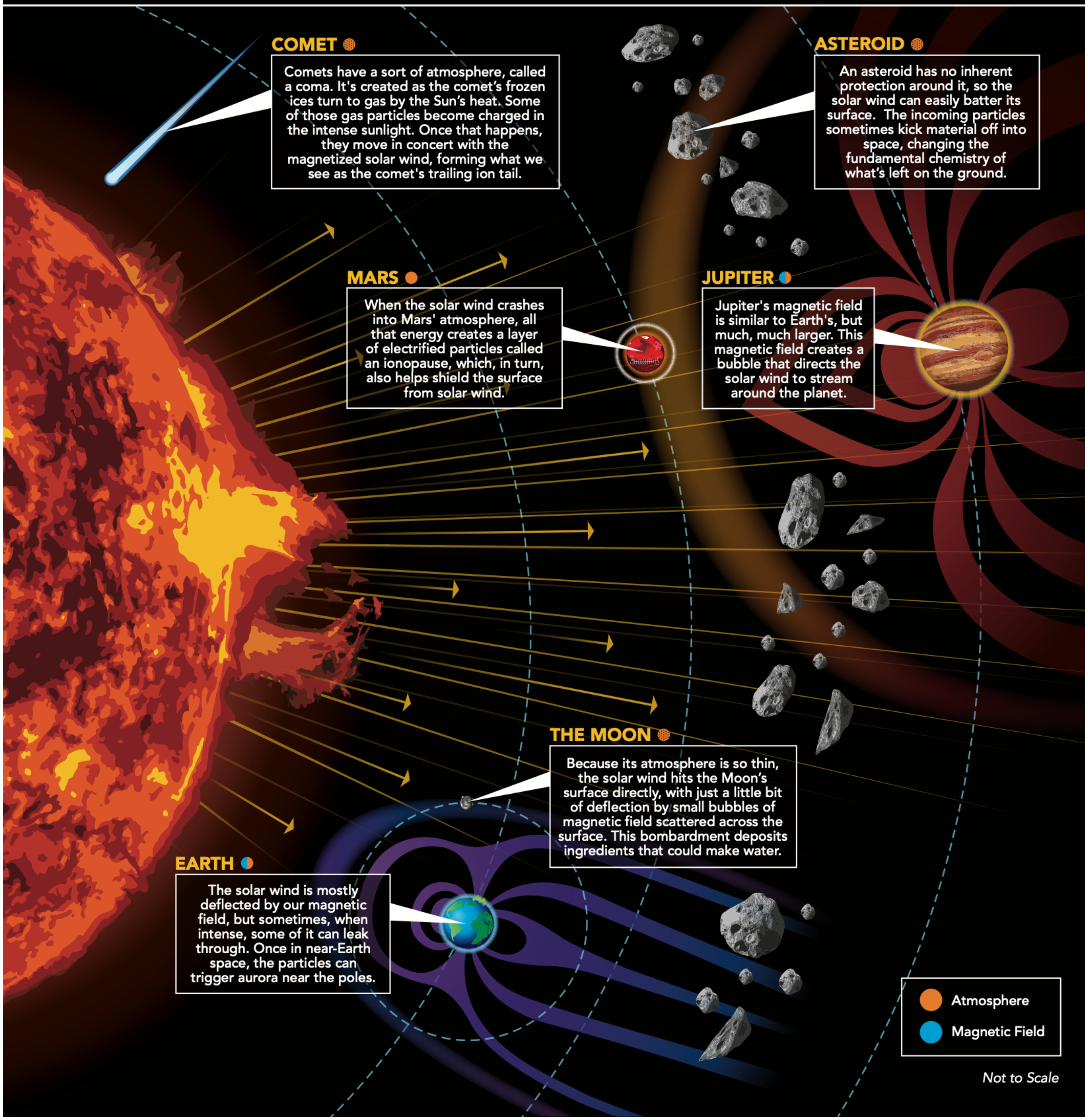
culturalconnections.gi.alaska.edu

The aurora seen from the International Space Station. Image: NASA.

Joe Huff / NASA

UNIVERSITY OF ALASKA MUSEUM OF THE NORTH

The Sun releases a constant stream of particles and magnetic fields called the solar wind. This solar wind slams worlds across the solar system with particles and radiation – which can stream all the way to planetary surfaces unless thwarted by an atmosphere, magnetic field, or both. Here's how these solar particles interact with a few select planets and other celestial bodies.



Intentionally left blank

↑ **tape** ↑ **tape**

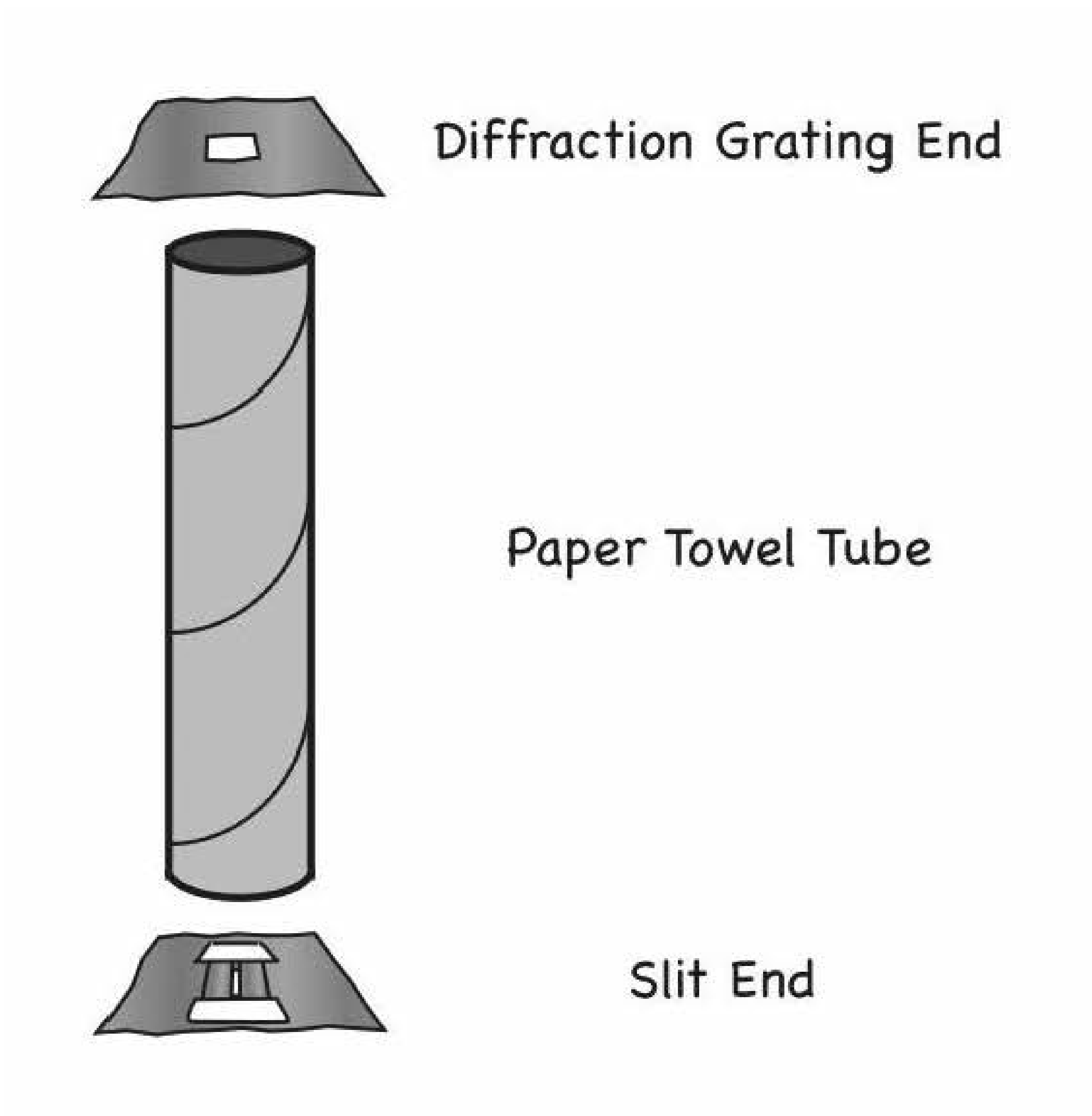
Do NOT use this to look at the Sun!

↓ **roll and tape here** ↓

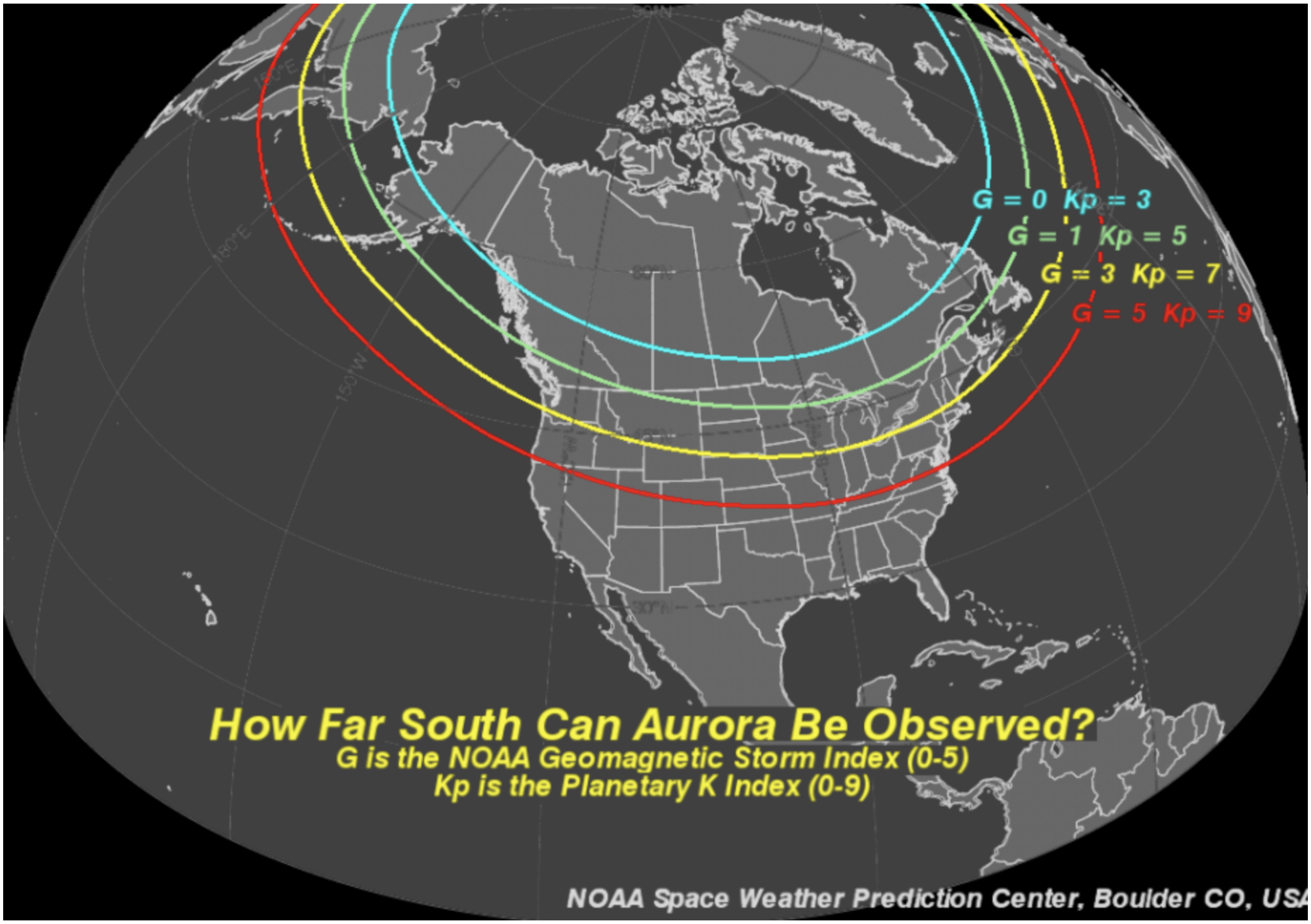
roll this side under

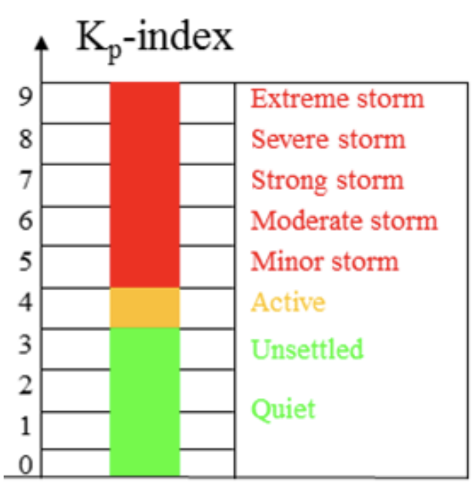
Intentionally left blank

Spectroscope Diagram



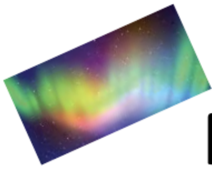
Aurora Kp Map of North America





Remember that the **solar wind** is constantly flowing from the Sun, and even during times when there aren't any solar storms (Kp 1-2), **aurora** is commonly seen at high latitudes – places like Alaska and Northern Canada.

Credit: NOAA



Make an Aurora Bracelet

Different gases in Earth's atmosphere, including oxygen and nitrogen, cause the different colors of the northern lights. Make a bracelet to remind you of the aurora colors!

Materials Needed:

String (about 12 inches long), 2 red pony beads, 4 green pony beads, 2 purple pony beads, 1 "O" bead, 1 "N" bead, scissors.

Note: Pony beads can be found at most craft stores. If you don't have beads, you can make your own from paper. Follow the instructions here: www.bigbeadlittlebead.com/guides_and_information/guide_to_making_paper_beads.php

Instructions:

Step 1: Cut a piece of string about 12 inches long. Find the center of your string. Tie a **red** bead slightly to one side of the middle.

Step 2: String your aurora beads in order:

- One more **red** bead
- An O bead for Oxygen
- Four **green** beads
- An N bead for Nitrogen
- One **purple** bead

Step 3: Tie on the last **purple** bead to secure the beads.

Step 4: Tie the ends of the string together and wear your bracelet!

Learn more about the colors of the northern lights:
culturalconnections.gi.alaska.edu/multimedia/gas.html

UNIVERSITY OF ALASKA MUSEUM OF THE NORTH

Aurora Chalk Art

Create your own artwork inspired by the northern lights!

Materials Needed:

Aurora stencil (or draw your own), black paper, colored chalk, scissors. *Optional:* Tissues.

Instructions:

Step 1: Cut out the aurora stencil. If making your own, cut a strip of white paper or cardstock in a wavy aurora shape.

Step 2: Color the top edge of the stencil with colored chalk.

Step 3: Place the colored stencil on your black paper, chalk side up. Smudge the chalk onto the black paper using your finger or a tissue.

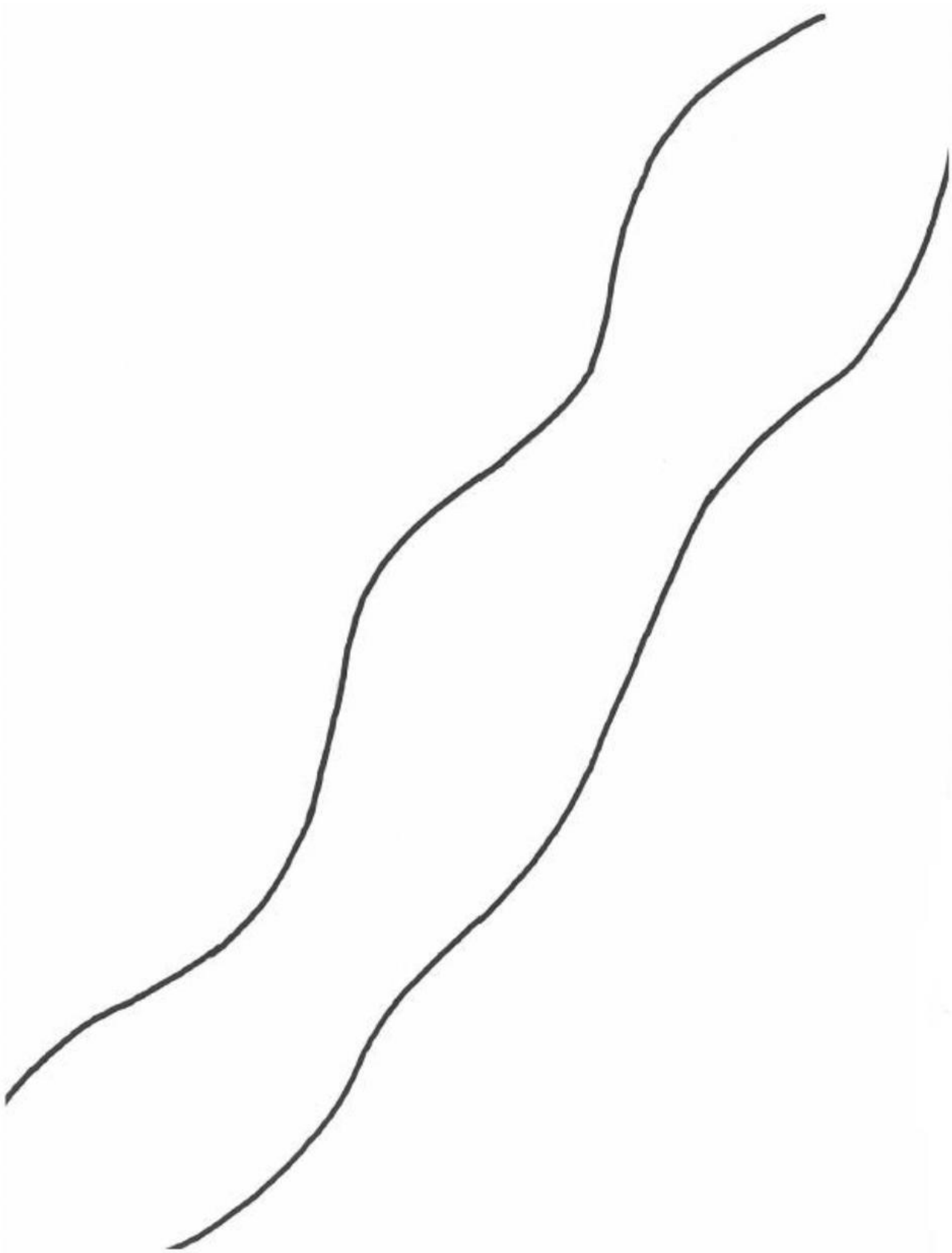
Step 4: Repeat using different colors to fill the sky with the colors of the aurora.

Step 5: Add a cabin, trees, campfires, or other things you might see under the northern lights. Be creative!

Activity adapted from Cultural Connections Project, UAF Geophysical Institute: [culturalconnections.gi.alaska.edu]

UNIVERSITY OF ALASKA MUSEUM OF THE NORTH

Aurora Stencil



Intentionally left blank

Session 5: Notes

Session 6

Materials

- ❑ (1) ping pong ball
- ❑ (1) tennis ball
- ❑ (Optional) Poster Paper

Basics:

- writing tools (pens or pencils)
- art supplies (markers or crayons)
- (1) pair of scissors
- (1) roll of tape

Vocabulary

Astrobiology- a discipline of science dedicated to the study of the origins, evolution, distribution, and future of life in the universe

Astrophysics - a branch of space science dedicated to the study of the universe with a focus on how the universe works, how the universe began and developed into its present form, and the search for life elsewhere

Black Hole- a place in space where gravity pulls so much that even light can not get out; black holes can form after a supernova event

Dark Matter- an invisible form of matter that makes up most of the universe's mass and creates its underlying structure

Exoplanets- planets that orbit around other stars

Extrasolar- outside of the Solar System

Extremophile - an organism that can survive in extreme environments, for example, environments that are extremely hot or cold, extremely acidic, or environments without sunlight

Galaxy- a large group of stars, gas, and dust bound together by gravity

Gas Giant Planet- a large planet mostly composed of helium and/or hydrogen

Habitable Zone- the 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; also known as the **Goldilocks Zone**

Light Year- the distance light travels in one year; 186,000 miles (300,000 kilometers) per second

Main Sequence Star- the phase in the life cycle of a star when the star is fusing hydrogen into helium in their cores

Milky Way Galaxy – the name of the galaxy where the Solar System is located

Neptune-like Planet- planets similar in size to Neptune and Uranus, typically having hydrogen and helium-dominated atmospheres with cores of rock and heavier metals

Neutron Star- the dense, collapsed core of a massive star that exploded as a supernova

Nuclear Fusion- a process that produces energy when two nuclei join to form a heavier nucleus

Planetary Nebula- a phase of stellar evolution that the Sun should experience several billion years from now (does not relate to a planet)

Protostar- the beginning formation of a star which has not yet developed the energy-generating capabilities of a Sun-like star, which fuses hydrogen into helium in its core

Red Giant- a dying star in the final stages of stellar evolution

Session 6

Stellar (star-forming) Nebula- an enormous cloud of dust and gas occupying the space between stars and acting as a nursery for new stars

Supernova- a large explosion that takes place at the end of a star's life cycle

Super Earth Planet- a class of planets that are more massive than Earth, yet lighter than ice giants like

Supernova Remnant- the remains of a supernova explosion

Terrestrial Planet- planets with a compact, rocky surface

Transits- when one object crosses in front of another in space

White Dwarf- an extremely dense object formed from a dead Sun-like star, after the star has exhausted their nuclear fuel

Digital Resources

Interactive: NASA's Eyes on Exoplanets
https://exoplanets.nasa.gov/eyes-on-exoplanets/#/

Webpage: NASA Space Place: What is a transit?
https://spaceplace.nasa.gov/transits/en/

Webpage: International Space Station Homepage
https://www.nasa.gov/mission_pages/station/main/index.html

Webpage: NASA/ESA Hubble Space Telescope Mission Homepage
https://www.nasa.gov/mission_pages/hubble/main/index.html

Webpage: NASA/ESA Top 100 Hubble Images
https://esahubble.org/images/archive/top100/

Webpage: NASA Chandra Mission Homepage
https://www.nasa.gov/mission_pages/chandra/main/index.html

Webpage: NASA James Webb Space Telescope Mission Homepage
https://jwst.nasa.gov/index.html

Webpage: NASA Kepler & K2 Mission Homepage
https://www.nasa.gov/mission_pages/kepler/overview/index.html

Webpage: NASA TESS Mission Homepage
https://www.nasa.gov/tess-transiting-exoplanet-survey-satellite

Webpage: NASA's Eyes on Exoplanets Interactive
https://exoplanets.nasa.gov/eyes-on-exoplanets/#/

Webpage: NASA Exoplanet Travel Bureau
https://exoplanets.nasa.gov/alien-worlds/exoplanet-travel-bureau/

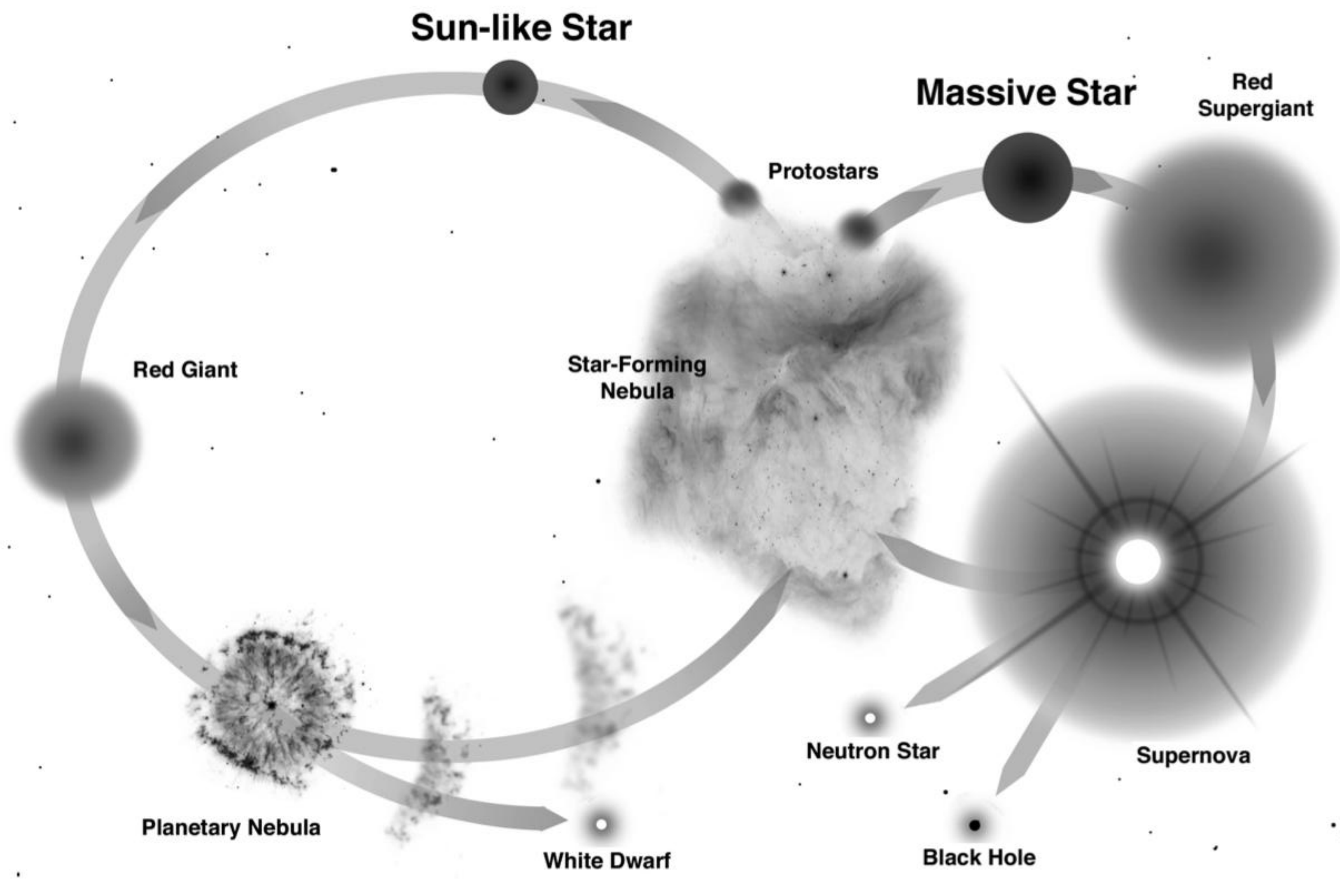
Webpage: NASA Spitzer Space Telescope Mission Homepage
https://www.nasa.gov/mission_pages/spitzer/main/index.html

Session 6: KWL		
K - what do we already know?	**W- what do we wonder about?**	**L- what did we learn?**
What do we already know about other star systems? Are other stars like our Sun? Do other stars have planets around them? If so, what are those planets like? How do we learn about distant stars?	**Record questions you have about other star systems in this column.**	**Record what you learned about other star systems in this column.**


OPERATING & FUTURE
SCIENCE FLEET
EARTH
HELIOPHYSICS
PLANETARY
ASTROPHYSICS
BIOLOGICAL & PHYSICAL
FUTURE LAUNCHES IN BOLD
*PARTNER-LED
~ COMMERCIAL PARTNERSHIP
SPHEREX
GUSTO
FERMI
XRISM*
STARBURST
CHANDRA
WEBB
TESS
ASPERA
HUBBLE
ROMAN
IXPE
GEHRELS SWIFT
XMM-NEWTON*
PANDORA
ARIEL*
PUEO
EUCLID*
NUSTAR
BEPICOLOMBO*
ENVISION*
DAVINCI
VERITAS
NEO SURVEYOR
OSIRIS-REX/APEX
NEOWISE
PARKER SOLAR PROBE
SUNRISE
WIND
SOLAR ORBITER*
STEREO
CARRUTHERS
GEOCORONA
OBSERVATORY
THEMIS
IMAP
TIMED
HELIOSWARM
HINODE*
ICON
EUVST*
GOLD
EZIE
MUSE
MMS
IBEX
PUNCH
SDO
TRACERS
IRIS
AIM
SOHO*
ACE
NEW HORIZONS
VOYAGER 1
VOYAGER 2
DRAGONFLY
JUICE*
LUCY
JUNO
EUROPA CLIPPER
PSYCHE
MSR EARTH
RETURN ORBITER*
MMX*
MRO
CURIOSITY
SRL-SRH
SRL-MAV
ROSALIND FRANKLIN*
PERSEVERANCE
MAVEN
MARS ODYSSEY
ESCAPADE
MARS EXPRESS*
TRACE GAS ORBITER*
TERRA
AQUA
CYGNSS
INCUS
TSIS-2
PACE
TEMPO
GLIMR
CALIPSO
MAIA
OCO-2
TROPICS
CLOUDSAT
GPM
AURA
NOAA-20, 21*
NISAR
ICESAT-2
ESO-1, 2, 3, 4
SMAP
ECOSTRESS
EMIT
GEDI
LIS
CLARREO-PF
TSIS-1
OCO-3
SAGE III
APH
PK-4*
XROOTS
MICRO
FLARE*
RR
DECLIC*
SPECTRUM
SENTINEL-6
MICHAEL FREILICH*
SENTINEL-6B*
GRACE-FO
PREFIRE
LANDSAT NEXT
LANDSAT 7, 8, 9
JPSS-3, 4*
DSCOVR*
SWOT
SUOMI NPP*
GOES-18*
THEMIS-ARTEMIS
HERMES
BRIC-LED
BRIC
BECCAL*
ELF*
MSRR
MHU*
ZBOT-NC
CAL
EML*
SOFIE
VEGGIE
PFMI
PH
AWE
FBCE
COMPACT*
TIGERISS
NICER
PEREGRINE-1~
LUNAR PATHFINDER*
1ST BLUE GHOST~
1ST NOVA-C~
2ND BLUE GHOST~
SERIES-2~
2ND NOVA-C~
GRIFFIN-1~
& VIPER
3RD NOVA-C~
LUNAR
TRAILBLAZER
BIOEXPT-02
LEIA
XL-1~
LRO
MAY 2023

the lives of stars

National Aeronautics and Space Administration



THE LIVES OF STARS

What is a red giant, a white dwarf, or a supernova? Where do these fit into the lives of stars? Follow the arrows on the diagram and discover the stages in the life of a small Sun-like star compared to the stages in the life of a massive star (a star more than 8 to 10 times the mass of our Sun).

Stars of all sizes are born as *Protostars* from a cloud of gas and dust in our galaxy (a *Star-Forming Nebula*). When the protostar compresses under the force of gravity and its core becomes hot enough, the star begins fusing hydrogen into heavier elements in its core.

Stages in the life of a sun-like star (A life of BILLIONS of years):

Sun-like Star: For billions of years, the star remains stable, fusing hydrogen in its core.

Red Giant: After several billion years, the star uses up the hydrogen in its core, and it turns into a red giant, now mostly fusing helium.

Planetary Nebula: At this point the star goes through an unsettled stage where it starts losing its outer atmosphere in a planetary nebula which forms around the star.

On the diagram, the cycle continues from the planetary nebula back into the cloud of gas and dust. This represents the recycling of the elements created in the star back into the interstellar medium to provide material to make new stars.

White Dwarf: The leftover core of the star cools down and shrinks to a white dwarf. After billions of years, the white dwarf cools off so much that it no longer glows and becomes the dark, cold remains of the star.

Stages in the life of a massive star (A life of MILLIONS of years):

Massive Star: For millions of years, the star remains stable, fusing hydrogen in its core.

Red Supergiant: After several million years, the star uses up the hydrogen in its core and it turns into a red supergiant. The star continues to fuse atoms in its core into heavier and heavier elements until the core starts filling up with iron. Because the fusion process stops at iron, the core collapses under its own weight, no longer held up by the heat generated during fusion.

Supernova: An explosive shock wave and the energy generated from the core collapse starts moving outward, heating the surrounding layers of the star, and BOOM. Most of the star is blasted into space in a supernova explosion. On the diagram, the cycle continues from the supernova back into the cloud of gas and dust. This represents the recycling of the heavy elements created in the star and during the supernova explosion into the interstellar medium to provide the material to make new stars — and planets.

Neutron Star or Black Hole: After the explosion, the remaining core of the star turns into a neutron star or, if the core is more than three times the mass of the Sun, it turns into a black hole.

Which NASA missions study supernovae, black holes, and high-energy radiation from space?

Some of the NASA missions are:

GLAST: http://www.nasa.gov/glast

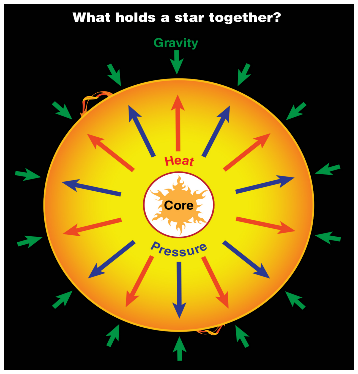
Swift: http://swift.gsfc.nasa.gov

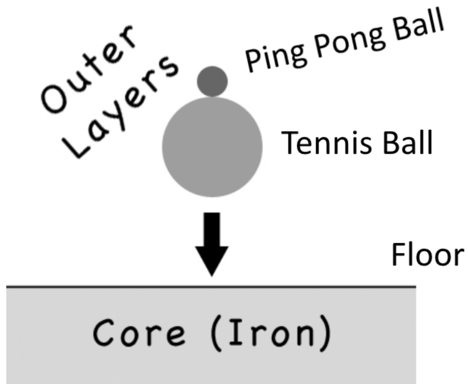
Chandra: http://chandra.harvard.edu/

In collaboration with European Space Agency (ESA)
XMM-Newton: http://xmm.sonoma.edu

In collaboration with Japanese Aerospace Exploration Agency (JAXA)
Suzaku: http://suzaku-epo.gsfc.nasa.gov/

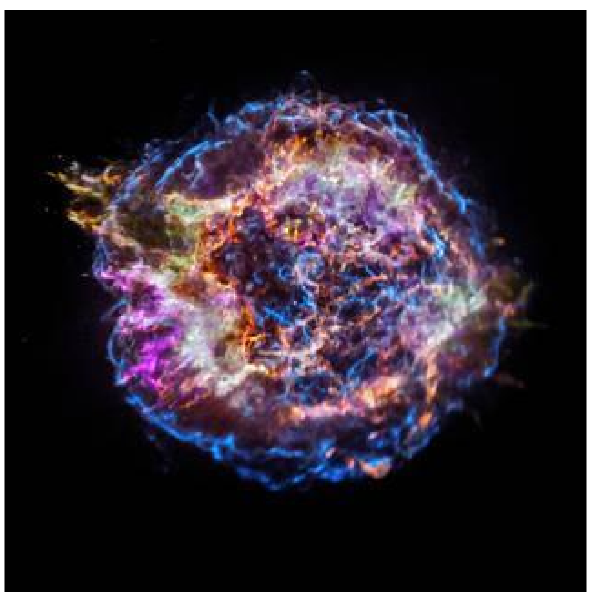
Modeling a Supernova





Credits: NASA Space Place (left), NASA Afterschool Universe (center), NASA HEAT (right)

Drop the balls at the same time, with the balls in contact with one another. You have the option of using one hand or two hands to drop the balls, just make sure they are touching when you drop them, see the right image above. **First, make a prediction!** How do you think each ball will behave? Record your results.



This image of supernova remnant Cassiopeia A, captured by NASA's Chandra X-ray Observatory, reveals the location of silicon (red), sulfur (yellow), calcium (green) and iron (purple) in the debris. Cassiopeia A lies about 11,000 light-years from Earth. ***Credits: NASA/CXC/SAO***

Session 6: Notes

Capstone Project: Mission Proposal

Background:

Now that you have explored some of NASA's missions, your challenge is to design your own mission. During this club you learned about many NASA missions, including missions that study the Sun, the solar system, and distant stars and galaxies. These missions, collectively, help NASA create a more comprehensive understanding of the universe.

- Earth Science – missions that study Earth
- Heliophysics – missions that study the Sun and the heliosphere
- Planetary Science – missions that study objects in the solar system
- Astrophysics- missions that study objects outside the solar system
- Biological and Physical Science – missions that use the spaceflight environment to study phenomena in ways that can't be studied on Earth

There are a variety of different kinds of missions, depending on the destination and what scientists are interested in learning about. Here are the different types of missions, with examples of each type:

- **Missions with Physical Samples:** Genesis, OSIRIS-REx, Stardust
- **Missions with Surface Exploration:** Curiosity, Apollo 11, Perseverance, Huygens
- **Orbiting Missions:** Solar Orbiter, Juno, Mars Reconnaissance Orbiter (MRO), Messenger, Cassini, Galileo, Magellan
- **Flyby Missions:** Voyager, New Horizons, Mariner 10
- **Other Missions:** International Space Station, NASA Hubble Space Telescope, Kepler, TESS, James Webb Telescope

There are many phases involved in developing a mission. After NASA has a mission concept in mind, they put out a call for proposals to get the best group of people to accomplish the mission (and for the right price). Many different teams of scientists and engineers collaborate to develop a plan for how to best carry out the mission. The teams compete with other teams to get their ideas picked by NASA.

Directions:

Now you get to design your own mission. ***What questions do you still have? What places or phenomena would you like to learn more about?*** You will plan a mission to a destination of your choice. Consider what type of science experiments you want to conduct at this location and the type of spacecraft you need to reach the destination. When you have decided on some of the details, complete the **Mission Proposal Letter (page 84)**.

The Mission Proposal Letter is designed to convince the mission review panel to choose your mission design. This proposal letter will give the review panel the top-level details of your mission, including the mission's name, destination, the reasons you chose the destination for the mission, the type of mission and the data you want to collect, and a rough sketch of the design of the spacecraft that will carry out the mission.

Use the **Criteria of Success** below to help you design the best possible mission.

Criteria for Success:

	Expert Design	Intermediate Design	Beginner Design
Mission Destination	Mission destination is unique and innovative with a strong science focus. Destination shows thoughtful consideration to current and past missions.	Mission destination is a popular hotspot for scientific exploration. However, this location has already been heavily explored.	Mission destination is not necessarily of scientific interest.
Phase A: Mission Science	Mission has a strong science goal and a clear plan for collecting data.	Mission has a valuable science goal.	Mission's science goal is unclear.
Phase B: Mission Design (Engineering)	Mission has an efficient design that matches the challenges of the destination. Design provides details about how the spacecraft and its instruments will be protected from the challenges of the specific space environment of the destination.	Mission has a thoughtful design that takes into consideration the general challenges of exploring the space environment.	Mission design doesn't directly address the challenges of exploring the general space environment.

Mission Proposal Letter

Proposed Mission Name: ______________________________

Proposed Mission Destination: _________________________

Lead Investigator: ______________________________ (your name)

Mission Question: ____

Mission Concept: ____

____

Dear NASA:

Our team of scientists and engineers is very excited about the study of the Sun and the heliosphere. We have examined the data gathered from previous and existing missions to the Sun, missions that study the magnetic fields around the Earth, missions to the edge of the heliosphere, and missions that search for planets around other stars. But there is more to discover!

Mission Justification

We think this would be a unique mission because...

____

____

____

____

____

Phase A: Project Plan:

The kind of data we will collect on this mission includes...

____

____

____

____

Phase B: Design: (include a rough sketch of your spacecraft and the special technology it will have to collect the data you want)

Thank you for taking the time to consider our proposal. If selected, we look forward to working with you on the next phases of mission development.

Sincerely,

______________,

Lead Investigator

Approved

Mission Stamp of Approval

Use this page for additional sketches of your mission.

This resource was developed by the NASA Heliophysics Education Activation Team (NASA HEAT), in collaboration with Maryland 4H. NASA HEAT is based at NASA Goddard Space Flight Center and funded by the NASA Science Mission Directorate. Publication number NP-2023-6-077-GSFC.