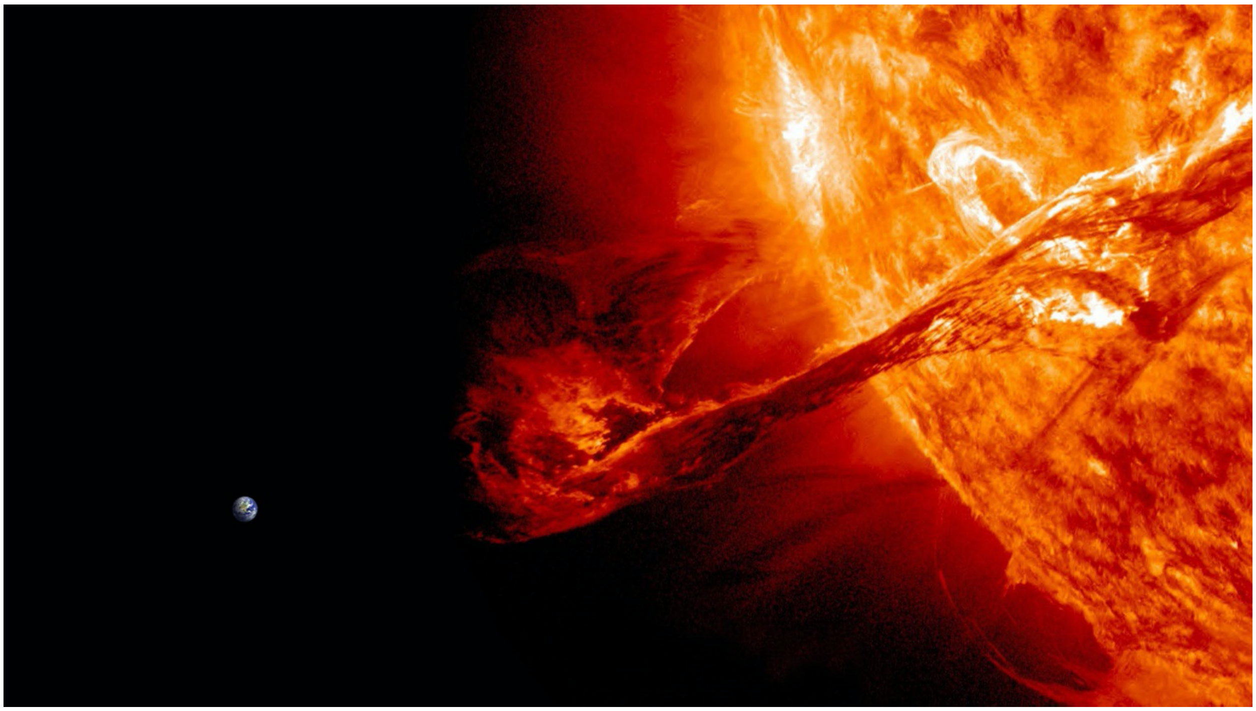
Heliophysics: How do Earth, the Planets and the Heliosphere Respond?
Lessons for 8th Grade

Prepared by:



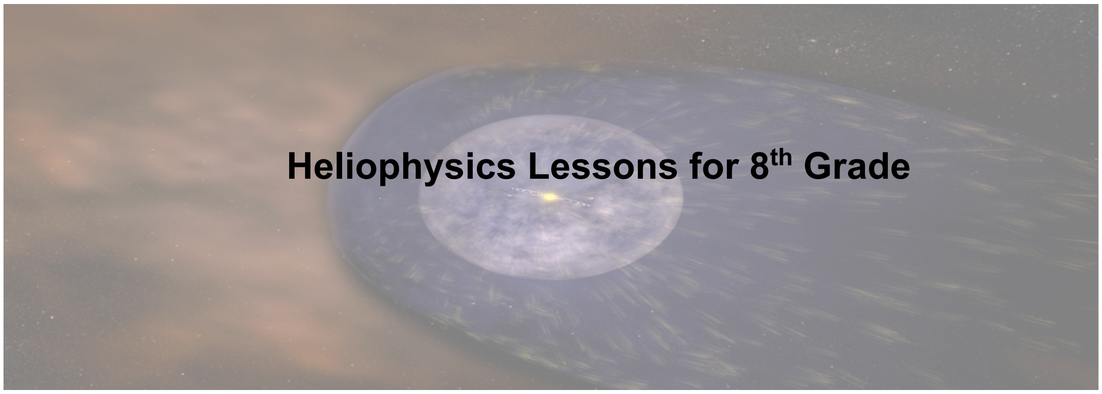
The Institute for the Integration of Technology into Teaching and Learning (IITTL) in collaboration with NASA HEAT Project

Authors: Rhonda Christensen, Gerald Knezek, Fred Hobbs and Jenna Kelley
Funded by NASA HEAT grant number: NNX16AL63A

UNT UNIVERSITY OF NORTH TEXAS®

HEAT HELIOPHYSICS EDUCATION ACTIVATION TEAM

Institute for the Integration of Technology into Teaching and Learning (IITTL) (2021)



Heliophysics Lessons for 8th Grade

This set of lessons is focused on the one of three essential questions highlighted in the heliophysics topic found at https://science.nasa.gov/heliophysics.

Essential Question: How do Earth, the planets, and the heliosphere respond?
https://science.nasa.gov/heliophysics/big-questions/what-are-the-fundamental-physical-processes-of-the-space-environment

The lessons are intended to engage learners in the concepts described. The lessons included are:

- Lesson 1: Solar Wind
- Lesson 2: Cause of Auroras
- Lesson 3: Solar Eclipses
- Lesson 4: Our Sun
- Lesson 5: Our Heliosphere

In many lessons there are activities that require technology apps and equipment. The following list contains the different apps and equipment needed for the activities. Each lesson includes several activities so if you don't have one of the needed tools, there are other ways to teach the concepts.

Lesson	Hardware and Software Requirements
Lesson 1	Computer with projection system and Internet access for videos; Internet access for Helioviewer; drone, drone targets
Lesson 2	Internet access; Sun Position, Sunrise, and Sunset AR app;
Lesson 3	Totality app; CoSpaces app; smartphone or tablet
Lesson 4	Computer with projection system and Internet access for videos; CoSpaces app; MergeCube or printed one; Titans of Space; Space 4D+ AR app and flash cards; Galactic Explorer app;
Lesson 5	Computer with projection system and Internet access for videos; Oculus Quest with Heliophysics Spacecraft Exploration App (NASA)

Concept:
The solar wind, along with other solar events like giant explosions called coronal mass ejections, influences the very nature of space and can interact with the magnetic systems of Earth and other worlds. The sun periodically sends out bursts of charged particles (solar wind).

Objective:
Students will be able to identify that the sun releases charged particles, known as the solar wind.

Terms:
Solar wind - solar wind is a gas of charged particles known as plasma.
Magnetosphere: magnetic field around Earth which protects us not only from solar and cosmic particle radiation but also from erosion of the atmosphere by the solar wind. Planets without a shielding magnetic field, such as Mars and Venus, are exposed to such processes and have evolved differently.

Standards Addressed (Grades 5-8)

- **TEKS** (10) (A) Recognize that the sun provides the energy that drives convection within the atmosphere and oceans, producing winds; (2)(E) Analyze data to formulate reasonable explanations, communicate valid conclusions supported by the data, and predict trends.
- **NGSS** Analyze and interpret data to provide evidence for phenomena. **(**MS-ESS2-3) Construct a scientific explanation based on valid and reliable evidence obtained from sources and the assumption that theories and laws that describe nature operate today as they did in the past and will continue to do so in the future. (MS-ESS2-2) Analyze and interpret data to determine similarities and differences in findings. (MS-ESS1-3)

Materials:
Computer and projection system for videos; drone; cones; take-off and landing sites (visuals printed)

Activities:

1. Effects of Solar Wind

a. View the video: NASA Science Casts: Effects of the Solar Wind (3 m 45s) https://www.youtube.com/watch?v=twB62NYsaIg&t=22s
   Concepts addressed:
   - Solar wind average speed 0.87 million miles per hour
   - Corona is the sun's inner atmosphere and can be seen surrounding the sun during an eclipse; home to solar wind
   - Parker Solar Probe's orbiting the sun and mission is to (1) examine energy that heats the corona and speeds up the solar winds and (2) determine the structure of the wind's magnetic fields
   - The solar wind impacting Earth's magnetosphere is responsible for triggering auroras, typically seen close to the north and south poles
   - Solar wind can set off space weather storms that disrupt satellites in space, ship communications on the oceans, power grids on land, astronauts in space and technology

b. "Can you feel a solar wind?" (Ask an Astronomer) (1m 50s) https://www.youtube.com/watch?v=hisU8ksHQpI&feature=emb_logo also mentions the purpose of the earth's magnetic field
   Concepts presented:
   - Temperatures on the sun are so hot that hydrogen atoms are broken into electrons and protons which are churned by the sun's strong magnetic field and flung out into the solar system forming solar wind
   - Solar flares increase the force of the solar wind
   - Earth is protected by a magnetic field
   - Spacecraft beyond the Earth's magnetic field have no protection and their electronics can be disrupted by solar wind – thus the need to make specially protected instruments on the spacecraft
c. Listen to sounds of the solar wind from the Parker Solar Probe (PSP) https://www.youtube.com/watch?v=hgzGET6owYk (42s)

2. All About Space Weather
   a. Watch short video (2m 47s) about space weather at https://www.pbs.org/wgbh/nova/labs/lab/sun/2/1/ and answer two questions provided in the "Lab Report". This can be done individually online or viewed as a class and answered online in a learning management system.
   b. How is "space weather" similar to or different from "normal" weather here on Earth?
   c. What causes big solar storms, and what are the two main types?

3. Helioviewer
   a. Go to student.helioviewer.org to view the sun and specifically the eruptions and coronal mass ejections (CME) that are captured in these real photos.
   b. Note there is a "date option" and a "time step" option and a "make an observation" option in the Viewport in the top left side of the screen.

c. To view eruptions and coronal mass ejections, select that from the drop-down options in “Make an observation”. Put the current date in the “Date” box. For now, select “one year” under “Time Step.
d. While watching what happens to the surface of the Earth, click the back arrow one year at a time to see the changes that have occurred over time. What observations can you make?
e. Use the “Take a photo” option to take screen shots of 2 different times. Paste the images into a document and include when each was taken. Write a paragraph about the differences you see between the photos and why you think they are different.

4. **Drone challenge**: Launch the drone from Kennedy Space Center, fly it to the moon and then to the sun trying to land on the Parker Solar Probe and not burn up by touching the sun. You must go around the solar flares (cones) in order to survive.

Assessment:
After watching the PBS video, students will answer the following questions:

- How is “space weather” similar to or different from “normal” weather here on Earth?
- What causes big solar storms, and what are the two main types?

After completing the activities, students should be able to answer

- What is the solar wind?
- Explain the similarities and differences between the wind we experience from weather on Earth and the solar wind from the sun.
- Explain the changes that occur in the sun over time.
- Evidence for understanding could also include having students analyze solar wind data found online at https://www.swpc.noaa.gov/products/real-time-solar-wind.

Lesson 2: Cause of Auroras

Concept:
The interaction of the **solar wind** with Earth's magnetosphere and atmosphere creates a phenomena at Earth's poles called **aurora.**

Objective:
Students will be able to identify that aurora, or Northern/Southern Lights, occur at the Earth's poles because of the interaction of the solar wind with Earth's magnetosphere and atmosphere.

Standards Addressed (Grades 5-8)

- **TEKS** (10) (A) recognize that the sun provides the energy that drives convection within the atmosphere and oceans, producing winds; (6) (A) demonstrate and calculate how unbalanced forces change the speed or direction of an object's motion;
- **NGSS** Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe. **(**MS-ESS1-2) Patterns can be used to identify cause-and-effect relationships. (MS-ESS1-1) Develop and use a model to describe phenomena. (MS-ESS1-1),(MS-ESS1-2)

Materials:
computer and projection system to play video; Aurora Forecast 3D app downloaded on smartphone or tablet

Activities:

1. View video on space weather and auroras
    a. Space Weather and Earth's Auroras (4m 49s)
    https://www.youtube.com/watch?v=HJfy8acFaOg&feature=emb_logo
    Concepts addressed:
        - The aurora starts on the sun.
        - The sun is a star of average size among many others in our Milky Way Galaxy.
        - Energy is created deep inside the core of the sun (temp over 14 million degrees).
        - Convection cells – electrical currents of charged gas create magnetic fields inside the sun.
        - Sun spots.
        - The sun's magnetic field stretches like a rubber band and then breaks causing plasma to hurl out: solar storm

- Takes 18 hours for the solar storm to reach the Earth but the Earth's magnetic field deflects the storm to run down the magnetic lines toward the poles (day or night auroras depending on which side of the Earth).

2. Exploring the Auroras (Northern Lights)
    a. Visit the website: https://www.icelandair.com/en-gb/northern-lights/
    b. Click on the 3 lines in the top, right corner to navigate the site.
    c. Choose any of the options to find out more about the Northern Lights (aurora).
    d. Click on "Create Your Own Aurora" to create an aurora. You can adjust the sliders for oxygen/nitrogen levels, altitude and KP index.
    e. What is the KP index and how does it impact the auroras? Are you more likely to see an aurora when there is a higher or lower KP index?
    f. How do each of the three indicators impact the color of the auroras?
    g. What triggers the lights?
    h. For more information on the KP index and predictions of auroras, visit https://en.vedur.is/weather/forecasts/aurora/

3. Exploring the sun's position, moon phases and more in augmented reality in user's location
    a. Download the Sun Position, Sunrise, and Sunset Demo AR app (only on Android).
    b. Explore the sunrise and sunset times in your current location. Change the day of the year and look at the sunrise and sunset 6 months ago. What is different? Which day is longer and why?
    c. Explore the solar and lunar path in the AR camera view currently and also 6 months ago. How does it change?
    d. Explore other data features such as moon rise and moon set times, moon phases.

4. Citizen Scientists Report Auroras
    a. AuroraSaurus is a site that allows users to report their sightings of auroras. However, it also shows probabilities of where the auroras will occur.
    b. Go to https://www.aurorasaurus.org/ and view where auroras are currently expected to be. Note that there are auroras at both the north and south poles. You can change the calendar to look back in time to see where the auroras occurred before. Look back to find when the last auroras were visible in the U.S. When was that and where were they visible?

Assessment:
What causes auroras (Northern and Southern Lights)?
Why do the auroras come in different colors?
Evidence for understanding could include having students looking at data on solar activity and predict aurora events.

Lesson 3: Solar Eclipses

Concept:
Solar Eclipses happen when the moon moves between Earth and the sun.
Eclipses do not occur every month because our moon's orbit is tilted with respect to Earth's orbit around the Sun by about five degrees.

Objectives:
Students will be able to use models to show the position of the Earth, sun, and moon during lunar phases and different types of eclipses. Students will be able to show the position of the Earth and sun as the seasons change.

Standards Addressed (Grades 5-8)

- **TEKS** (7)(B) demonstrate and predict the sequence of events in the lunar cycle;
- **NGSS** (MS-ESS1-1) This model of the solar system can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.

Materials:
Totality app downloaded on smartphone or tablet,

Activities:

1. Exploring eclipses
    a. Download the app called "Totality".
    b. The app default shows the next total eclipse that will occur nearest to the user's location. For the US, the next total eclipse is April 8, 2024.
    c. Explore that eclipse and the path. Determine how long the total eclipse will last where you are located and the time it will occur.
    d. Select the date feature at the top to see where other eclipses are occurring. What is the next one and where is it occurring?

2. Exploring pattern of motion in eclipses
    a. Download CoSpaces on a mobile device or view online at https://edu.cospaces.io/CTX-PTU. On a mobile device, put in the code "CTX-PTU"
    b. Explore the path of motion of the moon in relation to the sun. What will occur when the moon moves between the Earth and the Sun?

Assessment:
How do the patterns of motions in the Earth-Sun-Moon system create lunar phases, eclipses, and seasons?
Why don't we have solar and lunar eclipses every month?
Evidence for understanding could include having students build/draw models of: lunar phases, solar eclipse, lunar eclipse, and the seasons.

Lesson 4: Our Sun

Concept:
The sun is the center of our Solar System and is the largest, most massive object in our Solar System

Objectives:
Students will be able to identify the sun as the object at the center of our Solar System and that it is the largest, most massive object in the Solar System.
Students will be able to identify that the planets move around the sun in an elliptical orbit, which is nearly circular, due to the gravity of the sun.

Standards Addressed (Grades 5-8)

- **TEKS**: (8) (B) recognize that the sun is a medium-sized star located in a spiral arm of the Milky Way galaxy and that the sun is many thousands of times closer to Earth than any other star; (7)(A) model and illustrate how the tilted Earth rotates on its axis, causing day and night, and revolves around the sun, causing changes in seasons
- **NGSS**: Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe. (MS-ESS1-2) The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. (MS-ESS1-2), (MS-ESS1-3)

Materials:
smartphone/iPad; Titans of Space VR app; goggles; CoSpaces app on Smartphone or tablet (iPad); MergeCube; Galactic Explorer app

Activities:

1. View the video about Parker Solar Probe
   5 New discoveries from PSP (3m 26s)
   https://www.youtube.com/watch?v=ReQAUocScw0&feature=emb_logo

   Concepts presented:
   - Parker Solar Probe is the closest spacecraft to the sun
   - PSP has shown that the sun has a dust free zone
   - Magnetic field lines flip in a whip-like motion, different than we had thought before
   - PSP has observed several tiny bursts of solar energetic particles

2. Parker Solar Probe in CoSpaces (use MergeCube and smartphone)
   https://edu.cospaces.io/BET-VKC
   a) If a MergeCube is not available, print out the paper version of the cube and tape together or glue onto blocks.

https://www.google.com/search?client=safari&rls=en&q=printout+merge+cube&ie=UTF-8&oe=UTF-8
b) Download the Cospaces Edu app on your smartphone
c) Try out the Solar Exploration Merge Cube AR Experience on CoSpaces at https://edu.cospaces.io/BET-VKC
d) There you can explore two spacecraft, Parker Solar Probe (PSP) & Solar Obiter, that are helping scientists better understand the sun and space weather! Note that different faces of the cube will trigger different views of the spacecraft under examination. Does the PSP or the Solar Orbiter have larger solar panels?
e) Explore the orbits of PSP and Solar Orbiter, using the CoSpaces app and/or your web browser on your computer. How are the missions of these two similar? What are the big differences in the orbits of these two? Why?

3. Titans of Space VR
   a) Go to http://parkersolarprobe.jhuapl.edu on your computer and find out the current location of PSP
   b) Find out PSP's current orbit and retrace its path from Earth to the sun using Titans of Space VR. Use the information feature as you view the Earth and moon, then Venus, then Mercury, to find out things like:
      a. How far is the Earth from the sun and what is this distance called?
      b. How much smaller is the moon than the Earth?
      c. Which planet is the hottest in the solar system"?
      d. How close is Mercury to the sun, and how does that compare with how close the Parker solar probe will go?
   c) Do you think that the "gravity assist" of Venus that occurs on some PSP orbits make the spacecraft go closer to or farther from the sun?
   Concepts addressed:
      - Elliptical solar orbits
      - Farthest point, aphelion, and the nearest point, perihelion, of an orbit around the sun
      - Relative speed of solar orbiters: Why does the PSP make 2-3 orbits around the sun and back out to the Earth's distance from the sun in the time the Earth orbits once? Answer: 67,000 mph speed of earth around sun; 83,000 mph speed of PSP?

4. Space 4D + AR to explore the solar system and spacecraft
   a. Download the Space 4D+ AR app on a smartphone or tablet (Requires flash cards with code to work)
   b. View the instructional video on how to use the app https://www.youtube.com/watch?v=SAfrBYlhR84
   c. Open the app and scan one of the cards in camera view. Input the provided serial number in the requested location. Once the authorization is complete, the images come alive!

d. Using the Solar System card, compare the size of the sun to the planets. To explore the Solar System, go to the Home screen and click on the six small boxes in the top right corner of the screen. Click on Solar System to view the planets revolving around the sun. The app allows the user to enlarge or minimize the objects to learn more about each planet.
e. Explore more about the planets, satellites, spacecraft (rovers), space objects and past space missions.
f. As you are exploring, what do you notice about the size, shape and color of the sun? Which planet is closest to the sun? Which planet is furthest from the sun? What is the current mission to “Touch the Sun”?

5. Explore the launch of the Parker Solar Probe
   a. Show the 360 video of the launch of the PSP(3m22s) (narrated by the head of NASA’s Heliophysics division, Nikki Fox) https://www.youtube.com/watch?v=BUClxcUbuNM

   Concepts addressed:
   - Purpose is to reach the sun
   - Protective heat shield
   - Corona

   b. Why was it necessary to use such a powerful rocket to launch the PSP which is roughly the size of a small car? What is the mission of the Parker Solar Probe?
   c. Download the “Galactic Explorer” app on a smartphone or tablet to use with the MergeCube.
   d. Explore the way in which the planets orbit around the sun. Touch each planet to explore more about it. Which ones have moons? Which planet is thought to be the first one formed in our solar system?

      We usually think of Saturn when we think of rings around a planet. Which planet has 13 rings? Which planet is considered our sister planet and why?

Assessment:
What object is at the center of the Solar System?
Why is the sun at the center of the Solar System, as opposed to a planet or moon?
How is gravity important to us?
Evidence for understanding could include drawing/labeling a diagram of the Solar System, emphasizing scale of the sun compared to the size of the planets.
What is the shape of the orbit of the planets around the sun?

Concept:
Our heliosphere acts as a giant shield, protecting the planets from galactic cosmic radiation.

Objectives:
The student will understand the importance of the heliosphere in protecting the Earth.

Background information
on the heliosphere https://science.nasa.gov/heliophysics/focus-areas/heliosphere

Terms:
heliosphere: giant bubble around the sun and its planets, known as the heliosphere. Acts as a giant shield, protecting the planets from galactic cosmic radiation

Standards Addressed (Grades 5-8)

- **TEKS** (3)(B) use models to represent aspects of the natural world such as an atom, a molecule, space, or a geologic feature (10) (B) identify how global patterns of atmospheric movement influence local weather using weather maps that show high and low pressures and fronts;
- **NGSS** Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (M S-ESS1-3) Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models. (MS-ESS1-1)

Materials:
computer and display for videos; Oculus Quest with Heliophysics Spacecraft Exploration App (NASA)

Activities:

1. View these background videos for content foundation
   a. https://svs.gsfc.nasa.gov/13642 11 Years Charting the Edge of The Solar System (Show the first 1m 30s of video) (4m 16s)
   Concepts addressed:
   - solar cycles (11 year)
   - how they heliosphere protects the solar system
   - solar wind

   b. https://svs.gsfc.nasa.gov/11429 Sun Magnetic Field Flip Live Shots and Media Resources (3m 17s)
   Concepts addressed:

- Magnetic fields
- Sun spots
- Solar activity
- Solar cycle (minimum to maximum and back; 2021 nearing peak
- Coronal mass ejections – interruptions in our communications and power grid
- Auroras

2. To view the orbits of different sun-observing spacecraft, go to the "Coordinated Heliosphere: How Solar Missions Work Together" https://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=4805&button=recent

   Concepts Addressed:
   - Satellite orbits
   - Complementary instruments

3. Challenge: Scroll down to the table of important events when the orbits of satellites align to make special measurements possible. One example listed is:

Encounter Window (yyyy-mm-dd)	Imagers	*in situ* Instruments
2021-04-24 to 2021-05-01	STEREO-A, SOHO, Solar Orbiter	Parker

What are "in situ" instruments? Can you name two of these on Parker Solar Probe? What do you think is the role of "Imagers" in this encounter? Why do you think a combination of these four spacecraft might give a better explanation of the sun and the heliosphere than one alone?

Assessment:

How many miles is 1 Au? Why is this distance important to people on Earth?

The heliosphere extends 11 billion miles out from the sun. How much farther is that than the distance from the sun to the Earth? Does knowing this make you feel protected (by the Sun) while living on Earth?

NASA is creating a better picture of how the Sun and magnetosphere work by combining views from the instruments on several satellites. Based on the video productions you have viewed, can you explain why a picture taken of solar plasma being ejected from the sun by two satellites while a third satellite is measuring energy released might give a better explanation of the event than either alone?

Additional Resources Related to the Sun

Additional background info on the sun
Sun 101: National Geographic (5 min)
https://www.youtube.com/watch?v=2HoTK_Gqi2Q

Sun as Art: NASA Thermonuclear Art
An hour of footage showing the vast changes in the sun
https://www.youtube.com/watch?v=6tmbeLTHC_0

Solar Cycles (26m 22s)
https://science.nasa.gov/science-at-nasa/episode-21-our-next-solar-cycle
Solar cycle #25 began in Sept 2020
Concepts: Solar minimum (not as active), Solar maximum (very active), sun spots

First ever 3D VR filmed in space: One Strange Rock (4m 32s)
https://www.youtube.com/watch?v=dwHBpykTloY

VR Spacewalk Experience in 360 (6m 23s)
https://www.youtube.com/watch?v=hEdzv7D4CbQ

Solar Wind Prediction Center provided by NOAA
https://www.swpc.noaa.gov/products/real-time-solar-wind

Solar Week hosted each year by Multiverse
http://multiverse.ssl.berkeley.edu/Solar-Week
In 2021, Solar Week is March 22 – 26 but the resources are there all the time.

The Sun is not an average, yellow star (solar radiation spectrum)
https://bjmendez.blogspot.com/2015/11/the-sun-is-not-average-yellow-star.html

PBS Nova Labs: An Educator's Guide to the Sun
https://www.pbs.org/wgbh/nova/labs/about-sun-lab/educator-guide/

NASA Coding Challenges https://www.tynker.com/hour-of-code/nasa-moon-2-mars

NASA Space Place about Eclipses: https://spaceplace.nasa.gov/eclipse-snap/en

UNT UNIVERSITY OF NORTH TEXAS

NASA Partner