



Name: \_\_\_\_\_ Date: \_\_\_\_\_ Class: \_\_\_\_\_

Title: What do Scientists Learn about the Universe from Observing Solar Eclipses?

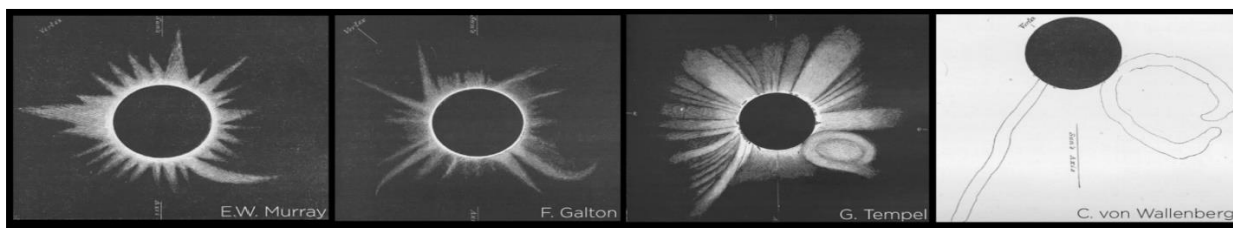
## Student Sheet

### 1. Total Eclipse Background

1. [A Total Solar Eclipse Revealed Solar Storms Years Before Satellites](#) video questions.
  - a. What scientific discoveries were made by viewing total solar eclipses, even before the modern satellite age, in the 1970s?
  
  
  
  
  
  
  
  
  
  
  - b. What is a coronal mass ejection (CME)?

### 2. Early Eclipse Images -

These drawings made by early scientists, seen in the video, were made by using small-aperture telescopes between 6 and 10-inches in diameter with carefully designed filters so that the faint atmosphere of the Sun, the corona, could still be viewed.



Early eclipse images from 1860. Sketches of the corona from different scientists who observed the eclipse. All the images show a version of a curved extension of the corona., Credit: NASA Scientific Visualization Studio,

<https://mynasadata.larc.nasa.gov/sites/default/files/inline-images/Early%20Eclipse%20Images%20cropped.png>

- a. What did these early observations reveal during the 1860 eclipse?



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- c. Comparing images: Examine the two images of the Sun below, figures 1 and 2.



Figure 1: A photograph of a total solar eclipse.  
Credit: NASA/Nat Gopalswamy

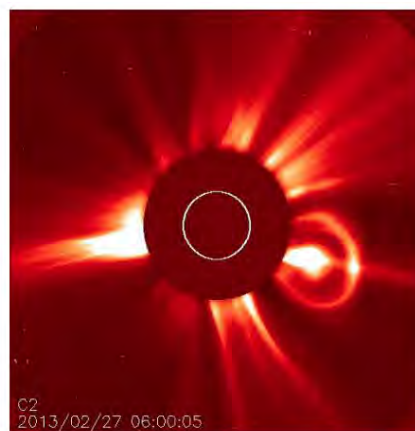


Figure 2: A coronagraph showing the Sun's corona. This image shows solar eruptions including solar flares and a coronal loop. Credit: NASA/ESA SOHO

The image in Figure 1 is what you would expect to see during a typical total solar eclipse, during the moment of totality when it is safe to remove your solar eclipse glasses. When the Moon blocks the bright light of the Sun's surface, you are able to see the Sun's atmosphere, the corona, shown as white light shining out from behind the Moon.

The image in Figure 2 is a coronagraph image, taken by NASA's SOHO spacecraft. A coronagraph simulates a total solar eclipse, blocking the Sun with an occulting disk to reveal its outer atmosphere, the corona. The Sun, behind the occulting disk, is outlined by the white circle in the center.

1. How are these two methods of viewing the Sun similar?



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## 2. Explore: Solar Eclipse Discovery Cards

Using the information on the [Solar Eclipse Discovery Cards](#), work together as a group to construct a timeline of how total solar eclipses have helped humans form a new understanding of the universe.

## 3. Explore Solar Wind

Have students use the WSA-Enlil model to analyze space weather predictions. WSA-Enlil is a large-scale, physics-based prediction model of the heliosphere, used by the Space Weather Forecast Office to provide 1-4 day advance warning of solar wind structures and Earth-directed coronal mass ejections (CMEs) that cause geomagnetic storms. [NOAA Space Weather Prediction Center WSA-ENLIL Solar Wind Prediction link](#)

Have students answer the questions about the solar wind.

1. Record the dates of the collected data: \_\_\_\_\_
2. Record the dates of the predicted data: \_\_\_\_\_
3. Pinwheel Plot Observations:
  - a. Is there an increase in the plasma density and velocity of the solar wind during the time period of collected data?
  - b. How does the collected data inform the predicted data?
4. Line Graph Observations:
  - a. Is there an increase in the plasma density and velocity of the solar wind during the time period of collected data?
  - b. How does the collected data inform the predicted data?
5. Compare the pinwheel plot and line graph.
  - a. How do the graphs change as the solar wind hits the two STEREO observatories and Earth on the pinwheel plot?
6. Analysis: If a solar eruption, like a coronal mass ejection (CME) can take several days to reach Earth, how does the collected data help scientists predict the effects of space weather on Earth? Provide reasoning and evidence to support your claim.



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#### 4. Explore Solar Features

1. Two videos of the August 2012 solar event
  - a. What did you see? Describe it in as much detail as you can.
  - b. Where on the Sun did you see it?
  - c. Record at least three observations of changes you observe in the features of the Sun in the data Data Table 1: 304 Angstrom Filter on the Student Sheets.
  - d. Repeat the process with the second video and complete Data Table 2: 171 Angstrom Filter.



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Data Table 1: 304 Angstrom Filter		
UTC Timestamp	Observation	Location
Initial Observations Aug. 31 11:00 - 14:30		



Name: \_\_\_\_\_ Date: \_\_\_\_\_ Class: \_\_\_\_\_

Data Table 2: 171 Angstrom Filter		
UTC Timestamp	Observation	Location
Initial Observations Aug. 31 11:00 - 14:30		





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- b. Compare the data from each video and record similarities and differences in Table 3 in the student sheets.

*Remember that these two videos were taken in different wavelengths of UV light, which we cannot see. Orange was assigned to one wavelength (304 Å) and yellow was assigned to another wavelength of light (171 Å). Different wavelengths of light are better for viewing some features of the Sun than others. Some features show up in one wavelength that don't show up in another.*

1. Compare the general features of the Sun that you observe in each video. What are the similarities and differences? Record your observations in Data Table 3.

Data Table 3		
304 vs. 171 Angstroms (Å)	Similarities	Differences
<b>General Features of the Sun</b>		

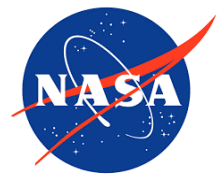


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2. Then do an in-depth analysis of the observations you made with each filter and determine if the events coincide. Record your observations in Data Table 4.
  - i. If you observed something on one video that you didn't observe on the other video, go back and take a second look. Add your observations to your analysis below.

Data Table 4				
Timestamp	304 Angstrom Filter Observation + Location	171 Angstrom Filter Observation + Location	Is this the same feature?	Justify your analysis





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**Solar Wind**  
The solar wind is 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. While it is much less dense than wind on Earth, it is much faster, typically blowing at speeds of one to two million miles per hour. The solar wind is made of charged particles — electrons and ionized atoms — that interact with each other and the Sun's magnetic field.

**Plumes and Plumelets**  
Plumes are streams of solar material that stretch out from coronal holes — dark patches of open magnetic field — on the Sun. They appear bright in extreme ultraviolet views of the Sun, and are made up of many smaller streamers, called plumelets. Plumes play a role in creating the high-speed solar wind.

**Sunspots**  
Sunspots are cooler regions on the Sun's visible surface caused by a concentration of magnetic field lines. Sunspots are the visible component of active regions, areas of intense and complex magnetic fields on the Sun that are the source of solar eruptions. Lasting from days to months, sunspots typically stretch 1,000 to 100,000 miles across. The number of sunspots goes up and down as the Sun goes through its natural 11-year cycle.

**Supergranules**  
Supergranules are networks of cells covering the Sun's visible surface that stretch some 18,000 miles across — more than large enough to frame two Earths side by side. They are caused by the convection of material in the Sun.

**Spicules**  
At any given moment, as many as 10 million wild jets of solar material burst up from the Sun's surface. Known as spicules, these grass-like tendrils of plasma erupt as fast as 60 miles per second and can reach lengths of 6,000 miles before collapsing.

**Flux Rope**  
A flux rope is kind of a magnetic structure that is thought to be at the heart of many of the Sun's eruptions. Flux ropes form in plasmas, such as the Sun's corona, when loops of magnetic field lines connect with each other. The resulting flux ropes are formed from bundles of magnetic fields that have a magnetic field wrapped around them, like the stripes on a candy cane. These twisted structures extend in a series of loops from the Sun's surface, and can be carried away from the Sun by a coronal mass ejection.

**Filament Eruption**  
Filaments are strands of solar material, cooler and denser than their surroundings, suspended above the Sun by magnetic forces. They appear as dark lines when seen against the bright Sun. (When a solar filament is seen at the edge of the Sun, against the blackness of space, it is called a prominence.) When solar filaments become unstable they can either fall back onto the Sun or erupt into space, sending a coronal mass ejection away from the Sun.

**Nanojets and Nanoflares**  
Nanojets are bright, thin tendrils of plasma that travel perpendicular to magnetic structures in the outer solar atmosphere, reaching lengths of thousands of miles. They are spawned by nanoflares, tiny explosions on the Sun caused by a process known as magnetic reconnection, which occurs in tangled magnetic field lines.

**Coronal Rain**  
Coronal, or plasma, rain is made of giant globs of plasma that drip from the Sun's outer atmosphere back to its surface. It occurs when particular conditions, such as magnetic field line configurations and local heating events in the corona, cause the plasma globs there to become cooler and denser than their surroundings, making them rain down.

**Coronal Mass Ejection (CME)**  
Coronal mass ejections, or CMEs, are large clouds of solar plasma and embedded magnetic fields released into space after a solar eruption. CMEs expand as they sweep through space, often measuring millions of miles across, and can collide with planetary magnetic fields. When directed at Earth, a CME can produce geomagnetic disturbances that ignite bright aurora, short-circuit satellites and power grids on Earth, or at their worst, even endanger astronauts in orbit.

**Sunquakes**  
Sunquakes are seismic-like activity on the Sun that ripple across the visible surface, not unlike earthquakes. They are known to accompany some solar flares, but scientists are uncertain how exactly they are triggered.

**Solar Flare**  
Solar flares are energetic bursts of light and particles triggered by the release of magnetic energy on the Sun. Flares are by far the most powerful explosions in the solar system, with energy releases comparable to billions of hydrogen bombs. The energetic particles accelerated by flares travel nearly at the speed of light, and can travel the 93 million miles between the Sun and Earth in less than 20 minutes.

**Coronal Hole**  
A coronal hole is a patch of the Sun's atmosphere with much lower density than elsewhere. In ultraviolet views of the Sun, coronal holes appear as dark splotches. These are regions where the Sun's magnetic field lines are connected directly to interplanetary space, allowing solar material to escape out in a high-speed stream of solar wind, leaving a dark "hole" near the surface of the Sun.

At the heart of our solar system is the Sun. Constantly churning material and magnetic fields there create an ever changing landscape of features that last from milliseconds to days. Here are a few of the most common features that can be seen on the Sun.

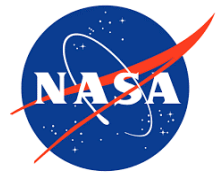
Credits: NASA/Mary Pat Hrybyk-Keith



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a. Identify Features

1. Graphic showing different features of the Sun.

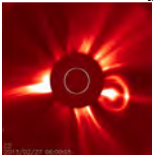
i. Which features do you think you observed in the videos?

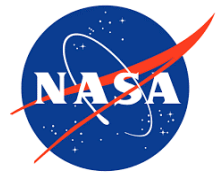
5. Complete your final analysis of the methods for observing the Sun.

a. What features of the Sun are best seen with different SDO's AIA filters?



b. What features of the Sun are best seen with a coronagraph?





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c. What features of the Sun are best seen during a total solar eclipse?



d. Why do NASA scientists use multiple methods for viewing the Sun?