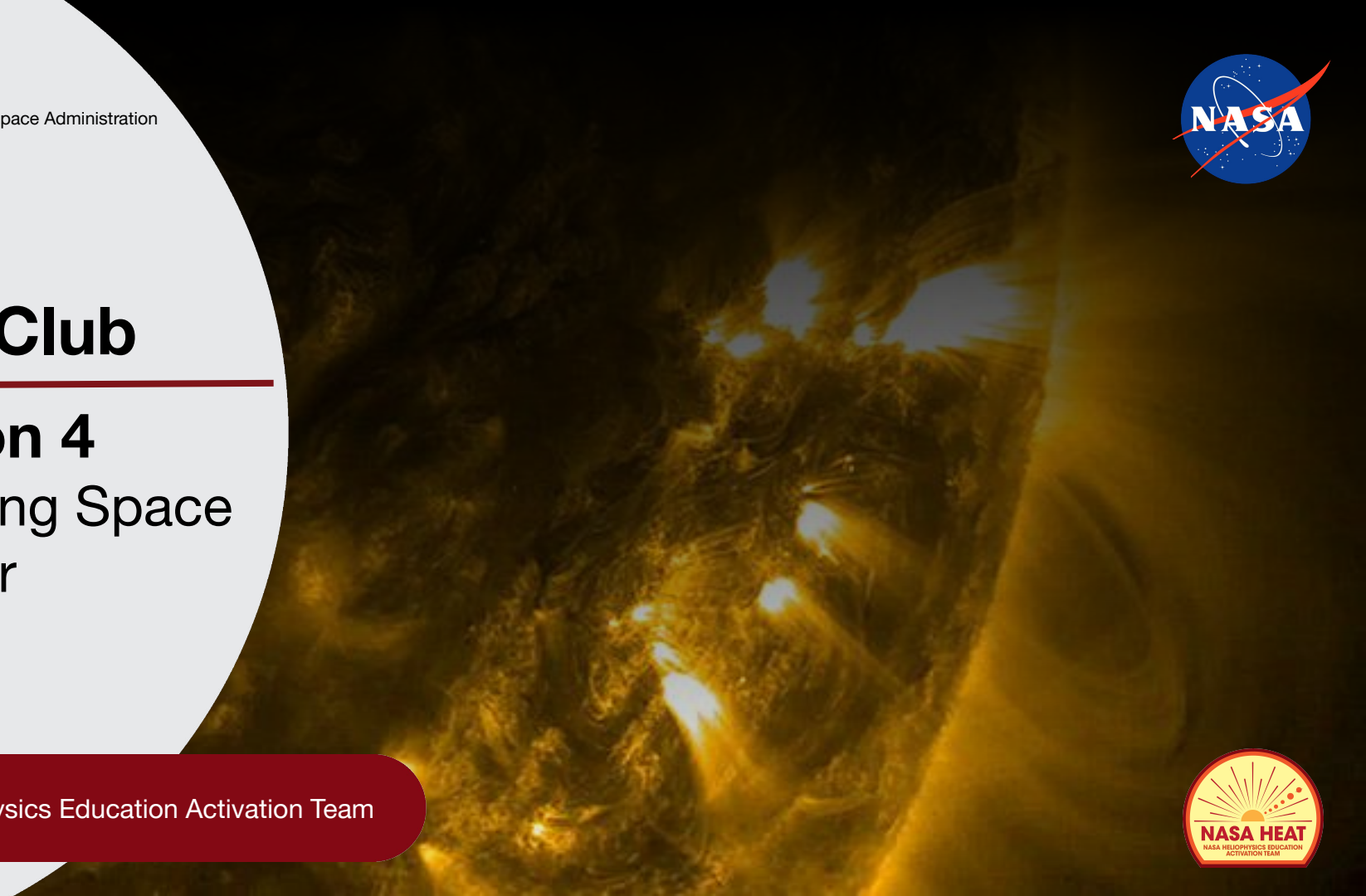
National Aeronautics and Space Administration

NASA Helio Club

Session 4

Predicting Space Weather



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Materials Needed for this Session

Youth Guide Page 46

Basics

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

Prior Knowledge/Evaluate

- ❑ (1) Handout_KWL_Session 4

Engage

- ❑ Digital Resources

Explore: Activity 1

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

Explain: Activity 2

- ❑ (1) Handout_NOAA Sunspot Data

Extend: Activity 3

- ❑ (1) Handout_MMS Model/Bookmark

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Youth Guide Page 57

Use a notebook or the extra paper in the NASA Helio Club Youth Guide to record observations, collect data, and organize ideas.

Session 4: Notes

What do you already know about space weather?

Youth Guide Page 48

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?	Record questions you have about space weather in this column.	Record what you learned about space weather in this column.

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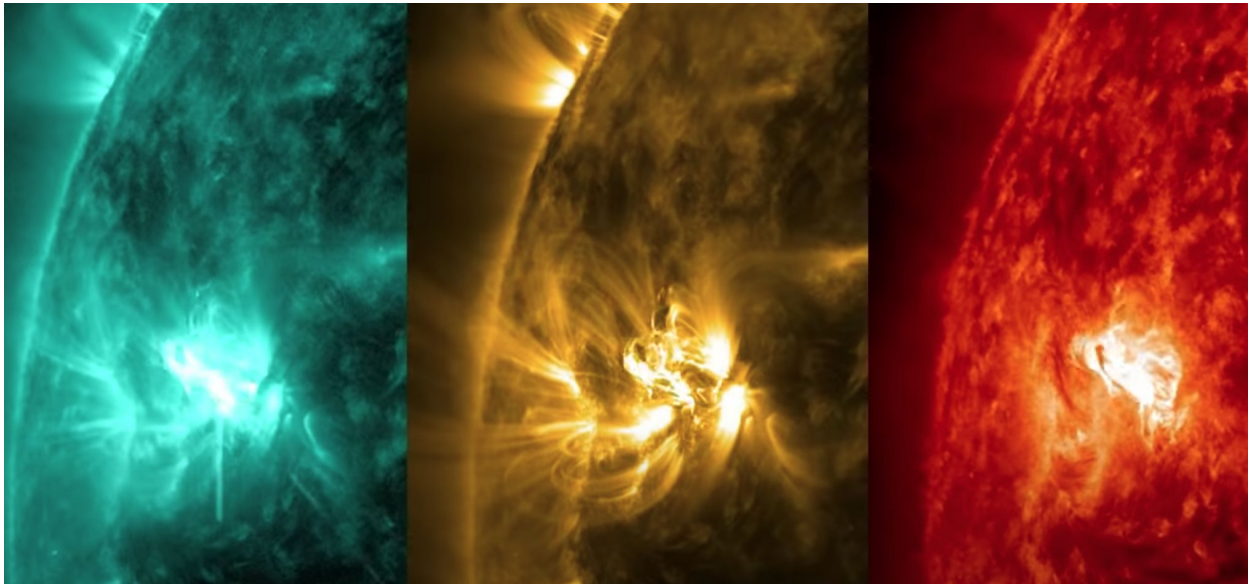
Video

The Difference Between CMEs and Solar Flares



Credits: NASA/SDO/ESA/SOHO/S. Nune

Solar Cycle

Approx. 11-year cycle

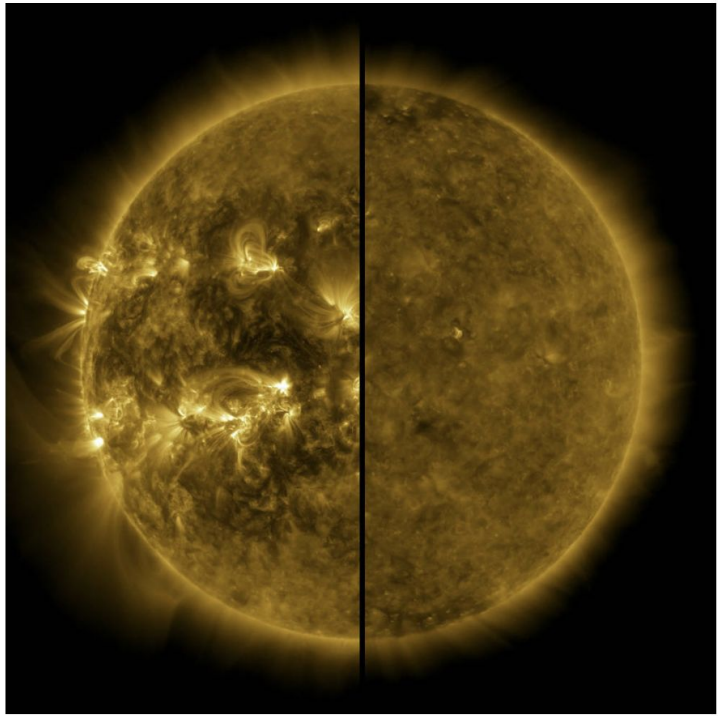
Last Solar Max = **2014**

Last Solar Min = **2019**

Next Predicted Solar Max = **2025**

2025 Peak Sunspot Prediction = **115 sunspots**

Solar Maximum 2014 | **Solar Minimum 2019**



Credit: NASA SDO

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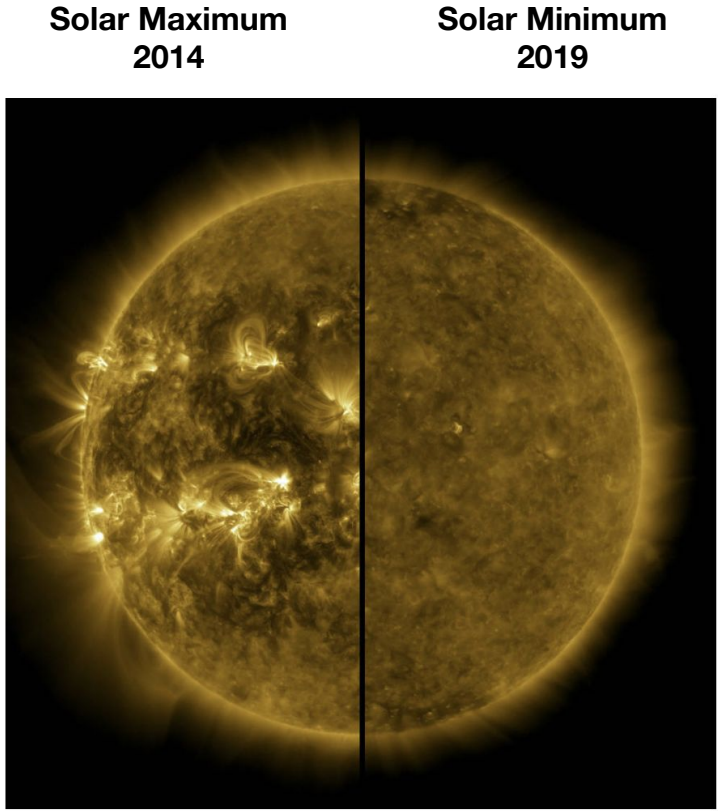
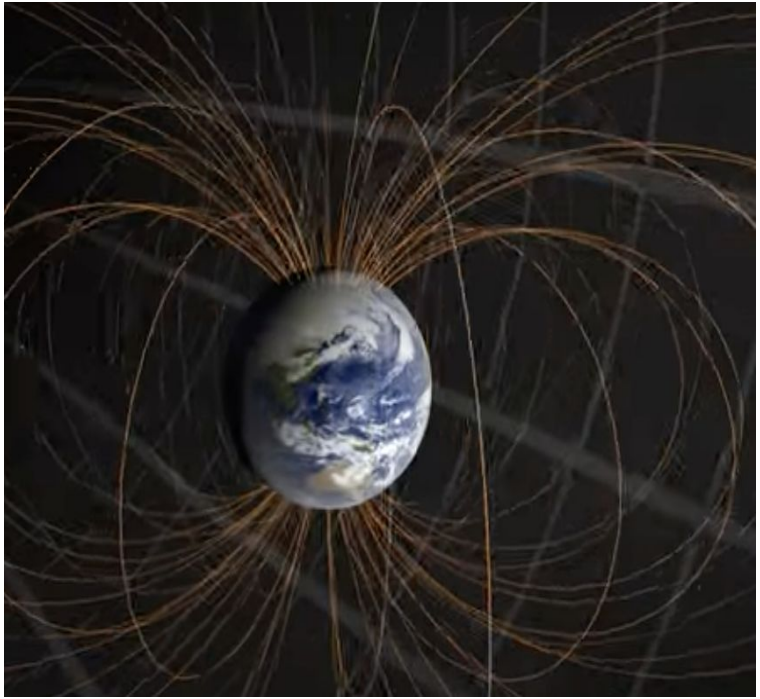
Video

[The Solar Cycle as Seen from Space]



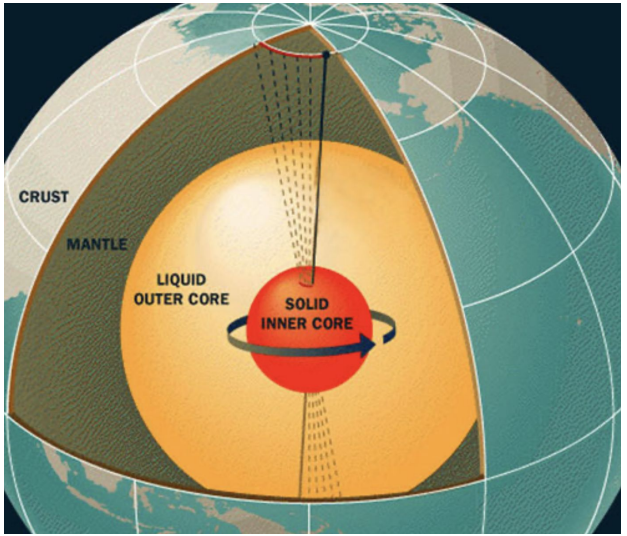
Credit: NASA SDO

Earth’s Magnetic Field



Visualization of Earth’s Magnetic Field
Credit: NASA SVS

Earth’s spinning, liquid metal outer core is responsible for Earth’s magnetic field.



Earth’s internal structure: dense solid metallic core, viscous metallic outer core, mantle and silicate-based crust. *Credit: NASA*

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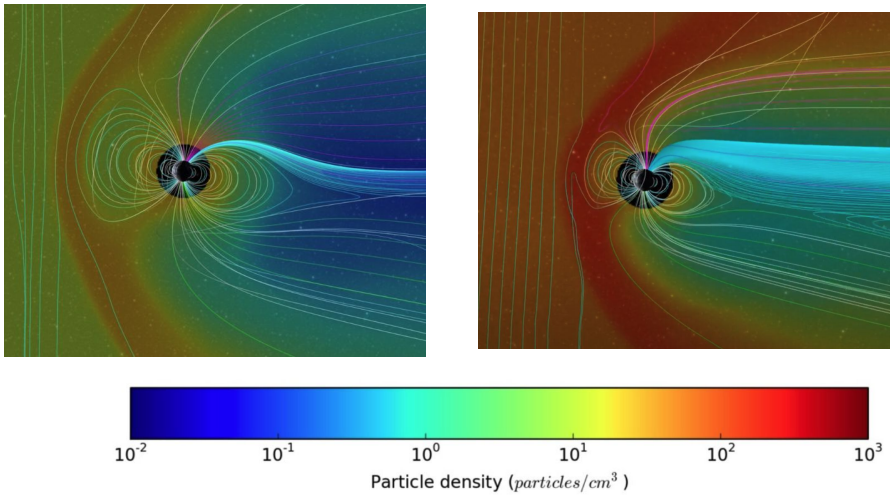
Video: CME Interacting with Earth's Magnetosphere

Comparative Magnetospheres: A Noteworthy Coronal Mass Ejection

This animation from NASA's Scientific Visualization Studio is a computer model made from real data collected during a **Coronal Mass Ejection (CME)** that erupted from the Sun in 2006, launching particles Earthward.



Credit: NASA SVS/ GSFC

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

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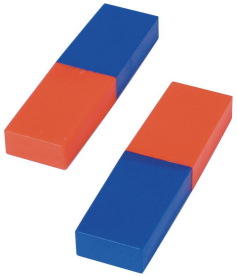
Magnetism is a Key Ingredient in Space Weather

How does a compass work?

What will happen when you put a bar magnet near the compass?



Plotting Compass

Gyrocompass

A gyrocompass has the ‘north arrow’ always oriented to magnetic north of Earth.

A plotting compass has the needle always oriented to magnetic north.

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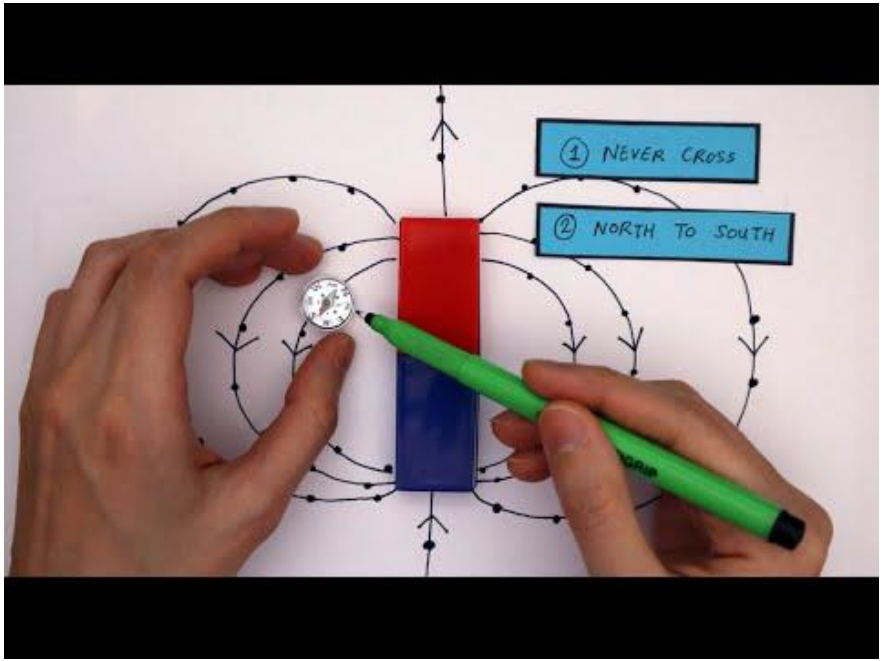
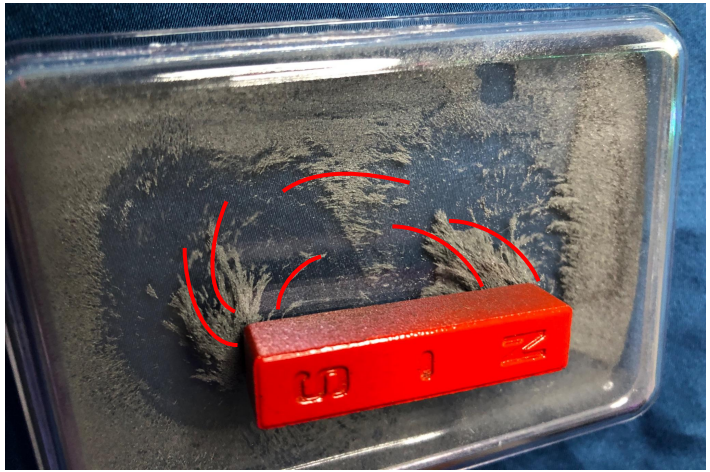
Drawing a Magnetic Field of a Bar Magnet



Credit: VT Physics

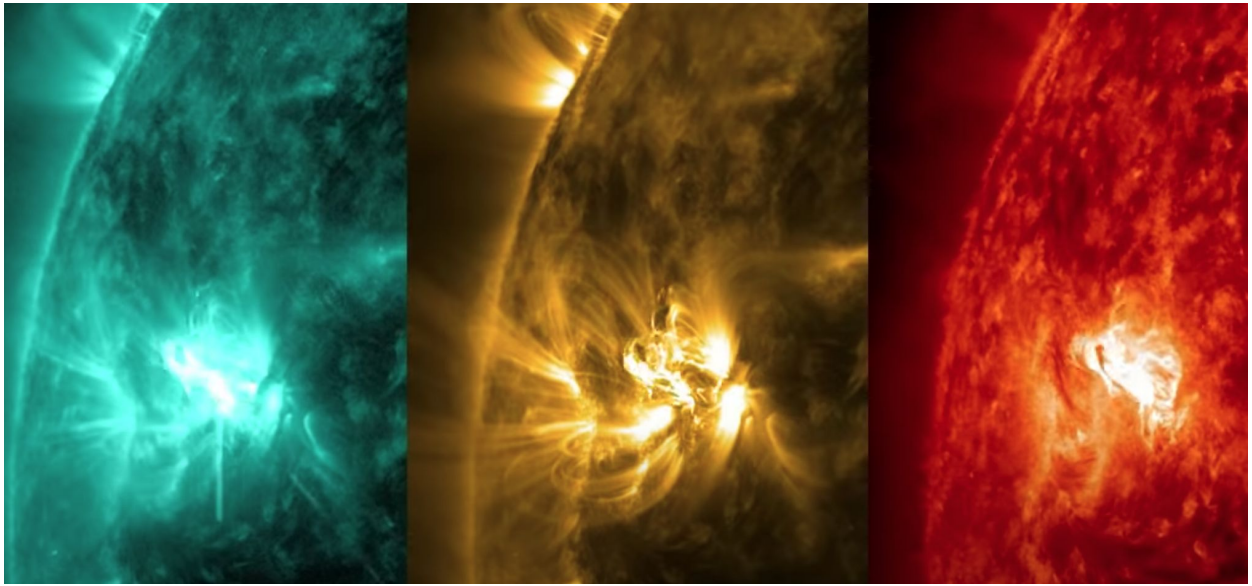
Experimenting with Magnetic Fields

Verify your results by using iron filings to visualize the magnetic field of the bar magnet. Notice the iron filings show a pattern of radiation out from each pole.



Video

The Difference Between CMEs and Solar Flares



Credits: NASA/SDO/ESA/SOHO/Nune

Can you find evidence of magnetic fields on the Sun in the images in the video?

Ways to Predict Space Weather

When the **solar wind** intensifies **geomagnetic storms** can occur, which are disturbances in Earth's **magnetic field**. The severity of a **geomagnetic storm** is measured by how much Earth's **magnetosphere** is disturbed as a result of the **solar wind**.

- ★ We can monitor the Sun's activity and predict **geomagnetic storms** by counting the number of **sunspots**, which occur in greater numbers when the Sun is active.
- ★ We can also measure the intensity of the **solar wind** by monitoring the changes in Earth's **magnetosphere,** which scientists can do with instruments on spacecraft and with magnetometer stations on Earth.

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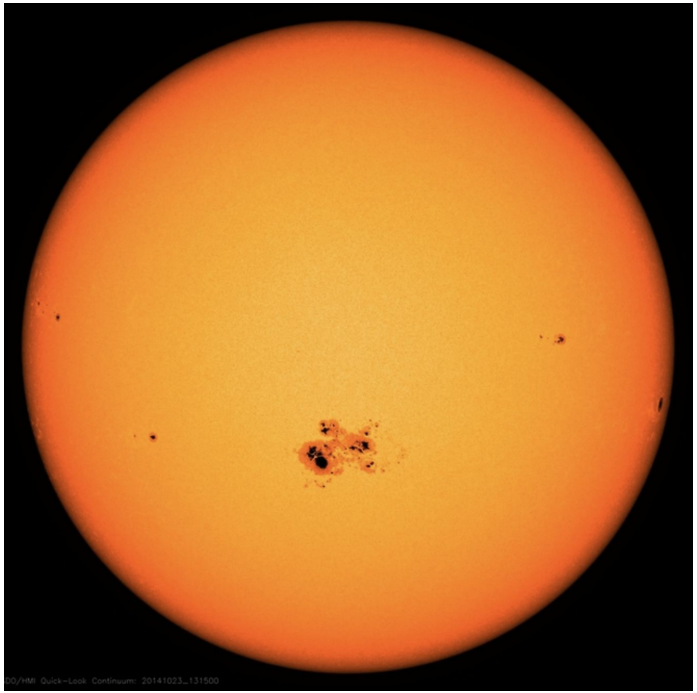
Sunspots



Sunspots are dark, cooler regions on the Sun's visible surface caused by a concentration of magnetic field lines, which make the plasma in these regions cooler and less luminous so that they appear dark.

A gigantic sunspot – almost 80,000 miles across -- can be seen on the lower center of the Sun in this image from NASA's Solar Dynamic Observatory captured on Oct. 23, 2014.
Image Credit: NASA/SDO

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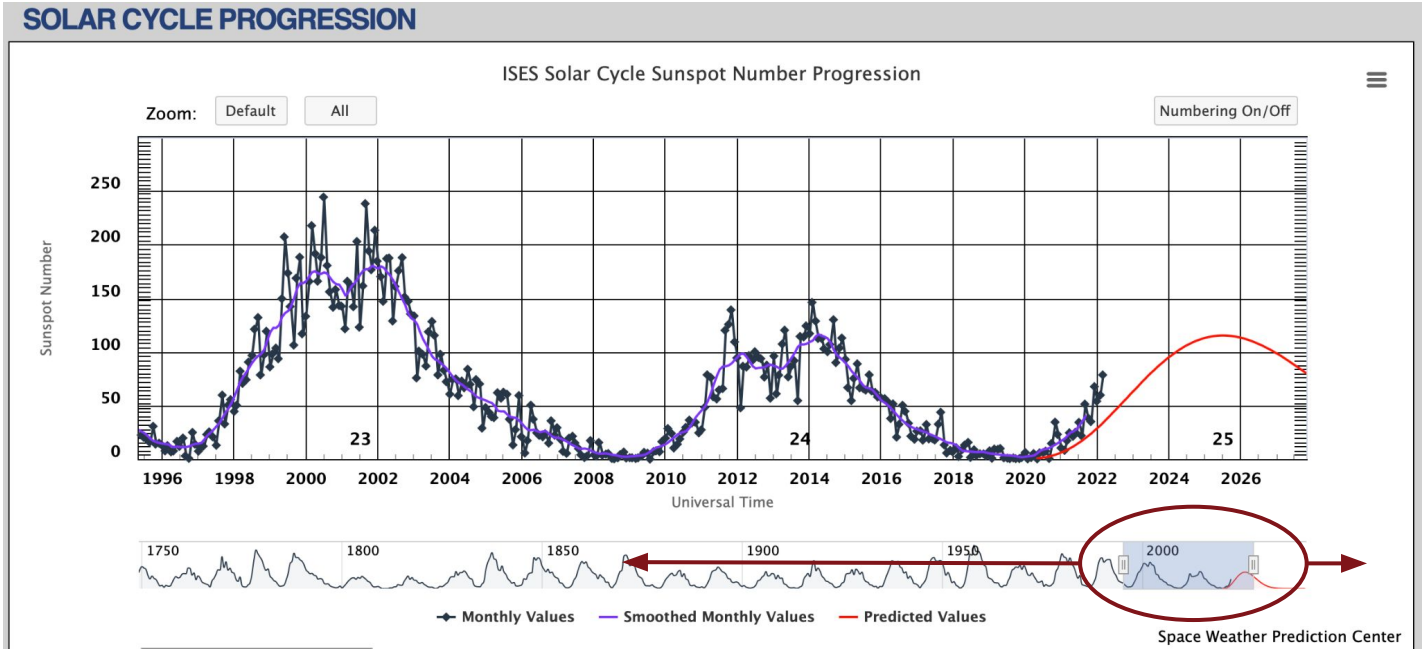
Solar Cycle: Sunspot Data 1750-2022

This interactive graph displays sunspot data from 1750 to the present.



Credit: NOAA

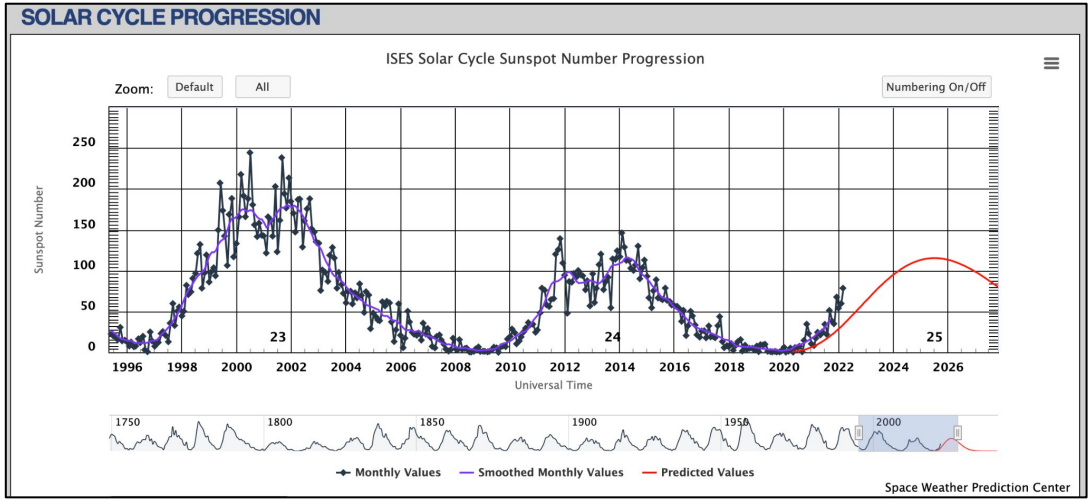
Use slider below the graph to view data from different time periods.

Analyze Sunspot Data

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	



Using the Kp-Index to Predict Space Weather

The **Kp-index** comes from the German words “planetarische kennziffer,” which translates loosely to “planetary index number.”

- 13 magnetometer stations around the world measure the level of geomagnetic fluctuation (not raw values).
- Measurements are taken every 3 hours.
- “K-value” ranges between 0-9, higher values mean higher fluctuations.
- The Kp-index is set by averaging the K-values from all 13 stations.

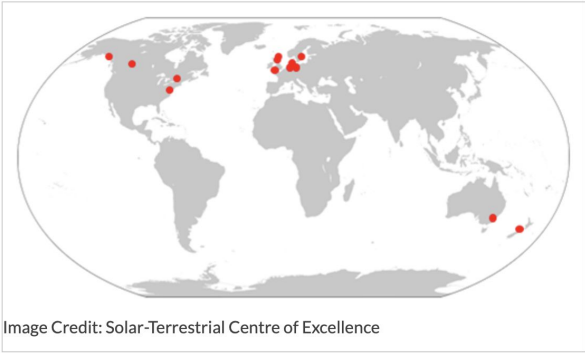
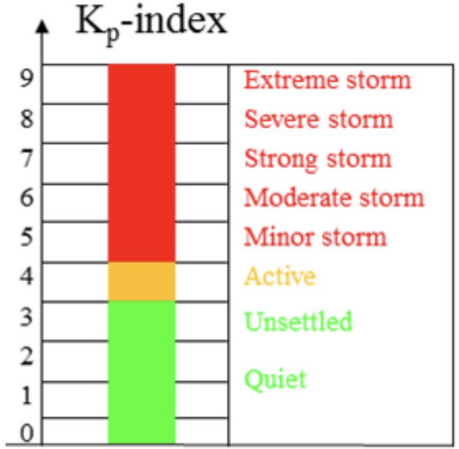


Image Credit: Solar-Terrestrial Centre of Excellence



Credit: NOAA

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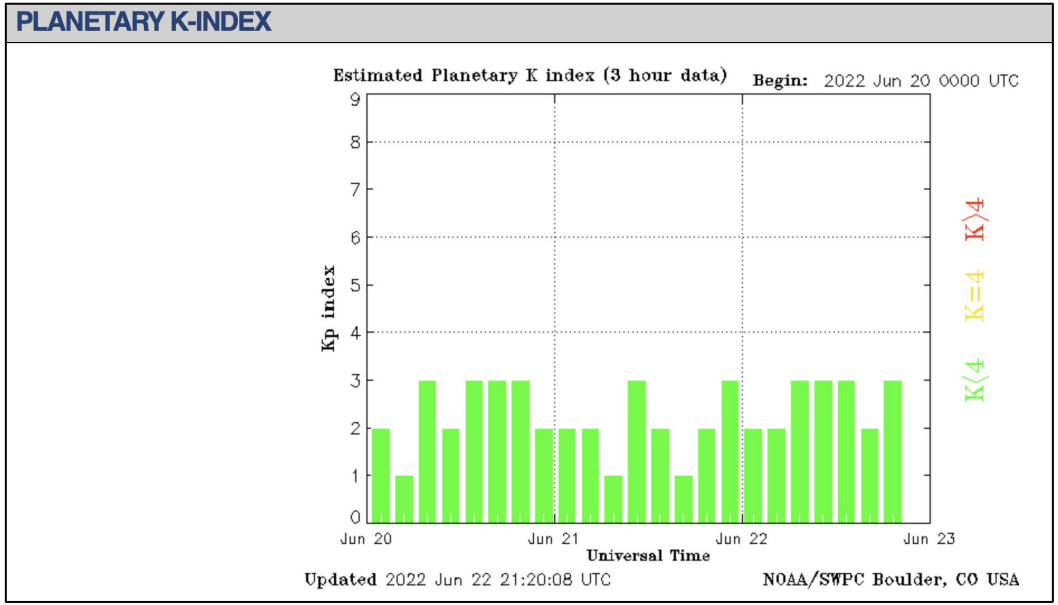
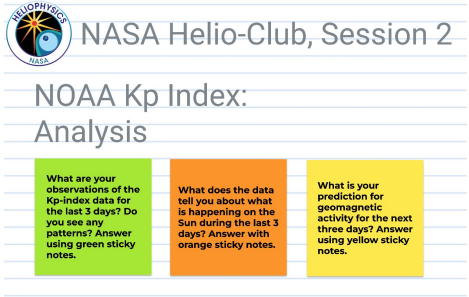
KP Index

Examine NOAA's Planetary K-Index Graph to see what the Kp-index was for the last 3 days.



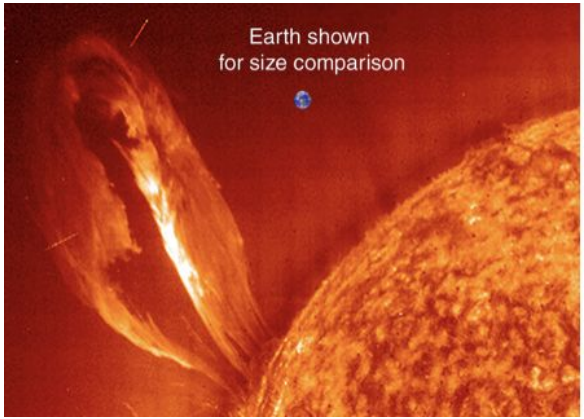
Credit: NOAA

Optional: Record your observations on the Google Jamboard [Board 3].



The Carrington Event

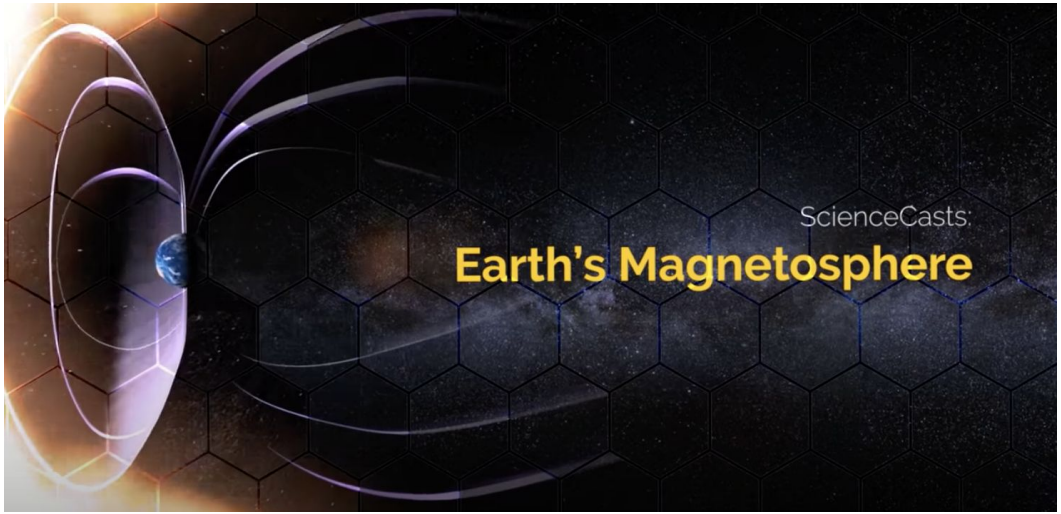
- The geomagnetic storm of 1859 (during Solar Cycle 10), also called the Carrington Event, was the largest geomagnetic storm ever recorded.
- This storm was associated with both solar flares and a pair of CMEs.
- According to NOAA, a solar storm on the scale of the Carrington Event today (Kp > 8) could severely damage satellites; disable communications via telephone, radio, and TV; and cause electrical blackouts.
- A gigantic storm, bigger than Carrington, nearly missed Earth in 2012.



Coronal Mass Ejection
Credit: ESA/ NASA / SOHO

Video: Earth's Magnetosphere

ScienceCasts: Earth's Magnetosphere



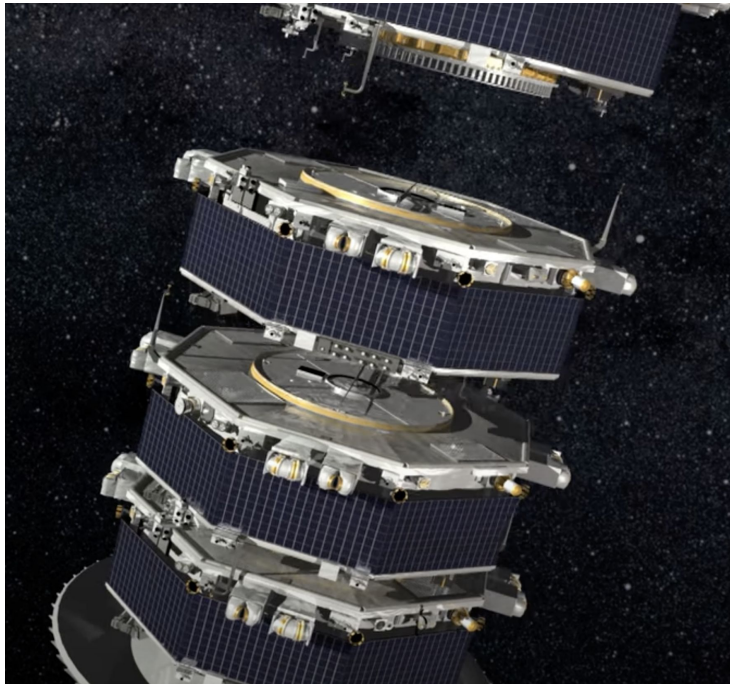
Credit: NASA

Consider:

- Why is Mars' atmosphere so thin?
- What does it mean that Earth's **magnetosphere** is permeable?
- How would you describe **magnetic reconnection**?

Video: NASA's Magnetospheric MultiScale (MMS) Mission

How Will the 4 MMS Spacecraft Launch and Deploy?



Animation of the MMS Spacecraft
Credit: NASA

Consider:

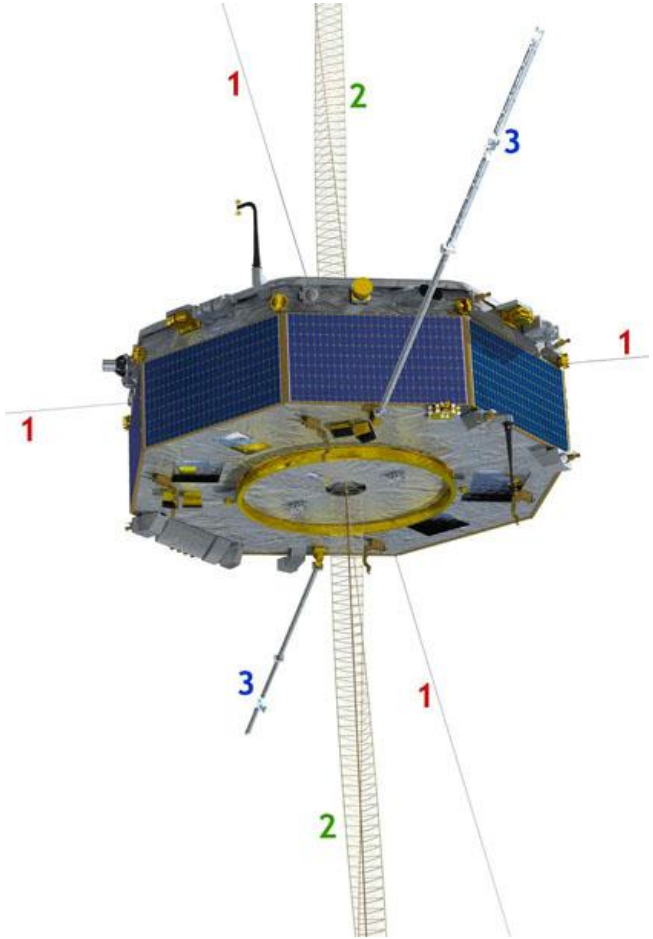
Why are there four spacecraft and what shape is their formation in?

MMS Instruments

1. **SDP-Wire Booms**
2. **ADP-Antenna Masts**
3. **Magnetometer Booms**

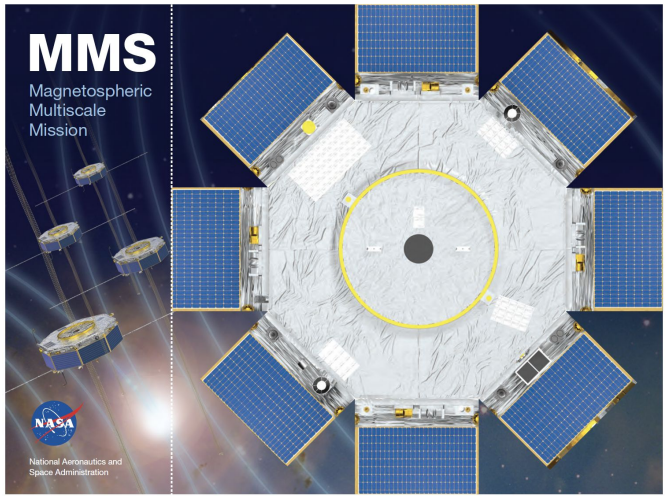
The **Spin-plane Double Probe (SDP) instrument** and the **Axel Double Probe (ADP) instrument** work together to measures the 3-D electric field, and the **Magnetometer instruments** measure the magnetic field.

Magnetic fields and electric fields are perpendicular to one another. Each field affects the other.

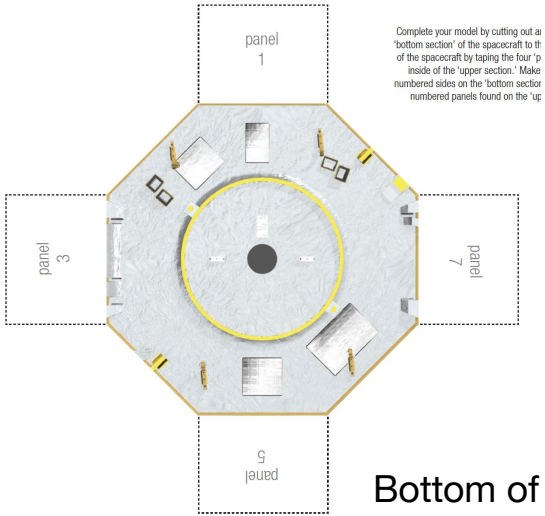


MMS Model + Bookmark

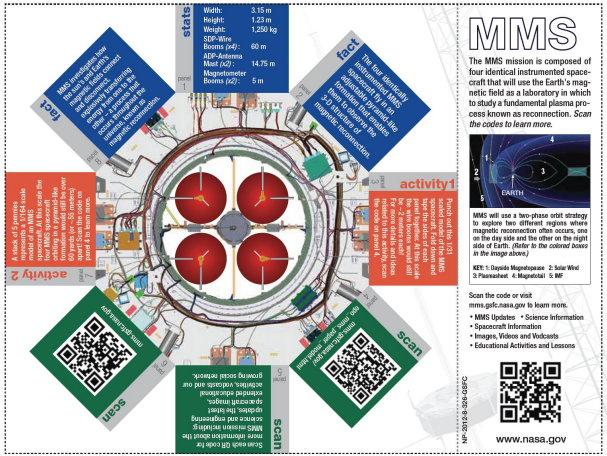
Youth Guide Page 51



Front of Model
Credit: NASA GSFC



Bottom of Model
Credit: NASA GSFC



Back of Model
Credit: NASA GSFC

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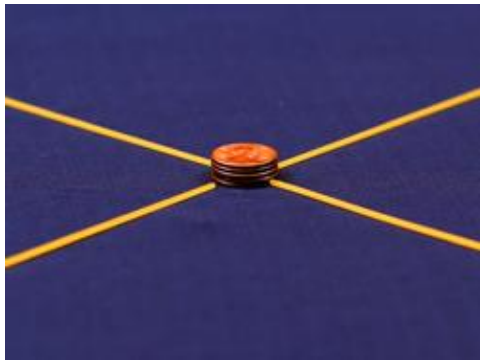
MMS Model + Bookmark

A stack of 5 pennies represents a 1/164 scale model of an MMS spacecraft.

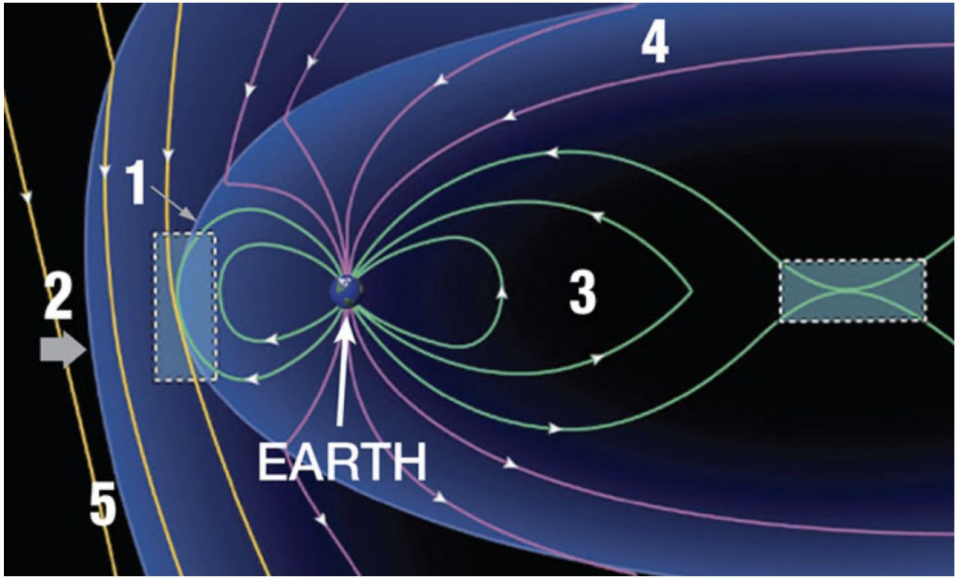
Spaghetti strands (typically 26-cm in length) simulate the 8 deployable booms.

At this scale the four MMS spacecraft orbiting in a tetrahedron-like formation would still be over 60 yards (or ~55 meters) apart! That's over half the length of a football field!



Credit: NASA GSFC

The magnetosphere has different parts.



1. **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.
2. **Solar Wind:** The plasma of charged particles coming out of the Sun in all directions at supersonic speeds.
3. **Plasma Sheet:** A sheet of plasma that extends down the magnetotail dividing the two lobes of the Earth's magnetic field.
4. **Magnetotail:** The extreme extension of a magnetosphere, on the side of a planet opposite the Sun, shaped by the solar wind.
5. **Interplanetary Magnetic Field (IMF)**: The solar magnetic field carried by the **solar wind** among the planets of the solar system.

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What did you learn about space weather?

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?	Record questions you have about space weather in this column.	Record what you learned about space weather in this column.

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Session 4 Major Concepts

- ★ The Sun is made of a superheated matter called **plasma**, which constantly flows outward from the Sun as the **solar wind**.
- ★ While the **solar wind** is constantly flowing from the Sun, sometimes it can intensify because of complex **magnetic fields** on the Sun, which cause solar eruptions that release enormous amounts of energy into the **heliosphere**.
- ★ Approximately every 11 years the Sun's magnetic poles switch, causing a fluctuation in magnetic activity from low to high and to low again. This is called the **solar cycle**.
- ★ During **solar maximum,** the Sun's **magnetic fields** are very active and become entangled, causing huge bursts of energy in the form of **solar flares** and **coronal mass ejections (CMEs)**.
- ★ During **solar minimum**, a period when the Sun's **magnetic fields** are more stable, the likelihood of solar eruptions is very low.

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Session 4 Major Concepts

- ★ Both Earth and the Sun have **magnetic fields**.
- ★ A **magnetosphere** is the region around a planet dominated by the planet's magnetic field.
- ★ Earth's **magnetosphere** protects Earth from the **solar wind** and other harmful effects of the Sun.
- ★ **Space weathe**r describes the variations in the space environment between the Sun and Earth. In particular **space weather** describes the phenomena that impact systems and technologies in orbit and on Earth.
- ★ When the **solar wind** intensifies **geomagnetic storms** can occur, which are disturbances in Earth's **magnetic field**.

Session 4 Major Concepts

- ★ Scientists can monitor how active the Sun is during the **solar cycle** by counting **sunspots** and by using ground stations to monitor the changes in Earth's **magnetic field.**
- ★ The **Kp-index** is a nine-point scale that measures the level of disturbance in Earth's **magnetosphere.**
- ★ The process of connecting and disconnecting magnetic fields occurs throughout the universe and is known as **magnetic reconnection**.
- ★ The Sun's and Earth's **magnetic fields** connect and disconnect explosively, transferring energy from one to the other. This energy can create **space weather** and **geomagnetic storms**.
- ★ Earth's magnetic field has different parts, which is determined by how the **solar wind** interacts with the **magnetosphere.**

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