National Aeronautics and Space Administration

The Heliophysics Big Year

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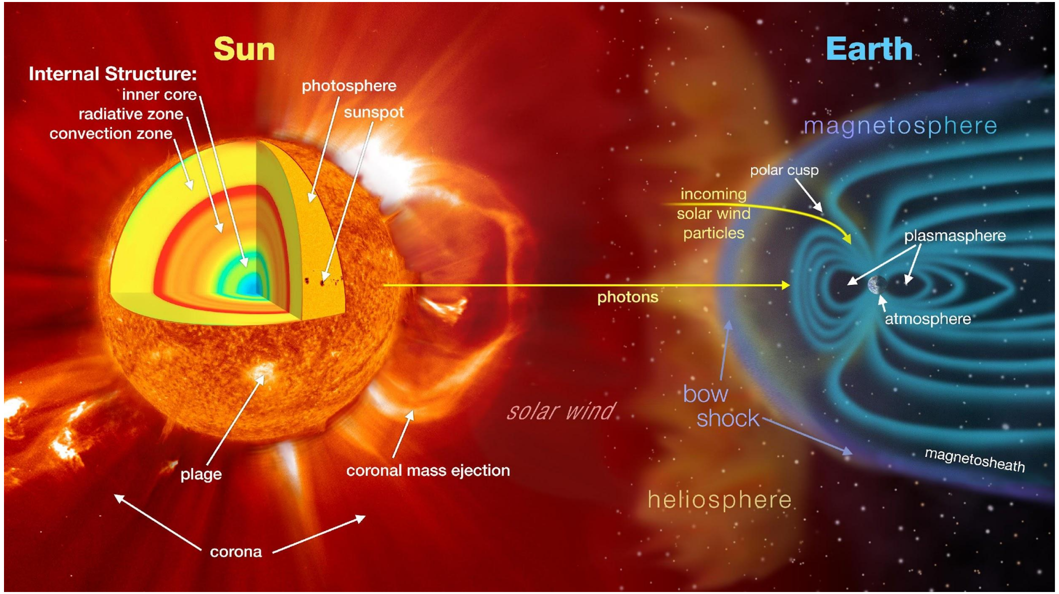
NASA Heliophysics Education Activation Team

March 2023: What is Heliophysics?

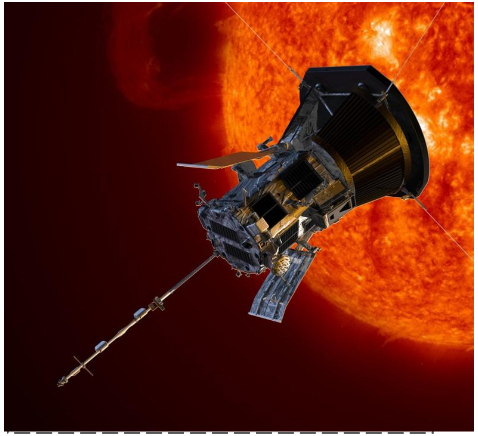
Heliophysics is the discipline in space science that deals with the matter and energy of our Sun and its effects on the solar system.

It also studies how the Sun varies and how those changes pose a hazard to humans on Earth and in space



Heliophysics Big Year Timeline

Annular Eclipse	Total Eclipse	Solar Parker Probe Perihelion
October 14, 2023	April 8, 2024	December 24, 2024



Heliophysics Big Year Themes

2023

- ☑ **October-** Annular Solar Eclipse
- ☑ **November-** Mission Fleet
- ☑ **December-** Citizen Science

2024

- ☑ **January-** The Sun Touches Everything
- ☑ **February-** Fashion
- **March-** Experiencing the Sun
- **April-** Total Solar Eclipse
- **May-** Visual Art
- **June-** Performance Art
- **July-** Physical and Mental Health
- **August-** Back to School
- **September-** Environment / Sustainability
- **November-** Bonus Science
- **December-** Parker's Perihelion

https://www.nasa.gov/science-research/heliophysics/nasa-announces-monthly-themes-to-celebrate-the-heliophysics-big-year/

March 2024 : NASA's Big Questions

1. What causes the Sun to vary?
2. How do the Earth and the heliosphere respond?
3. What are the impacts on humanity?

These Big Questions form the basis for the

Framework for Heliophysics Education

https://science.nasa.gov/learn/heat/big-ideas/

How to Teach Heliophysics

Framework for Heliophysics Education

3 Heliophysics Investigatory Questions

3 NGSS-aligned Big Ideas per Question

3 Guiding Questions per Idea
-1 Question per Level-

Heliophysics Resource Database

1. **What causes the Sun to vary?**
   1.1 The Sun is really big and its gravity influences all objects in the solar system. (PS2, ESS1)
   1.2 The Sun is active and can impact technology on Earth via space weather. (PS1,PS2, PS4, ESS2, ESS3)
   1.3 The Sun's energy drives Earth's climate, but the climate is in a delicate balance and is changing due to human activity. (PS1, PS2, PS3, LS4, ESS2, ESS3)

1. **How do Earth, the solar system, and the heliosphere respond to changes on the Sun?**
   2.1 Life on Earth has evolved with complex diversity because of our location near the Sun. It is just right! (PS3, PS4, LS1, LS2, ESS2)
   2.2 The Sun defines the space around it, which is different from interstellar space. (PS2, ESS1, ESS2)
   2.3 The Sun is the primary source of light in the solar system. (PS1, PS2, PS3,PS4, ESS1)

1. **What are the impacts of changes on the Sun on humans?**
   3.1 The Sun is made of churning plasma, causing the surface to be made of complex, tangled magnetic fields. (PS1, PS2, ESS1, ESS2)
   3.2 Energy from the Sun is created in the core and travels outward through the Sun and into the heliosphere. (PS1, PS3, PS4, ESS1, ESS2, ESS3)
   3.3 Our Sun, like all stars, has a life cycle. (PS1, LS1, ESS1)

March 2024 – Experiencing the Sun

How does the sun affect us?

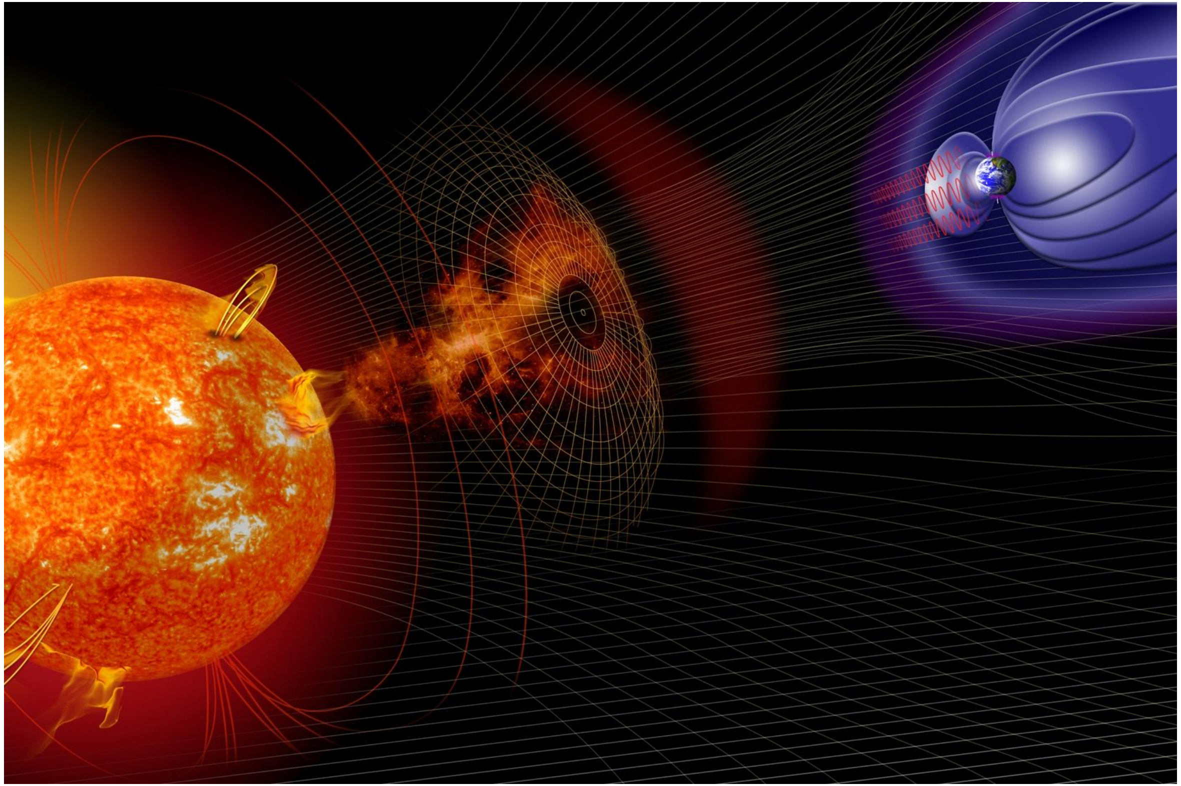
Gravity

Visible Light

Solar Flares

Coronal Mass Ejections

Solar Wind



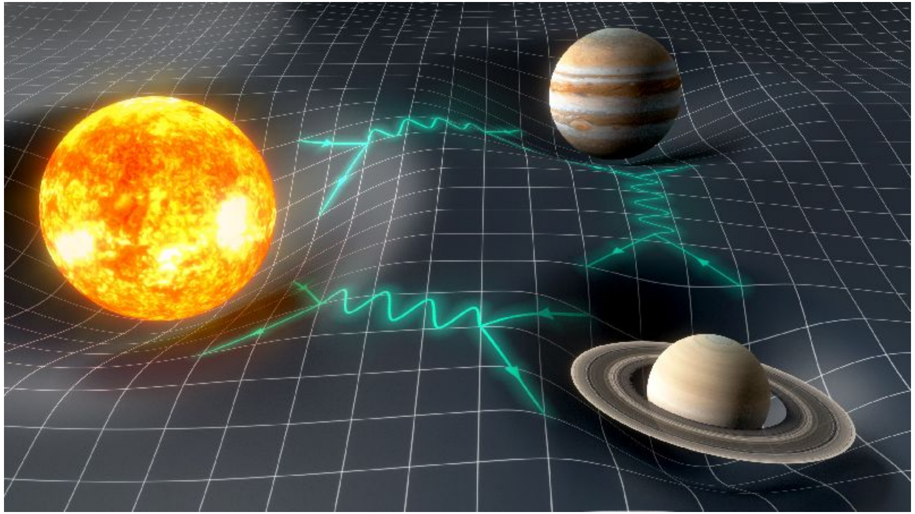
March 2024

1.2 The Sun is active and can impact technology on Earth via space weather. (PS1,PS2, PS4, ESS2, ESS3)

3.1 The Sun is made of churning plasma, causing the surface to be made of complex, tangled magnetic fields. (PS1, PS2, ESS1, ESS2)

March 2024: Easy Stuff - Gravity

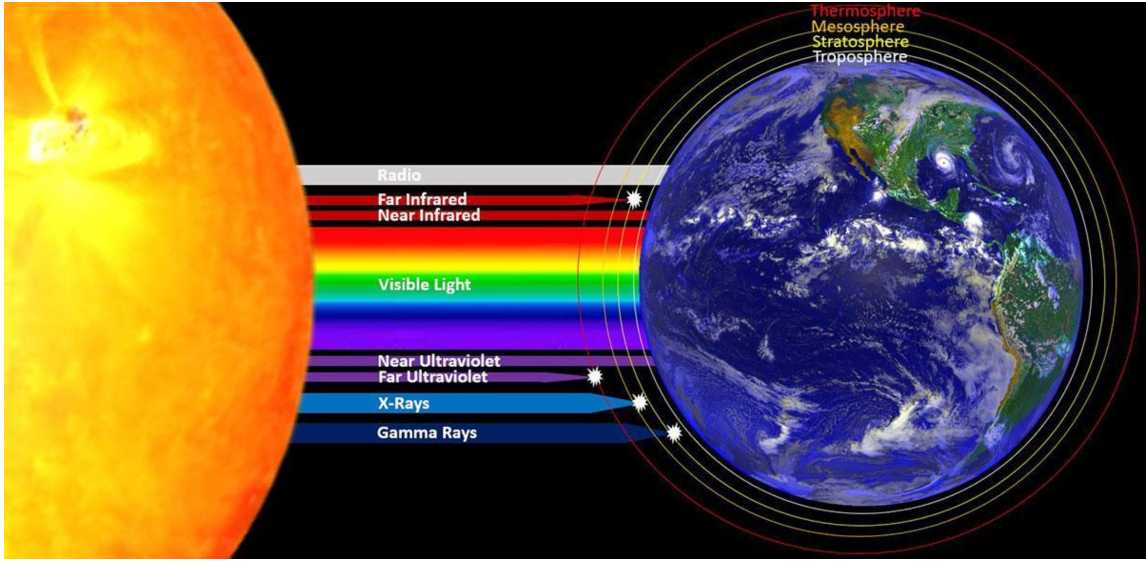
Gravity is not really a force.



Credit: Y. Gominet/Paris Observatory
https://physics.aps.org/articles/v12/113

March 2024: Easy Stuff - Radiation

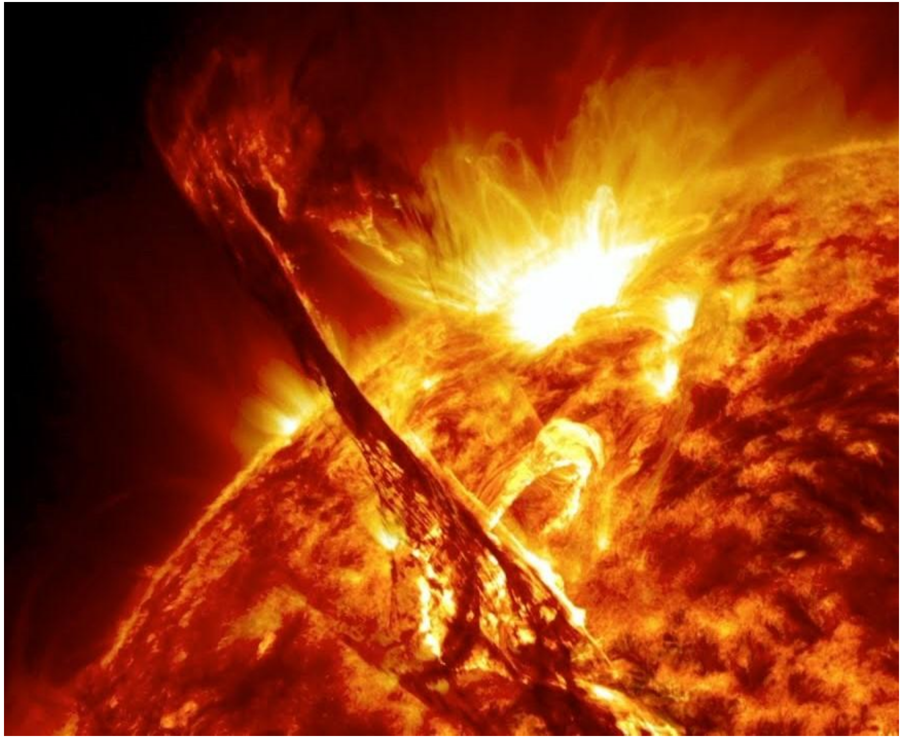
Light is produced by photons that carry energy.



Global Geoenginnering:
https://geoengineering.global/solar-radiation-management/

March 2024: Harder Stuff - Solar Flares

- Solar flares are created when magnetic fields near the sun’s surface get tangled up.
- The energy stored in the magnetic fields gets explosively released.
- This heats up nearby matter to millions of degrees.
- This hot plasma emits x-rays to give us an electromagnetic ‘blast’ that takes 9 minutes to get to Earth...if we are unlucky.

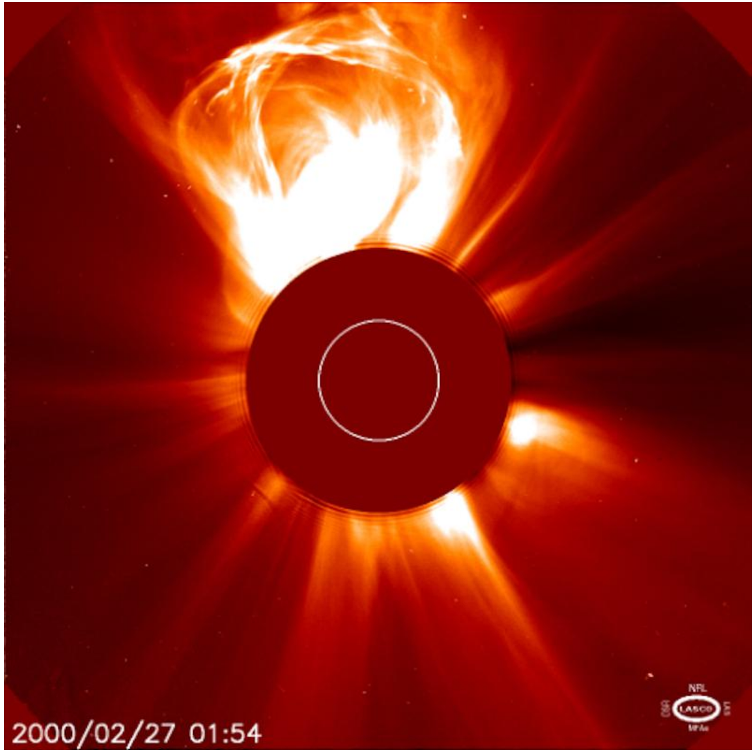


March 2024: Harder Stuff - Coronal Mass Ejections

Some of the energy in a flare can accelerate matter, ejecting it into space. These are called coronal mass ejections because we see them as clouds bursting out from the corona.

CMEs contain billions of tons of plasma and magnetic fields from the sun dragged along for the ride.

If a CME is directed at Earth, powerful disturbances are produced in Earth's magnetic field that cause spectacular aurora...and can harm our technology.

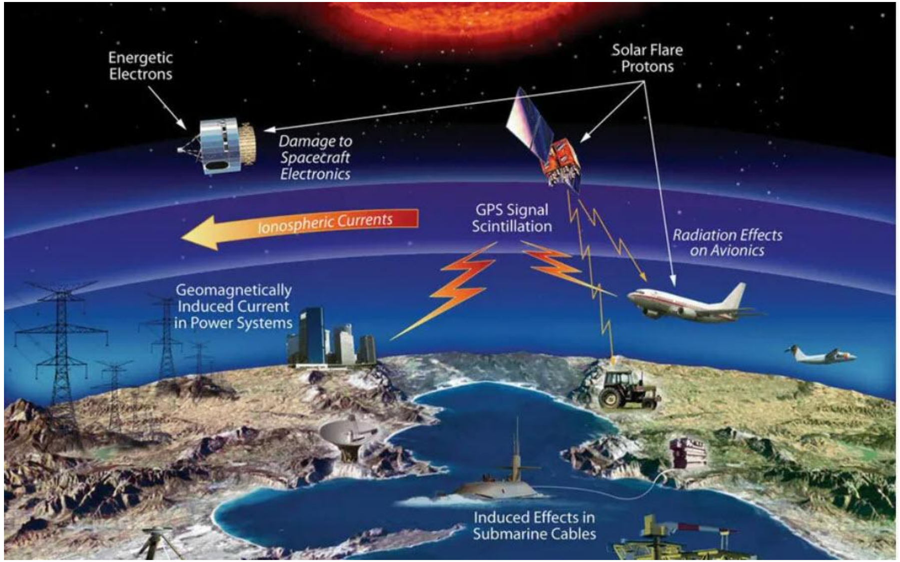


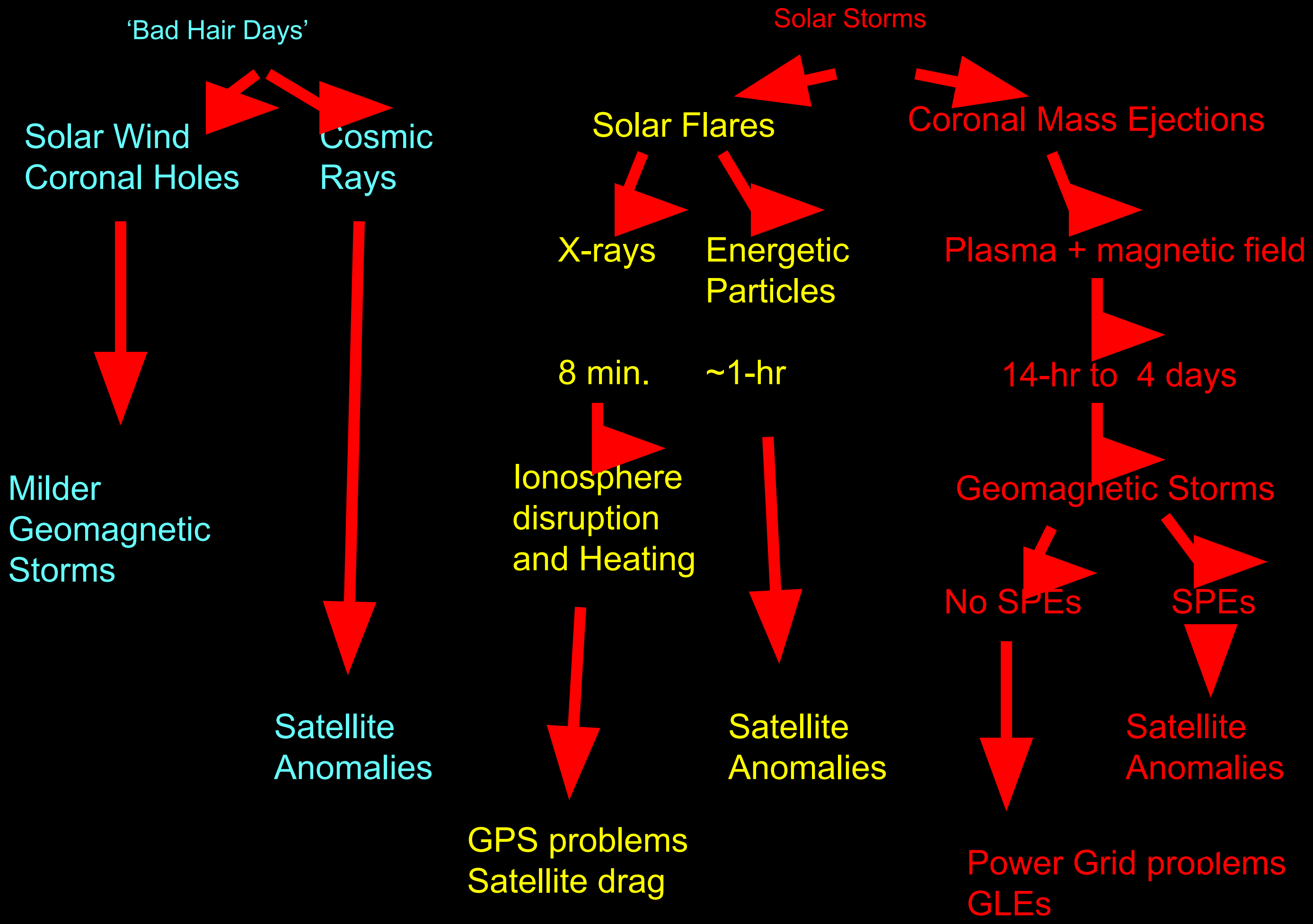
March 2024: Space Weather

A famous actress once said ‘*Lions and tigers and bears, oh my!”.*

Solar flares, coronal mass ejections, high-speed wind streams and the solar wind are ingredients to the bad things we call space weather.

Space weather affects many Earth systems, and can also invade our technology to cause electrical power outages and satellite failures.





‘Bad Hair Days’
Solar Storms
Solar Wind
Coronal Holes
Cosmic
Rays
Solar Flares
Coronal Mass Ejections
X-rays
Energetic
Particles
Plasma + magnetic field
8 min.
~1-hr
14-hr to 4 days
Milder
Geomagnetic
Storms
Ionosphere
disruption
and Heating
Geomagnetic Storms
No SPEs
SPEs
Satellite
Anomalies
Satellite
Anomalies
Satellite
Anomalies
GPS problems
Satellite drag
Power Grid problems
GLEs

March 2024: Beginners – Space Weather

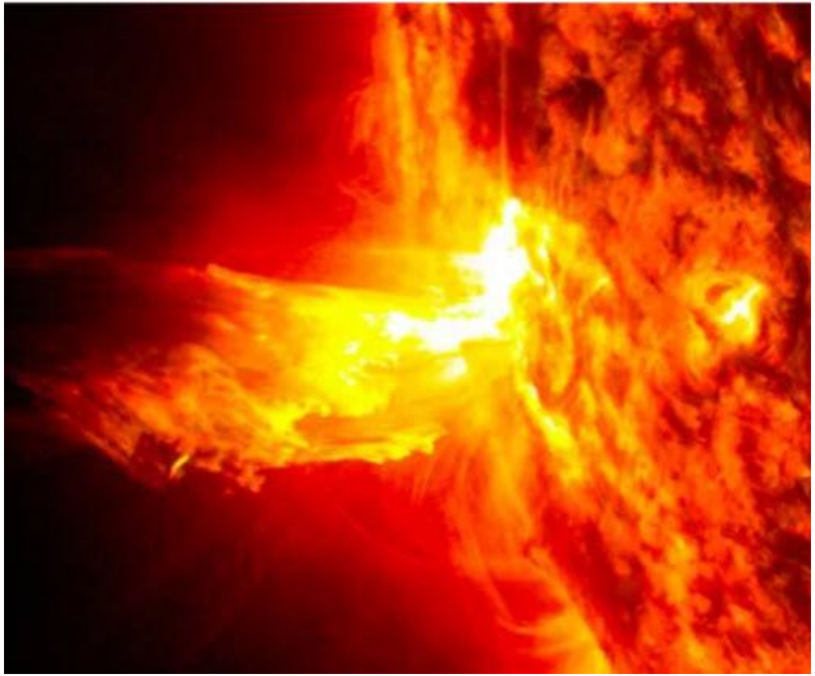
During a particular month the following events were recorded:

Total solar flares: 22

Total CMEs: 12

Both Flares and CMEs: 7

Based on this data, if you see a flare on the sun, what is the probability that a CME will also occur?



March 2024: Beginners – Space Weather

Total solar flares: 22

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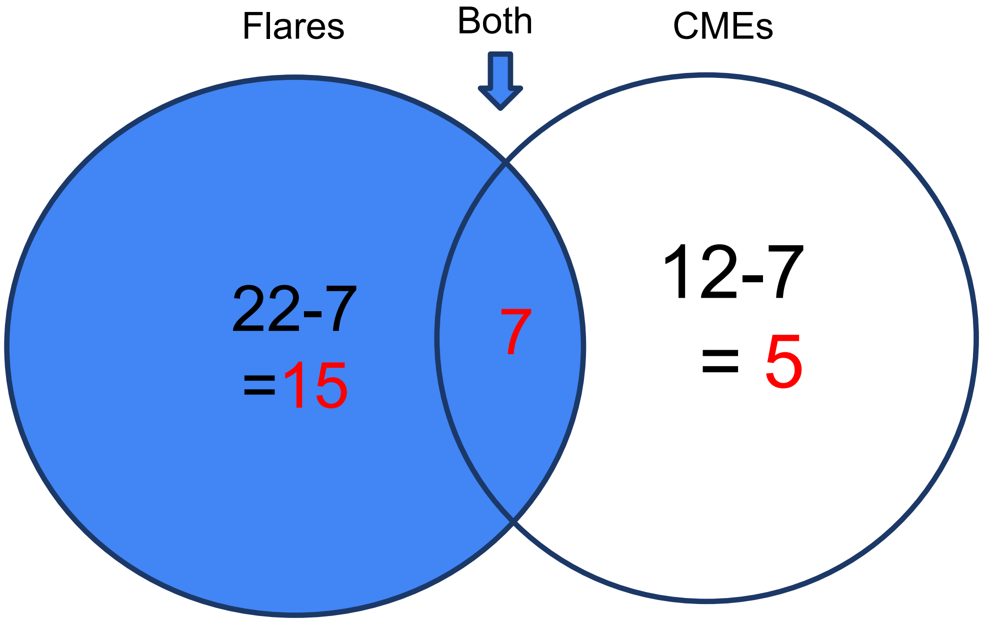
Venn Diagrams!



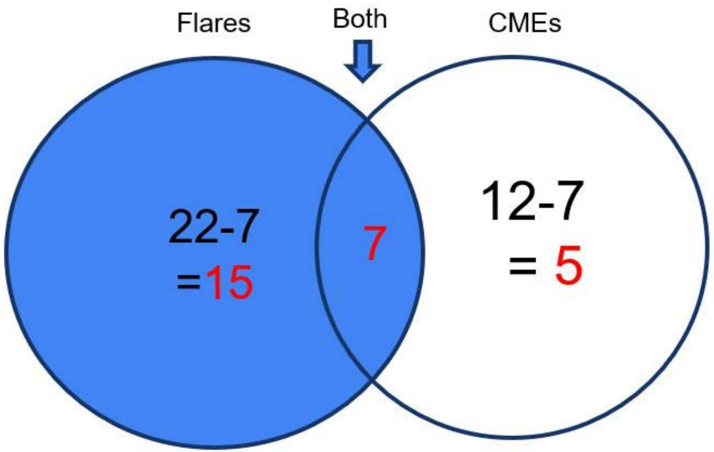
March 2024: Beginners – Space Weather

Based on this data, if you see a flare on the sun, what is the probability that a CME will also occur?

$$P = \frac{\text{Both CME and Flare}}{\text{All Flares Observed}} = \frac{7}{22}$$

= 0.32 or 32%

or about 1 in 3 odds.



March 2024: Intermediate – CME speeds and arrival

Top sequence: 12:39, 13:09 and 13:39.

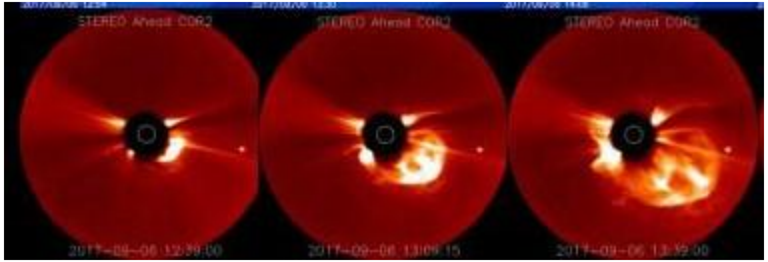
(NASA, SoHO LASCO Sep 6, 2017)

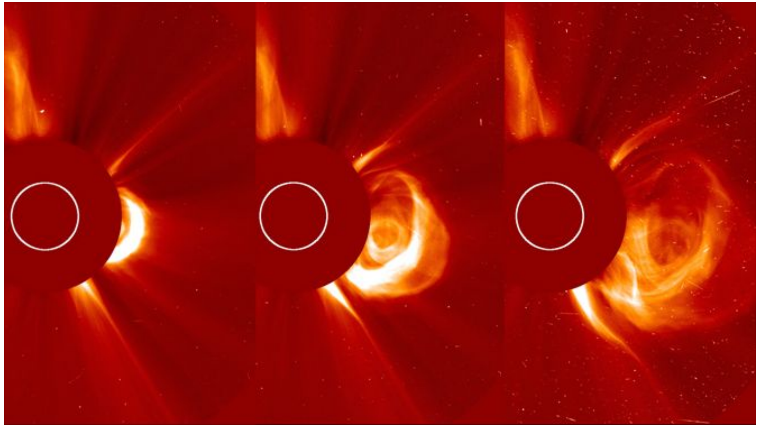
Solar disk diam: 2mm = 1.4 million km

CME Pos 1 = 4mm at T = 12:39

Pos 2 = 7mm at T = 13:09

Pos 3 = 12mm at T = 13:39





March 2024: Intermediate – CME speeds and arrival

Solar disk diam: 2mm = 1.4 million km

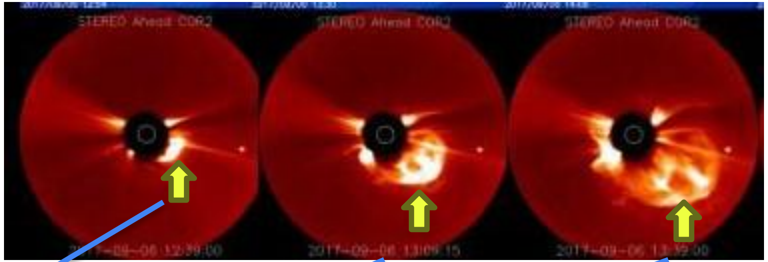
So 1 mm = 700,000 km

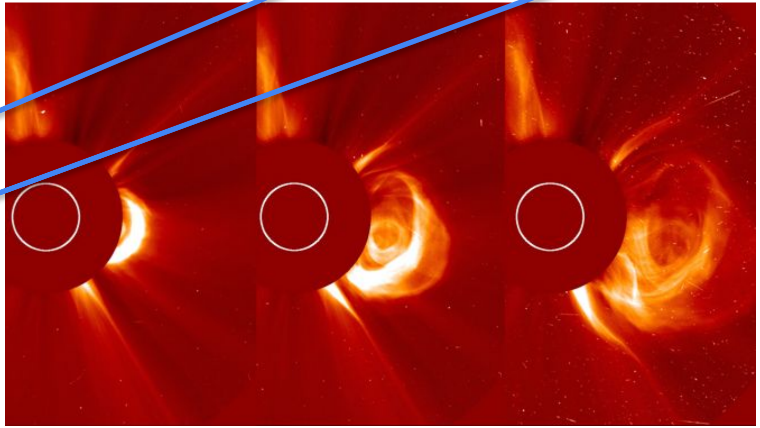
Convert mm to km to get:

Pos 1 = 2.8 megaKm at T = 0 min

Pos 2 = 4.9 megaKm at T = 30 min

Pos 3 = 8.4 megaKm at T = 60 min





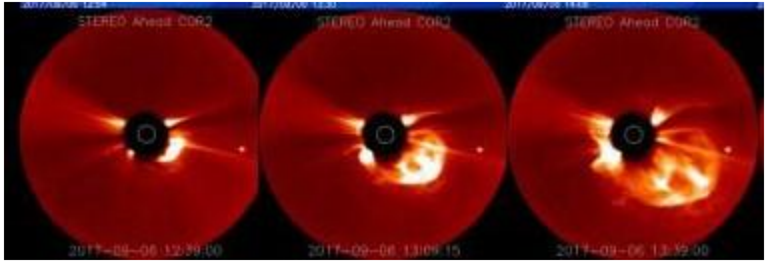
March 2024: Intermediate – CME speeds and arrival

Speeds:

S1 = (Pos2 – Pos1)/30 min

S1 = (4.9-2.8)/30 megaKm/min

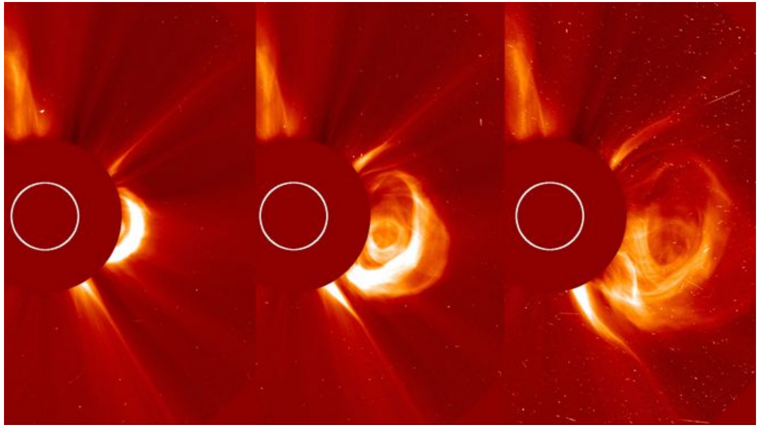
S1 = 70,000 km/min or 1,166 km/s



S2 = (Pos3 - Pos2)/30 min

S2 = (8.4 – 4.9)/30 megaKm/ min

S2 = 117,000 km/min or 1,944 km/s.



March 2024: Intermediate – CME speeds and arrival

Arrival time at Earth:

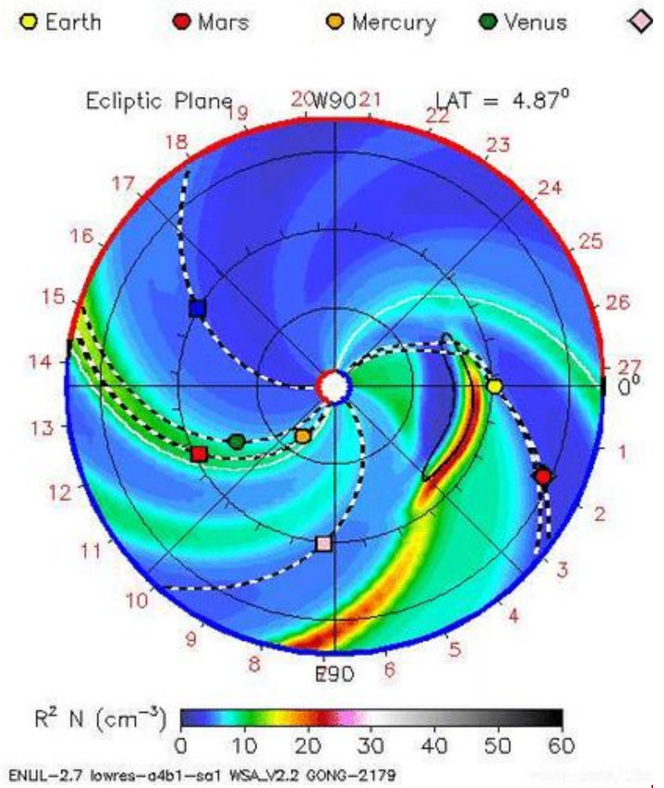
150 million km.

At speed S2 of 117,000 km/min

T = 150 million / 117,000

= 1,282 minutes

or 21 hours.



NASA HEAT

March 2024: Advanced – CME Deceleration

Our previous CME was traveling at 1,944 km/s as it left the solar corona. At this constant speed it would take 13.3 hours to reach Earth.

But solar gravity will cause it to decelerate as it goes outwards.

Suppose that the CME decelerates at a rate of -10 km/s per hour

If the speed of the CME follows the formula:

V = -10T +1944 where T is the time in hours.

where Vinitial = 1944 km/sec

Deceleration = -10 km/sec/hour

How long will it take to get to Earth at a distance of 150 million km?

March 2024: Advanced – CME Deceleration

Let's put all units in terms of hours so that T is in hours and:

solar deceleration a = -10 km/sec/hr so a = -10 km/sec/hr x (3600 sec/hr) **a = -36000 km/hr/hr**.

The initial speed is 1,944 km/sec so V = 1,944 km/sec x (3600 sec/hr) **V= 6.7 million km/hr**.

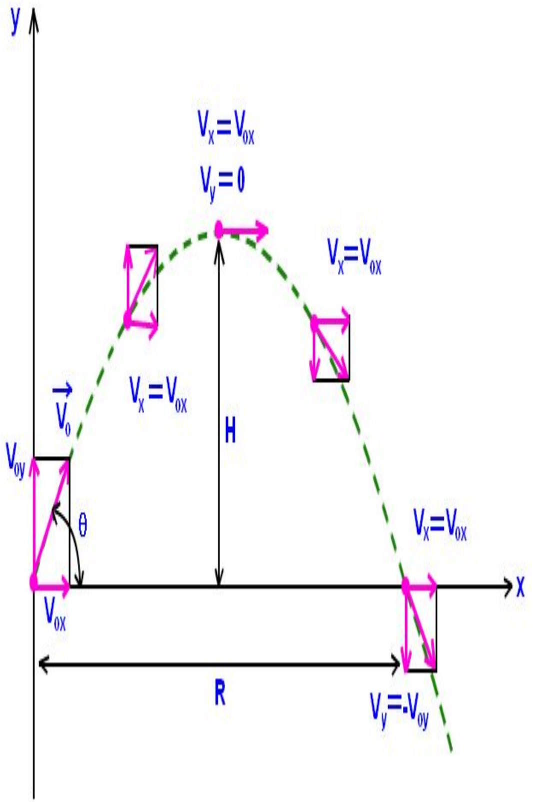
Ballistic Formula: D = d0 + VT - ½ a T^2 with deceleration where a = +36000 km/hr/hr

At the sun, d0 = 0. We want to get to D = 150 million km.

So $0 = ½aT^2 - VT + D$ Or **$0 = 18000T^2 – 6.7\text{million}T + 150$ million.**

This is a quadratic equation where **A = 18000**. **B = -6.7 million** **C = 150 million**

Quadratic formula: $$T = \frac{- B + (B^2 - 4AC)^{1/2}}{2A}$$



March 2024: Advanced – CME Decelleration

A = 18000.

B = -6.7 million

C = 150 million

$$\text{Quadratic formula:} \quad T = \frac{-B \pm (B^2 - 4AC)^{1/2}}{2A}$$

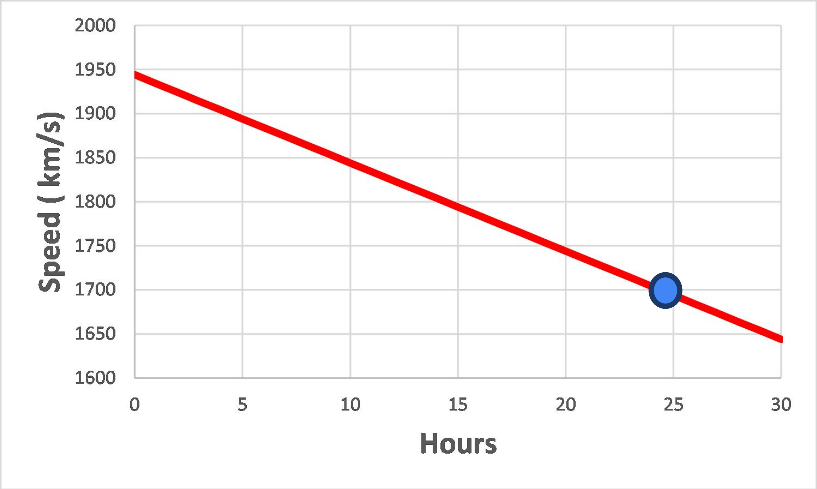
So $(B^2\text{-}4AC)^{1/2} = (4.48\text{x}10^{13} - 1.08\text{x}10^{13})^{1/2}$ = 5.8 million km/h

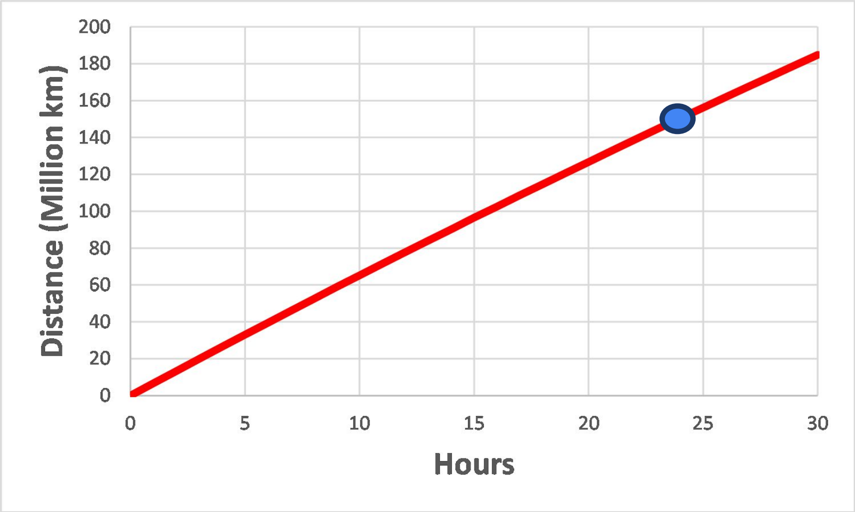
T+ = (6.7million + 5.84 million)/(2x18000) = 348 hours. CME returns to the sun....Not a physical result

T- = (6.7 million – 5.84 million)/(2x18000) = 24 hours. That's more like it!!

This is a bit slower than the 21 hours we estimated without including a model for the deceleration by the sun's gravity.

March 2024: Advanced – CME Decelleration





CME arrival time = 24 hours   Speed = 1,700 km/s

April 2023: Total Solar Eclipse

Next Time!

The Sun may be 93 million miles away, but we can still experience it from home, whether its watching eclipses, auroras, or observing its daily influence on our lives.