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Introduction to Space Weather

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AFI Workshop on Space Weather

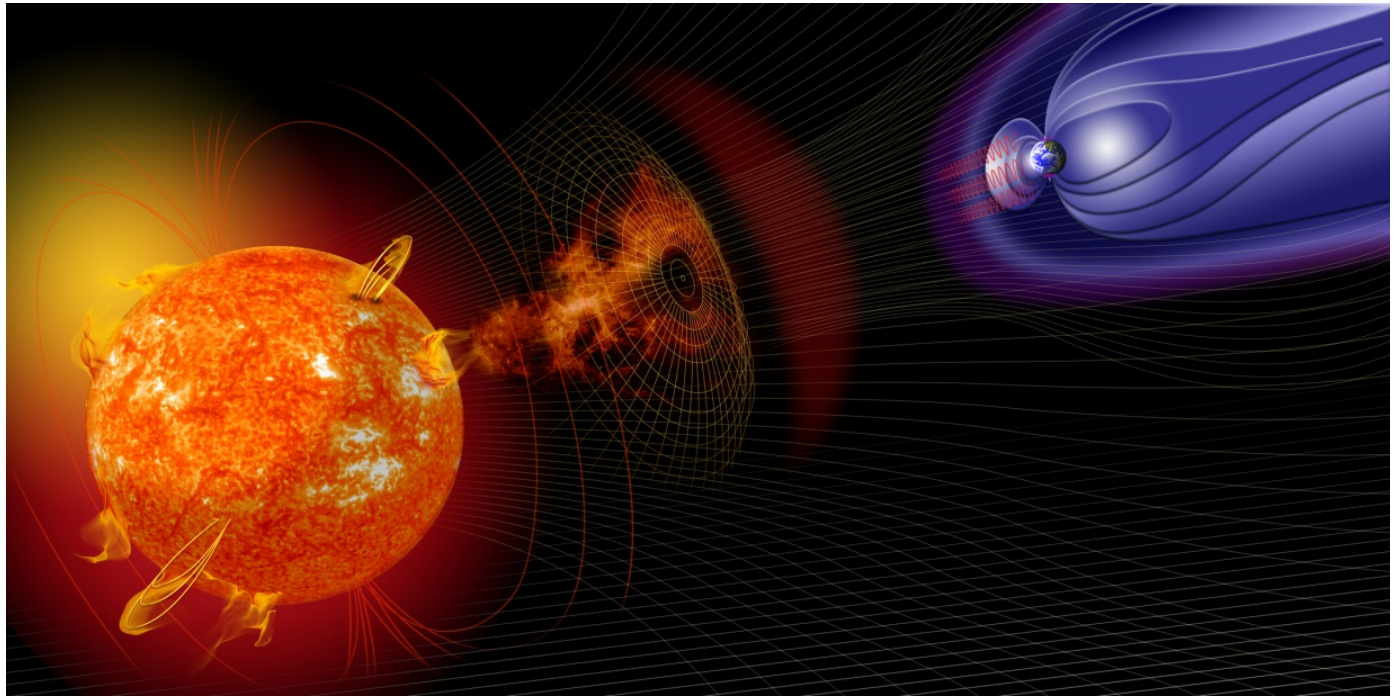
28 to 29 July 2021

CONTENT

- What is Space Weather?
- Impact on Technology
- Space Weather Activities
- Importance of Monitoring Space Weather
- Space Weather Drivers
- International Collaboration
- Conclusion

WHAT IS SPACE WEATHER?

Space Weather refers to conditions on the Sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems.



Space weather is a consequence of the behaviour of the sun, the nature of Earth's magnetic field and atmosphere, and our location in the solar system

IMPACT ON TECHNOLOGY

In the 4IR technology continues to play an ever-increasing role in our society and the potential for space weather storms to impact our daily lives is also growing. Technological infrastructure, including the power grid, GPS and satellites used for communication and navigation, are vulnerable to space weather effects.

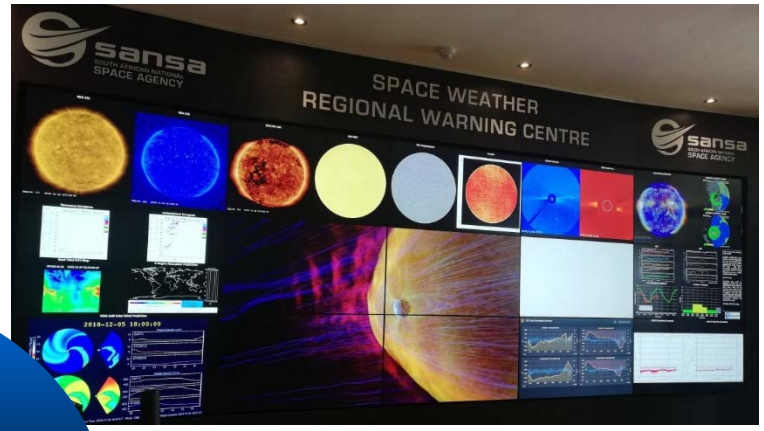
SPACE WEATHER ACTIVITIES

Space weather research
Model developments

SW Forecast
HF predictions
Warning/Alert
Bulletins

Weekly tours
Information days
Training

Expansion and usage of data network



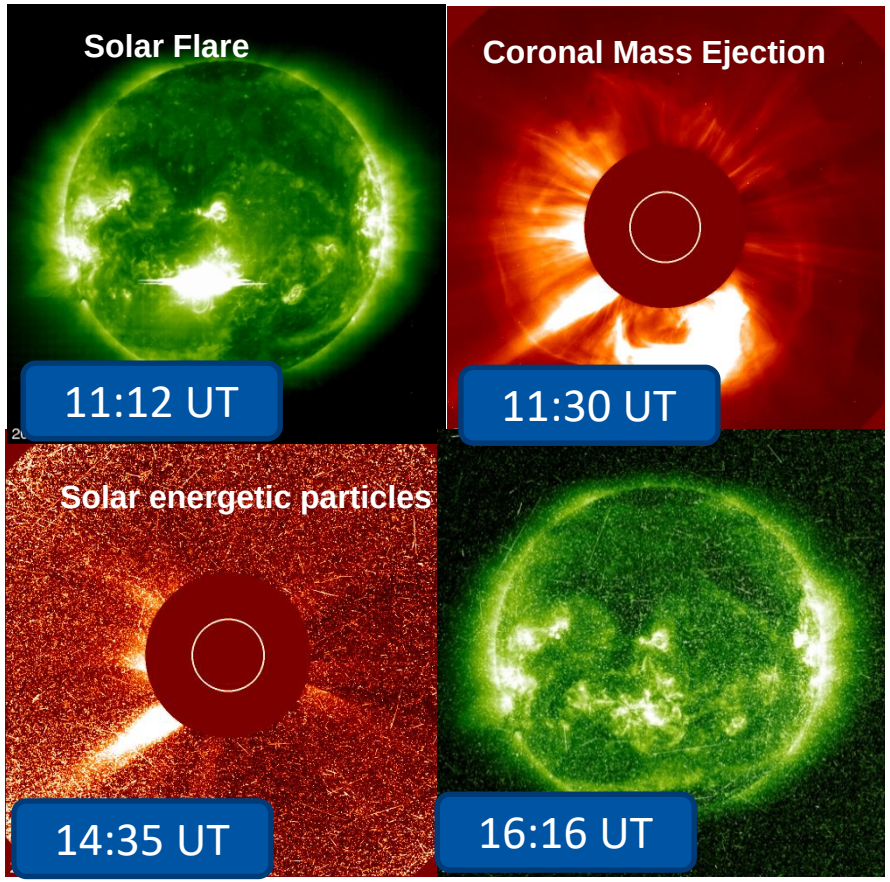
IMPORTANCE OF MONITORING SPACE WEATHER

Space weather monitoring, forecasting and predictions.

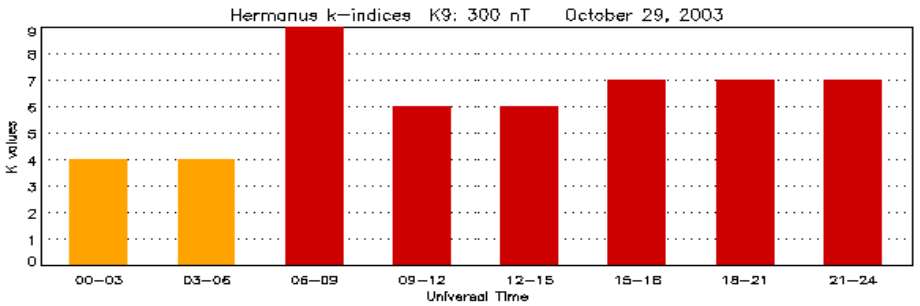
Disseminate SW information to clients and public via website, emails, sms and fax

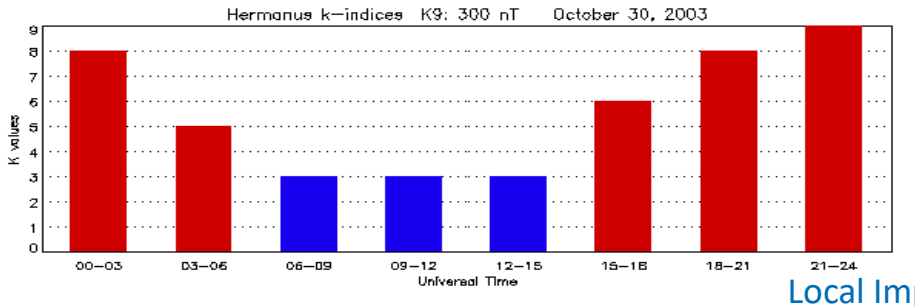
Space weather analysis and verifications of forecasts and predictions

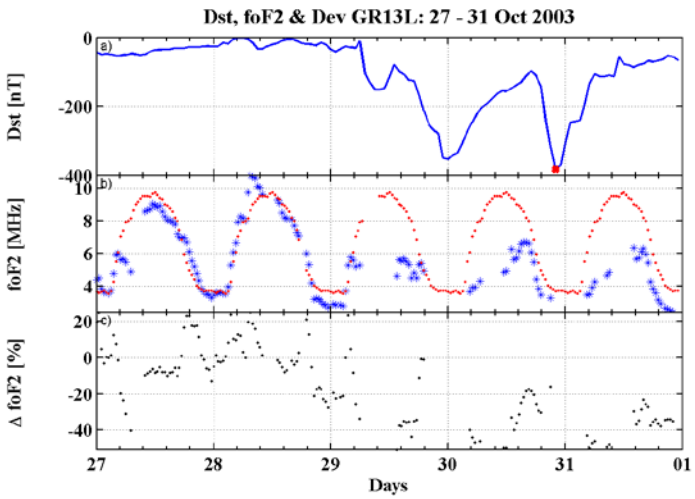
HALLOWEEN STROM: OCTOBER 2003



Solar flare, coronal mass ejection and solar energetic particles observed on October 28, 2003.

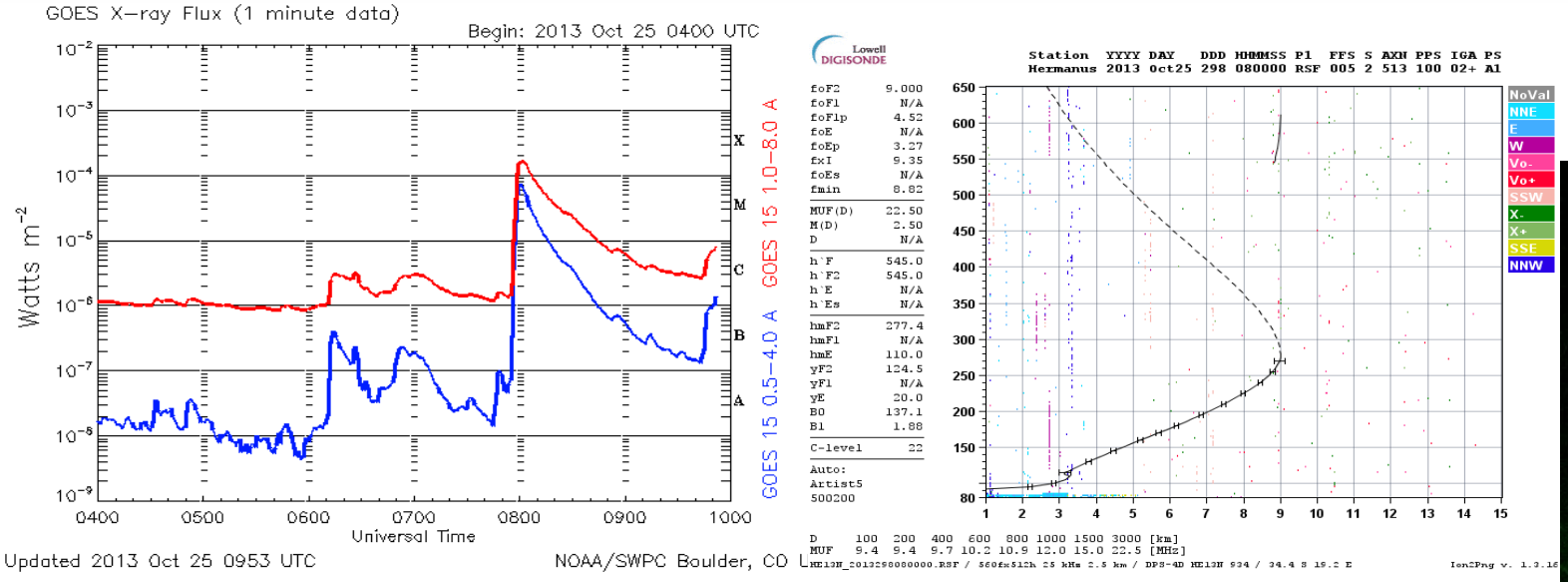


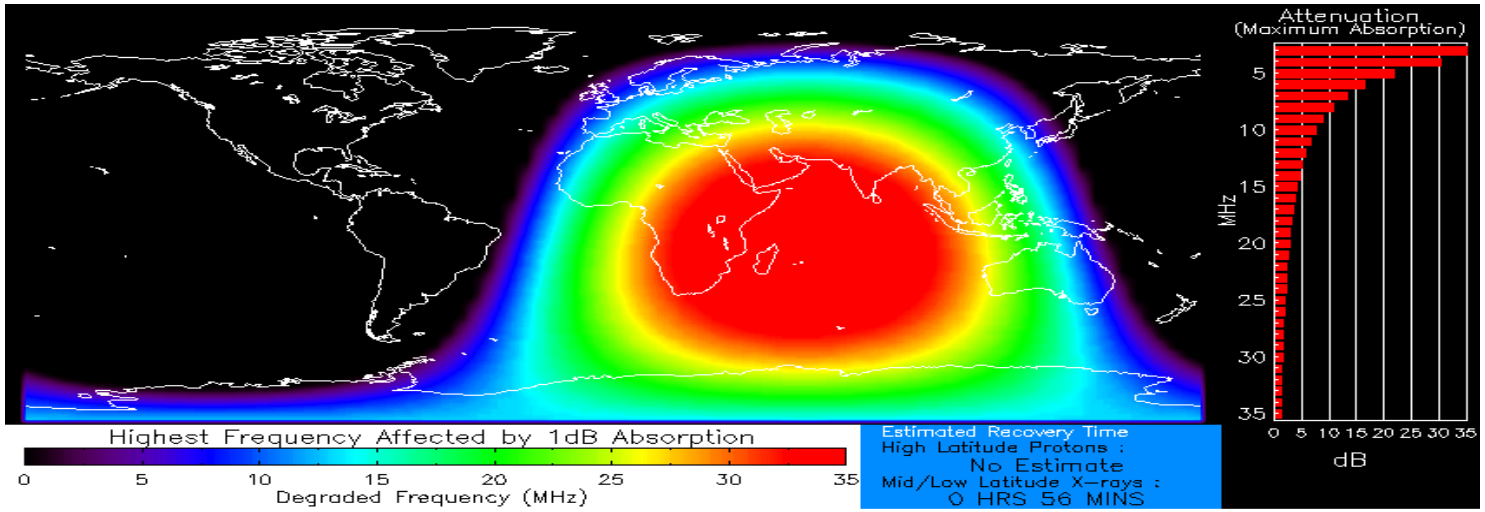


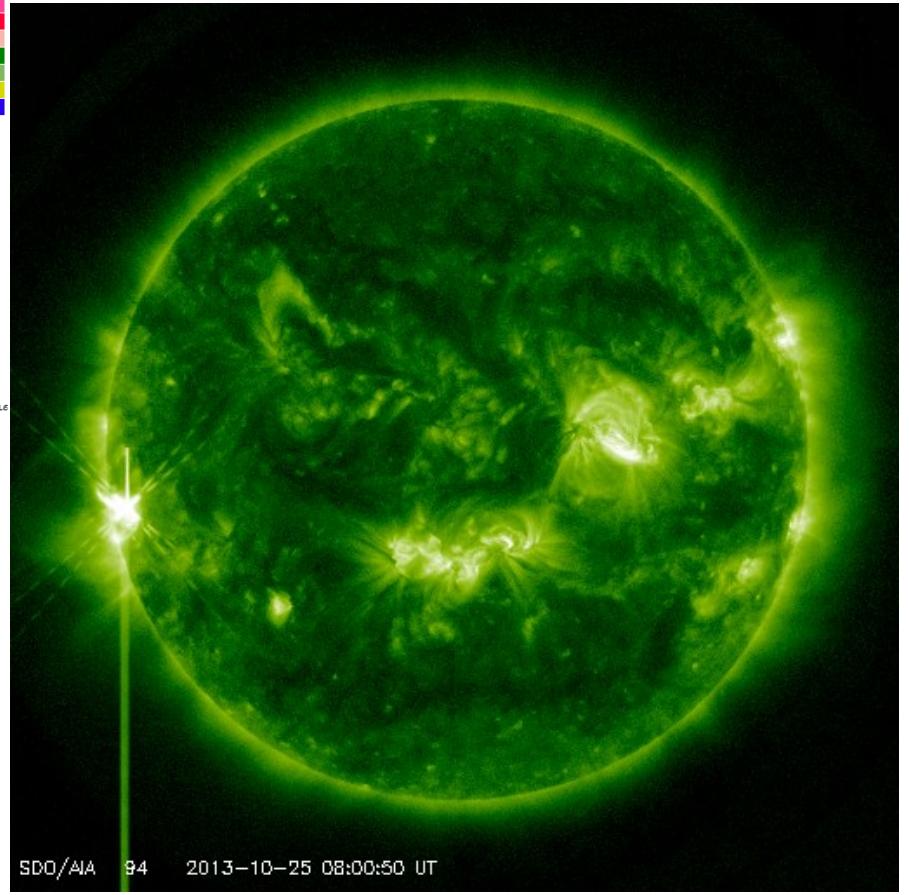


Local Impact on Magnetosphere and Ionosphere

SOLAR FLARE EVENT



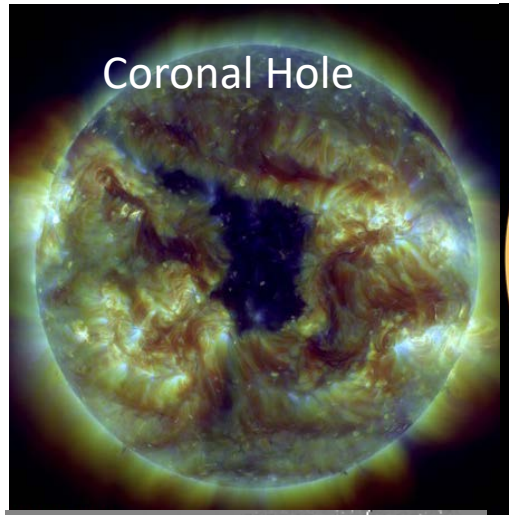


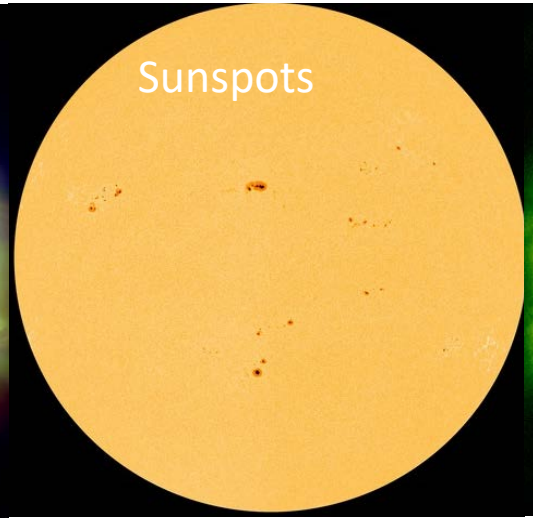


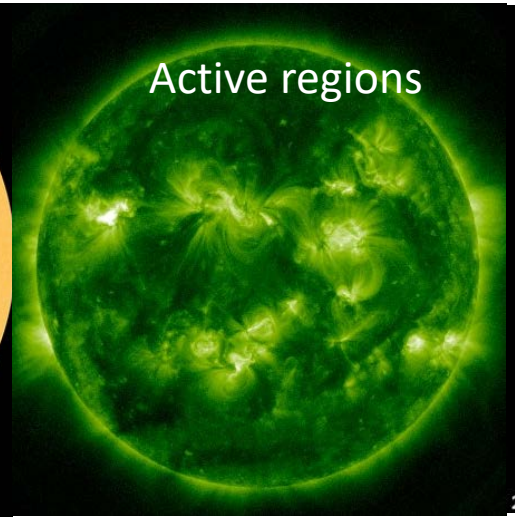
Moderate X-ray flux
Product Valid At : 2013-10-25 08:09 UTC

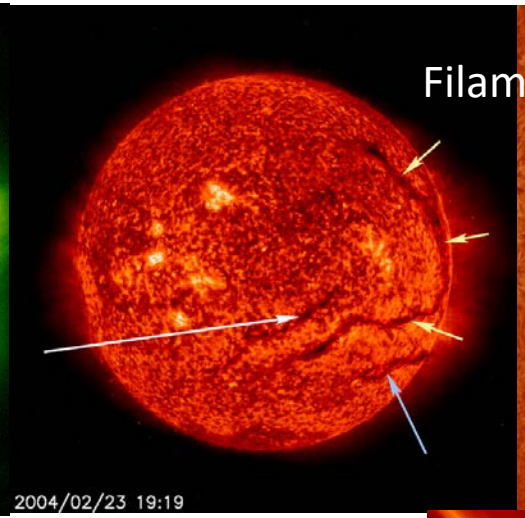
Normal Proton Background
NOAA/SWPC Boulder, CO USA

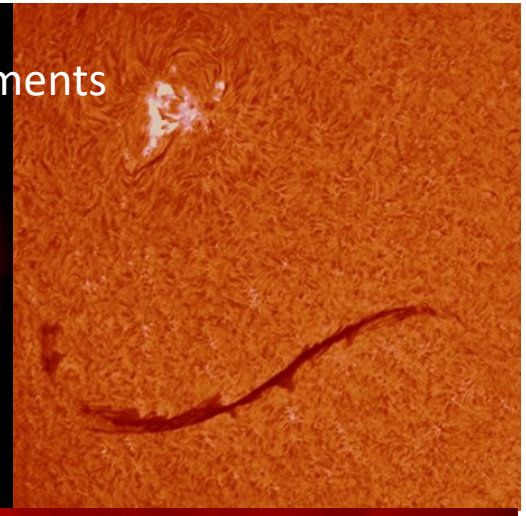
SPACE WEATHER DRIVERS

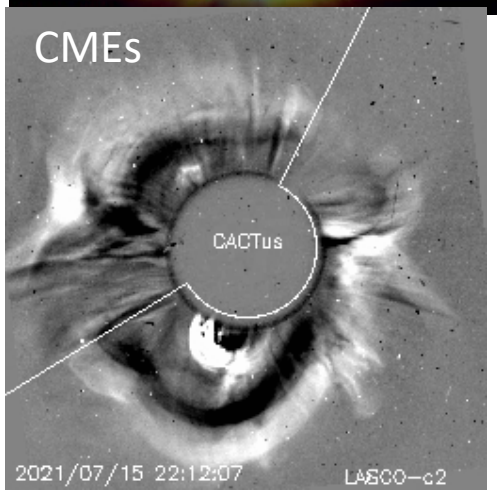




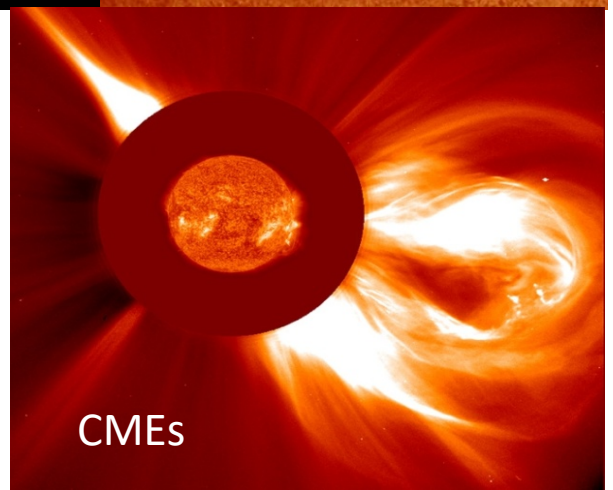




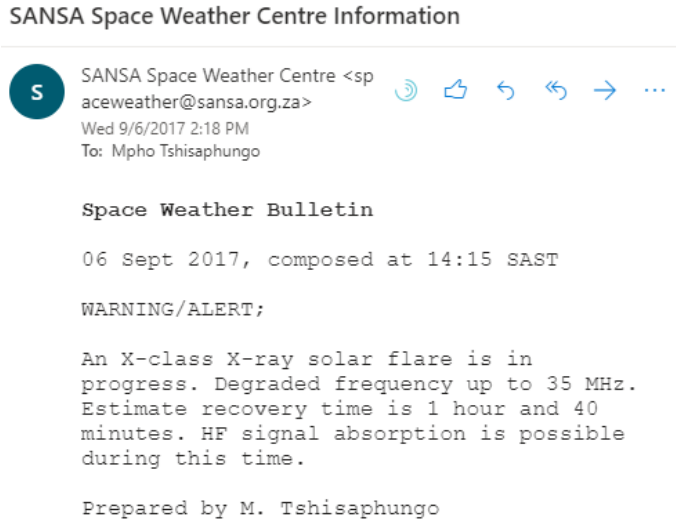




- Solar flares
- Coronal mass ejections (CMEs)
- High speed solar wind stream
- Filamentsments



SANSA SPACE WEATHER INFORMATION



Website Info
Email and SMS Bulletin
Alert and warning messages

INTERNATIONAL COLLABORATION

- One of the 22 member of ISES (International Space Environment Service) as a Regional Warning Centres for Space Weather.
- Representation on WMO, UNCOPUOS and ICAO expert groups on Space Weather.
- African Instrumentation Network partners (e.g. Kenya, Zambia)
- High quality regional data is benchmarked with international databases to deliver accurate well researched information.
- Regional designation by ICAO as Space Weather Information Provider for international air navigation.
- SANSA is leading the ICAO Met Project 3 entitled “Implementation of Annex 3 provisions relating to Space Weather requirements within the AFI Region”.

CONCLUSION

- → Space Weather events can create vulnerabilities within our technology dependencies and is a risk to the 4IR.
- → Space Weather affects safety of live principles for aviation operations, and compliance with ICAO is now a requirement.
- → SANSA is addressing operational capability for Space Weather information provision as a service to the African region.
- → SANSA will continue to utilize its existing capability and global networks to ensure that the most optimum solution for dealing with the threat of Space Weather is developed for the continent.

- → SANSA will continue to partner with the various role players to ensure an adequate readiness level on both sides (provider & user) for space weather information.

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The origin of space weather

Martin Snow

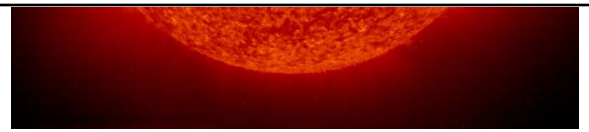
Research Chair in Space Weather

AFI Workshop on SWx

olar system.

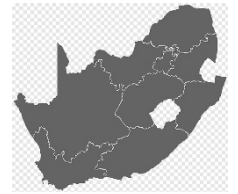
uclear fusion turns hydrogen
y to the surface over thousands

d by convective overturning.
agnetic field.

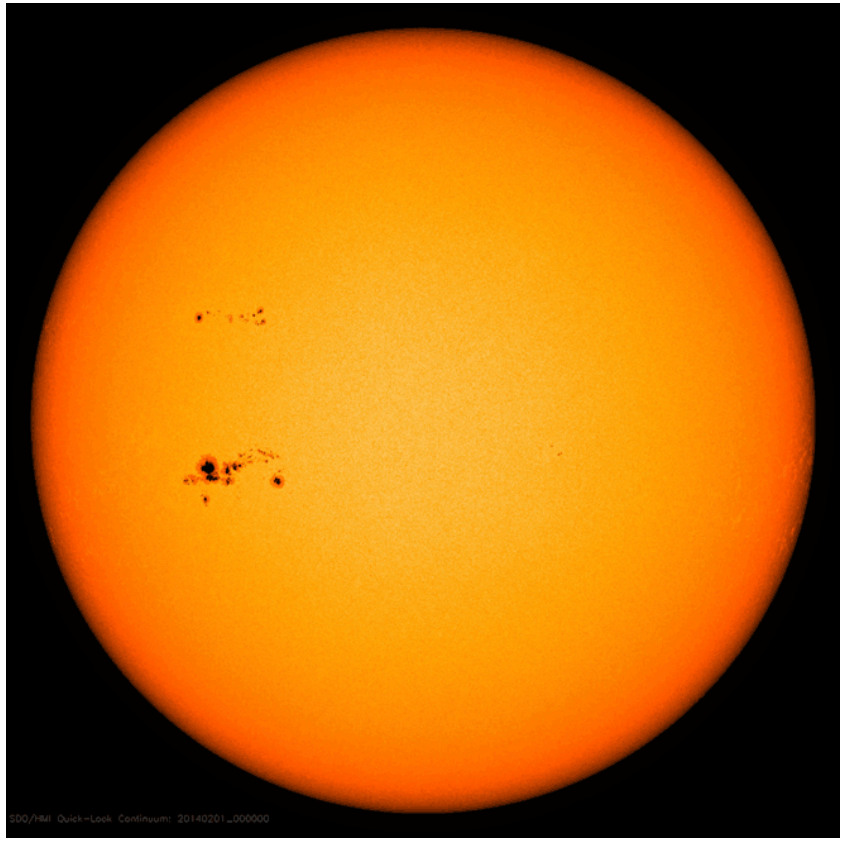


Close up of the surface: constant motion

Cat not to scale.



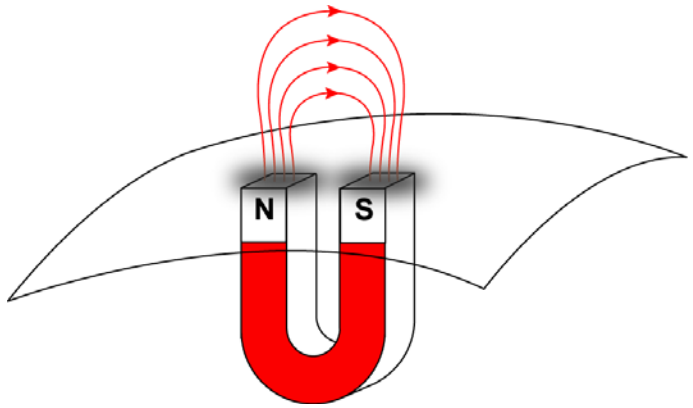
Sun in visible light

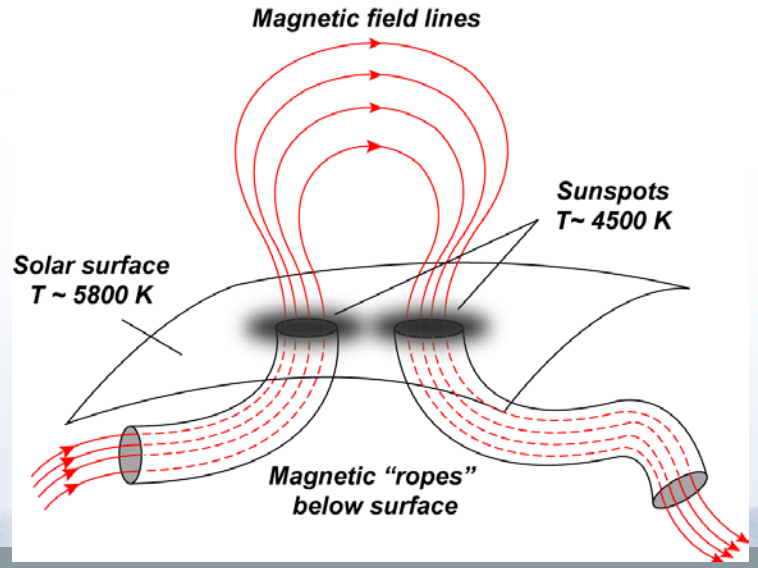


The Sun rotates with a period of about 27 days.

Unlike the Earth, there are no permanent features on the Sun. There are magnetic structures that emerge and last for a few months, then dissipate.

The formation of sunspots





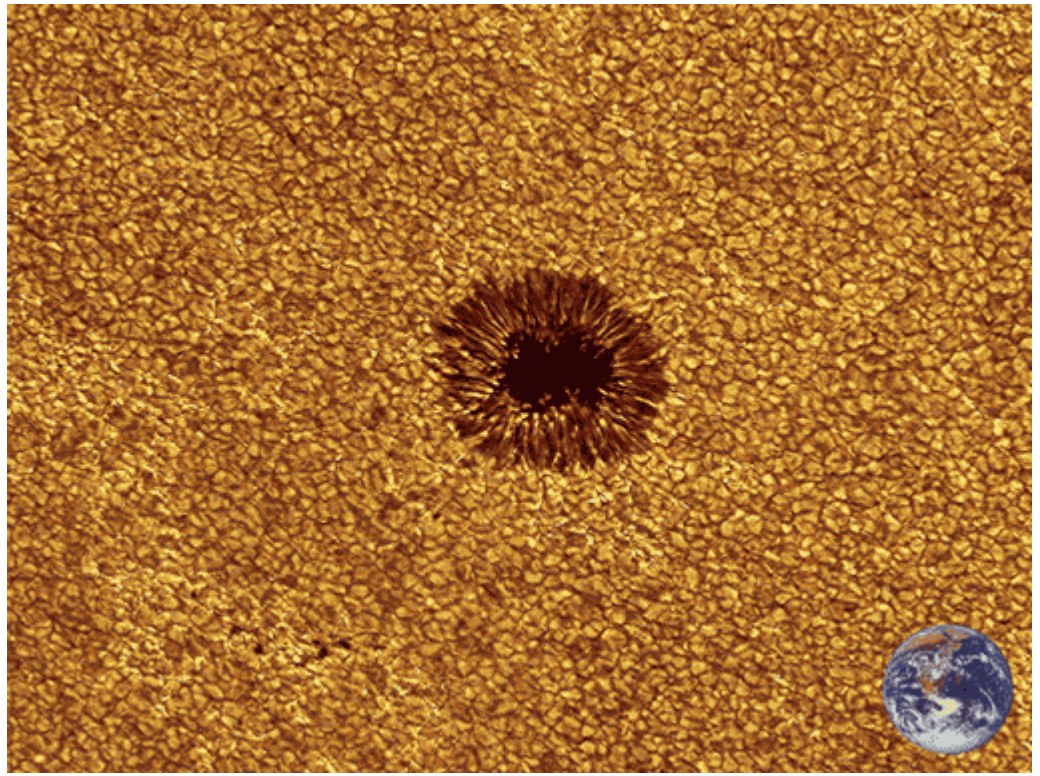
Sunspot

A sunspot is part of a larger structure known as an Active Region.

Sunspots are dark, but only last about one rotation.

The bright region surrounding a sunspot is known as “facula” and can last for several rotations.

The interplay between bright faculae and dark sunspots causes variations in solar irradiance.



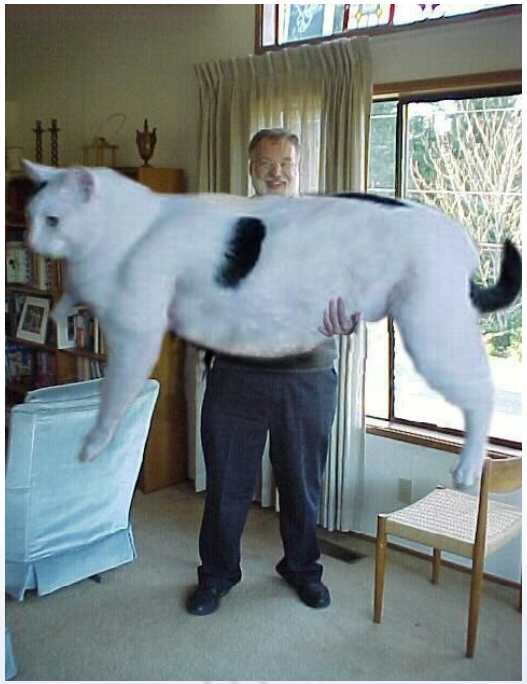
Sunspots usually come in pairs, connected by magnetic field.

Charged particles (plasma) stay trapped in the magnetic field.

The plasma illuminates the magnetic structures.

Connection between active regions can extend very far.

Remember how large the Sun is compared to the Earth!

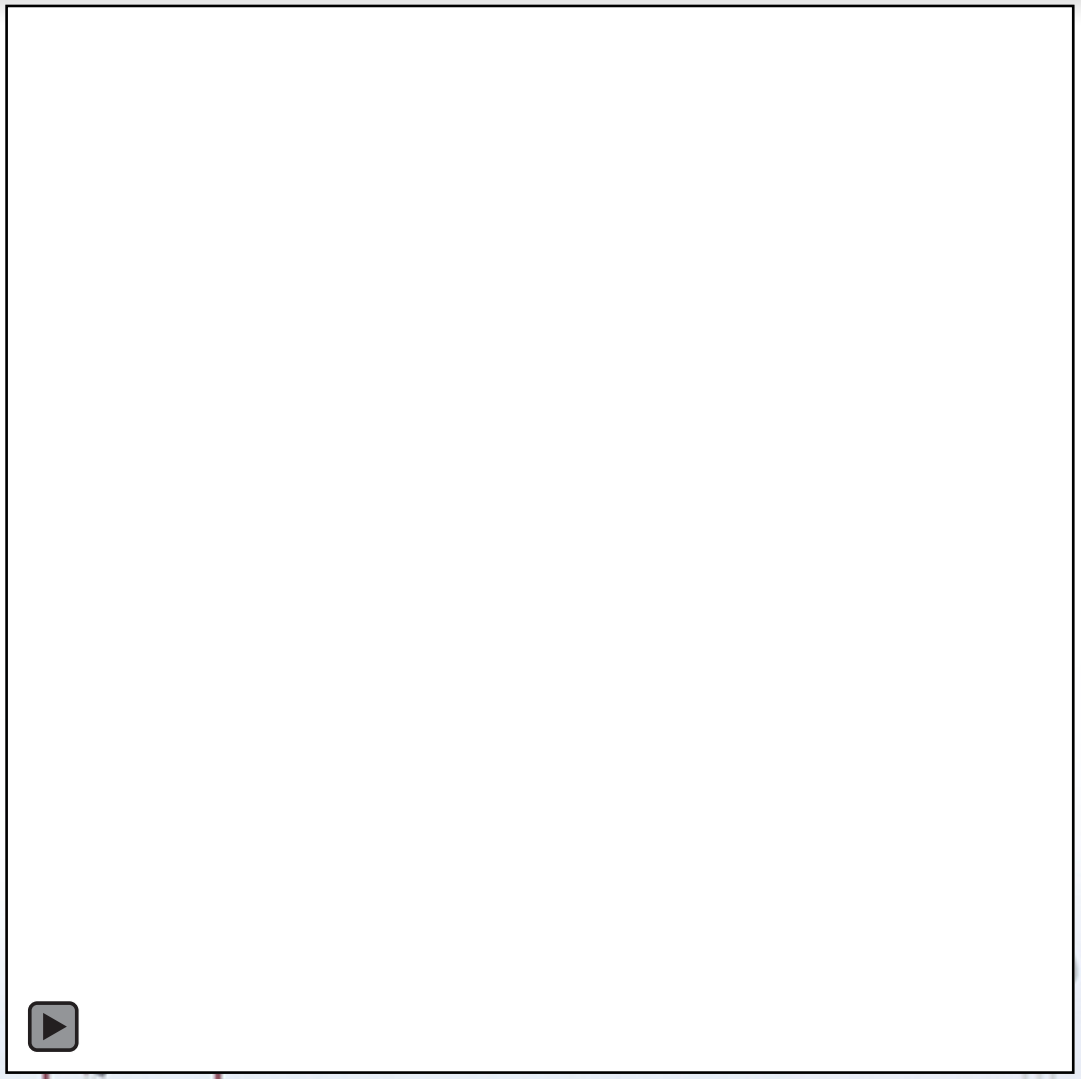


Earth to scale

Motion on the surface can twist the magnetic field like a spring.

The magnetic field can reconnect to a simpler geometry,
which can release enormous amounts of energy.

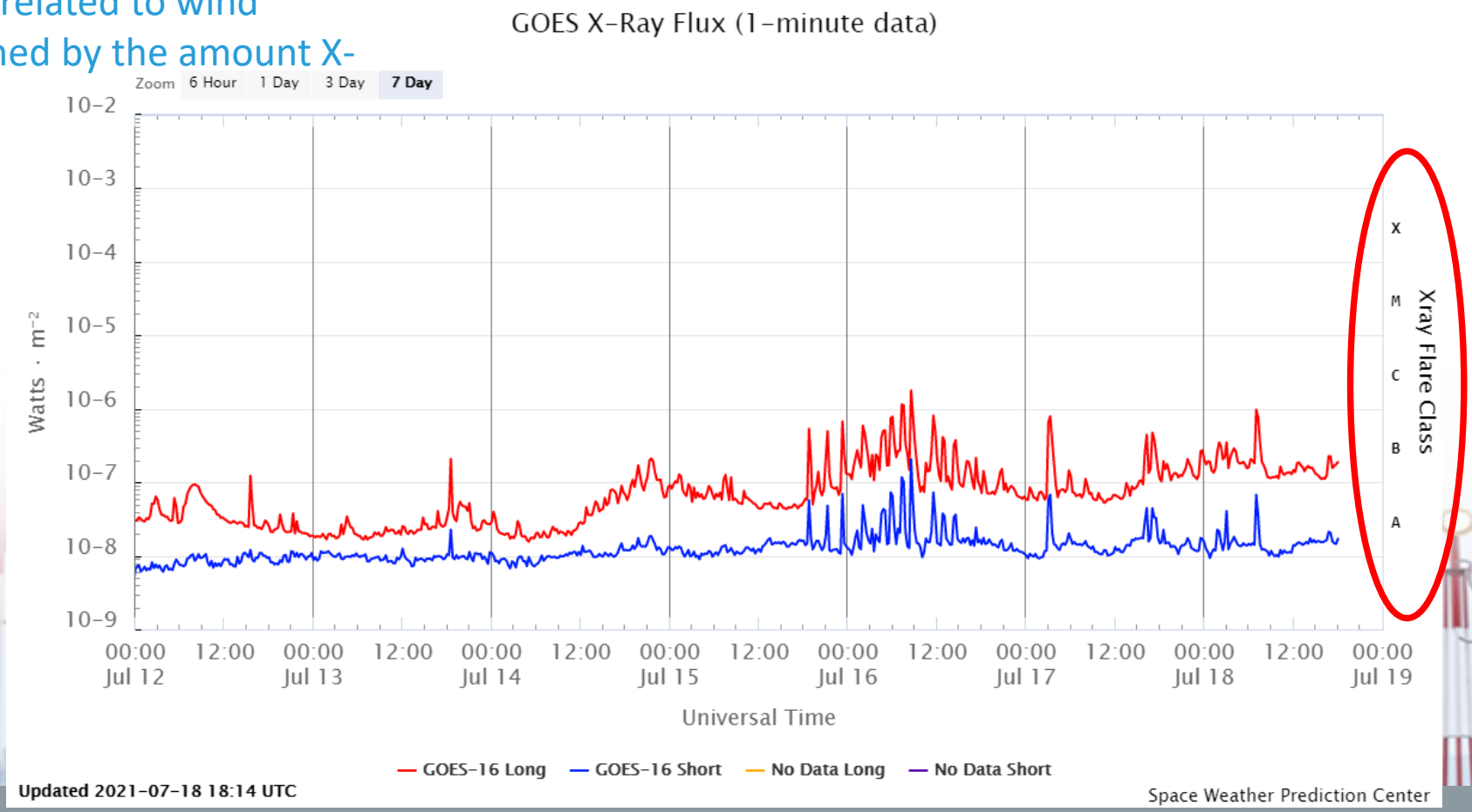
These events are known as flares.



Sizes of flares:

Much like storms on Earth, flares are classified according to strength. A hurricane's strength is related to wind speed. A solar flare's strength is defined by the amount X-rays it emits.

X – extreme
M – medium
A, B, C – all small



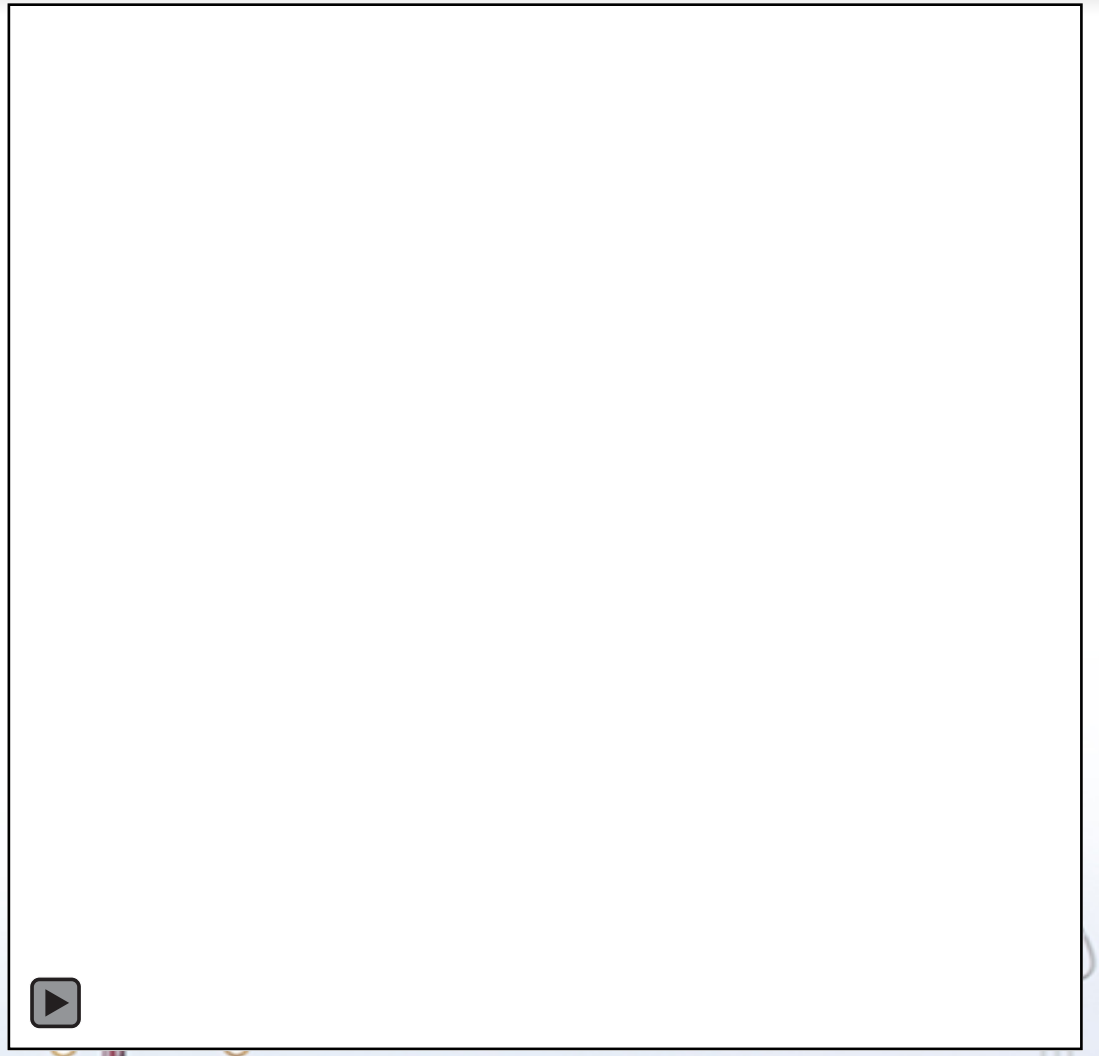
Effect of solar x-rays on the atmosphere: HF radio disruption.

Scale	Description	Effect	Physical measure	Average Frequency (1 cycle = 11 years)
R 5	**Extreme**	**HF Radio:** Complete HF (high frequency) radio blackout on the entire sunlit side of the Earth lasting for a number of hours. This results in no HF radio contact with mariners and en route aviators in this sector. **Navigation:** Low-frequency navigation signals used by maritime and general aviation systems experience outages on the sunlit side of the Earth for many hours, causing loss in positioning. Increased satellite navigation errors in positioning for several hours on the sunlit side of Earth, which may spread into the night side.	X20 (2×10^{-3})	Less than 1 per cycle
R 4	**Severe**	**HF Radio:** HF radio communication blackout on most of the sunlit side of Earth for one to two hours. HF radio contact lost during this time. **Navigation:** Outages of low-frequency navigation signals cause increased error in positioning for one to two hours. Minor disruptions of satellite navigation possible on the sunlit side of Earth.	X10 (10^{-3})	8 per cycle (8 days per cycle)
R 3	**Strong**	**HF Radio:** Wide area blackout of HF radio communication, loss of radio contact for about an hour on sunlit side of Earth. **Navigation:** Low-frequency navigation signals degraded for about an hour.	X1 (10^{-4})	175 per cycle (140 days per cycle)
R 2	**Moderate**	**HF Radio:** Limited blackout of HF radio communication on sunlit side, loss of radio contact for tens of minutes. **Navigation:** Degradation of low-frequency navigation signals for tens of minutes.	M5 (5×10^{-5})	350 per cycle (300 days per cycle)
R 1	**Minor**	**HF Radio:** Weak or minor degradation of HF radio communication on sunlit side, occasional loss of radio contact. **Navigation:** Low-frequency navigation signals degraded for brief intervals.	M1 (10^{-5})	2000 per cycle (950 days per cycle)

Magnetic field can become extremely twisted.

When the magnetic field tension is released, it can carry material out in to space.

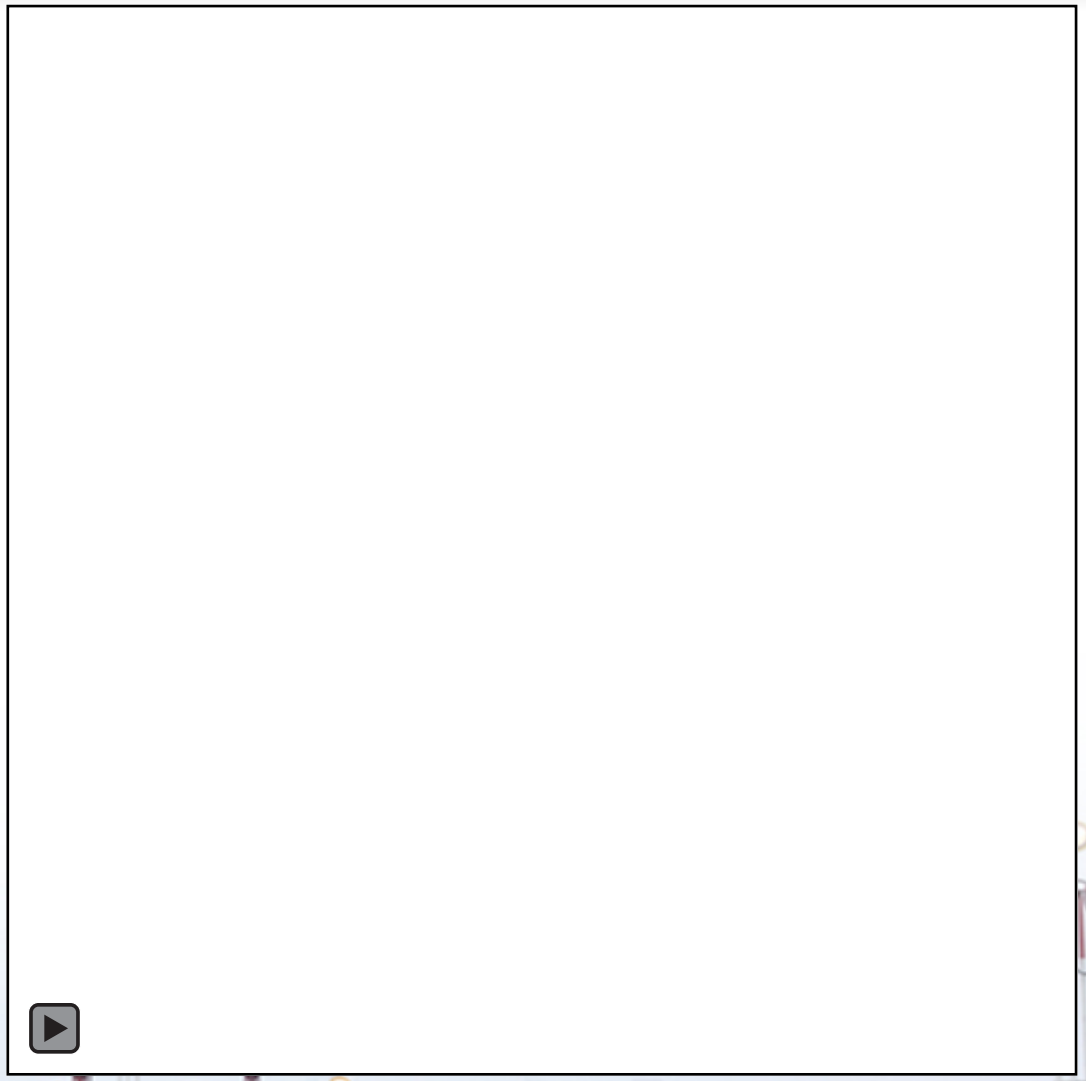
This is called a Coronal Mass Ejection.



What does a CME look like from far away?

Coronagraph blocks out light from the Sun, allowing us to see faint gas expelled from the Sun.

An image of the Sun has been superimposed on the occulted region.



Eruptions do not always move with the same apparent speed.

Is the eruption at the top moving slower, or is it coming straight at us?

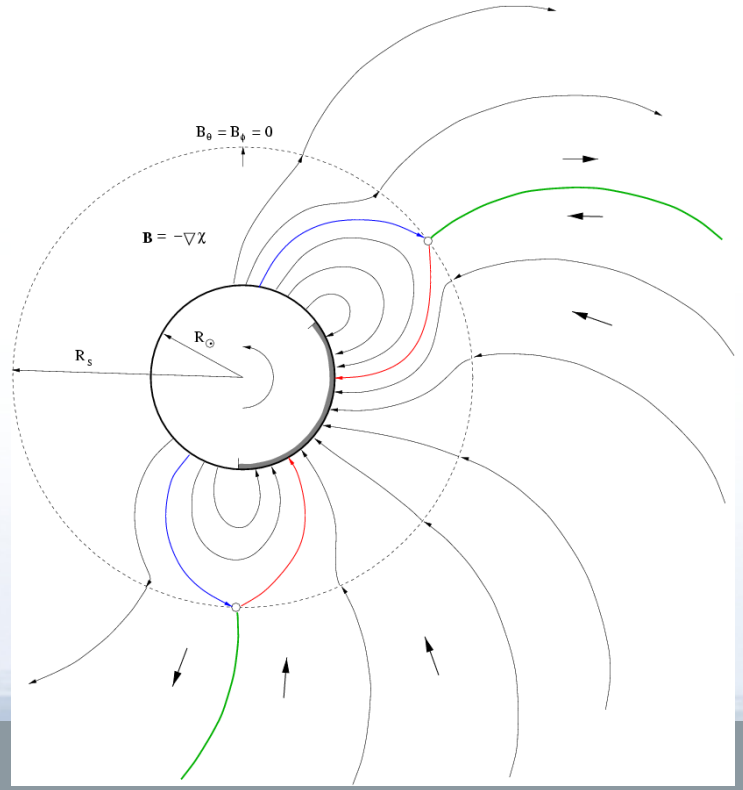
How do we know if the ejected material will hit the Earth?

We shall see….

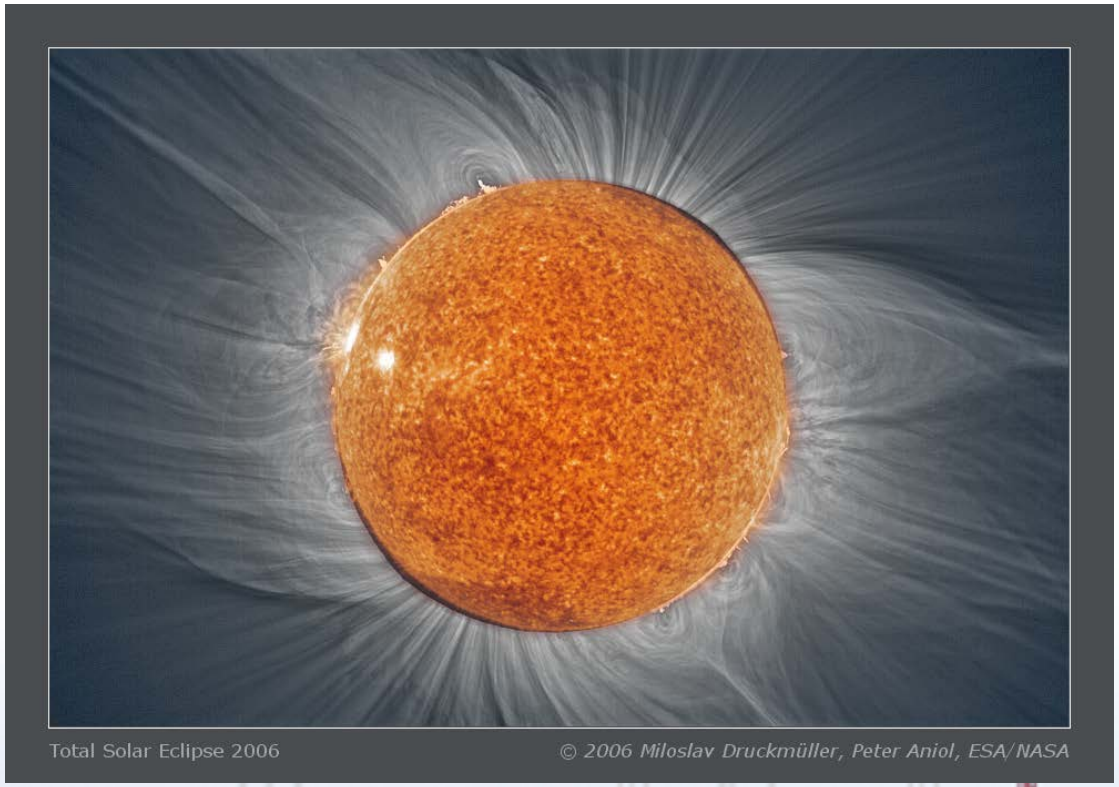
Magnetic structures connect one area on the Sun to another.

Spaces in between are known as Coronal Holes.

A continual stream of plasma flows out of these holes, known as the solar wind.



CMEs burst out on top of the steady solar wind.



Since the Sun is rotating, the solar wind looks bent in a spiral pattern.

Slow solar wind 400 km/s

Fast solar wind 800 km/s

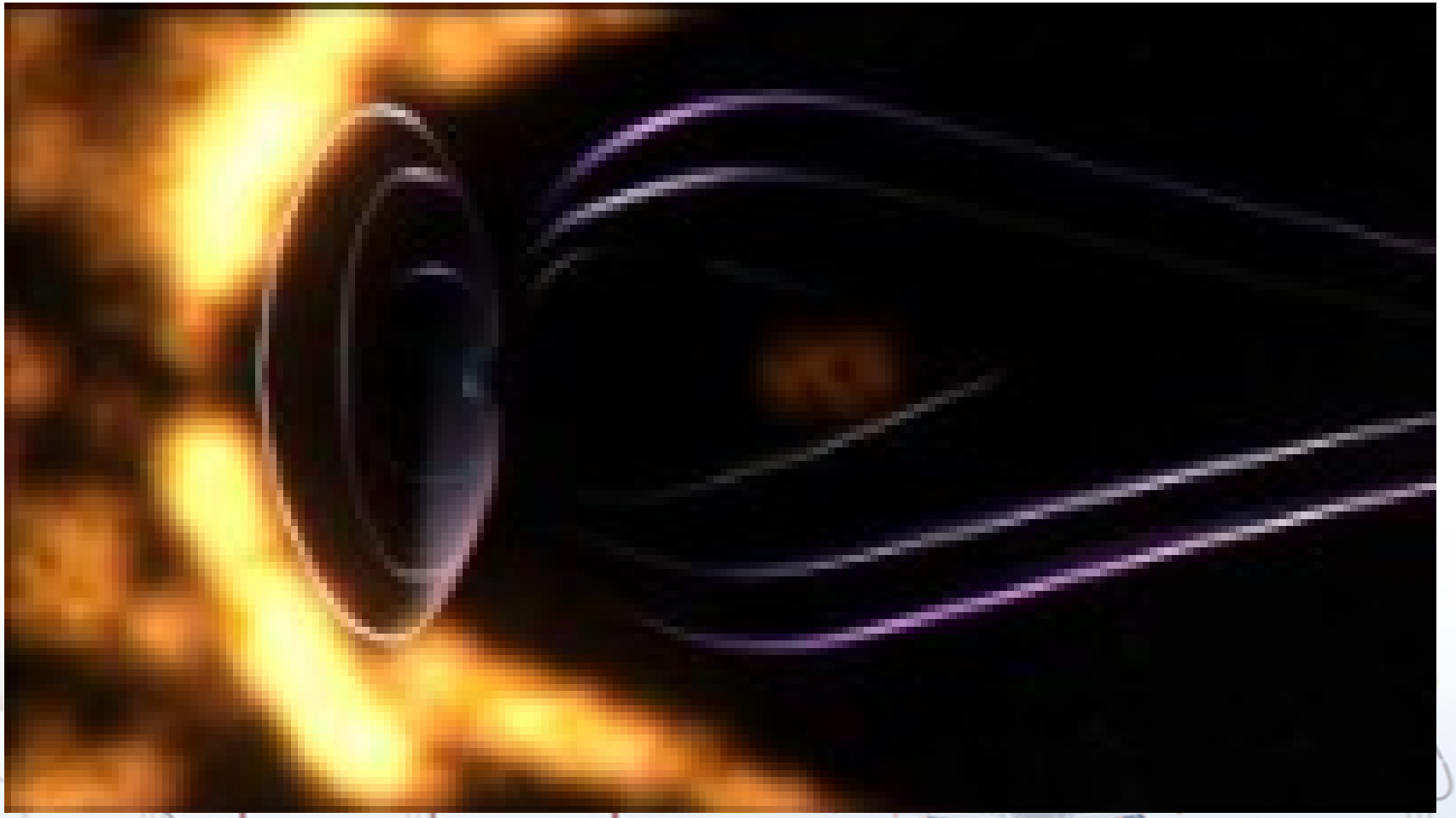
What happens when a CME hits the Earth?

Does it hit directly?

What is the magnetic field orientation of the CME?

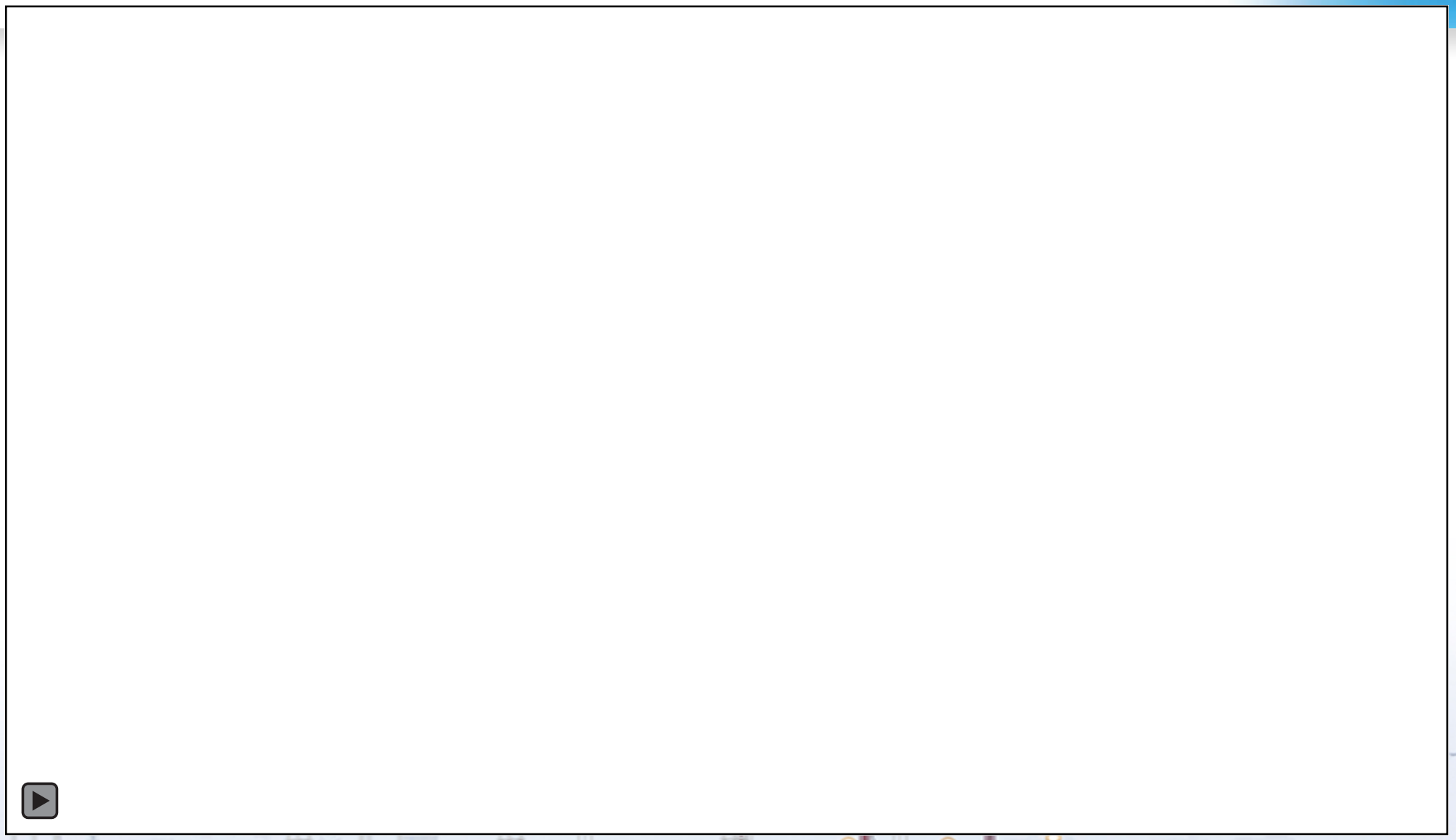
What is the density of the CME?

Why are there so many questions?



What is coming around the corner?

Only Space Weather Forecasters know!



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