Impacts of Solar Storms On Energy and Communications Technologies.

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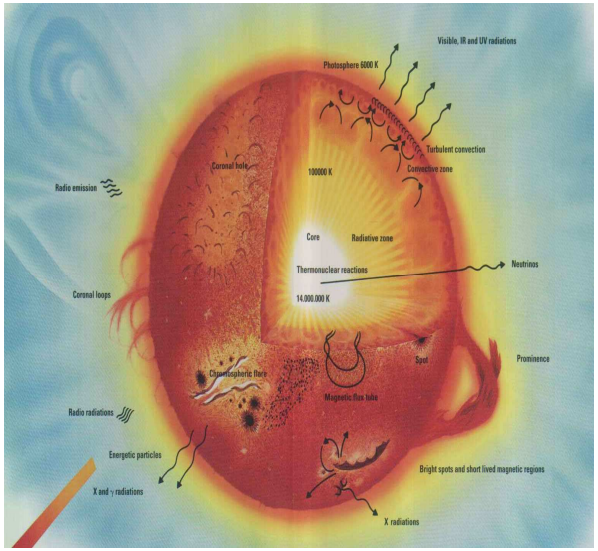
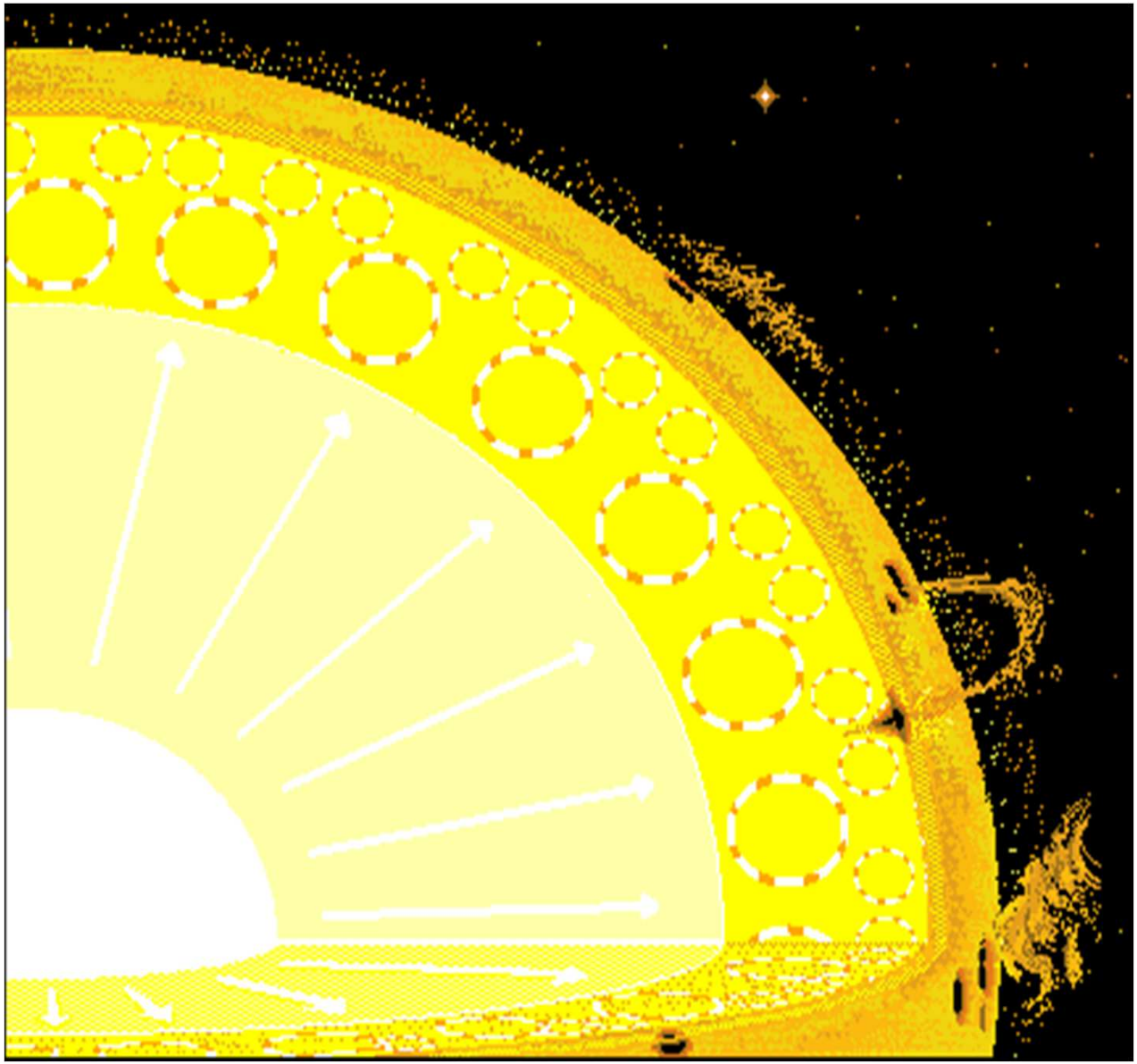
Sun



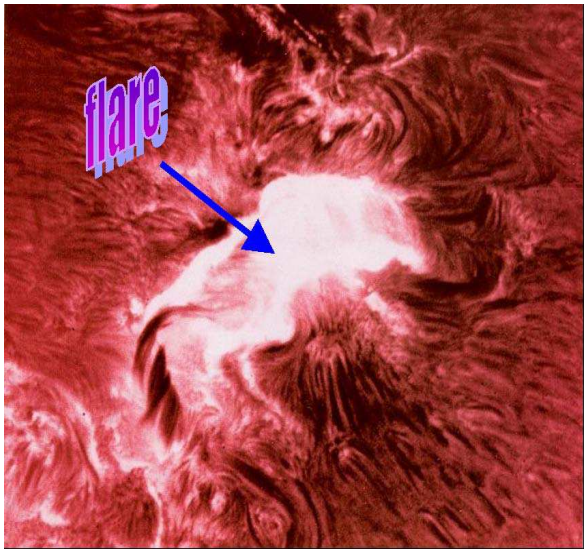


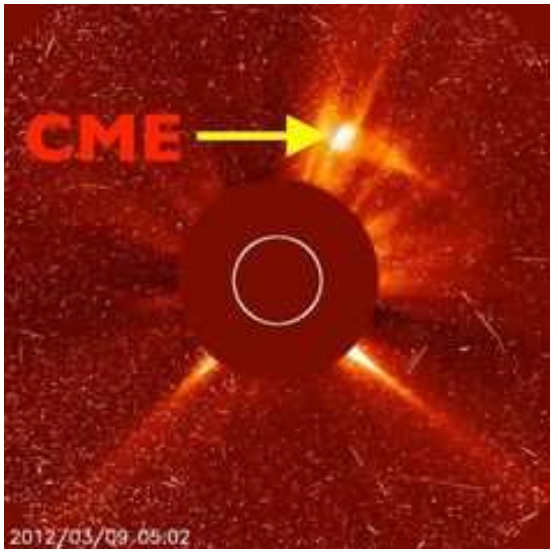
Solar Structure:

- **Core**
- **Radiation Zone**
- **Convention Zone**
- **Photosphere**
- **Chromospheres**
- **Corona**

Solar Storms

- Solar Flares
- Solar proton Events (SEPs)
- Coronal Mass Ejections (CMEs)





Solar flares

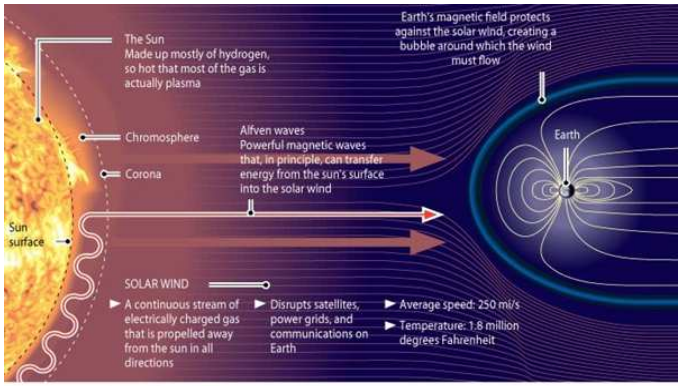
- A flare is defined as a sudden, rapid, and intense variation in brightness.

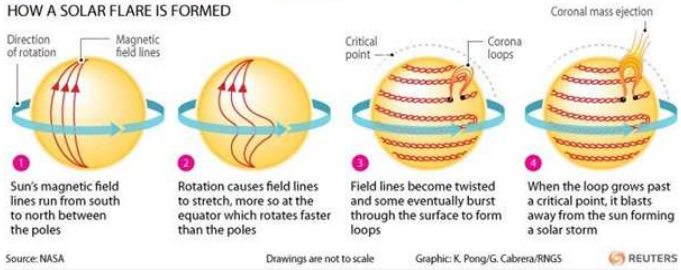
❖Transient, explosive perturbations in the solar atmosphere.

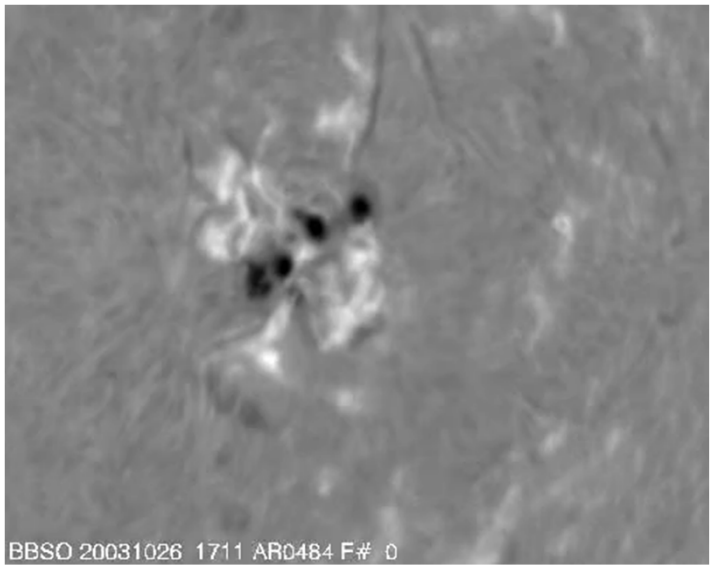
~Millions of 100-megaton hydrogen bombs exploding at the same time! (The energy released in the explosion of one megaton of TNT is equal to 4.2 x 10^{22} ergs.)

~ Ten million times greater than the energy released from a volcanic explosion

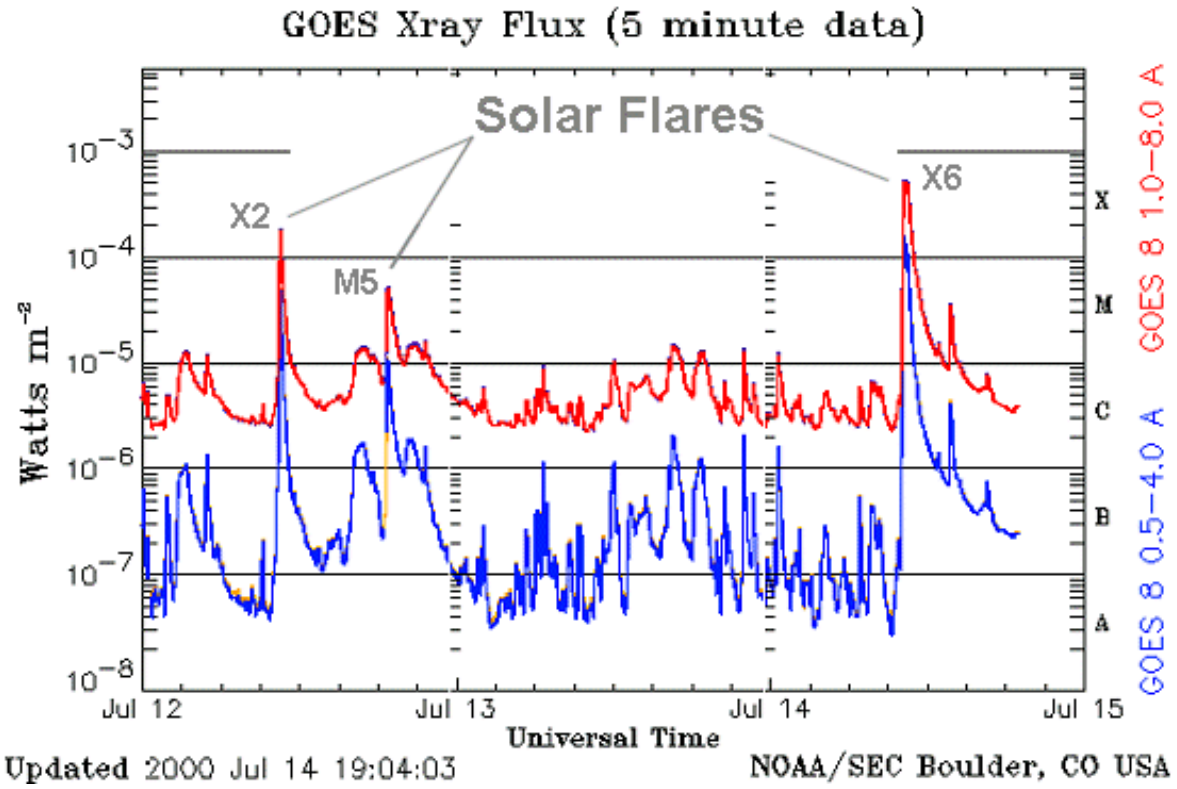
❑Magnetic reconnection has been recognized as the the fundamental process for the rapid conversion of stored magnetic energy into heat and kinetic energy of plasma and particles.







Flare classification:



Classes	Flux (peak) 0.1-0.8 nm [W/m^2]
A	10^{-8}-10^{-7}
B	10^{-7}-10^{-6}
C	10^{-6}-10^{-5}
M	10^{-5}-10^{-4}
X	$>10^{-4}$

Solar Proton Events (SPEs)

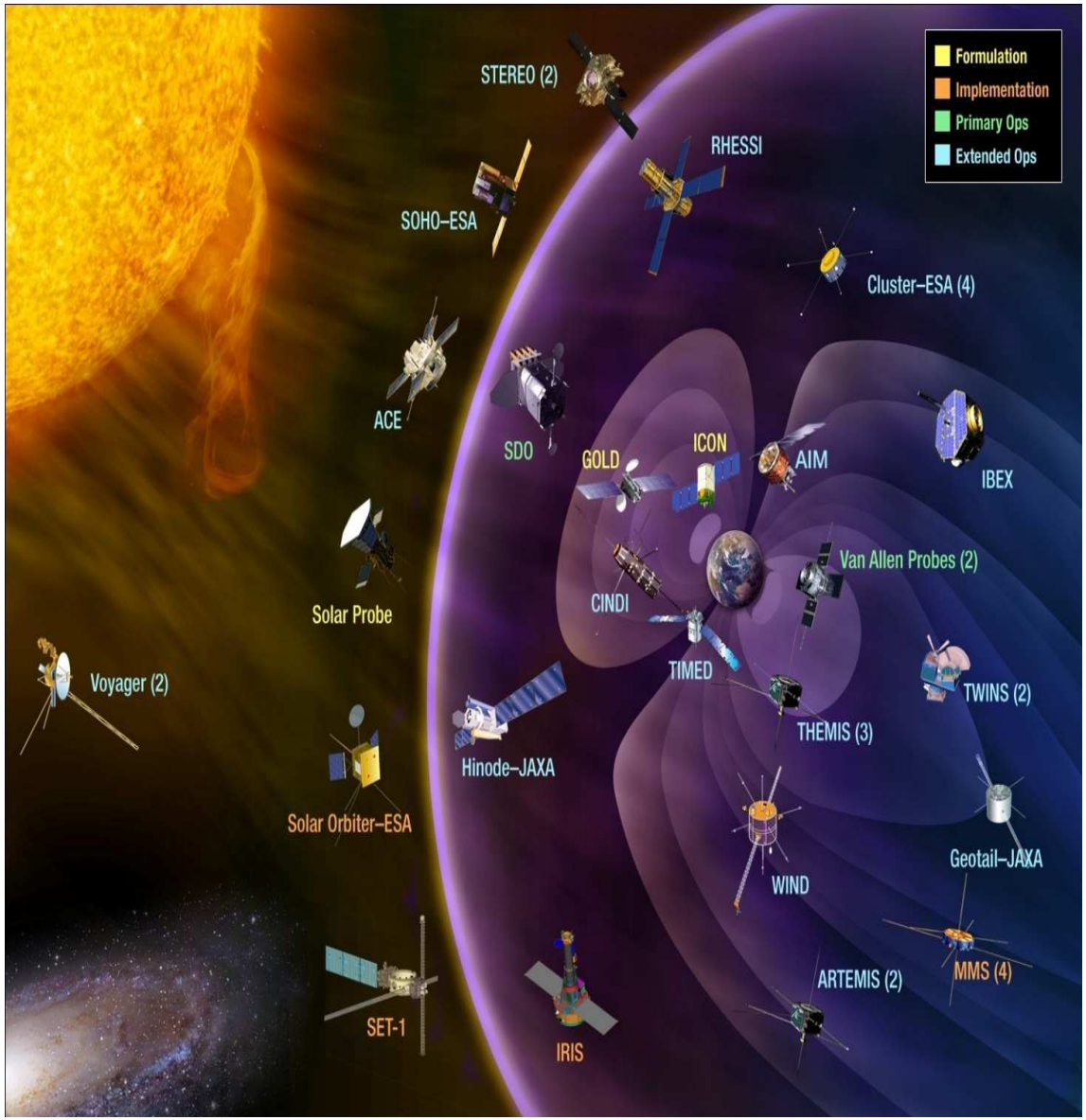
- Solar Proton Events are the high energy cosmic rays(protons and ions) having energies from 10 MeV to 100 MeV .

Arrival time of protons based on Energy:

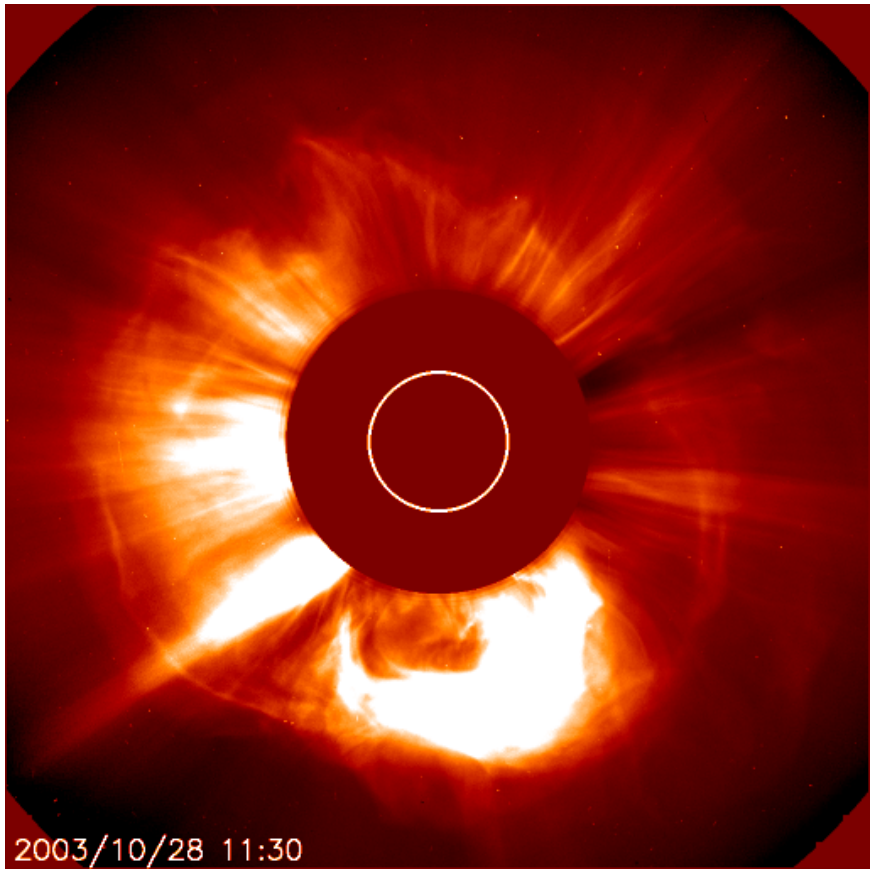
Energy	Velocity (speed of light)	Arrival time
1 MeV	0.46c	2.9hrs
10MeV	0.145c	49min
1000MeV	0.429c	11.1min
1GeV	0.875c	1.2min

Effects of Solar Proton Events:

- Satellite Disorientation.
- Spacecraft Electronics Damage.
- Spacecraft solar panel degradation.
- Extreme Radiation hazards to astronauts.
- Launch payloads failure.
- High altitude aircraft radiations.
- Shortwave radio fades and disruptions in polar regions.
- And Many more . . . . . .



Coronal Mass Ejection(CMeS)



A white light images of a CME observed from LASCO onboard SOHO satellite

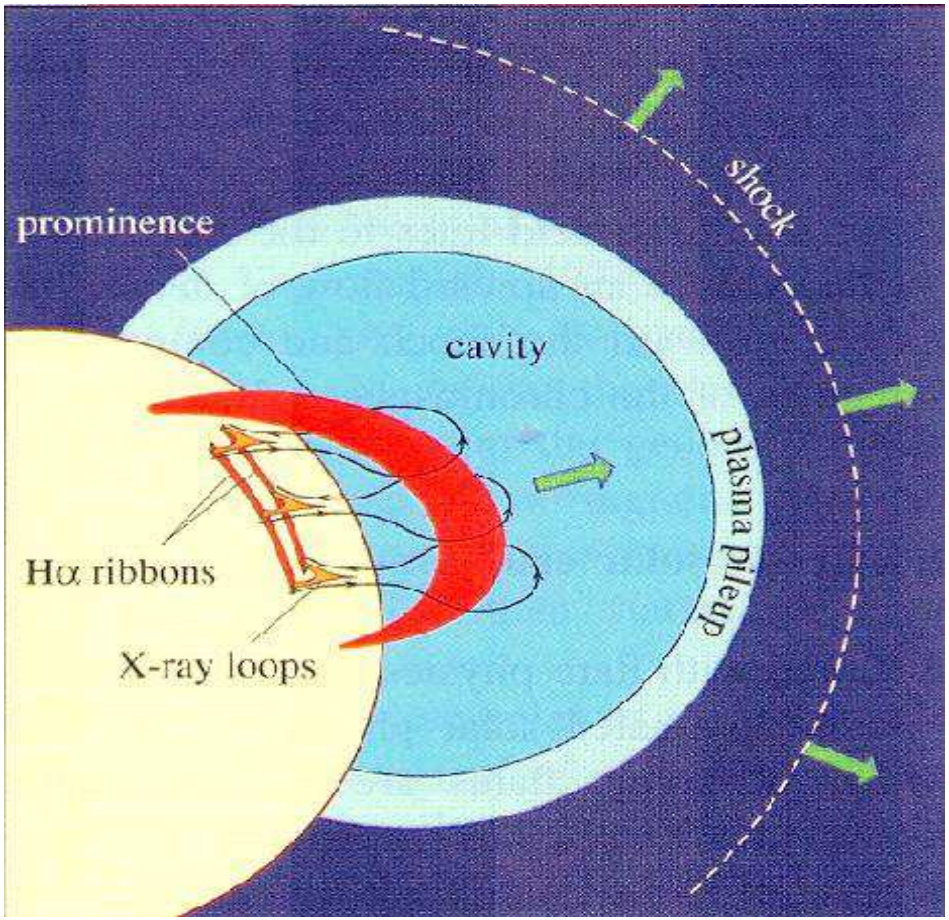
❖A coronal mass ejection is an ejection of material from the solar corona, usually observed with a white-light coronagraph.

❖ The ejected material is a plasma consisting primarily electrons and protons plus the entraining coronal magnetic field.

❖ When ejected material reaches the Earth it may disrupts the Earth's magnetosphere, compressing it on the day side and extending the night-side magnetic tail.

❖ CME events, along with solar flares, can disrupts radio transmissions, cause power outages and can cause damage to satellites

Standard "three-part" structure of a CME



✓A leading edge: Plasma that piles-up ahead of eruption.

✓Cavity: Low electron density (loop system is leading a region of depleted density).

✓Core: Prominence or filament material, high density, appears bright.

- Mass: $10^{15\text{-}16}$ g
- Speed: 20-2000 km/s (average ~300-400 km/s)

Polar Cap Absorption (PCA), Aurora Absorption, multipatting and non great circle propagation effects are associated with CMeS that disrupt the radio communication.

RECORDED EVENTS

28th Aug -Sep2
1859
Carington flare

- **Numerous sunspots and solar flares observed in sun.**
- **Largest Geomagnetic storm occurred Observed in Colaba Observatory Bombay India. These are recorded in Boston that light was so bright that even at 1 am it was possible to read a newspaper.**
- **The combination of Solar flare and CMEs caused a geomagnetic storm that creates strong currents in long telegraph wires in US and Europe causing fires.**

March 13th 1989
15th July 2000
6th Nov 2001
Nov 2003

- **A severe geomagnetic storm caused the collapse of Hydro Quebec power grid Six. million peoples were left without power for nine hours.**
- **The storms even caused auroras in Texas.**
- **GIS flow in the network were observed in Japan.**
- **5 major stations 15 transformers encountered an unknown storm which led to collapse due to GIS activated storm.**

Feb (9-12) 2011
Largest flare:2003
Extreme CMeS
July 23, 2012

- Another storm affect the microchips leading to a half on Toronto stock market.
- Power companies in NA UK NE evaluated the risks of GIC and development strategies.
- Sunspots 1153 grew more active crackling with C and M class solar flares .

POWER GRIDS

➢When a magnetic fields move in a vicinity of a conductor a geomagnetically induced current is produced in the conductor.

➢Power companies which operate long transmission lines are thus subjected to damage by this effects.

➢Electrical transmission equipments like Generators and transformers .

➢Since they induce core saturation, decreases their performance causes coils and cores to heat up.

Susceptibility of Electric power and grids to disruption and damage from solar storms also depends on latitude, strength of geomagnetic strength, earth ground conductivity, orientation of power line length and power grid construction.

Some examples on the Power Grid failures

- August 2 1972: A solar storm caused a 230 000 volt transformer located at the **British Columbia Hydro and Power Authority** to explode (Odenwald .S . 2000).

- December 19 1980 : A very expensive 735KV transformer failed 8 days after the **Great Red Aurora at St James Bay Canada**.

- April 13 1981: A replacement of 735 KV transformer at **St James Bay Canada** also failed the failing year during another geomagnetic storms.

- In 1989 the **Salem Pressurized Water Reactor PWR in New Jersey was affected**. The solar storm induced a large current into the PJM 500 KV transmission system which damaged the Salem unit step up transformer resulting in a large melted mass of copper and copper shot .(Oscar . W . 2012).

- October 30 2003 : A power grid in the southern **Sweden 20- 30** min electrical blackout .

OIL & GAS PIPLINES

In pipelines GIC and the associated pipe-to-soil voltages can increase the rate of corrosion in pipelines especially in high latitude regions that can eventually lead to pipeline integrity failure and major fuel leaks. (Marusek.J .A . 2007)

Some Effects:

- Solar storms may had encourage the gas and pipeline rupture and explosion on 4th june 1989.
- Also the induced currents can also affects the flow meter that transit the flow rate producing false reading.

Effects of Solar Storms on Radio communication

- ❖ HF Radio communication(3-30MHz)
- ➢ Increased absorption. .
- ➢ Depressed maximum usable frequency.
- ➢ Increased fading and flutter.
- ➢ Increased lowest usable frequency.
- ❖ VHF Propagation(30-300MHz)
- ➢ Effects pagers and cellular phones.
- ➢ Fadeout of the high and low band in mobile voices communication for dispatching utility company line crews.
- ❖ Satellite communication(200MHz to several GHz)
- ➢ Increased scattering of satellite to ground ultra high frequency.
- ➢ Radio frequency interfere.
- ➢ Loss of phase lock.
- ➢ Severe distortion of data transmission.
- ➢ Erroneous positioning information from single frequency GPS.
- ➢ Drastic loss in spacecraft electrical power.
- ❖ Radar Surveillance system
- ➢ Azimuth angle error .
- ➢ Range error Radar energy scatter due to auroral interference.
- ➢ Elevation angle error.

Preventive Measures

- Use of series capacitor to block of GIC in transmission lines.
- Putting sunscreen on all technology.
- Replacement of copper wires with optical fibre by telecommunications operators.
- Installation of solar storm warning system that can offer up to date information on solar activity including images flare, locations and flares prediction.
- Use of shorter transmission cables.
- Reducing operative voltages of transformers.
- By receiving geomagnetic storm alert and warning(e. g by Space weather prediction centre) Power companies can minimize damage to power transmission equipment by momentarily disconnecting transformers.

Conclusion

- Economics around the globe have become increasingly vulnerable to ever changing nature of sun.
- So effective alerts and warnings should be developed so that power grids can be modified and polar flights can be rerouted.
- Scientists and forecasters could work closely with government and research partners to develop predictions models to improve service to the space weather community to provide timely accurate information.

- THANK YOU!