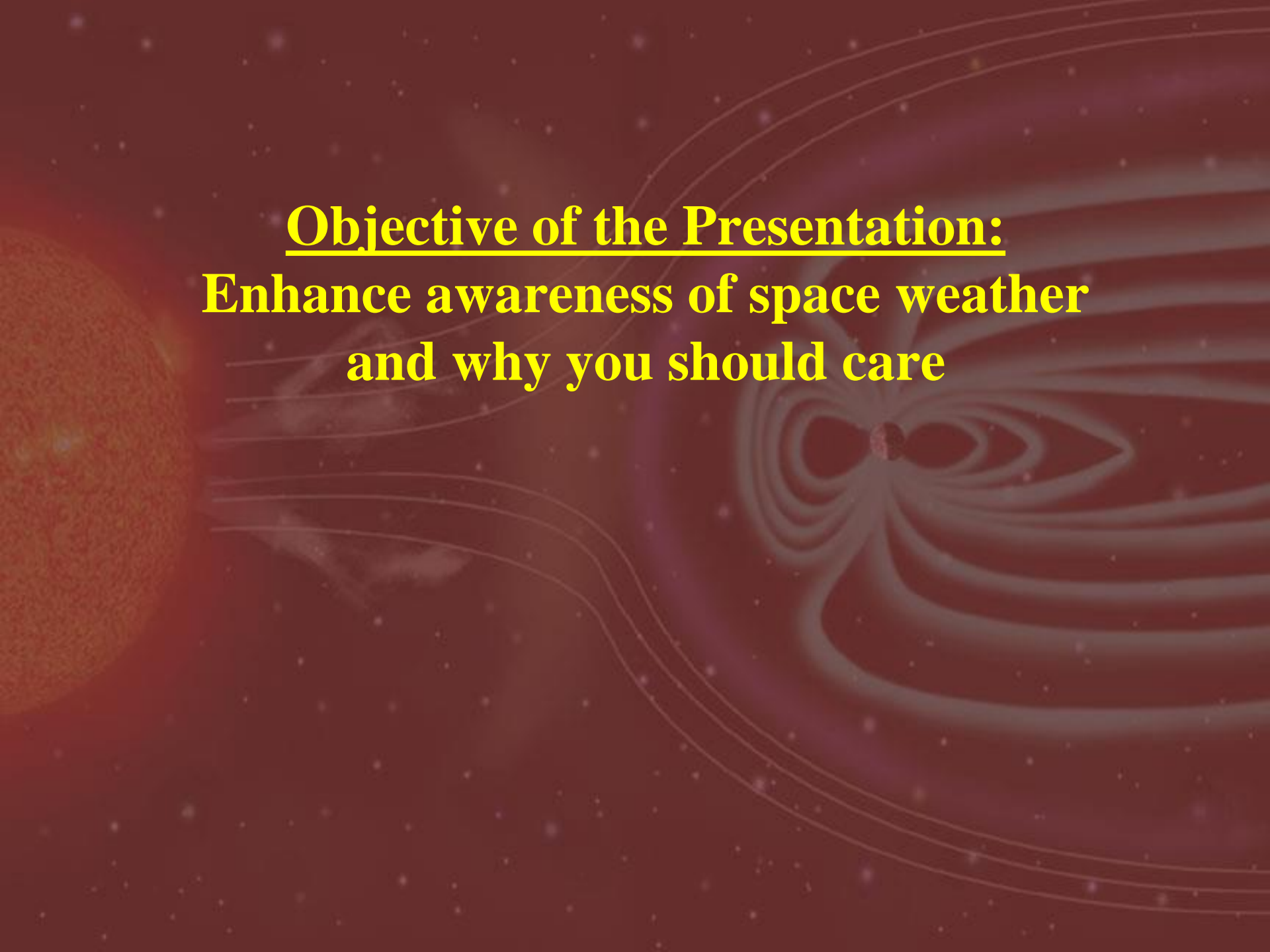


Space Weather: From Fire to Ice and the Parker Solar Probe Mission

Dr. Dennis Gallagher

NASA Marshall Space Flight Center

Dennis.Gallagher@nasa.gov

The background of the slide features a stylized representation of space weather. On the left, a large, textured orange sphere represents the Sun. From the Sun, several thin, white, curved lines representing magnetic field lines or solar wind flow towards the right. In the center-right, a small, dark, spherical planet (Earth) is shown with a complex, multi-lobed magnetic field structure, likely representing the magnetosphere. The entire scene is set against a dark red background with numerous small, white, star-like specks scattered throughout.

Objective of the Presentation:
**Enhance awareness of space weather
and why you should care**

Definition of Space Weather:

The conditions on the Sun, in space, and in our upper atmosphere that can influence the performance and reliability of space-borne and ground-based technological systems and endanger human life or health.

Weather on Earth

What's does Weather mean to you?



Weather on Earth

What's does Weather mean to you?



Weather on Earth

What's does Weather mean to you?



Weather on Earth

What's does Weather mean to you?



Weather on Earth

What's does Weather mean to you?



Images courtesy of pixabay.com

Weather on Earth

What's does Weather mean to you?



Images courtesy of pixabay.com

Weather on Earth

What's does Weather mean to you?



Images courtesy of pixabay.com

Weather on Earth

What's does Weather mean to you?



- Precipitation
- Light Displays
- Power of Nature
- Societal Danger



Images courtesy of pixabay.com

Weather in Space?



Image courtesy of pixabay.com

Weather in Space?



- **Precipitation**
- **Light Displays**
- **Power of Nature**
- **Societal Danger**

Shock and Awe?

Outline of Topics

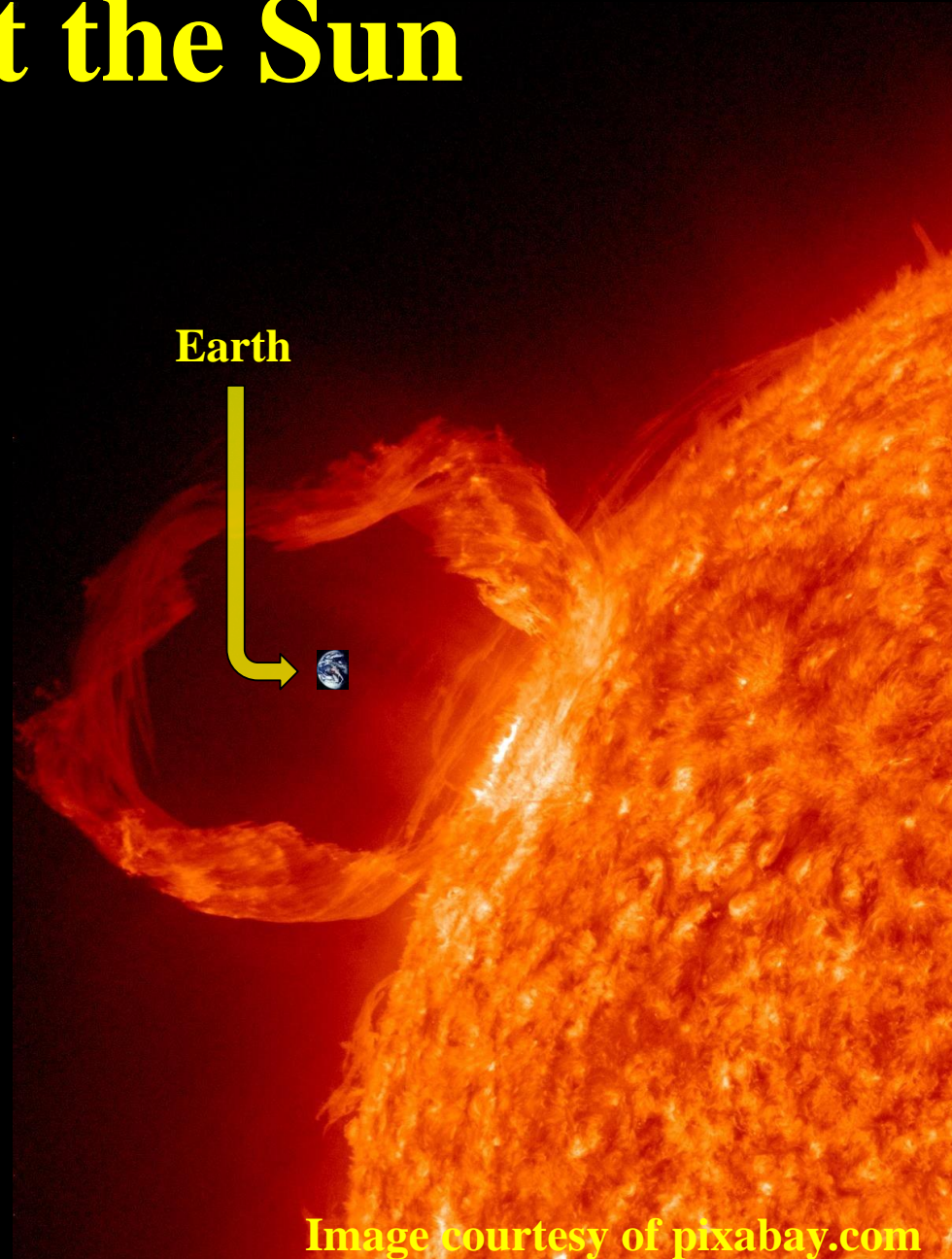
- **In our solar system space weather starts at the Sun**
- **Parker Solar Probe: Mission to the Sun**
- **Cosmic Radiation: A Galactic Rain**
- **Our Local Space Environment: Trouble at Home**
- **What is All the Noise about Earth's Magnetic field**

Start at the Sun

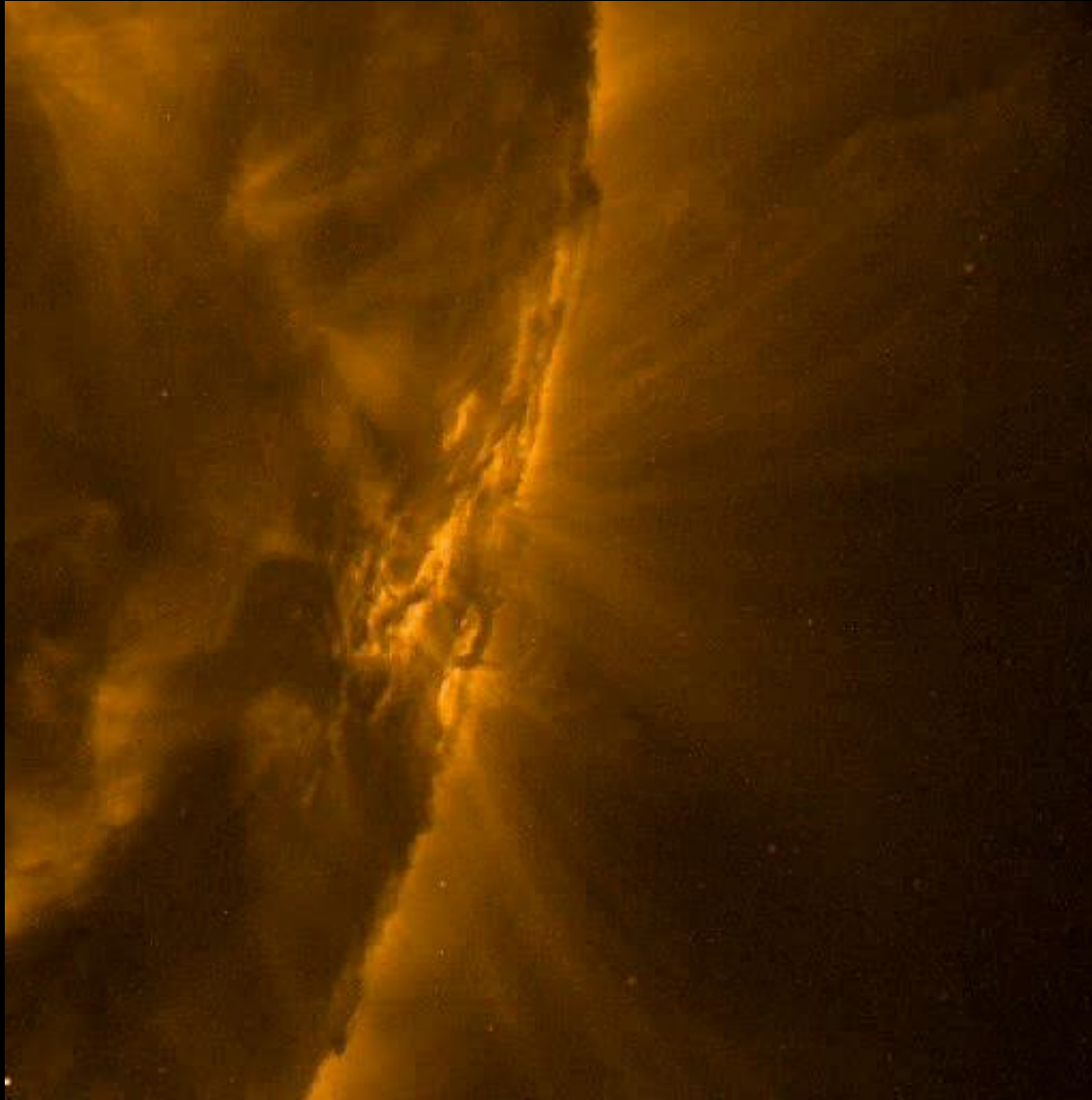
Coronal Mass Ejection:

Violent release of as much as a billion tons of matter (36 moderate sized mountains).

Can be equivalent of 40 billion Hiroshima-sized atomic bombs (enough to destroy everything on Earth's surface more than 900 times).



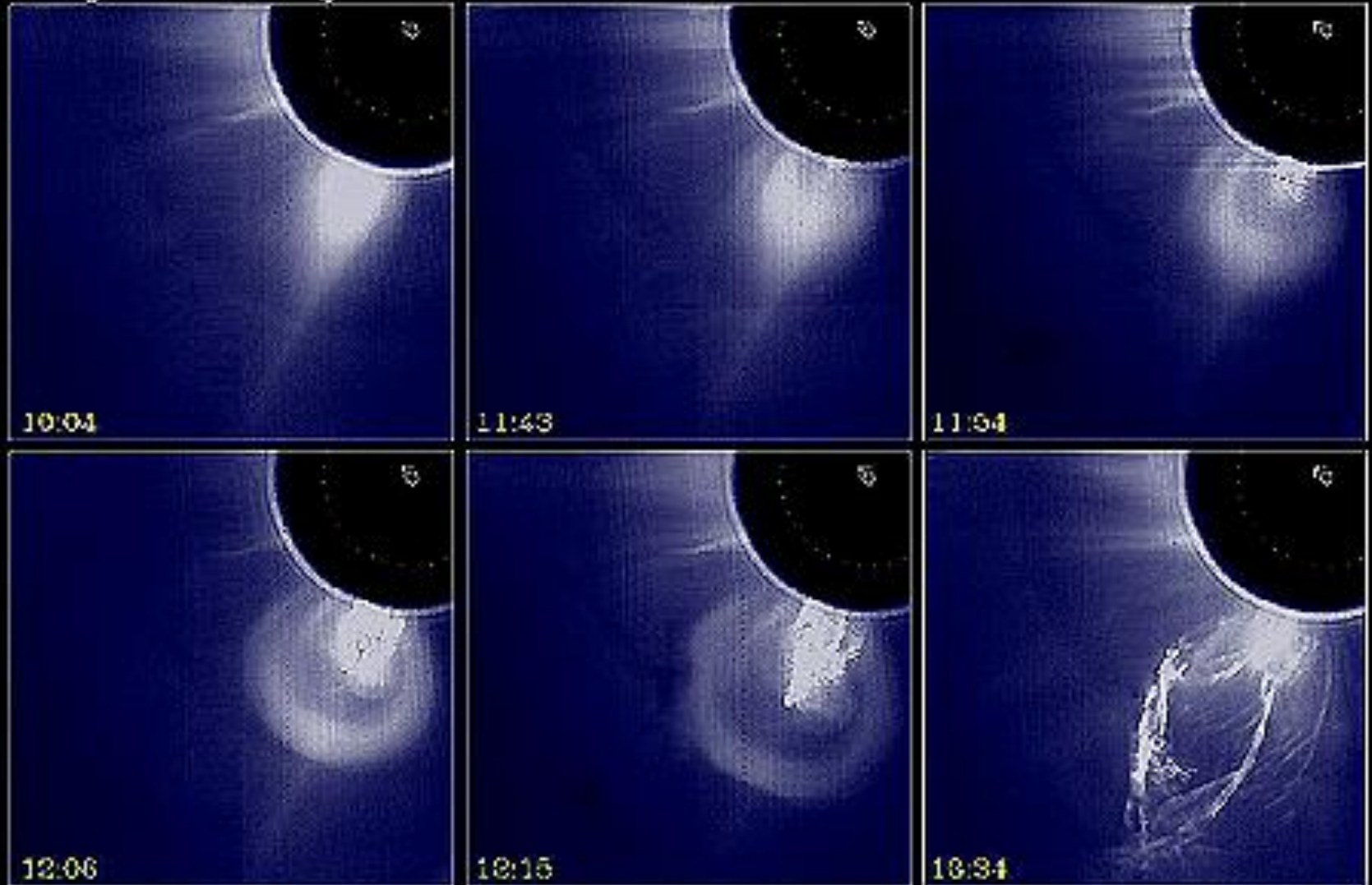
Eruptive solar flares



**Source: NASA's
TRACE mission**

Coronal mass ejections

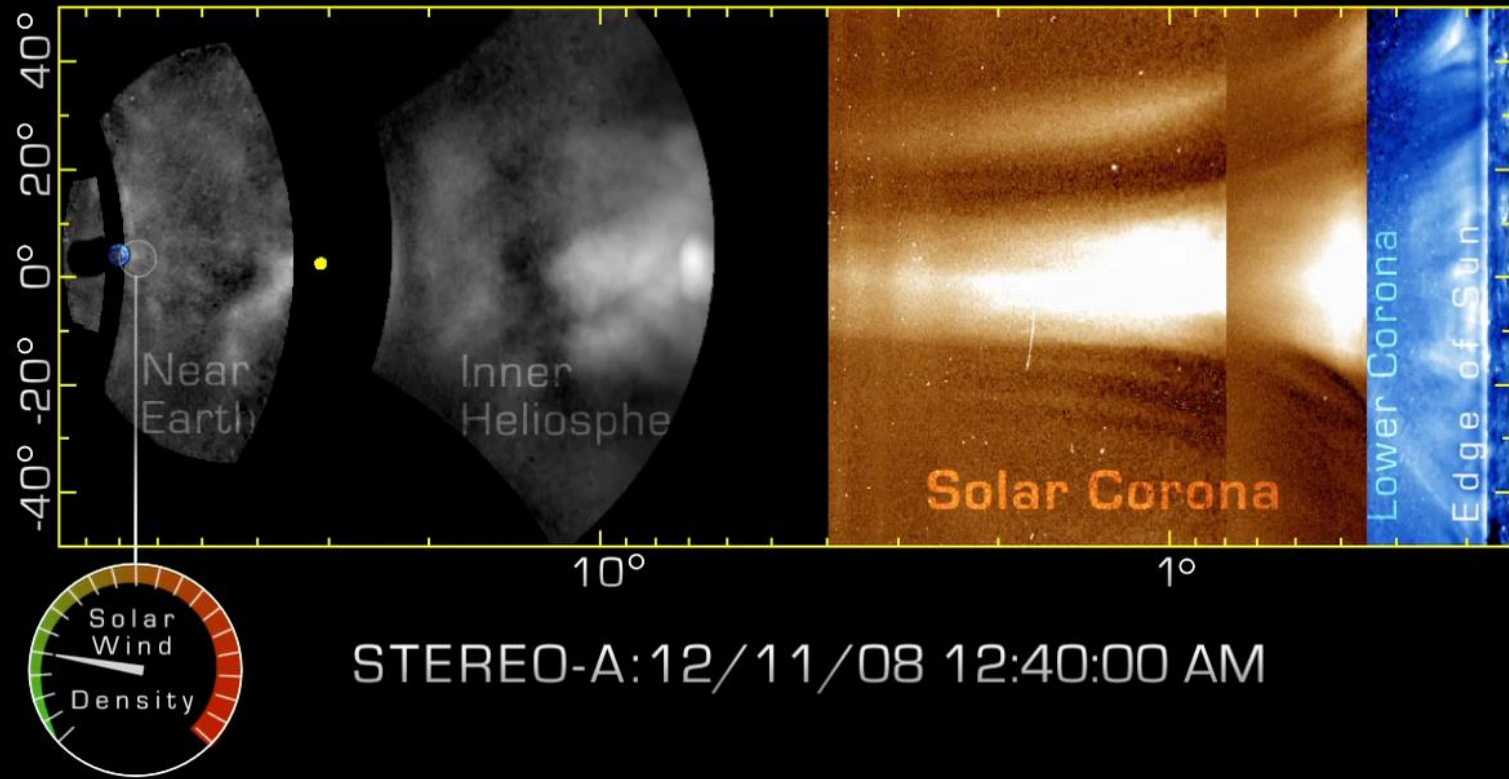
18 Aug 1980: White light



Source: High Altitude Observatory/Solar Maximum Mission Archives

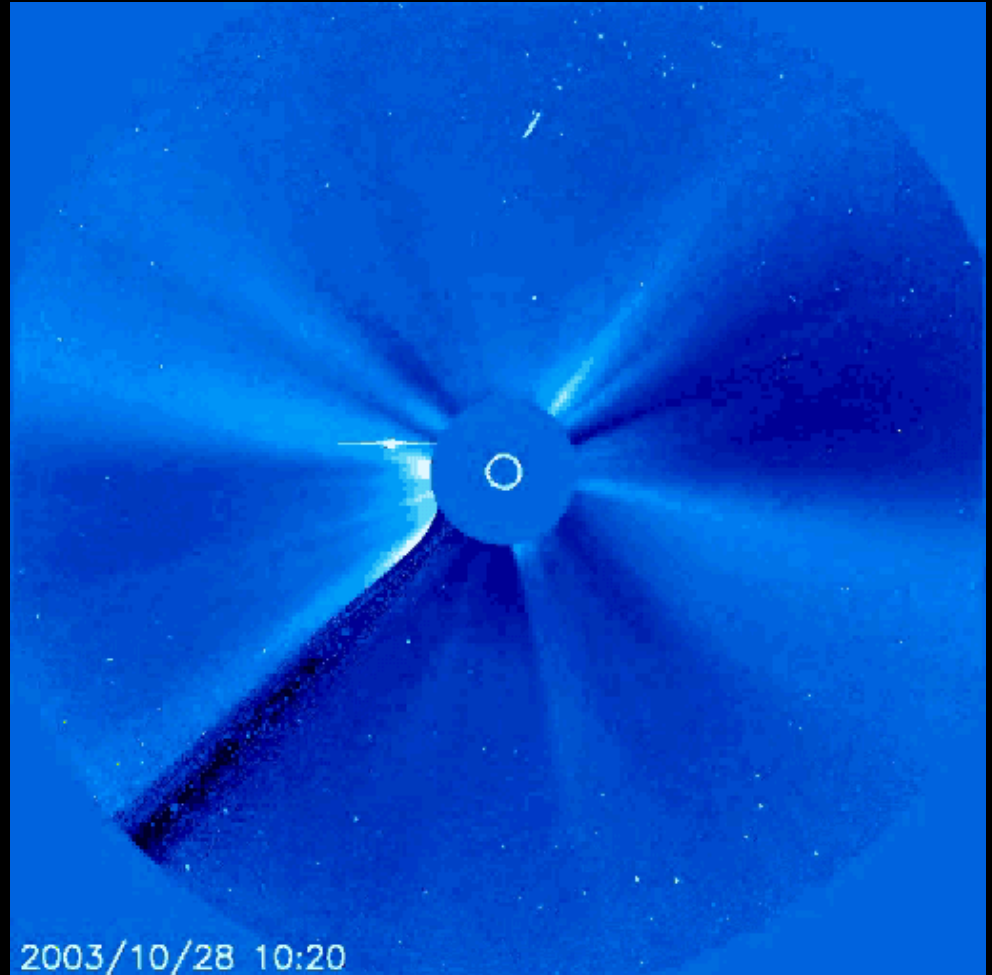
HAO A-013

Coronal Mass Ejections

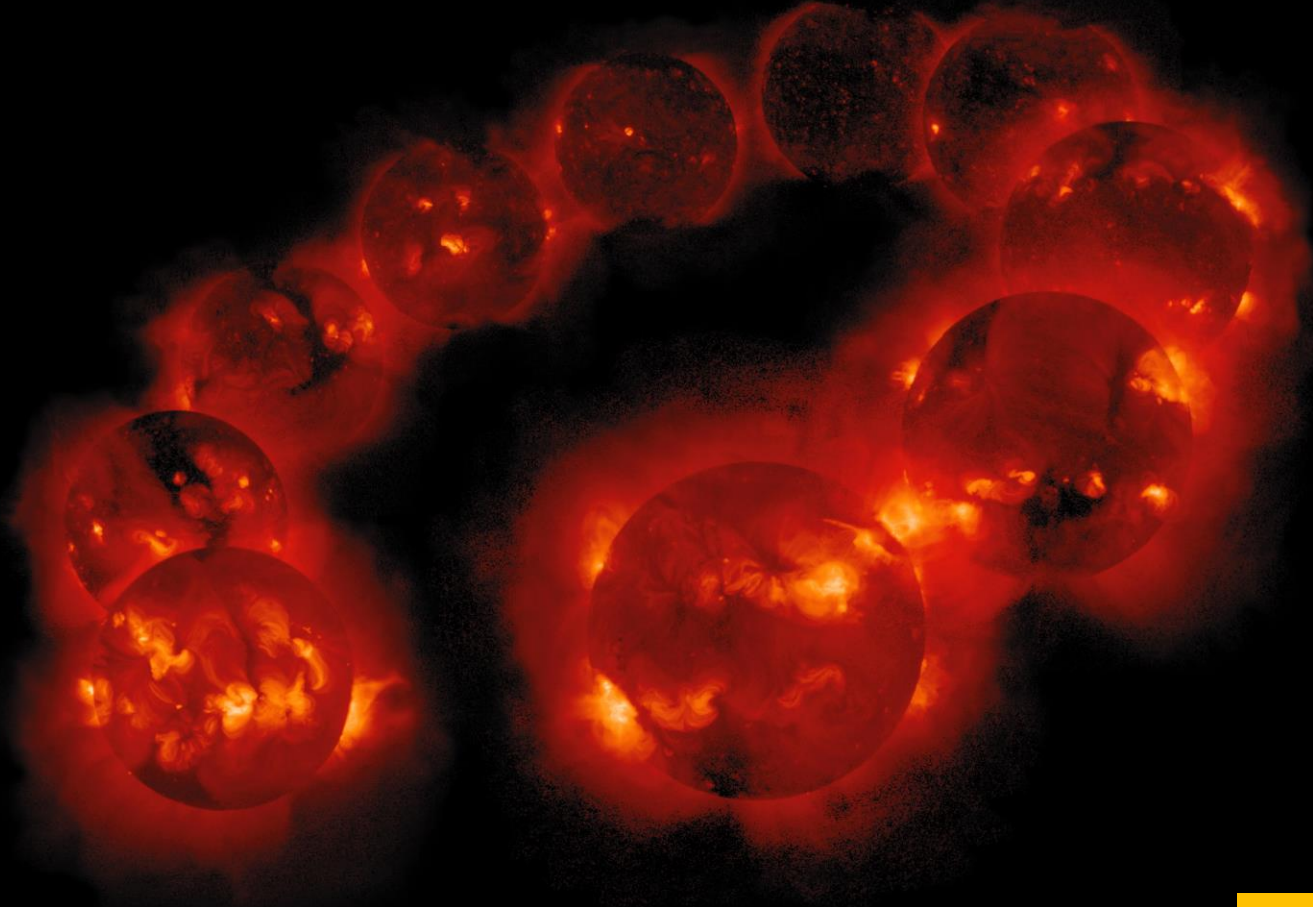


Weather at the Sun or Elsewhere Means There are Events

- What do you see?
- Near the Sun?
- Far from the Sun?

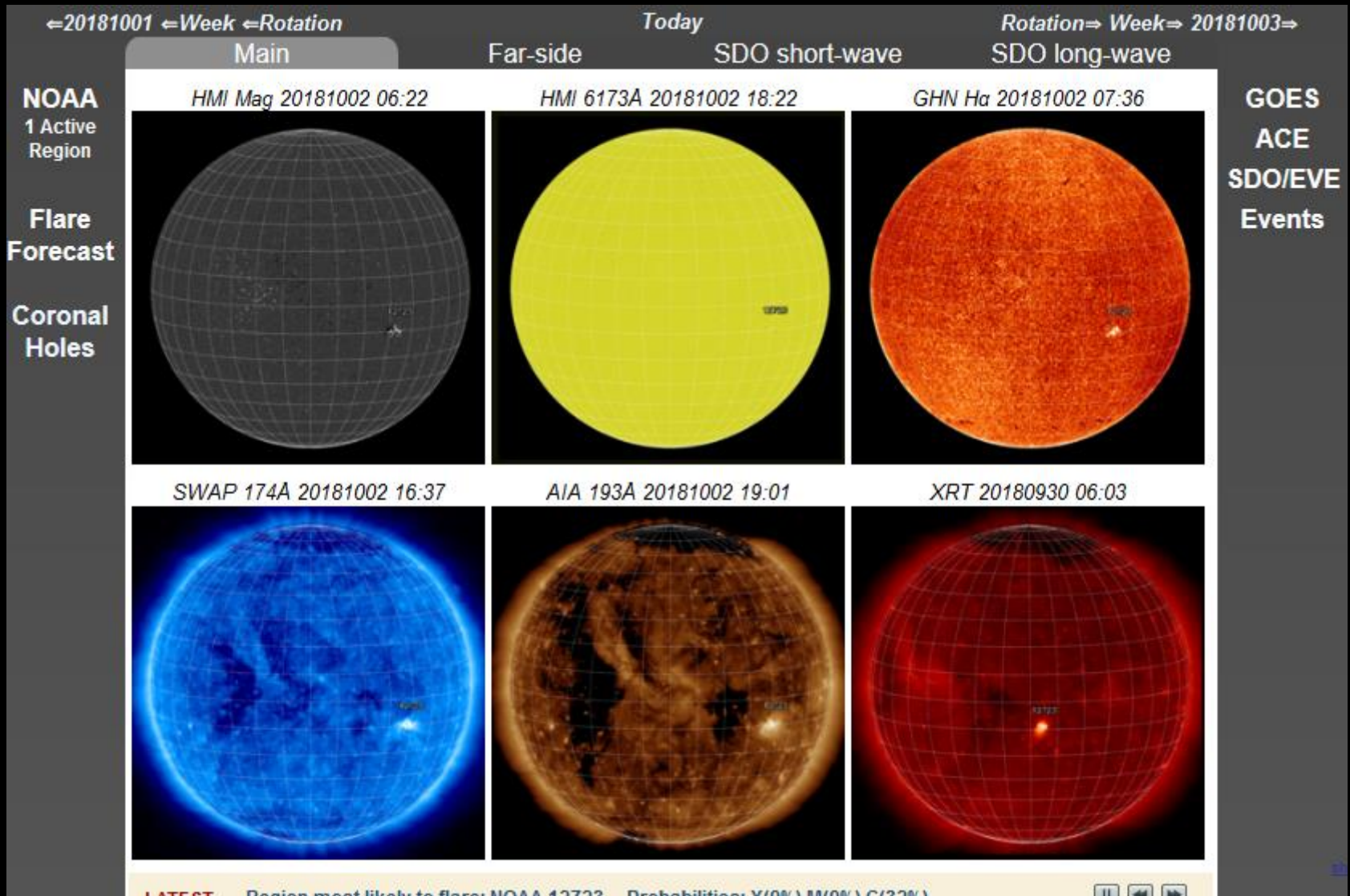


The solar activity cycle

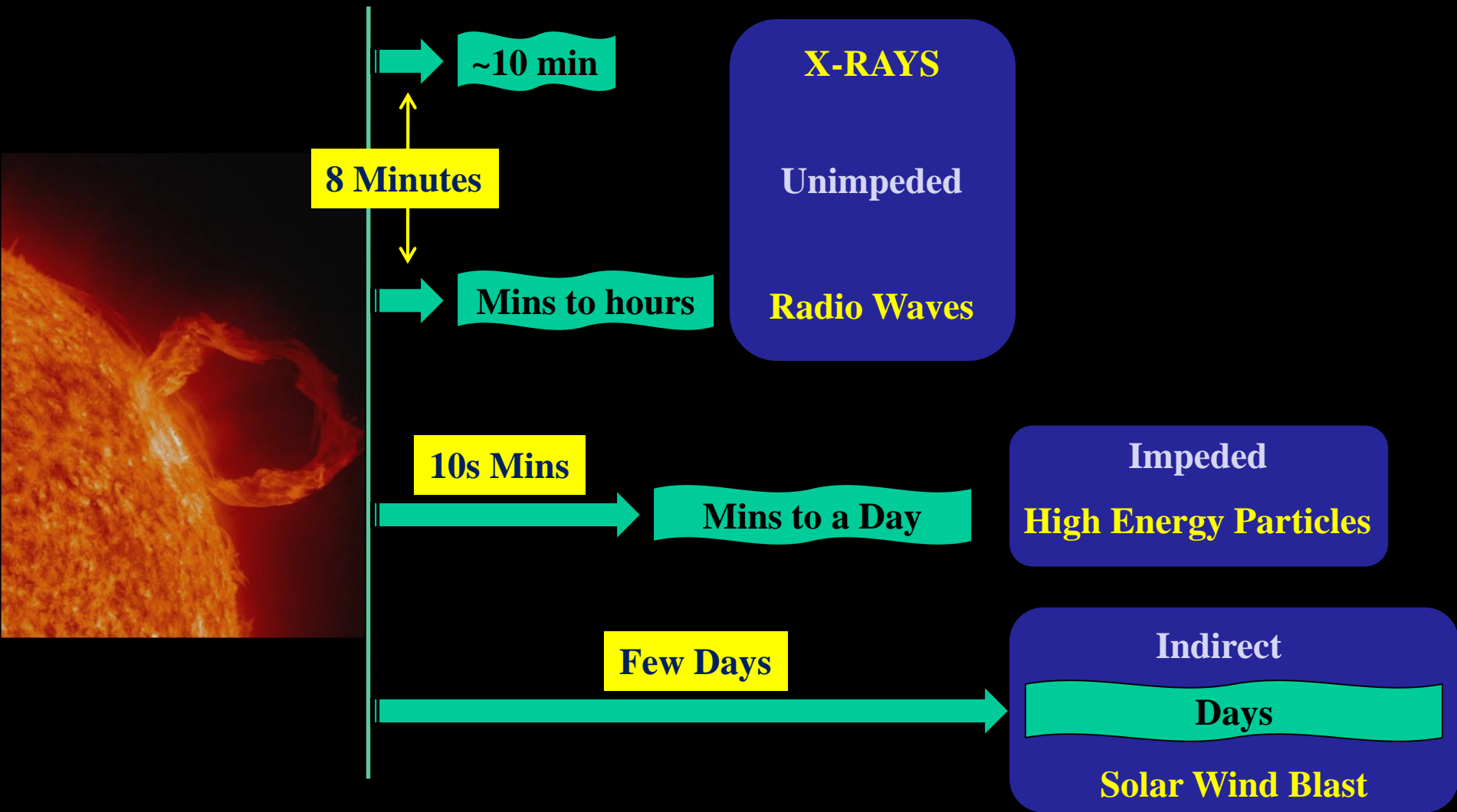


Source:
ISAS/NASA
Yohkoh mission

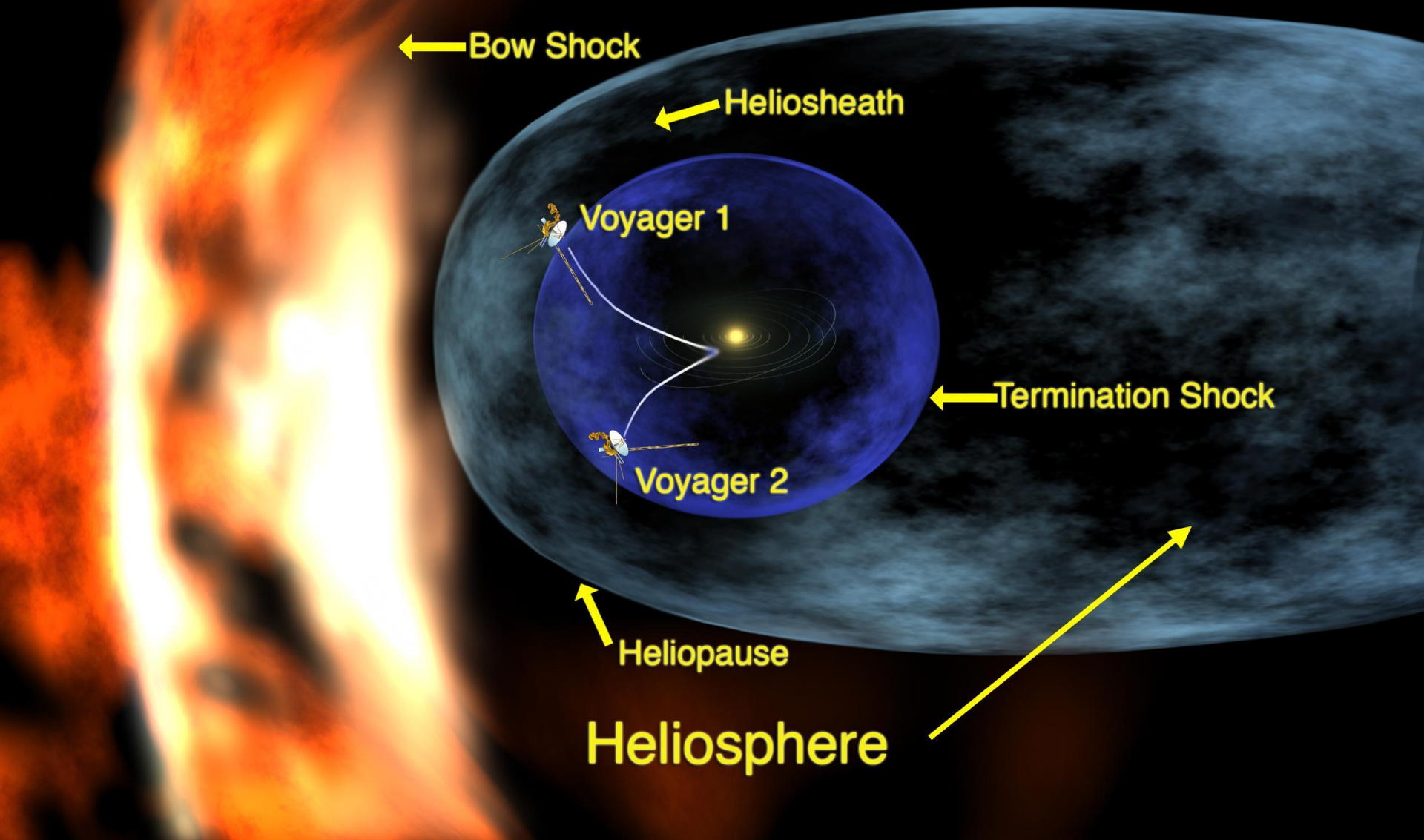
The Sun Yesterday



Time Scale for Solar Effects at Earth



Any Questions about the Sun and Its Contribution to Space Weather?

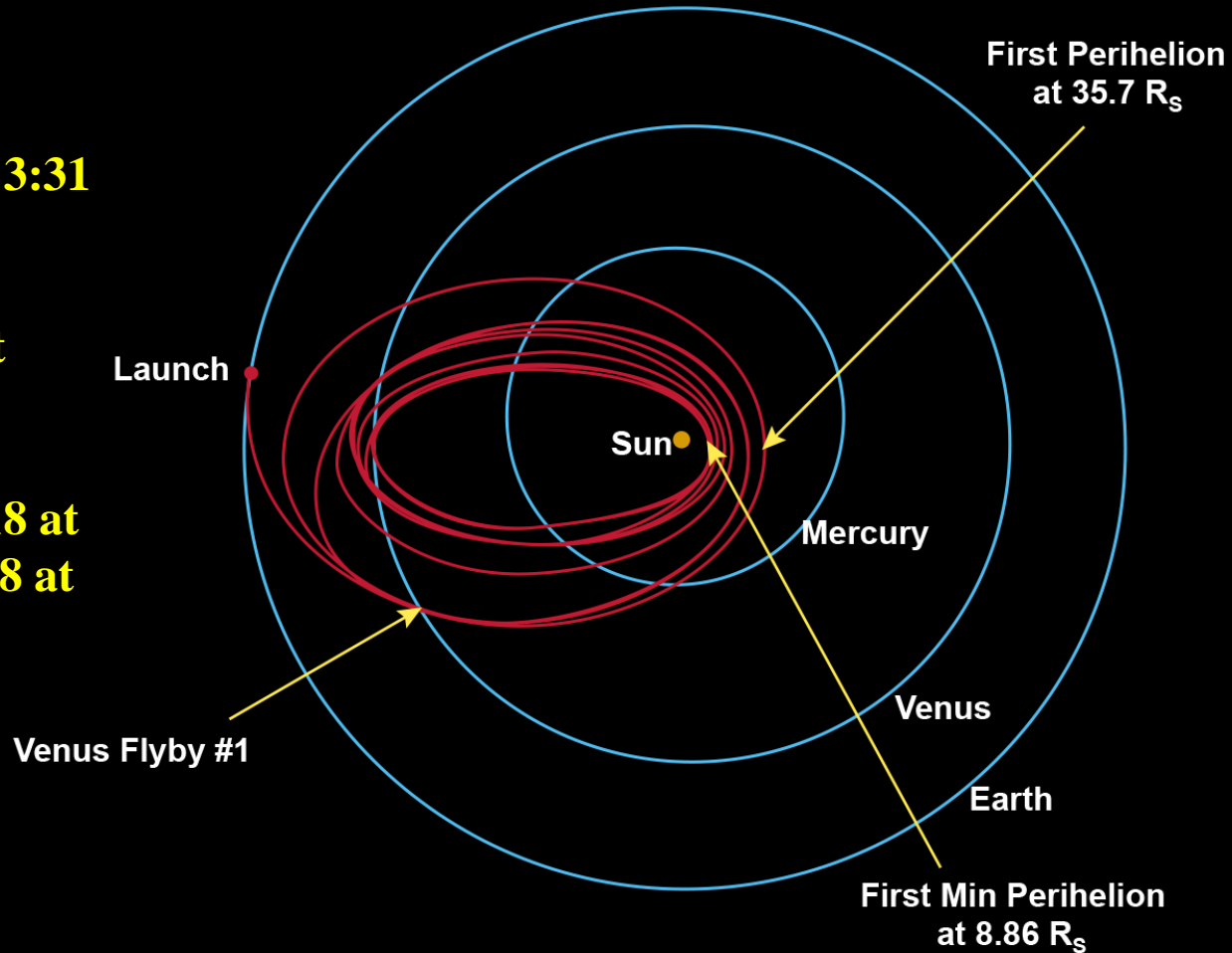


Parker Solar Probe Mission



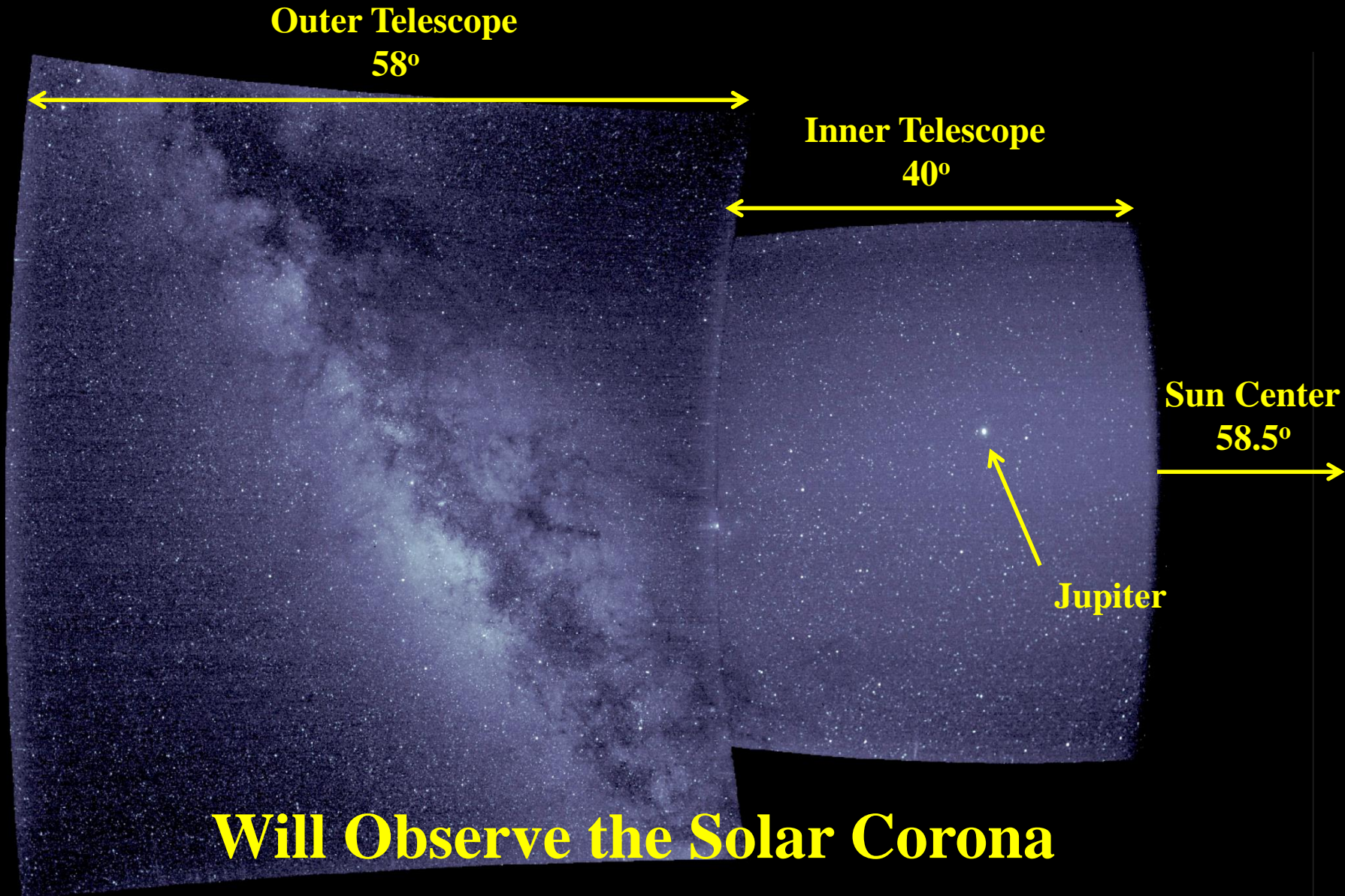
PSP Orbit

- **Launch: August 12, 2018 at 3:31 a.m. EDT (7:31 UTC)**
- **Venus Flyby: Oct. 3, 2018 at 4:44 a.m. EDT (08:44 UTC)**
- **First Perihelion: Nov. 5, 2018 at 10:27 p.m. EST (Nov. 6, 2018 at 03:27 UTC)**

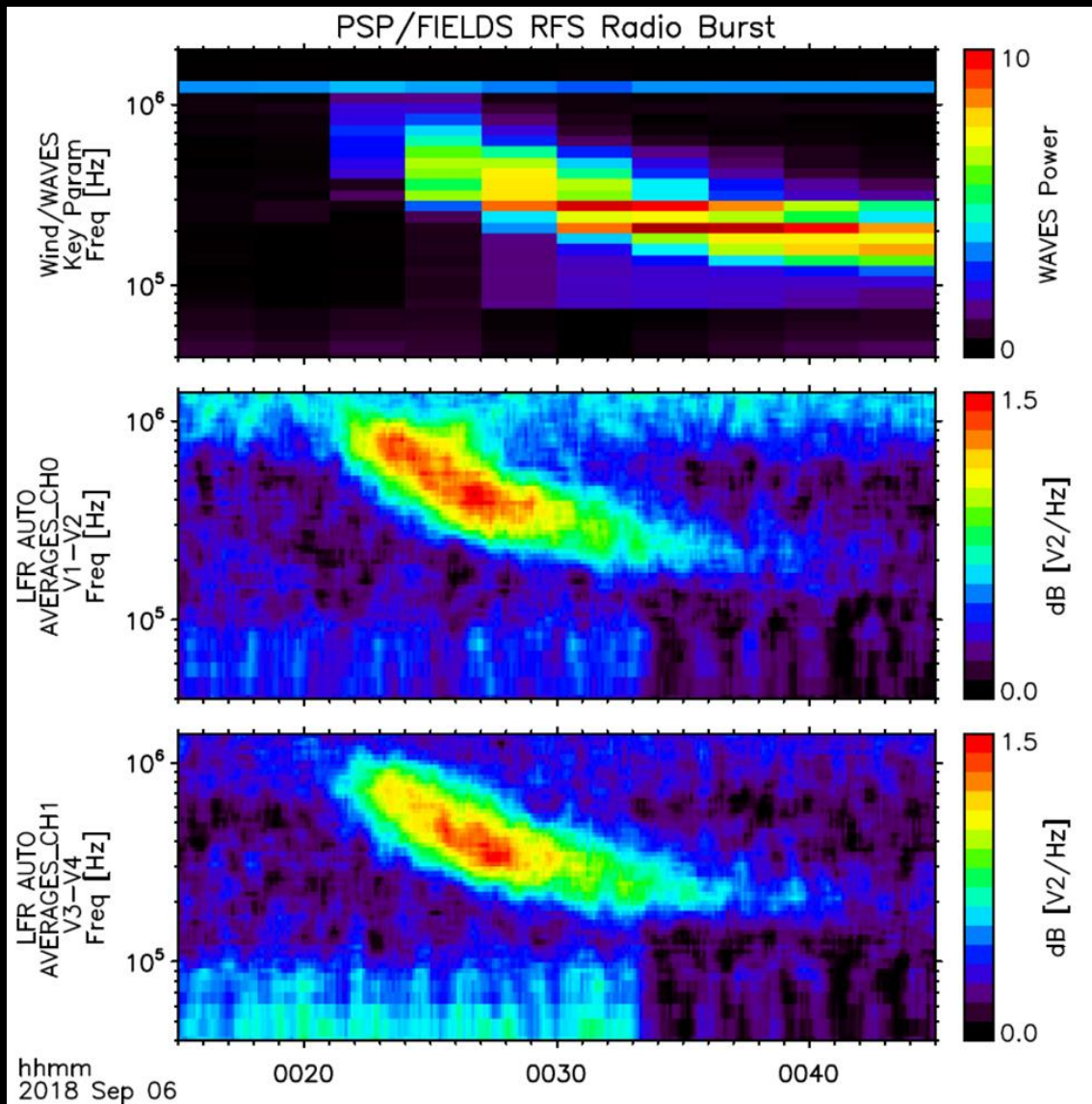


PSP Heat Shield -vs- Blow Torch

Instruments-First Light: WISPR

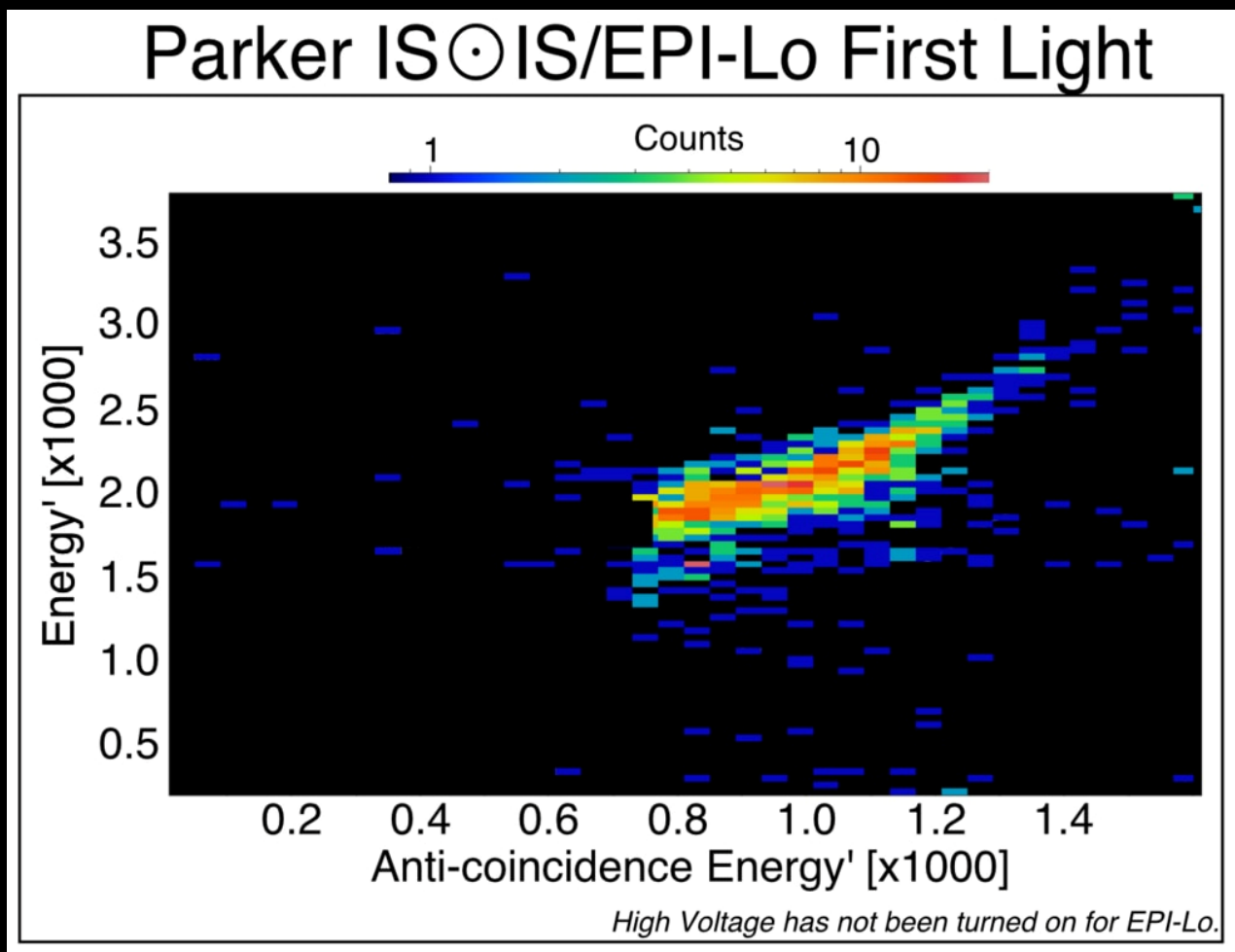


Instruments-First Light: FIELDS



Will Observe Waves in the Corona

Instruments-First Light: ISOIS Energetic Particle Instrument-Lo

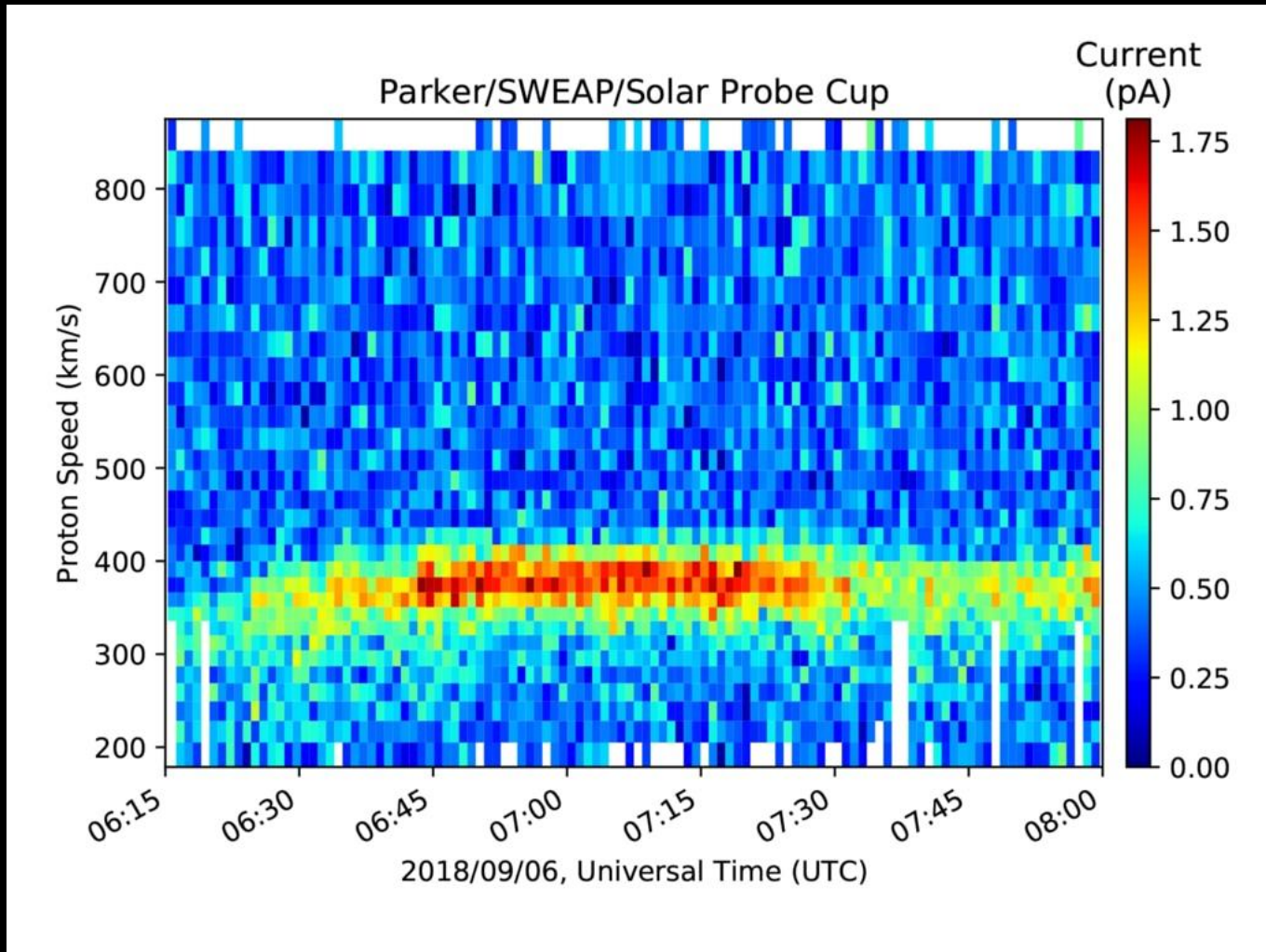


“ee-sis”

Will Observe High Energy Particles

Instruments-First Light: SWEAP

Solar Probe Cup

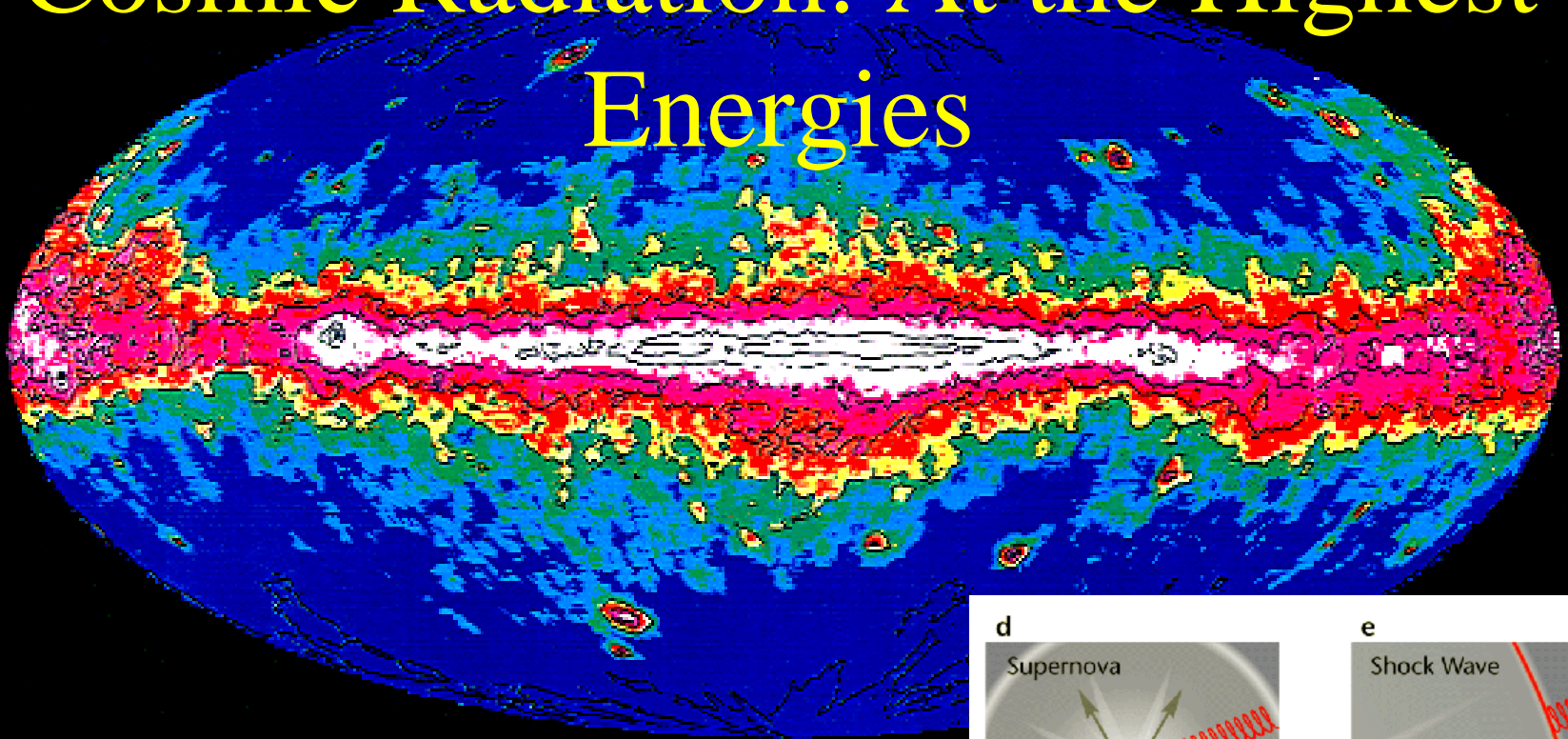


Will Observe the Solar Wind

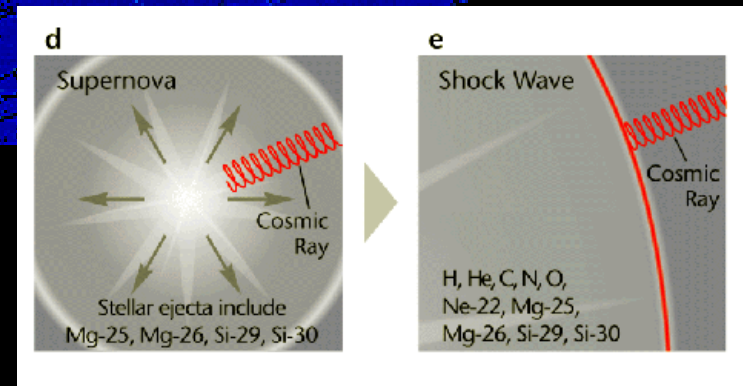
**Any Questions about
Parker Solar Probe?**



Cosmic Radiation: At the Highest Energies

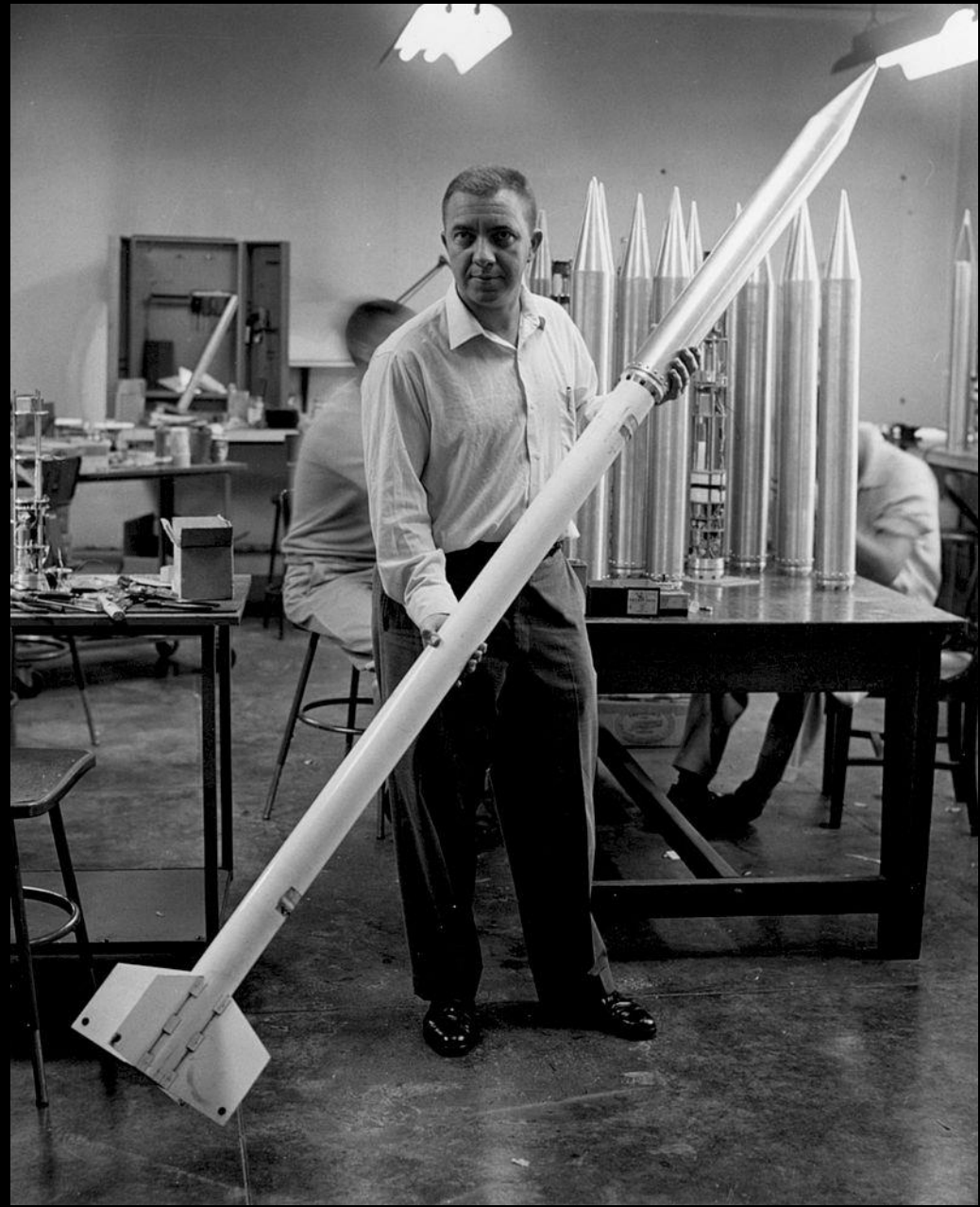
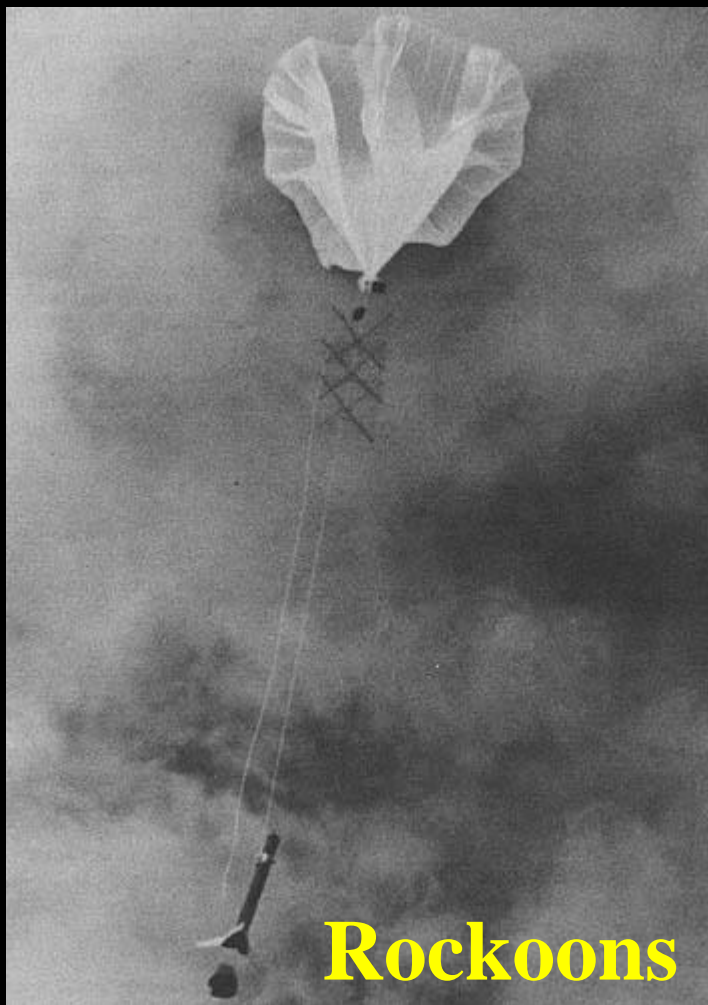


Cosmic radiation comes mostly from the galaxy and from the Heliopause at the edge of our solar system.



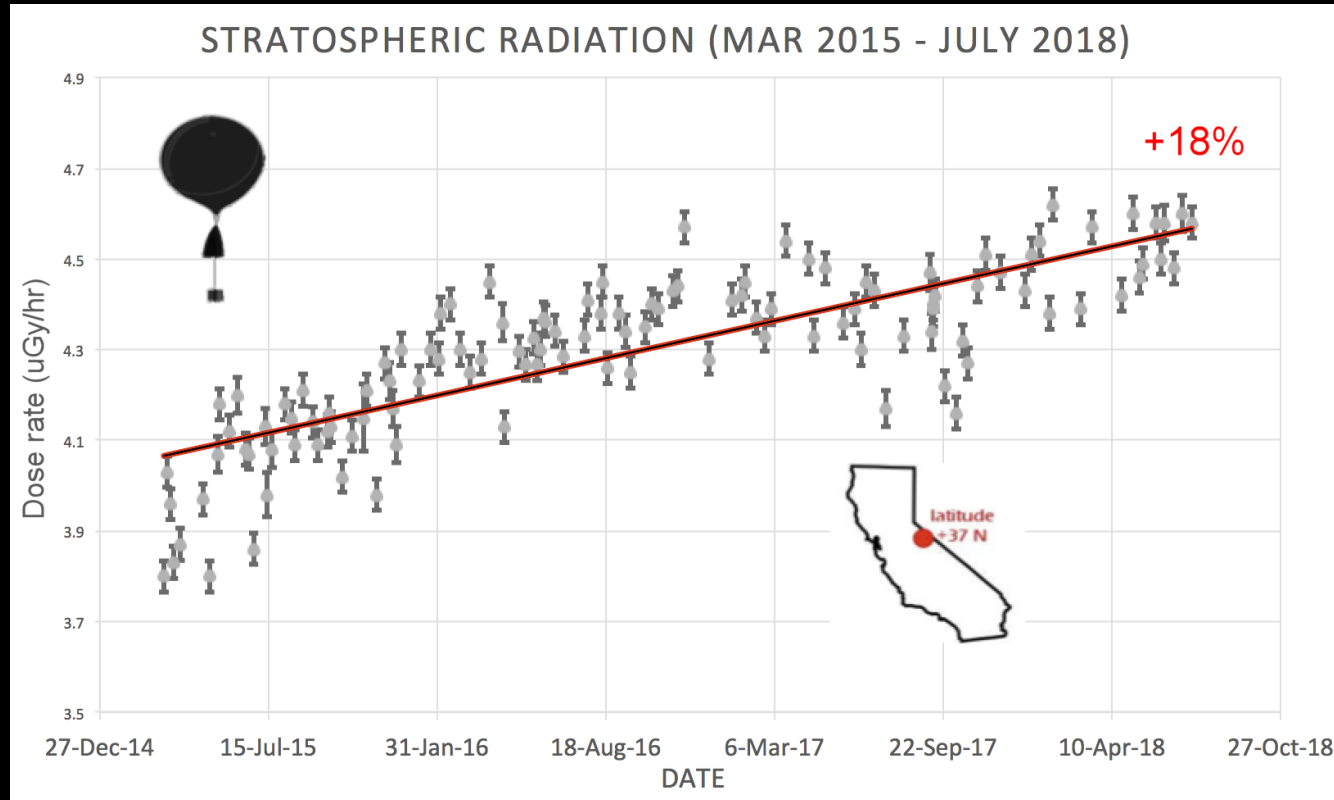
Cosmic radiation particles impact the atmosphere at a rate of about 1 per day per km² across the surface with energies from 10⁶ to 10²¹ eV → 10²¹ eV = 100 mph baseball in energy

Cosmic Radiation



Professor James A. Van Allen ca. mid-1950s at the University of Iowa.

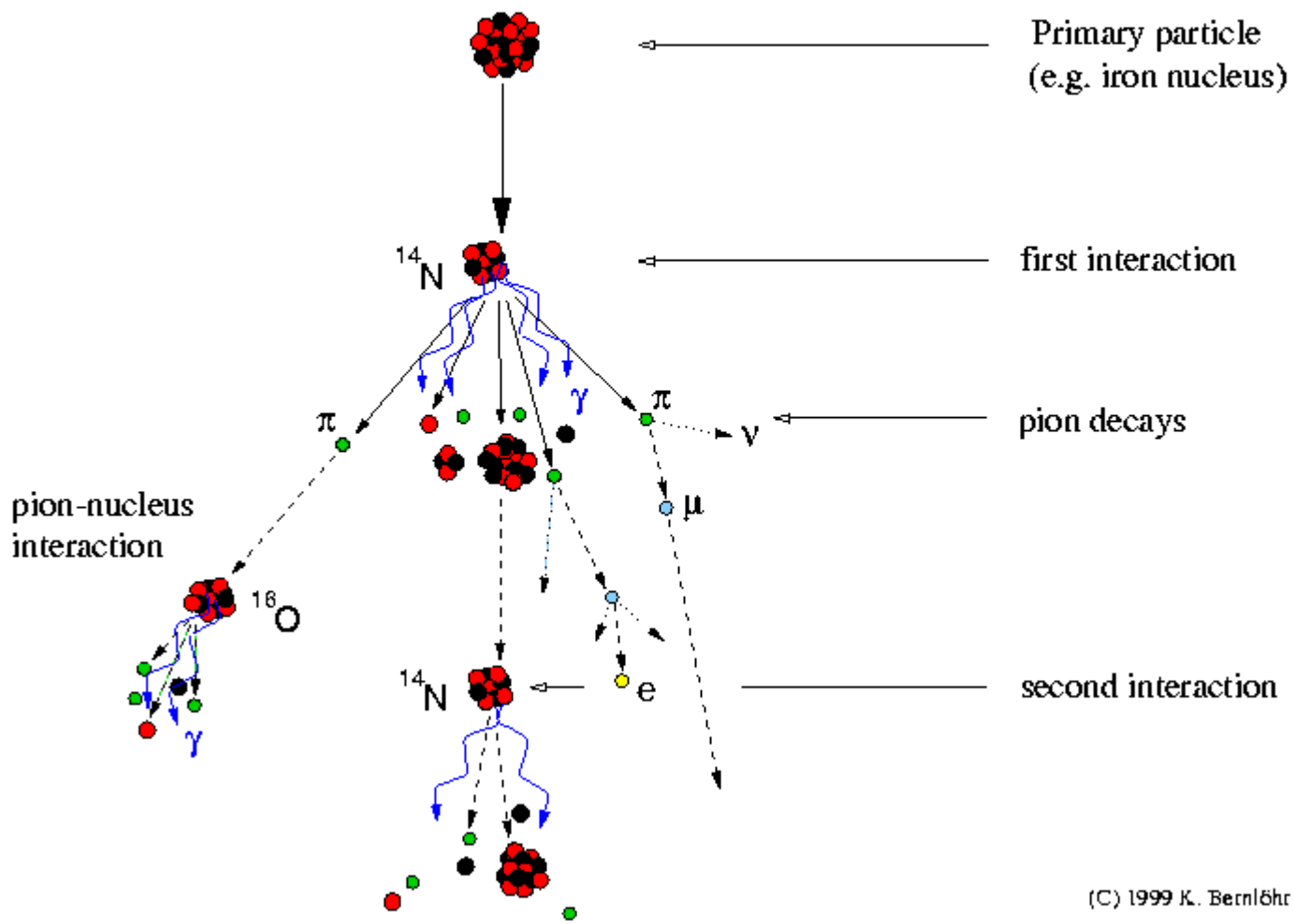
Spaceweather.com and the Students of *Earth to Sky Calculus*



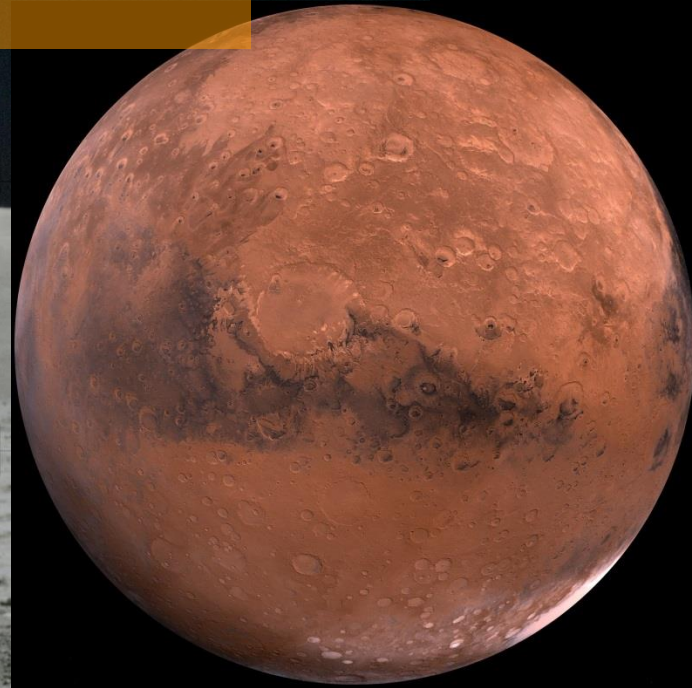
Spaceweather.com and the students of Earth to Sky Calculus fly space weather balloons to the stratosphere over California. These balloons are equipped with radiation sensors that detect cosmic rays

Any Questions about Cosmic Radiation

Development of cosmic-ray air showers



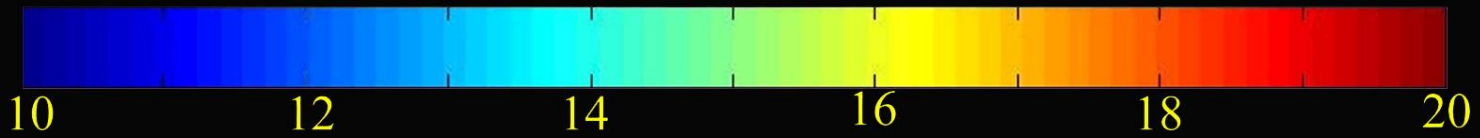
Hazards to Humans in Space



Images courtesy of pixabay.com

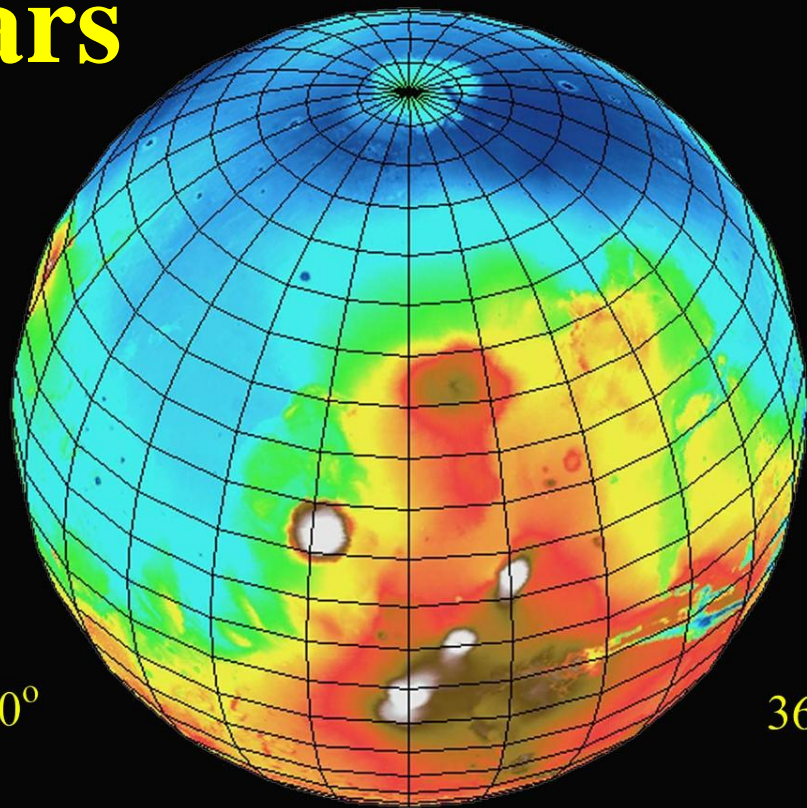
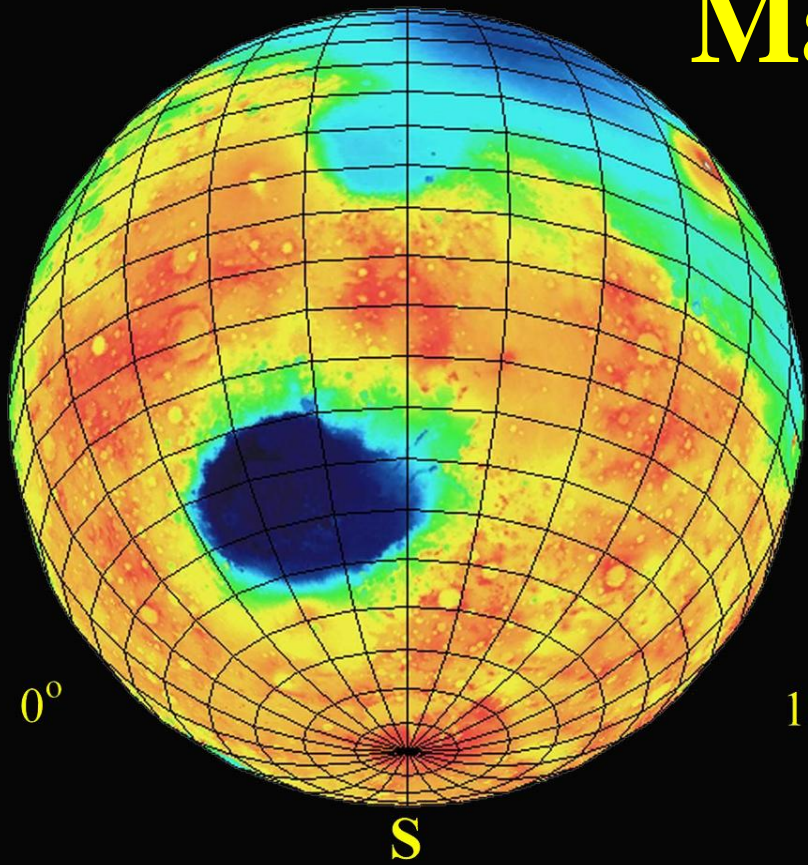
Cosmic Ray Environment

Dose Equivalent Values (rem/yr)



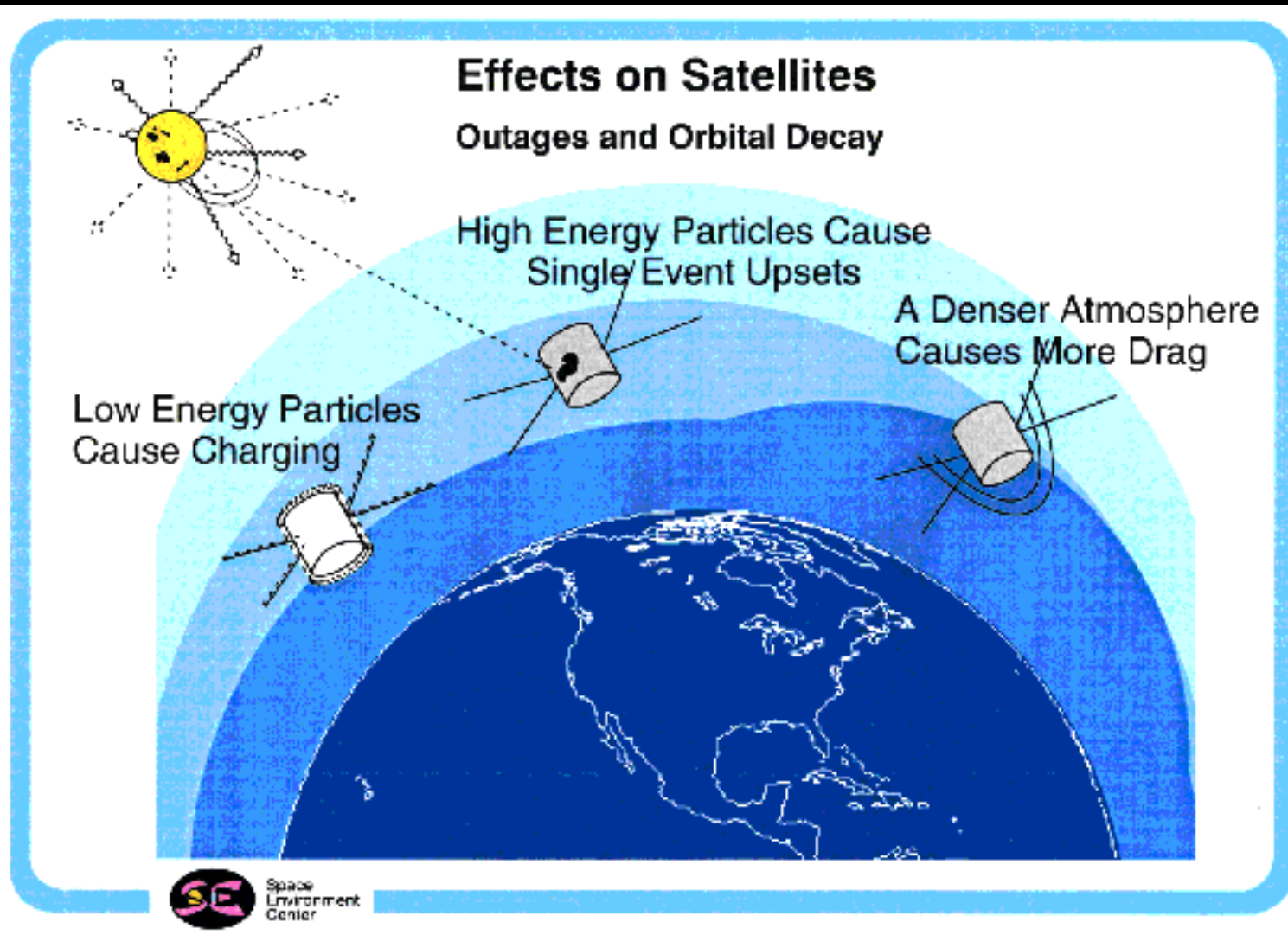
Mars

N



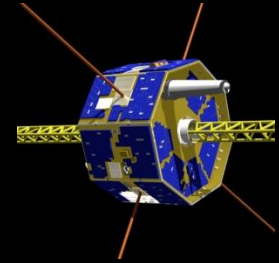
Annual Total Dose Equivalent for the Whole Body is 5 rem/yr

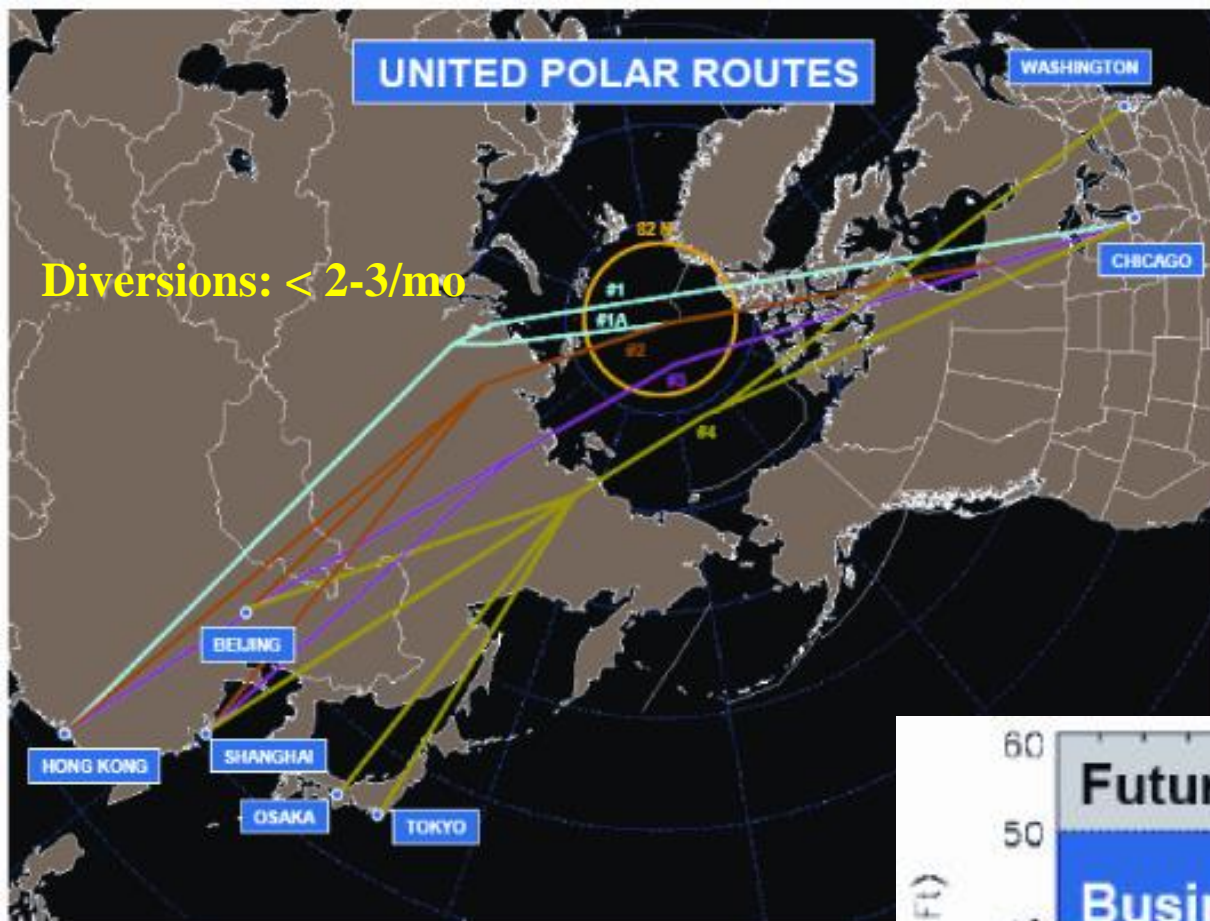
Satellite Hazards



Risks for Electronics

- In space single event upsets (SEUs) cause satellite control errors, risking damage or loss
- In aircraft SEUs cause upsets of about 1 per 200 hours of operation measured on a Boeing 777 autopilot: (designed for 1:1 million); pacemakers have been used to measure SEUs in commercial aircraft
- On the ground SEUs are thought to have caused power losses in German high-speed trains in the 1990's from cosmic radiation.



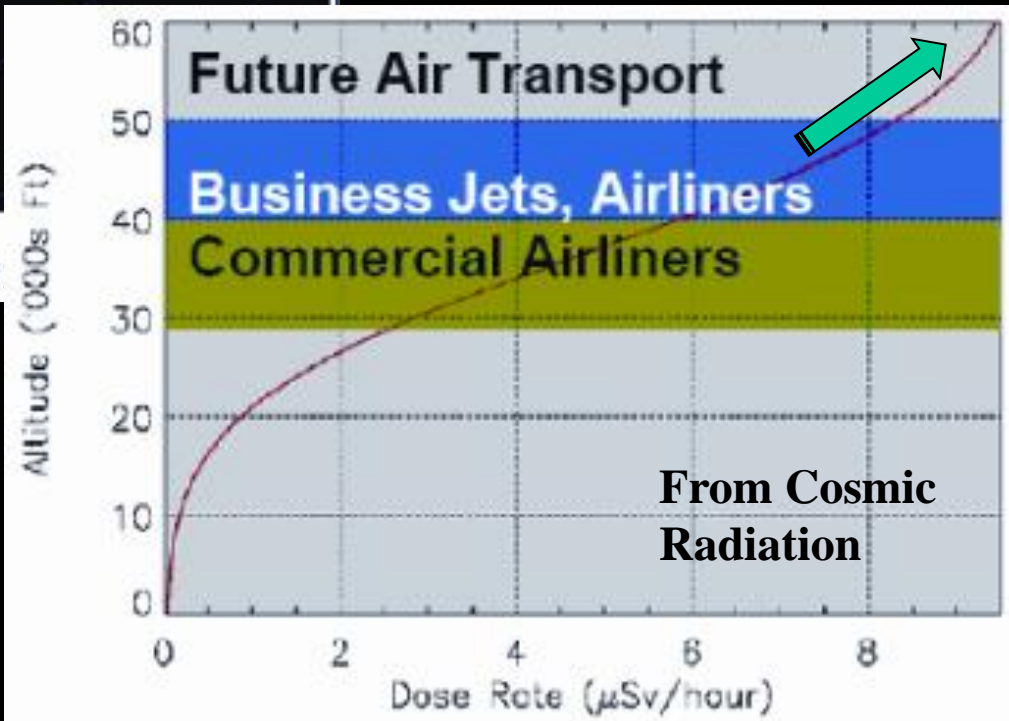


**Transpolar
Flights and
cosmic
radiation risks
are increasing**

Figure 1. Polar Routes used by United Airlines (source:

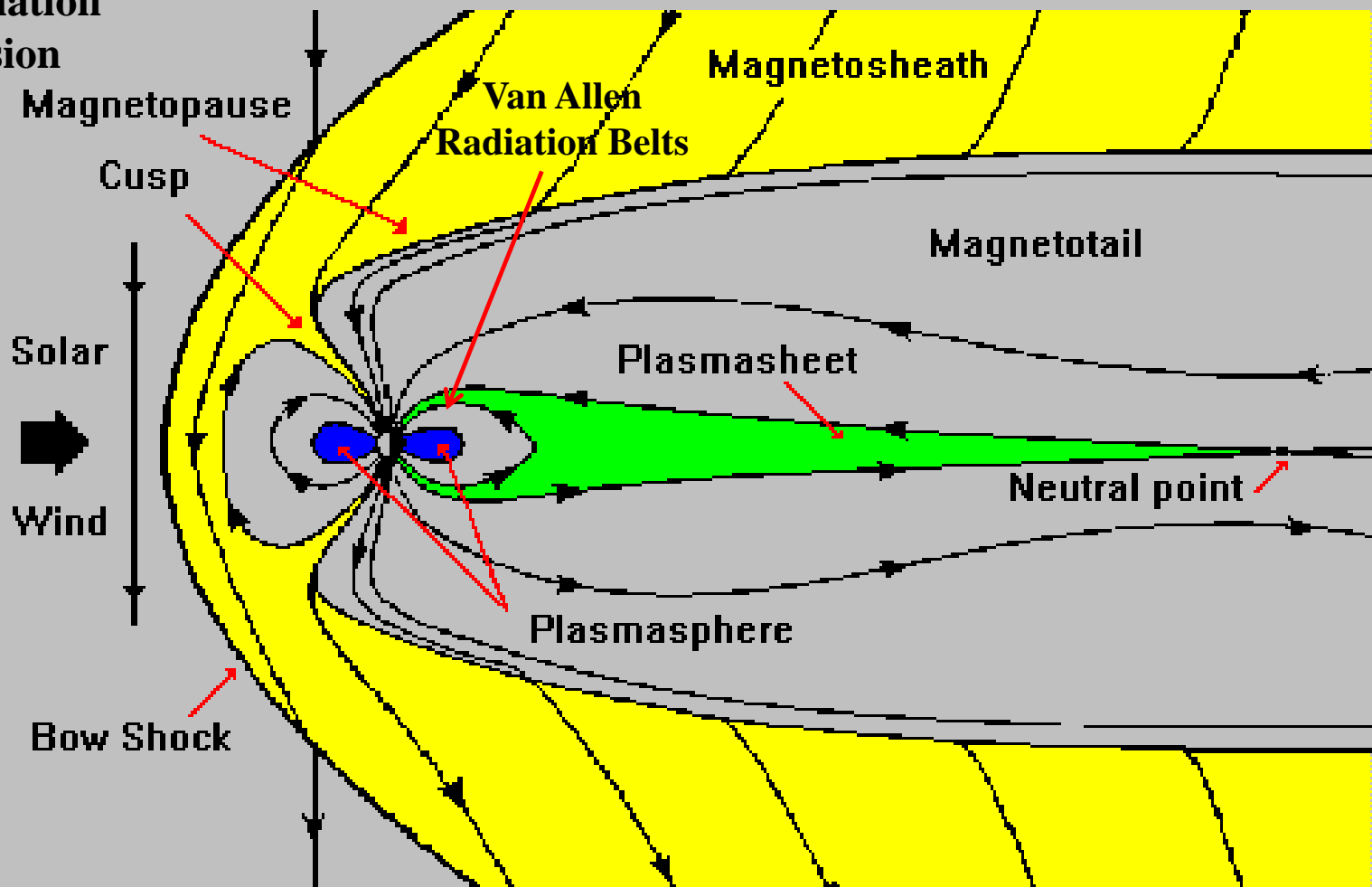
**From the American
Meteorological Society &
SolarMetrics Policy Workshop
Report March 2007**

**Max permissible mean dose
rate limit: 7.5 mSv/hour**



Earth's Magnetic Environment "The Magnetosphere"

Precipitation
Electric Currents
Ionospheric scintillation
10MW radio emission
Radiation



The greatest show on Earth... Precipitating high energy particles



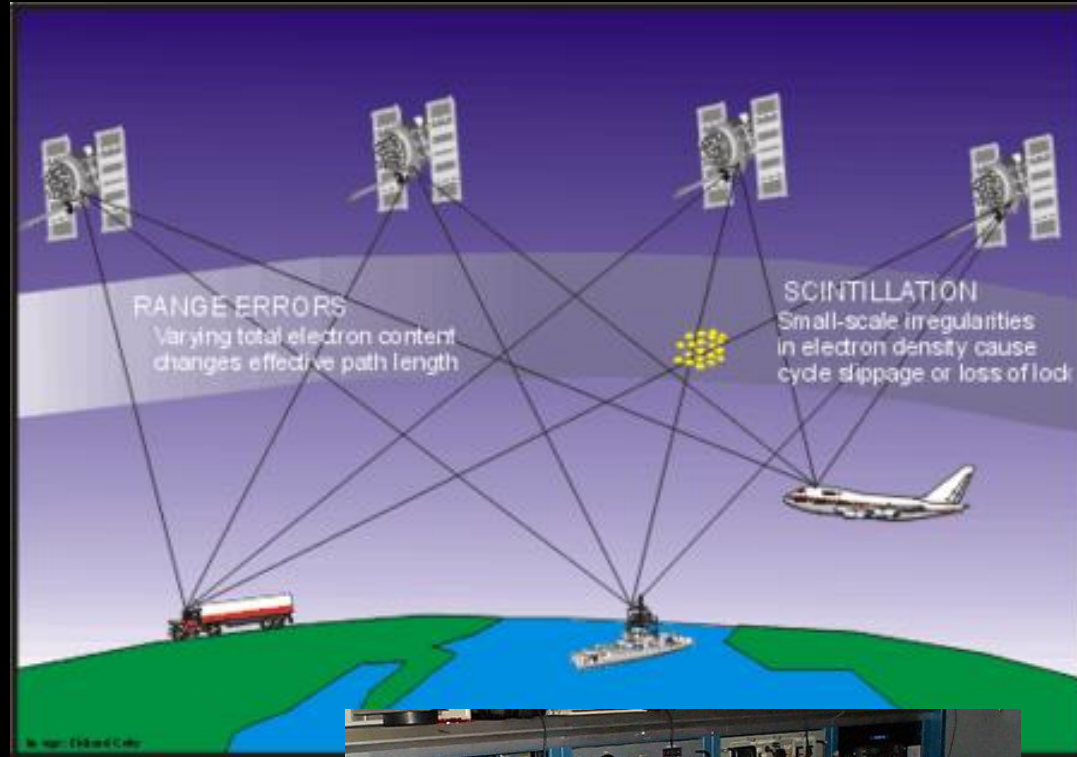
Image courtesy of pixabay.com

Disruption of:

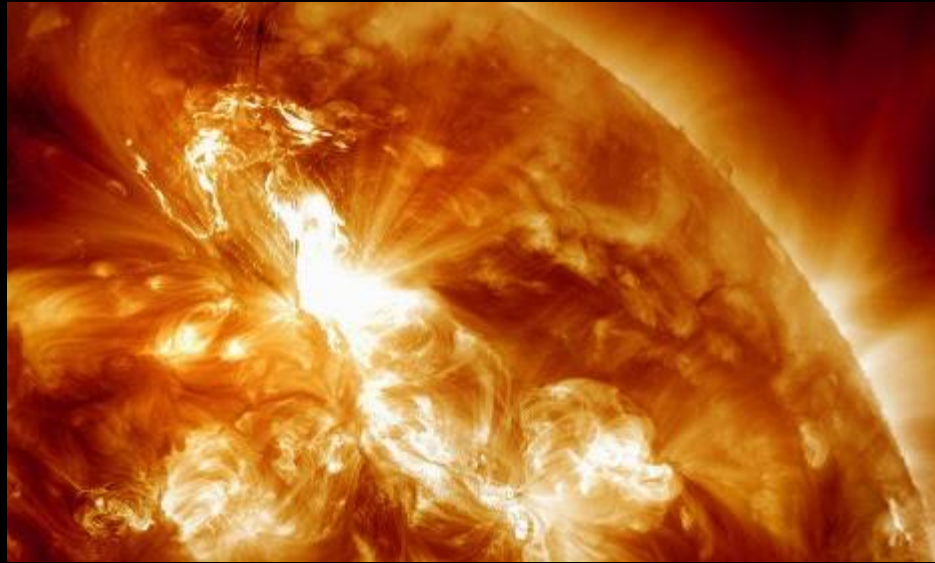
HF

Communication

Navigation



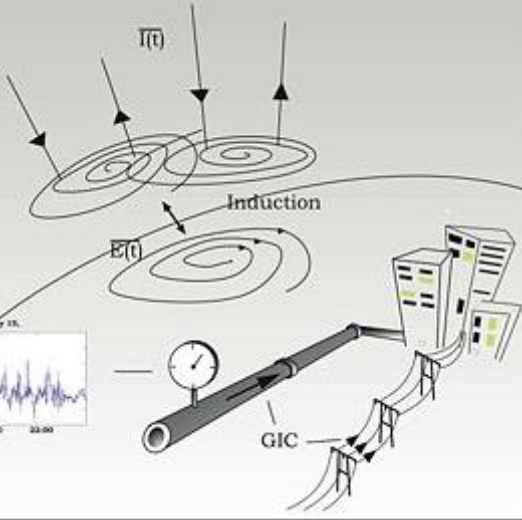
‘Solar storm’ grounds Swedish air traffic



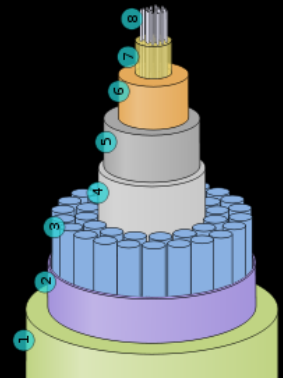
Reported in the December 1, 2015 issue of “The Local Europe AB” an English version of Sweden’s news:

Planes were grounded at some of Sweden's busiest airports on Wednesday afternoon because of a "solar storm" interfering with air traffic control radar systems, authorities said.

Ground Induced Currents (GIC)



- Railroads:
 - Sweden in 1982, railway signals failed to switch correctly
 - Norway in 2000, 19 lives were lost
- Deep Sea Cables:
 - Space Weather can generate hundreds to thousands of volts



Pipeline Corrosion



**To Fight
Corrosion**

Image courtesy of pixabay.com

**Applied
Voltage**

-

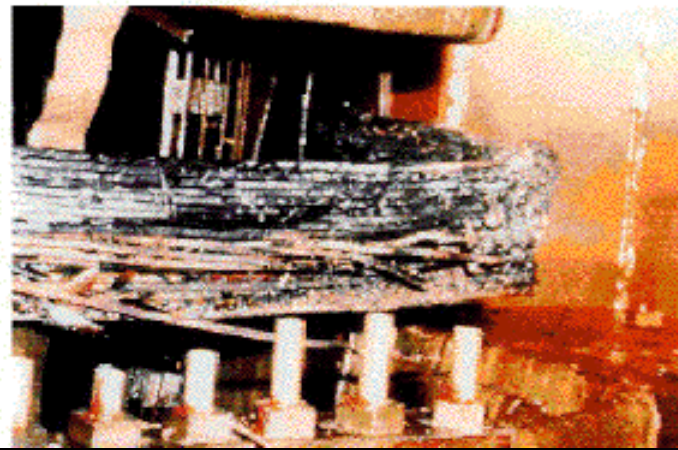
+

Electrical Power Disruption Due to Induced Electric Currents

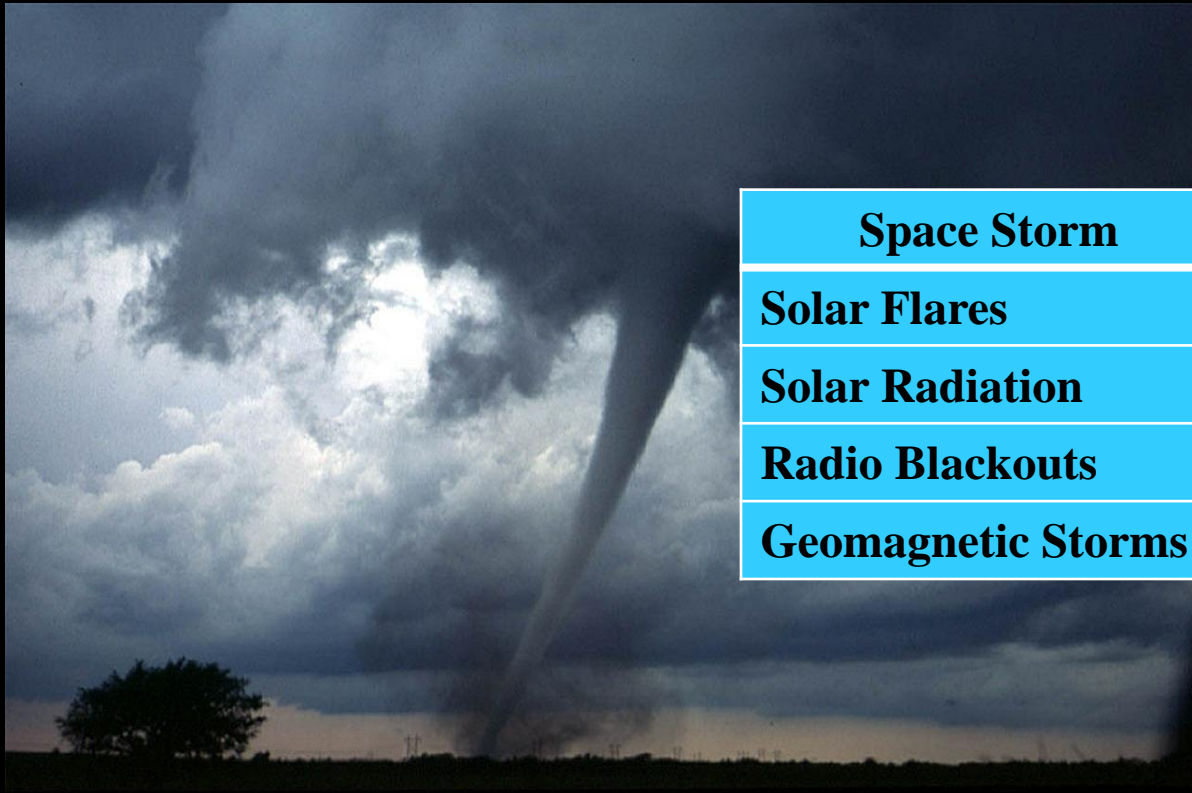









PJM Public Service
Step Up Transformer

Severe internal damage caused by
the space storm of 13 March, 1989



Atmospheric storms are measured.
Space storms are too.

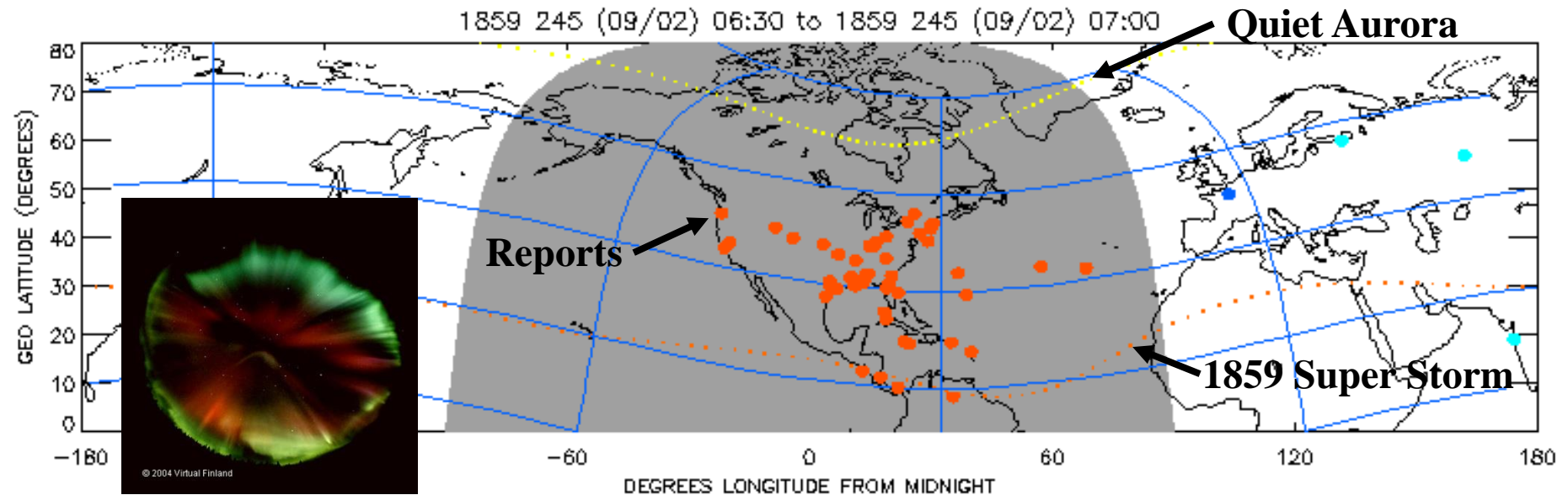


Space Storm	Minor  Extreme
Solar Flares	B  C  M  X
Solar Radiation	S1  S5
Radio Blackouts	R1  R5
Geomagnetic Storms	G1  G5

<https://www.swpc.noaa.gov>

September 2, 1859 Event

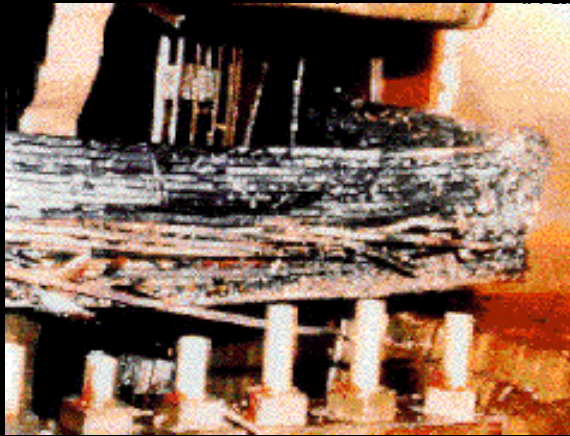
3X recent storm strength / 1/3 strongest ever



- Messenger (deck log: Lat. 49°) “we witnessed the most magnificent display of the aurora boreales (sic) imaginable ... the whole firmament was a blaze of Crimson shooting up from all points of the compass but the most splendid from the South W. I have not the language to describe it”

Courtesy James L. Green, NASA/GSFC

Weather in Space – Questions?



- Precipitation
- Light Displays
- Power of Nature
- Societal Danger



Shock and Awe

Images courtesy of pixabay.com

Reversal of Earth's Magnetic Field

No Sweat --vs-- OMG!

NASA: Based on geologic and fossil records we have from hundreds of past magnetic polarity reversals, **no problem**.

ExtremeTech: **No**, the impending geomagnetic reversal probably won't cause some kind of apocalypse. Organisms that use **magnetoception** to navigate — birds, bacteria, bees — might be confused.

National Geographic: Lots of doomsday prophets have tried to equate geomagnetic flips with mass extinctions, but **the data just aren't there**.

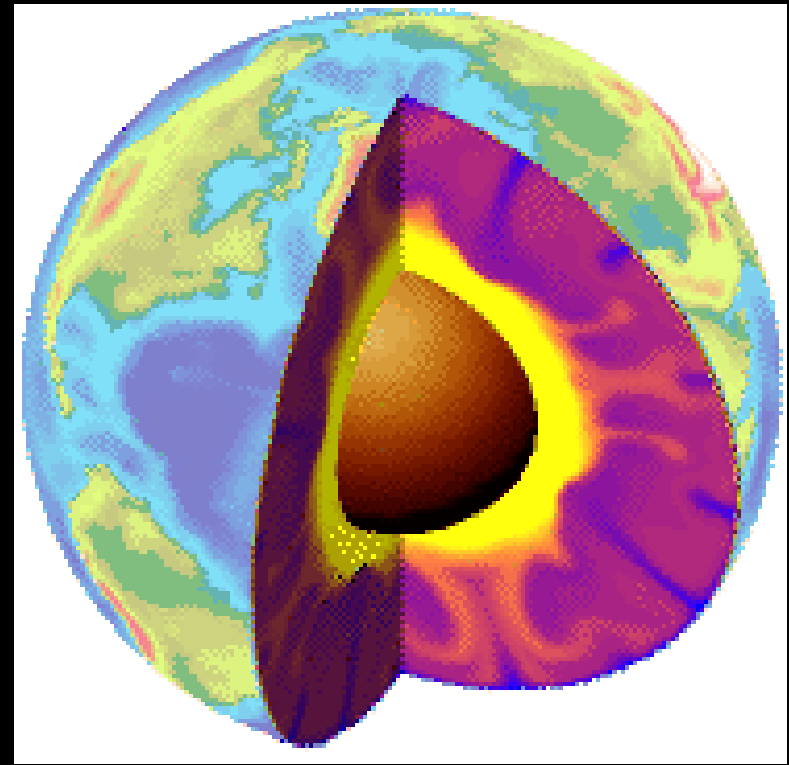
LIVESCIENCE: Like the Death Star force shield, Earth's magnetic field made by molten iron swirling around the core — has had our backs preventing Earth from becoming an **irradiated, electrified wasteland**. Until it doesn't!

Astronomy Now: Could cost trillions in damage to **power and communications** systems, the researchers say, while exposing the biosphere to increased levels of solar **radiation**.

The Conversation: Affect our **navigation & transmission** of electricity. More **radiation** would reach Earth's surface might affect rates of **cancer**.

Earth's Magnetic Dynamo

- Solid rotating core at Earth's center
- Around it a molten iron, perhaps with nickel and sulfur
- Thermal circulation dissipates heat
- Motion through initial magnetic field generates currents
- Currents create a larger magnetic field

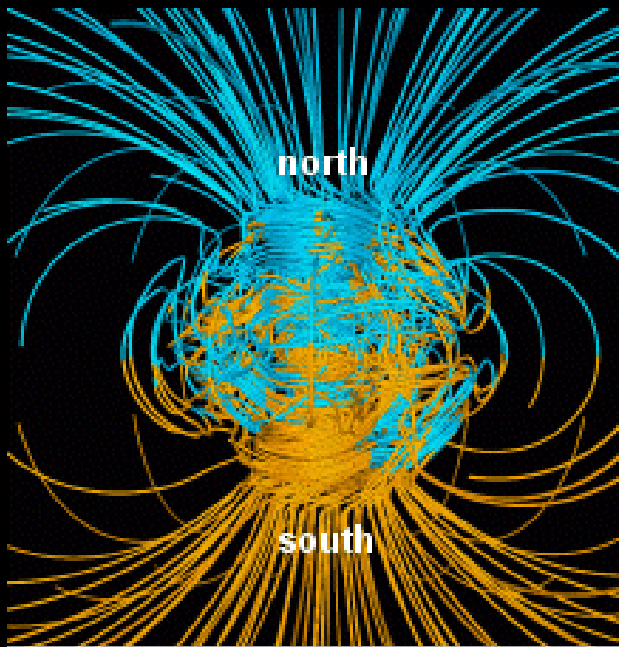


Earth's Changing Magnetic Field

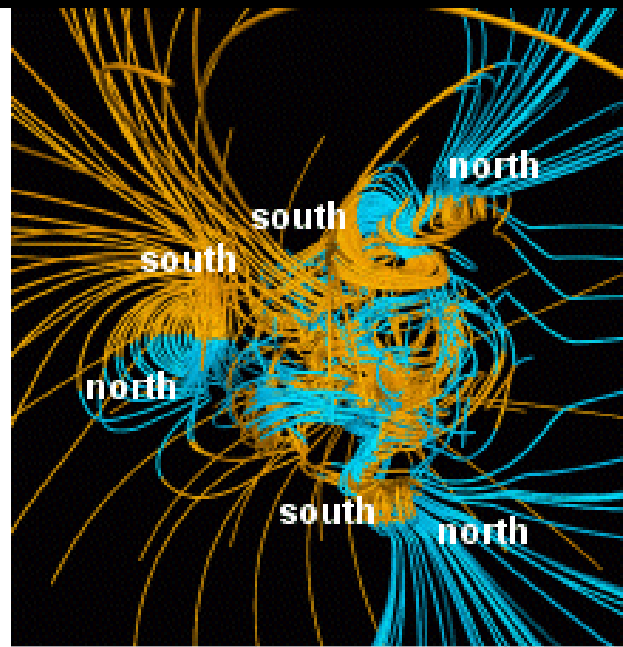
- Motion of the north hemisphere magnetic pole from 1831 to 2001
- 10 km/yr initially, now accelerated to 40 km/yr
- Field has weakened 10% since the 19th century



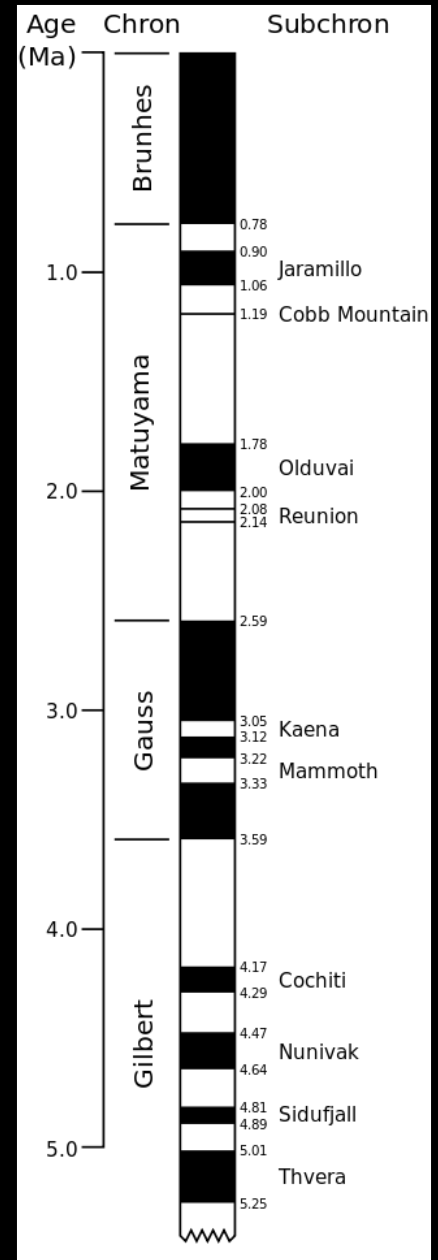
Magnetic Field Reversals



between reversals



during a reversal



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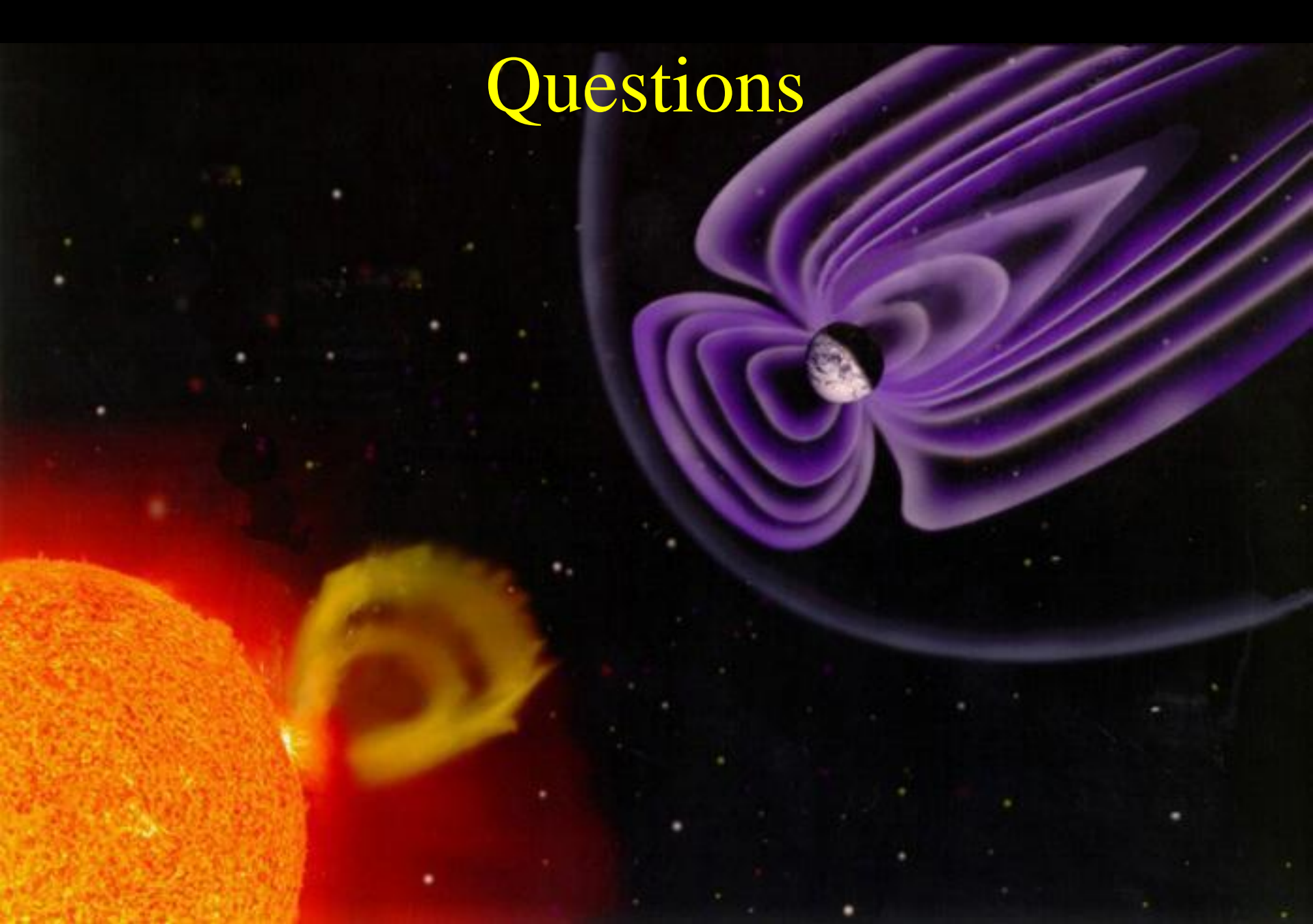
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Questions



dennis.gallagher@nasa.gov