ACE, magnetosphere and heliosphere

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Wind Crest Learners 3 – Mar 5
Academy for Lifelong Learning

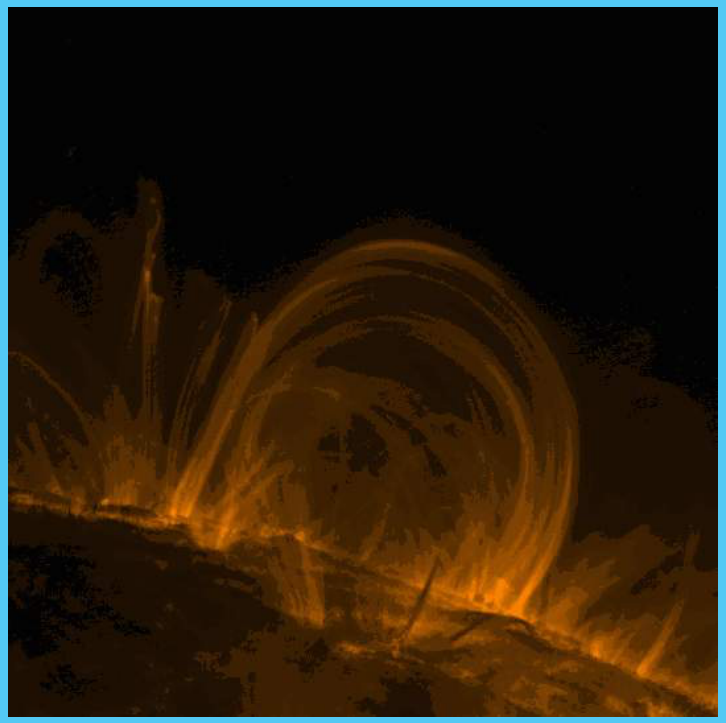
What other eyes do we have?

- UHECR
- GAMMA RAYS finish origin of cosmic rays
- X-rays
- The Heliosphere
  - ACE
  - Solar and Hemispheric Observatory (SOHO)
  - Ramaty High Energy Solar Spectroscopic Imager (RHESSI)
  - Stereo
  - Solar Observatory
  - Parker probe

Solar eclipse

Prominences

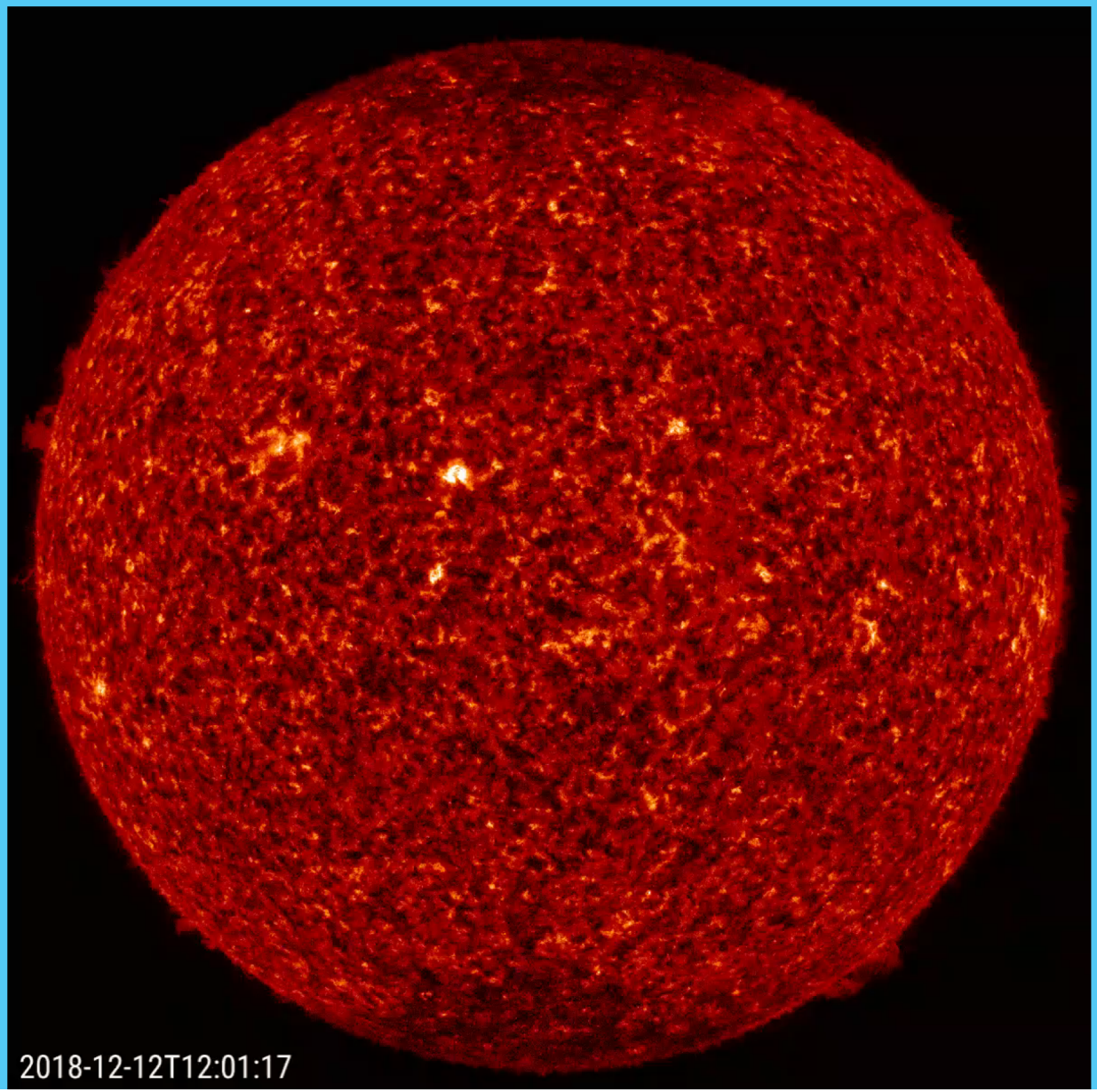
Prominences are magnetic loops, anchored in the photosphere, that arise above the solar surface. Clouds of charged particles in the plasma spin along these magnetic field lines emitting ultra-violet light. They are suspended above the sun by magnetic forces. This prominence was observed in a wavelength of extreme ultraviolet light. They are hotter than the photosphere but cooler than the surrounding corona. They may play a role in transferring energy to the corona.



Photosphere: 6×10^3 Kelvin
Prominences: 6×10^4 Kelvin
Corona: 10^6 Kelvin

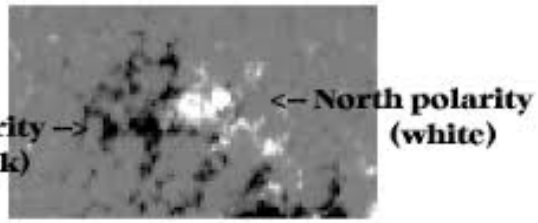
Photo in EUV light by SOHO

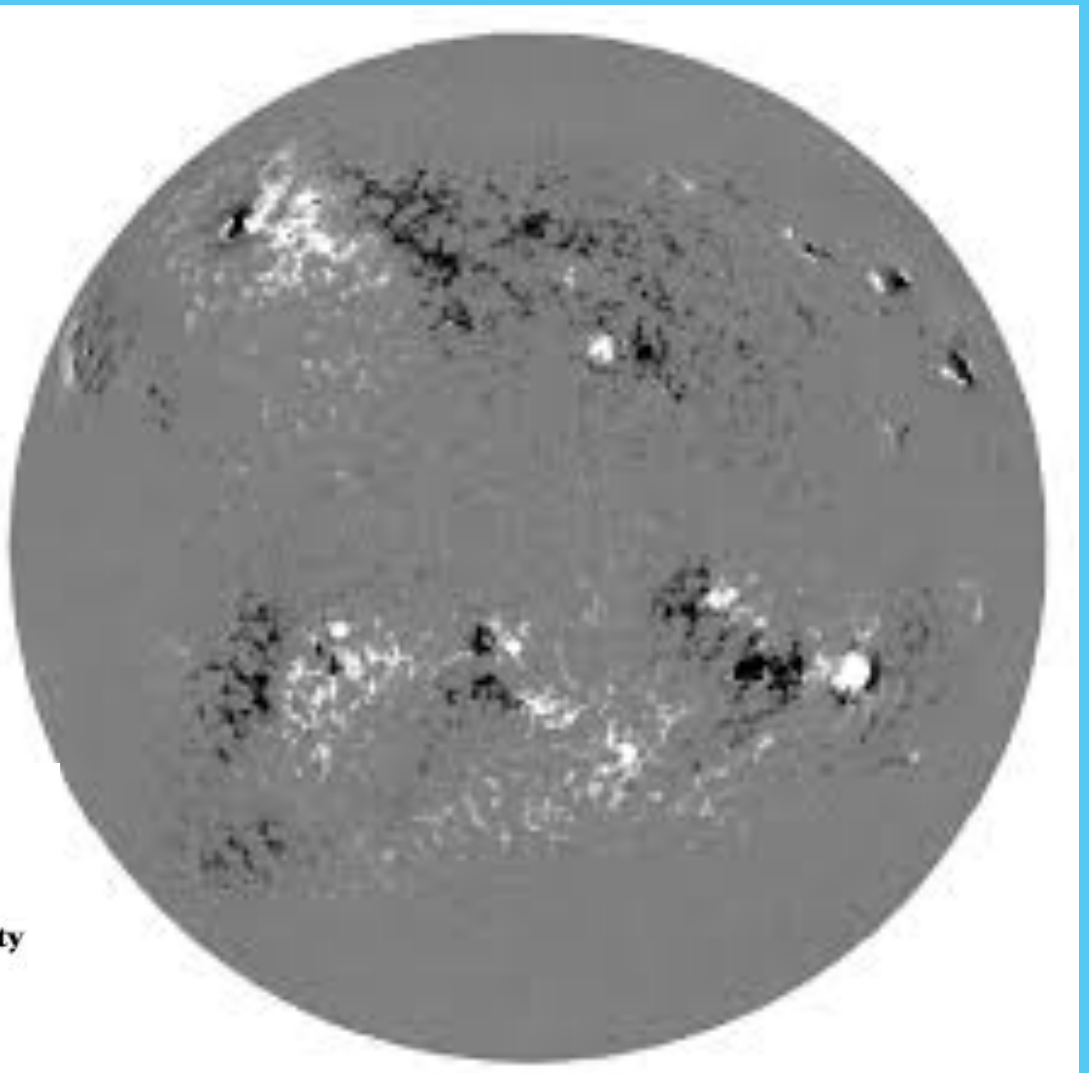
A 2 day long movie of the sun



Solar magnetic fields

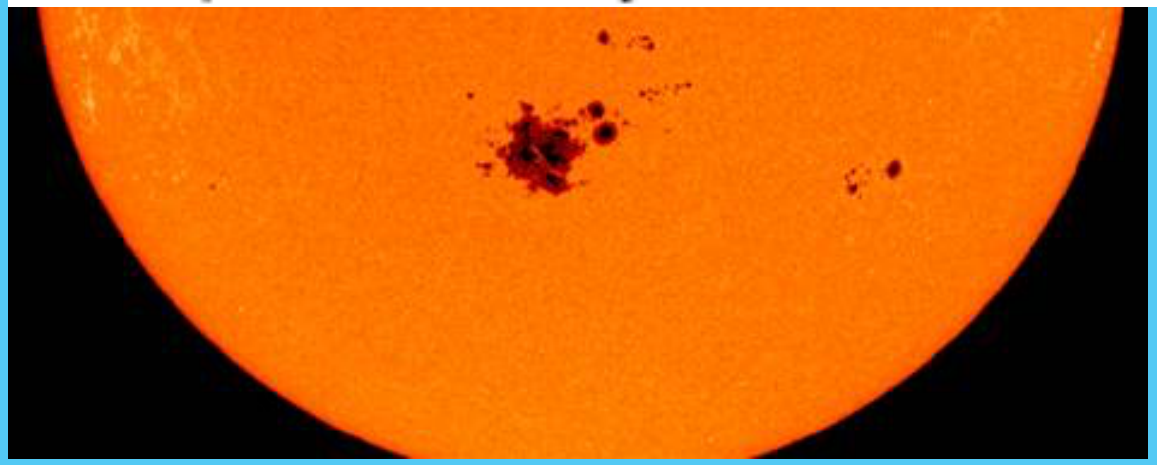
These images show the bipolar magnetic fields at the surface of the photosphere.





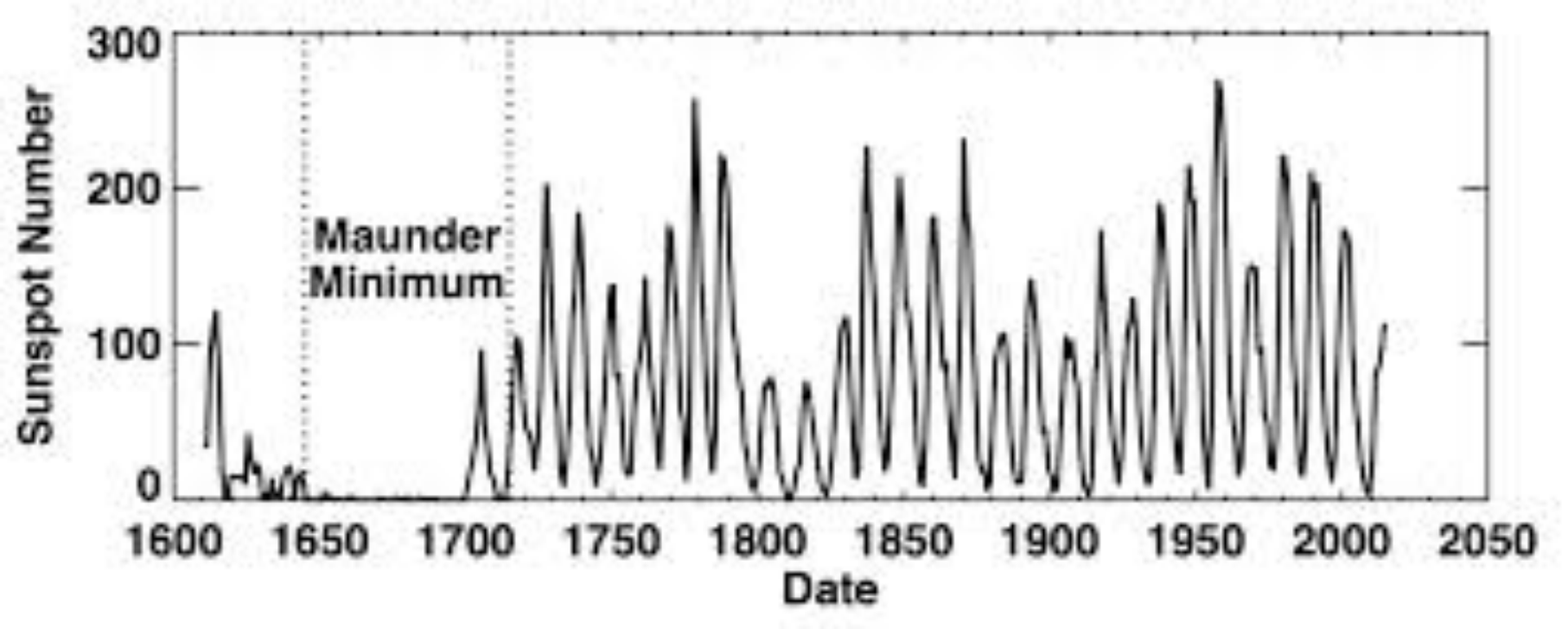
Sunspots

Can be seen with a pinhole camera on a clear day. They have been monitored since the time of Galileo.

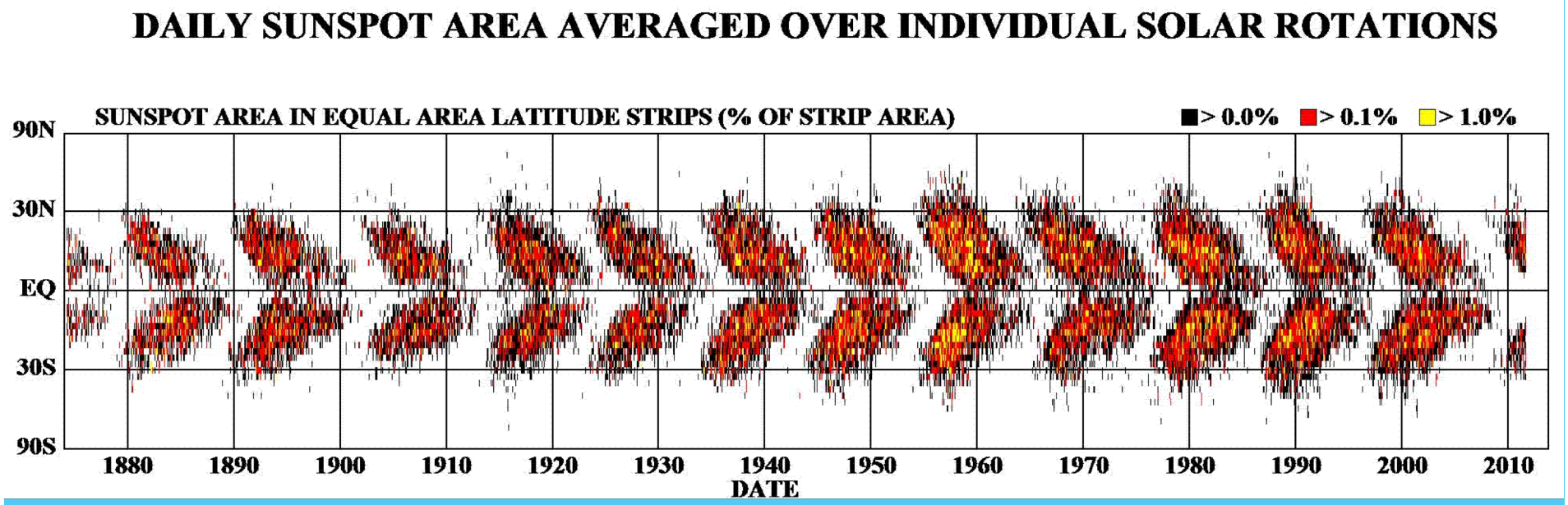


Period about 11 years

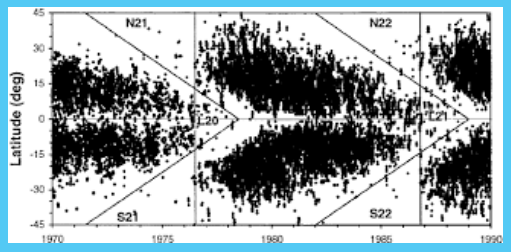
Sunspots: 11 year solar cycle



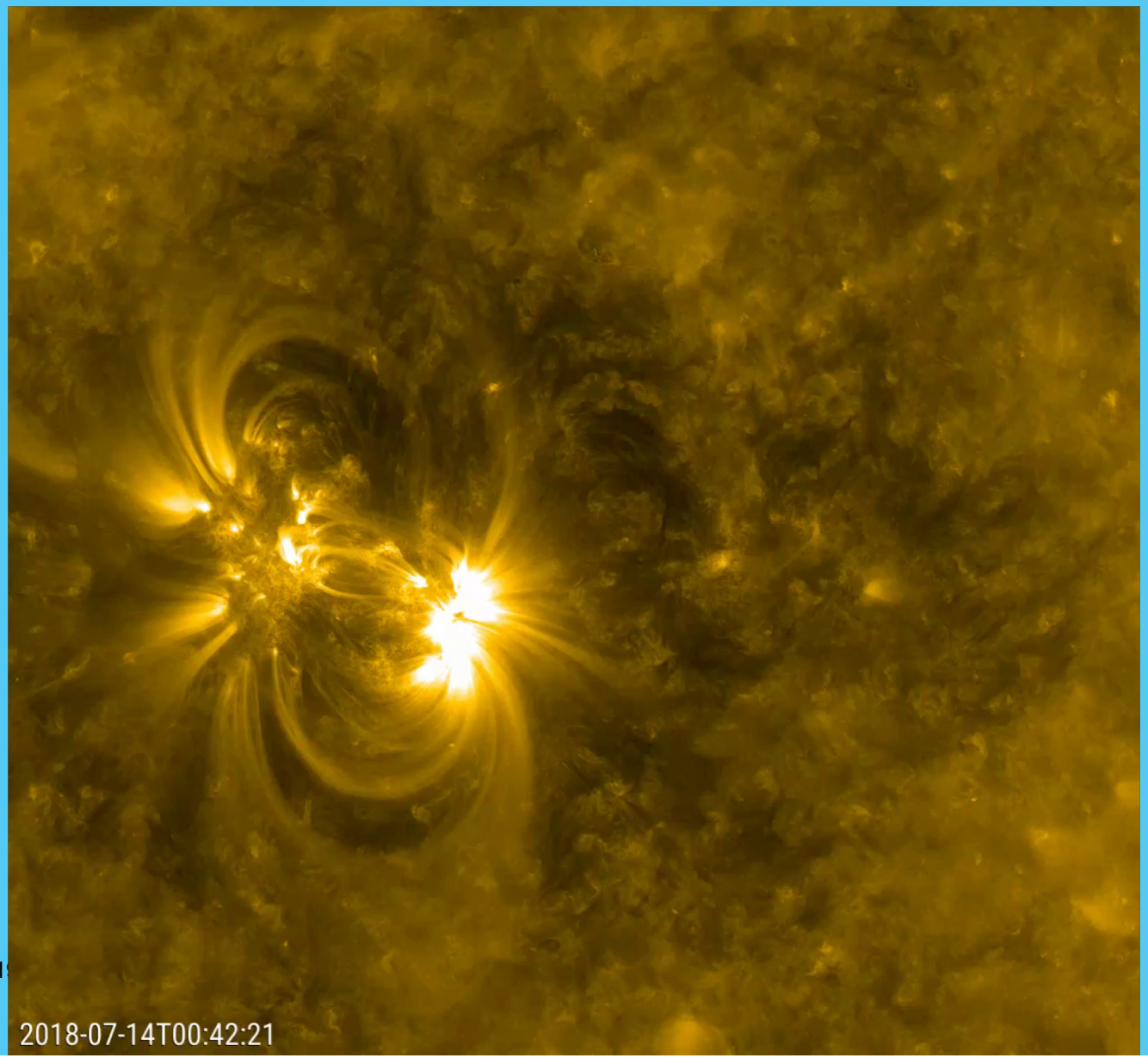
Evolution of sunspots on the solar surface



The actual underlying period is 22 years. The sun switches polarity every 11 years, so a full cycle of N to S takes 22 years.

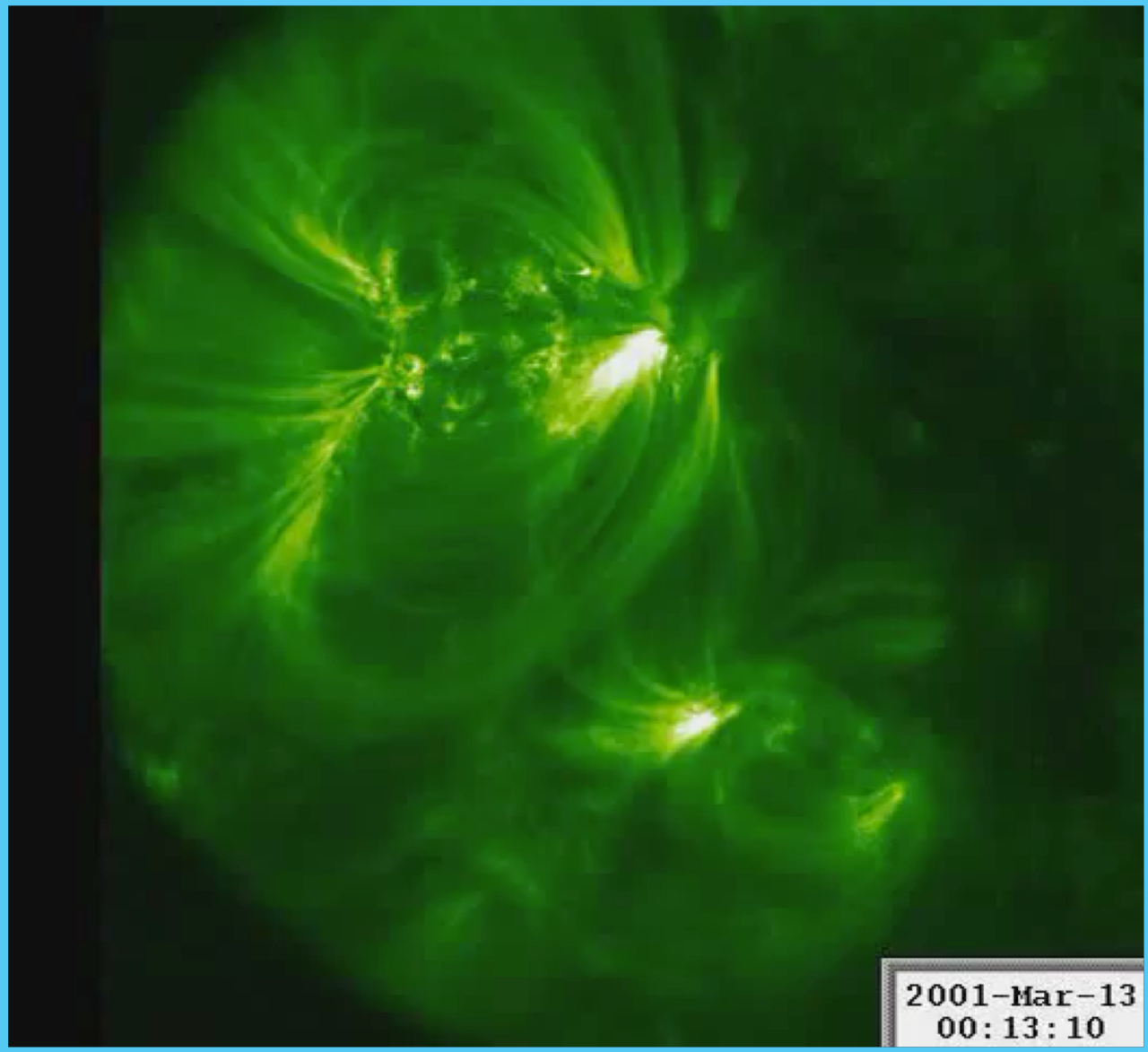


A solar flare from a bipolar sunspot

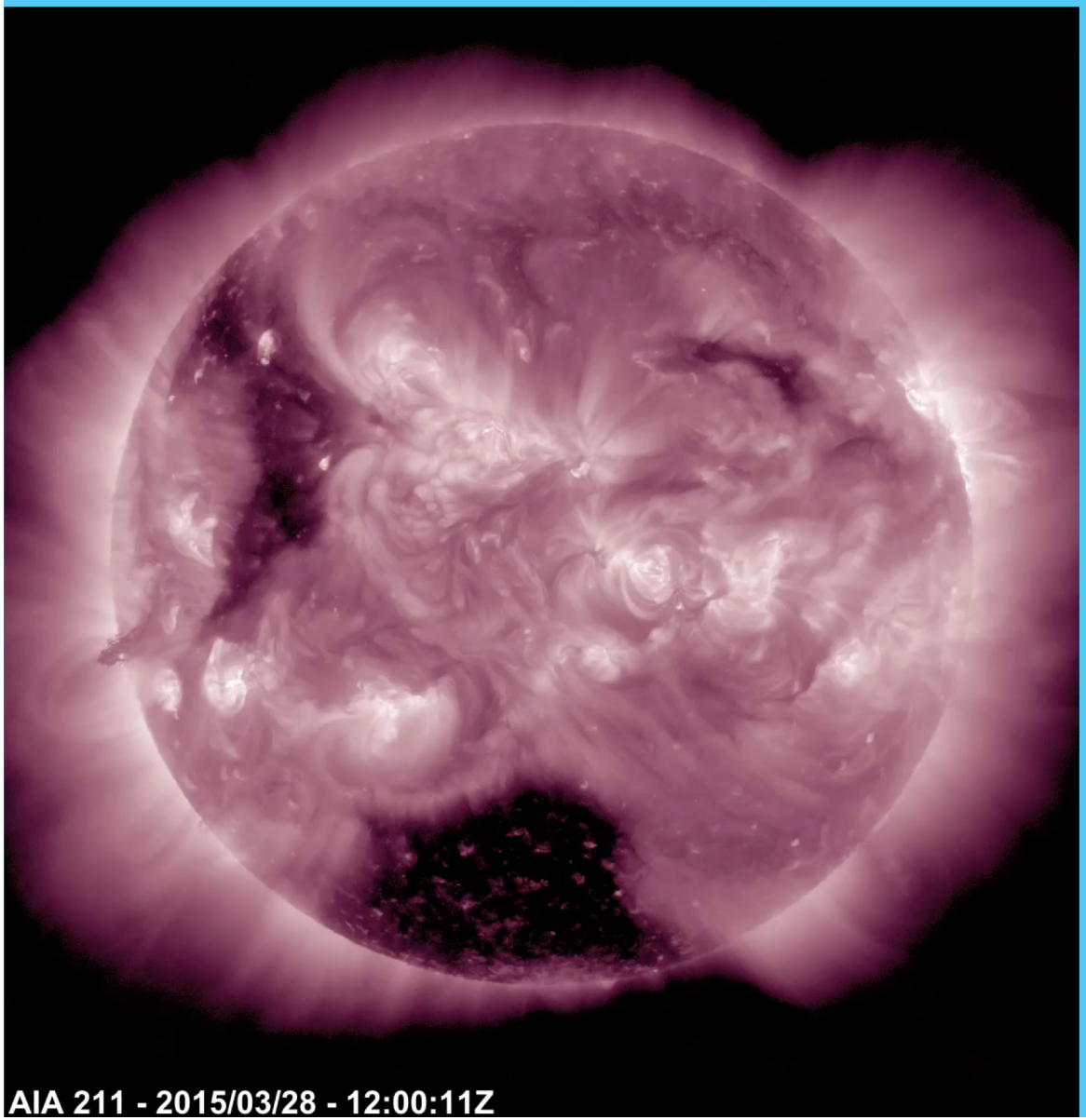


Credit: SDO

An Active region

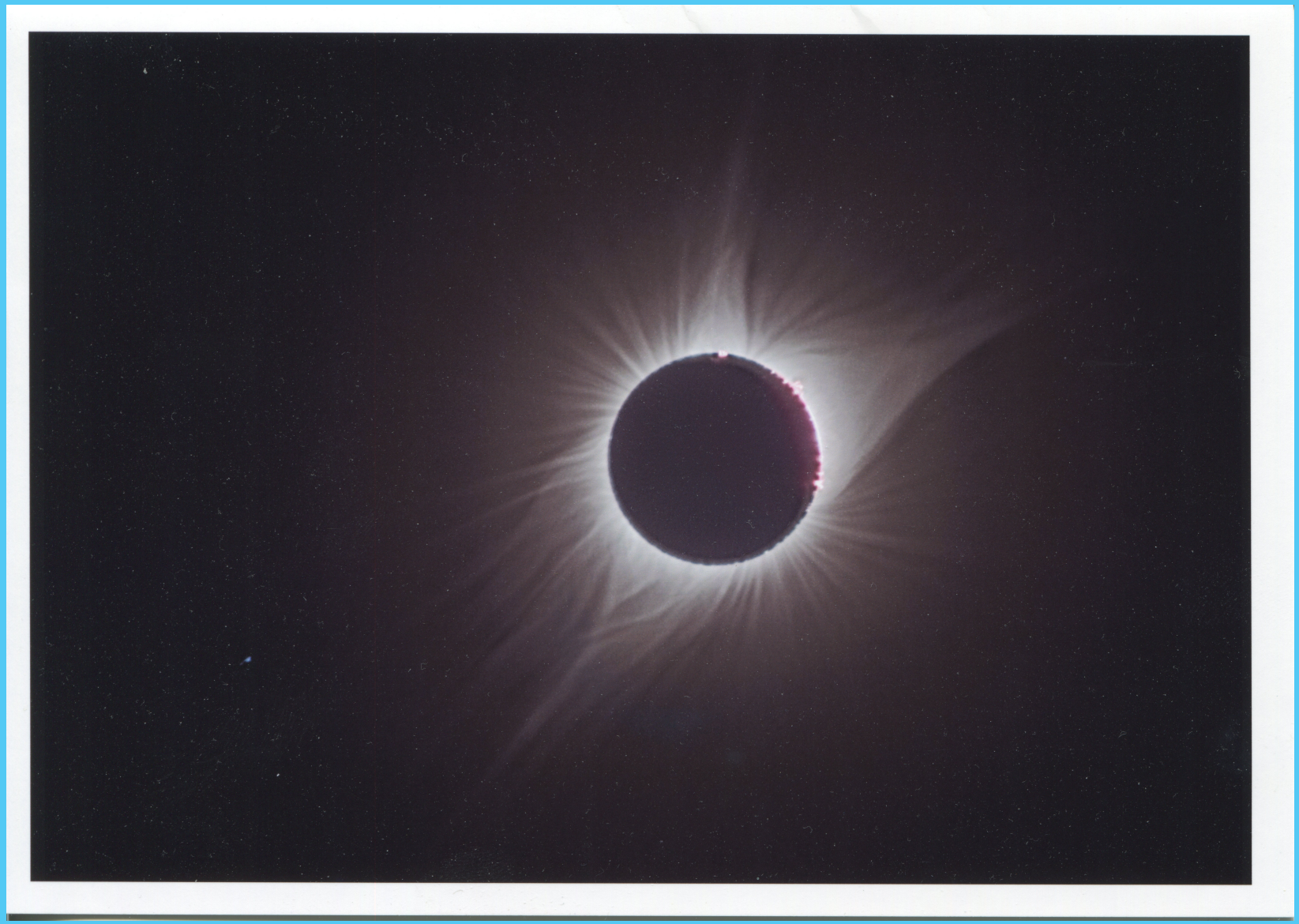


Coronal holes



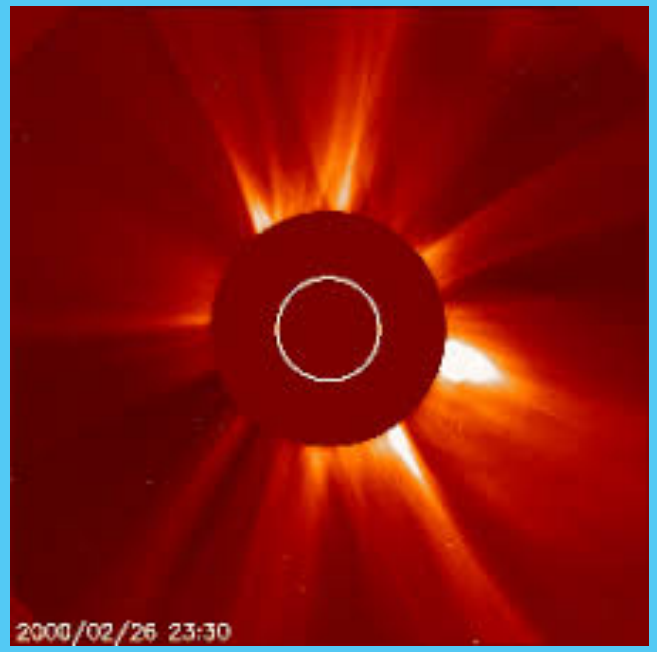
Dark regions are known as coronal holes. Magnetic field lines from these holes do not return to the sun but go out into interplanetary space. The plasma flows out along these field lines and becomes the solar wind. The sun looks different at different wavelengths in the ultra-violet.

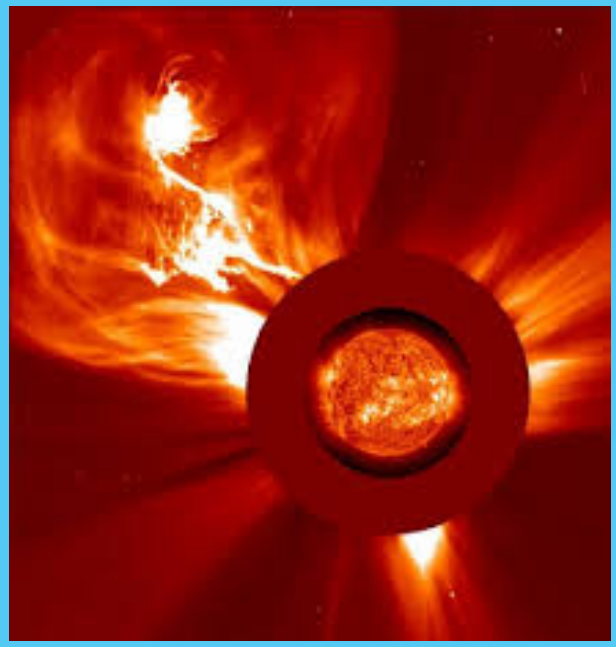
Solar streamers; eclipse Aug. 21, 2017



Coronal mass ejection

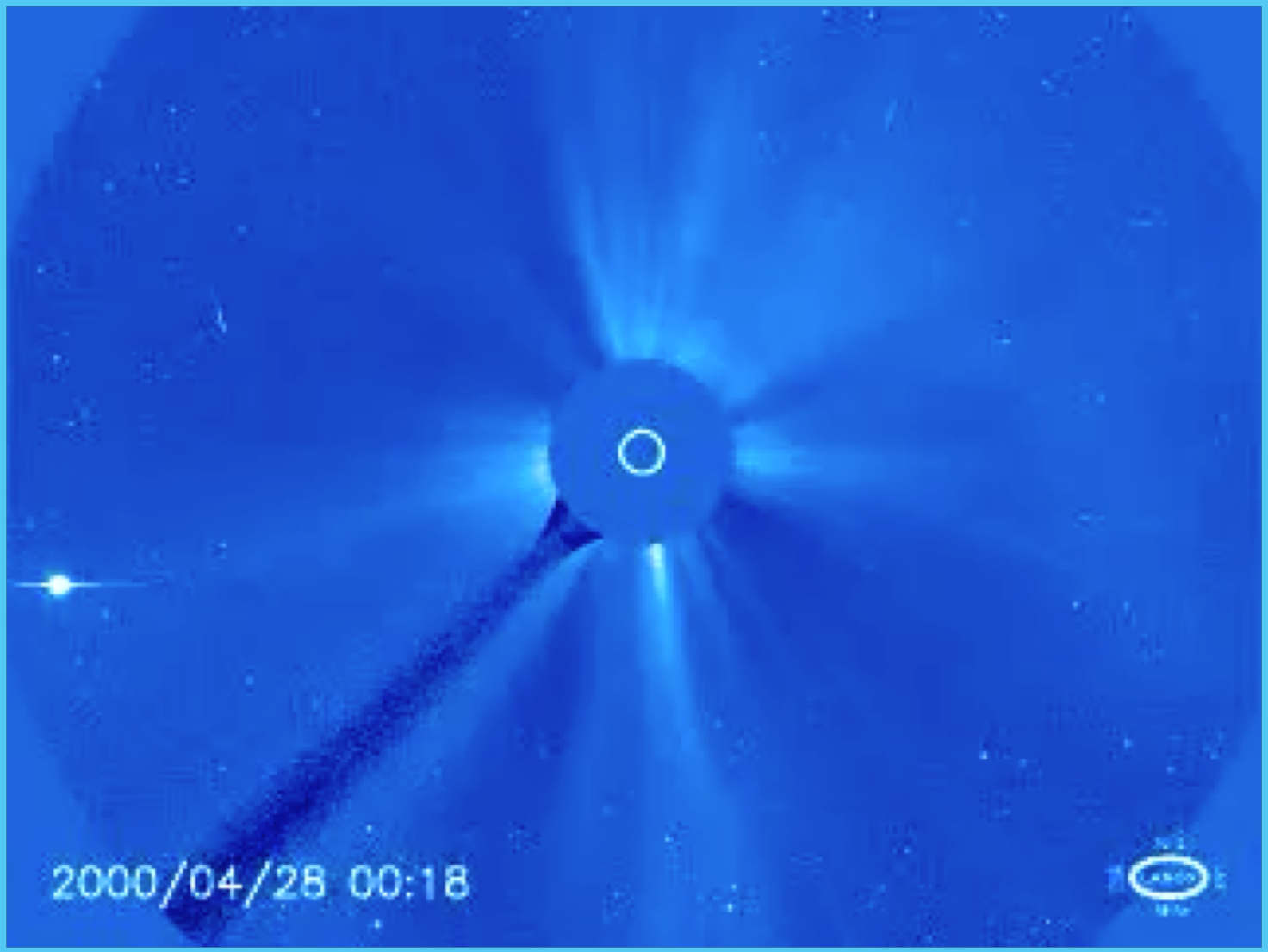
Solar and Heliospheric Observatory SOHO



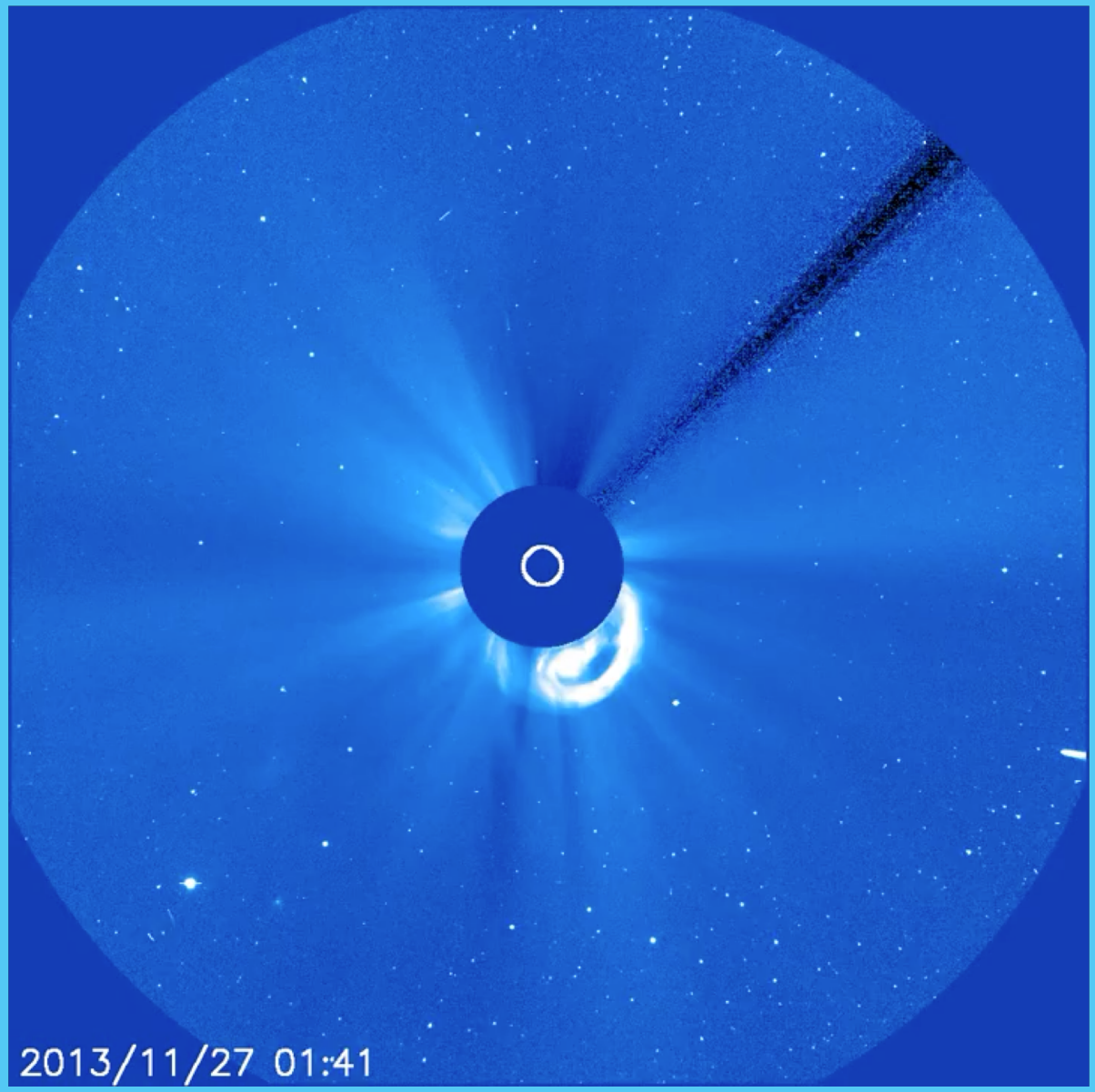


https://www.youtube.com/watch?v=ZPUi254YbQw

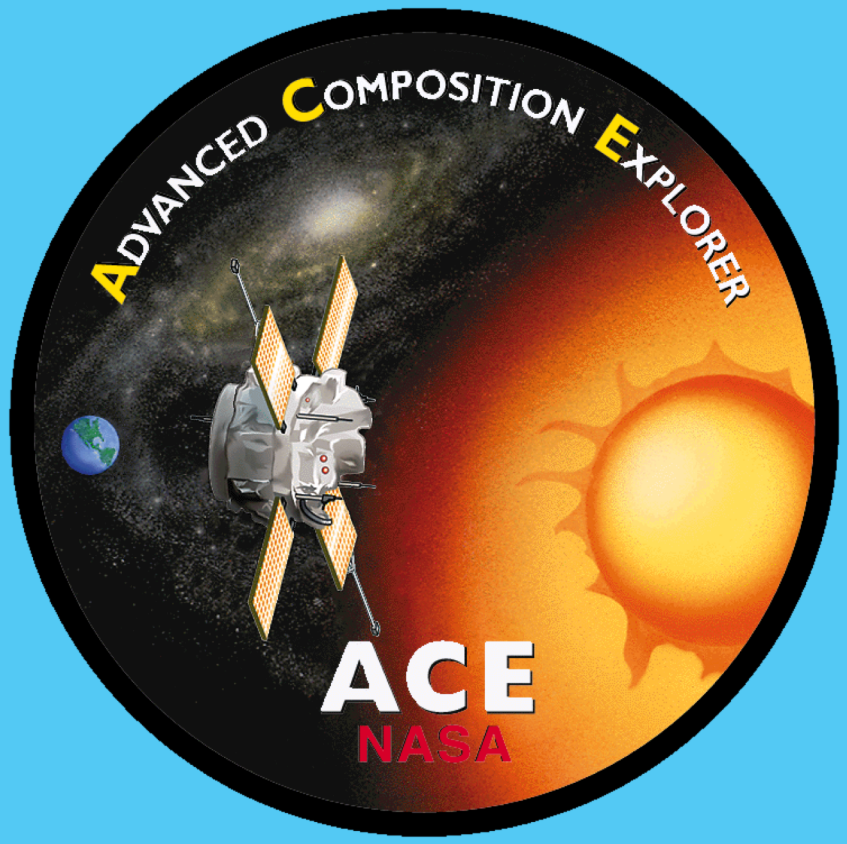
LASCO movie



LASCO and comet

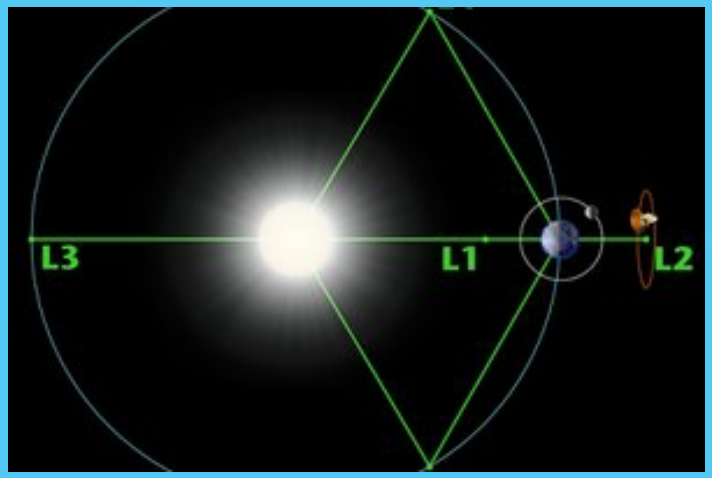


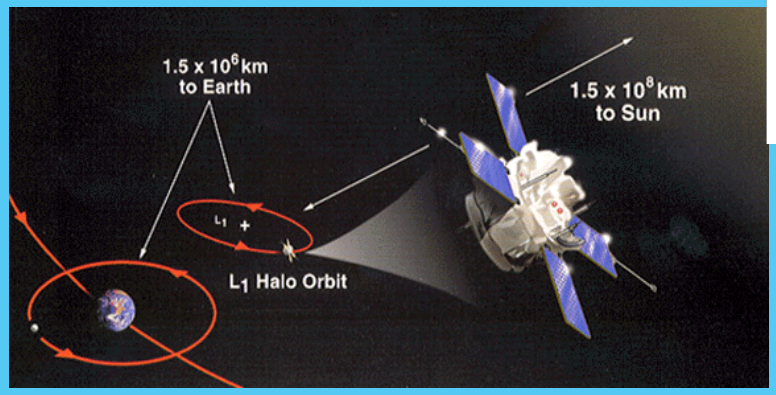
Advanced Composition Explorer (ACE)

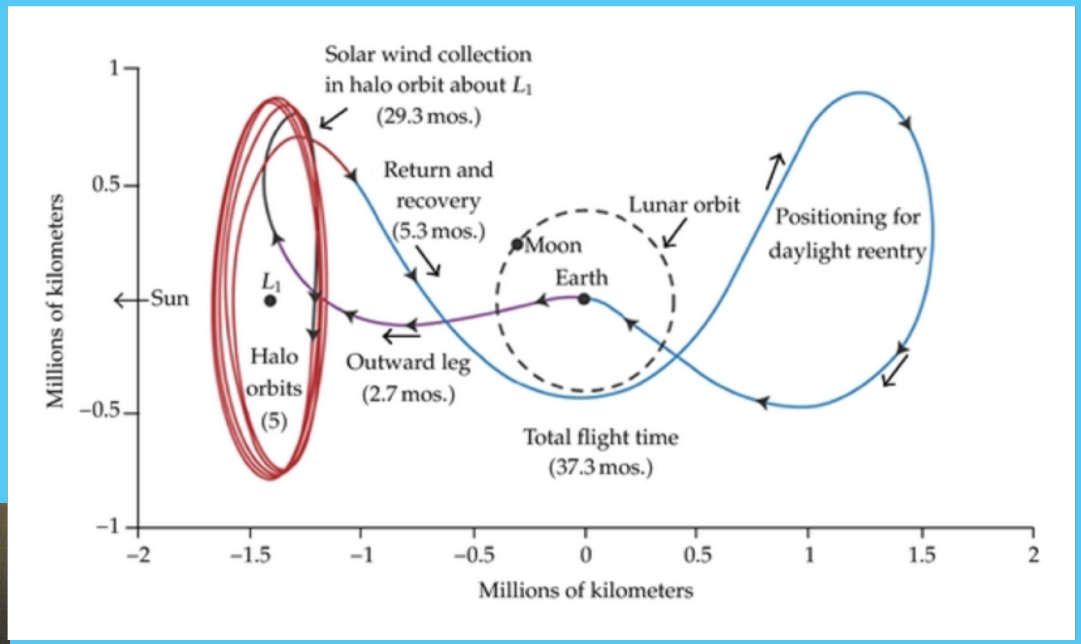


Lagrange points

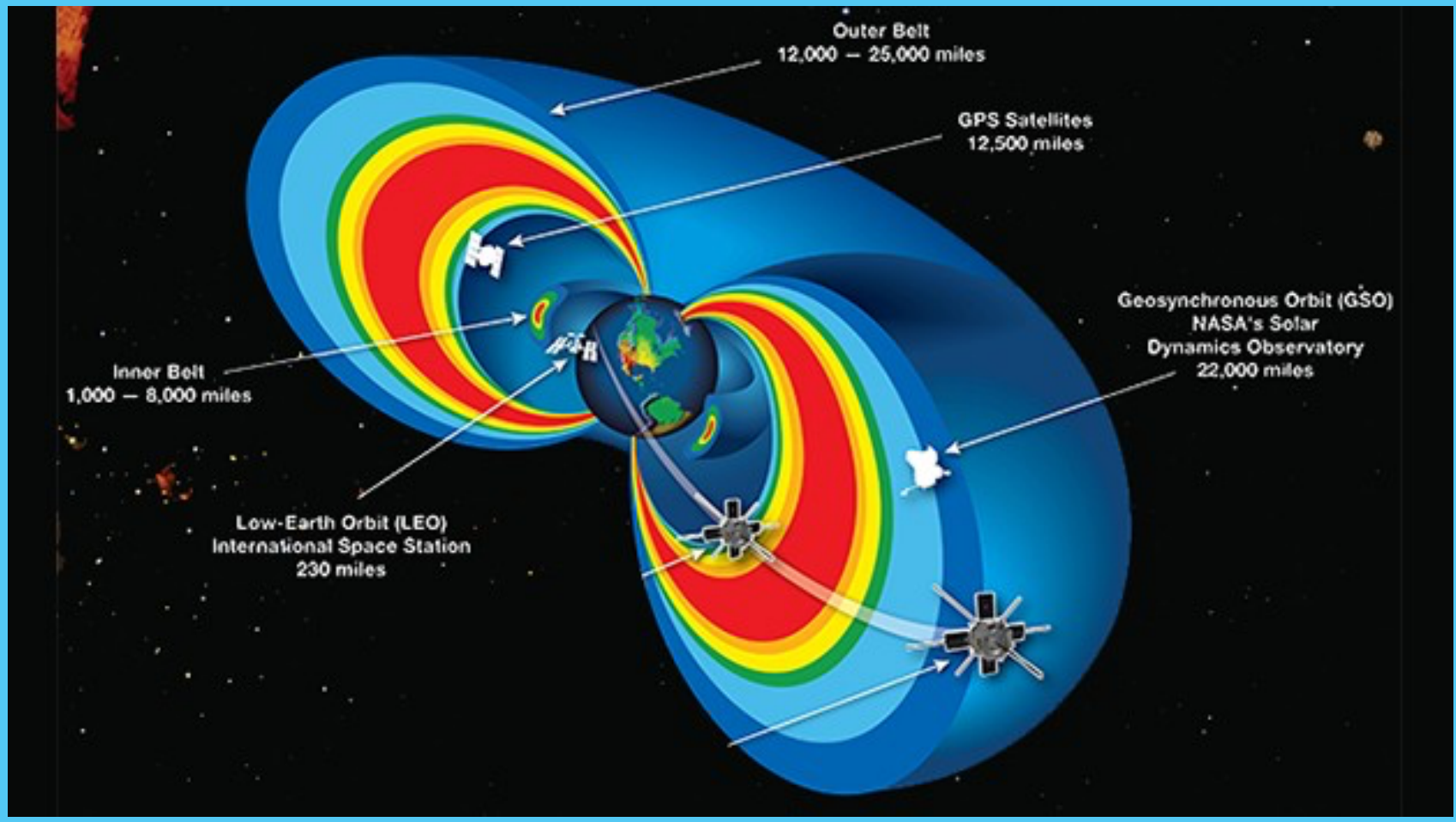
L1 & L2 Earth and sun gravity is equal. Orbits are semi-stable. Imagine a saddle. Release a marble. It will go down one way, but not the other. Requires much less fuel to keep a satellite at this orbit.





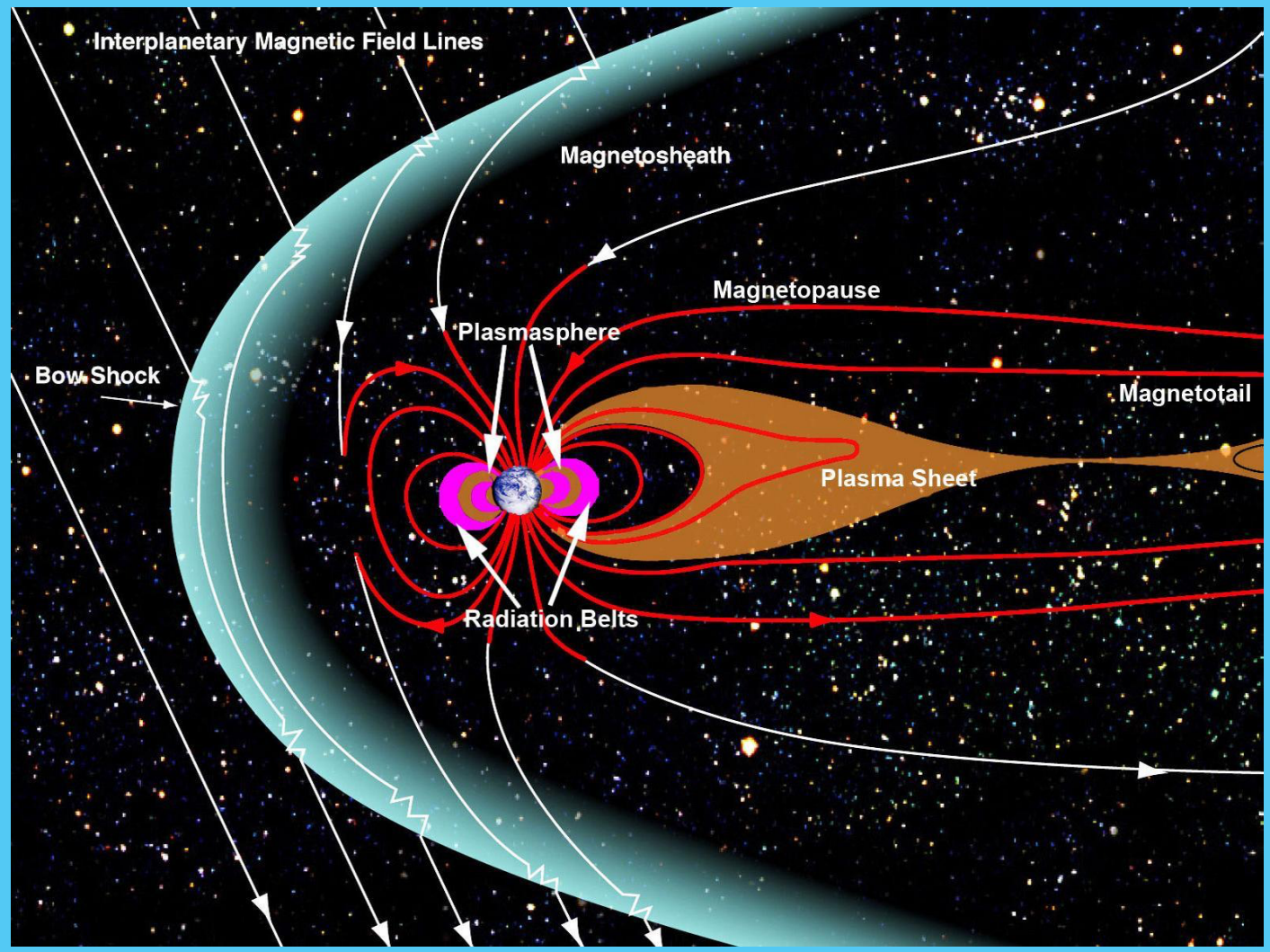


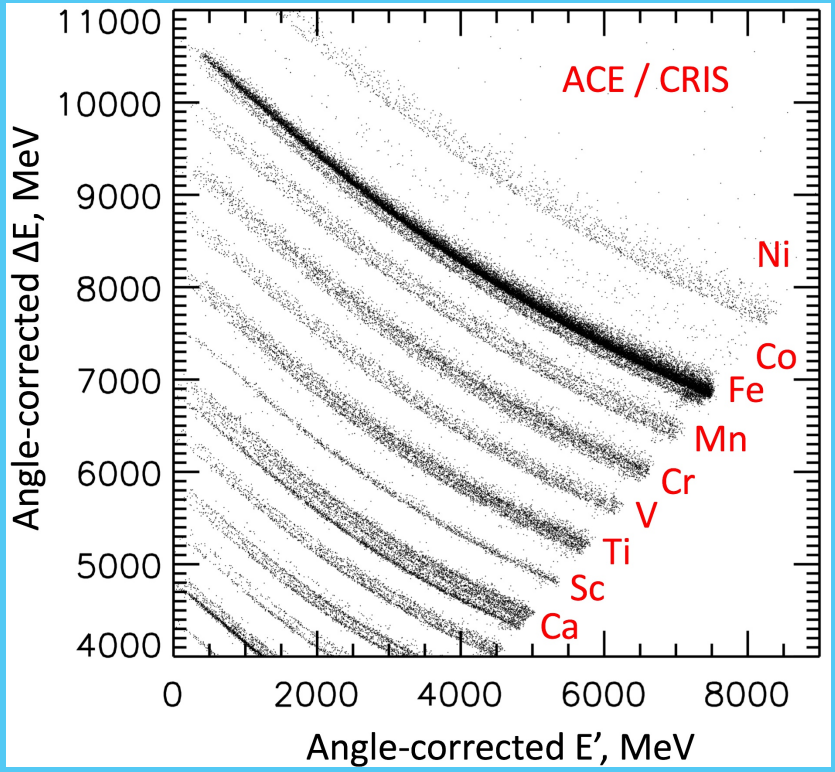
Van Allen radiation belts

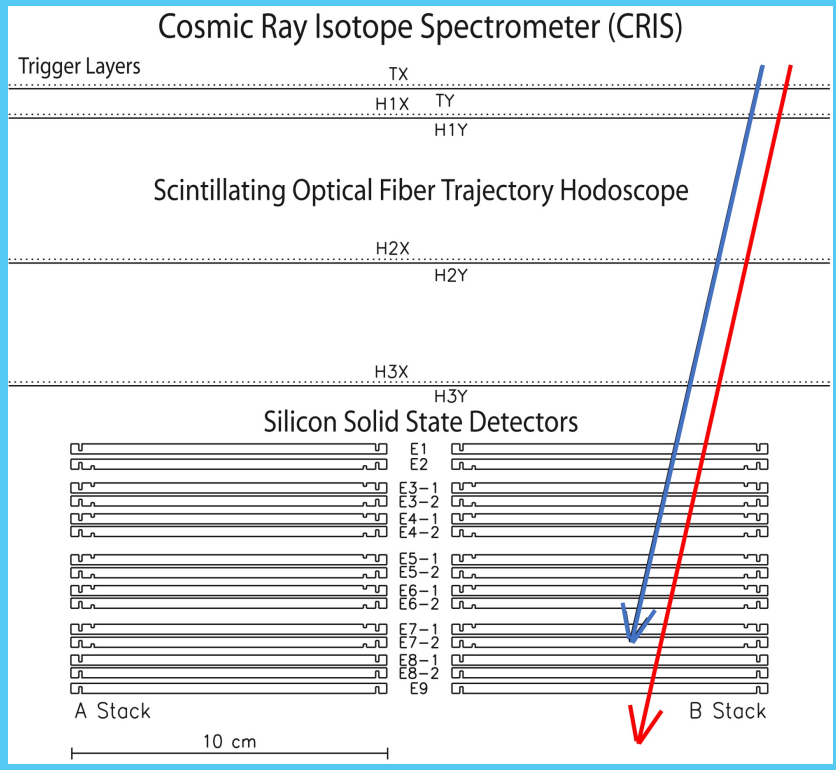


The Earth's Magnetosphere

90,000 km = 56,000 miles




ACE / CRIS
Ni
Co
Fe
Mn
Cr
V
Ti
Sc
Ca
Angle-corrected ΔE, MeV
Angle-corrected E', MeV
11000
10000
9000
8000
7000
6000
5000
4000
0
2000
4000
6000
8000


Cosmic Ray Isotope Spectrometer (CRIS)
Trigger Layers
TX
H1X
TY
H1Y
Scintillating Optical Fiber Trajectory Hodoscope
H2X
H2Y
H3X
H3Y
Silicon Solid State Detectors
E1
E2
E3-1
E3-2
E4-1
E4-2
E5-1
E5-2
E6-1
E6-2
E7-1
E7-2
E8-1
E8-2
E9
A Stack
B Stack
10 cm

Parker Solar Probe

Named after U. of Chicago Prof. Eugene Parker,

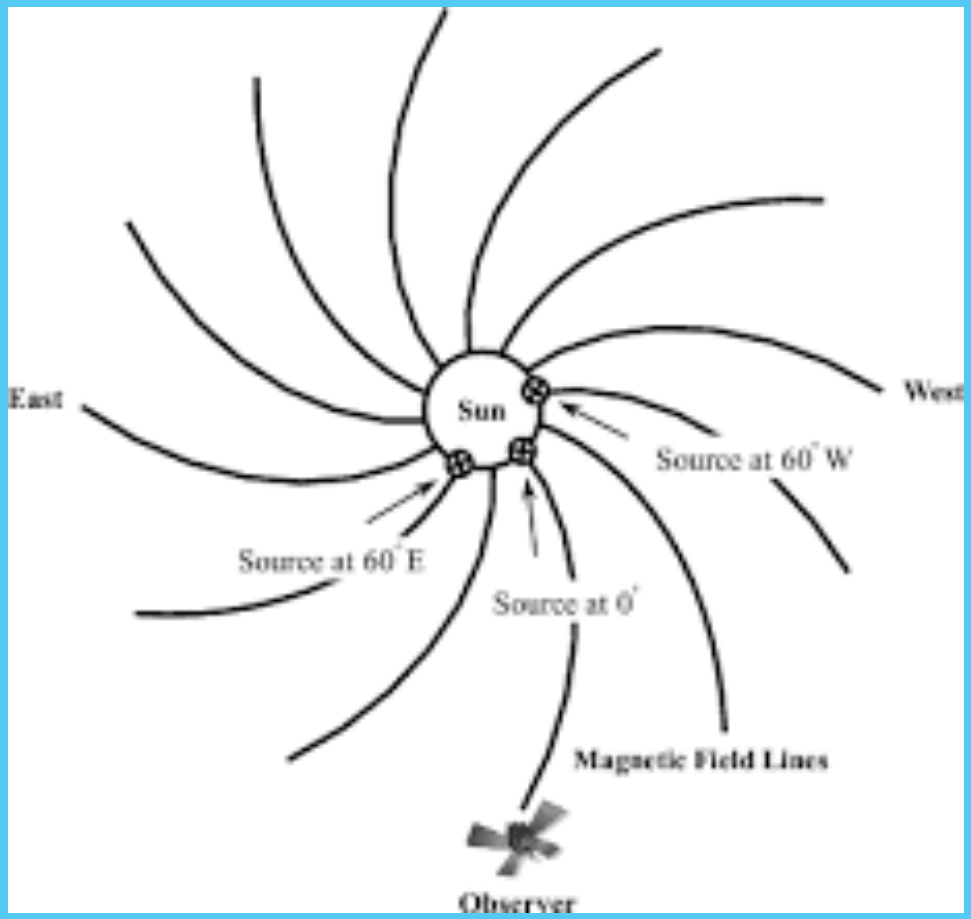
Eugene Newman Parker is an American solar astrophysicist who—in the mid-1950s—developed the theory of the supersonic solar wind and predicted the Parker spiral shape of the solar magnetic field in the outer solar system.

Left unsolved was the problem of what heated the corona and provided the energy that drives the solar wind.

First spacecraft to be named after a living scientist.

Particles and fields in the heliosphere

Parker spiral



Parker Solar Probe

- Approach sun within 9.86 solar radii (0.046 AU)
- Maximum speed 430,000 mi/hr
- Cost $1.5 B
- Launch 29 October 2018
- Flux 650 kW/m^2 (at Earth 1.36 kW/m^2)
- Solar shield made of reinforced carbon-carbon composite.
  - 4.5 inches thick
  - 7.5 ft diameter
  - T_{max} 2500 ^oF

Parker Solar Probe orbit and timeline

Parker Probe Objectives

- Trace the flow of energy that heats the corona and accelerates the solar wind.
  - Plasma above the sun
  - Visible during eclipse
  - Why million Kelvin? Sun is 6000 K.

- Determine the structure and dynamics of the magnetic fields at the sources of solar wind.
- Determine what mechanisms accelerate and transport energetic particles.
  - These particles create “space weather” at the Earth

- Stop here

Parker Probe Orbit

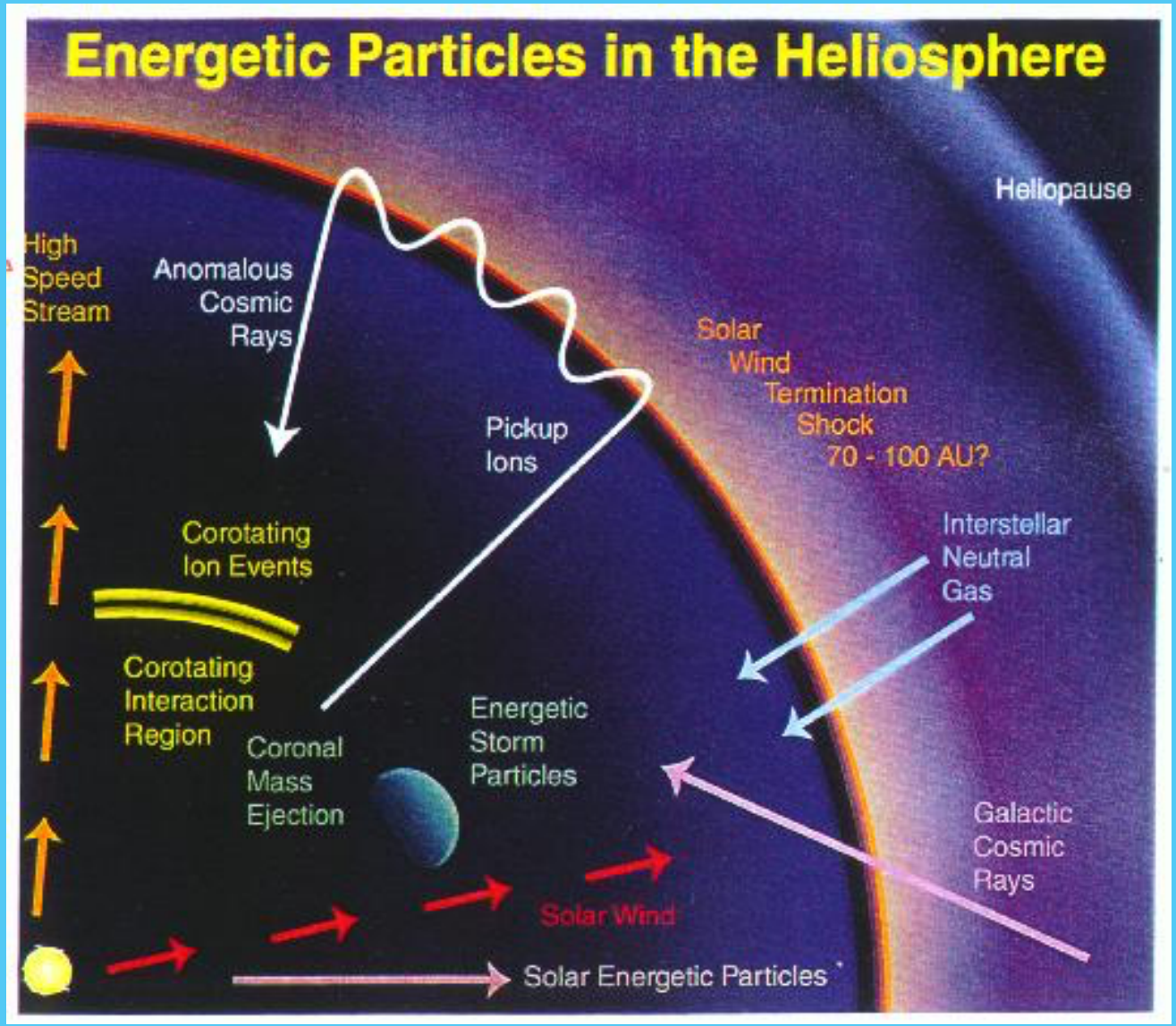
- 7 Venus flybys
- Period starts at 150 days, decreases to 88 days
- 10 days of data taking each pass by sun
  - Spacecraft out of touch – operations autonomous
  - Rest of orbit data sent to Earth
  - First pass Oct. 29, 2018 successful
  - Last pass Dec. 12, 2025

https://www.youtube.com/watch?v=cMNQeCWT09A

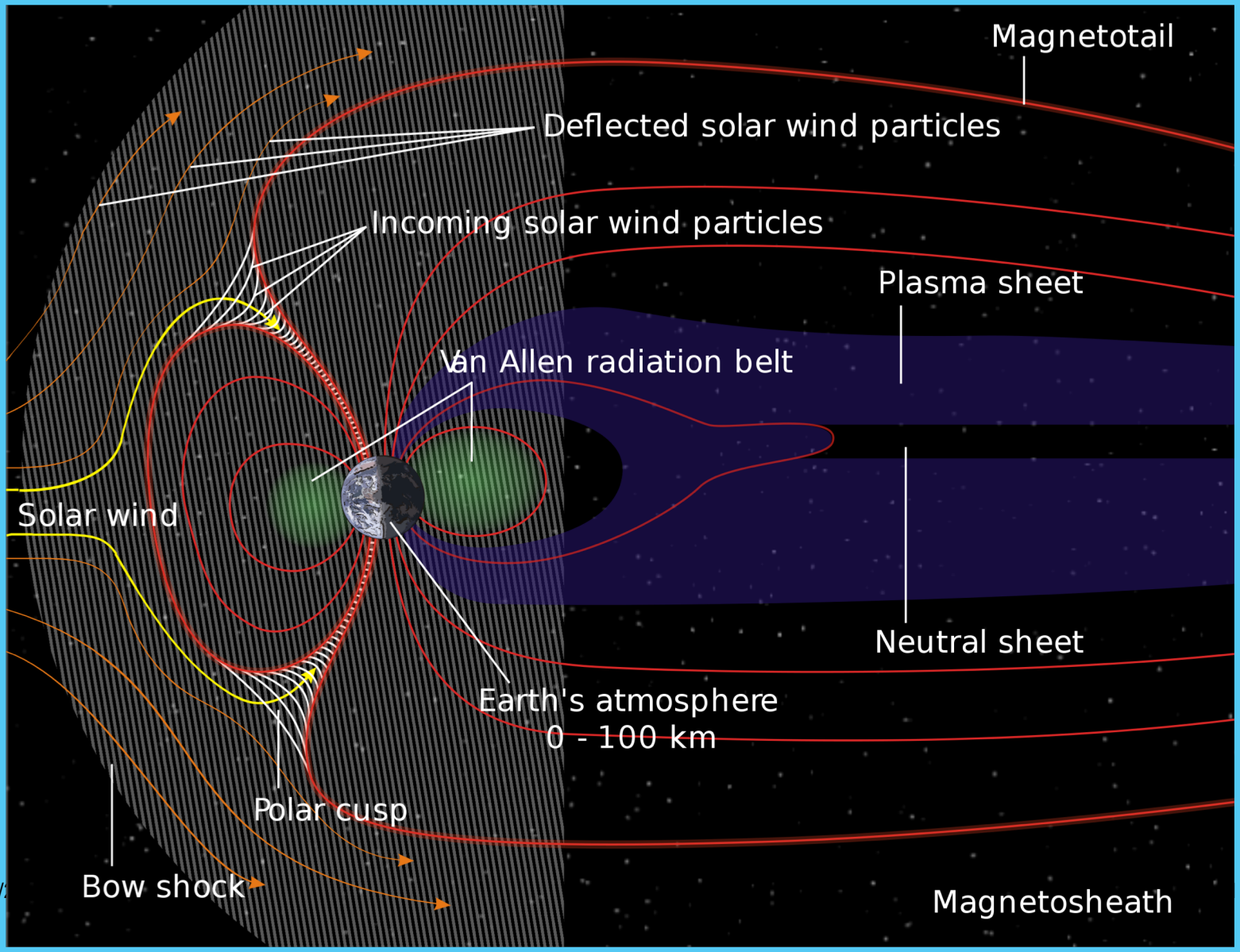
- Dark blue is Earth
- Purple is Mercury
- Yellow is Venus

- Light blue is the probe

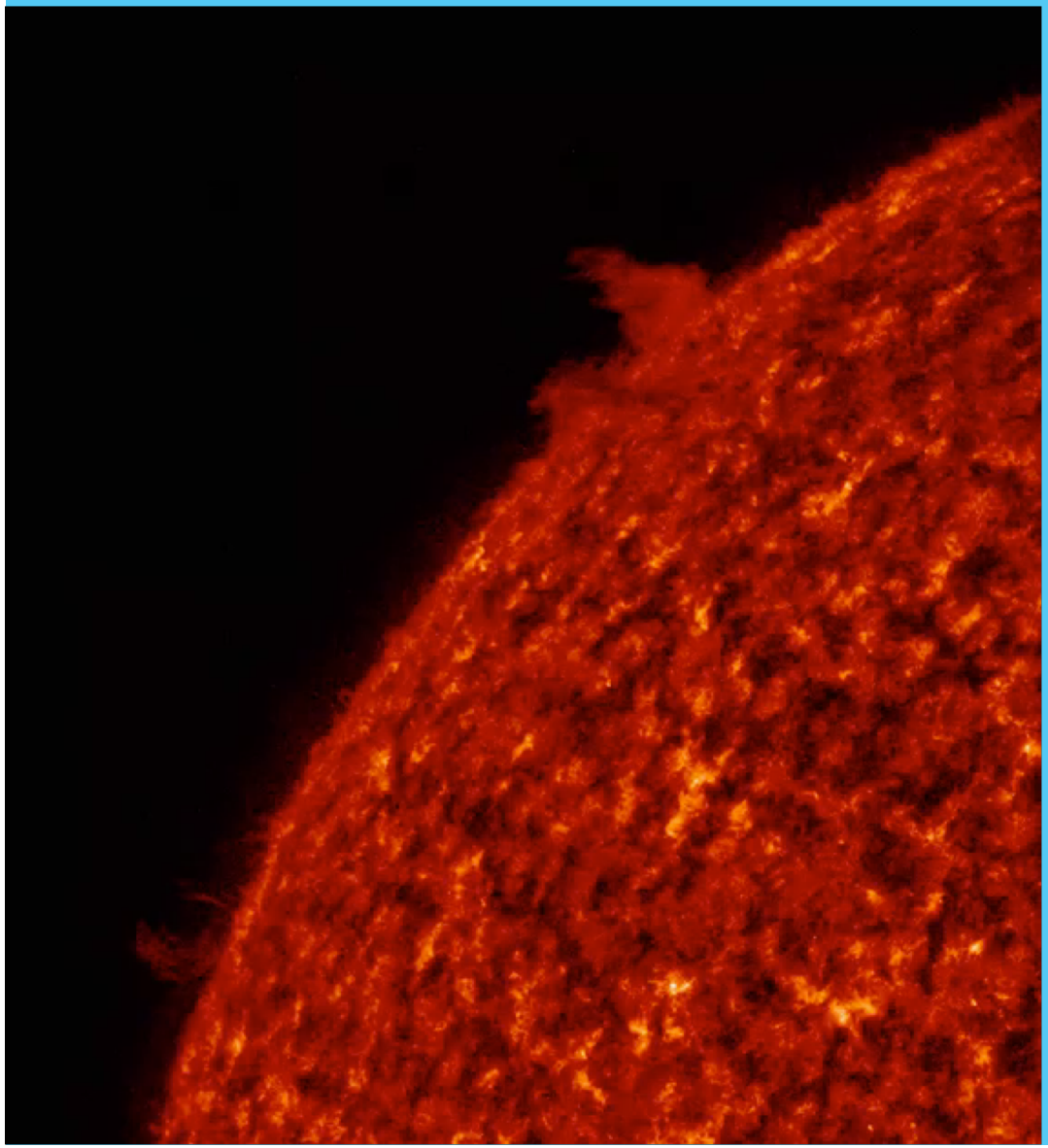
Particles in the heliosphere



Magnetosphere



Solar Dynamics Observatory



A prominence rose up above the sun, sent an arch of plasma to link up magnetically with an active region over a one-day period (Jan, 9-10, 2018). Then the flow of plasma seemed to largely change direction and head back where it came from. Finally, amidst the confused patterns of movement, it dissipated and fell away. Prominences are cooler clouds of charged particles tenuously tethered to the sun by magnetic forces. Images were taken in a wavelength of extreme ultraviolet light.

Credit: Solar Dynamics Observatory, NASA.

Solar Dynamics Observatory

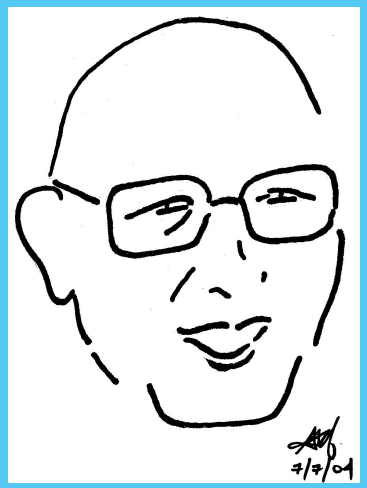
Launch Feb. 11, 2010

United Launch Alliance, Headquarters here in Denver, Colorado.

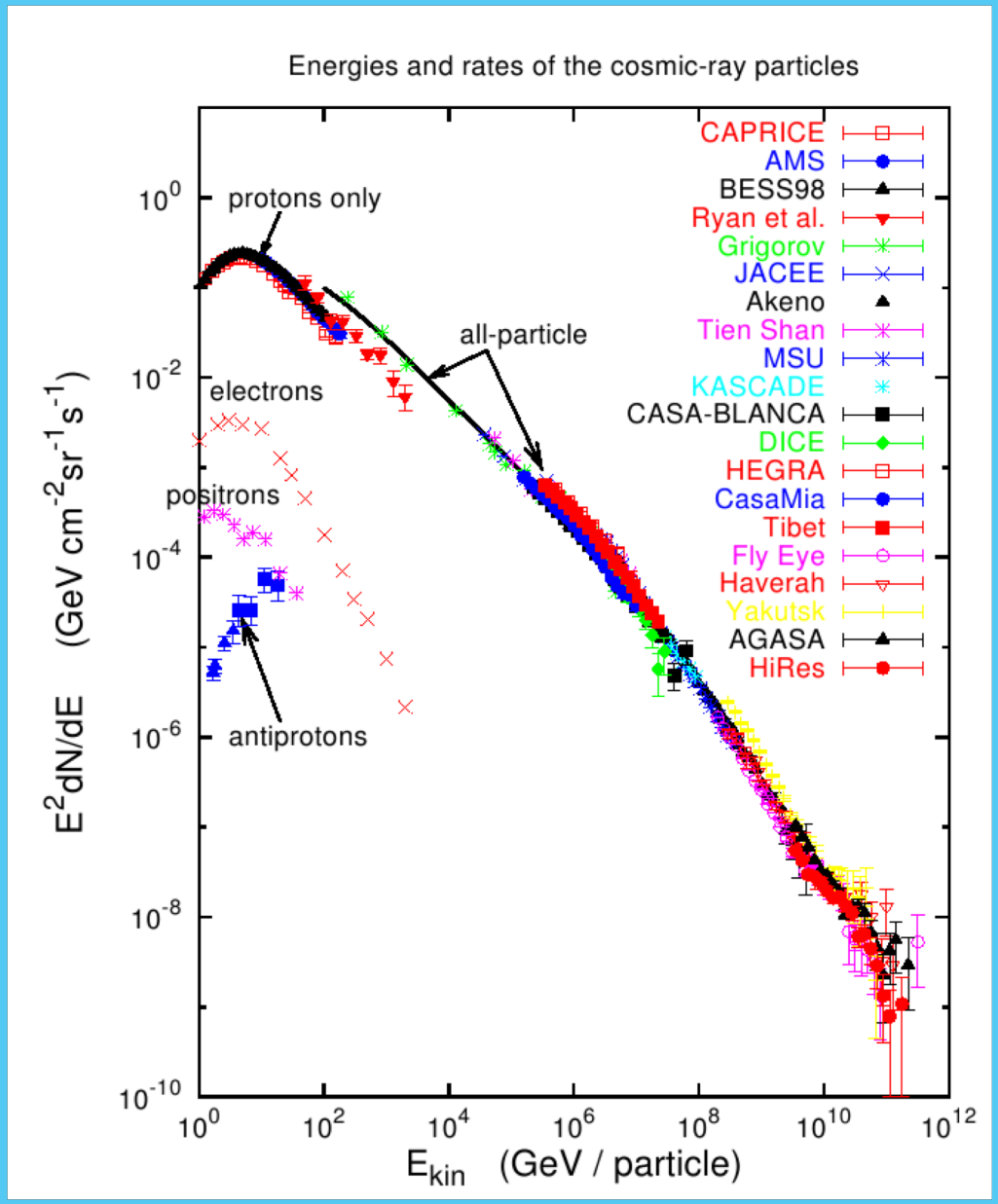
- Lockheed Martin Space Systems
- Boeing Defense, Space and Security

Atlas V launch vehicle
also Delta IV

Credit: Solar Dynamics Observatory, NASA.



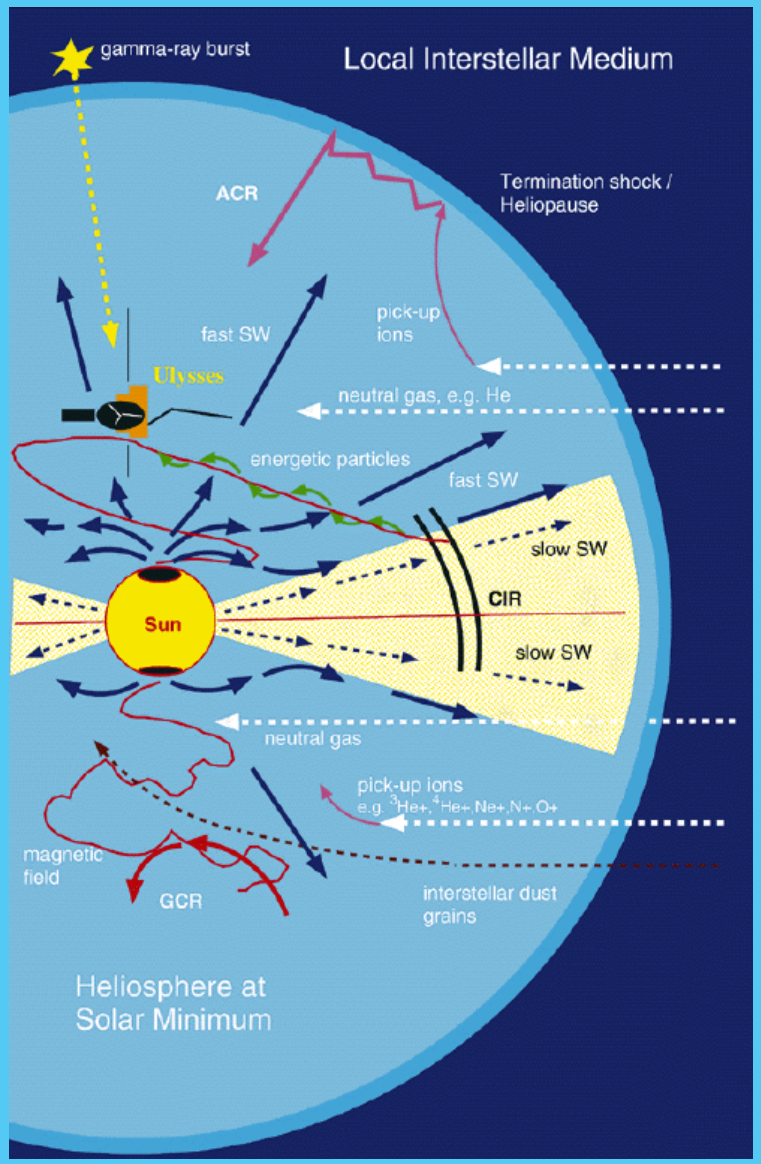
By the time of my retirement, the plot has been filled in considerably.



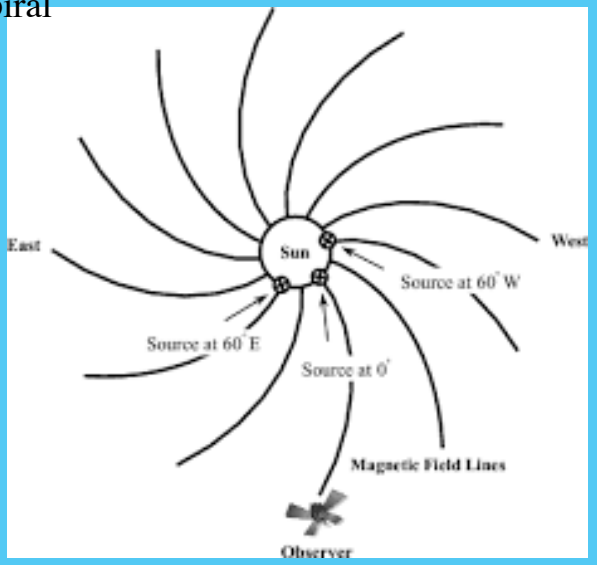
Solar field is a self-sustaining dynamo

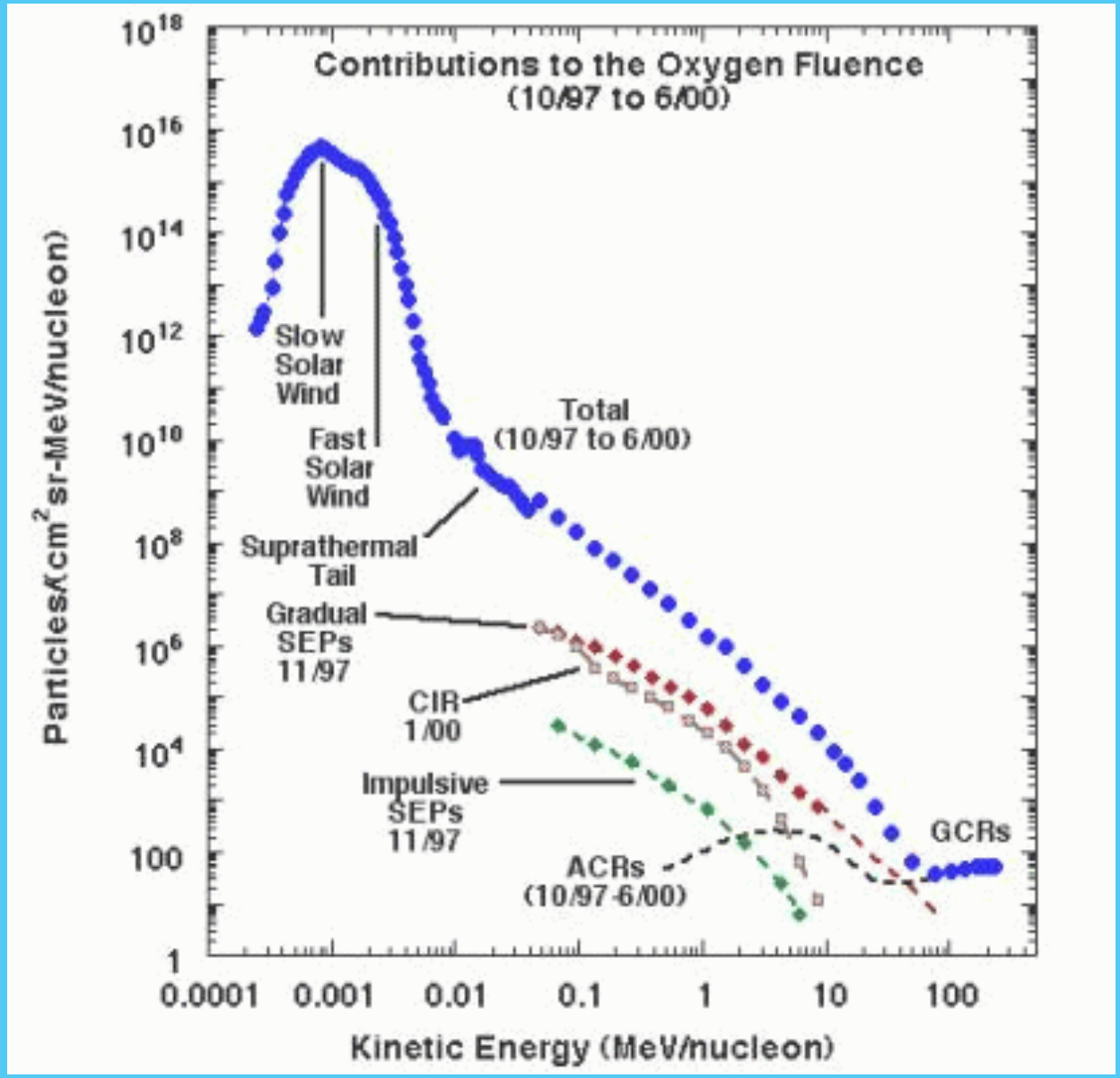
- Earth's field is, too
  - Mars had a magnetic field but planet cooled and it's gone
- Solar field is basically a dipole like Earth's field or that of a bar magnet
- Sun (and most stars) are natural electric generators
  - Rotation
  - Magnetic field captured and amplified during the gravitational collapse
  - Currents make magnetic fields that then organize the currents
- Requires molten core
  - Turbulence and/or shear
  - Convection cells

Particles and fields in the heliosphere

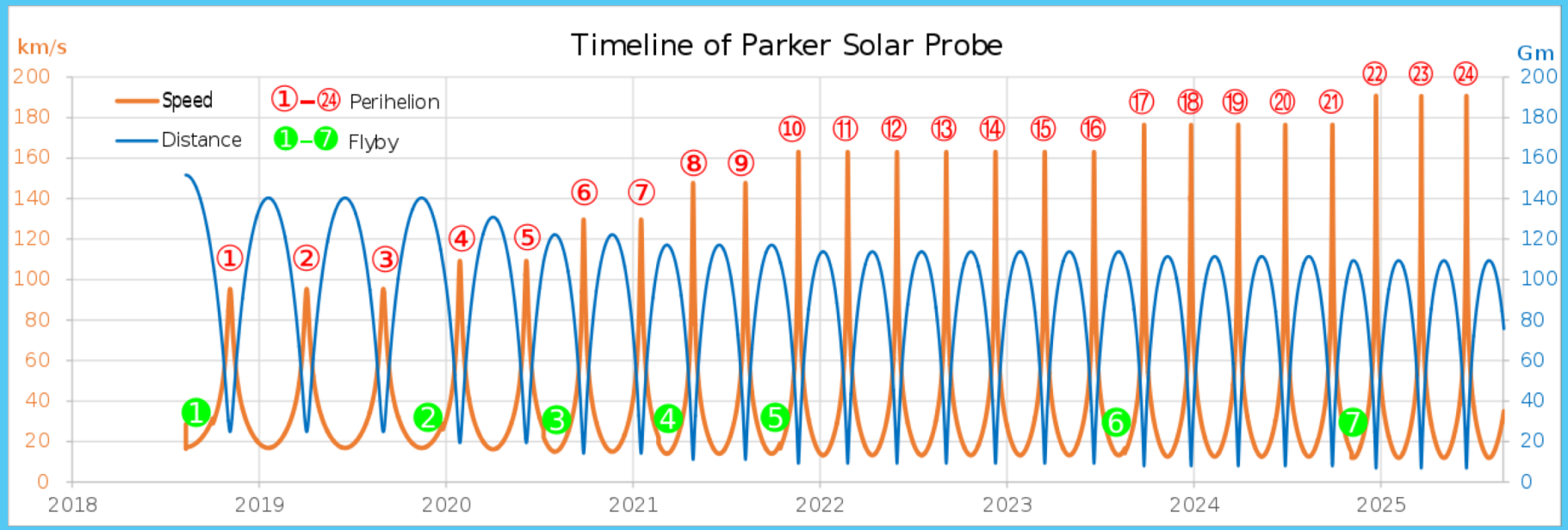


Parker spiral




Contributions to the Oxygen Fluence
(10/97 to 6/00)
Particles/(cm^2 sr-MeV/nucleon)
10^{18}
10^{16}
10^{14}
10^{12}
10^{10}
10^{8}
10^{6}
10^{4}
100
1
0.0001
0.001
0.01
0.1
1
10
100
Kinetic Energy (MeV/nucleon)
Slow Solar Wind
Fast Solar Wind
Suprathermal Tail
Total (10/97 to 6/00)
Gradual SEPs 11/97
CIR 1/00
Impulsive SEPs 11/97
ACRs (10/97-6/00)
GCRs

Timeline



Green numbers are the 7 Flybys of Venus
Red numbers are 24 solar observations