Space Weather from

Coronal Holes and High Speed Streams

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Based on a presentation by
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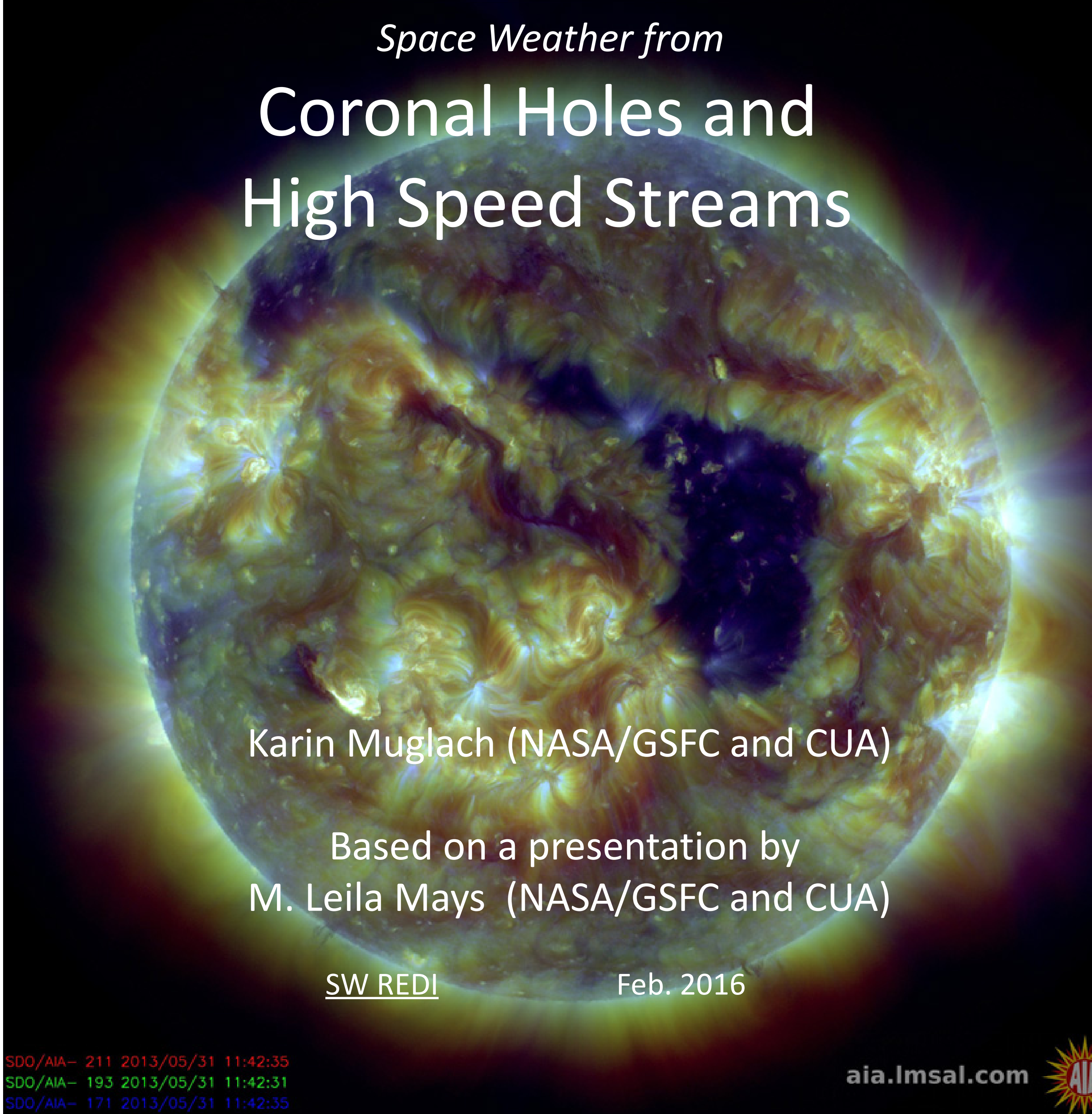
Community Coordinated Modeling Center

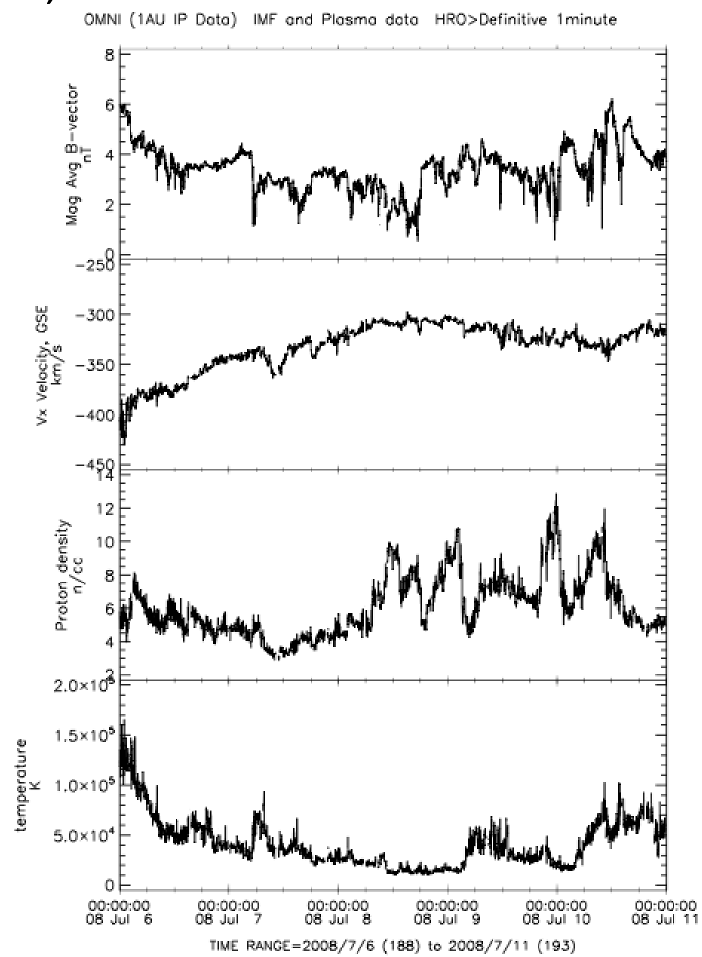


The **solar wind** is a flow of **plasma** and the frozen-in solar **magnetic field** from the Sun. The outward flow is due to the gas pressure difference between interplanetary space and the solar corona.

Changes in the solar magnetic field (from solar activity) influence the solar wind which, in turn, influences planets, spacecraft, and other bodies inside the solar wind (the **heliosphere**).

TABLE 4.1. Observed Properties of the Solar Wind near the Orbit of the Earth (1 AU)

Proton density	6.6 cm^{-3}
Electron density	7.1 cm^{-3}
He^{2+} density	0.25 cm^{-3}
Flow speed (nearly radial)	450 $km \cdot s^{-1}$
Proton temperature	1.2×10^5K
Electron temperature	1.4×10^5K
Magnetic field (induction)	7×10^{-9} tesla (T)



near the Earth, compared to the magnetosphere, the solar wind plasma (mostly ionized Hydrogen) is hot, tenuous, and fast moving, and the weak magnetic field is nearly parallel to the ecliptic plane, but 45˚ to the Sun-Earth line

Due to solar **rotation** parcels of solar wind plasma leaving the sun form a spiral (analogous to the water spirals formed from a rotating sprinkler), which is called the **Parker spiral.** The angle that a solar wind magnetic field line makes at 1 AU is close to 45 degrees.

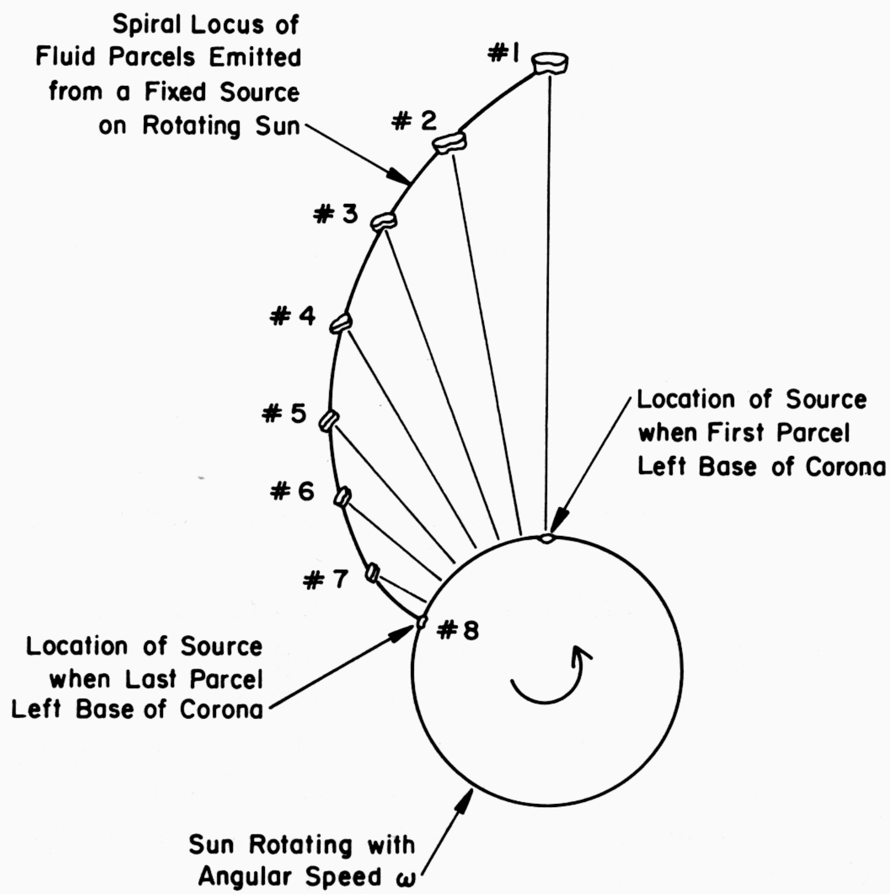
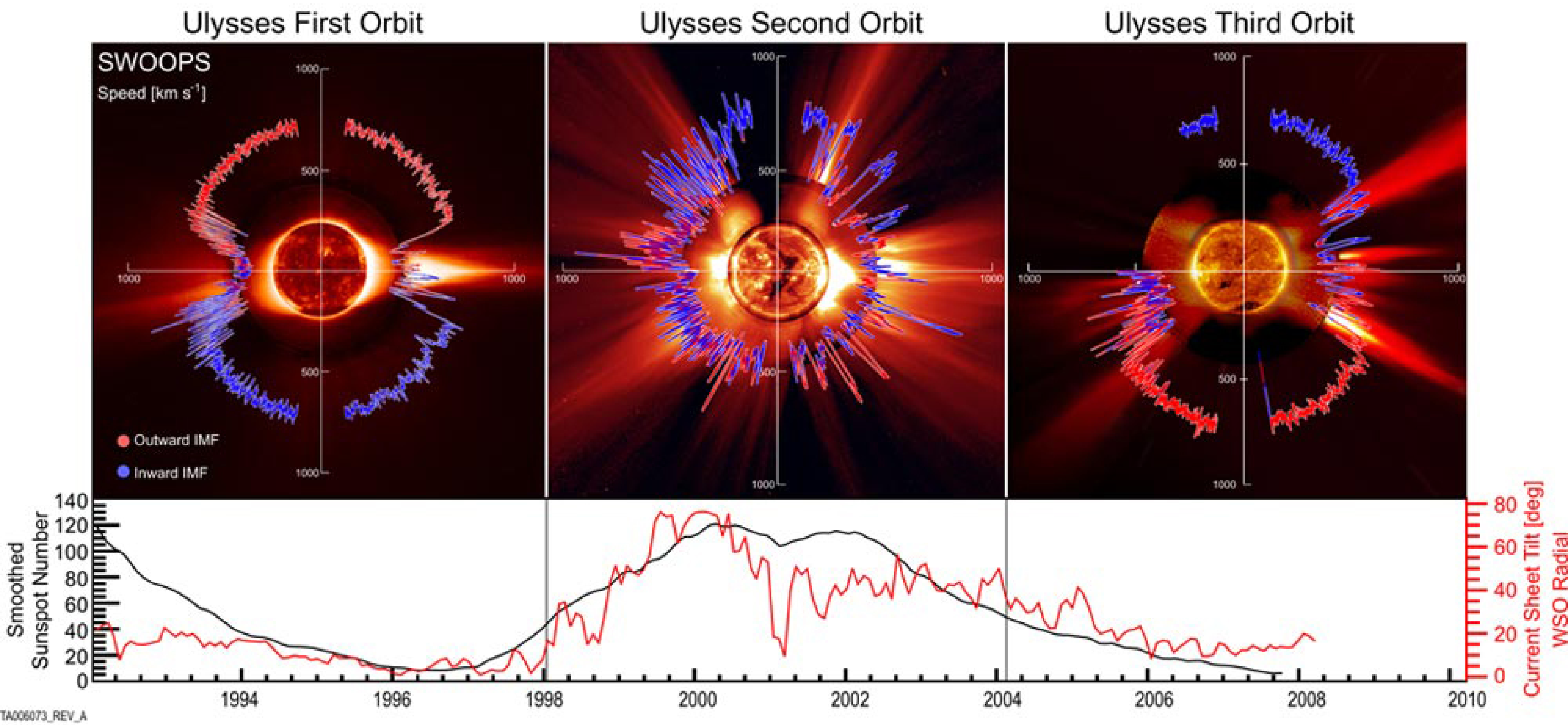


FIG. 4.5. Loci of a succession of fluid parcels (eight of them in this sketch) emitted at constant speed from a source fixed on the rotating sun.

$$U_\varphi = -\omega r$$

Solar wind can be divided into fast and slow wind components.



solar minimum

solar maximum

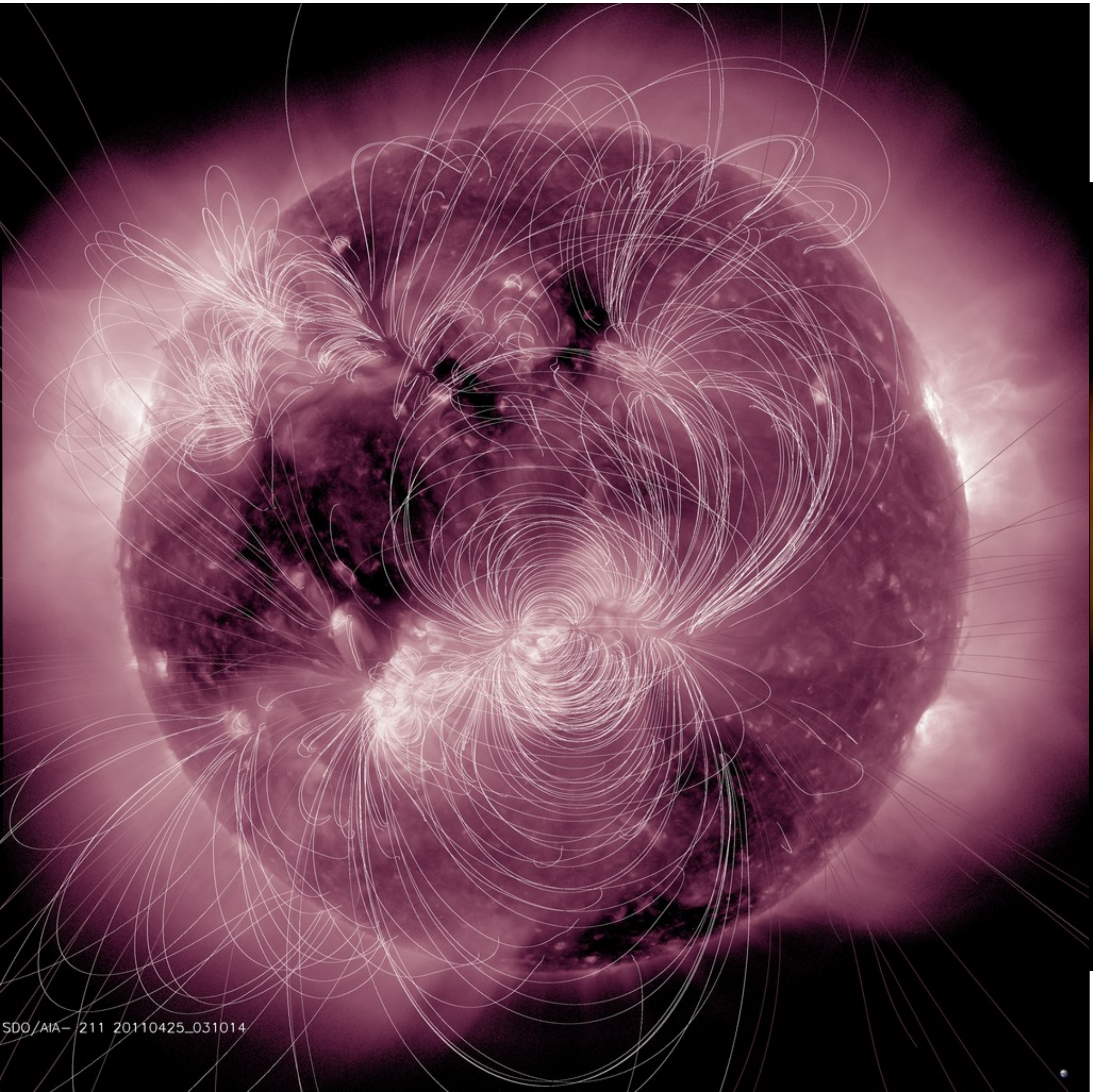
solar minimum

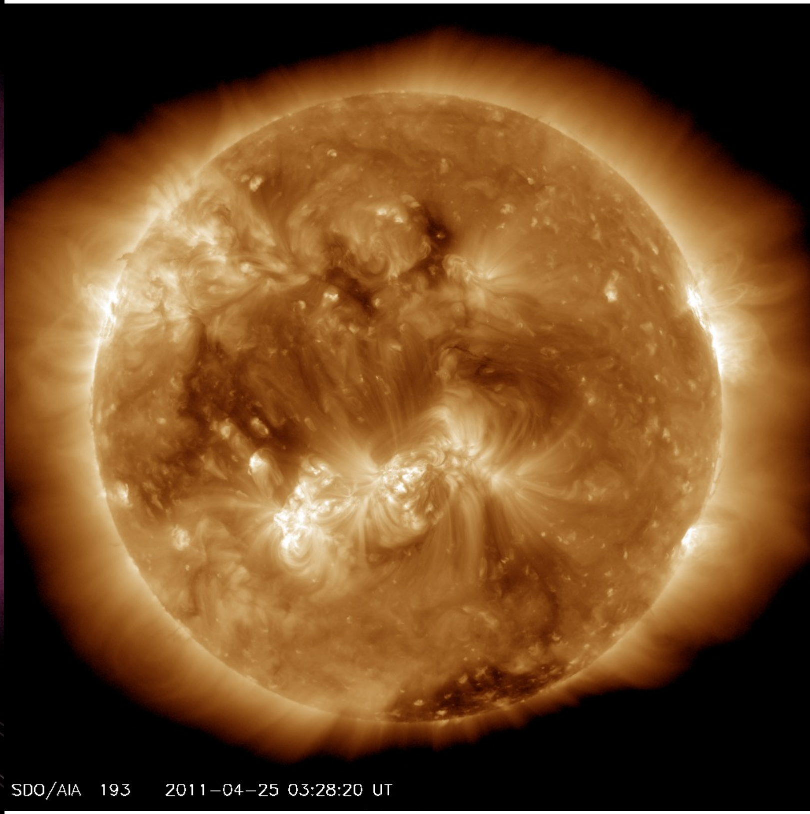
Solar wind can be divided into fast and slow wind components.

Fast wind	Slow wind
450–800 km/s	<~450 km/s
$n_P \sim 3\ \mathrm{cm}^{-3}$	$n_P \sim 7\text{–}10\ \mathrm{cm}^{-3}$
~95% H, 5% He, minor ions and same number of electrons	~94% H, ~4% He, minor ions and same number of electrons – great variability
$T_P \sim 2 \times 10^5$ K	$T_P \sim 4 \times 10^4$ K
$B \sim 5$ nT	$B \sim 4$ nT
Alfvénic fluctuations	Density fluctuations
Origin in coronal holes	Origin 'above' coronal streamers and through small-scale transients

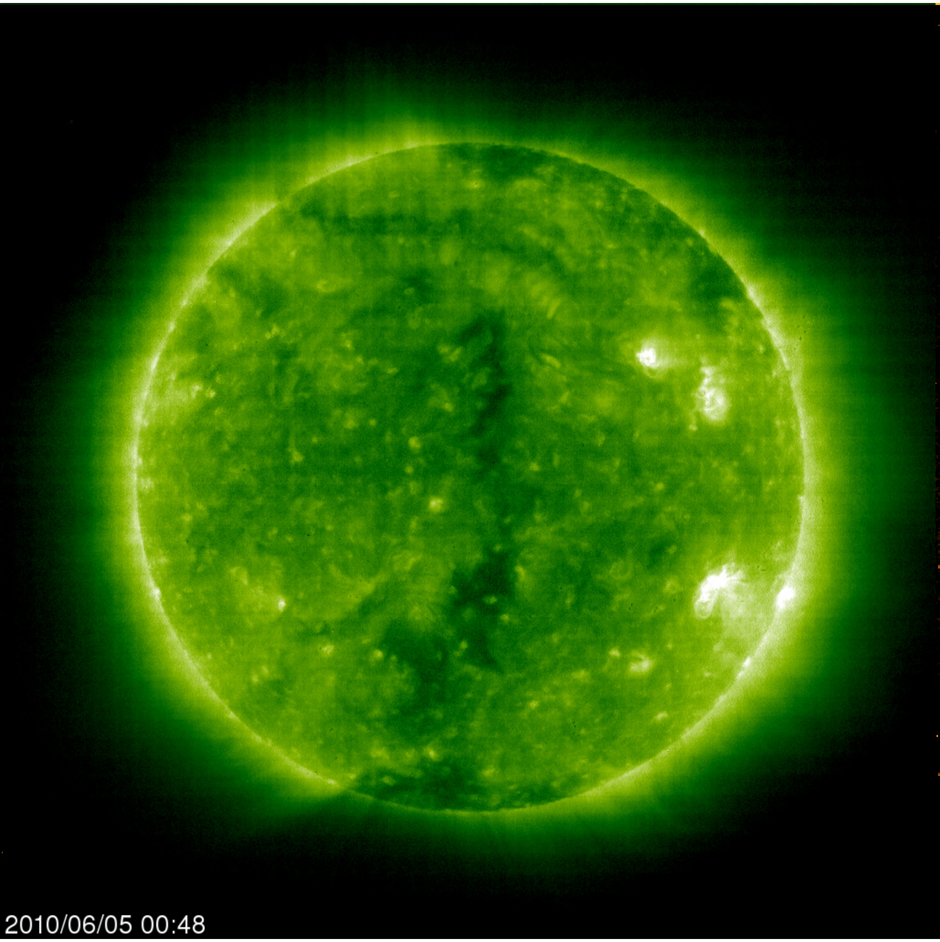
(Bothmer and Zhukov, 2007)

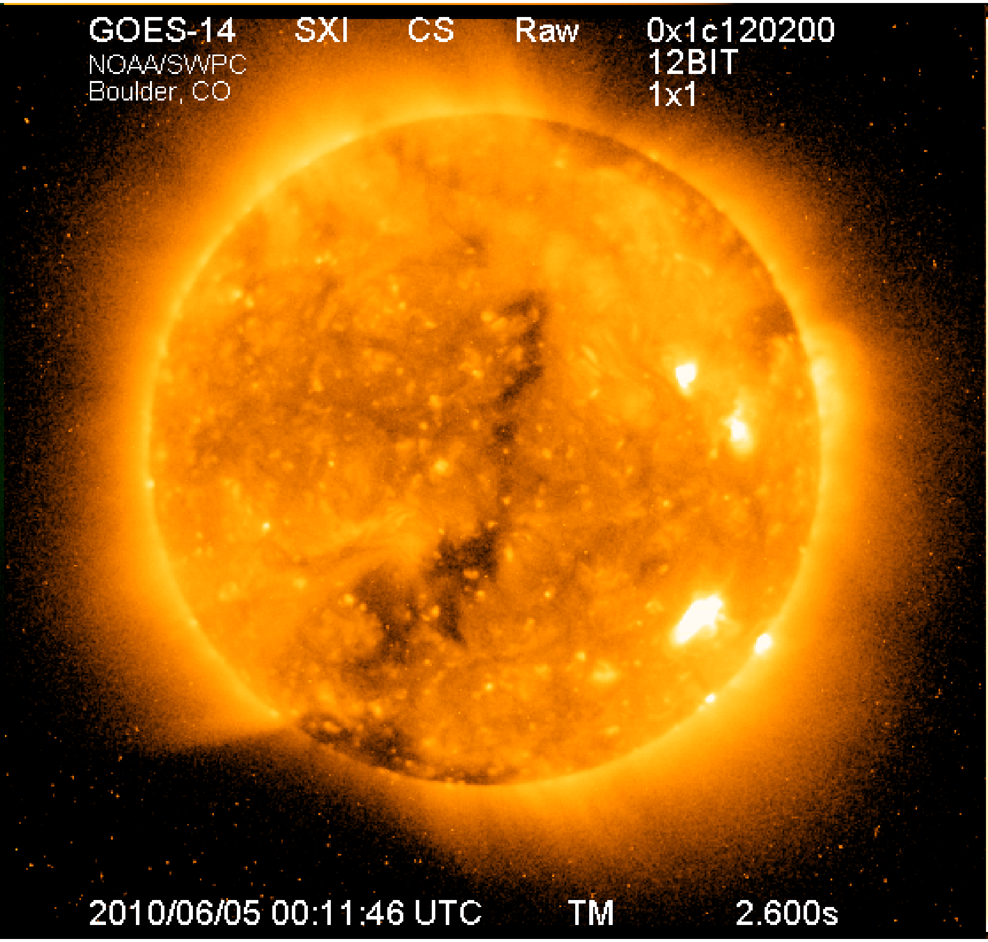
Coronal holes appear as dark areas on the solar surface in the **EUV** (extreme ultraviolet) and **X-ray** radiation. They have a **lower density** and **temperature** compared to the surrounding corona. **Coronal holes** correspond to regions of open magnetic fields. Visible best in lines with temperatures more than 1.5 MK.





Large **polar coronal holes** are persistent for about 7 years around solar minimum. During solar maximum and high solar activity **coronal holes** exist at all latitudes, but are less persistent.





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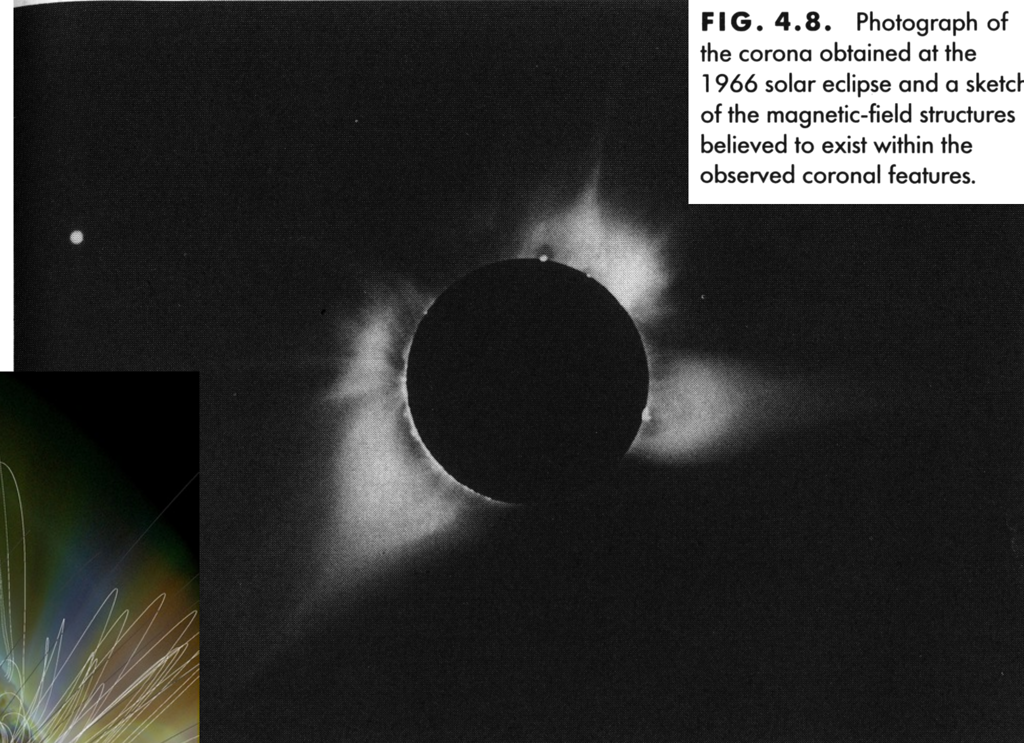
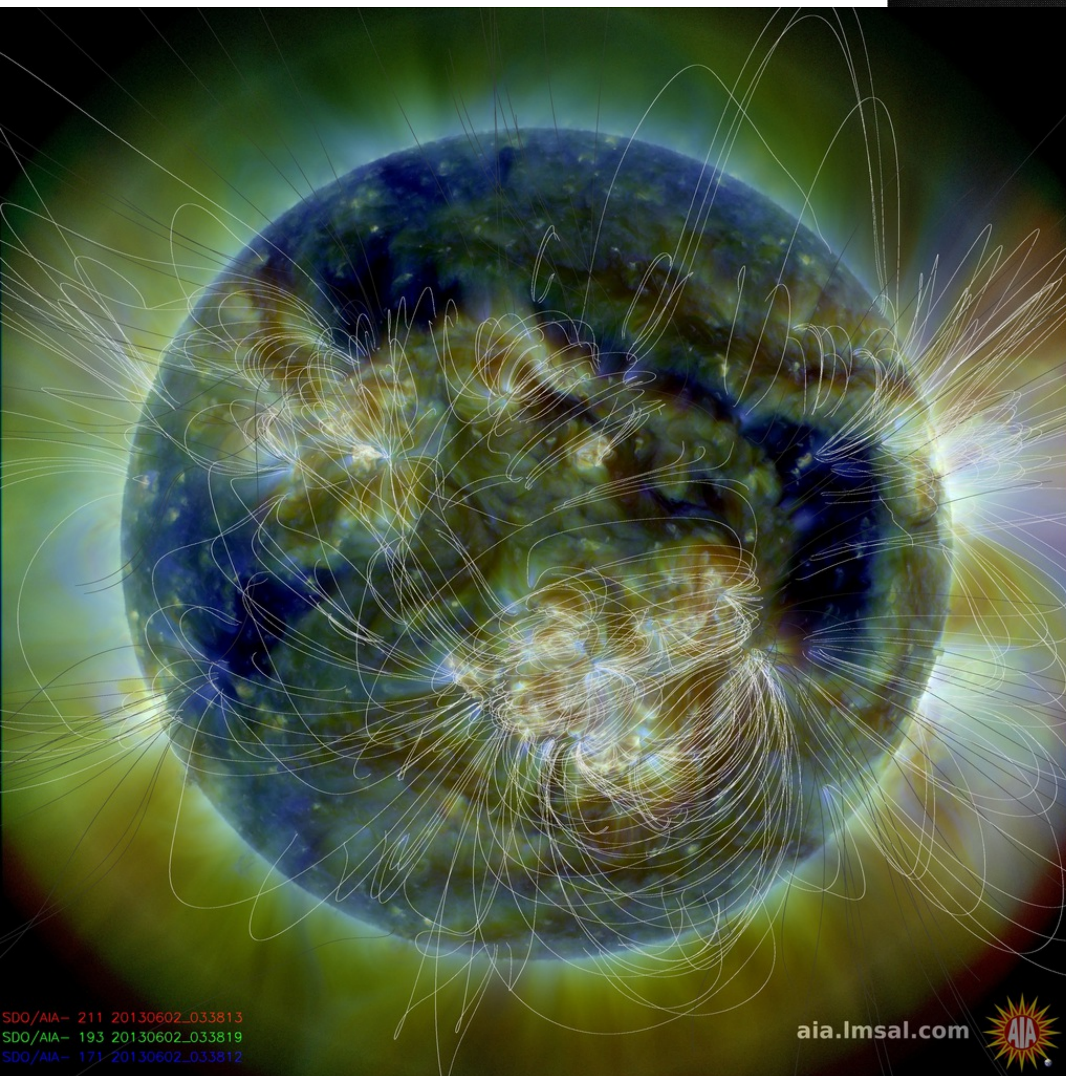
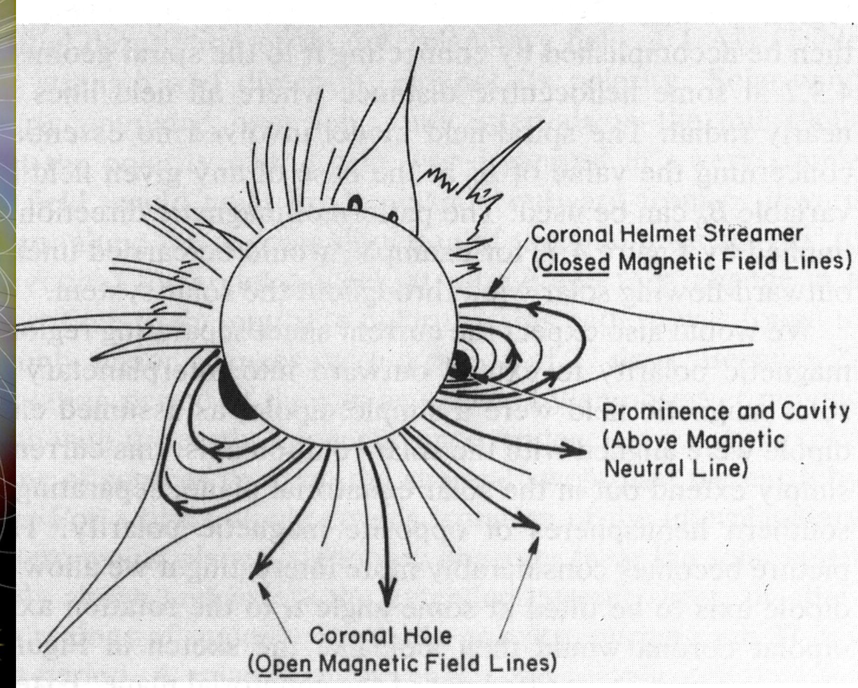


FIG. 4.8. Photograph of the corona obtained at the 1966 solar eclipse and a sketch of the magnetic-field structures believed to exist within the observed coronal features.





High speed solar wind streams are formed by higher speed solar wind originating from **coronal holes**. Higher speed streams are less tightly wound in the Parker spiral compared to slower ones, and at various distances the faster solar wind **overtakes** the slower wind ahead of it.

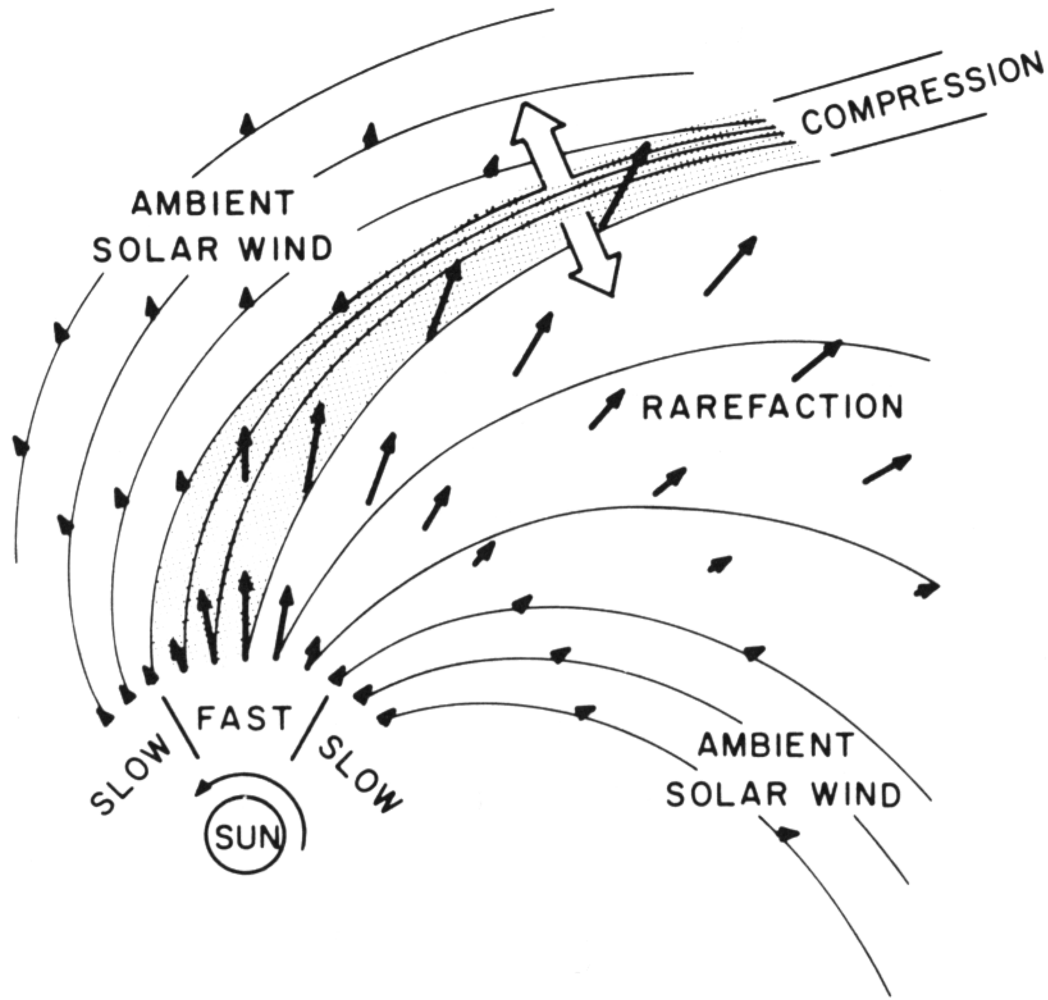
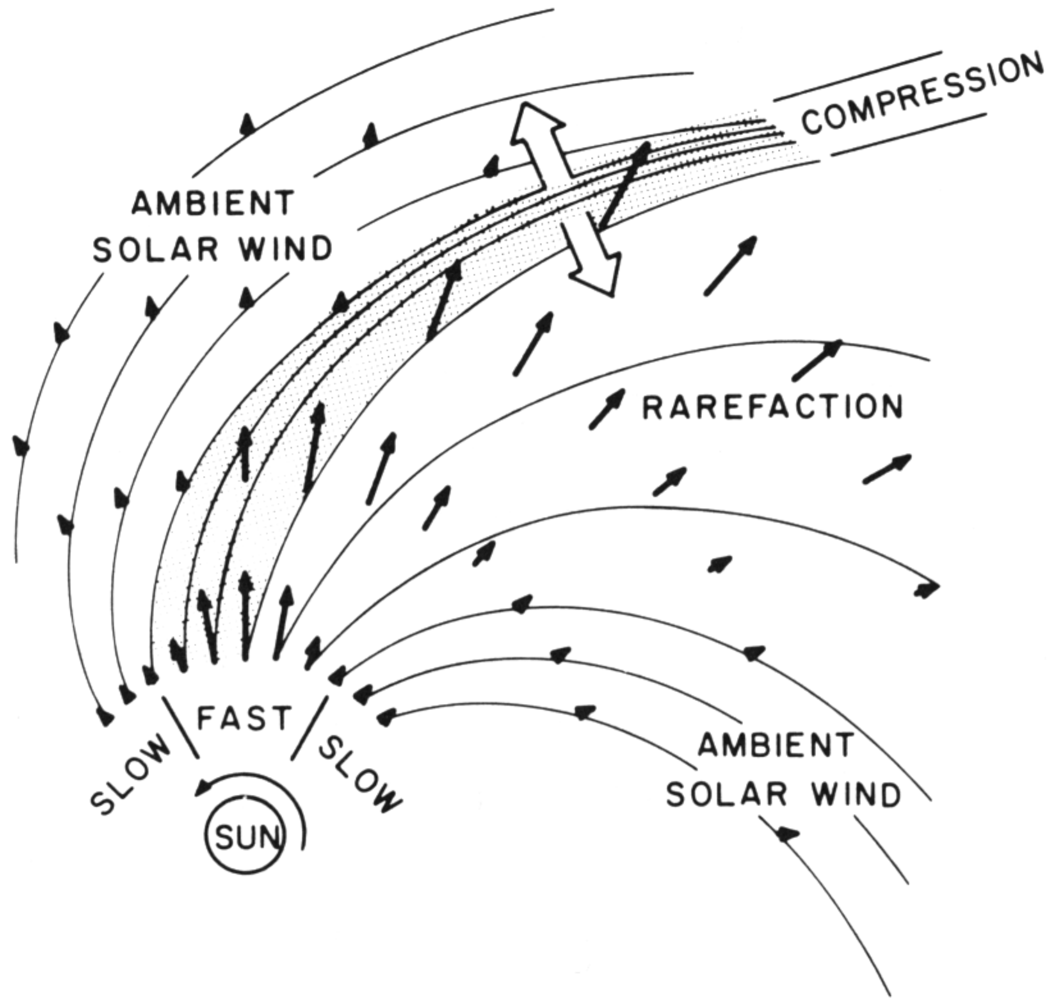


FIG. 4.13. Geometry of the interaction between fast solar wind (on less tightly wound spiral streamlines) and ambient solar wind (on more tightly wound spiral streamlines). The plasma is compressed where streamlines converge. (From Pizzo, 1985.)

A **stream interaction region** (SIR) forms at the compressed boundary between the fast and slow solar wind in a high speed stream. High speed streams from persistent coronal holes over multiple solar rotations are called **corotating interaction regions** (CIRs).



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Example of an **high speed solar wind stream** observed in-situ at ACE

iSWA layout: http://go.nasa.gov/17nkicp

The increase in speed from a solar wind high speed stream pumps energy into the magnetosphere which can cause **geomagnetic storms** and **energizes particles**.

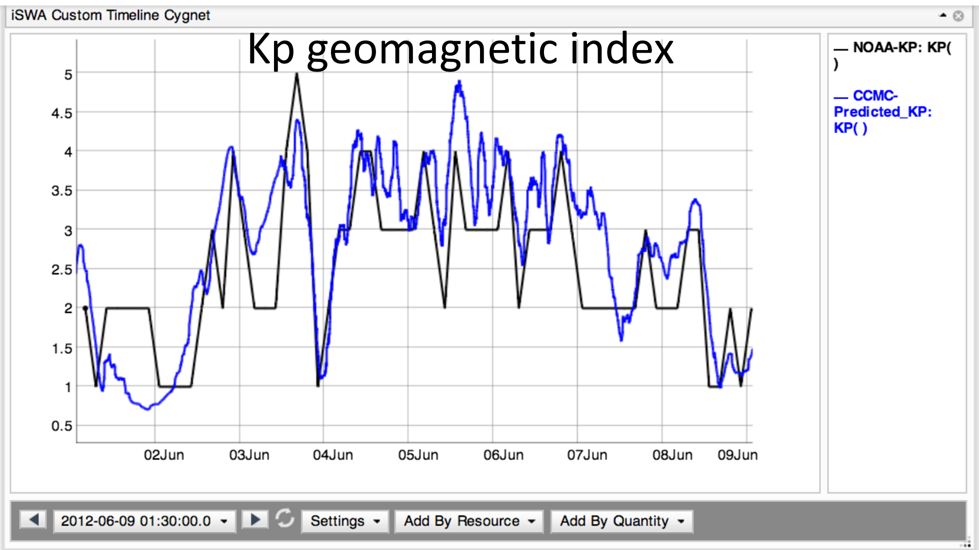
They can produce energetic **electron flux enhancements** in the radiation belt.

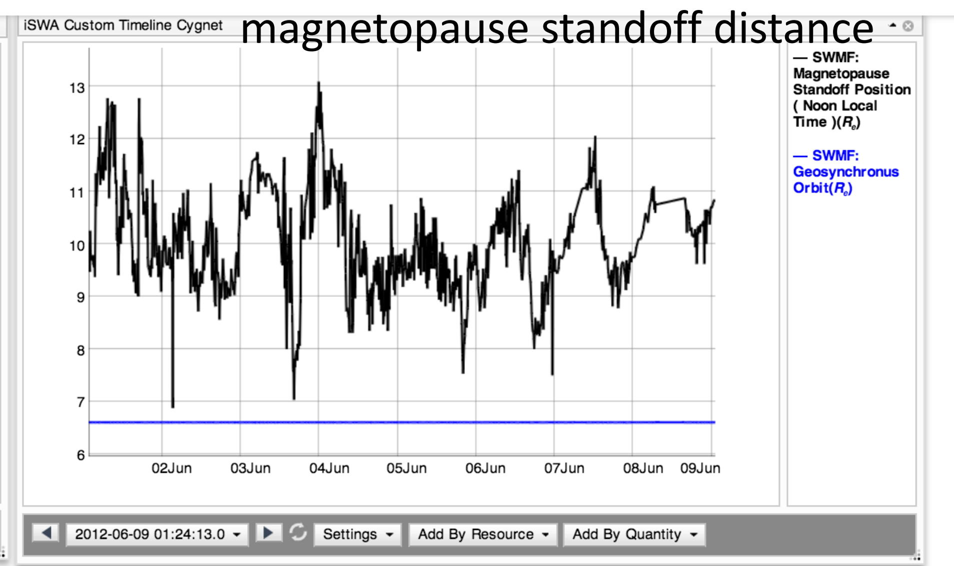
Geomagnetic storms are disturbances/changes in Earth's magnetic field due to changes in solar wind conditions typically lasting 3-6 days.

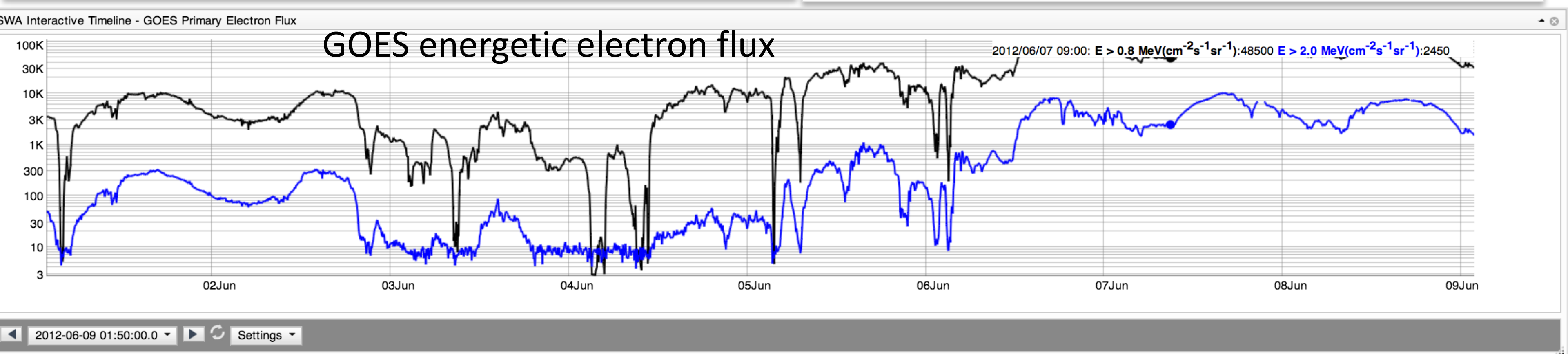
High speed streams can also cause geomagnetic storms, however they are longer in duration and not as strong as geomagnetic storms caused by CMEs.

(the magnetosphere lesson will go into more detail)

A high speed stream can cause an energetic **electron flux enhancement** in the radiation belt.







iSWA layout: http://go.nasa.gov/17nkicp

Slide link summary

SW REDI website

http://ccmc.gsfc.nasa.gov/support/SWREDI/swredi.php

iSWA http://iswa.gsfc.nasa.gov

iSWA Cygnet Glossary http://iswa3.ccmc.gsfc.nasa.gov/wiki/index.php/Full_iSWA_Cygnet_List

iSWA Space Weather Glossary http://iswa3.ccmc.gsfc.nasa.gov/wiki/index.php/Glossary

Most figures and tables in the slides are from the "Introduction to Space Physics" textbook

http://www.cambridge.org/us/knowledge/isbn/item1145043

iSWA layout of a high speed stream observed at ACE http://go.nasa.gov/17nkicp