

# Why „Space Physics“?

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- Plasma physics in a natural system
- Complex natural system (no laboratory plasma)
- Vivid examples for basic plasma-physical concepts
  - Storage and conversion of magnetic energy
  - Magnetic tension and pressure
  - Reconnection (merging of magnetic fields)
  - Collisionless shock waves
  - Magnetohydrodynamic dynamo



# Some useful ressources on the WEB

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- Plasma simulations: [http://www-ssc.igpp.ucla.edu/ssc/spgroup\\_edu.html](http://www-ssc.igpp.ucla.edu/ssc/spgroup_edu.html)
- Some tutorials: <http://www-ssc.igpp.ucla.edu/ssc/tutorial.html>
- Space Physics TextBook Oulu: <http://www.oulu.fi/~spaceweb/textbook/>
- NASA: [http://www.nasa.gov/externalflash/Anniversary\\_VisMar/index\\_noaccess.html](http://www.nasa.gov/externalflash/Anniversary_VisMar/index_noaccess.html)
- ESA: <http://www.esa.int/esaCP/index.html>
- Collections of links: <http://www-pw.physics.uiowa.edu/links/space.html>, [http://www.sec.noaa.gov/Education/ed\\_sites.html](http://www.sec.noaa.gov/Education/ed_sites.html)
- Virtual Solar Observatory: <http://umbra.nascom.nasa.gov/vso/>
- Plasma Physics at the Naval Research Lab: <http://wwwppd.nrl.navy.mil/nrlformulary/nrlformulary.html>
- Space Weather Ressources: <http://space.rice.edu/ISTP/>, [http://spdf.gsfc.nasa.gov/space\\_weather/Space\\_Weather\\_at\\_SSDOO.html](http://spdf.gsfc.nasa.gov/space_weather/Space_Weather_at_SSDOO.html)



# Definition of a plasma

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- A plasma has the following properties:
  - It also contains charged particles
  - The number of charged particles is large enough to allow for electromagnetic interactions
  - A plasma is quasi-neutral: the number of positive and negative charges is almost equal
- A plasma can interact with itself!
- The behavior of a plasma is determined by electric and magnetic fields
  - Large number of different types of waves

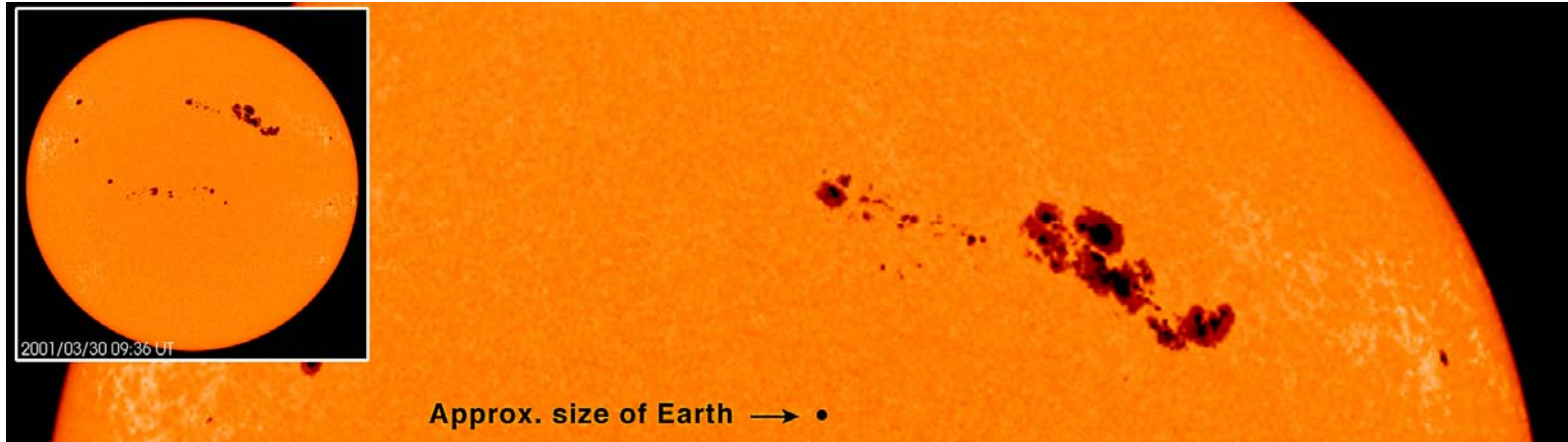


# Why study plasma physics?

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- 99% of the matter in the universe is plasma,
- The upper atmosphere, lightning, the liquid core of the Earth are natural plasmas in our direct environment,
- Technical applications
  - Plasma fusion: containment of a hot plasma in a magnetic field.
  - Chemical industry, e.g. cyan synthesis
  - Welding of metals
  - Implantation of semiconductors
  - .....

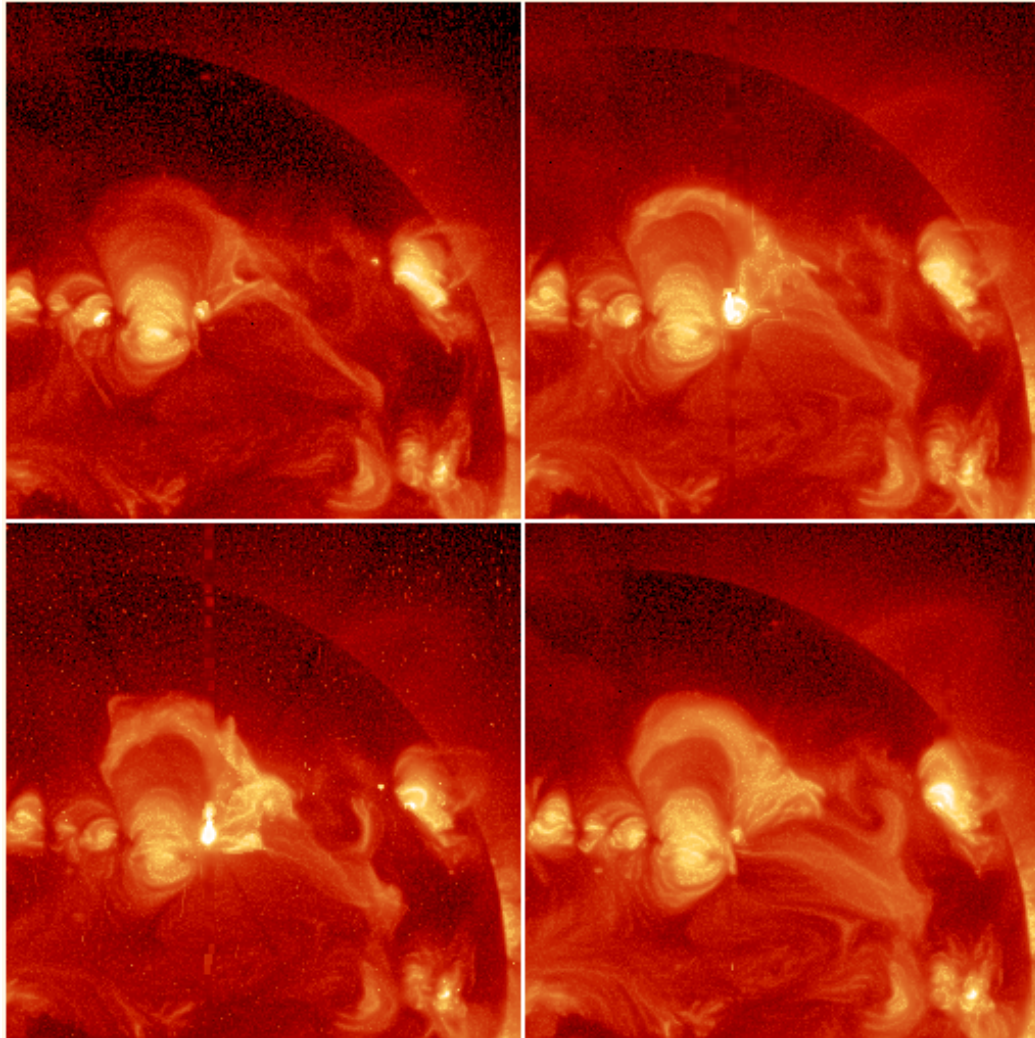
# Plasmas behave counter-intuitively



<http://sohowww.nascom.nasa.gov>

- Sunspot:
  - Cold gas (4000K) in a hot (5800K) surrounding
  - Long-lived (some solar rotations)
- Stability due to the magnetic field:
  - Magnetic pressure compensates the difference in gas-dynamical pressure in- and outside the sunspot

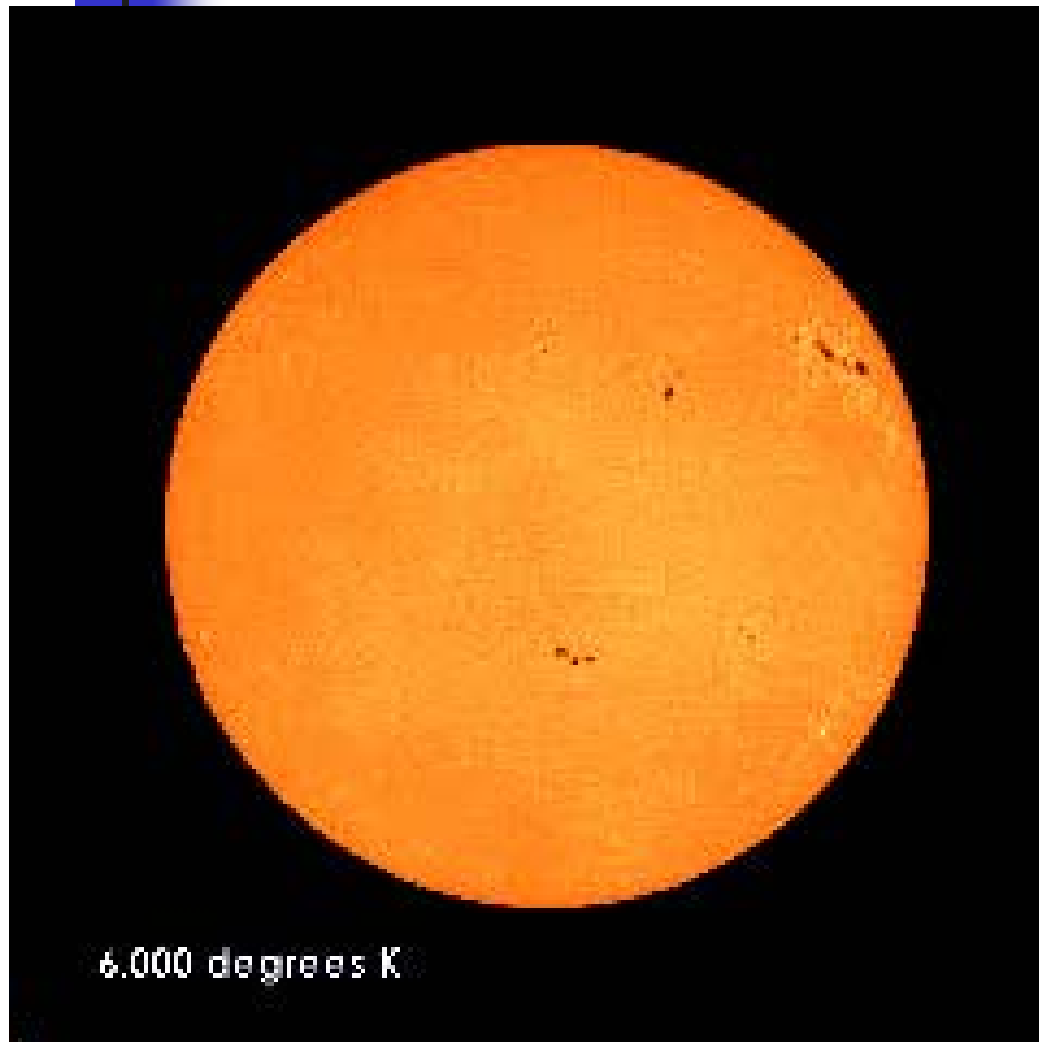
# Counter-intuitive II



Yohkoh Soft X-rays

- Filament:
  - Arc of cold matter in the hot corona high above the photosphere
  - No mixing with the surrounding gas
  - Does not sink
  - Occasionally violent eruption
- Magnetic tension acts against gravity to keep the filament in balance, magnetic pressure prevents mixing with the hot environment.

# Different layers of the Sun



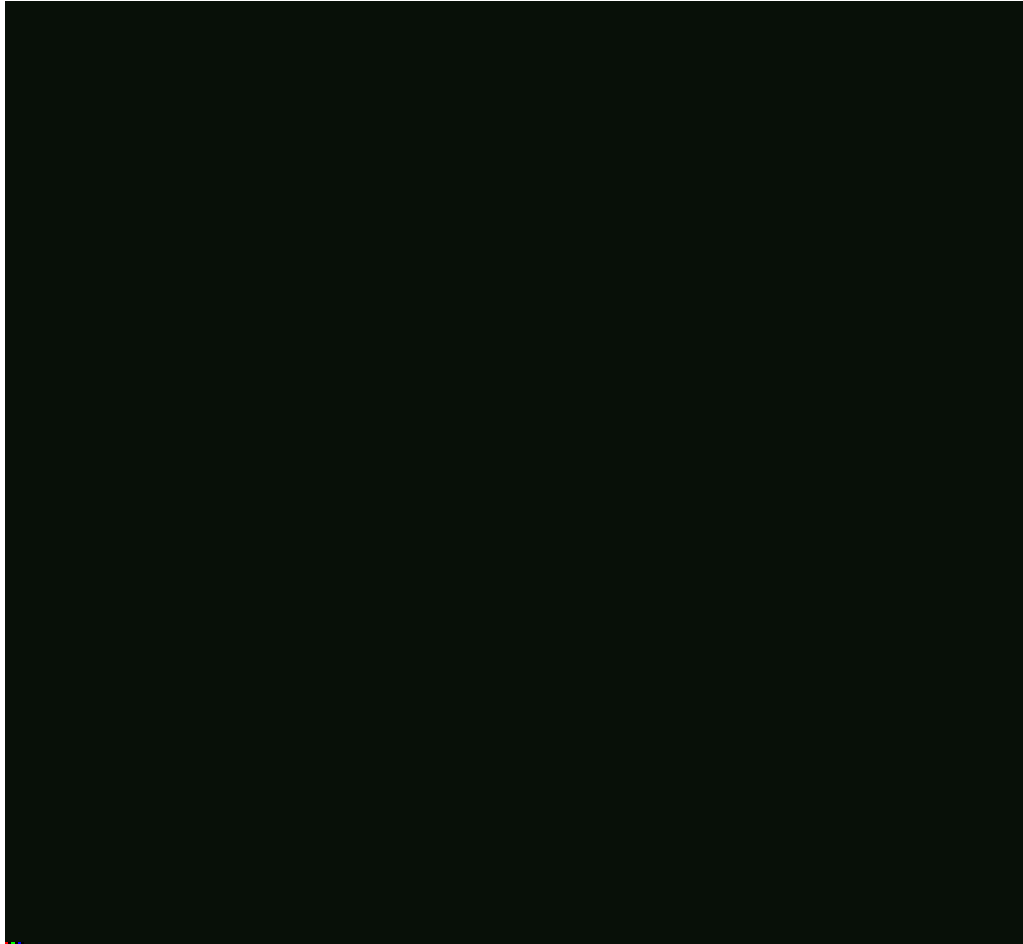
<http://sohowww.nascom.nasa.gov>

Coronal temperature varies with height: different wave length are emitted from different heights in the corona.



# Dynamics I: the Sun

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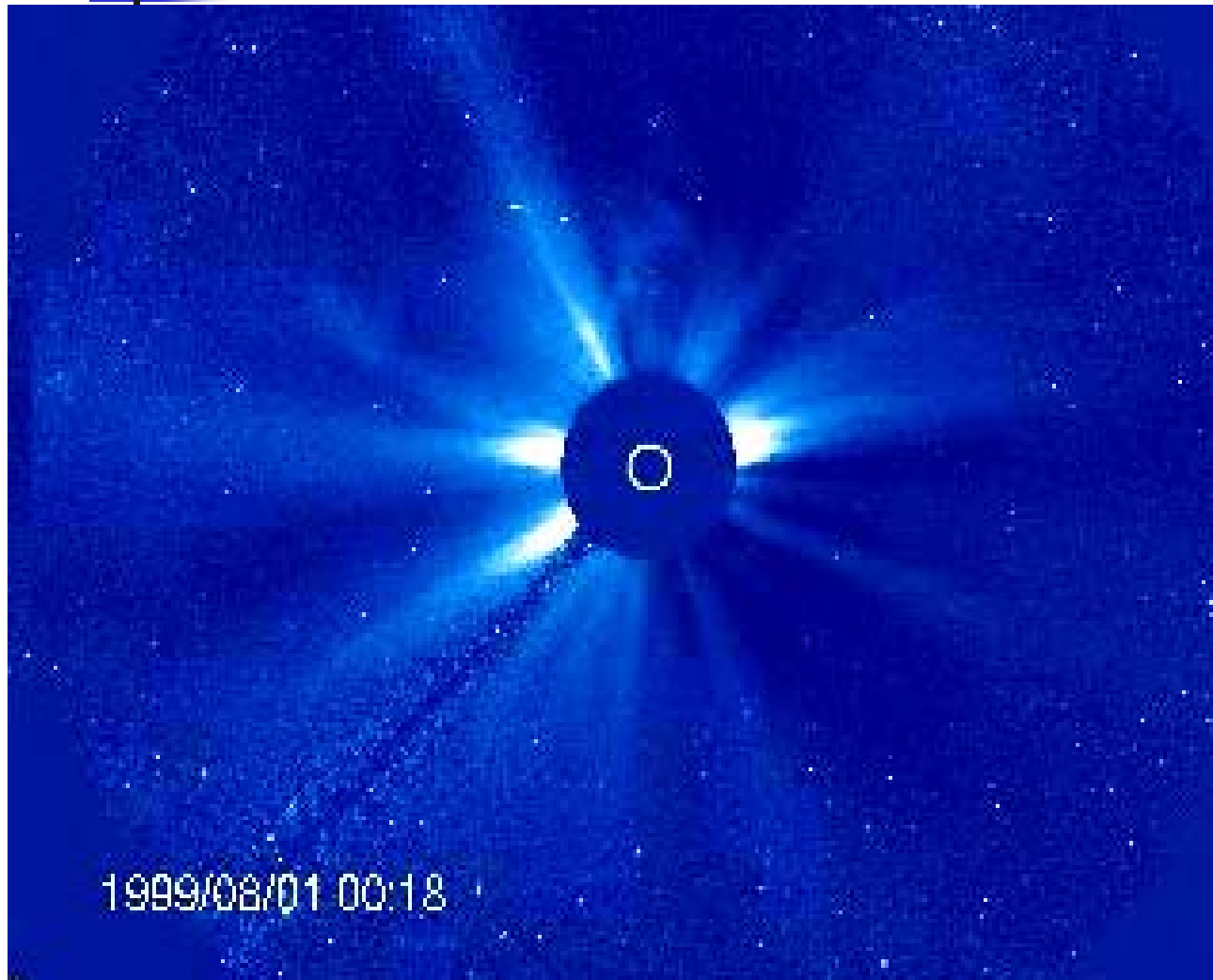


<http://vestige.lmsal.com/TRACE/POD/TRACEpodoverview.html>

- The Sun is a source of plasma: solar wind, coronal mass ejections, and energetic particles



# Dynamics II: the Sun

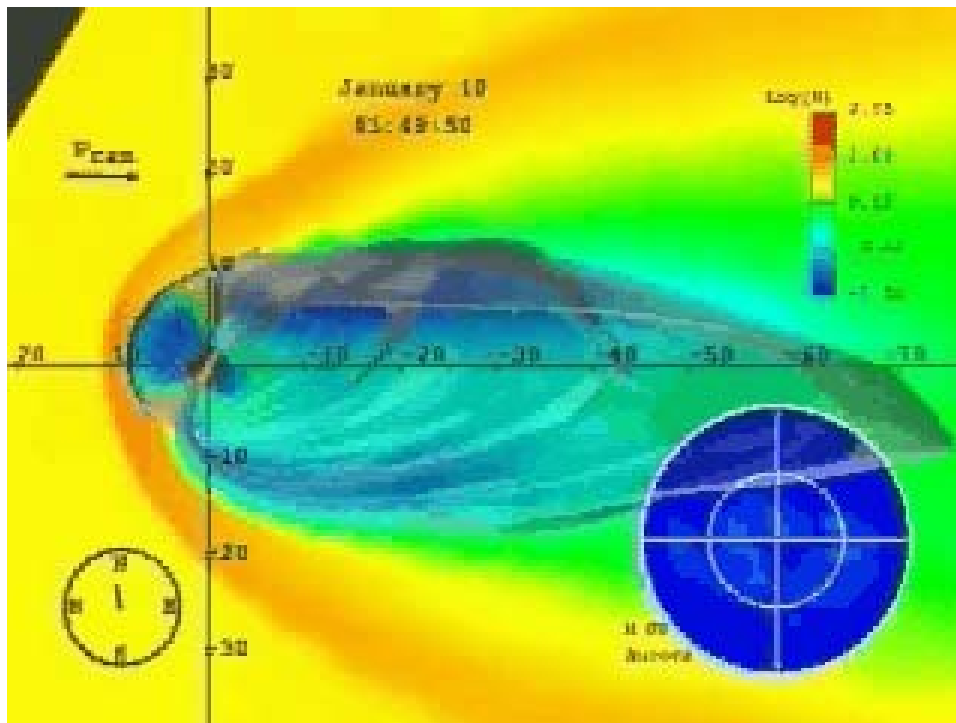
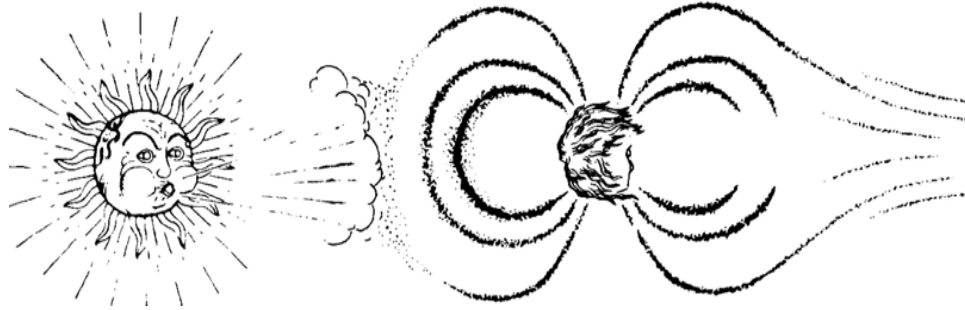


The sun is a source of plasma:

- Solar wind
- Coronal mass ejections (CMEs)
- Energetic particles

<http://sohowww.nascom.nasa.gov>

# Dynamics III: the magnetosphere

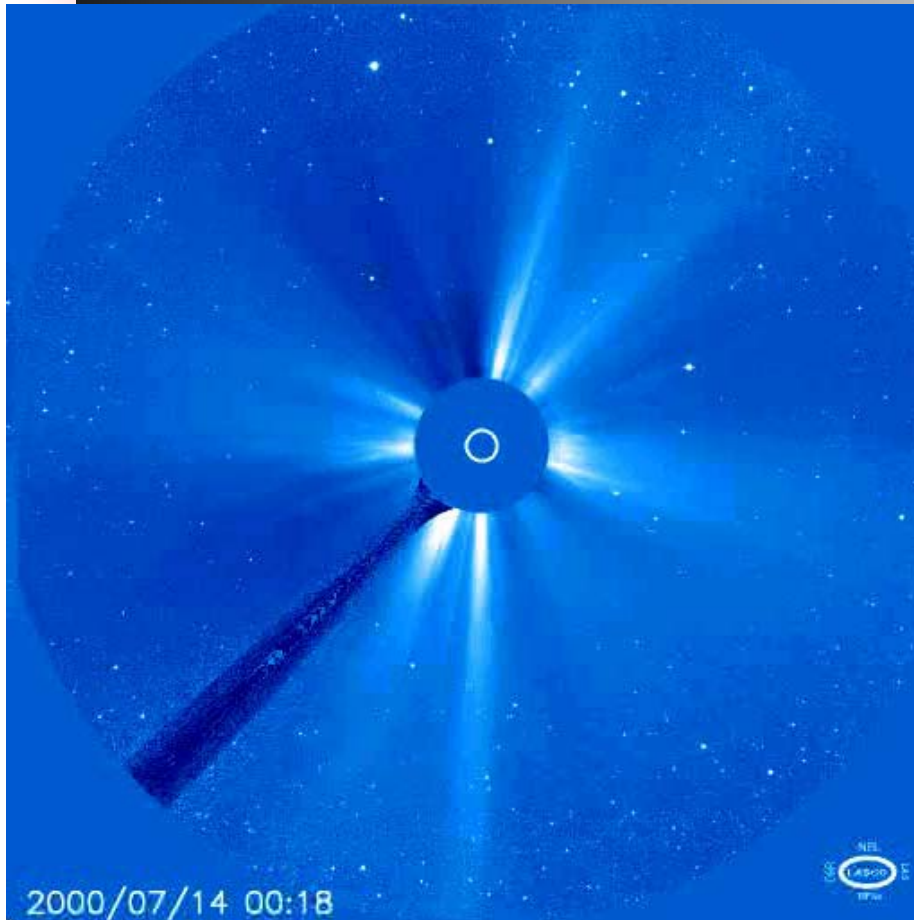


The magnetosphere results from the interaction of the solar wind with the geomagnetic field.

Fluctuations in the solar wind lead to a dynamical magnetosphere.

[http://www.psc.edu/science/Goodrich/Images/ion-ms-jan\\_1.mpeg](http://www.psc.edu/science/Goodrich/Images/ion-ms-jan_1.mpeg)

# Dynamics IV



<http://www-spf.gsfc.nasa.gov/istp/polar/>

- Aurora is a consequence of the interaction of the atmosphere with particles accelerated during a large geomagnetic storm

# Dynamics V: Aurora

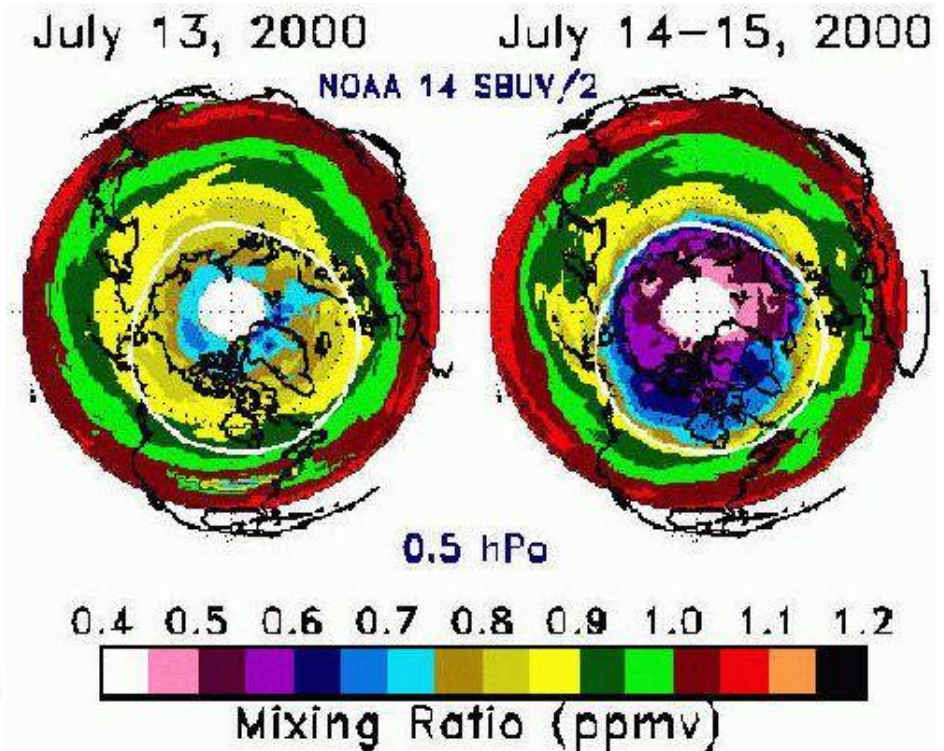
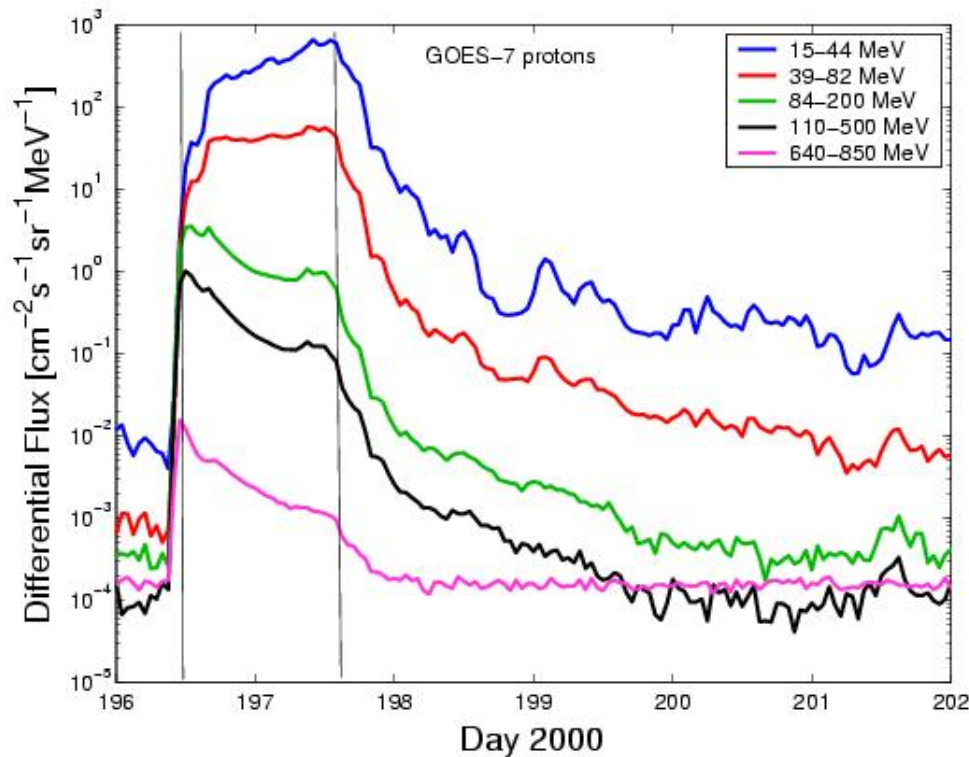
POKER FLAT ALL-SKY CAMERA

TIME-LAPSE ANIMATION



Geophysical Institute  
University of Alaska  
Fairbanks, Alaska

# Terrestrial consequences

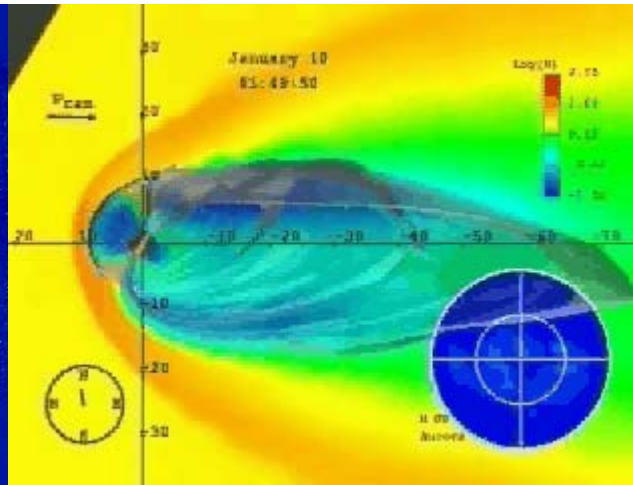
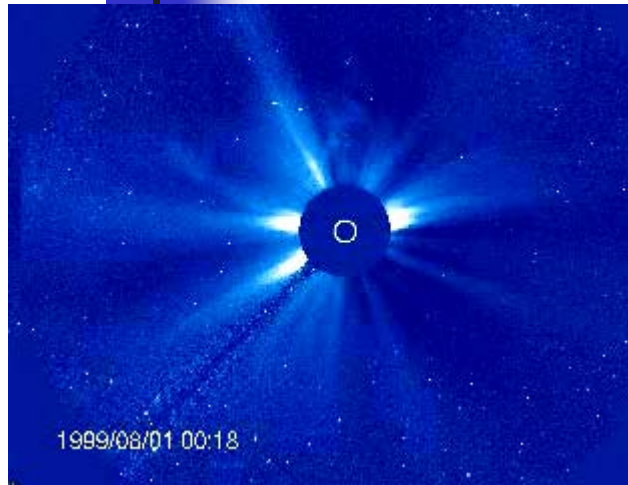


Jackman et al., 2001

- Ionization of the atmosphere
- Changes in atmospheric chemistry
- Influence on the climate?



# Summary



- The Sun is a source of plasma: solar wind, coronal mass ejections, energetic particles.
- The magnetosphere results from the interaction of the solar wind with the terrestrial (or more general planetary) magnetic field.
- Aurora is the visible consequence of the interaction of the atmosphere with particles accelerated during a geomagnetic storm.



# Modules

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1. What is a plasma?
2. Motion of charged particles in electromagnetic fields
  1. Gyration
  2. Drift
  3. Adiabatic invariants
3. Magnetohydrodynamics
  1. Magnetic pressure and tension
  2. Frozen-in magnetic fields
  3. reconnection
  4. Magnetohydrodynamic dynamo
4. Plasma waves
5. Kinetic theory
6. Sun and solar wind
7. Energetic particles
8. The magnetosphere
9. Planetary magnetospheres
10. Solar-terrestrial relations
11. Instruments
12. Physics in a complex environment.