Why Go To Space?

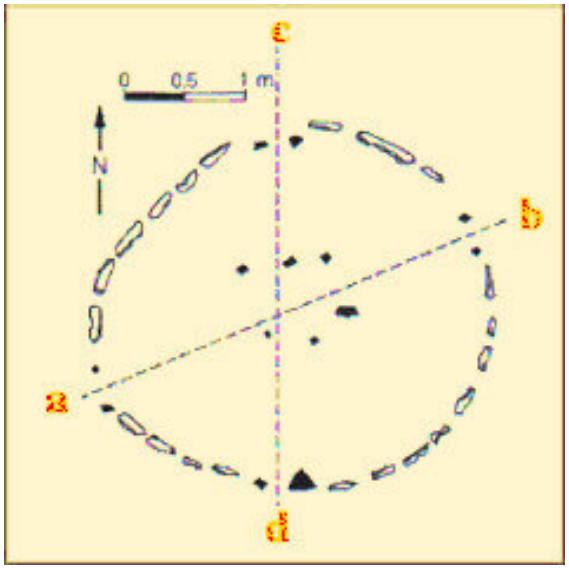
Leon Golub, SAO
BACC, 27 March 2006

Smithsonian Astrophysical Observatory

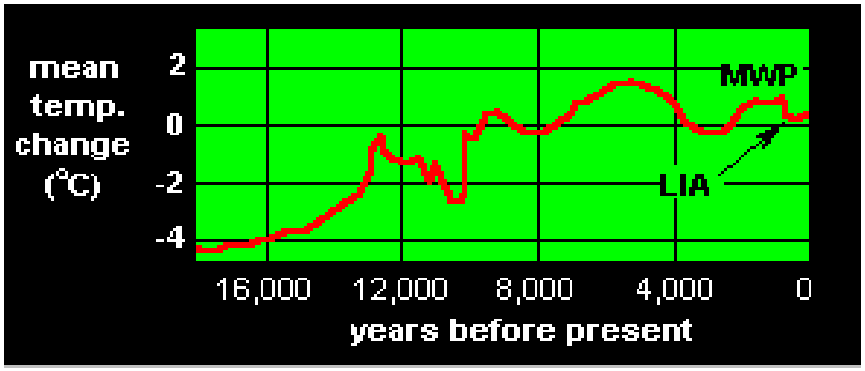
Solar Observation

Observation of the Sun has a long and distinguished history

Especially important as calendar where e.g. seasonal monsoons produced temporary lakes…



Nabta Playa



Solar Observation

… and in high-latitude farming societies for knowledge of the seasons.

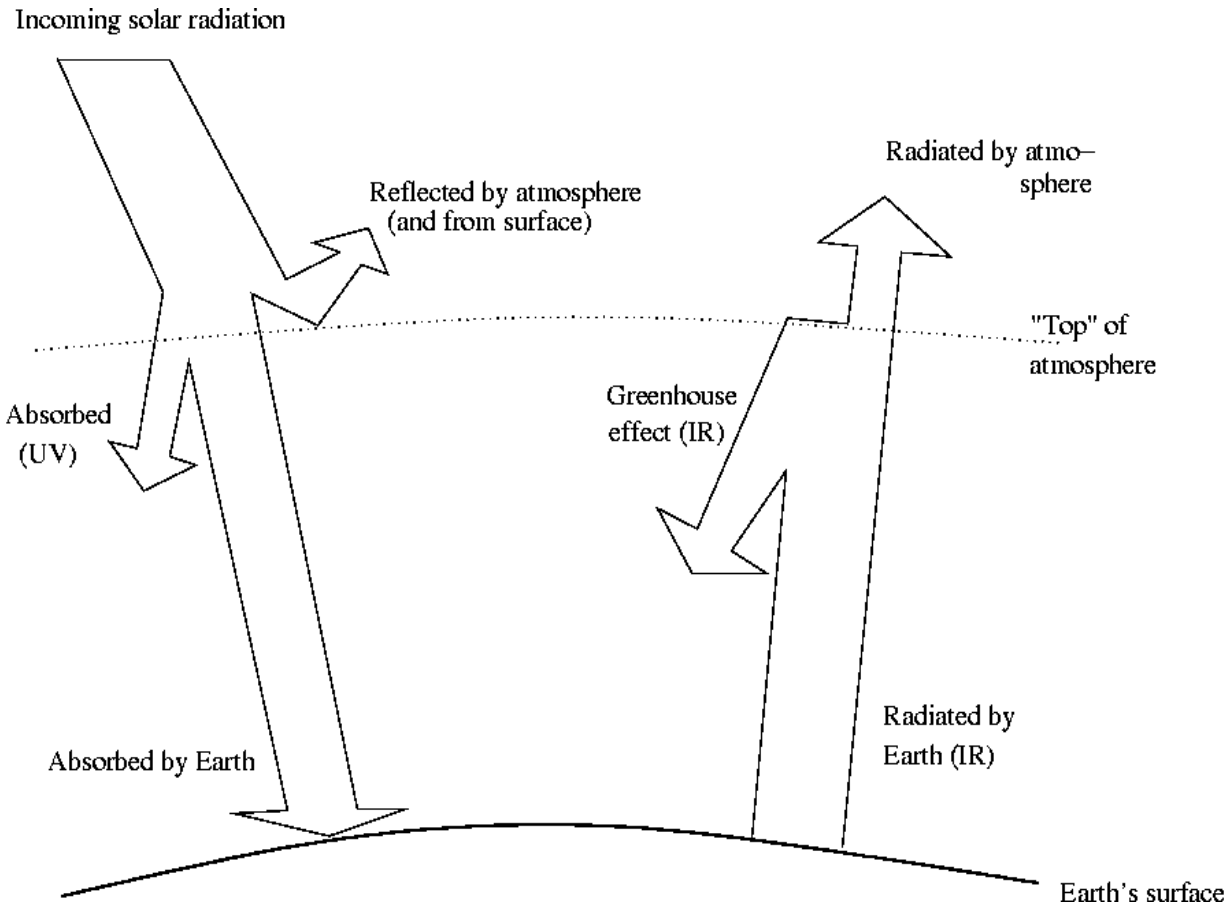
Sun-Earth Connection

- Importance of the Sun for life on Earth has long been recognized

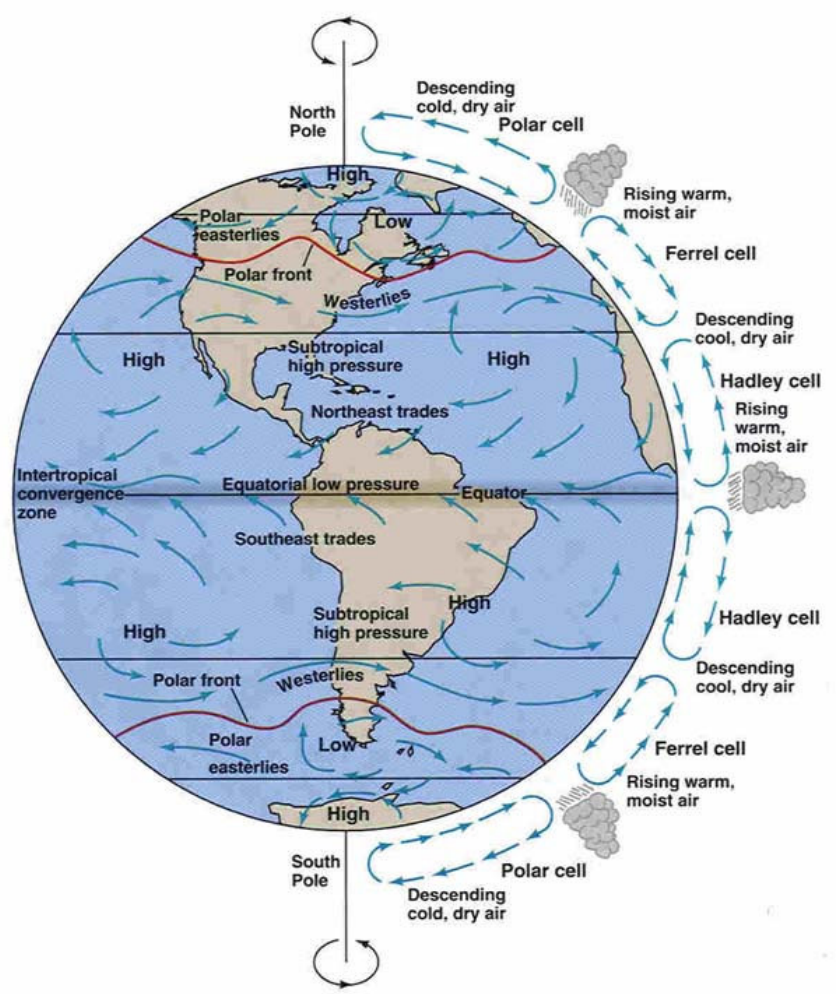
  -- particularly noticeable near the equator where Sun's energy is strongest.

The Climate System

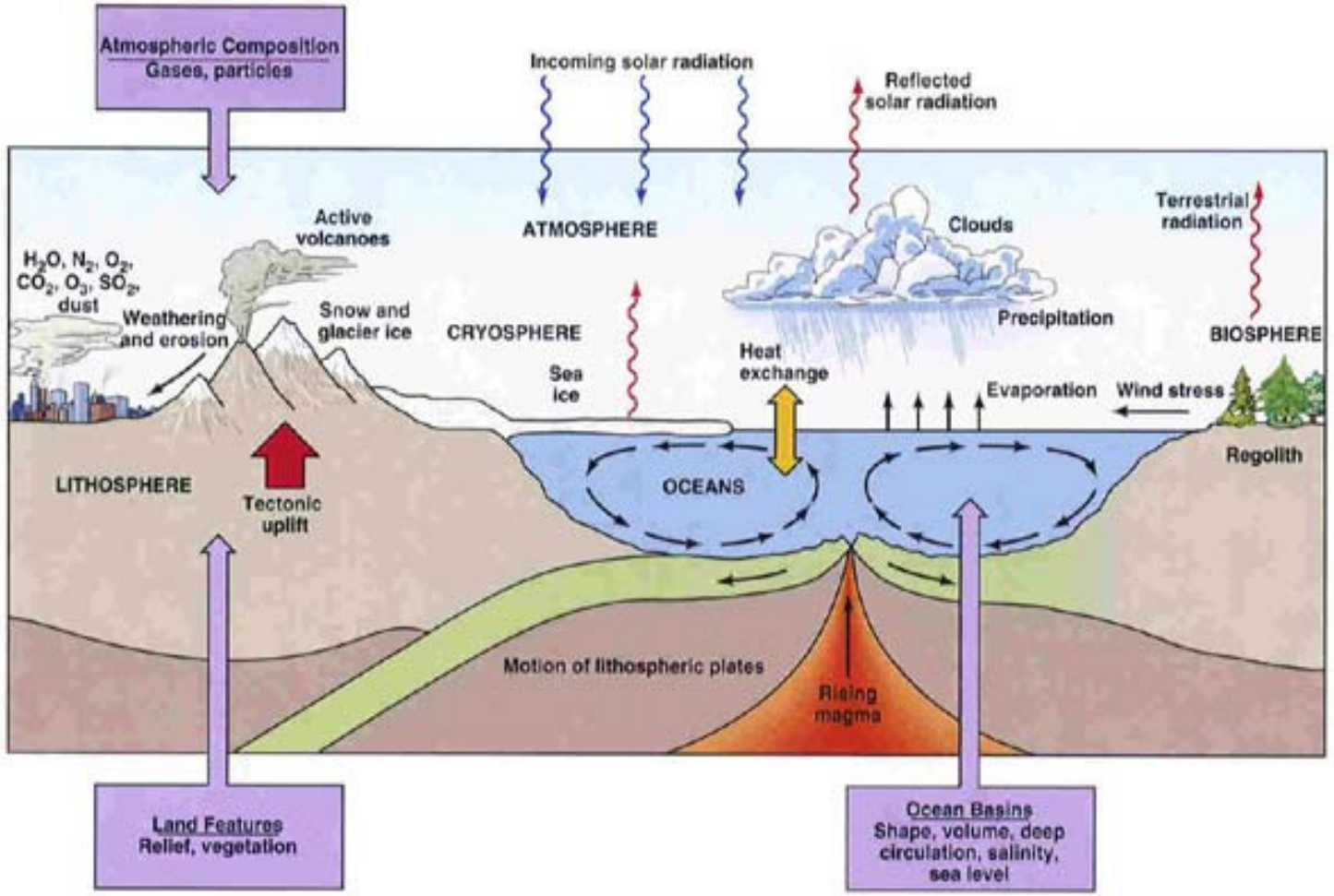
- Earth's climate is dominated by the Sun:



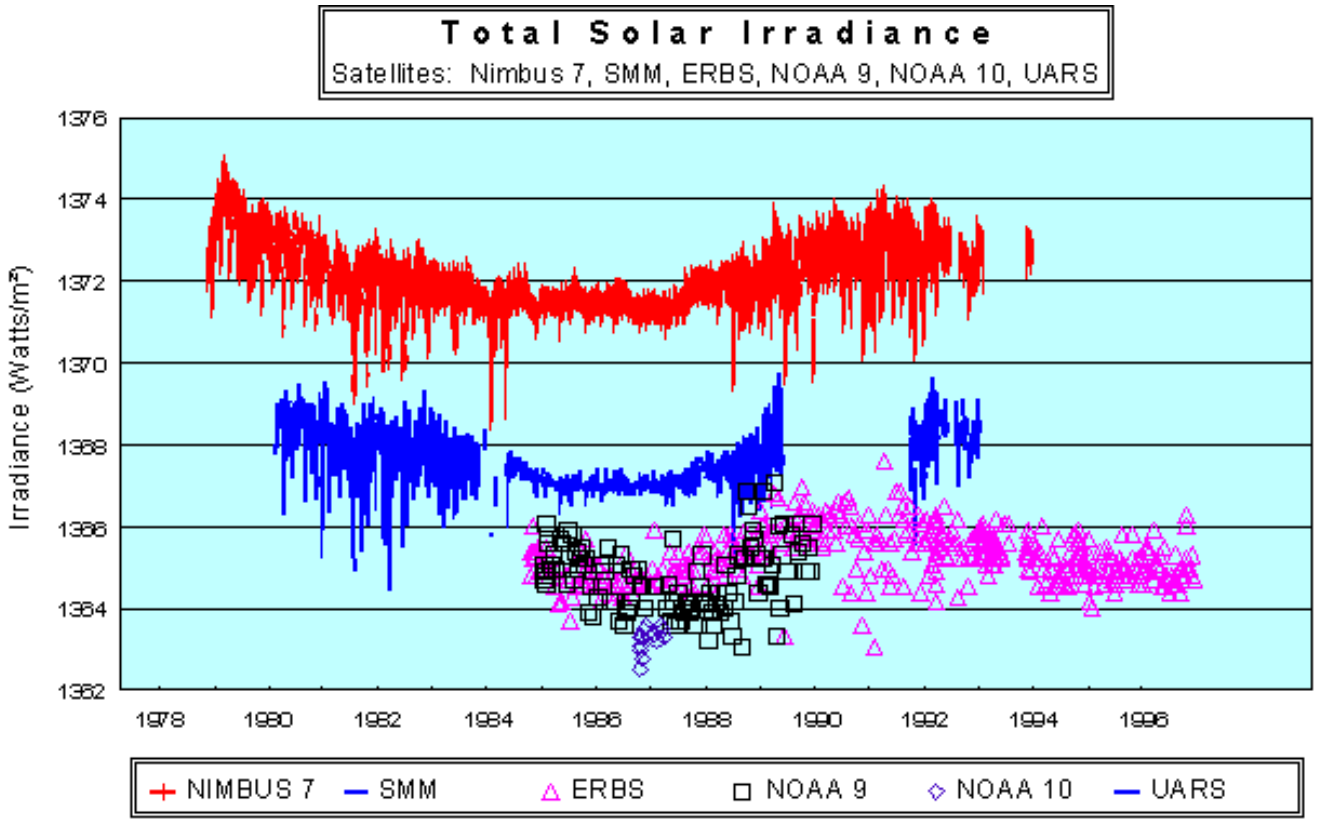
The Solar Energy Input is Distributed by Currents



The Climate System is Complex

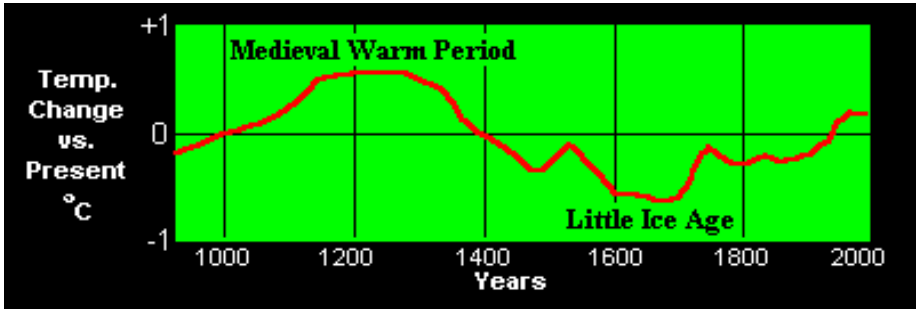


The Not-quite-constant Solar Constant

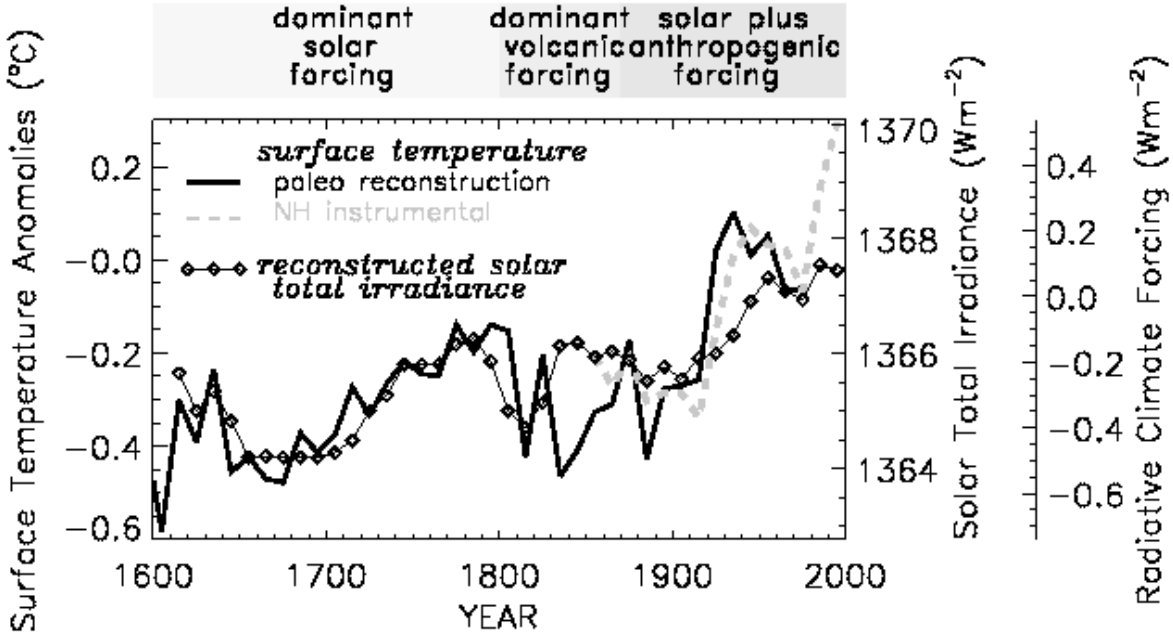


The Sun and Global Climate, Long-Term

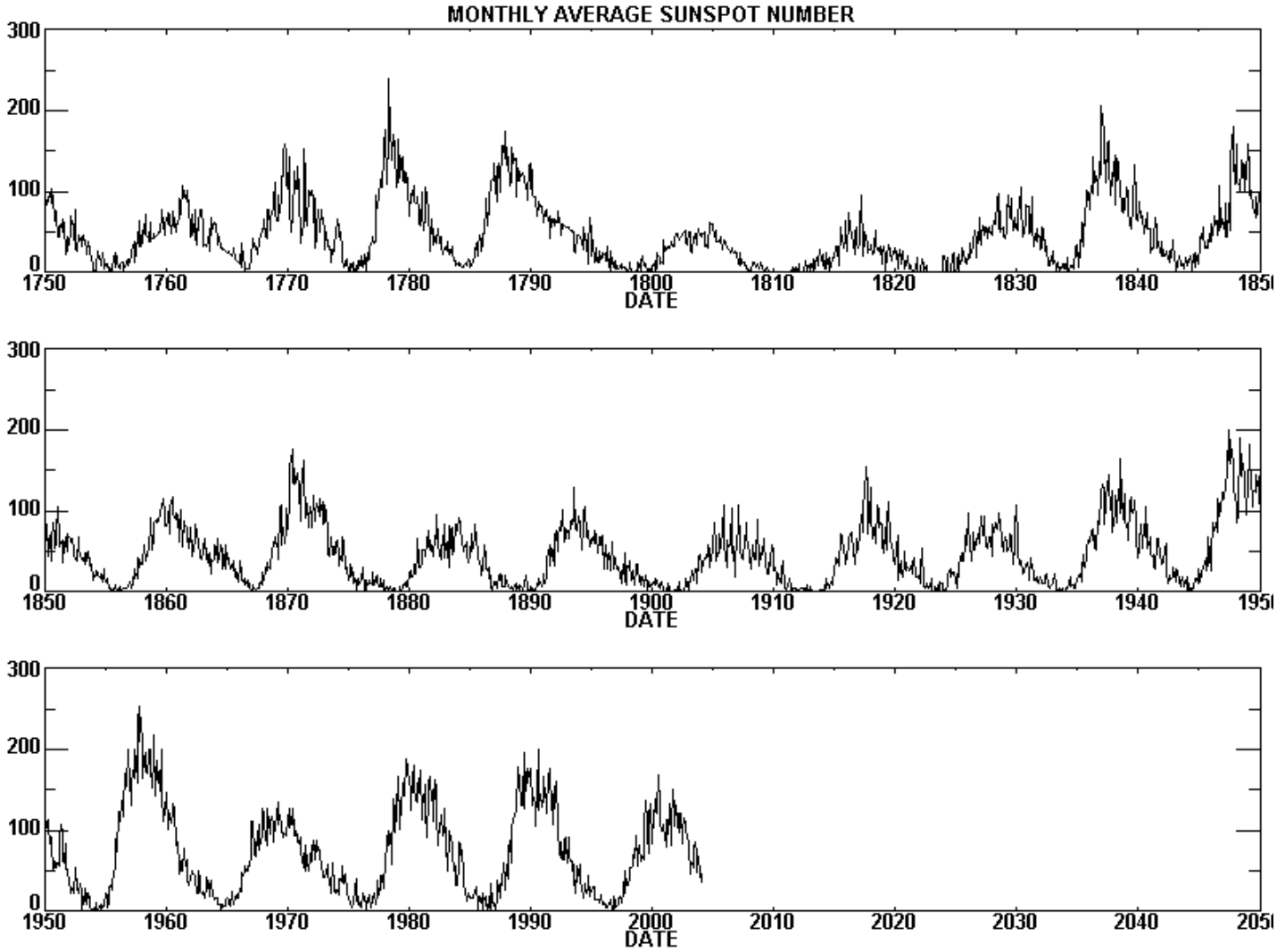
Past 1000 years
- Solar influence is suspected but is not certain.



Past 400 years - Human influence now dominates.



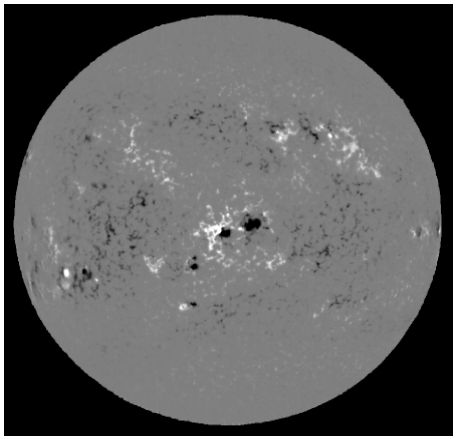
Solar Constant Varies With Sunspot Cycle



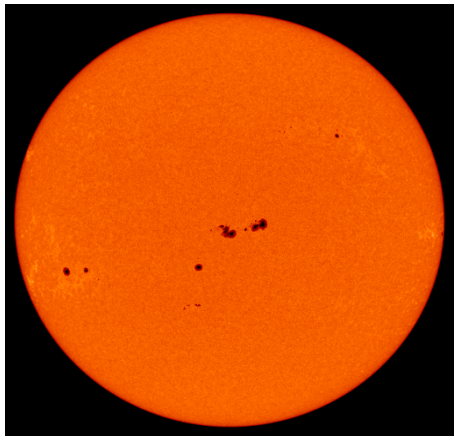
The solar magnetic activity is cyclical.

The Magnetic Sun

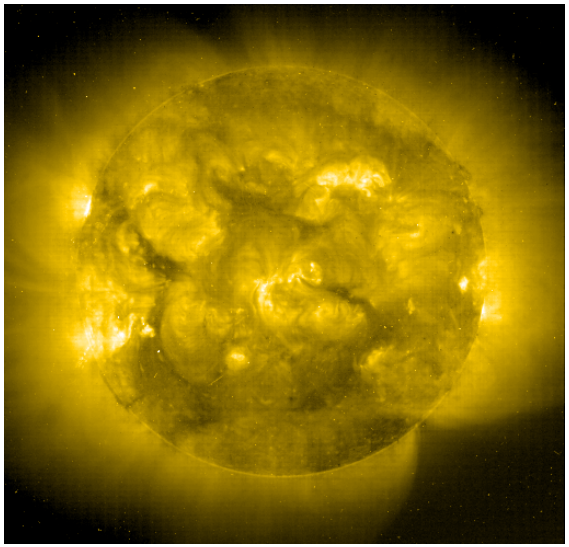
- The variations of the Sun are due to magnetic fields generated inside the Sun which then emerge at the solar surface:



Magnetic fields

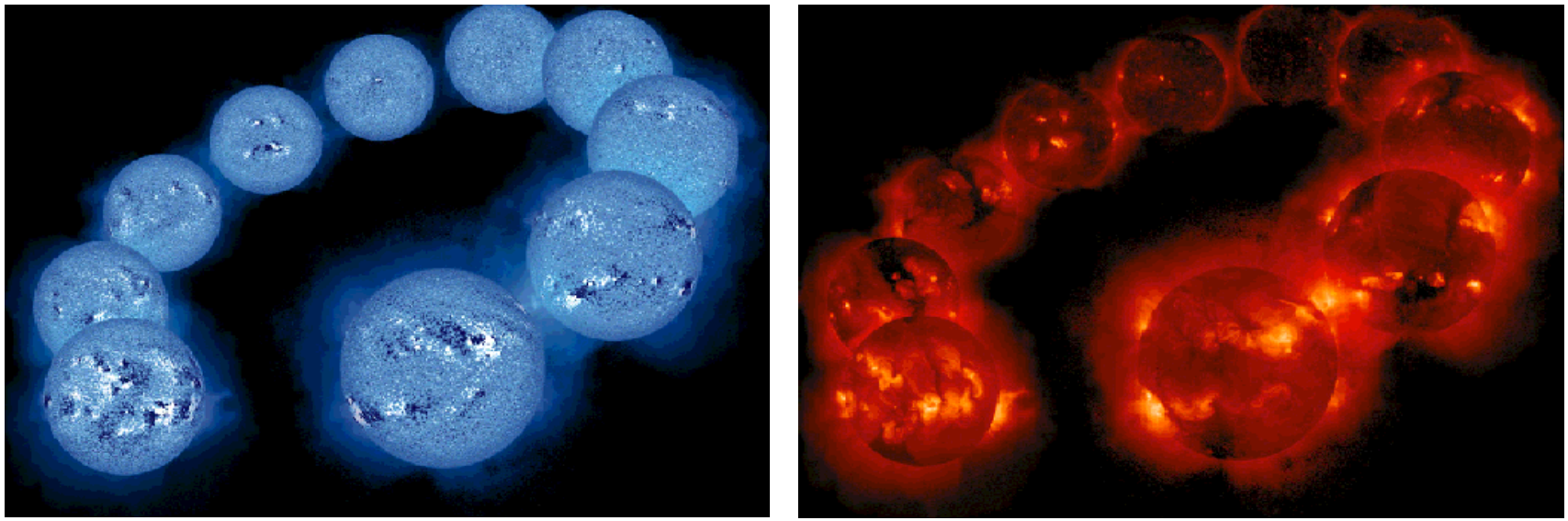


Sunspots in visible light



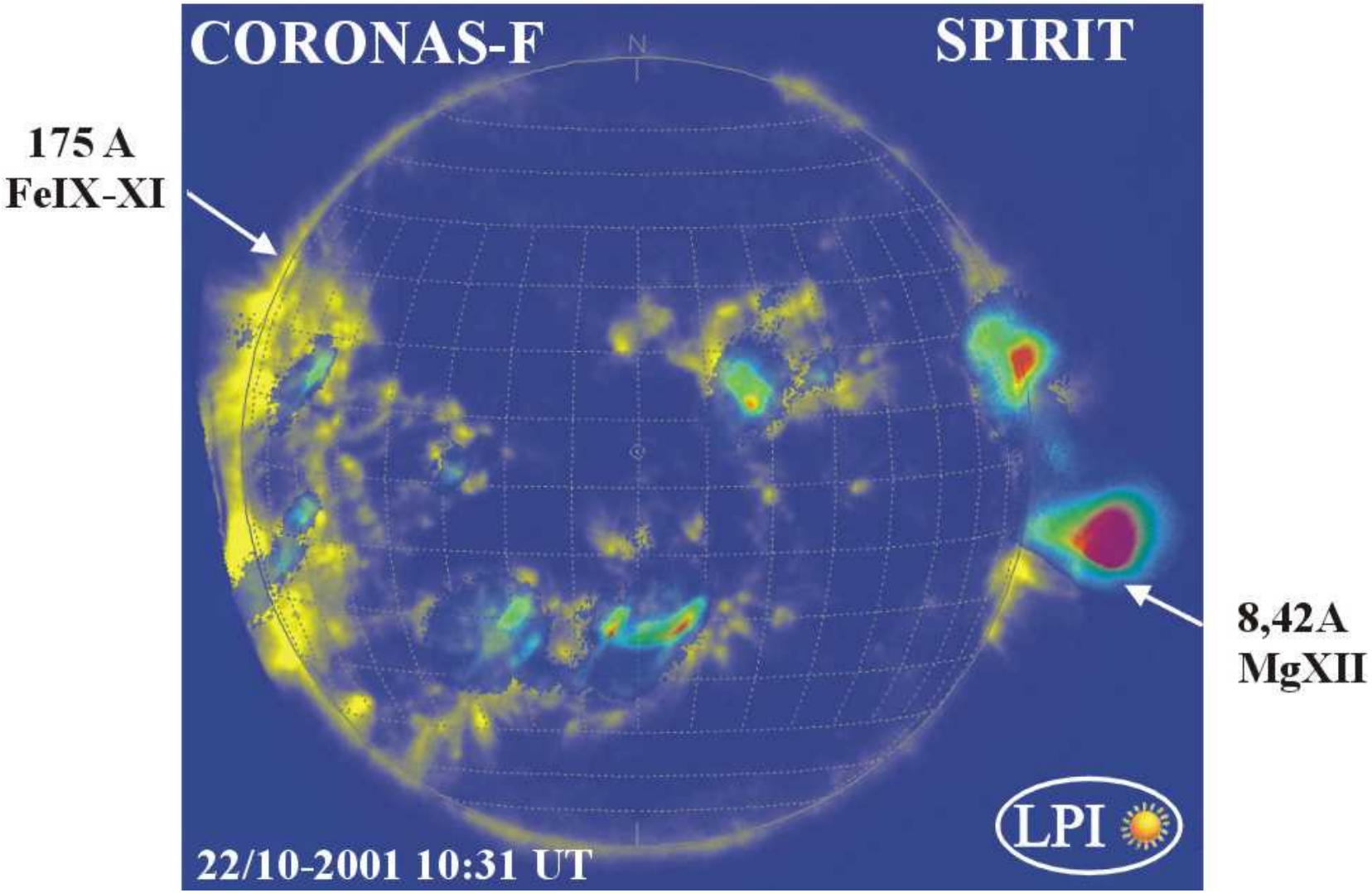
The X-ray corona

The Sun's Magnetic Cycle



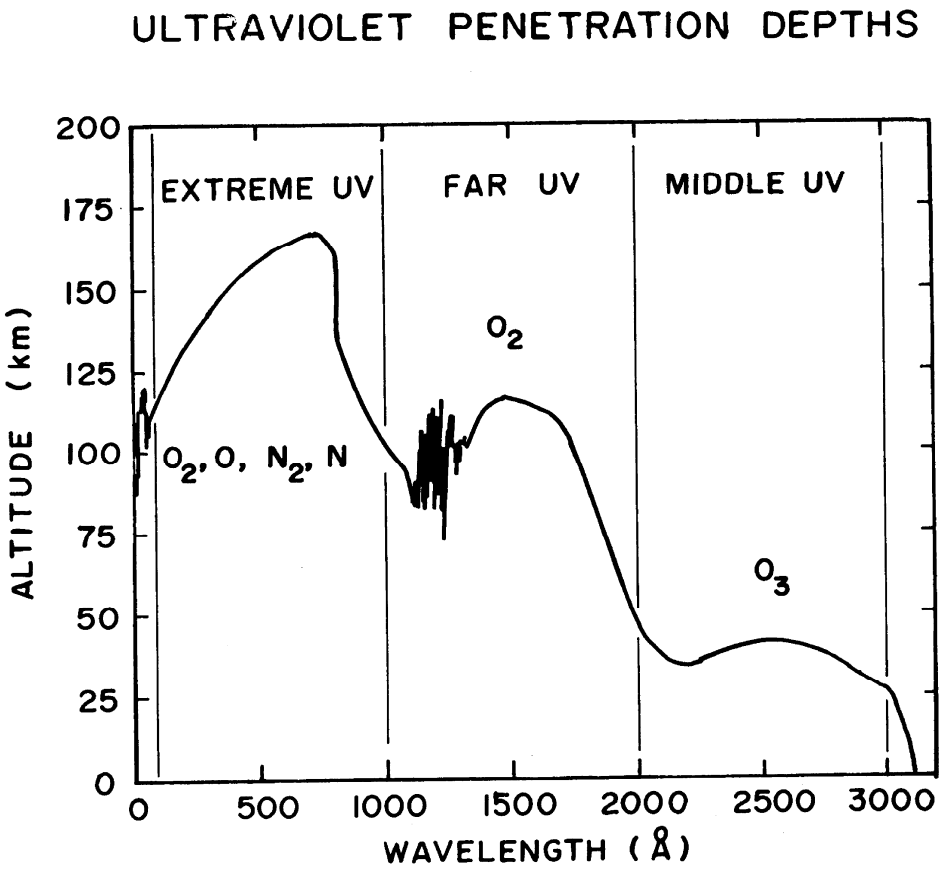
A decade of solar magnetic variability.

Superposition of full Sun images in 10 MK band (MgXII 8.42 A) and in 1.6 MK band (FeIX-XI, 175 A)



Corona is hot and dynamic in magnetic regions.

Why We Observe From Space

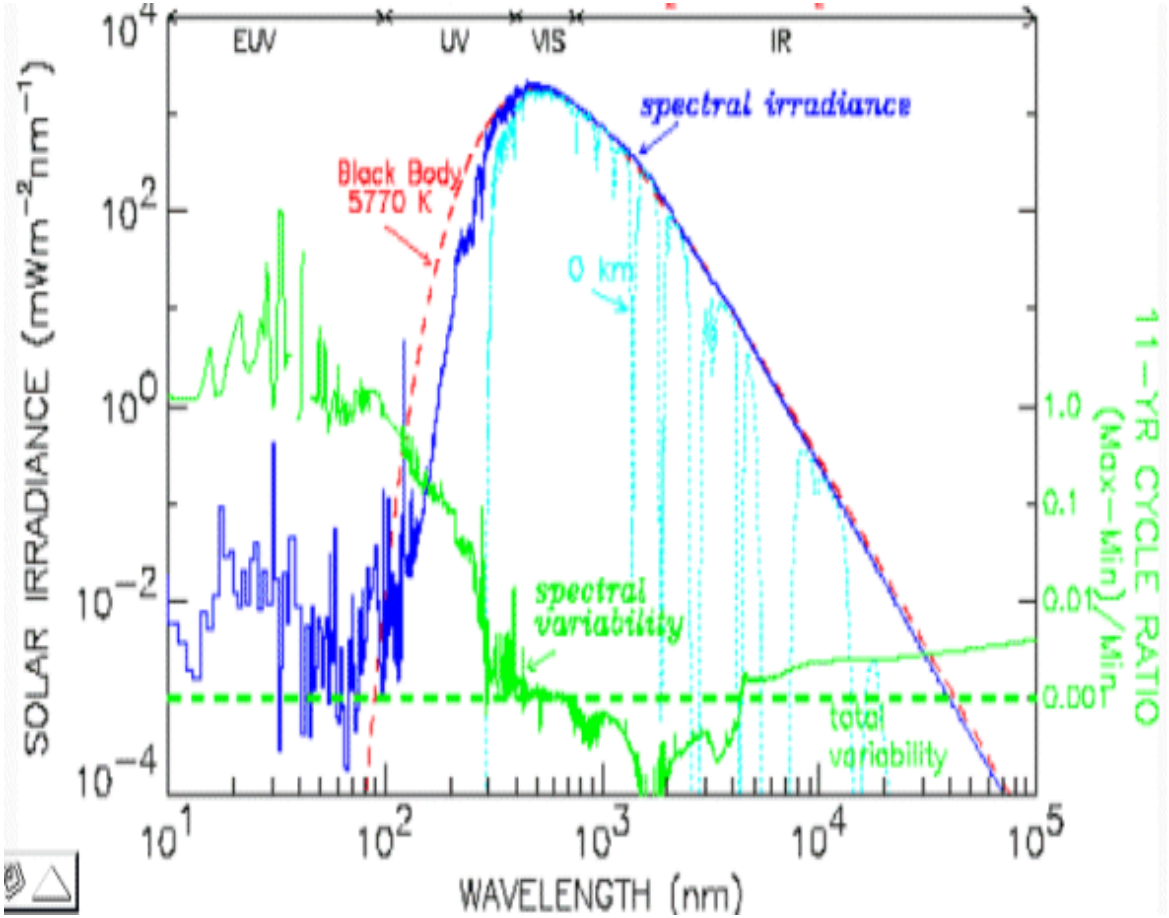


Wavelengths shorter than 3000Å do not reach ground Level. They do not even reach down to mountain top observatories.

The X-ray corona and its activity cannot be seen from ground-based observatories.

Ground level

The Solar Spectrum and Solar Variability



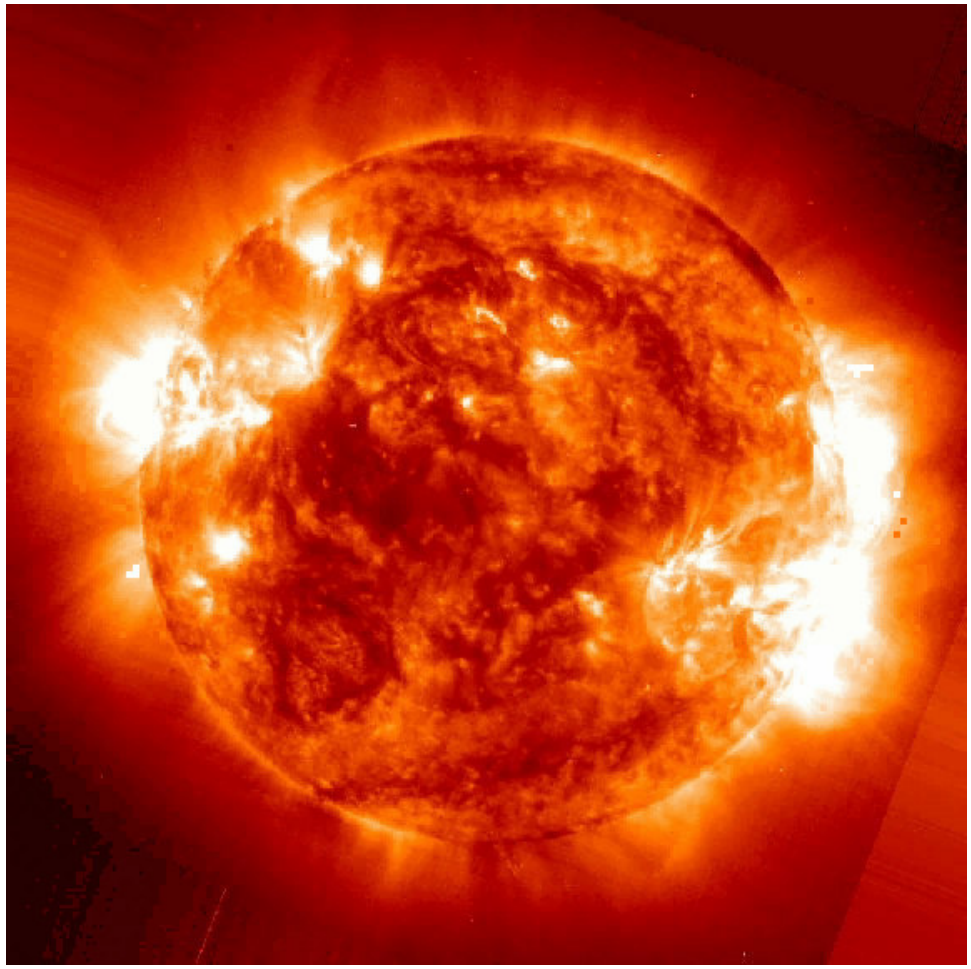
Courtesy Judith Lean NRL

The **spectrum** of solar radiation, its **variability** between Solar Maximum and Solar Minimum (green) and the relative **transparency** of Earth's atmosphere at sea level (light blue).

-- At *short wavelengths* there is a large variation in the Sun's output (greater than 1%), but the Earth's atmosphere is nearly opaque at those wavelengths.

The best wavelengths for seeing solar activity do not reach the ground!

Solar Activity at Extreme Ultraviolet (EUV), UV and Visible wavelengths

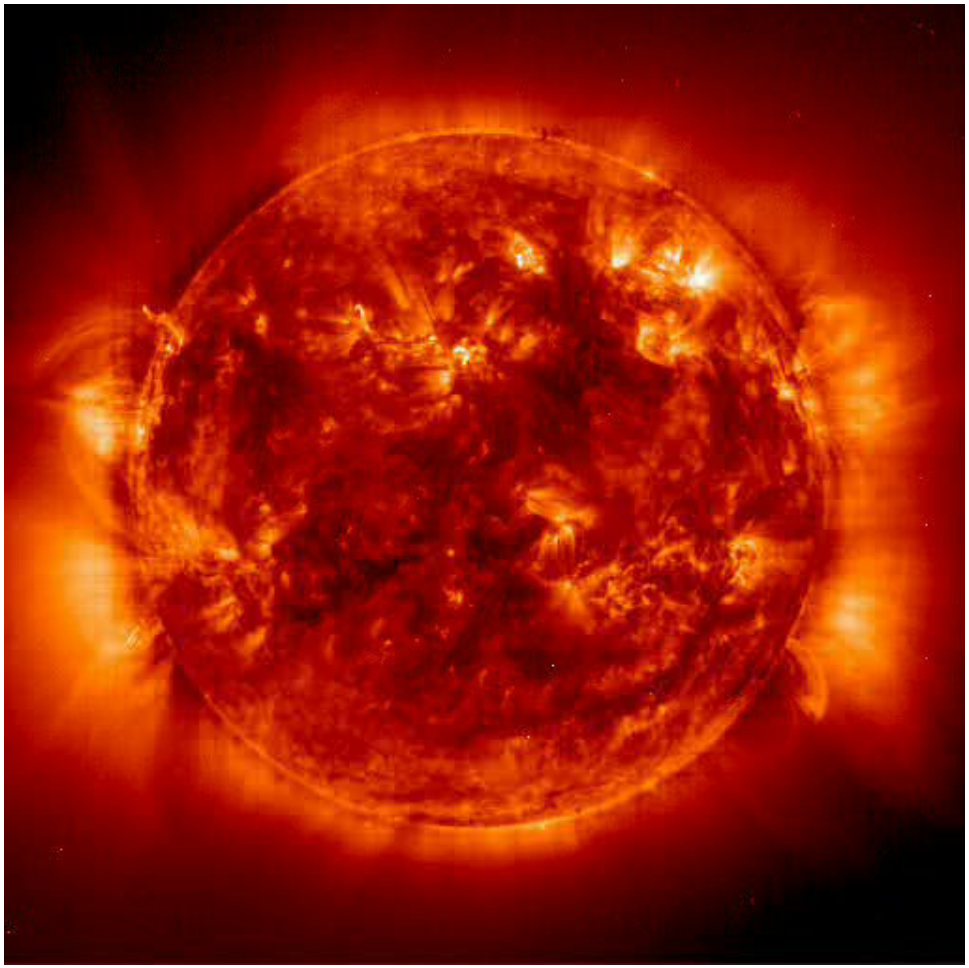


EUV

UV

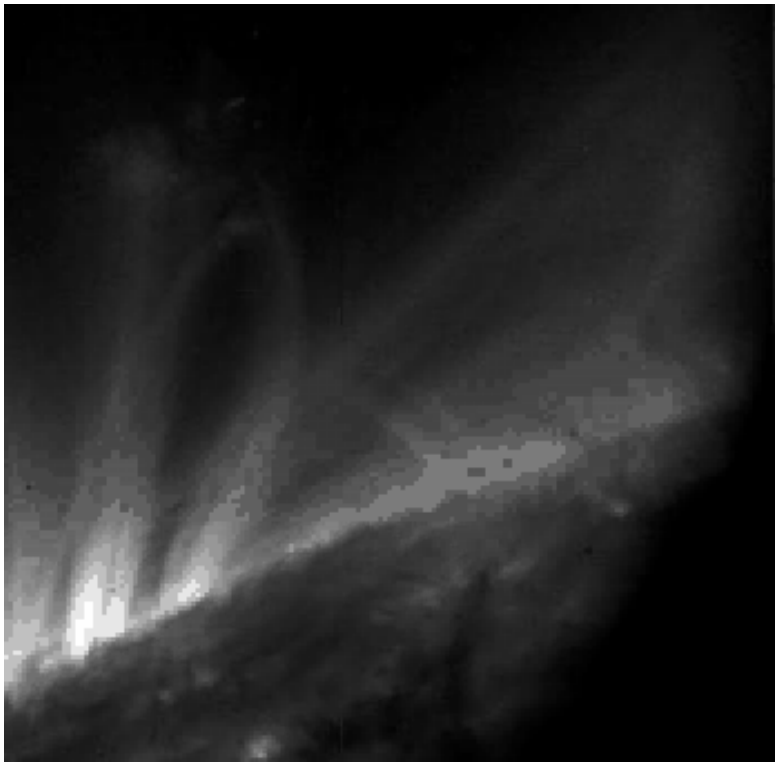
Visible

The Inner Corona is Especially Active and Dynamic

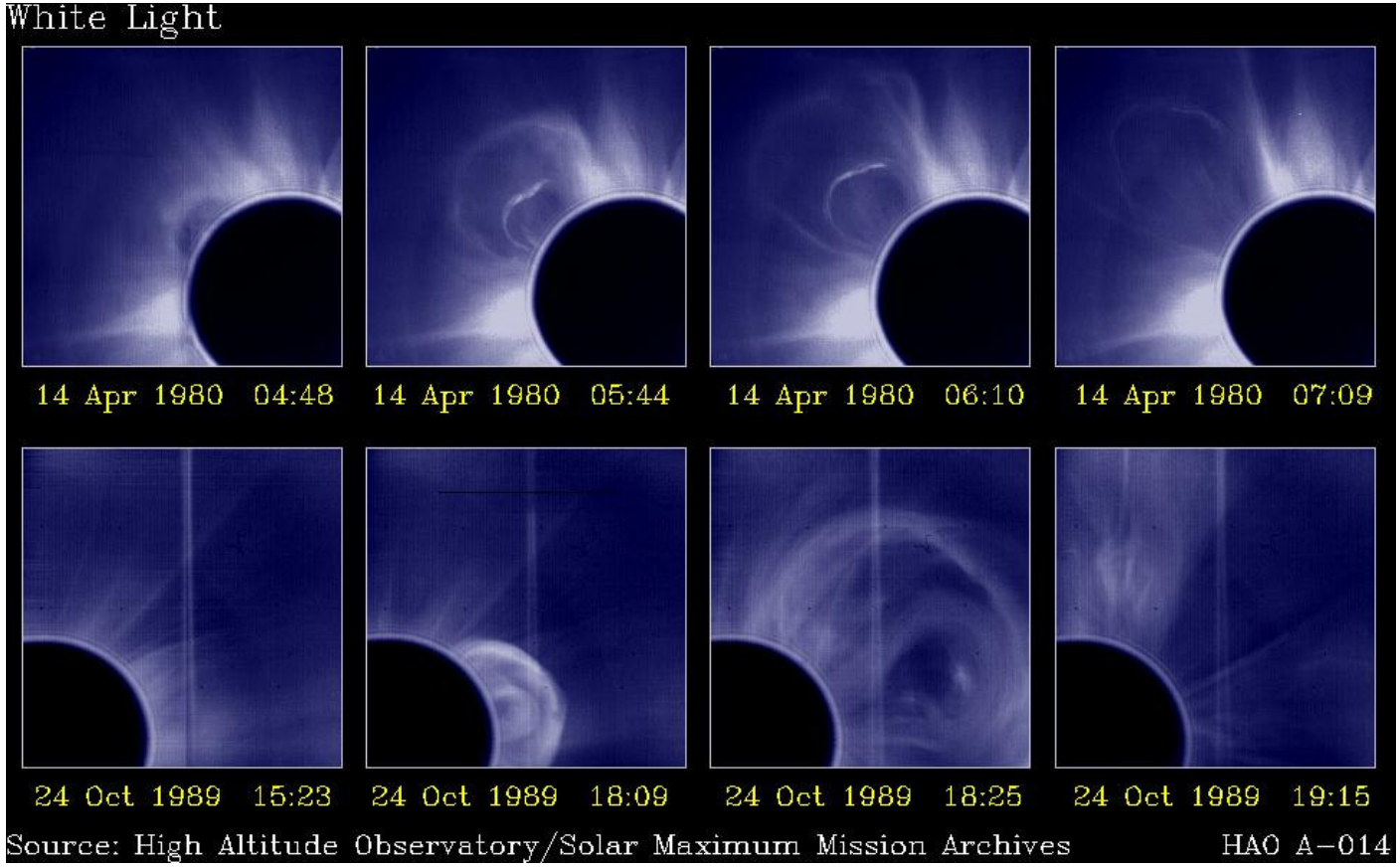


Magnetic Fields and the Solar Corona

- The corona is filled with hot plasma (gas hotter than one million K).
- Plasma follows the direction of the magnetic field in the corona.
- Magnetic fields emerging into the corona produce dramatic changes.

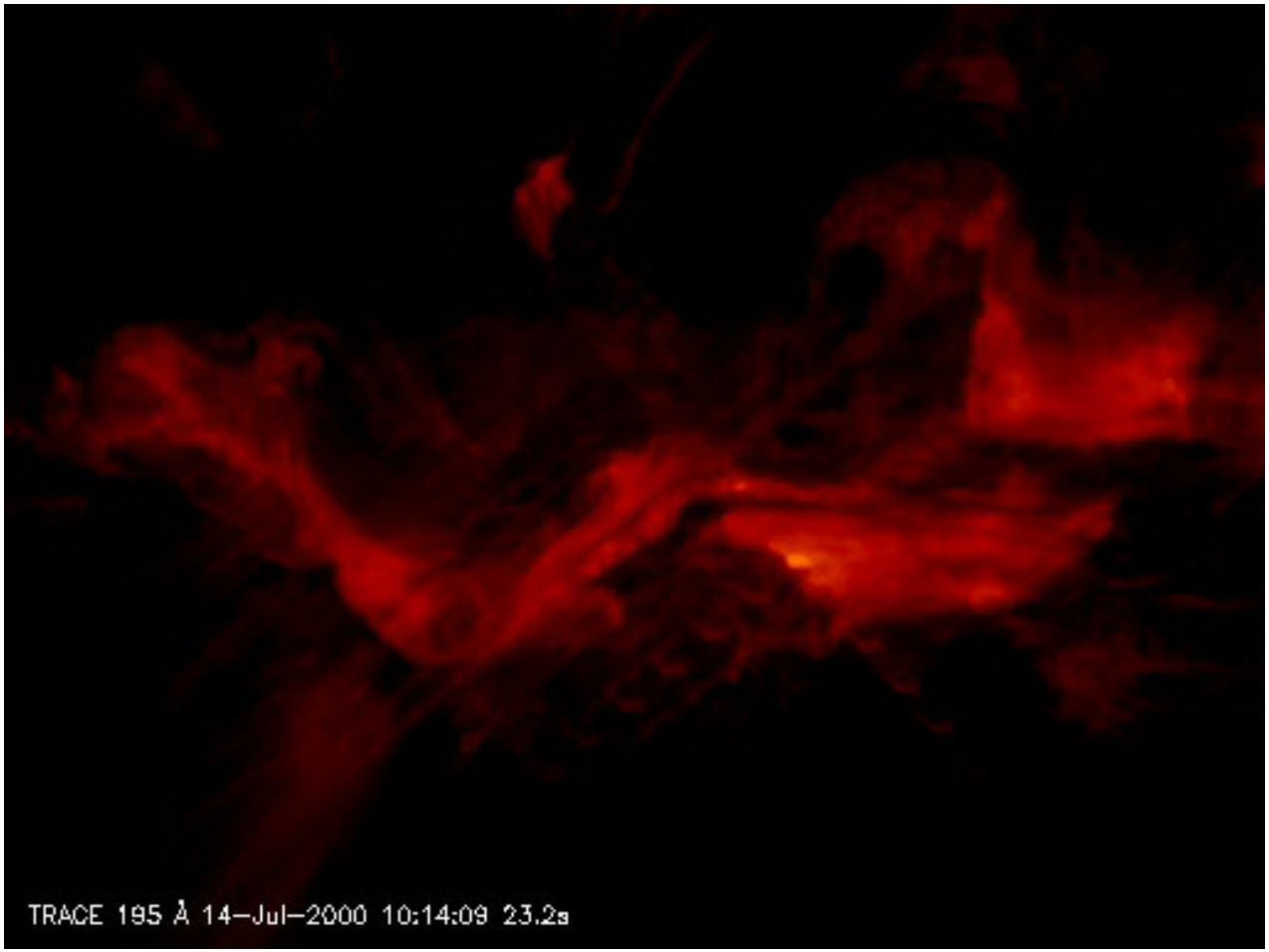


Coronal Mass Ejections (CMEs)

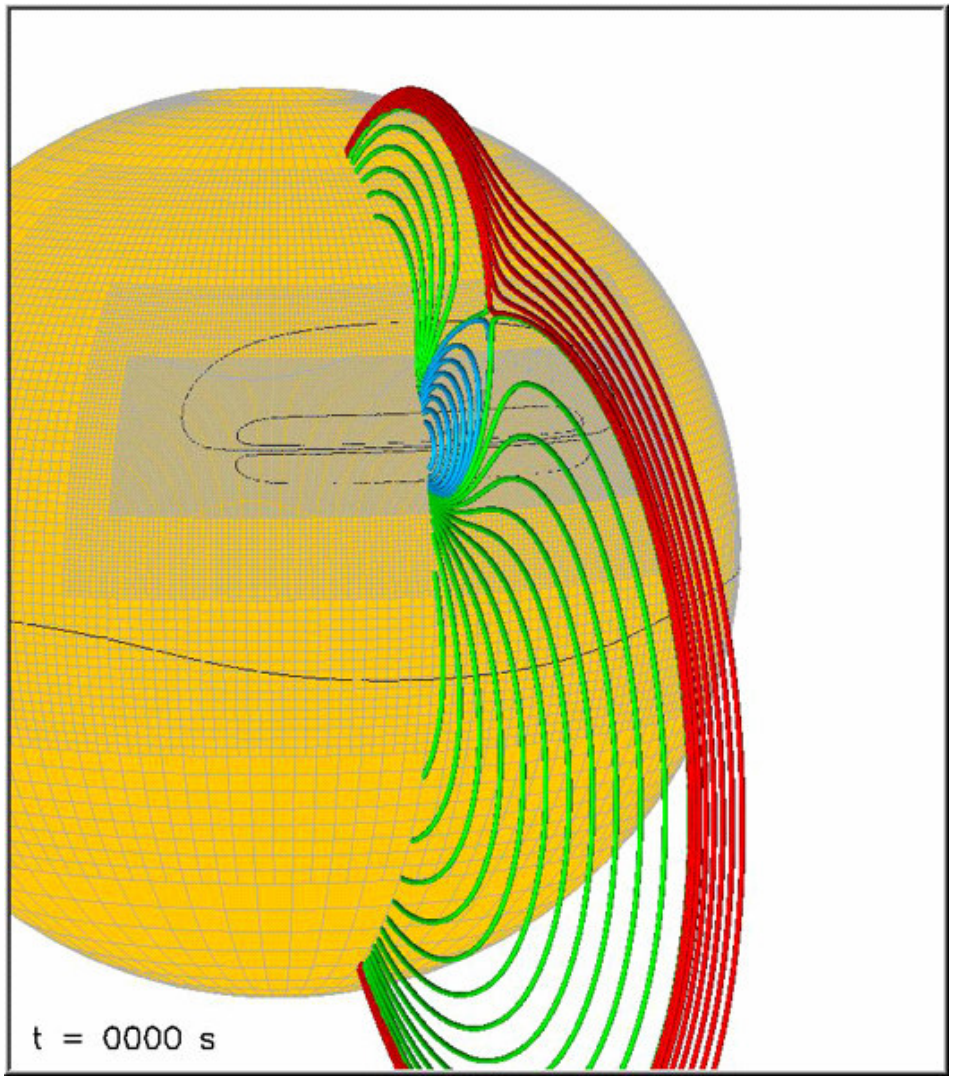


A billion tons of matter ejected at a million miles per hour.

Coronal Mass Ejections Originate in the Solar Corona



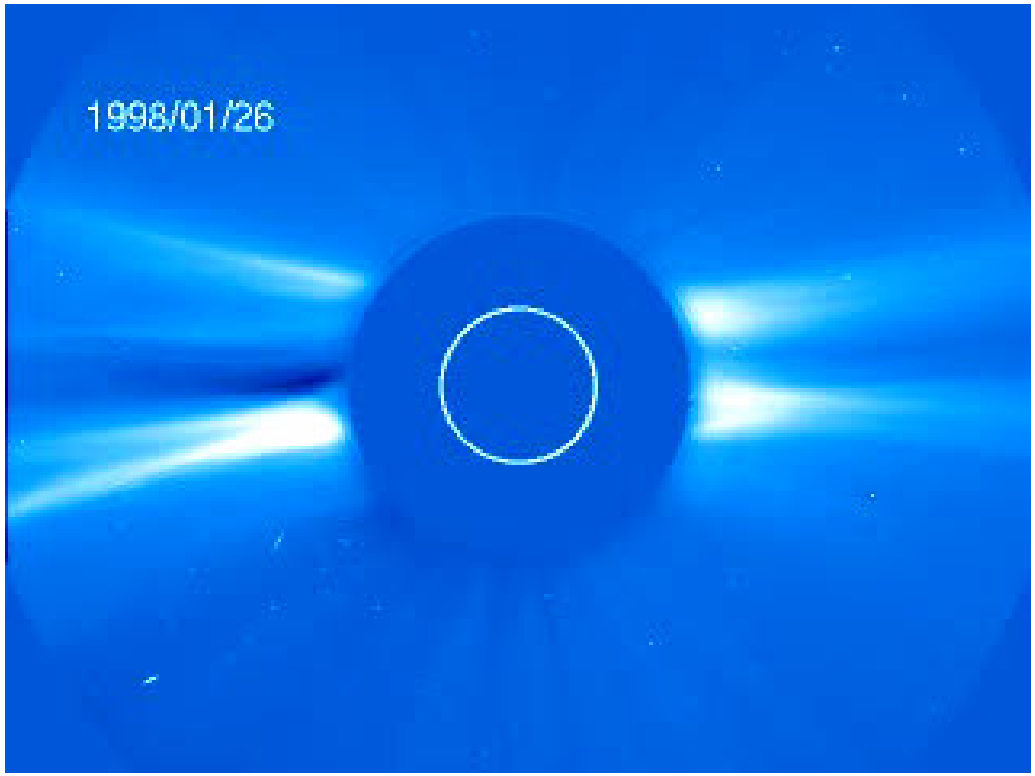
A CME is a magnetic event



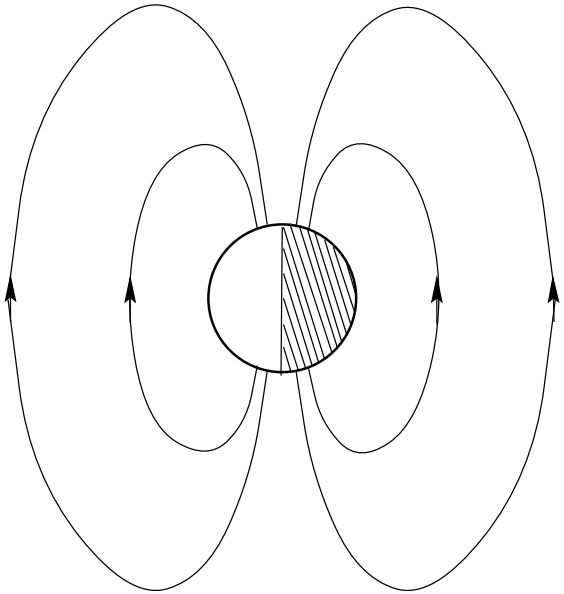
Energy is released by a geometrical rearrangement of the magnetic field

The Expanding Corona

The solar corona is constantly expanding outward and is filled with CMEs.

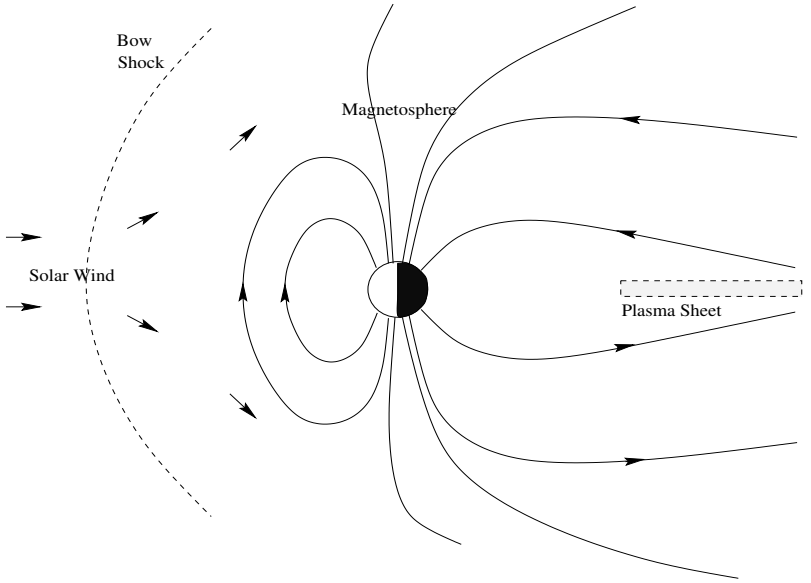


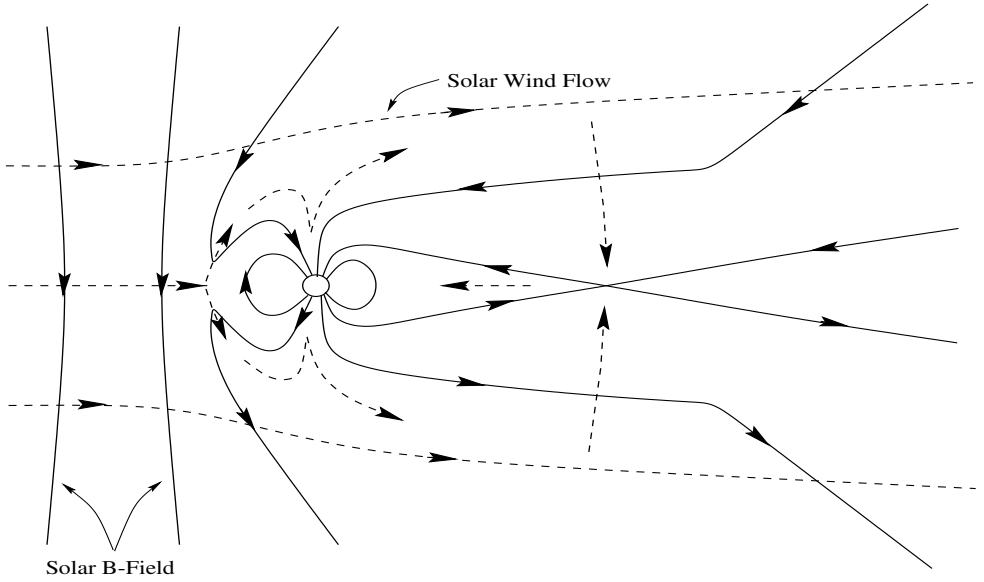
CMEs Interact With Earth's Magnetic Field



1. Undisturbed field

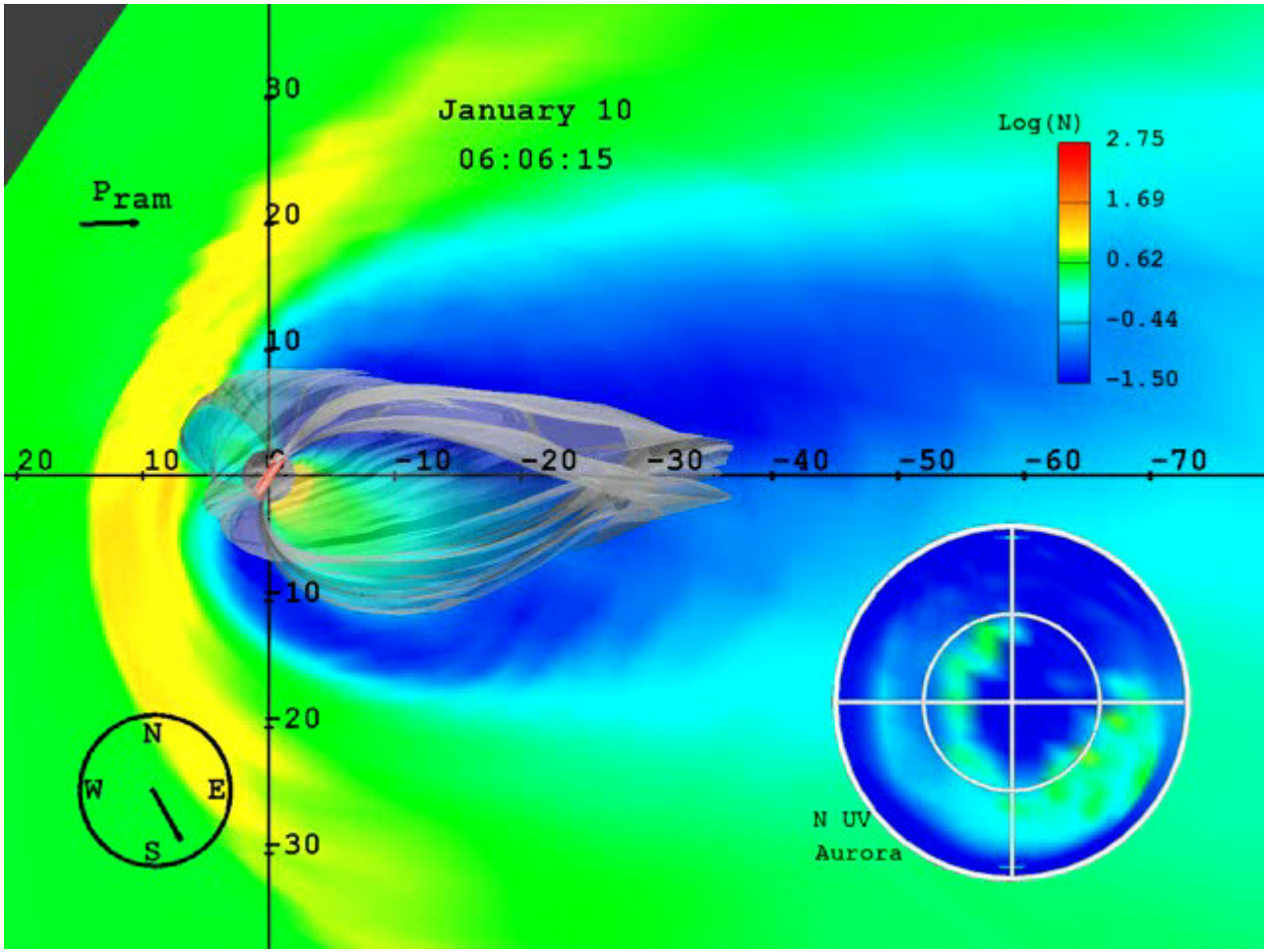
2. Influenced by solar wind

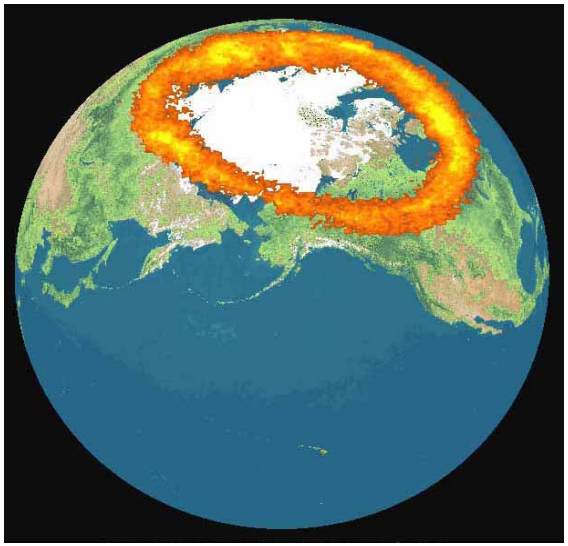




3. Response to Coronal Mass Ejection

… and can dramatically affect the Earth

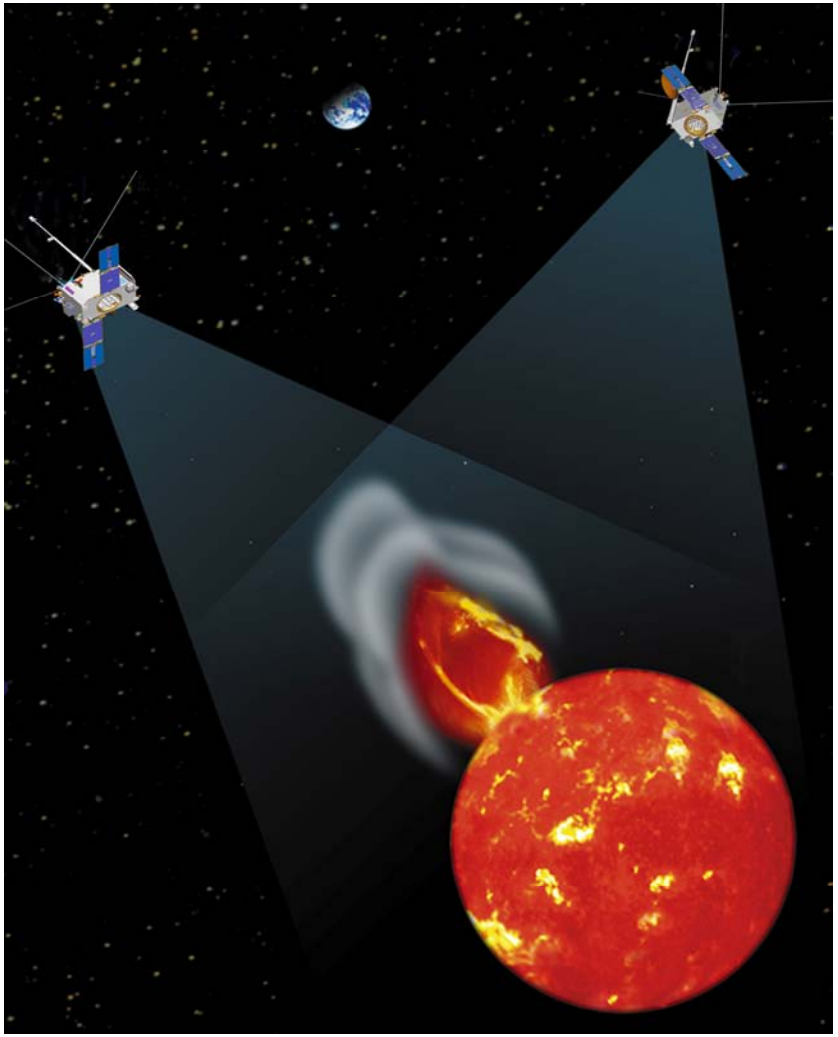




The Next Generation of Space Missions to Study Coronal Activity

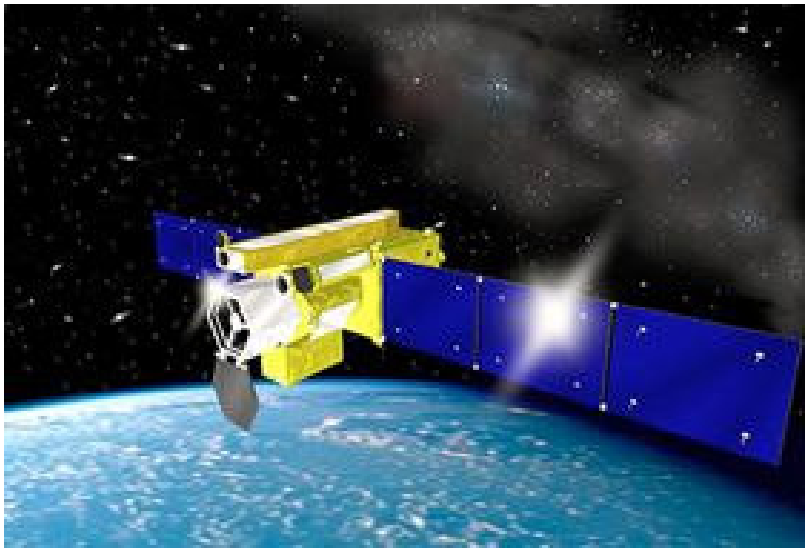
- STEREO
  - Launch mid-2006
- Solar-B
  - Launch late 2006
- SDO
  - Launch mid-2008

STEREO



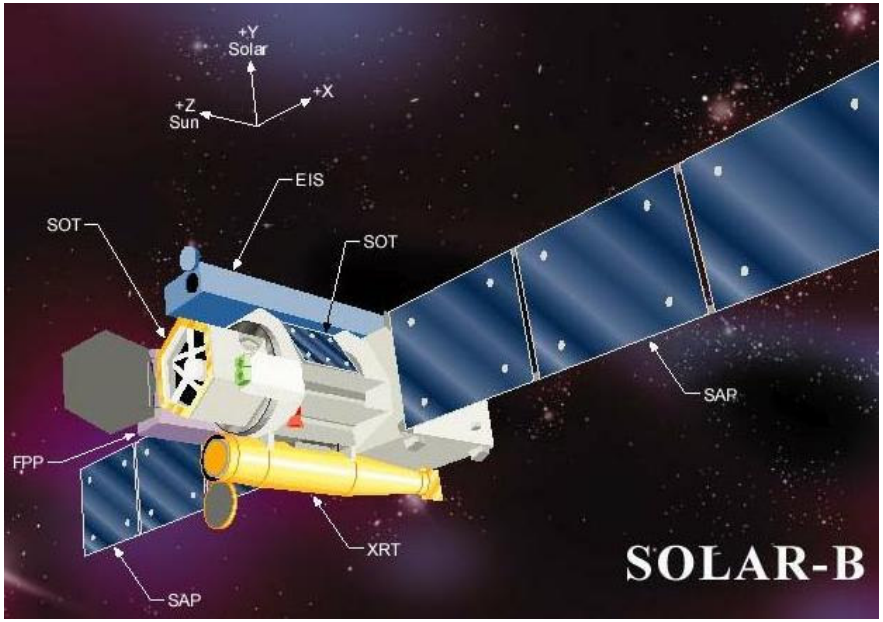
- Two nearly identical satellites - one ahead of Earth in its orbit, the other trailing behind - provide first-ever stereoscopic views of coronal mass ejections, or CMEs.
- Total of 16 instruments per observatory.
- Four instrument packages are mounted on each of the two STEREO spacecraft

Solar-B: The Spacecraft

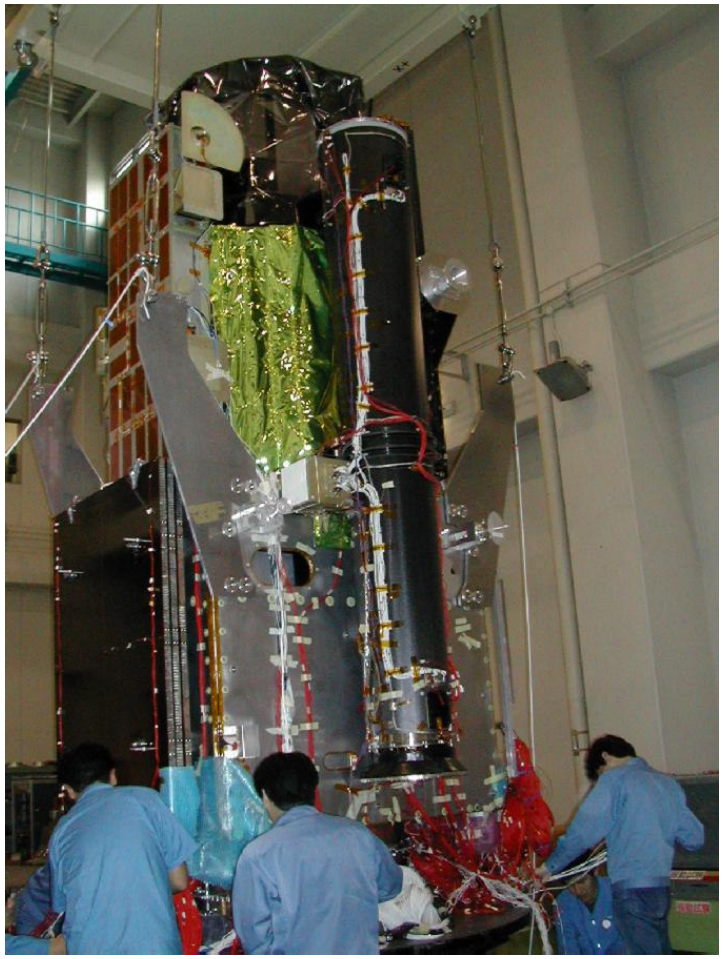


- Mass: 875 kg
- Power: 1000W
- Telemetry: 4Mbps
- Data Recorder: 3Gbit
- Attitude: Solar pointed
- Stability: 0.3 arcsec over 1s
- Launch: Summer 2006
- Orbit: Polar, Sun Syn, 600km

Solar-B: The Instruments



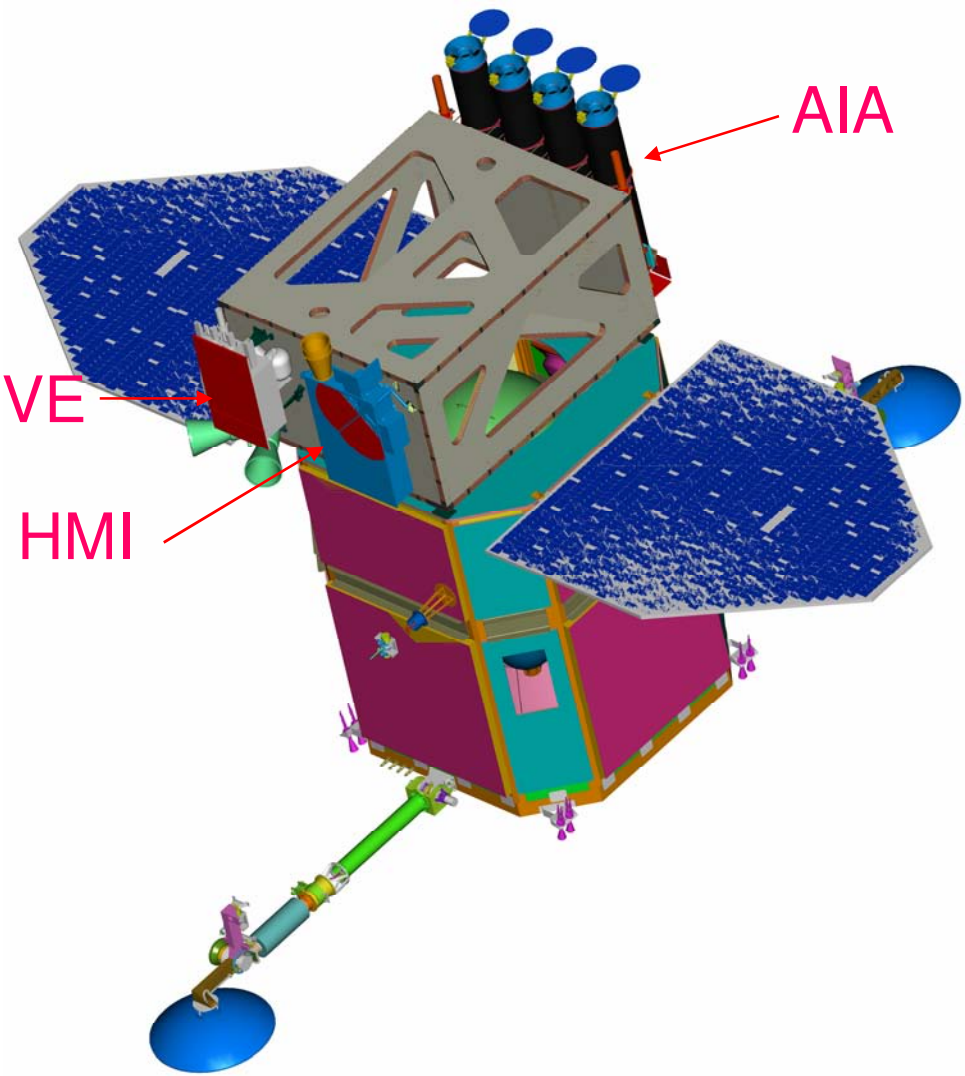
Optical telescope: SOT/FPP
Spectrometer: EIS
Xray Corona: XRT



The Real Thing

Solar-B Launch: Late 2006

Next Mission: SDO

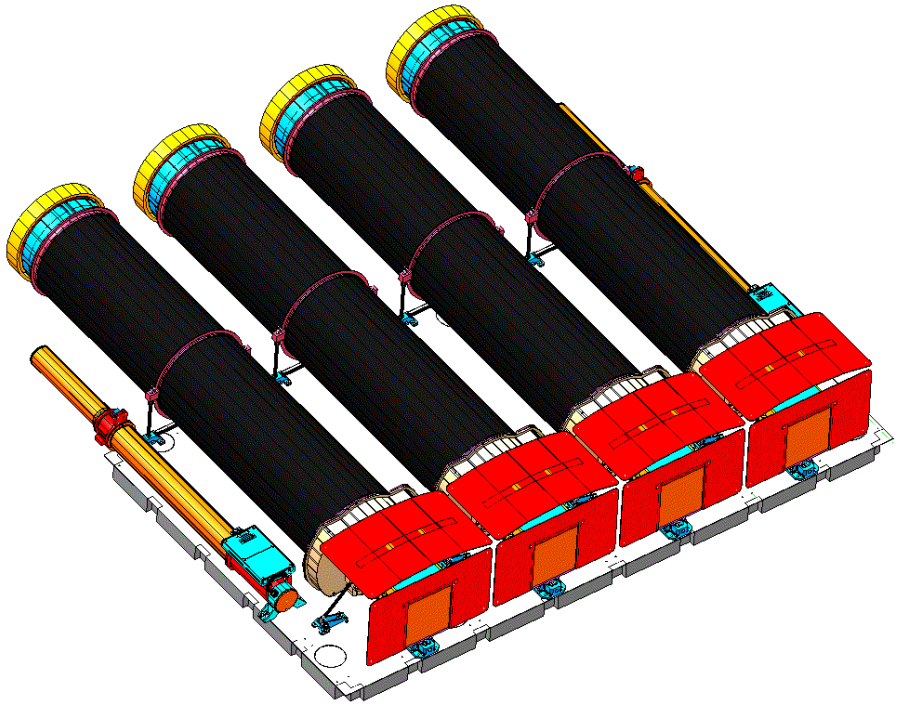


PI Institution for HMI/AIA is Lockheed Martin

AIA Description

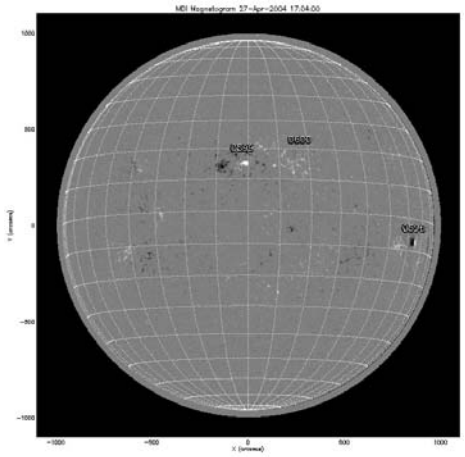
AIA is an array of EUV and UV solar telescopes that will observe the full solar disk and lower solar atmosphere with high resolution (4k x 4k) CCD detectors providing 8 images each 10 seconds

AIA is an evolution of TRACE. It images the entire Sun with 0.6 arc second pixels. As part of the Solar Dynamics Observatory it will observe continuously at ~60Mbps data rate.

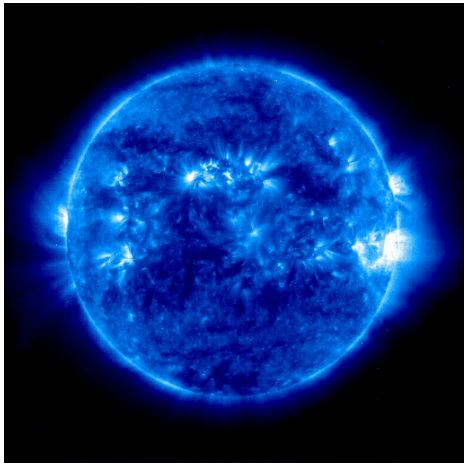


The Multithermal Corona

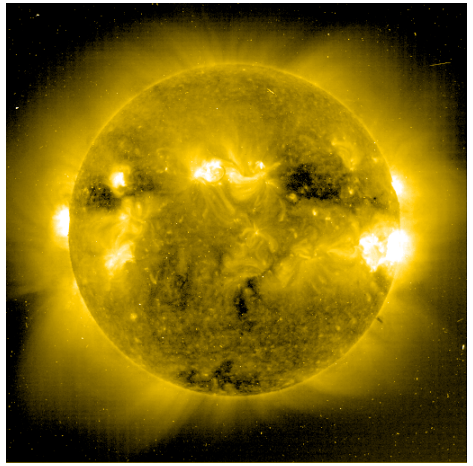
SDO observes B-field, UV and 7 EUV passbands



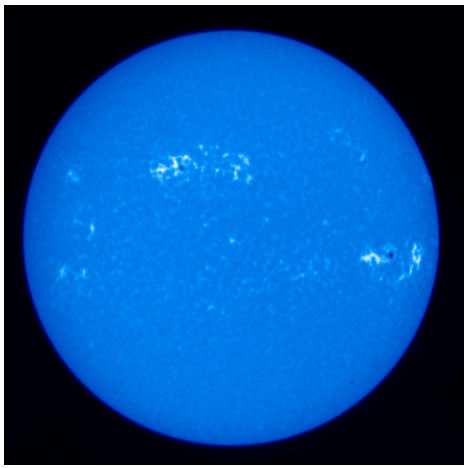
B-field



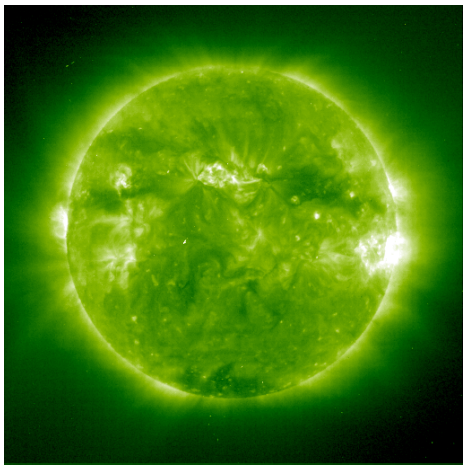
Fe IX/X



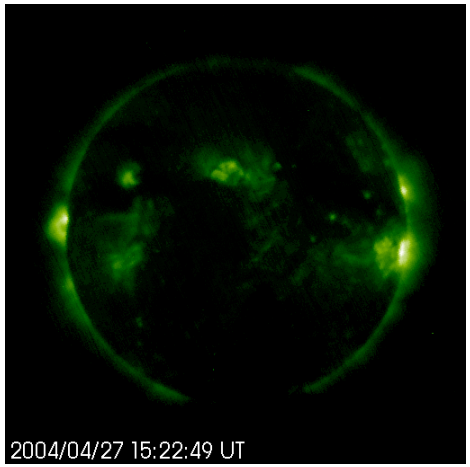
Fe XV



Ca II

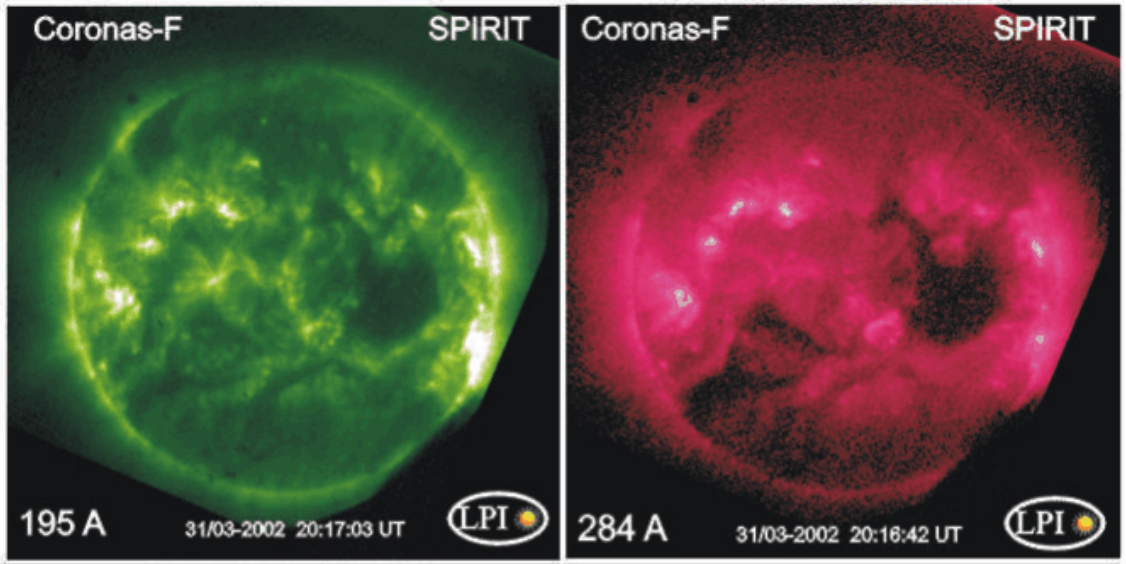


Fe XII



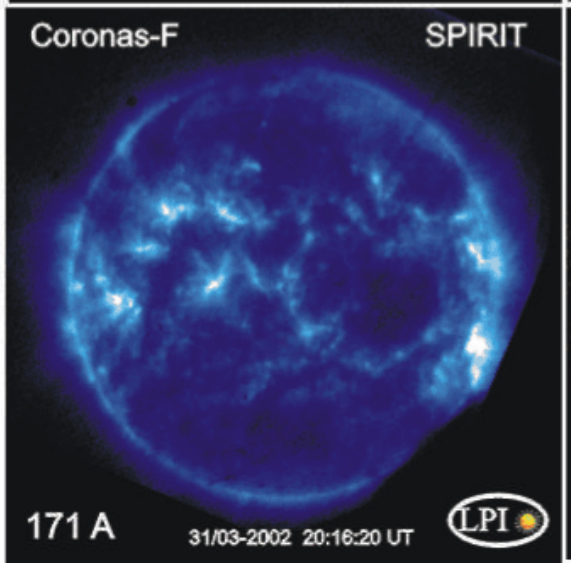
SXR

XUV solar images in 171, 195, 284 and 304 A spectral bands of the SPIRIT Ritchey-Chretien telescope

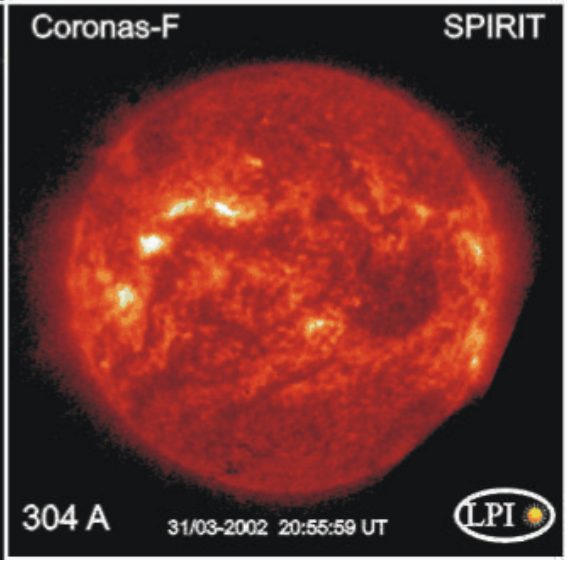


1,6 MK

2 MK

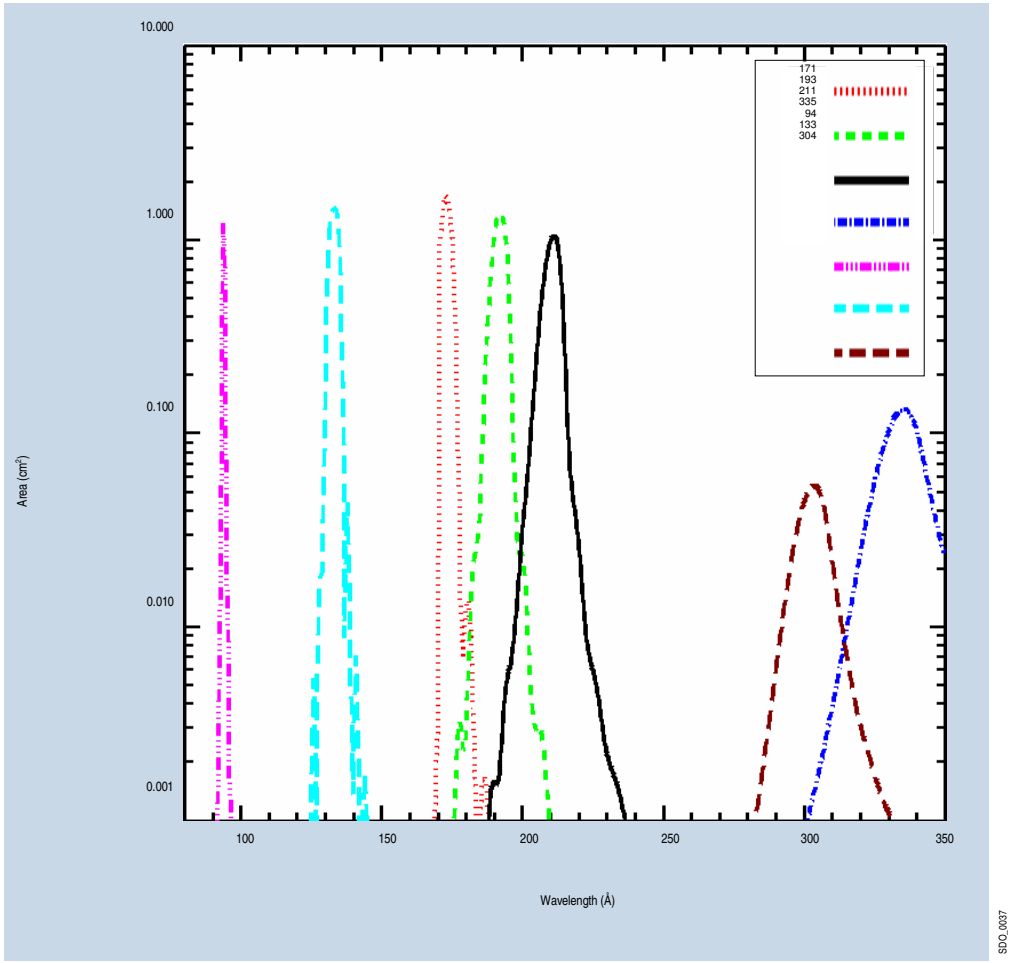


1,3 MK

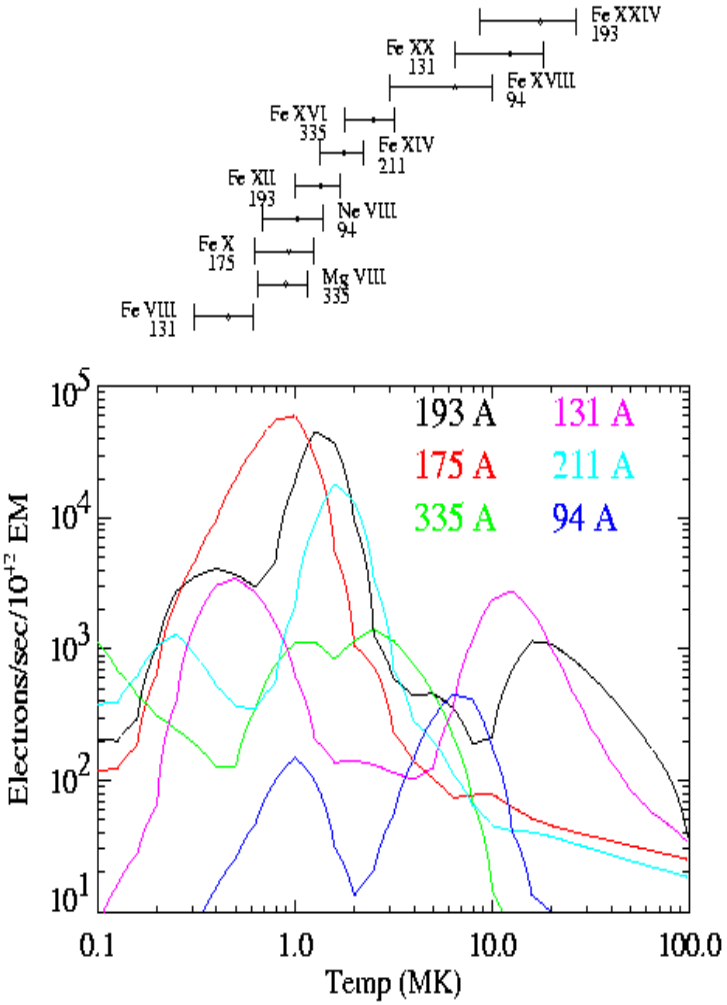


0,05 MK

AIA Spectral Characteristics



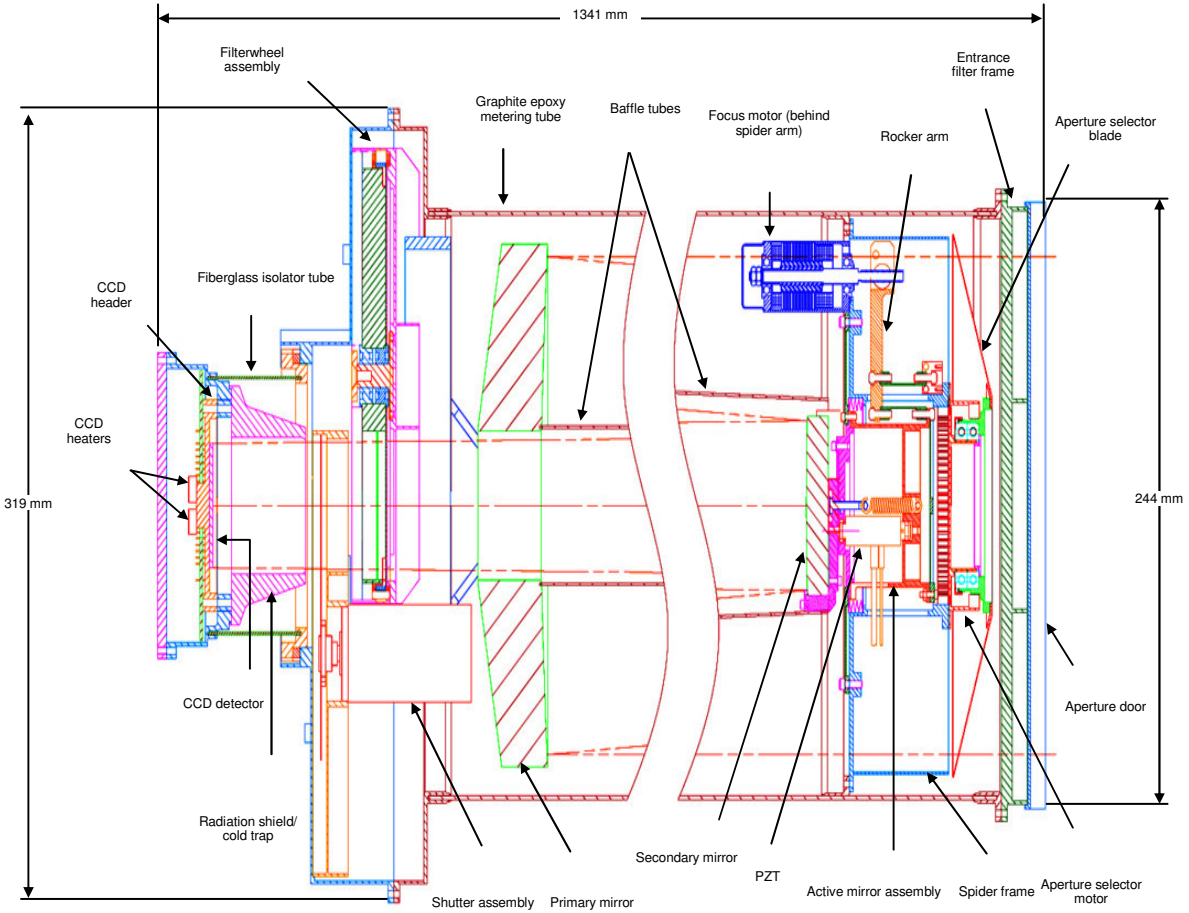
The AIA wavelength channels



The AIA temperature response functions

Telescope Details

Temperature range	7 EUV+2 UV+1 vis. Channels covering 5,000 K-20 MK
Time cadence	10 sec in 8 channels
Spatial resolution	1.2 arcsec
Field of view	41 arcmin along detector axes 46 arcmin along detector diagonal
Dynamic range	10^4 within single exposure
Overall length	1.34 m
Mass	72.7 kg (excluding reserve & GT)
Optics	Ritchey-Chrétien
Focal length	4.125 m
Primary mirror diameter	20.5 cm
Mirror coatings	Narrowband multilayers (EUV) Al (UV)
Filters	Thin film Al and Zr (EUV) Coated MgF_2/fused silica (UV)
Detector	Marconi back-thinned CCD 4096×4096 pixels, 0.6 arcsec/pixel
Mechanisms	Filter wheels, shutters, doors, ISS, aperture selector (one telescope)
Particle shielding	Fully baffled



AIA Major Partners

- Smithsonian Astrophysical Observatory
  - Responsible for telescope structure, mirrors with UV & EUV coatings, entrance filters, and door
  - Development of EPO and Science investigation
- e2v in the UK (also on HMI)
  - Development of back thinned 4096 x 4096 CCD detectors
- RAL in the UK (also on HMI)
  - Development of CCD Camera electronics

SDO Launch: 2008

Is There A Future For Space Research?

- Technological societies are vulnerable to solar disturbances.
- Astronauts in space can be harmed by solar events (radiation, high energy particles).
- Earth's climate variability may be influenced by changes in the Sun.
- Progress in astrophysics depends on understanding solar variability.

Yes, there is no turning back!