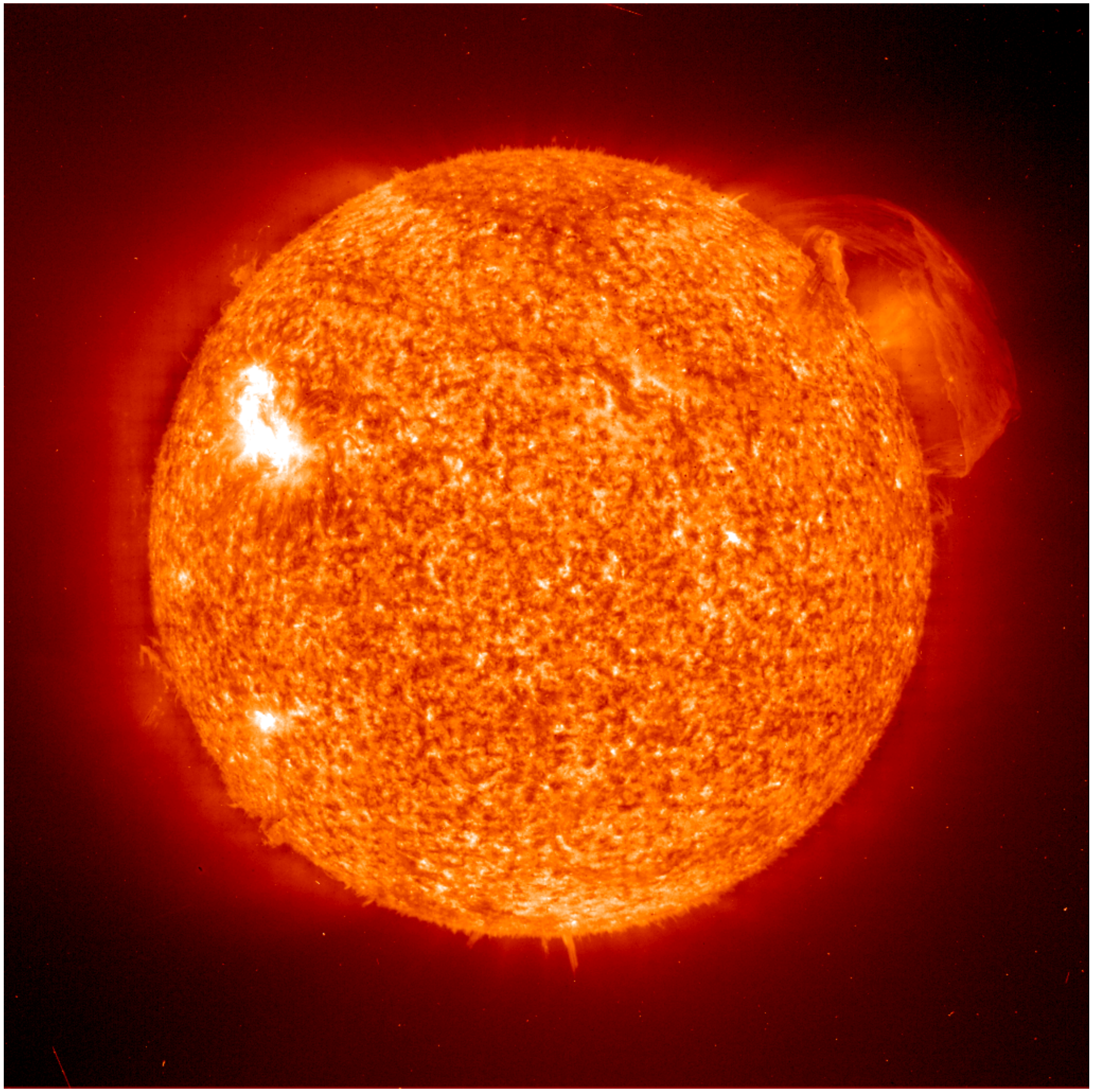
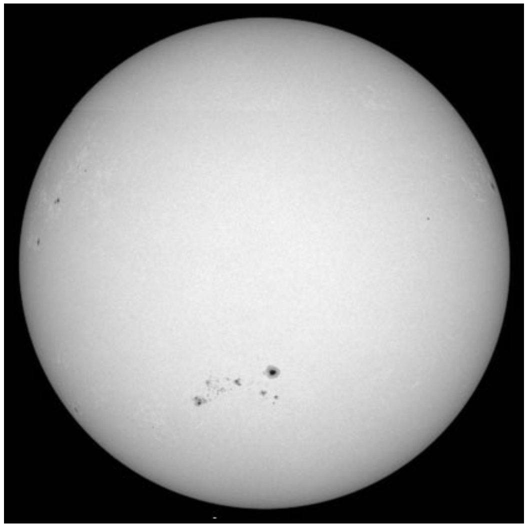
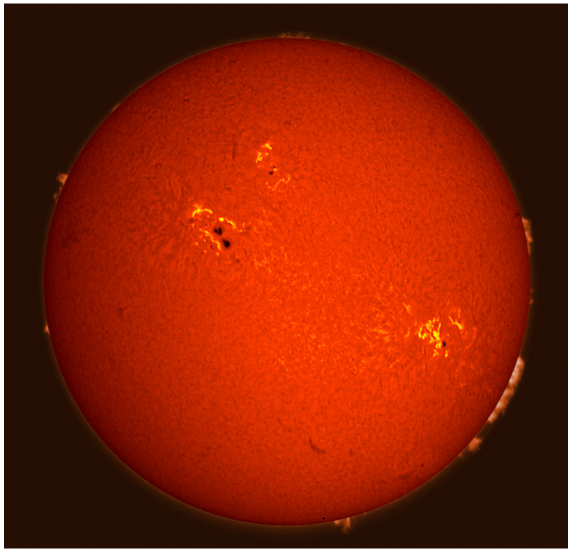
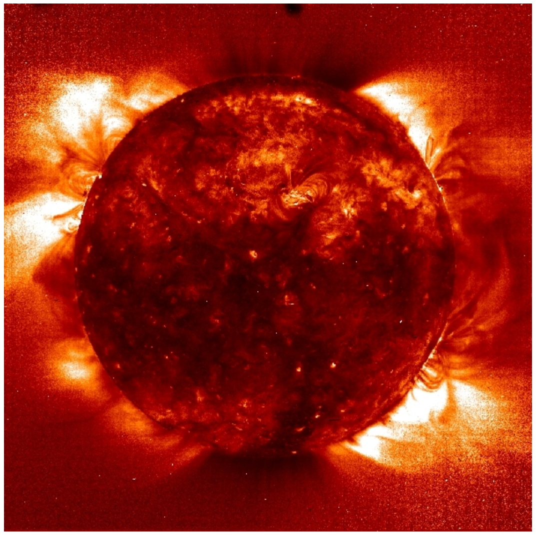
The Solar Atmosphere



Remote Sensing of Solar Atmosphere

- Solar images from SOHO satellite found at

http://sohowww.nascom.nasa.gov/gallery/

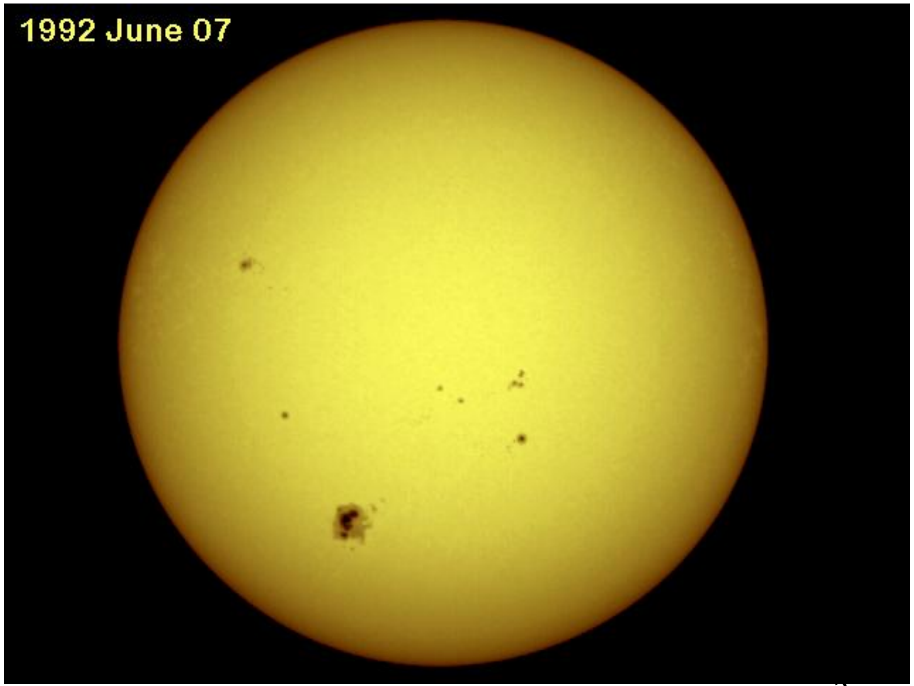
The Solar Atmosphere:

The base of the solar atmosphere is called the 'Photosphere' because this is where nearly all the light energy comes from.

• **Photosphere:** The photosphere is really just the visible 'surface' of the sun. It is the thin (~300 km thick) altitude range where convective cells break and the Sun's blackbody radiation is emitted.

• It's 6000K, and produces the bulk of the light from the Sun.

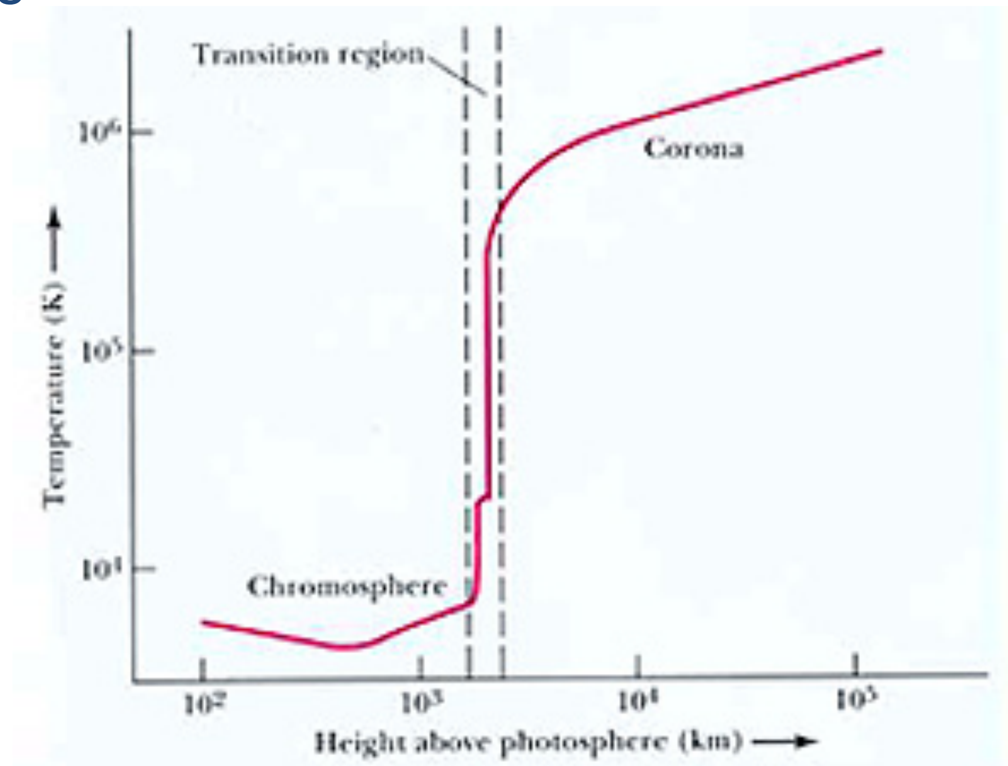
Sharp edge is an illusion. Negative hydrogen ions (H with an extra electron) here absorb all light from below and re-emit it.



The Chromosphere:

• **Chromosphere:** The chromosphere is a diffuse region from 300 to 10,000 km above the photosphere.

• Most of the chromosphere is hotter than the photosphere and reaches up to 20,000K.



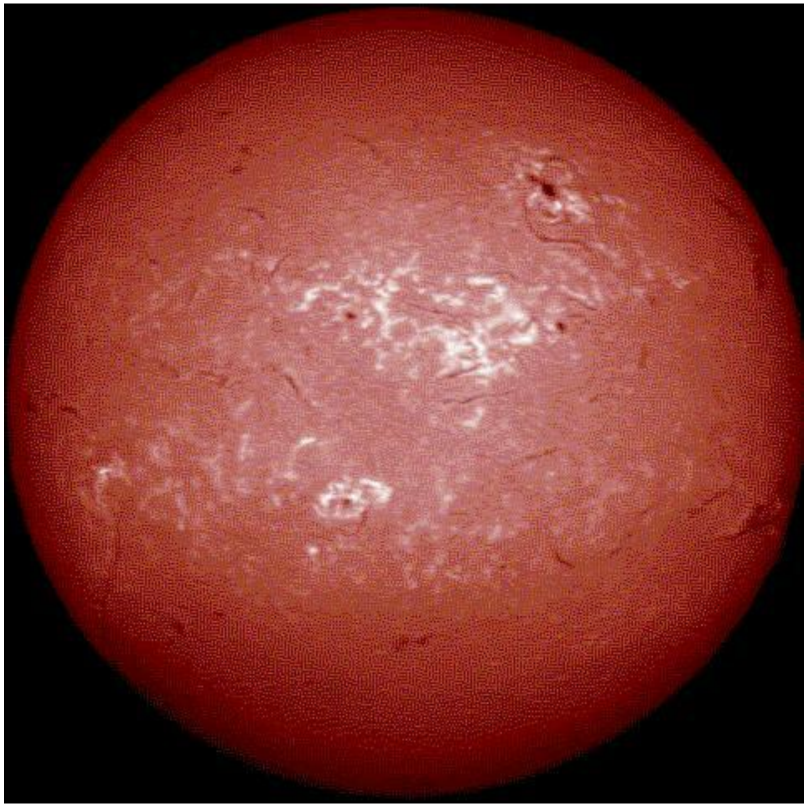
The Chromosphere:

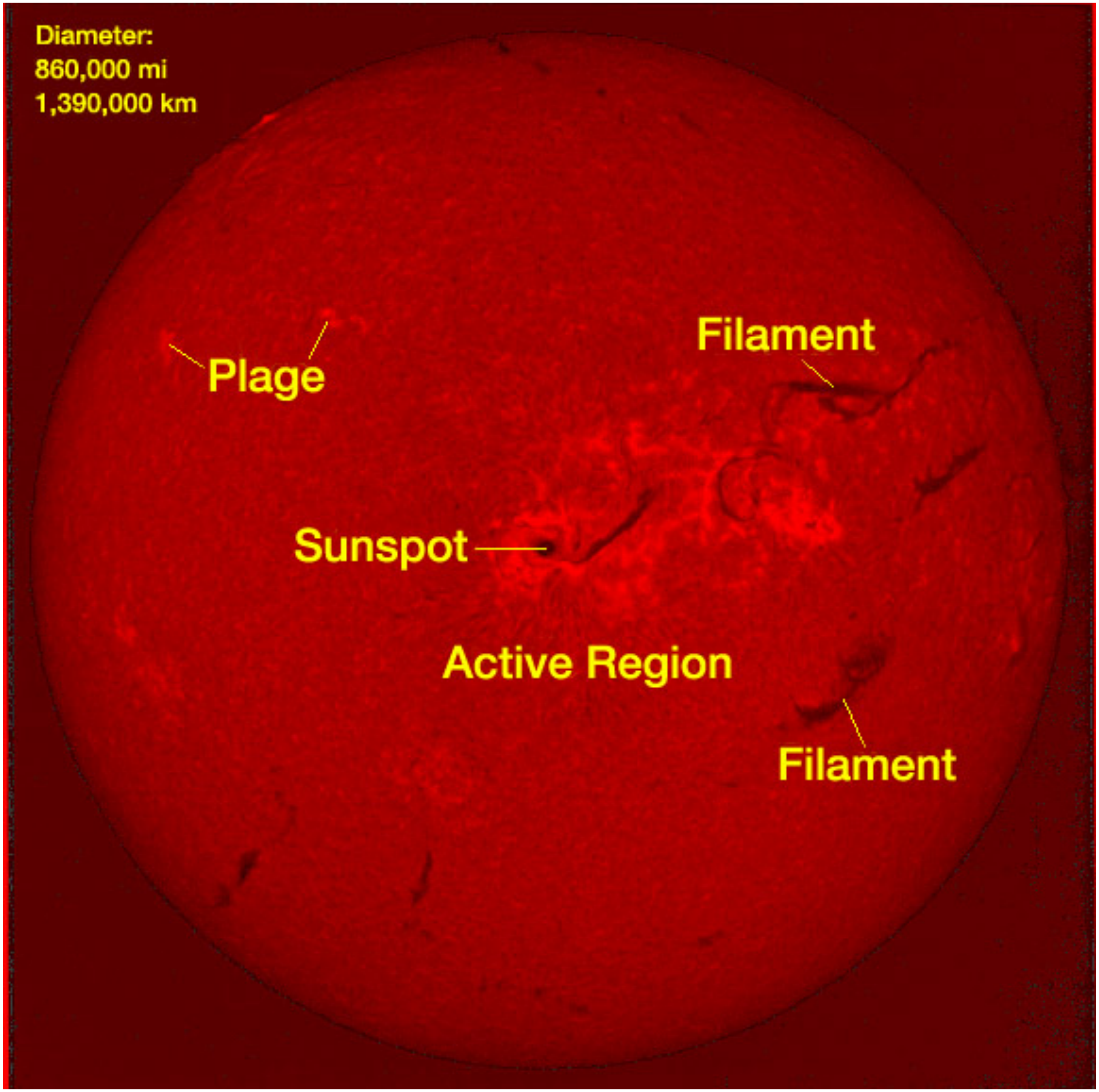
- **<u>Chromosphere:</u>** The chromosphere is a diffuse region from 300 to 10,000 km above the photosphere.

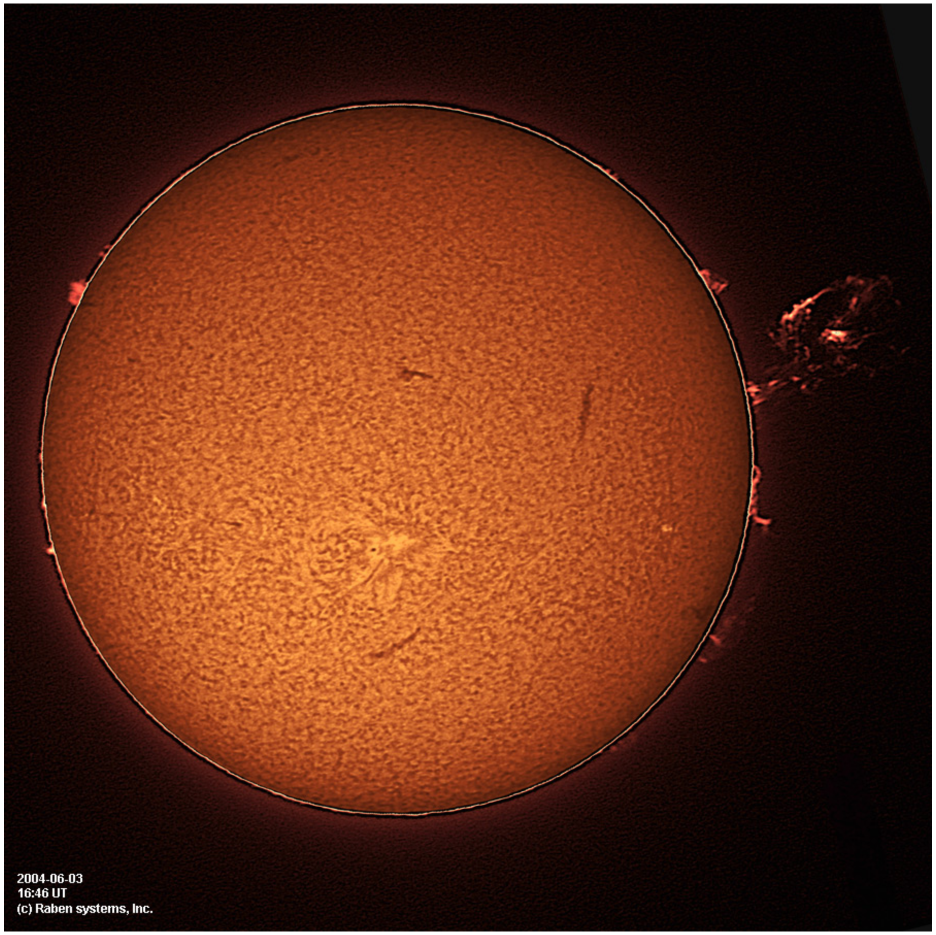
- The chromosphere is hotter than the photosphere and reaches up to 20,000K.

- The Chromosphere is easily observed by looking at the $H\alpha$ transition of Hydrogen.

- In Chromosphere images we see many structures, including filaments, arching prominences, and sunspots (these are *active*).

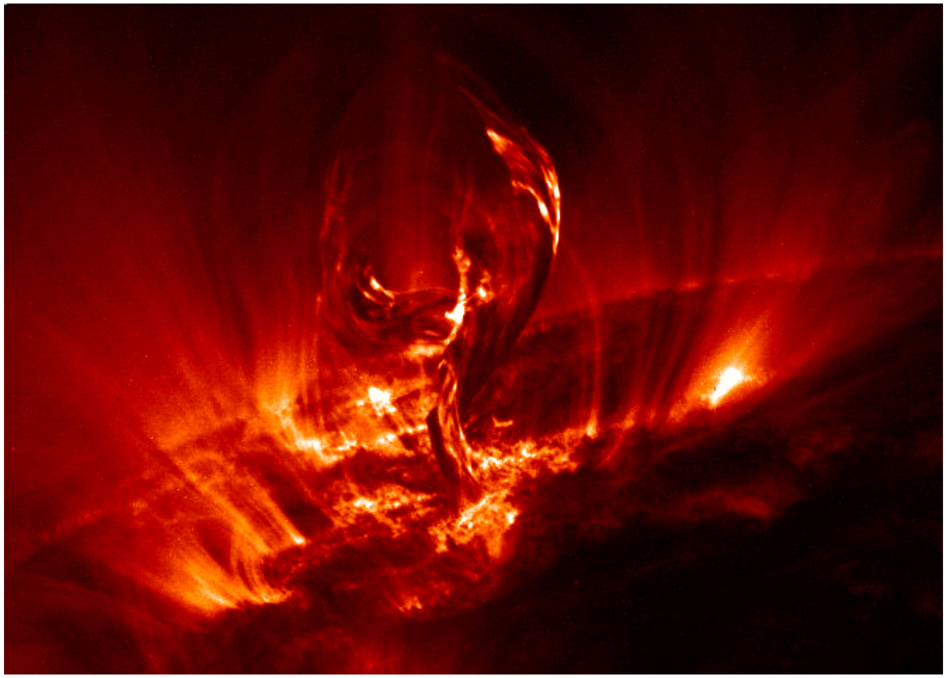



Diameter:
860,000 mi
1,390,000 km
Plage
Filament
Sunspot
Active Region
Filament



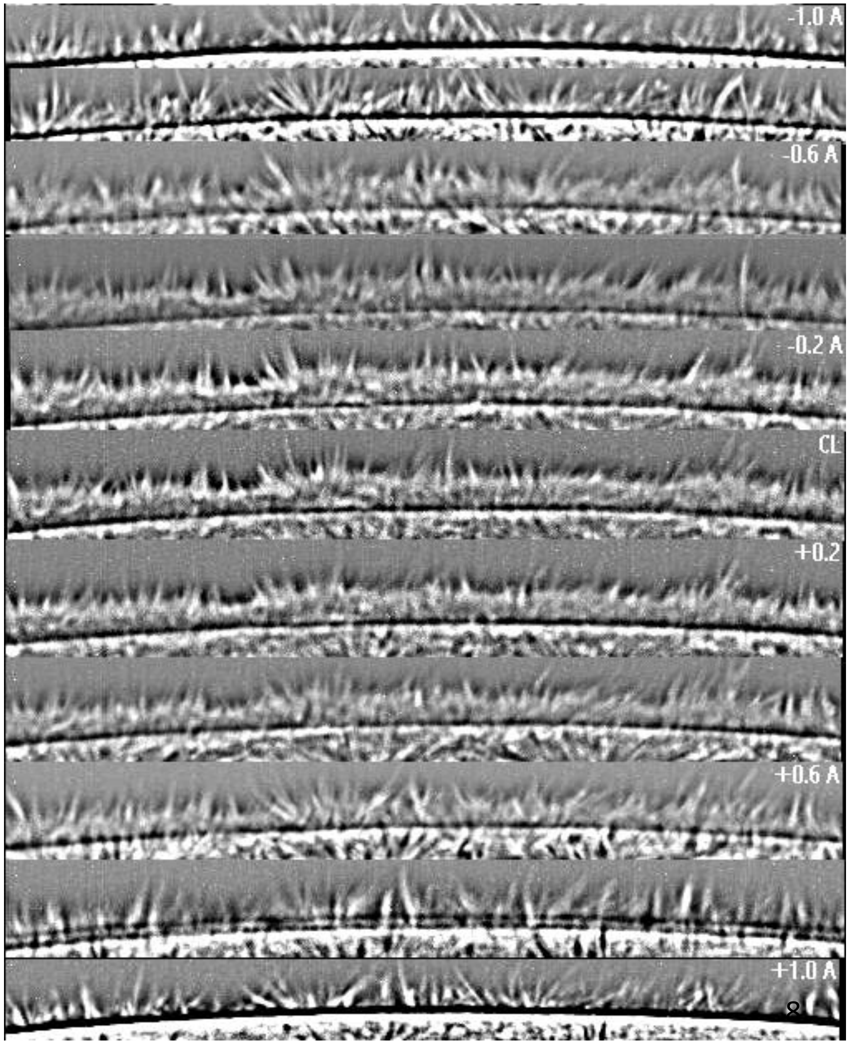
Prominences & Filaments

Filament



The Chromosphere:

- **<u>Chromosphere:</u>** The chromosphere is a diffuse region from 300 to 10,000 km above the photosphere.



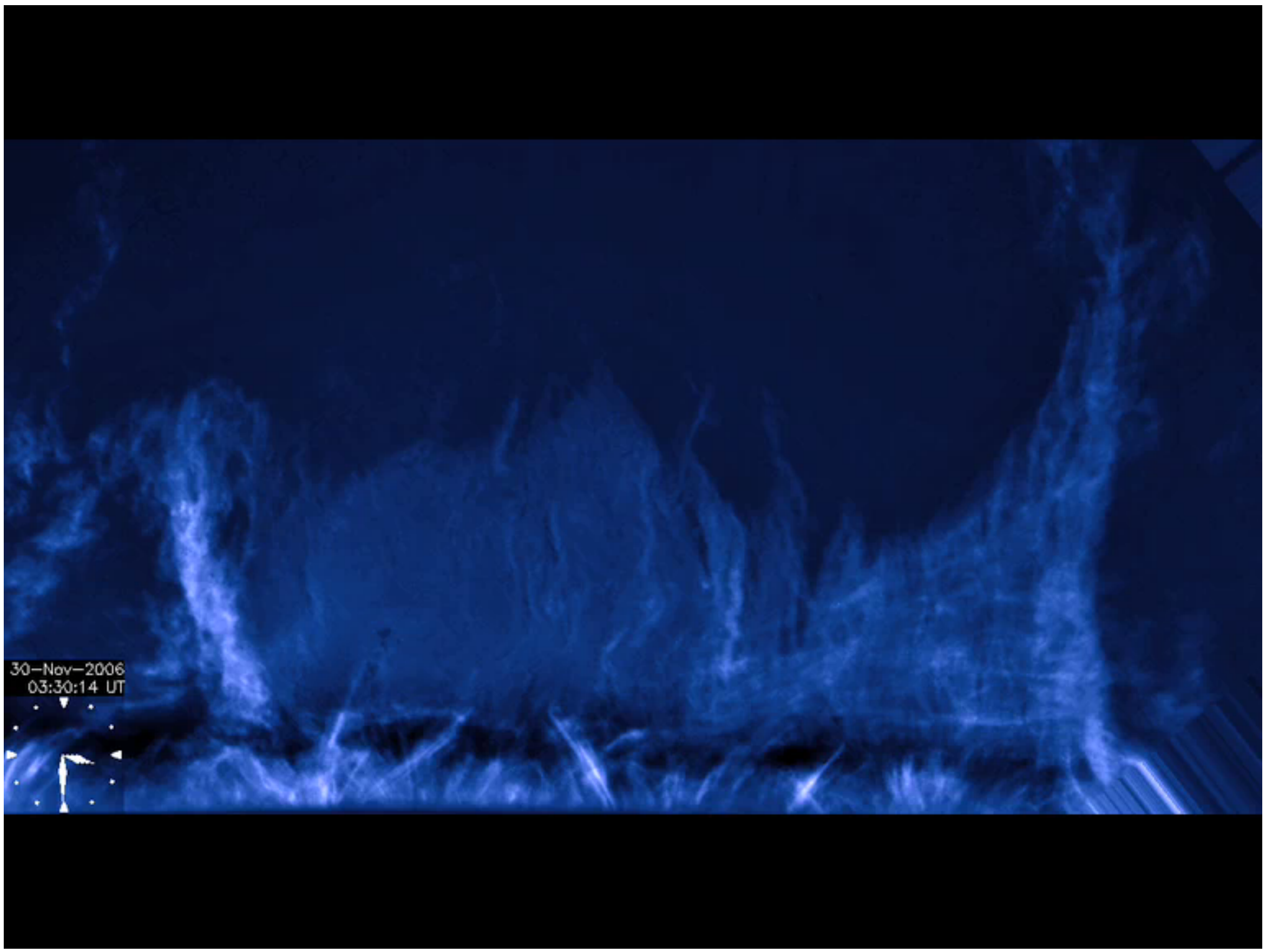
- Close-in we see *<u>spicules</u>*, which are pillars of rising gas (like flames) that extend upwards about 10,000 km.

- Each spicule has a lifespan of about 5-10 minutes.

- There are about ~10^5 spicules at any given time.

The Chromosphere:

• Close-in we see <u>*spicules*</u>, which are pillars of rising gas (like flames) that extend upwards about 10,000 km.



The Corona:

• **Corona:** The corona is the largest, hottest, and least massive part of the Sun's atmosphere.

• The corona is more than 100x hotter than the chromosphere.

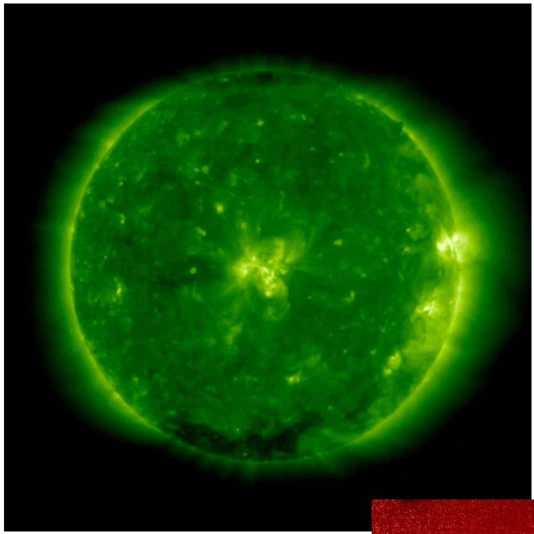
• It's very diffuse, but is so hot that it's luminous anyway.

• We require an eclipse to see it by eye, but most coronal emission is from ***discrete*** ion and neutral emission lines.

• Most coronal emissions are in the UV where the photosphere is dark.

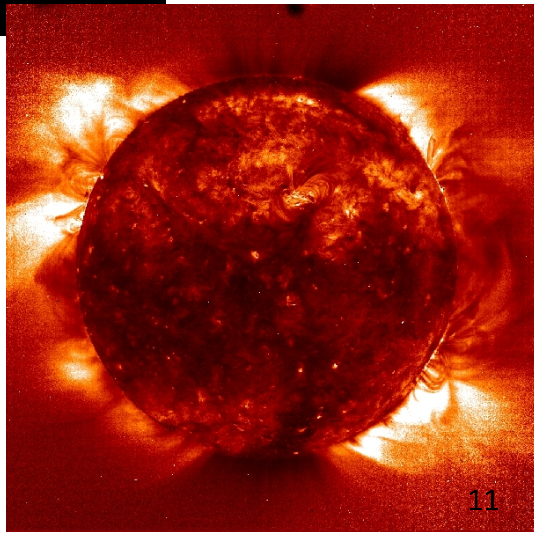
The Corona:

• The corona is a mix of quiescent and active features. The energy density in this diffuse medium is very high.



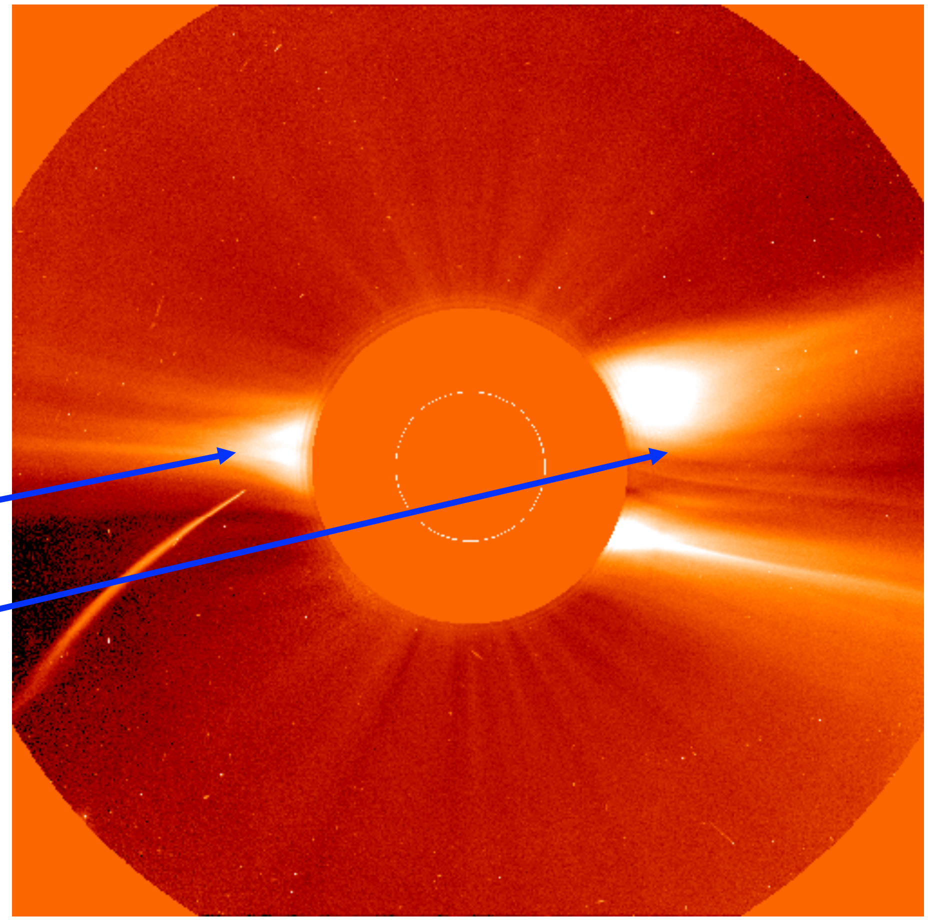
• Above we see the Sun in light from iron that has lost *11 electrons* (Fe XII). The bright regions are more than *1 million degrees*.

• If we compare the corona at two different emission lines we can map the temperature.



The Corona:

• **Corona:** The shape of the white light corona shows streamers and confined, flame-like features.

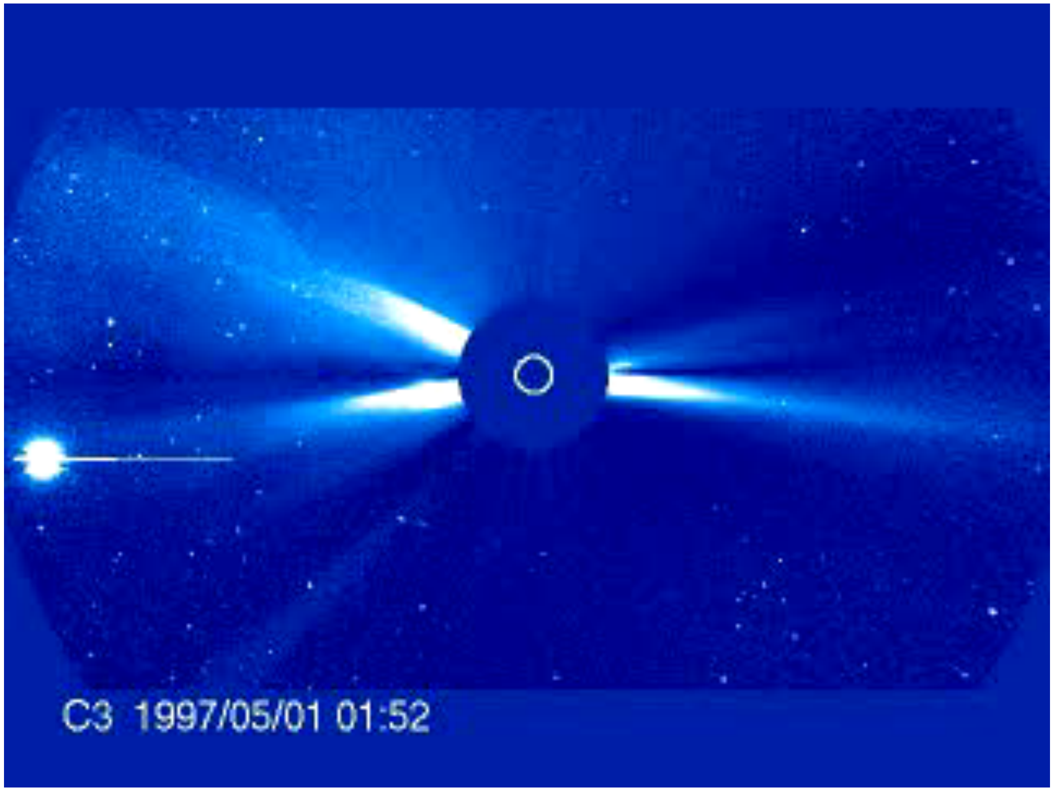


• The largest flame-like features are called '*Helmet Streamers*'.

The Corona:

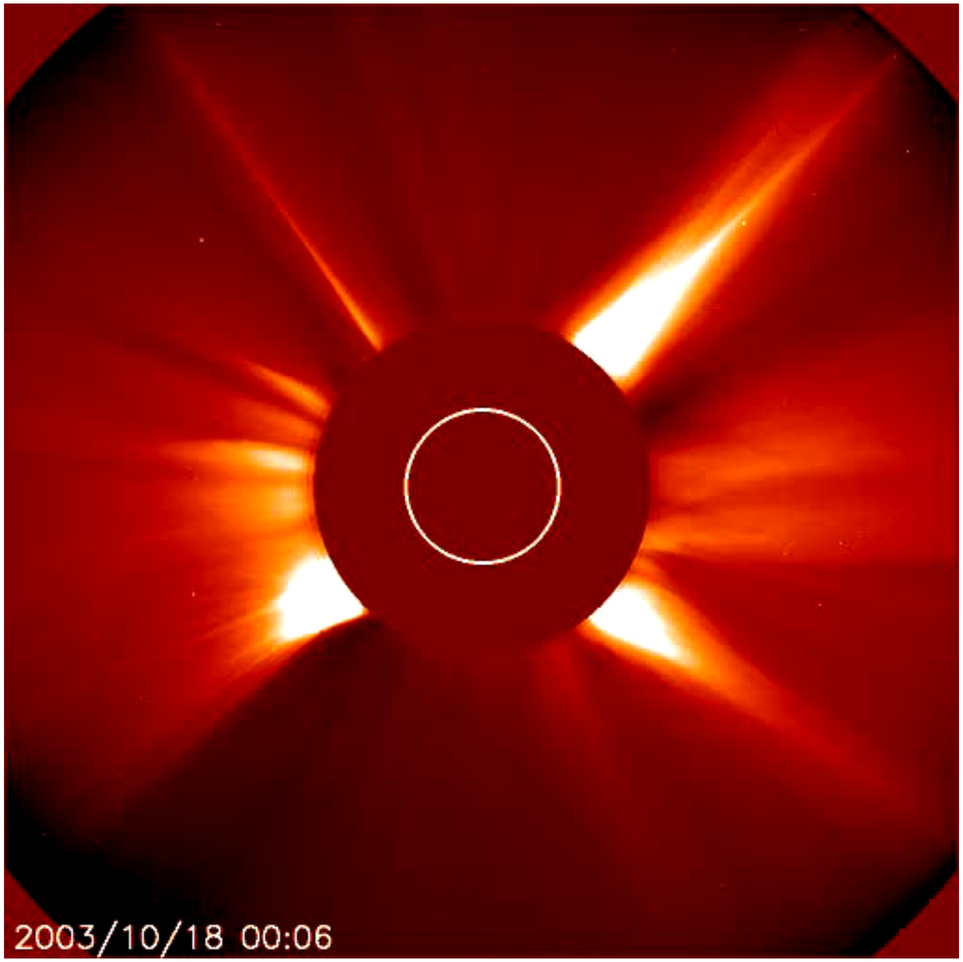
• **<u>Corona:</u>** The shape of the white light corona shows streamers and confined, flame-like features.

• Occasional gigantic outbursts called ***Coronal Mass Ejections (CMEs)*** project material millions of km into space.



The Corona:

• **Corona:** The shape of the white light corona shows streamers and confined, flame-like features.

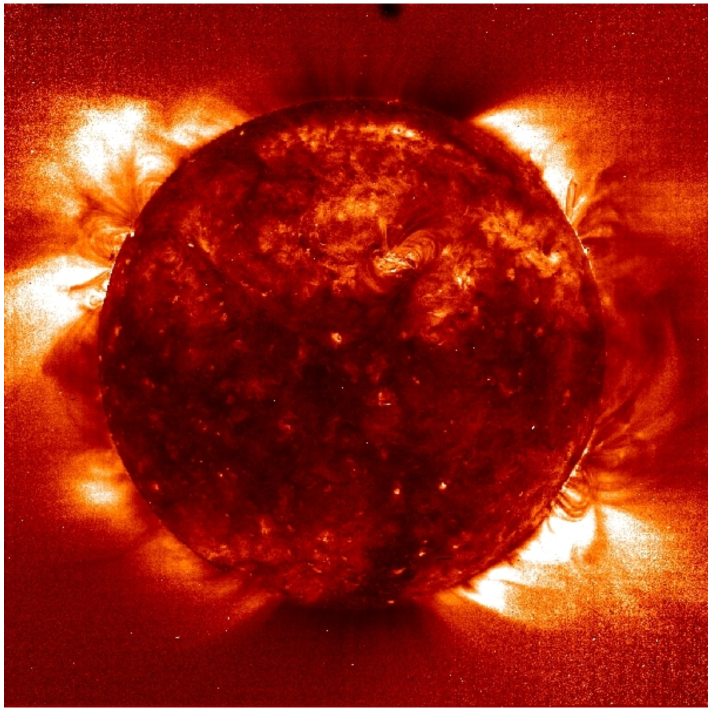


• We worry when they come directly at us. These are called **Halo Events**.

• In the movie we can see **Solar Energetic Particles (SEPs).** These are a **big** concern regarding the safety of astronauts.

Coronal Heating

Chromosphere Temperature: 20,000 K
Corona Temperature : > 1,000,000 K

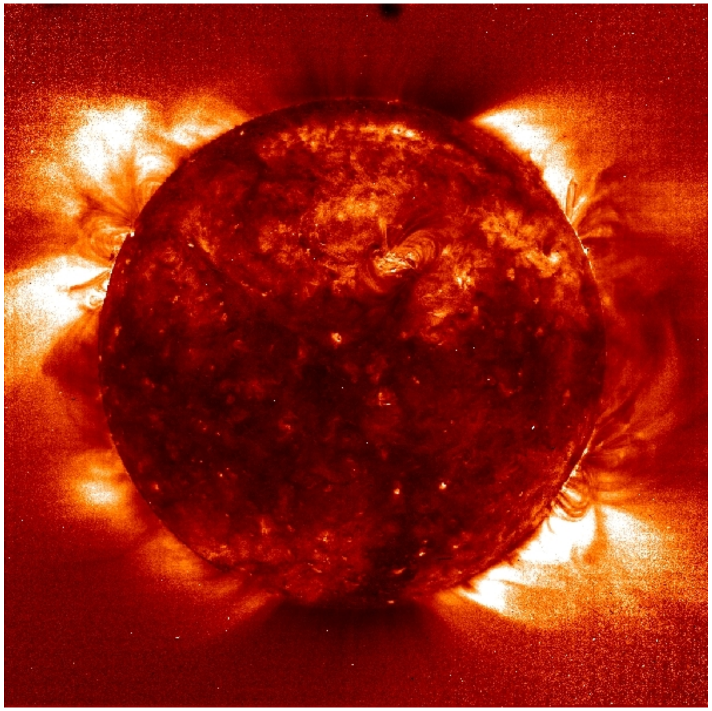


How can this be?

Short answer: We don't know.

Coronal Heating

Chromosphere Temperature: 20,000 K
Corona Temperature : > 1,000,000 K



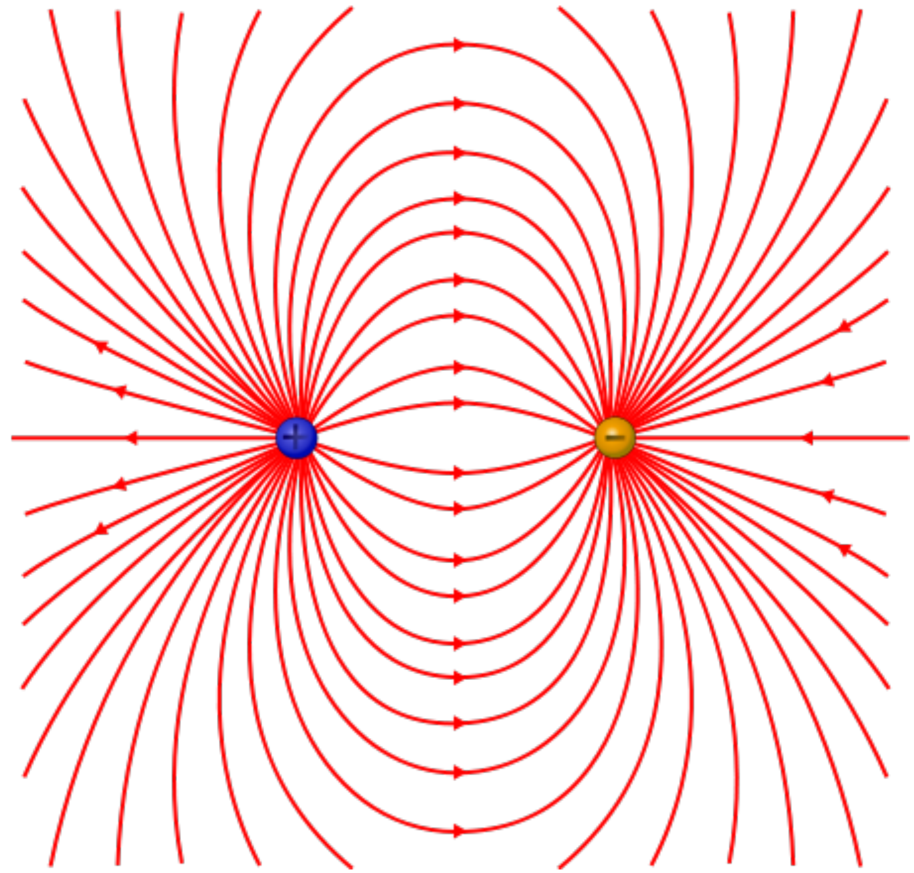
How can this be?

Longer answer: We've got some ideas.

- Wave heating
- Magnetic Reconnection
- Type II Spicules
- Many others

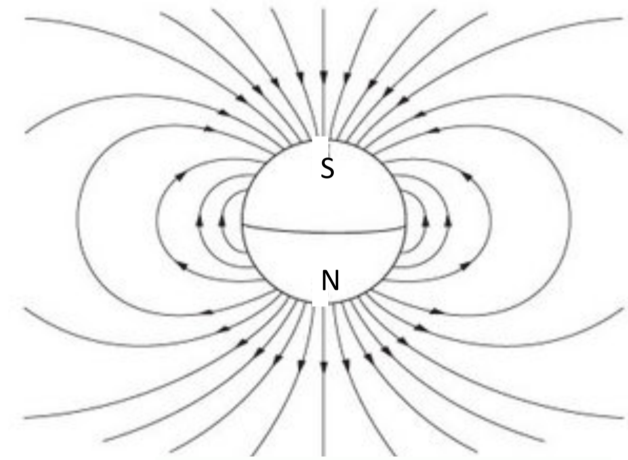
Electric Fields

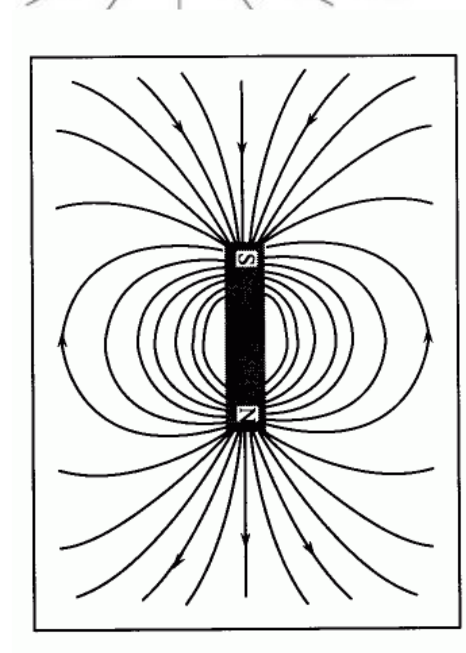
- Charged particle interact via E-fields
  - Like charges repel
  - Opposite charges attract
- E-field lines: show the direction a positive charge would move



Magnetic Fields

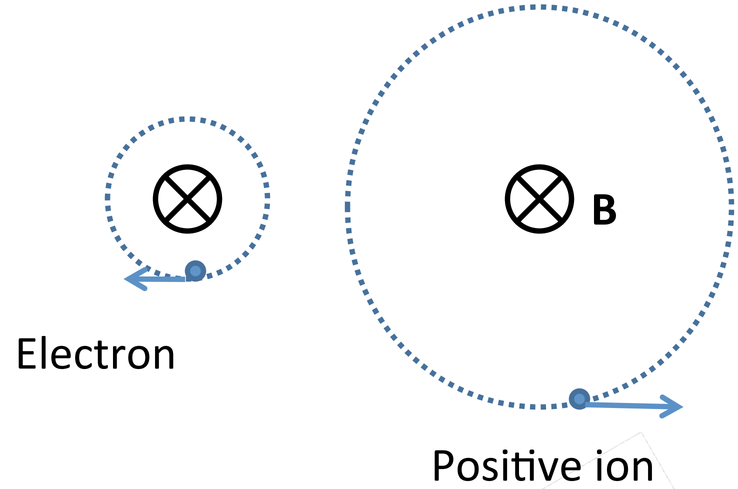
- Moving charged particles are electric currents.
- Currents generate magnetic fields
- Magnetic field lines point from magnetic North pole to magnetic South pole

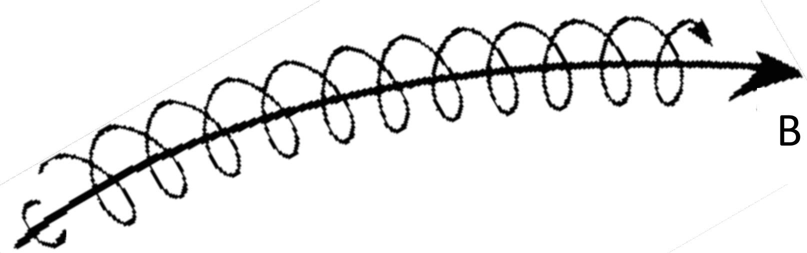




Plasma and Field Interactions

- Magnetic field cause moving charges to perpendicular to the field lines
- Charges are bound to magnetic fields
- Charges can move along field lines



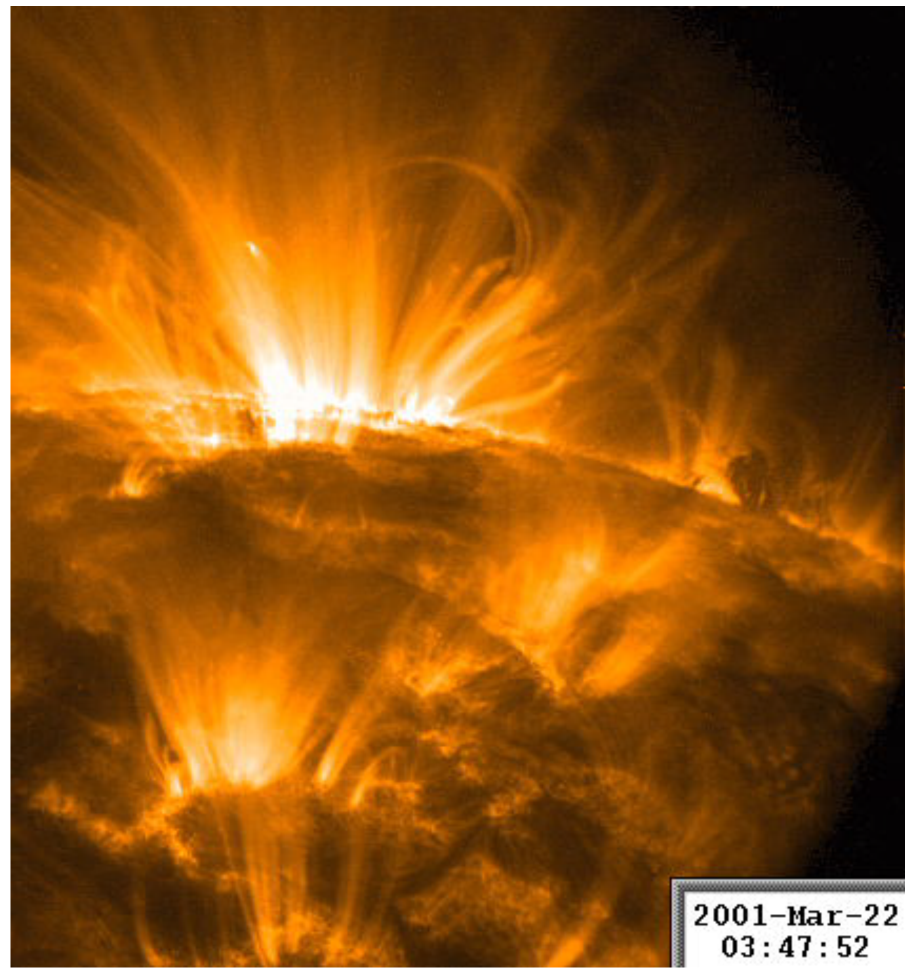


$\otimes$ = Magnetic field into the page

Plasma is bound to the magnetic field.
AND
Magnetic fields are bound to the plasma.

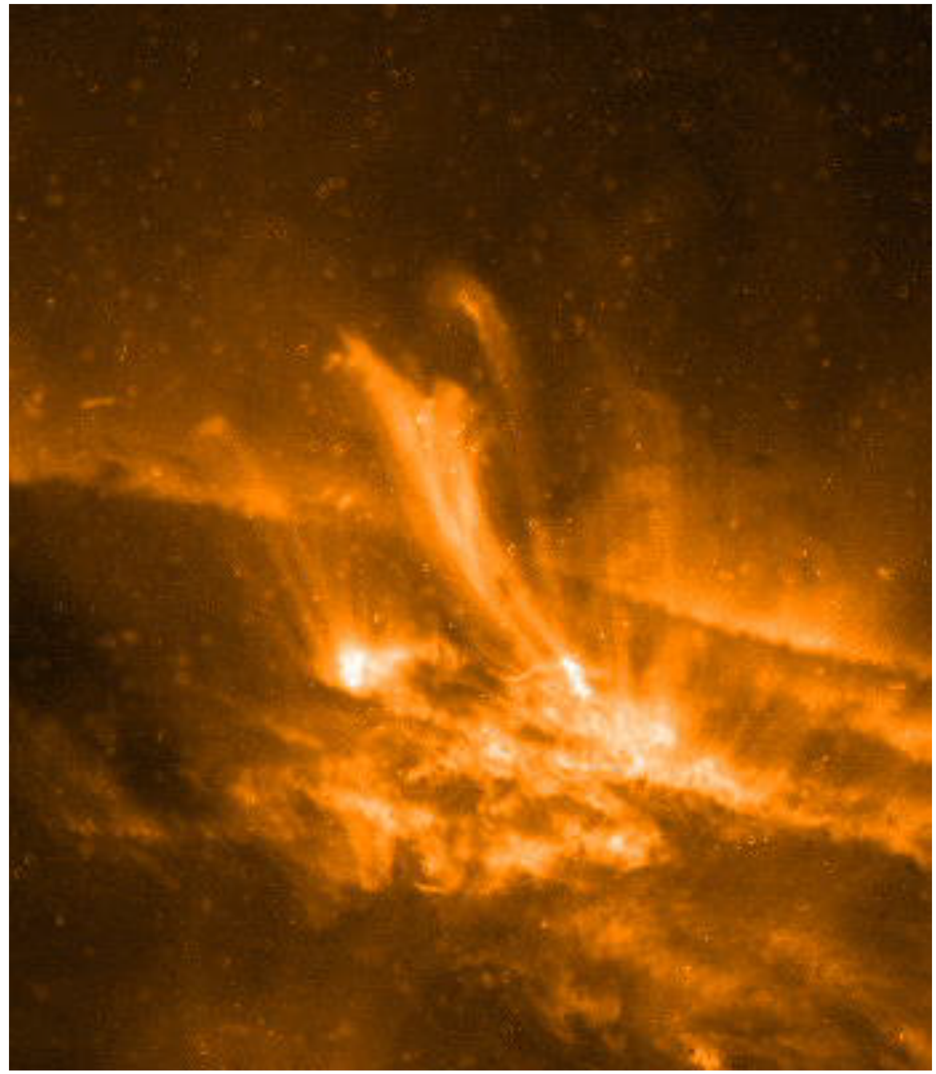
We can see this happening on the Sun

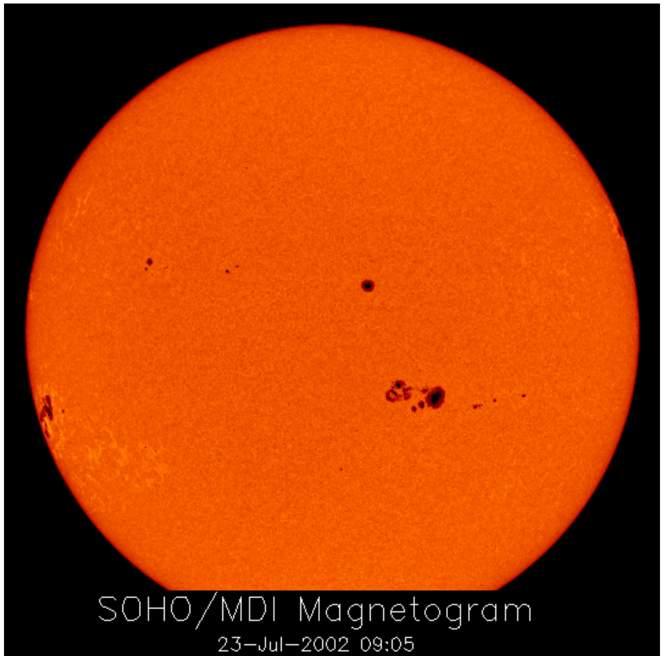
- We can’t see magnetic fields but we can see particles traveling along them

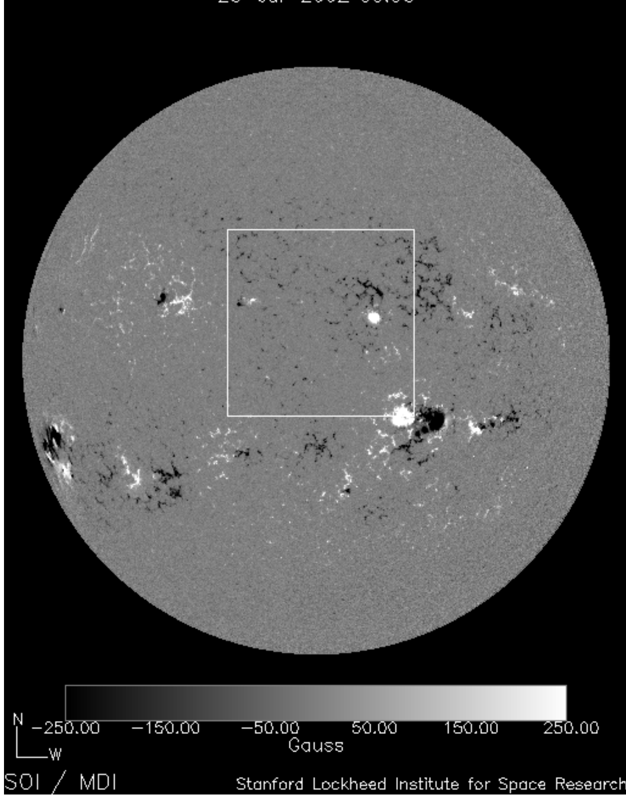


We can see this happening on the Sun

- We can't see magnetic fields but we can see particles traveling along them



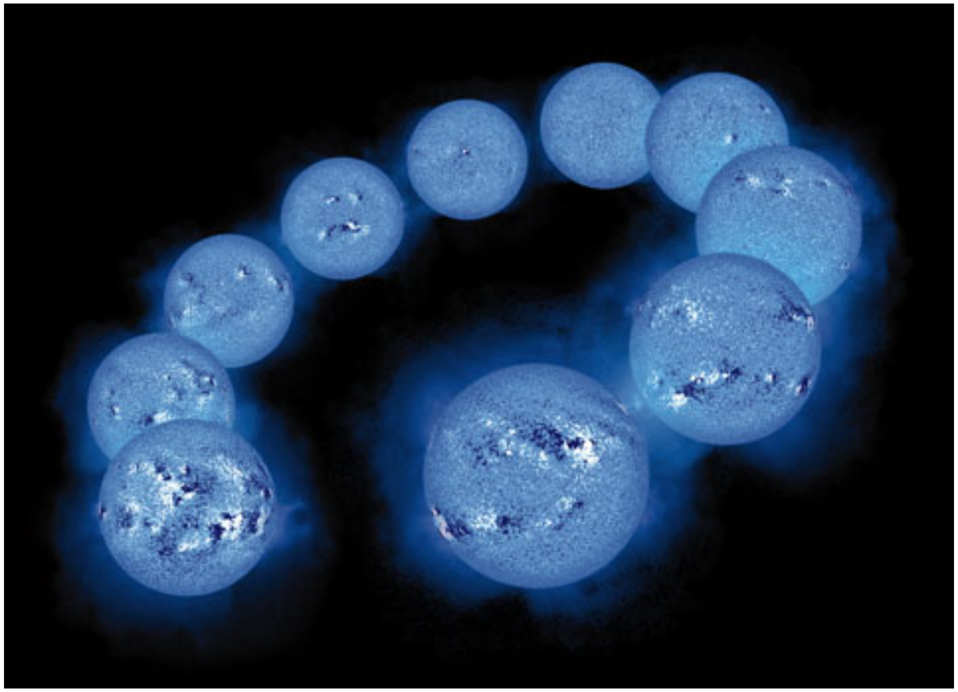




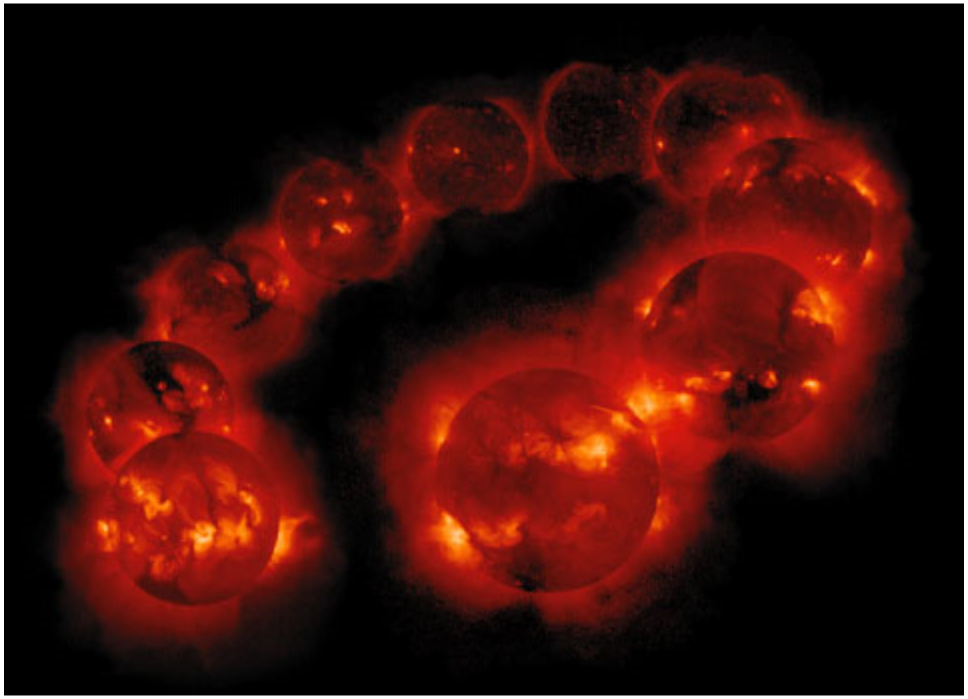
Viewing the Sun's Magnetic Field

- Sunspots give a visible indication where the magnetic field is strongest
- Sunspots are not the whole story
- Magnetograms give much, much more detail
- This is why we see prominences and filaments without sunspots - precursors

The 11 Year Cycle



Magnetic Field Map

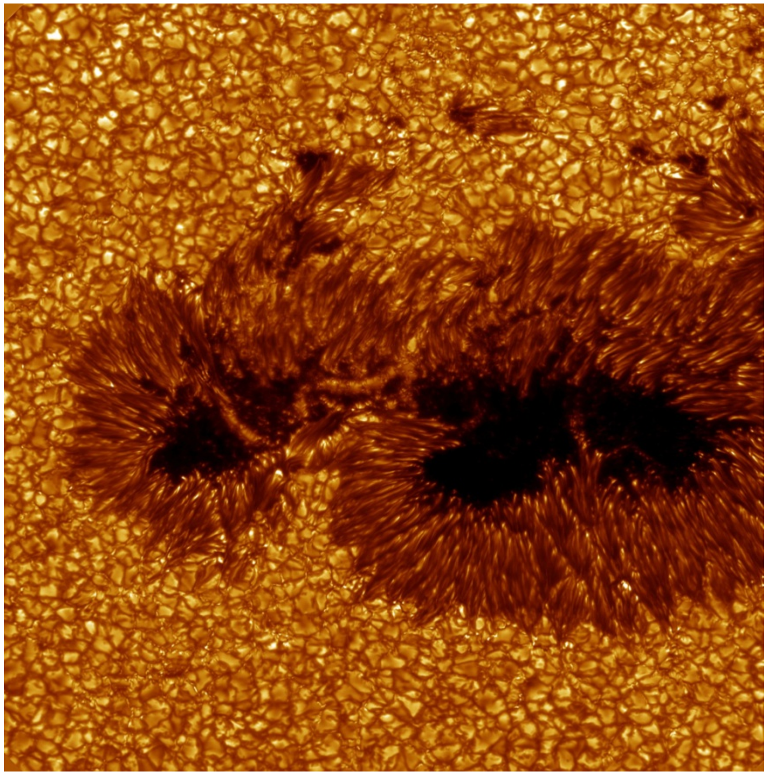


Corona X-ray Emissions

Sunspot Characteristics:

• Sunspots are ***transient*** features in the solar atmosphere. Their total number changes with time as well.

• Sunspots are typically ***paired*** on the surface of the Sun.



• They are often seen ***connected to filaments*** on the surface.

• They are clustered near the ***middle regions*** of the Sun and rotate with it.

• Sunspots are not 'dark', but ***cool*** (about 3000K).

Sunspot Characteristics:

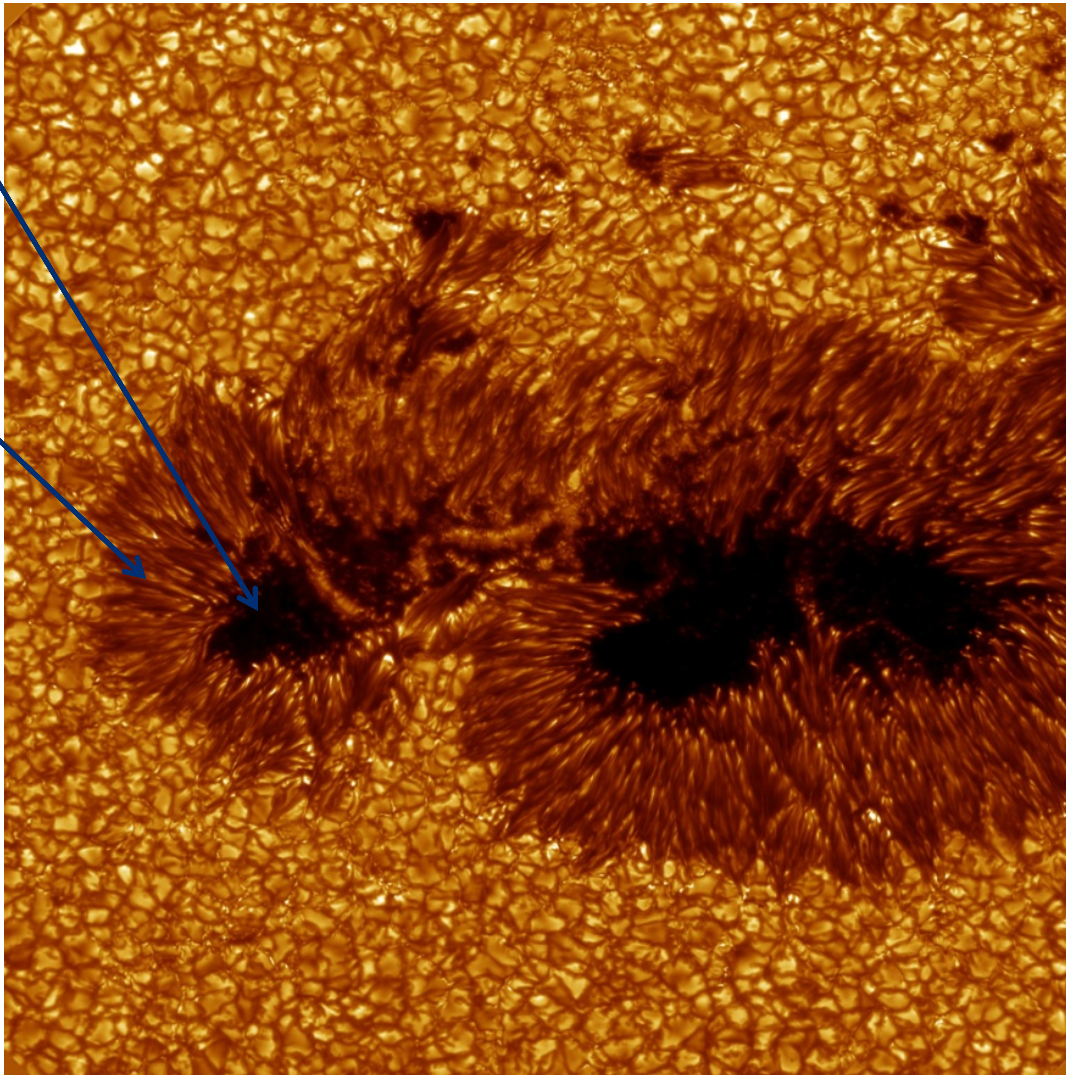
Umbra: dark center of the sunspot

Penumbra: lighter color region surrounding the umbra

- Constant area fraction
- Diameter = 20,000-60,000 km

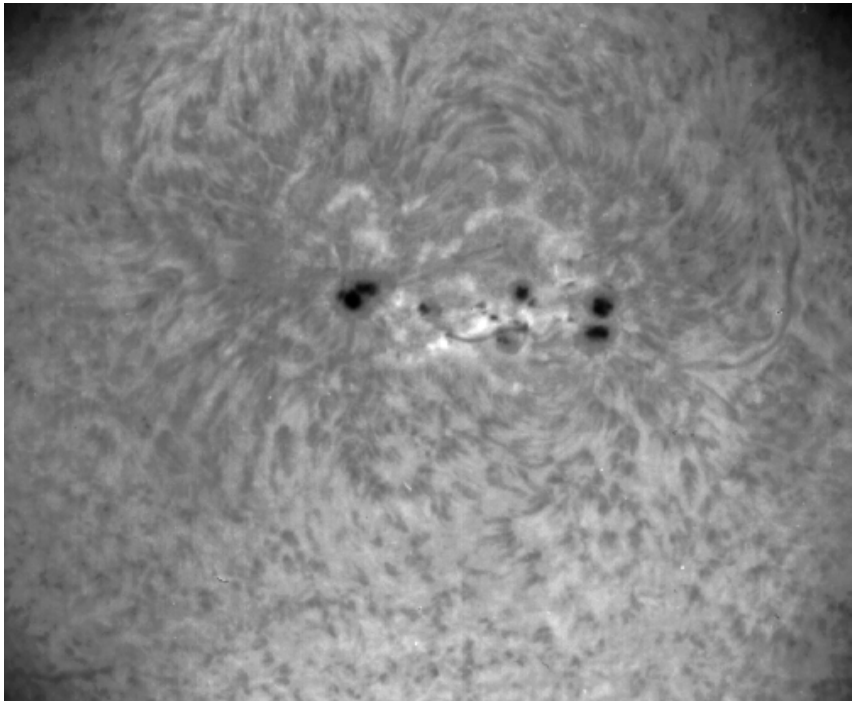
Color is due to magnetic field orientation

- Umbra – vertical field
- Penumbra – inclined field



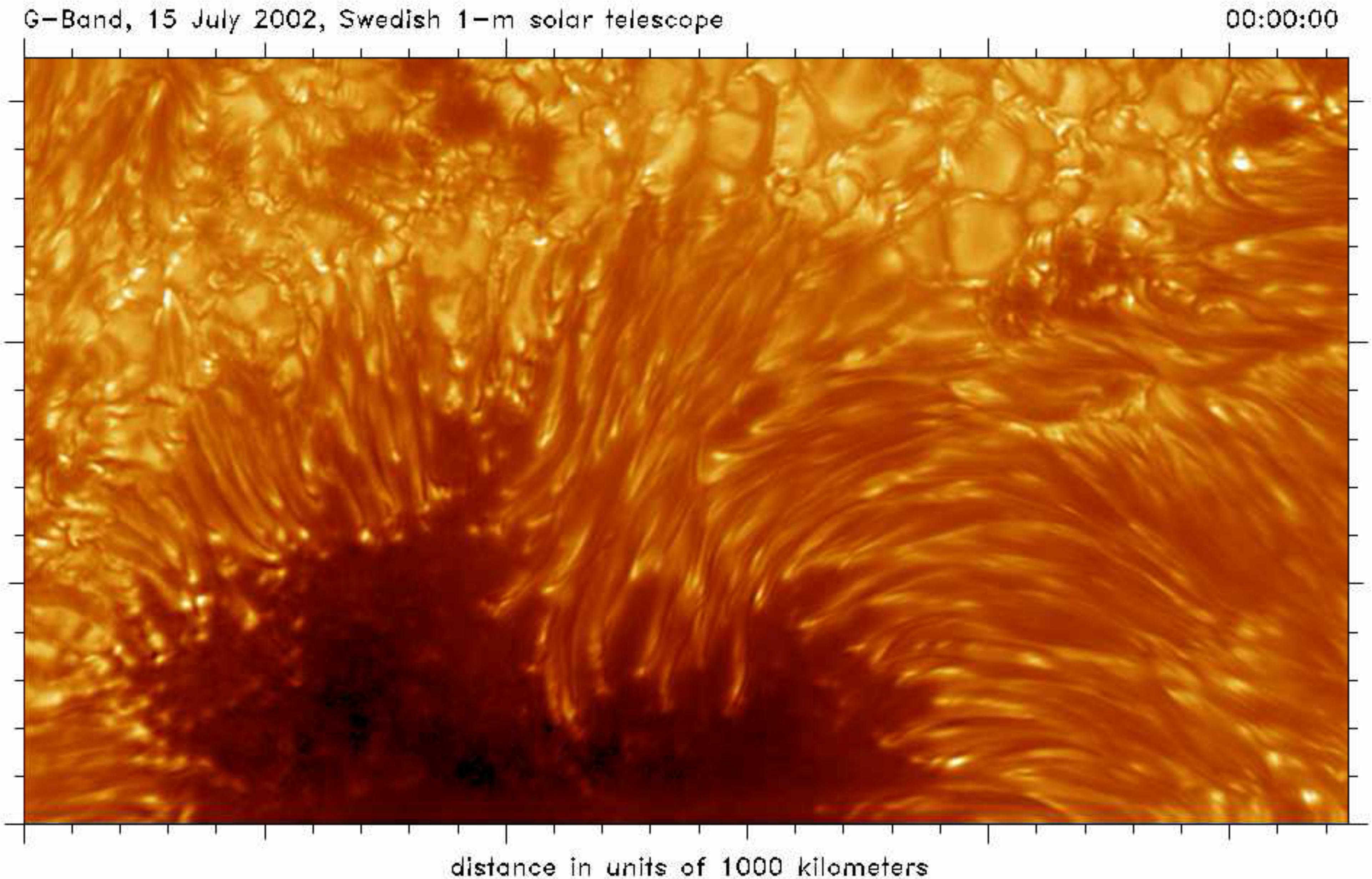
Not So Dark….

• Sunspots have strong fields that contain lots of plasma that doesn't want to move.



• This would be ok, except that the Sun's convection zone would like to move neutral material to the surface.

• The 'magnetic bubble' around the sunspot prevents convection from being as efficient. So less energy is delivered to the surface, and the gas is cooler there (*only 3000K*).


G-Band, 15 July 2002, Swedish 1-m solar telescope
00:00:00
distance in units of 1000 kilometers