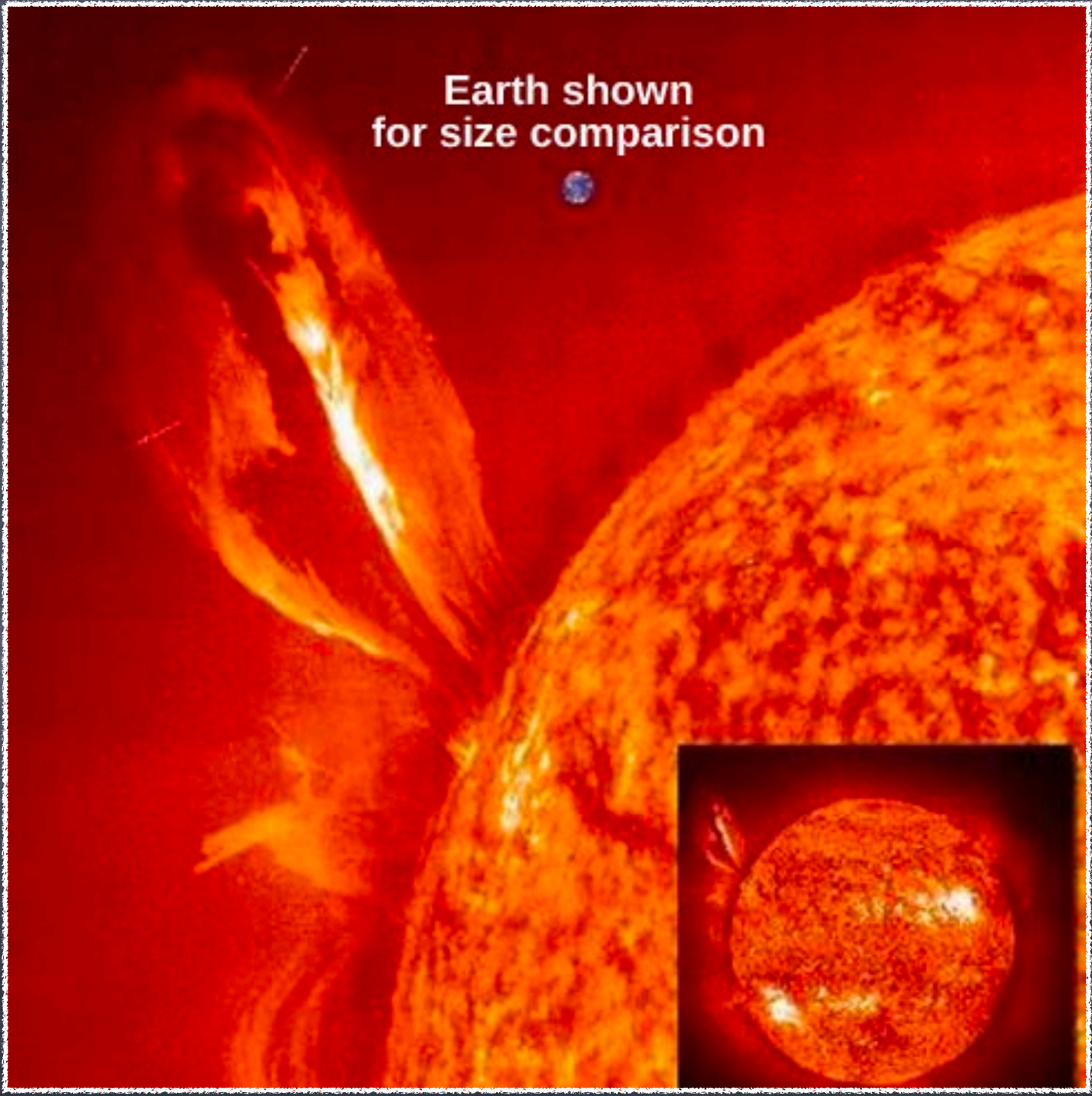
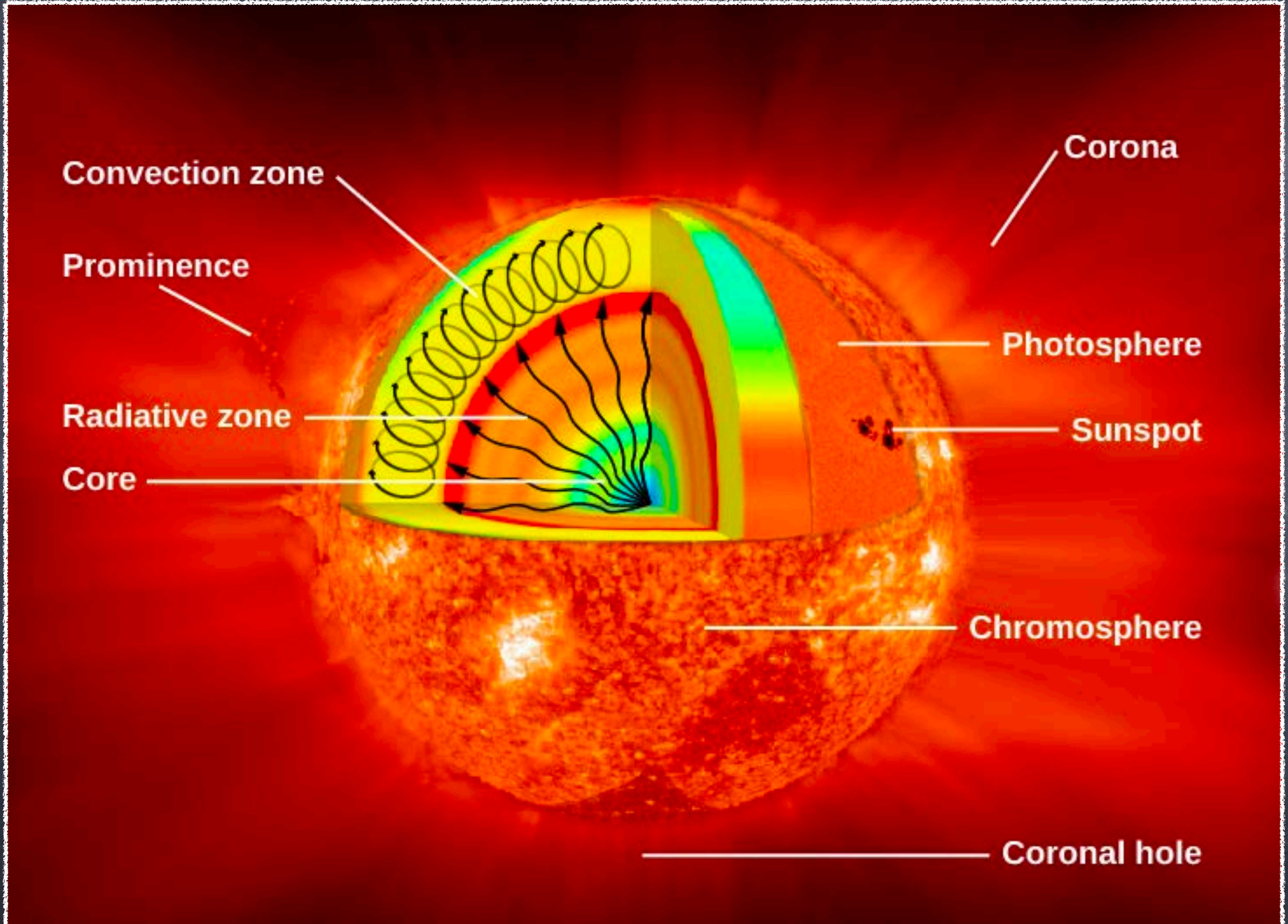
The Sun: A Regular Star

Chapter 15

- The sun is a normal star, which means it is a gigantic ball of hot gas compared to the Earth.
- The sun is much bigger than a planet, 109 times the size of the Earth and more than a million times the volume.
- The sun is 73% hydrogen and 25% helium with everything else less than 1.5%.
- The sun's rotation period at the equator is 24.6 days.



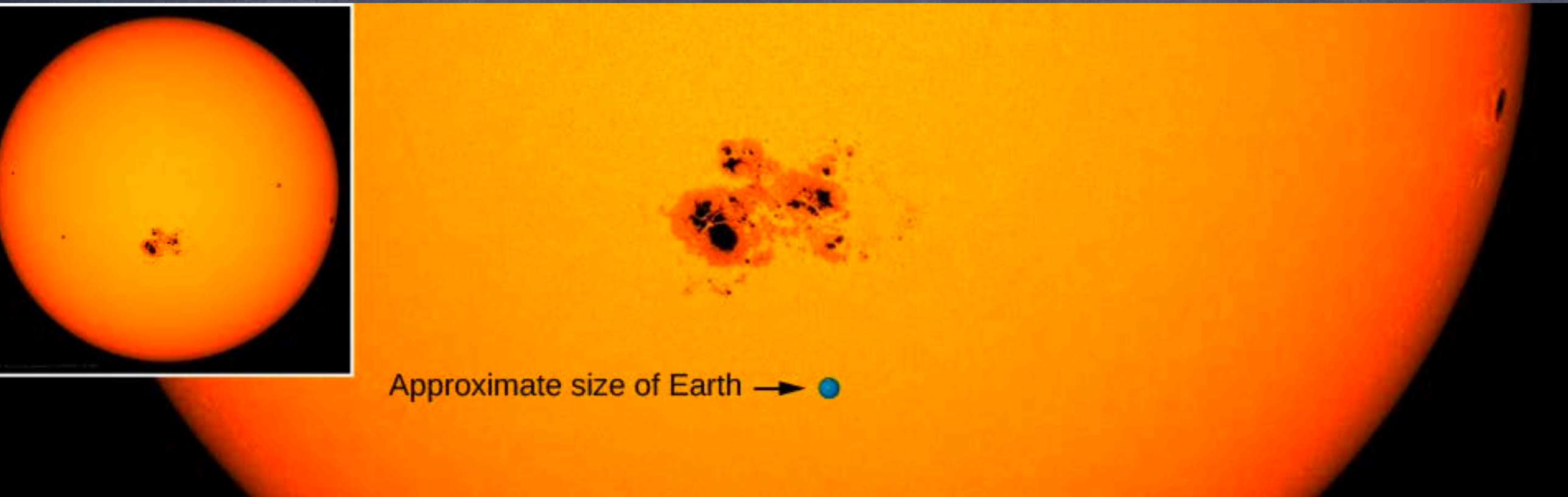

Convection zone
Prominence
Radiative zone
Core
Corona
Photosphere
Sunspot
Chromosphere
Coronal hole

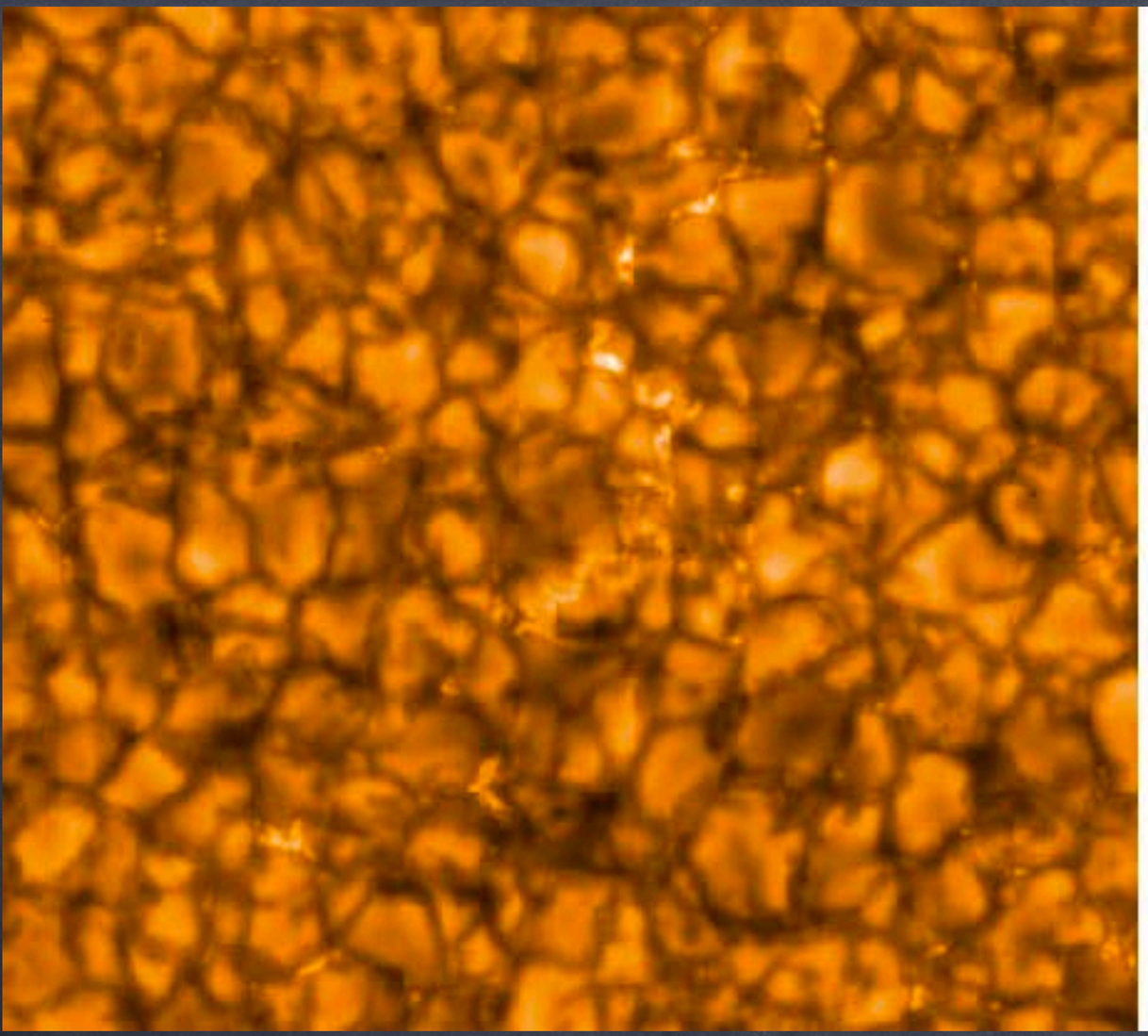
Layers of the Sun

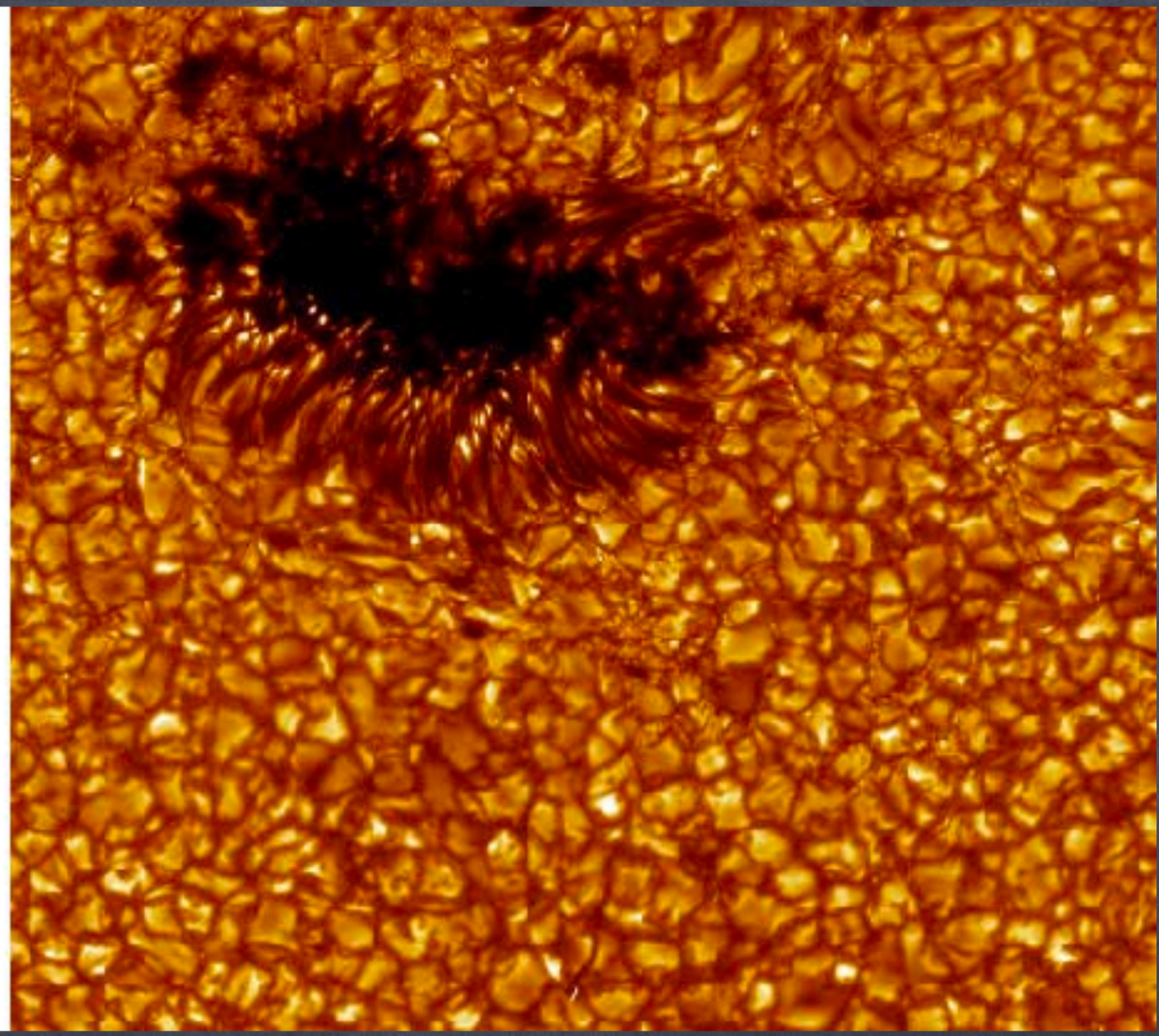
- Core - about 20% the size, very dense and hot, 15 million K. Nuclear fusion occurs the source of a star's energy.
- Radiative Zone - almost 50% of the radius, in this region energy is transported by radiation.
- Convection Zone - the last 30%, in this region energy is transported by convection.
- Photosphere - the part of the sun we actually see, the final layer before the light mostly escapes the sun.

The photosphere is the layer of the sun we see. It is like looking at a forest, you only see the last layer of trees, but you know there is an entire forest behind them.

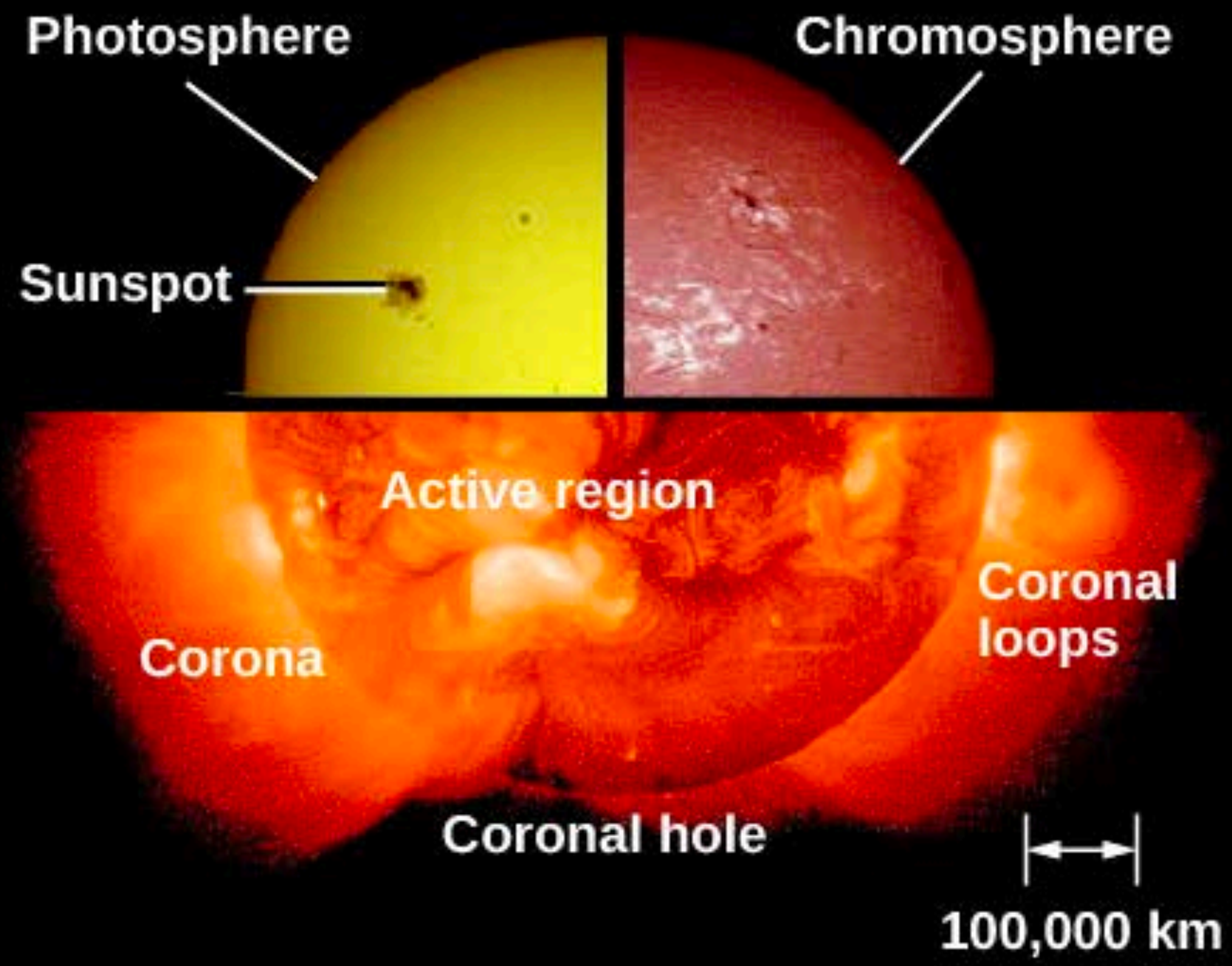
But here it is just gas that has become opaque to radiation, there is no actual surface. The photosphere corresponds to a temperature of 5780K.





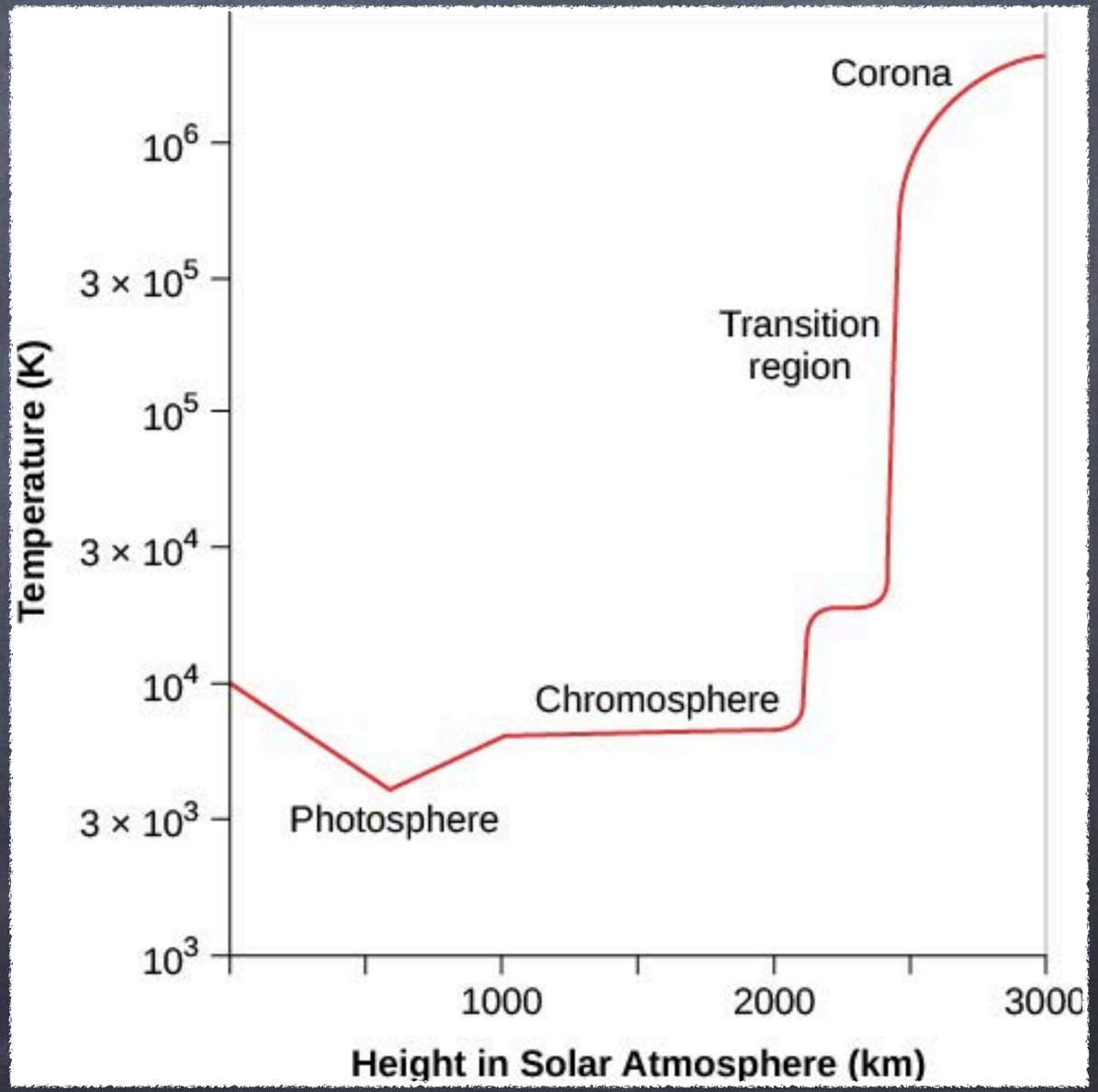


Greatly magnifying the photosphere we can see that it is not smooth but has granules, these are about 1000km across. They are bubbling from the convection zone. The bright regions are moving up at a few km/s and are a bit hotter, 50 - 100 degrees

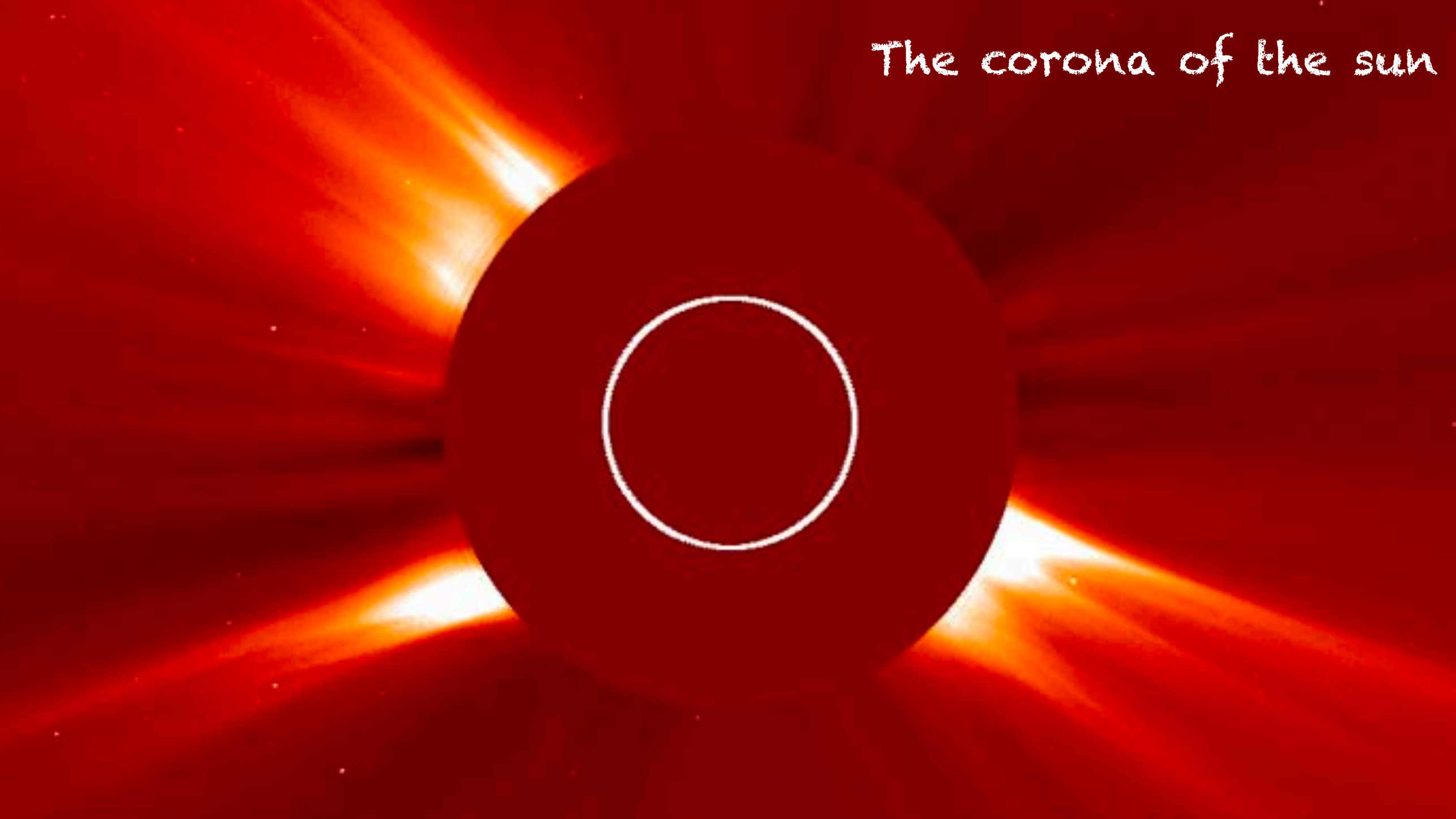

Photosphere
Chromosphere
Sunspot
Active region
Coronal loops
Corona
Coronal hole
100,000 km

Sun's 'atmosphere'

- Beyond the photosphere there are more layers of the Sun which are transparent. Thus they are referred to as the sun's atmosphere. These layers are best seen during an eclipse.
- Chromosphere – 2 to 3 thousand km it is hotter than the photosphere at 10,000K.
- Corona – extends millions km and is half as bright as the full moon, you can see it by eye during a total solar eclipse. It is very hot, millions of degrees and very low density.

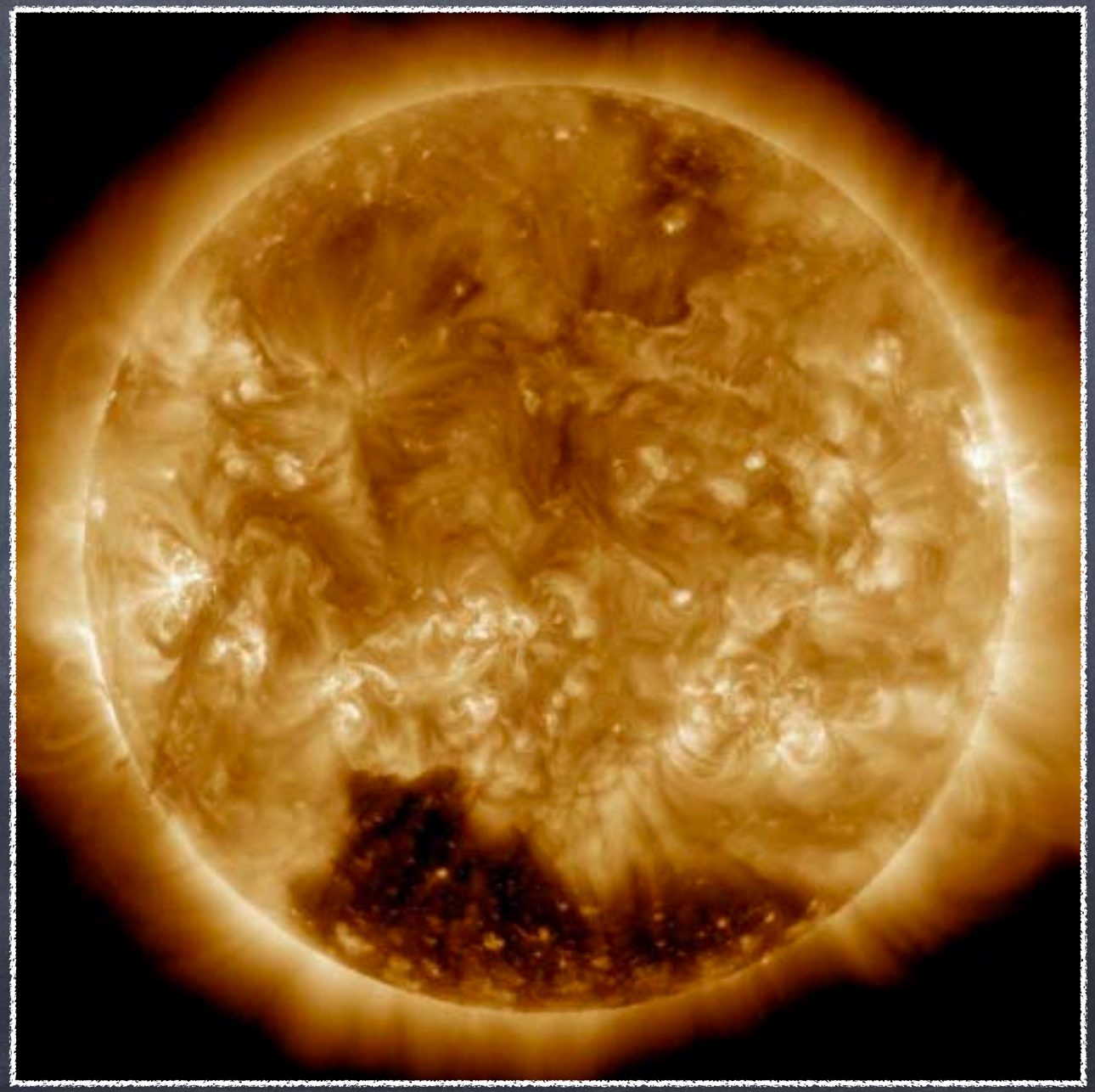


The corona of the sun



Solar Wind

- There is also a 'wind' of charged particles that blow away from the sun at 400 km/s. That's a million mph.
- It is estimated that the sun looses 1-2 million tons of material each second to the solar wind.
- The solar wind is made from particles in the corona that escape the sun. The corona is too hot to stay bound to the sun and regions escape forming coronal holes.

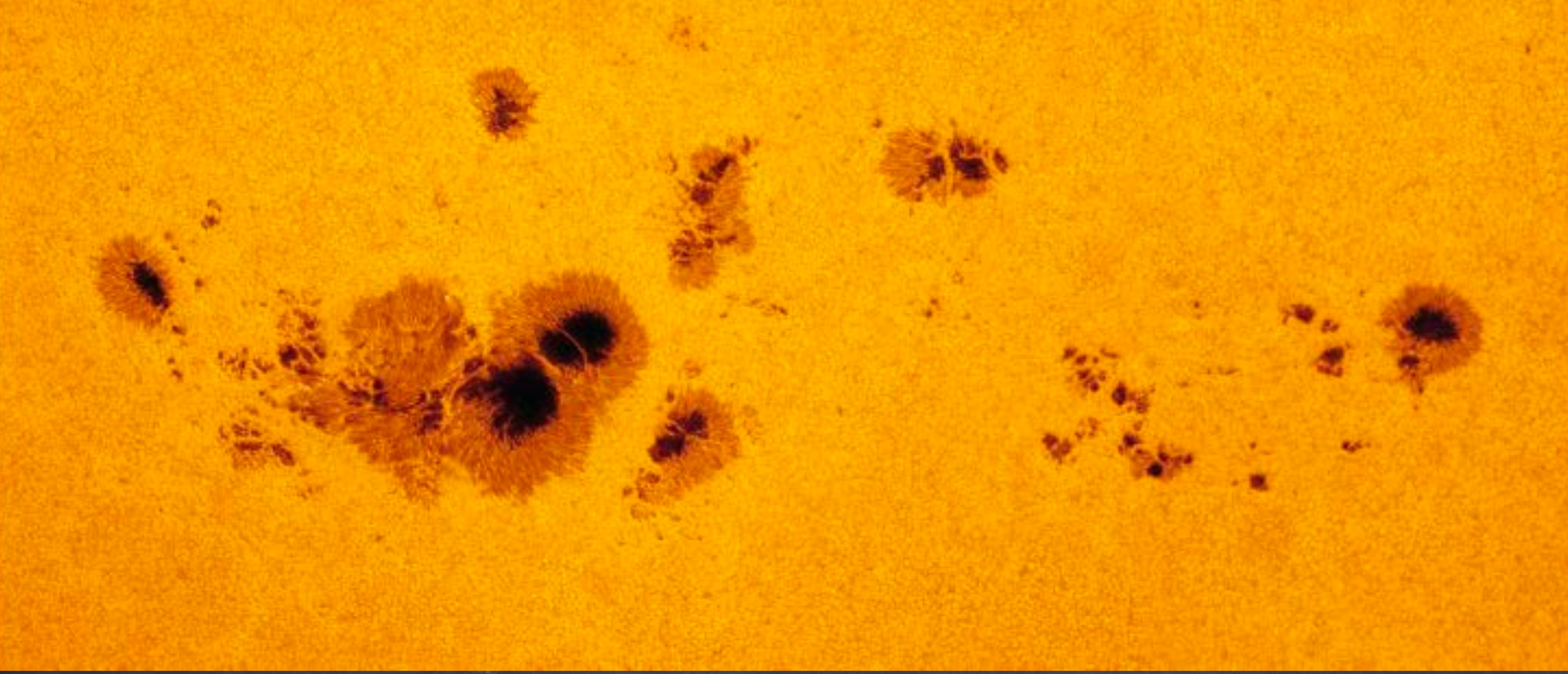


When the solar wind interacts with the Earth's magnetic field it forms the auroras

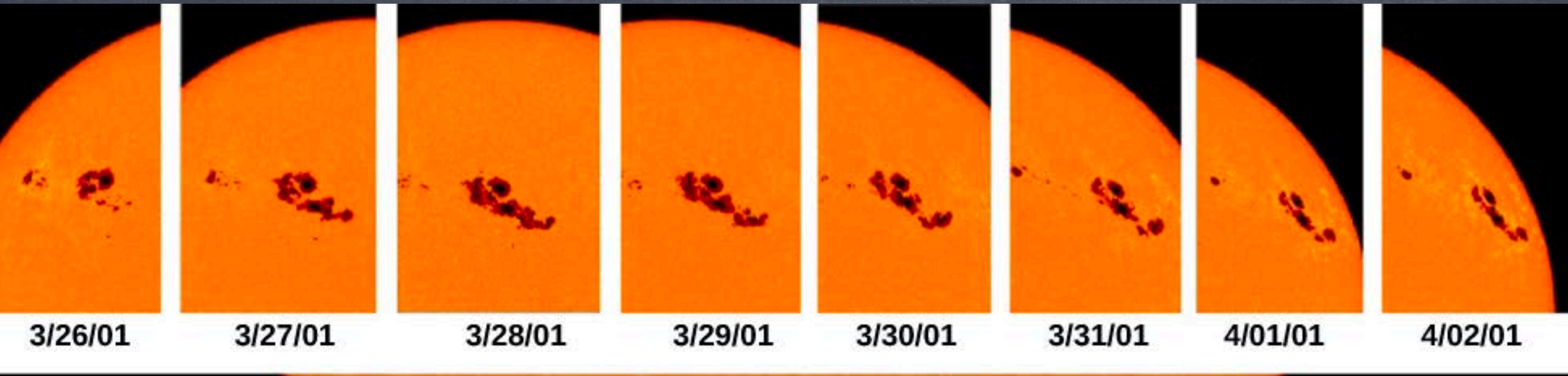
https://www.youtube.com/watch?v=fVMgnmi2D1w

Sunspots

- Galileo first discovered sunspots as they are visible with just a bit of magnification. Occasionally they are visible to the naked eye, if very large.
- Sunspots look dark because they are about 2000K cooler than the bright parts of the sun.
- They are caused by the sun's magnetic field and vary during the solar cycle as the magnetic field varies.



Sunspots last a few hours to a few months. They often become larger than the Earth and often cluster in groups of around 20. Though they can become much larger and be in larger groups.



March 30, 2001

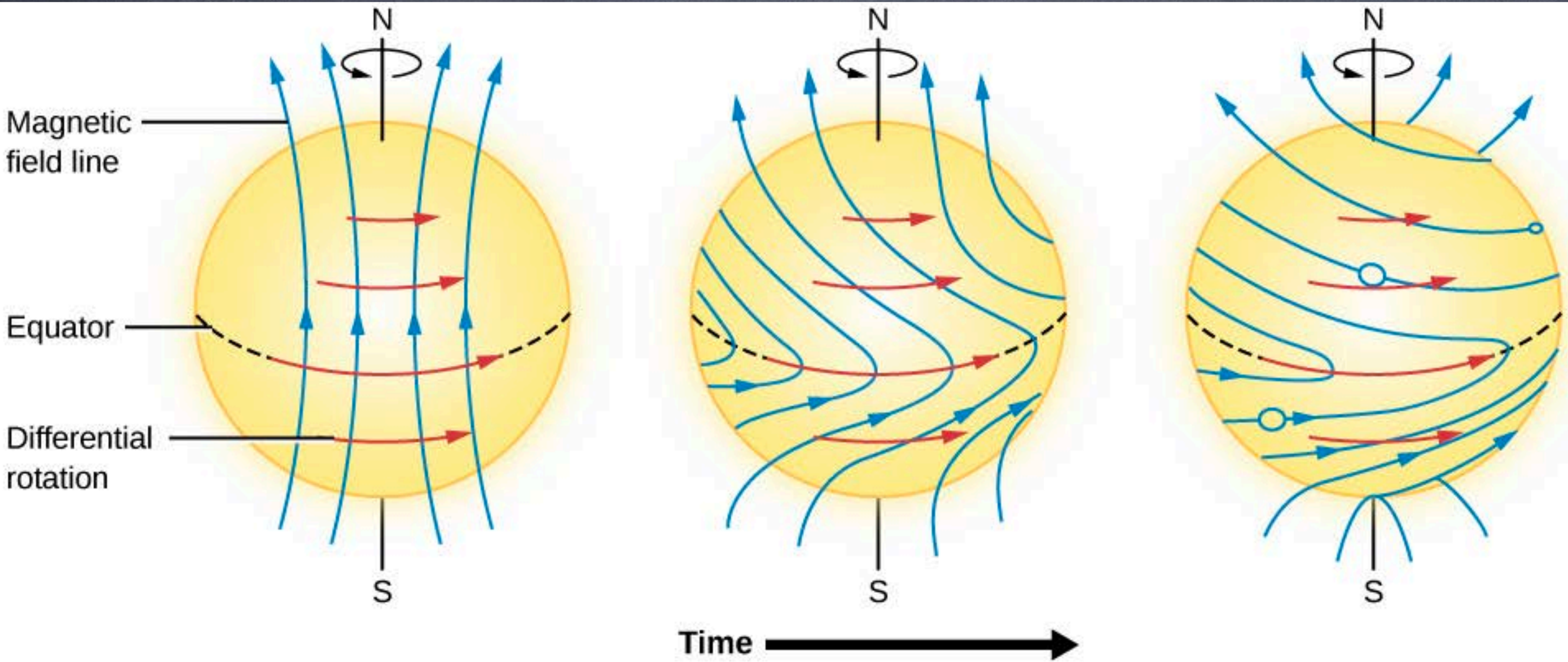
The Solar Cycle

- It can be observed that the total number of sunspots varies over the years, hitting a maximum of about 100 sunspots at a time to no sunspots.
- This cycle averages 11 years, but varies between 8 and 14 years.
- Sunspots are caused by the sun's magnetic field, which switches between poles every 11 years. Magnetic field lines that exit the photosphere cool the gas creating the sunspots. When the sun's field is weak there are fewer sunspots and other forms of activity.

https://www.youtube.com/watch?v=sASbVkK-pOw

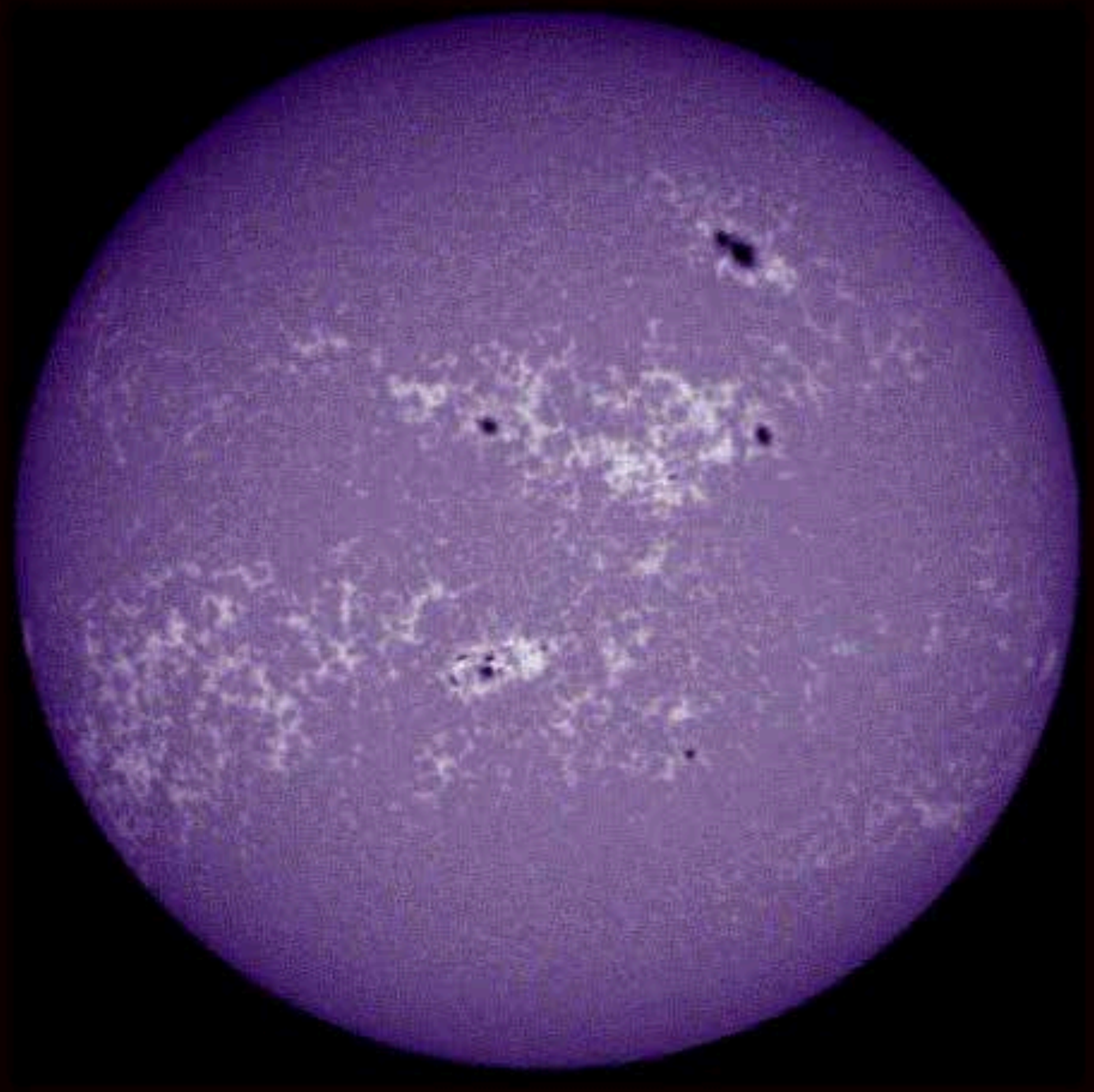
The sun's rotation drags and breaks magnetic field lines, creating a dynamo that switches the direction of the magnetic poles. The same thing happens on Earth, but the cycle is 50-100 thousand years.

https://www.youtube.com/watch?v=2g1epPppIOM



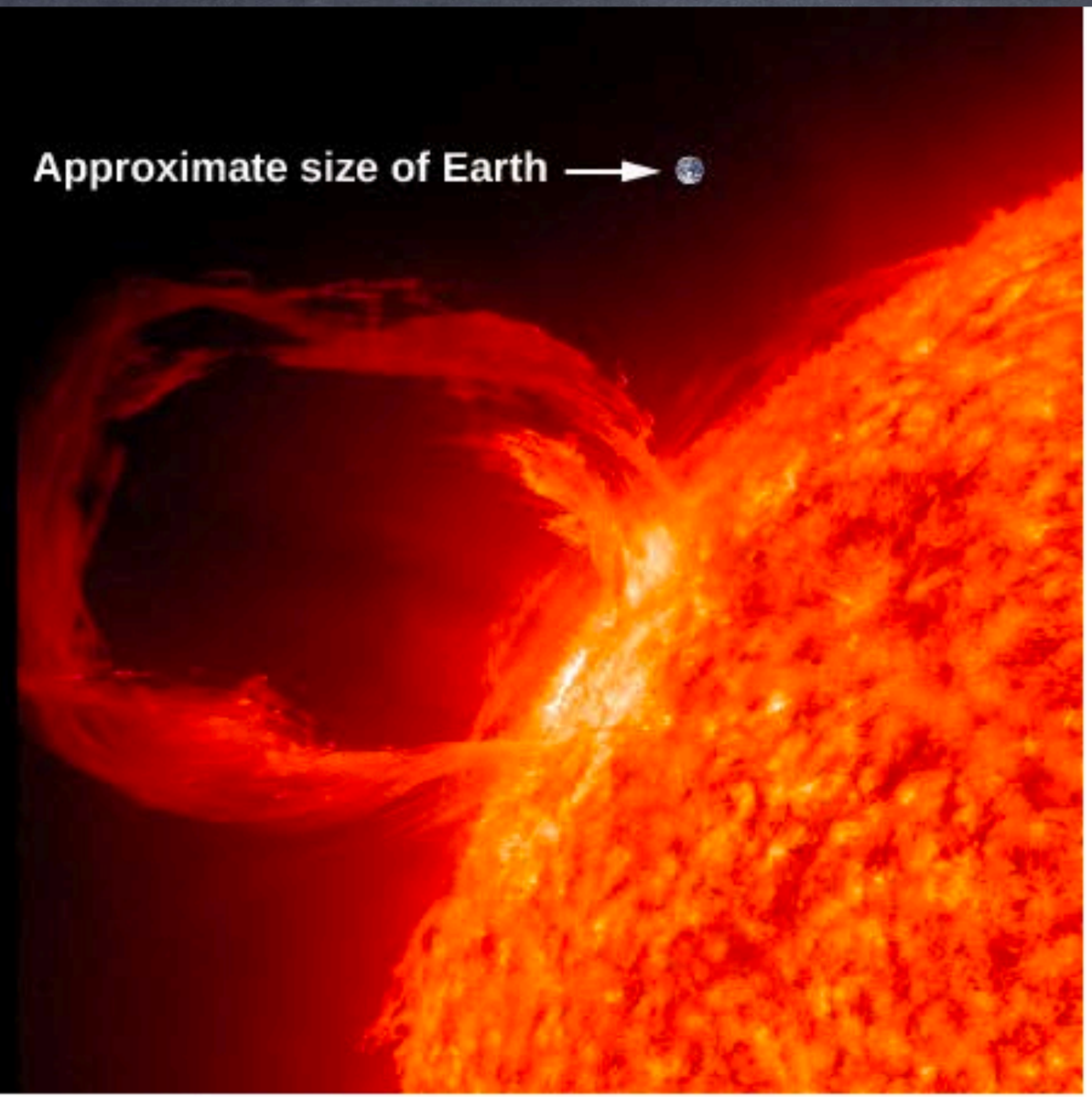
Solar Activity

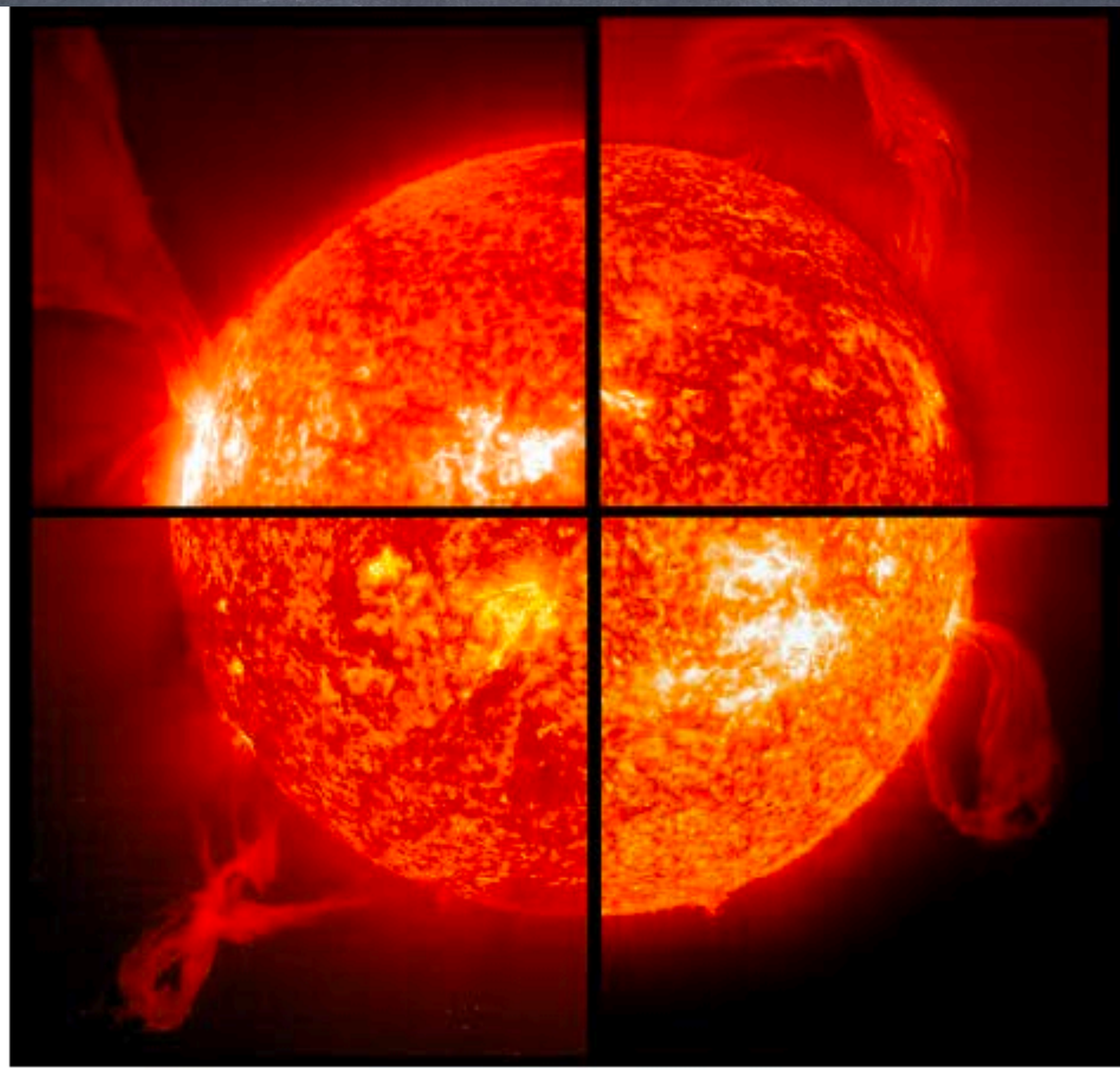
- There are many other phenomena associated with the sun's magnetic field:
  - plages - clouds above sunspots where the gas is hotter.
  - prominences - loops of plasma that come out of the photosphere, some erupt.
  - solar flares - massive explosions on the sun that last from 5-10 minutes to hours and release the energy of a millions of hydrogen bombs.
  - coronal mass ejections - some flares can eject large amounts of corona material and send it flying out into the solar system.



plages – image is taken in a single spectral line

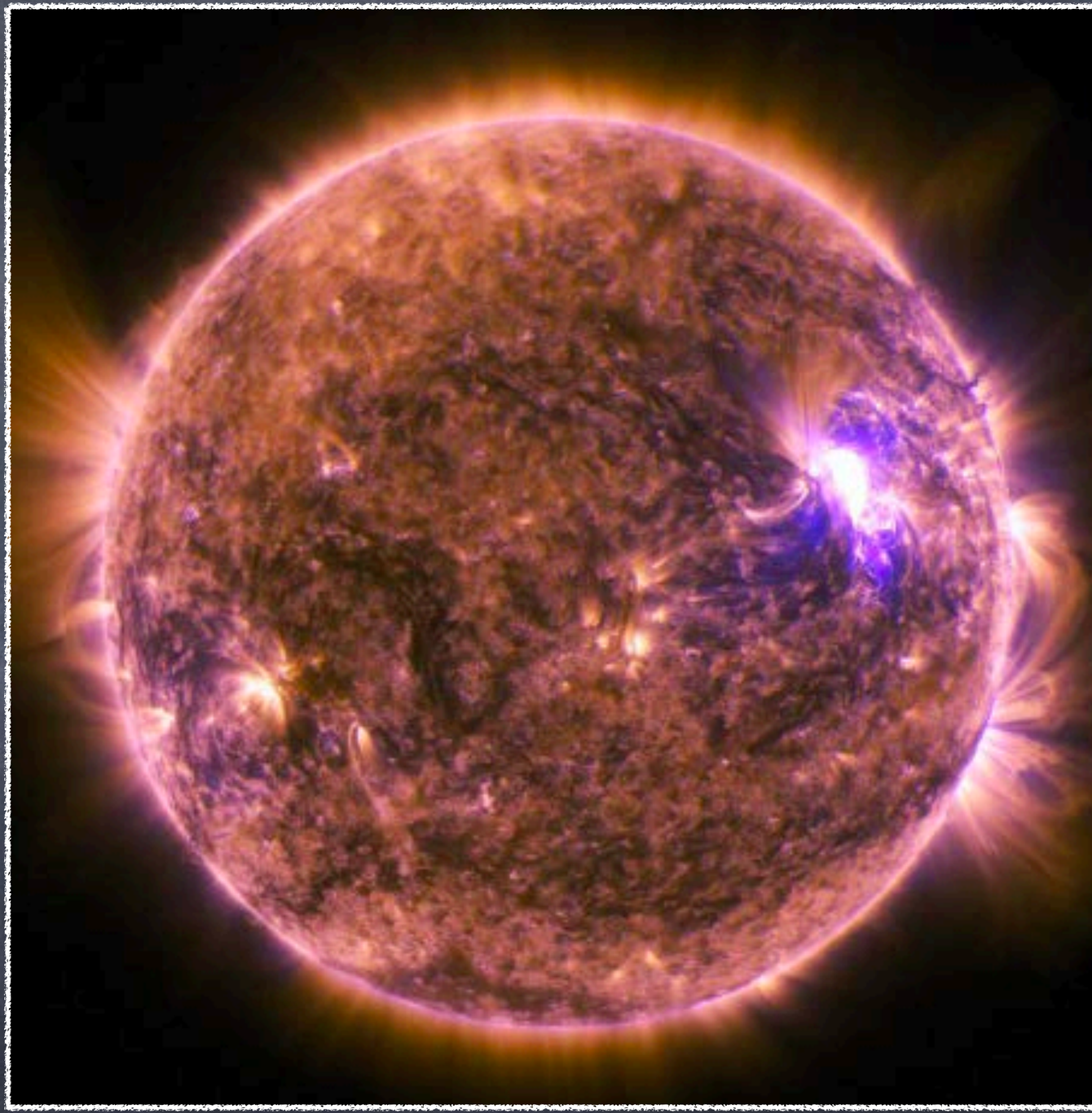
Solar Prominences



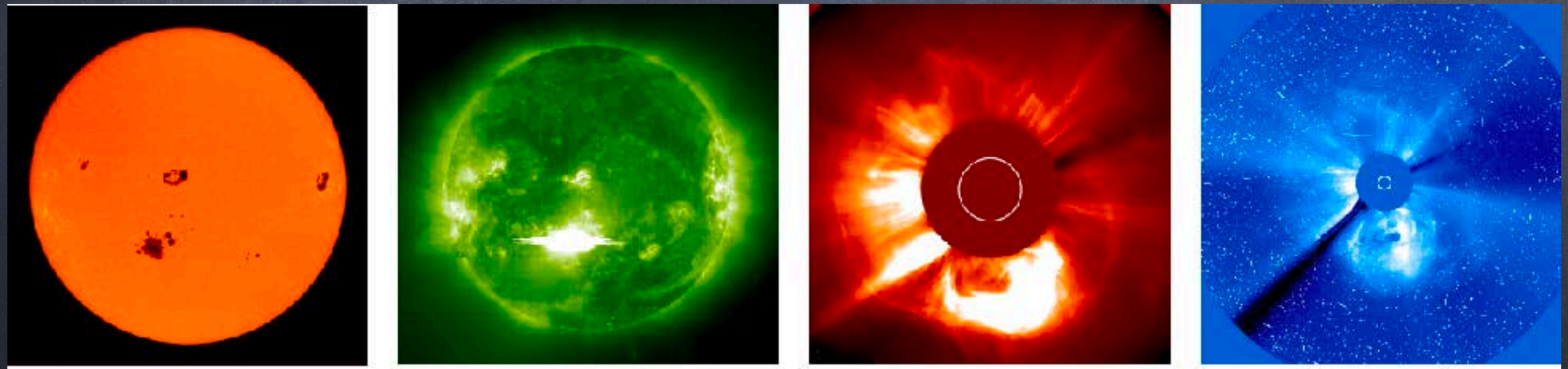


Solar Flares

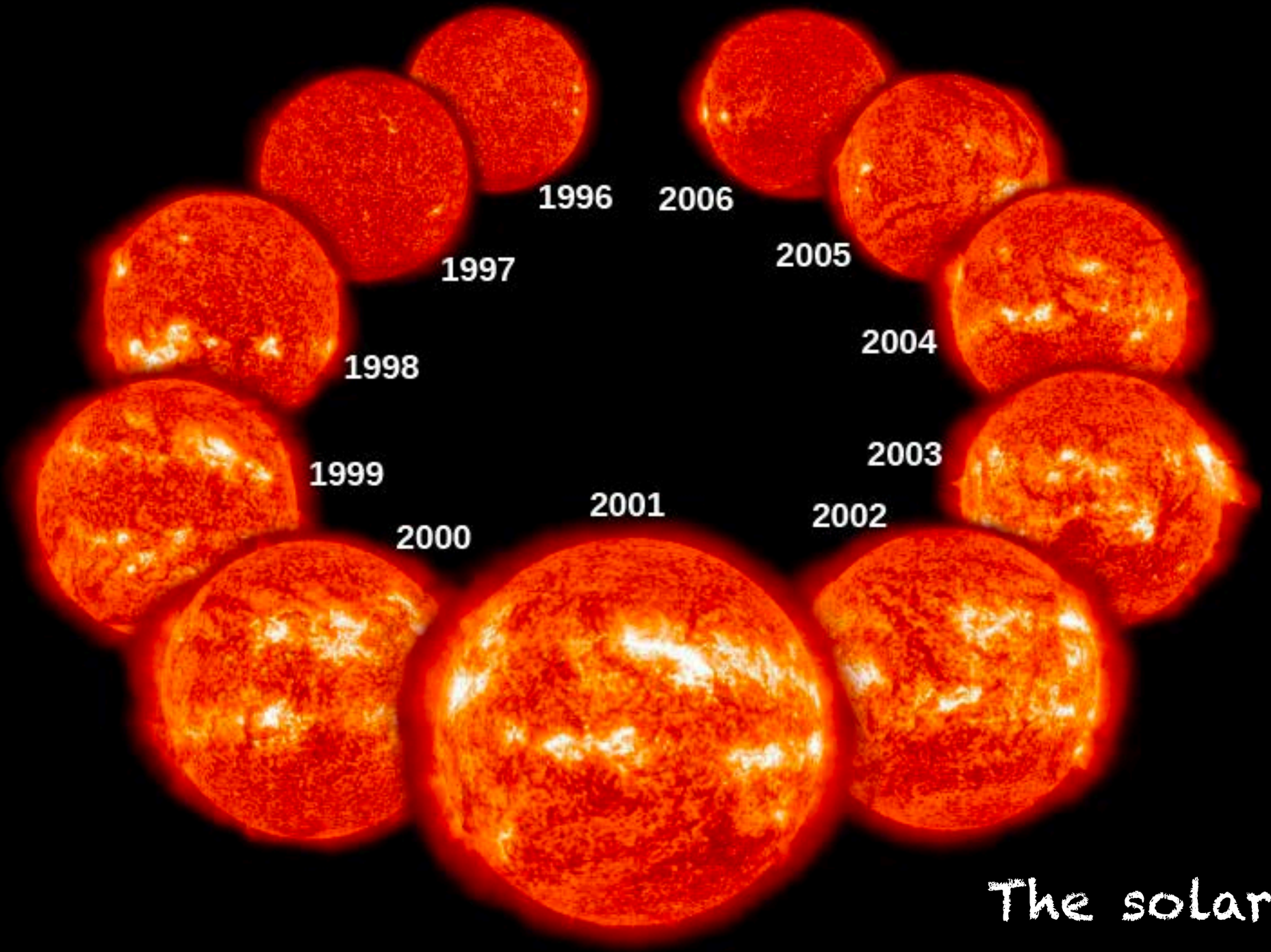
- Explosions last from minutes to hours and release tremendous amounts of energy.
- The largest flares emit 100,000 times the energy use of the US for a year.
- They heat gas to 10 million K and occur when magnetic fields collide and annihilate.



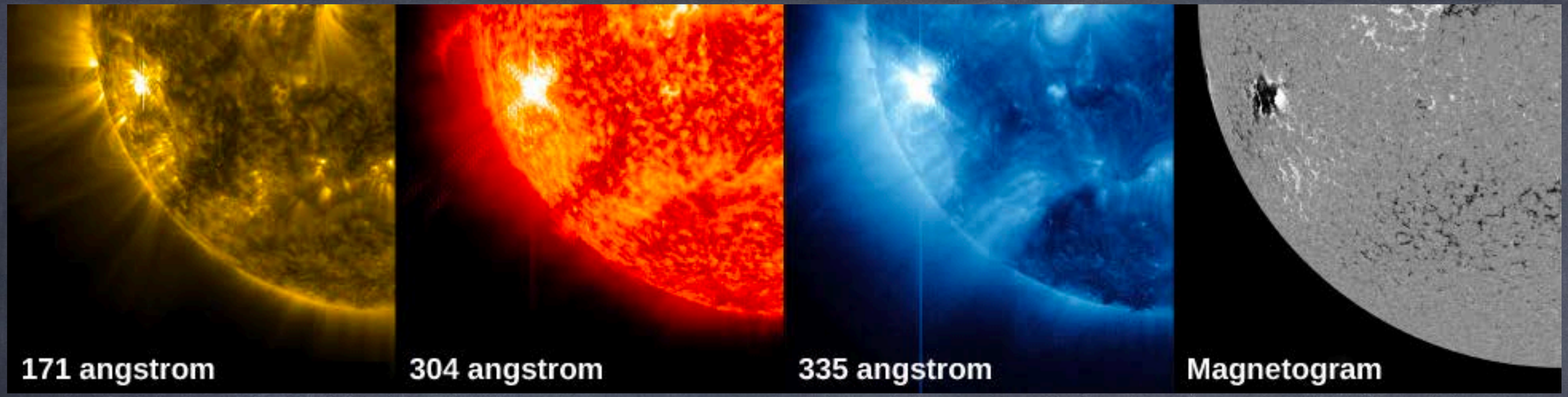
This sequence of four images shows the evolution over time of a giant eruption on the Sun. (a) The event began at the location of a sunspot group, and (b) a flare is seen in far-ultraviolet light. (c) Fourteen hours later, a CME is seen blasting out into space. (d) Three hours later, this CME has expanded to form a giant cloud of particles escaping from the Sun and is beginning the journey out into the solar system. The white circle in (c) and (d) shows the diameter of the solar photosphere.



(a) (b) (c) (d)



The solar cycle



These four images of a solar flare on October 22, 2012, show from the left: light from the Sun at a wavelength of 171 angstroms, which shows the structure of loops of solar material in the corona; ultraviolet at 304 angstroms, which shows light from the region of the Sun's atmosphere where flares originate; light at 335 angstroms, which highlights radiation from active regions in the corona; a magnetogram, which shows magnetically active regions on the Sun.

Space Weather

- Solar flares and coronal mass ejections can have noticeable effects around Earth.
- In particular they can damage satellites that aren't prepared for the increase in radiation.
- Charged particles can also reach the surface in northern regions and damage electronics.
- Satellites monitor the sun to detect these phenomena and warn the Earth when they occur.

https://www.spaceweather.com/