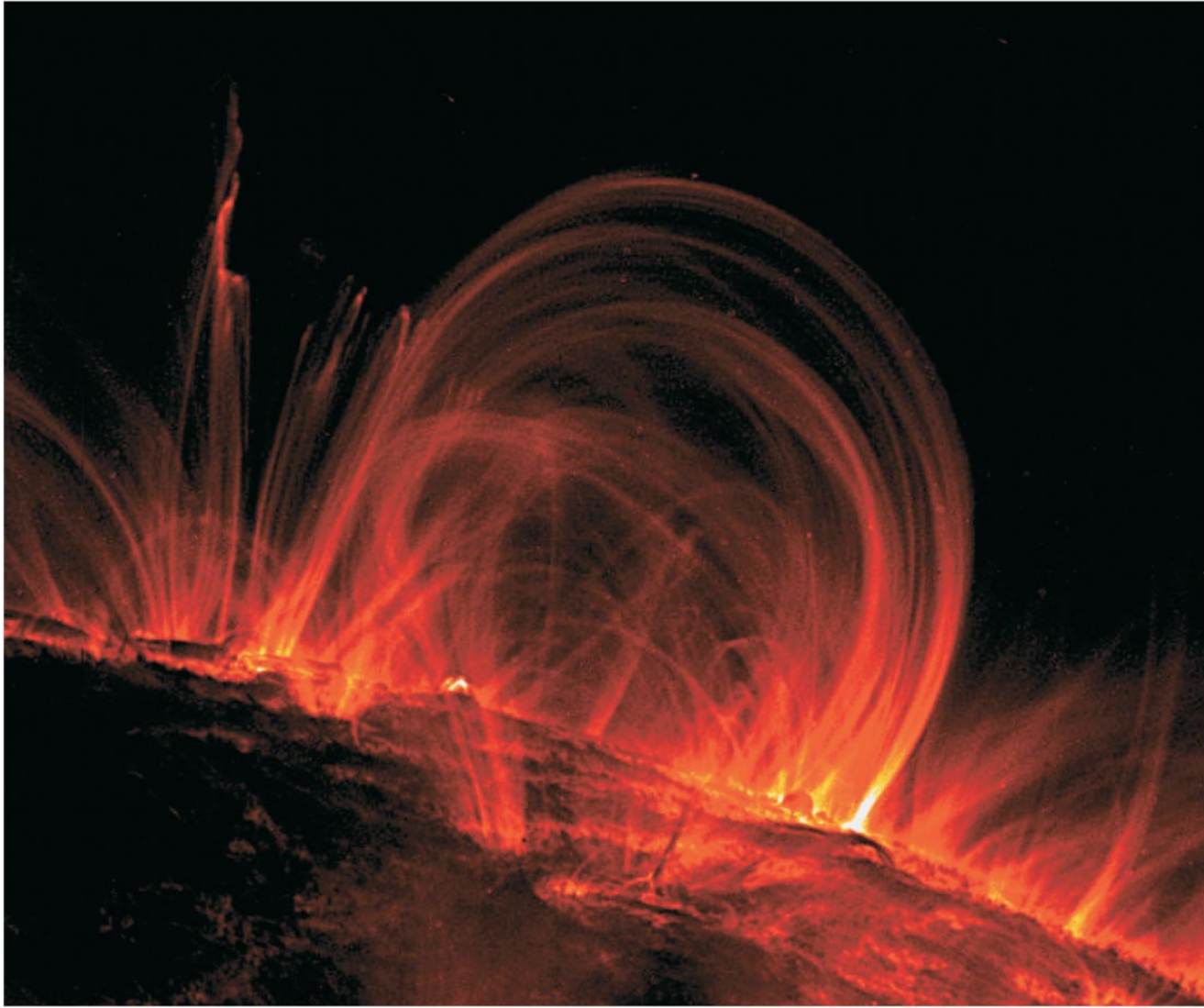


14.3 The Sun–Earth Connection

- Our goals for learning:
 - **What causes solar activity?**
 - **How does solar activity affect humans?**
 - **How does solar activity vary with time?**

What causes solar activity?



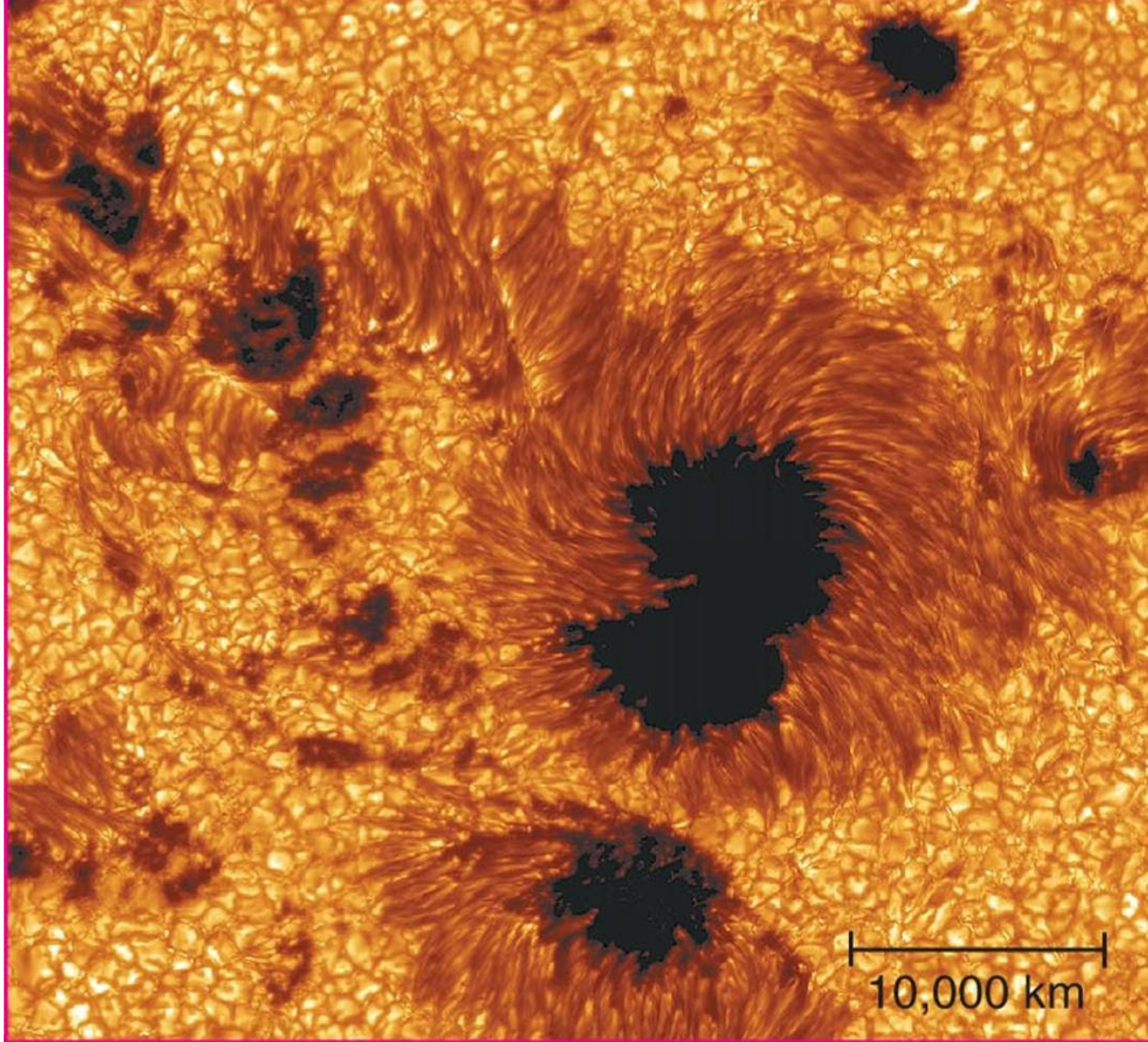
b This X-ray photo (from NASA's *TRACE* mission) shows hot gas trapped within looped magnetic field lines.

Solar activity is like "weather".

- Sunspots
- Solar flares
- Solar prominences

All these phenomena are related to the Sun's magnetic field. They expel hot gas and charged particles into the solar wind.

Take a look at the daily solar weather at spaceweather.com



Sunspots

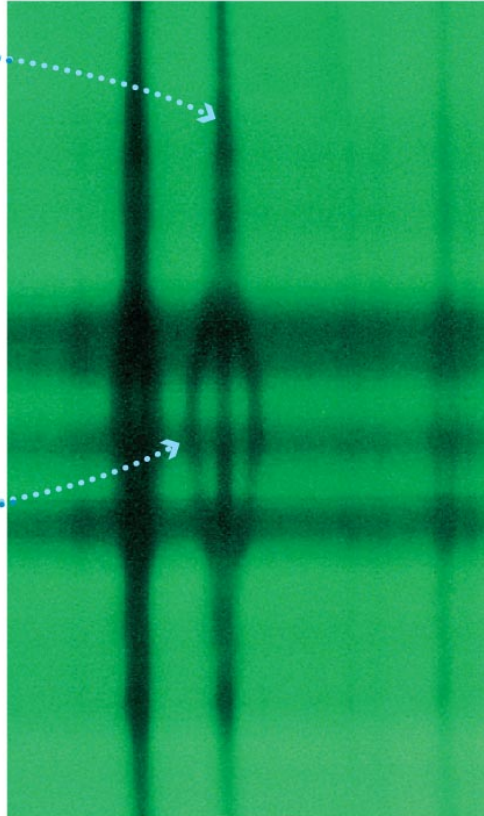
Are cooler
(~4000 K) than
the rest of the
Sun's surface
(~5800 K)

Are regions with
strong magnetic
fields

Last for days to
weeks

*Outside a sunspot
we see a single
spectral line . . .*

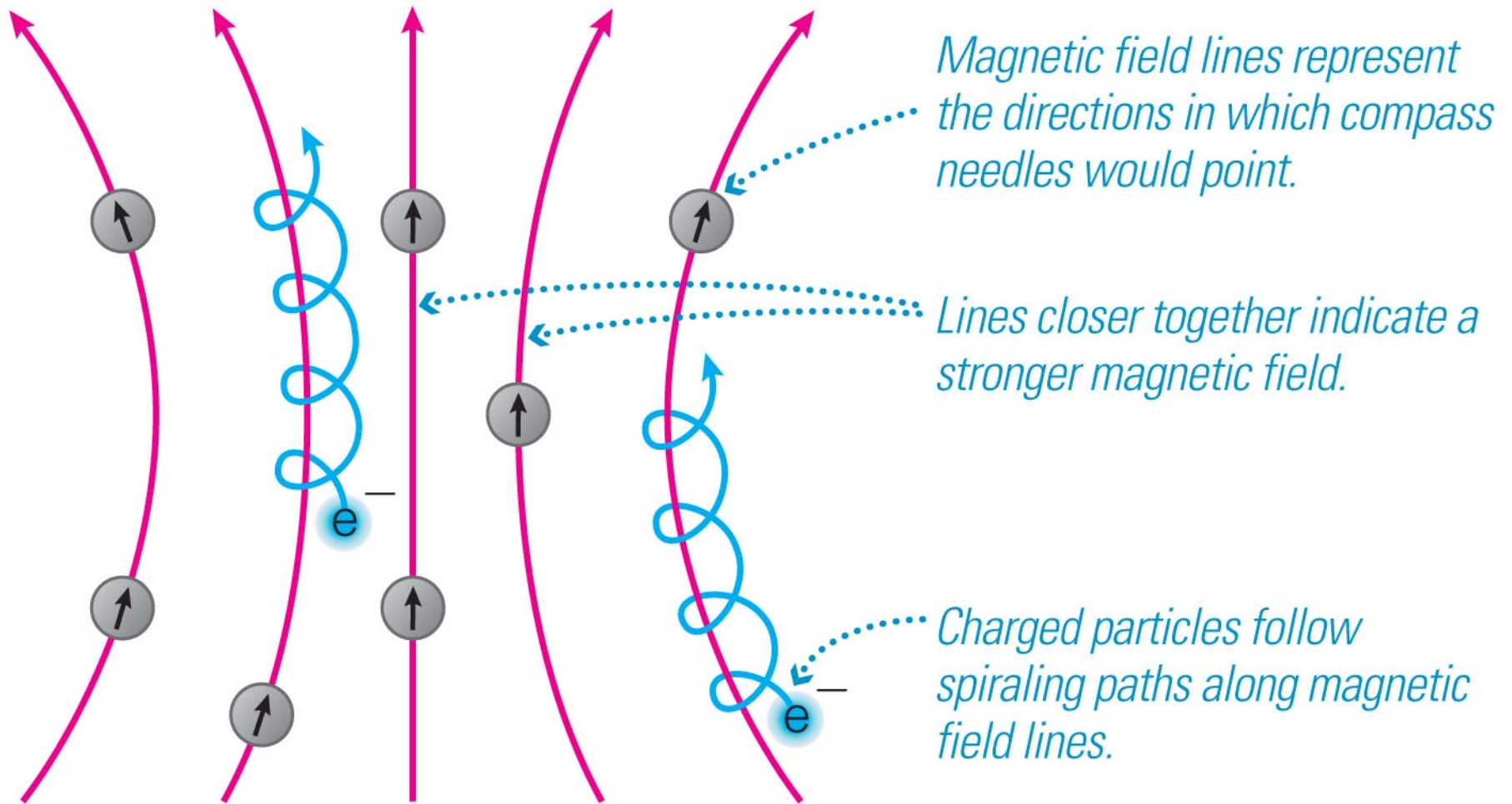
*. . . but the strong
magnetic field
inside a sunspot
splits that line
into three lines.*



b Very strong magnetic fields split the absorption lines in spectra of sunspot regions. The dark vertical bands are absorption lines in a spectrum of the Sun. Notice that these lines split where they cross the dark horizontal bands corresponding to sunspots.

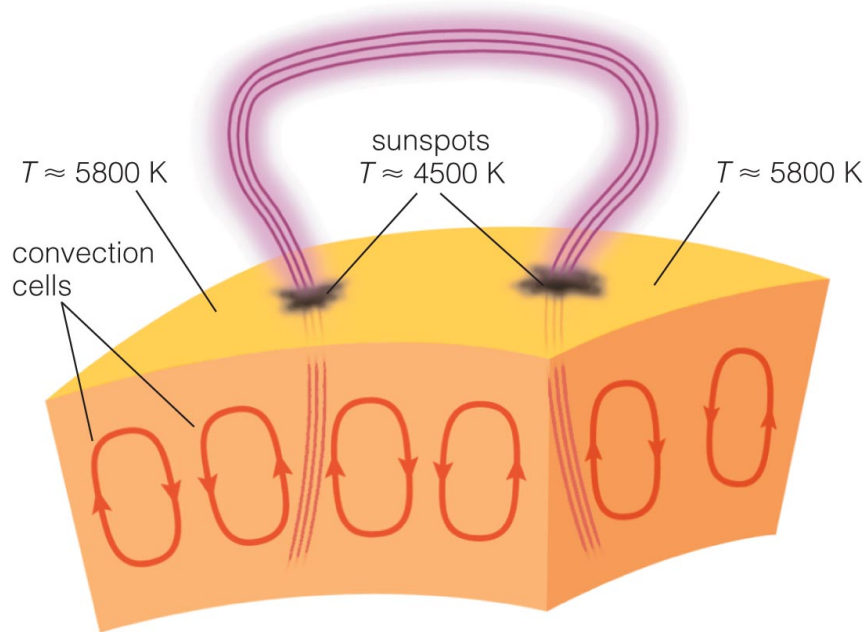
Zeeman Effect

- We can measure magnetic fields in sunspots by observing the splitting of spectral lines.

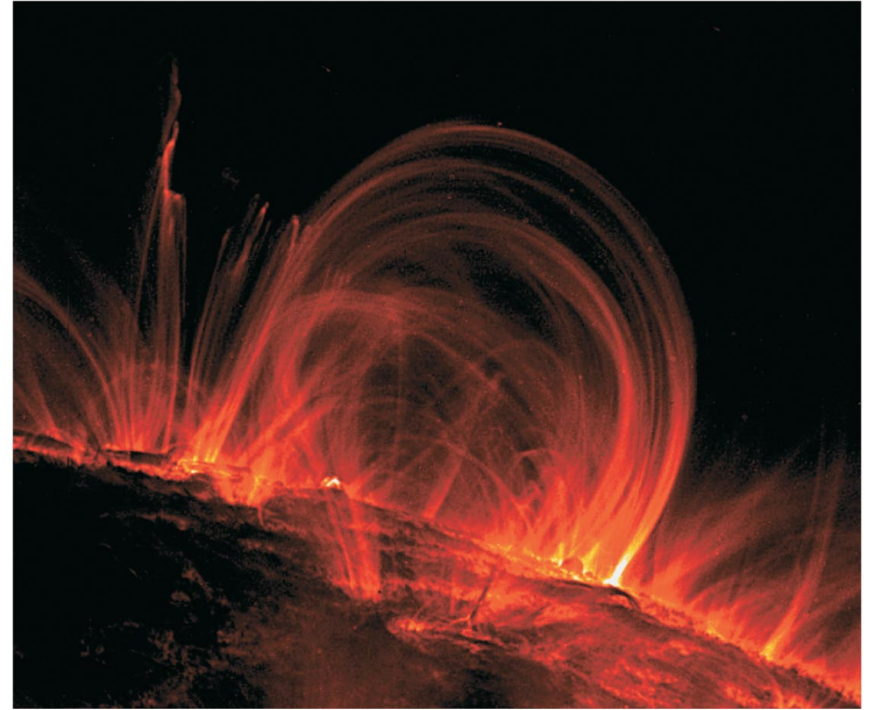


Charged particles (protons, electrons, nuclei) spiral along magnetic field lines.

Loops of bright gas often connect sunspot pairs.

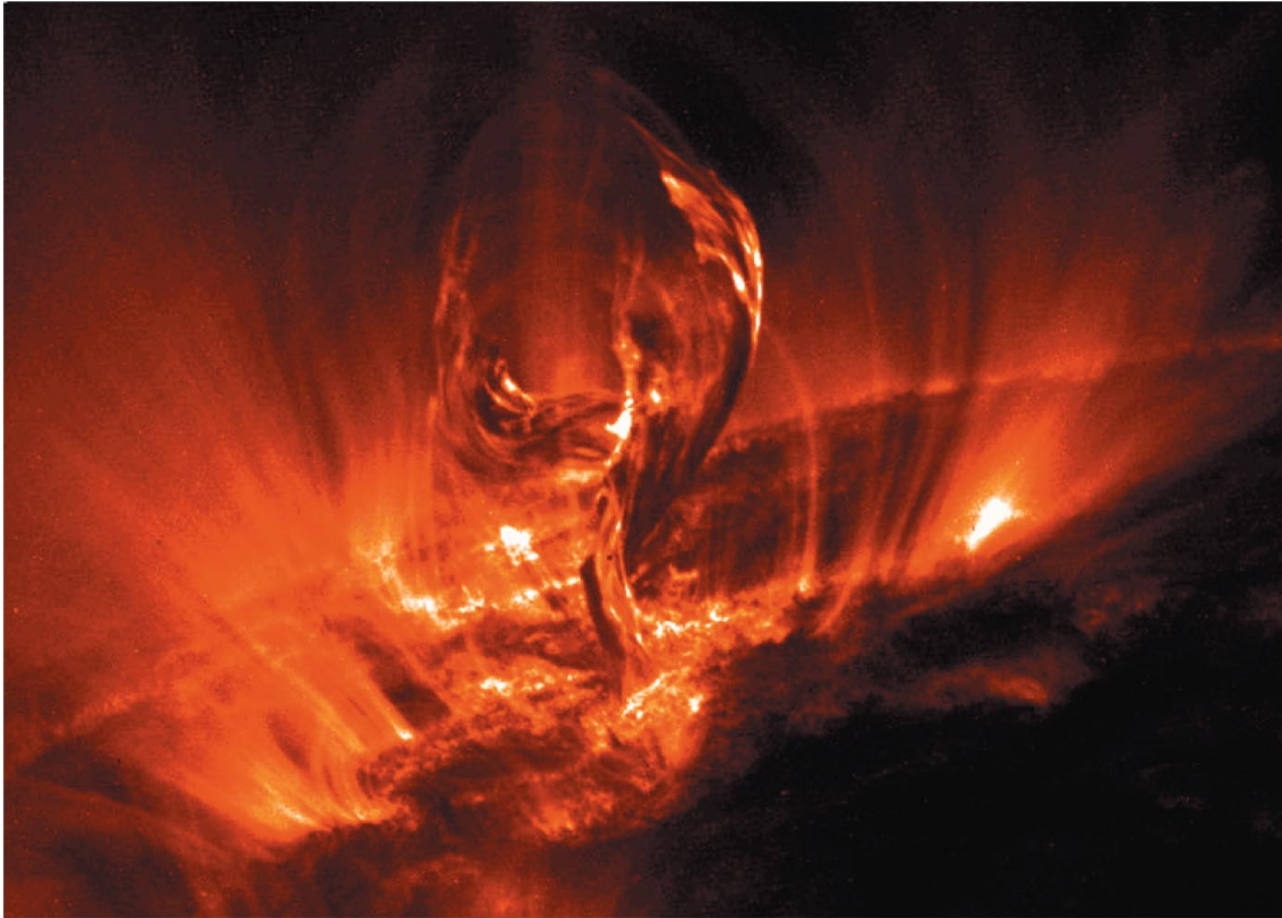


a Pairs of sunspots are connected by tightly wound magnetic field lines.



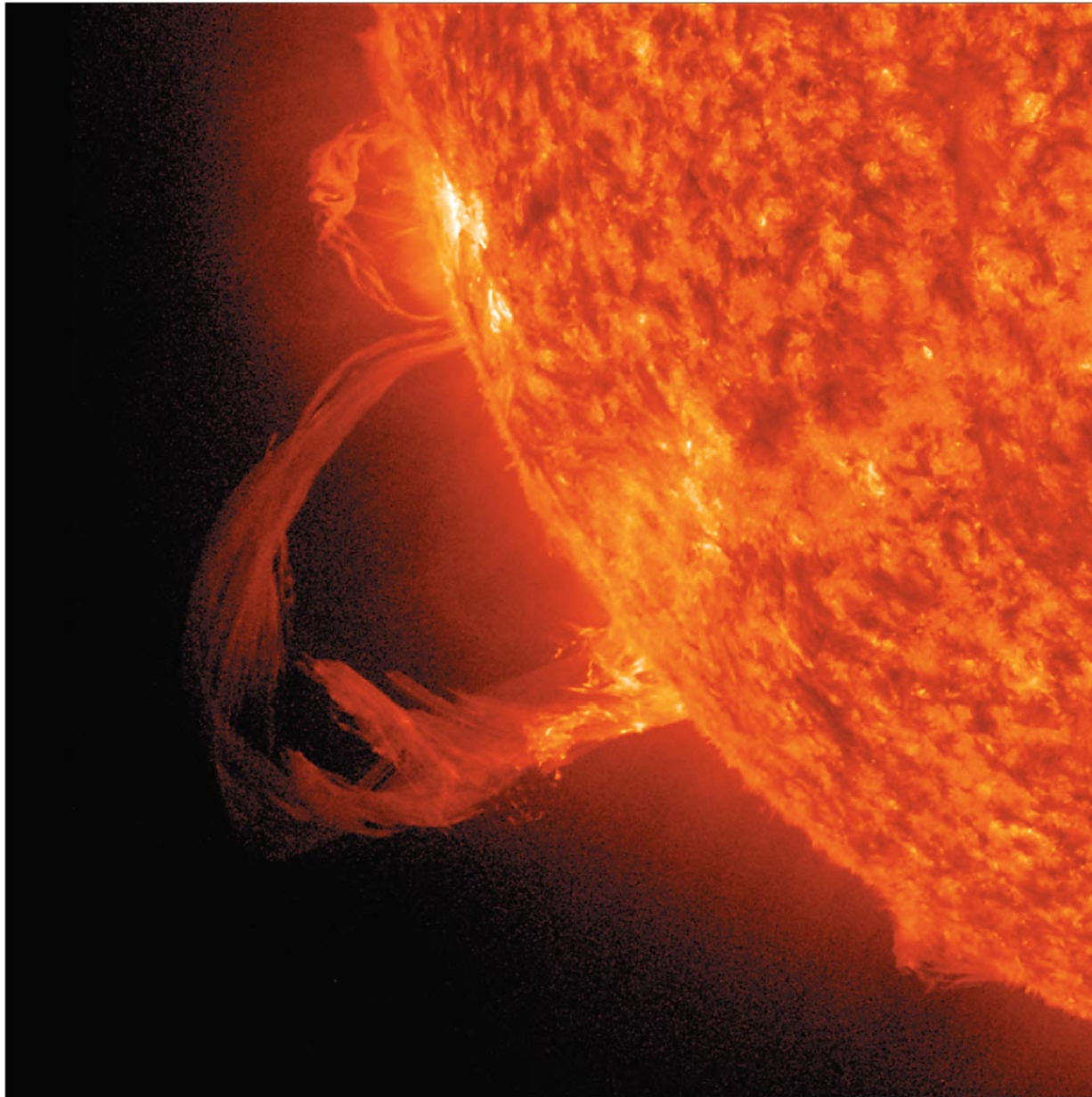
b This X-ray photo (from NASA's *TRACE* mission) shows hot gas trapped within looped magnetic field lines.

Gas entrained along magnetic loops



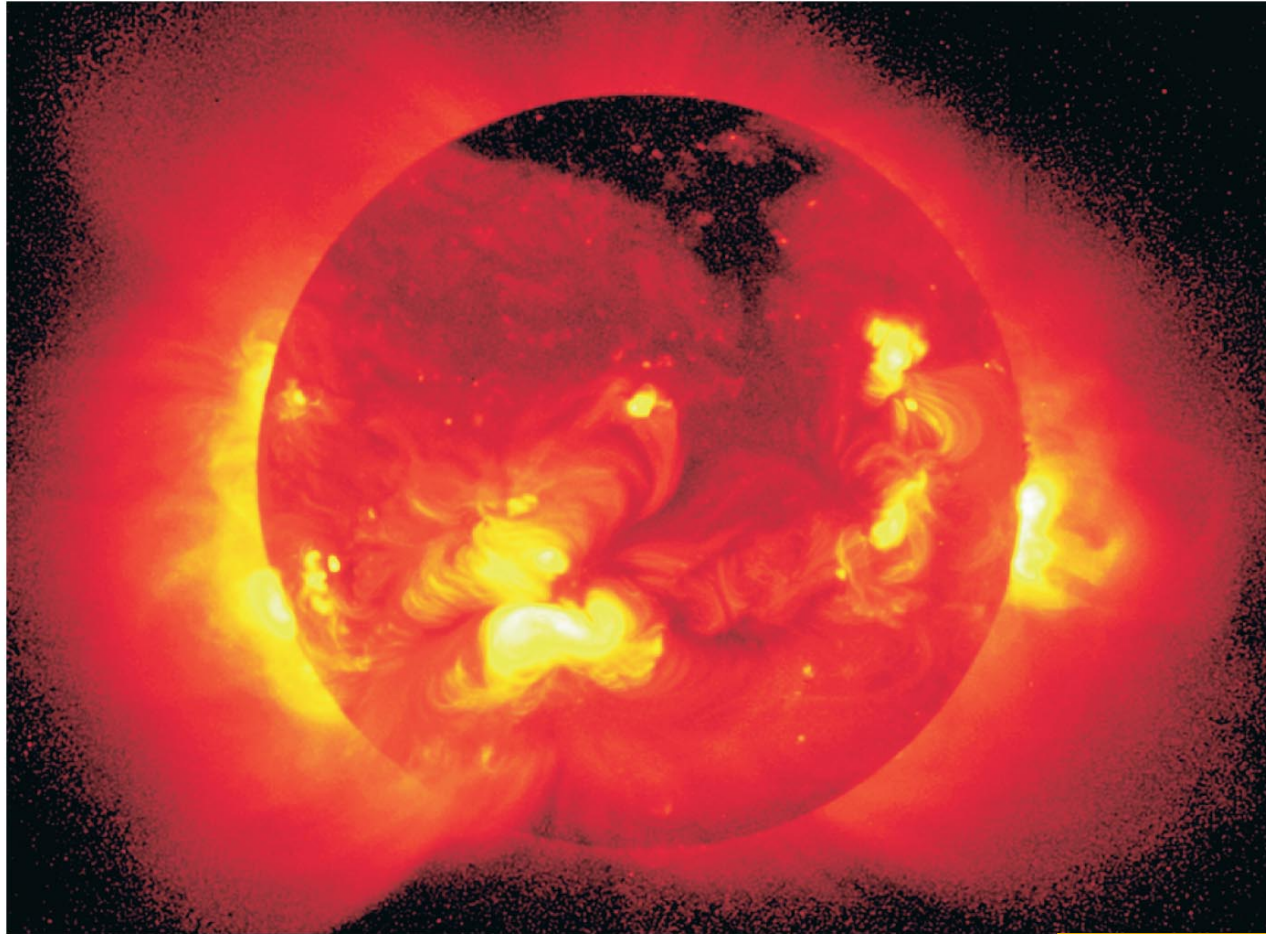
Magnetic activity causes ***solar flares*** that send bursts of X rays and charged particles into space.

[\(solar flare video\)](#)



Magnetic activity also causes ***solar prominences*** that erupt high above the Sun's surface.

[\(solar prominence video\)](#)

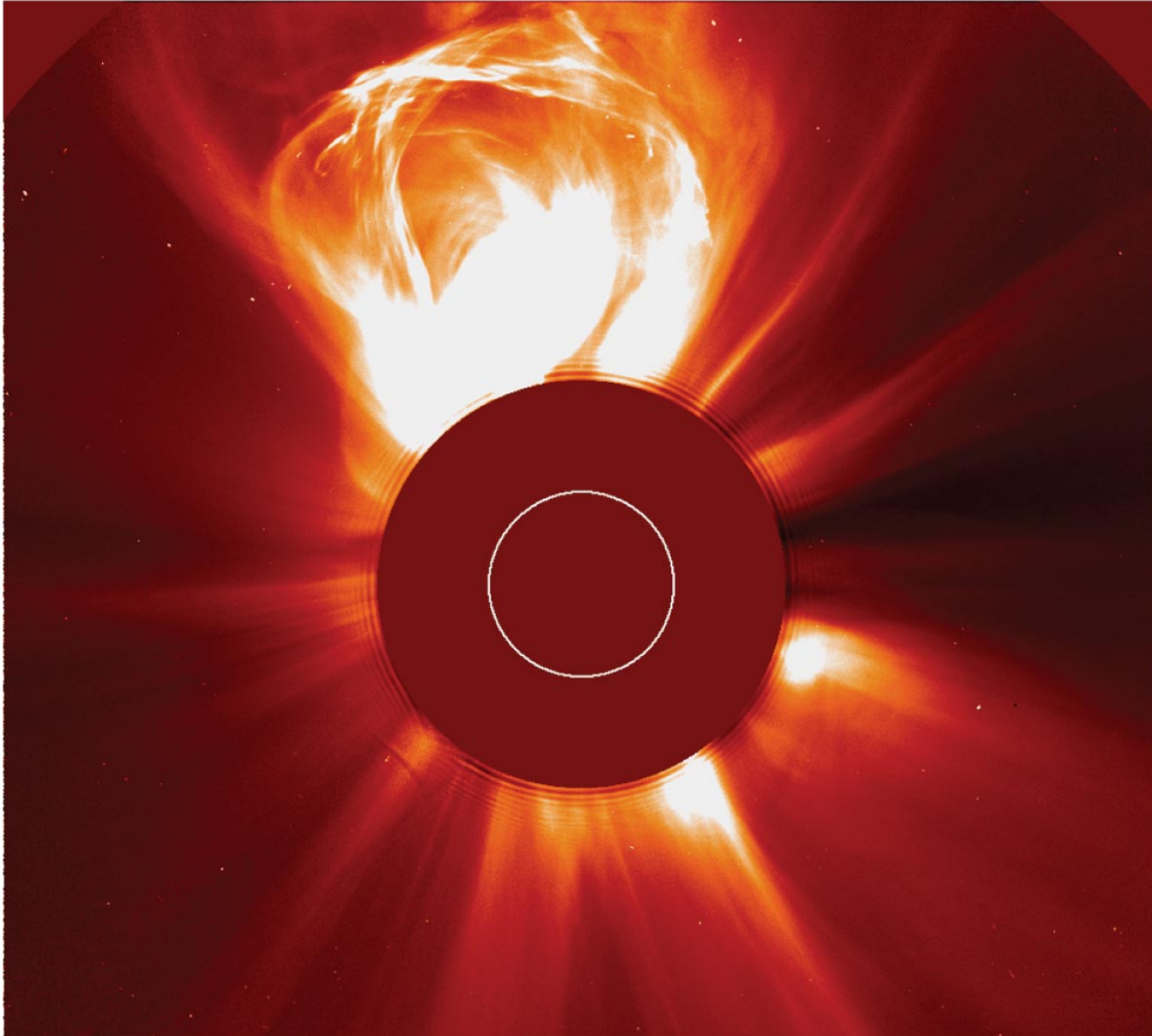


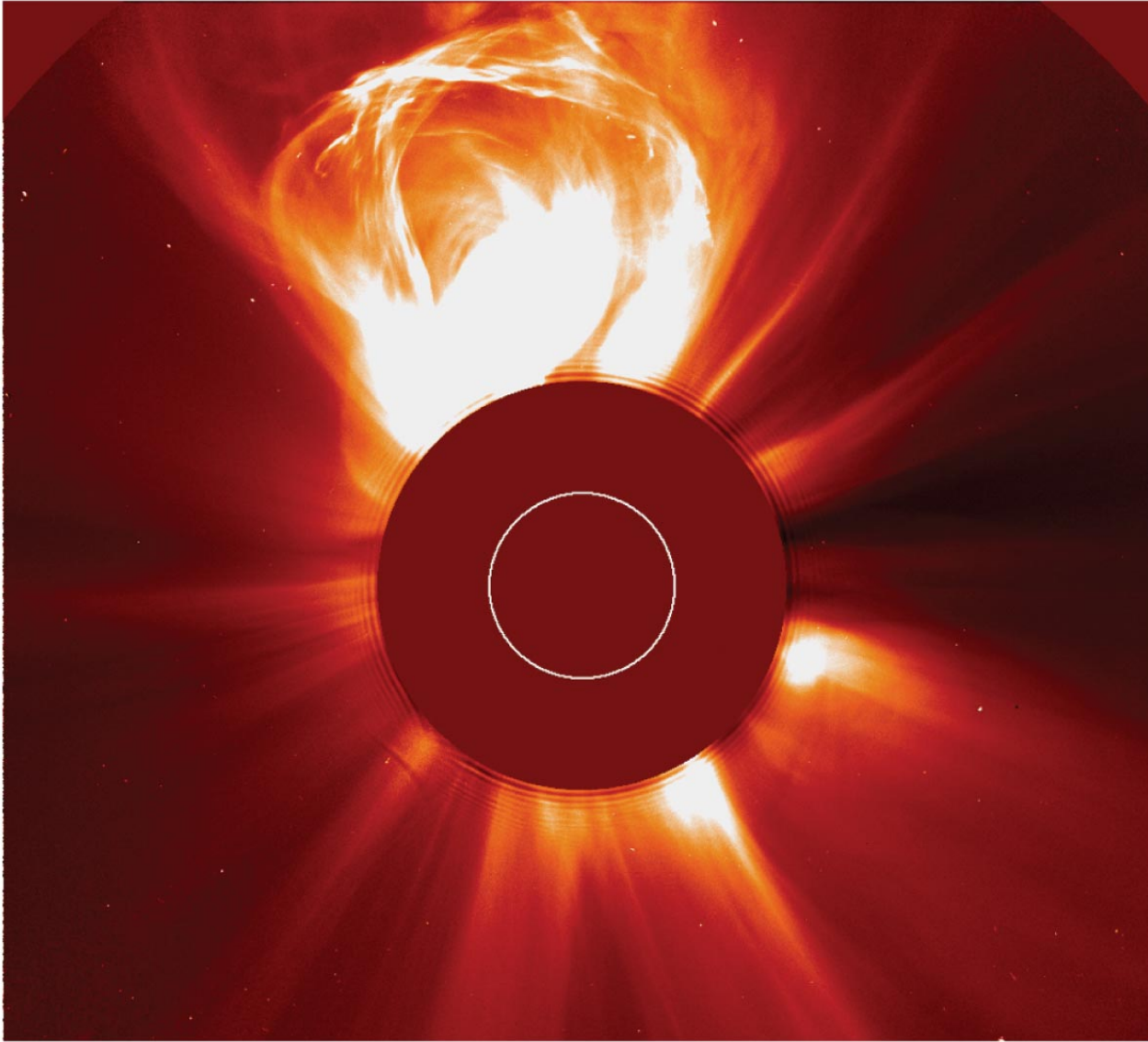
Interactive Figure 

The corona appears bright in X-ray photos in places where magnetic fields trap hot gas.

The heating of the upper layers of the Sun is due to this strong solar activity

How does solar activity affect humans?

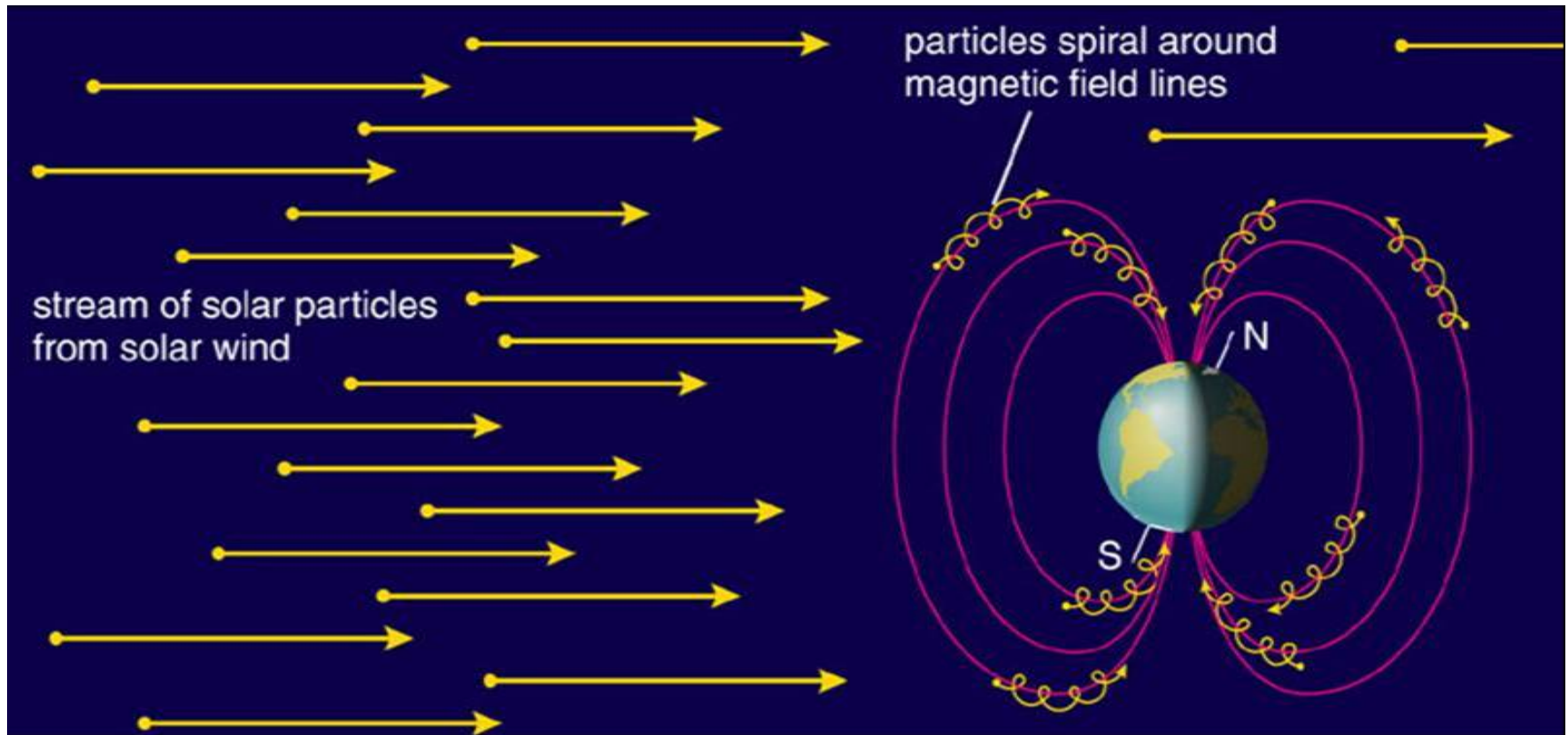




Coronal mass ejections send bursts of energetic charged particles out through the solar system.

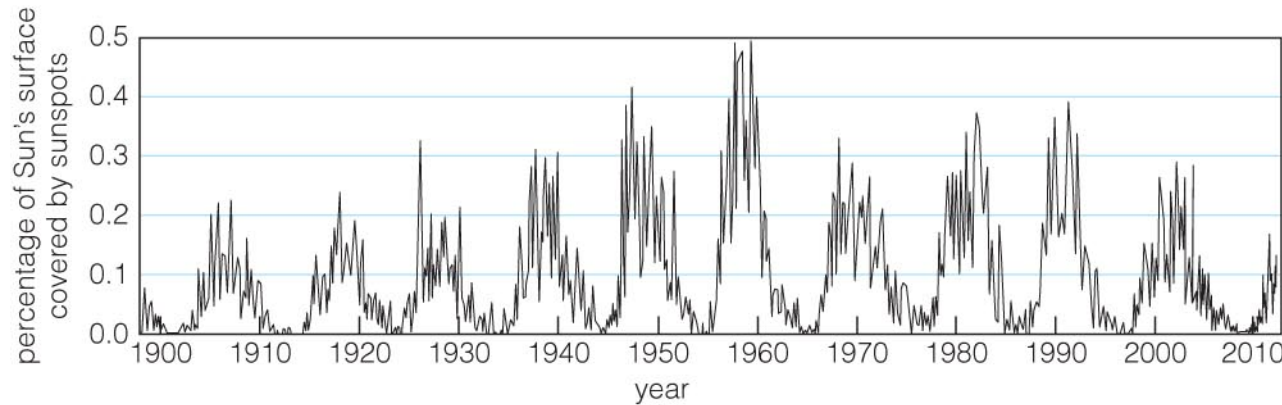
[CME movie](#)

[CME + Comet Machholtz](#)



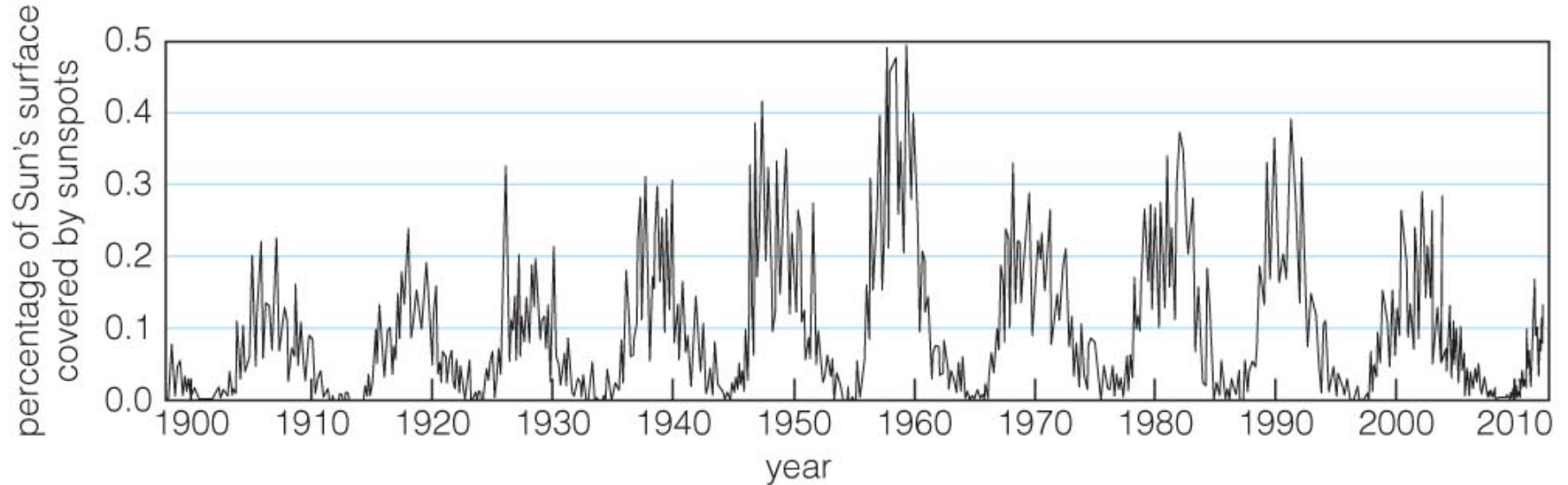
- Charged particles streaming from the Sun can disrupt electrical power grids and can disable communications satellites. ([1989 Quebec blackout](#))
- They also produce spectacular auroras! ([spaceweather.com](#))

How does solar activity vary with time?



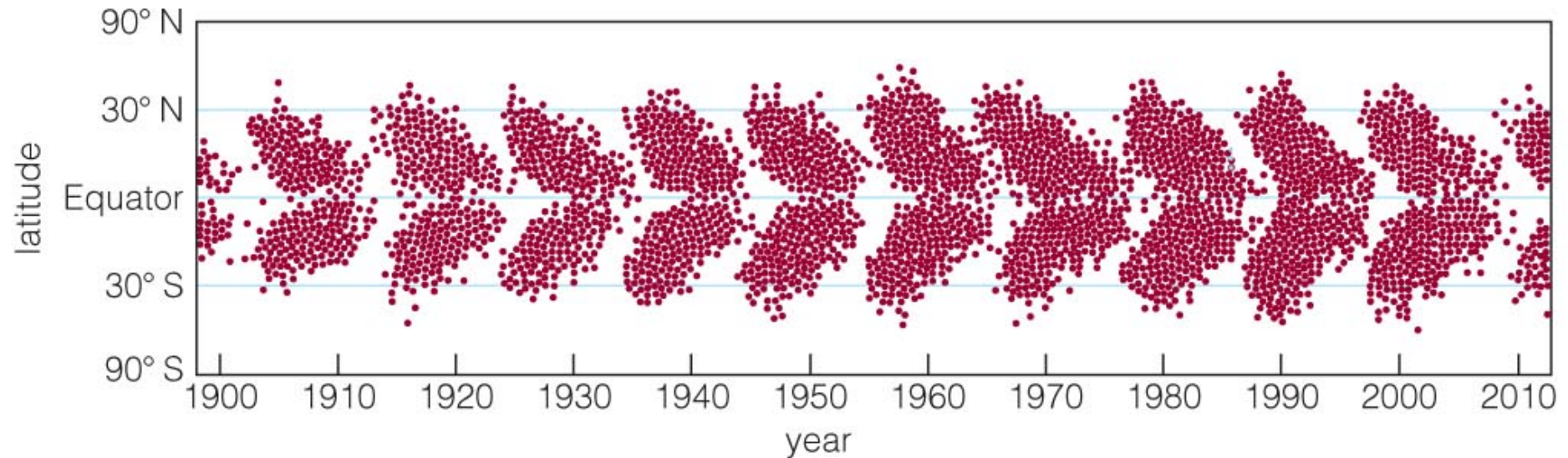
a This graph shows how the number of sunspots on the Sun changes with time. The vertical axis shows the percentage of the Sun's surface covered by sunspots. The cycle has a period of approximately 11 years.

Sunspot numbers



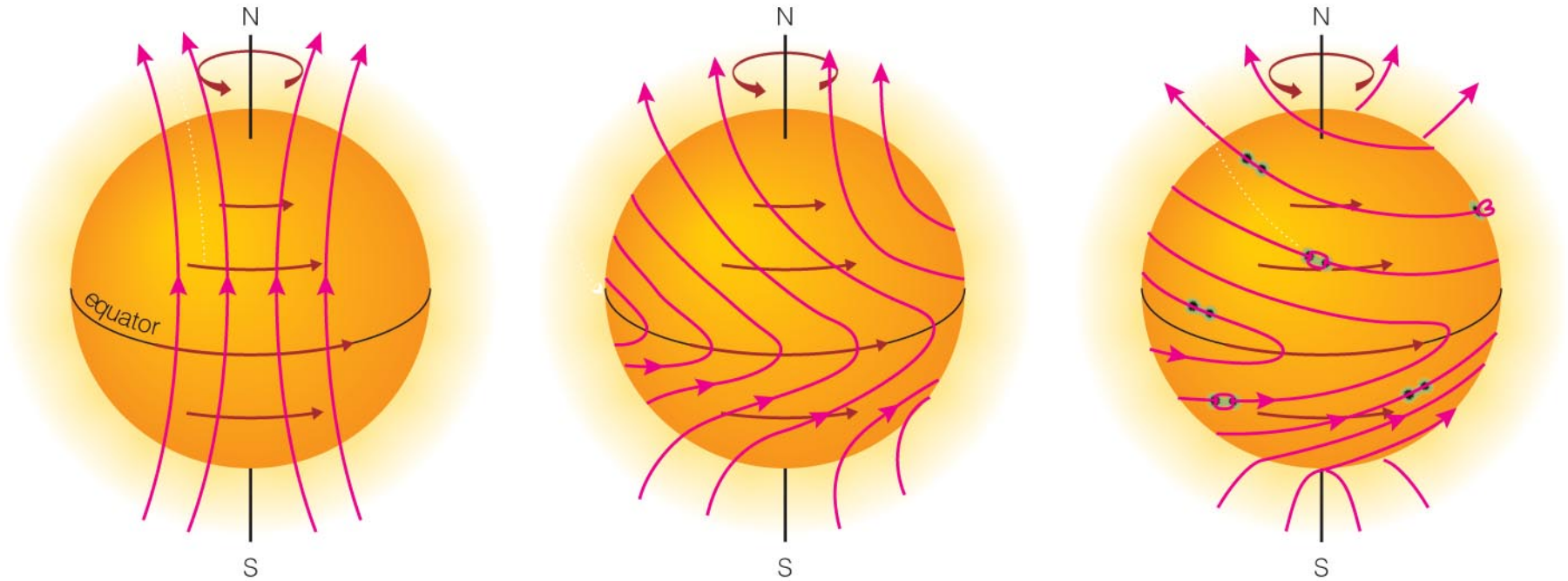
The number of sunspots rises and falls in an 11-year cycle.

Sunspot locations



At the beginning of the cycle, sunspots appear near the mid-latitudes but later show up progressively closer to the Sun's equator (but sunspots themselves don't move...).

The Sun's magnetic field



- The Sun rotates differentially – equator rotates faster than poles. This winds up and kinks the solar magnetic field.
- Where kinked magnetic field lines pop out of the surface, you get sunspots and solar activity.
- The more contorted the magnetic field, the more solar activity.
- Eventually (somehow) the field “reconnects” into a simple form and everything calms down.... for a while.

What have we learned?

- **What causes solar activity?**
 - Stretching and twisting of magnetic field lines near the Sun's surface cause solar activity.
- **How does solar activity affect humans?**
 - Bursts of charged particles from the Sun can disrupt radio communication and electrical power generation and damage satellites.
- **How does solar activity vary with time?**
 - Activity rises and falls with an 11-year period.