Reminders

- Test tomorrow
- MA Week 2 Homework Due Tomorrow
  - Email us once you complete the “tutorial style” activities (Telescopes and Measuring Cosmic Distances)
- Review will be before the test
  BRING QUESTIONS!

ASTR 1120
:: Star and Galaxies ::

The Sun (cont'd) and other Stars

Adam Ginsburg & Devin Silvia
July 2010

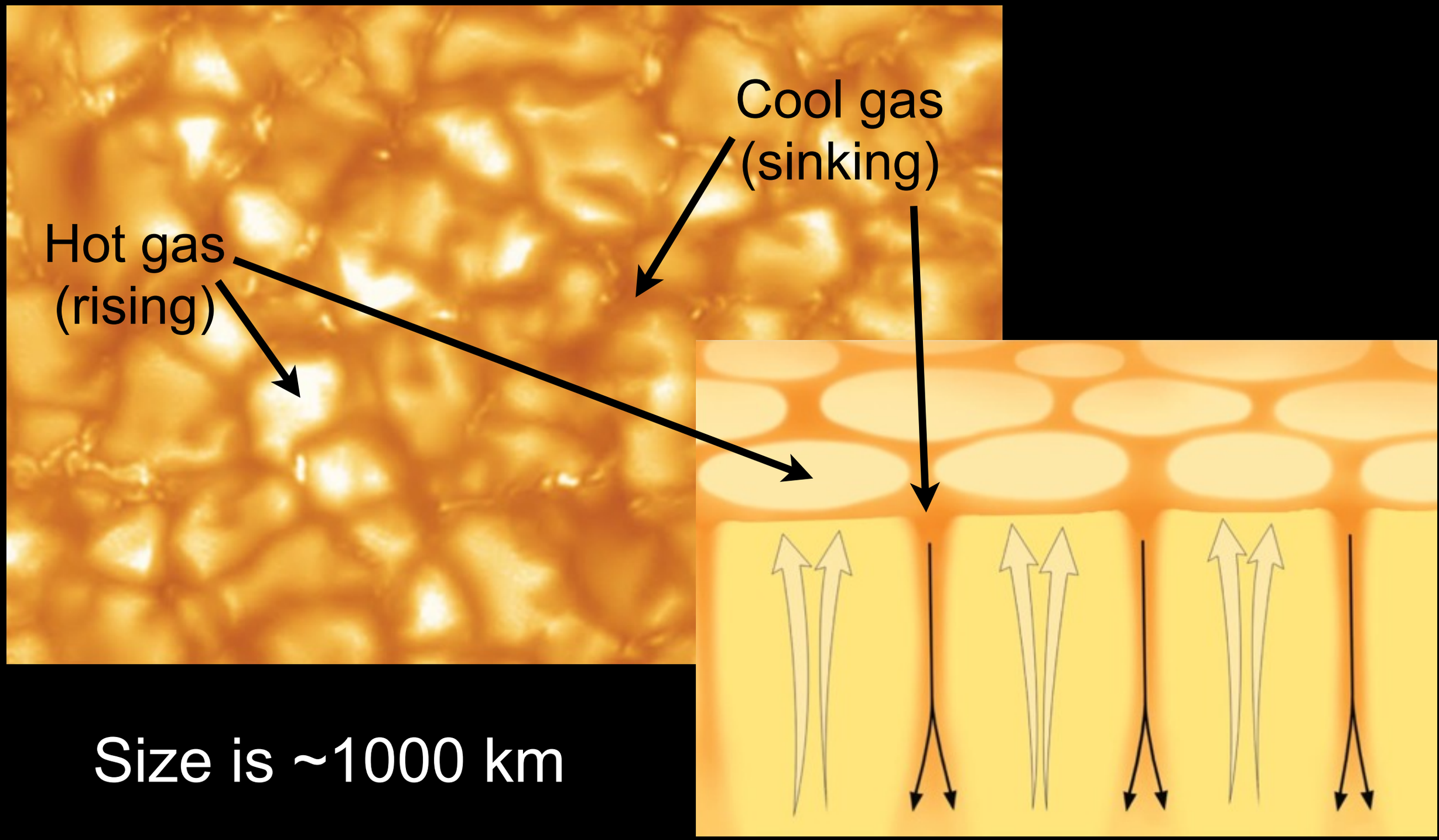
Learning Goals

- Complete our understanding of the Sun
  - Surface features
  - Methods for peering inside the Sun
  - Earth-Sun connection
- What about other stars?
  - How do their properties compare?
  - How can we determine those properties?

(Suggested readings: Chapters 14 and 15)

What does the surface of the Sun look like?

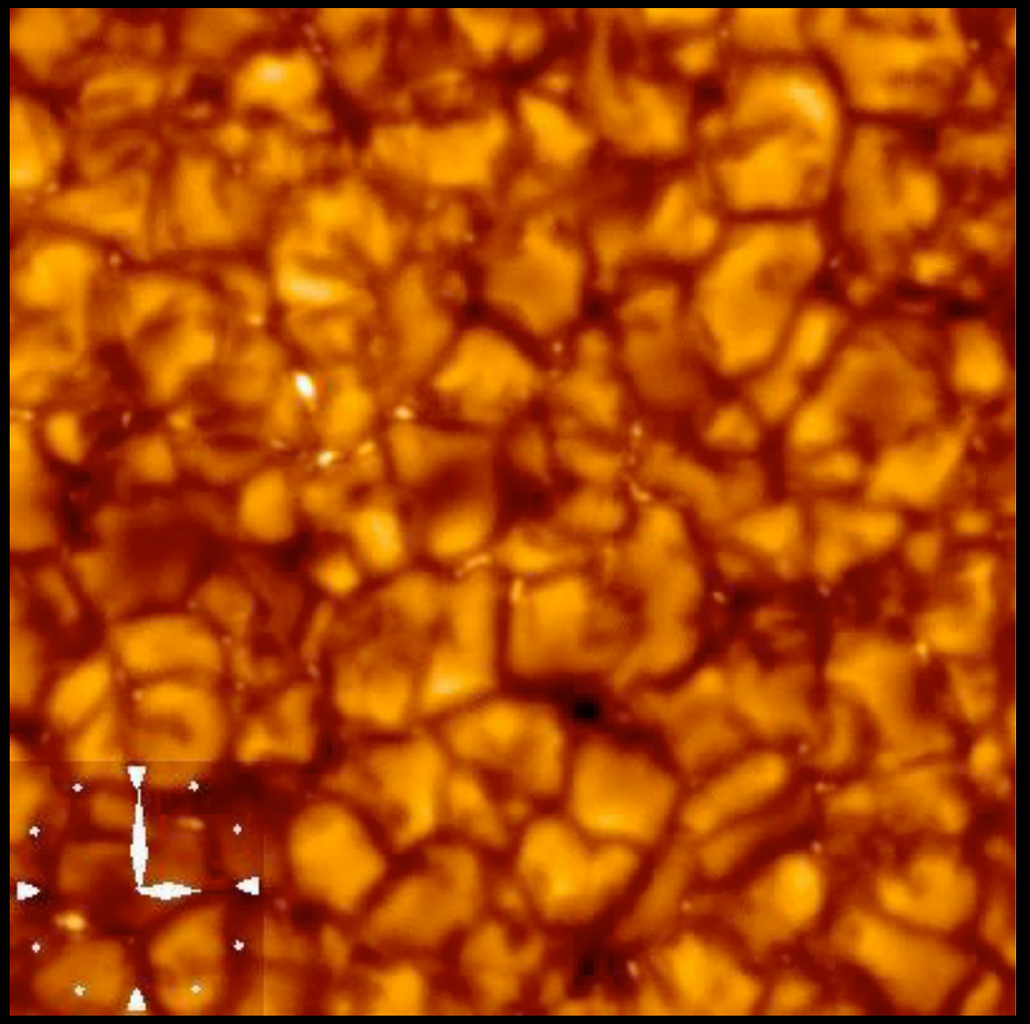
Solar Granulation



Size is ~1000 km

Let’s see it in action!

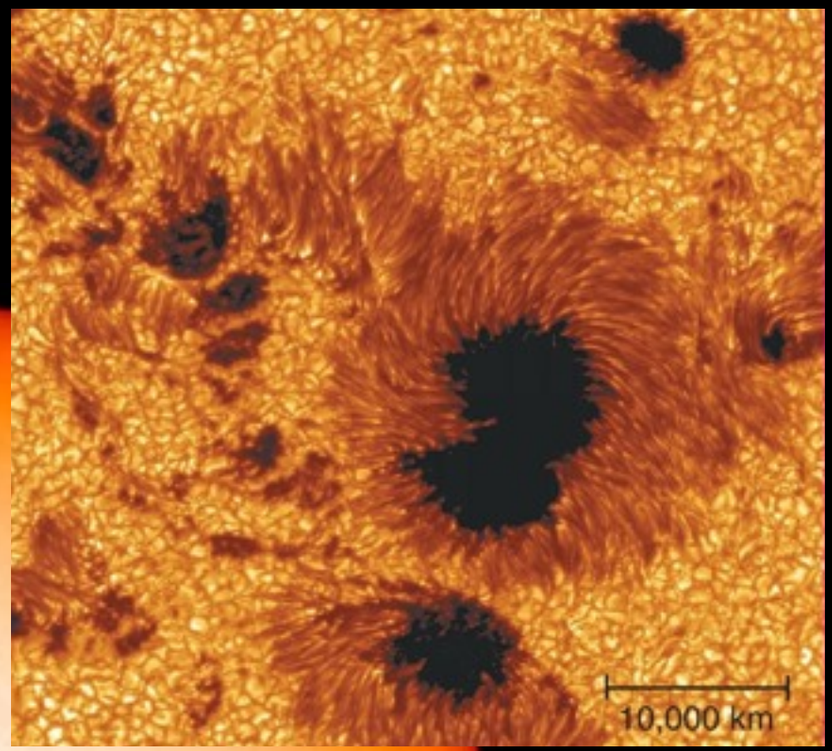
Granules typically only last 8-15 minutes



Movie is from the Japanese Hinode spacecraft

Sun spots

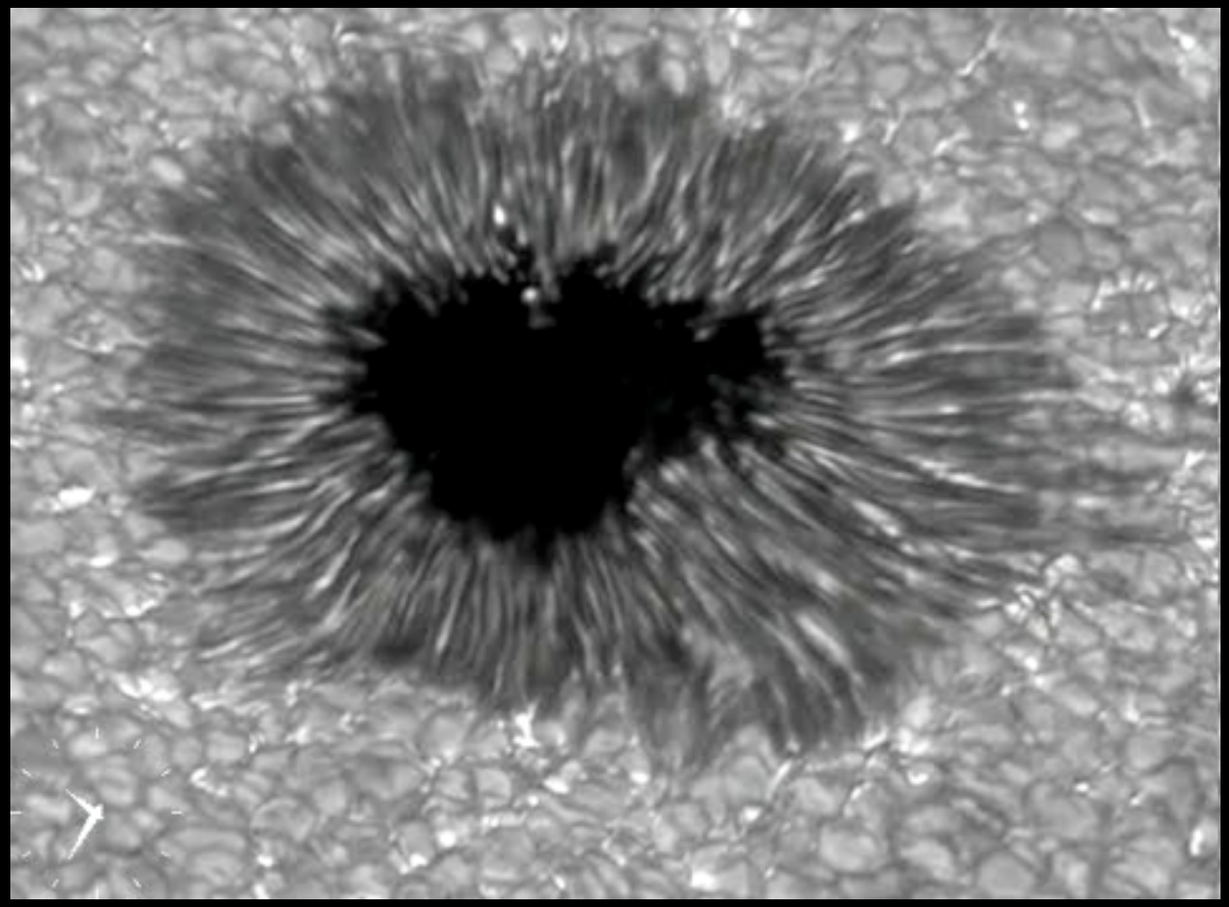
Darker because they are cooler,
but still ~4000 K



This “spot” covers
and area comparable
to ~15 Earths!

Image from the
Solar and
Heliospheric
Observatory
(SOHO)

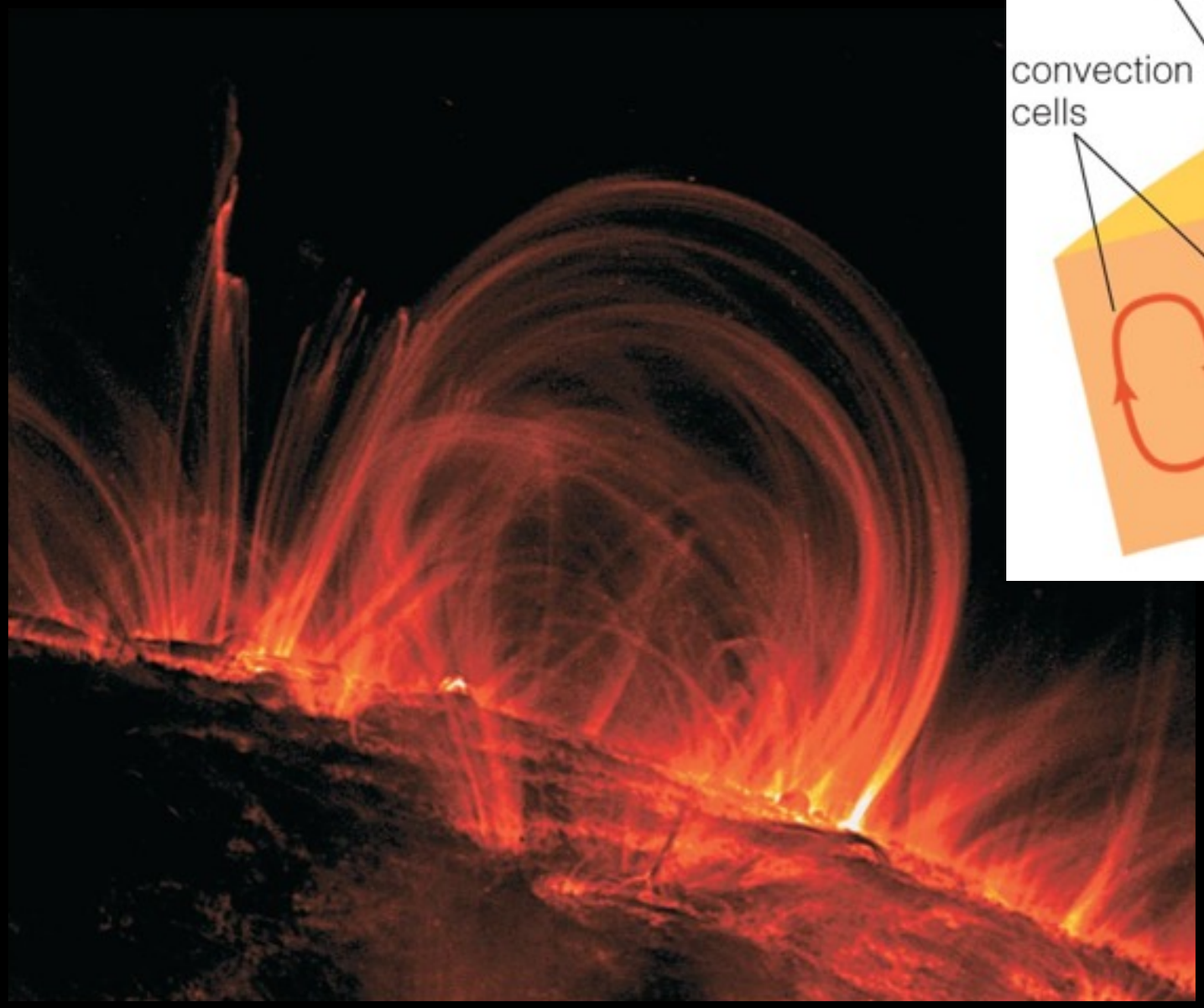
Sun Spot Activity

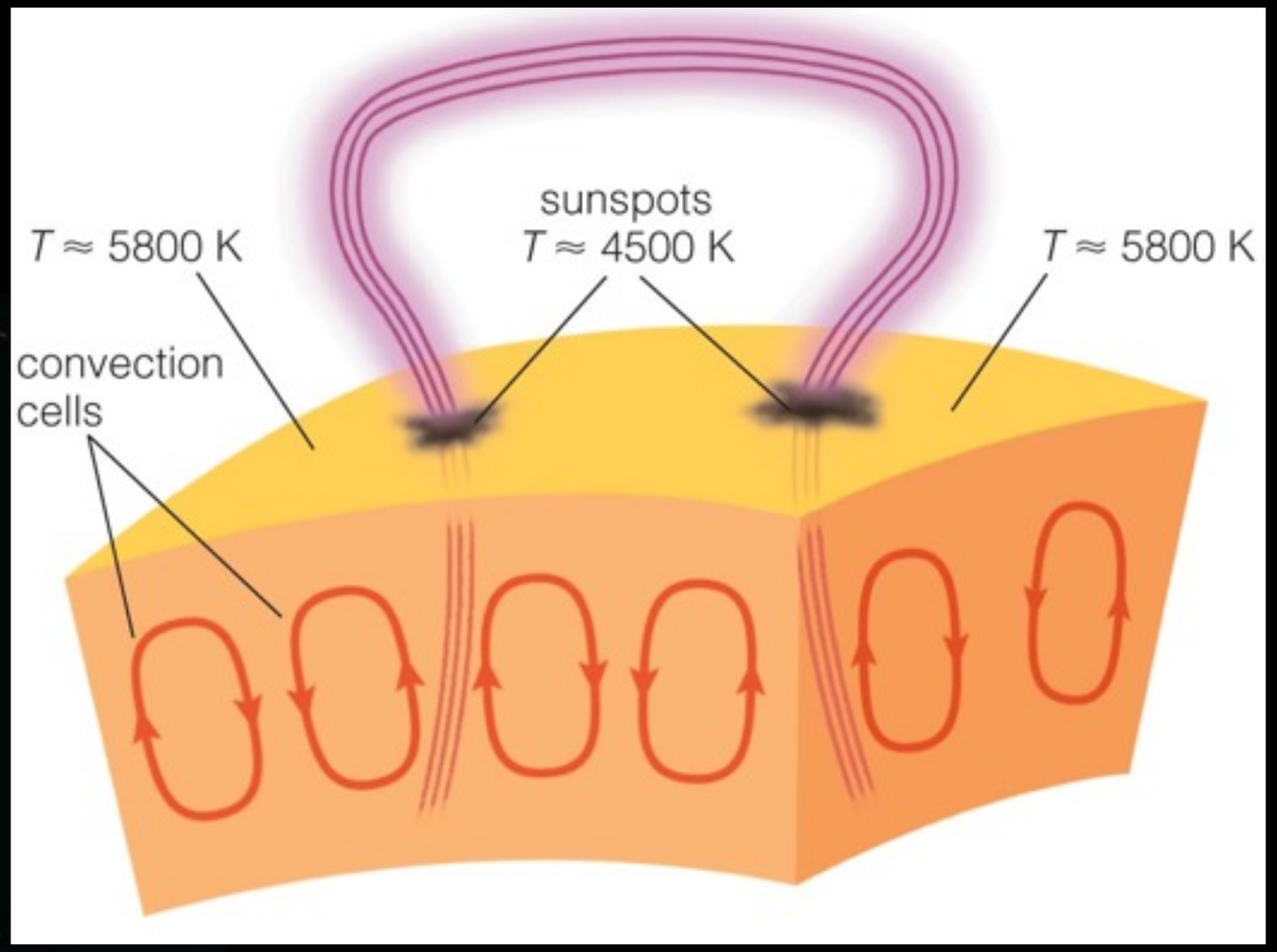


Is there something controlling where the spots are located?

What creates sun spots?

Magnetic Fields!



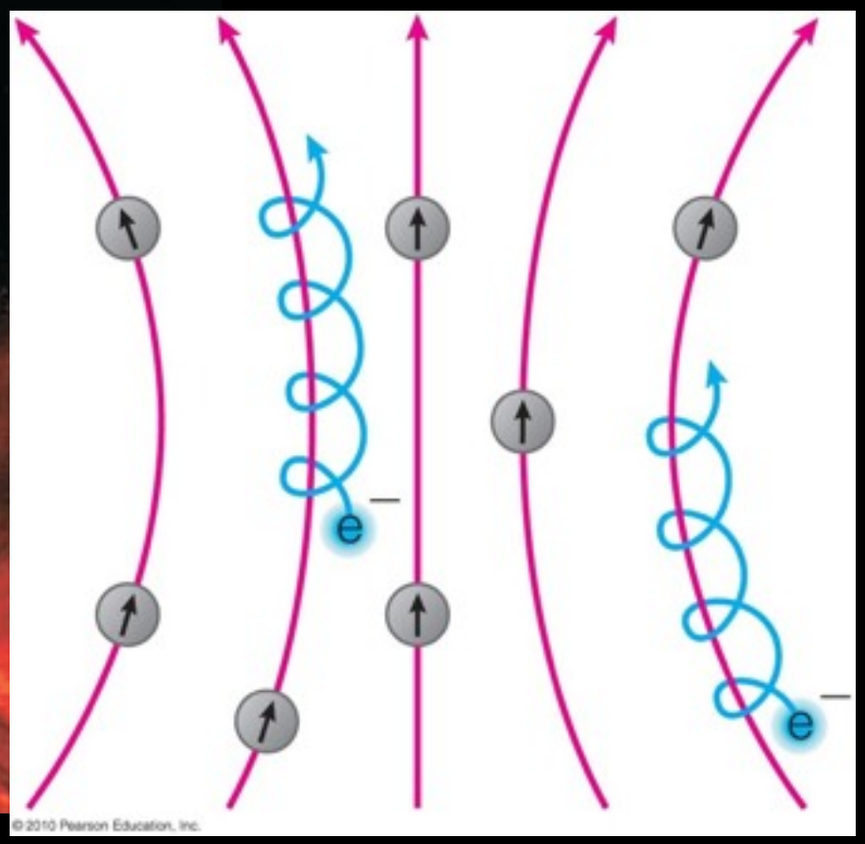


magnetic pressure
helps support the gas,
allowing it to be cooler

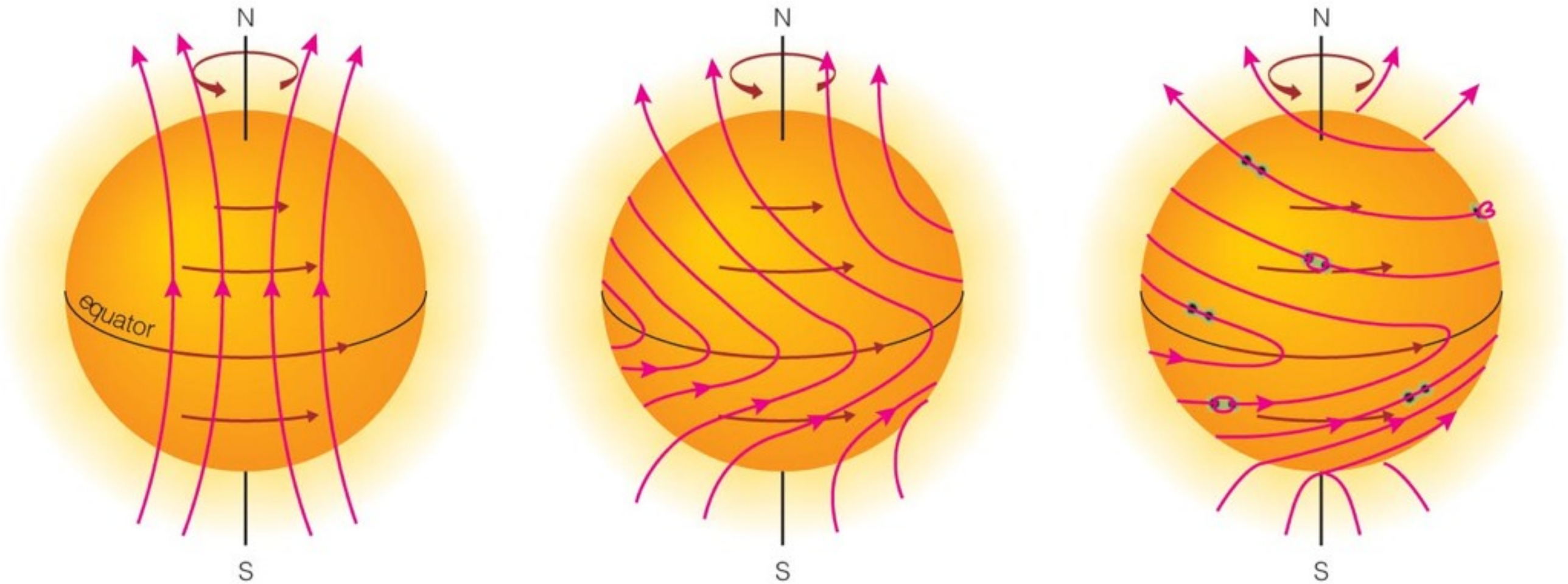
Magnetic loops

Why can we see this?

Charged particles flow along field lines



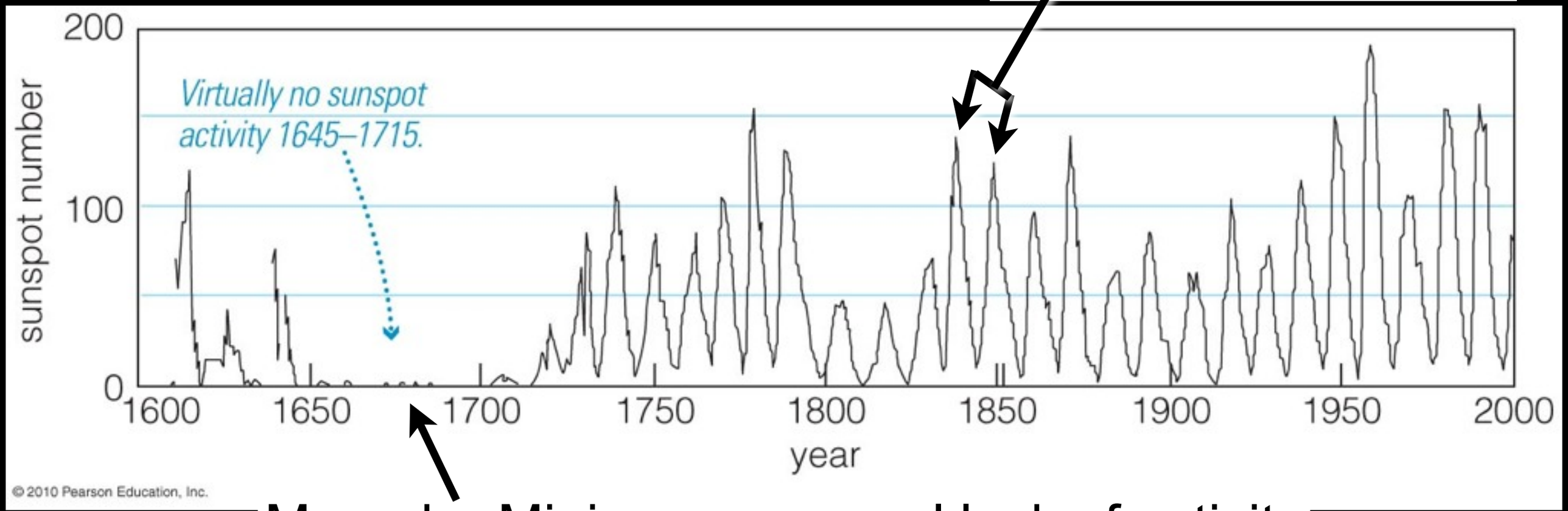
What makes the magnetic field pop out?



Differential rotation: The equator spins faster the the poles.
This causes the magnetic field to get twisted up.
Stress on the field causes distortions

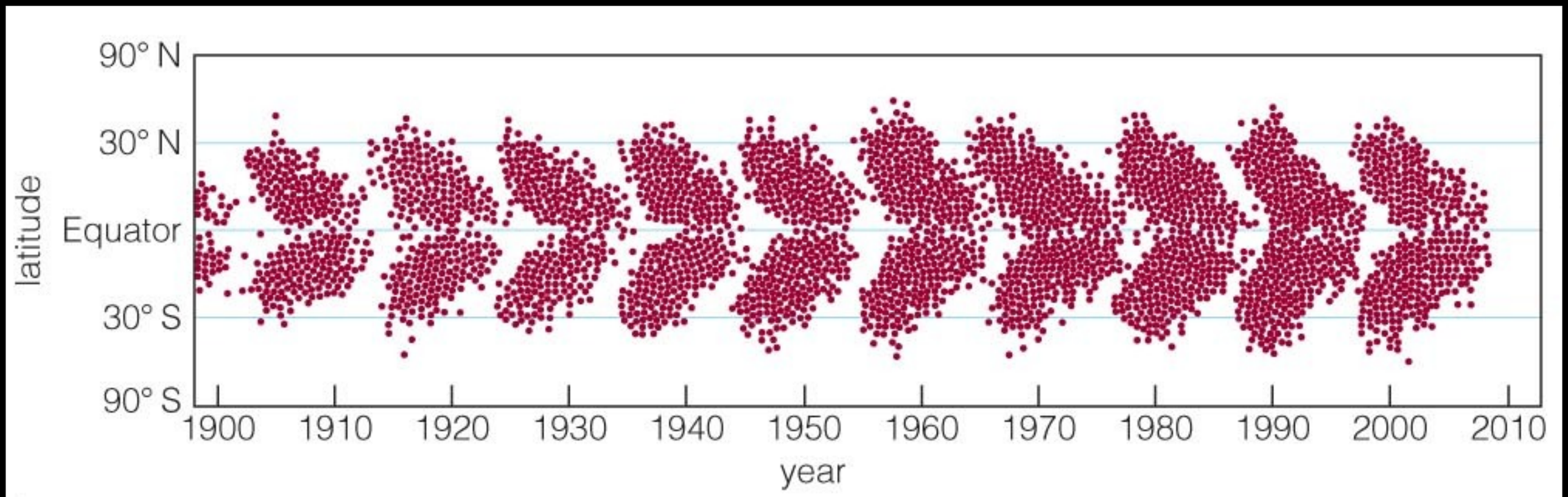
Solar "Wind up" leads to the Sunspot Cycle

Time between peaks is ~11 years

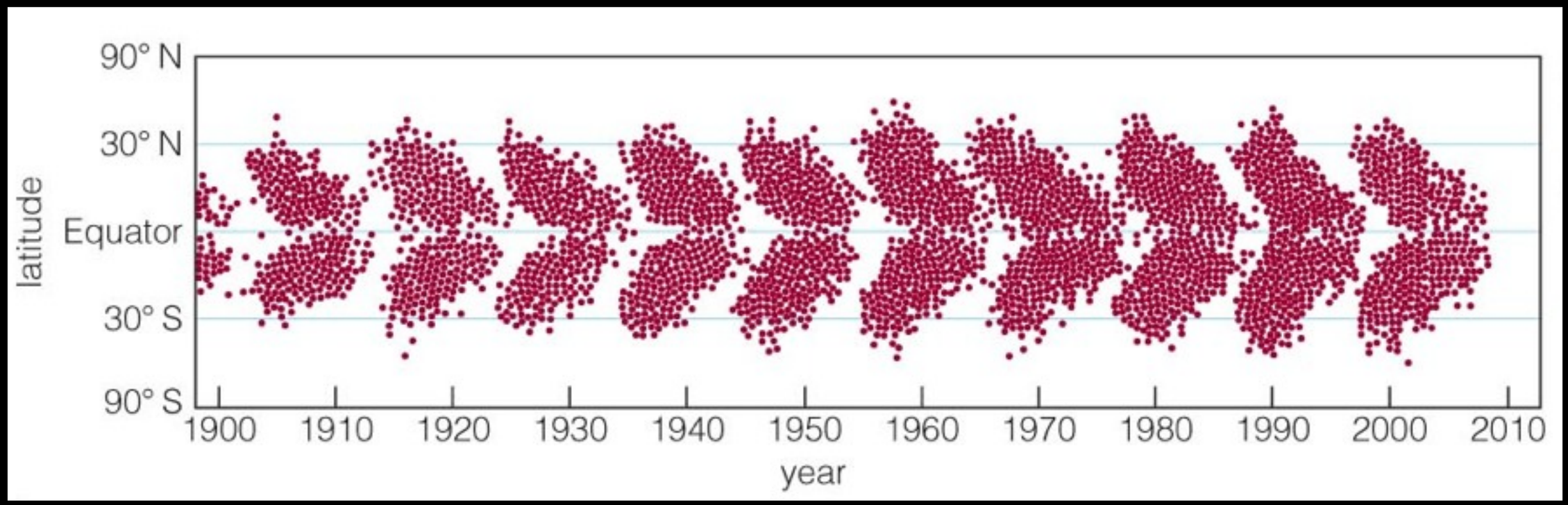


Maunder Minimum, unusual lack of activity

During the Sunspot Cycle, Sunspots form at Different Latitudes



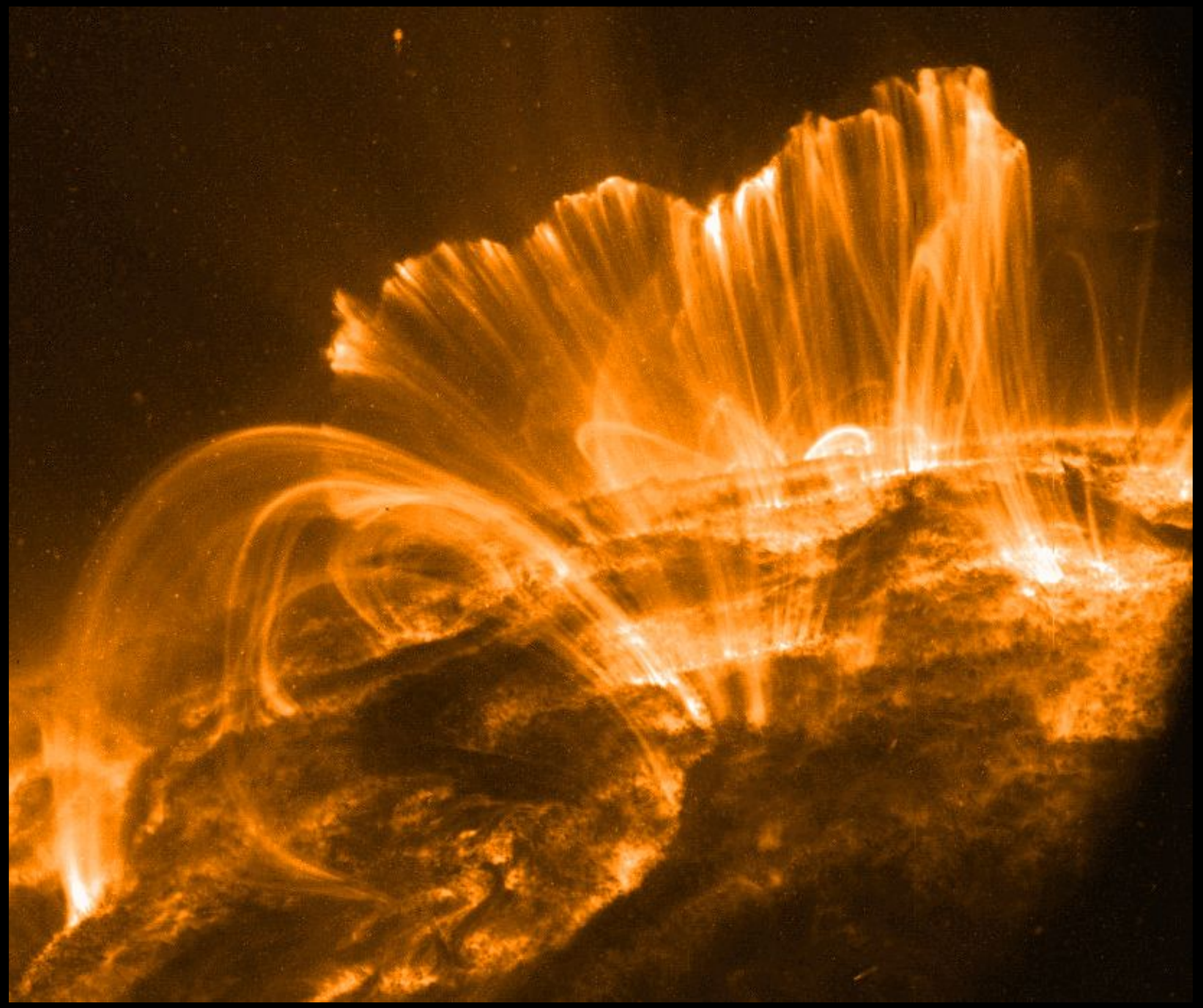
In January 2008, we started a new solar cycle. Where would the sunspots have been located at the start of the cycle?



A. Close to 30º (N or S)

B. Close to the equator

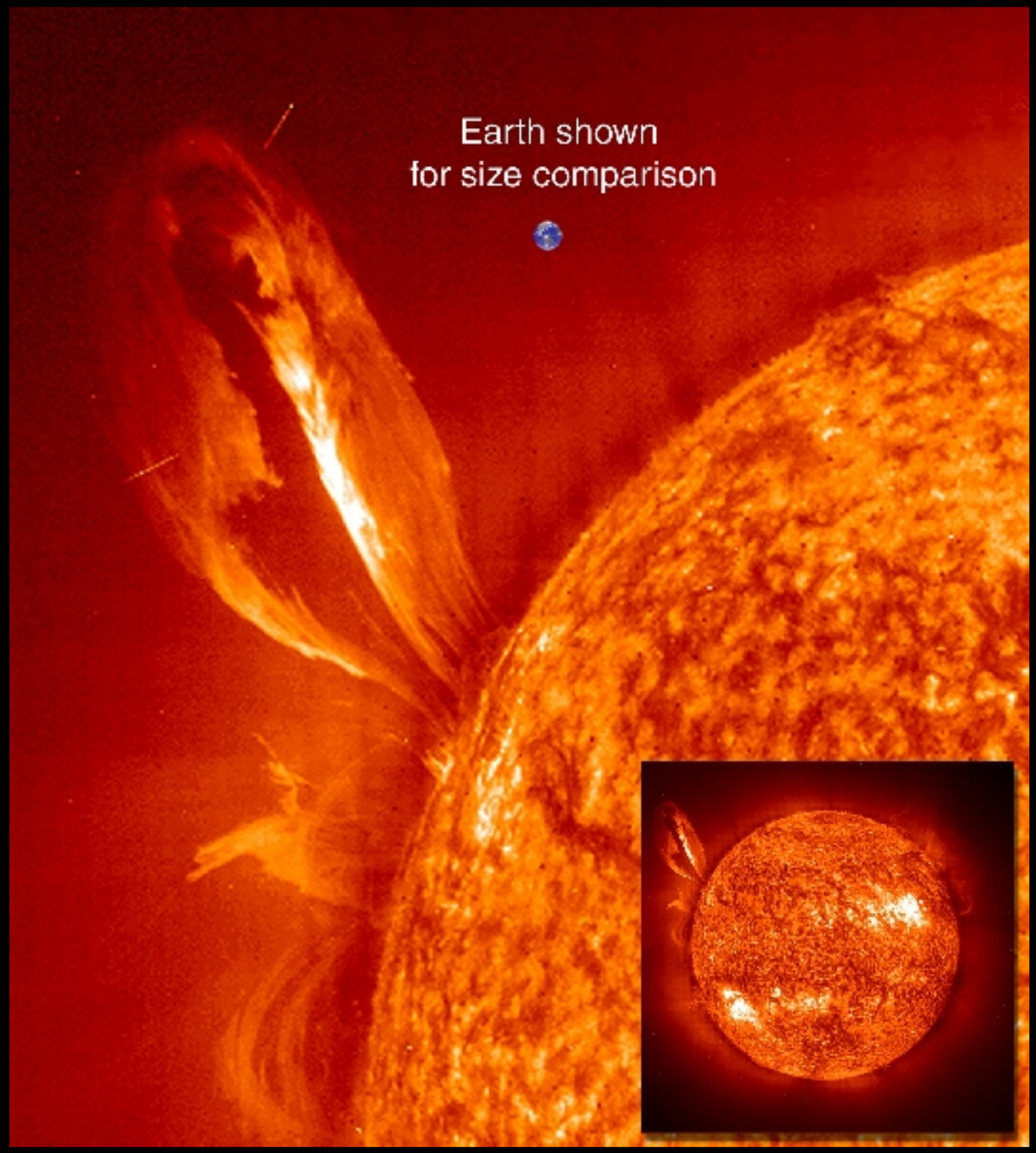
C. Anywhere on the face of the Sun



The glowing gas allows us to see the complex nature of the magnetic fields.

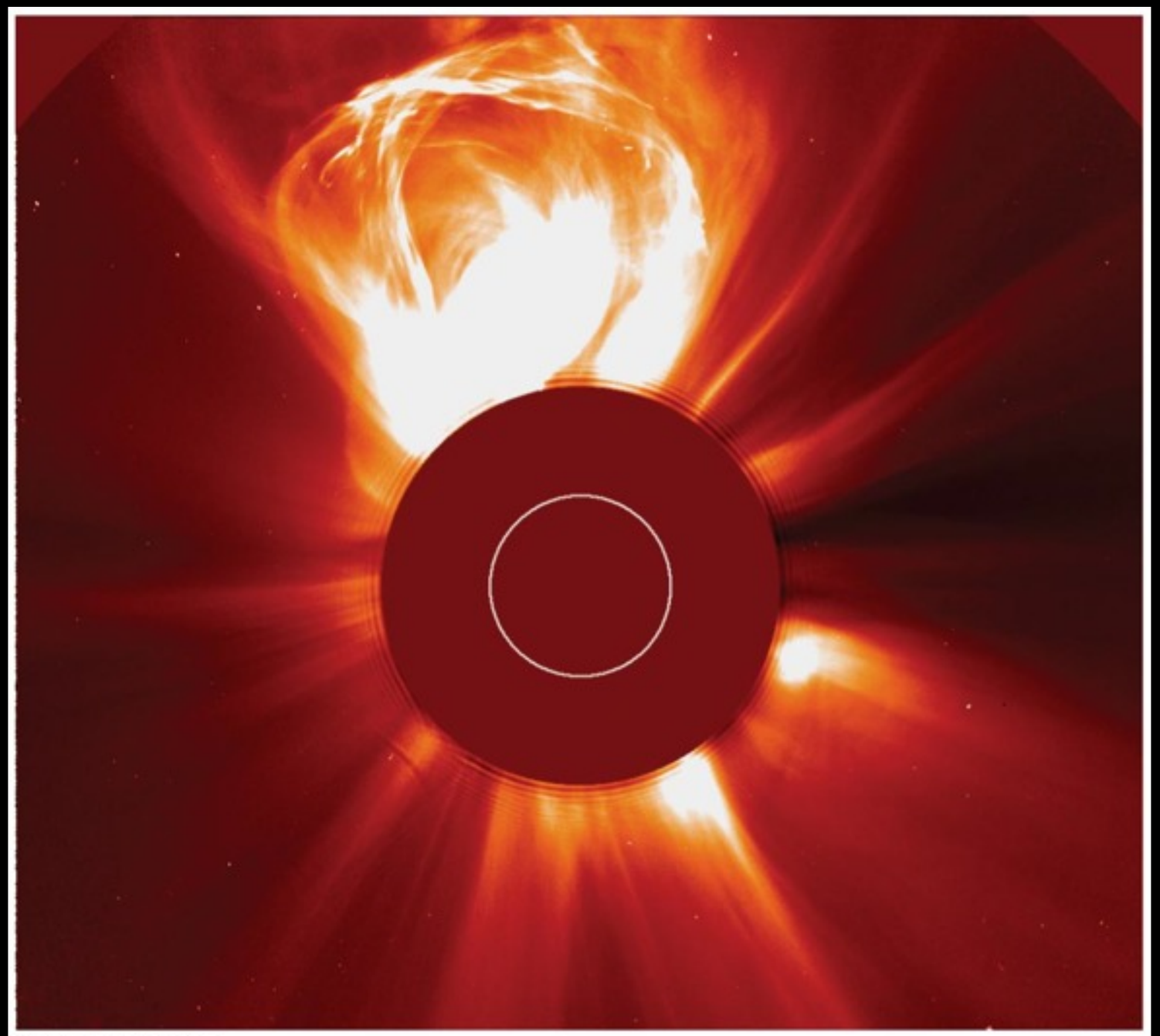
Prominences

- If we see a sun spot edge on, we see the magnetic loop as a prominence



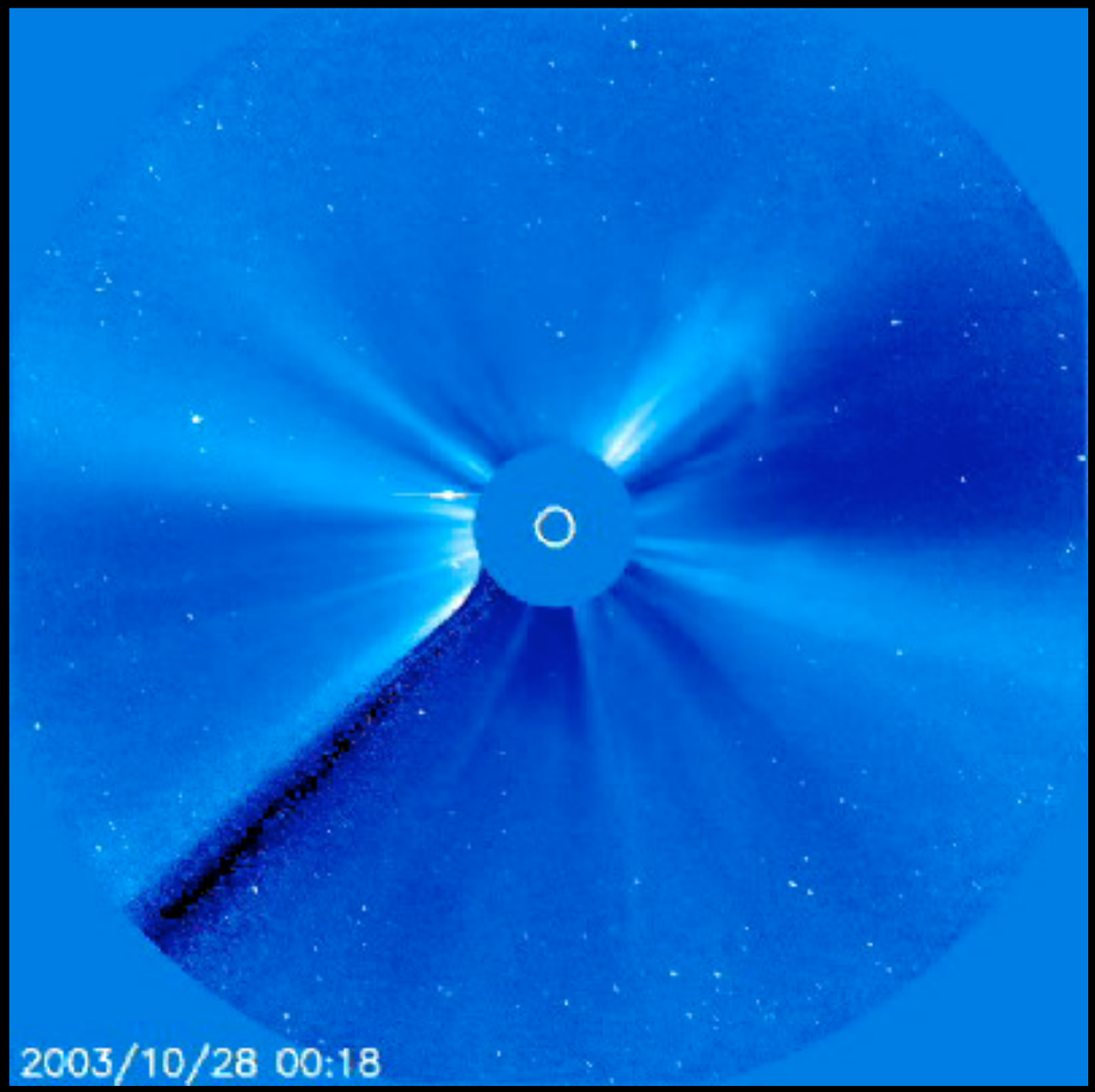
Prominences

- Occasionally the magnetic field lines in a prominence "snap"
  - Solar Flares
    - Massive amount of light and energy is released
  - Coronal Mass Ejections
    - Large bubbles of charged particles are thrown off the surface



Coronal Mass Ejection:
A freight train of charged particles

- Protons can be dangerous!
  - Damage satellites
  - Harm astronauts (think about hanging out in a spacecraft on your way to mars)
  - Induce currents on Earth and destroy electric transformers on the ground
  - Cause swelling in the Earth's atmosphere



How do we know when a coronal mass ejection is on its way?

A. We can detect vibrations in the Sun's surface right before a CME

B. We see the photons from a flare first.

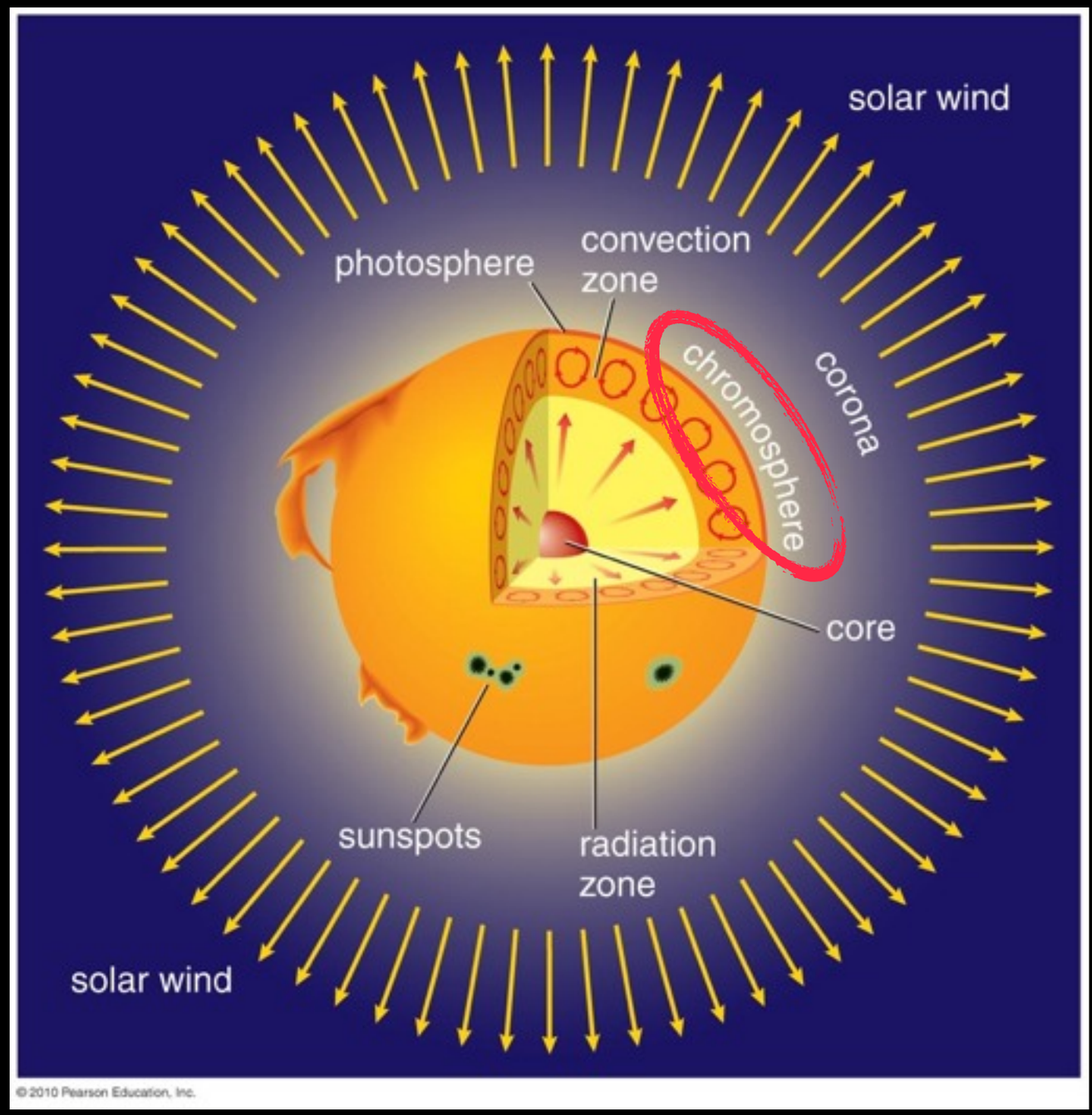
C. Neutrinos flying out of the Sun's core get to Earth first.

D. We don't! We just hope one doesn't happen while astronauts are outside the space station.

E. Aurora in the Earth's atmosphere precede a CME.

Chromosphere

- Temperature goes back UP!
- T ~ 6,000 - 10,000 K
- Very low density
- Must be heated by... magnetic field energy?



The chromosphere produces the majority of which wavelength of the Sun's light?

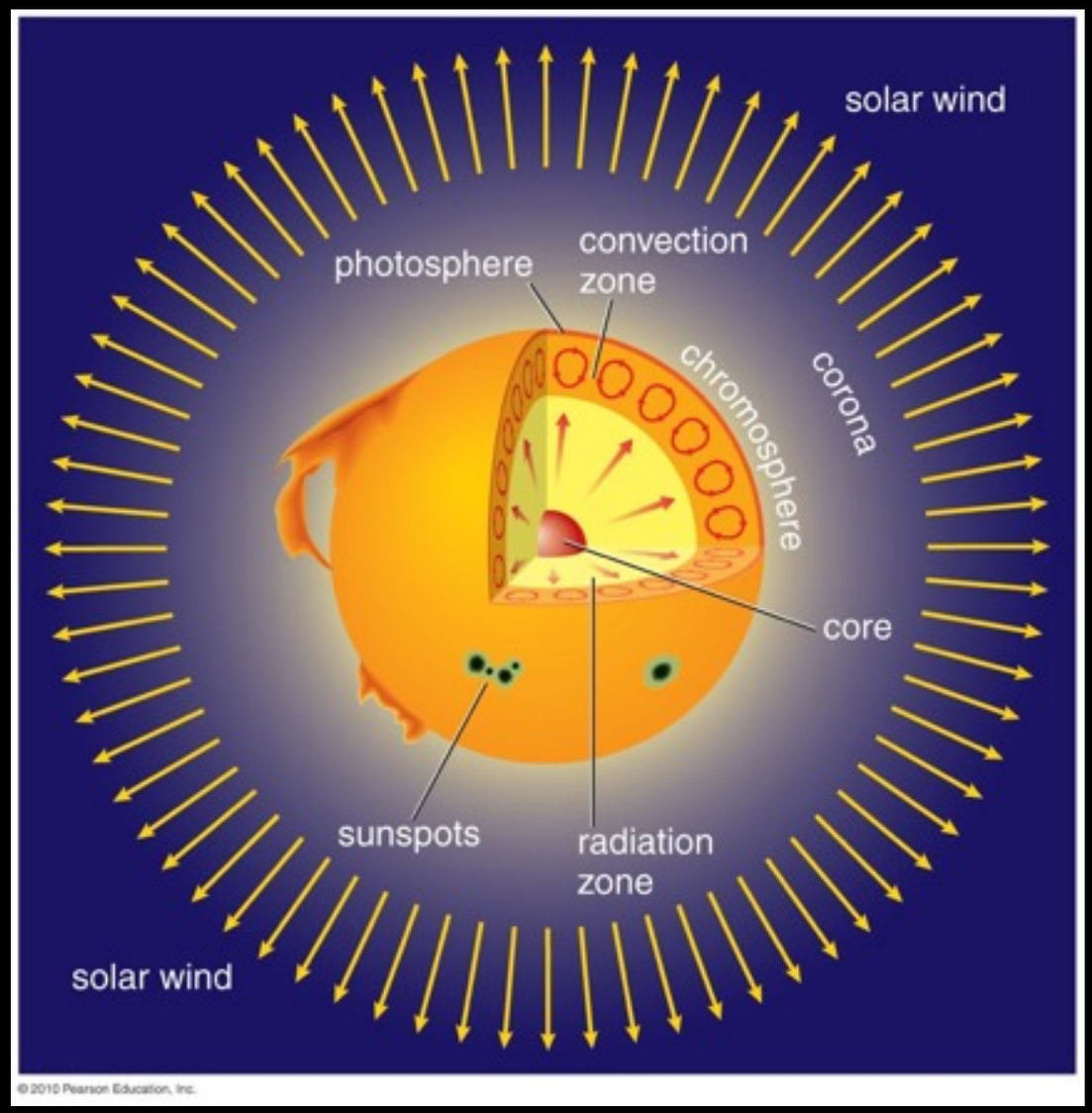
A. Radio waves

B. Ultra violet

C. Visible

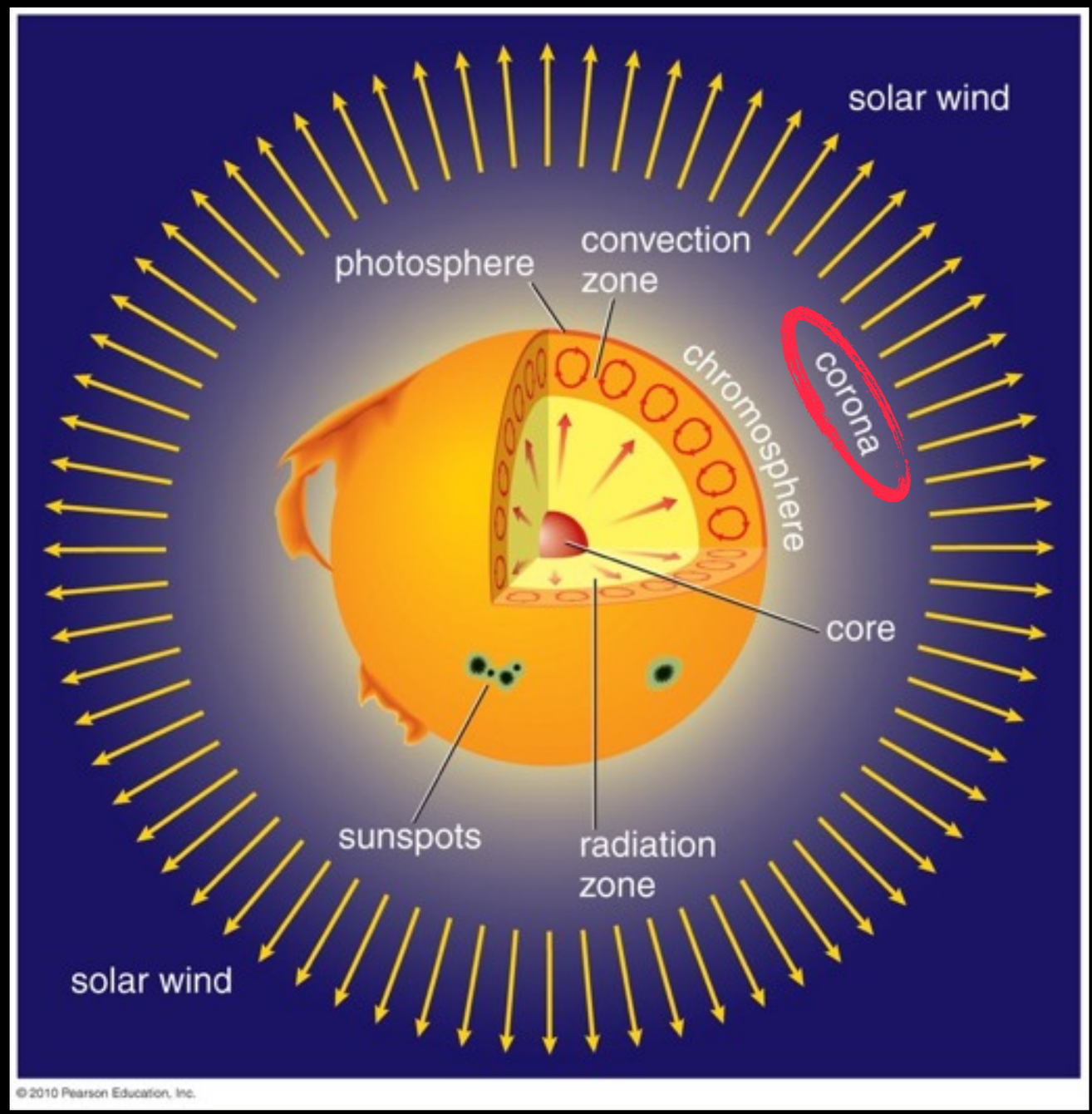
D. Infrared

E. X-rays



Corona

- Hotter still!
- T ~ 1 million K
- Extremely low density (so low, that it wouldn't feel very hot)
- More magnetic heating?



Last one... what wavelength will the corona be dominating?

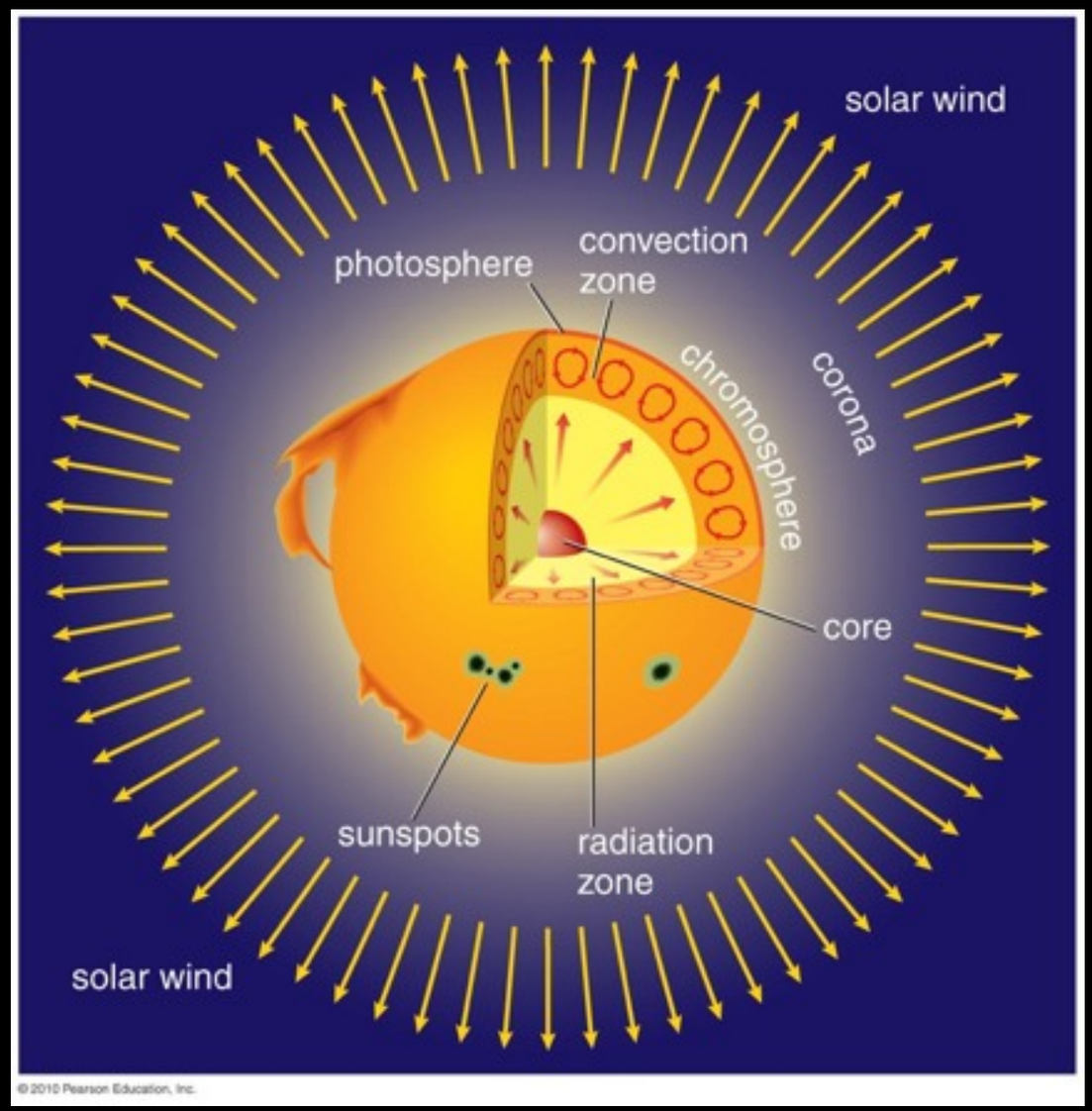
A. Radio waves

B. Ultra violet

C. Visible

D. Infrared

E. X-rays

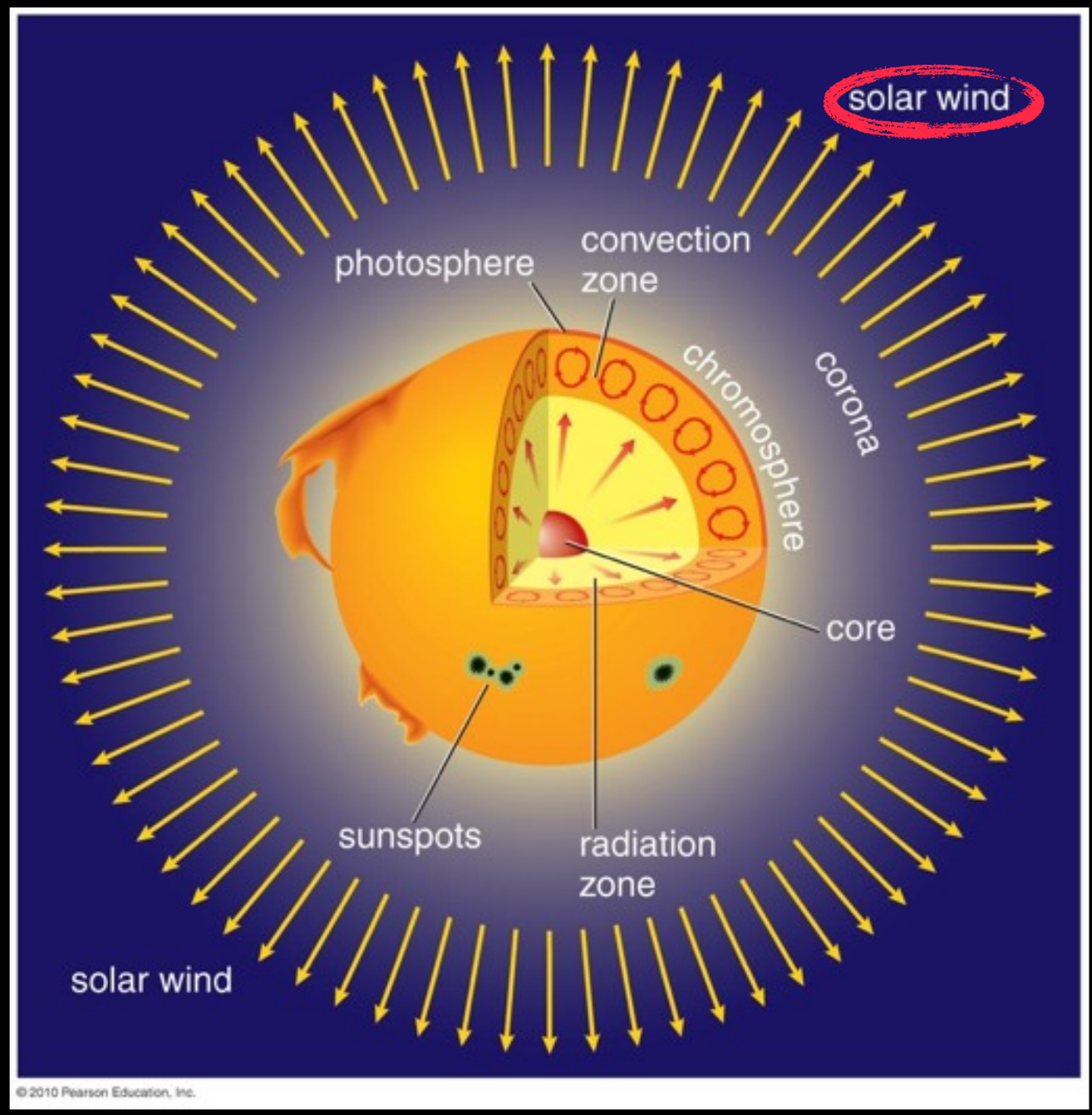


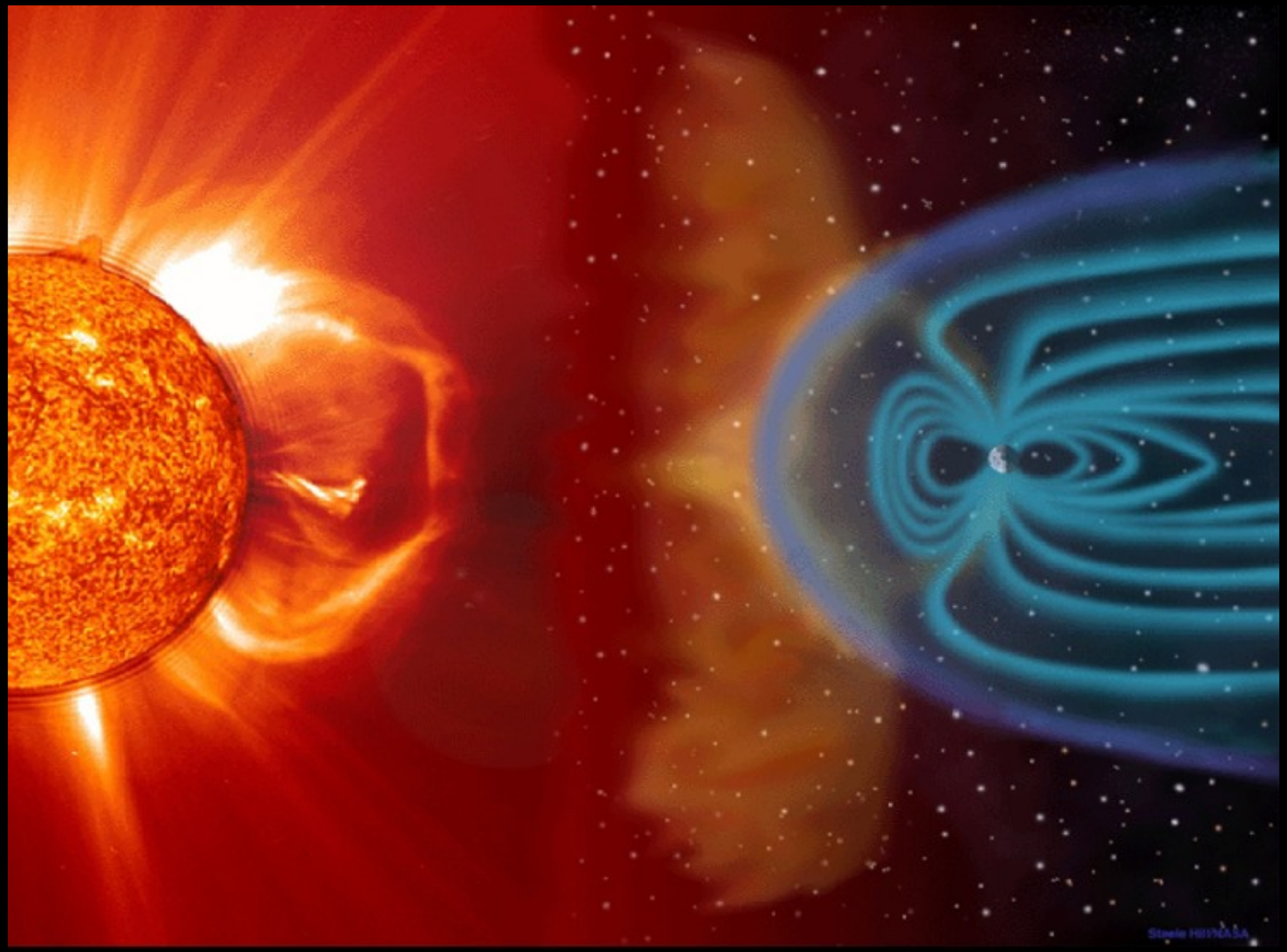
Solar eclipse: the natural coronagraph

Without the sun blinding us, we can see the corona!

Solar Wind: Feel the Breeze

- At the top of the corona, gas is hot enough (and far enough) to escape the gravity of the Sun
- In effect, the corona is “evaporating”
- Constantly replenished from below
- Solar wind carries about a million tons of solar matter per second!!





Earth's magnetic field, or magnetosphere, protects us from most effects of solar storms and the solar wind.

Credit: SOHO image composite by Steele Hill (NASA)

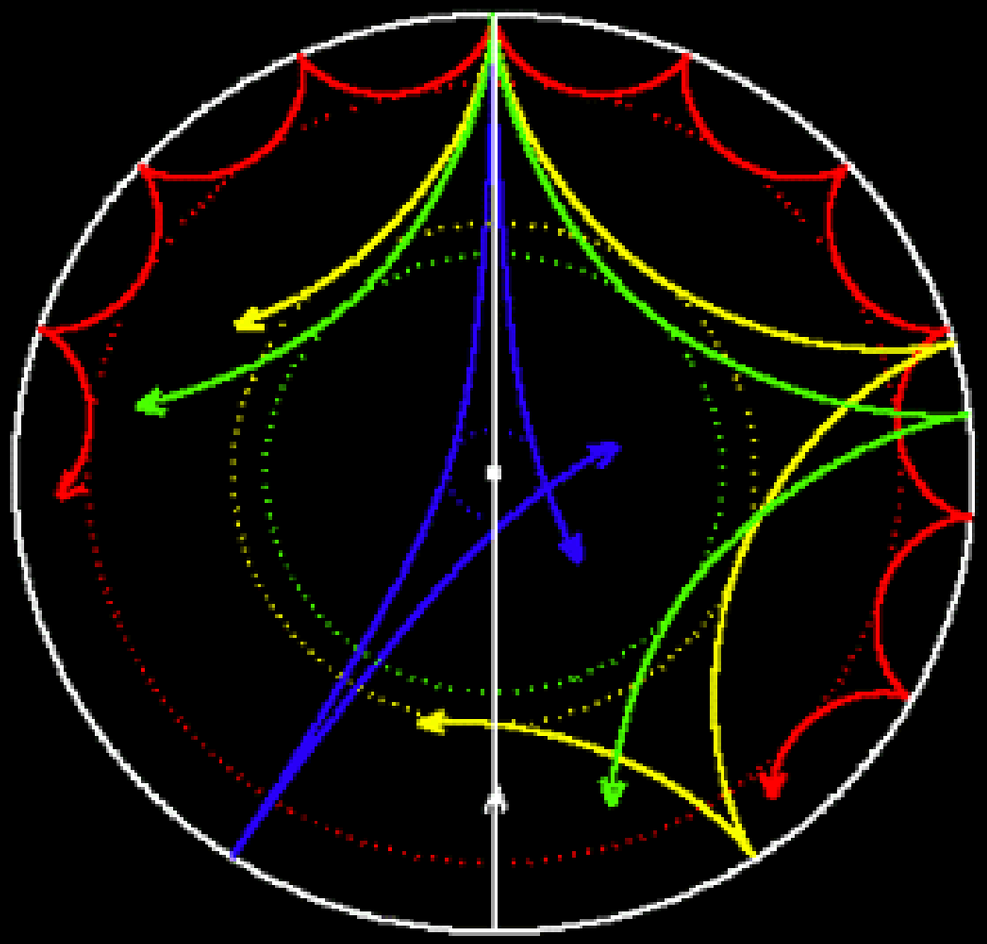
North and South Lights (Aurora)

Interactions between Earth magnetic field and the solar wind particles

How can we be so sure about what's going on inside the Sun?

- Neutrinos: proof of fusion (as discussed)
- Helioseismology
- Mathematical Models

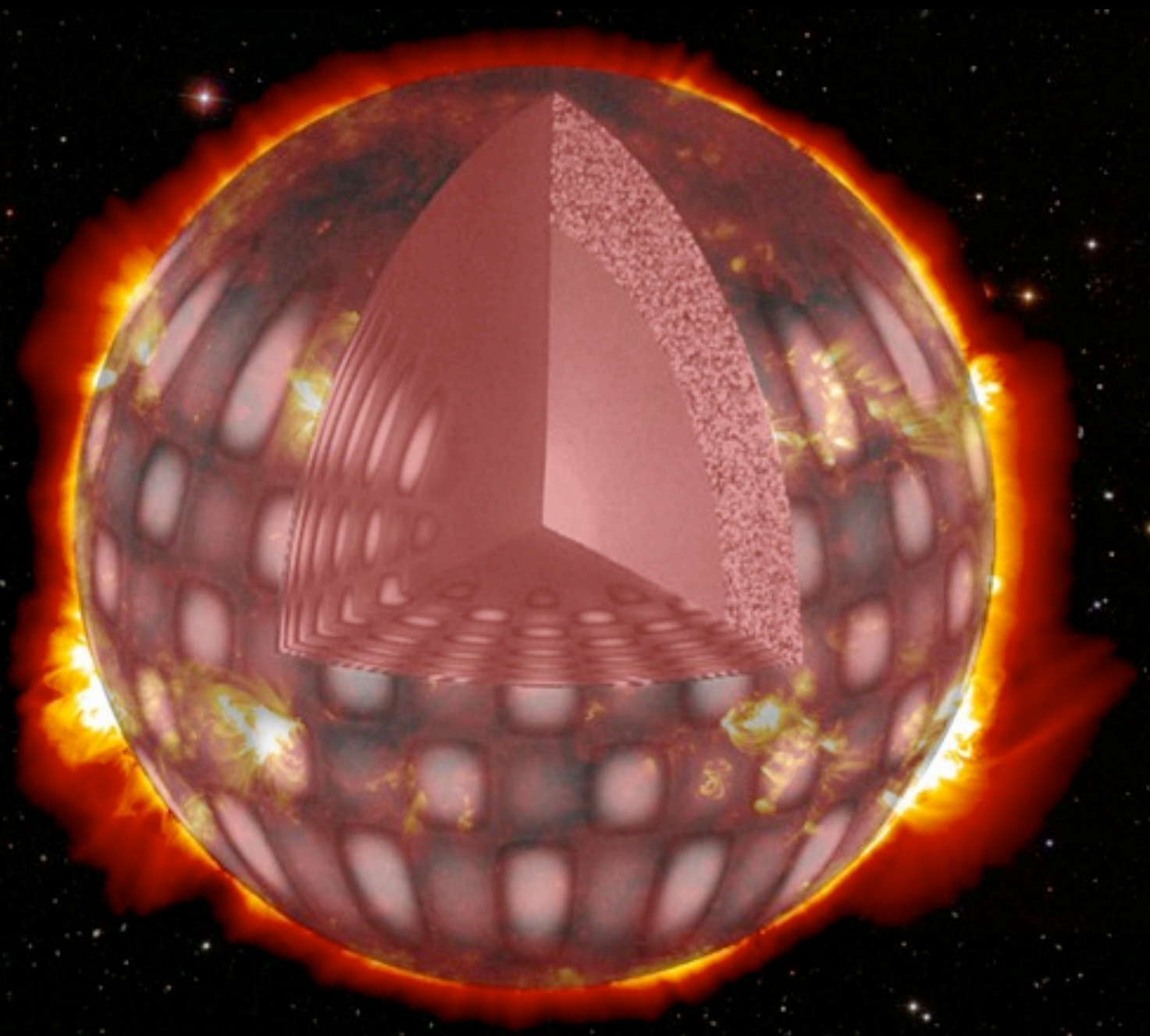
Helioseismology: the Sun makes sound!



- Millions of sound waves are used to probe the solar interior
- Some waves bounce back just below the surface
- Some almost make it to the center
- All are created by convective turbulence

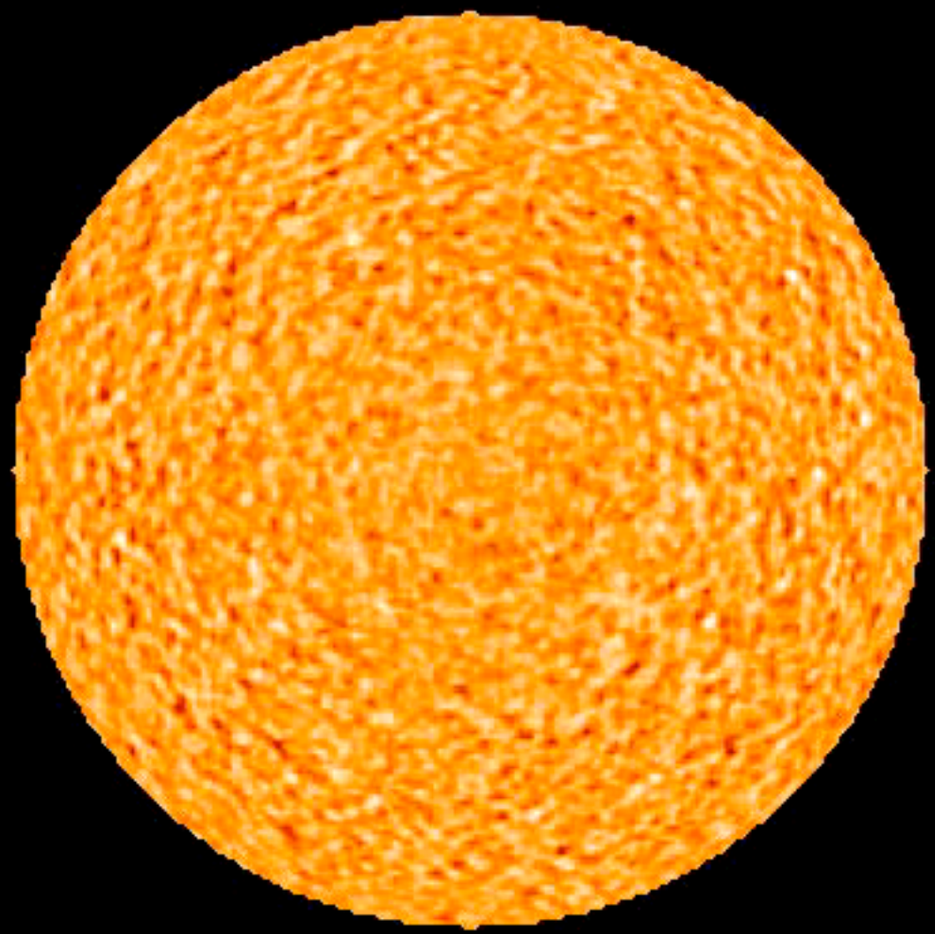
Solar Oscillation Patterns

Detected using doppler imaging

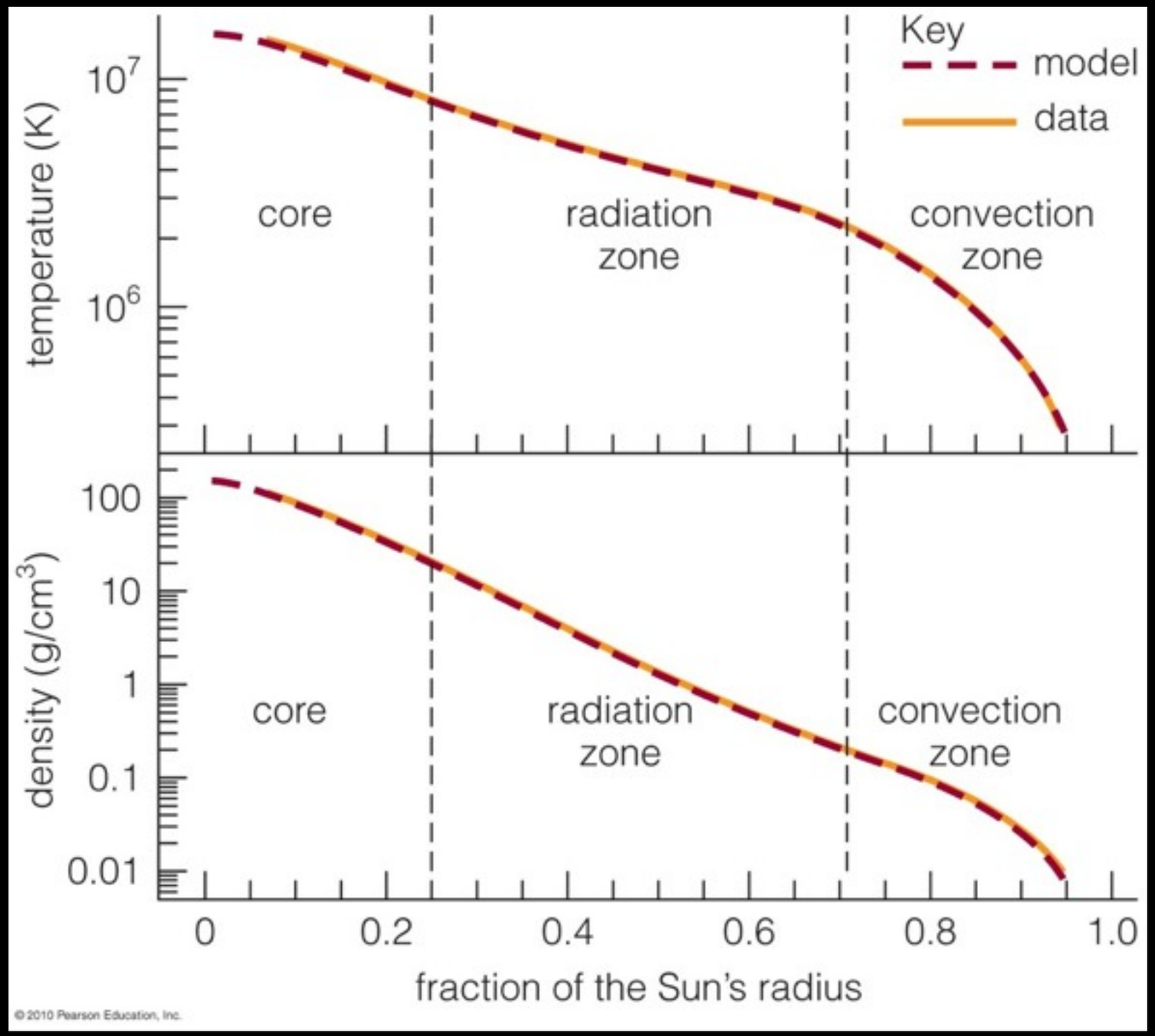


Just one of millions of patterns, each with a different tone!

See and Hear the Solar Music



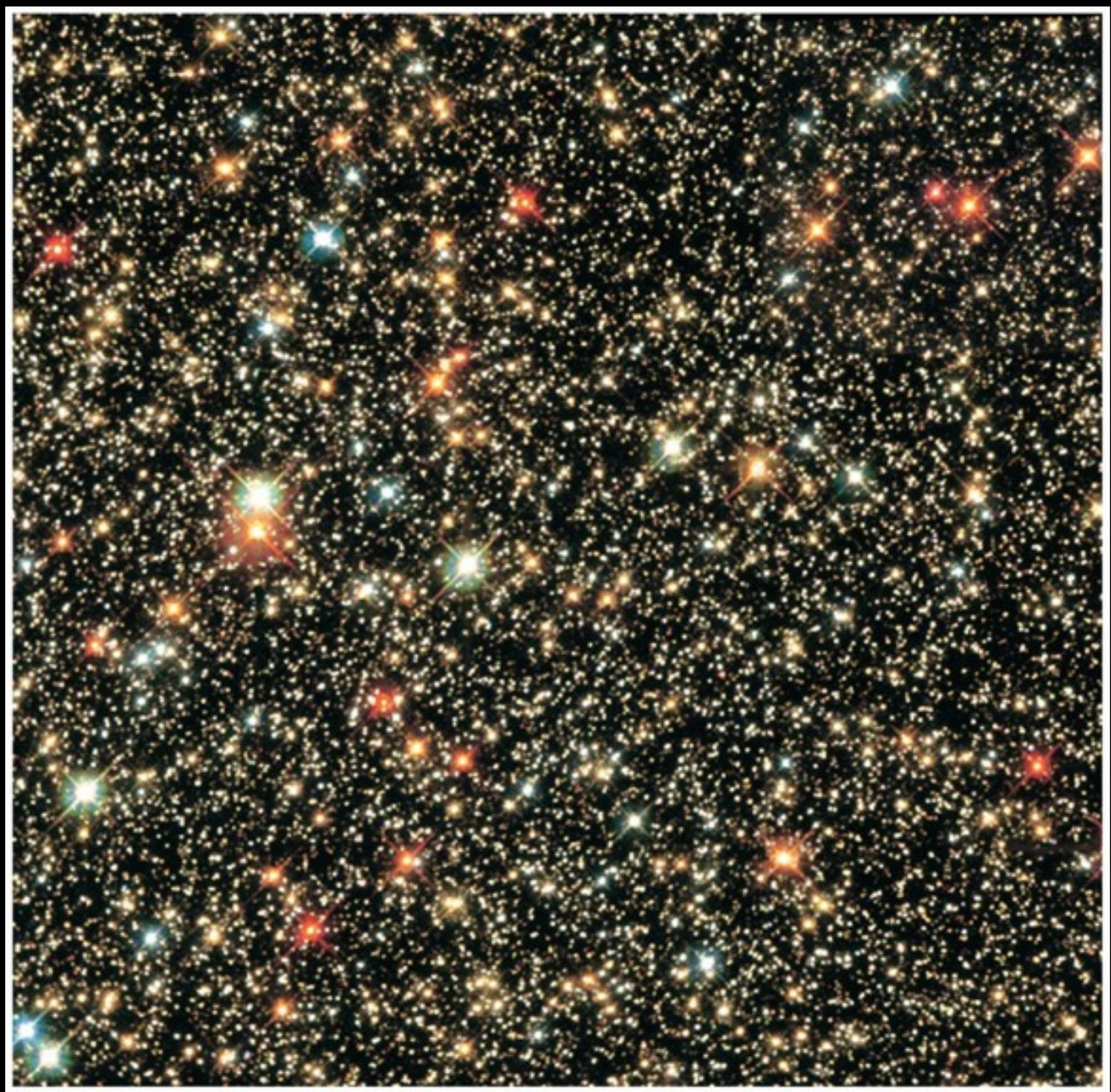
Mathematical Models of the Solar Interior



- Math and Physics really work!
- Models match helioseismology observations
- Score one for Science!

We've got the Sun covered, what about other stars?

- A full spectrum of stellar properties
- Temperatures from 3000 K to > 40,000 K
- Masses can range from 0.08 M_{sun} to 150 M_{sun}



How do we determine Temperature?

- Two methods for measuring temperature:

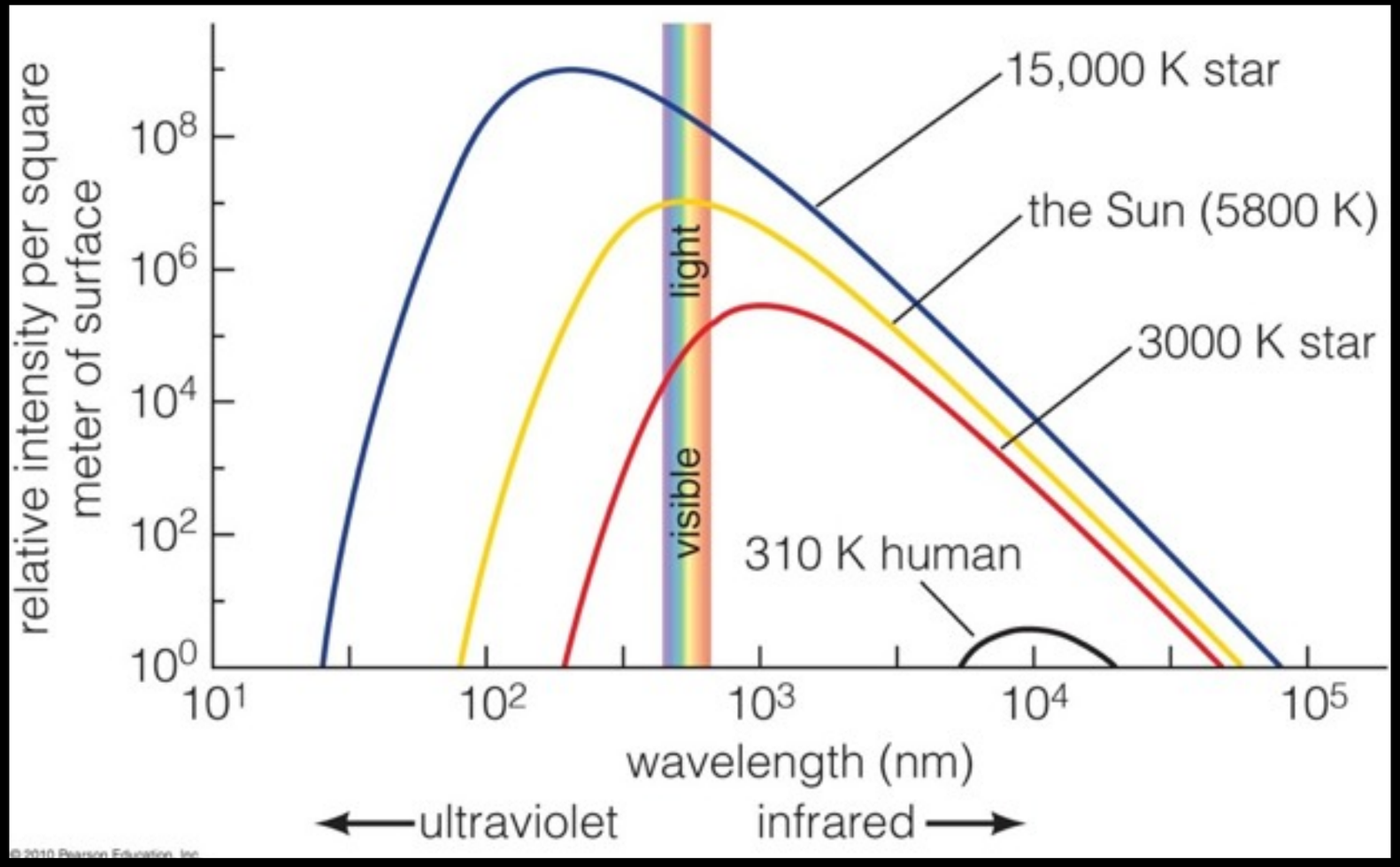
How do we determine Temperature?

- Two methods for measuring temperature:

1) Observe its thermal spectrum
2) Determine its spectral type

Thermal Spectrum Review

- Location of peak indicates temperature
- Bluer = Hotter, Redder = Cooler

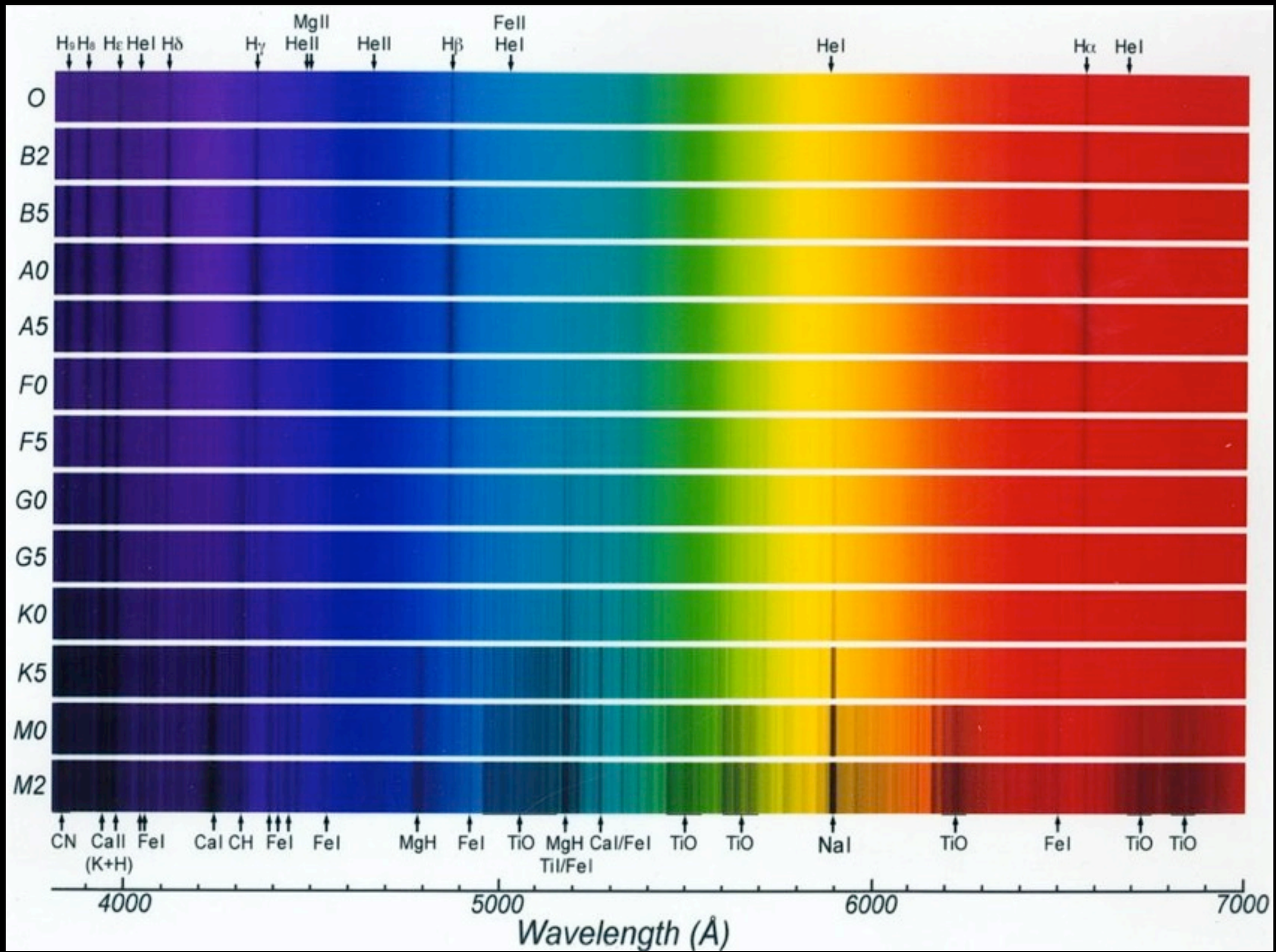


Spectral Classifications

- Using spectral lines to determine temperature often better than thermal radiation estimates
- Atoms and molecules can range from “tough” to “fragile”
- The more complex an atom or molecule is, the more fragile it is
  - Fragile types are more easily ionized or knocked apart by collisions in high temperature regions (remember, high temp = high energy of particles)

If there are signs of fragile atoms and molecules, the temperature must be low!

A spectrum of spectra

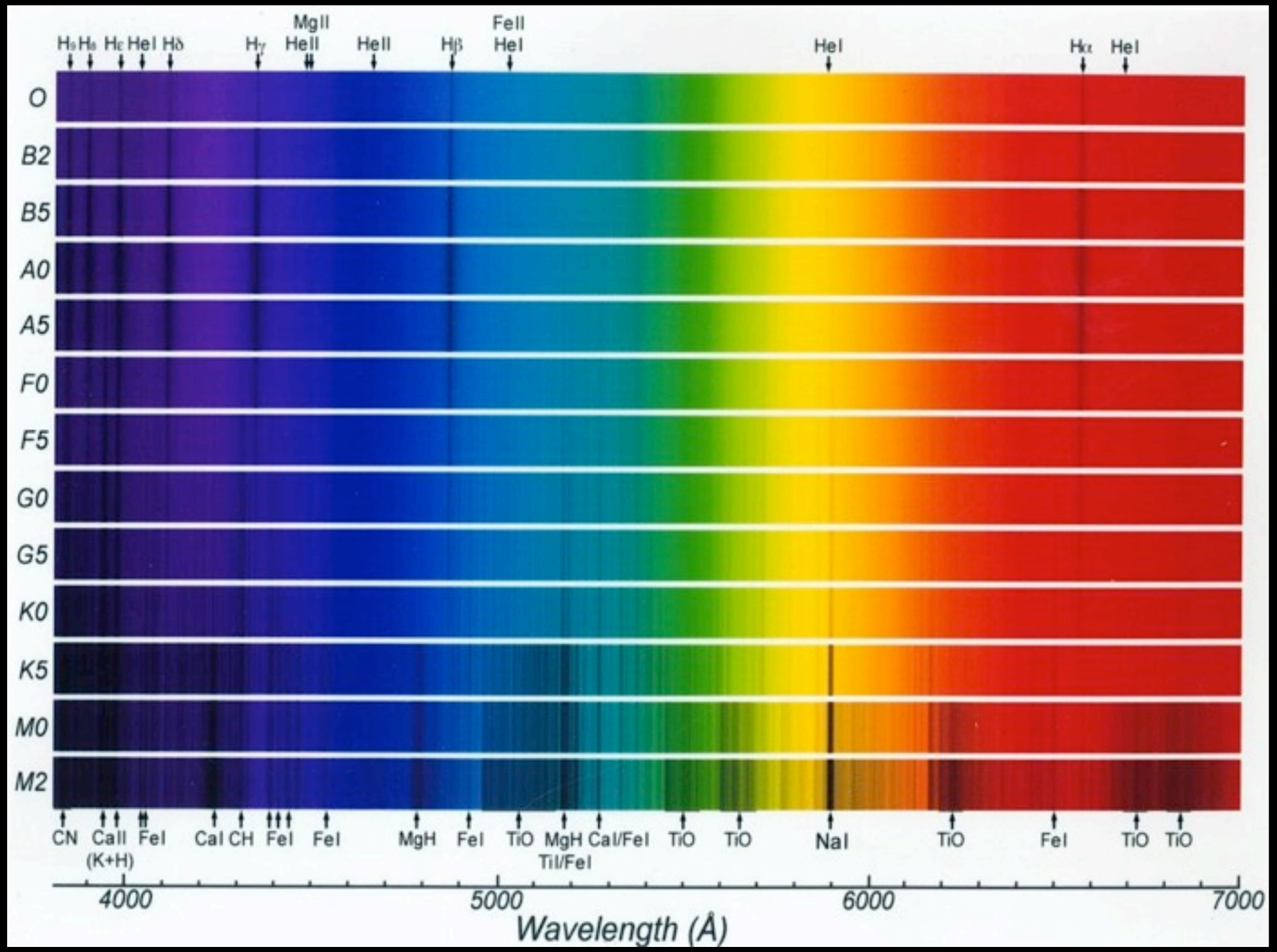


Which star is hotter?

A. This one at the top

B. This one at the bottom

C. We can't tell



Quick note on Spectral “Code Names”

- **OBAFGKM**
  - O = Hottest
  - G = Middle of the road (Sun = G2)
  - M = Coolest, Reddest

(Be aware of this, but you will not be directly tested on it)

How do we determine Mass?

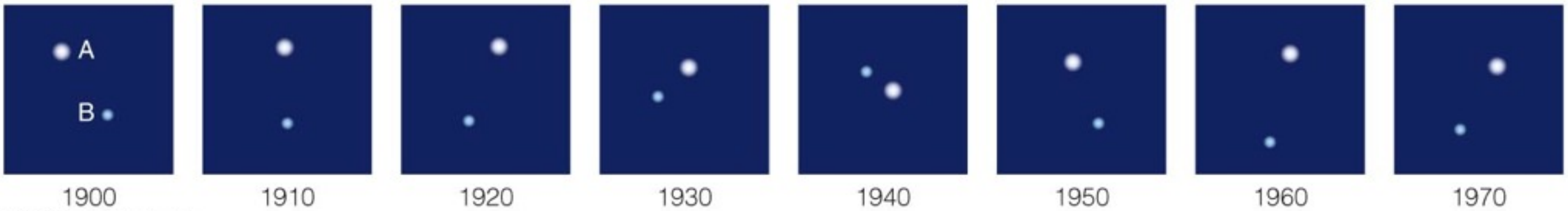
- Masses are tough to nail down
- Only seeing stars as point sources, so its tough to tell how big they are
- Could we use use gravity somehow?

Binary stars save the day!

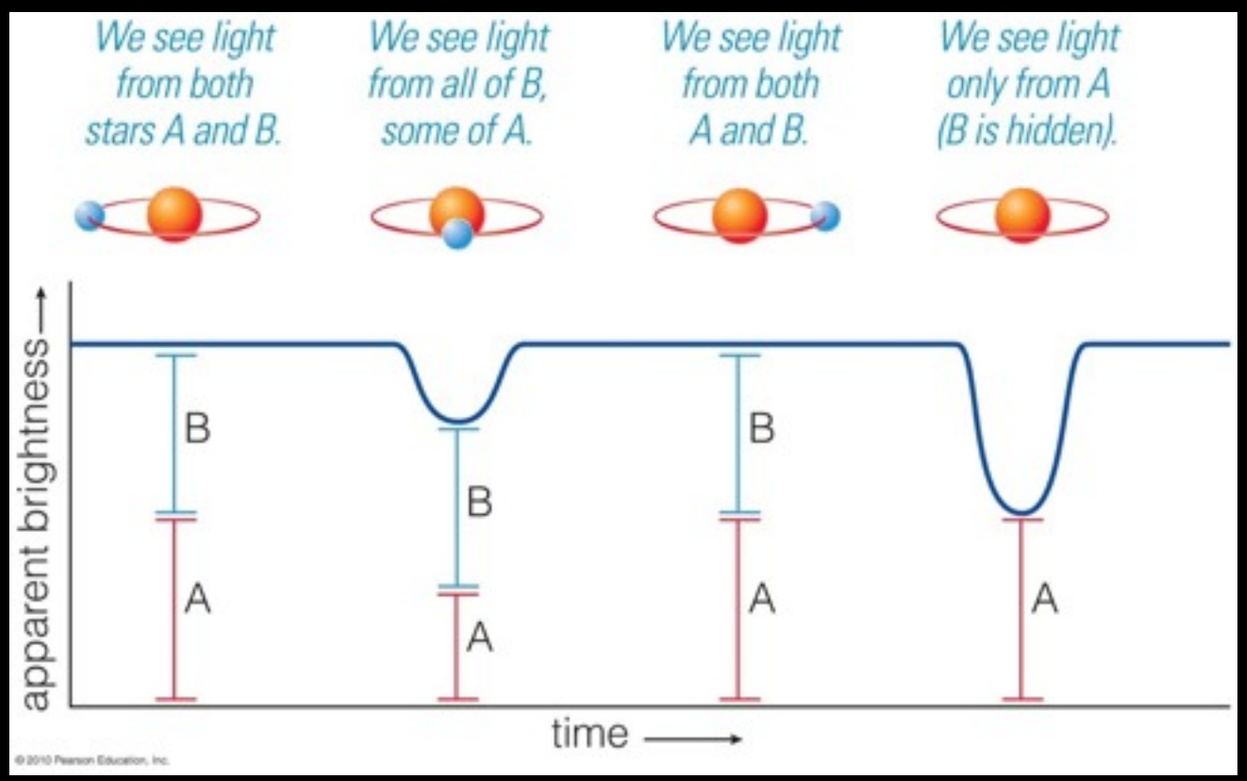
- Three types of binary systems:
  - Visual binary
  - Eclipsing binary
  - Spectroscopic binary
    (we've discussed these)
- Roughly half of all stars are in binaries

Visual Binary

Sirius is observed to "wobble" around its companion star

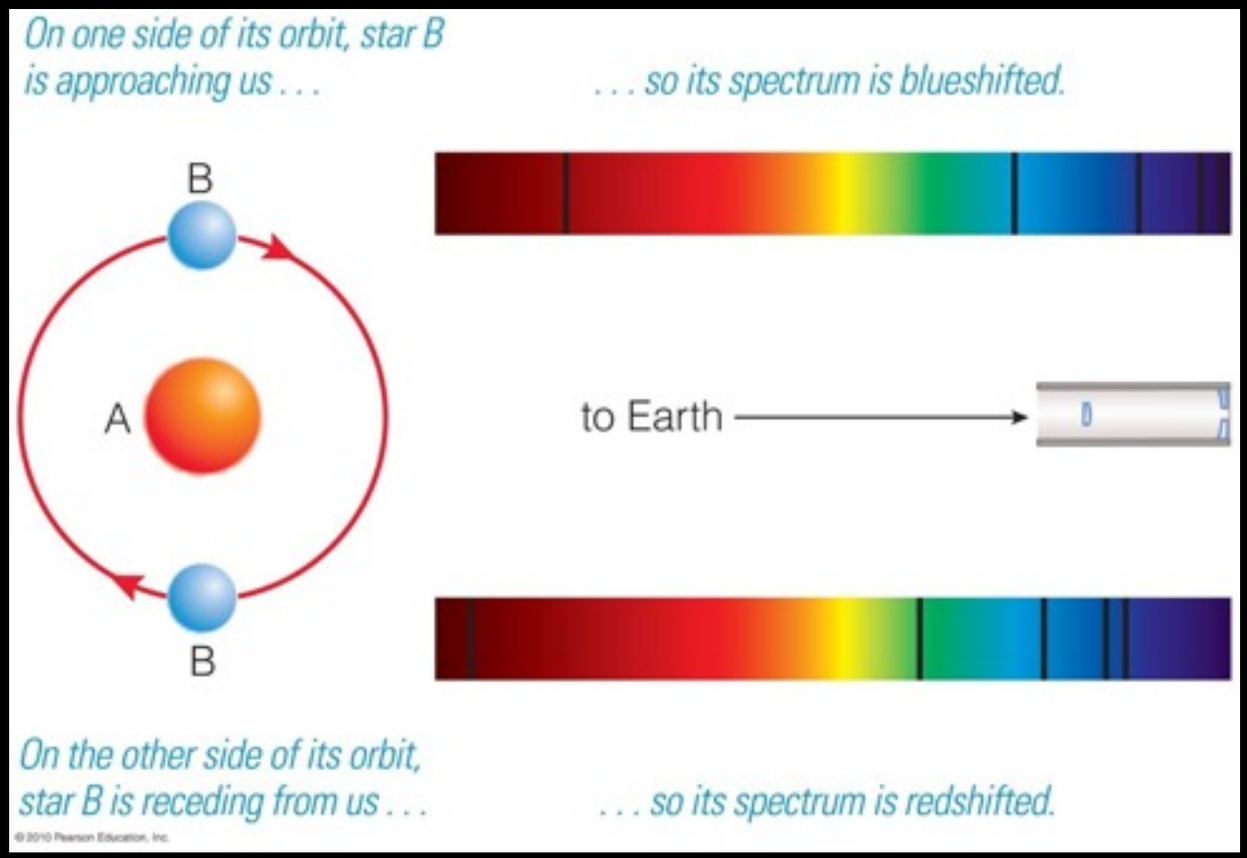


Eclipsing Binary



Periodic dips in brightness

Doppler shifts indicate motion

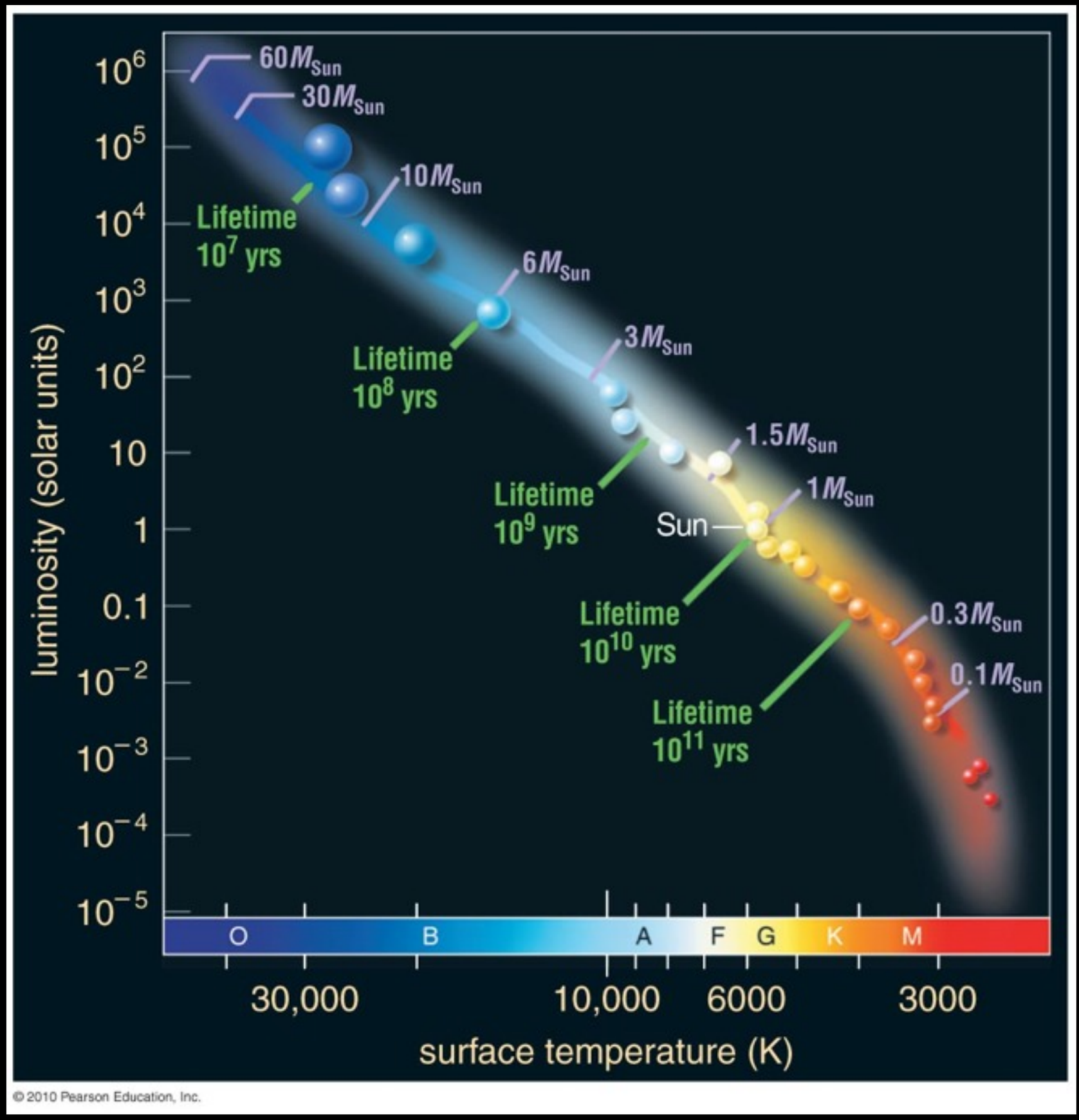


Spectroscopic Binary

If we put it all together...

Hertzsprung-Russell (H-R) Diagram

Mass, temperature and luminosity are all related for Main Sequence stars



Tutorials

- “Luminosity, Temperature, and Size” pg. 53
- “H-R Diagram” pg. 109