Today

- More on the Sun
- Stars
    - distances
    - spectral types
    - the HR diagram

Homework due Thursday

Extra credit (2 points)

- What is the main power source of the Sun?
- Be sure to include your name and section number
- You may consult your notes, but do not communicate with anyone else

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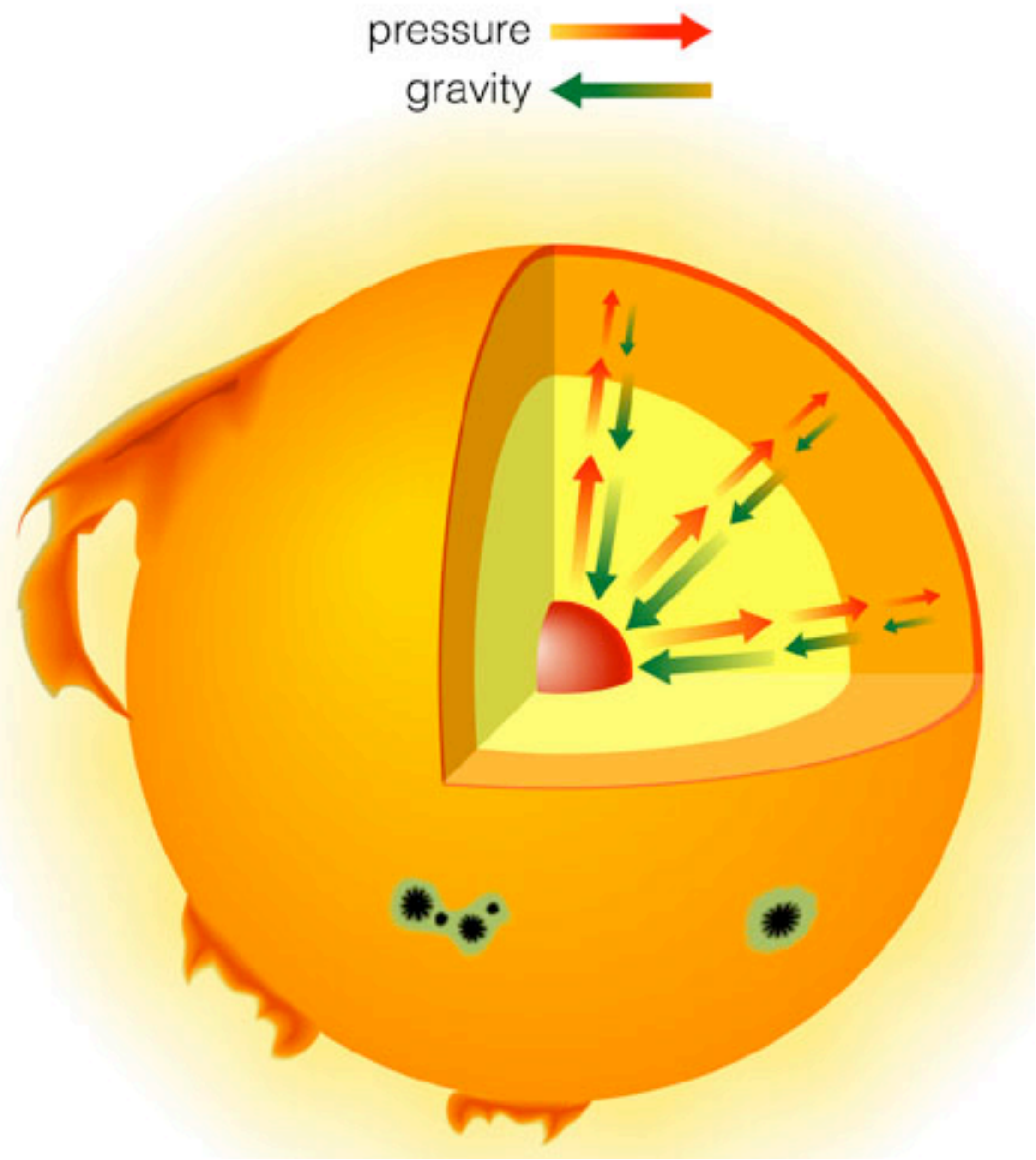

Stars are stable: pressure balances gravity.

E2-51

Hydrostatic equilibrium:

Energy released by nuclear fusion in the core of the sun heats the surrounding gas. The resultant pressure balances the relentless crush of gravity.

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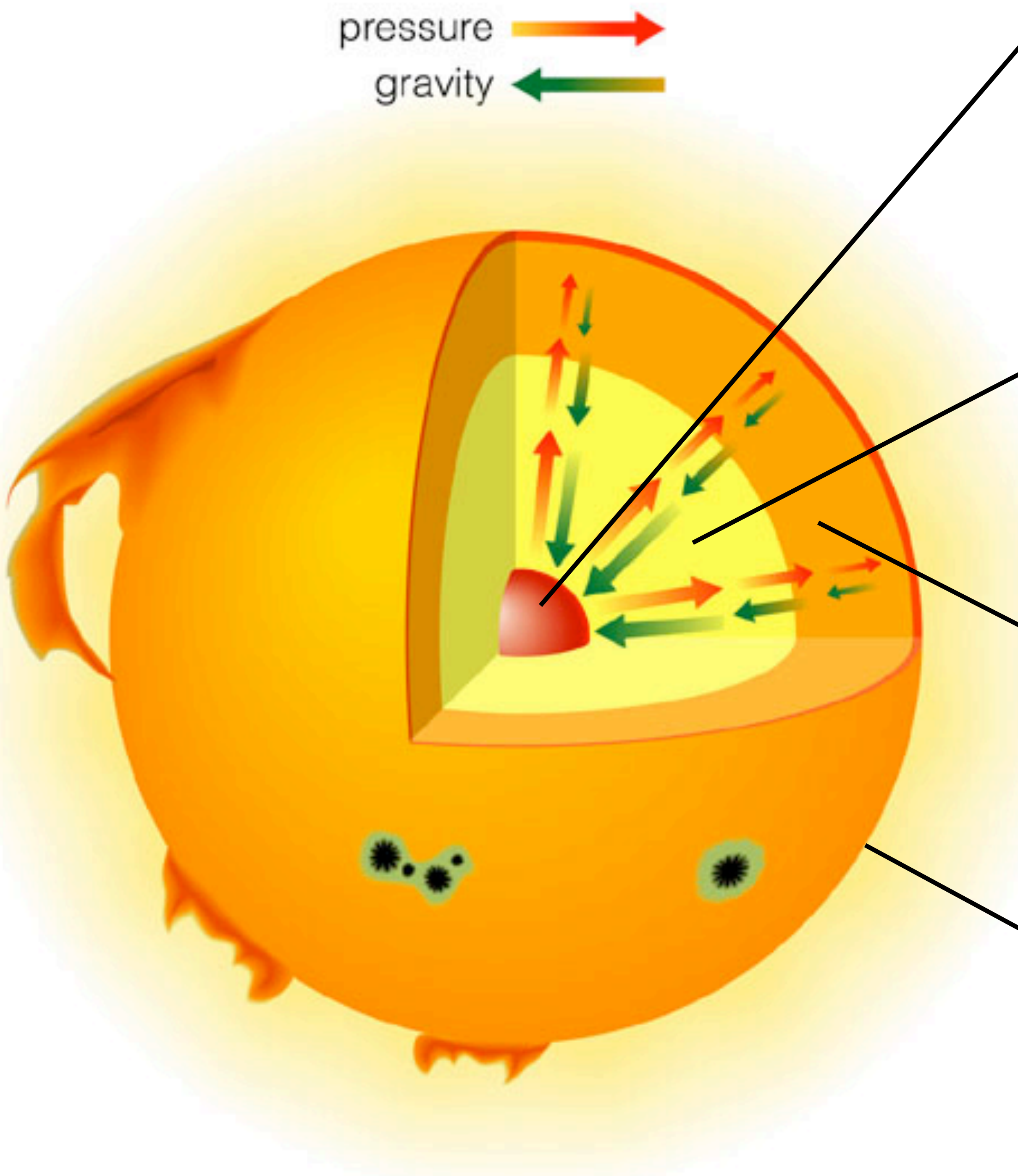


Core:

Energy generated by nuclear fusion

~ 15 million K

Radiation zone:

Energy transported upward by photons

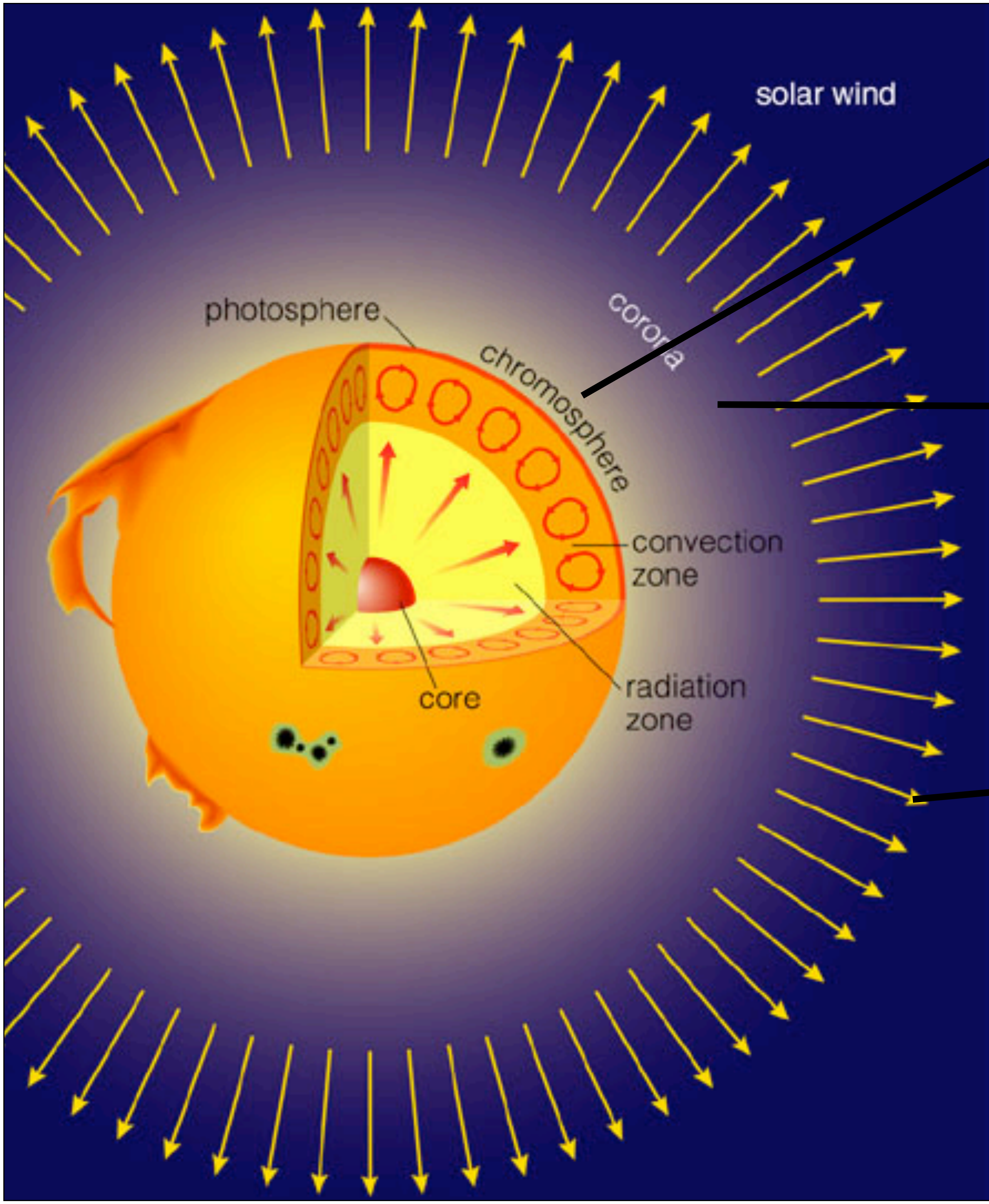
Convection zone:

Energy transported upward by rising hot gas

Photosphere:

Visible surface

~5,800 K



Chromosphere:

Middle layer of solar atmosphere

Corona:

Outermost layer of solar atmosphere

Solar wind:

A flow of charged particles from the surface of the Sun

Little mass in these components

Energy transport

- Energy generated by fusion deep in the core
- Energy transported outwards through sun by
  - radiation (photons), or
  - convection (churning gas motion)
- Energy radiated from surface into space as light

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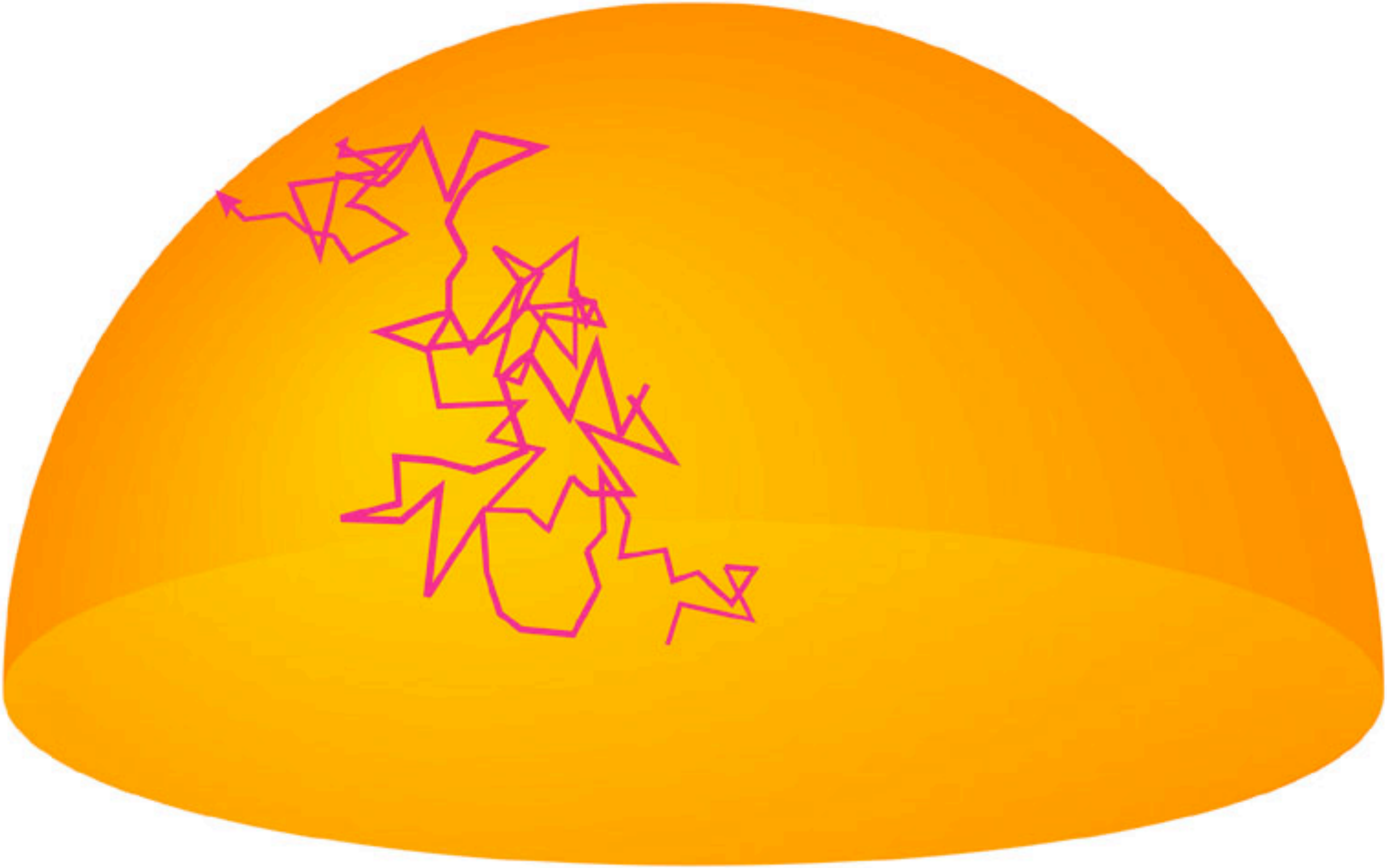

Energy gradually leaks out of the radiation zone in the form of randomly bouncing photons.

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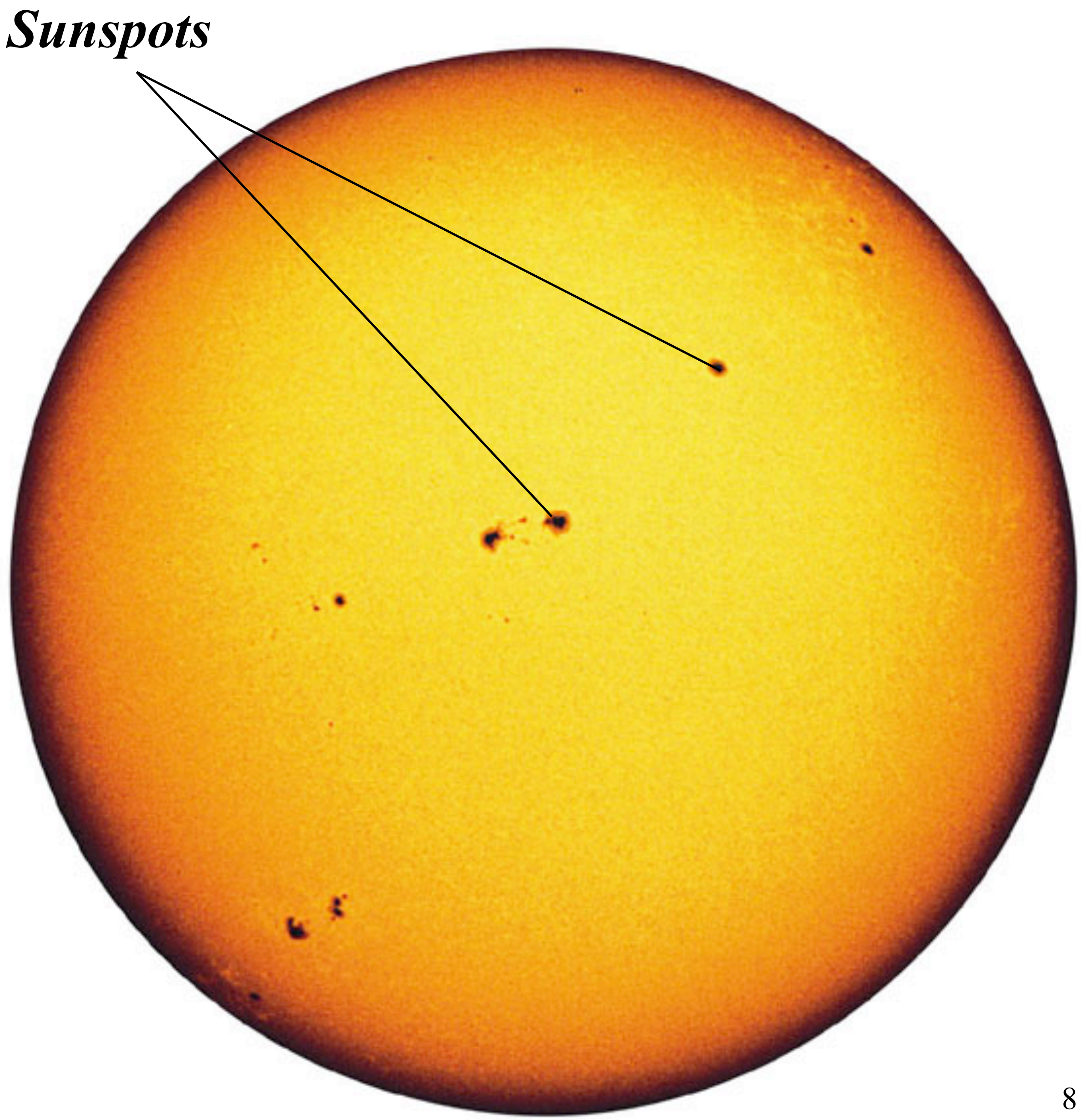

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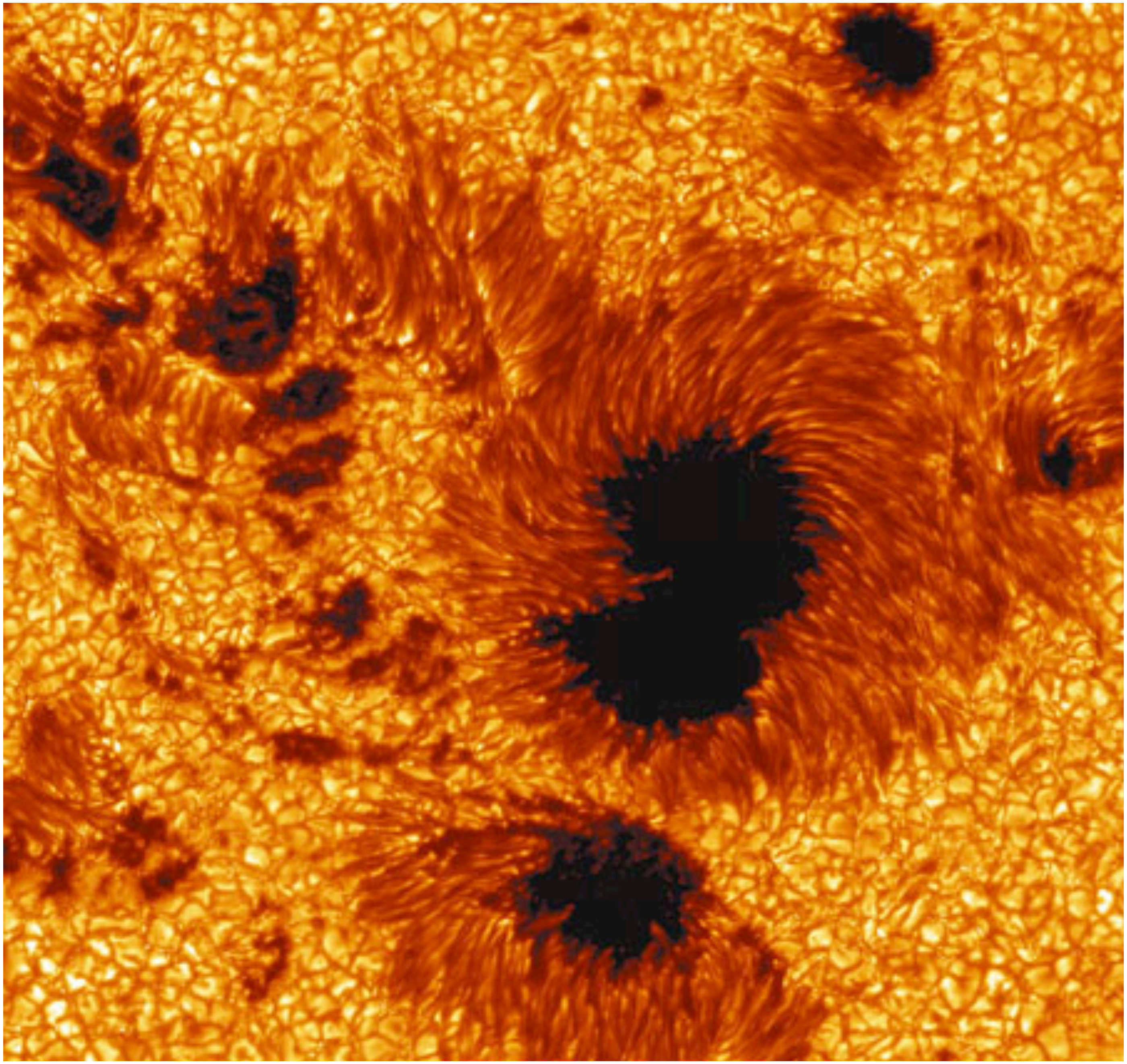

Sunspots…

Are cooler than other parts of the Sun's surface (4,000 K instead of 5,800 K)

They're regions with strong magnetic fields

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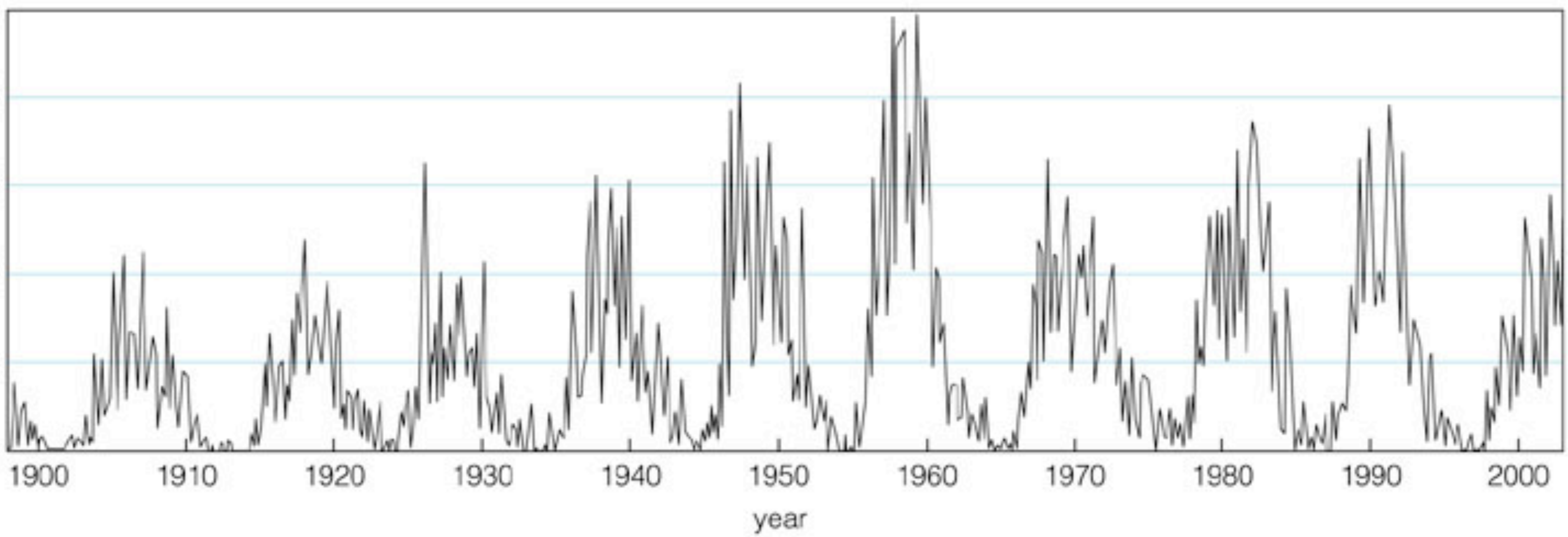
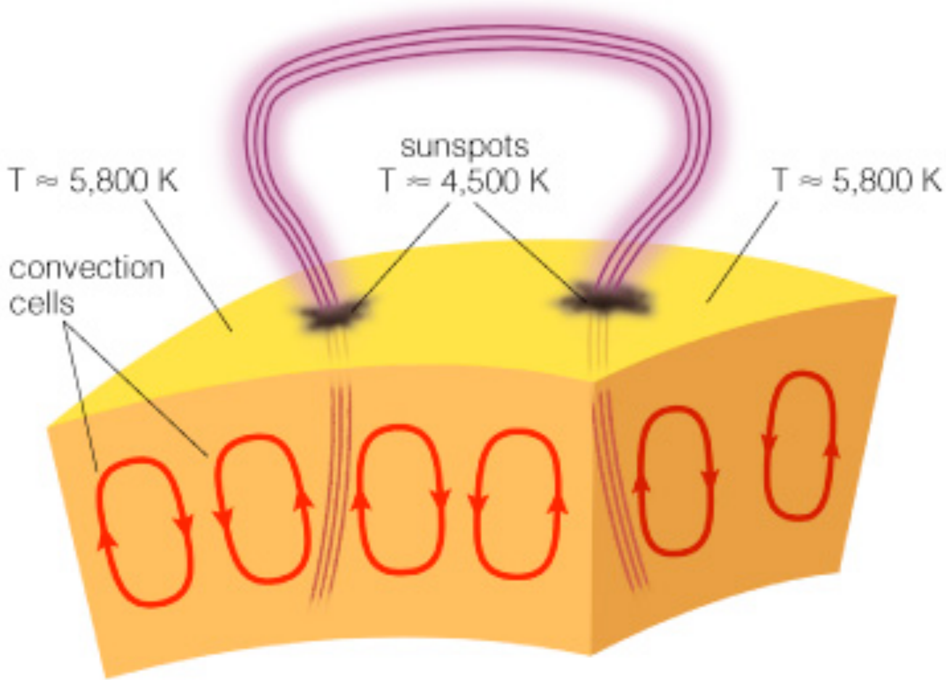
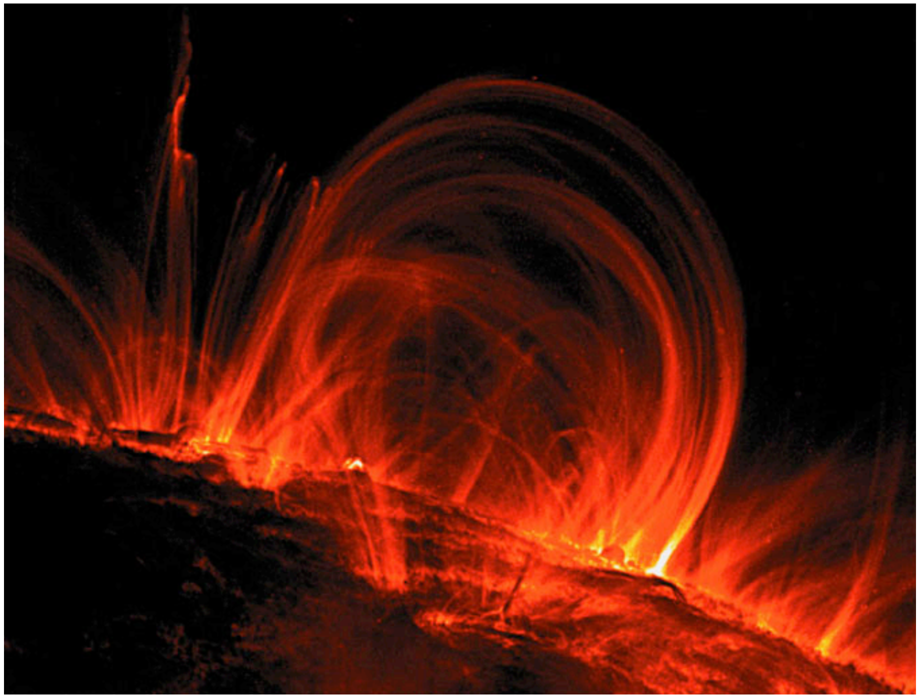
The number of sunspots rises and falls in 11-year cycles.



The sunspot cycle has something to do with the winding and twisting of the Sun's magnetic field.

Loops of bright gas often connect sunspot pairs.





Gas is trapped along magnetic field lines.

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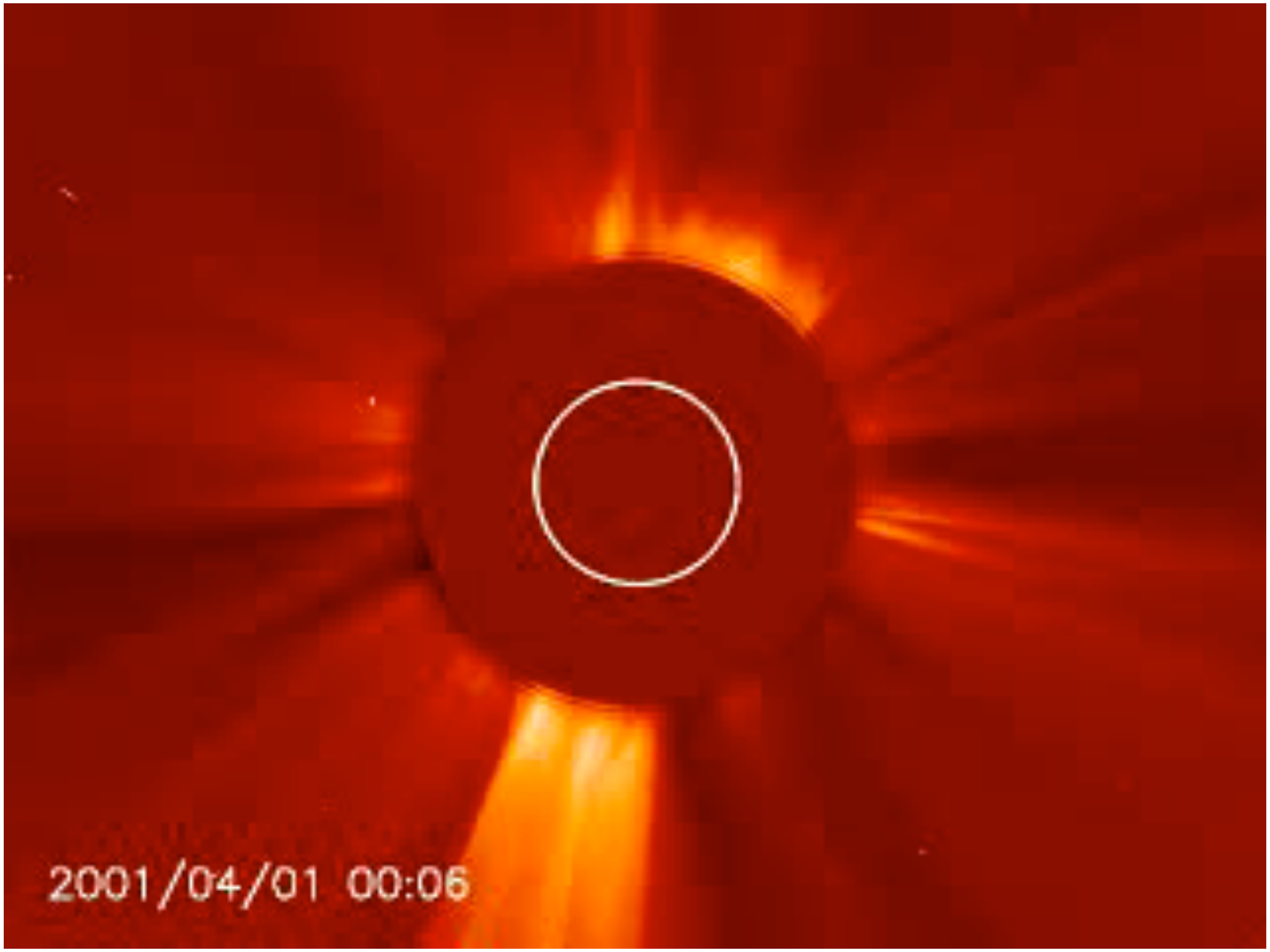

Coronal mass ejections send bursts of energetic charged particles out through the solar system.

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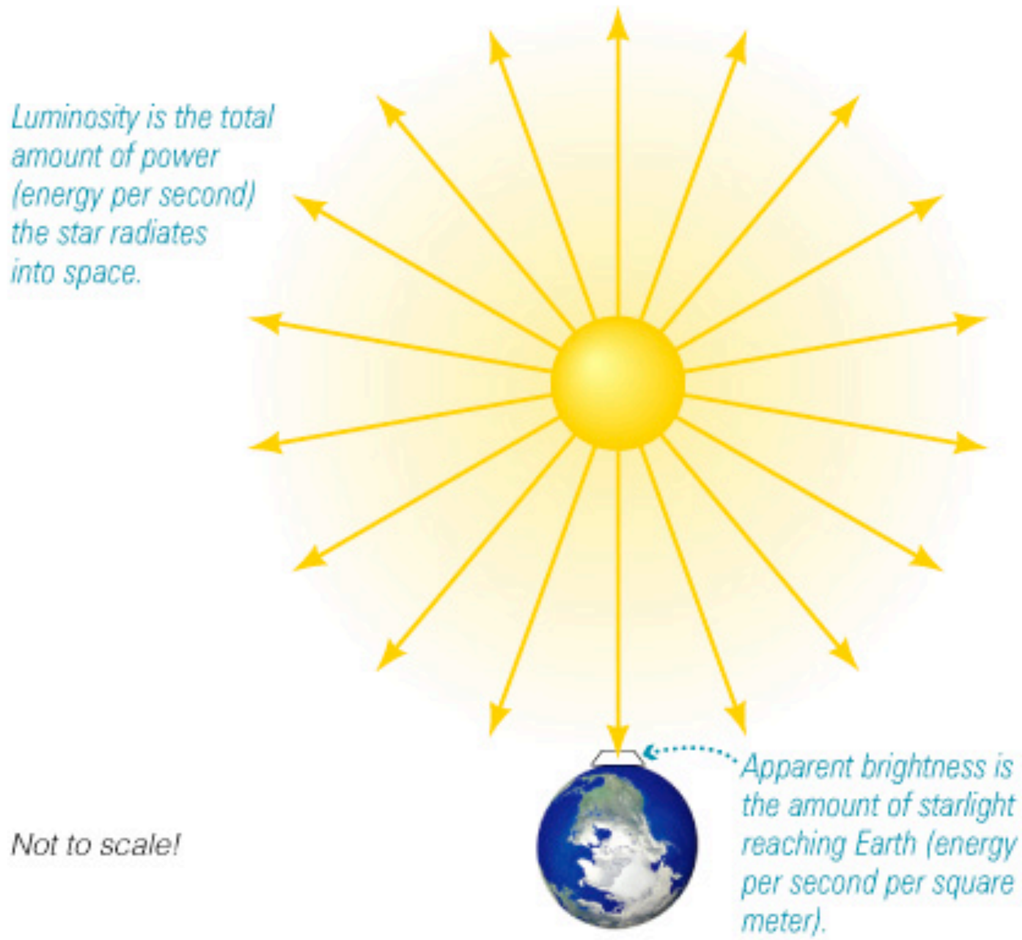
Stars



Luminosity: L

Amount of power a star radiates

(energy per second = watts)

Apparent brightness: b

Amount of starlight that reaches Earth

(energy per second per square meter)

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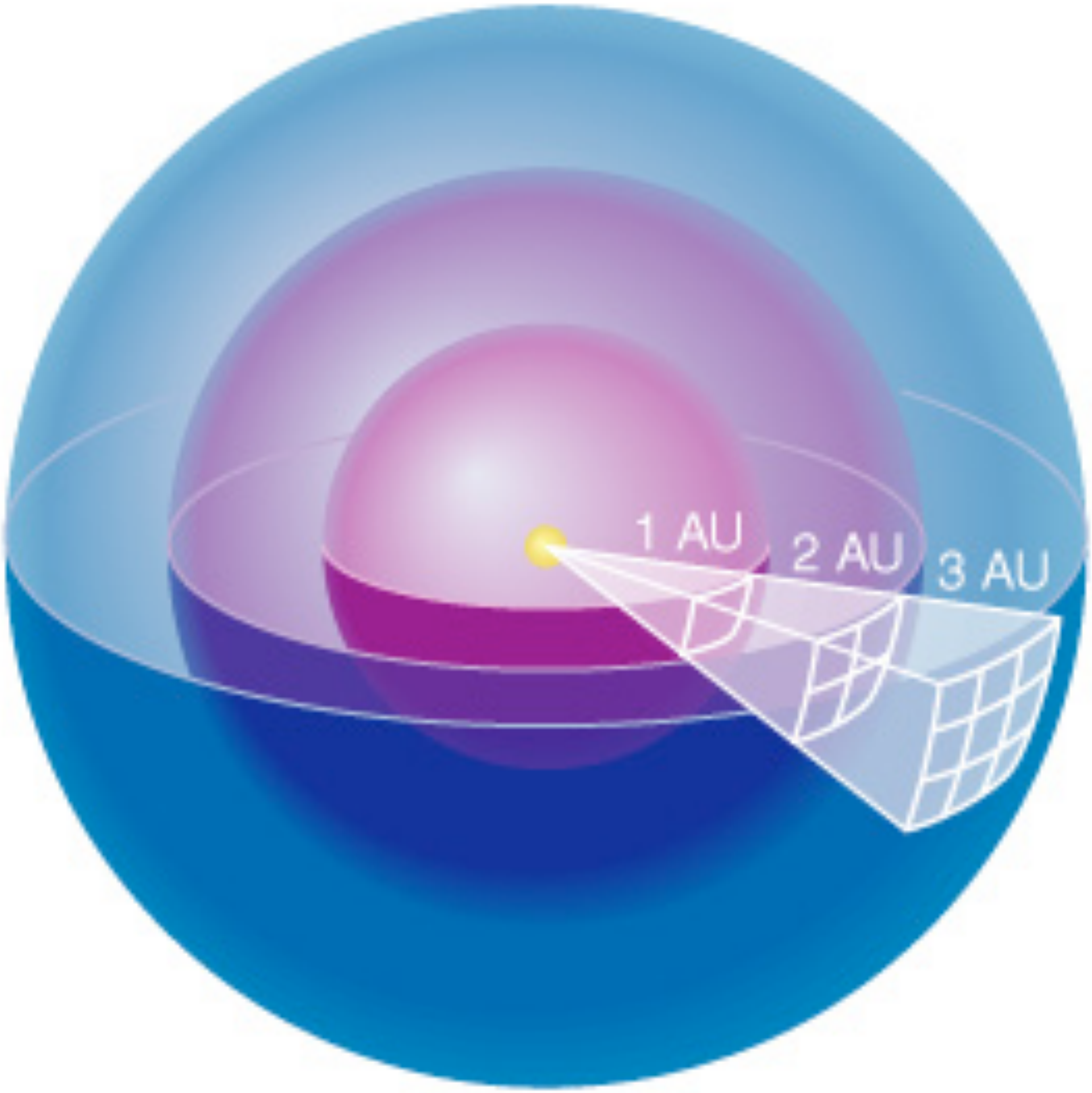

Luminosity passing through each sphere is the same

Area of sphere:

$$4\pi\ (\text{radius})^2$$

Divide luminosity by area to get brightness.

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The relationship between apparent brightness and luminosity depends on distance:

$$\text{Brightness} = \frac{\text{Luminosity}}{4\pi\,(\text{distance})^2}$$

$$b = \frac{L}{4\pi d^2}$$

intrinsic property

measurable quantities

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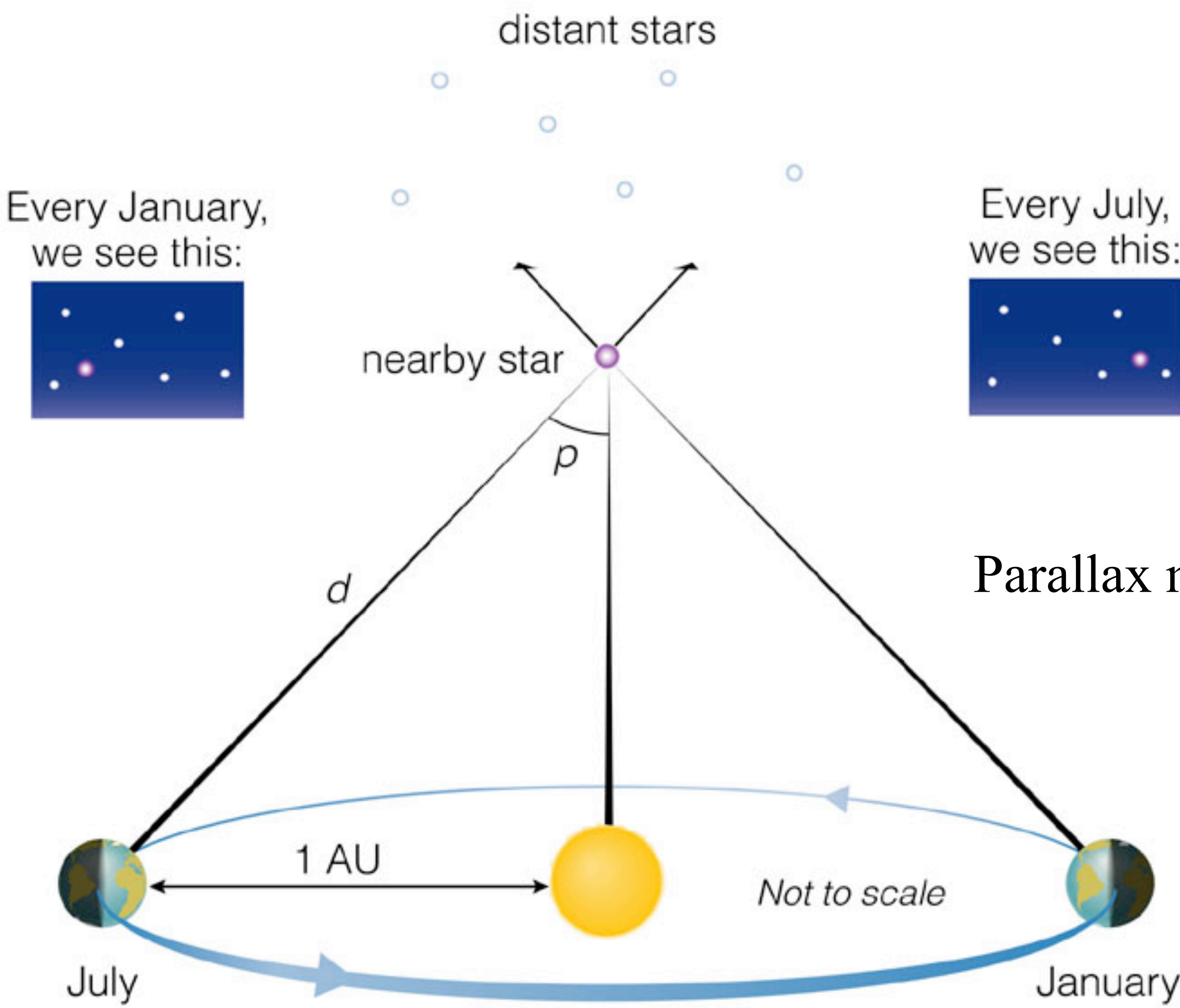
So how far away are the stars?

Start with a crude guess:
all stars are like the sun
with the same luminosity:

$$d = \sqrt{\frac{L}{4\pi b}}$$

With this crude approximation,
the brighter stars in the sky would
be about a light-year away.



Parallax movie

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Parallax and Distance

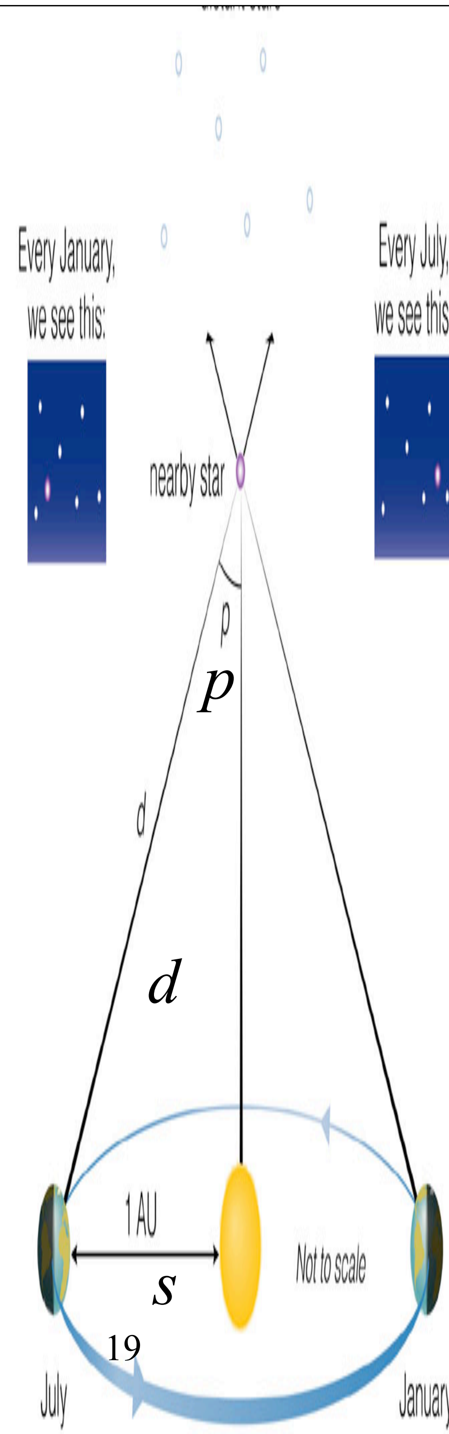
$$d = \frac{s}{p}$$

The natural units for the parallax angle *p* are radians.
Then distance *d* and separation *s* are in the same units.

For the special case of *s* = 1 AU
and *p* measured in arcseconds,   (1”=penny at 4 km!!)
d comes out in parsecs (pc).

1 pc = 3.26 light-years

The *closest* star (Proxima Centauri) is
4.2 light-years away, so *p* < 1”
- no wonder the ancients couldn’t detect parallax!



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Most luminous stars:

$10^6 \ L_{\text{Sun}}$

Least luminous stars:

$10^{-4} \ L_{\text{Sun}}$

30 x full moon at distance of sun

(L_{Sun} is luminosity of the Sun)

Size of stars

Hottest stars:

50,000 K

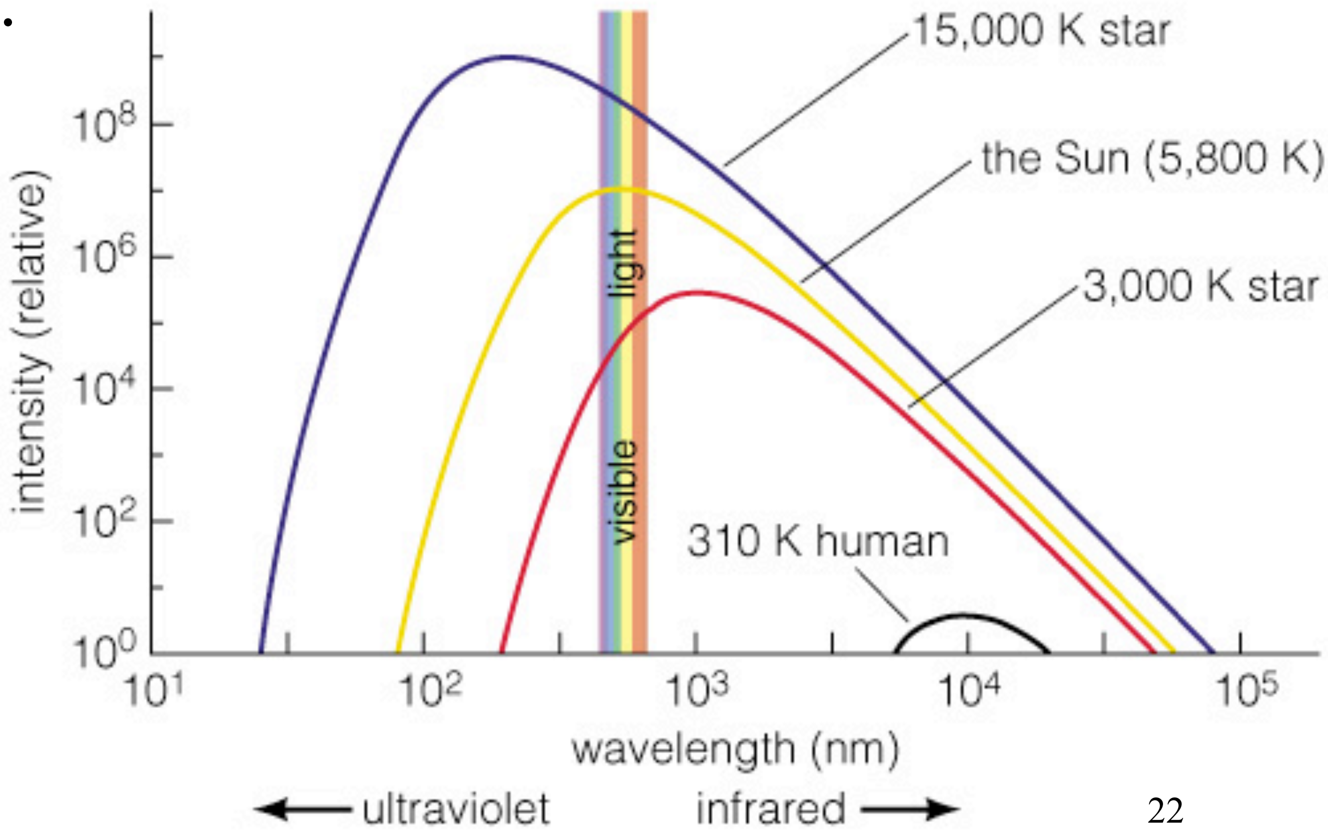
Coolest stars:

3,000 K

(Sun's surface is 5,800 K)

Properties of Thermal Radiation

1. Hotter objects emit more light per unit area at all frequencies.
2. Hotter objects emit photons with a higher average energy.



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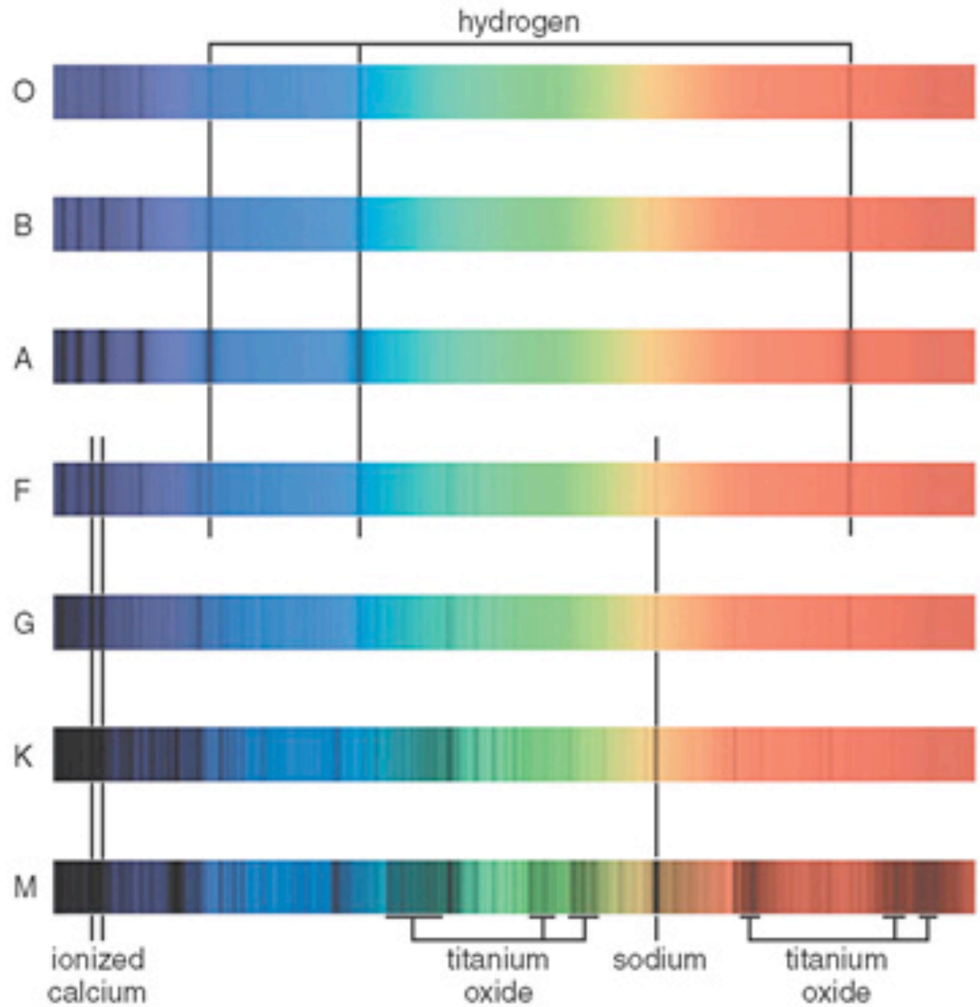

Lines in a star's spectrum correspond to a ***spectral type*** that reveals its temperature:

(Hottest) O B A F G K M (Coolest)

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Remembering Spectral Types

(Hottest) O B A F G K M (Coolest)

- Oh, Be A Fine Girl/Guy, Kiss Me

- You can pick your own mnemonics; note that the more explicit and graphic the mnemonic is, the easier it is to remember :)

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Pioneers of Stellar Classification

- Annie Jump Cannon and the "calculators" at Harvard laid the foundation of modern stellar classification.

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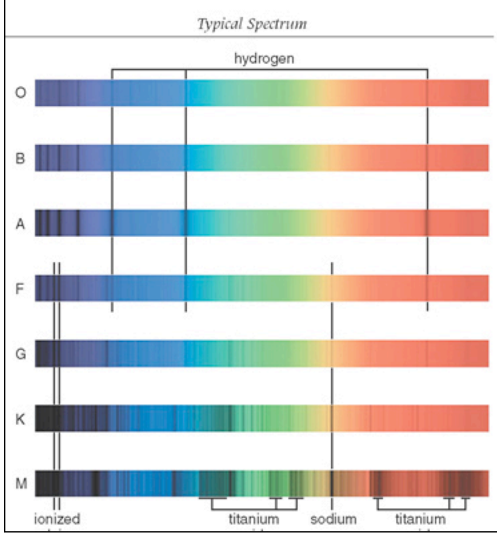
Spectral Types are a sequence in Temperature

Hot ⟷ Cool

O B A F G K M

...F8 F9 G0 G1 G2 ... G8 G9 K0 K1...



The Sun is type G2

Hertzsprung-Russell (HR) Diagram

- Plots Luminosity vs Temperature
- Luminosity requires measurement of
  - brightness
  - distance
- Temperature from
  - Wien's Law (color) or
  - Spectral Type

Omega Centauri

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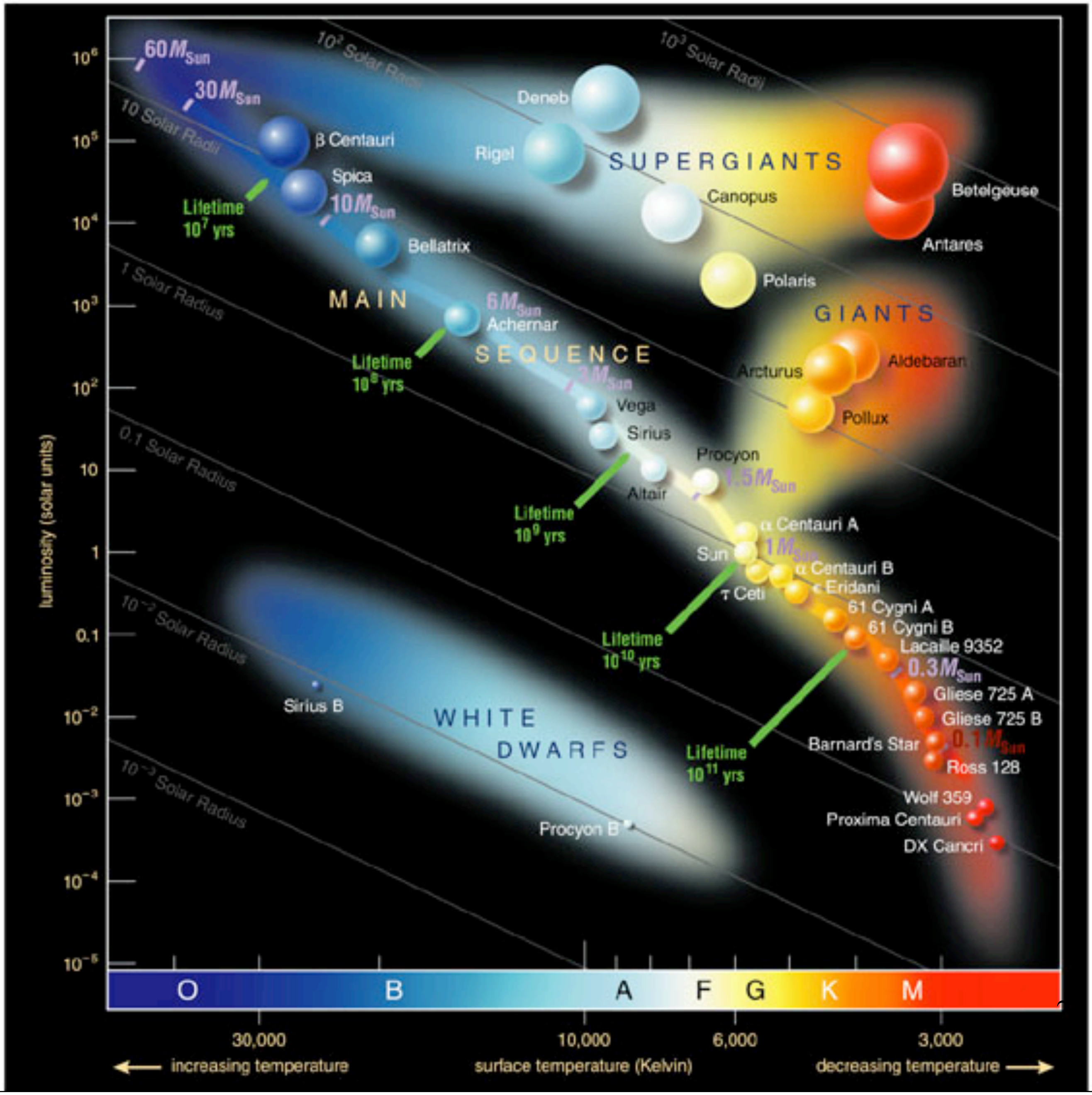
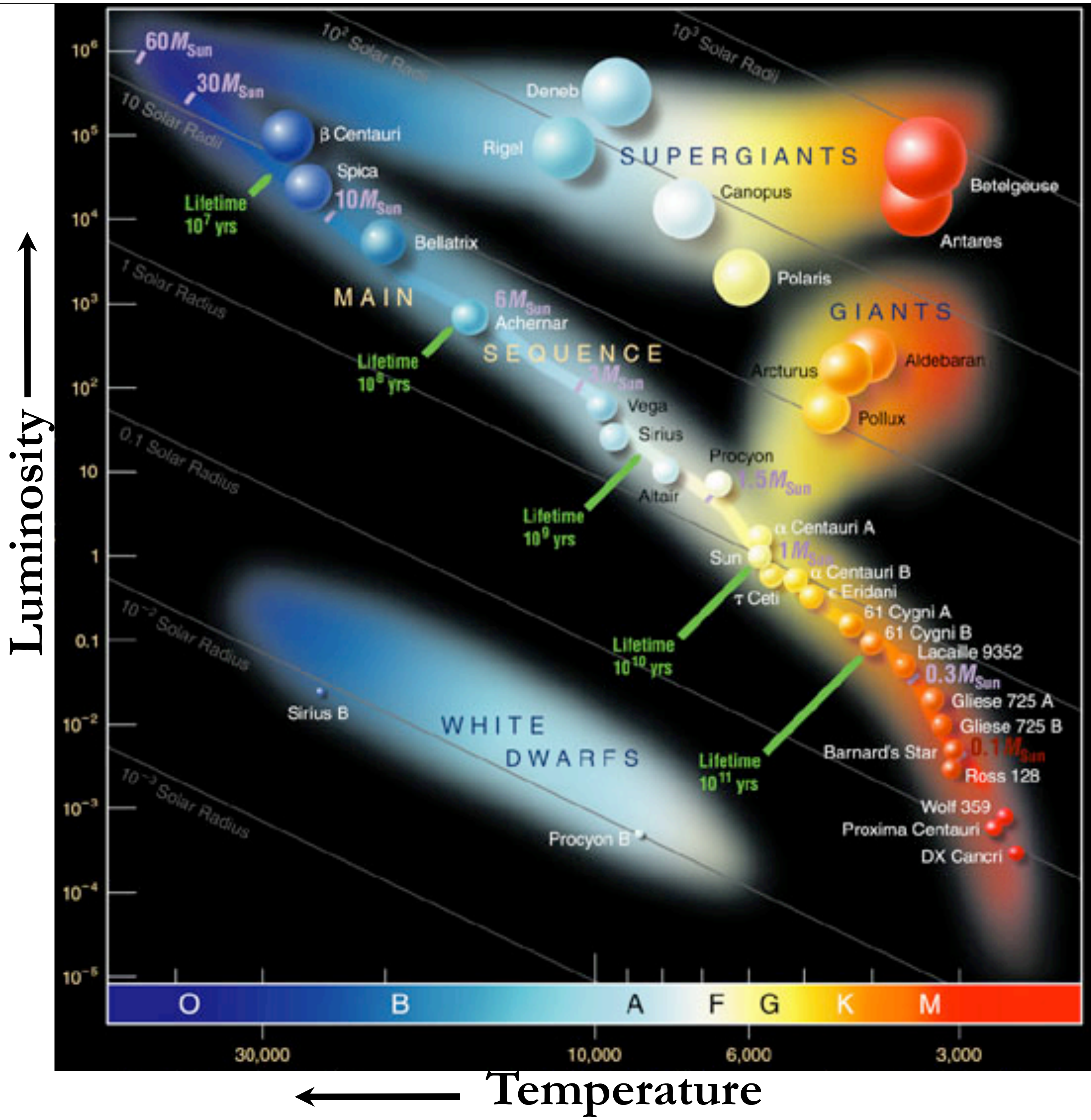
The Hertzsprung–Russell diagram





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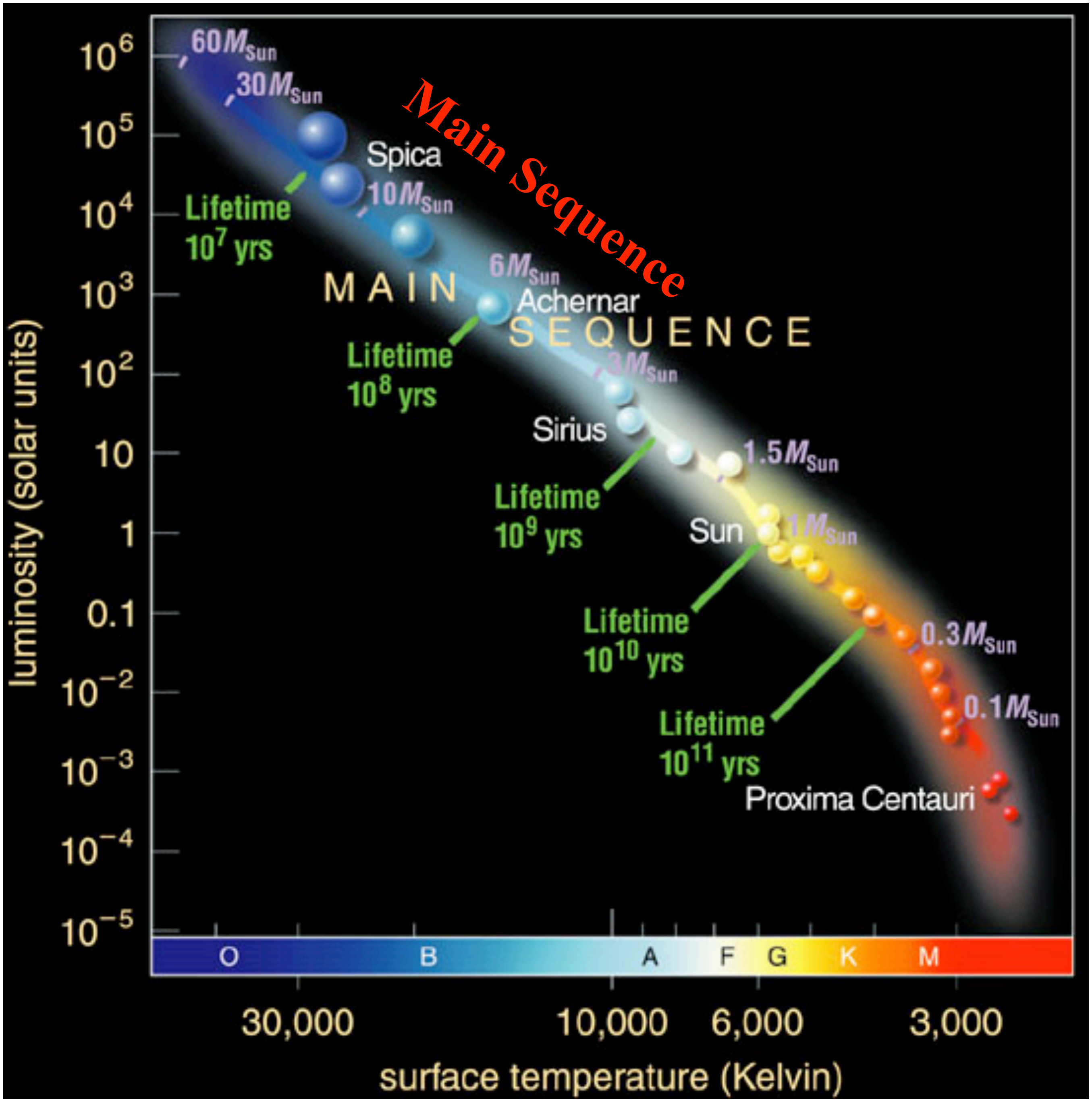
An H-R diagram plots the **luminosities** and **temperatures** of stars.

Each star is on point on this diagram.



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Most stars fall somewhere on the ***main sequence*** of the H-R diagram.

Hot stars tend to be brighter. Remember the Stefan-Boltzmann Law:

$$L \propto R^2 T^4$$

Star Size

Some stars are much more luminous, but are cooler, than the Sun. What does this mean about their size?

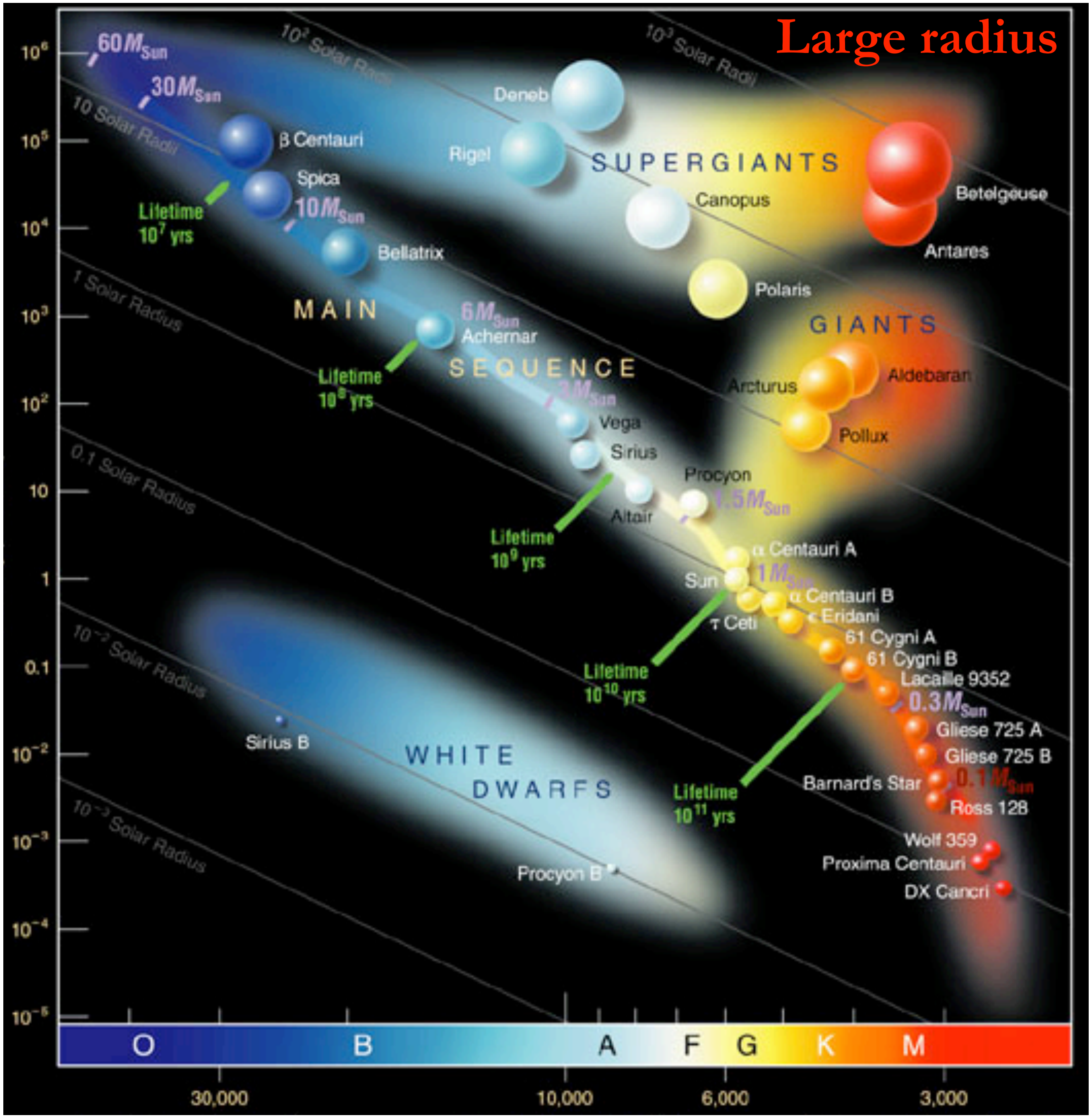
A. There is not enough information to say

B. They are much smaller than the Sun

C. They are about the same size as the Sun

D. They are much bigger than the Sun

E. I don't know



Stars with lower *T* and higher *L* than main-sequence stars must have larger radii:

giants and ***supergiants***

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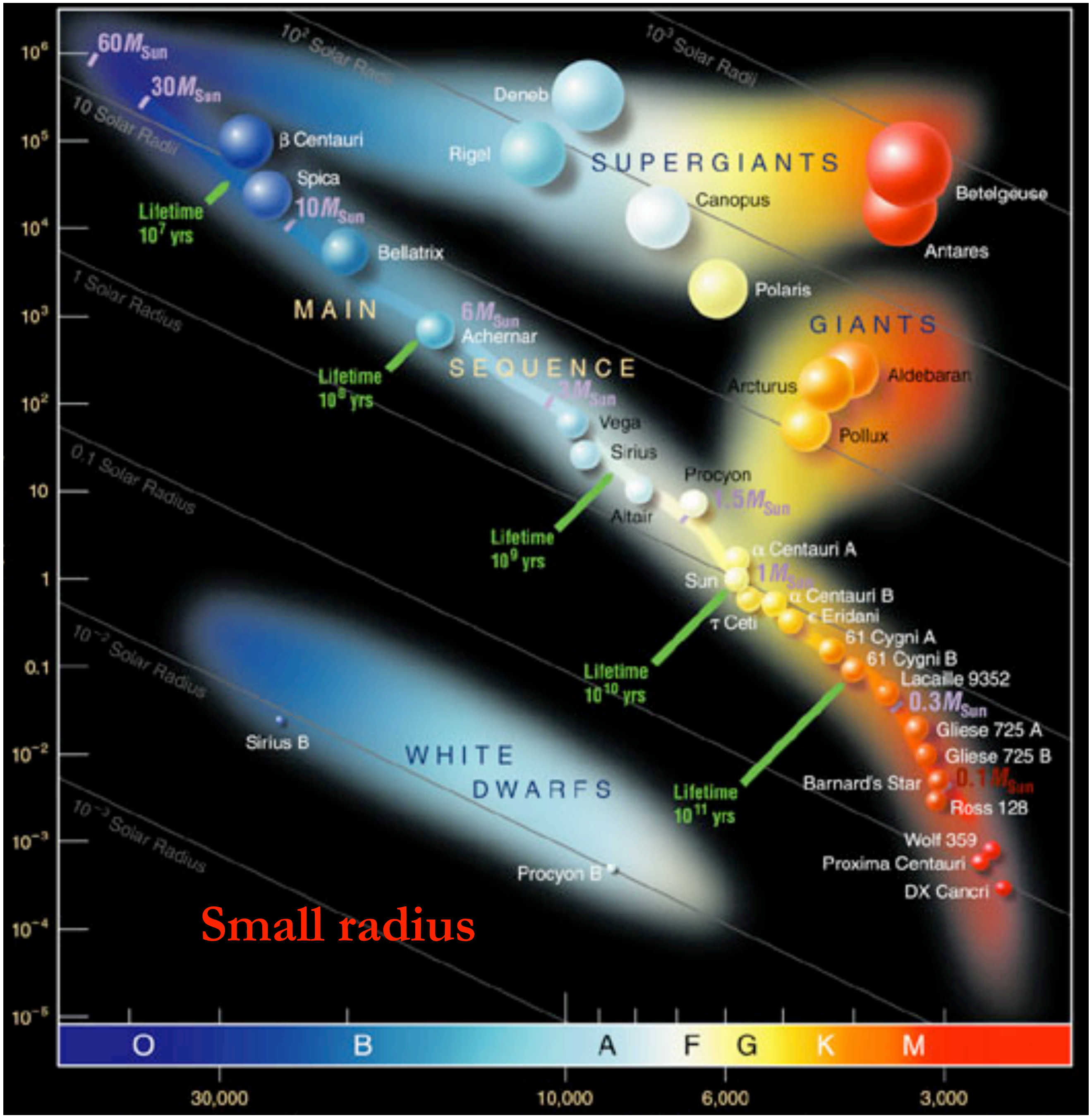

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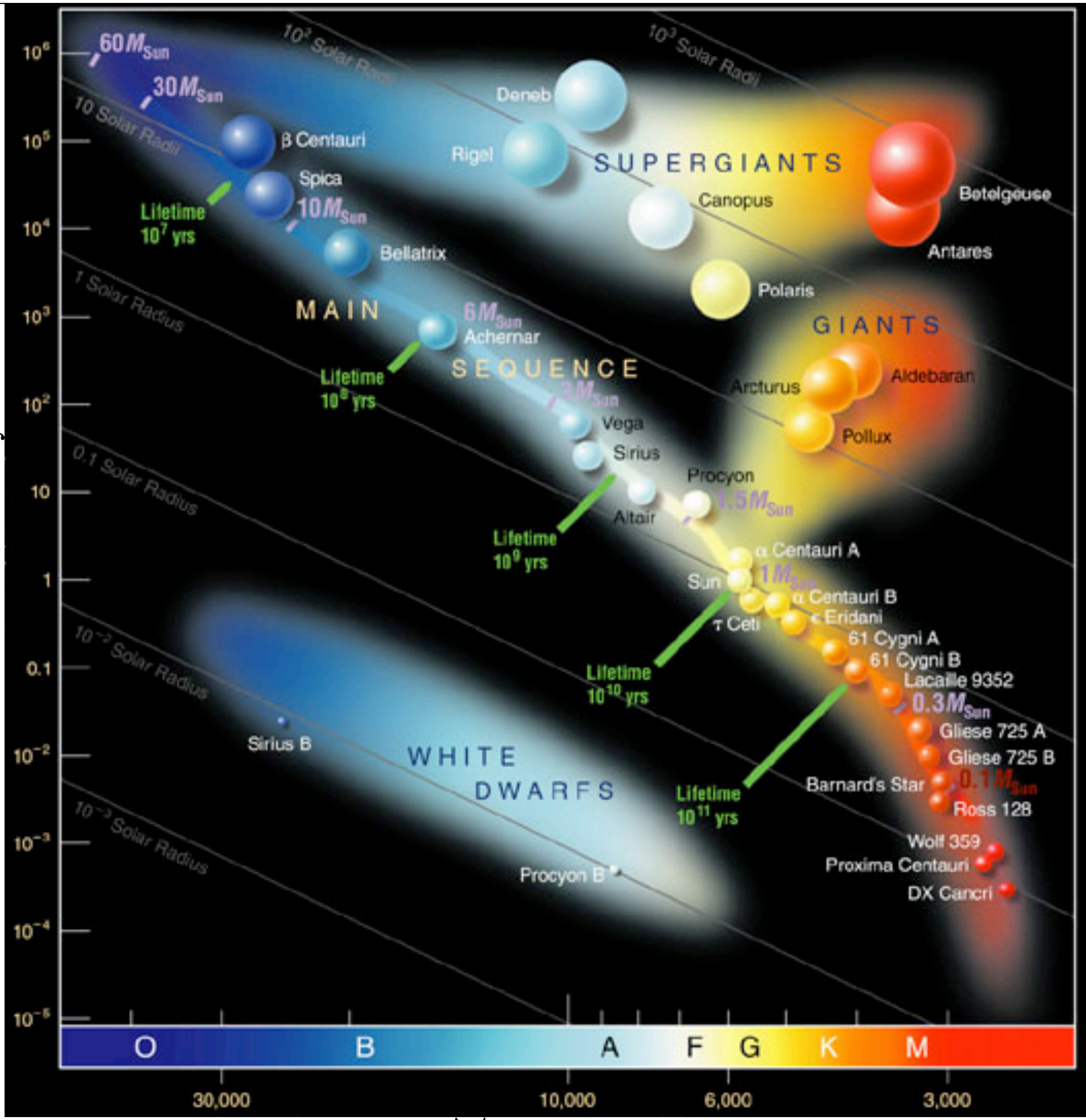
Stars with higher *T* and lower *L* than main-sequence stars must have smaller radii:

white dwarfs

Luminosity



Temperature

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H-R diagram depicts:

Temperature

Color

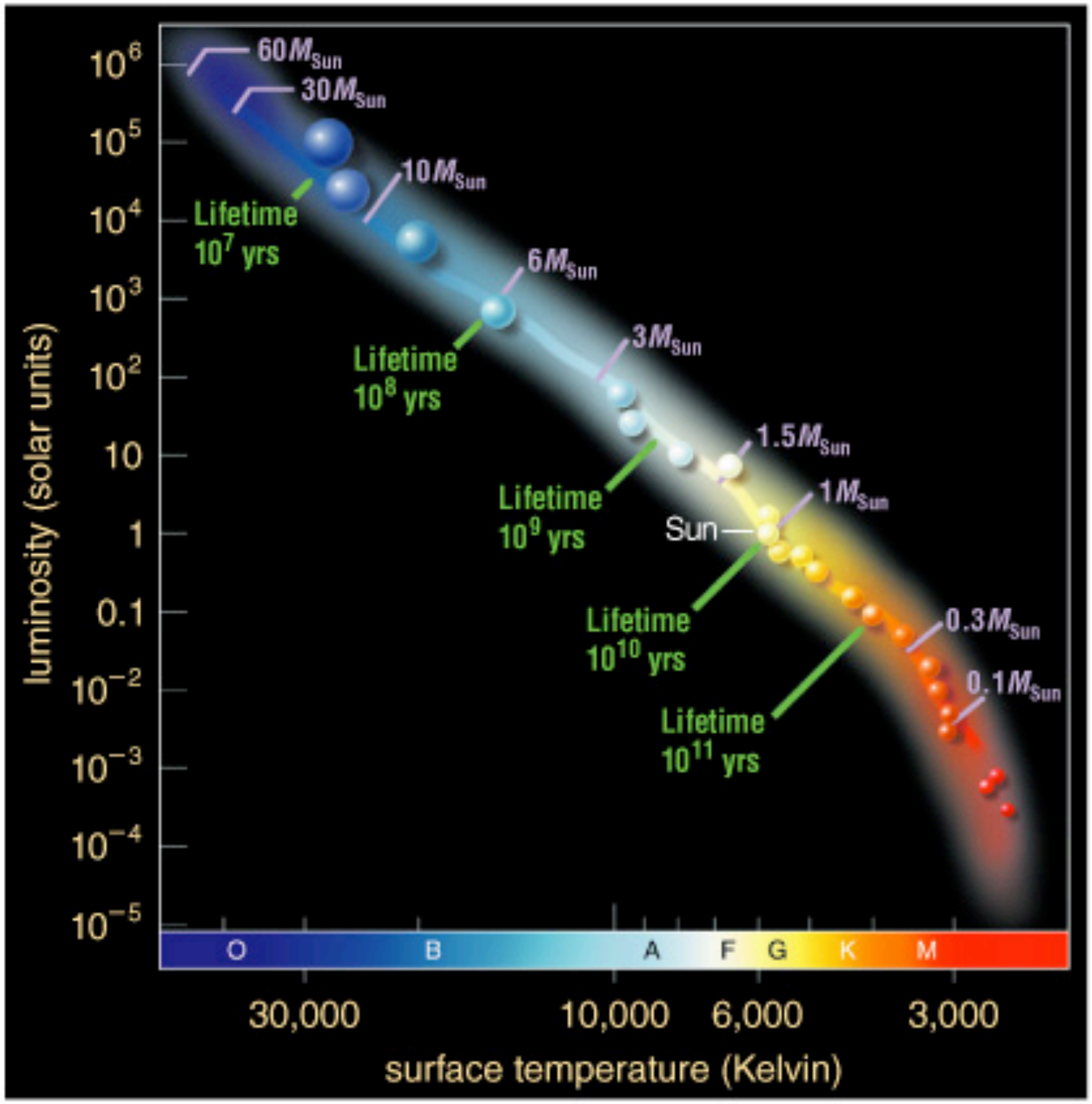
Spectral type

Luminosity

Radius

$$L = 4\pi R^2 \sigma T^4$$

The significance of the main sequence



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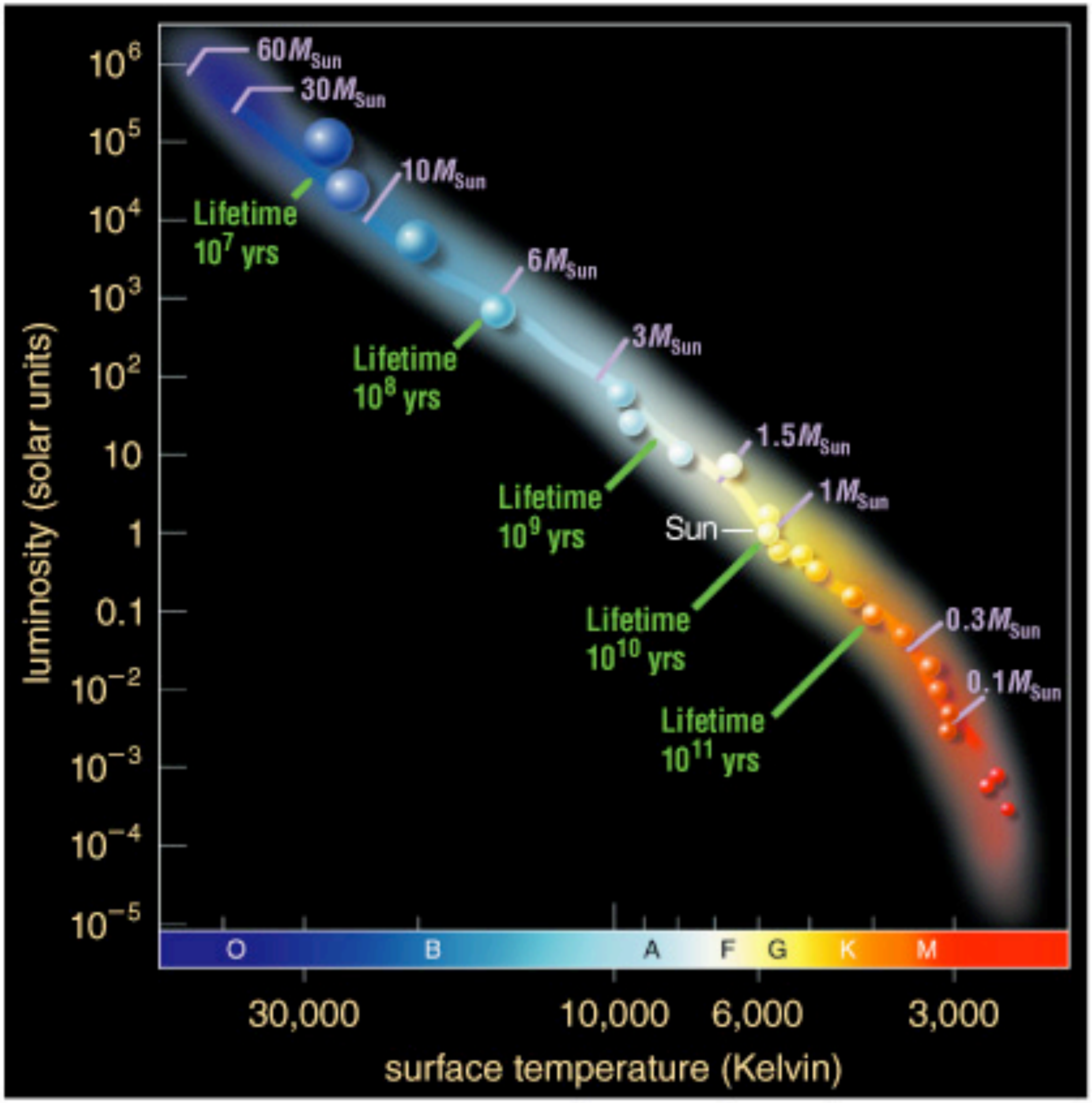

Main-sequence stars are fusing hydrogen into helium in their cores, like the Sun.

Luminous main-sequence stars are hot (blue).

Less luminous ones are cooler (yellow or red).

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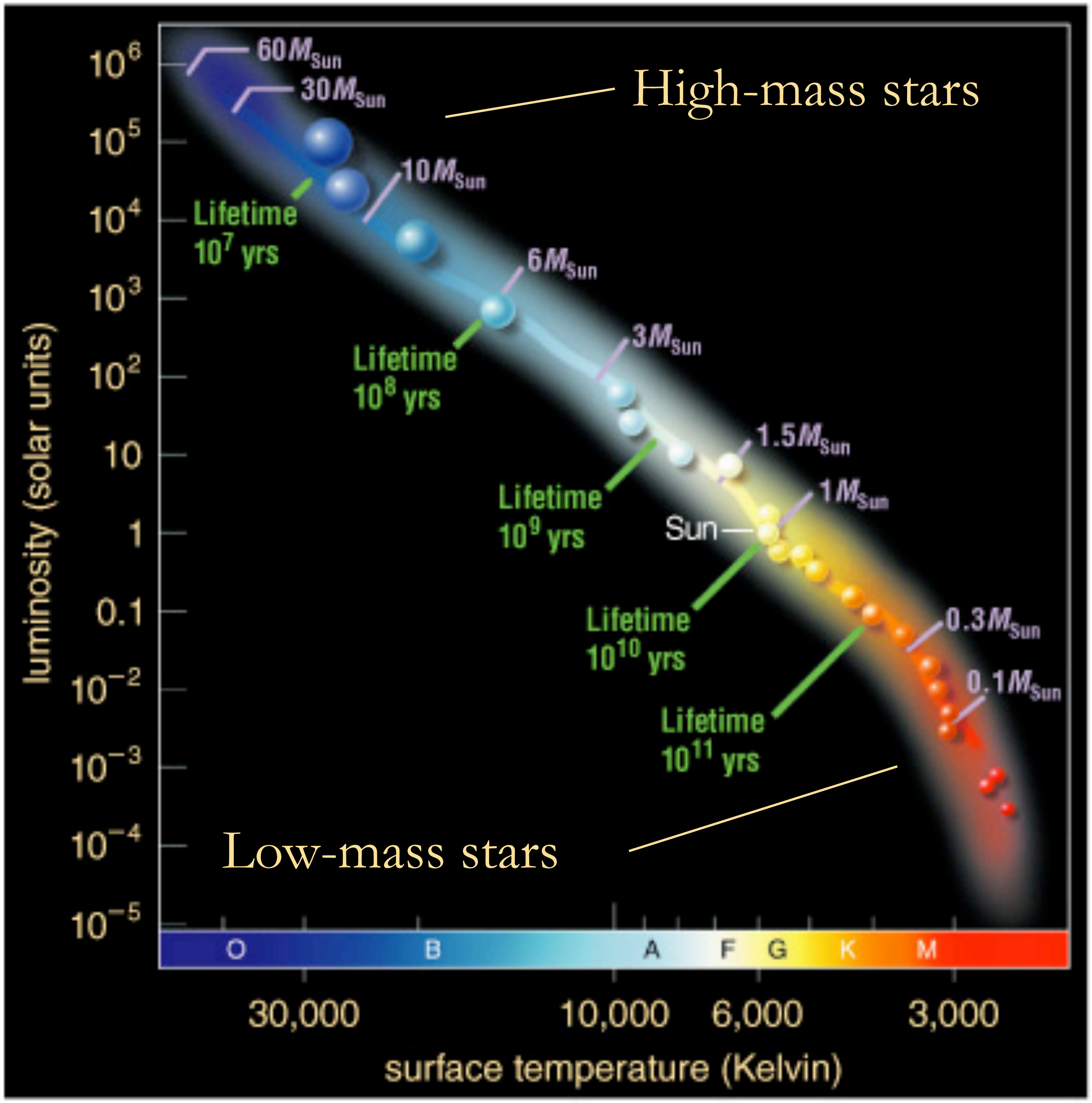

Mass measurements of main-sequence stars show that the hot, blue stars are much more massive than the cool, red ones.

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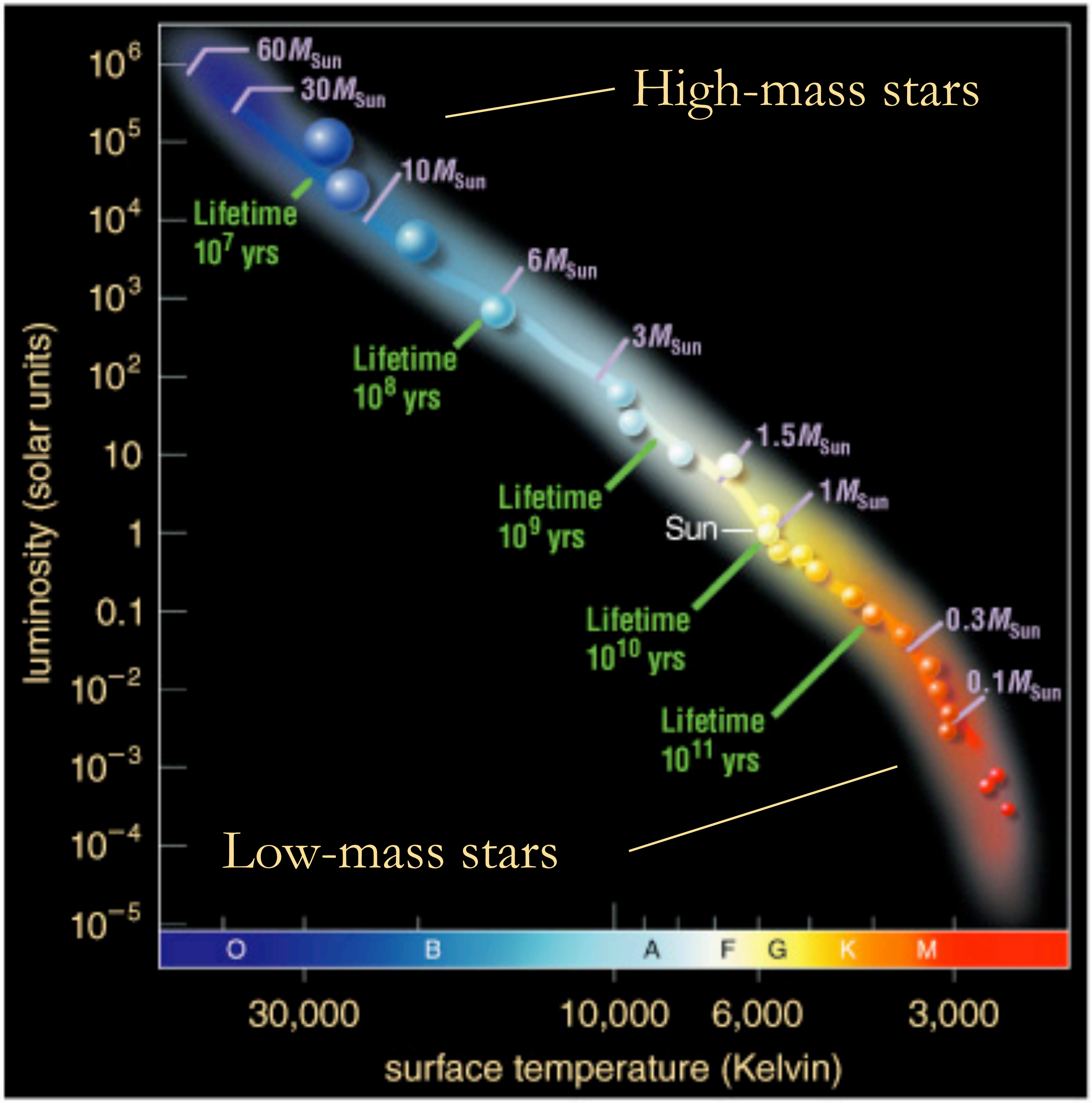

The mass of a main sequence star determines its luminosity and spectral type!

For stars, mass is destiny

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