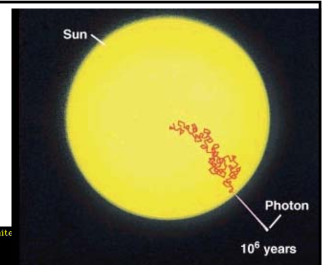
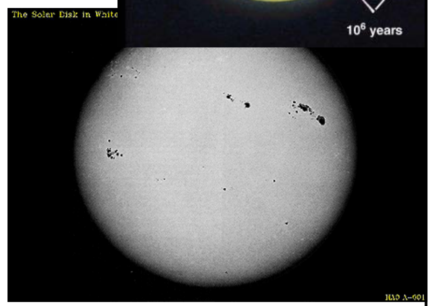
Photosphere

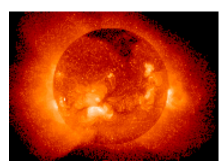
- Layer from which light escapes directly into space.
  - Photosphere is what we see.
  - Light from lower layers scatters.
- Q: Suppose we observe the neutrinos from the sun. The size of the sun when viewed with neutrinos is
  - A. Smaller
  - B. Same
  - C. Bigger
- Low density and pressure
  - 10^{-4} density in this room
  - 0.1 pressure in this room
- *Hot* (5800 K)
- Granules
  - Tops of convection bubbles. 700km size.



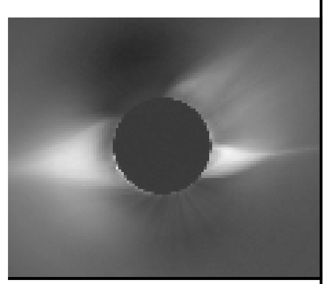


Bob Stein's simulation
movie

- Chromosphere
  - Transparent gas layer, reaches 2000-3000 km above photosphere.
  - Hotter than photosphere T ~5,000-10,000° K
  - Emission lines
- Corona
  - T > 1,000,000° K
  - Very low density: 10^{-10} bar.
  - Heated by magnetic energy.
  - Several x diameter of photosphere.
- Solar wind
  - Particles streaming from sun
  - Extends beyond the planets



Corona



Hot-plate model of stars

- Parts of the sun
- Hot-plate model of a star
- Hertzsprung-Russell Diagram
- Dwarfs, giants, & white dwarfs

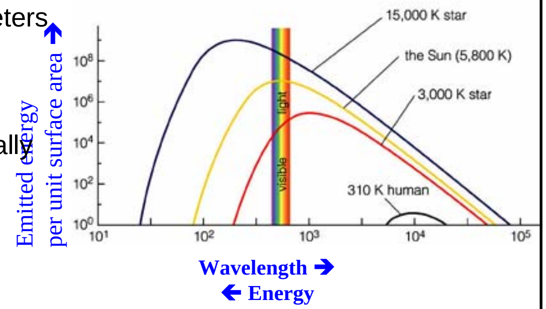
Hot-plate model of stars

- Q1 What quantities determine to a great extent the total amount of light that stars, the sun, a hot plate, and I emit? Composition, Temperature, Size
  a. C & T
  b. T & S
  c. S & C
  d. All 3

Orion constellation
http://lithops.as.arizona.edu/~jill/EPO/Posters/Orion/protoplanets.html

Hot-plate Model of a Star

- A hot plate emits light as a blackbody. The key parameters are
  - Temperature
  - Area
- A star is a really hot and really big hot plate.
- Ingredients
  - Radius: R. Area=$4\pi R^2$
  - Temperature: T
  - Distance: D
- Goal is to discover the model for flux, the amount of energy we on Earth receive per second per area of telescope.
- Reasoning process:
  - If the temperature is hotter, the flux is ___ (greater or less).



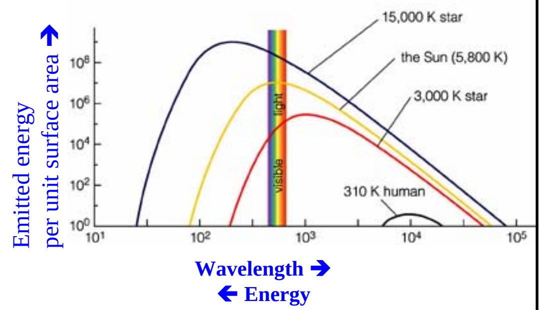
- Q: Should T, D, & R be in the numerator or denominator?
  a. NNN
  b. NND
  c. NDN
  d. DNN

Hot-plate Model of a Star

- A hot plate emits light as a blackbody. The key parameters are
  - Temperature
  - Area
- A star is a really hot and really big hot plate.
- Ingredients
  - Radius: R. Area=$4\pi R^2$
  - Temperature: T
  - Distance: D
- Hot plate model for flux

$$F = R^2 T^4 / D^2$$

Flux = Radius^2 Temp^4 / Dist^2



- Q2: Should T, D, & R be in the numerator or denominator?
  a. NNN
  b. NND
  c. NDN
  d. DNN

Hot-plate Model of a Star

- A Hot plate model for flux

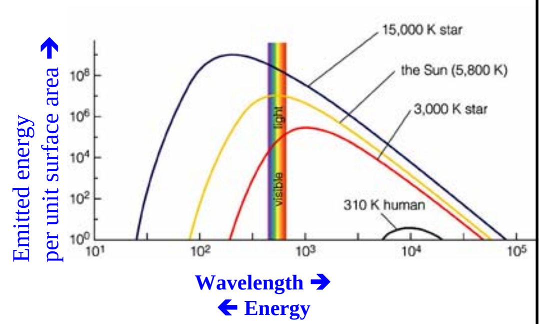
  $F = R^2\ T^4 / D^2$

  Flux = Radius^2 Temp^4 / Dist^2

- We measure *flux* incident on detector on Earth
  - Energy/unit time /unit area
- Luminosity is a quantity intrinsic to the star
  - Energy/unit time
  - Independent of distance to earth.

  $L = R^2\ T^4$

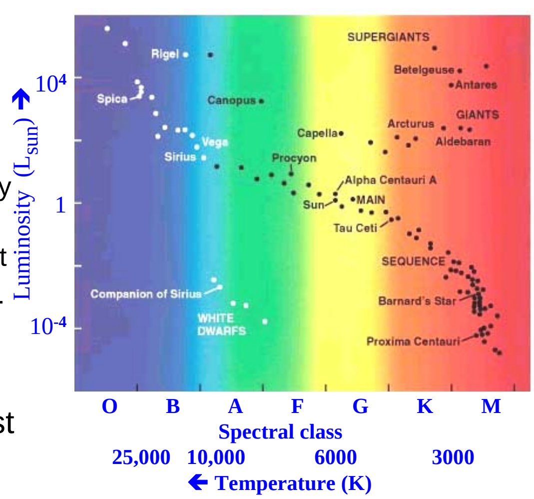
  - To find luminosity of a star, we need to measure its distance. (This is difficult.)



- Q3: A giant hand moved Betelgeuse closer. Its flux and luminosity would be___?
  a. Bigger & bigger
  b. Bigger & same
  c. Same & same

Hertzsprung-Russell (H-R) Diagram

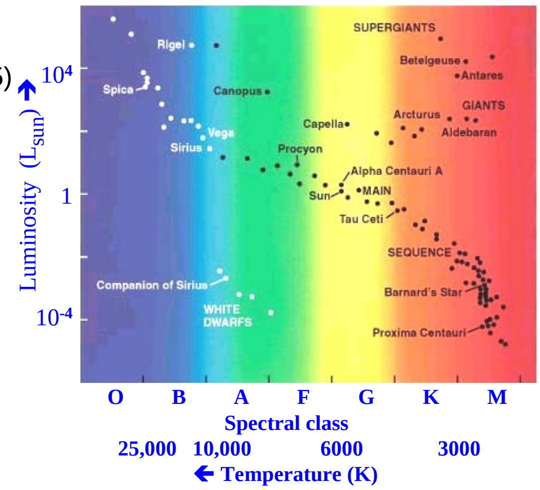
- H-R plotted luminosity vs. surface temperature (1905)
  - Spectral class is a proxy for temperature
  - OBAFGKM. O is hottest
- Stars: A-Aldebaran; B-Barnard's Star; C-Capella; D-Rigel
- Q4 Which is the hottest star?



[see Fig. 11.10]

Hertzsprung-Russell (H-R) Diagram

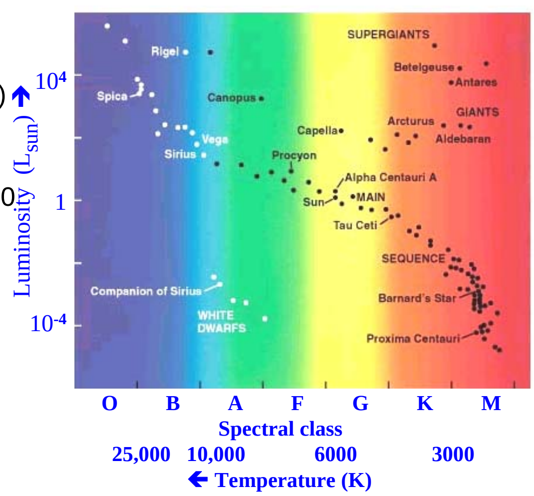
- H-R plotted luminosity vs. surface temperature (1905) & discovered a surprise.
  - Spectral class is a proxy for temperature
  - OBAFGKM. O is hottest
- Q4 Sirius A & Sirius B (companion of Sirius A) have about the same temperature. How can Sirius B be 10,000 times fainter?
  a. Sirius B is 100 times farther away.
  b. Sirius B is 100 times smaller
  c. Sirius A took away the mass
  d. Sirius A took away the light



[see Fig. 11.10]

Hertzsprung-Russell (H-R) Diagram

- H-R plotted luminosity vs. surface temperature (1905) & discovered a surprise.
- Sirius A is slightly larger than the sun. Sirius B is 100 times smaller. The same size as the Earth!
- Stars come in 3 sizes.
  - Main sequence: about the size of sun
  - White dwarf: size of Earth
  - Giants

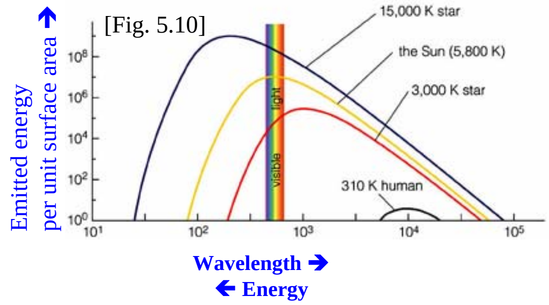


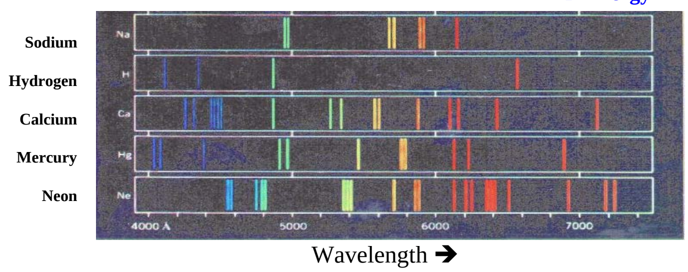
[see Fig. 11.10]

Taking a star's temperature

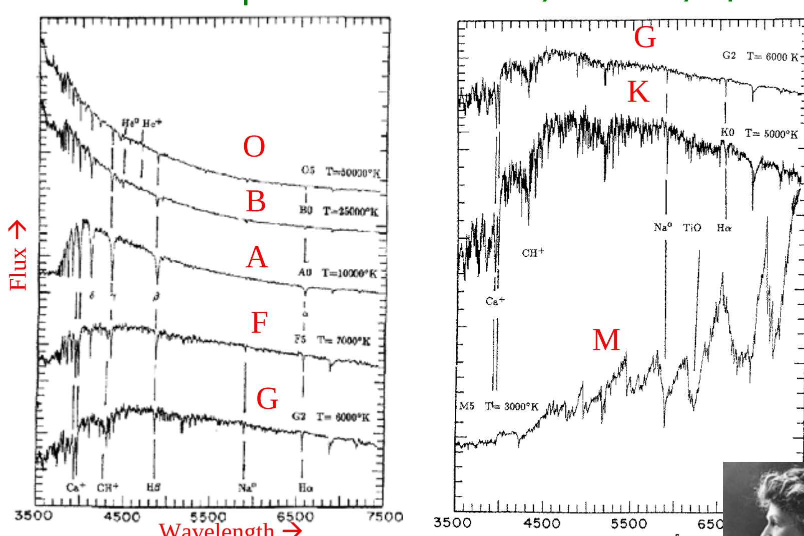
Two Ways:

- Compare amount of light in two colors
  - Blackbody curve
- Spectroscopy





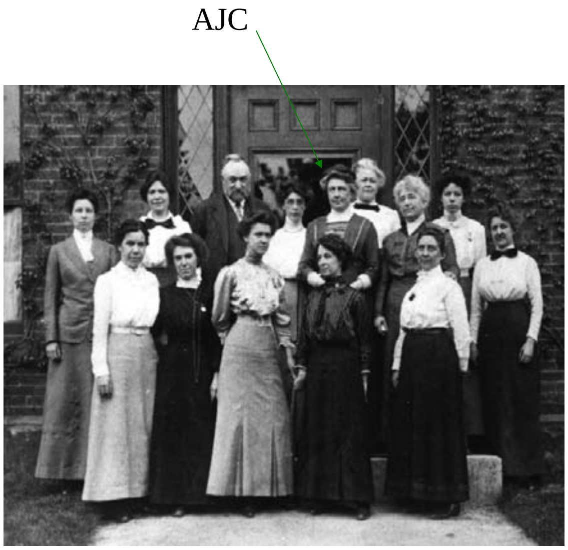
Annie Jump Cannon: Classify stars by spectra



Very efficient: Draper catalog has 250,000 stars

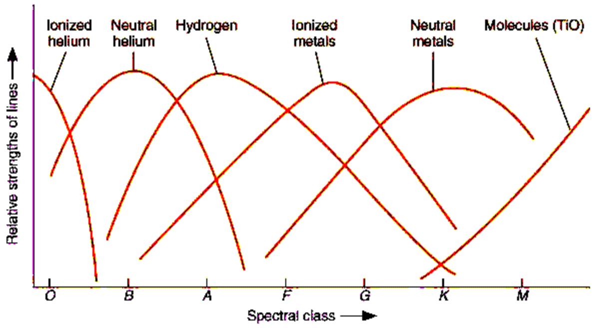
AJC 1863-1941

- Prof. Pickering's Team in 1913, from Barbara L. Welther, 1982, Isis 73, 94.
- AJC
  - BA, Wellesley, 1884
  - Pickering's assistant, 1896
  - Henry Draper catalog of stars, 1918-1924
  - Astronomer 1938



Stellar spectral types

- A Temperature Sequence



Type	Temperature
O	>30,000
B	10,000-30,000
A	7500-10,000
F	6000-7500
G	5000-6000
K	3500-5000
M	<3500

in K

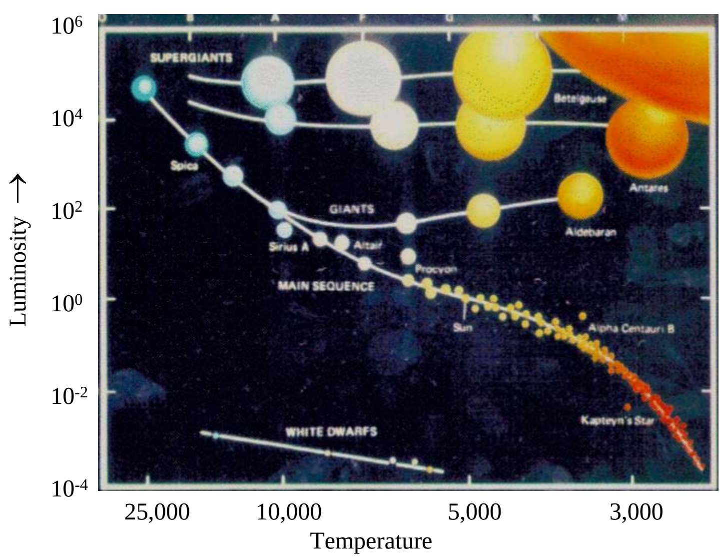
Extra-Credit for best OBAFGKM mnemonic.
- 3 clicker points for entering.
- 3 clicker points for 10 best answers that can be repeated in class.
- Enter in Angel before 31 March.

Observed properties of stars

- Mass
  - Measured in kg or $M_\odot$
  - 0.08-30 $M_\odot$
- Surface temperature
  - 5800K for sun
  - 3000 K for cool star
- Luminosity is amount of energy the star produces in a second
  - Watts=Joules/s or $L_\odot$
  - 40,000$L_\odot$ for Betelgeuse
- Flux or apparent brightness is amount of energy received from the star by a detector in a second.
  - Depends on distance
- Composition: abundances of elements.

Orion constellation
http://lithops.as.arizona.edu/~jill/EPO/Posters/Orion/protoplanets.html

The H-R Diagram with sizes



The H-R Diagram with schematic sizes

Luminosity ↑

10^6

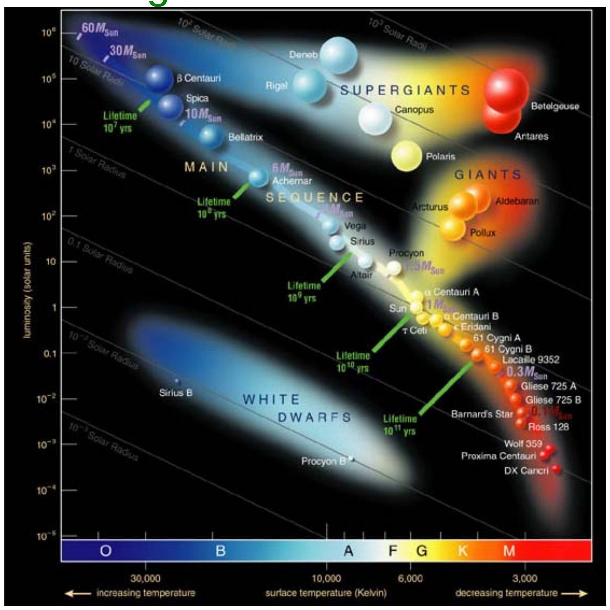
10^4

10^2

10^0

10^{-2}

10^{-4}



[Fig. 11.10]

25,000 10,000 5,000 3,000

Temperature

Mass determines location on main sequence

High mass

Luminosity ↑

10^6

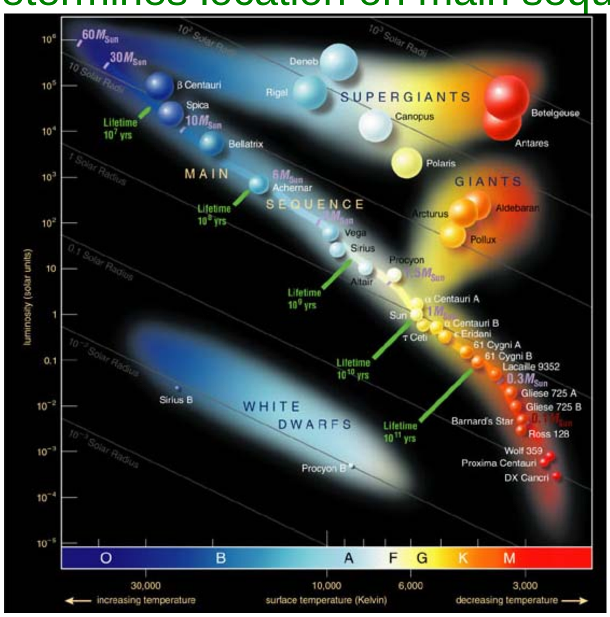
10^4

10^2

10^0

10^{-2}

10^{-4}



Low mass

25,000 10,000 5,000 3,000

Temperature