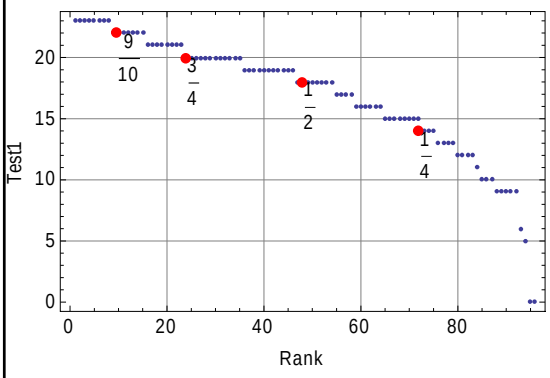
Model of Stars—6 Oct

- Hot-plate model of a star
- Thermal radiation
- Hertzsprung-Russell diagram

Test 1: Average 17 (75%)



- Answers: Link T1 on syllabus on angel
- Grade is on angel
  - Report>Report Setting
  - Choose "Grades"
  - Overall % (Course grade)
    - Eg., 90% (4.0)
- Course grade
  - Test 1 is weighted 63%, which is weight of all tests at end of course.
- Good news/ bad news
  - 75% of grade is in future.

The Hot-plate Model of a Star

- The surface of a star is made of tiles of hot plates.
- How does the energy from the hot-plate get to my hand?
  - Key observation: I can hold my hand much closer to the hot plate when it faces to the side, rather than up.

http://www.acemart.com/graphics/00000001/products/WELLh70_01.jpg

The Hot-plate Model of a Star

- How does the energy from the hot-plate get to my hand?
  - Key observation: I can hold my hand much closer to the hot plate when it faces to the side, rather than up.
- Energy moves from the hot plate to my hand by
  - movement of hot air
  - by radiation (mostly infrared light)
- Energy leaves stars primarily by radiation.
  - For the sun, the radiation is mostly ultraviolet light, visible light and infrared light.

http://www.acemart.com/graphics/00000001/products/WELLh70_01.jpg

The Hot-plate Model of a Star

- The surface of a star is made of tiles of hot plates.
- We concentrate on the radiation produced by the hot plate.

1. How can you make hot plates produce more energy per second? (The same question applies to a star: What (is) are way(s)s to make a star brighter or more luminous?) Make hot plates bigger. Make plates hotter.
   A. Make the plates hotter only.
   B. Make the plates bigger only.
   C. Make plates hotter & bigger.

- The luminosity of a star (the energy produced every second) depends on temperature and size.

http://www.acemart.com/graphics/00000001/products/WELLh70_01.

The Hot-plate Model of a Star

- The luminosity of a star (the energy produced every second) depends on temperature and size.

1. What can I do to make the same hot-plate at the same setting burn my hand and not burn my hand? (Without modifying the sun, what can I do to make the sun brighter or fainter?)
   A. Move my hand closer or farther.
   B. It is not possible.

- The flux of a star (the energy received at the earth every second) depends on temperature, size, and distance to the star.

http://www.acemart.com/graphics/00000001/products/WELLh70_01.jpg

Thermal radiation (Blackbody Radiation)

- Any object that absorbs light also emits light.
- Do people emit light?
  - People emit light in the "thermal infrared" part of the spectrum.
  - Your eyes cannot see infrared radiation. $8000 < \lambda < 12000$nm
  - You can see visible light
    - Blue 440nm
    - Green 550nm
    - Red 620nm
- A perfect absorber (perfectly black) emits a characteristic spectrum of light. (Called thermal or black-body radiation.)
  - Intensity depends only on
    - Temperature
    - Area
- A non-perfect absorber (grey body) with emissivity ε absorbs a fraction ε and reflects a fraction $(1-\varepsilon)$.
  - Intensity is ε that of thermal radiation.

Picture taken with an infrared camera
ornitorinko.org:8080/.../portrait-bits.jpg

Infrared camera—Seeing with infrared eyes

- A perfect absorber (perfectly black) emits a characteristic spectrum of light. (Called thermal or black-body radiation.)
  - Intensity depends only on
    - Temperature
    - Area
- A non-perfect absorber (grey body) with emissivity ε absorbs a fraction ε and reflects a fraction $(1-\varepsilon)$.
  - Intensity is ε that of thermal radiation.
- Thermal infrared
  - Wavelength is 8,000-12,000 nm
  - An object with a temperature of 300K emits most of its light in the thermal infrared.
  - Does infrared light show the same thing as visible light?

- Q Which is the hottest part of the man's face?
  A. His hair.
  B. His forehead.
  C. His eyeglasses.
  D. His moustache.

Thermal Radiation

- Spectrum (intensity vs. wavelength) of thermal radiation.
  - Hotter objects are brighter at all wavelengths.
- Wien's Law

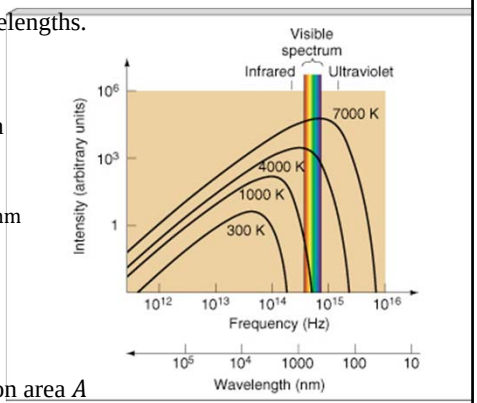
$$\lambda_{\text{peak}} T = 2.9\text{mm K}$$

  - Wavelength changes inversely with temperature
    - For the sun, T=5700K.

$$\lambda_{\text{peak}} = \frac{2.9\text{mm K}}{5700\text{K}} = 0.0005\text{mm} = 500\text{nm}$$

    - For a person, T=273+37=310K.

$$\lambda_{\text{peak}} = \frac{2.9\text{mm K}}{310\text{K}} = 0.01\text{mm} = 10\mu\text{m}$$

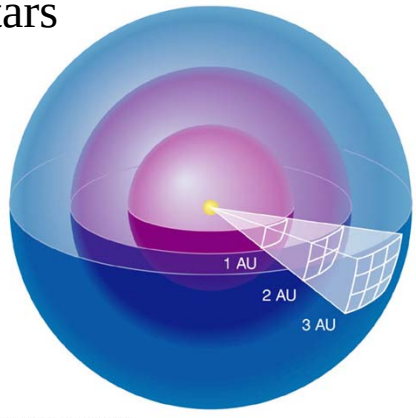


- Stefan-Boltzmann Law
  - Energy emitted per second depends on area A (or radius R for a sphere) and temperature T

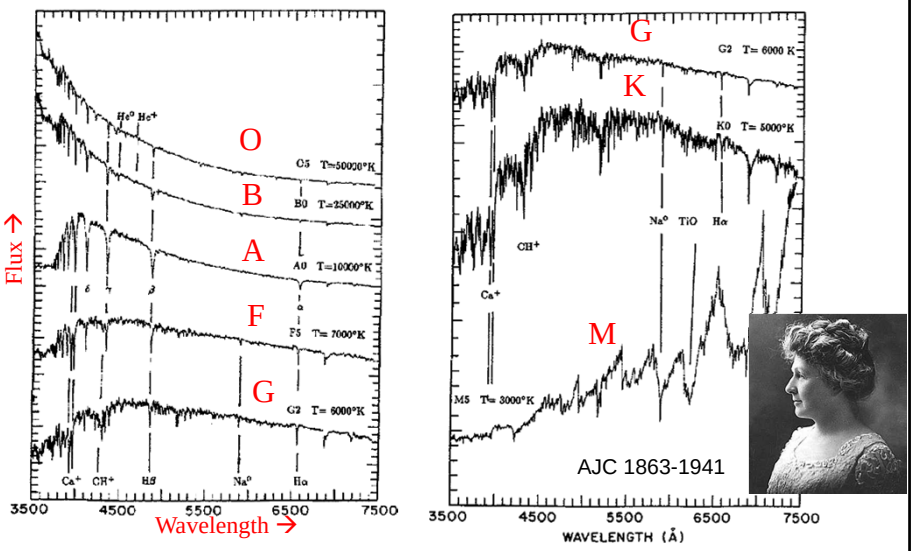
$$L = AT^4$$
$$L = R^2T^4$$

Luminosity & Flux (apparent brightness) of Stars

- Luminosity is amount of energy per second (Watt) produced by the star.
  - Intrinsic to the star.
  - With constants suppressed, $L = R^2T^4$
- Flux is energy per second received by a detector on earth (Watt/m^2).
  - Depends on distance of star $F = L/D^2$
  - At greater distances from star, light is spread over larger area. Flux is lower.



Annie Jump Cannon: Classify stars by spectra



- Classification is very efficient: Draper catalog has 250,000 stars.
- Spectral class was later found to be related to temperature.
  O be a fine girl kiss me.

AJC

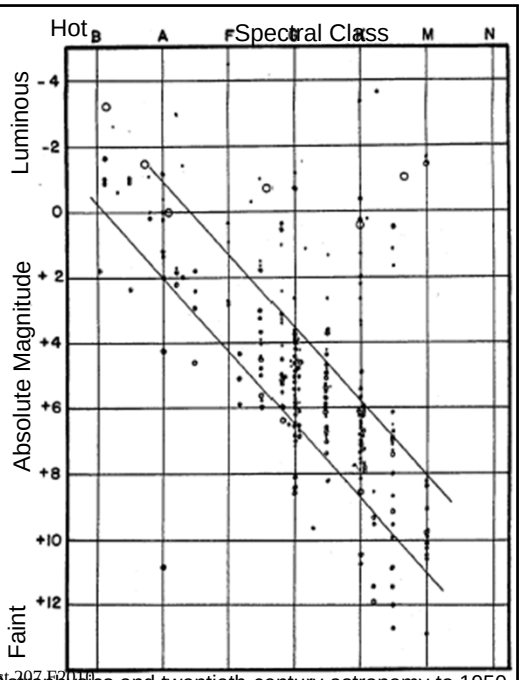
- Prof. Pickering's Team in 1913, from Barbara L. Welther, 1982, Isis 73, 94.
- AJC
  - BA, Wellesley, 1884
  - Pickering's assistant, 1896
  - Henry Draper catalog of stars, 1918-1924
  - Astronomer 1938

Hertzsprung-Russell diagram

- H-R Diagram is plot of temperature & luminosity
  - Hotter stars are on left.
  - More luminous stars are on the top.
  - Stars exist only with certain combinations of luminosity and temperature.

Ejnar Hertzsprung
1873-1967 (Danish)

Arthur Stanley Eddington
1882-1944 (English)

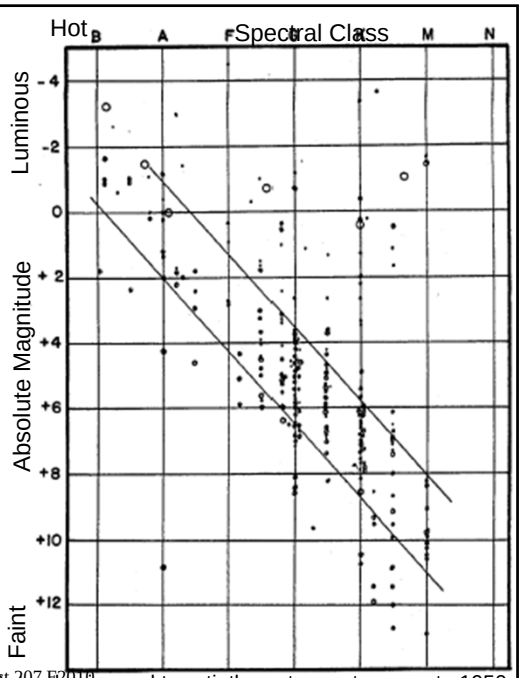


Astrophysics and twentieth-century astronomy to 1950, O Gingerich, ed., Cambridge, 1984

Hertzsprung-Russell diagram

- H-R Diagram is plot of temperature & luminosity
- Stefan-Boltzmann Law: $L = AT^4$

1. A star is moved 10 times farther away. In the H-R diagram, it moves
   A. up
   B. down
   C. left
   D. right
   E. not at all



Astrophysics and twentieth-century astronomy to 1950, O Gingerich, ed., Cambridge, 1984