Review of Star Intro

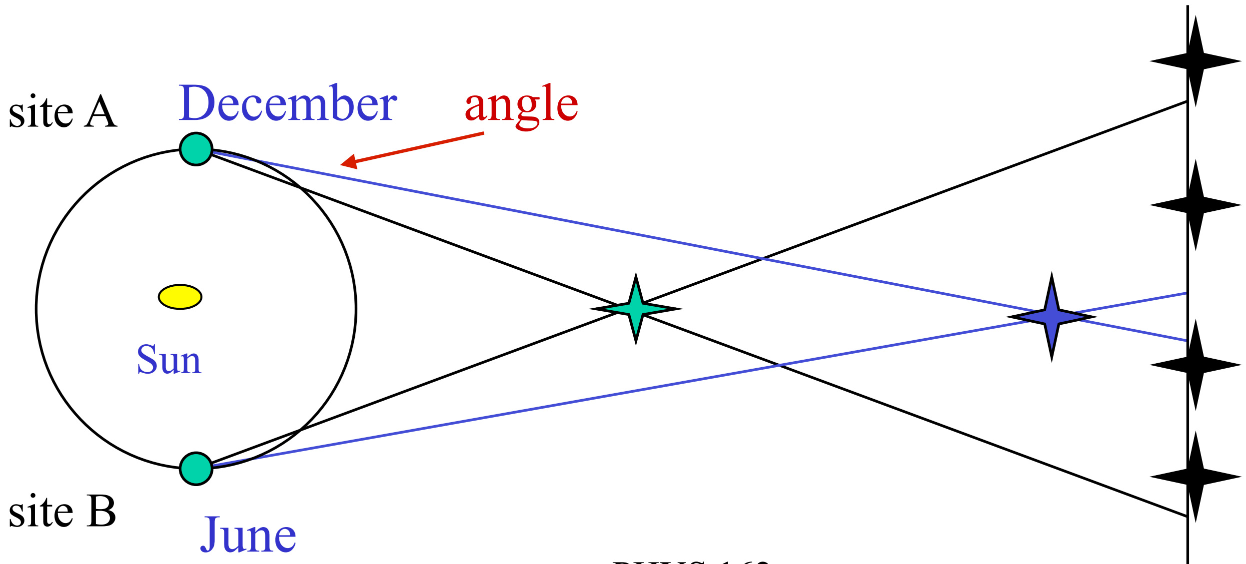
- Parallax - geometric method of determining star distance
- Absolute and apparent luminosity.
- Temperature
- Spectrum: What characterizes the star's surface
  - Is related to its **temperature**
  - Can use **spectral information** to determine **masses** of binary stars..
  - Can use spectral information to determine **absolute luminosity**, then use the **apparent luminosity** to determine **distance**

Shifting Star Positions

- The orbit of the earth is used as the base.
- Near stars appear to move more than far stars
- Distance = (base length)/angle
- Define: 1 parsec = 1 AU/(angle of 1 second of arc) = 3.3 LY

  PARallax of one arc **SEC**ond

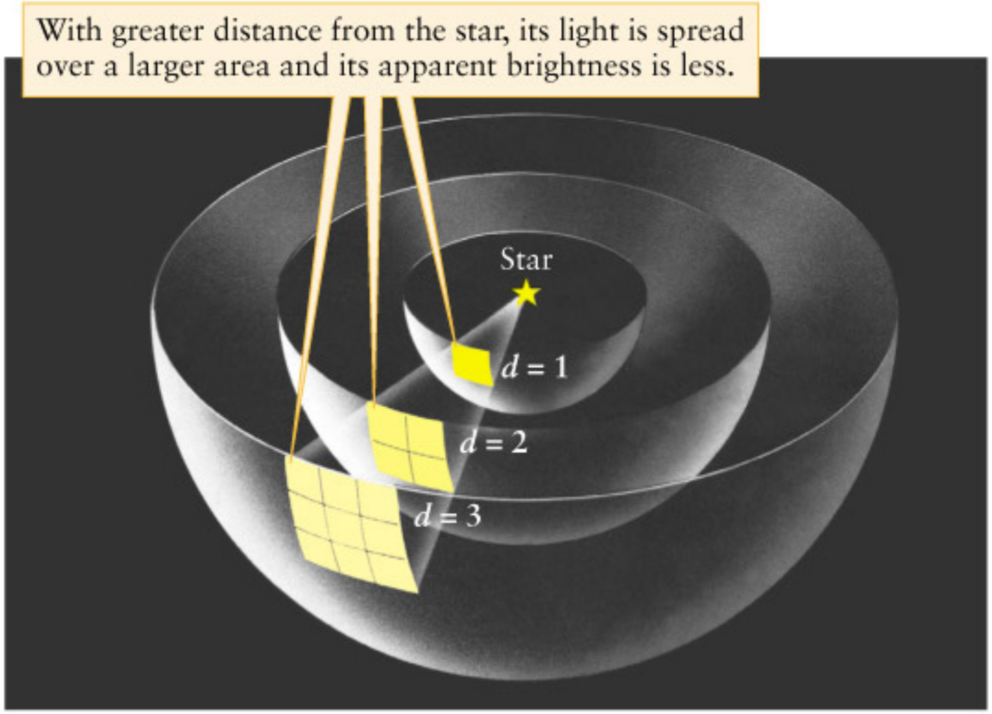
1 sec arc = 1 deg/3600 = 1 rad/206,265



Absolute vs Apparent Brightness

Absolute Brightness/Luminosity means total energy output

Apparent Brightness is what is seen by eye or in a telescope and so depends on distance (1/Distance^2)



Binary Star Systems

- Many stars come in groups of 2 or 3 that are close (few AU) to each other: BINARY Star Systems
- Gravitationally bound and probably formed at the same time
- SiriusA is 23 times as bright as our Sun
  SiriusB is 0.005 times as bright as the Sun
  Their separation varies from 8 to 31 AU

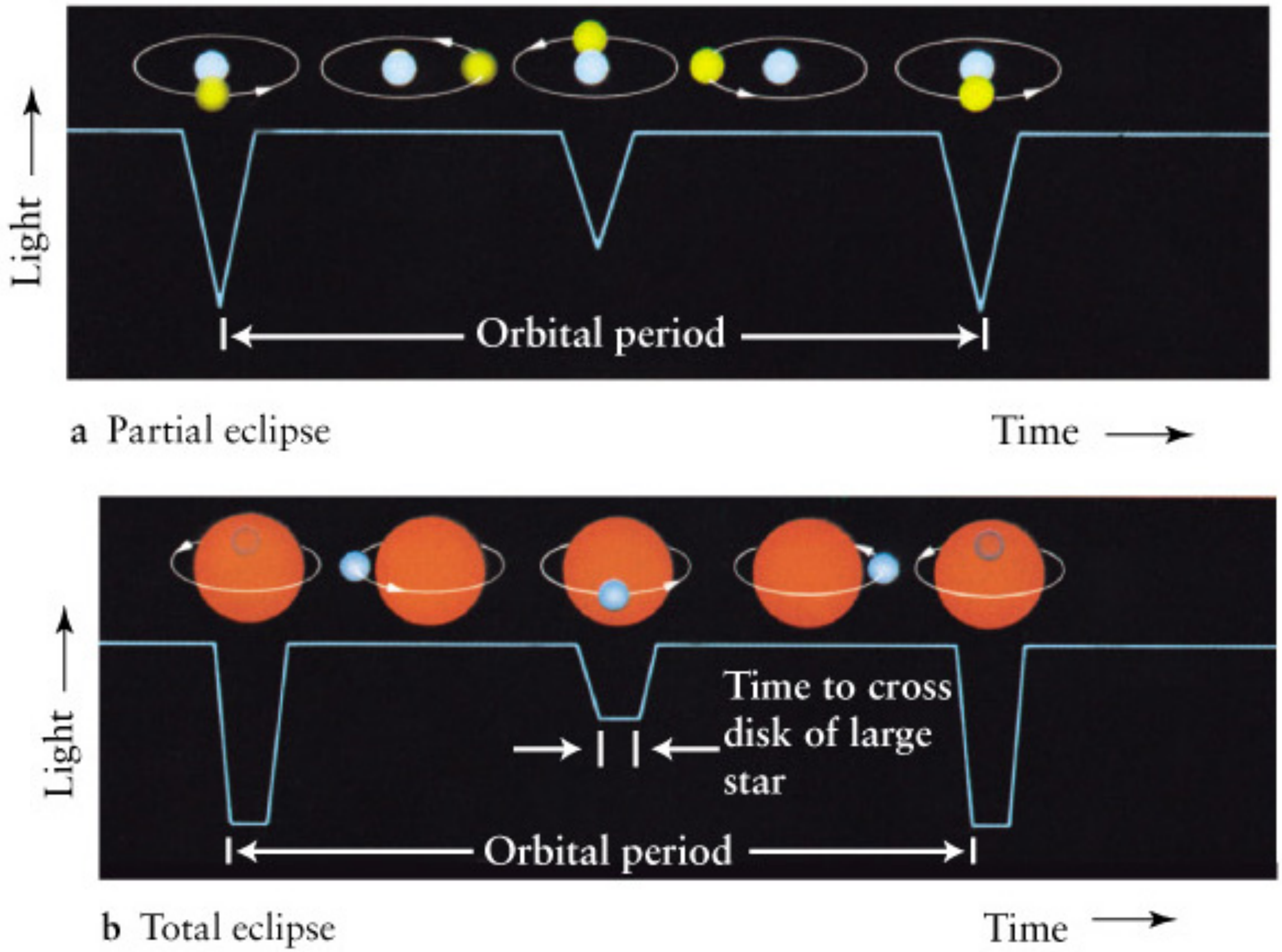
Binary Stars → Stellar Masses

→Visual Binary: If can visually observe **both** stars

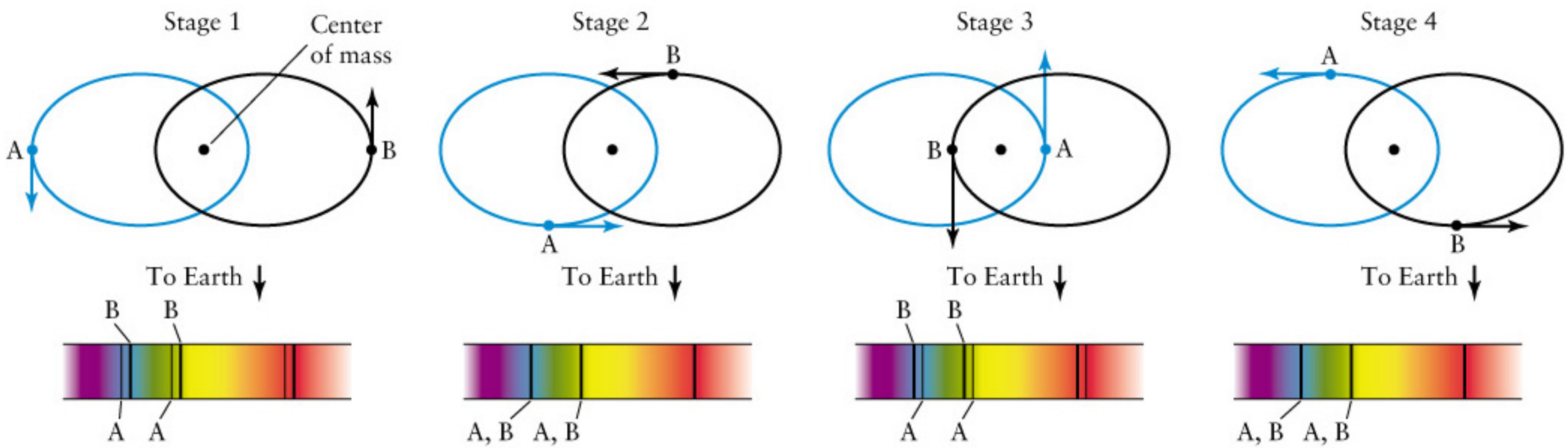
→ Spectroscopic Binary: If one can only separate into 2 stars by looking at the spectrum (they eclipse each other plus wil have different Doppler shifts)

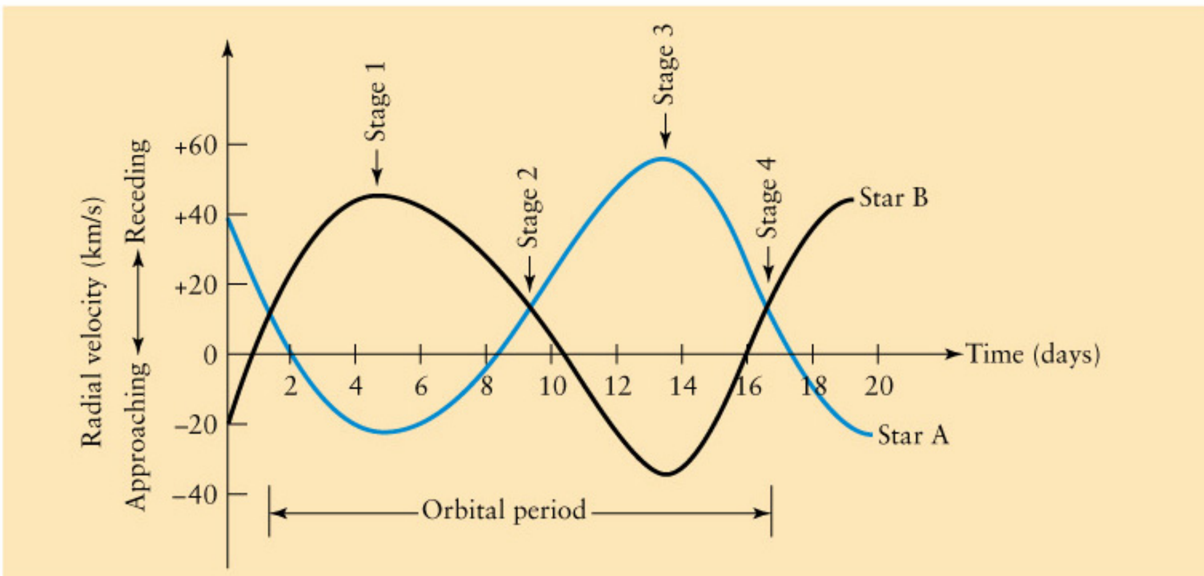
→Measure the **orbital** information like **period** and **separation distance**. Get Mass though Kepler/ Newtonian-like methods

Binary Star Orbits - Eclipses



Binary Star Orbits – Doppler Shifts

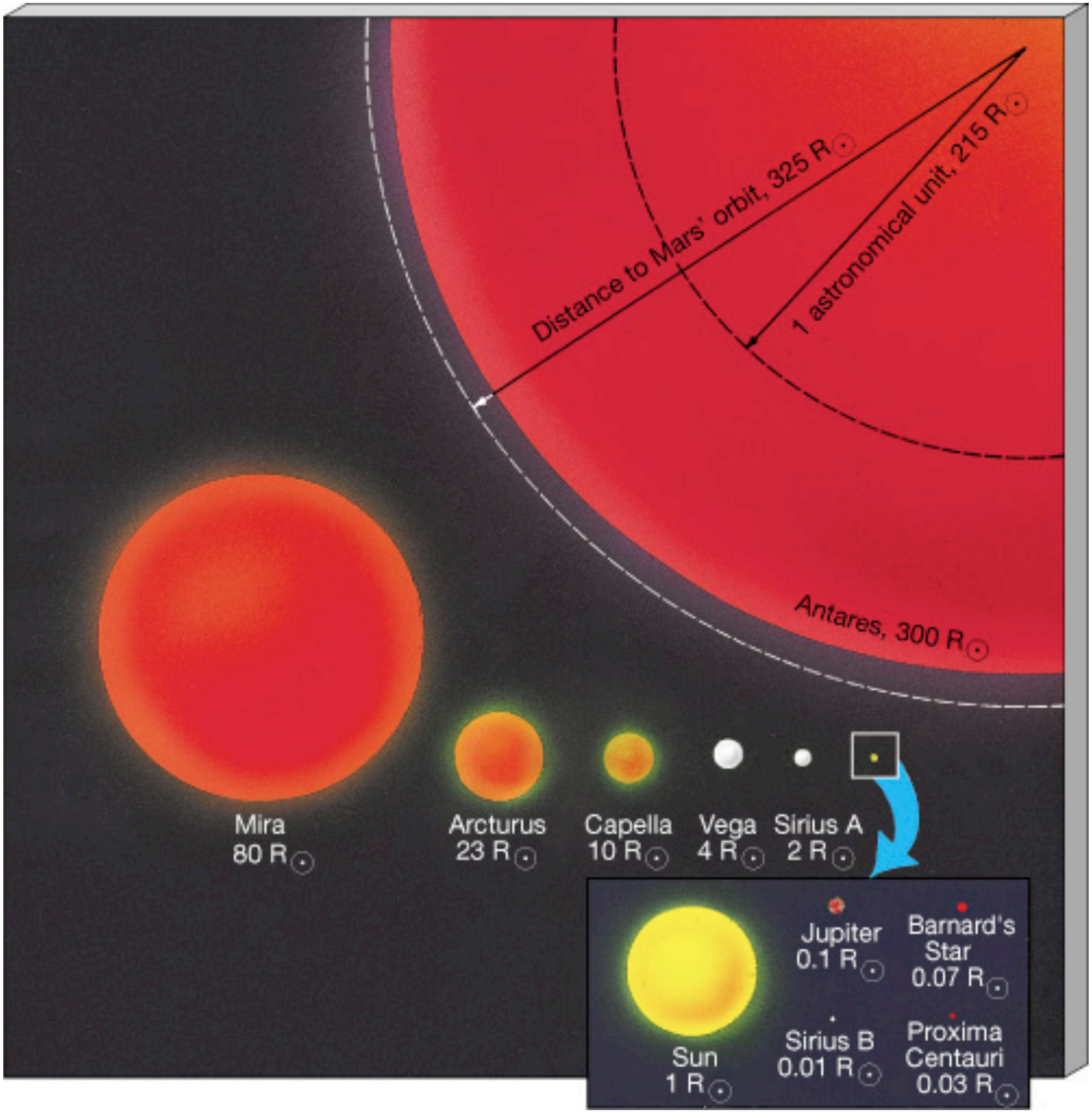




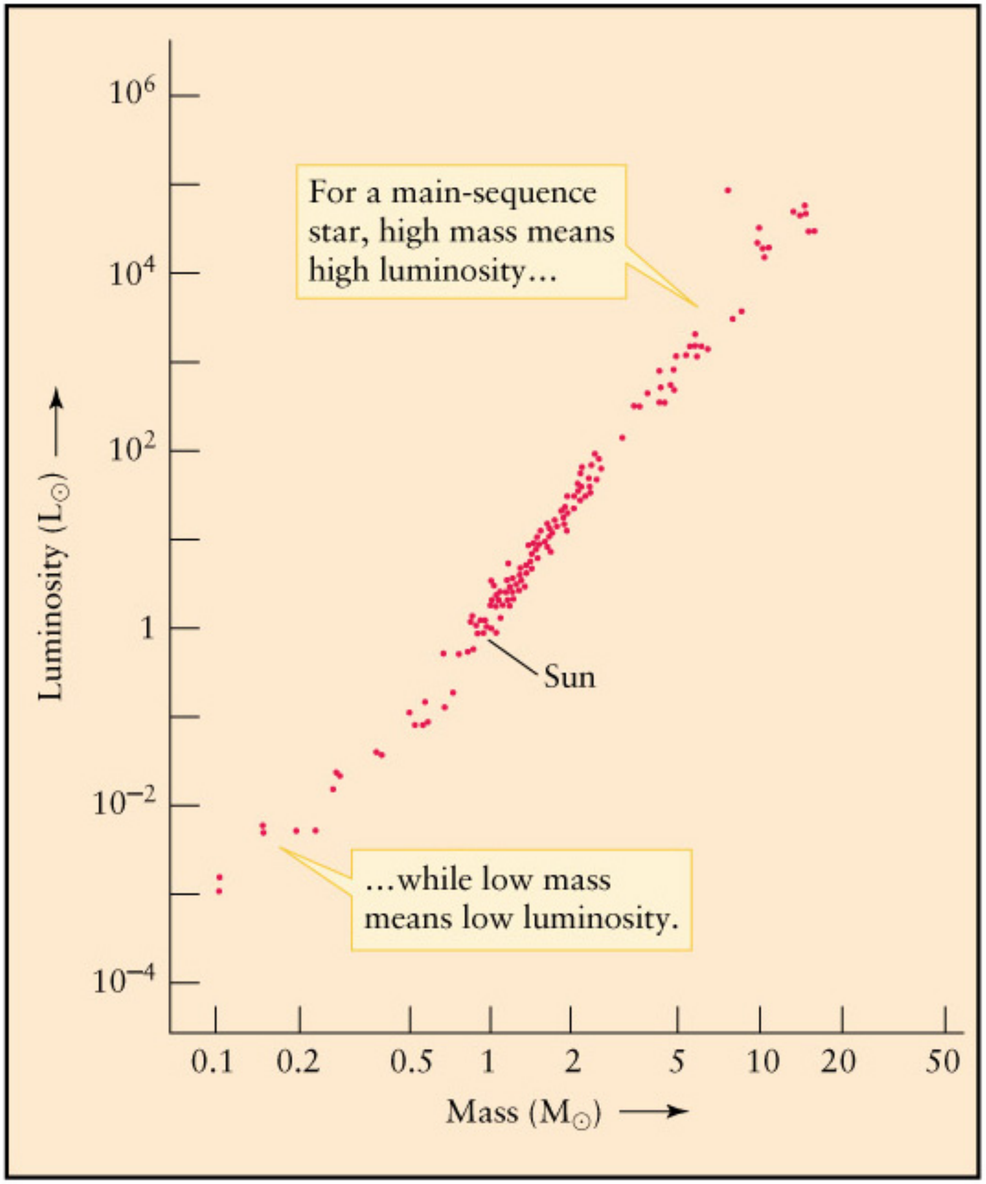
Stellar Sizes

- For a few close, big stars, they can be seen in a telescope as non-point objects
- Measure **angular size**; if one knows the distance, can get the **actual size** of star

  Example: Betelgeuse 300 times larger radius than the Sun
- If further away but a **binary star**, then can get size of stars when they eclipse each other → length of time one star passes in front or behind each other



Stellar Sizes



Mass vs Luminosity

always on these plots it is the Absolute Luminosity of the star

High mass → High brightness

Surface Temperature of Stars

- Continuous spectrum and the **peak wavelength** tells temperature

  lambda(max) = constant/Temp

where lambda=wavelength

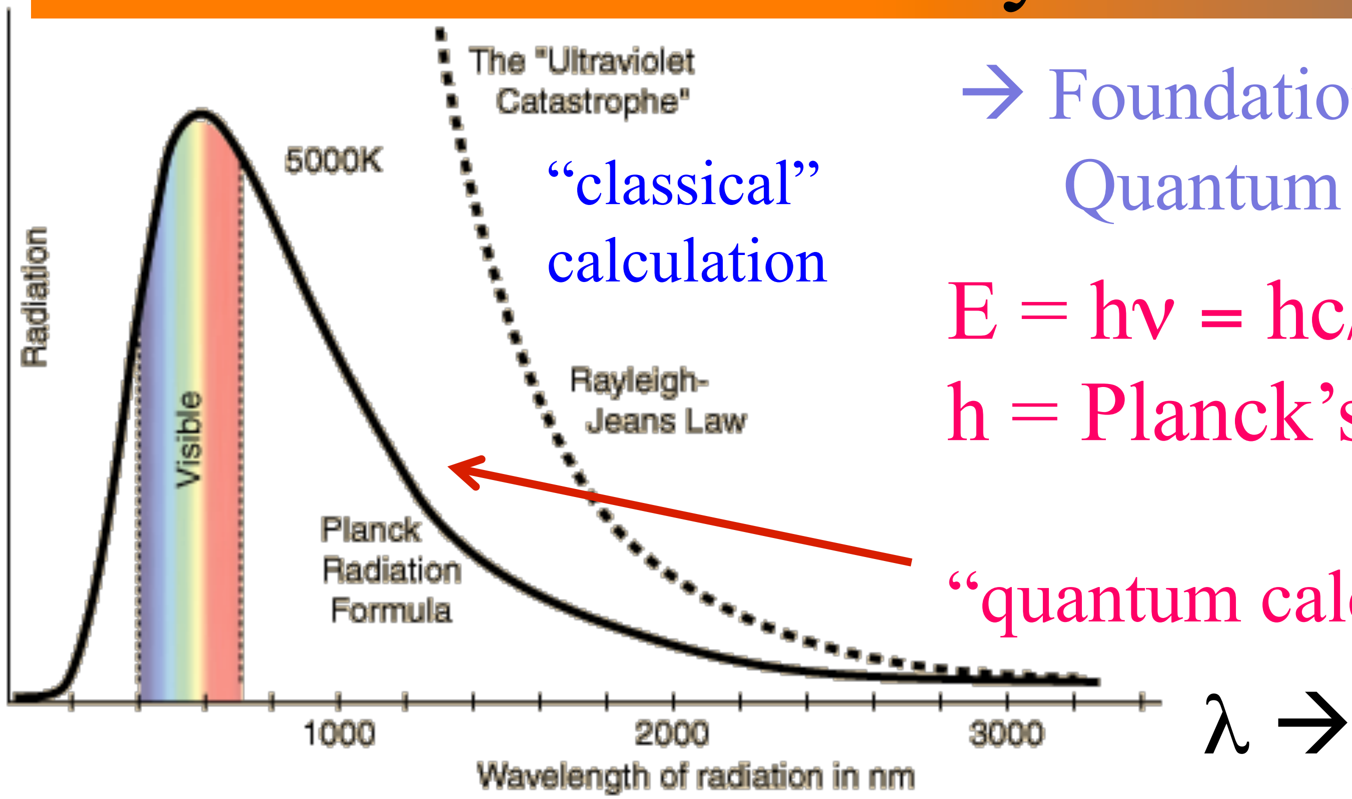
- OR measure relative intensity at a few wavelengths like

  RED

  GREEN

  BLUE → Easy to do

More on "Blackbody" Radiation



→ Foundation of modern Quantum theory

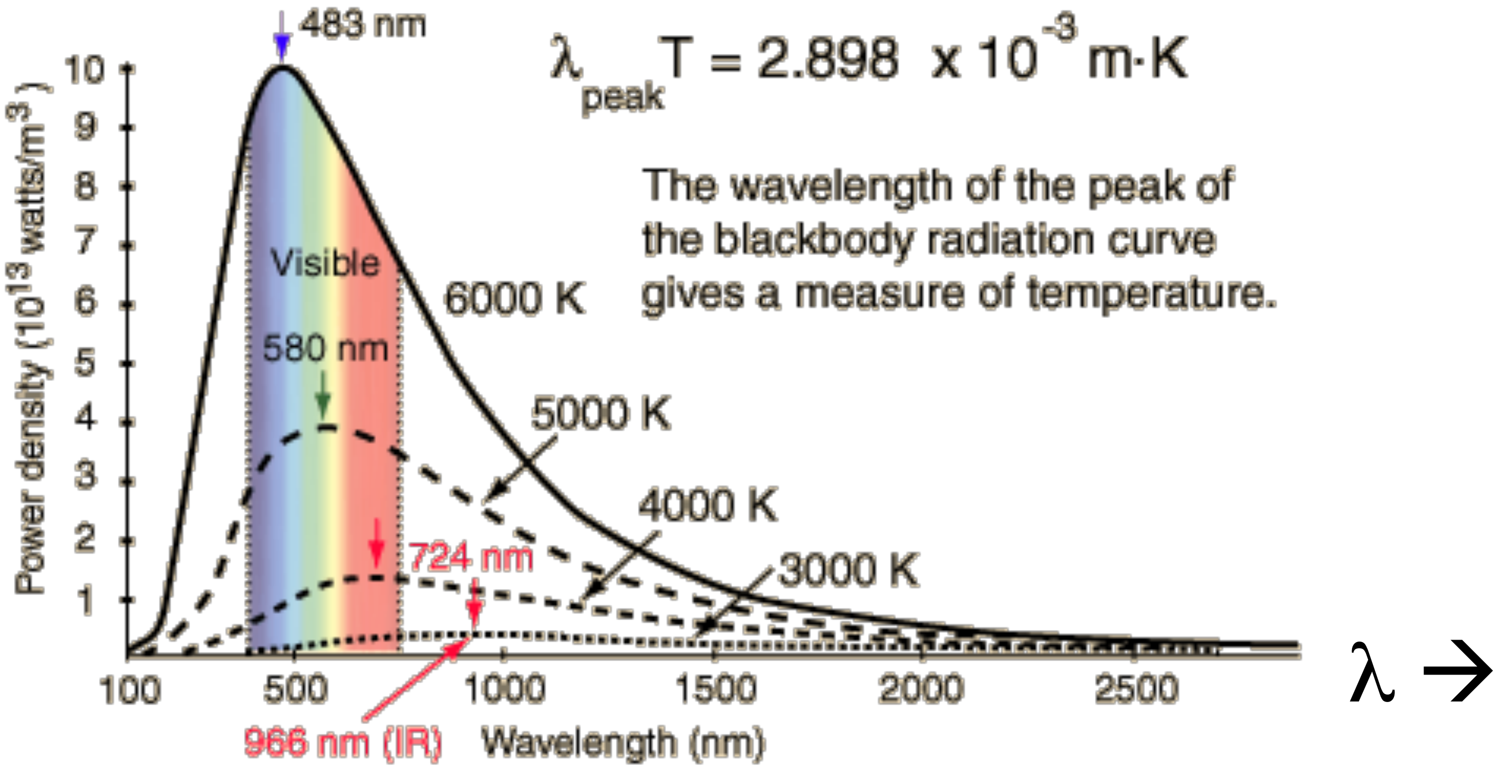
$E = h\nu = hc/\lambda$

h = Planck's constant

"quantum calculation"

In order to explain the frequency distribution of radiation from a hot cavity, Planck proposed the **ad hoc** assumption that the radiant energy could exist only in **discrete quanta** which were proportional to the frequency. In which case, higher modes would be less populated and avoid the "ultraviolet catastrophe".

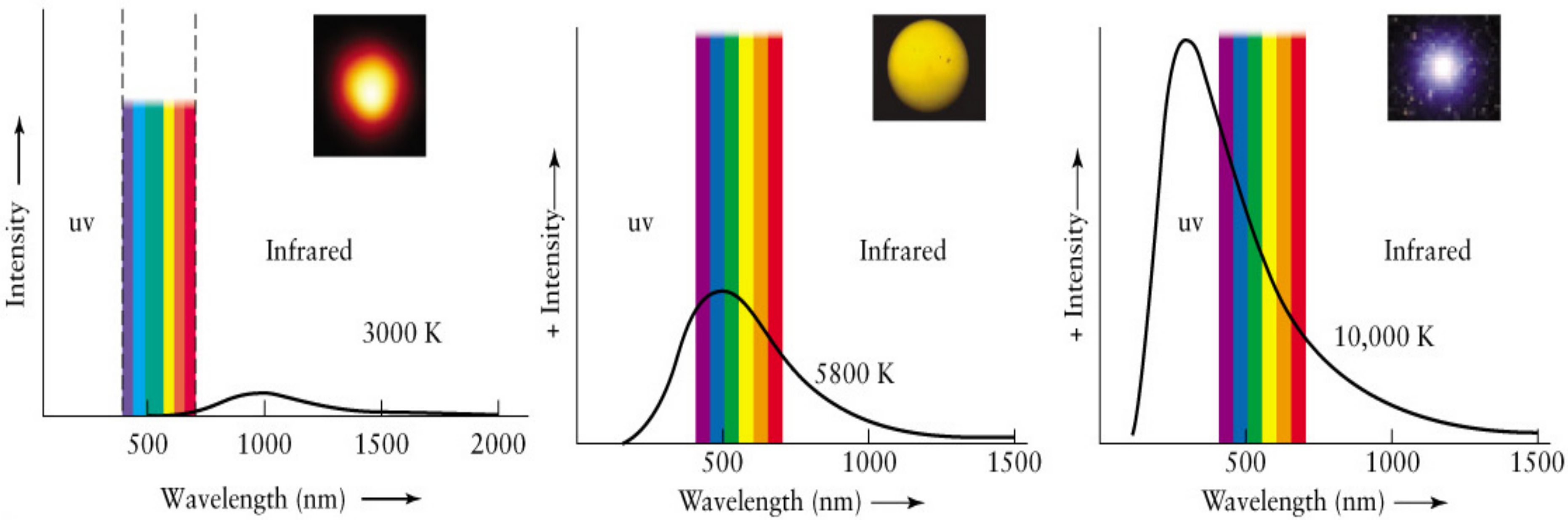
Wien's Displacement Law



When the temperature of a **blackbody radiator** **increases**, the overall **radiated energy** **increases** and the **peak** of the radiation curve moves to **shorter** wavelengths.

The product of the **peak wavelength** and the **temperature** is found to be a constant.

HST image. "add" together images taken with different color filters

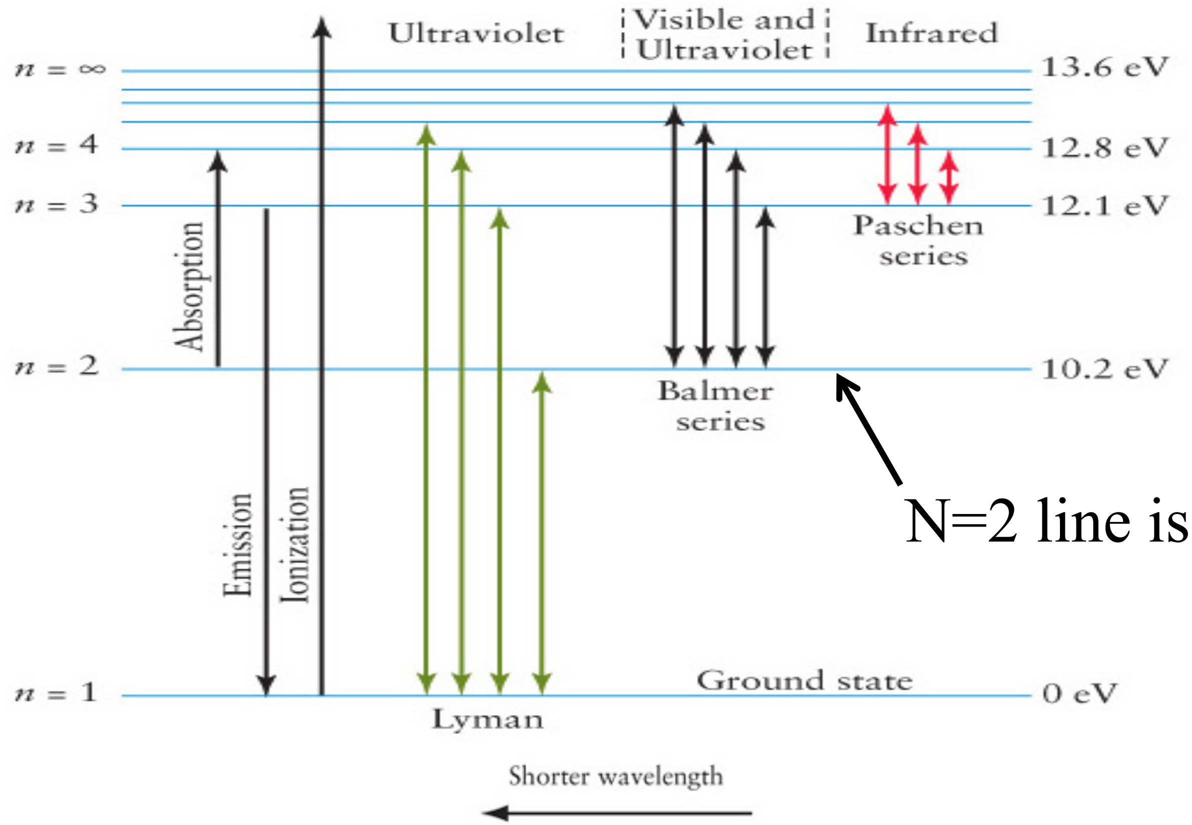


Spectral Classes

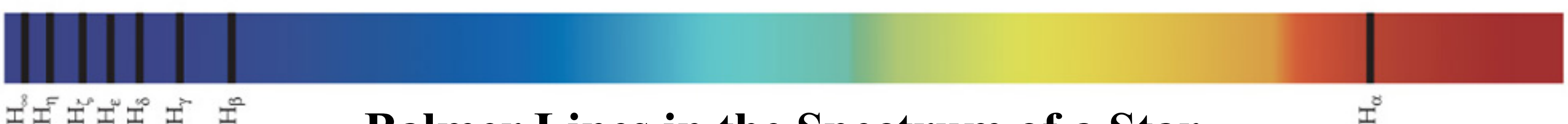
Light passing through a star's atmosphere gives dark line **absorption** spectrum. Tells:

- What atoms are present
- Motion of the star by the Doppler shift of the absorption lines
- Temperature of the photosphere by **relative intensity** of different absorption lines and by amounts of different molecules and ions

Quantum Mechanical Model of H Atom



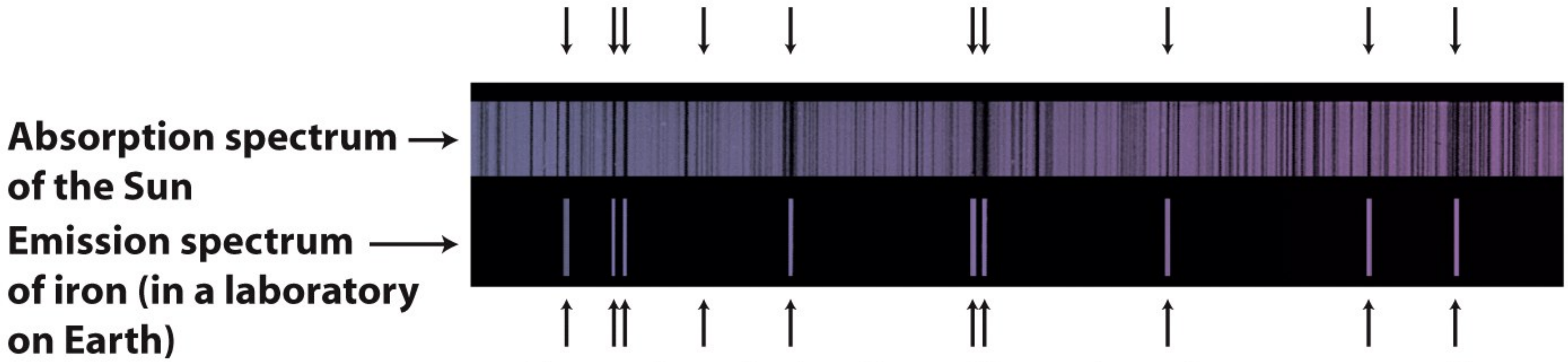
N=2 line is "excited"



Balmer Lines in the Spectrum of a Star

This portion of the spectrum of the star Vega shows eight Balmer lines, from H_α at 656.3 nm through H_θ at 388.9 nm.

Spectrum of Sun



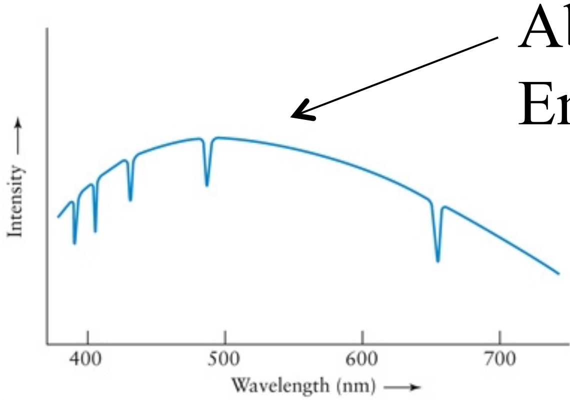
For each emission line of iron, there is a corresponding absorption line in the solar spectrum; hence there must be iron in the Sun's atmosphere


a

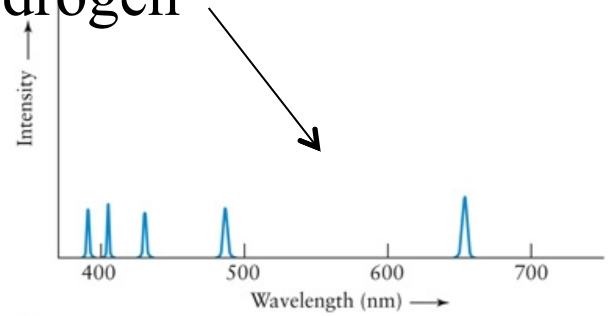

c

Absorption spectrum of hydrogen

Emission spectrum of hydrogen



b



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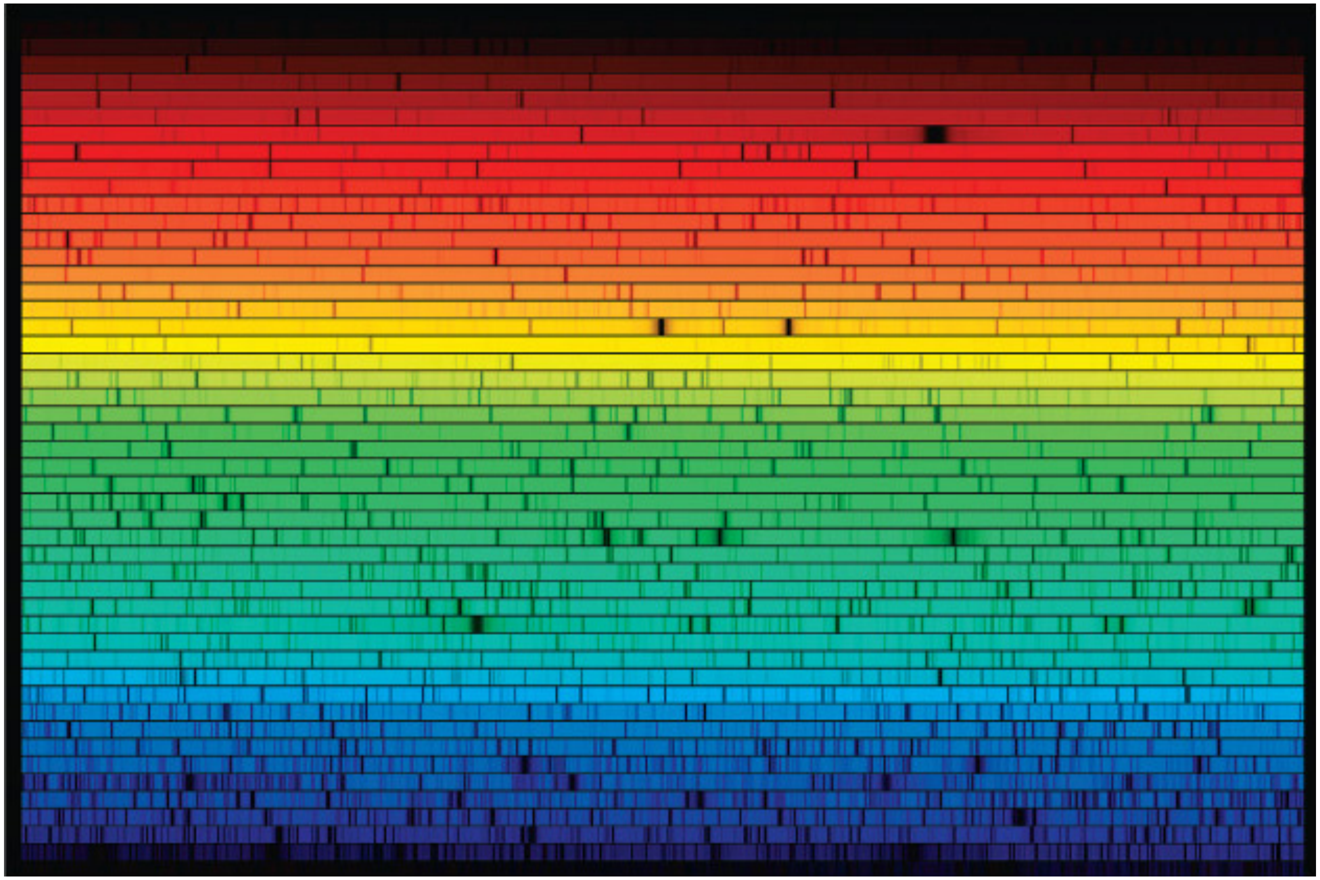
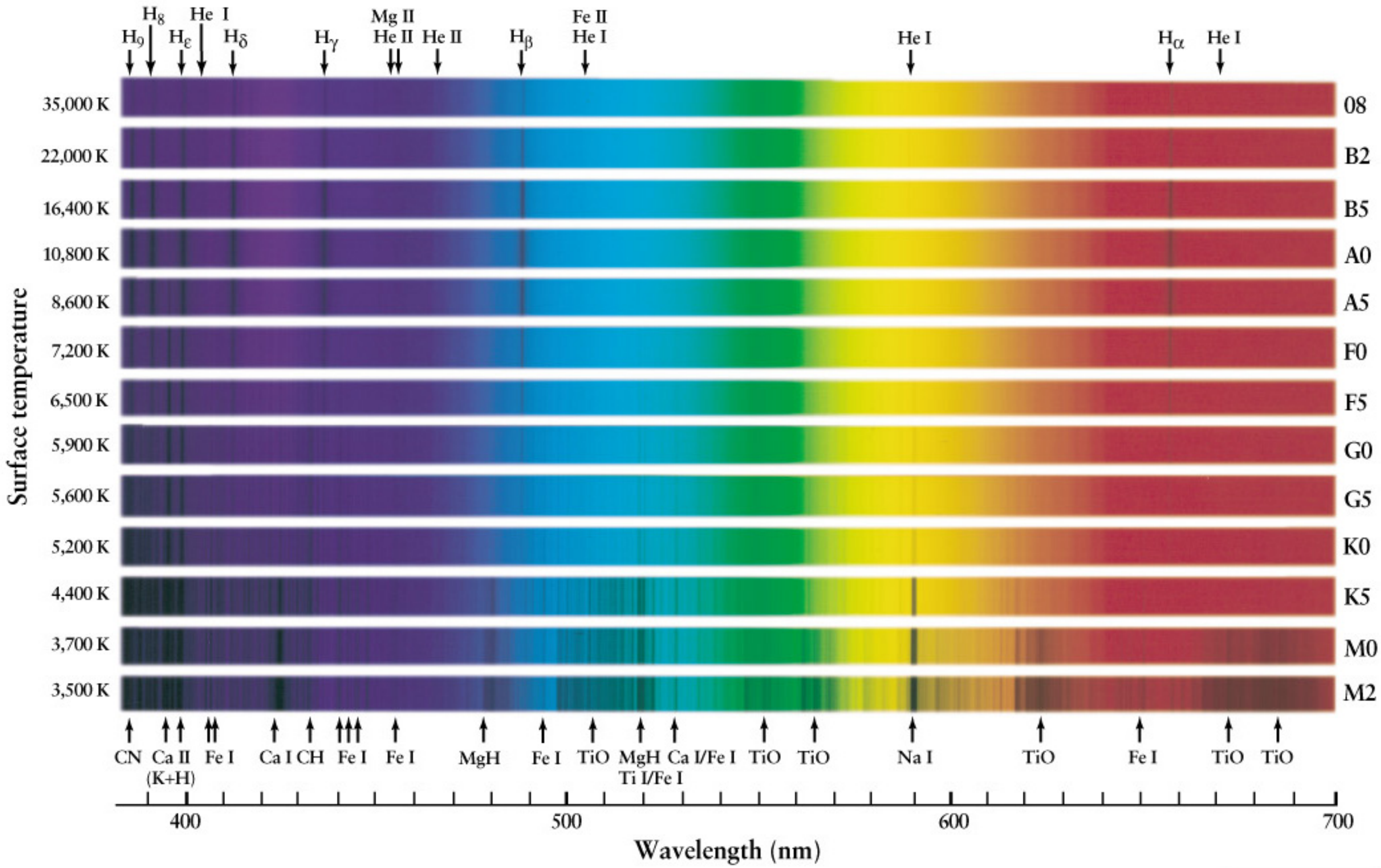
Spectrum of Sun



The combination of lines from the solar spectrum allows us to determine which chemicals are present and in what abundance…

Spectral Classes



→ Energy is enough to be "excited", but not ionized ←

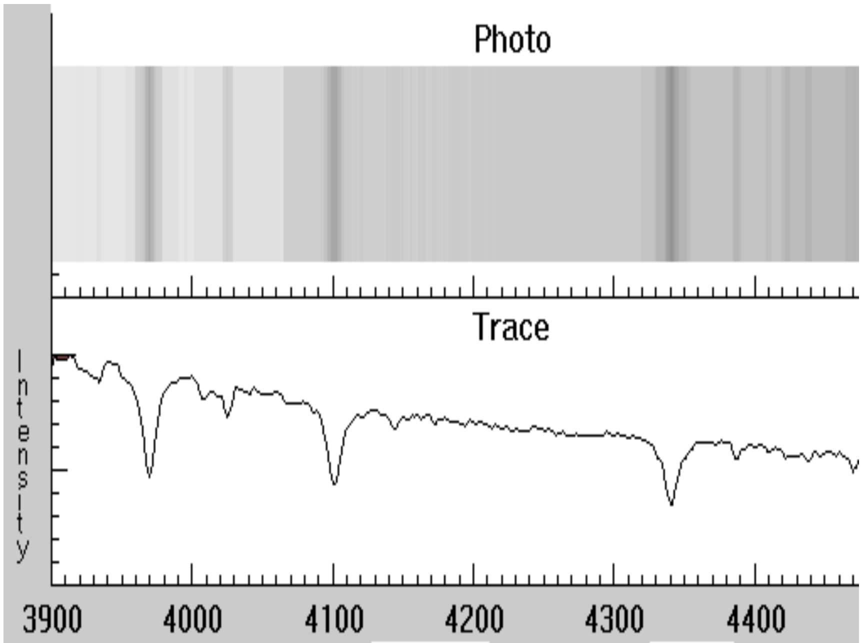
Stellar Spectroscopy

Spectral classes **originally** ordered A,B,G,M… based on the amount of hydrogen, helium, ionized calcium and metals. absorption in the visible range…

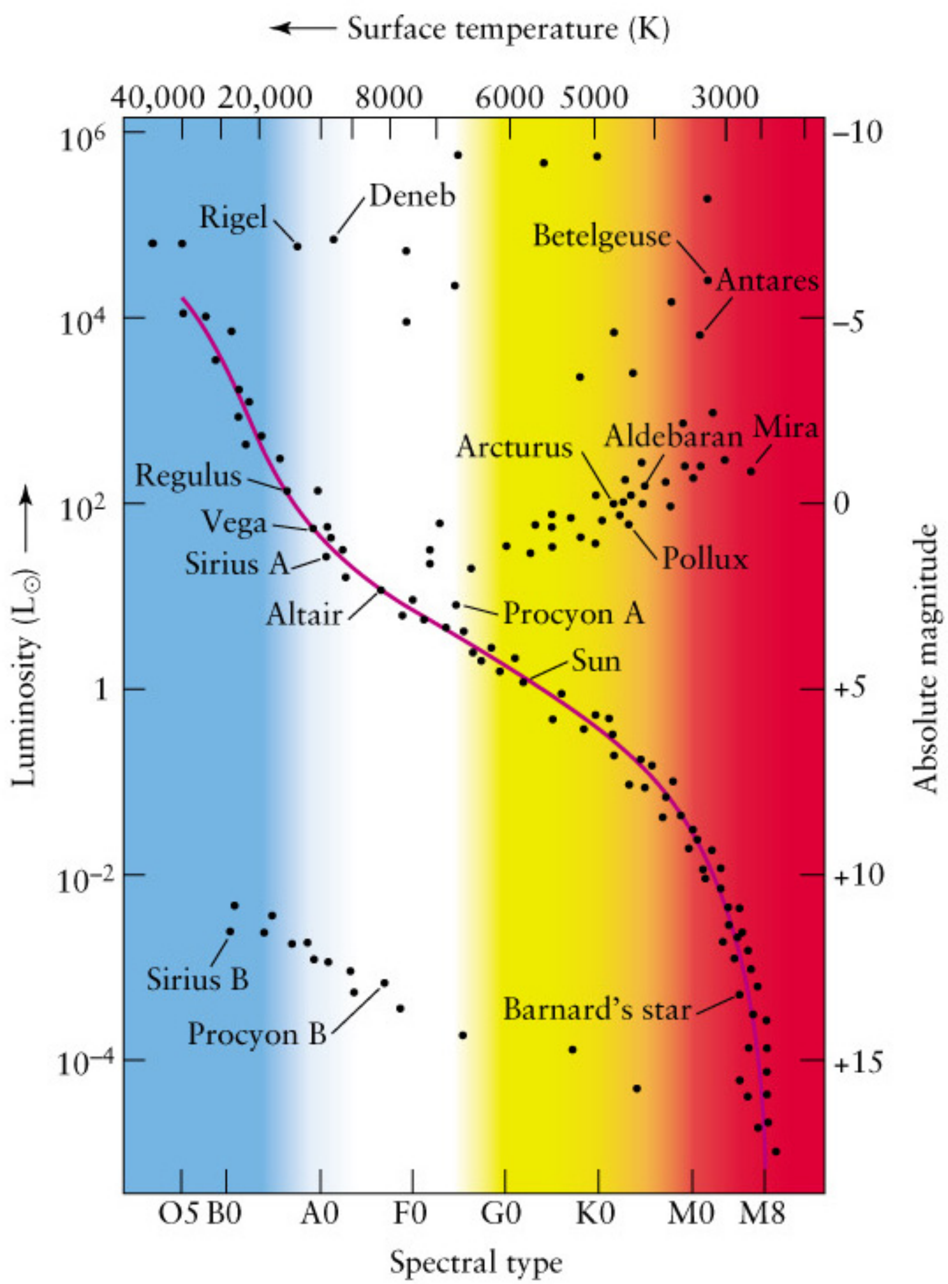
- Now order by **surface temperature**
  - (**Cecilia Payne** applied Quantum Mechanics).

Spectral Class		Temperature
O	oh	hottest
B	be	
A	a	
F	fine	
G	girl/guy	
K	kiss	
M	me	coolest

Don't need to know

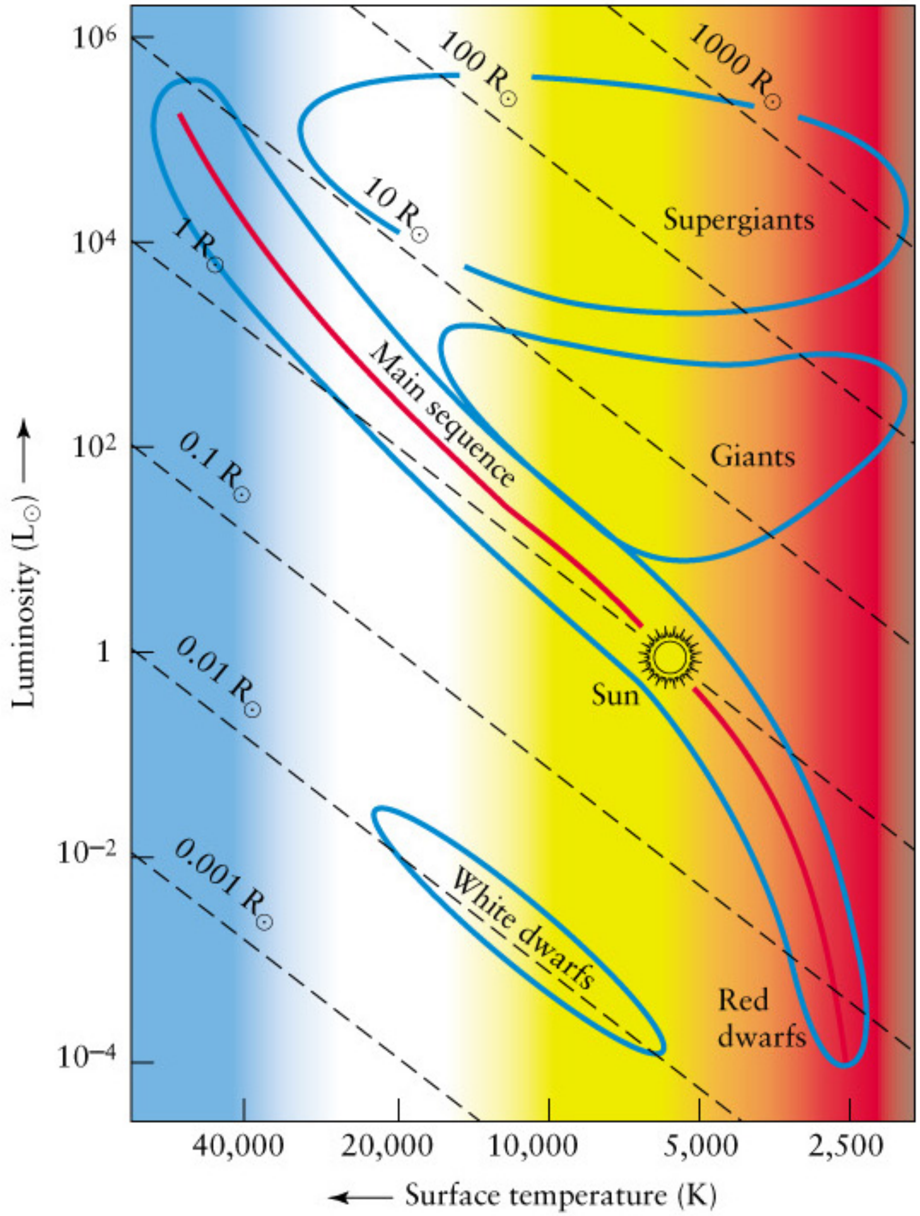


1910s: Annie Jump Cannon and others working at Harvard developed an empirical scheme for classifying the spectra



Hertzprung-Russell Diagram

Plot Luminosity versus surface temperature



Hertzprung-Russell Diagram

Stars with larger sizes are brighter then a smaller star with the same surface temperature

Temperature vs Luminosity vs Radius of Stars

Energy emitted by surface of star due to EM radiation is Energy/(surface area) = σT^4. Examples:

- Two stars. Same temperature and radius → same Luminosity
- Two stars. Same temperature. Radius(B) = 2xRadius(A). So surface area(B)= 4xsurface area(A) → Luminosity(B)= 4xLum(A)

Radius = 1 Radius = 2

Temperature vs Luminosity vs Radius of Stars

Energy emitted by surface of star due to EM radiation is Energy/(surface area) = σT^4. Examples:

- Two stars. Same radius. Temperature(B) = 2xTemp(A).
  $(\text{Energy/Area})_B = 2^4 \text{ X } (\text{Energy/Area})_A$ ~ or ~
  $(\text{Energy/Area})_B = 16 \text{ X } (\text{Energy/Area})\text{B}$
  → Luminosity(B) = 16 X Lum(A)

Temp = 6000 Temp = 12,000

Hertzprung-Russell Diagram

- Most stars are on a “line” called the MAIN SEQUENCE with

  hot surface temp <-> large radius

  medium temp <-> medium radius

  cool surface temp <-> small radius

- There are also stars with cool surface temperature but very large radius: RED GIANTS
- Stars with hot surface temperature but very small radius: WHITE DWARVES

Key Properties of Main Sequence Stars

Mass/M_{Sun}	Luminosity/L_{Sun}	Effective Temperature (K)	Radius/R_{Sun}	Main sequence lifespan (yrs)
0.10	3×10^{-3}	2,900	0.16	2×10^{12}
0.50	0.03	3,800	0.6	2×10^{11}
0.75	0.3	5,000	0.8	3×10^{10}
1.0	1	6,000	1.0	1×10^{10}
1.5	5	7,000	1.4	2×10^{9}
3	60	11,000	2.5	2×10^{8}
5	600	17,000	3.8	7×10^{7}
10	10,000	22,000	5.6	2×10^{7}
15	17,000	28,000	6.8	1×10^{7}
25	80,000	35,000	8.7	7×10^{6}
60	790,000	44,500	15	3.4×10^{6}

Spectroscopic Parallax

- If we use well-understood close stars to determine the overall brightness scale of a specific class of star, then measuring the spectrum can be used to give the distance for stars > 500 LY away

1. Determine Surface Temperature + spectral class of star
2. Determine where on HR diagram should go
3. Read off absolute luminosity from HR diagram
4. Measure apparent luminosity and calculate distance

- works best if many close-by stars