An introduction to

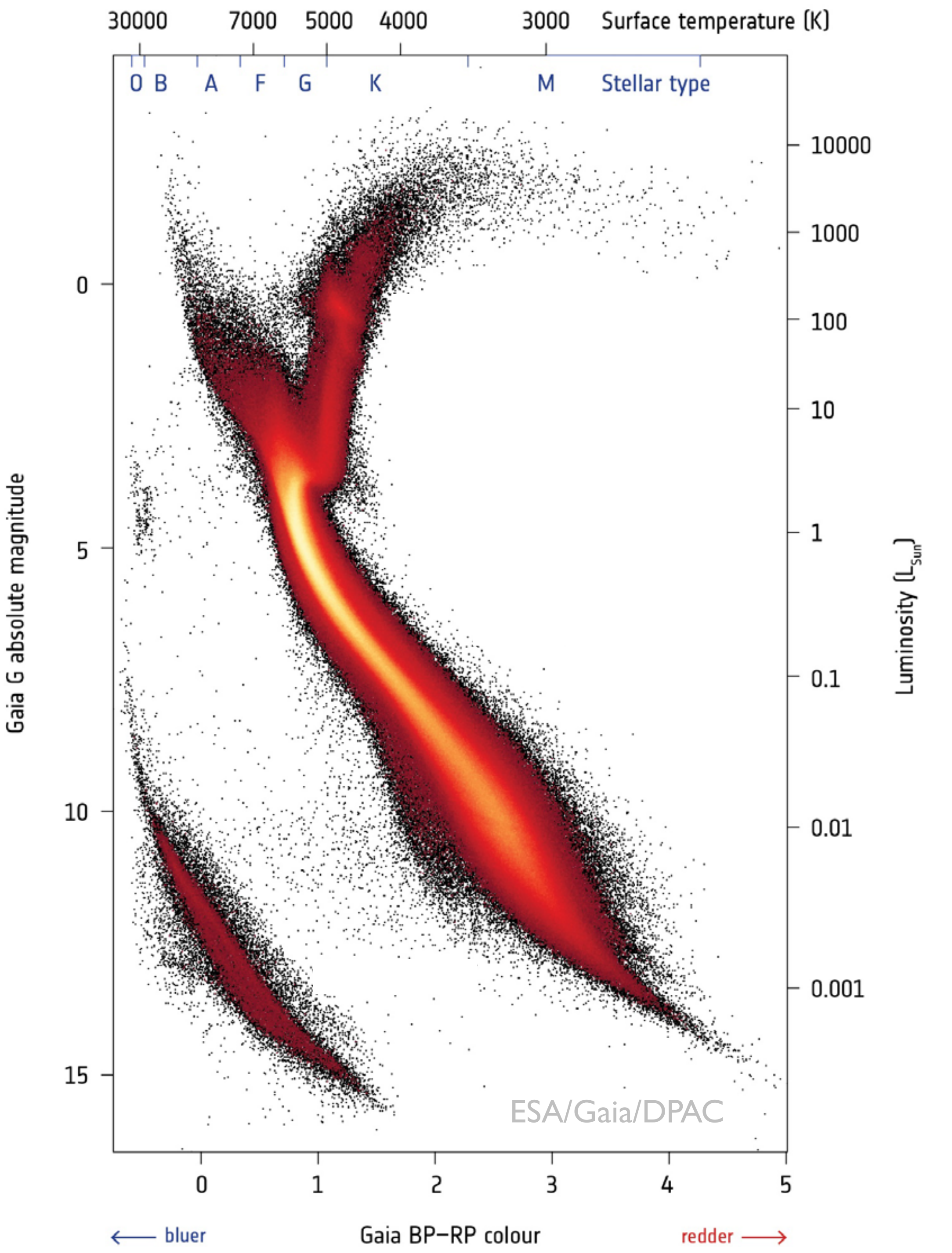
The Hertzsprung-Russell Diagram

Zach Meisel

Ohio University - ASTR1000

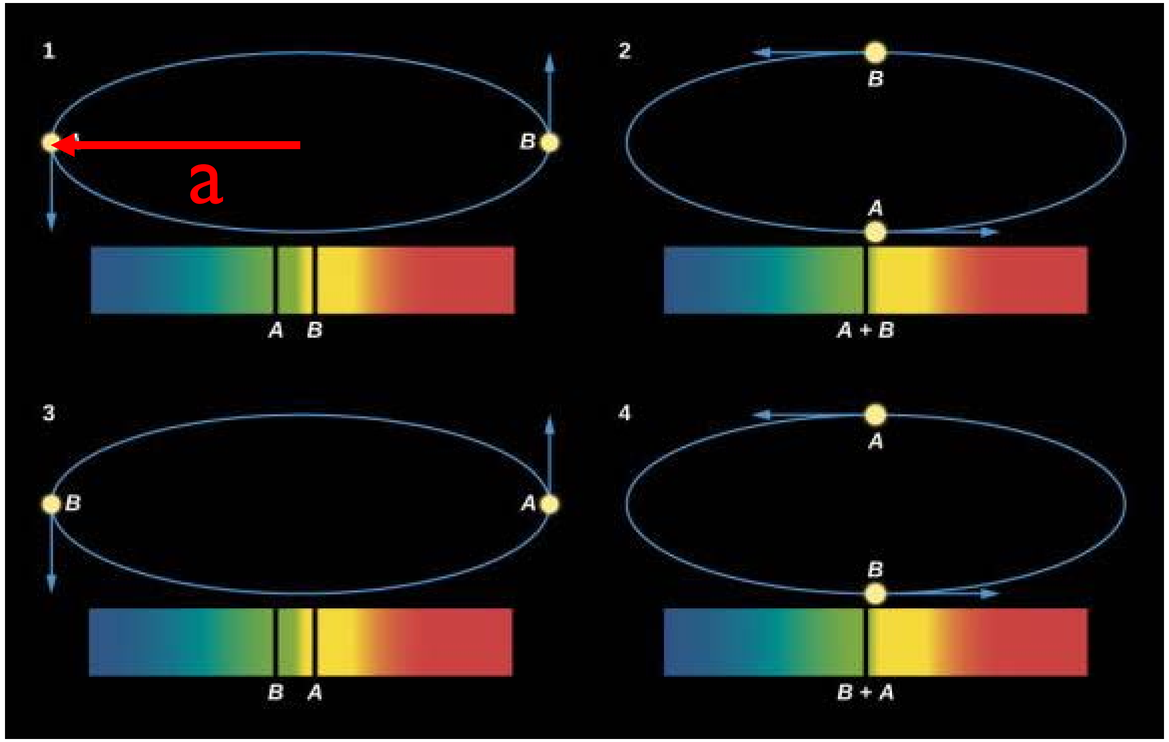
HR-diagram for (relatively) nearby stars

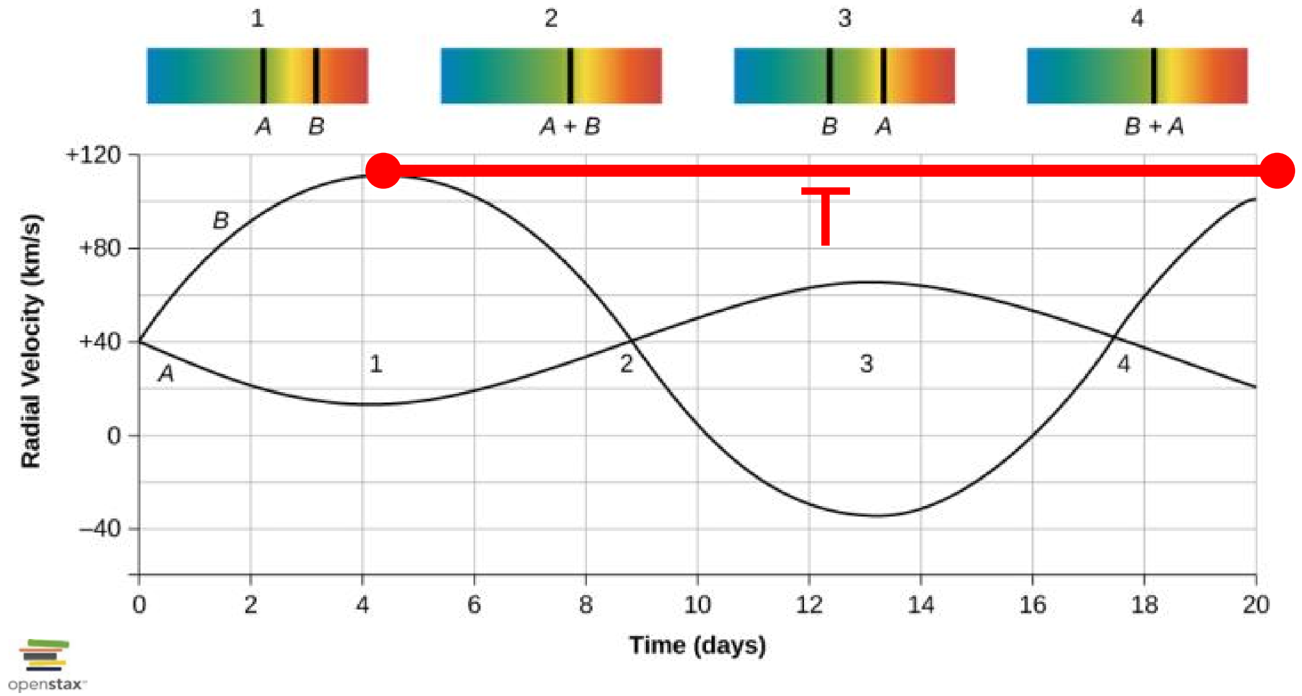
- For each visible star, we can determine its luminosity (see Introduction to Starlight) and temperature (see Introduction to Spectra) and place that as a point on a graph
- The result is the Hertzsprung-Russell (HR) diagram, shown on the right for ~4 million stars within ~5,000 ly of the sun
- This is an invaluable tool for understanding stellar evolution and can be used to date star clusters



Stellar masses from binary star systems

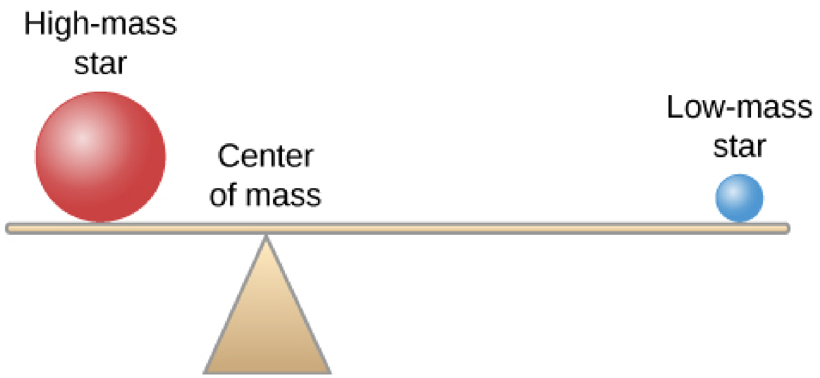
- Spectral lines can be used to map the radial velocity over time for a pair of orbiting stars





- From Kepler's 3[rd] law $a^3 = (M_A + M_B)T^2$

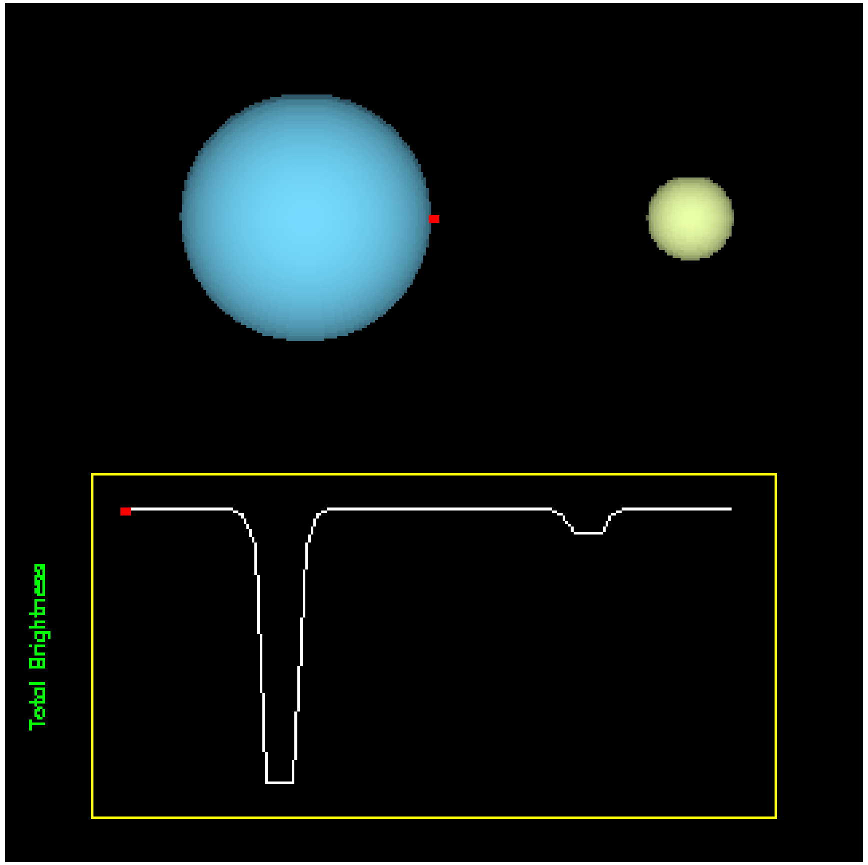
in solar masses ($M_A + M_B$), *in Astronomical Units* (a), *in years* (T)

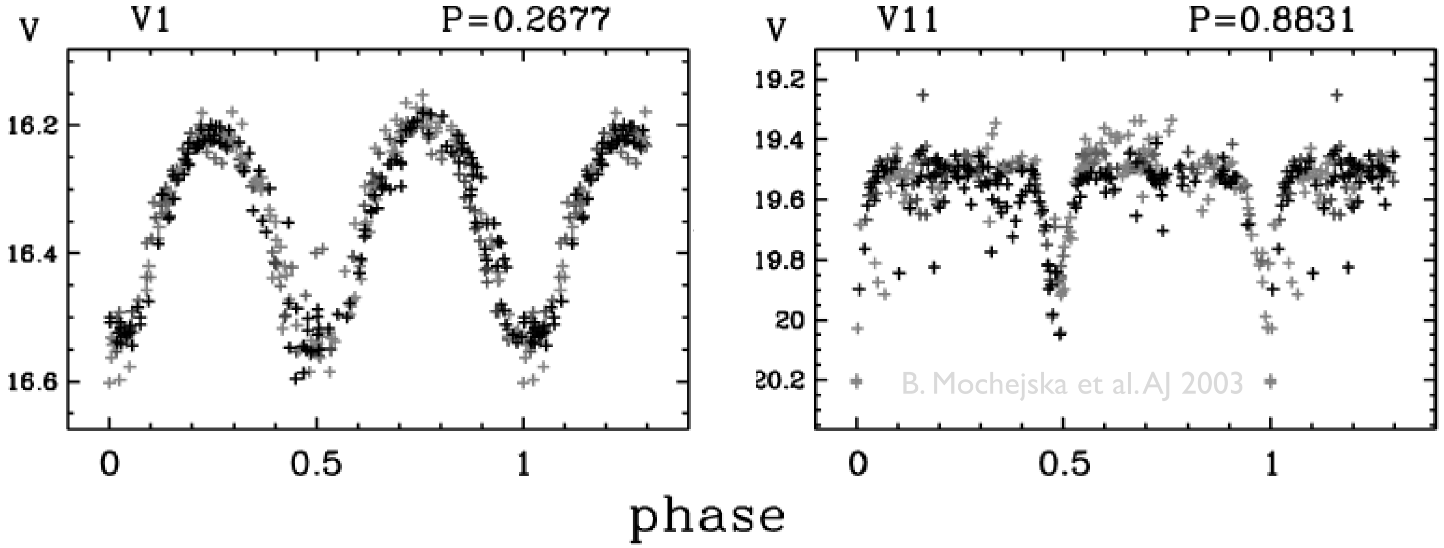


- Relative velocities give individual masses
- …though orbit inclination impacts the result

Stellar masses from **eclisping** binary star systems

For eclipsing binary systems, we know the star system is pretty close to edge-on, and so the radial velocities and period from spectral lines directly give the masses

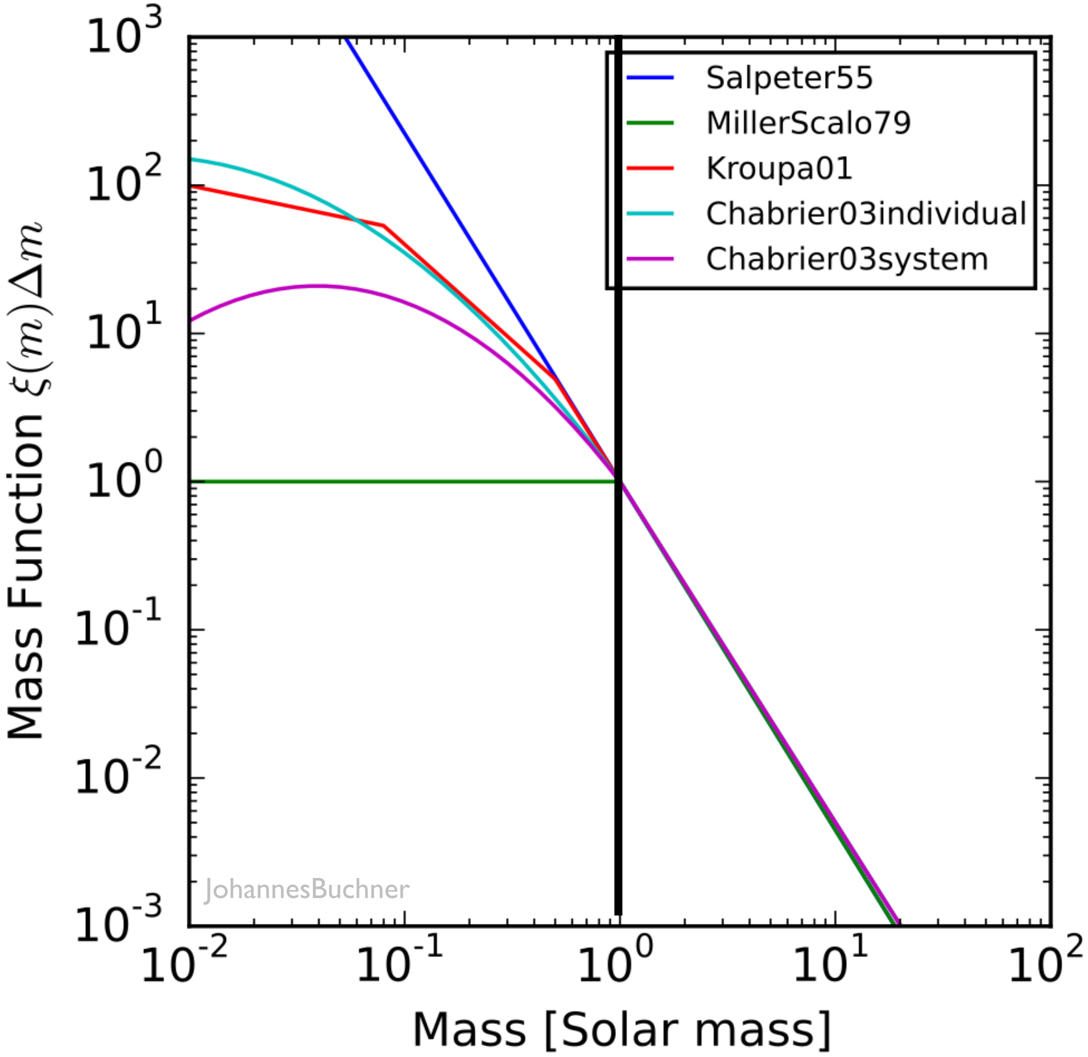




R. Pogge, OSU

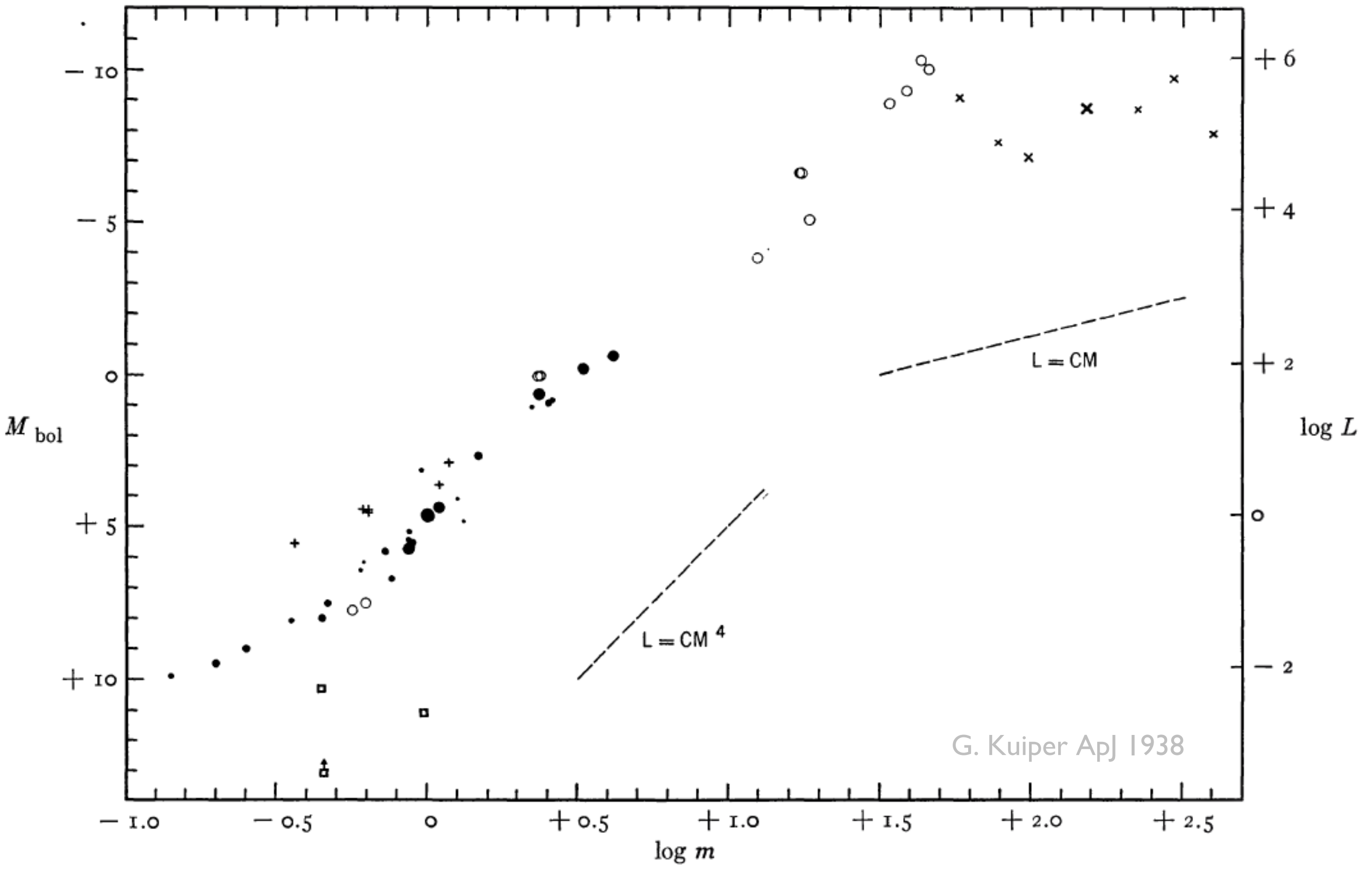
The (stellar) Initial Mass Function (IMF)

- Plotting the mass distribution of stars (technically the mass at birth, since mass loss occurs), one obtains the "initial mass function"
- Clearly, most stars are lower mass than the sun
- To make a useful connection to the HR-diagram, we need to link stellar mass to luminosity



The Mass-Luminosity Relation (for main sequence stars)

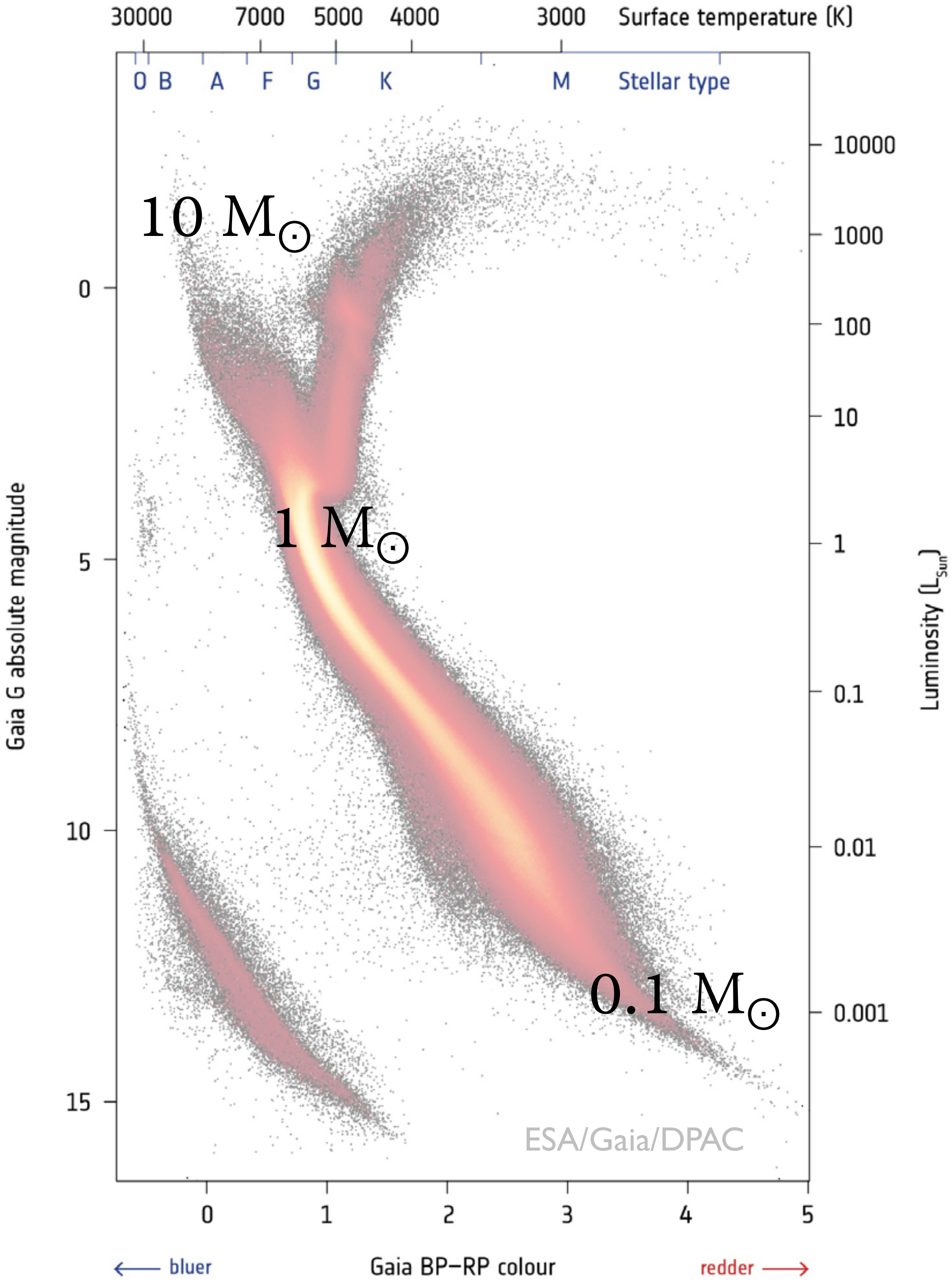
- If we plot the mass versus luminosity for most stars that we see, there is a clear relationship: $L \propto M^4$
- Explaining this requires a slightly more advanced knowledge of stellar structure *(take ASTR4201)*
- When a star does not follow this pattern, this is a sign there is something interesting about that star



G. Kuiper ApJ 1938

Mass on the HR-Diagram

Looking back at our HR-diagram, now we understand the distribution of stars along that main diagonal band (known as the "main sequence")



Stellar radii from the flux

- Recall from the "Introduction to Light" lecture:
- By approximating a star as a blackbody, determine the **effective temperature**:

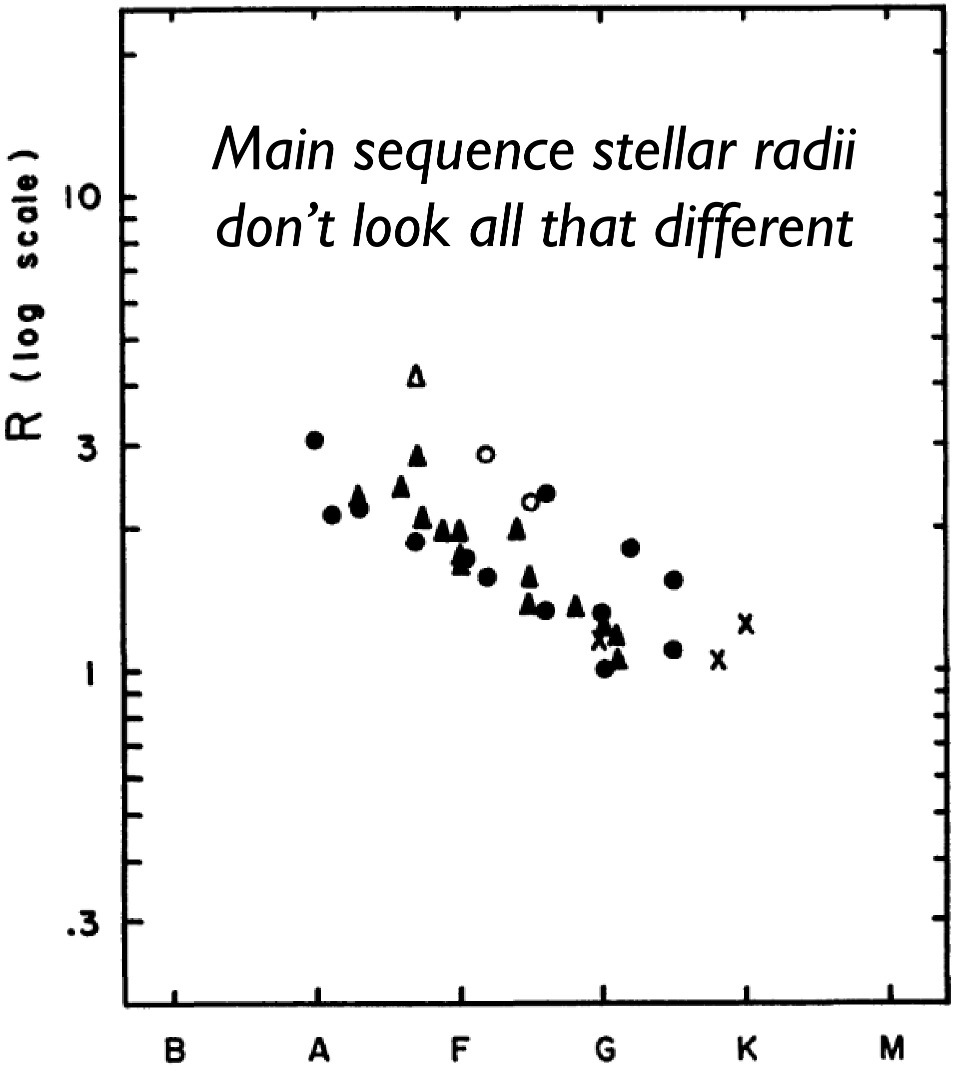
$$T_{\text{eff}} = \left(\frac{F}{\sigma_{SB}}\right)^{1/4}$$ Stefan-Boltzmann constant

- Meaning

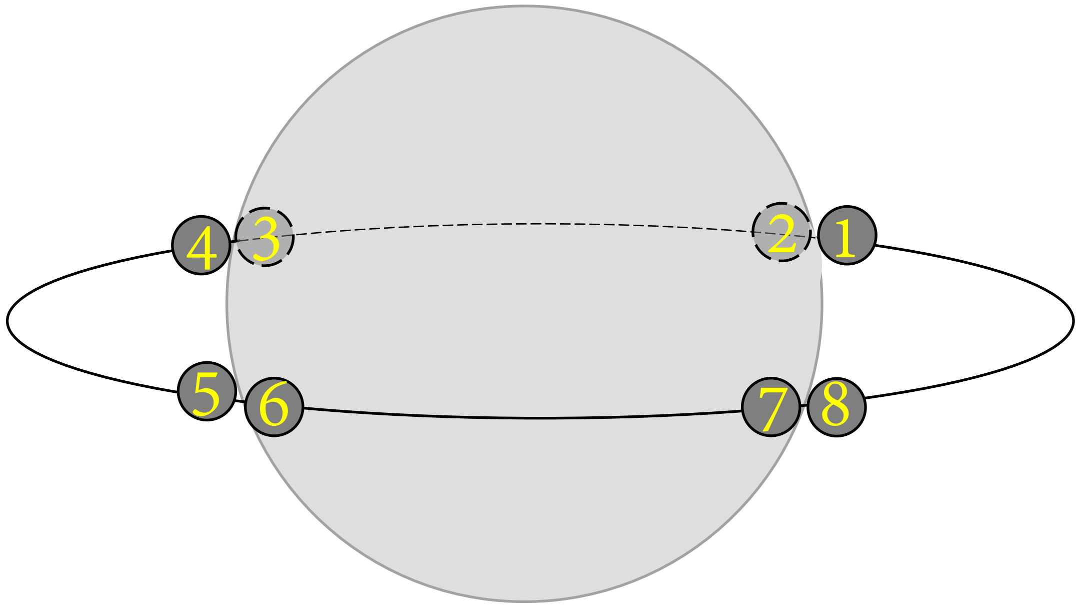
$$L = (\text{Area} * \text{Flux}) = 4\pi R^2 \sigma_{SB} T_{\text{eff}}^4$$

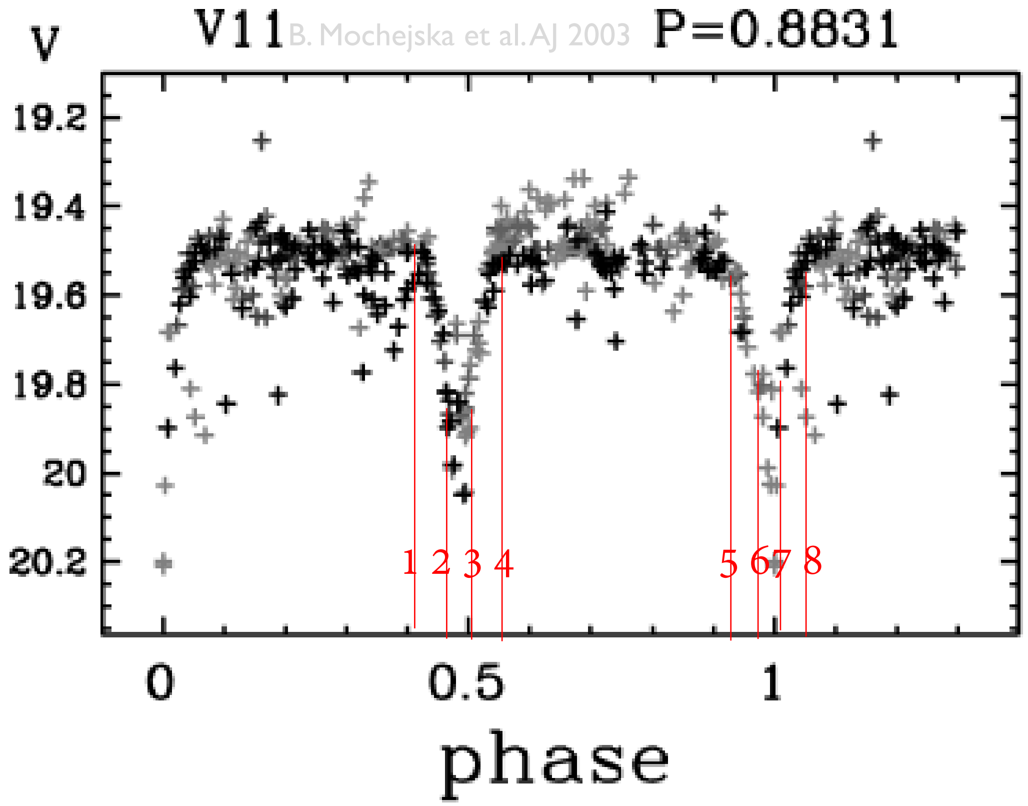
- A greater L for the same effective temperature (from λ_{peak} or spectra) means a larger R
  - $\frac{L_1}{L_2} = \frac{T_1^4}{T_2^4}\frac{R_1^2}{R_2^2}$
- ***Problems:***
  You need to be able to see these stars separately.
  T & L often not determined highly accurately.

D. Gray ApJ 1967



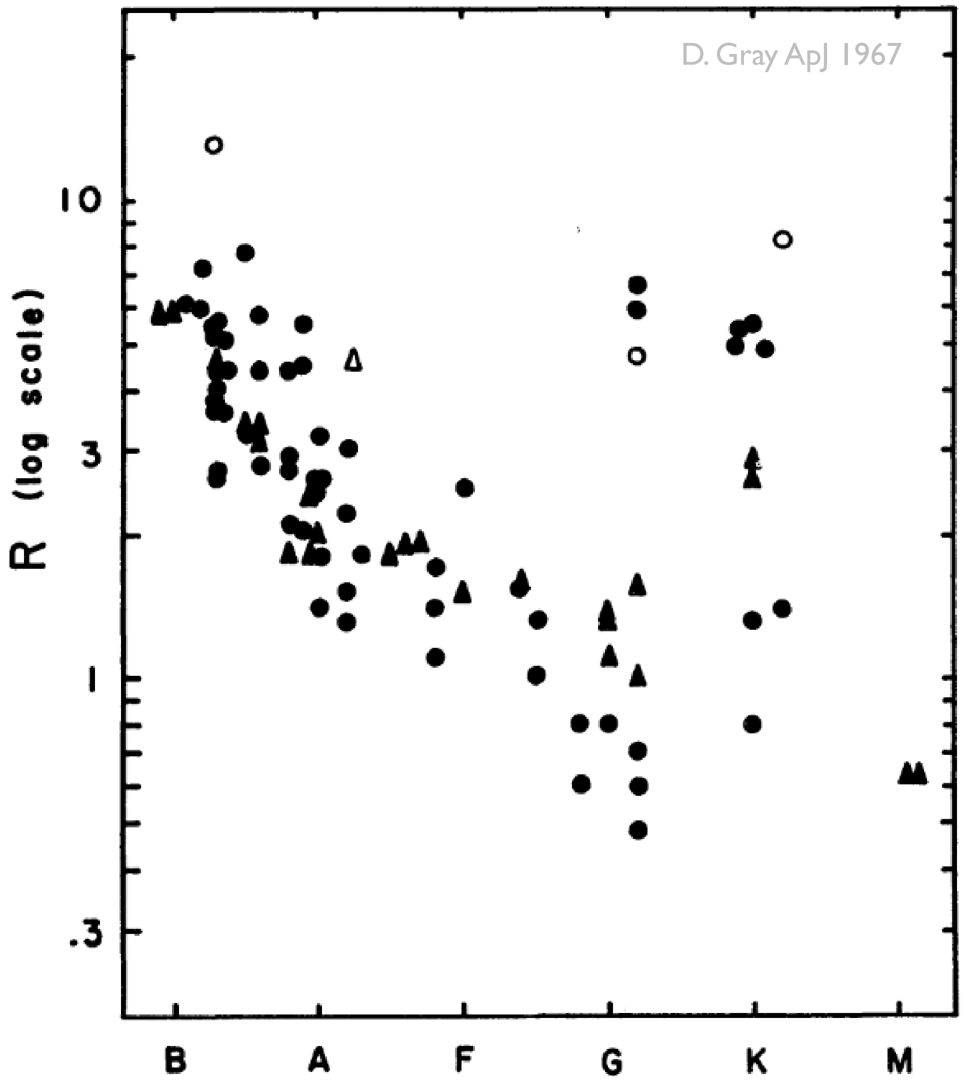
Stellar radii from eclipsing binary systems

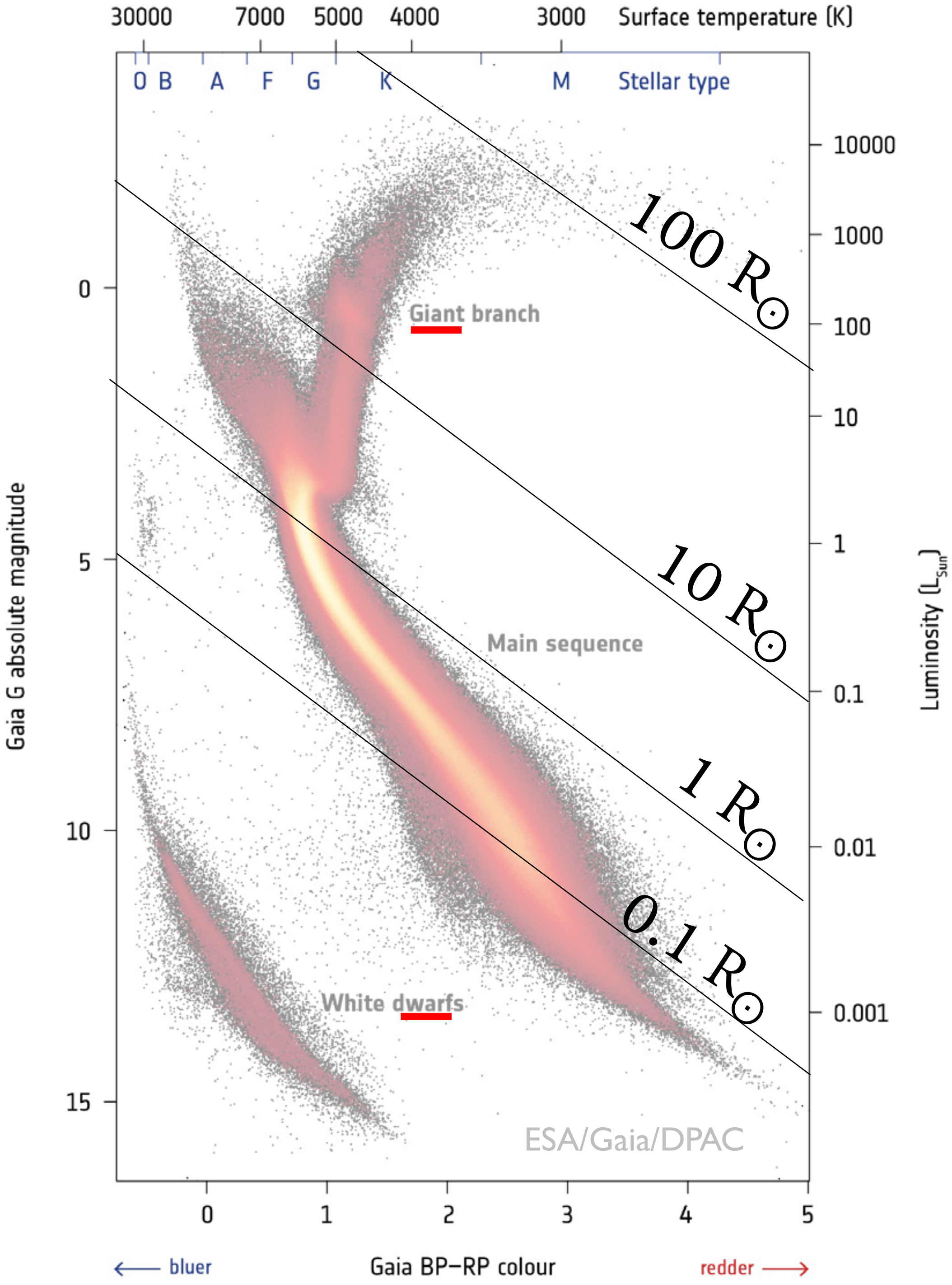




- Velocity = Distance/Time
- For a relative velocity v (from spectroscopy)
  - $r_{smaller} = \frac{v}{2}(t_2 - t_1)$
  - $r_{larger} = \frac{v}{2}(t_3 - t_1)$
- This gives extremely precise radii

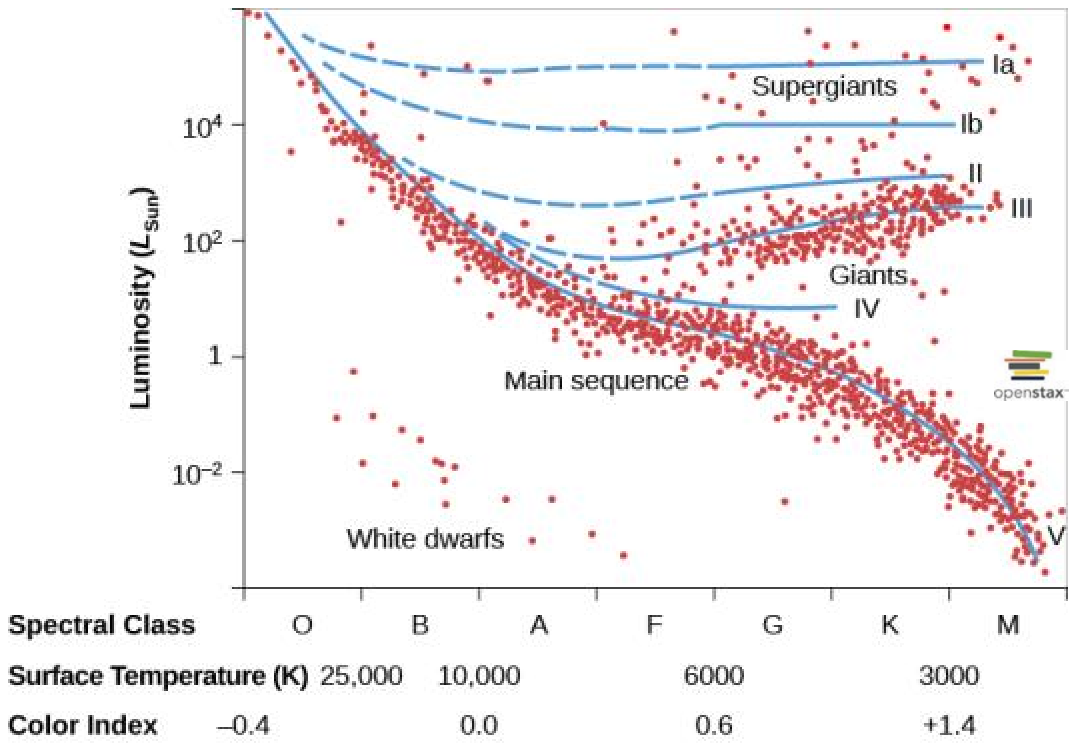
Radius on the HR-diagram





Using the HR-Diagram: *for distance*

- By determining a star's spectral class, we know where it is on the HR-diagram
- If we know where it is on the HR-diagram, we know it's luminosity
- If we know its luminosity and we measure it's brightness, we know its distance (see "Introduction to Starlight")



Using the HR-Diagram: *for age*

- In upcoming lectures, we'll discuss how stellar lifetimes are related to the initial stellar mass
- Since mass is related to lifetime, we can determine the age of a star cluster by determining where the "main sequence turnoff" is located