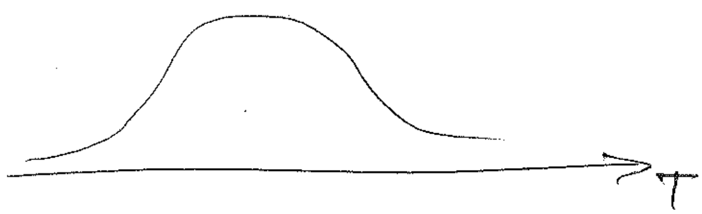
(finished 10 minutes earlier)

P1

lecture 13 H-R diagram.

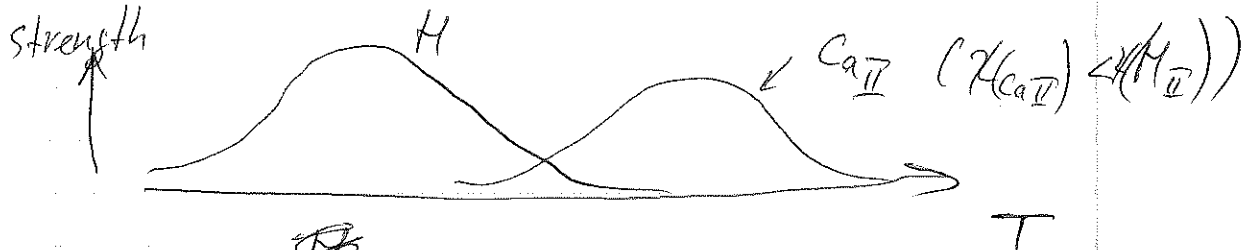
From previous lecture we see that a particular element spectral line will have characteristic temperature dependence



Different ionization energy
$\Rightarrow$ different position along T

$$\frac{N_{i+1}}{N_i} \sim (T)^{3/2} e^{-\chi_0/T}$$

smaller χ earlier appearance at low T



This nice but what can we say about relative abundance?
Above is a profile per particular element

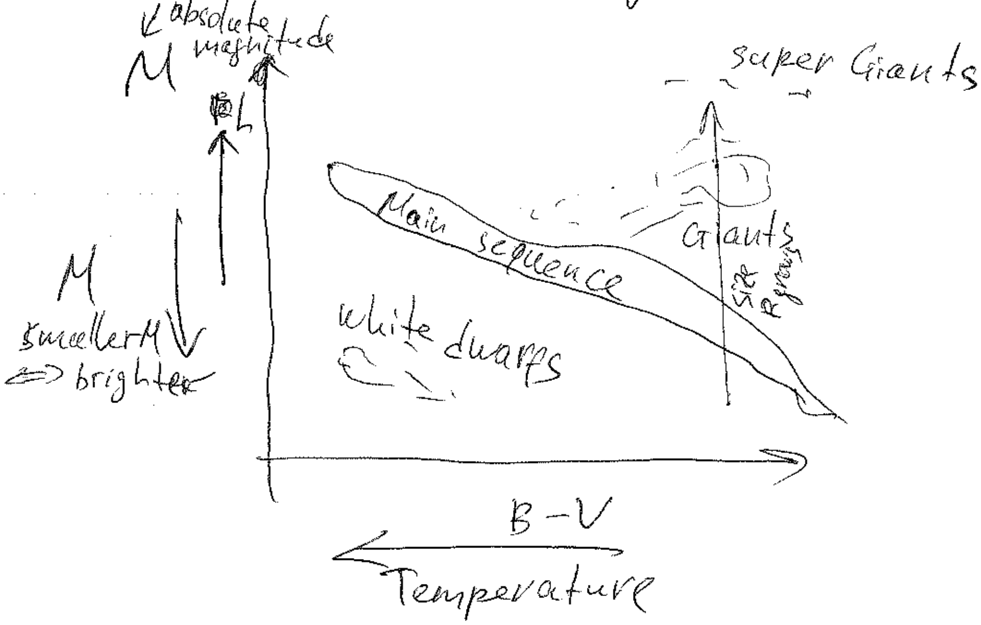
Overall line strength (observed)

$\sim N_{particles} \cdot$ (line strength per element) $\cdot\ \sigma$

σ — measured in labs at Earth; absorption cross section (depends on element dipole)

line strength per element — from Saha

Hertzsprung - Russel diagram
(H-R) diagram



Peculiar observations dependence
⟷

How do we know size?

Recall that position along B-V related to temperature,

$M \sim \log L = \log 4\pi R^2 \sigma T^4$
so for the same temperature large star is more luminos
$\Rightarrow$ smaller M.

Note also that temperature places a star in particular O, B, A, F, G, K, M class right away.

But so far no way to say something about luminocity ⟷ or size

Fortunately there is one more parameter in spectra → line width, do not mix it with strength!

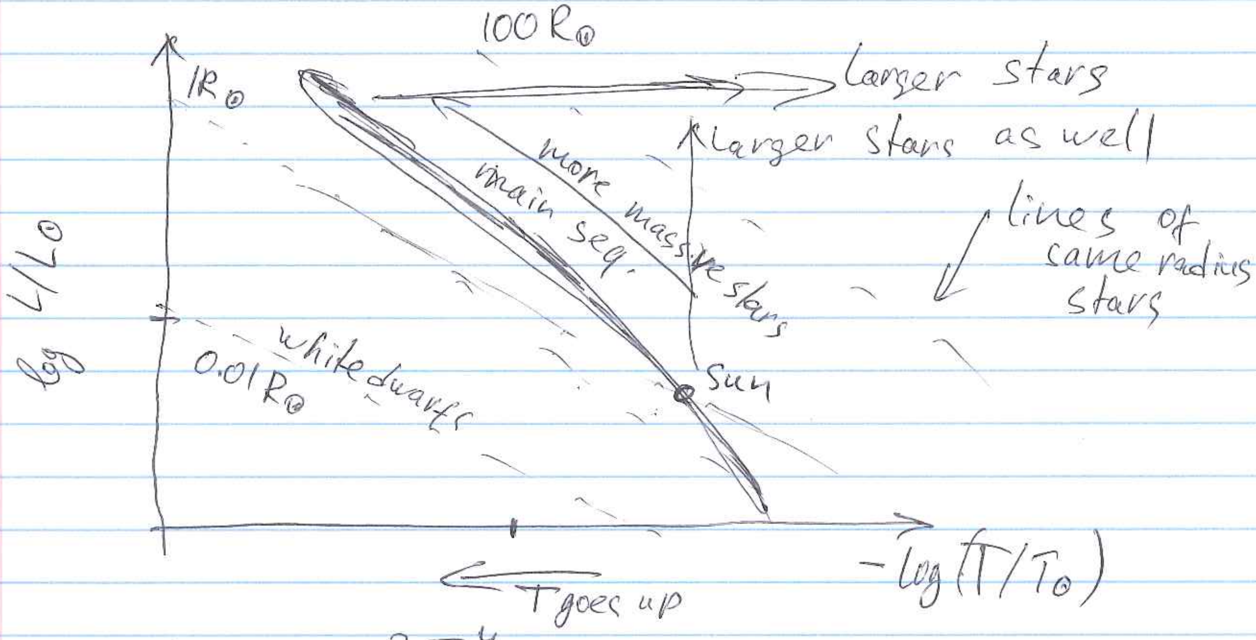
The same ~~time~~ type let's say 'A' will have a narrower lines as we go to a brighter star.

So now just looking at spectra we will now placement of a star at H-R ~~dg~~ diagram, i.e its T and M notice absolute magnitud M, now if one measure observed 'm' we will know the distance as well.

$$d = 10^{(m-M+5)/5}$$

d in pc

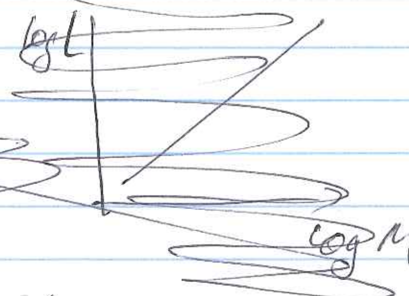
let's draw L T diagram closely related to M-R



$L \sim R^2 T^4$

$\log L/L_\odot \sim 4 \log(T/T_\odot) + 2 \log \frac{R}{R_\odot}$

Recall experimental observation that $M \uparrow \Rightarrow L \uparrow$



For stars around ($M_\odot$)

not always true

$M_\odot \quad \frac{L}{L_\odot} = \left(\frac{M}{M_\odot}\right)^4$

$\frac{L}{L_\odot} \sim \frac{R^2 T^4}{R_\odot^2 T_\odot^4} = \left(\frac{M}{M_\odot}\right)^4$

$\Rightarrow \frac{(M_\odot)^4}{R_\odot^2} \frac{1}{T_\odot^4} \quad \frac{M^4}{R^2} \frac{1}{T^4}$

Finally, why lines a narrower for giant stars.

Line width related to pressure broadening (spektras show line width to large to be explained by Doppler broadening $\sim v_{\substack{thermal\\average}} \sim \sqrt{T}$)

Pressure broadening $\sim 1/t_{between\ collision}$

$\sim \frac{density}{average\ velocity}$ $\sim\sqrt{T}$

$\Rightarrow \frac{density}{\sqrt{T}}$

So for the same T giants must have a less dense structure

$$\rho_\odot = \frac{M_\odot}{\frac{4\pi}{3} R_\odot} = 1410\ \frac{kg}{m^3}$$

a bit more than water (1000 kg/m³)

Betelgeuse

$$\rho_B = \frac{10 M_\odot}{\frac{4\pi}{3}(1000 R_\odot)^3} \approx \frac{10\rho_\odot}{10^9} = \frac{\rho_\odot}{10^8}$$

$$= \frac{1410}{10^8} \approx 1.4 \cdot 10^{-5} \approx$$

$$\approx 0.14 \cdot 10^{-6}\ \frac{kg}{m^3}$$

Compare to the air density $1\ \frac{kg}{m^3}$