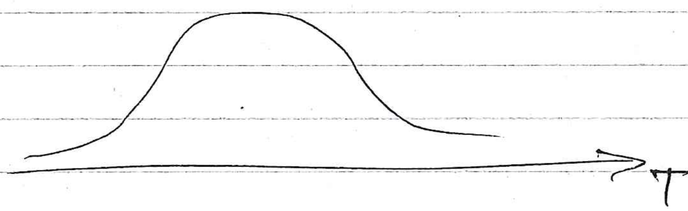
(finished 10 minutes earlier) ~~[illegible]~~

p1

lecture 14 H-R diagram.

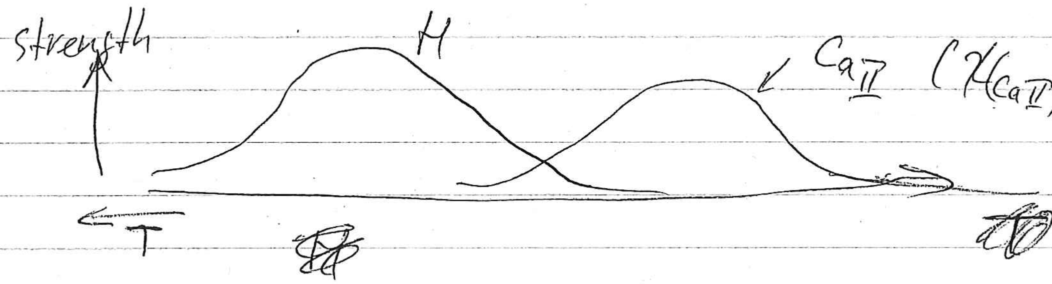
From previous lecture we see that a particular element spectral line will have characteristic temperature dependence



Different ionization energy
$\Rightarrow$ different position along T

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

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)

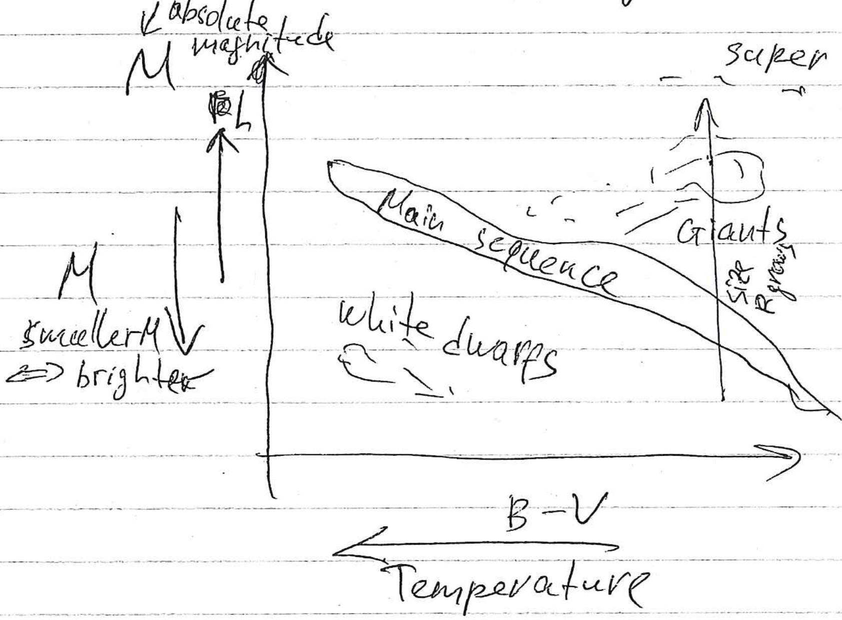
$\sim N_{particles} \cdot$ (line strength per element) $\cdot\ \sigma$

measured in labs at Earth

From saha

absorption cross section (depends on element dipole)

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
⟹ 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

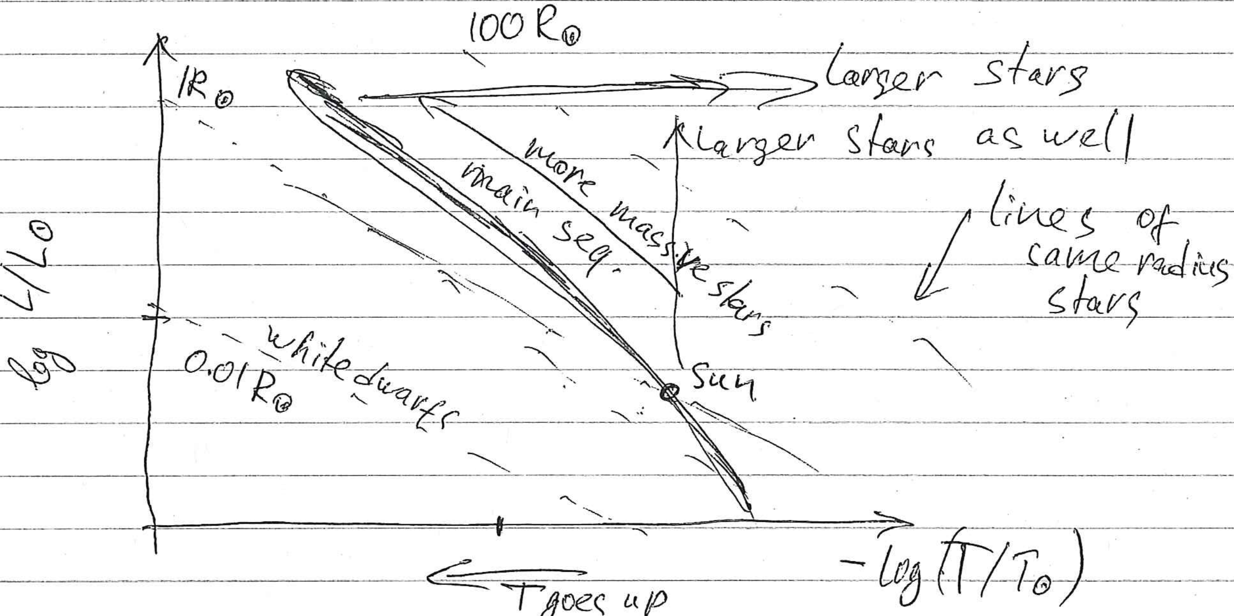
Fortunately there is one more parameter in spectra → line width, do not mix it with strength!

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 ~~dig~~ diagram, i.e its T and M notice absolute magnitud M, now if one measure observed 'm' we will know the distance as well.

$$\boxed{d = 10^{(m-M+5)/5}} \quad \boxed{d \text{ in } pc}$$

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 $M \uparrow \Rightarrow L \uparrow$~~

$\log L$ / $\log M$

~~For stars around $M_\odot$~~

not ~~always~~ true ~~$M_\odot \Rightarrow \frac{L}{L_\odot} \approx \left(\frac{M}{M_\odot}\right)^4$~~

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

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

Finally, why lines a narrower for giant stars.

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

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

$\sim \cancel{\frac{1}{\text{density}}} \quad \sim \frac{\text{density}}{\text{average velocity}}$ $\sim \sqrt{T}$

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

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 $1 \frac{kg}{m^3}$