lecture 2 — dark cloud composition, proto star behaviour/evolution

Why cloud are completely opaque? and not just an absorption lines.? $\Rightarrow$ **dust**

The Mie theory

Optical depth $\tau_\lambda = \sigma_\lambda N_d$ ← column density (cm^{2}?)

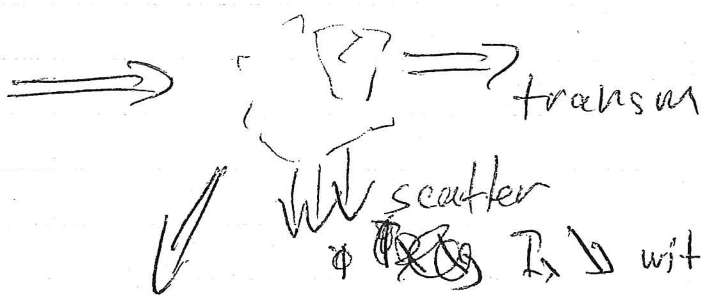
$\langle\langle \sigma_\lambda \int_0^s n\, ds \rangle\rangle$

dust part size a

$\sigma_\lambda \approx \frac{a^3}{\lambda}, \; \lambda \gtrsim a \;\; | \;\; \sigma_\lambda \sim a^2 \; (\lambda \ll a)$

so bluish light absorbed stronger and transmitted appears <u>reder</u>.

Scattered though is bluish



$I_\lambda \nearrow$ with λ

ϕ $I_\lambda \searrow$ with λ

Sky is blue, sun set/sunrise is red

Cloud Composition - Inter stelar Medium (ISM)

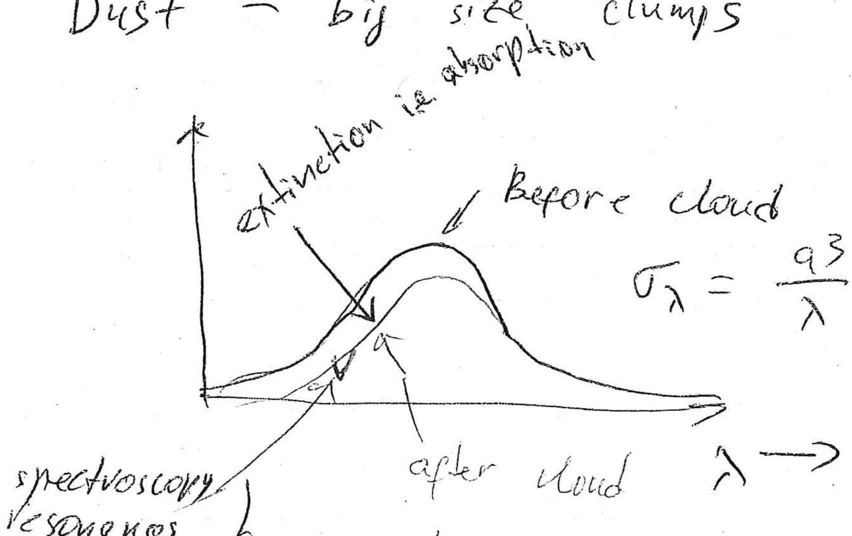
H - hard to detect but there is forbiden transition ~~of~~ due to splitting of ground level (spin interaction)

at $\lambda = 21$ cm $\Leftrightarrow$ $f \simeq 1.4$ GHz

H_2 - molecular hydrogen
only at high temperature $> 2000K$
when vibration band are exited

PAH - polycyclic aromatic hydrocarbons
↳ complex moleculars
↙ resonance lines

Dust - big size clumps



$$\sigma_\lambda = \frac{a^3}{\lambda}$$

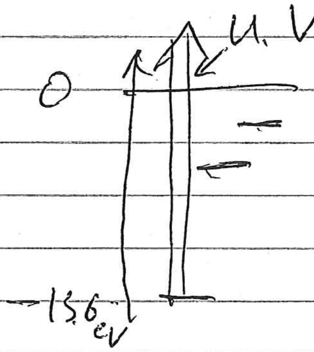
So spectrum is more red which need to be taken in account or thus give information on cloud composition

light after cloud is polarized ⇒ need B field to orient moleculare or dust

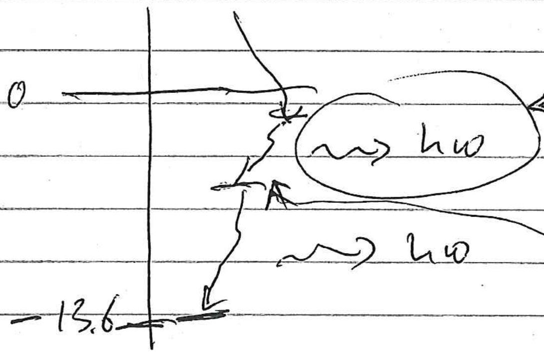
Emission nebula

Emission of recombination of H ions (H_{II}) created by U.V. radiation of nearby stars

U.V. photon absorbed ($\lambda < 91.2$ nm)



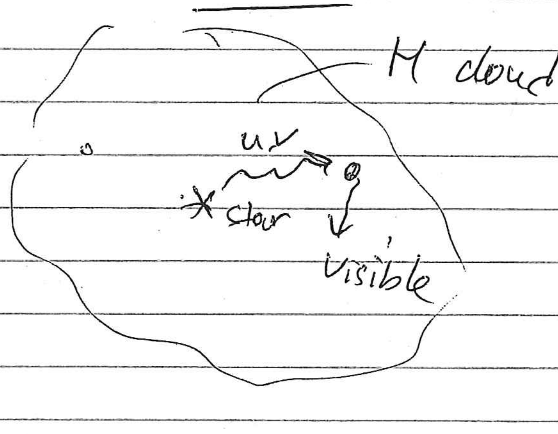
when it recombines back it emit a lower ~~????~~ energy (higher λ) photons



← these are not absorbed since it require an electron on a higher exited level

so we see these photons in visible. (Balmer lines give redish tint)

emission



Size of emission nebula

we see emission only till propagating light has U.V. photons

N_0(U.V) ↝ H_{II} H_{II} H_{II}

↑ # of photons

but then ion (H_{II}) recombines and is available for U.V. absorption

so recombination # = # photons in U.V.

$$(\alpha \cdot n_e \cdot n_{H_{II}}) \cdot V = \frac{\#\text{photons}}{\text{sec}} = \frac{L}{\hbar\omega_{\text{ionization}}} = N$$

↑ [m^3/s] recombination coef, $\alpha \simeq 3.1 \cdot 10^{-19} \frac{m^3}{s}$ for T=8000 K

Note $(\alpha \cdot n_e \cdot n_{H_{II}}) \cdot V$ is recombination rate [$\frac{\#/s}{\text{unit}}$]

size of nebula

$$\alpha \cdot \underbrace{n_e}_{n_H} \cdot \underbrace{n_{H_{II}}}_{n_H} \cdot \frac{4\pi}{3} R_s^3 = N$$

$$\boxed{R_s = \left(\frac{3}{4\pi} \frac{N}{\alpha}\right)^{1/3} \cdot \frac{1}{n_H^{2/3}}}$$ Size of Emission nebula

Strömgren radius

typically $R_s \simeq 0.1 \div 100\,pc$, $n_H \approx 10^8 \frac{1}{m^3}$

Why there are no super heavy star, but a bunch of smaller one

(P6)

Angular momentum issue

So far we assumed that matter fell straight to center of the cloud.

But if it rotates just a bit than we have to worry about speed up of rotation

faster rotation

initial angular momentum of outside region

~~$m v_0 r_0$~~

$$m v_0 r_0 = m v_f r_f$$

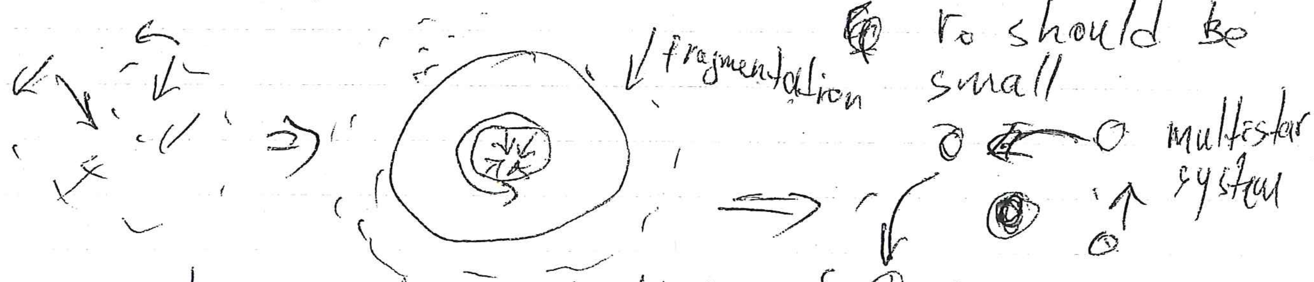
r_f ‖ $r_0 = 7\cdot10^8$

if $r_0 = 3\cdot10^{15}$ m
$= 0.1$ pc
$v_0 = 1$ km/s

$$v_f = v_0 \frac{r_0}{r_f} = 10^4 \cdot \frac{3\cdot10^{15}}{7\cdot10^8} \simeq 4\cdot10^{10} \text{ m/s}$$

↑ faster than speed of light!

So only part of cloud could compress
→ r_0 should be small

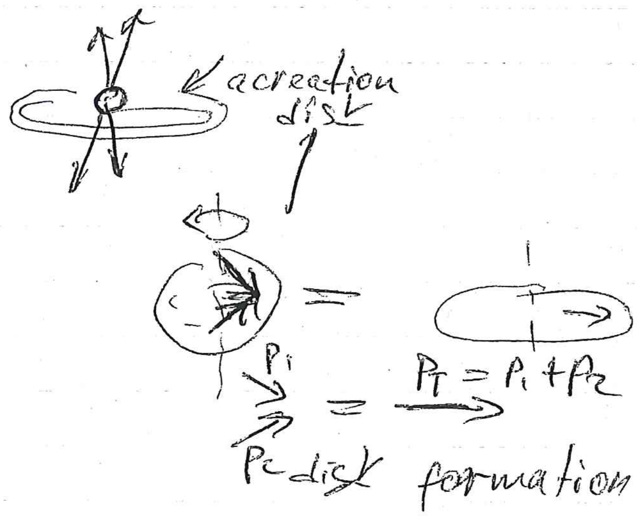


~~or angular momentum should be~~

ends here

Another option = angular momentum should be "droped" away

⇒ Jets



Another way to see it