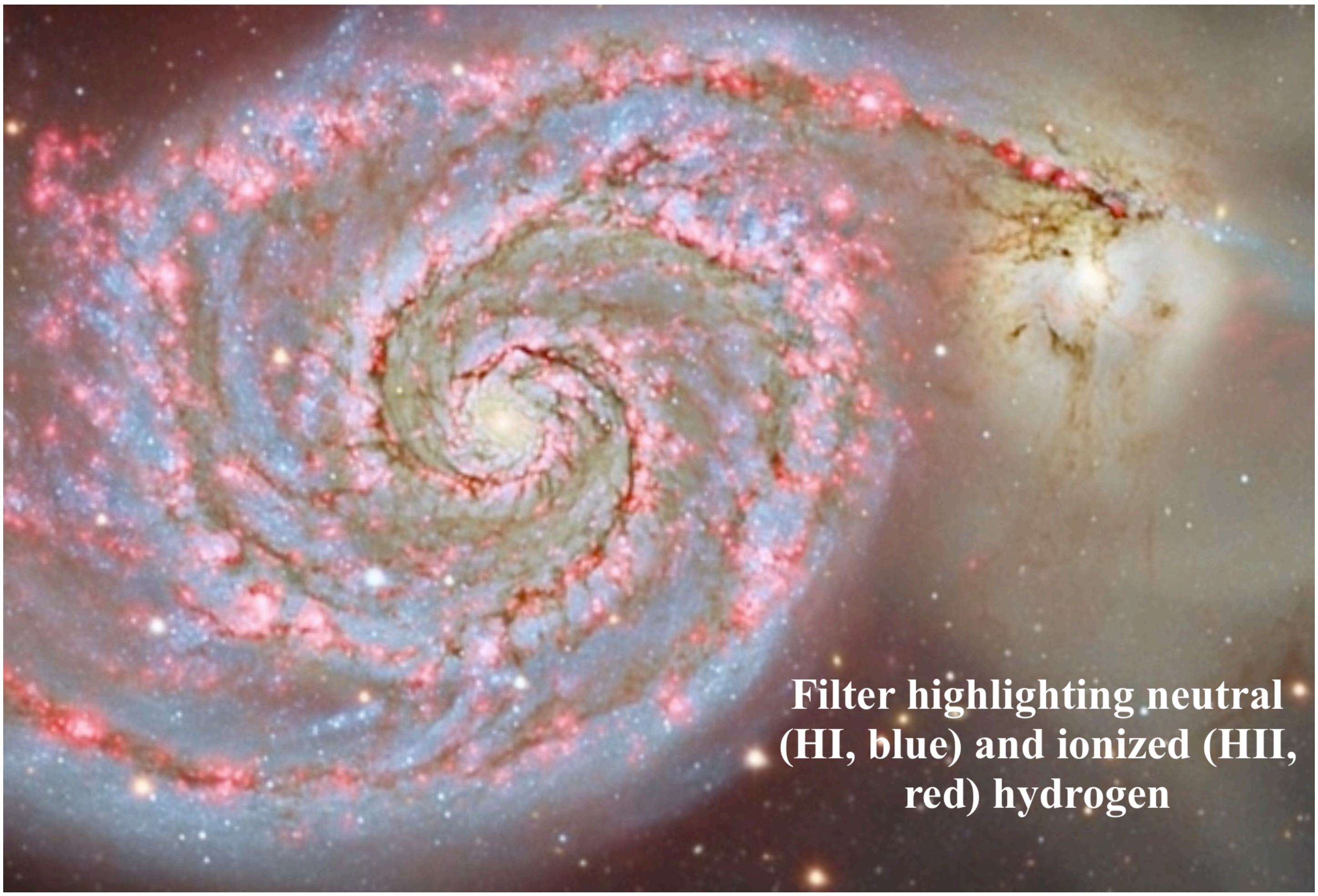


This is the Whirlpool galaxy. What is going on here? What are all those red blobs of ionized hydrogen coming from?

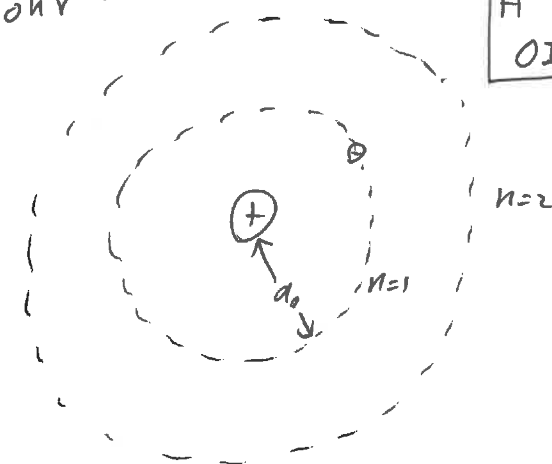
These are HII Regions!
Ionized by young, hot massive stars.

First, some review of things you know.

Cosmology: Universe mostly H → "HI"
neutral Hydrogen.

Aside: notation in astronomy
HI → neutral
H^+, ion → HII
OI → neutral O^{++} → OIII → two e^-'s gone

Remember Bohr model.



e^- can be in different states...
n=1 ground state
or excited states.

REMEMBER LARMOR RAD LIFETIME FOR n=1?

n=1 stable → quantum effects

$n \geq 2$ rad lifetime → very short.

How much energy does it take to fully ionize H?

$$HI \rightarrow HII \text{ requires } E \geq 13.6\,eV$$
$(2 \times 10^{-18}\,J)$

So if you hit HI atom with this energy it will ionize this takes a photon with wavelength

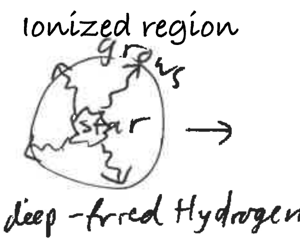
$$E = h\nu = \frac{hc}{\lambda} > 13.6\,eV \Rightarrow \lambda \leq 912\,\text{Å} \quad (10^{-7}\,m)$$

A short-wave photon will ionize. Blast Hydrogen w/ short-wave photons, & ionize it.

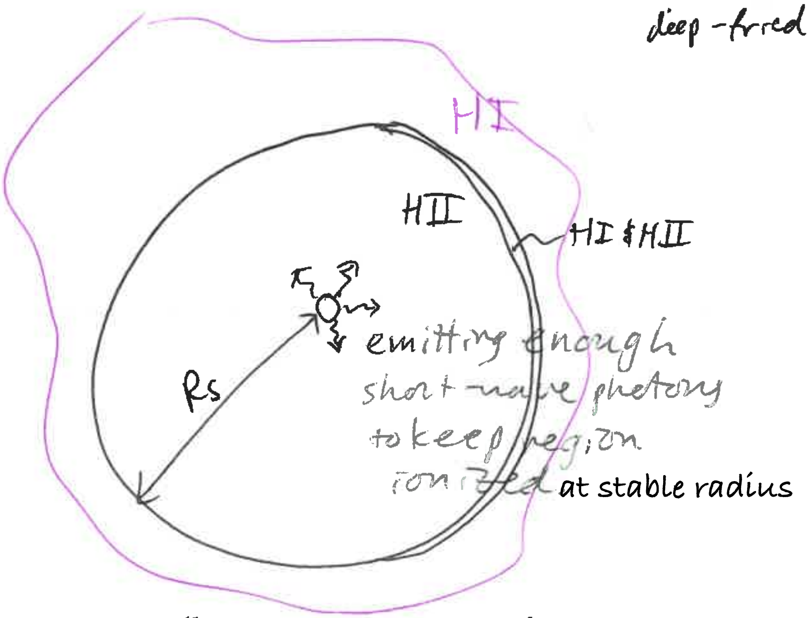
like the Universe, the ISM dominated by H. Mostly molecular, but big regions of HII. (ionized hydrogen)

WHAT'S GOING ON HERE?

Basic stellar evolution:

Molecular gas & H collapse → 

→ Eventual LTE



How big is R_s?

"Strömgren Sphere"

↳ HII assoc. w/ star formation.

Consider:

ionization rate $\geq$ recombination rate

ionization rate → Q_H

rate star produces photons $\leq 912\,\text{Å}$

recombination rate → Rate of e^- collision w/ ion.

$N_r \times$ volume

rate per volume — times total volume considered.

Let's first consider ionization rate.

$$Q_{*H} = \int_{\nu_0 = \frac{13.6\,eV}{h}}^{\infty} \frac{L_\nu}{h\nu}\, d\nu$$

Star to remind you it's from star...

i.e.

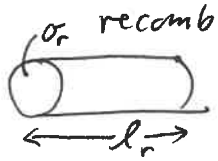
We'll leave it at that.

Now consider Recombination...

What's rate per volume (N_r)?

Consider some volume in which the e^- will recombine:

σ_r recomb cross-section



So get
$$\frac{1 \text{ recomb}}{\sigma_r l_r} = n_p$$

$$\frac{\#\text{recomb}}{\text{volume}} = \frac{\#\text{protons}}{\text{volume}}.$$

typical time til' recombination

$$t_r = \frac{l_r}{v_e} = \frac{1}{n_p \sigma_r v_e}$$

v_e: electron speed.

→ happens sooner w/ higher density or higher e^- velocities.

For each electron in a volume,
get ~~[illegible]~~ a recomb once
every t_r. So for all electrons in volume:

$$N_r = \frac{n_e}{t_r} = n_e n_p \sigma_r v_e$$

what is v_e?
In a thermal distro, particles have some velocity distribution. Let's define...

Define "recombination coefficient"

$$\alpha_r = \langle \sigma_r v_e \rangle$$

where v_e has Maxwell-Boltzman distrib.

$$\left[F(v)\,dv \propto T^{-3/2} v^2 e^{-mv^2/2kT} \right]$$

(SEE ERA B.8)

Details of MB distrib don't matter except to note that

$$\alpha_r (T_e)$$

!!! Typical HII region in LTE: $T_e \sim 10^4$ K !!!

$$\alpha_r (10^4 K) \simeq 3 \times 10^{-19} \frac{m^3}{s}$$

Bring it together.

1. ~~Hydrogen:~~ $N_r = n_e n_p \alpha_r$
2. Hydrogen: $n_p = n_e$ $\rightarrow N_r = n_e^2 \alpha_r$
3. In sphere, equalize ioniz & recomb.

$$Q_{*H} = N_r \underbrace{\tfrac{4}{3}\pi R_s^3}_{\text{volume sustained.}}$$

$$\Rightarrow \boxed{R_s = \left[\frac{3 Q_{*H}}{4\pi \alpha_r n_e^2} \right]^{1/3}}$$

EX

O stars → young.

pretty hot, main sequence

O6 V star $Q_{*H} \sim 5\times 10^{48}$ $\frac{\text{phot}}{s}$ ($T_* \simeq 4\times10^{4}$ K)

$n_e \sim 10^{7}\ m^{-3}$

$\langle \alpha_r \rangle = 3\times10^{-19}\ m^3/s$

$\Rightarrow R_s \simeq 10$ pc

will hotter/colder T stars have larger/smaller R_s? Why?

Sun: $R_s \simeq 4$ AU (10^{-5} pc!!) ($T_* \simeq 5800$K)

$Q_* \simeq 10^{35}$ phot/s.

HII Regions: fun science potential.

- Trace high-mass (O/B) star formation and white dwarfs.

- Place to find HII and molecular lines (as in your project 1).

- Physically very compact HII regions can only be seen in radio (they're hidden from other bands by dense molecular clouds and dust)

- HII region brightness and spectrum can give you electron densities, electron temperatures, star-formation rate, and physical properties in the region!

Herzsprung-Russel Diagrai

(You get HII regions for the hottest stars)