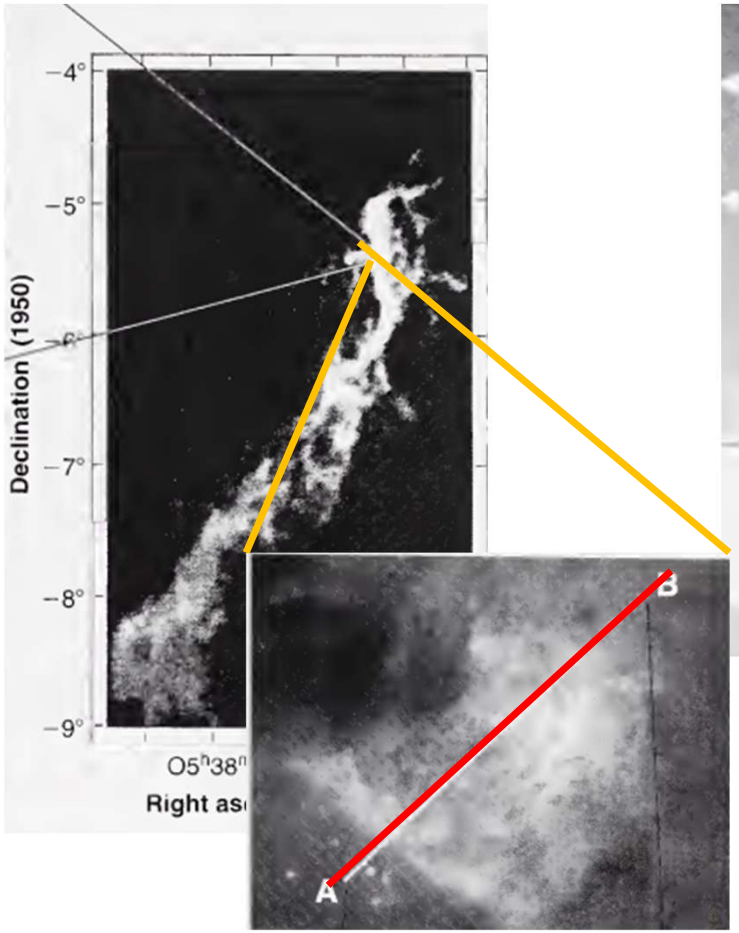
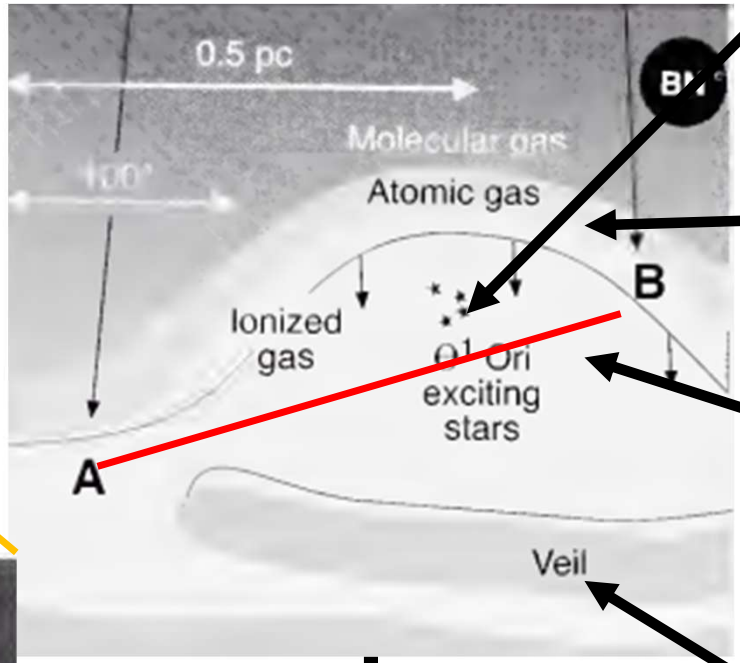
AGNAGN seminar
Sec.8.5~End of Sec.8

Tomoya Yukino

8.5 Comparison with Observations

Geometry of Orion Nebula





Observer

θ^1 Ori(Trapezium Cluster):
Main ionization source

HII region:
- Layer of ionized gas
- Little of the extinction due to dust in here

"Void" region:
Radiation pressure and stellar wind blow the gas

"Veil" region:
・Main cause of extinction
・Layers of neutral gas
between the sun and cluster

Radiation from each region and approaches to physical

- **Neutral gas region(“Veil region”)**
  - Radiation: **21cm absorption lines** in radio continuum from H^+ region
  - Approach: **Measurement of magnetic field**

Zeeman effect:

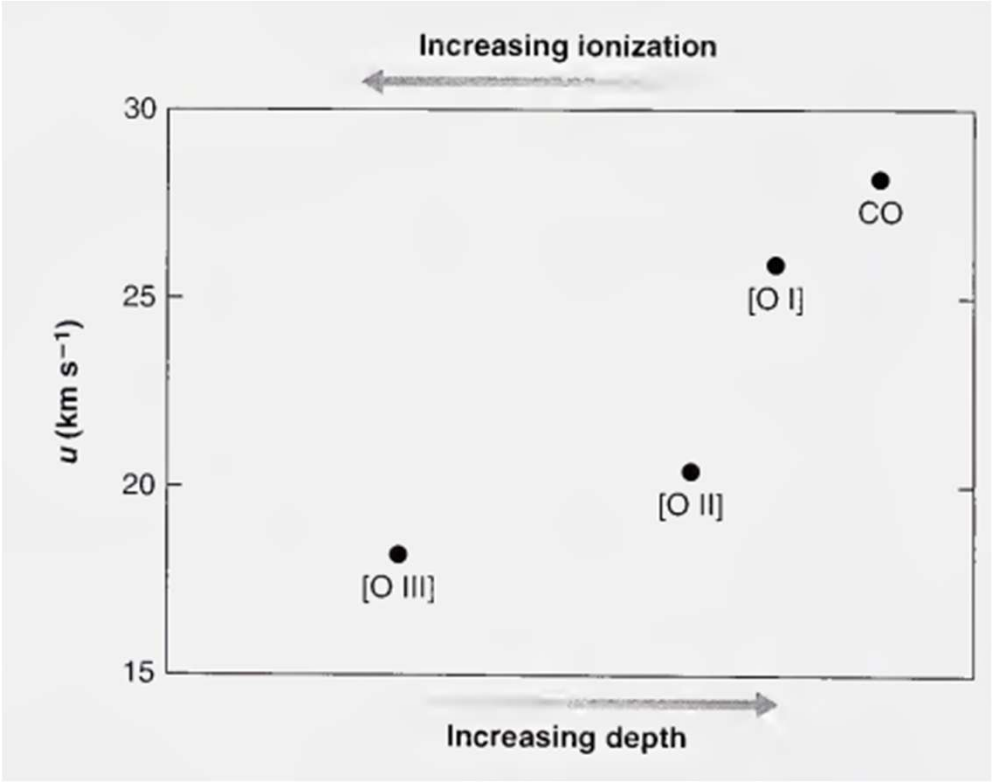
- Splitting of a spectral line into several component in the presence of a static **magnetic field B**

⇒Line-of-sight component in Veil region is possible to be measured and mapped with 21cm line

Radiation from each region and approaches to physical

- **HII region near the Trapezium**
  - Radiation: Emission lines from various ions, atoms and moleculars
  - Approach: Measurement and mapping of **Velocity of gas** along a line of sight

※Gas is accelerated by flows from OMC1

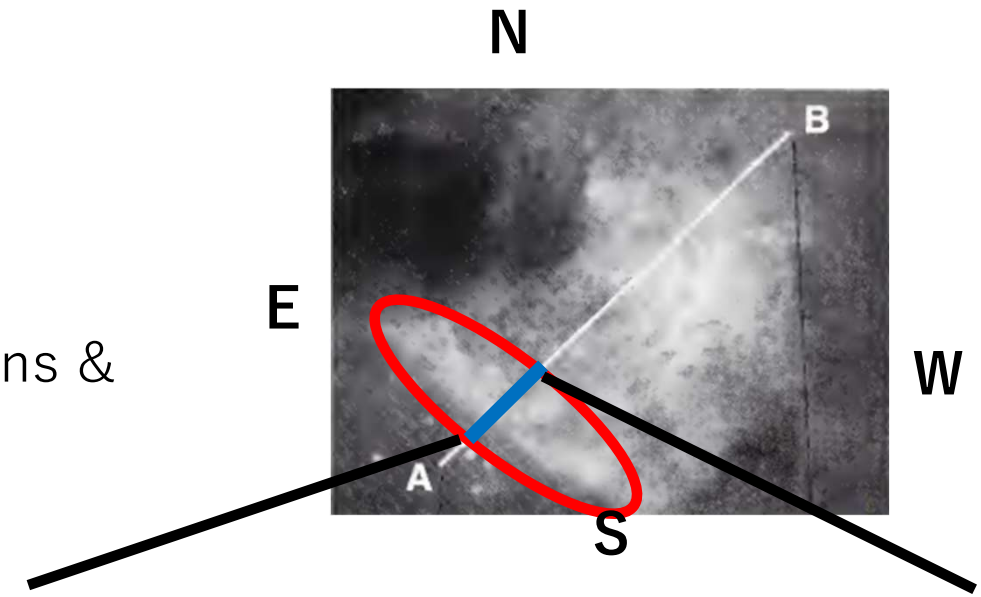


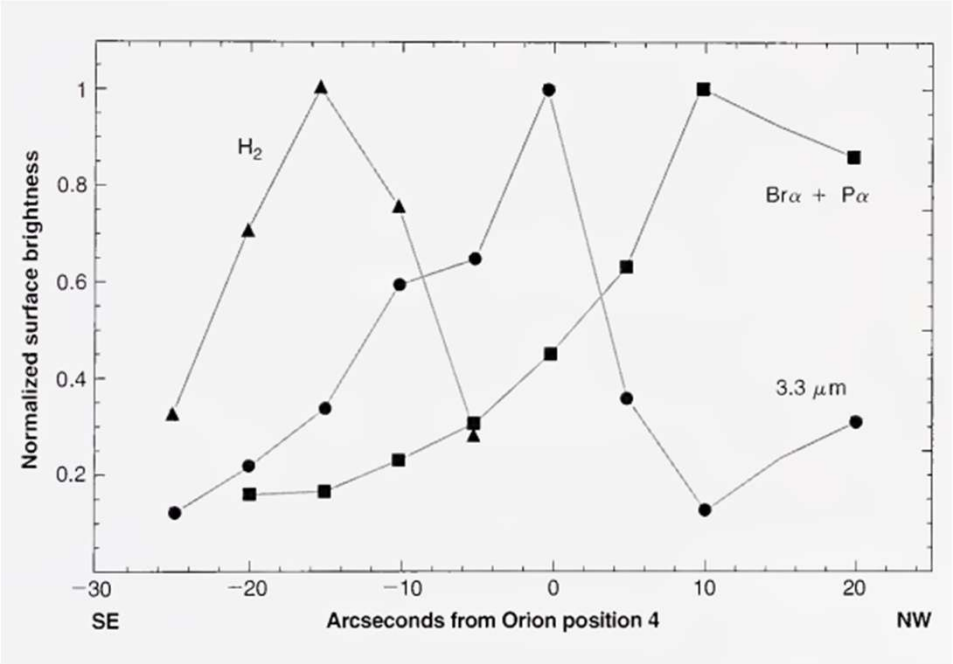
Velocity of gas measured by each emission lines (standard velocity: OMC1)
(Velocity of ions with small ionization potential are ~0km/s, like Fe^+, C^+)

Radiation from “Orion bar”

- **Edge-on ionization front?**
- NW edge: Exposed to the central stars
  ⇒**Strong HI recombination line**
- Intermediate point: Gas contains small grains & large molecules
  ⇒**Strong 3.3μm feature**
- SE side: H_2 formation happens
  ⇒**Strong H_2 lines**

(※Decline of emission in SE edge is due to the extinction of UV continuum)





Surface brightness of blue area

Emission lines from HII region, PDR region

HII region

- Emits Hβ and [OIII]
- (IR lines are too weak to be detected)

PDR region

- Emits IR emission lines (O, C, CO and H_2)
- Ionized by high-energy portion of the stellar Balmer continuum (less luminosity)
- Strong extinction prevents us to detect optical lines
  ⇒**IR and radio observations are important to approach!**

Table 8.1
Emission-line spectrum of the Orion PDR and H II Region

Line	Wavelength	Surface brightness (erg cm^{-2} s^{-1} sr^{-1})
Hβ	λ4861 Å	0.2
[O III]	λ5007 Å	0.8
[O I]	λ63 μm	$4–6 \times 10^{-2}$
[O I]	λ145 μm	$3–6 \times 10^{-3}$
[C II]	λ158 μm	$4–7 \times 10^{-3}$
[C I]	λ610 μm	7×10^{-6}
CO $J = 1 – 0$	λ2.59 μm	6.5×10^{-7}
CO $J = 2 – 1$	λ1.29 μm	6.0×10^{-6}
CO $J = 3 – 2$	λ0.863 μm	1.9×10^{-5}
H_2 (1,0) S(3)	λ1.957 μm	6.6×10^{-5}
H_2 (2,1) S(1)	λ2.247 μm	2.5×10^{-5}

8.6 Molecules Around H II Regions

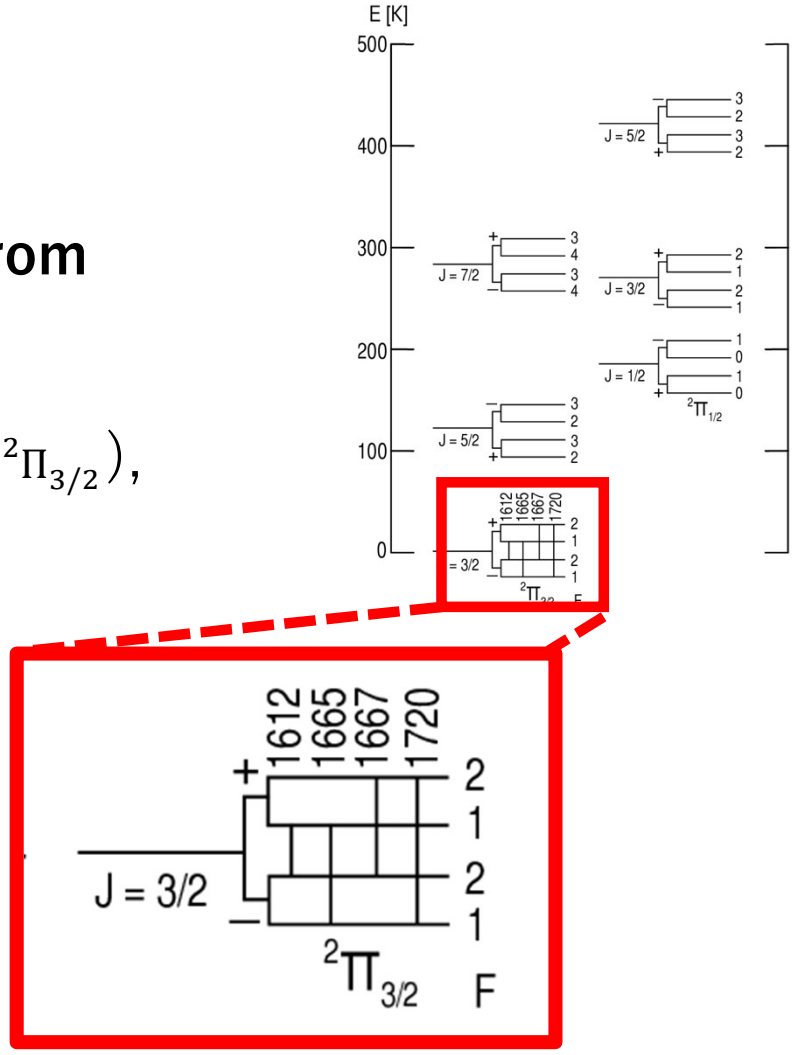
OH lines

- **Representative molecular emission lines from HII region**
- Transition:
  Between the two components of the ground($^2\Pi_{3/2}$), split by hyperfine interactions
- Frequencies: 1612, 1665, 1667, 1720 MHz
- Source in HII region:

1. Extended region
2. **Cluster of small sources(Size: 0.005~0.5”(Individual), 1”(Cluster))**

- Narrow lines, circular/linear polarization, high brightness temperature

⇒**Strong evidence for maser activity**



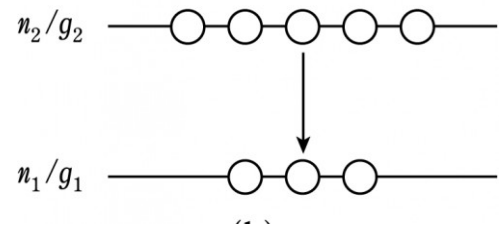
Energy level diagram of OH

https://www.researchgate.net/figure/The-rotational-energy-level-structure-of-OH-The-fine-and-hyperfine-structure-levels-are_fig1_285619489

OH maser(Microwave Amplification by Stimulated Emission of Radiation)

Radiated by stimulated emission

1. **Maser goes through population inverse region**
2. **Strengthen maser by stimulated emission**
3. **Repeat 1., 2.⇒We can observe OH maser**



Energy level diagram
of population inverse

OH maser from HII region

OH molecules should be dissociated by strong UV radiation

⇒**Tend to occur in areas of strong extinction**

(Emission lines from other molecules can be emitted from the same region)