Ionization Fronts and Photo-Dissociation

1.Introduction:

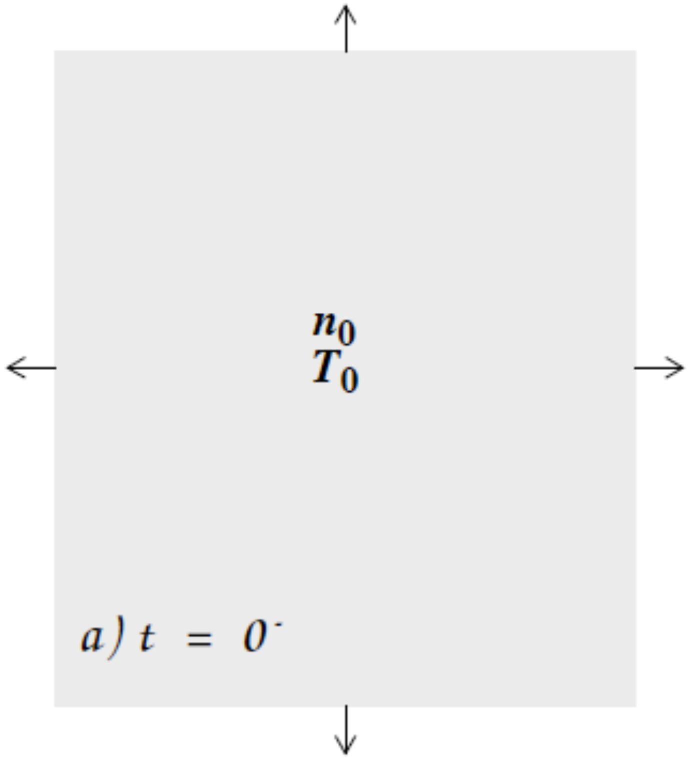
-Ionization fronts: boundary regions between ionized and neutral matter in space.

-Sections:

a) HII regions: Theory
b) HII regions: Observables
c) HII regions: Classification
d) Photo-Dissociation Regions (PDRs)

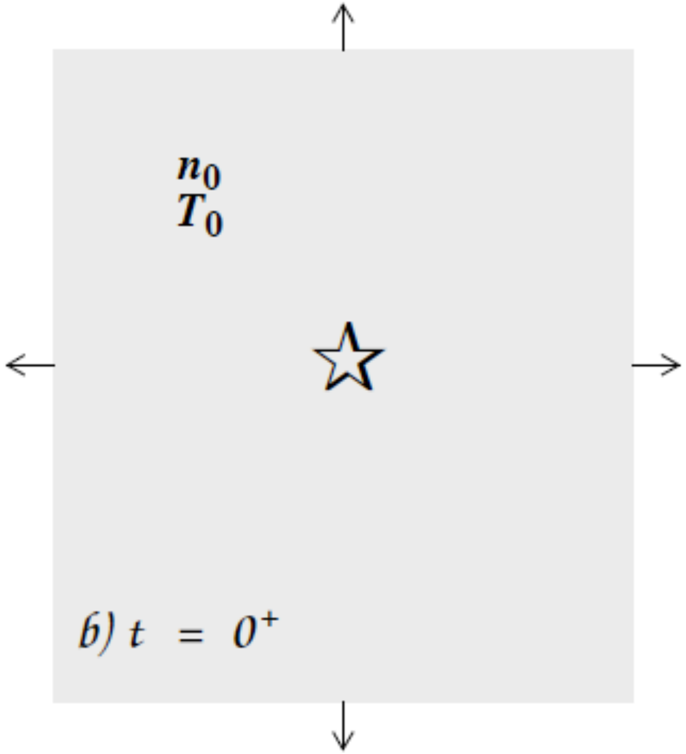
2. HII regions: Theory

i. Initial Model System: T_0=100K, n_0=100cm^{-3}



n	T
n_0=100 cm^{-3}	T_0=100 K
$n_1 >> n_0$ at first but converges towards n_0 with time	T_1=T_0
n_2=n_0 at first but converges towards $n_{final} << n_0$ with time	T_2=10^4 K

ii. Model Stimulus: massive O, B stars



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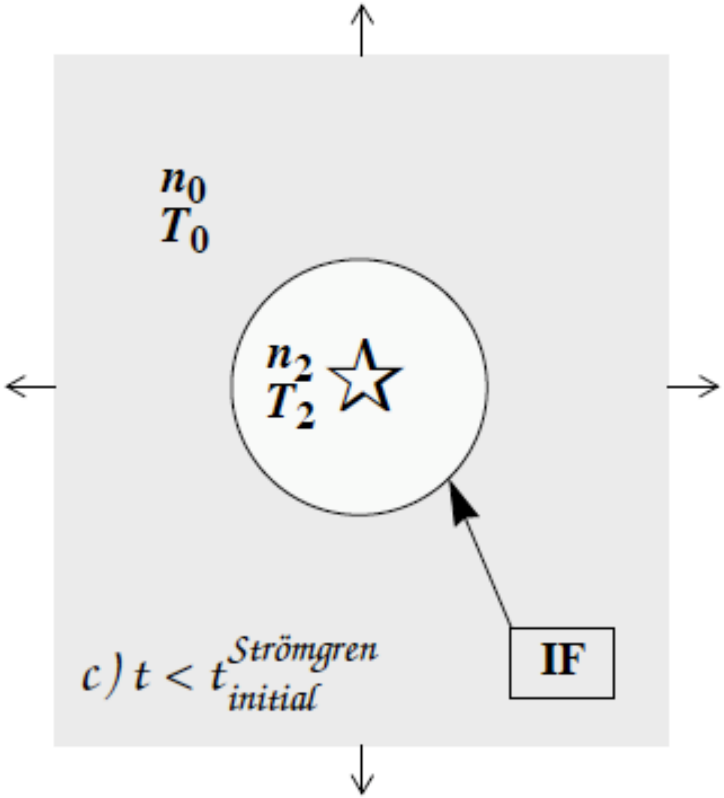
In the model, we keep the temperature in the ionized gas at 10000K

iii. Stage A: Formation Phase



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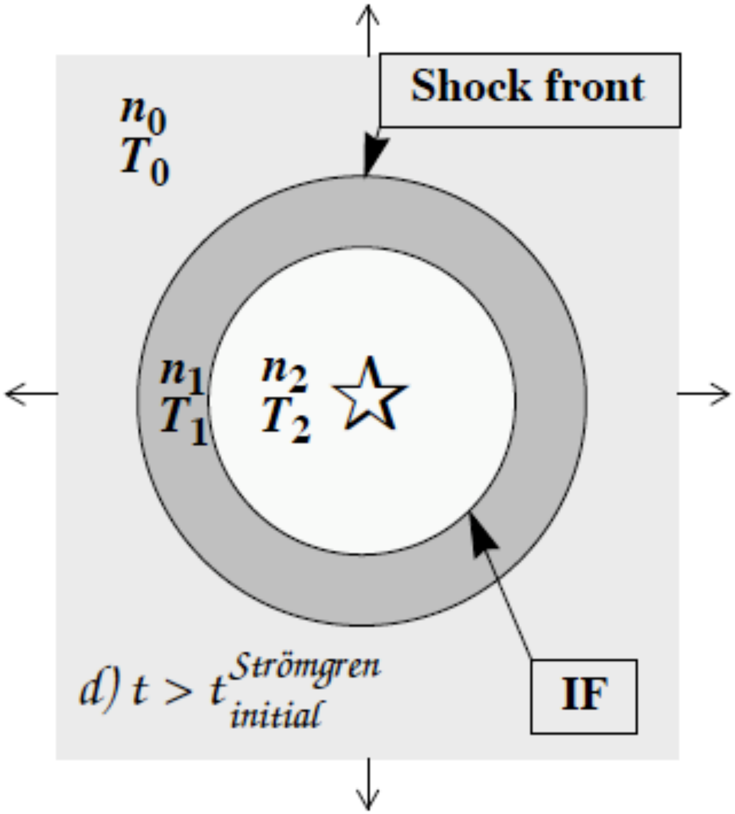
$$N_* = \frac{4}{3}\pi R^3 n_0^2 \alpha \qquad R_{\text{initial}}^{\text{Strömgren}} = \left(\frac{3N_*}{4\pi n_0^2 \alpha}\right)^{\frac{1}{3}} \approx 5.6 \text{ pc}$$

iv. Stage B: The Expansion Phase



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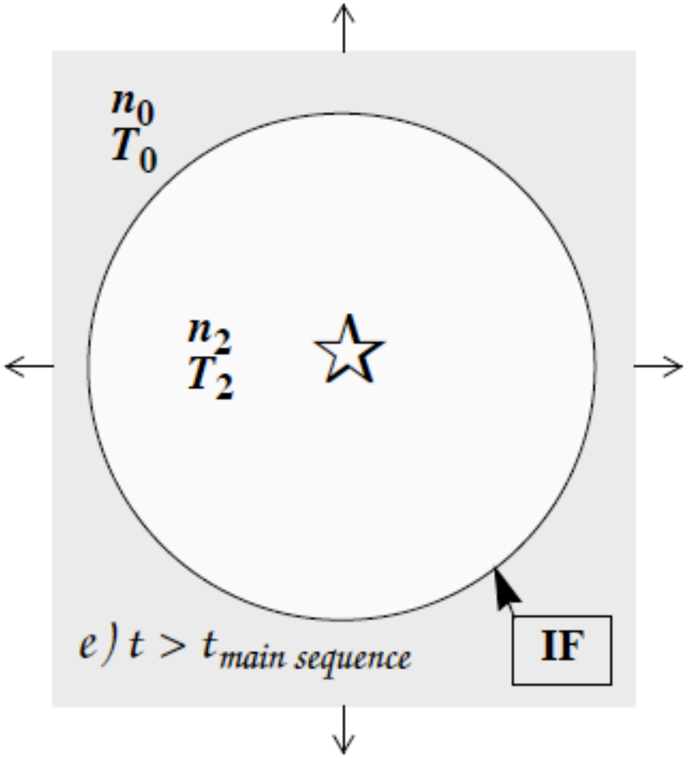

n	T
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n_1>>n_0 at first but converges towards n_0 with time	T_1=T_0
n_2=n_0 at first but converges towards n_{final} <<n_0 with time	T_2=10^4 K

$$2n_{\rm final}T_2 = n_0T_0 \quad R_{\rm final}^{\rm Strömgren} = \left(\frac{3N_*}{4\pi n_{\rm final}^2\alpha}\right)^{\frac{1}{3}}$$

$$R_{\rm final}^{\rm Strömgren} \approx 200 \text{ pc}$$

Classification of Ionization Front

- IFs are classified into two groups: the velocity at which matter flows into the IF from the outside, relative to the motion of the IF itself

$$v_1 \geq v_R \quad \text{or} \quad v_1 \leq v_D$$
$$\text{"R-type"} \qquad \text{"D-type"}$$

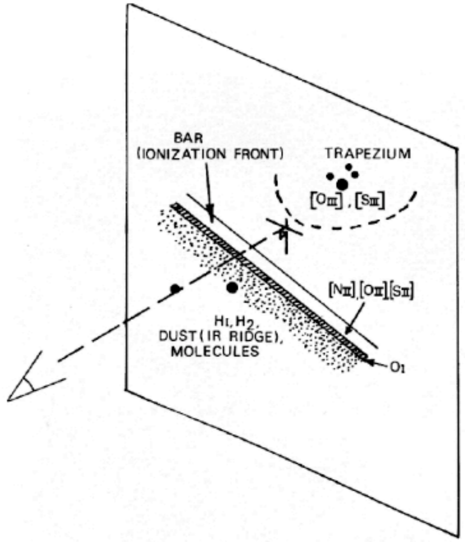
- Further classification: ratio of densities outside and inside the IF

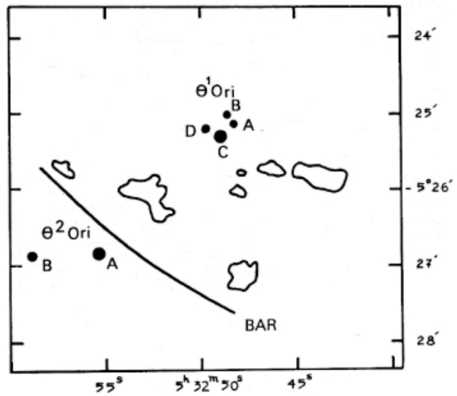
$$\rho_2 \text{ closer to } \rho_1 \text{ in allowed range} \Rightarrow \text{"Weak"}$$
$$\rho_2 \text{ further away from } \rho_1 \text{ in allowed range} \Rightarrow \text{"Strong"}$$

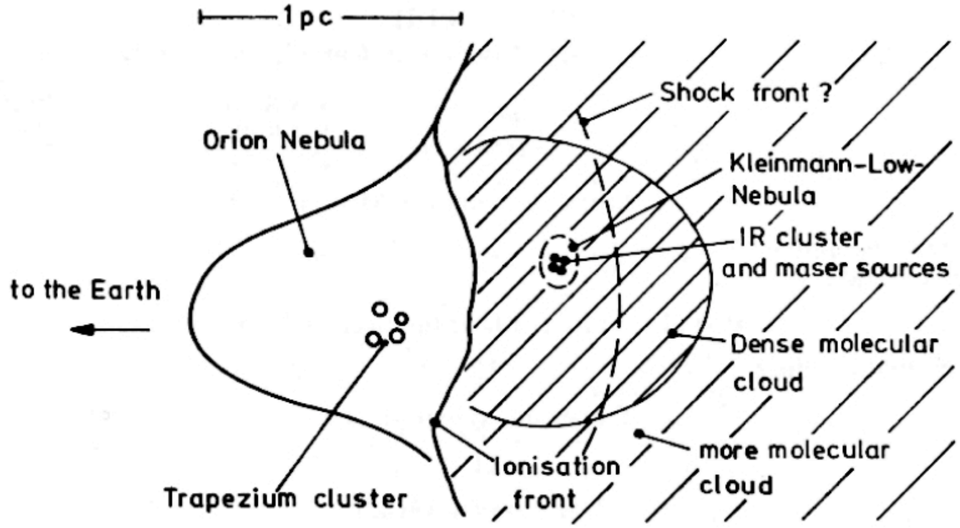
- The evolution of the IF model

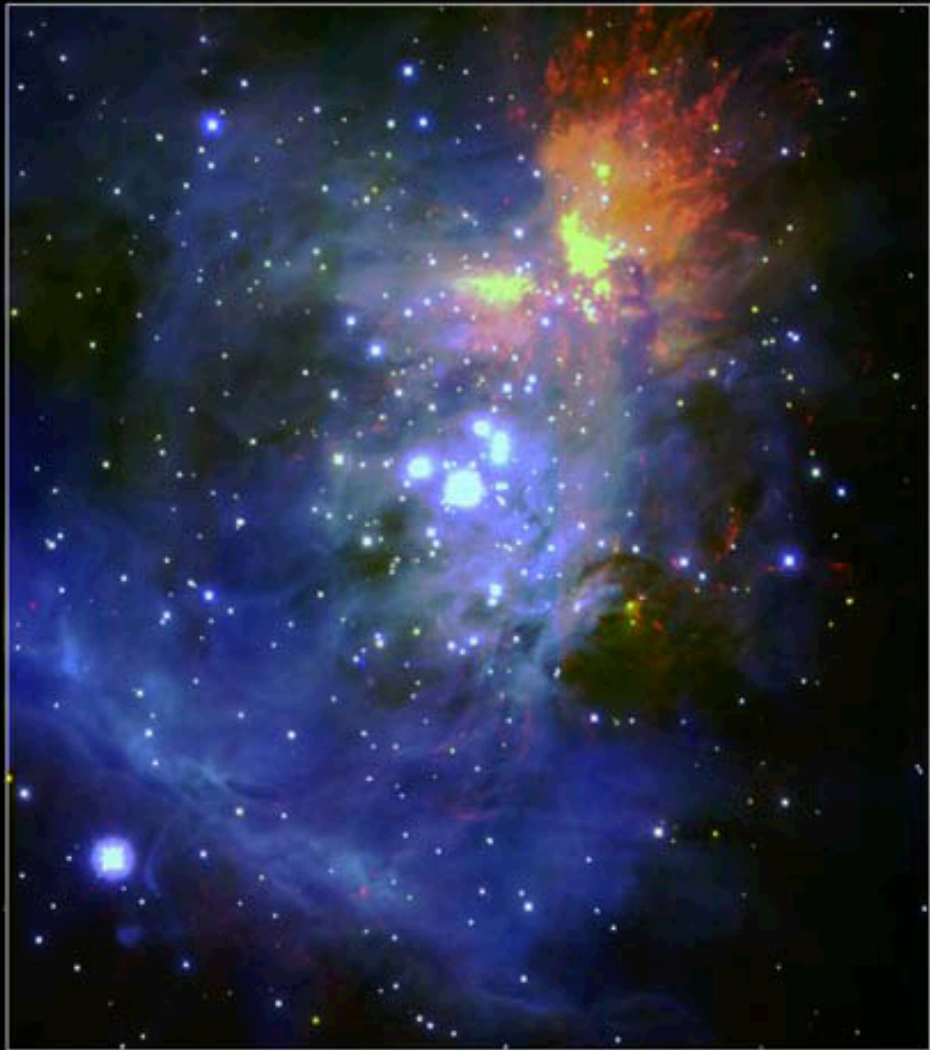
$$\text{Weak R-type} \longrightarrow \text{R-critical } (v_1 = v_R) \longrightarrow \text{D-critical } (v_1 = v_D) \longrightarrow \text{Weak D-type}$$

Orion Nebulae:







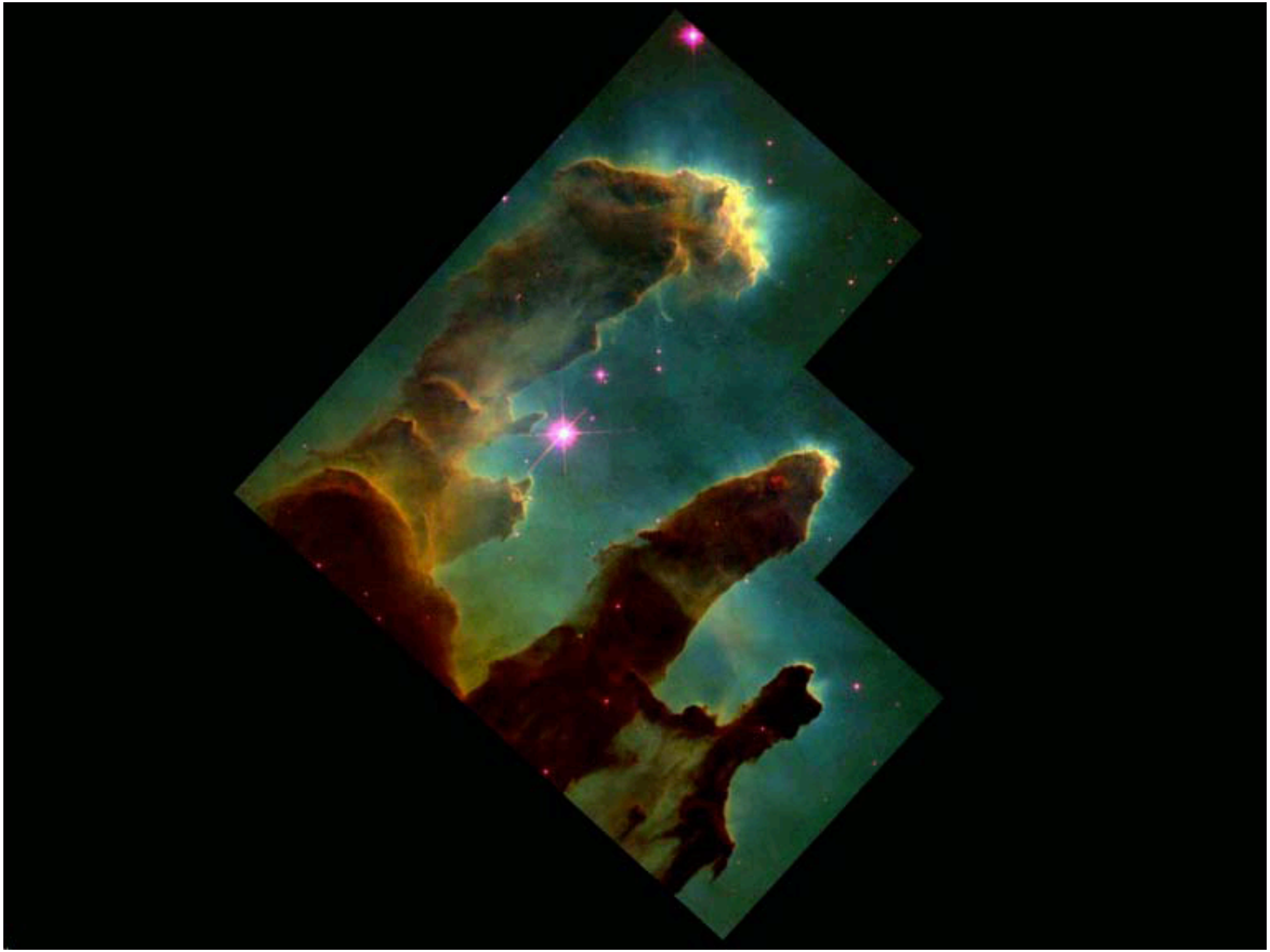


Orion Nebula

Subaru Telescope, National Astronomical Observatory of Japan

CISCO (J, K' & H_2 (v=1-0 S(1))

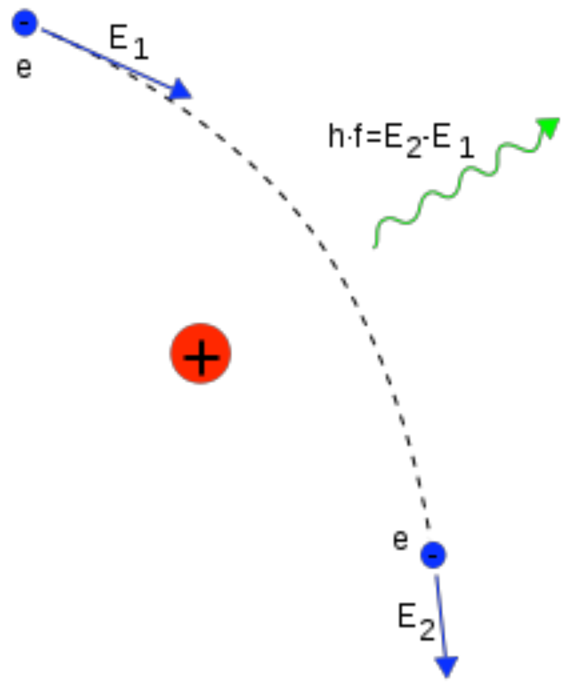
January 28, 1999



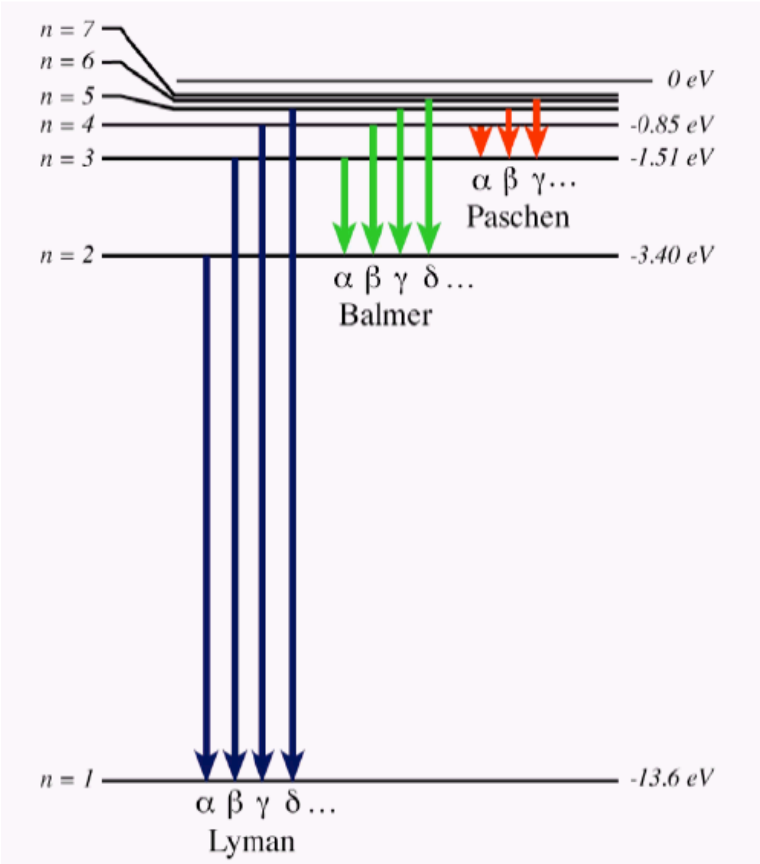
3. HII regions: Observables

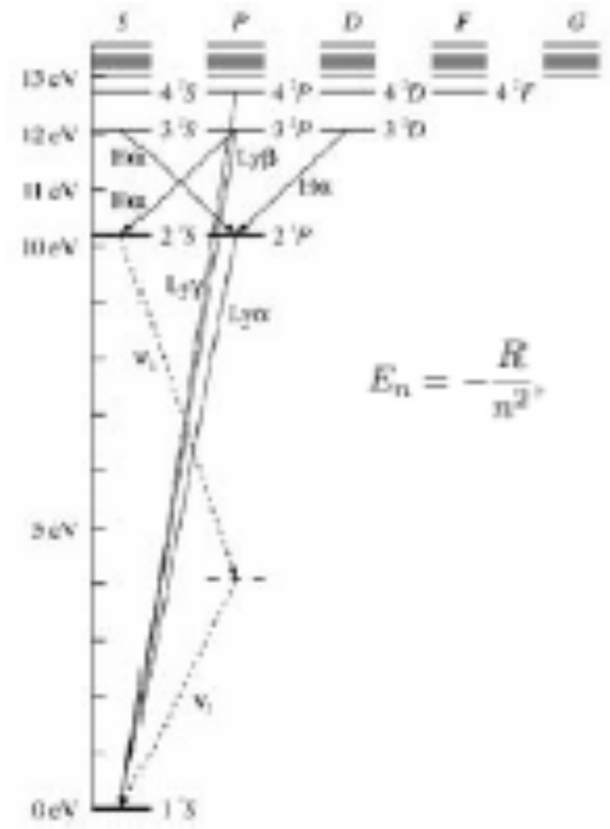
-Signpost of an HII region:

a) Bremsstrahlung or ‘free-free emission’



b) Recombination lines

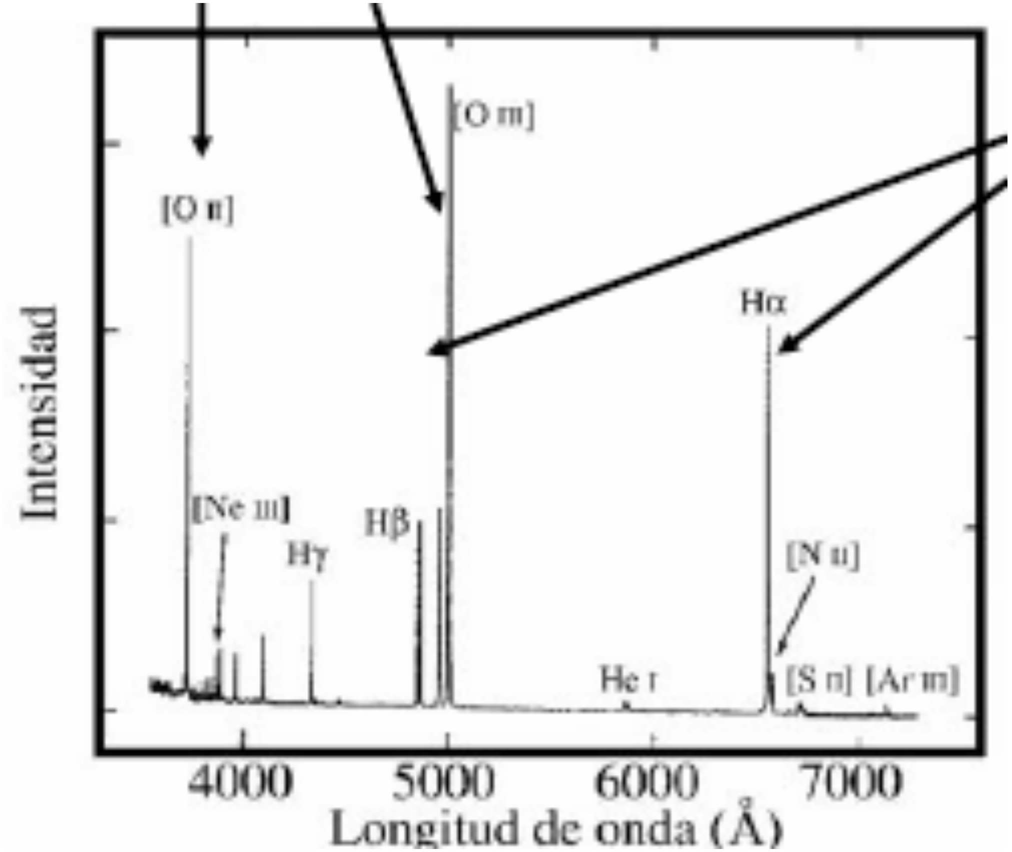




We can determine the ionization of the region with the balance between photo-ionization and recombination

c) Infrared (IR) emission is observed

d) Forbidden lines from singly or multiply ionized metal



4. HII regions: Classification

a) Giant HII regions: huge, irregularly shaped regions. 100-1000 pc

b) Hollow HII regions: somewhat more regularly shaped

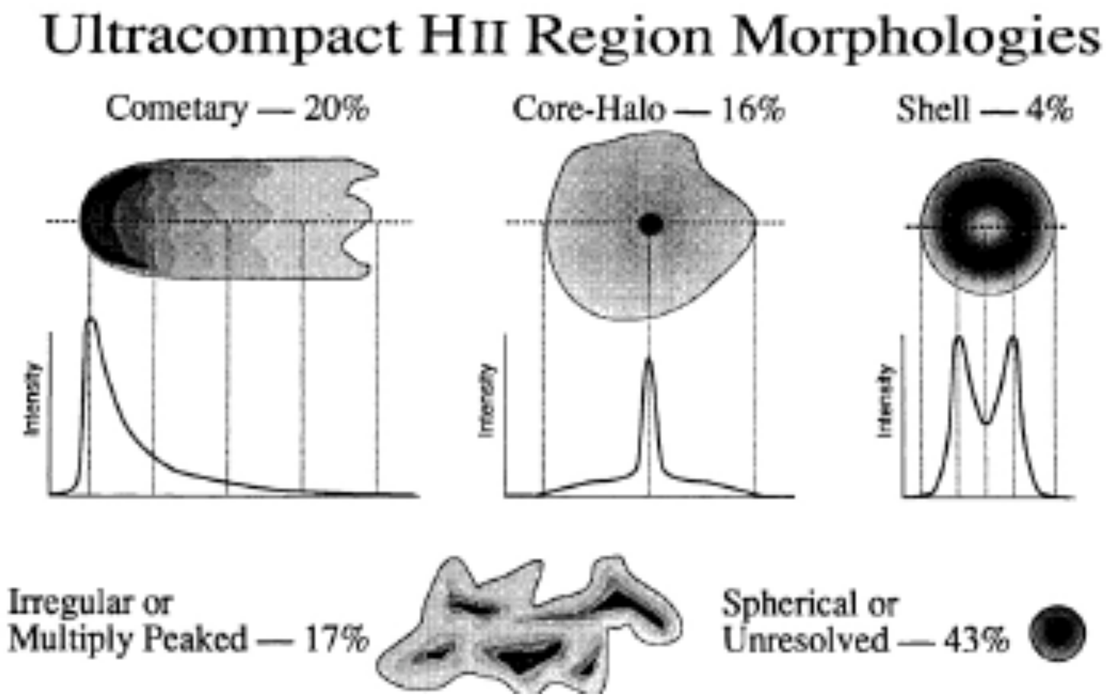
c) Extended HII regions: low density. Around 20 pc

d) ‘Normal’ HII regions

e) Evolved HII regions: few pc sized and regularle shaped

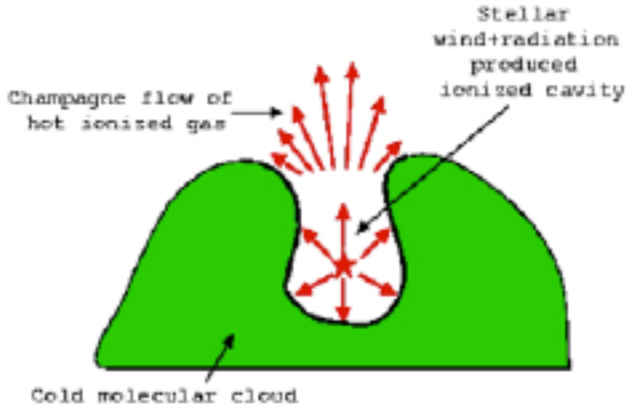
f) Compact HII regions (CHII): embedded in GMCs (Grand Molecular Clouds)

g) Ultracompact HII regions (UCHII)



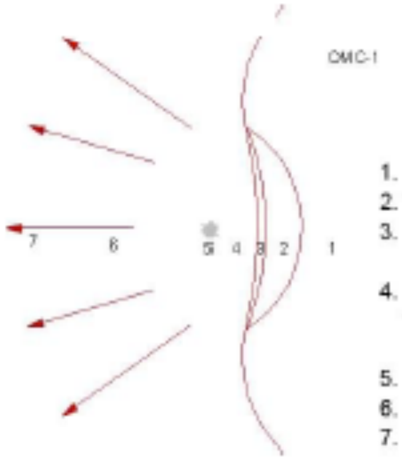
h) Diffuse HII regions: weak emitters

Others shapes of HII regions



Nebulosas gaseosas

HII 'blister' y 'champagne flow'



1. Cold dense molecular cloud.
2. Warm dense dust and gas.
3. Ionization front of dense ionized gas and hot dust.
4. Dense ionized gas and hot dust flow from ionization front into blister cavity.
5. Exciting star.
6. Moderately dense ionized gas.
7. Low density ionized gas.

Observations and theory, problems that we have:

1- An easy way out would be to assign all the categories in different evolutionary stages.

2- It is set the density to a value of the diffuse gas.

3- Further complications in GMCs is molecular in its constitution.

There are things left out:

1- The role of HII regions in the recycling process of matter in the galaxy

2- Other topics like metallicity, dust and heating, magnetic fields...

5. Photo-Dissociation Regions

Definition: region where the chemistry or thermal balance is no longer heavily affected by penetrating energetic photons.

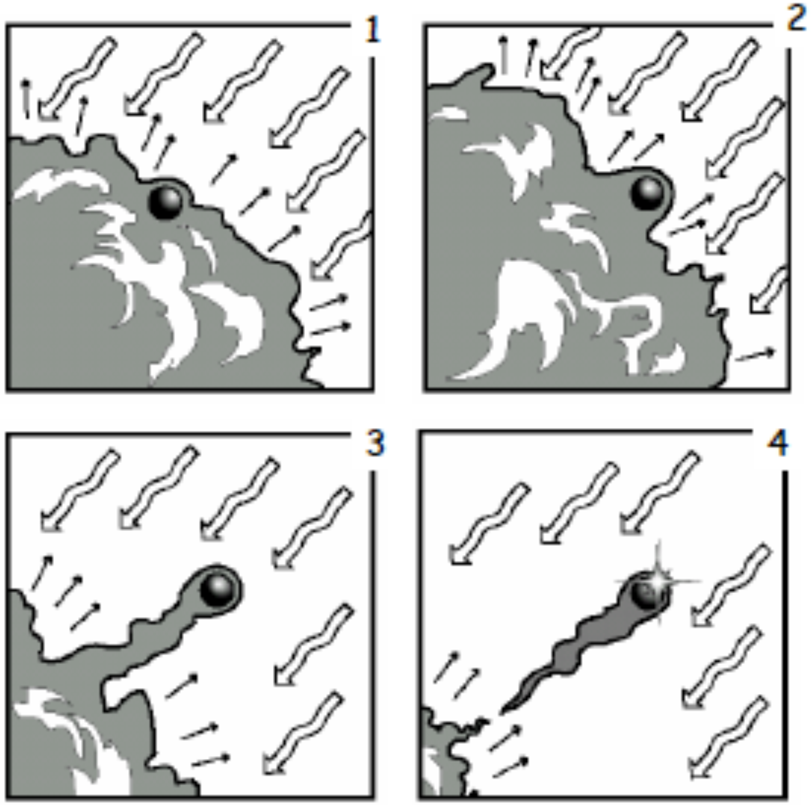
- It is a transition zone separating hydrogen atoms from hydrogen molecules.

The PDRs model:

- A far ultraviolet (FUV) field is injected into a semi-infinite molecular cloud through a planar interface.

- It is considered that an isothermal shock has passed through the material.

- We can observe filaments favoured by PDR processes.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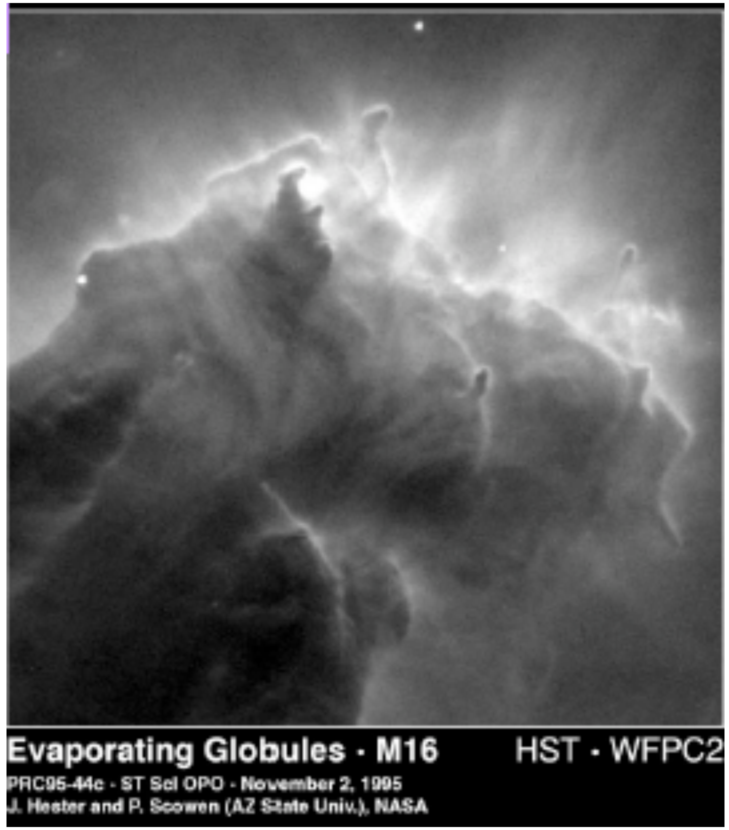
Evaporating Globules · M16
HST · WFPC2
PRC95-44c · ST ScI OPO · November 2, 1995
J. Hester and P. Scowen (AZ State Univ.), NASA