Galactic star formation triggered by HII regions

A WIRCAM dedicated study

Star formation triggered by HII regions

- Some statistics
- Mechanisms triggering star formation at the periphery of HII regions

A WIRCAM dedicated study

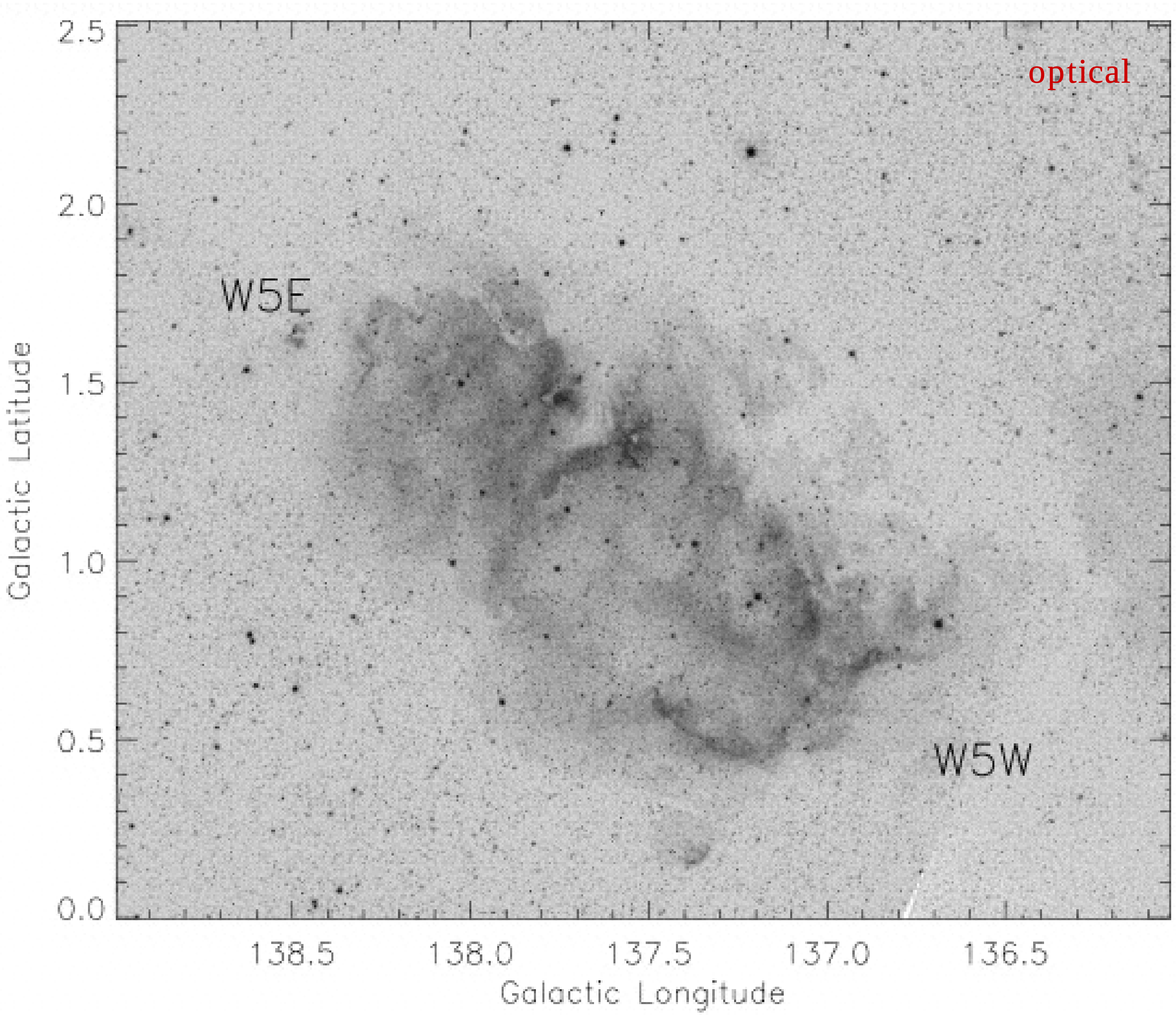
- Scientific goals
- Why WIRCAM?
- The sample
- The observations
- Time estimate

Star formation triggered by HII regions

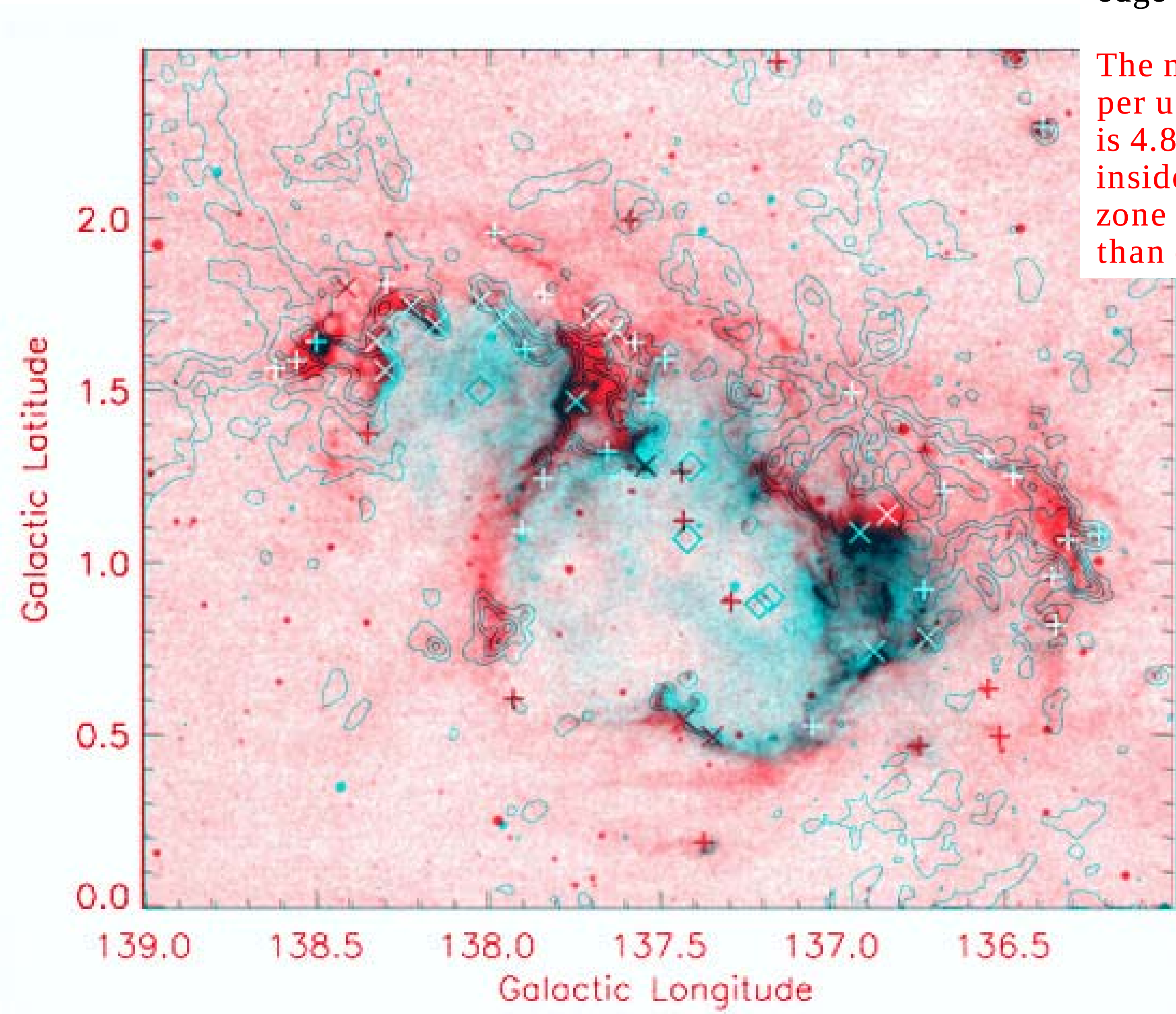
Some statistics

Karr & Martin, 2003, ApJ 595, 900

The HII region W5 (IC1848) D=2 kpc, W5E: O7, W5W: 4 OB



Integrated ^{13}CO emission (contours)
Radio continuum emission at 21 cm
MSX 8.3 μm emission



Most of the YSO- selected IRAS sources lie at the edge of the ionized gas

The number of sources per unit CO area is 4.8 times higher inside the influence zone of the HII region than outside

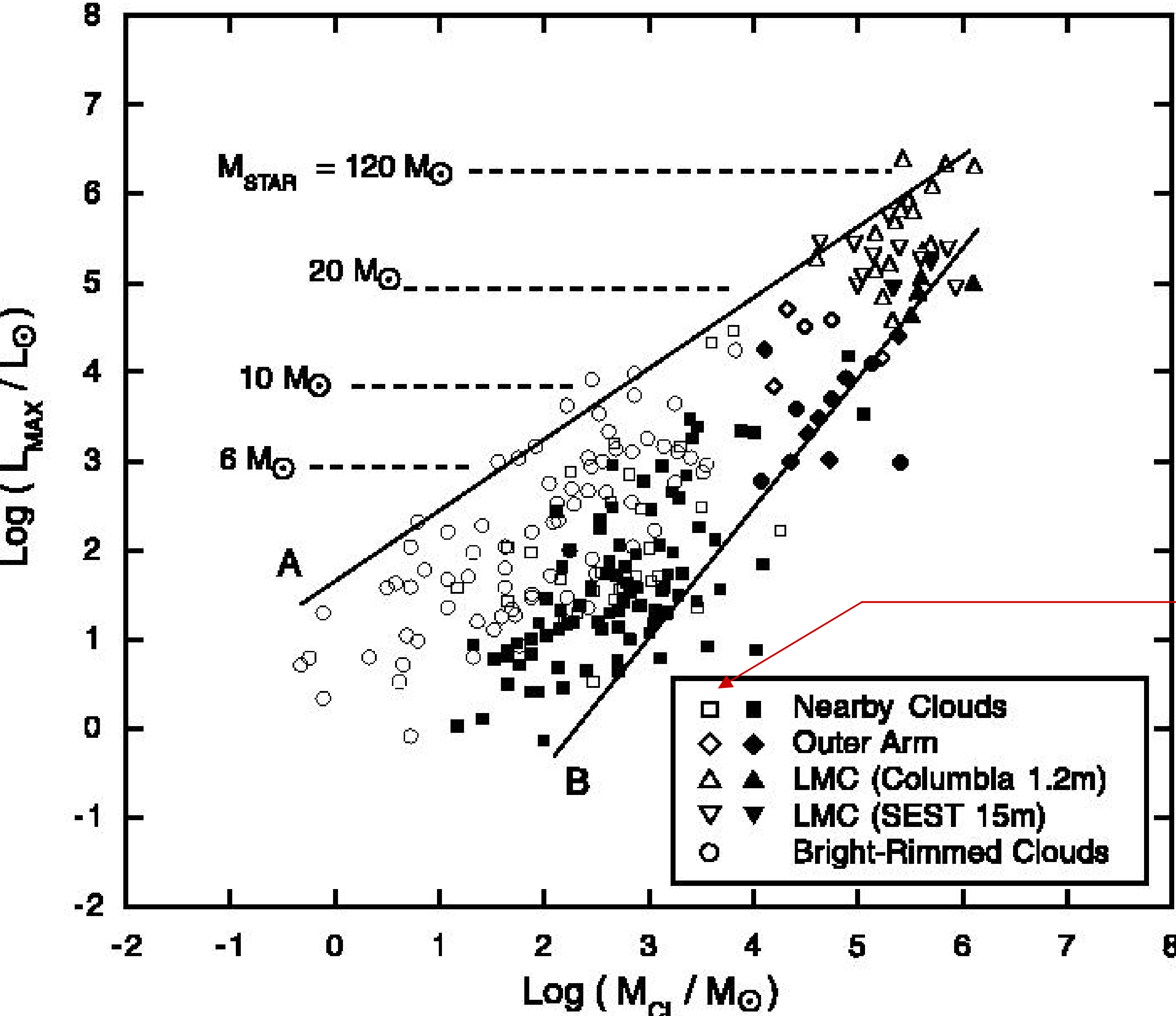
Dobashi et al. 2001, PASJ 53, 85

499 molecular clouds from the literature

253 associated with protostellar candidates

^{13}CO --> Mass IRAS --> Luminosity

Protostars in clouds associated with HII regions are more luminous than those in clouds away from HII regions



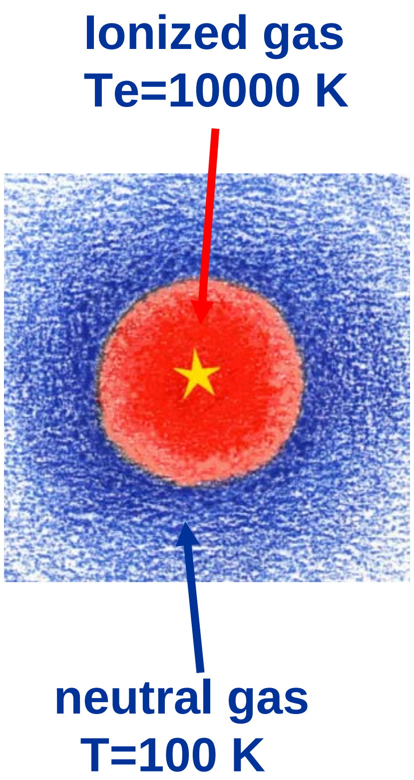
Clouds associated with HII regions

Star formation triggered by HII regions

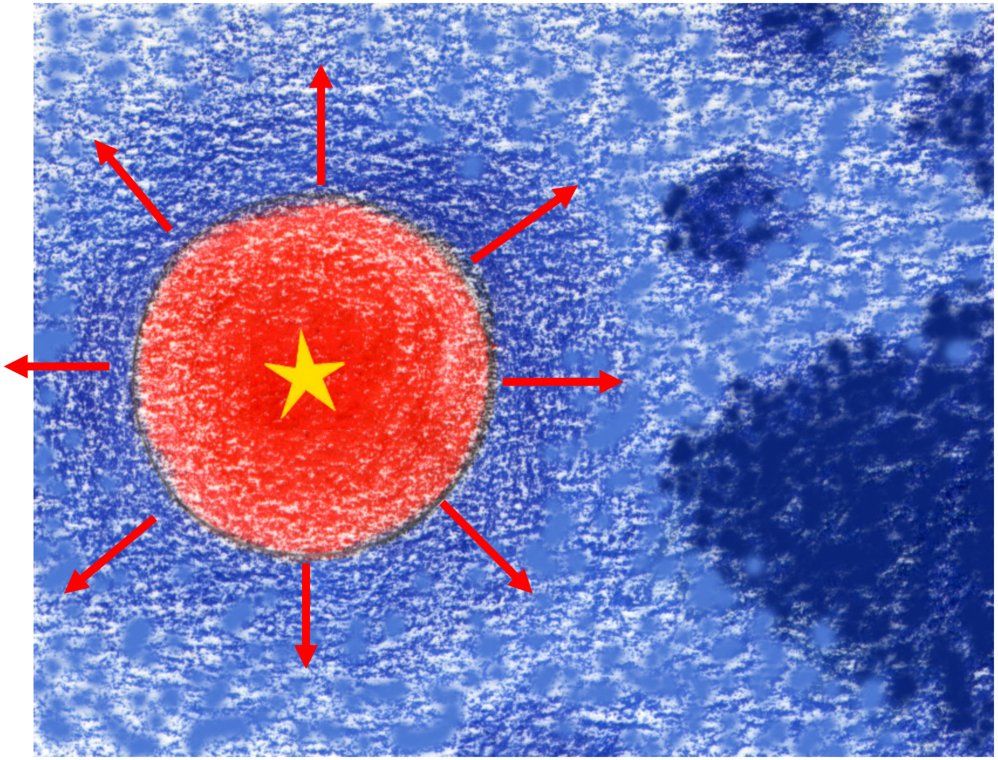
Mechanisms triggering star formation at the periphery of HII regions

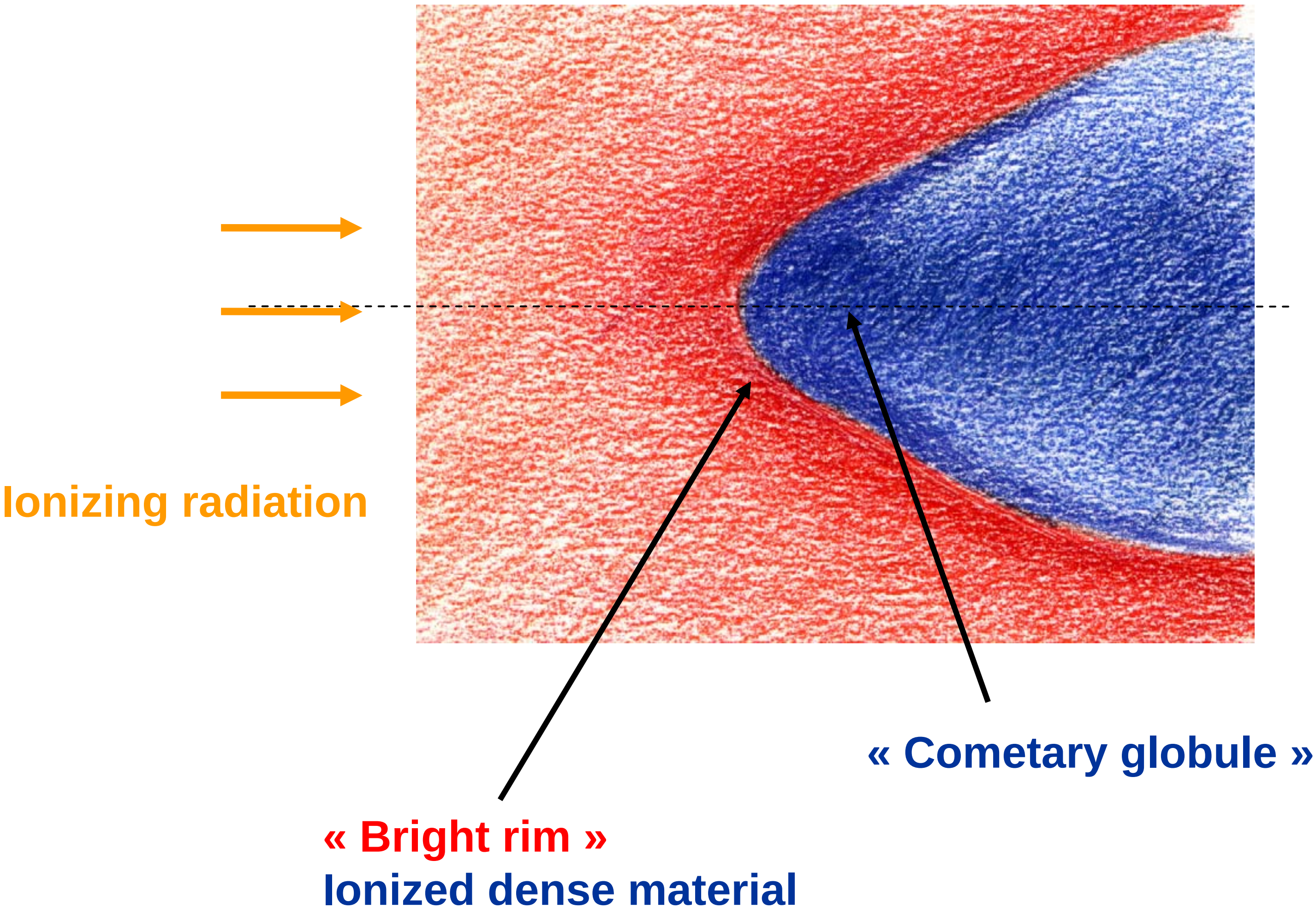
Mechanism 1: Radiation driven implosion
Bright rims and cometary globules

HII regions expand

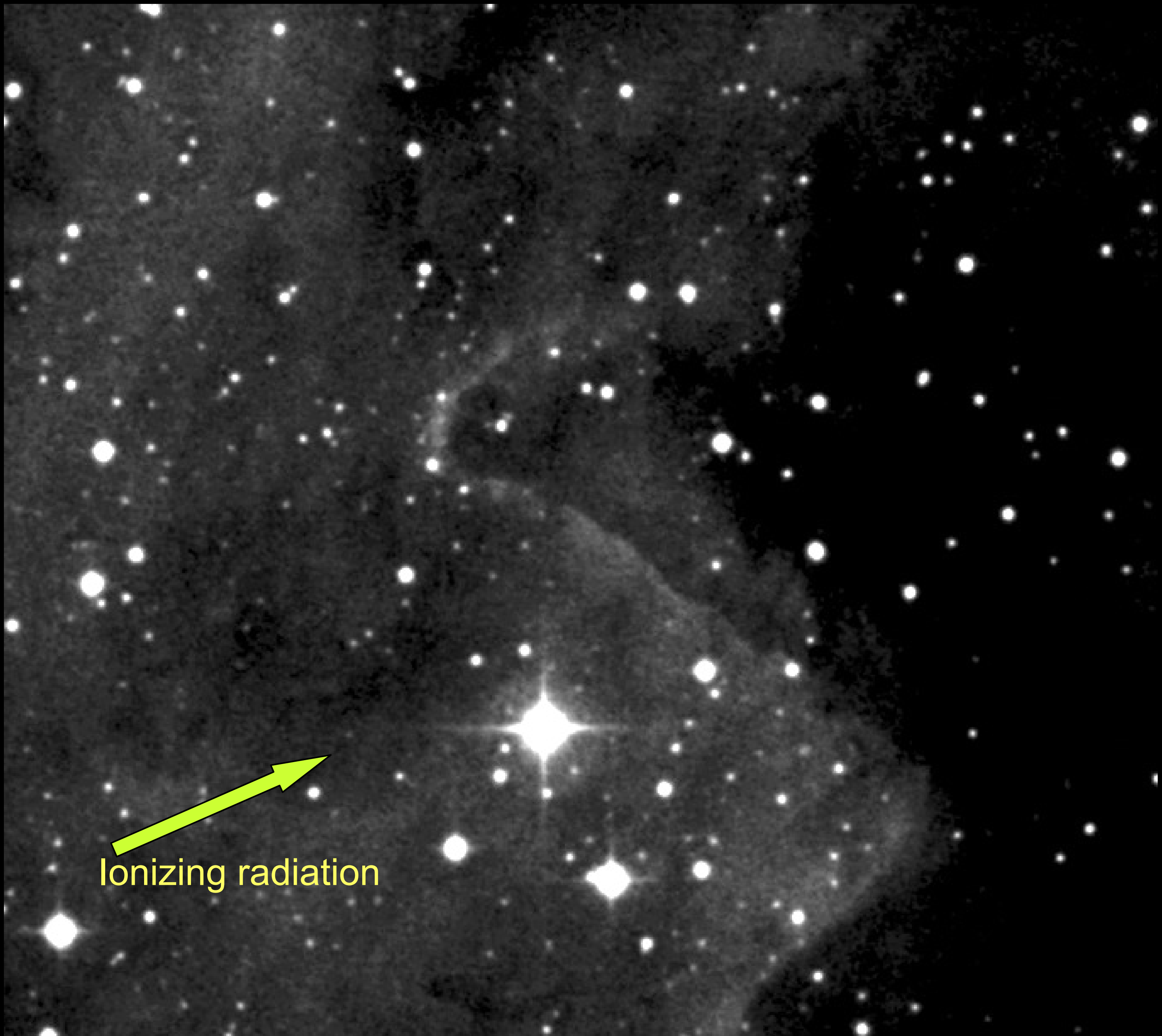


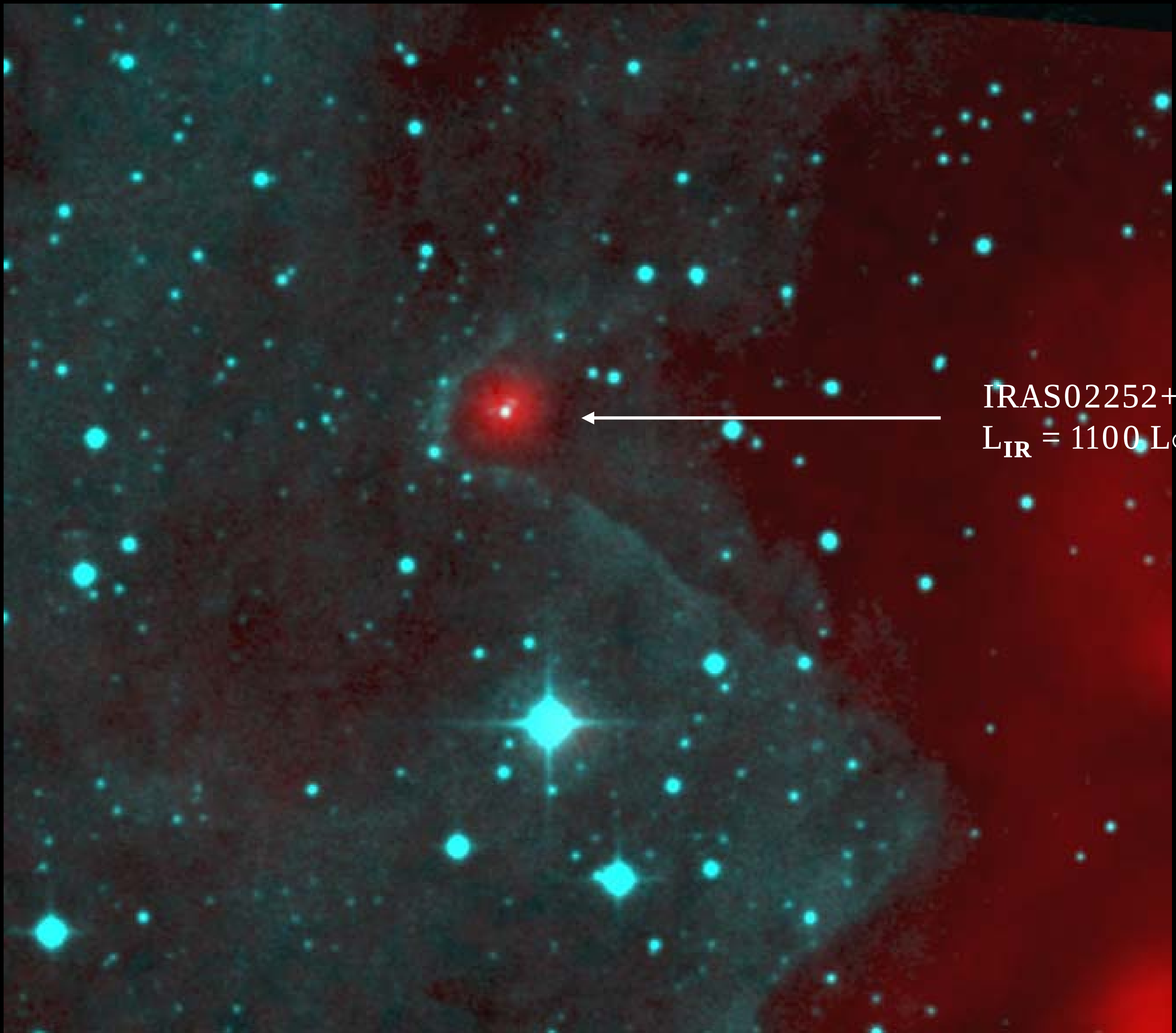
They may expand into an inhomogeneous medium containing pre-existing dense molecular clumps



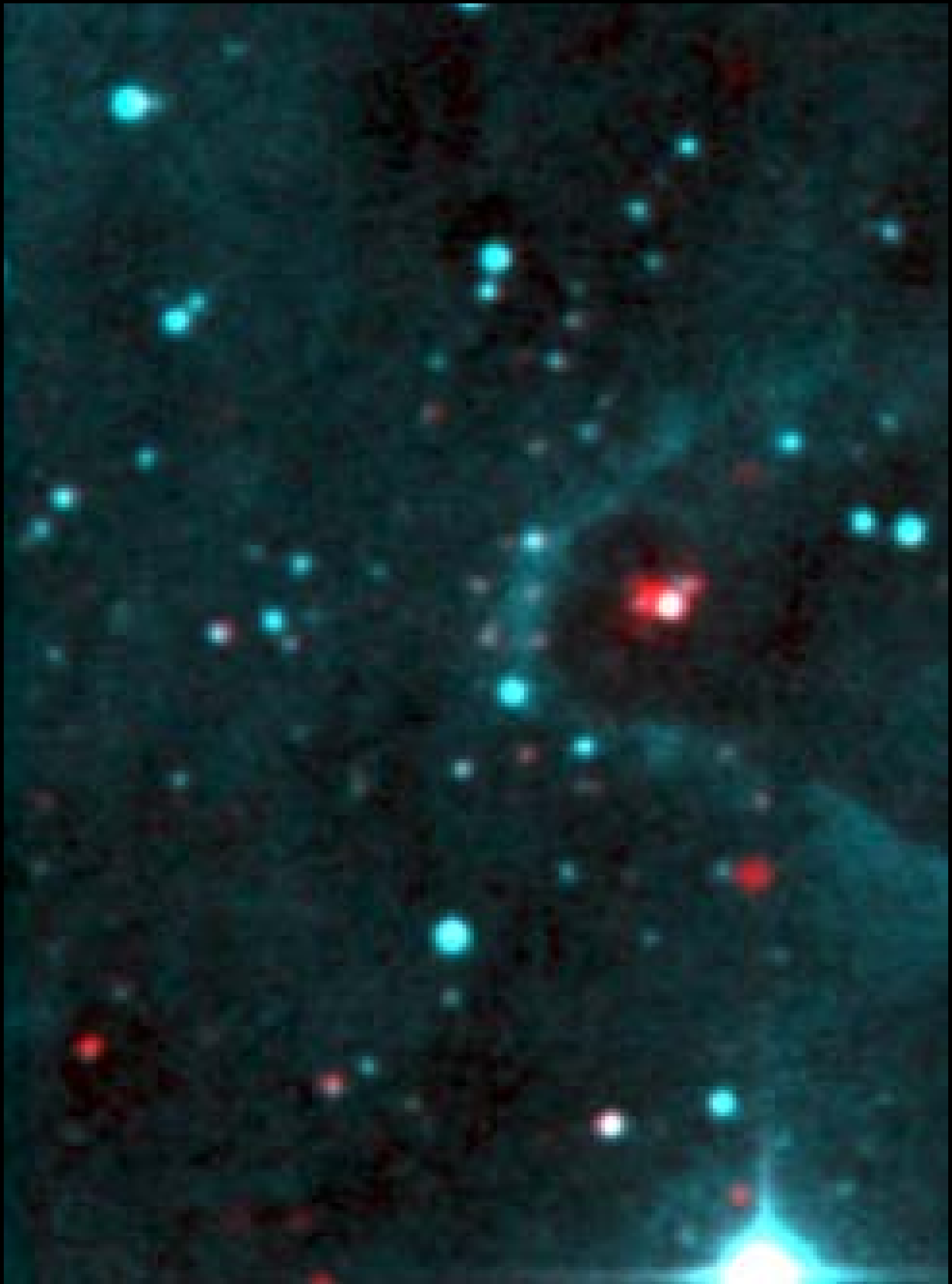

Ionizing radiation
« Cometary globule »
« Bright rim »
Ionized dense material

CG5 in IC1848 *Lefloch et al., 1997* D = 1.9 kpc



DSS2-red ionized gas
MSX 8.3 μm dust emission

IRAS02252+6120
L_IR = 1100 L⊙

DSS2-red ionized gas 2MASS K frame



Molecular clump:

from ^{13}CO $n(H_2) = 3.9\ 10^4\ cm^{-3}$

$M = 135\ Mo$

from CS $n(H_2)$ up to $1.5\ 10^6\ cm^{-3}$

$L_{IR} / M(^{13}CO) = 1100/135$

$= 8.2\ Lo/Mo$

CO outflow

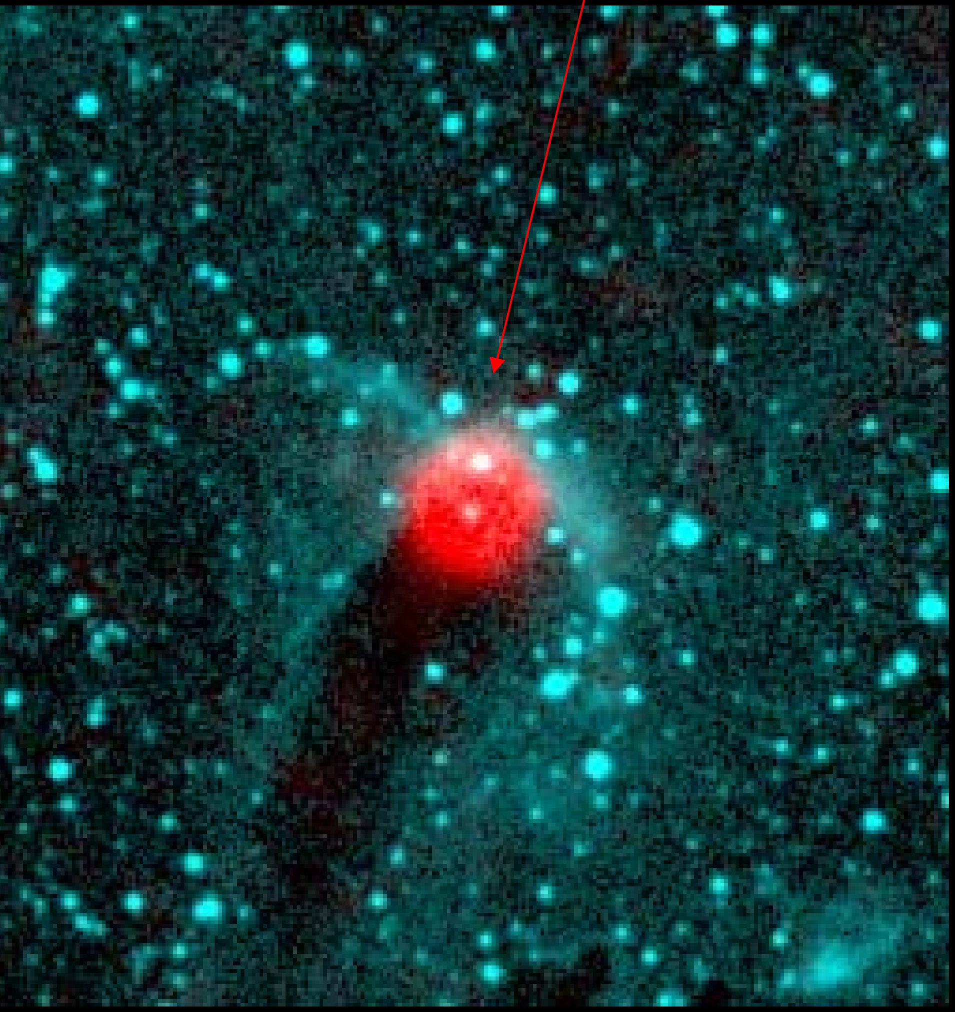
dynamical age of about $1.5\ 10^4$ yrs

SFO37 in IC1396

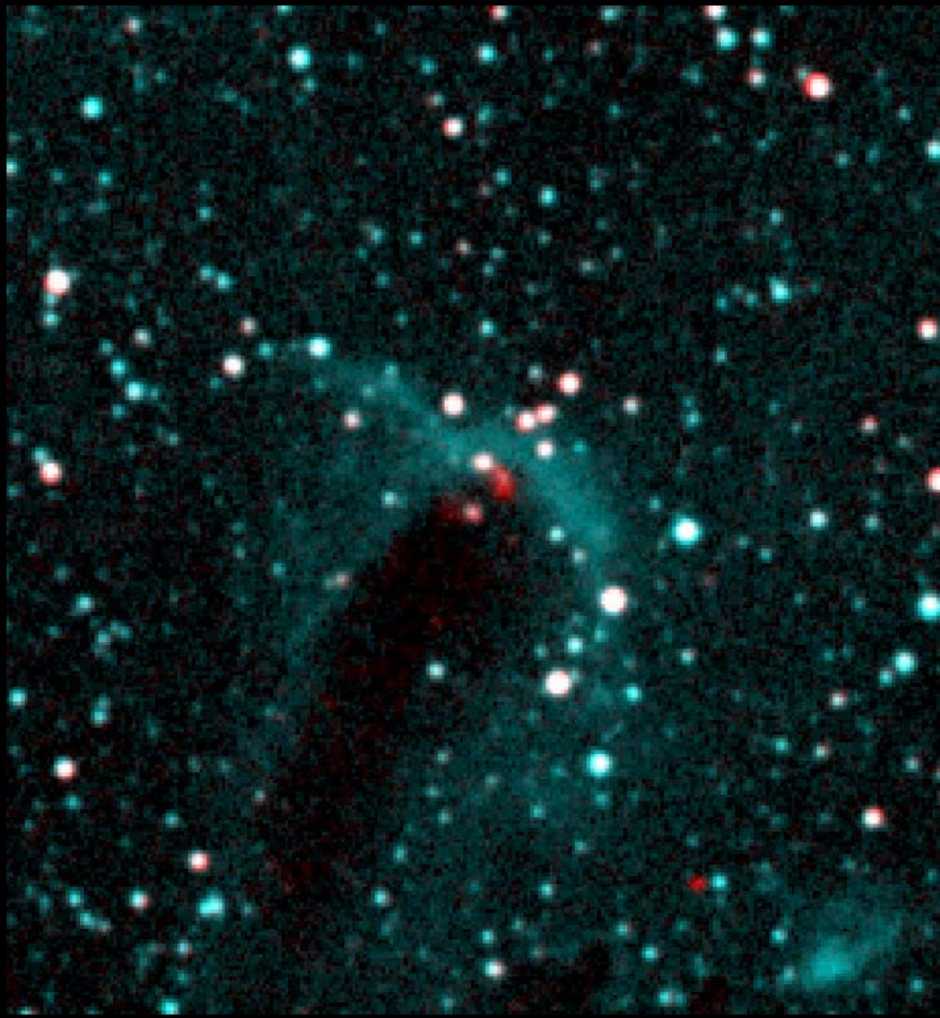
Duvert et al, A&A 233, 190 *Sugitani et al., ApJ 486, L141*

D=750 pc, IRAS21389+5622 L_{IR} = 110 Lo, molecular clump M = 18 Mo, CO outflow $3\ 10^{5}$ yrs

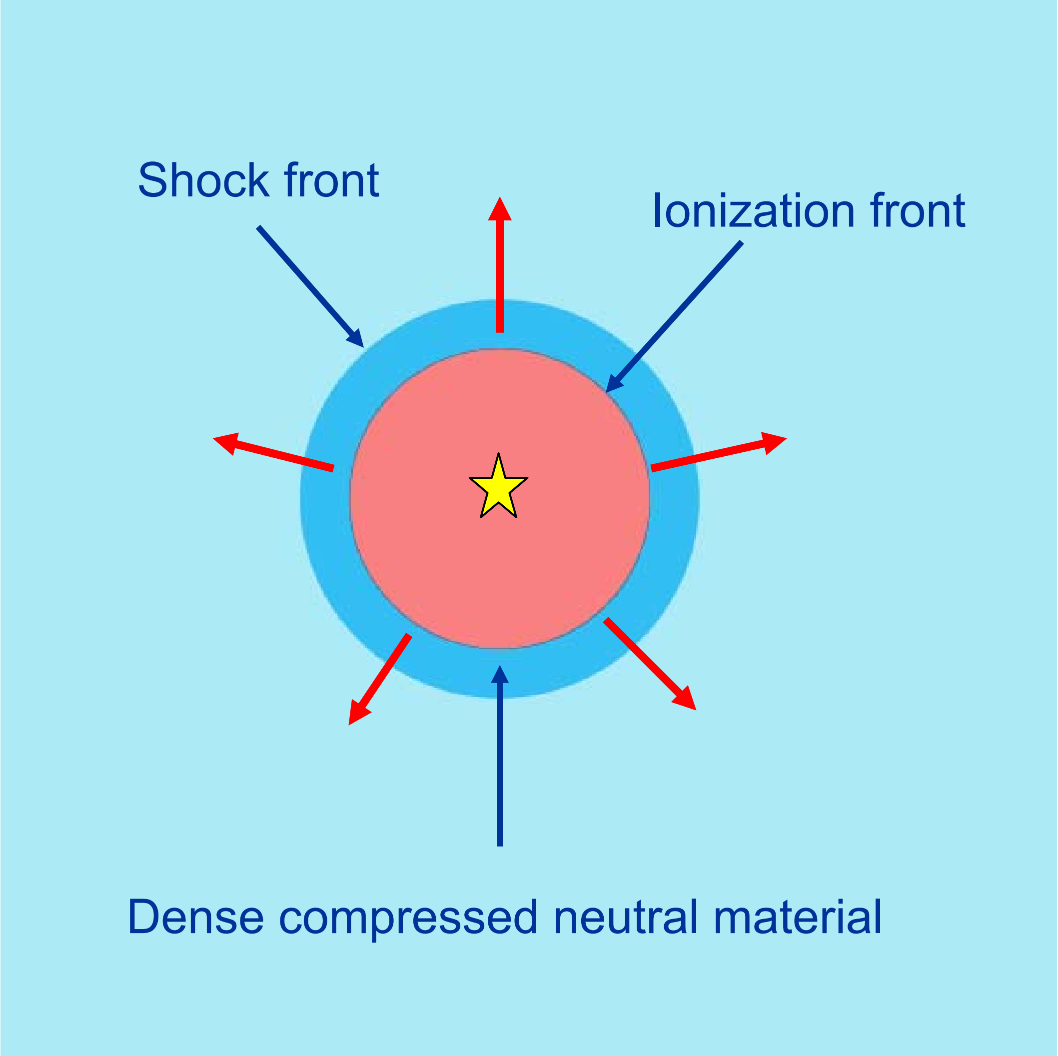
DSS2-red MSX / 8.3 µm



DSS2-red 2MASS K frame



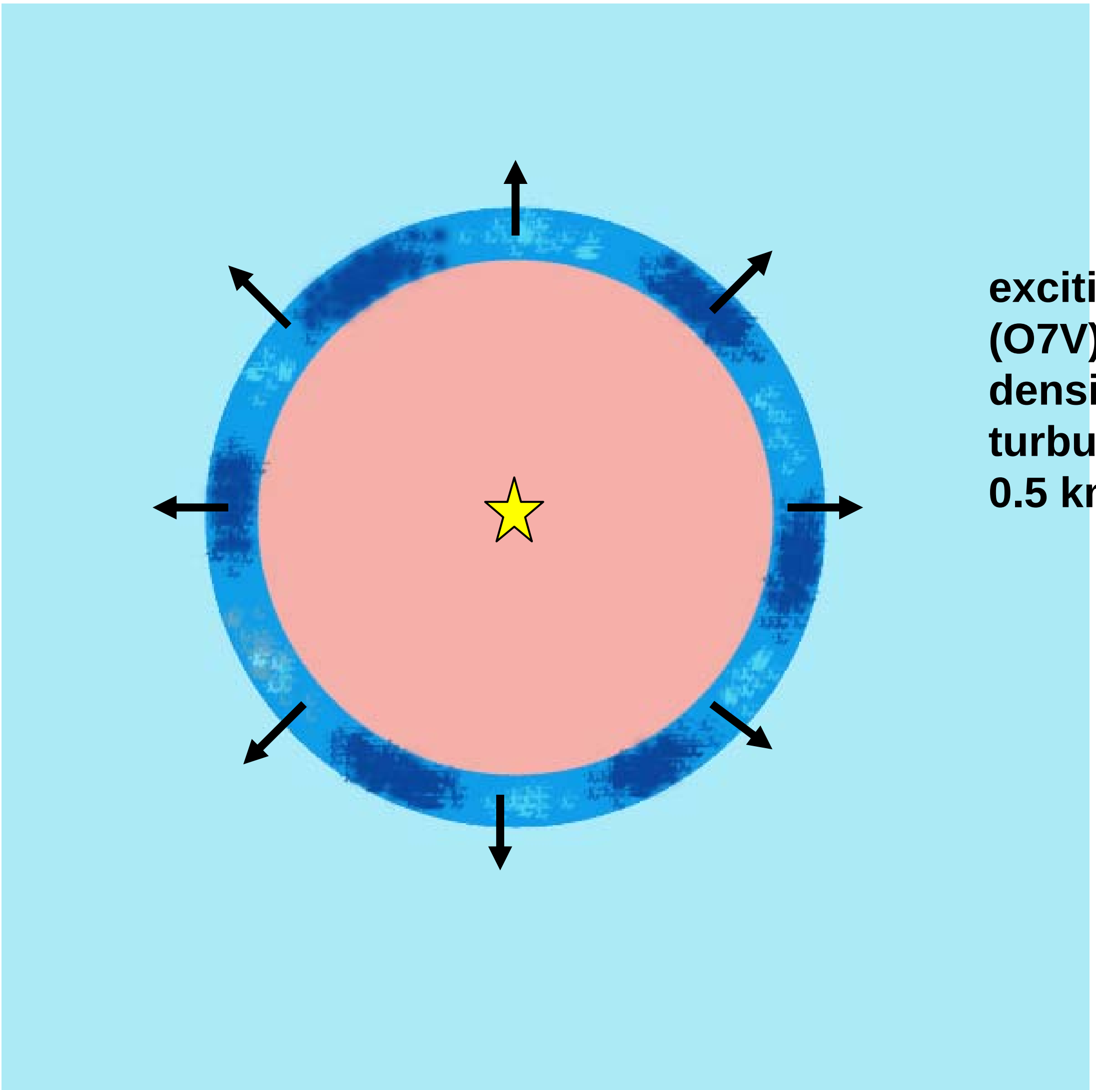
Mechanism 2: the "collect and collapse" process" *Elmegreen & Lada (1977)*



A layer of dense shocked neutral material forms between the ionization front and the shock front.

It should be observed as
- a ring of molecular emission
- a ring of dust emission

Gravitational instabilities can develop along the length of the layer, **on a long timescale**



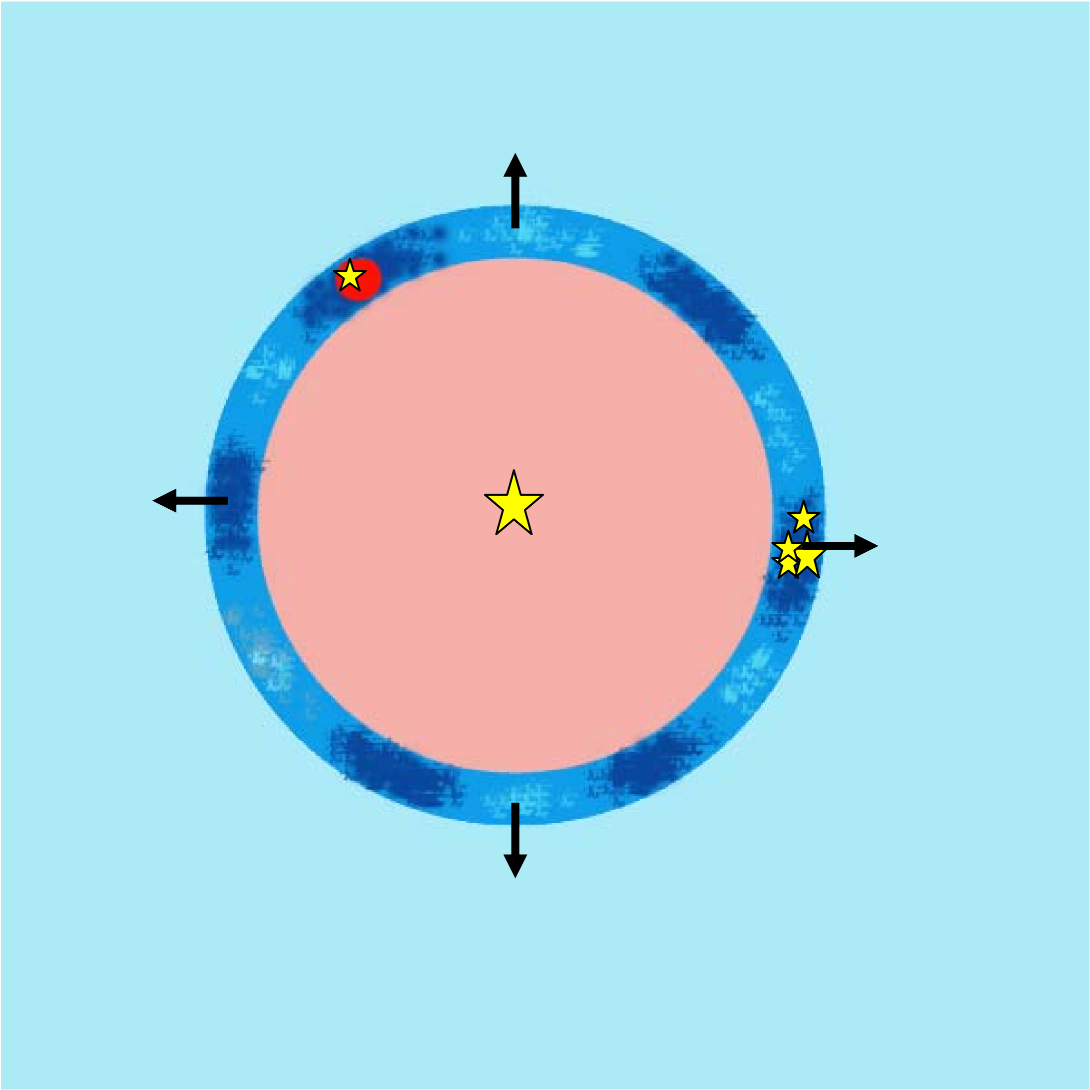
Observations / predictions:

Whitworth et al. (1994)

exciting star: 10^{49} ionizing photons s^{-1} (O7V)
density: 10^3 cm^{-3}
turbulence velocity in the layer: 0.5 km s^{-1}

fragmentation after 2.8 Myrs then:

- **HII region diametre=16 pc**
- **7 fragments of 600 M_{sun}, separated by 3.7 pc $N(H_2)$=8 10^{21} cm^{-2}**



Observations / predictions:

Formation of massive objects, stars or clusters

A second-generation cluster is observed in the direction of the layer

Possibly, a UC HII region is observed in the direction of the layer

Sh 104

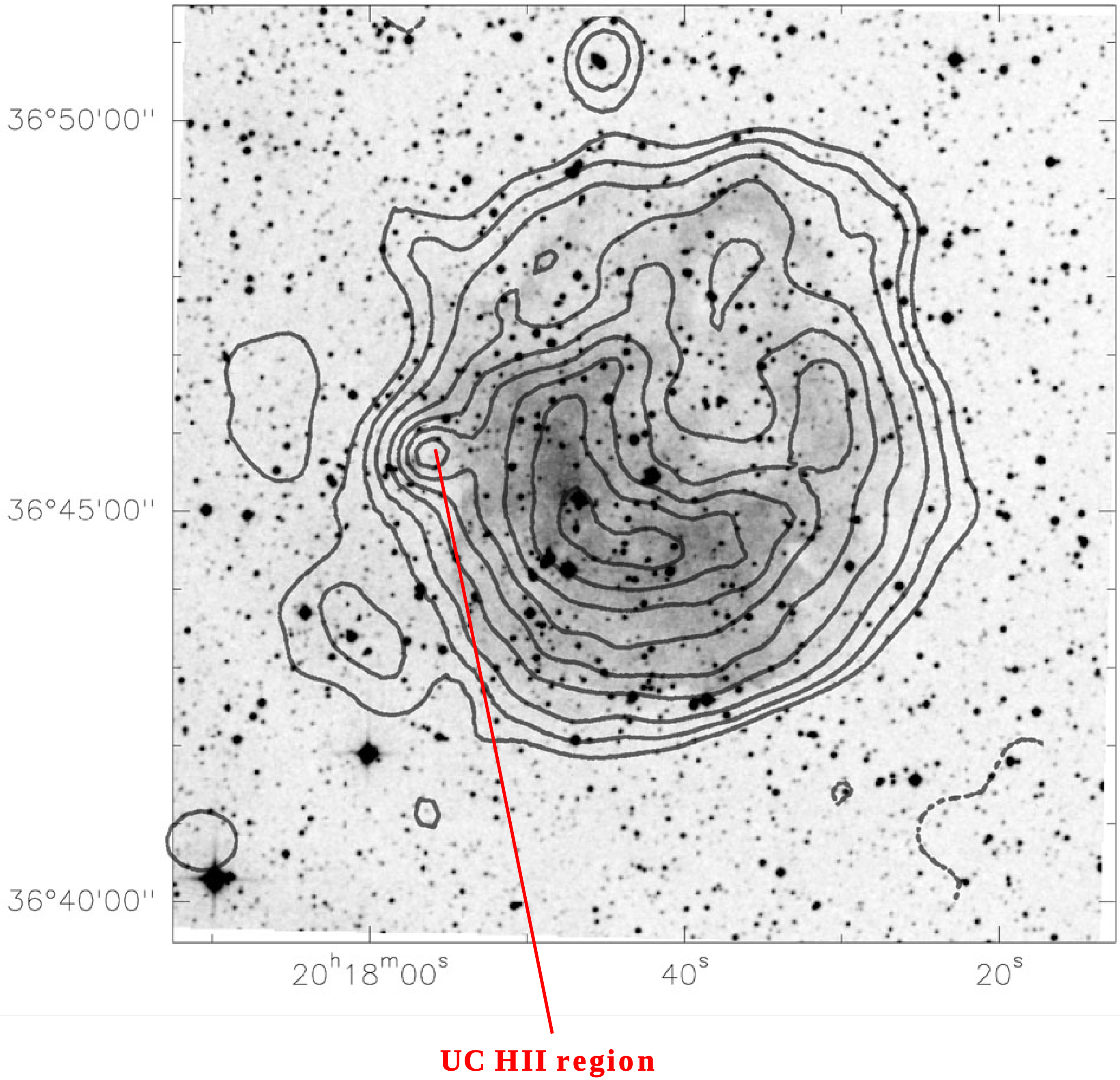
D=4 kpc
O6V
diameter=8 pc

Hα
[SII]

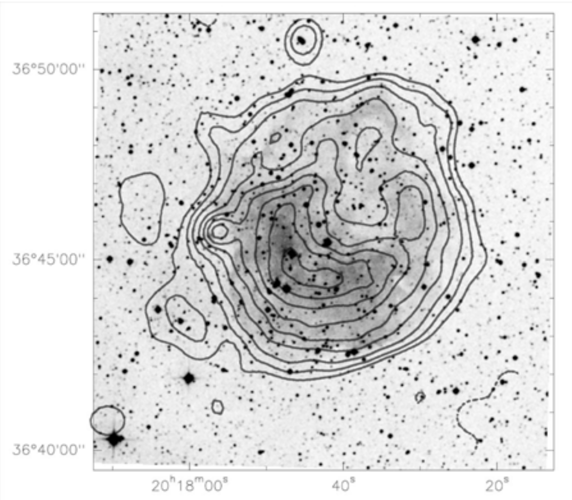
Deharveng et al. 2003

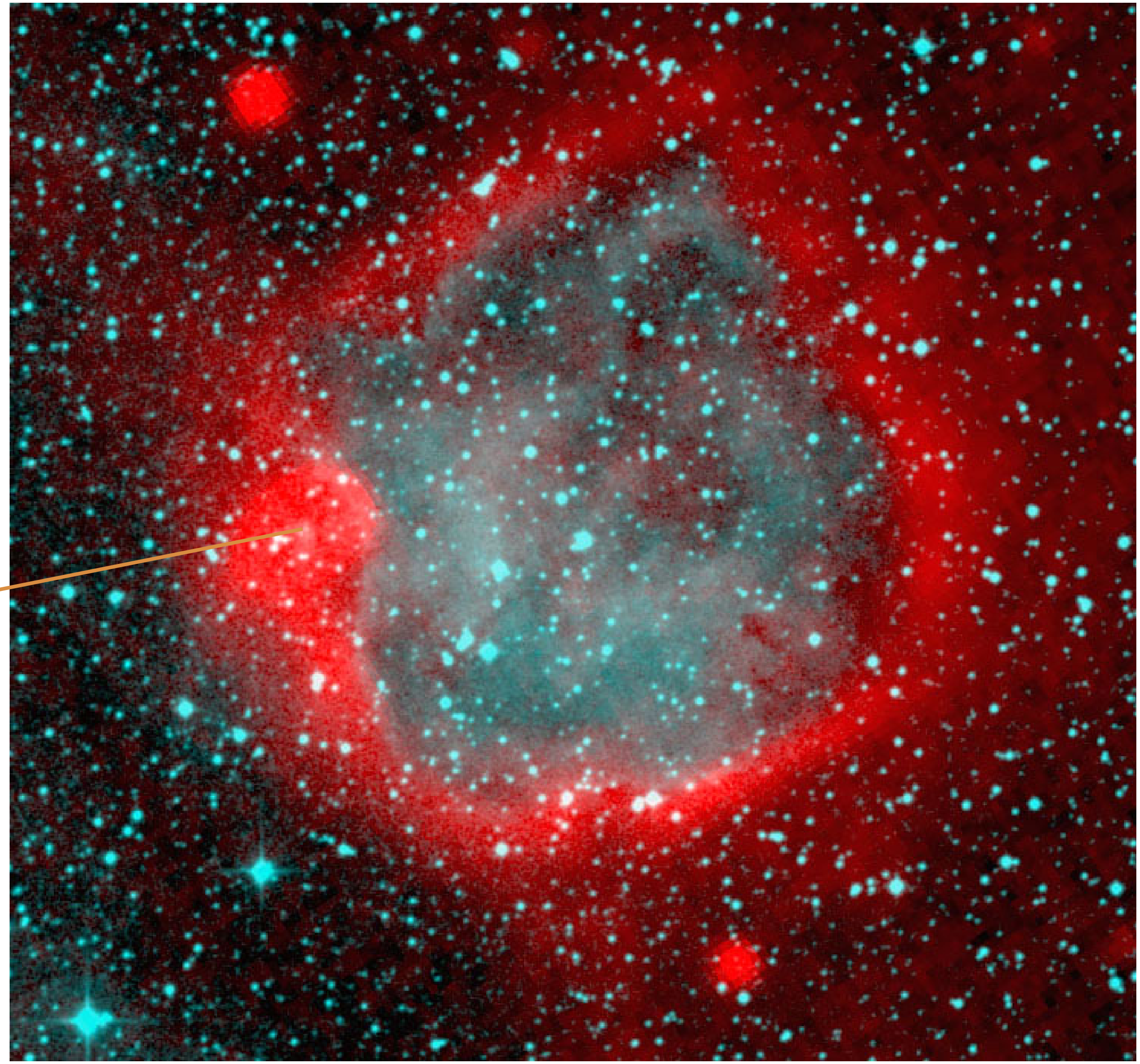
Sh 104

Radio continuum at 21 cm



MSX Survey, dust emission at 8.3 μm



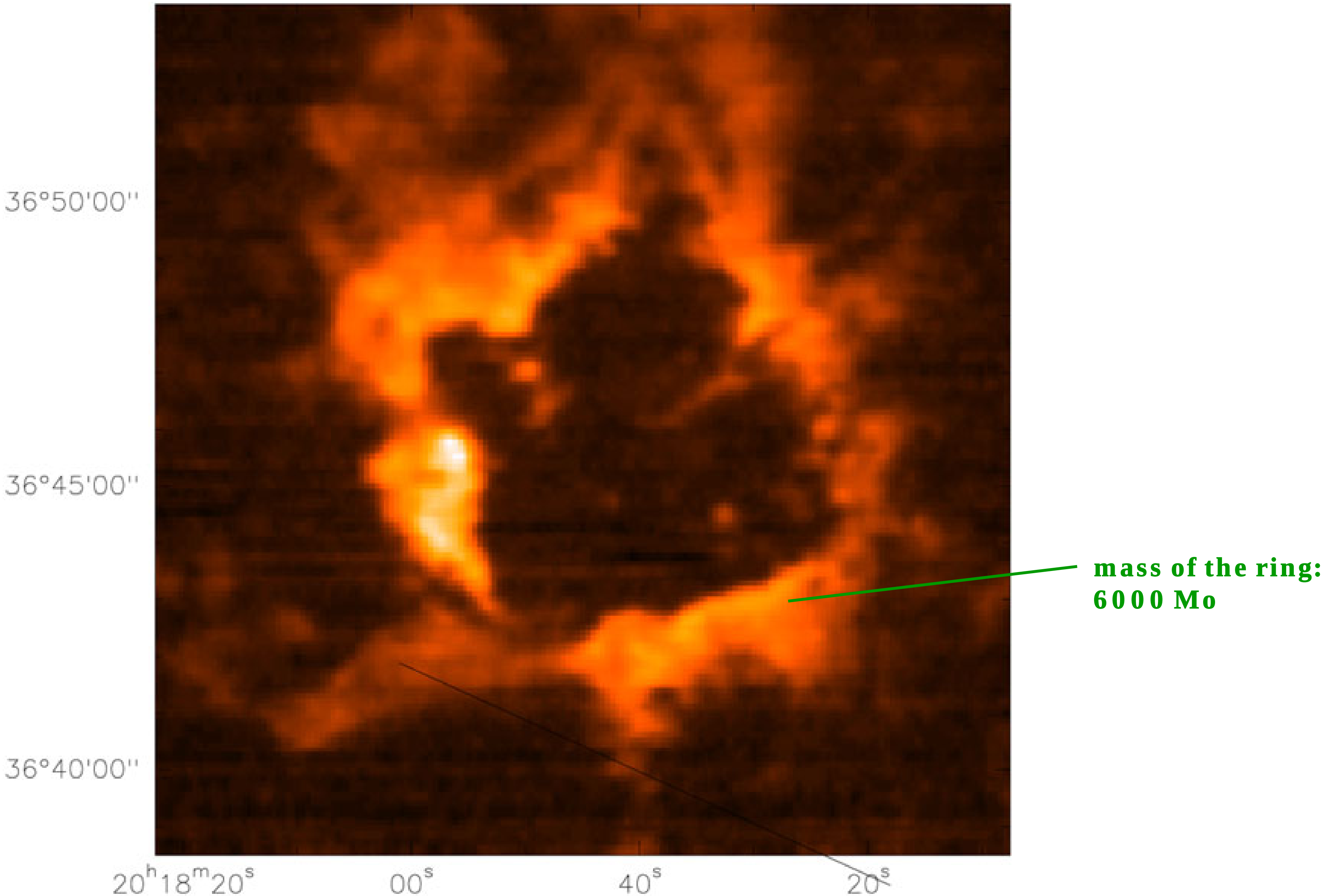


MSX point source

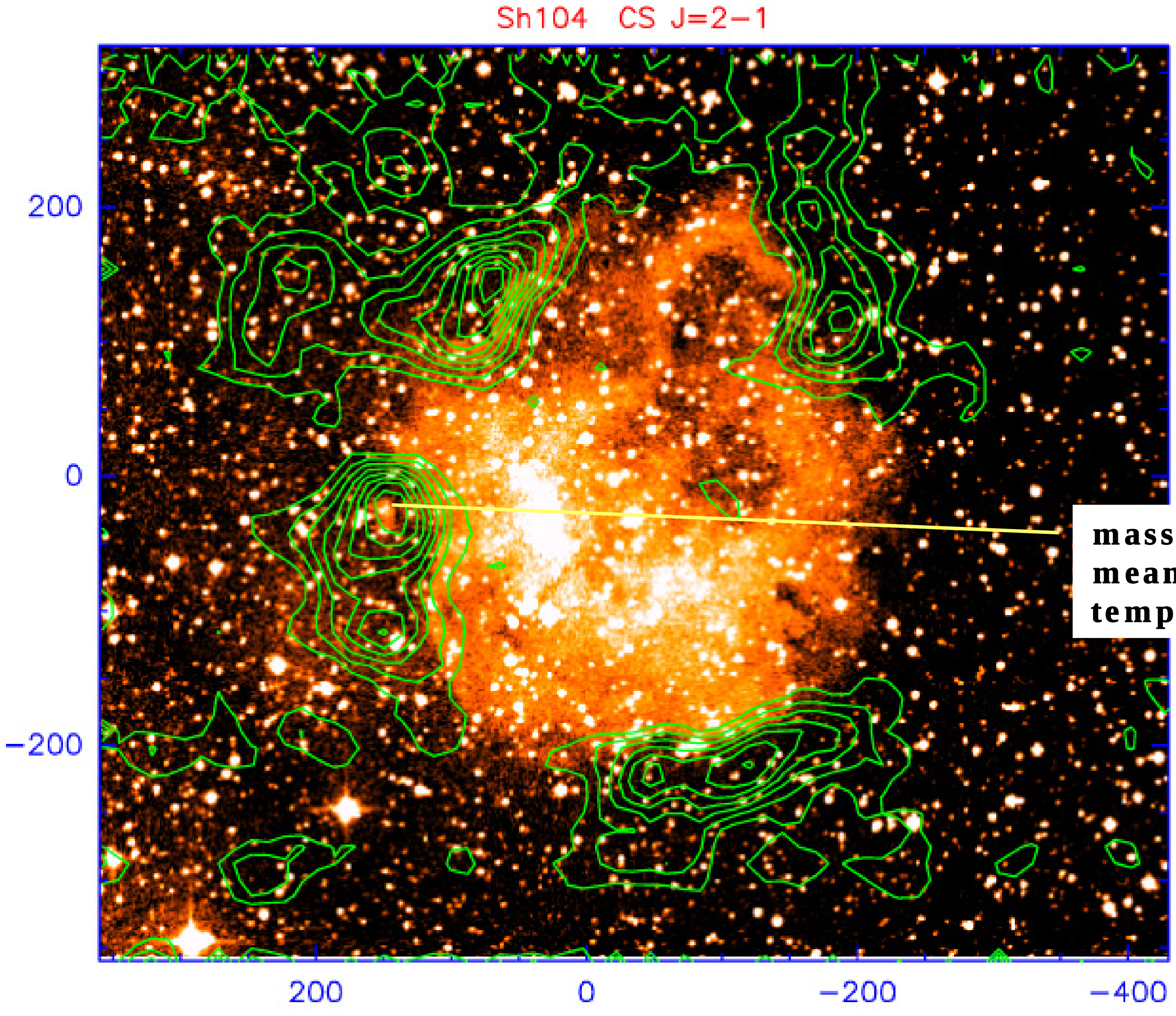
IRAS 20160+3636 $3\ 10^4$ Lo

Near-IR cluster

CO (2-1) emission at 1.3 mm *IRAM*

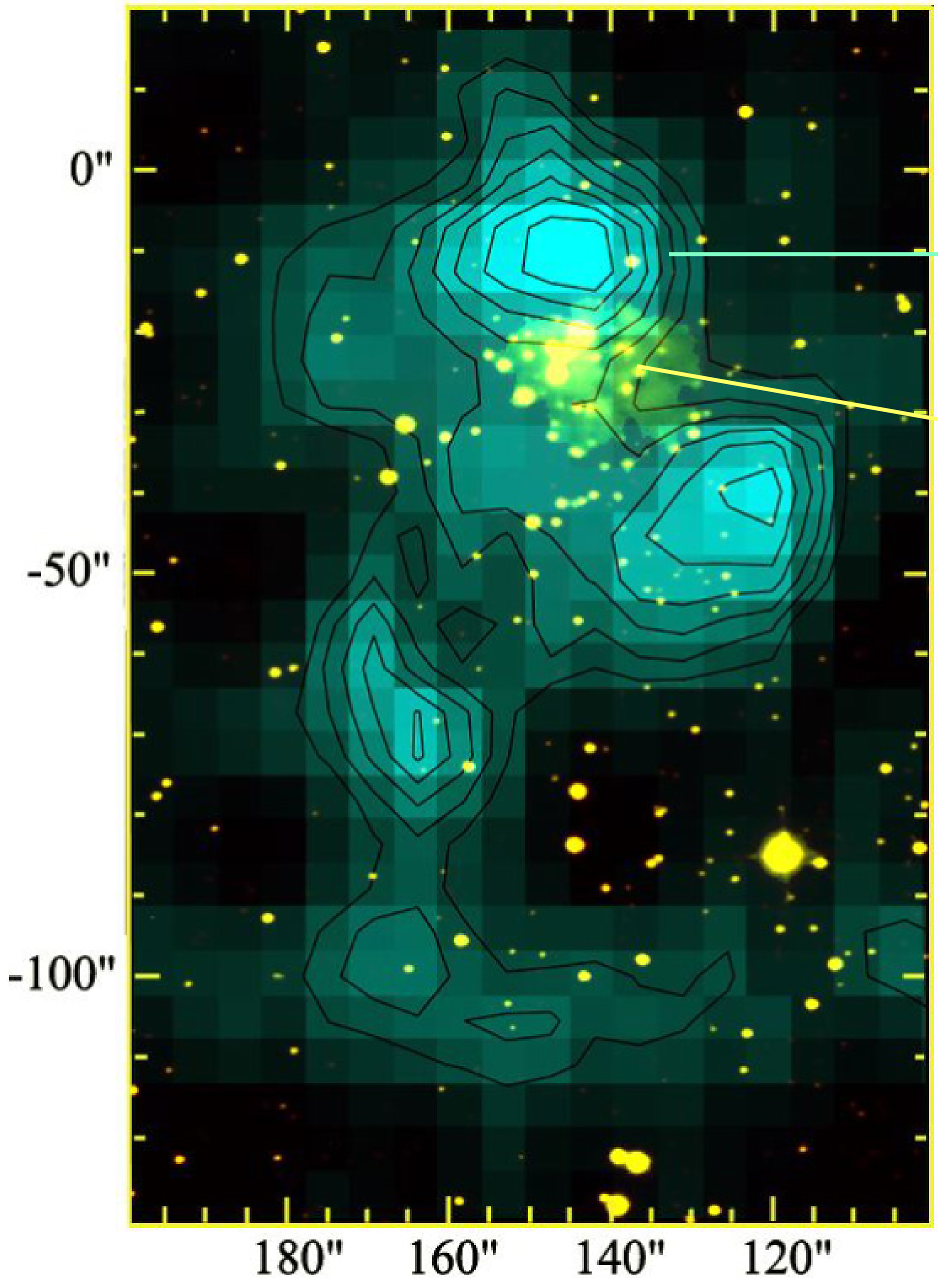


CS (2-1) emission



mass of the fragment: 670 Mo
mean density: 3100 cm^{-3}
temperature: 30 K

The main fragment



C^{18}O emission (*IRAM)*

mass of the cores: 100 Mo
density up to 2 10^{5} cm^{-3}

Near-IR cluster
K band (*CFHT)*

A WIRCAM dedicated study

Scientific goals

Scientific goals

- Near-IR characterization of the different triggering mechanisms
- Answer the following questions
  - Is there a predominant mechanism (as a function of the geometry, the exciting star, the local conditions) ?
  - Is there a given range of stellar mass (for the second generation stars) associated with a given mechanism ?
  - IMF in the second-generation clusters ?
  - Isolated versus clustered formation for massive stars ?
  - Evolution of the stellar clusters ?
  - Co-existence of different mechanisms ? → need for a large scale study

Scientific goals

- Ongoing multi-wavelengths studies (visible to the millimeter, lines and continuum).
- *Spitzer* and *Herschel* perspectives (dedicated Guaranteed Time proposals on *Herschel*)
- Coupled with other galactic surveys (CGPS HI, CO, *APEX*, *Herschel*)

Why WIRCAM ?

As compared with existing near-IR surveys

- Need for a **large field** study
- Need for **sensitivity**
- Need for **spatial resolution**

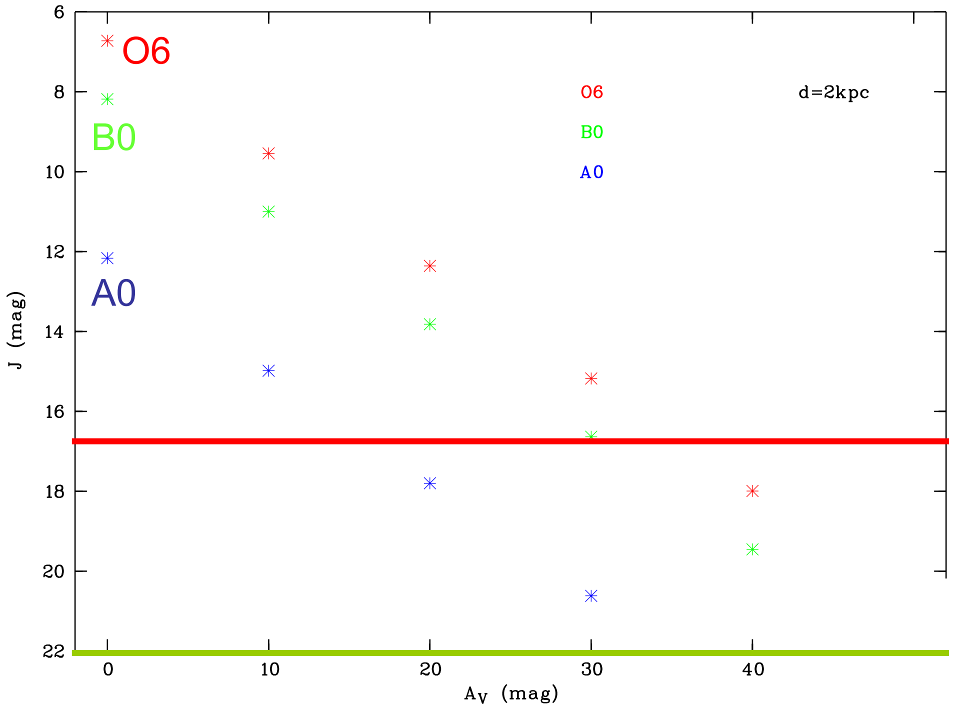
Large field

- Possibility to study the **co-existence** of different mechanisms

- Characterizing the stellar content of both the first and the second generation stars

- Mosaicing on large regions

Sensitivity Access, for a given distance, to a given stellar mass



J mag versus A_v

2MASS limiting mag

16.5 mag in *J*

16.0 mag in *K'*

WIRCAM desired mag

22 mag in *J*

20 mag in *K'*

WIRCAM desired mag

22 mag in *J*

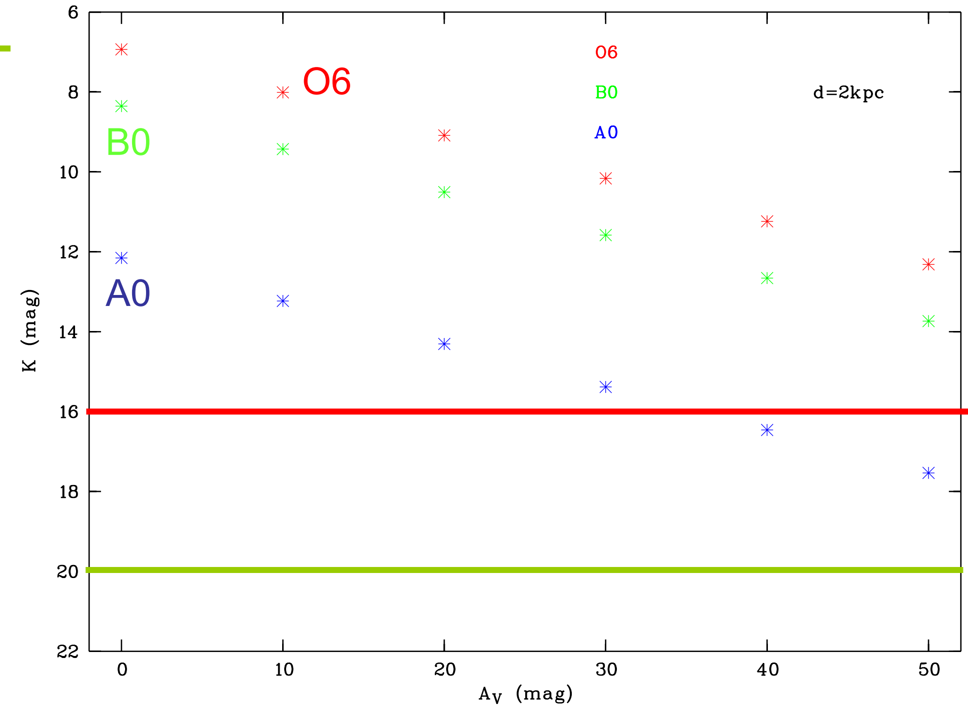
allows to reach a A0 with A_v=35mag

20 mag in *K'*

allows to reach a A0 with A_v=60mag

For d=2kpc

K mag versus A_v

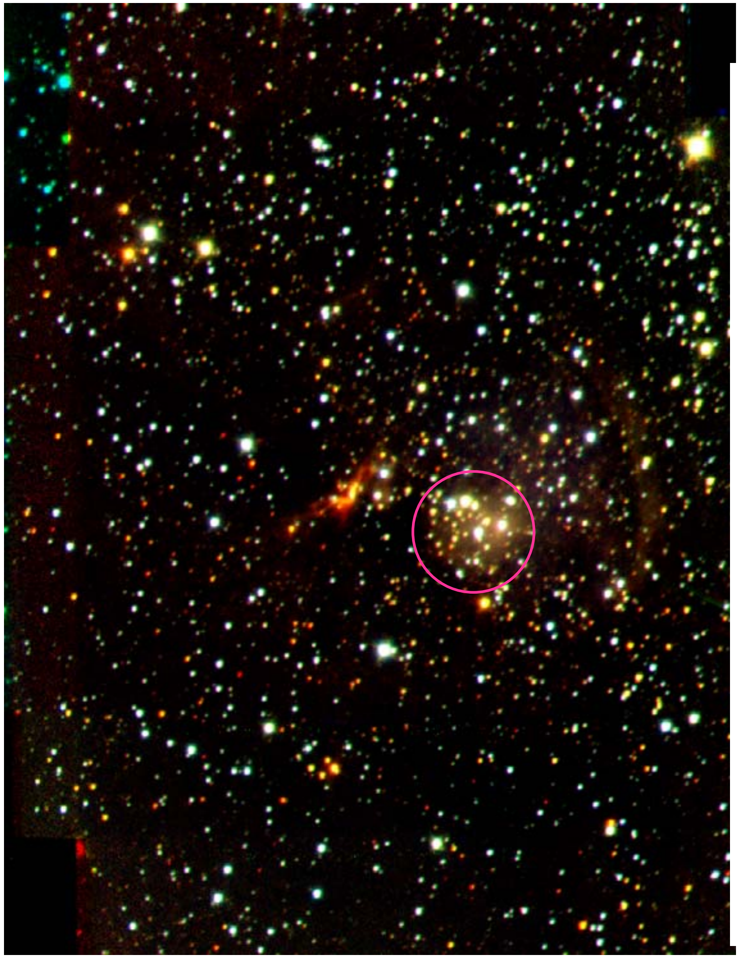


Sensitivity

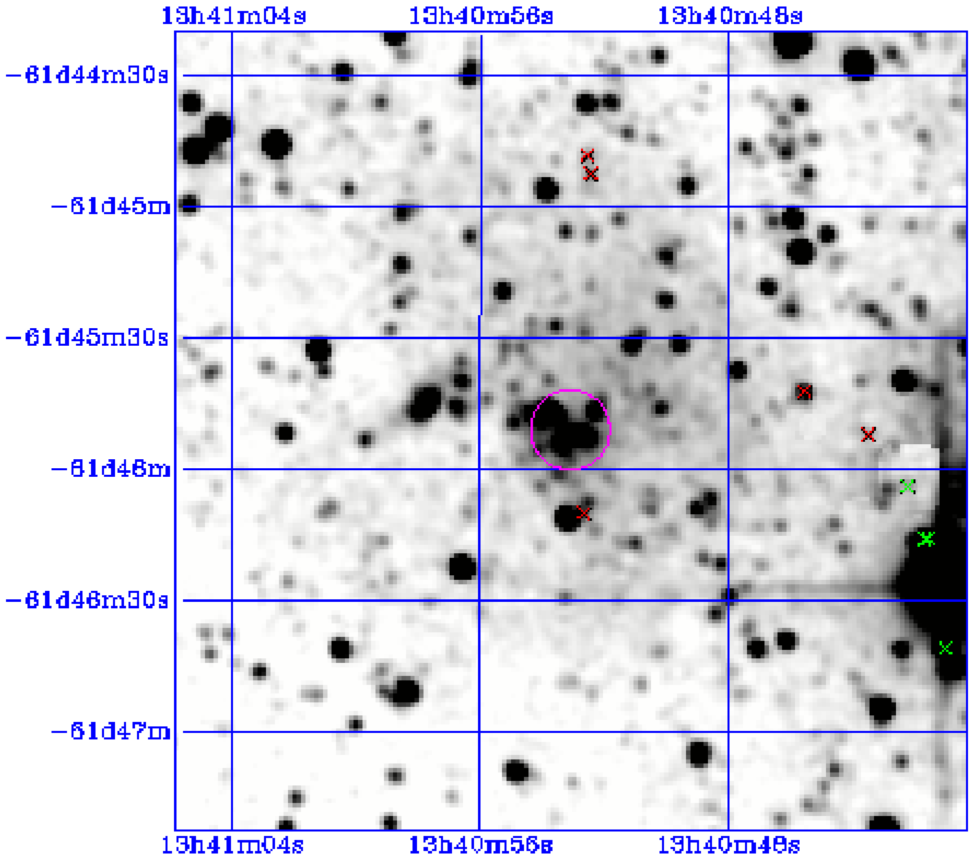
Possibility to study the stellar masses distribution within the clusters (IMF)

Interest in the APEX community on nearby star forming regions (Rho Oph, ….)

Spatial resolution



ESO-NTT *JHKs* image



2MASS *Ks* image

The sample

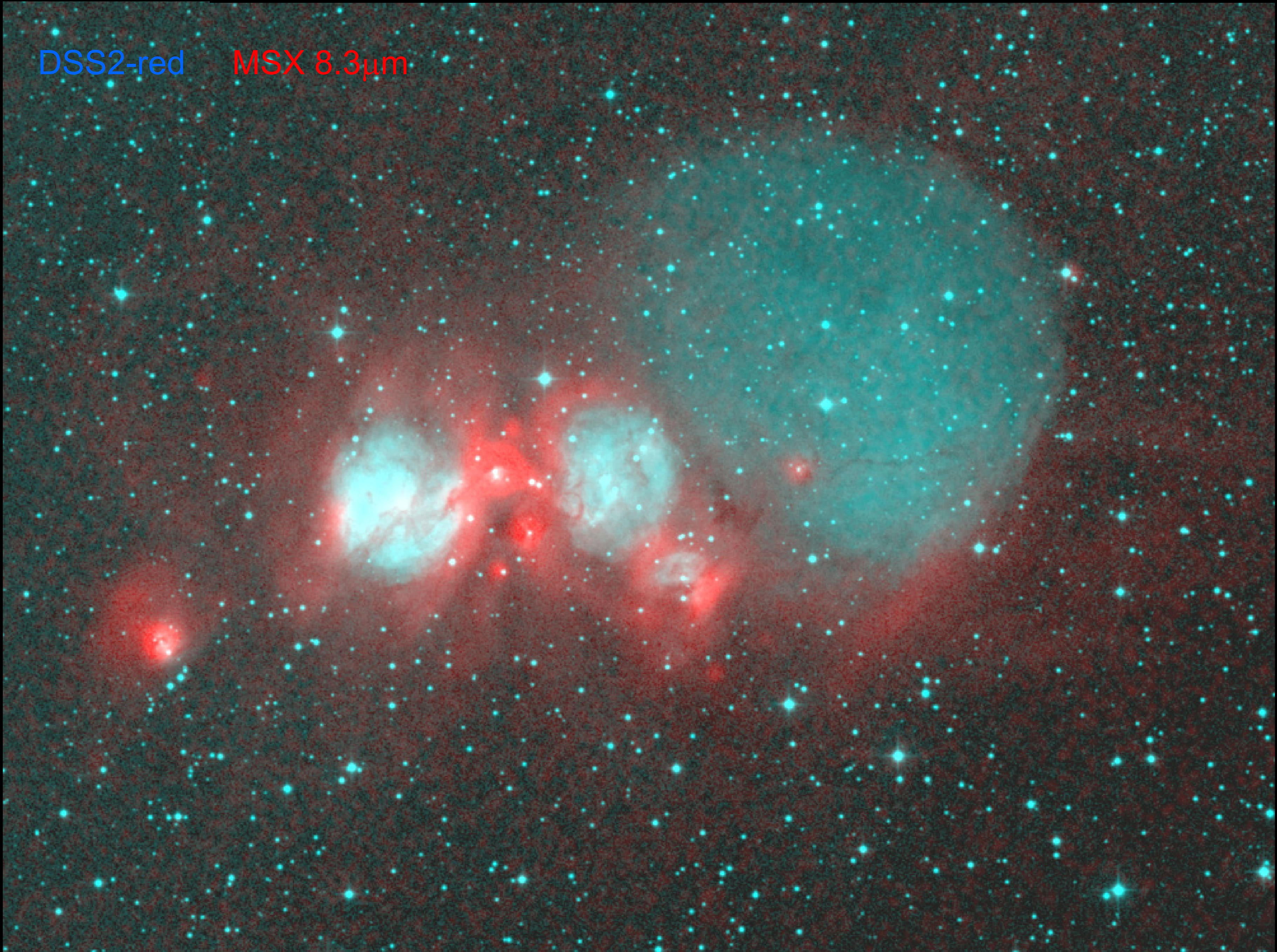
- Nearby (< 3 kpc) HII regions spanning a large range of physical conditions

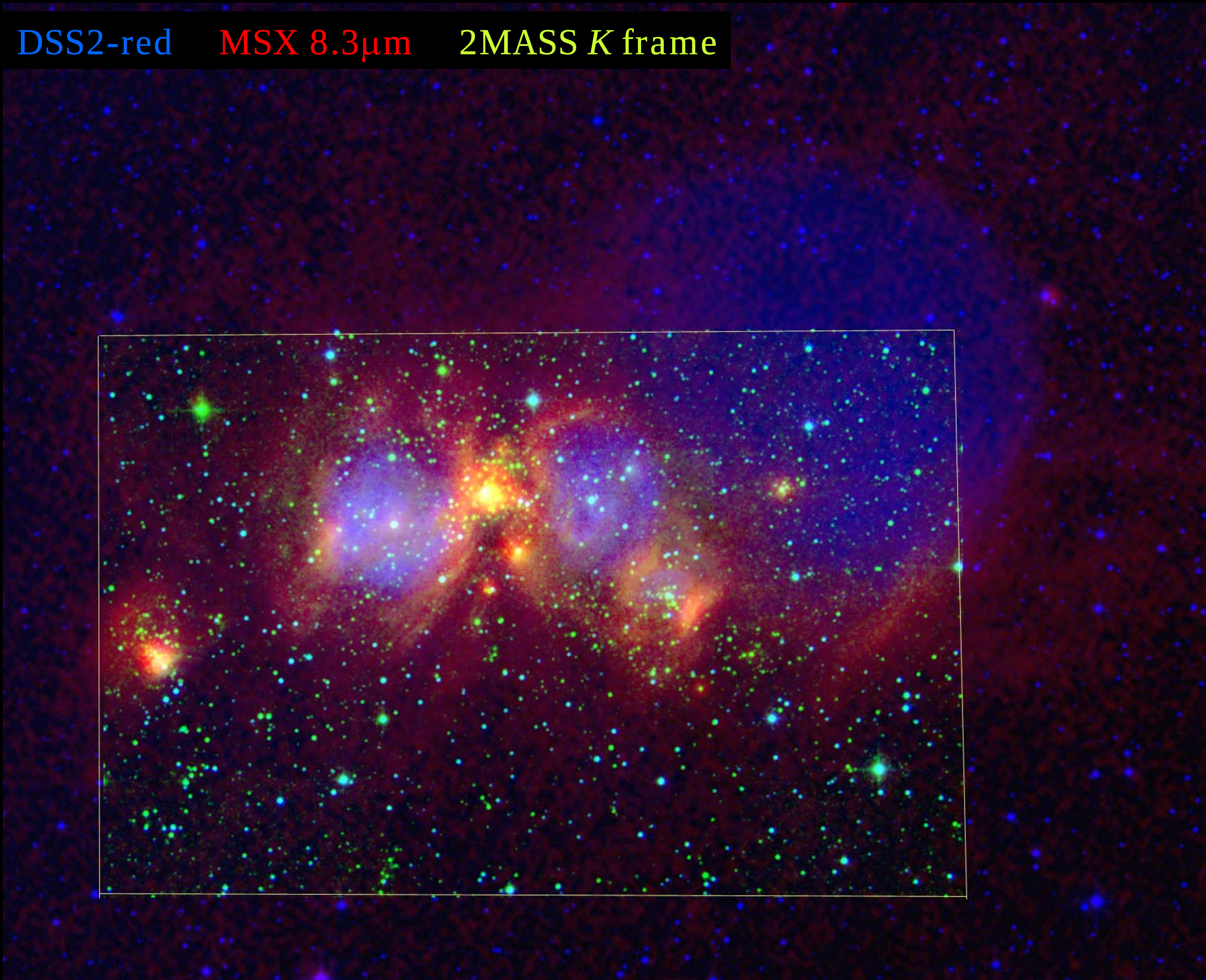
  - Spectral type of the first generation exciting stars

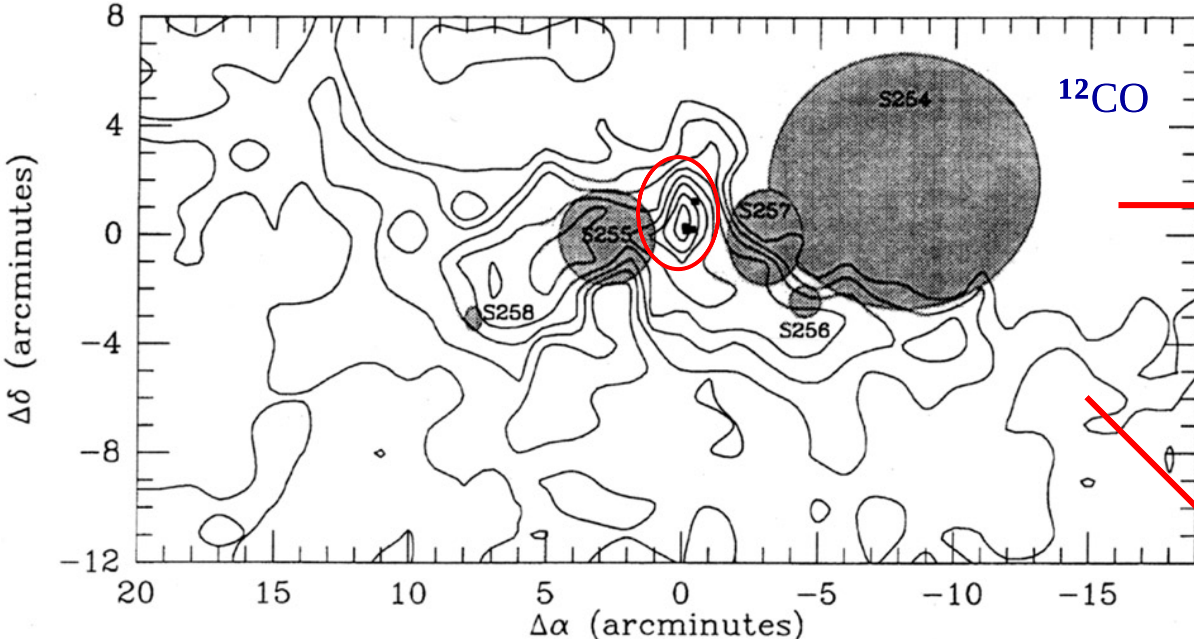
  - Surrounding medium (isolated / groups of HII regions)

  - Different HII region sizes → testing, for a given distance, the evolutionary stage

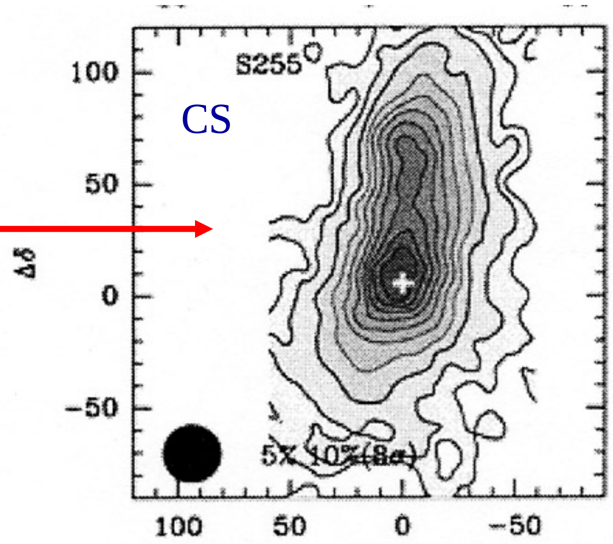
Sh 255 - 257 D=2 kpc, IRAS sources L=10^4 $L_\odot$ and 2.6 10^4 $L_\odot$, masers, CO outflow t=10^5 yrs




DSS2-red
MSX 8.3μm
2MASS *K* frame

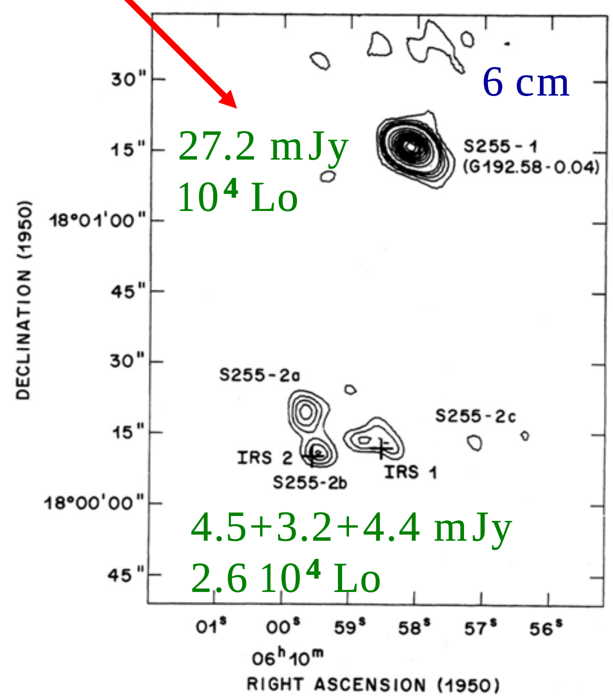


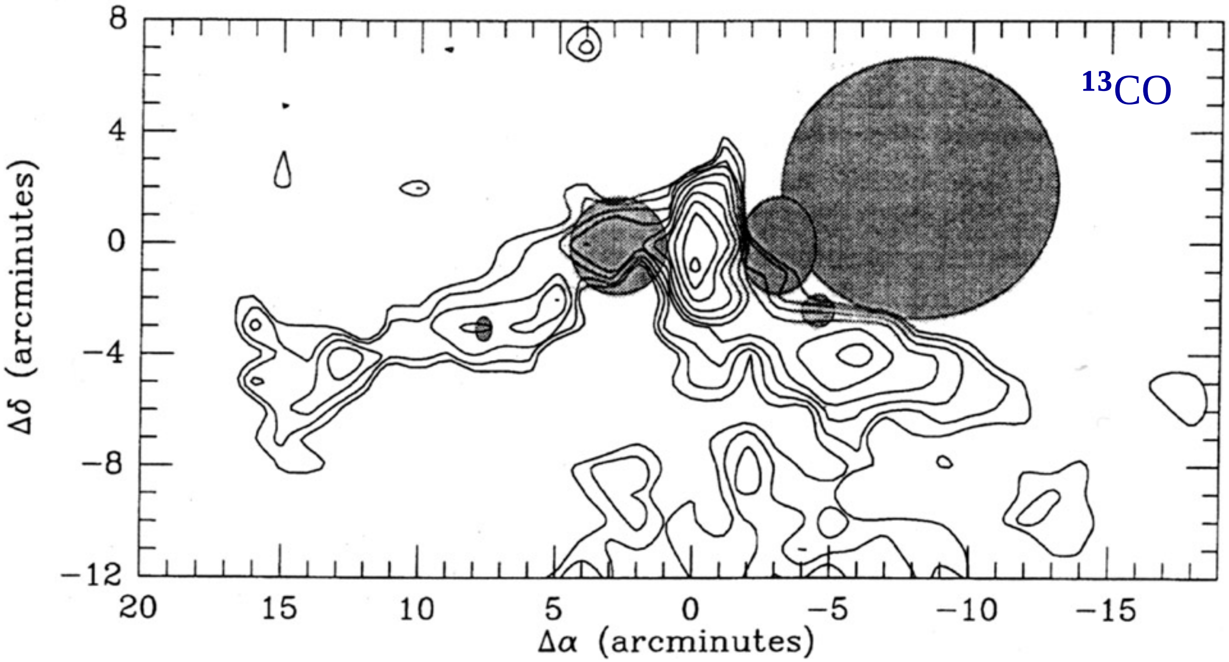
Heyer et al., 1989



Shirley et al., 2003

Snell & Bally, 1986





Wircam observations

- *J, H, K'* images on the selected regions

Characterizing the stellar content of formed clusters

- Br γ and [FeII] on selected zones (about 1/3 of the total surveyed area)

Testing the existence of

  - ultra-compact HII regions,
  - ionized winds,
  - high velocity shocks

  → information on mass and evolutionary status of the formed stars

Time estimates

For one 20’ x 20’ field :

- 2500 s *J H K’* filters
  - 1200 s in J ↔ limiting magnitude (at 5σ) 22.0
  - 600 s in *H* 20.5
  - 700 s in *K’* 20.0

  Allowing the **color measurements** of all B0V stars with A_V<50 mag or all F0V stars with A_v<30 mag

- 3600 s for each filter / Brγ and [FeII]
  - Limiting magnitude (at 5σ) : 19 in Brγ, 20 in [FeII]

Photometric calibration : 1/3 of the total observing time ~ 2000 s

Total time estimate

Total covered area ~ 8 deg^2

70 x (20' x 20') with large filters = 60 x 2500 s

~ 5**0 hours**

15 x (20' x 20') with Brγ and [FeII] filters = 15 x 7200 s

30 hours

Calibrations ~ 30 **hours** (1/3 of the total time)

Total time : **110 hours**

~ 14 **nights**