Star Formation at the edges of HII regions

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Blitzed65 – Berkeley, 29-30 October 2010

Massive stars ($M > 8\ M_o$):

-May disperse parental molecular cloud via ionization, winds, supernova explosions, thus preventing subsequent SF;

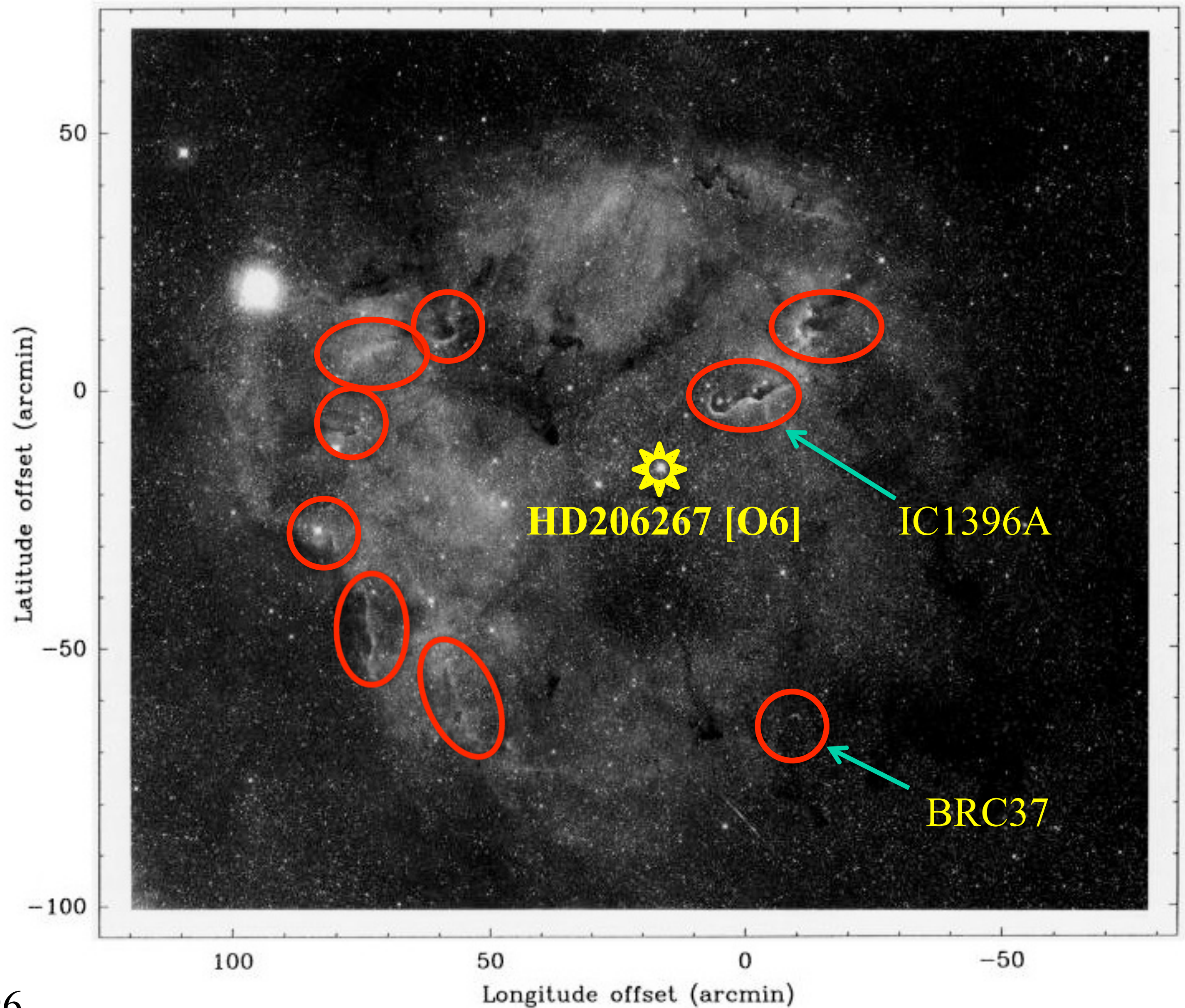
-May give rise to new generation of stars through:

★compression of pre-existing dense condensations by IF + shock front (RDI)

★accumulation and subsequent collapse of gas swept-up by expansion of HII region (collect & collapse)

Star formation in pre-existing clumps

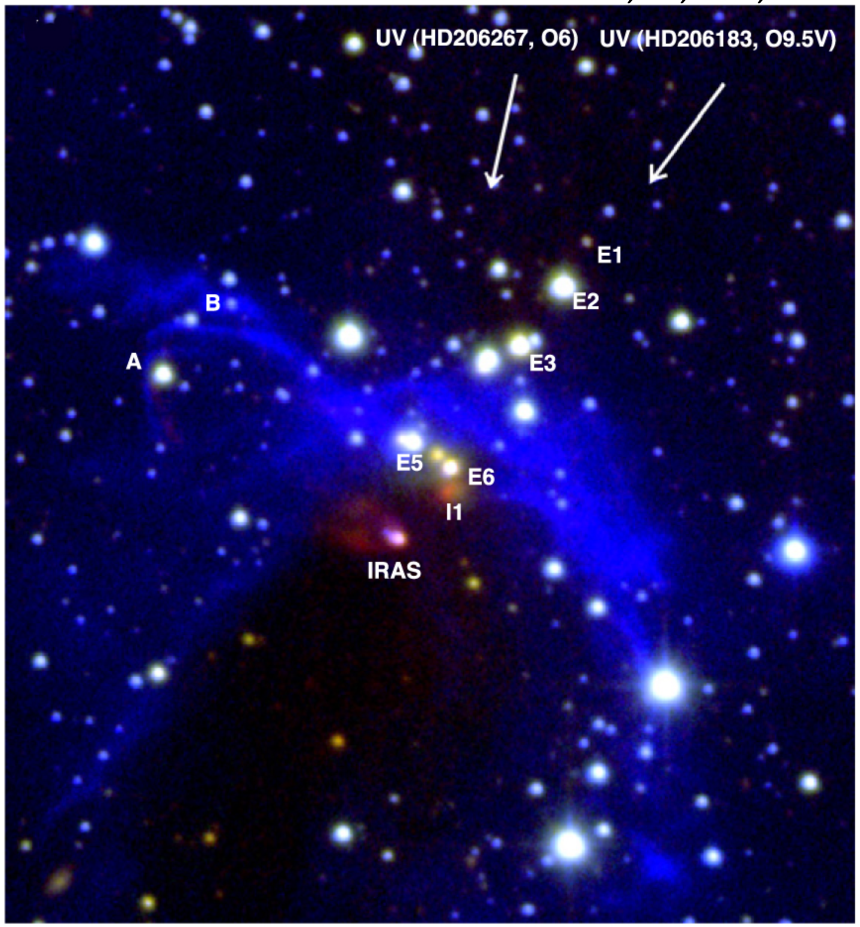
Cep OB2

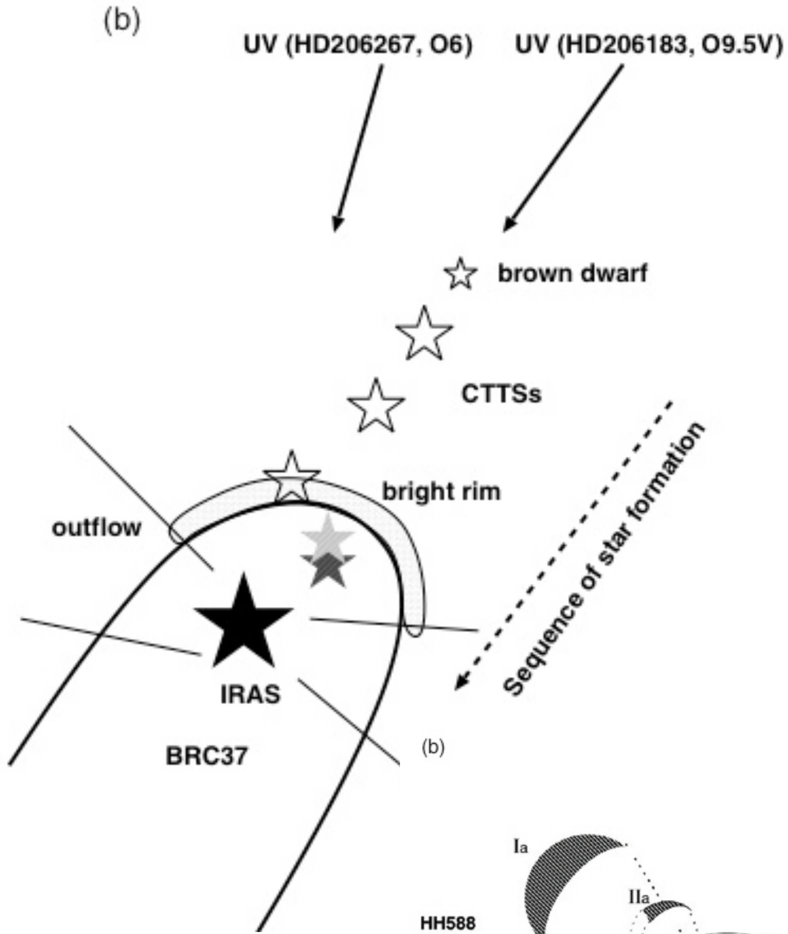


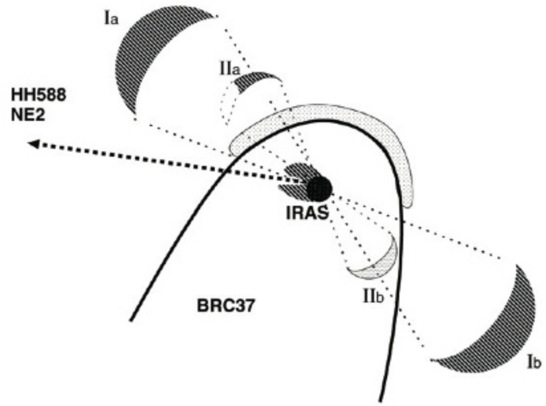
Weikard et al. 1996

BRC37

H α H K *Ikeda et al. 2008, AJ, 135, 2323*





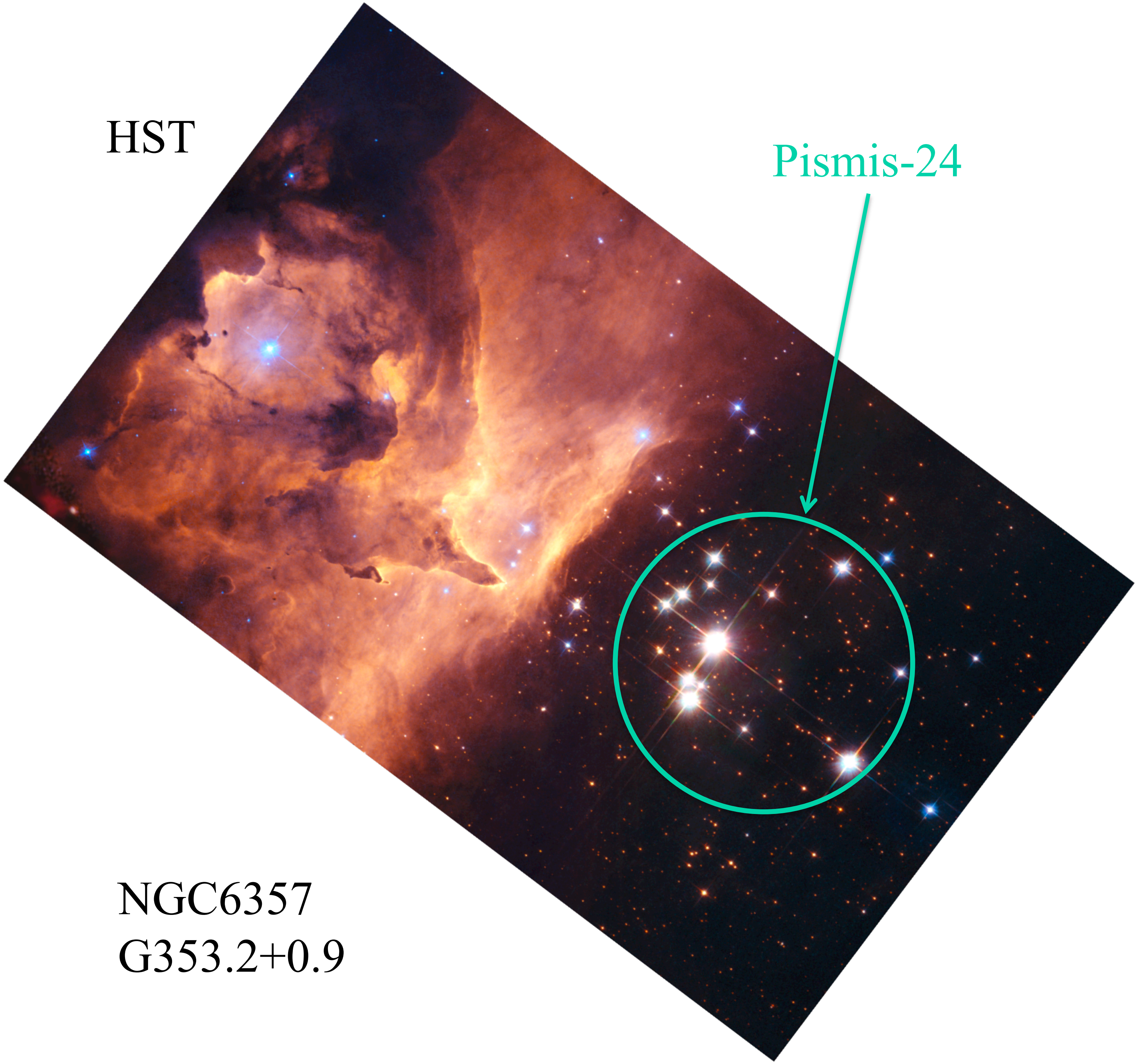


E2, E3, E5, E6: $H\alpha$ emission stars
= Classical T Tauri stars 1 Myr 0.2 – 0.5 M_o

I1, IRAS 21388+5622: YSOs with near IR excess and bright mid-IR emission
110 L_o (late B)

IRAS 21388+5622 associated with H2 jets, HH588, and a CO outflow of 3 10^5 yr *Duvert et al 1990, A&A, 233, 190*
I1 associated with an H2O maser *Valdettaro et al., ApJ, 675, 1352*

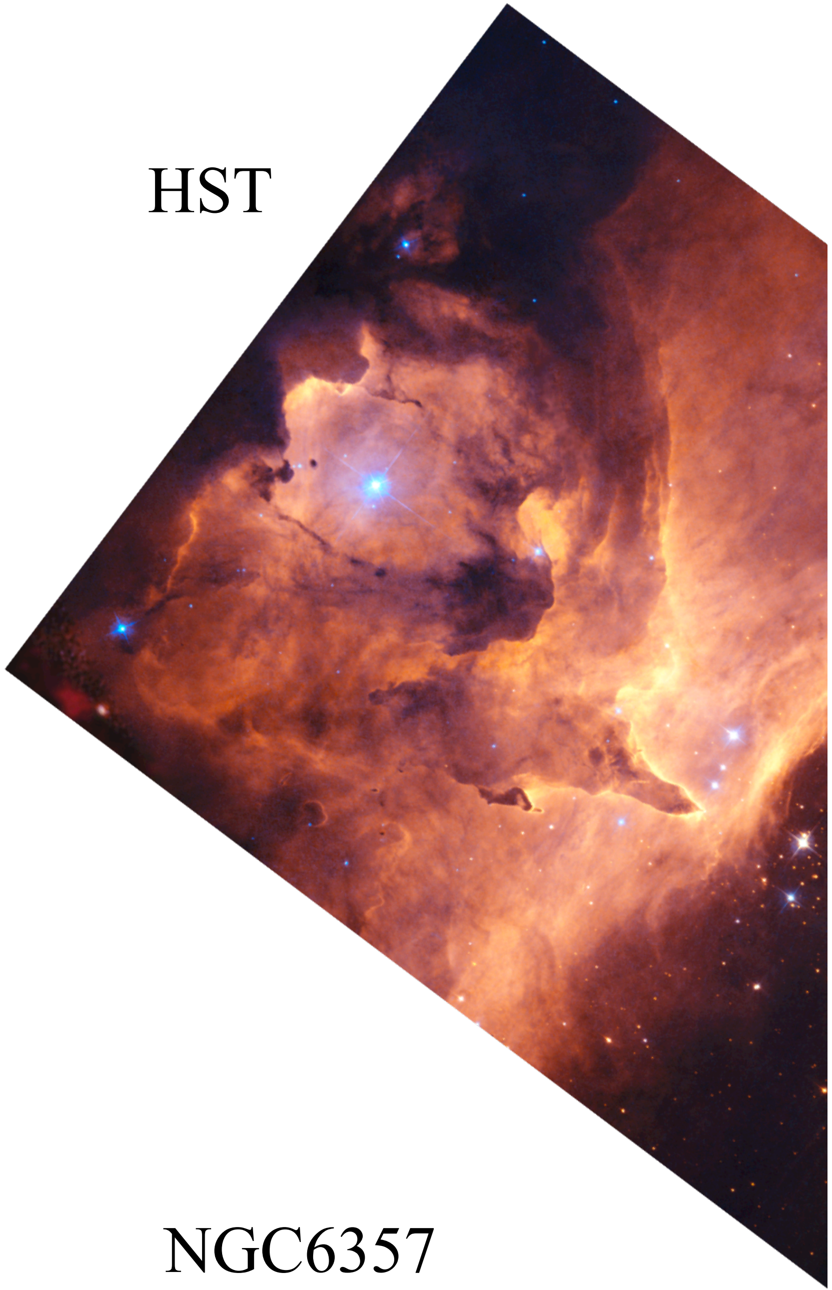
HST



Pismis-24

NGC6357
G353.2+0.9

HST



NGC6357
G353.2+0.9

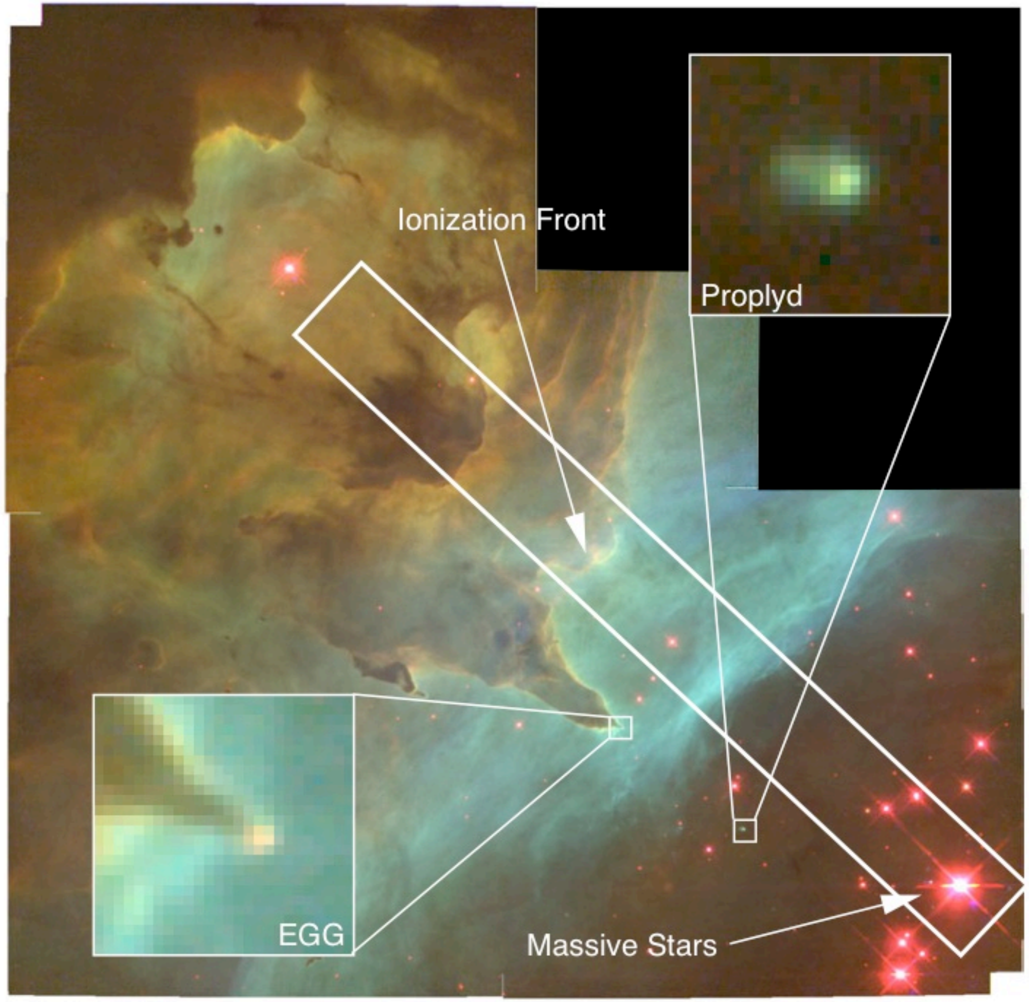
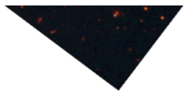


Figure 3. An *HST* WFPC2 image of the G353.2+0.9 H II region in NGC 6357 (Healy et al. 2004). This figure illustrates the astrophysical context for the sequence of events described in 4.

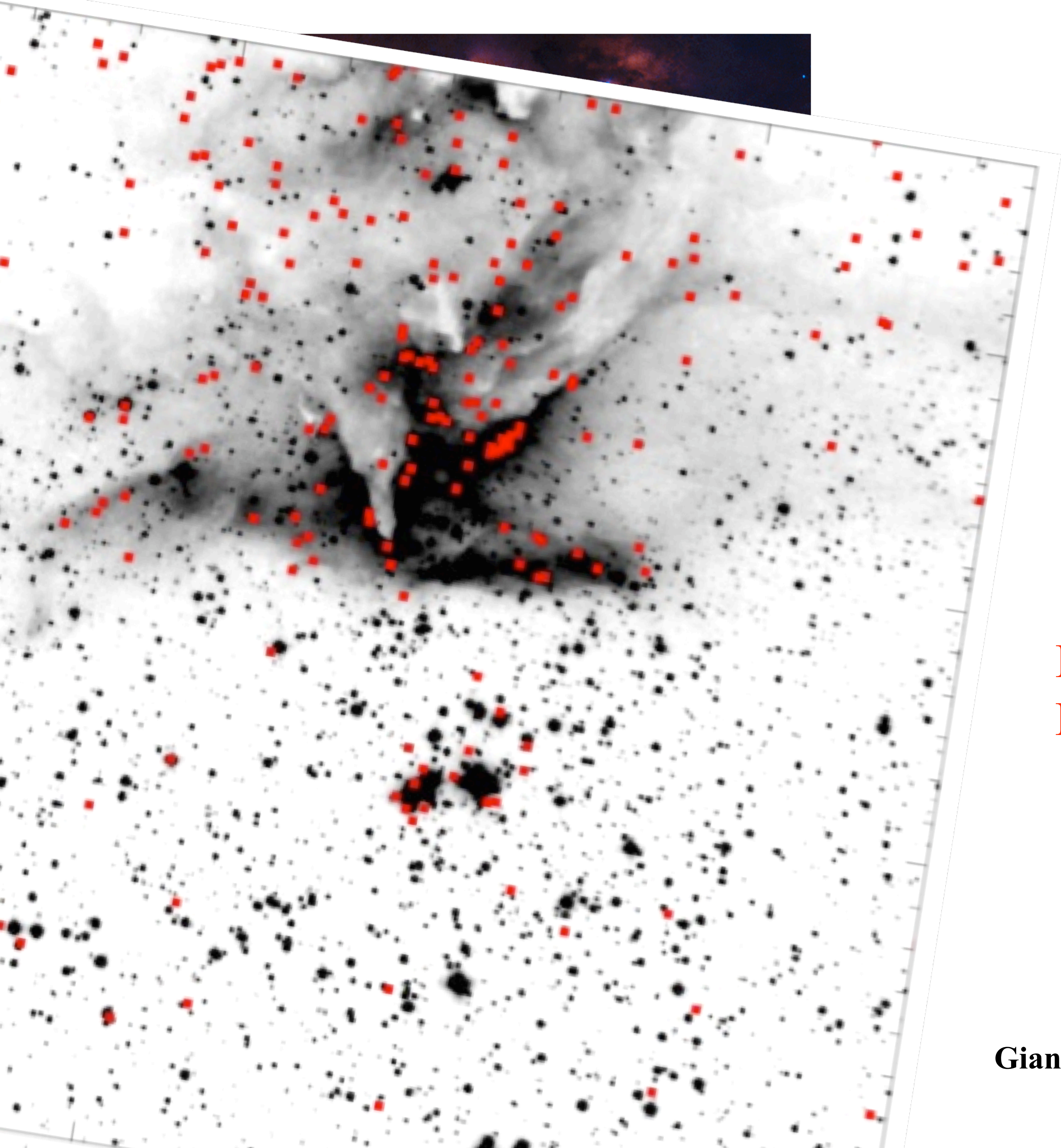


Hester & Desch, 2005 ASP 341

NGC6357-complex:

G353.2+0.9

HST



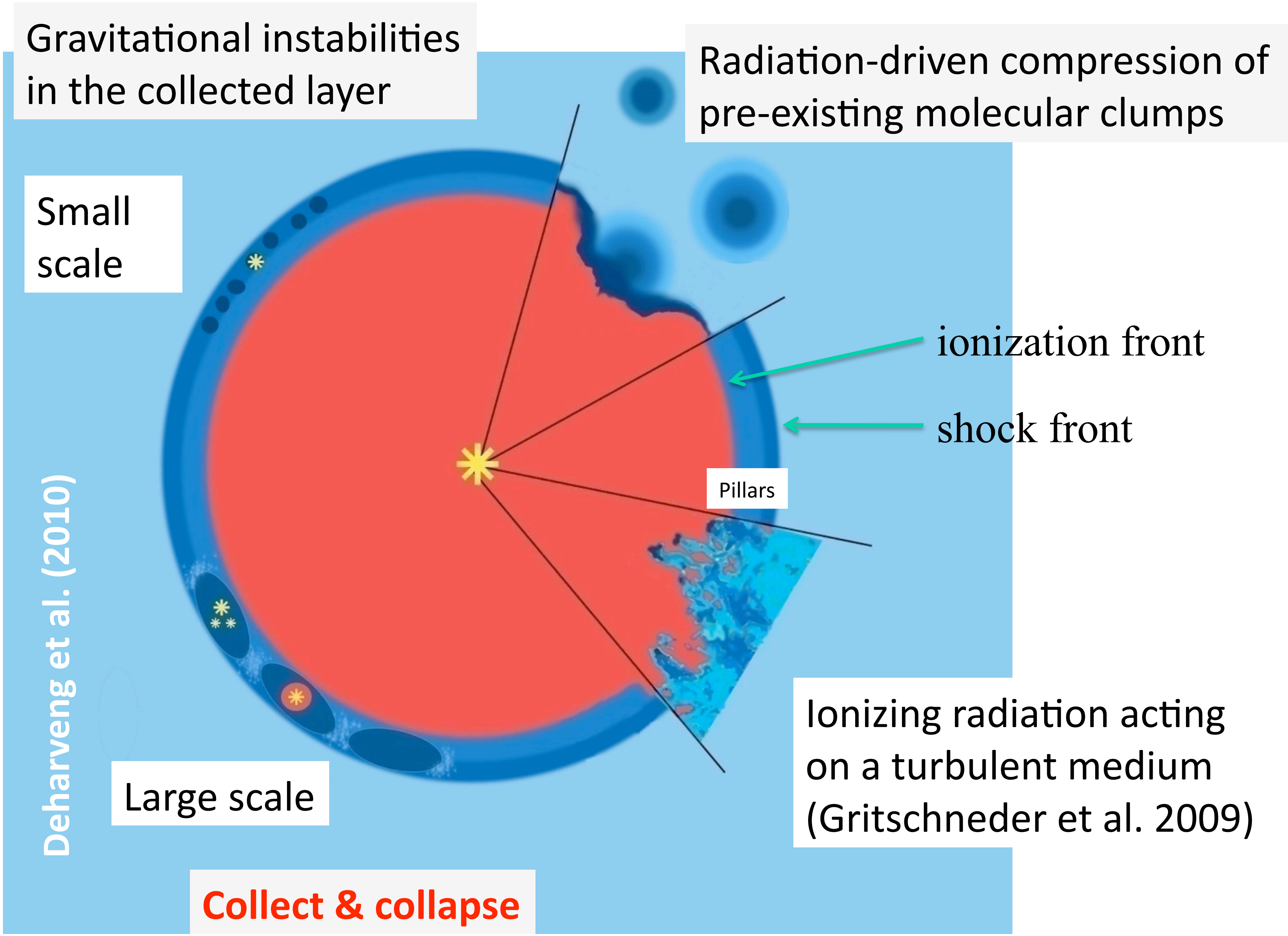
NGC6357-complex:

G353.2+0.9

HST

ESO-NTT
K-band detections

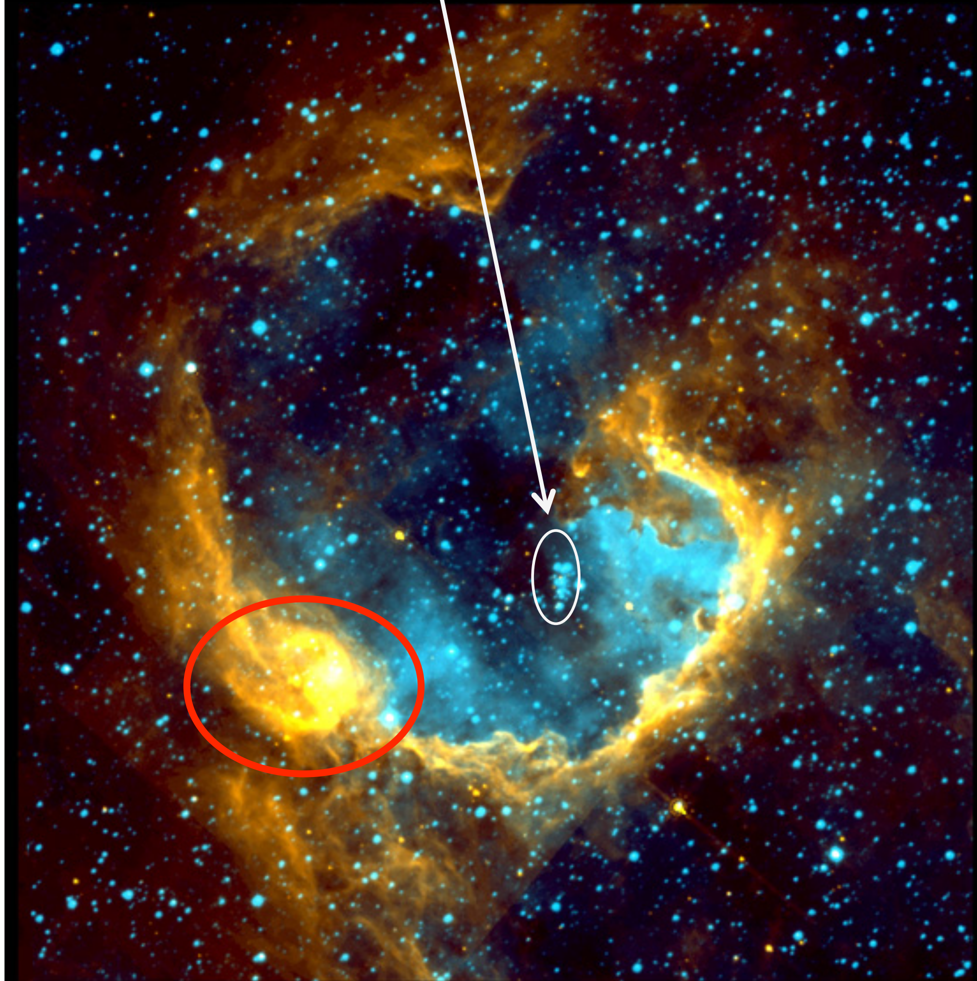
Giannetti, Brand, Massi 2010


Gravitational instabilities in the collected layer
Radiation-driven compression of pre-existing molecular clumps
Small scale
ionization front
shock front
Pillars
Deharveng et al. (2010)
Large scale
Ionizing radiation acting on a turbulent medium (Gritschneder et al. 2009)
Collect & collapse

RCW 79

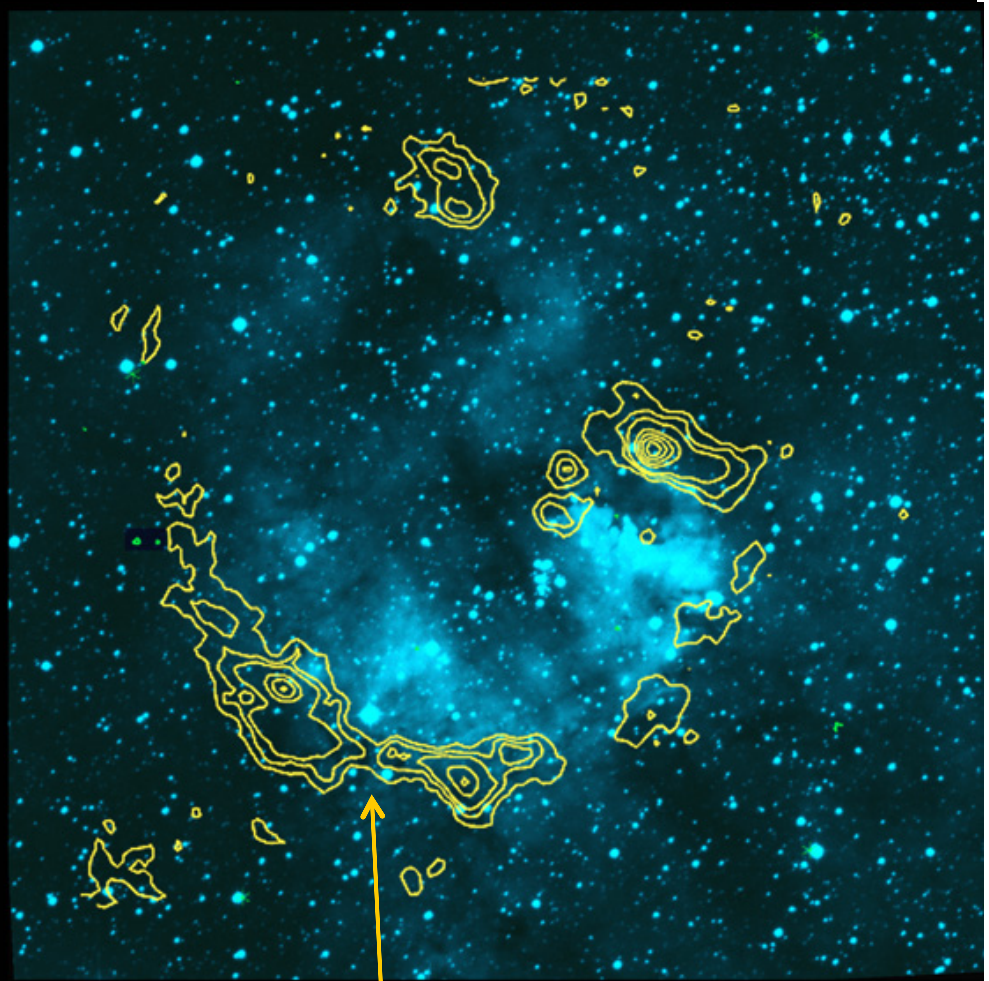
Distance = 4.3 kpc
Diameter = 15 pc

Exciting cluster: a dozen O stars   2.5 Myr   (negligible stellar winds)   *Martins et al. 2010, A&A, 510, 32*



Spitzer-GLIMPSE 8µm   Hα SuperCOSMOS

HII region



1.2mm continuum emission   Hα SuperCOSMOS

Zavagno et al. 2006, A&A, 446, 171

Shell of collected material: > 3600 $M_\odot$

RCW 79

ESO-NTT
JHK

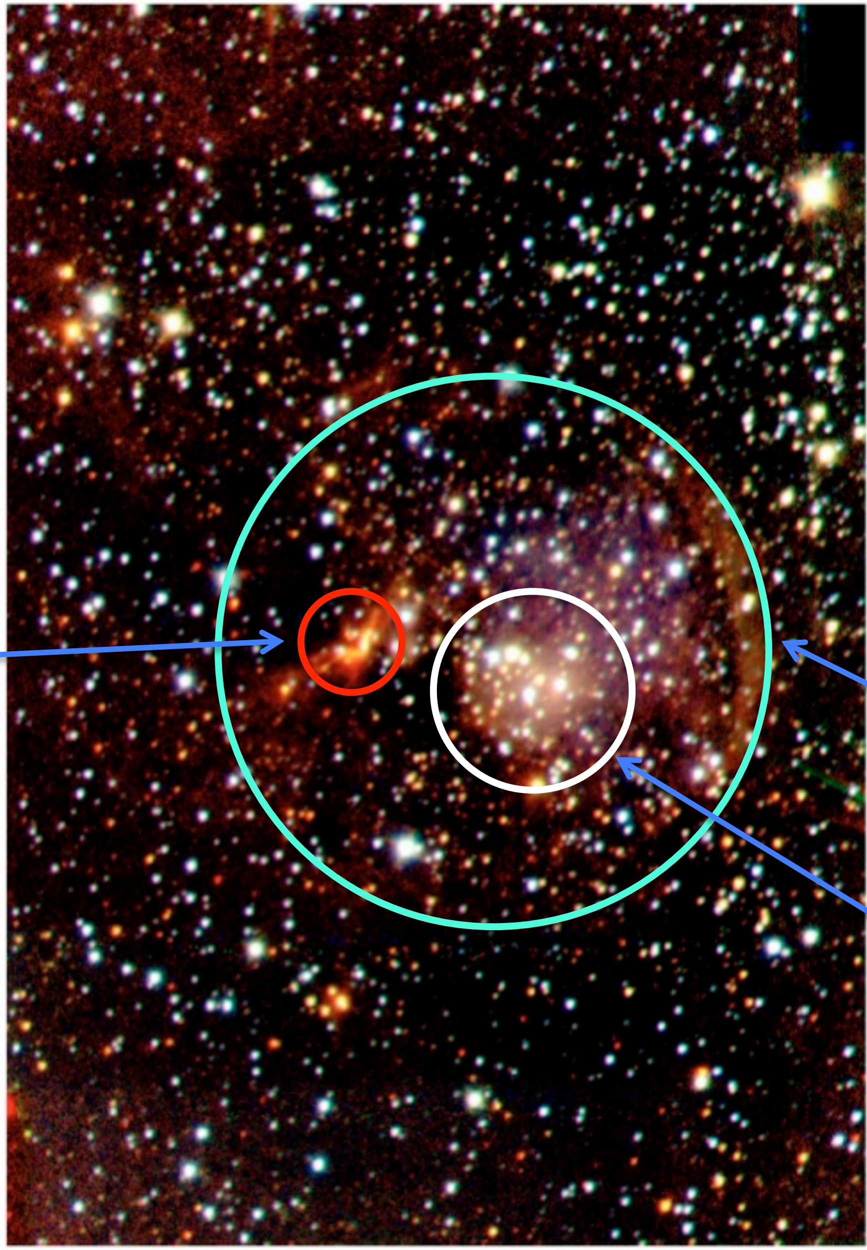
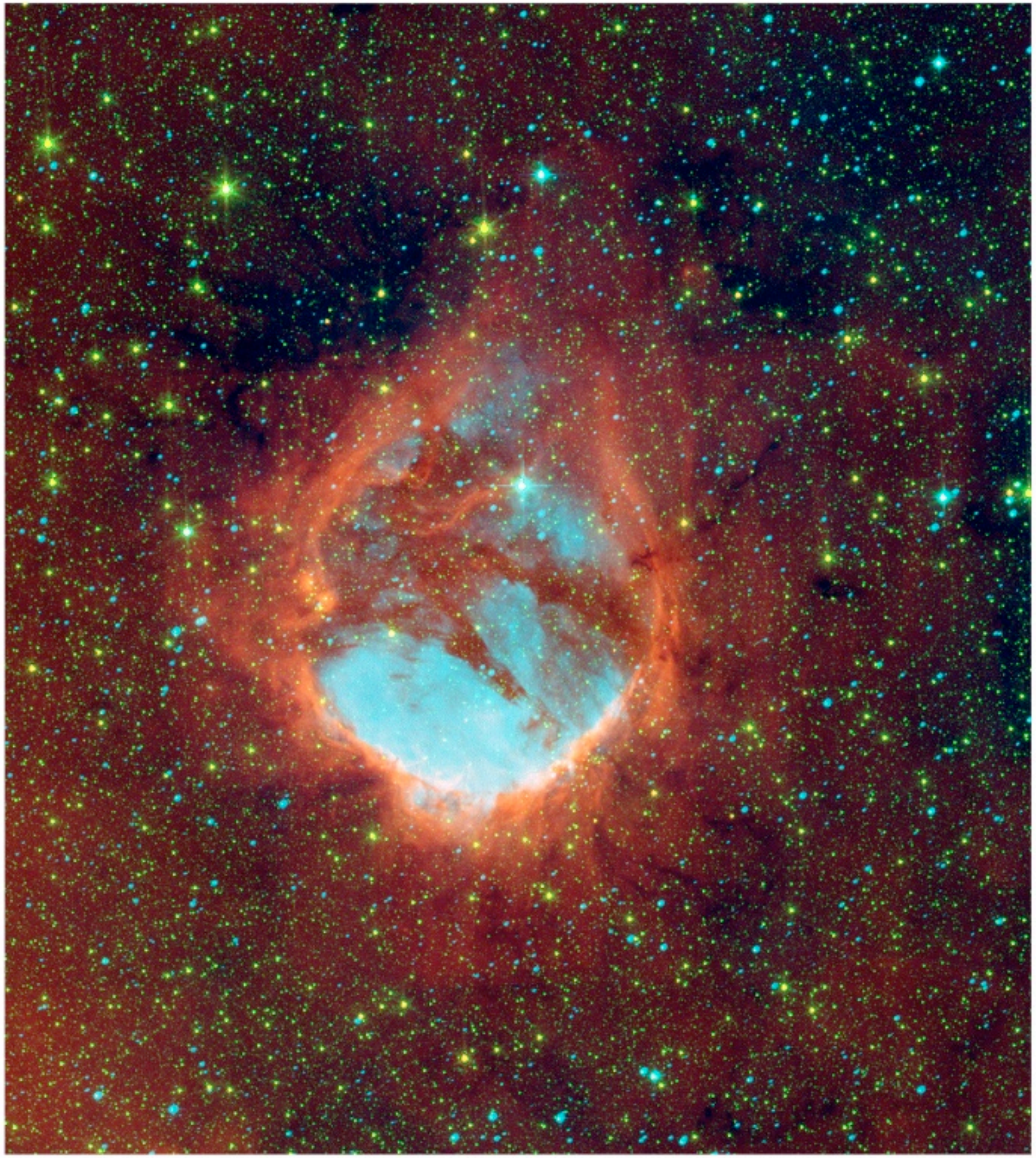


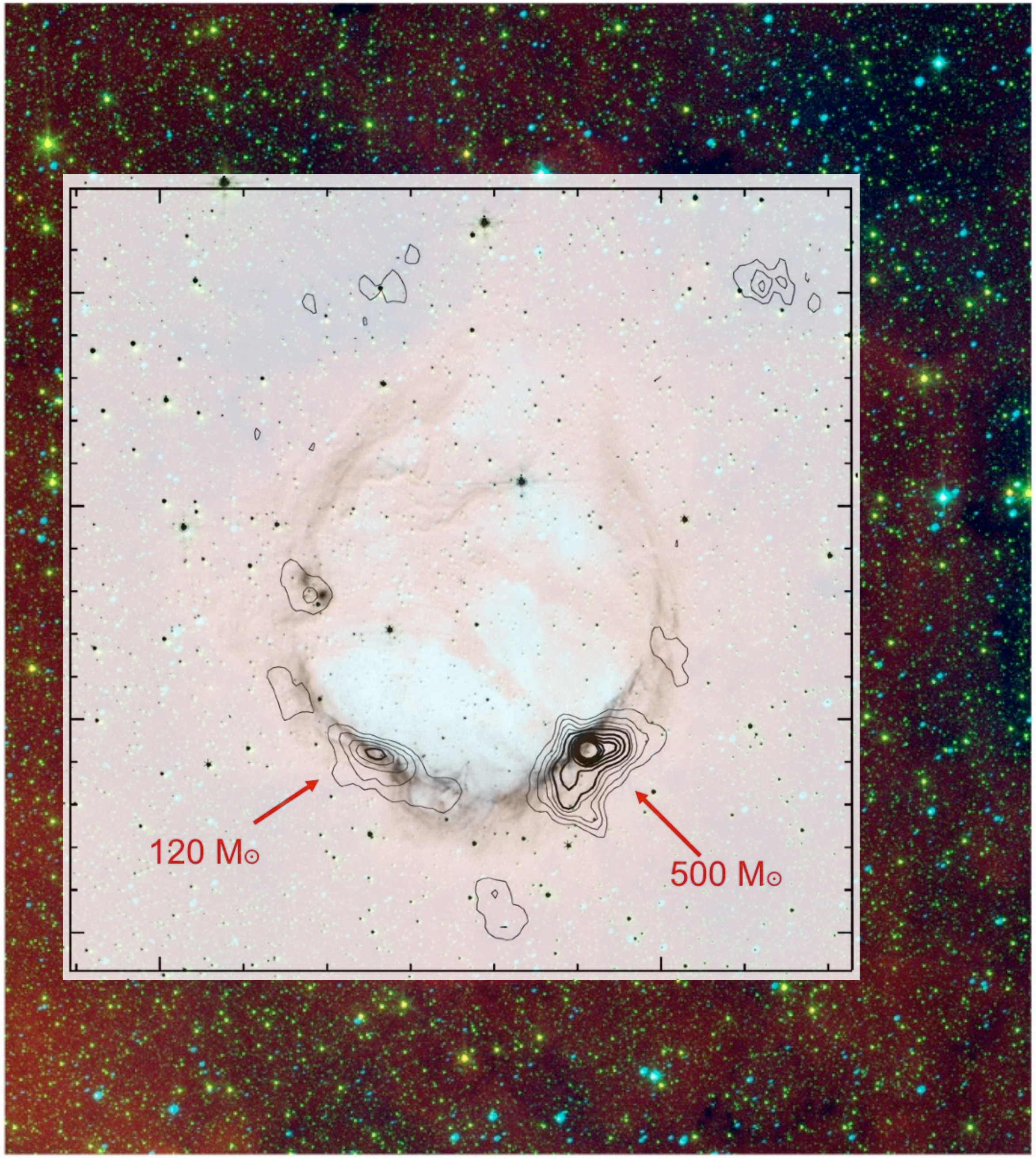
Fig. 10. *J* (blue), *H* (green) and K_S (red) composite colour image of the cluster ionizing the compact H II region (NTT observations). The field size is 2′.66 × 3′.85. North is up, east is left.



RCW 120

4.5 μm
8.0 μm
Hα

Zavagno et al. AA 472, 2007



RCW 120

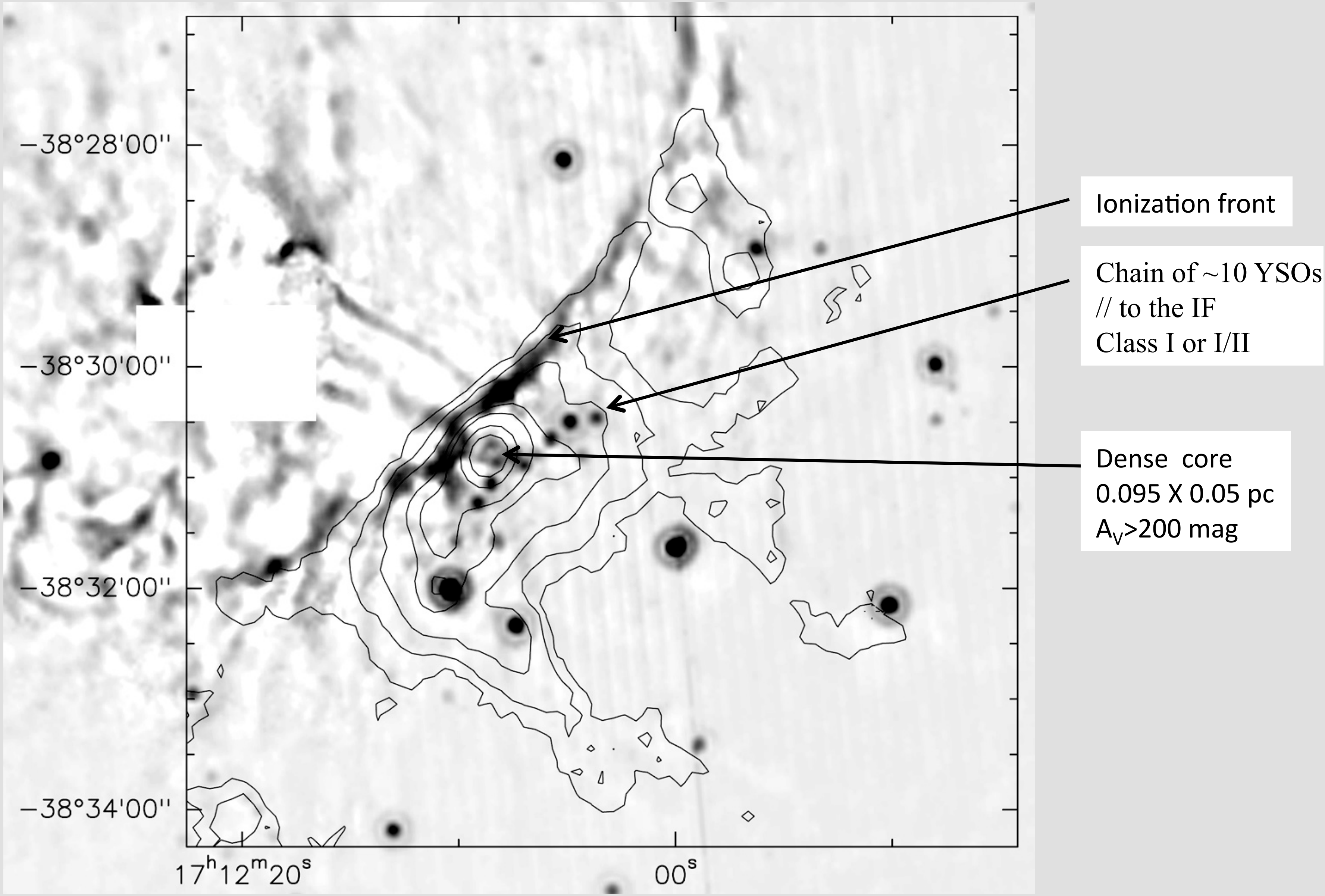
4.5 μm
8.0 μm
Hα

1.2 mm

Zavagno et al. AA 472, 2007

Star formation by collect and collapse

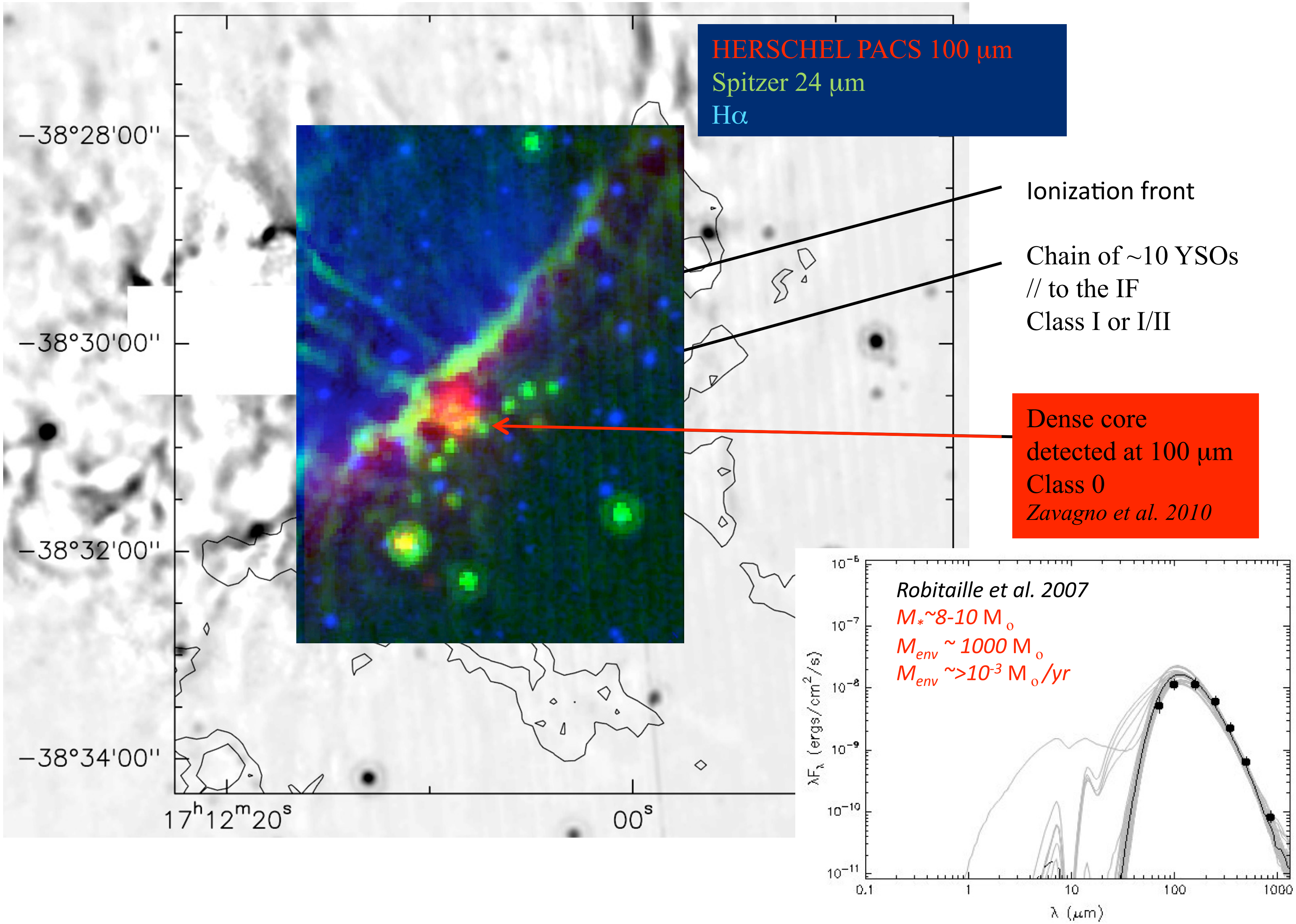
Apex-LABOCA 870 μm contours unsharp-mask image Spitzer 24 μm



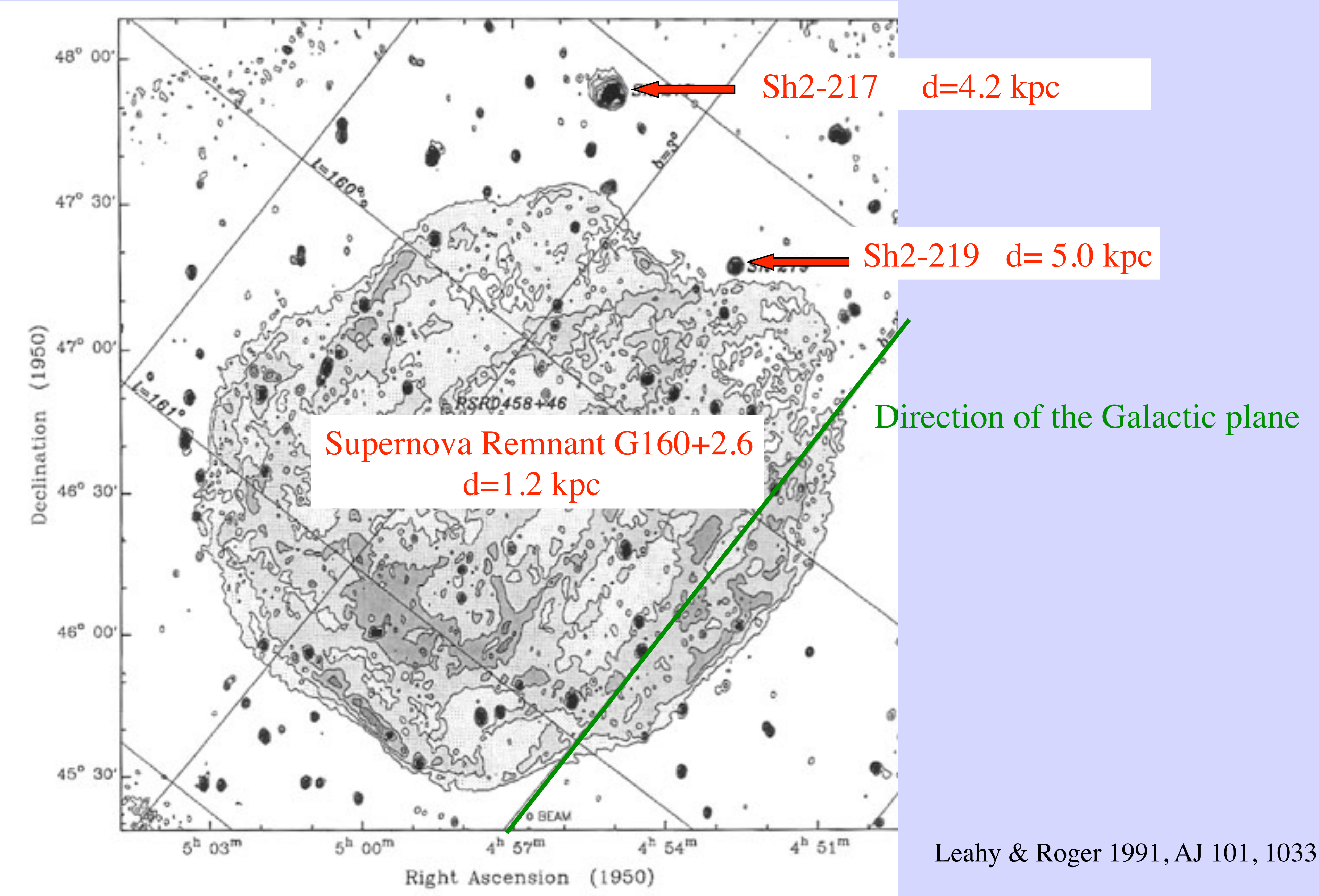
Deharveng et al. 2009 A&A 496

Star formation by collect and collapse

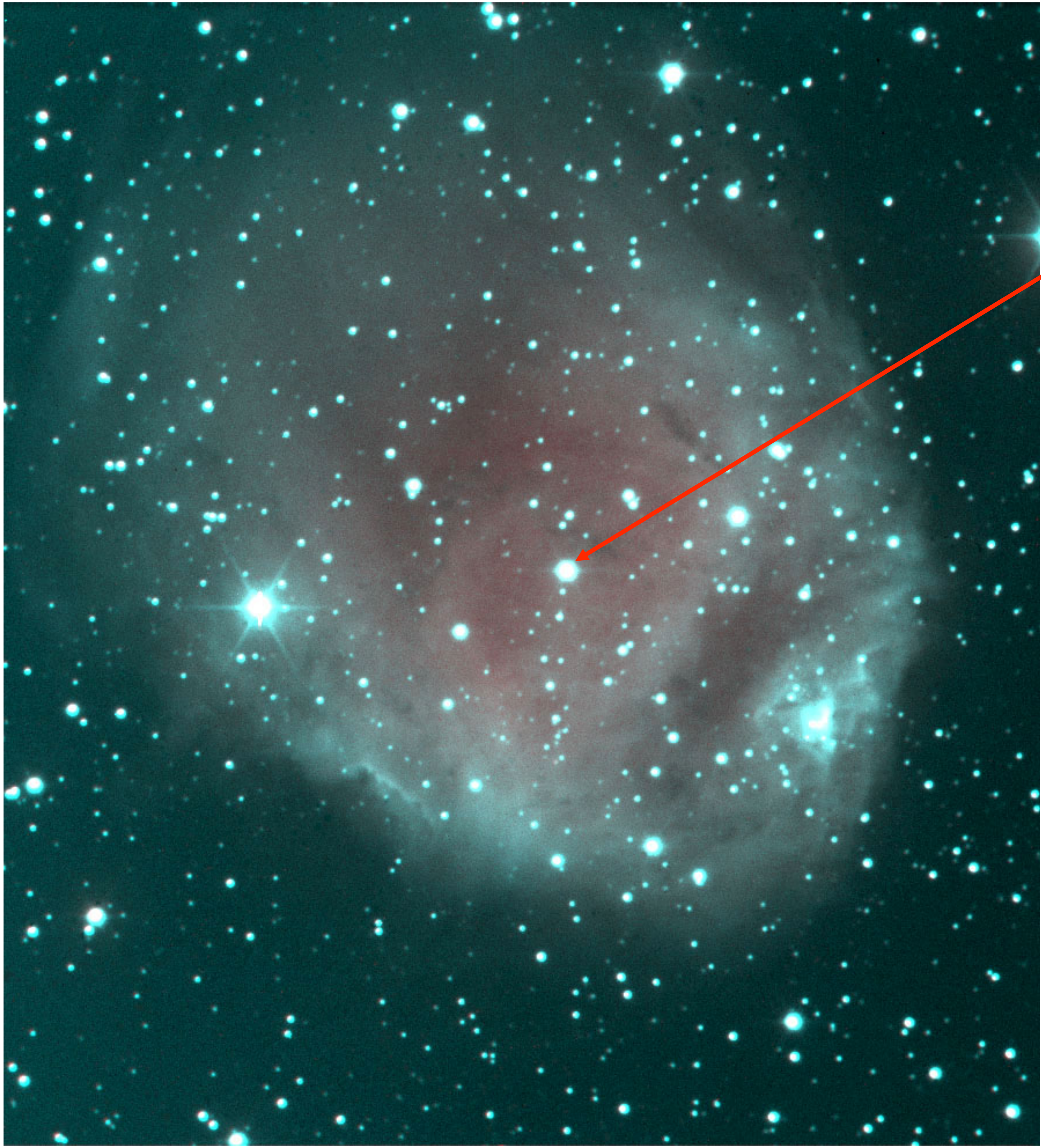
Apex-LABOCA 870 μm contours unsharp-mask image Spitzer 24 μm



The case of Sh2-217 and Sh2-219



Leahy & Roger 1991, AJ 101, 1033



Sh2-217

Exciting star:
O9.5 V
(A_V = 2.1 mag.)

Diameter:
11 x 9 pc^2

Distance: 4.2±0.3kpc

Image: Hα + [SII]
OHP, 120-cm

Brand et al. 2010

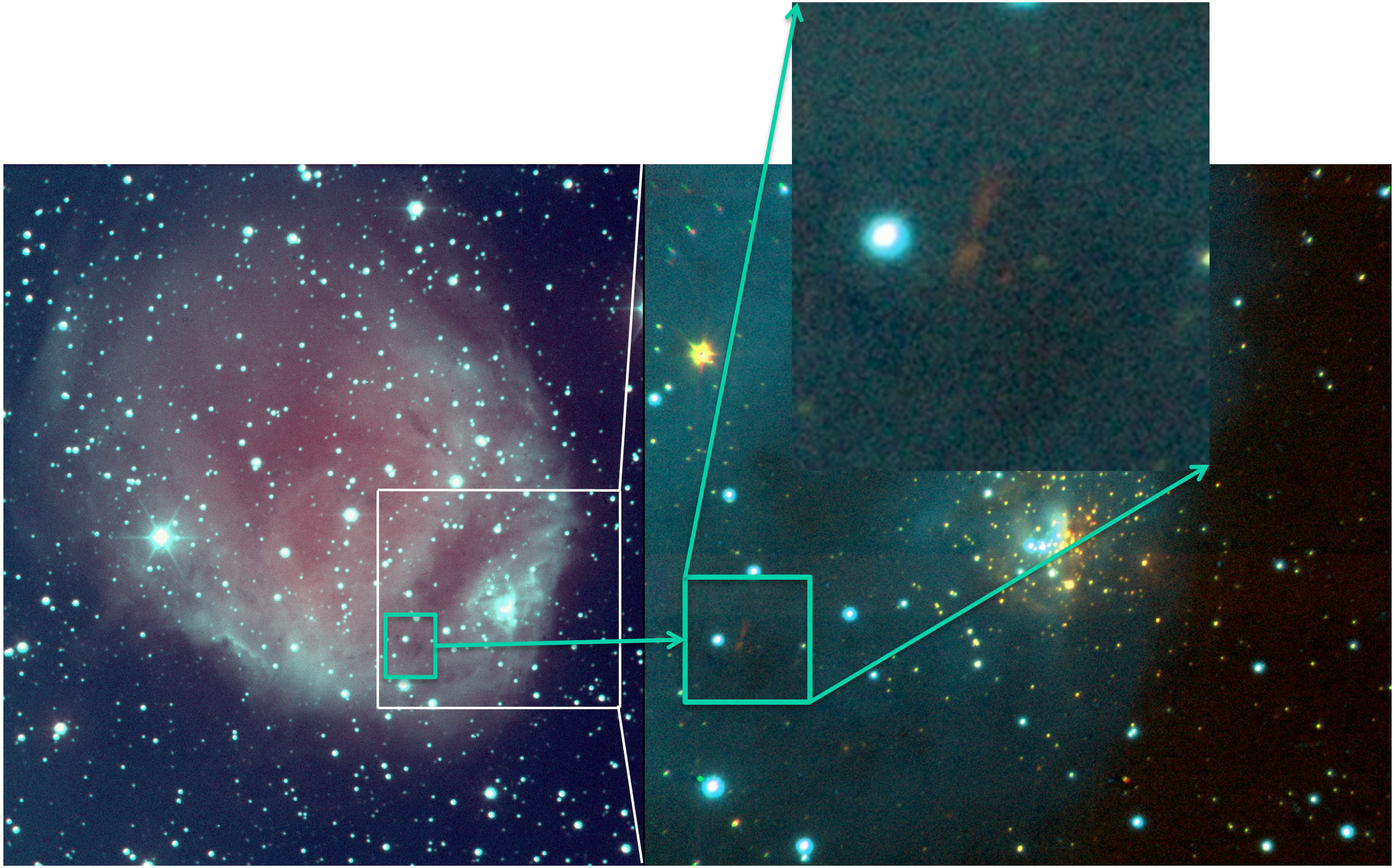


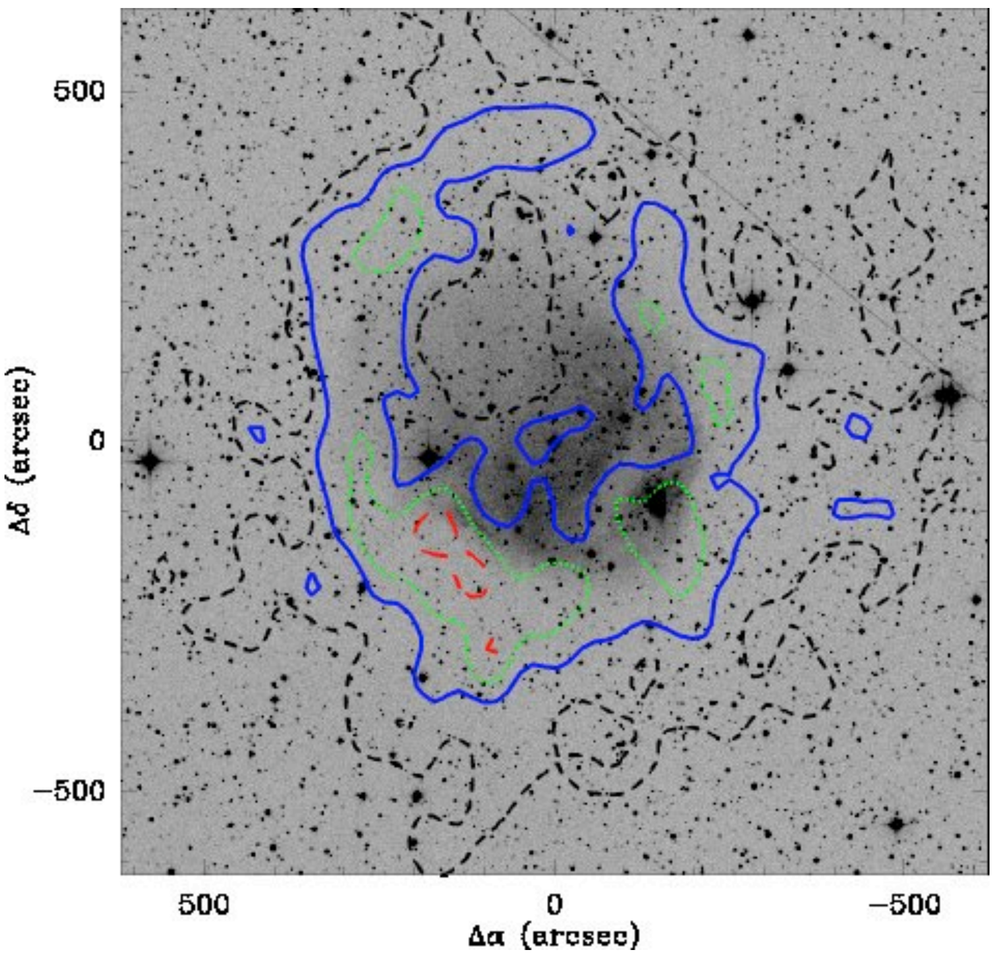
Image: Hα + [SII]
OHP, 120-cm

Image: Hα + H & K
OHP, 120-cm   TNG, 3.6-m

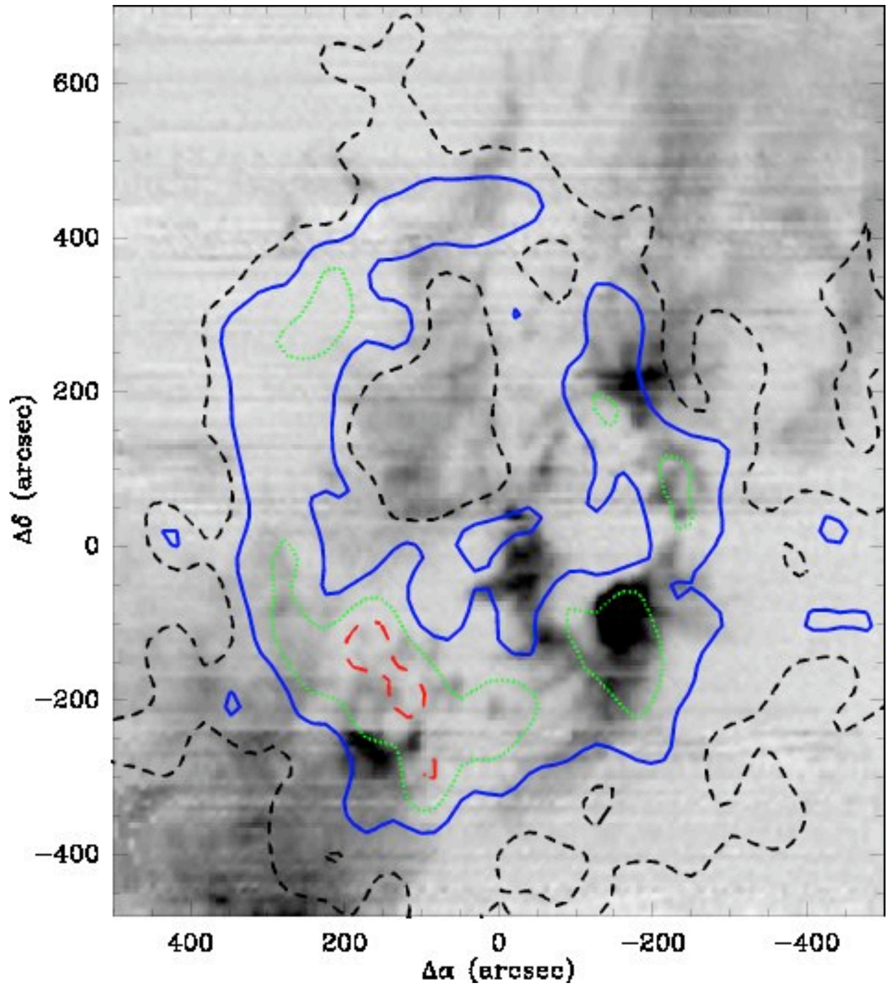
Optical HII region (DSS2)
(greyscale)

CO(2-1) −23 to −15 km/s
(greyscale)

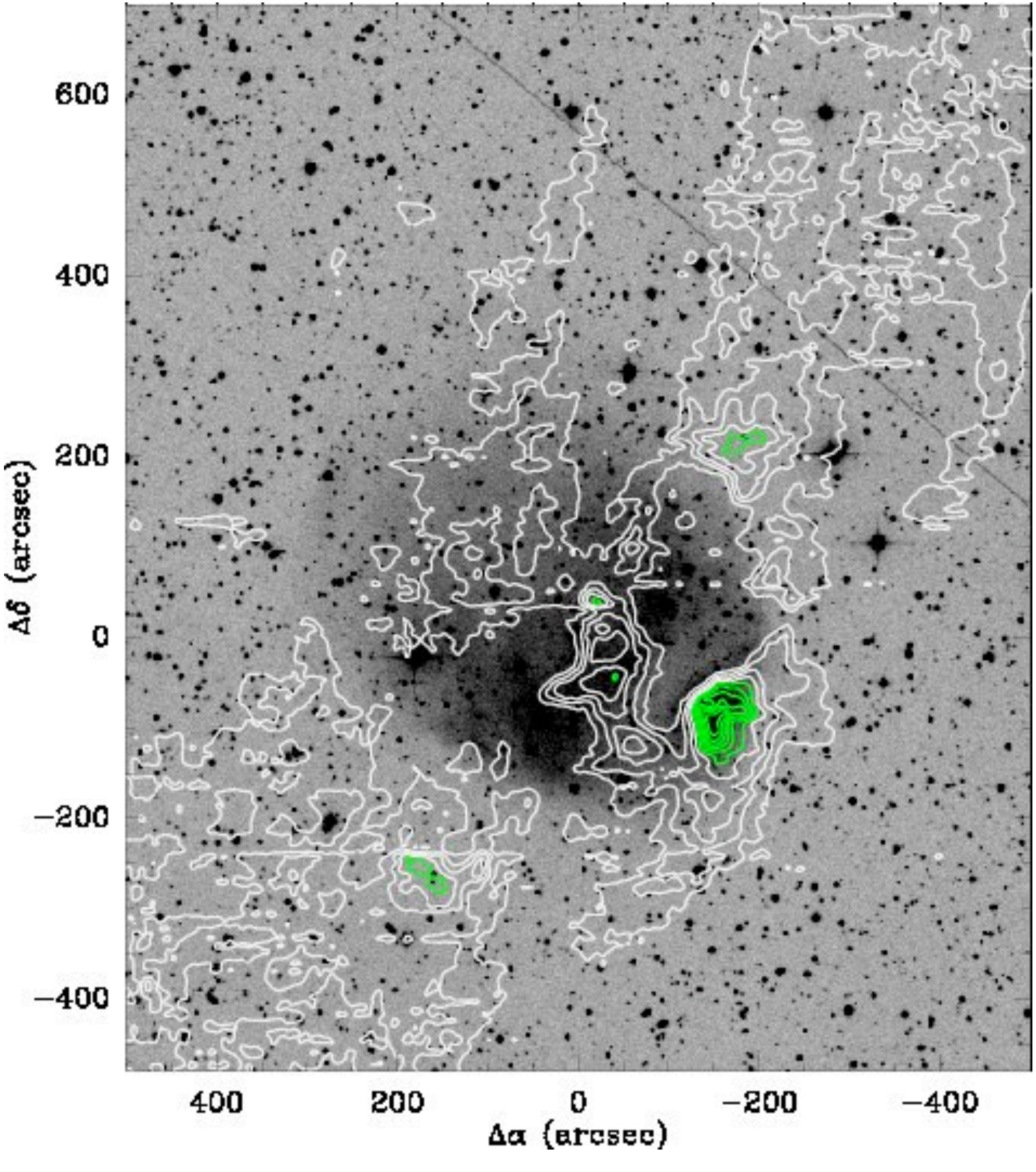
HI: –22.9 to –14.7 km/s; M(HI) = 1.4 × 10^3 $M_\odot$
(contours)



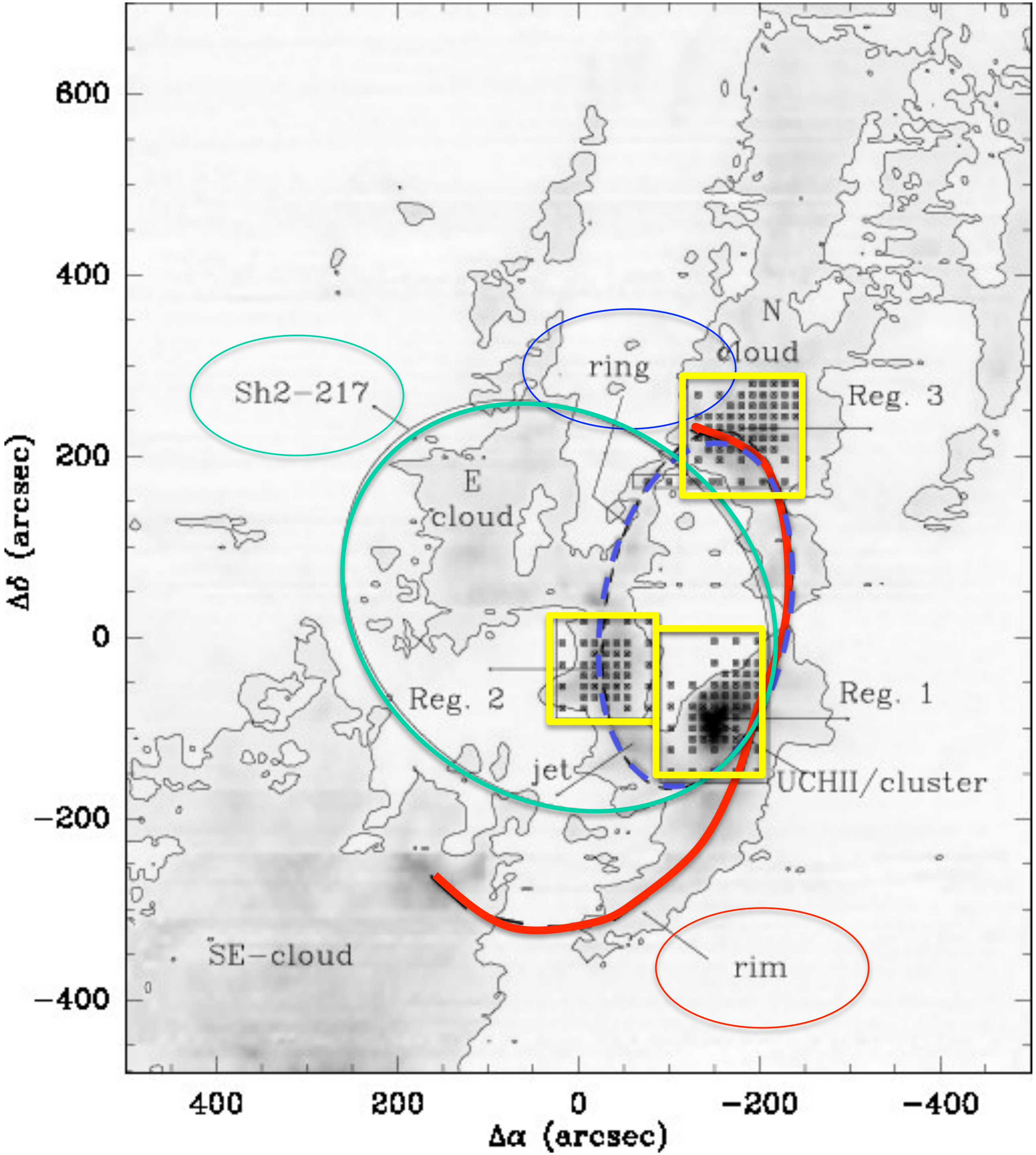
Brand et al. 2010



HI data from CGPS; Taylor et al. 2003



CO(2-1)
−23 to −15 km/s

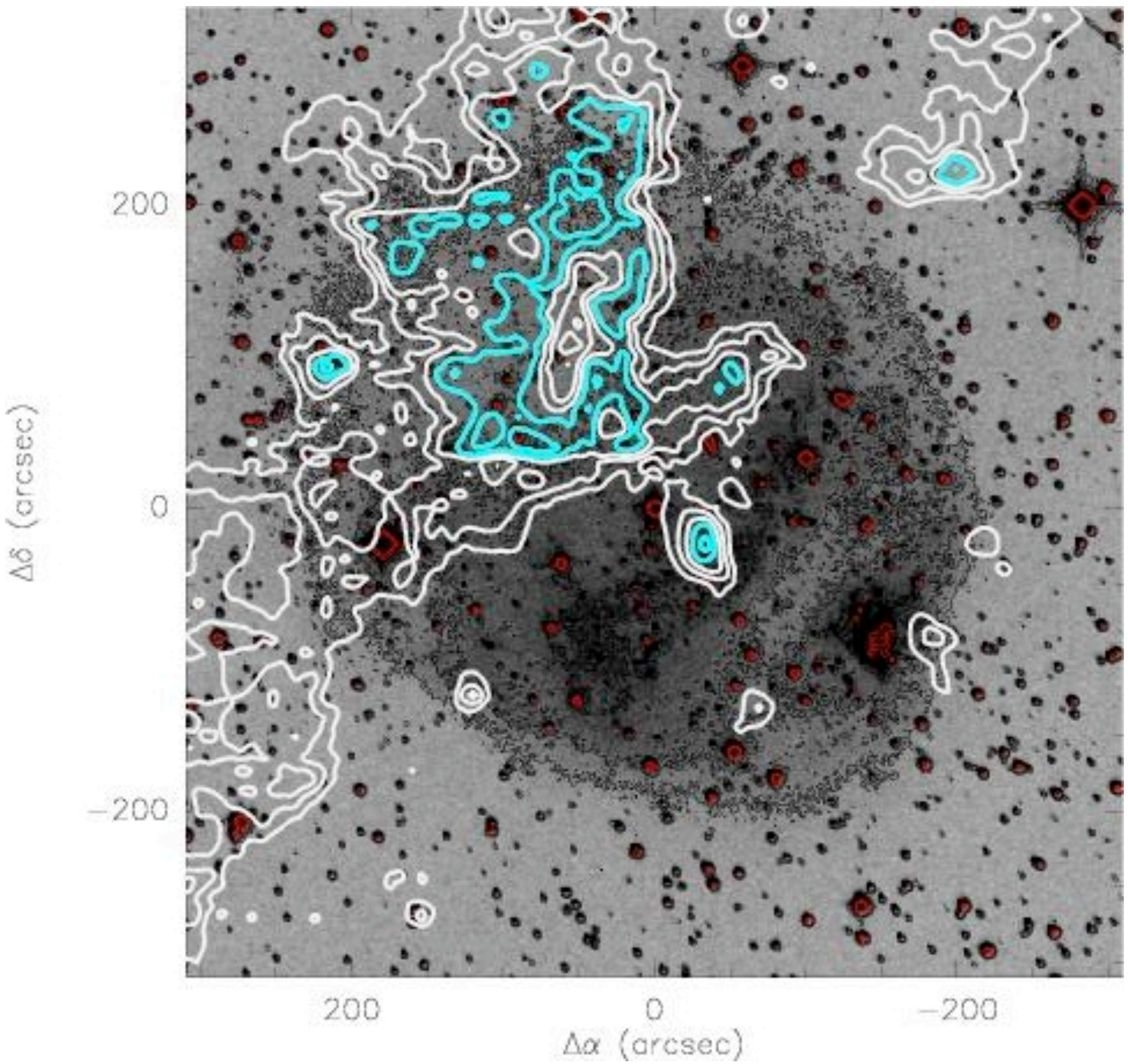


Sh2-217

CO(2-1)
10 Kkm/s contour

Identifying features

EASTERN CLOUD



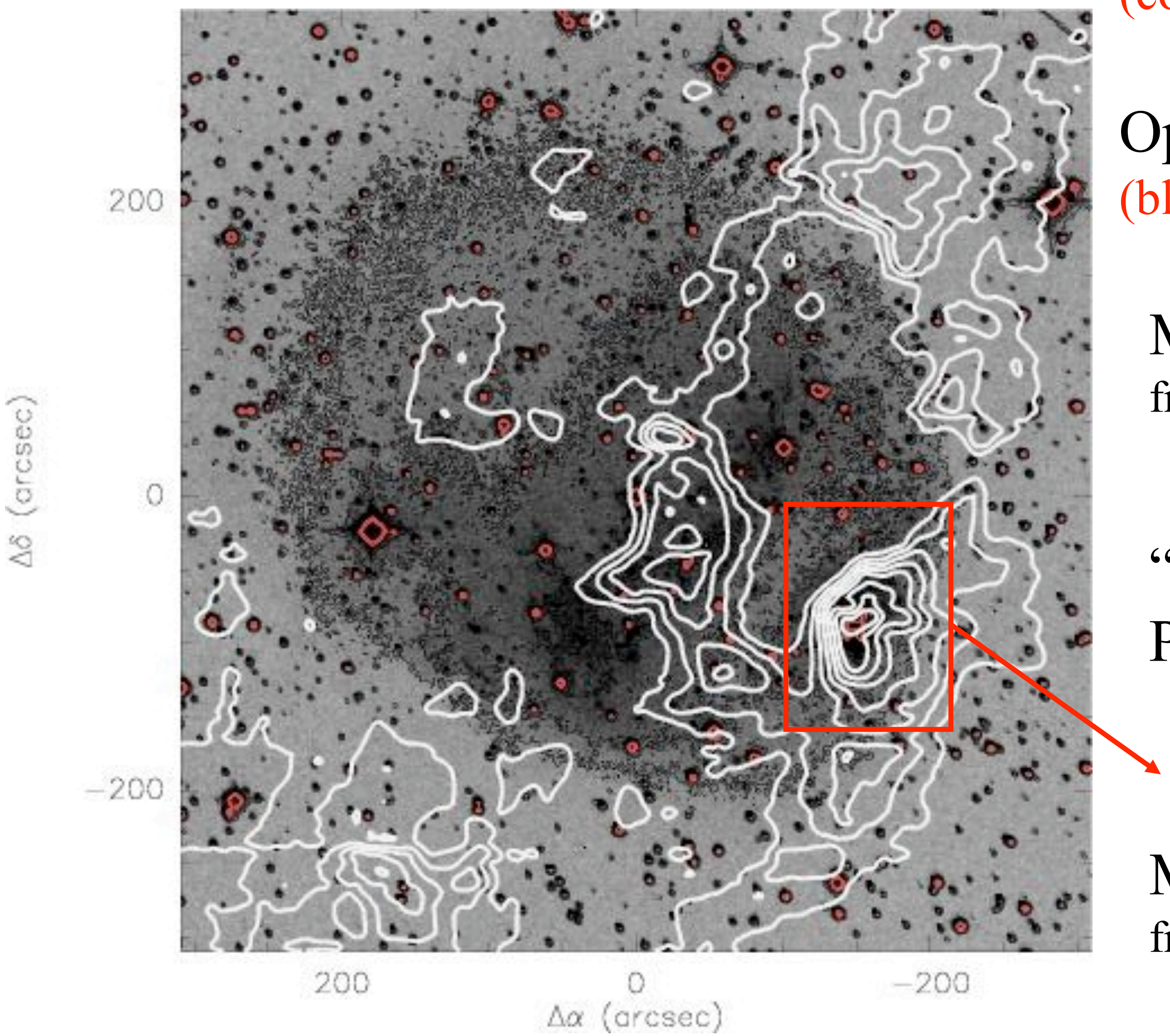
Optical HII region (DSS2)
(black contours)
V(Hα)= −20.4 km/s

CO(2-1): –22 to –21 km/s;
(coloured contours)

M = 1.5 × 10^3 $M_\odot$
from $^{12}CO(2\text{-}1)$

Eastern cloud
probably foreground

RING CLOUD



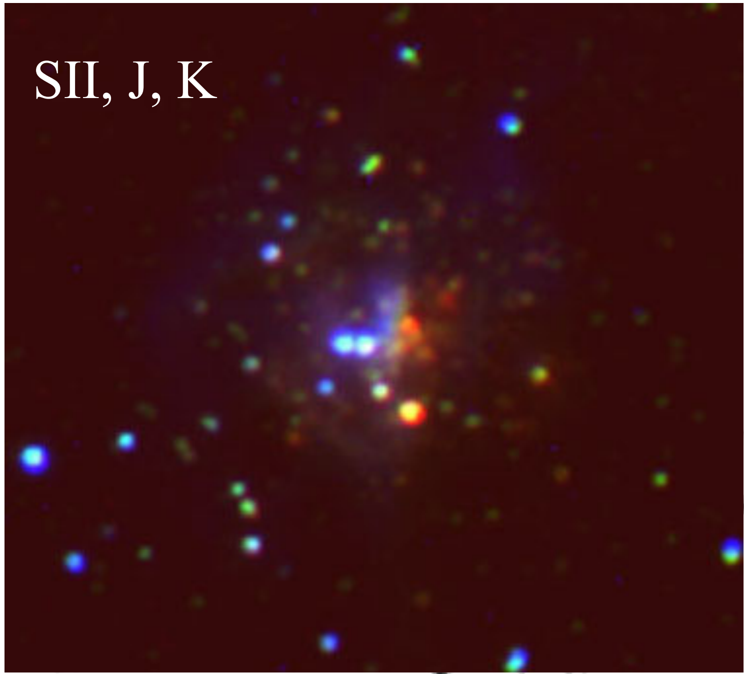
CO(2-1): –21 to –16 km/s
(coloured contours)

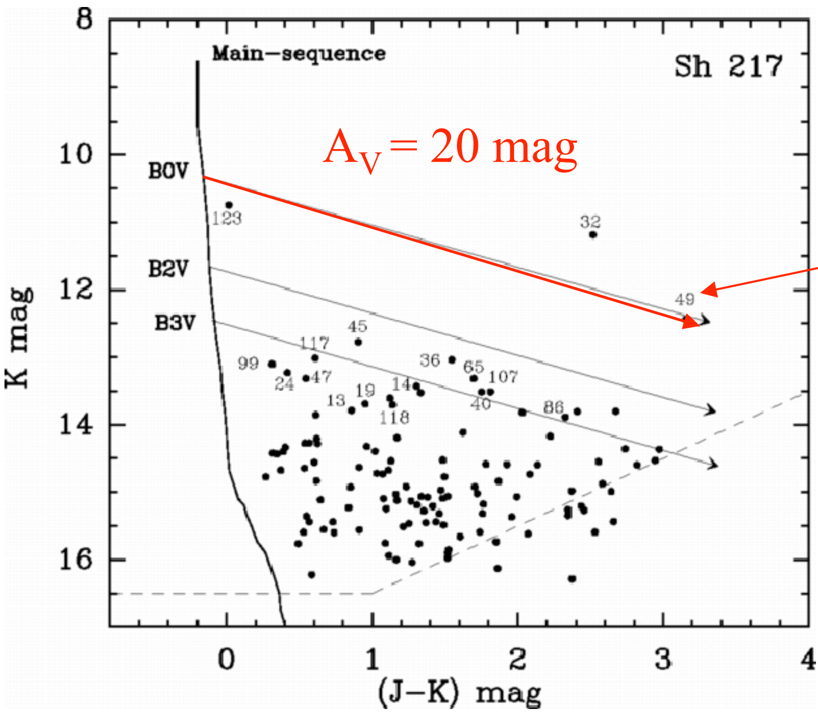
Optical HII region
(black contours)

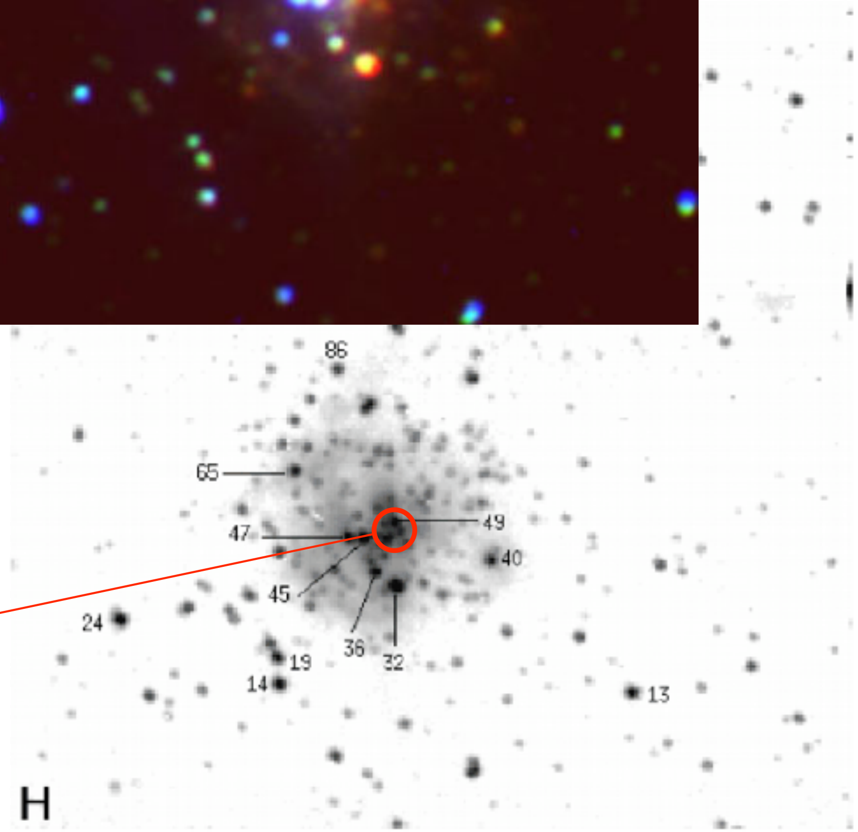
$M_{ring} = 5.8 \times 10^3\ M_{\odot}$
from $^{12}CO(2\text{-}1)$

“Ring” clumps
Probably background

$M_{clump} = 1.1 \times 10^3\ M_{\odot}$
from $^{12}CO(2\text{-}1)$, $^{13}CO(1\text{-}0)$,







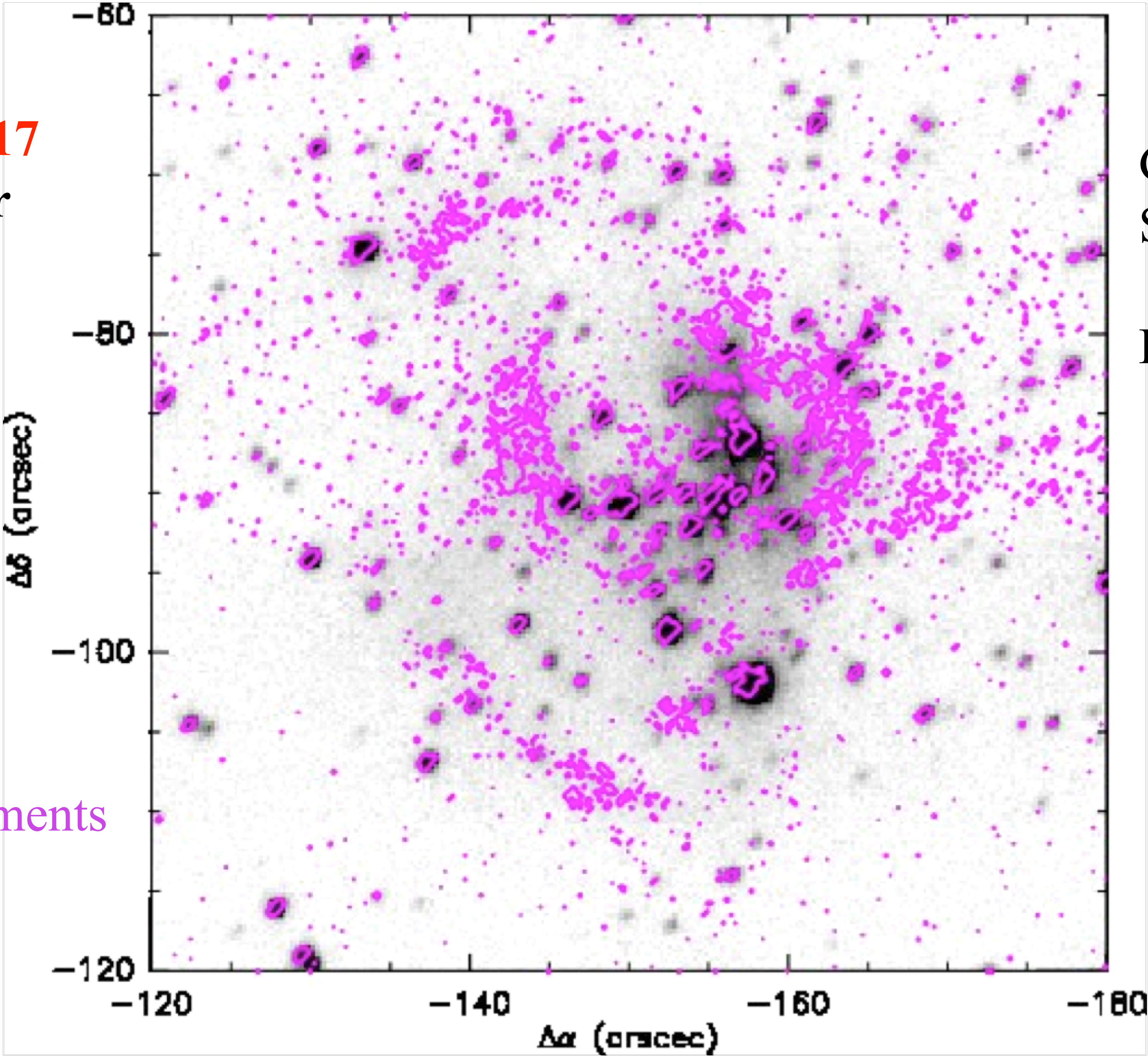
JHK for 121 stars; 90% within r=1.1 pc.

Star 49: B0V, A_V = 19.1 mag

Age ≤ 1 Myr

Deharveng et al. 2003; Brand et al. 2010

Sh2-217
cluster

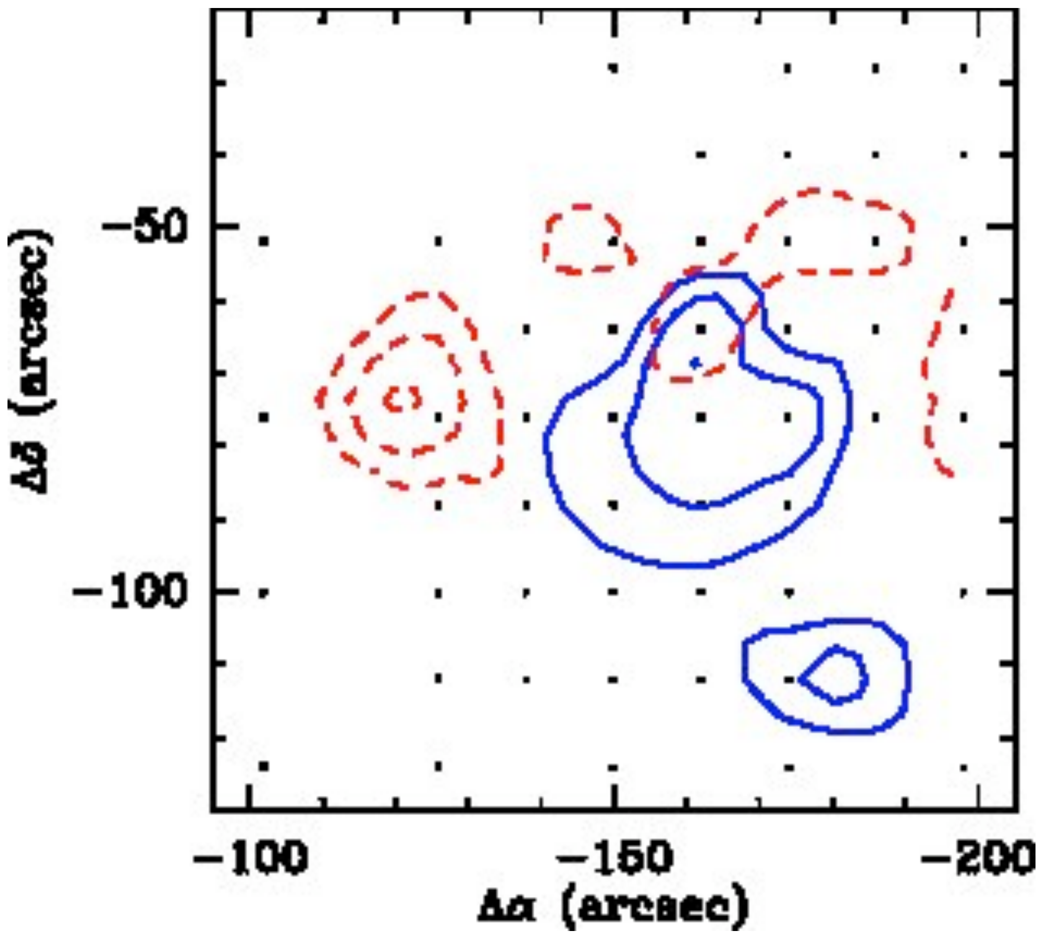


Grey-
Scale:

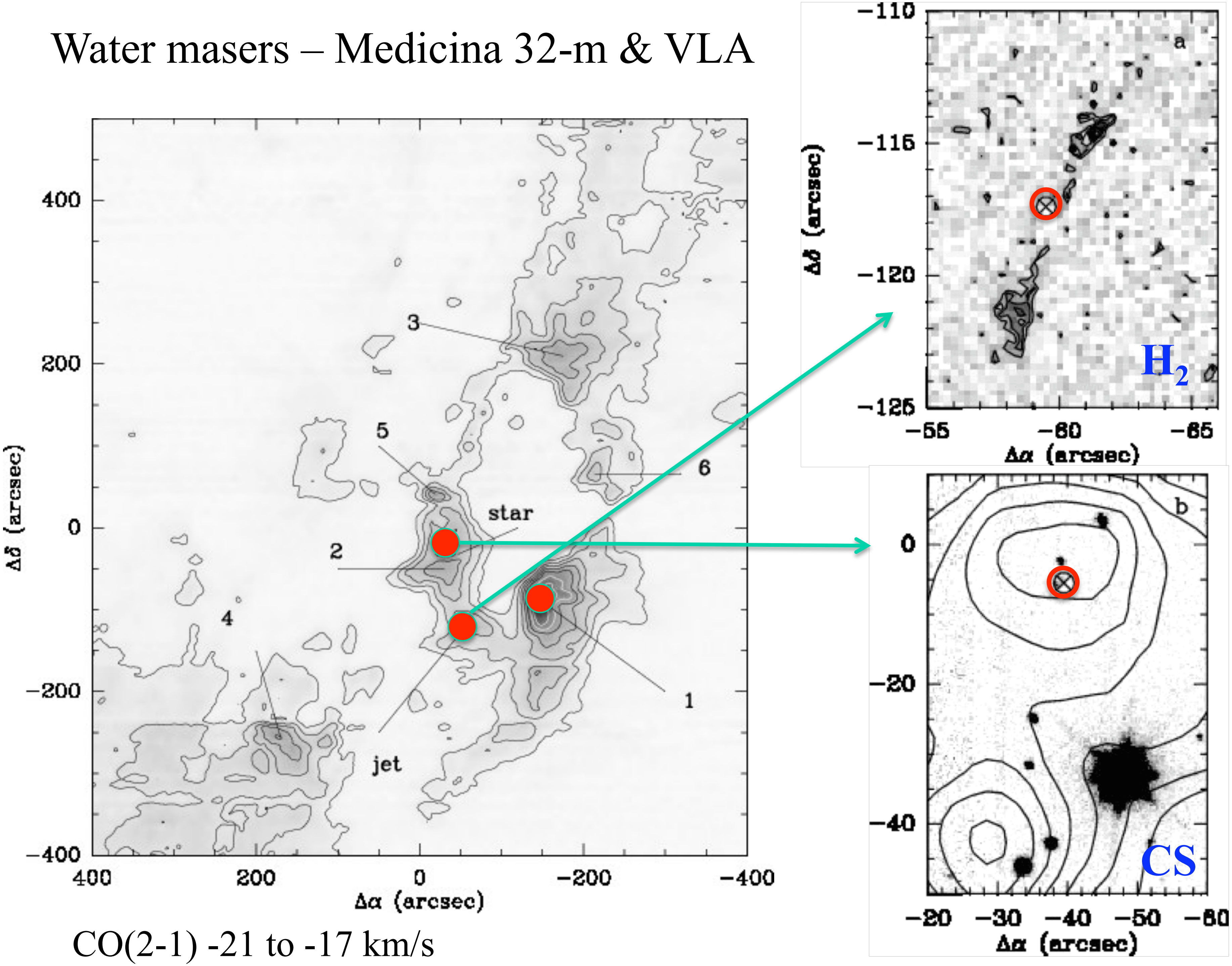
K'-band

H_2 filaments

Sh2-217: Integrated residual $^{13}CO(1-0)$ in cluster region

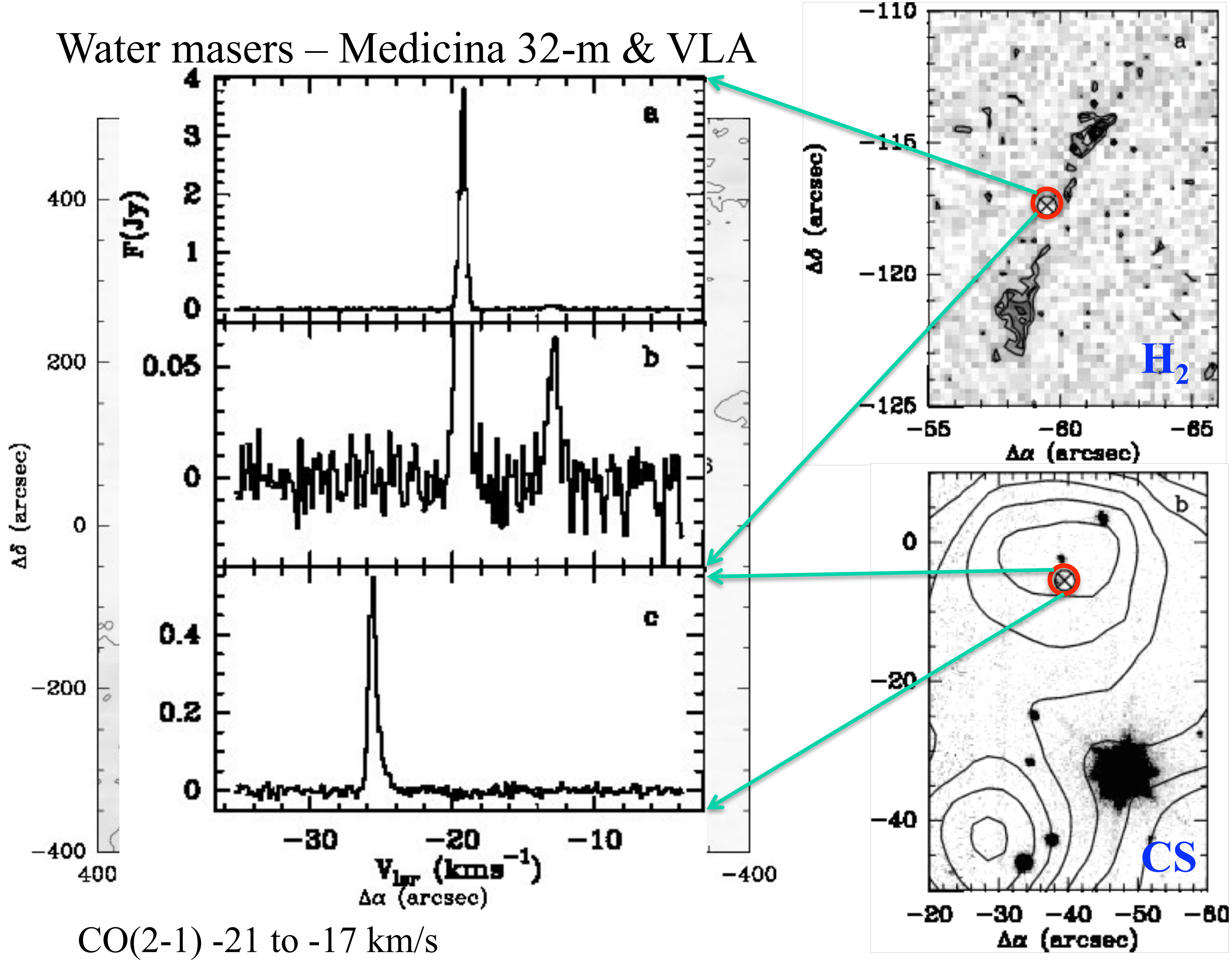


Water masers – Medicina 32-m & VLA



CO(2-1) -21 to -17 km/s

Water masers – Medicina 32-m & VLA



CO(2-1) -21 to -17 km/s

Application Whitworth et al. 1994 model on Sh2-217

Results

Dynamical age Sh2-217 (n_{init}=2000 cm^{-3}): 4 Myrs
Onset fragmentation: 0.9 – 1.2 Myrs ago (≈ age cluster)
Mass of fragments: 600 – 1200 M_o
Dynamical age UCHII: 0.3 – 0.5 Myrs (n_{init}=2000 - 5000 cm^{-3})

Hence: Age Sh2-217 ≥ Age UCHII + age cluster
Collect & collapse mechanism may be at work here

Sh2-219

d = 5.0 ± 0.8 kpc

Exciting star:
O9.5 V

Image: Hα + [SII]

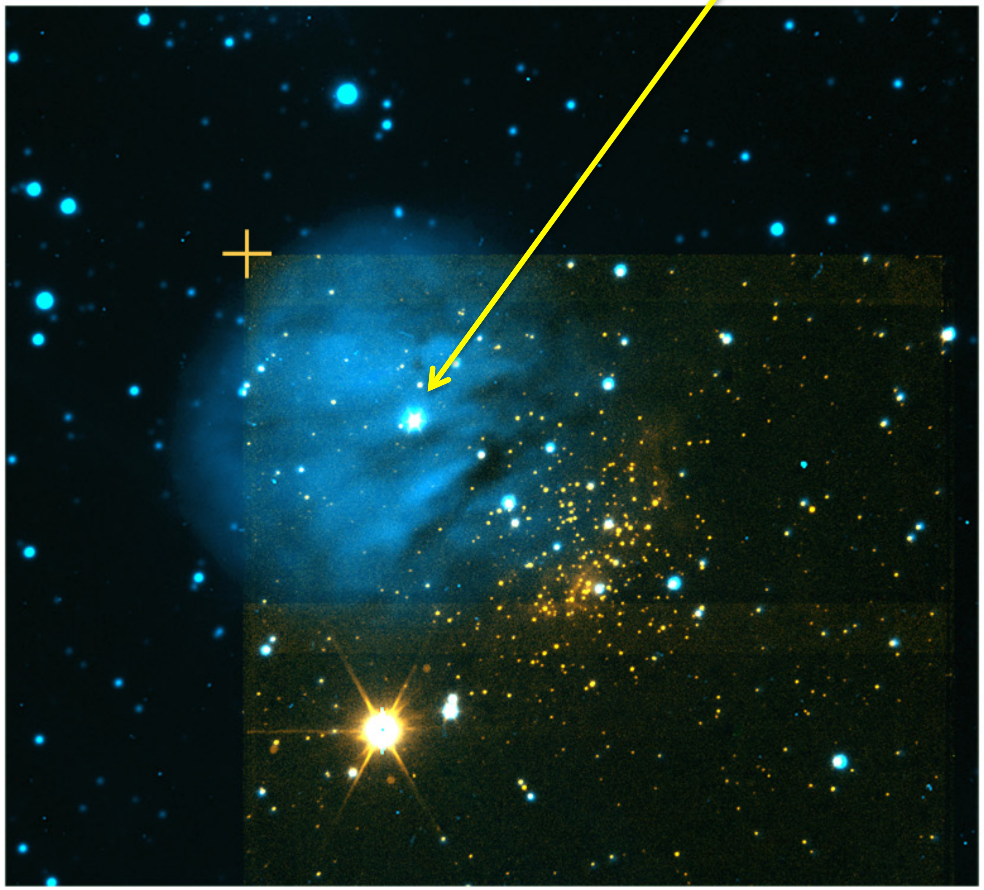


Image: Hα + H&K

Deharveng et al. 2006

Sh2-219

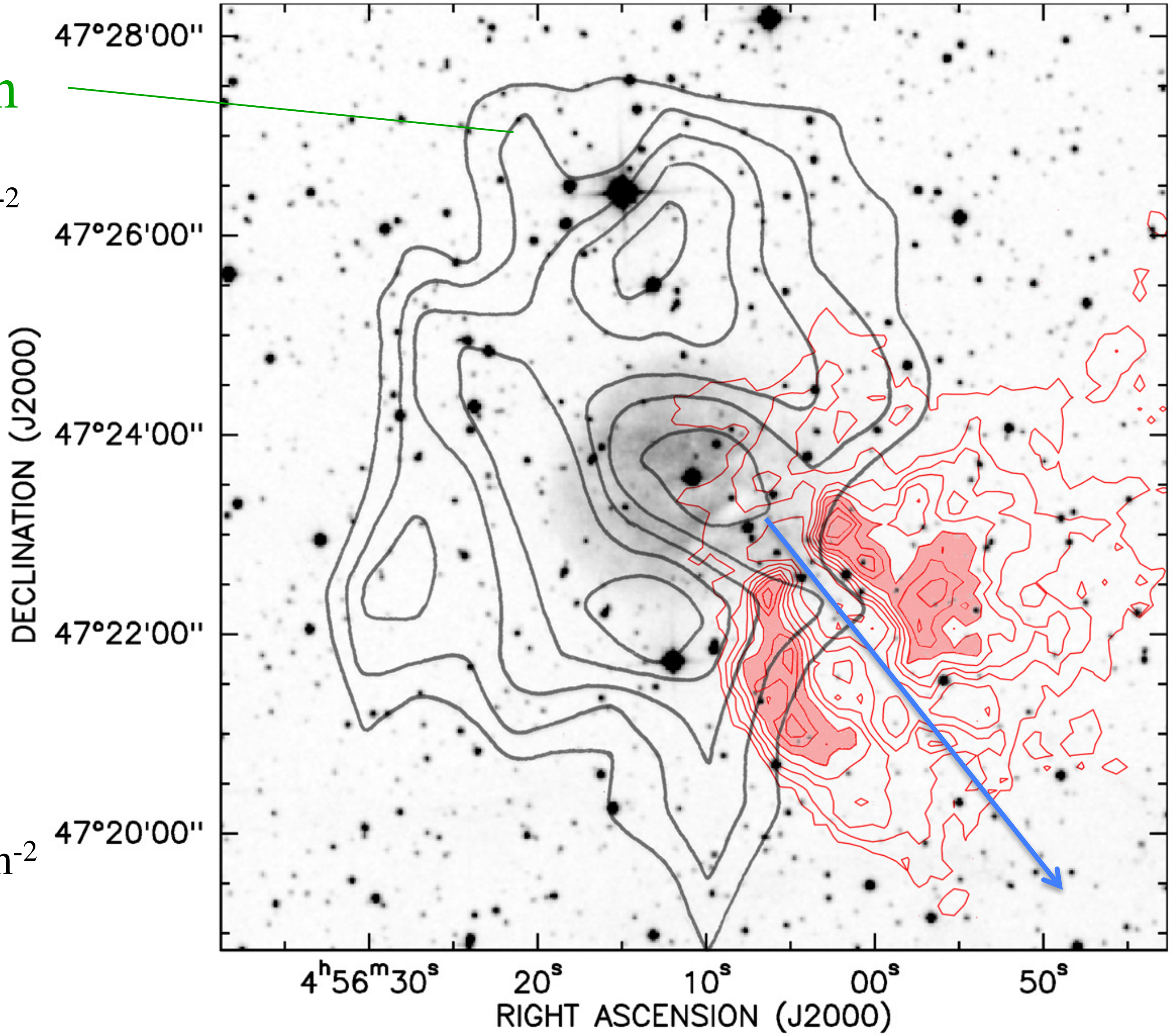
HI emission

M(HI) = 97 Mo

N(HI)peak = 1.8 10^{20} cm^{-2}

n(HI) = 9 cm^{-3}

Roger & Leahy 1993



CO emission

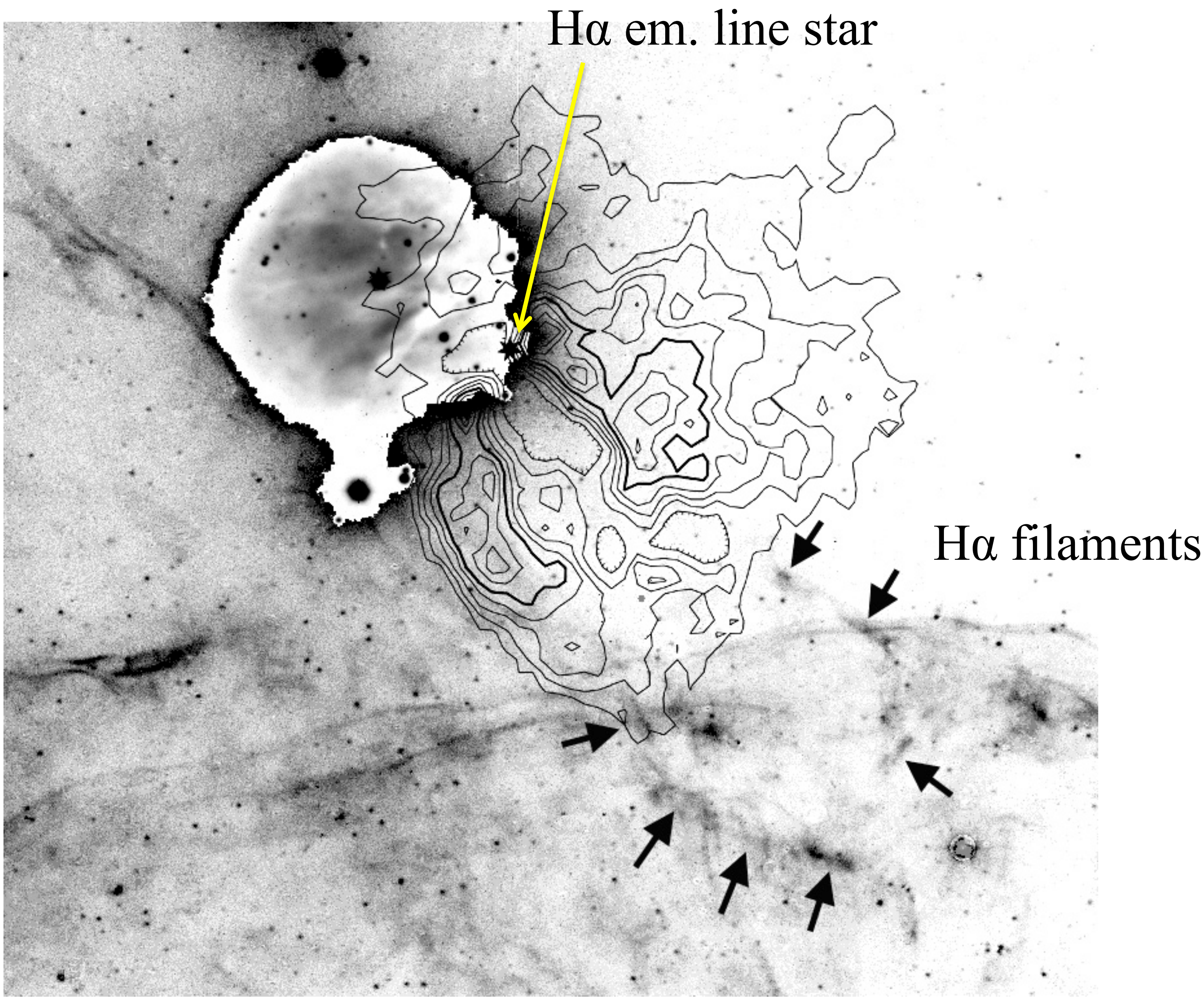
M = 2.1×10^3 Mo

$N(H_2)$peak = 1.0 10^{21} cm^{-2}

$n(H_2) = 8 \times 10^3$ cm^{-3}

Cavity 7.5 pc x 1 pc

Sh2-219

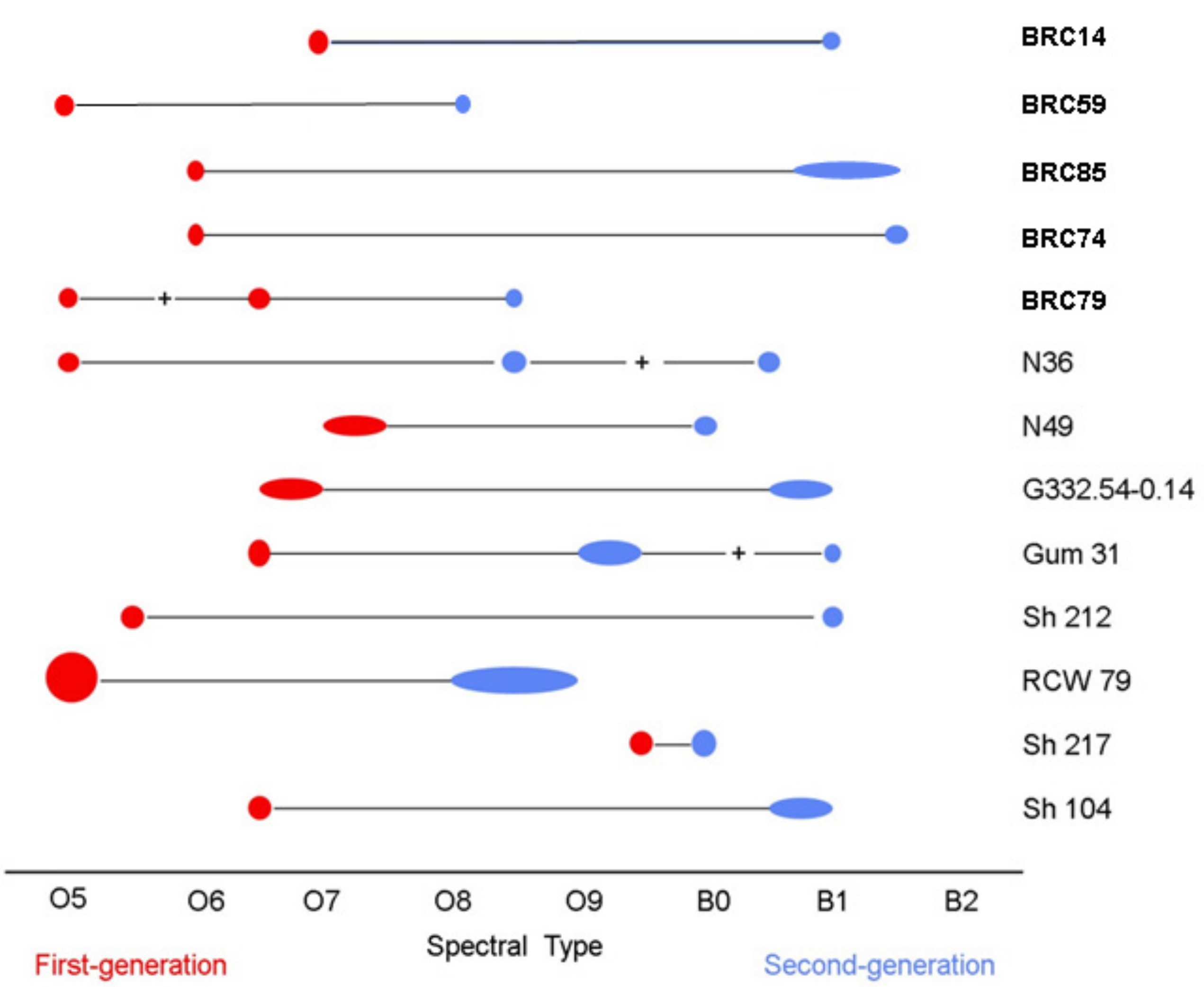


Deharveng et al. 2006

Likely SF in pre-existing clump

Can massive stars form via triggering by HII regions?   YES

Deharveng & Zavagno
2010, IAU270



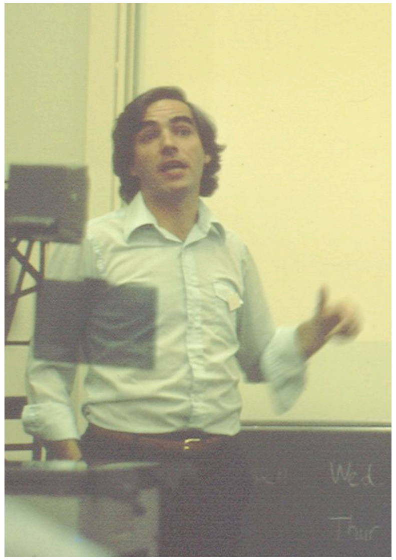
Morgan et al. 2004
Thompson et al. 2004
Thompson et al. 2004
Thompson et al. 2004
Thompson et al. 2004
Kantharia et al. 2007
Deharveng et al. 2010
Deharveng et al. in preparation
Cappa et al. 2008
Deharveng et al 2008
Zavagno et al. 2006
Brand et al. 2010
Deharveng et al. 2003

- ❑ The second-generation massive stars are less massive than the first-generation ones . Not predicted by the model of collect & collapse

- ❑ No second -generation star more massive than O8V   Look around larger bubbles?

All these objects need a distance…

Epilogue….how it began



1982

Leo & The Galactic Rotation Curve

Mike Fich, Tony Stark, Jan Wouterloot, Jan Brand


SIMON EPISCOPIUS, AMST. BATAV.
IOHANNES POLIANDER A KERCHOVE METENS.

Astron. Astrophys. 275, 67–90 (1993)

ASTRONOMY AND ASTROPHYSICS

The velocity field of the outer Galaxy*

J. Brand[1,2] **and L. Blitz**[3]

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[2] Istituto di Radioastronomia, CNR Via Irnerio 46, I-40126 Bologna, Italy
[3] Astronomy Department, University of Maryland College Park, MD 20742, USA

Received August 11, 1992; accepted February 11, 1993

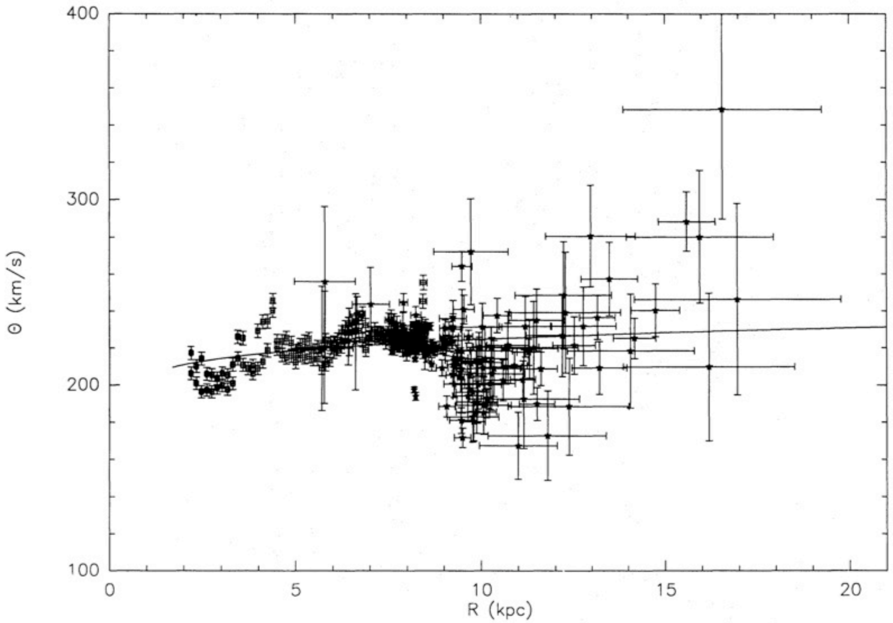

Fig 4b. As Fig. 3, but with error bars added. Errors in Θ are the result of those in ω and R

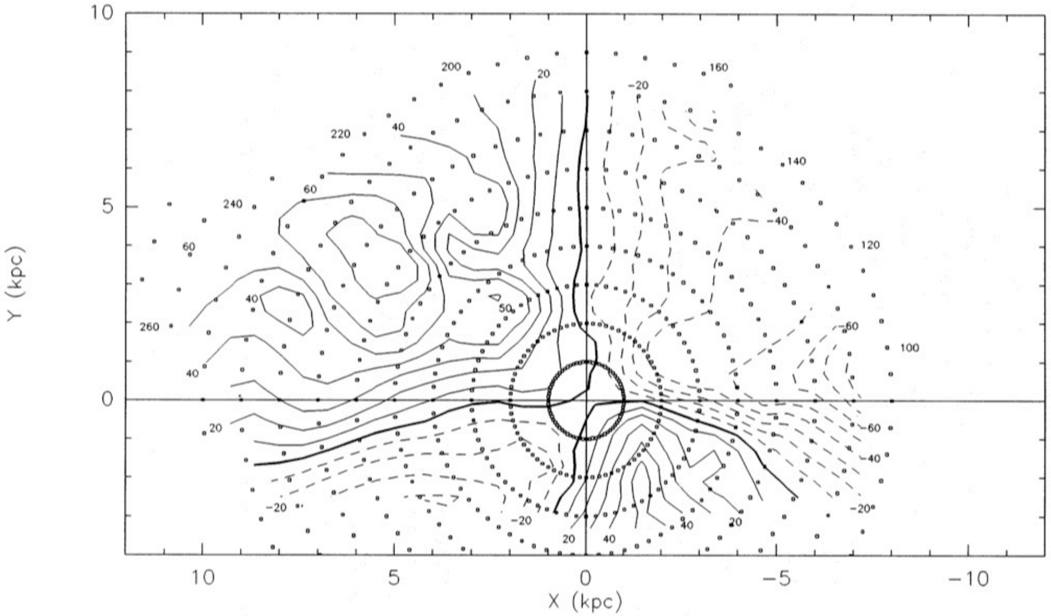

Fig. 2b. As Fig. 2a, but a grid has been superimposed, in which for every 5° in longitude distances have been marked every kiloparsec. This allows easier determination of kinematic distances for various combinations of longitude and velocity

Astron. Astrophys. 275, 67–90 (1993)

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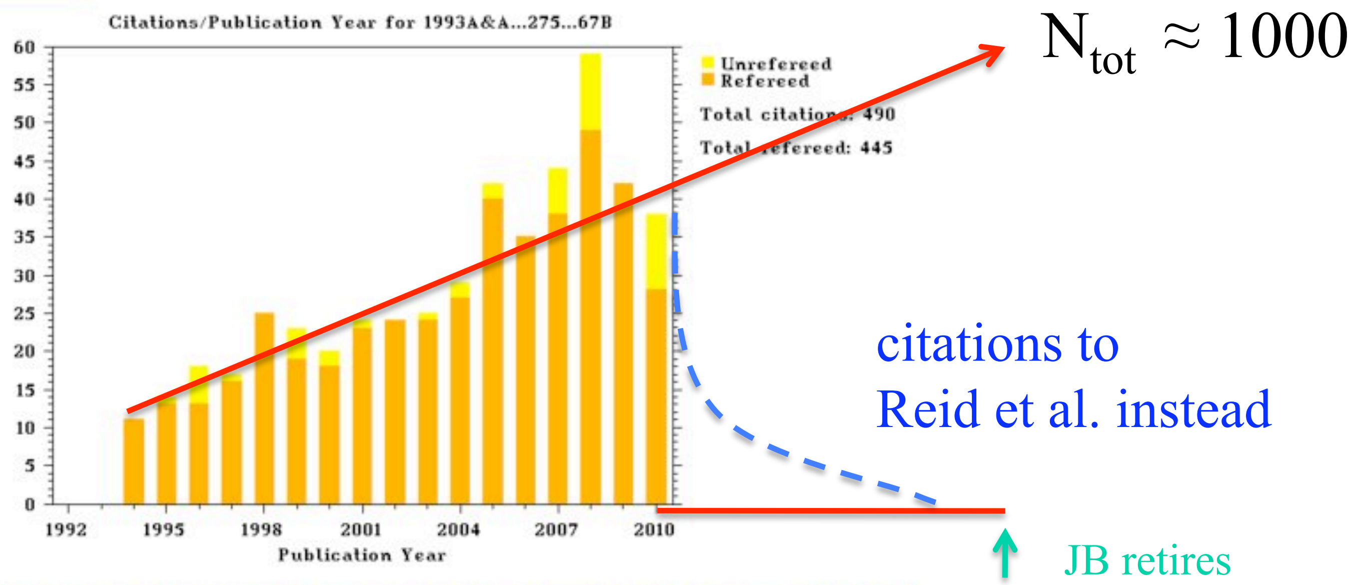

What would Leo do?

Then:

Do the exact opposite…..

Do likewise…..

Looking for Giant Molecular Clouds (GMCs) ?

Thank you, Leo!

Grazie 1003, Commendatore!