Wind Driven vs Pressure Driven Bubbles

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G28.83-0.25 (N49)
8(R), 4.5(G), 3.6(B) μm

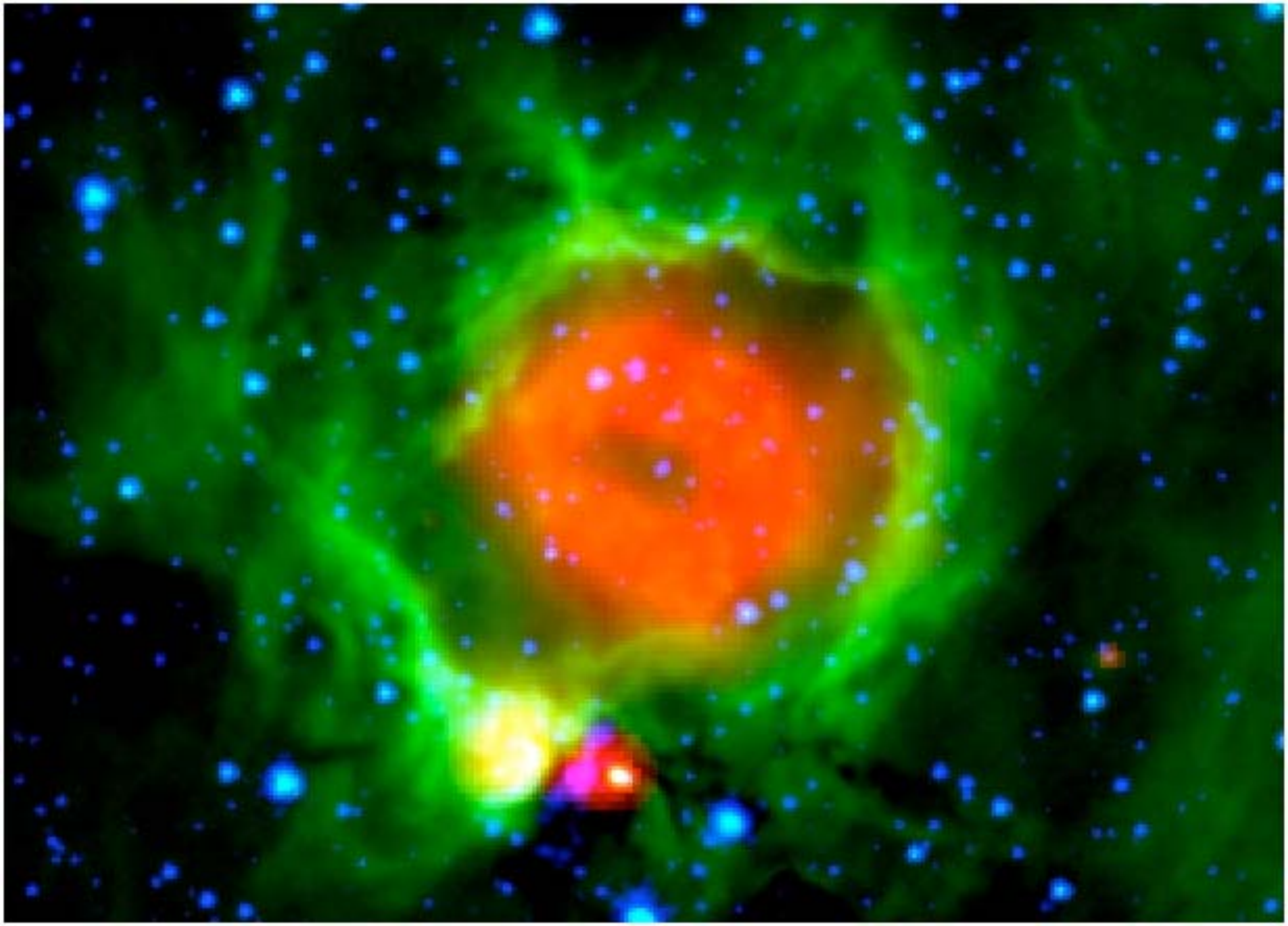
D=5.7±0.6 kpc

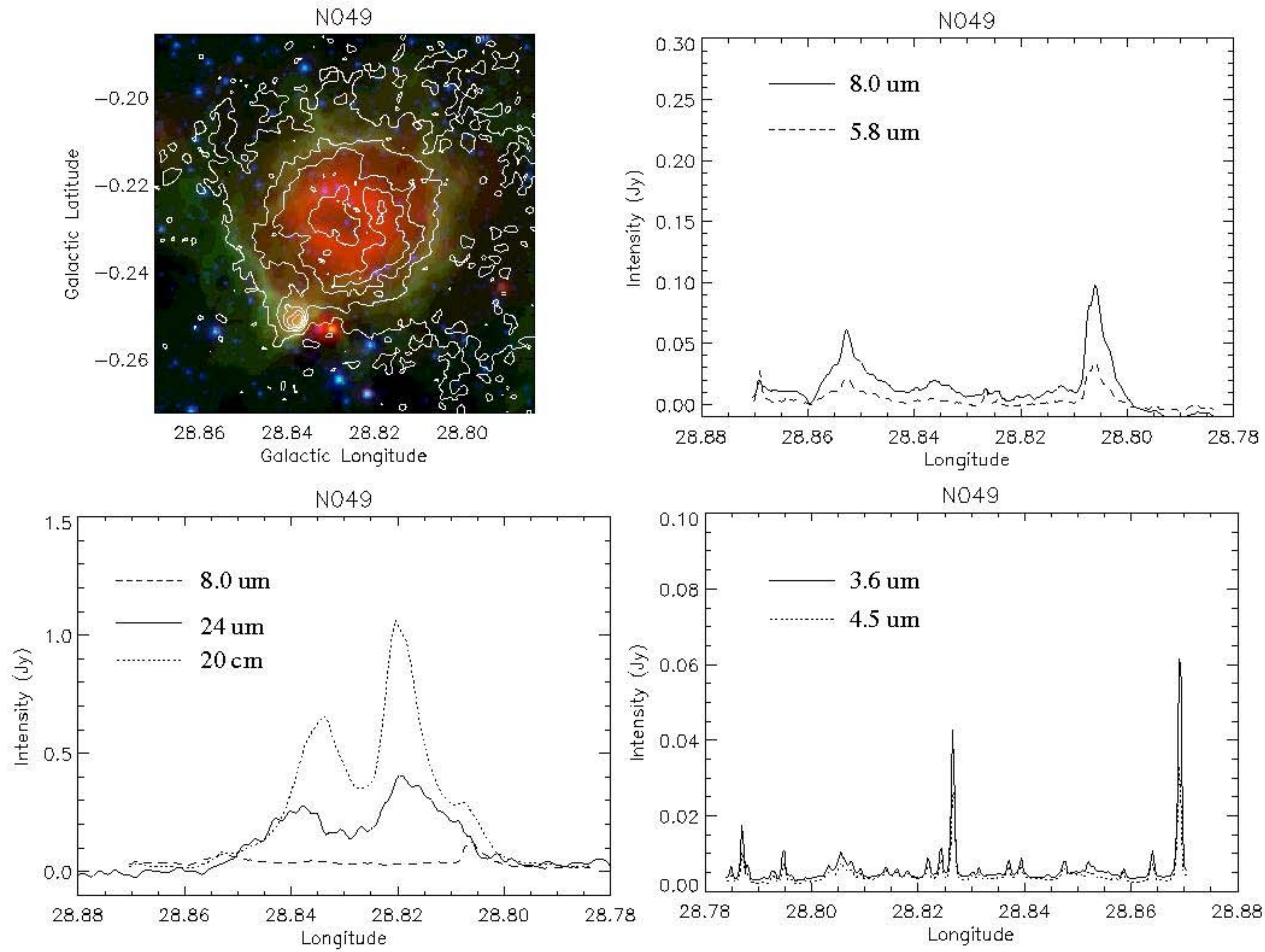
$N_{UV} \geq 7.8 \times 10^{48}\ s^{-1}$

=>O6V or hotter

Diam~5 pc

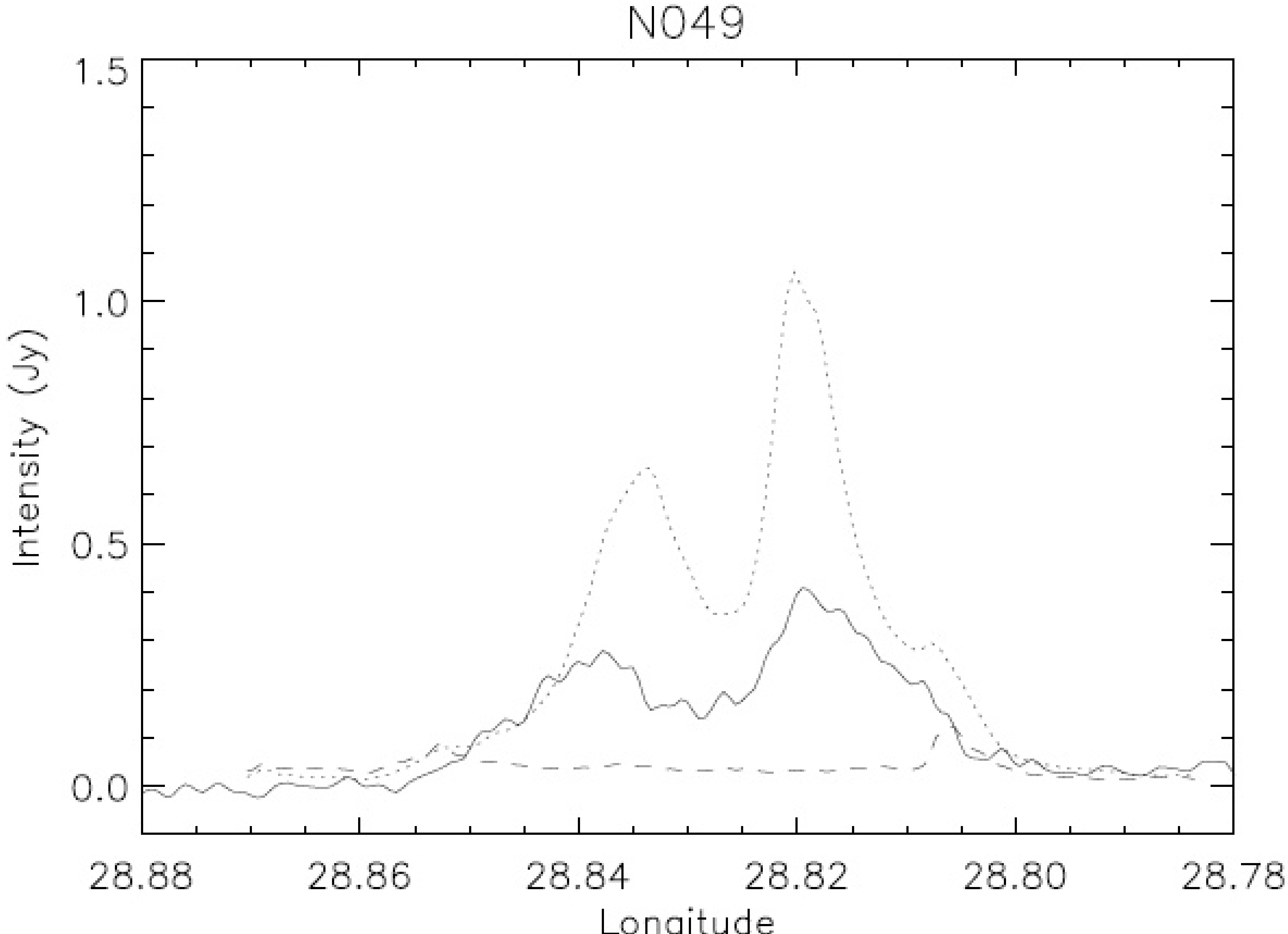
N49 (4.5, 8.0, 24μm)



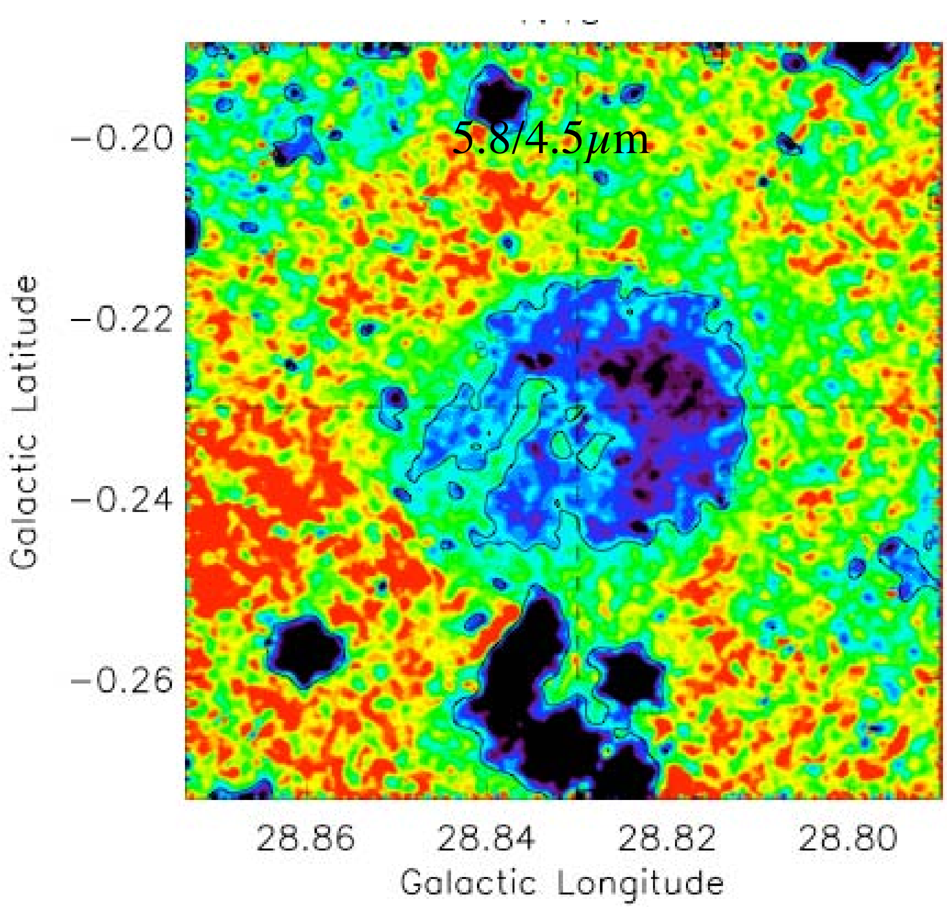


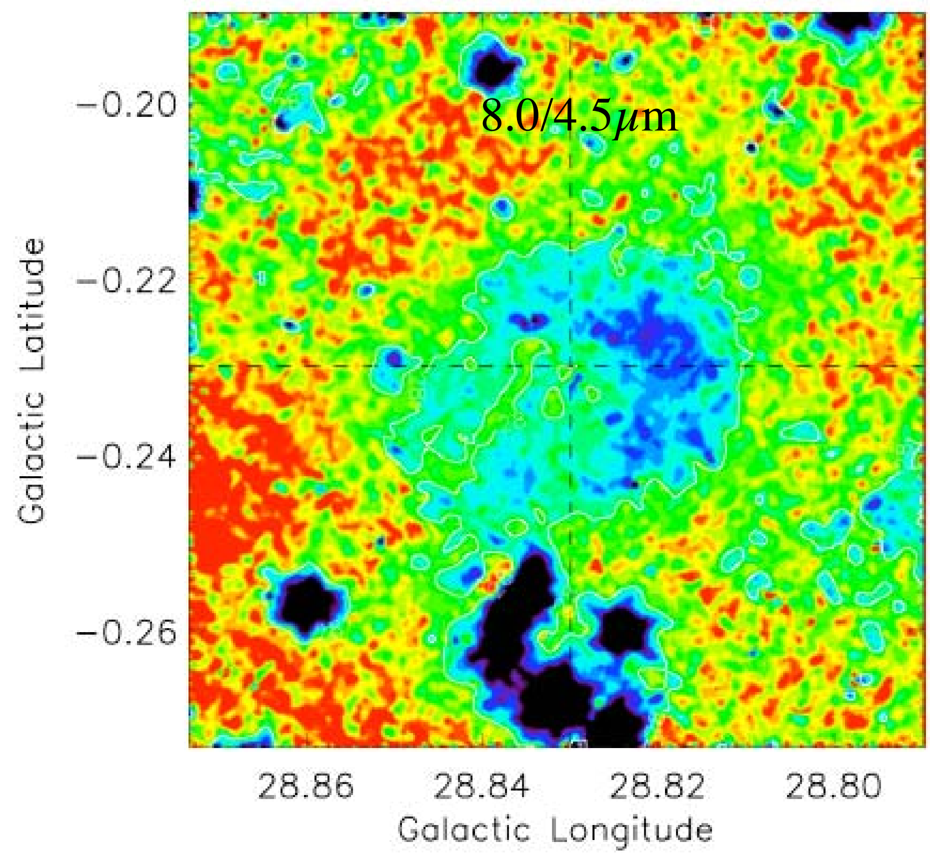
N049
Galactic Latitude
Galactic Longitude
−0.20
−0.22
−0.24
−0.26
28.86
28.84
28.82
28.80
N049
Intensity (Jy)
Longitude
8.0 um
5.8 um
N049
Intensity (Jy)
Longitude
8.0 um
24 um
20 cm
N049
Intensity (Jy)
Longitude
3.6 um
4.5 um

N49 8μm(dashed), 24μm(dotted), 20cm(solid x100)



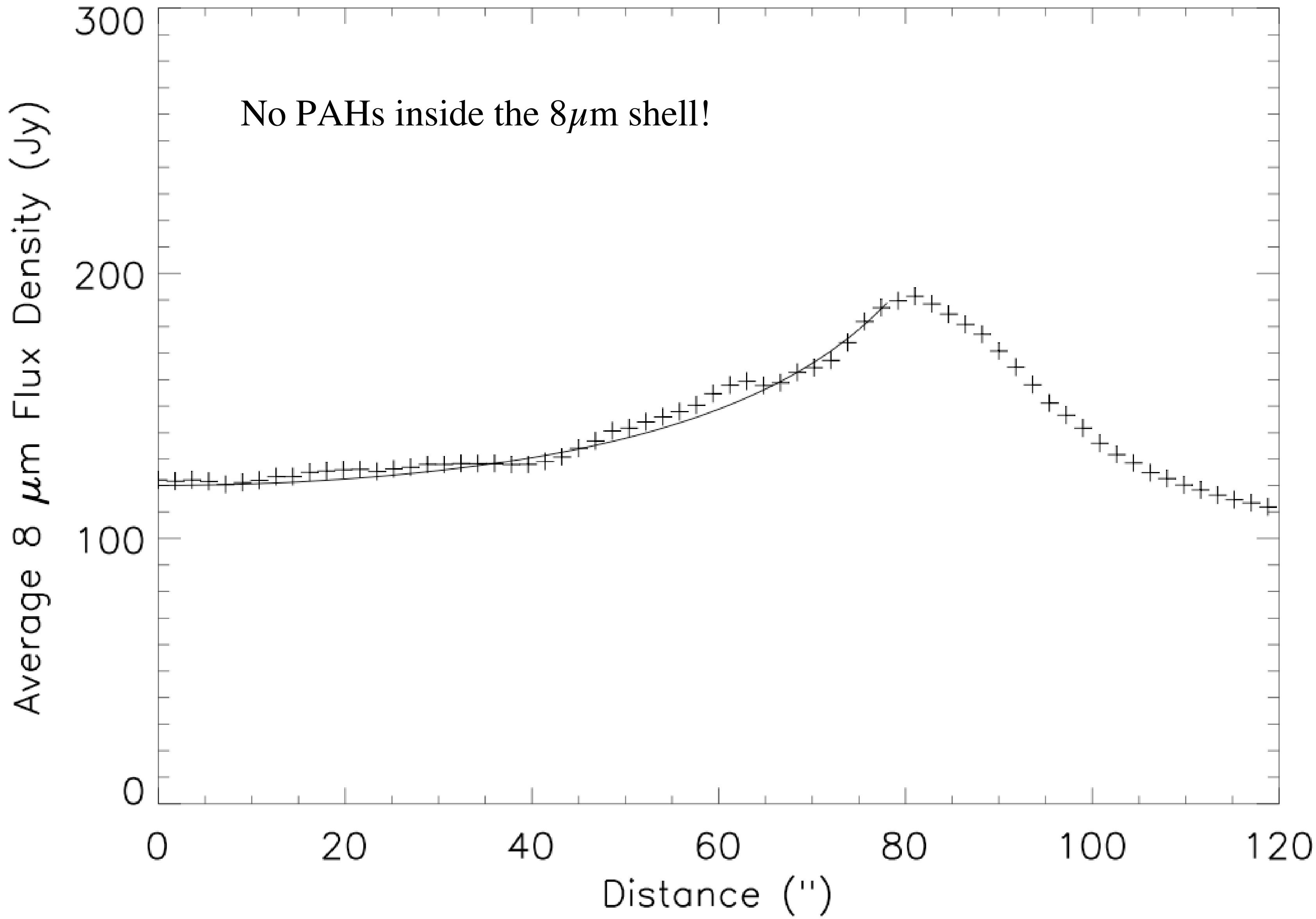
N49: PAH Destruction Radius





Ang. Diameter ~0.03^0 @ 5.7 kpc => R~1.5 pc

N49: 8μm Observations Azimuthally averaged (+);
Model of 8μm Shell Emission (solid curve)



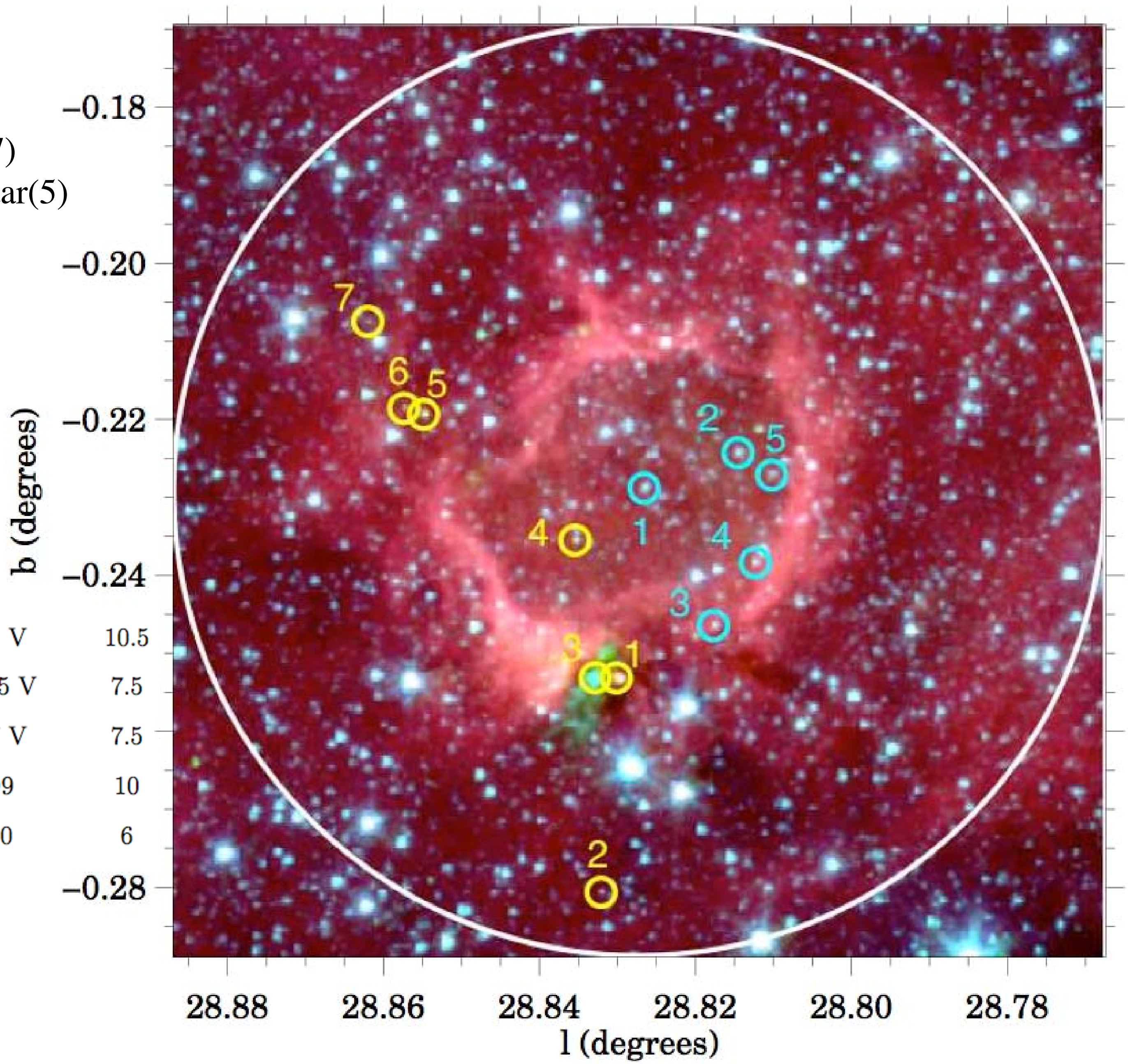
N49: Candidate YSOs & Ionizing Stars

Yellow: candidate YSOs (7)
Cyan: candidate ionizing star(5)

Within circle (R=6pc)
722 stars analyzed

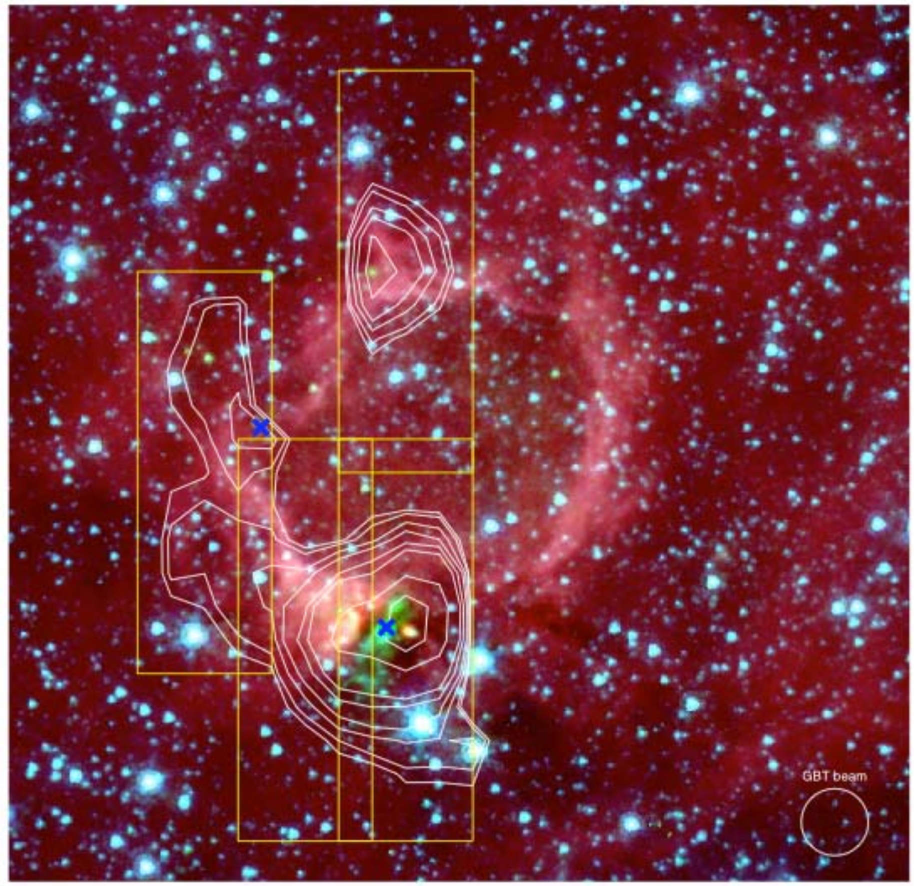
IR Model Predictions

IN49-1	28.8263-00.2287	O5 V	10.5
IN49-2	28.8142-00.2241	O5.5 V	7.5
IN49-3	28.8174-00.2464	O7 V	7.5
IN49-4	28.8119-00.2383	O9	10
IN49-5	28.8098-00.2270	B0	6



A Partial Image of $NH_3(1,1)$ Distribution Around N49

In all regions where NH_3 has been searched, dense molecular gas has been detected around the periphery of N49.

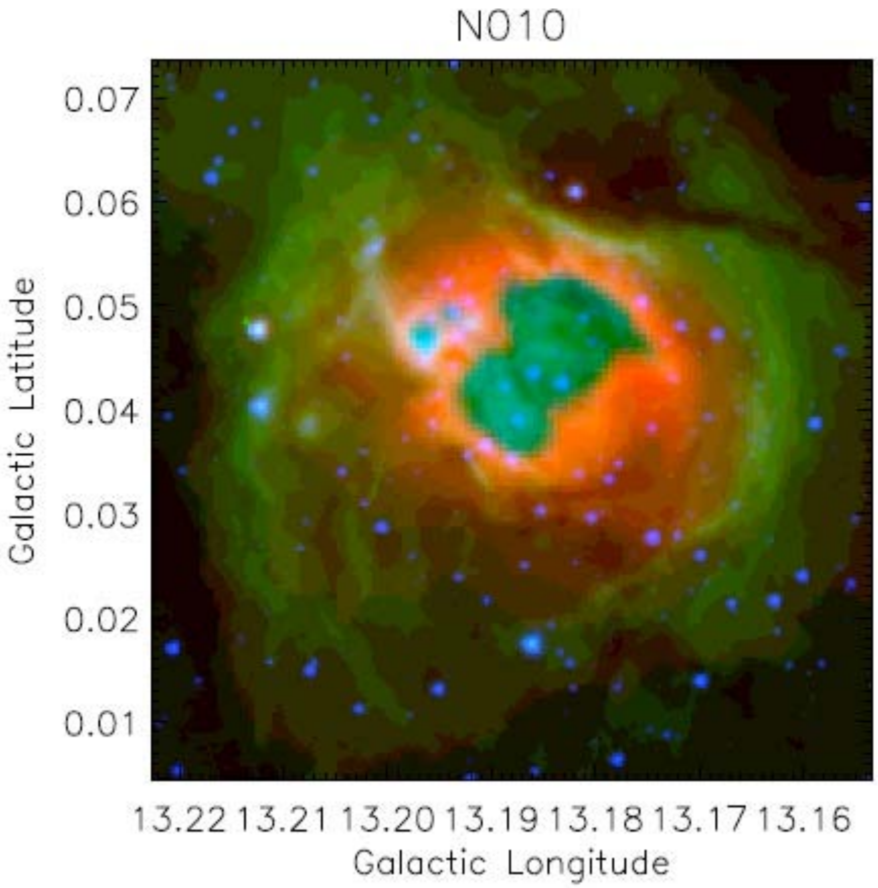


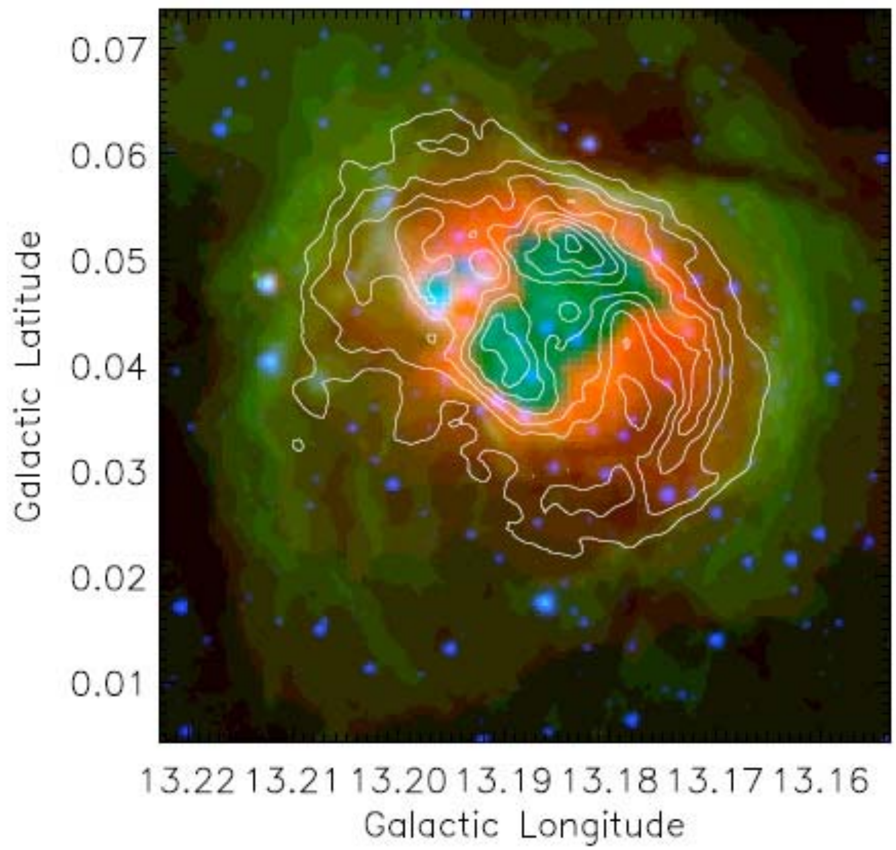
Age constraints on N49

- $R(t) \alpha n_0^{-1/5} L_w^{1/5} t^{3/5}$ => age $\alpha R(t)^{5/3} n_o^{1/3} L_w^{-1/3}$ => can infer age as a function of ambient density if the radius is measured and the star responsible for producing the bubble is known (i.e. L_w is known). N49 at a distance of 5.7 kpc, SpT~O5V star (L_w~$4x10^{36}$ erg s^{-1}) reaches a radius of 2.5pc within $5.5x10^5$ yr if n_0~10^5 cm^{-3} or $1.2x10^6$ yr if n_0~10^6 cm^{-3}.
- If N49-1&3 were triggered by expansion of N49, then the minimum age of N49 is set by the time required to produce a massive YSO (~10^5 yr). A maximum age is set by the ambient density becoming unreasonably high (≤10^6 cm^{-3} as implied by NH_3 observations).
- Conclusion: the N49 bubble is quite young (>10^5 yr and ≤10^6 yr)!
- But old enough to have spawned a second generation of stars.

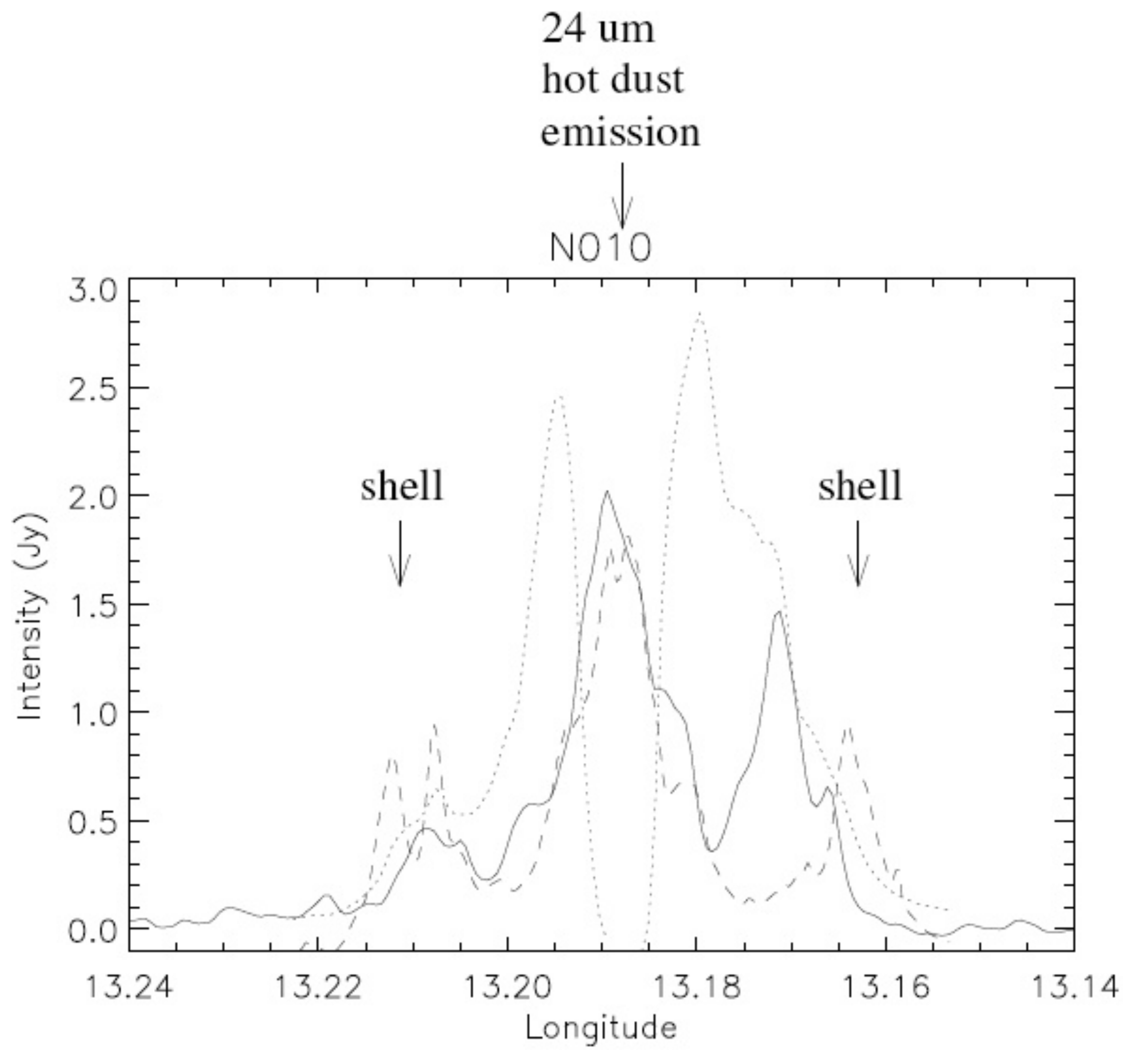
N10 (color [4.5, 8.0, 24μm]; contours 20cm)

D=4.9±0.5 kpc
N_{UV}~1.6x10^{49} s^{-1}
Diam.~3.6 pc

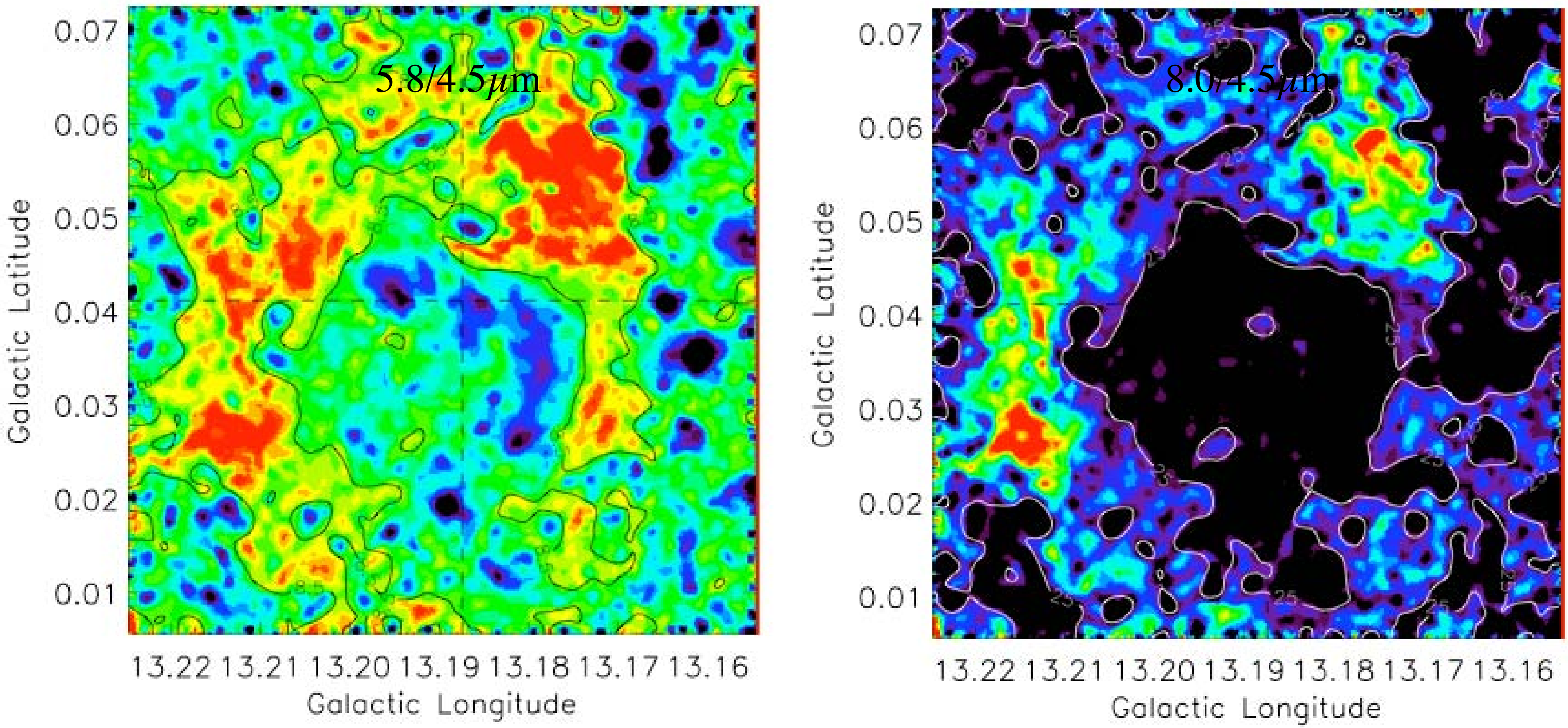




N10: Comparison of 8, 24μm, 20cm Emission



N10: PAH Destruction Radius

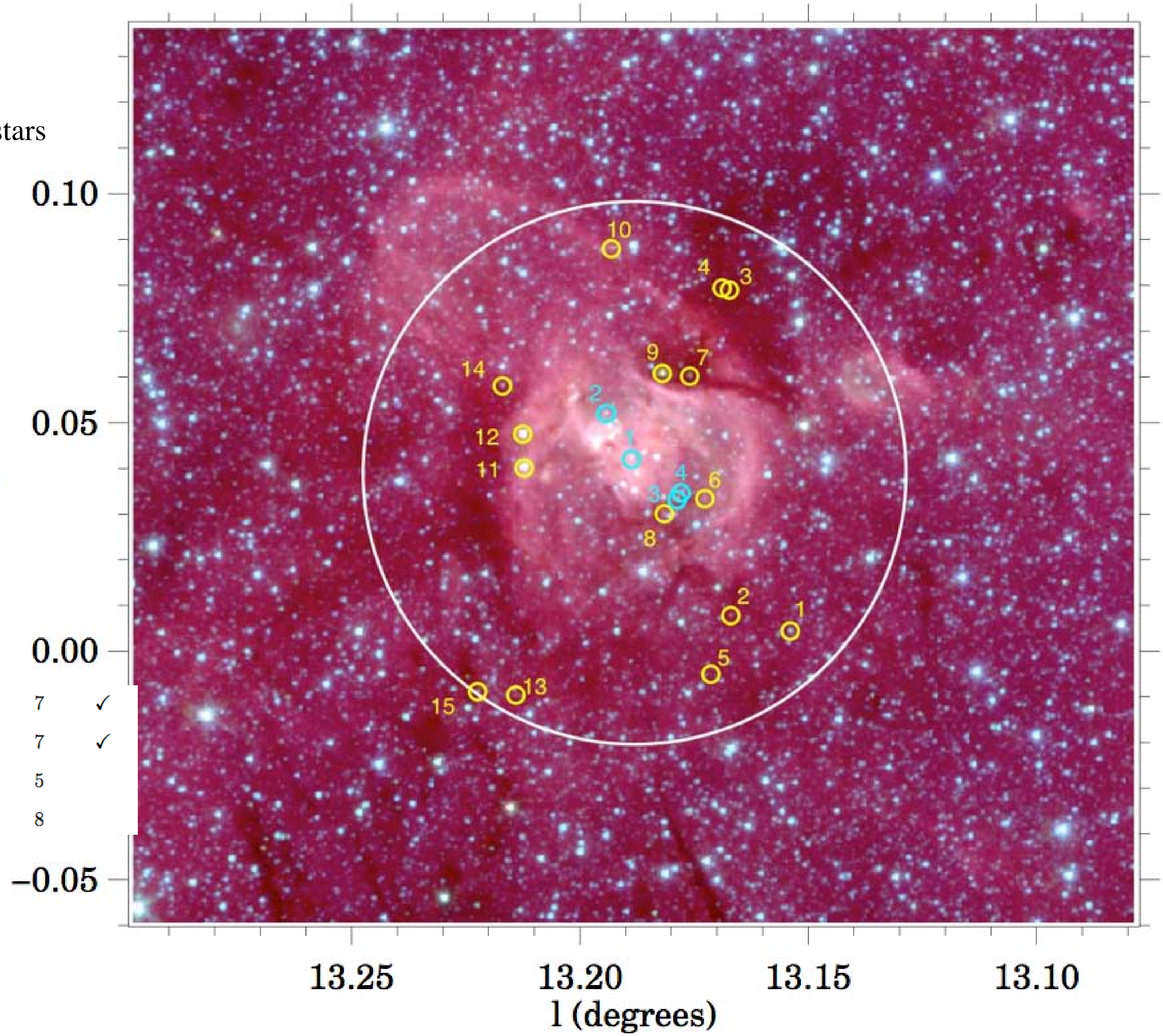


Ang. Diameter ~0.03^0 @ 4.9 kpc => R~1.3 pc

N10: Candidate YSOs and Ionizing Stars

Yellow: candidate YSOs
Cyan: candidate ionizing stars

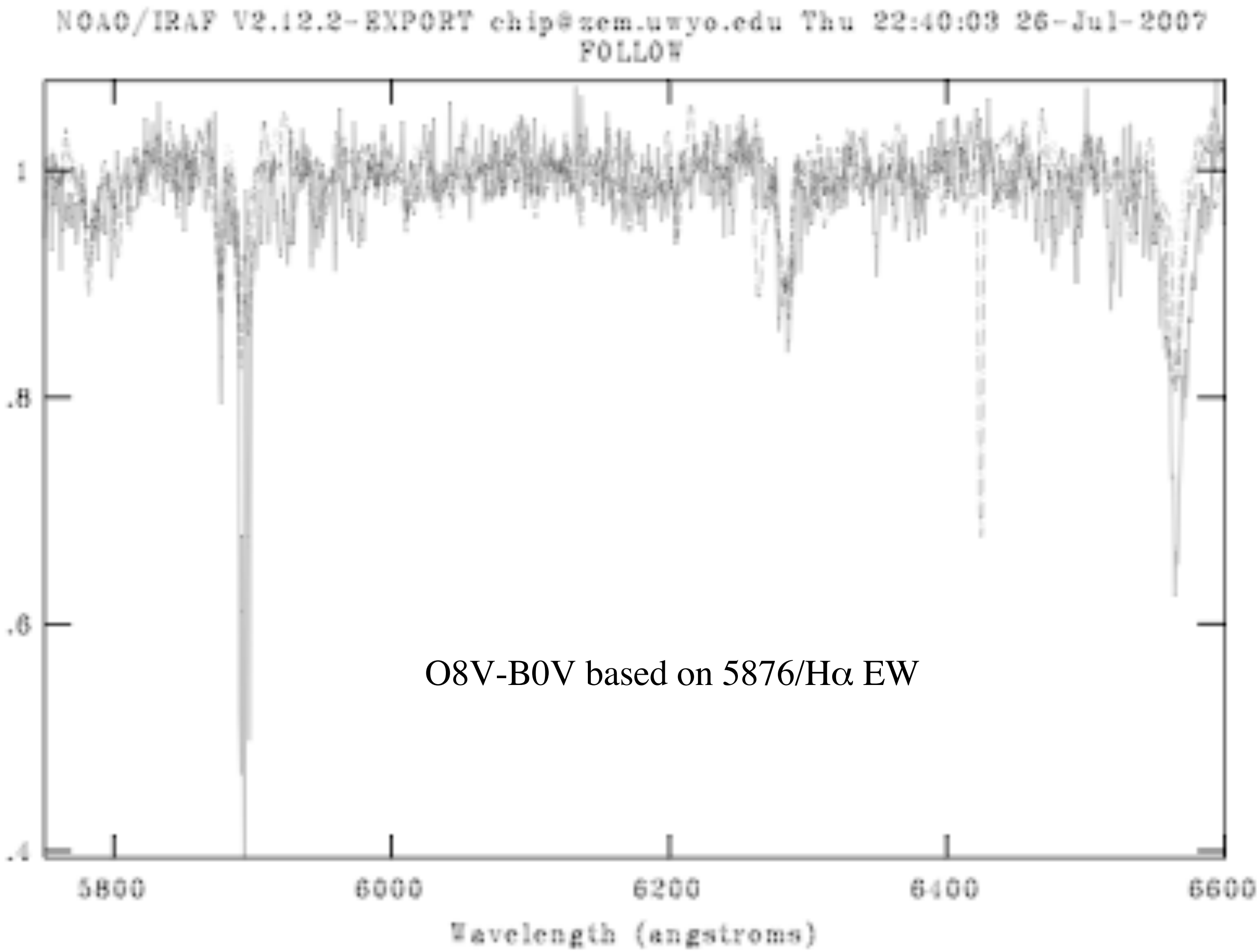
Circel R=5.2 pc
687 stars analyzed



IR Model Predictions

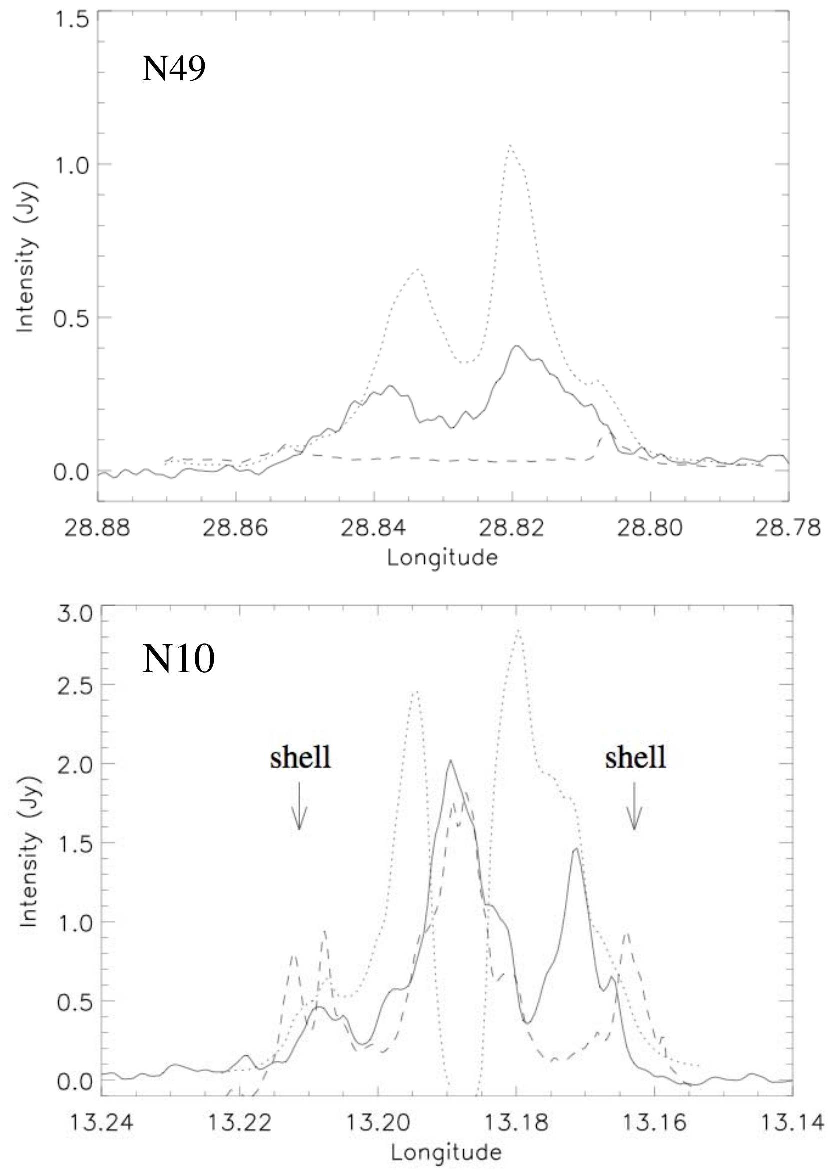
IN10-1	13.1887+00.0421	O7.5 V	7	✓
IN10-2	13.1942+00.0521	O6.5 V	7	✓
IN10-3	13.1786+00.0331	O6 V	5	
IN10-4	13.1777+00.0346	O7 V	8	

Optical Spectrum of N10_3 (WIRO)



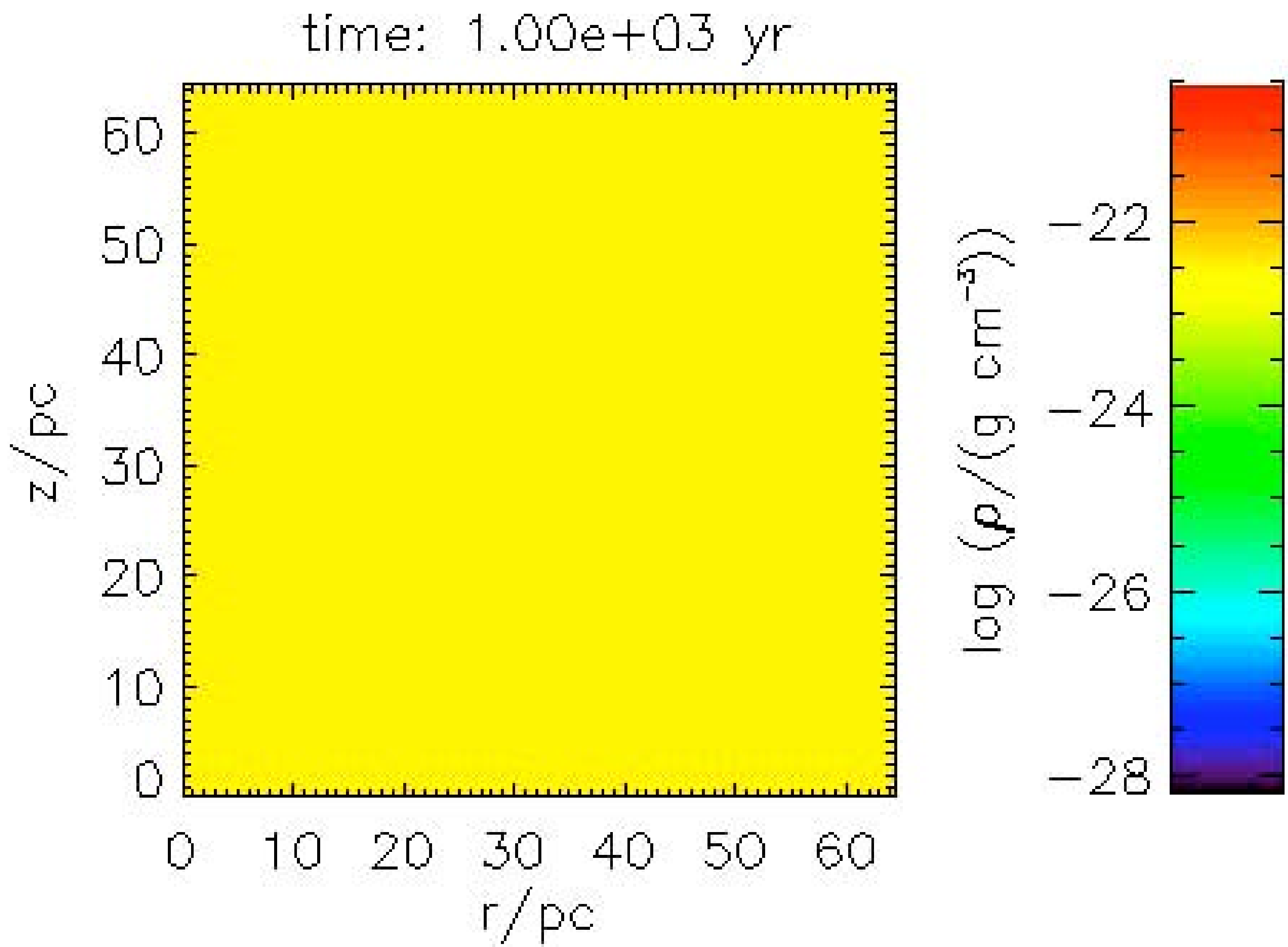
Comparison of N49 and N10

- Both 8μm & 24μm thermal emission peak at the center of N10. The 8μm emission <u>does not</u> peak nor follow the thermal 24μm dust emission at the center of N49.
- Reason: N49 has a central evacuated cavity with no dust and N10 does not. So in N10 one sees hot dust heated mostly by direct stellar radiation and secondarily by trapped Lα photons, and stochastically heated small grains out to about 0.85pc, beyond which geometrical dilution limits dust heating.
- Both have YSOs along their rims suggesting that both have triggered star formation implying minimum ages of a few x10^5 yr for both bubbles. An upper limits of ~10^6 yr is set for N49 by interstellar densities $\leq 10^6$ cm^{-3}. Upper limit for N10 cannot be set by the same scaling laws.
- Open questions: Why does dust exist at the center of N10? Why isn't the dust within N10 and N49 HII regions not blown entirely out by the stellar wind? N10 has ~ a factor of 4 weaker wind than N49, so maybe there is a threshold for dust clearing? Maybe dust is continuously replenished by embedded neutral globules that was overrun by the I-front?

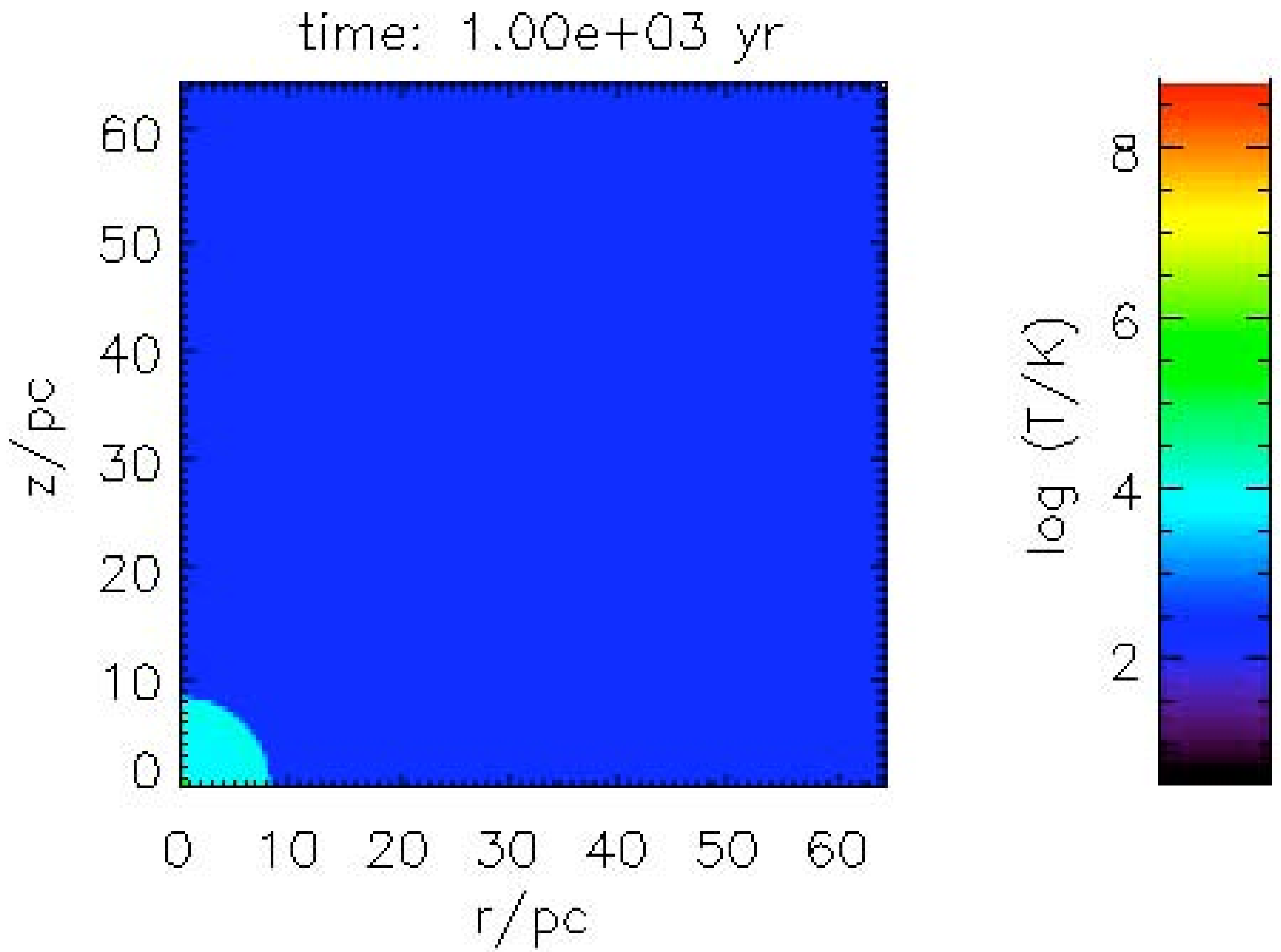


Density Evolution of a 60 Solar Mass Star

Freyer, Hensler, & Yorke 2003, A&A, 594, 888



Temperature Evolution of a 60 M_0 Star



Main Conclusions

- Expanding bubbles around OB stars appear to trigger new generations of star formation
  - An important but not a primary mechanism of star formation (>10%)
- PAHs are destroyed in HII regions but define the PDR areas around the bubbles =>
- PAHs are excited by soft UV radiation (non H-ionizing photons).
- Dust exists in HII regions
  - Bright 24 μm emission (thermal +trapped Lα + transiently heated small grains)
  - Generally confined within the radio continuum emission (i.e. inside the I-front)
  - Why is the dust not blown out by stellar winds or destroyed by radiation?
    - Possibly continuously replenished by dense neutral globules that were over-run by the I-front?
    - Wind luminosity threshold? (L_w(O5V) in N49~4 x L_w(O7V) in N10
- Stellar winds fundamentally alter the structure of HII regions
  - Ionization, temperature, and density structures are very different from classical picture of 10^4 K gas filled HII regions.
  - Around O stars with strong winds most of the bubble volume is filled with very hot (several x 10^7 K), low density, X-ray emitting gas.
- Some bubbles show evidence of evacuation of both gas and dust around the central star(s)--N049, others not--N10 and N21
- Open questions: Why does dust exist at the center of N10? Why isn't the dust in N10 and the N49 HII region not blown out by the stellar wind? N10 has a factor ≤ 4 weaker wind than N49, so maybe there is a threshold for dust clearing? Maybe dust is continuously replenished by embedded neutral globules that was overrun by the I-front?