Sterrewacht Leiden

The SOFIA/FORCAST view of the compact HII region W3A

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and the FORCAST team

Overview

- SOFIA / FORCAST
- HII regions
- W3 region analysis and results
- Summary & Conclusions

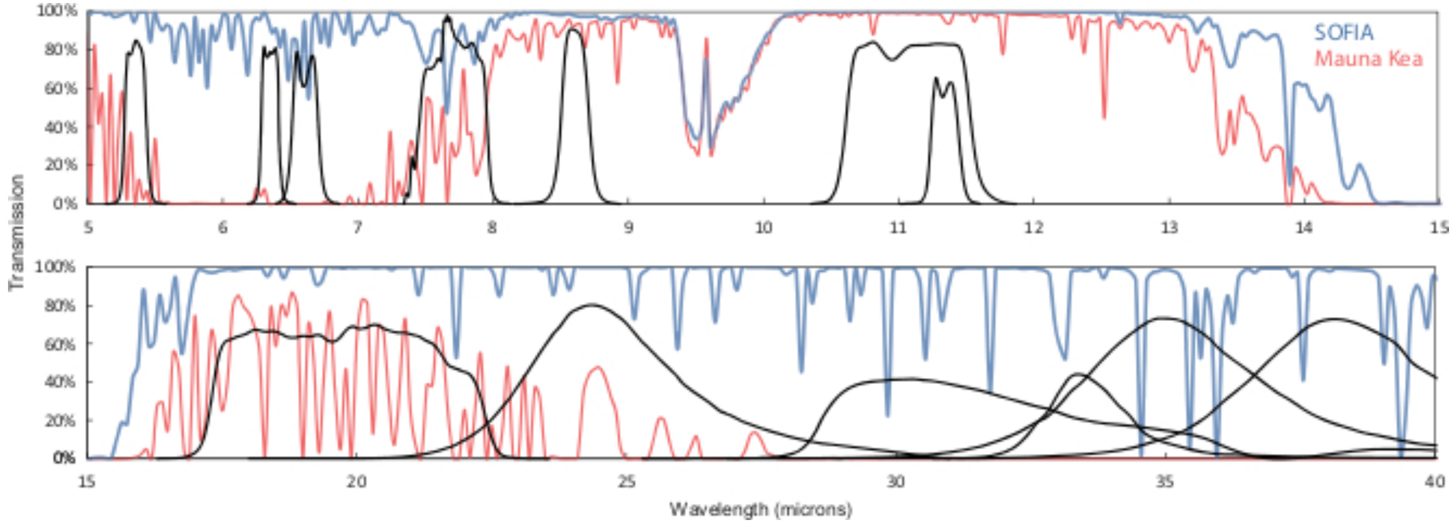
SOFIA/FORCAST

- Stratospheric Observatory For Infrared Astronomy

2.5 m telescope on board of a Boeing 747.

SOFIA / FORCAST

- FORCAST, wide field camera photometry and spectroscopy in the 5-40 um, perfect for studying dust properties.
- ~3 x 3 arcmin, pixelsize ~0.8 arcsec/pixel PSF ~3 arcsec



(Herter et al. 2012 ApJL 749, 18)

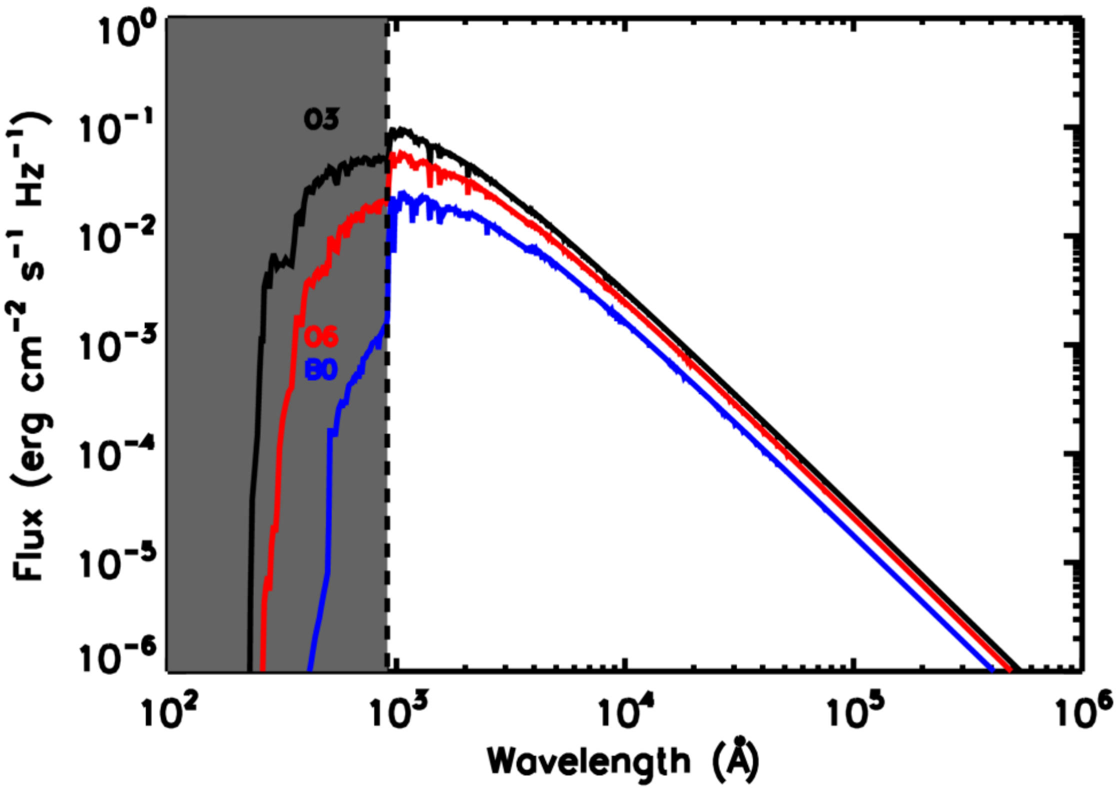
HII regions

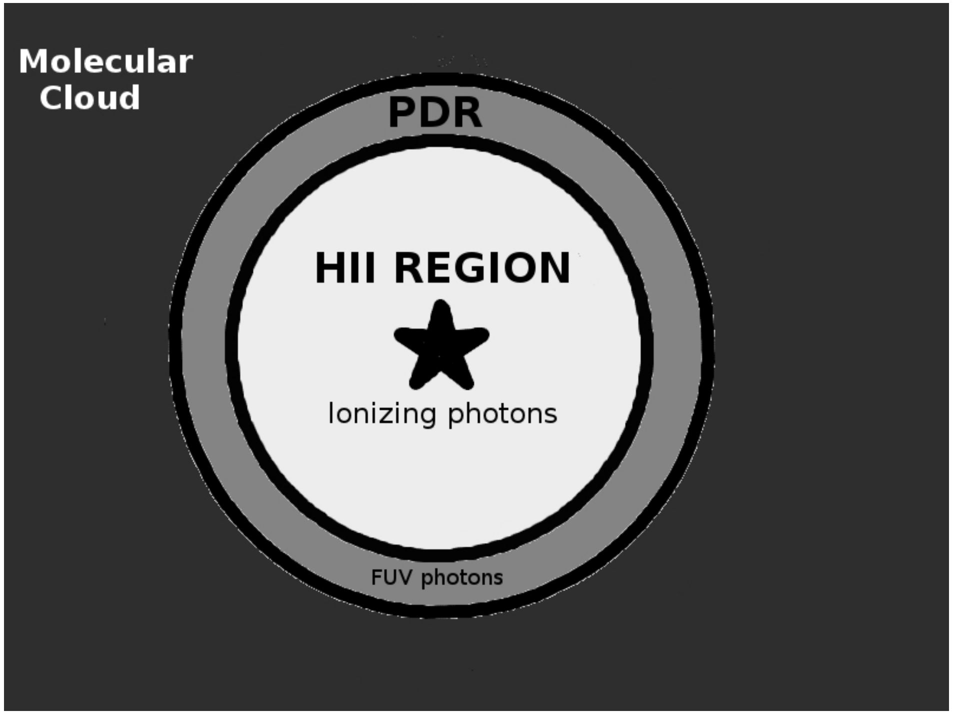
Massive stars (spectral type O-B, ~60-15 solar masses)

- At early stages are deeply embedded in molecular clouds (dust extinction, IR emission)
- Strong UV ionizing emission, ionize Hydrogen (H-lines and radio, free-free emission)
- Stellar winds (X-ray)

HII regions

Star ionizes the gas, surrounded by a PDR

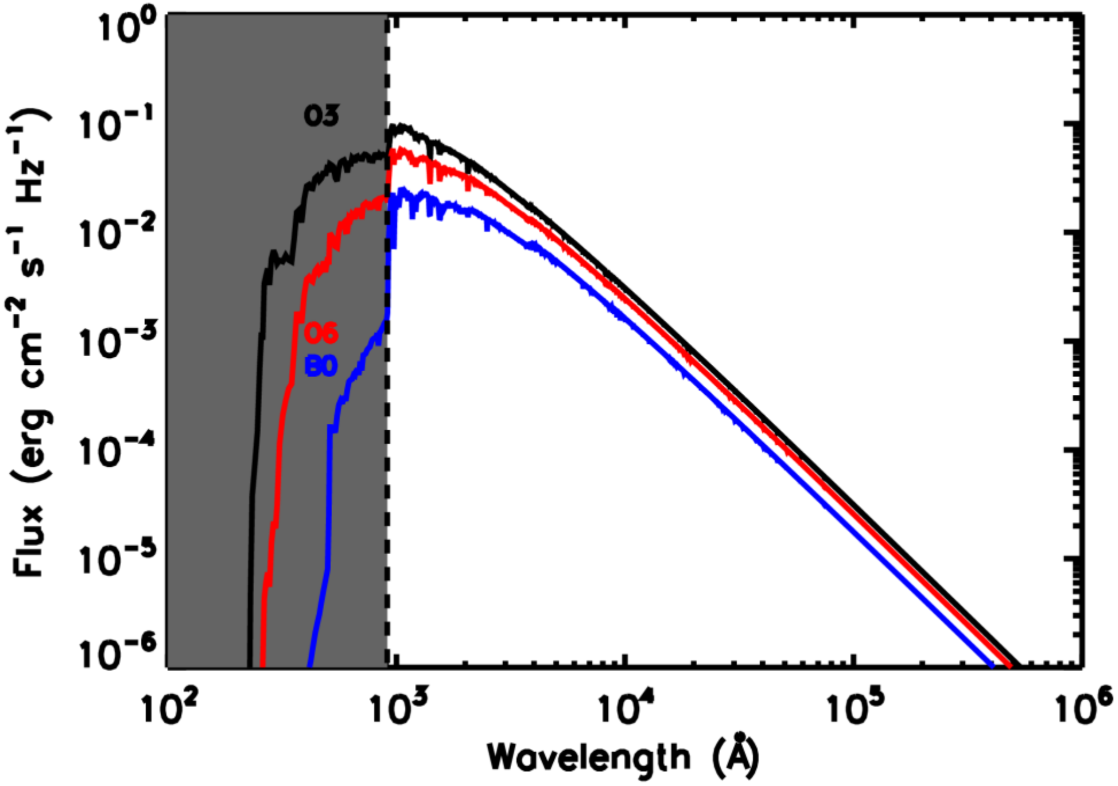


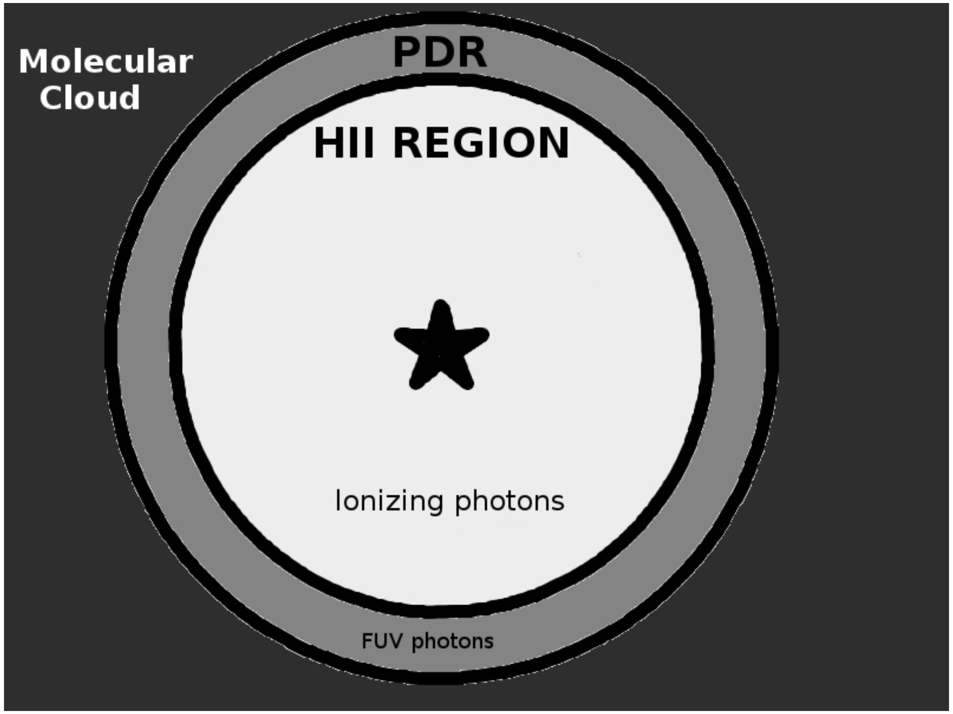


HII regions

The HII region expands

gas pressure





HII regions

- As the stars evolve, they change the cloud that surround them dispersing the gas and changing the properties of dust.
- Hypercompact → (~0.001 pc ~10^5 cm^-3)

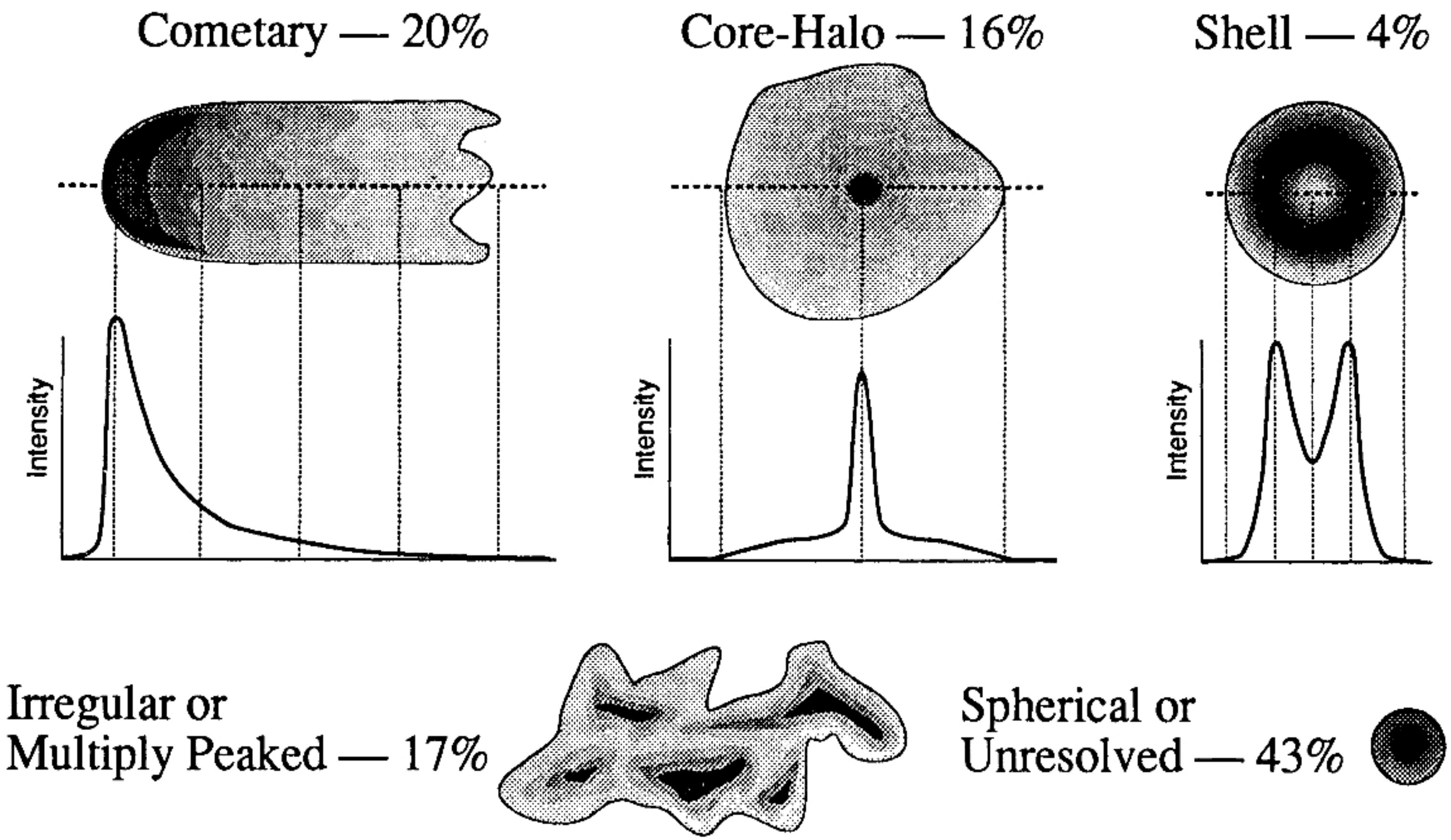
  Ultra Compact → (~0.01 pc ~10^4 cm^-3)

  Compact → (~0.1 pc ~10^3 cm^-3)

  HII regions → (> 1 pc ~10^2 cm^-3)
- At the end of their lives explode as supernovae injecting mass and energy into the ISM.

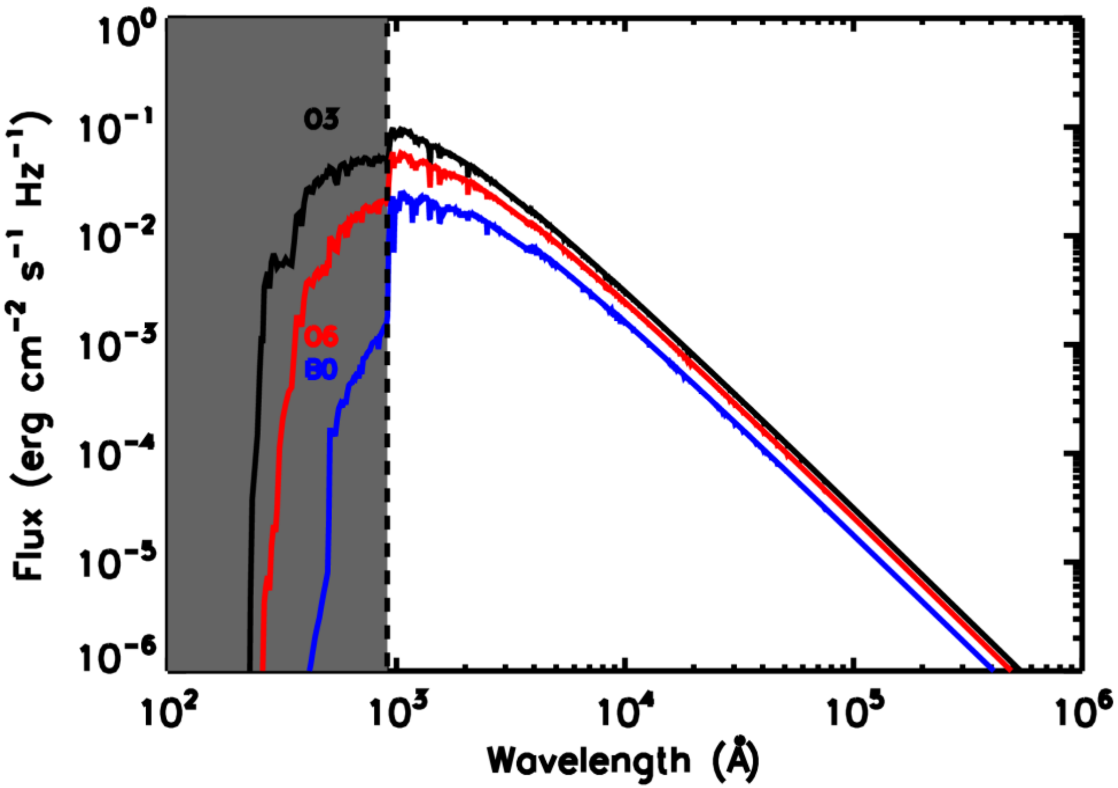
HII regions

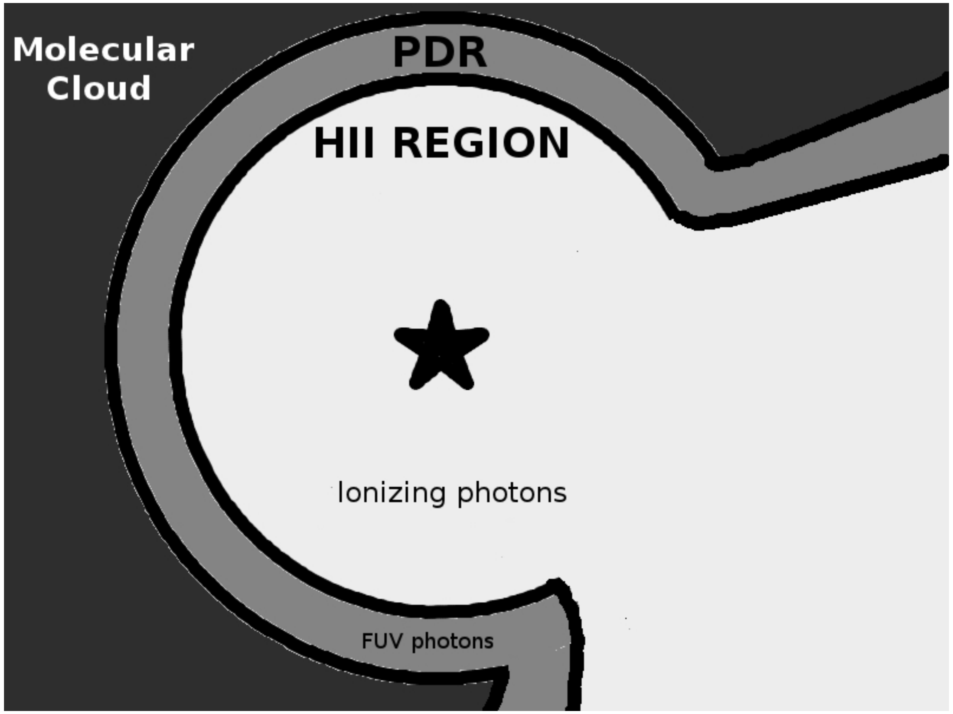
Wood and Churchwell 1989



HII regions

At some point the ionized region breaks into the ISM

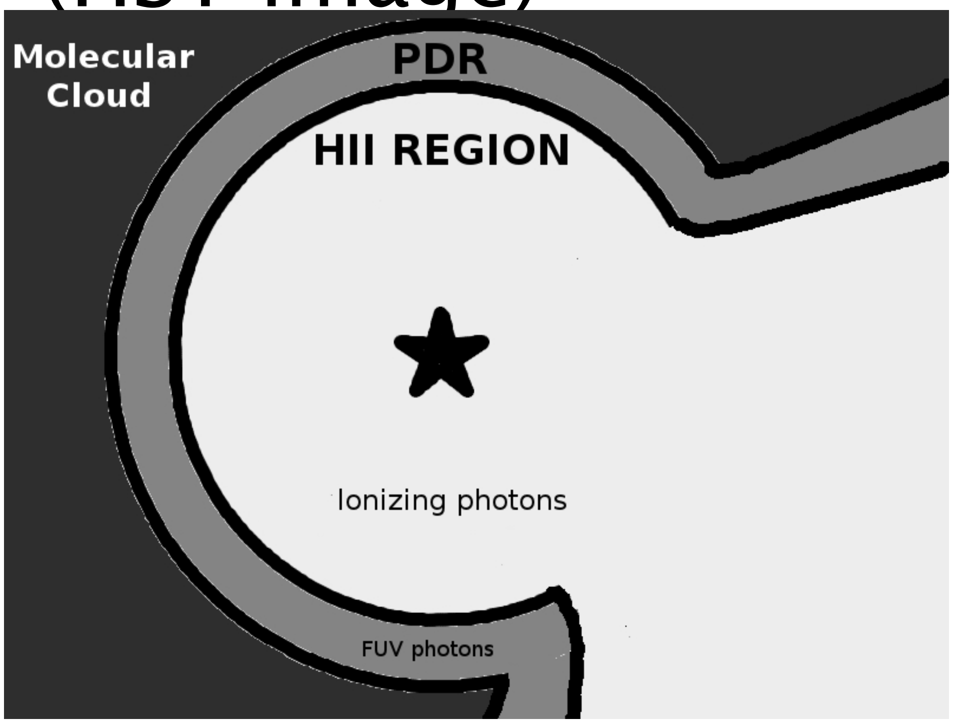


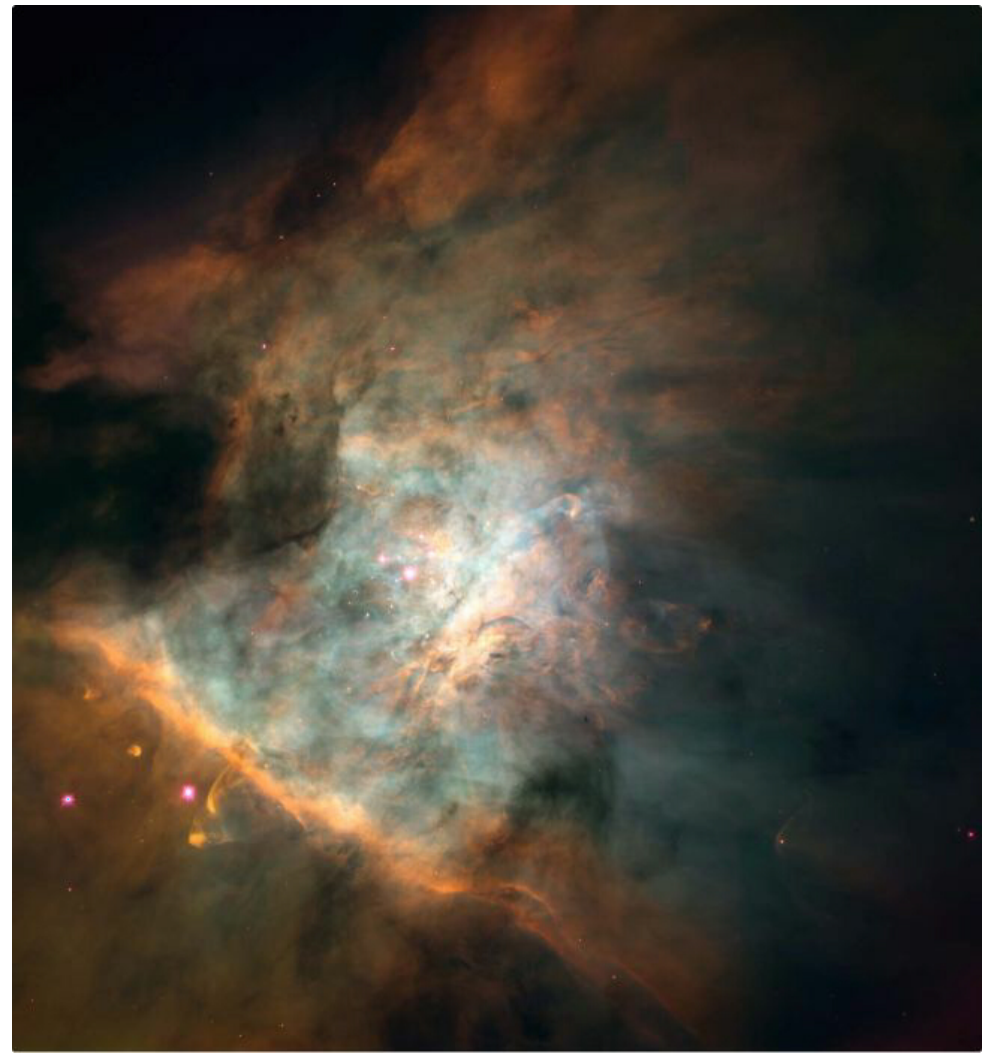


HII regions

Ex.: Orion HII region

(HST image)





HII regions in the infrared

Deharveng et al. (2010) evidence of dust inside the regions.

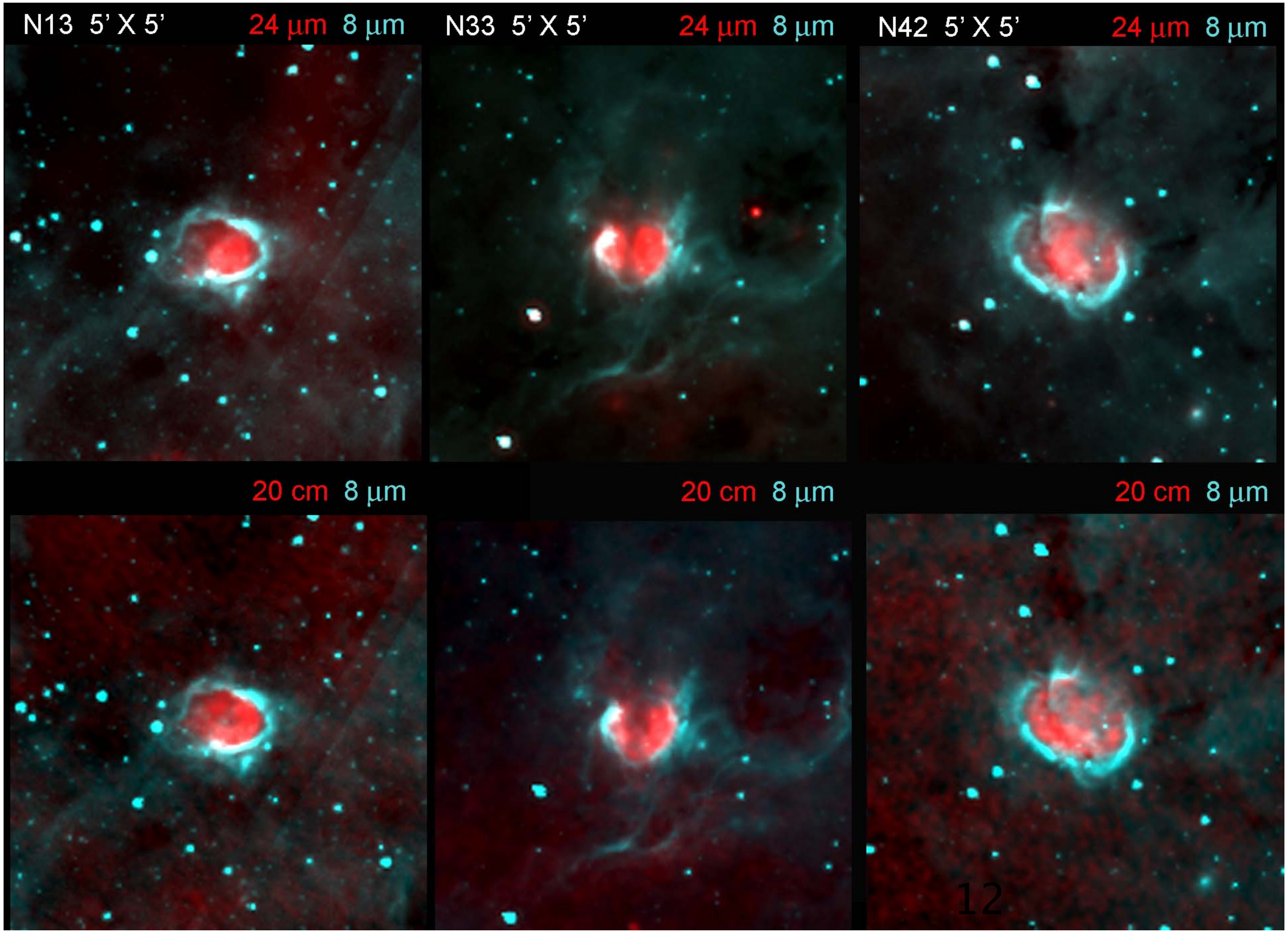
GLIMPSE

MIPSGAL

MAGPIS

20cm-HII

24um-dust



HII regions in the infrared

UV emission is absorbed by dust and re-emitted in the infrared.

The 8 um and 24 um emission has been shown to be a good tracer of star formation in other galaxies (e.g. Calzetti et al. 2007 & Calzetti et al. 2011).

HII regions in the infrared

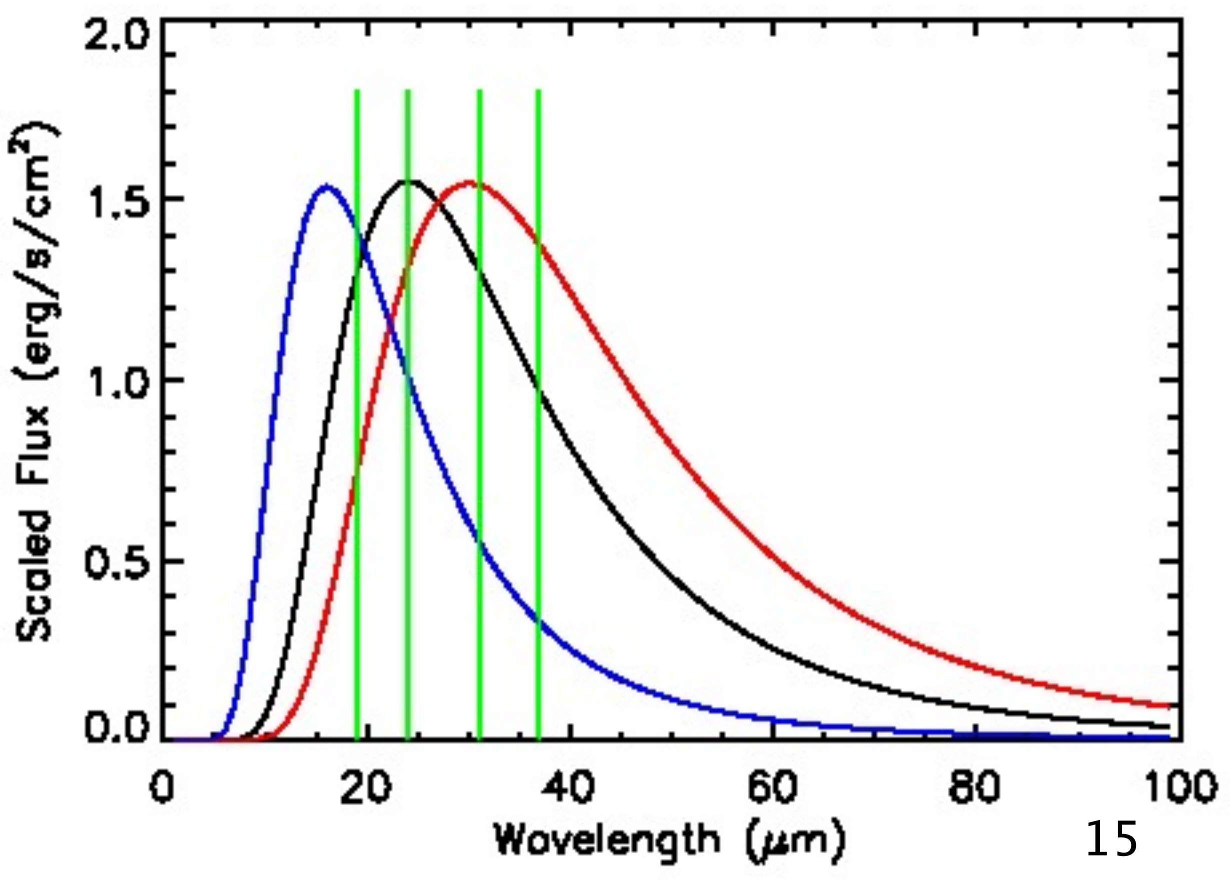
- What are the properties of dust inside the HII regions?

- Is dust processed? (How?)

- What role do dust grains play in massive star formation?

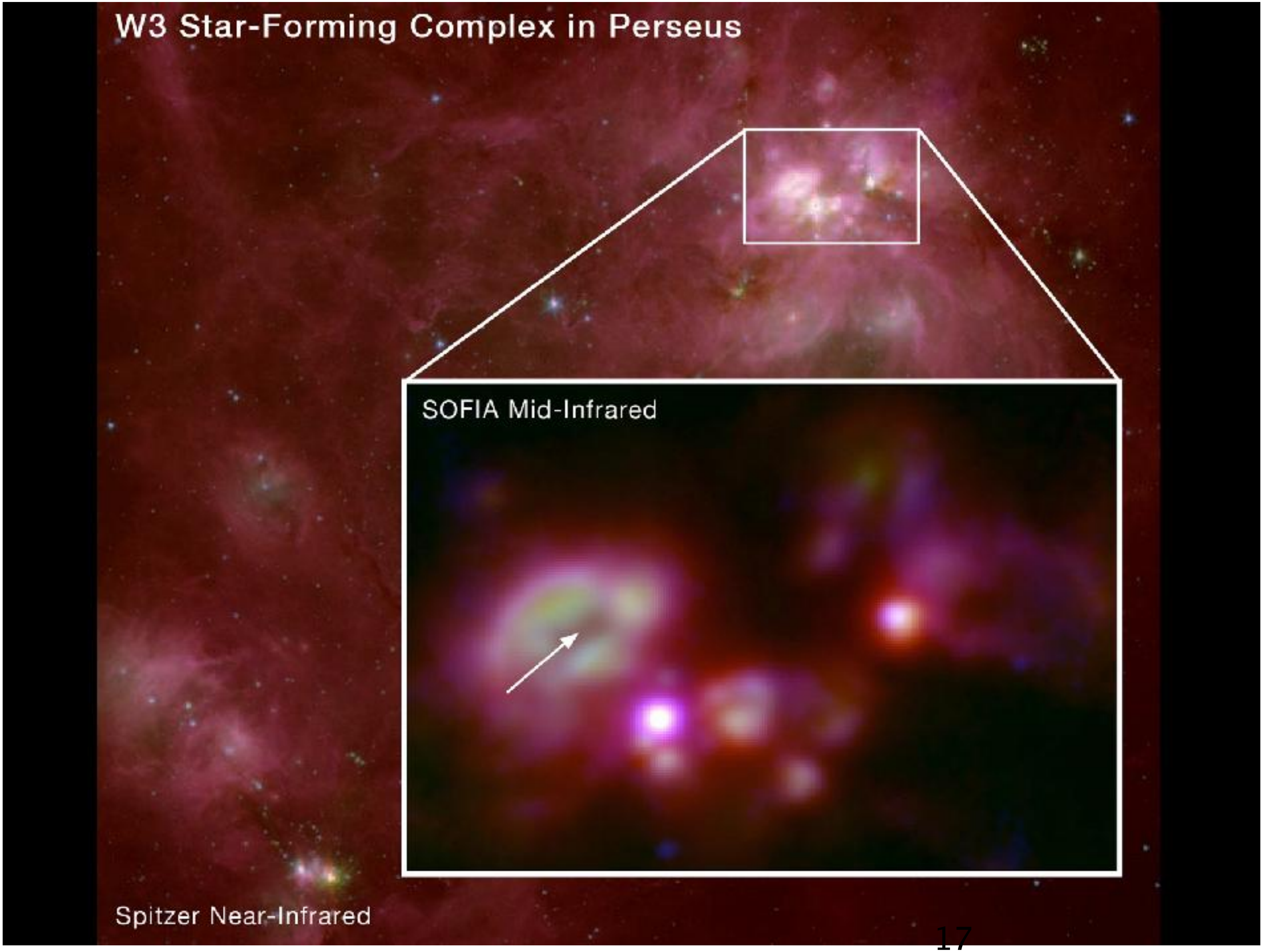
HII regions and FORCAST

FORCAST is the only available instrument that probes the peak of the dust emission.



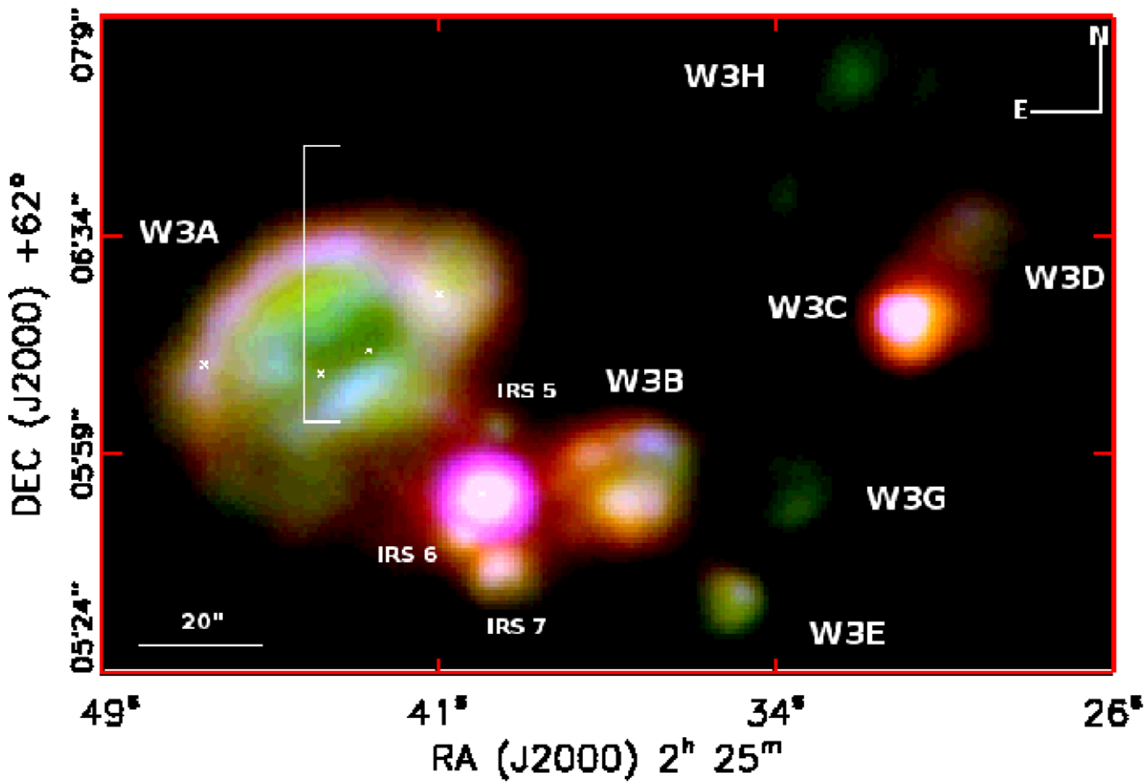
W3 main star forming region

- Massive star forming region located at 1.95 kpc
- 15 OB stars (Ojha et al. 2004, Bik et al. 2011)
- Bright infrared and radio sources, from embedded protostars to compact HII regions (Wynn-williams et al. 1976, Tieftrunk et al, 1997)


W3 Star-Forming Complex in Perseus
SOFIA Mid-Infrared
Spitzer Near-Infrared

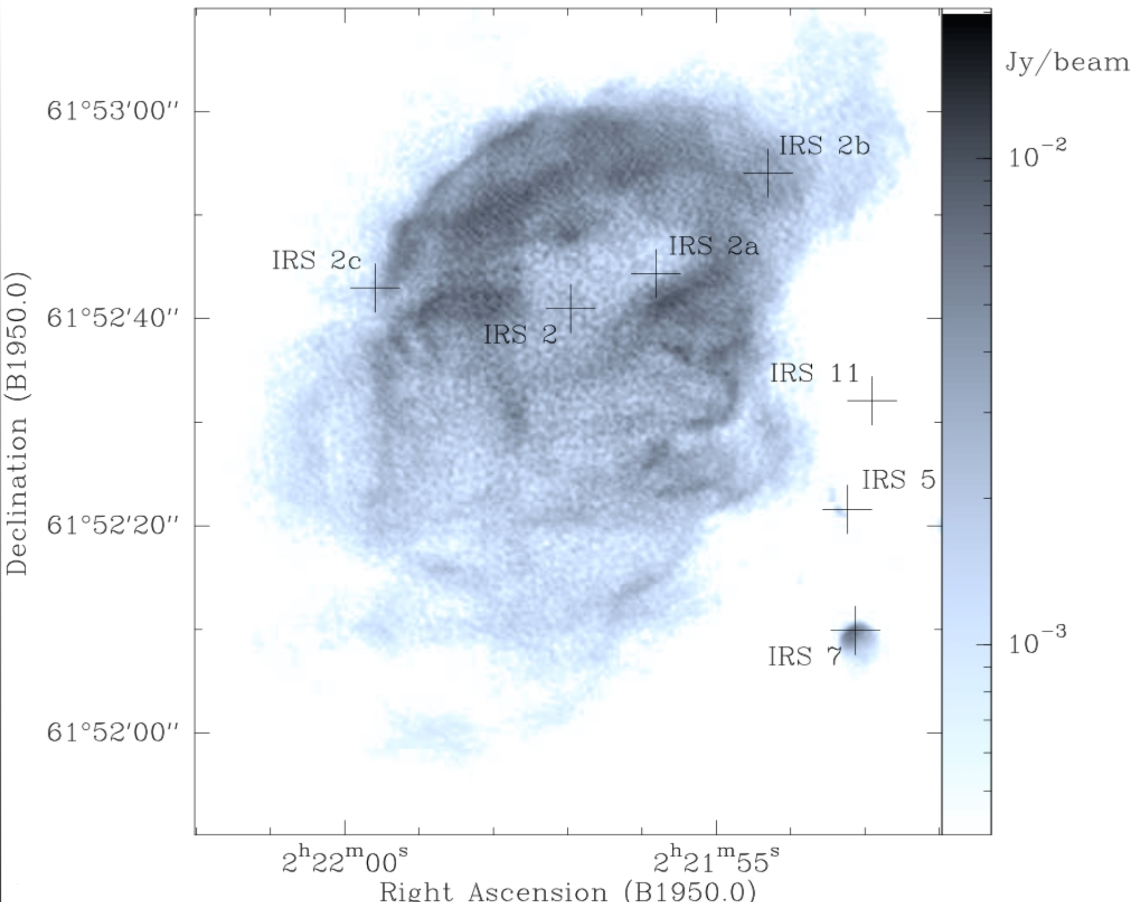
W3 main star forming region

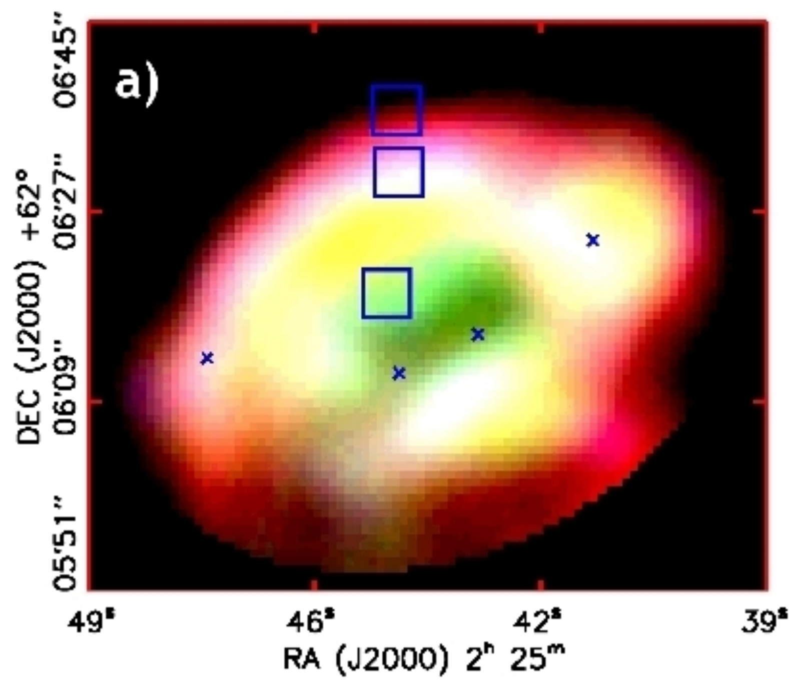
- Observed with FORCAST in the 6.4, 6.6, 7.7, 19.7, 24.2, 31.5, 37.1 um filters.
- 6.4 and 7.7 um trace PAH emission.
- 19.7, 24.2, 31.5 and 37.1 um trace dust grain emission.



The compact HII region W3A

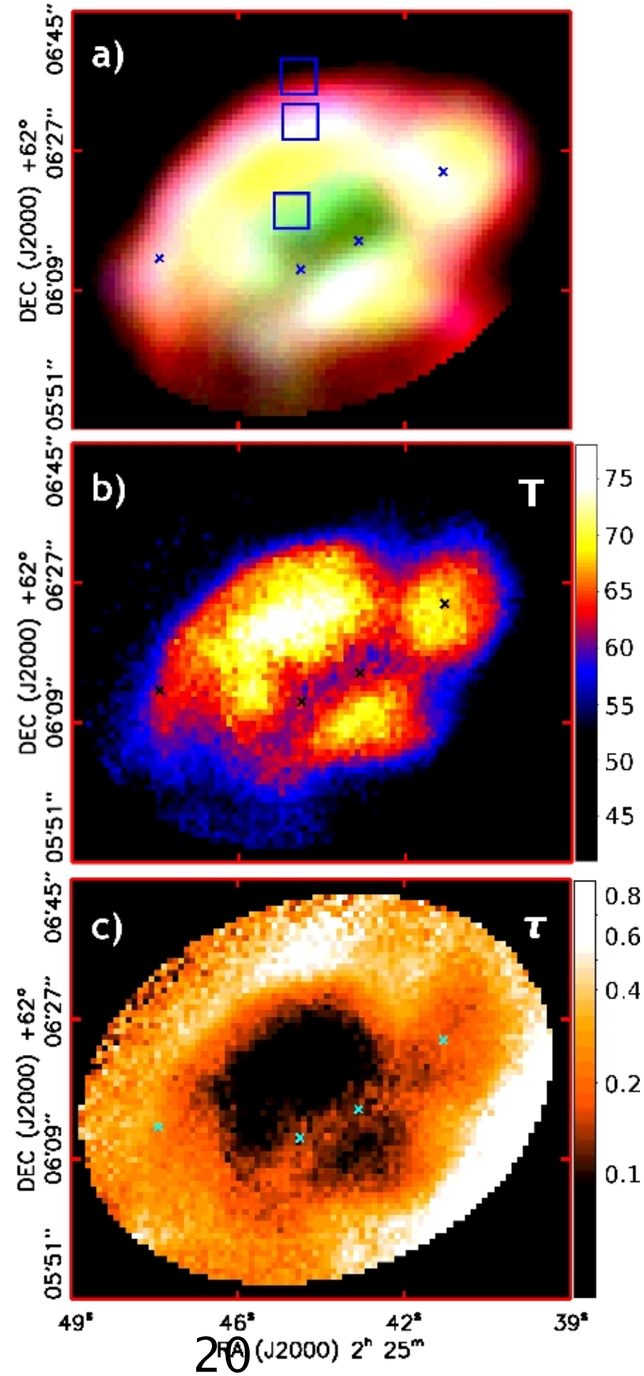
- Shell like compact HII region
- Contains 4 massive stars IRS2 (O6.5V), IRS2a (O8.5V), IRS2b (O8V) and IRS2c (B0.5V)



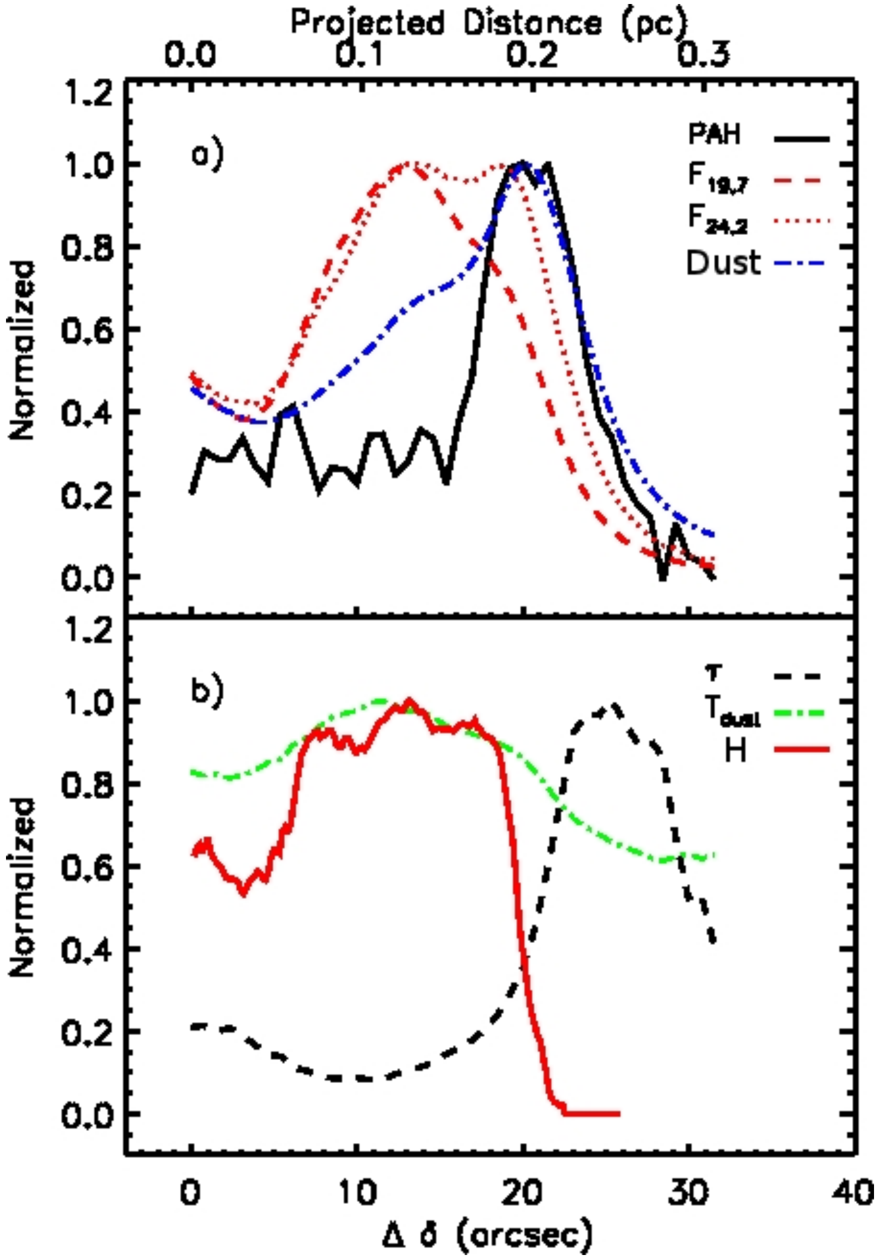


Color Temperature and Optical Depth

- We derived color temperature and optical depth maps from the 31.4 and 37.1 um images.
- Dust temperature peaks in the ionized shell ~80 K



Spatial distribution of dust (cuts)



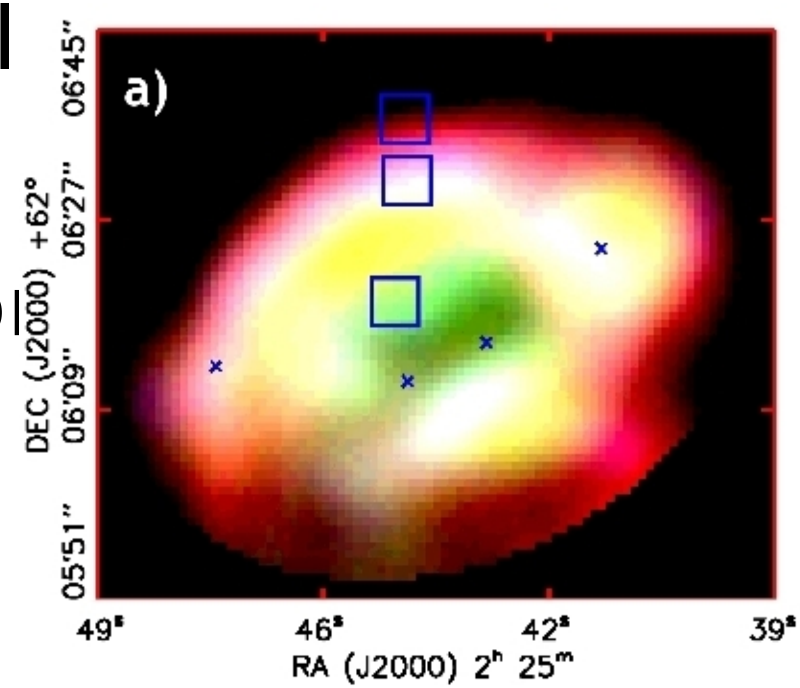
The 19 and 24 um emission peaks in the HII region.

The PAHs, 31 and 37 um emission peak in the PDR.

The IR luminosity inside the HII region is ~40%

IR SED W3A

We selected three regions
To study how the spectral
energy distribution (SED)
changes with distance fro[m]
the central star.

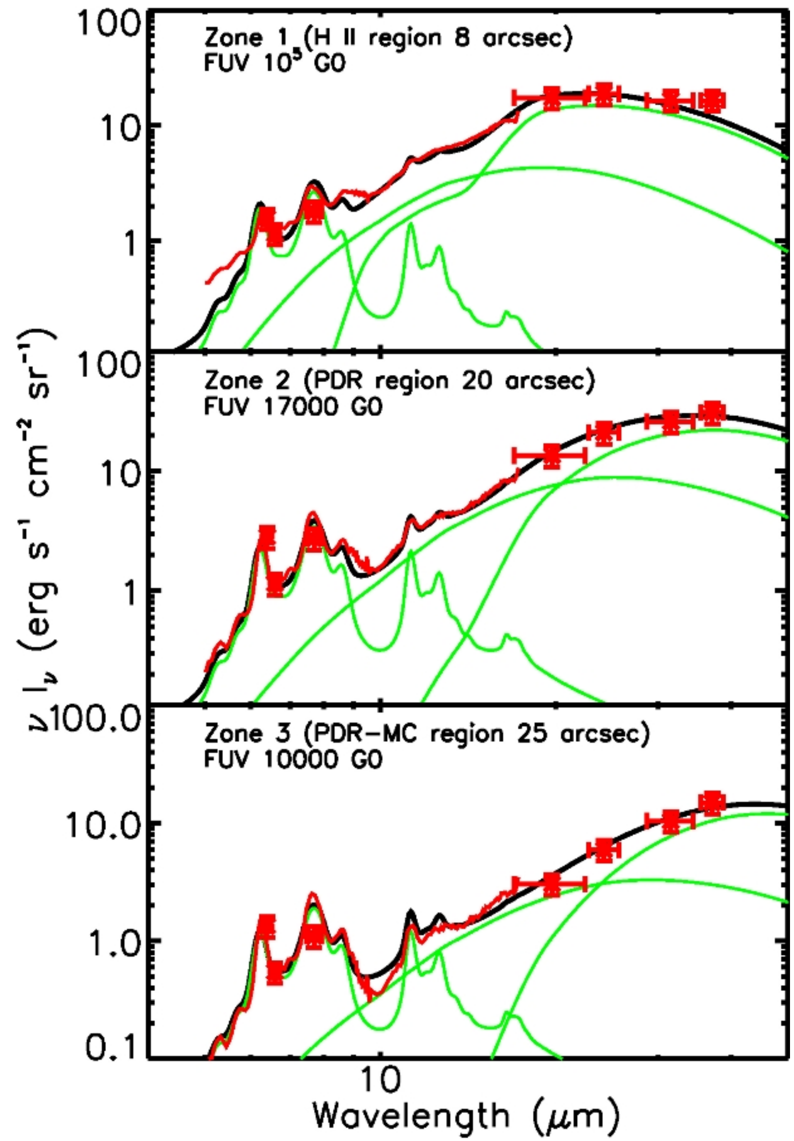


IR SED W3A

The SED peak moves to longer wavelengths.

Bgs (big grains) emission dominate the emission in the HII region.

VSGs (very small grains) mission start to be important deeper into the cloud.



The compact HII region W3A

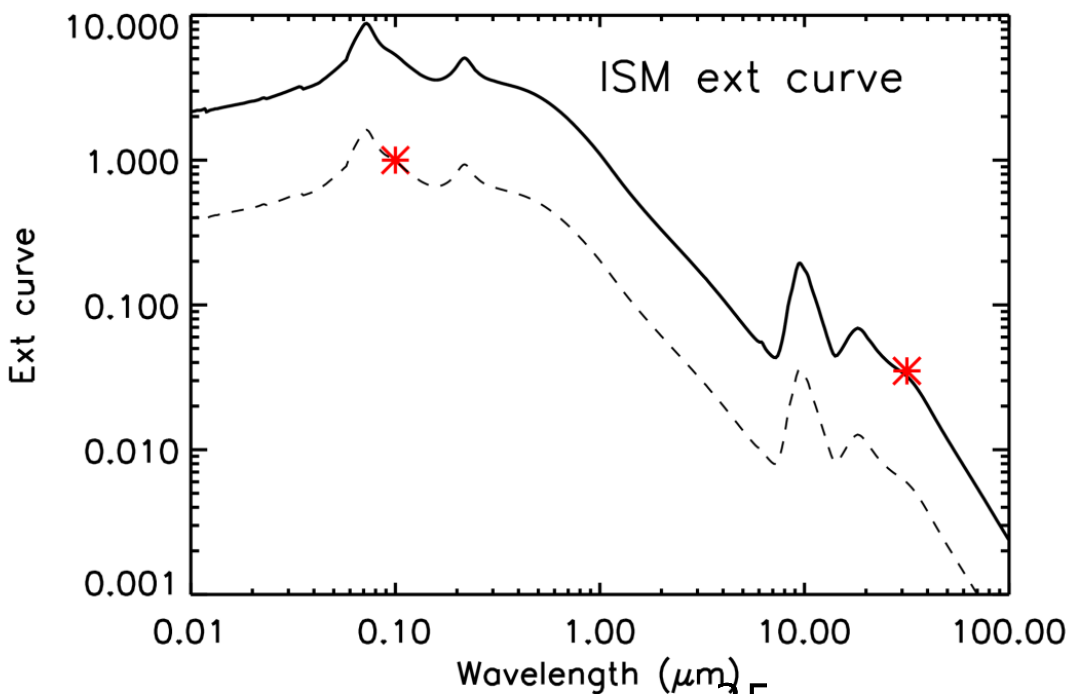
A simple energy balance analysis:

Luminosity of W3A (6-40um)= 3 10^5 Lo, and matches the sum of the stellar luminosity.

Luminosity IRS2 ~2 10^5, IR luminosity in the HII region 1.1 10^5 → UV optical depth ~1

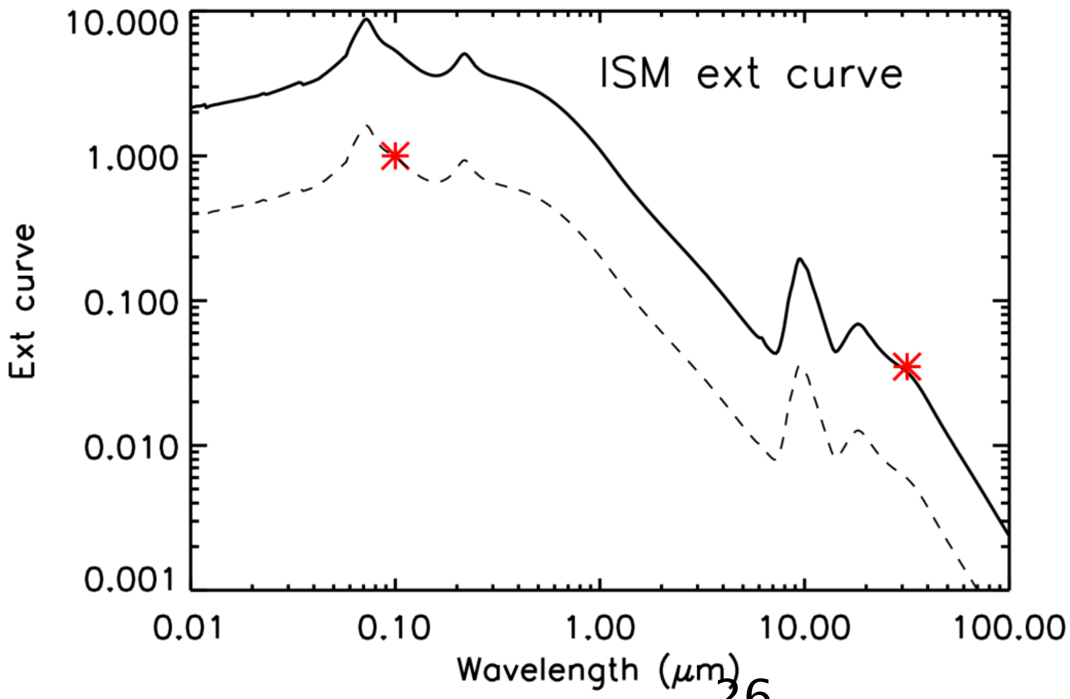
Dust to gas mass ratio HII region

- We get an estimate of the dust column density and a dust-to-gas ratio of 0.012
- UV optical depth = 1 → dust-to gas = 0.035 (3 times larger)



The problem

- A dust-to gas ratio of 0.035 is equivalent to an optical depth of ~4
- Only ~2% of the stellar photons are used to ionize the region.



The solution(s)

- Dust properties in the HII region are different that those in the ISM.
- We measured low emission of PAH and VSG (destruction?)
- Coagulation of dust grains in the molecular cloud phase also make the extinction curve “flatter”.

Summary and conclusions

- Using mid-infrared photometry obtained with FORCAST we studied the spatial distribution and physical properties of the dust in W3(A).
- Dust is present in the ionized shell and contributes to ~40% of the total MIR emission of the region.
- The dust grain size distribution must be different to that in the ISM.

FORCAST is the only available instrument that probes dust at these wavelengths!!