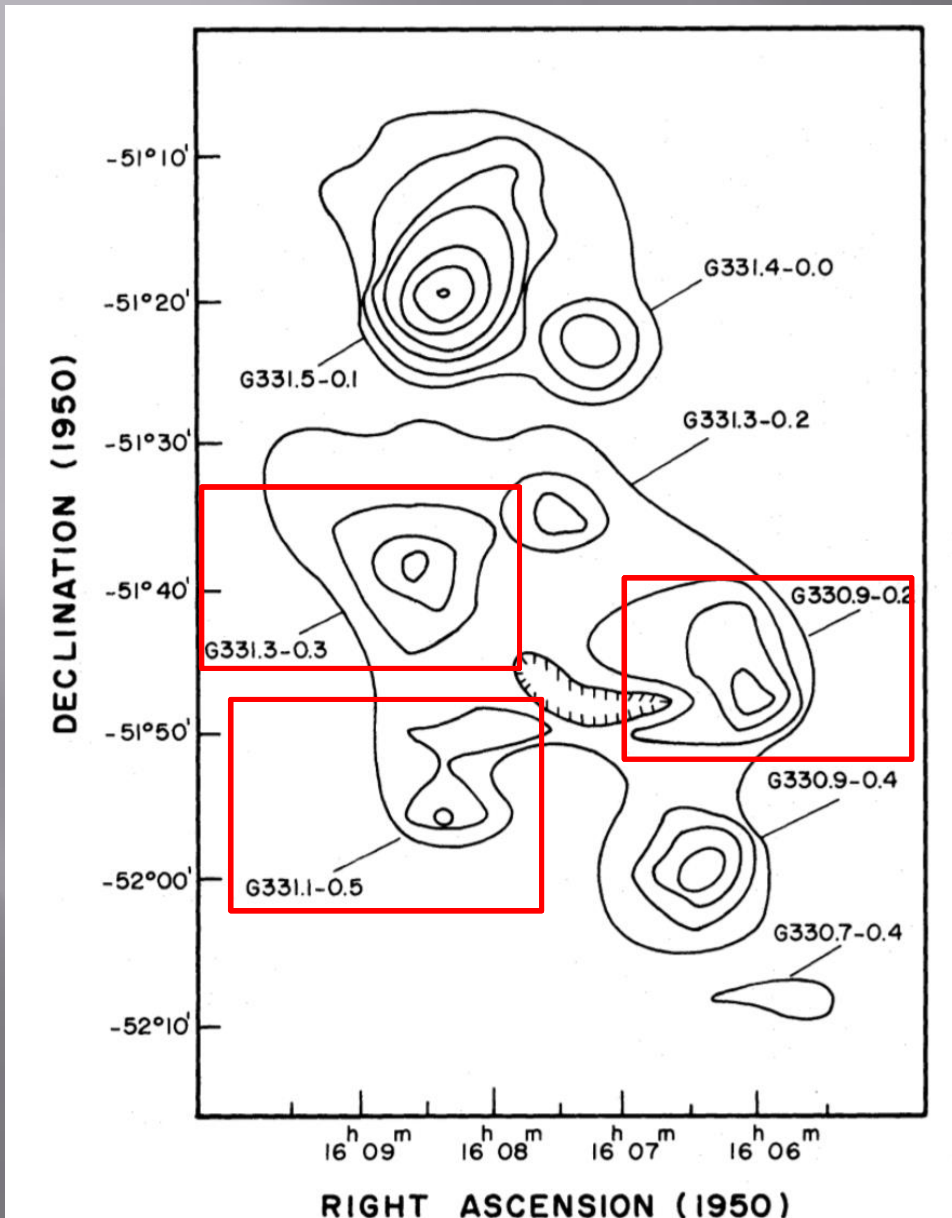
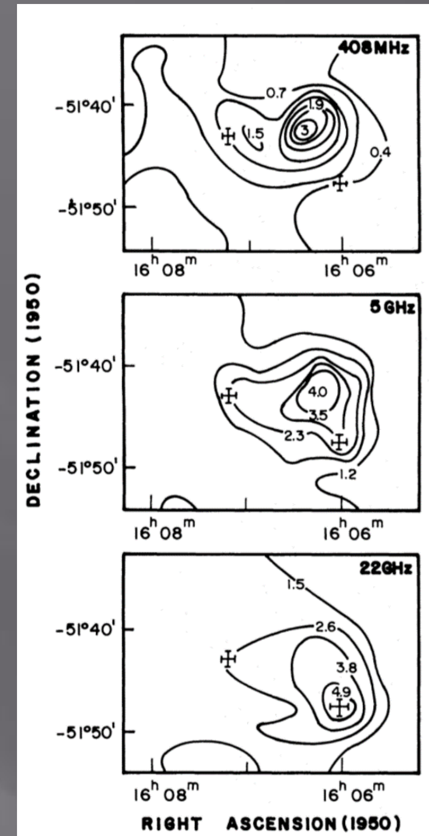
ALMA CONTINUUM AND H30α RECOMBINATION LINE OBSERVATIONS OF η CAR

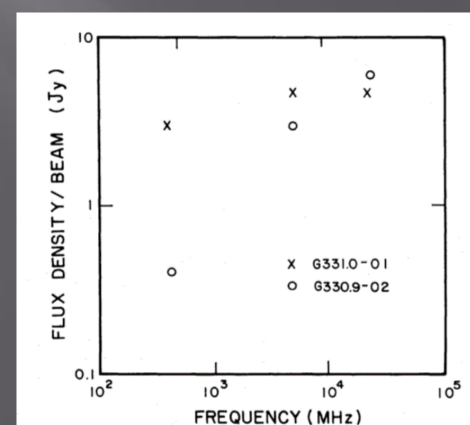
Zulema Abraham IAG/USP
Pedro P.B. Beaklini
Diego Falceta-Gonçalves
Pierre Cox
Lars-Ake Nyman

Radio map of the region G331.5-0.1 at 22 GHz

Amaral & Abraham, A&A 1991







The young stellar cluster [DBS2003] 157 associated with the H II region GAL 331.31−00.34*

M. C. Pinheiro,[1,2]† Z. Abraham,[3] M. V. F. Copetti,[1] R. Ortiz,[4] D. A. Falceta-Gonçalves[4] and A. Roman-Lopes[5]

Mon. Not. R. Astron. Soc. **423,** 2425–2435 (2012)

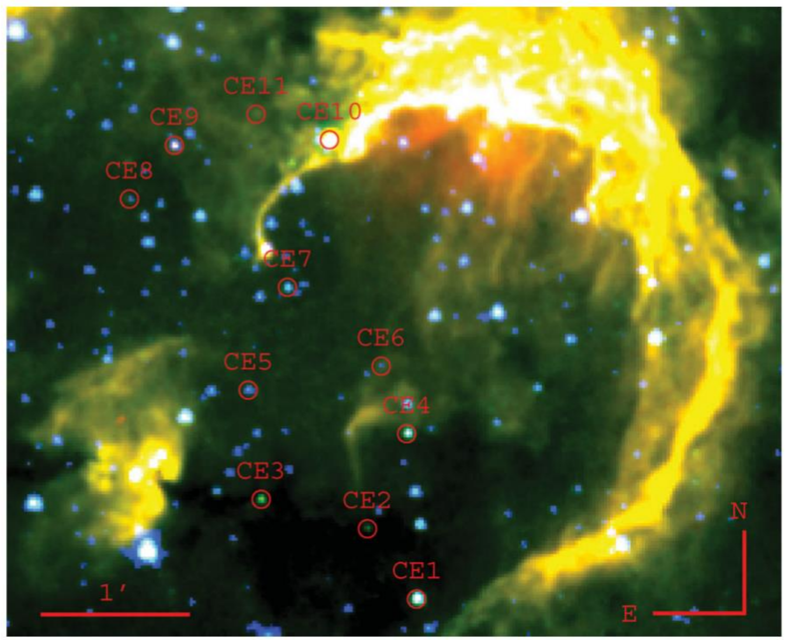


Figure 9. RGB combination of 8.0 μm (R), 5.8 μm (G) and 3.6 μm (B) GLIMPSE images. The red circles indicate the objects showing MIR CEs listed in Table 4. In these three MIR bands, the peak emission coincides with the source CE 10, which we identified as the GLIMPSE counterpart of IRAS 16085−5138.

Photometric and Spectroscopic Survey of the Cluster [DBS2003] 156 Associated with the H II Region G331.1−0.5★

M. C. Pinheiro[1], R. Ortiz[2,3], Z. Abraham[4], and M. V. F. Copetti[5]

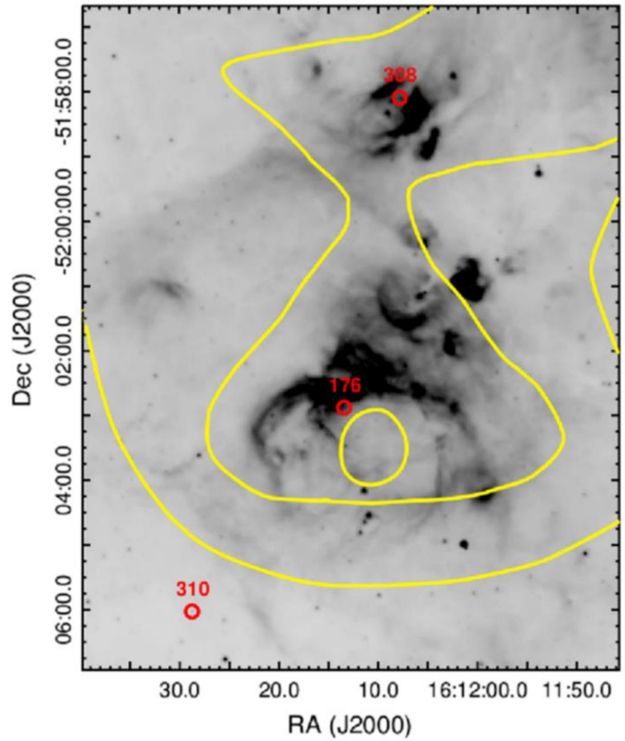
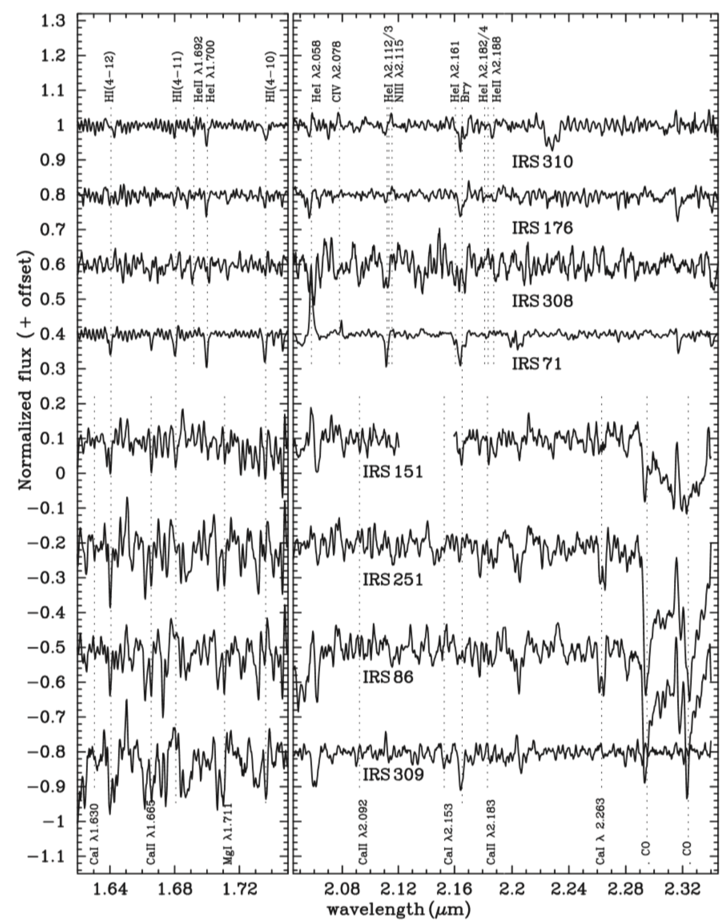


Figure 4. 8.0 μm GLIMPSE image and 22 GHz radio continuum isocontours in the area of [DSB2003] 156. The central contour represents the maximum antenna temperature and the other two 0.65 and 0.35 of that value. The red circles mark the positions of the three O-type stars found in the field.
(A color version of this figure is available in the online journal.)



Motivation

- η Car is a very strong source at millimeter and submillimeter wavelengths, both in the continuum and in H recombination lines

- For that reason it will be used for pointing the LLAMA radiotelescope, although due to its variability is not good for calibration.

- The strength of the recombination lines show that they are formed in regions of high electron densities, where the level population is in NLTE.

- The physical conditions of the region that emits the continuum and the recombination lines in η Car are the same as in hyper-compact HII regions,.

- Finally, I will show for the first time amazing high resolution images of the inner region of η Car obtained with ALMA.

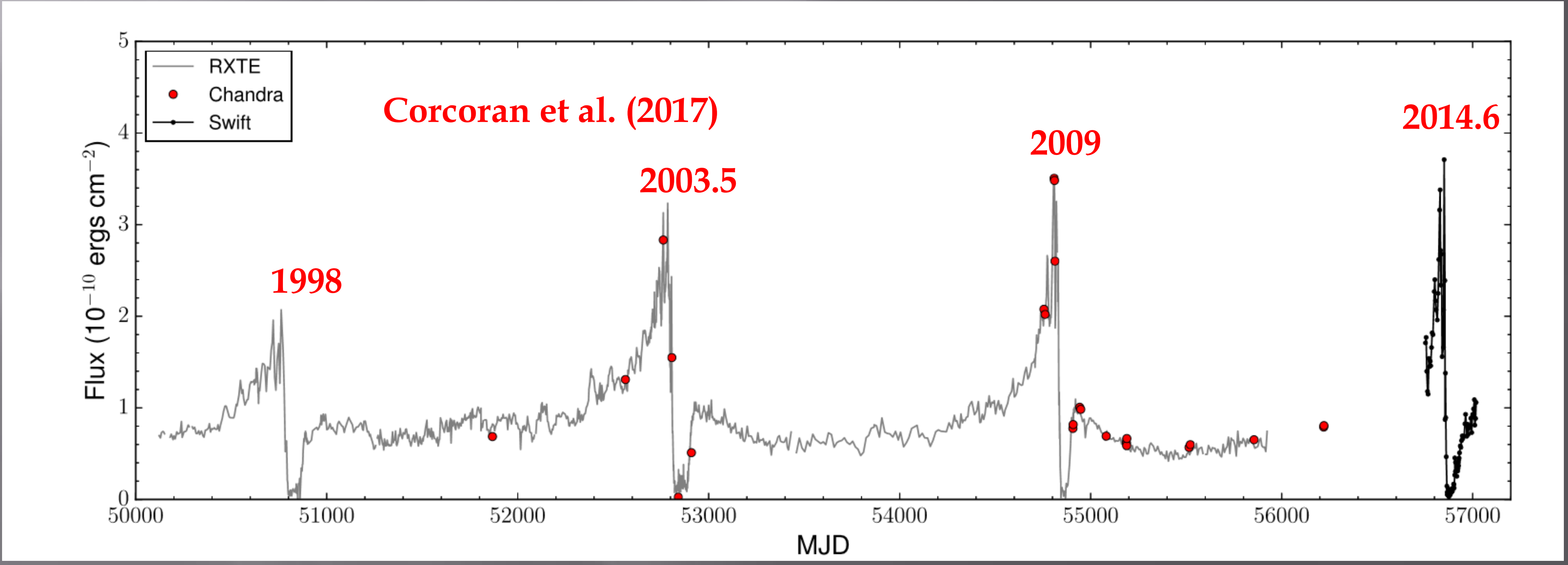
Introduction to η Carinae

- η Carinae is one of the most massive stars in our Galaxy
- In 1840 it had a very strong episode of mass loss (about 12 $M_{\odot}$) that formed the Homunculus Nebula
- It is really a binary system, but the companion star is not visible due to the absorption of the Homunculus nebula and the strong wind of η Carinae
- The existence of the binary system is confirmed by a very strict periodicity in the light curves of high ionization elements, X-rays and radio emission.
- The primary star is probably and LBV (Luminous Blue Variable), and the companion a Wolf Rayet star.

-----Binary system ------ Wind-wind collisions

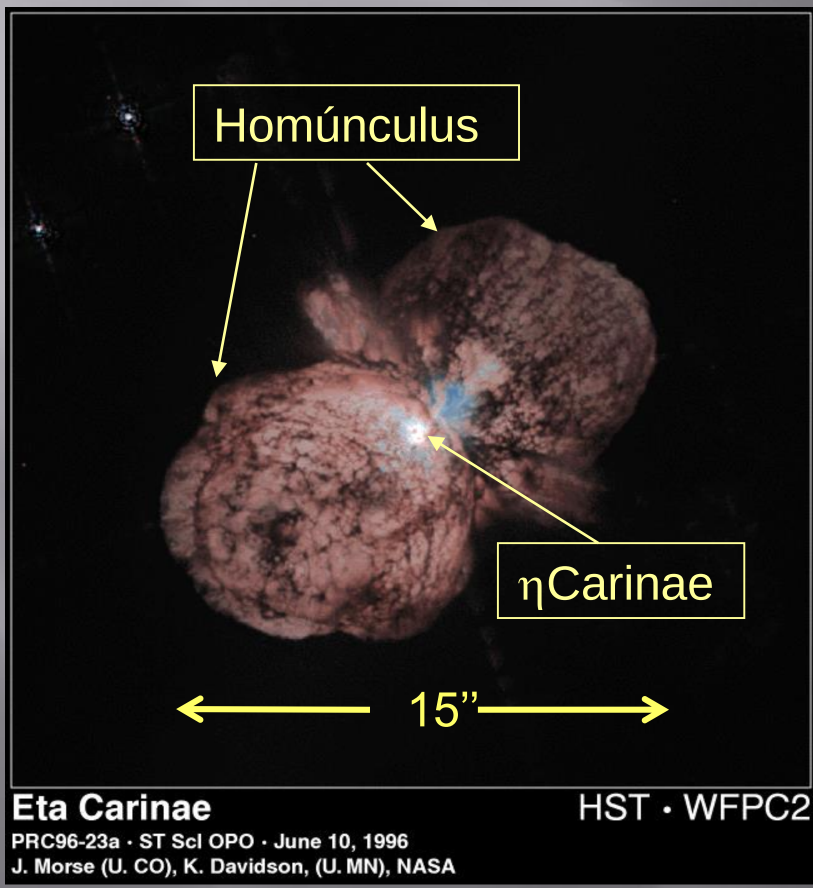
$\dot{M}_p = 3 \times 10^{-4}\ M_\odot/\text{year}$ $\quad v_p = 500\ \text{km/s}$

$\dot{M}_s = 10^{-5}\ M_\odot/\text{year}$ $\quad v_s = 1500\ \text{km/s}$

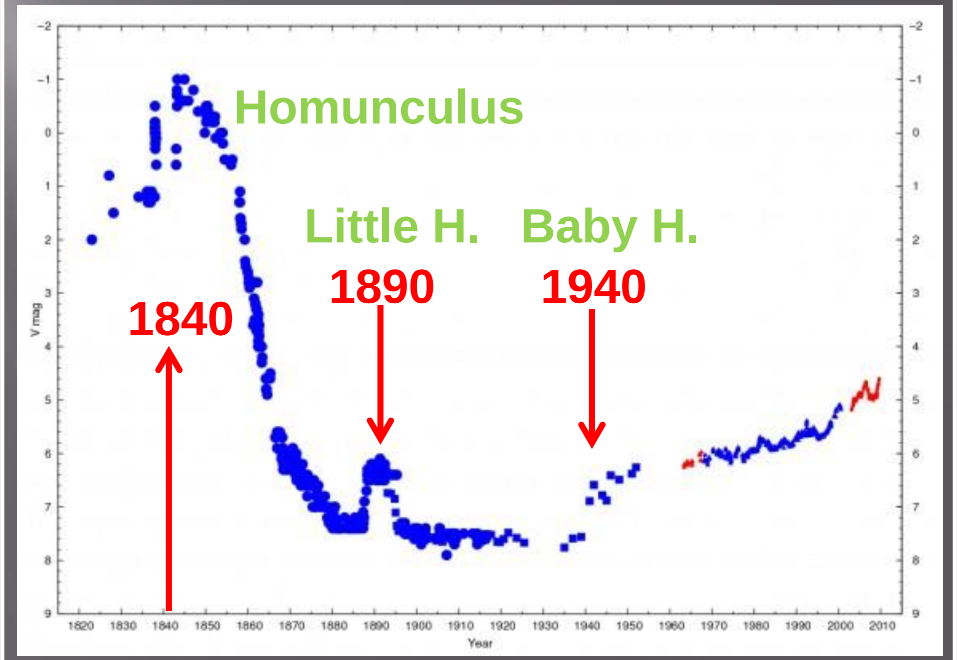


The Homunculus

Expansion velocity 650 km/s

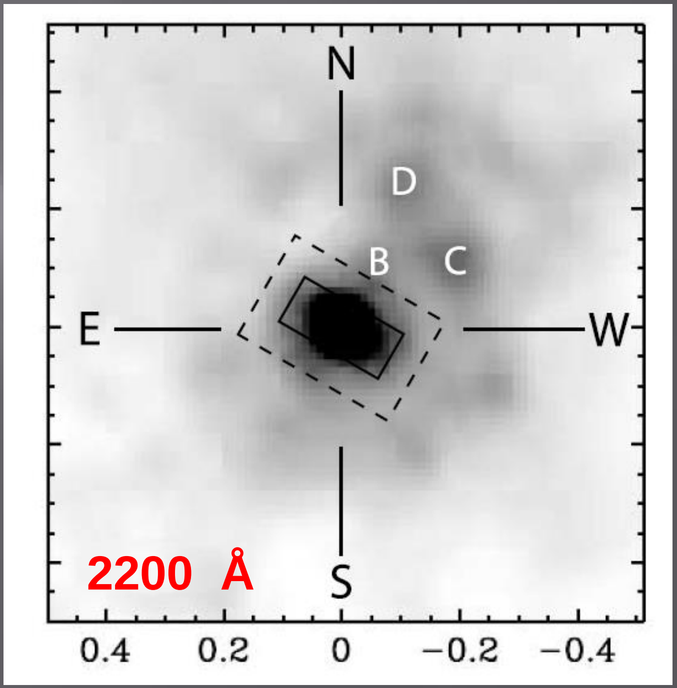


Historic Lightcurve

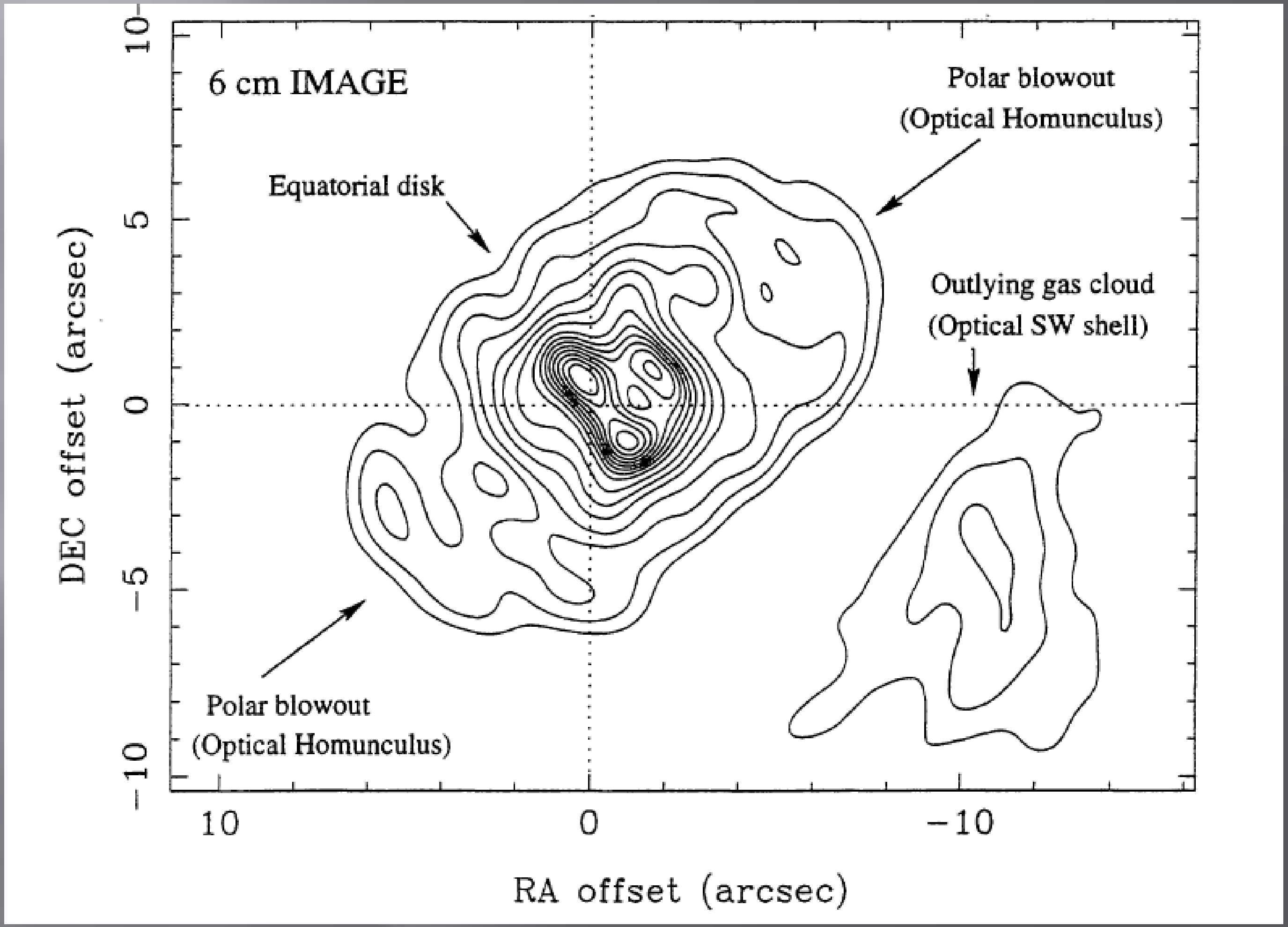


The Weigelt Blobs

- Small regions close to η Carinae (0.2 arc sec) that present lines of highly ionized elements.
- Velocities between -40 and -60 km/s
- Electron densities ~10^7 cm^{-3}
- The light curves of the line intensities present the same periodicity as the X-ray light curve.



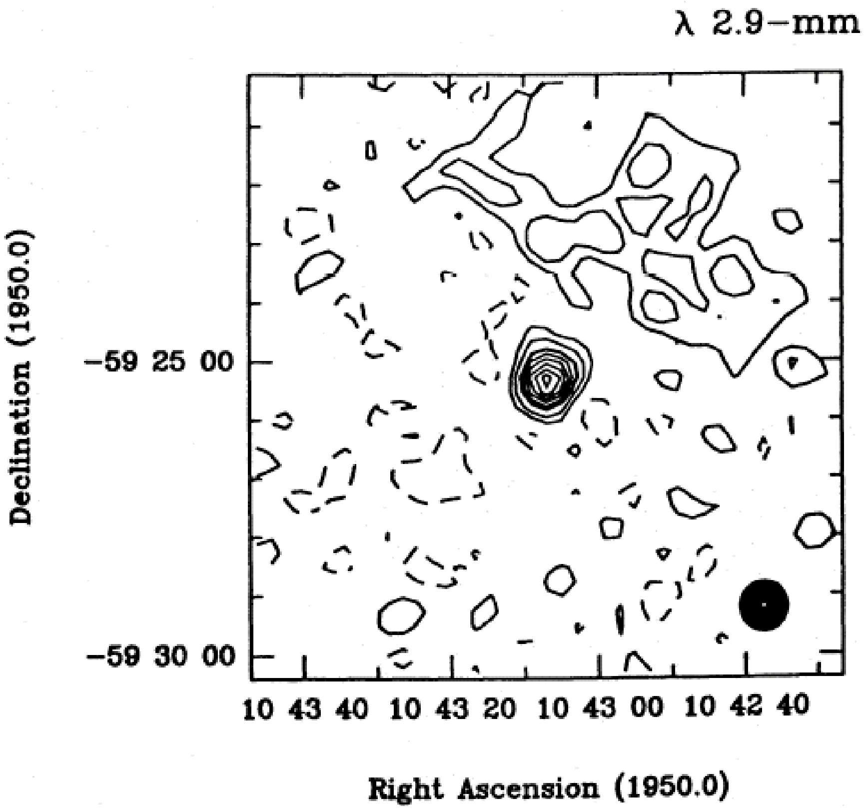
The Homunculus: radio (ATCA)

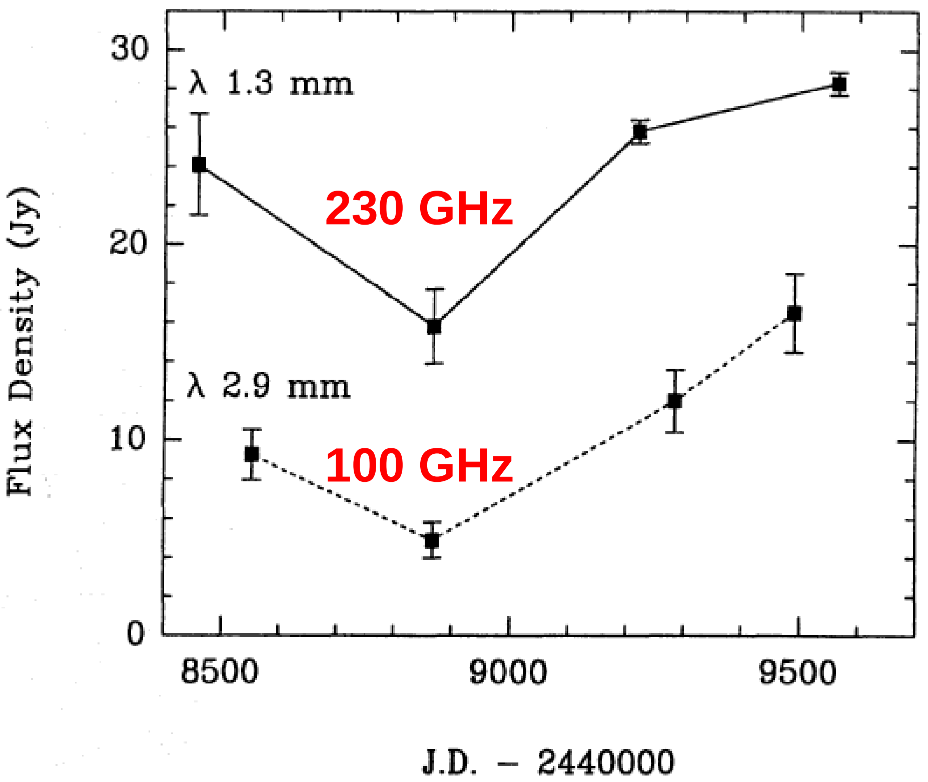


Higher frequencies: continuum

Cox et al. (1995)

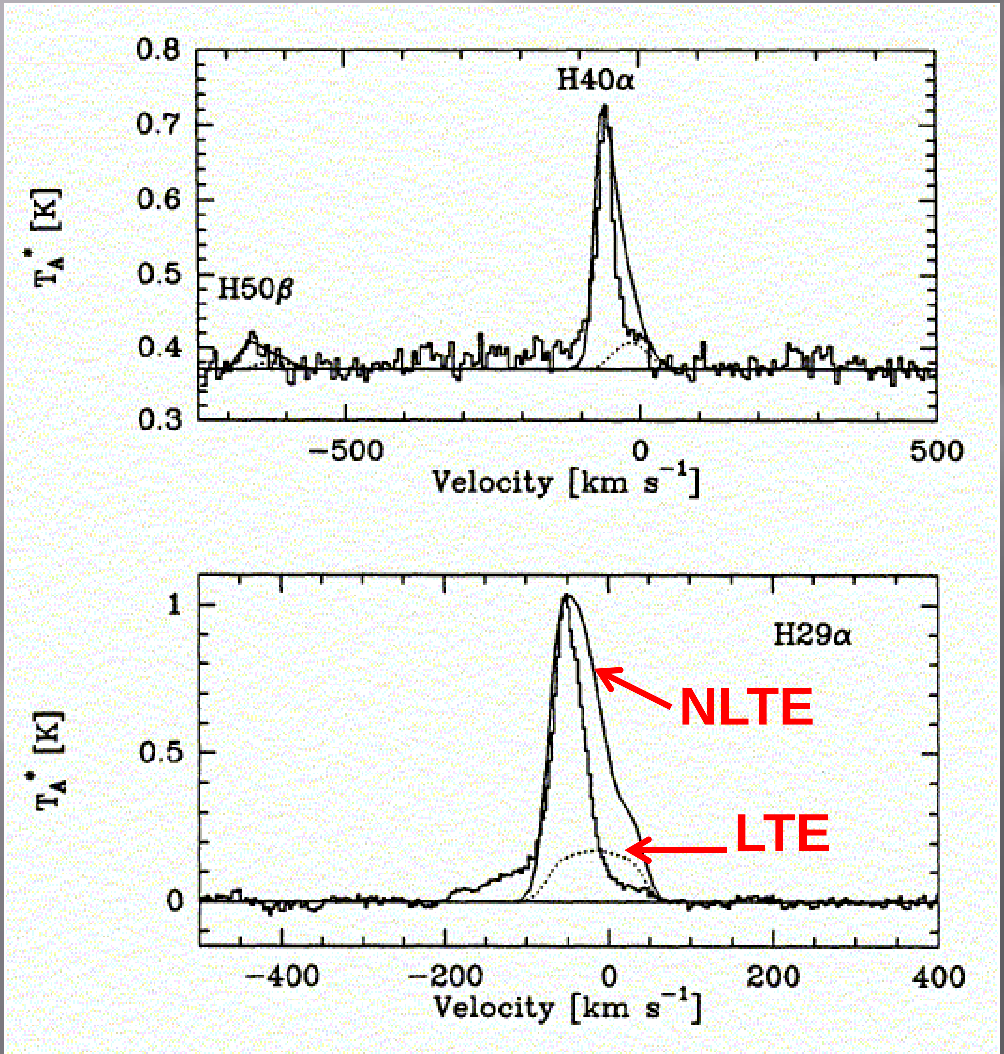
SEST





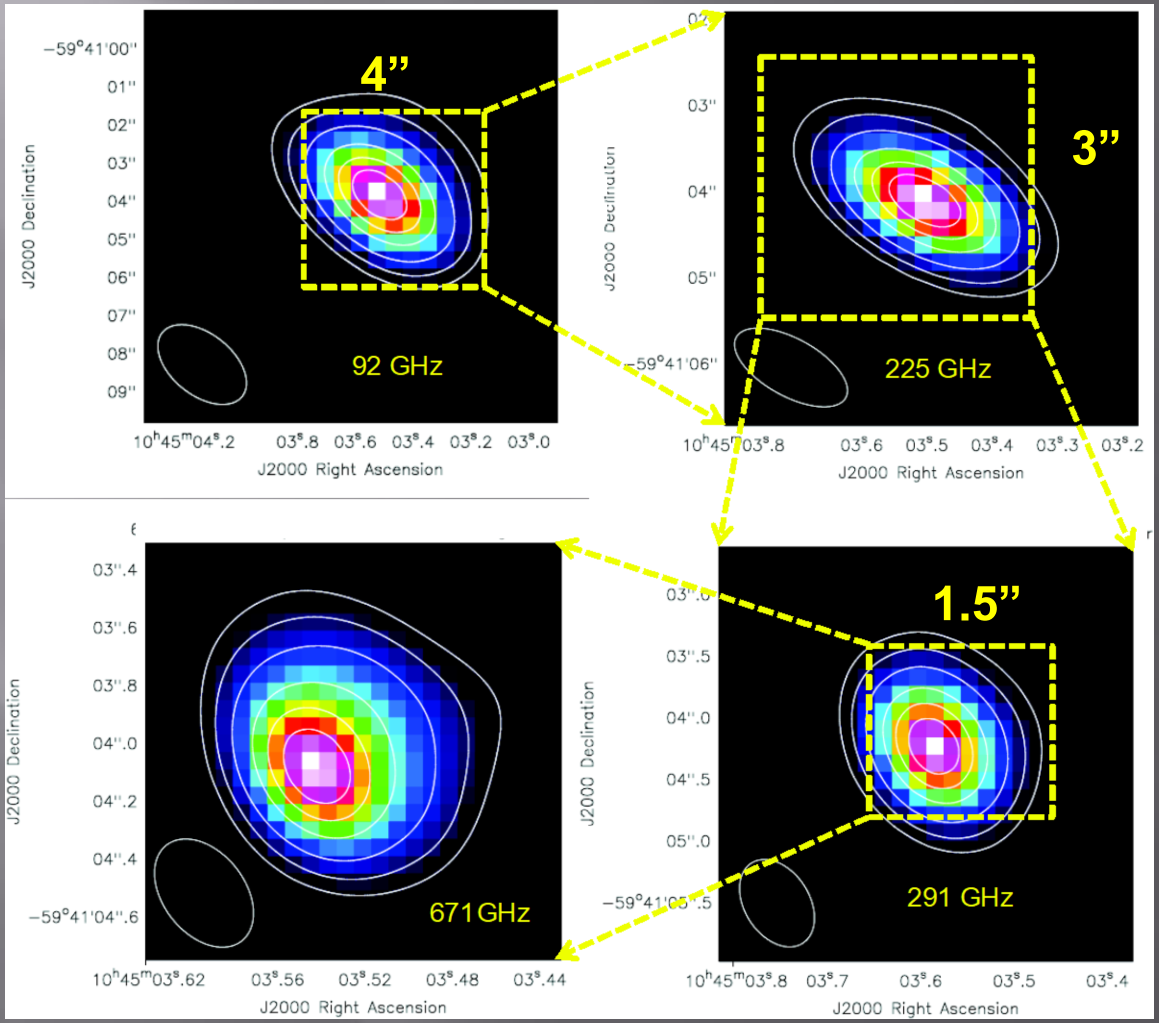
Recombination lines (maser)

Cox et al. (1995)



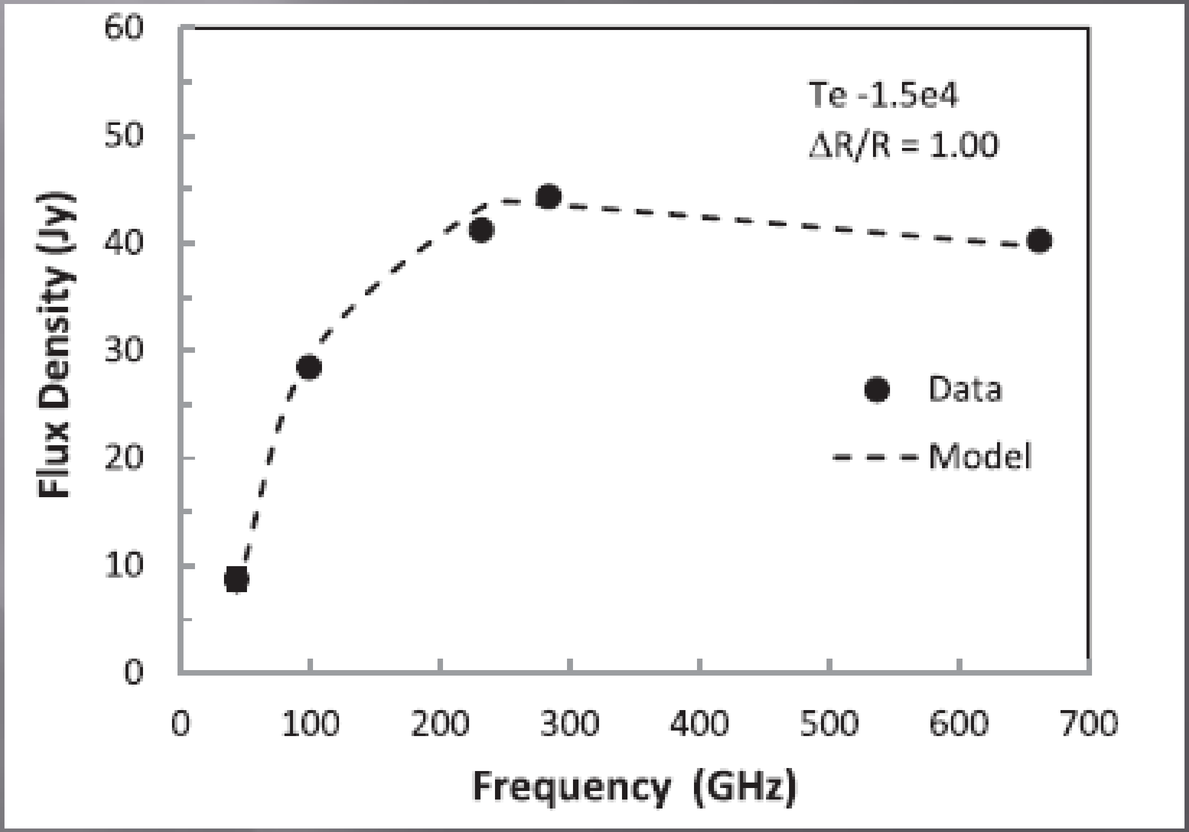
Velocity of the lines and physical conditions (density and temperature) were similar to those of the Weigelt blobs

ALMA observations: Continuum maps (Cycle 0, 2012, 26 elements)

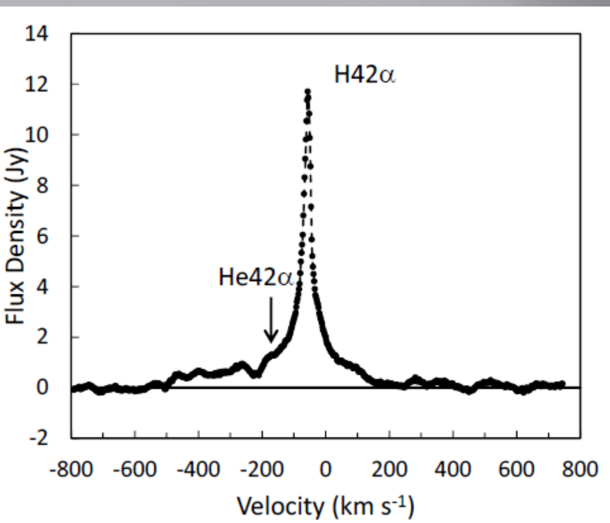


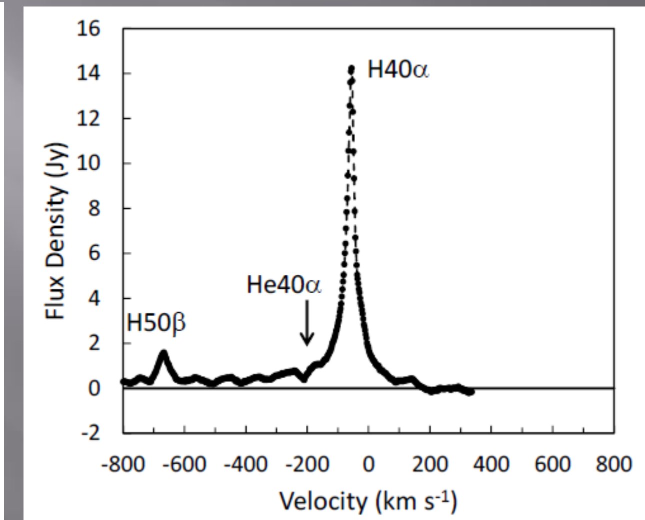
Continuum spectrum (integrated)

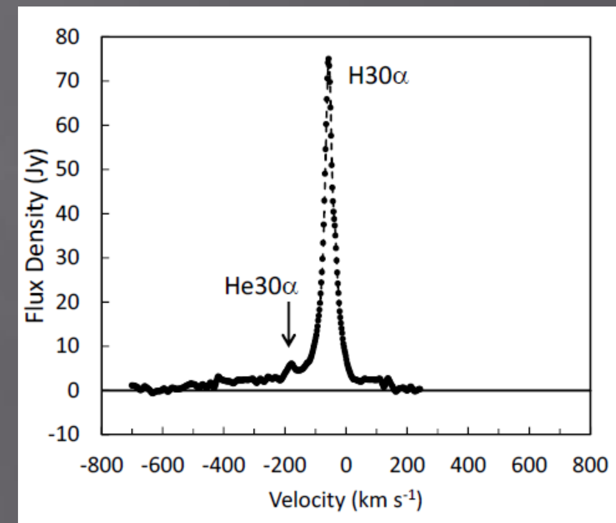
- Spectrum of compact HII region

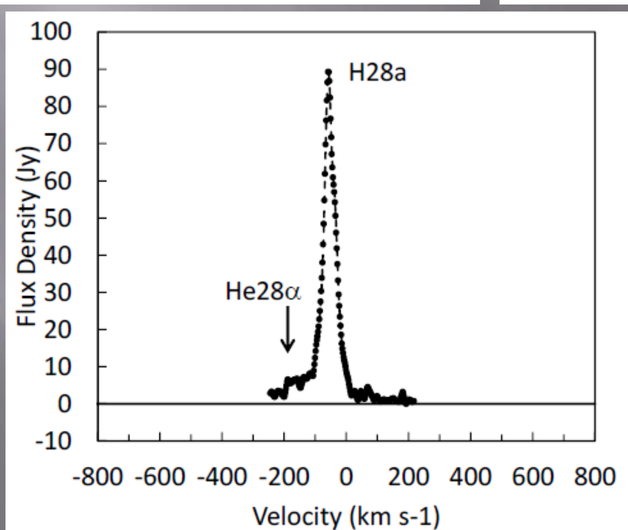


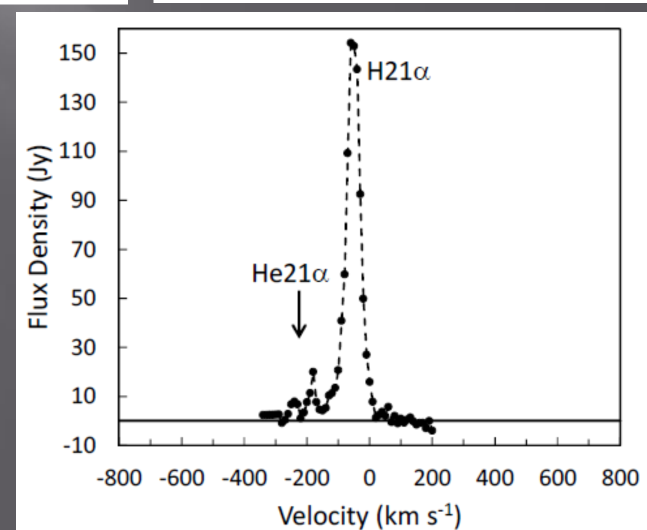
Recombination lines



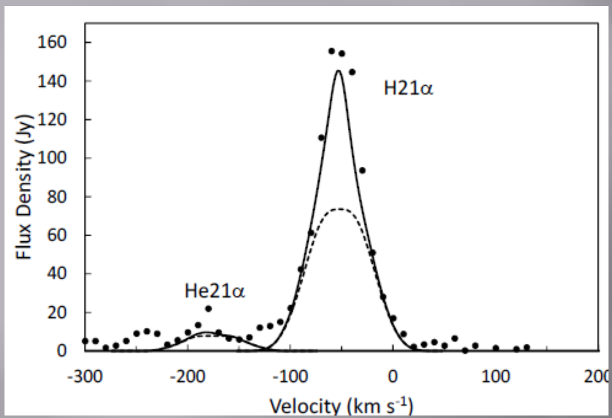


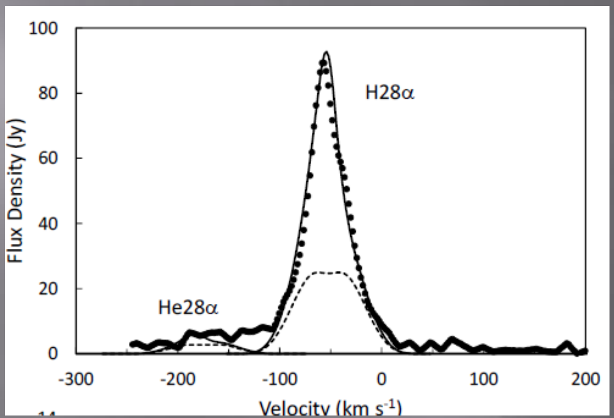


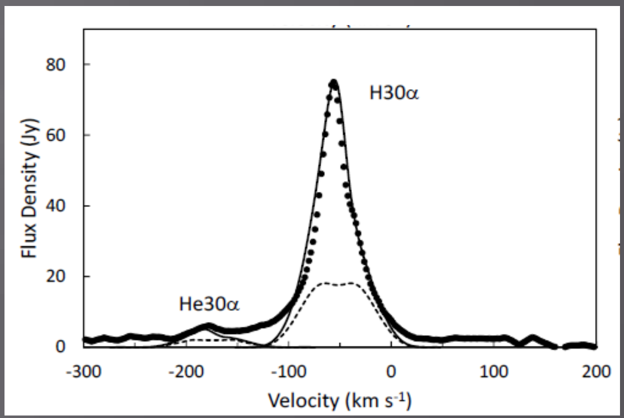


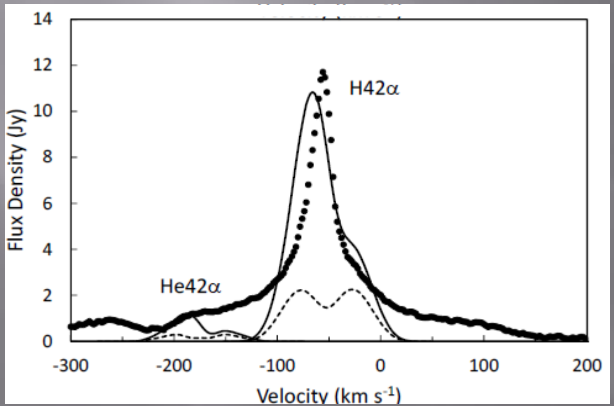


Best fit to the line profiles (expanding shell)

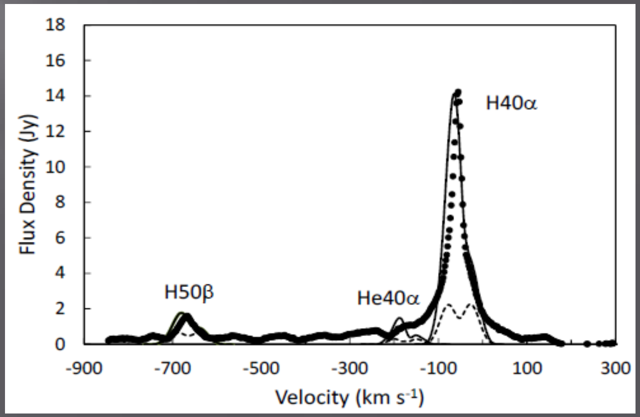






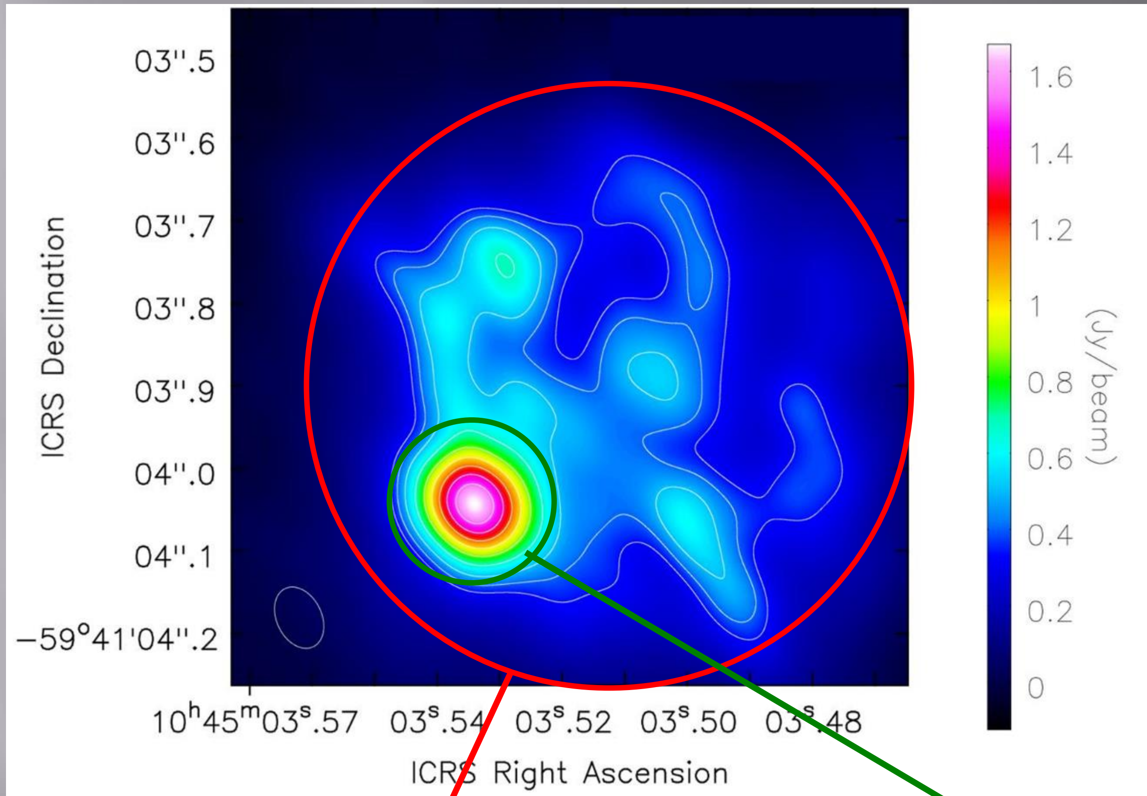


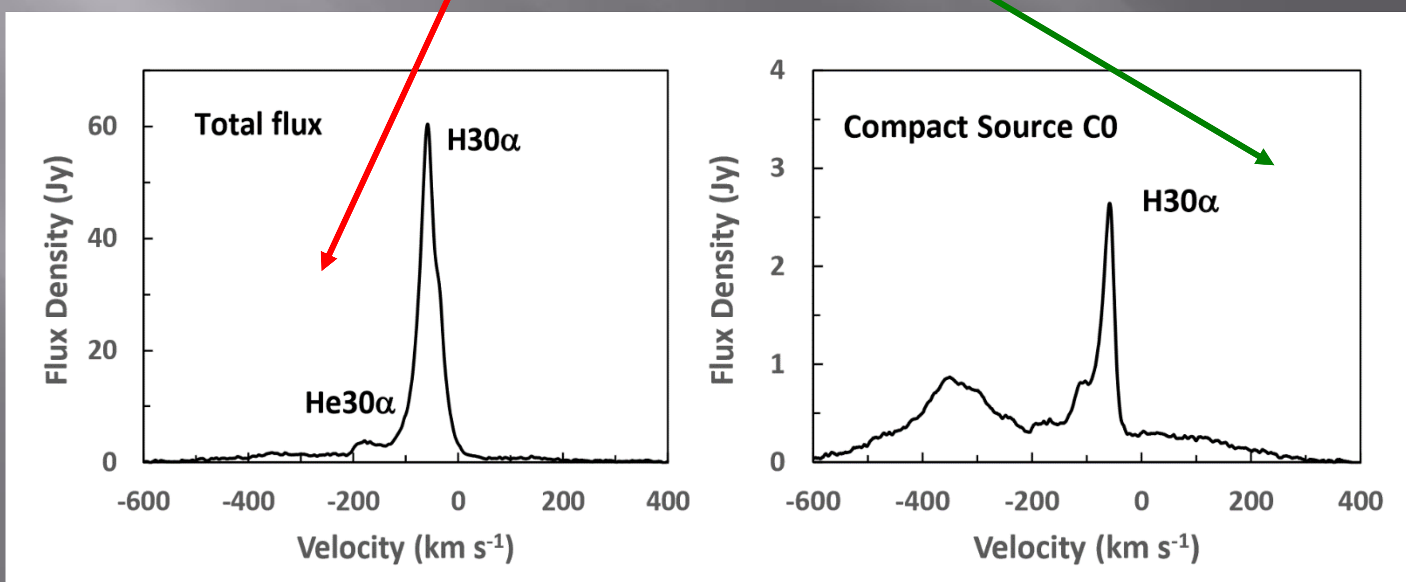
$R=2.2\times10^{-3}$ pc = 0.2″
$\Delta R/R=0.1$
$T_e=1.7\times10^4$ K
$N_e=1.25\times10^7$ cm^{-3}
$V_{bulk}= -52$ km/s
$V_e=-20$ km/s
$V_i=-60$ km/s
$M_{shell} = 0.002\ M_\odot$



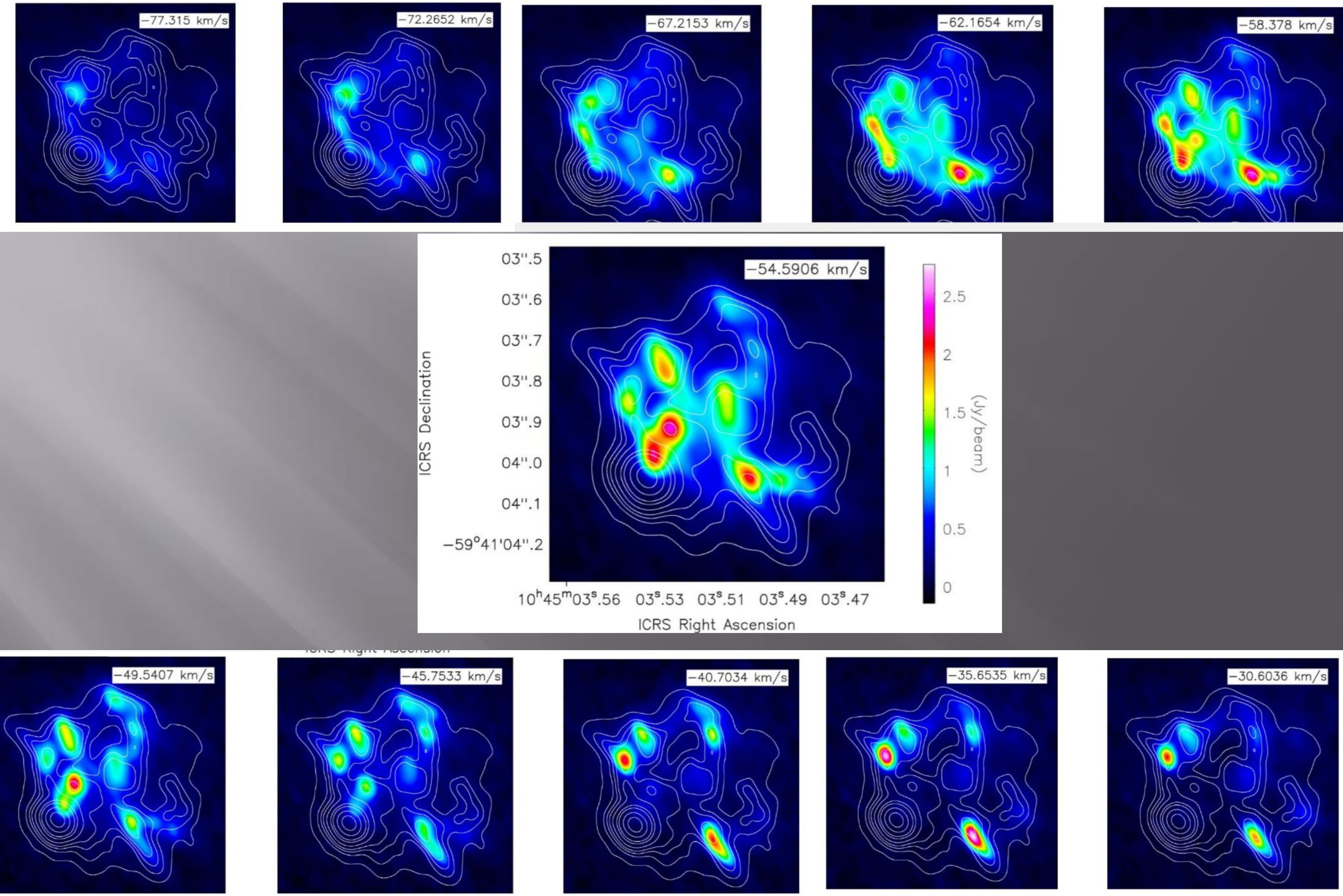
ALMA Cycle 5 (2017)

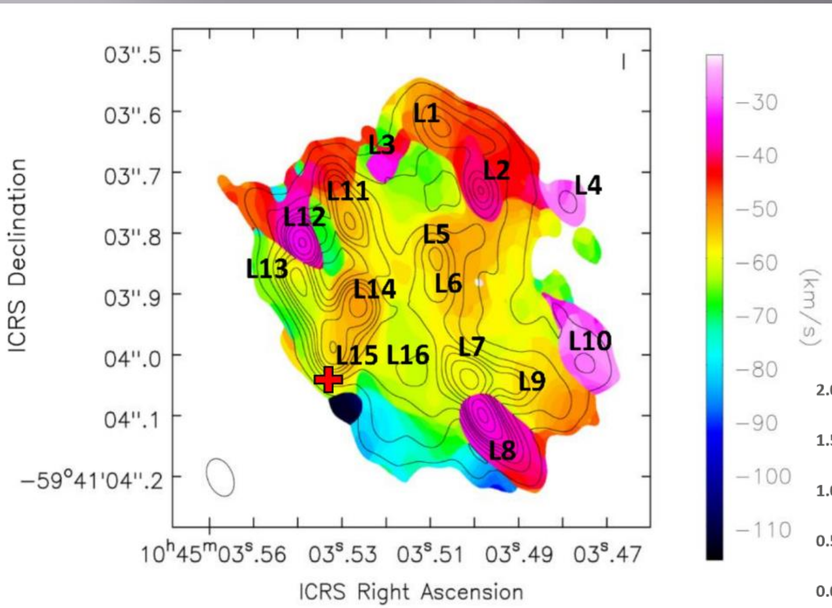
Resolution 0.05”





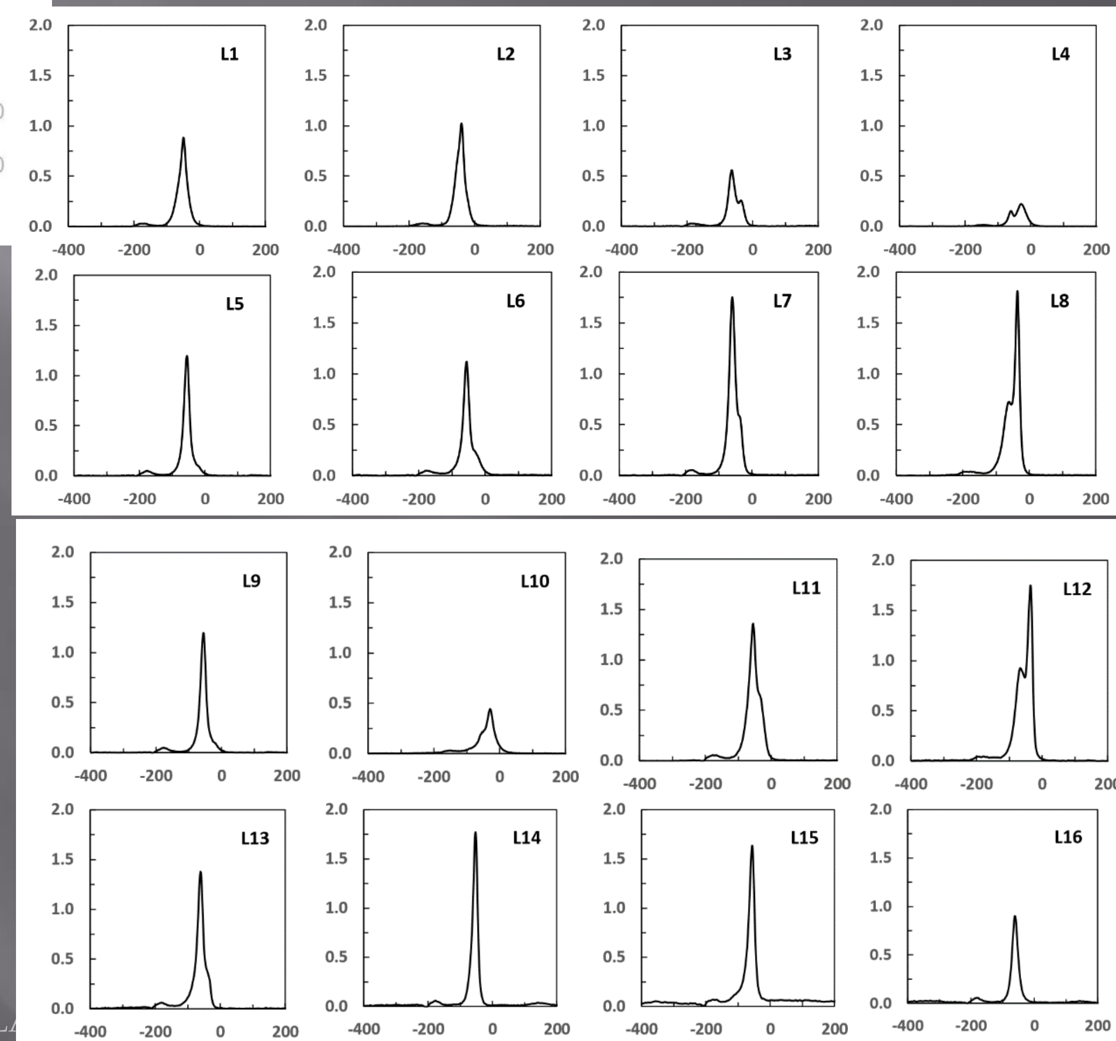
Iso-velocity images (1.2 km/s)





Contours: maximum line intensity

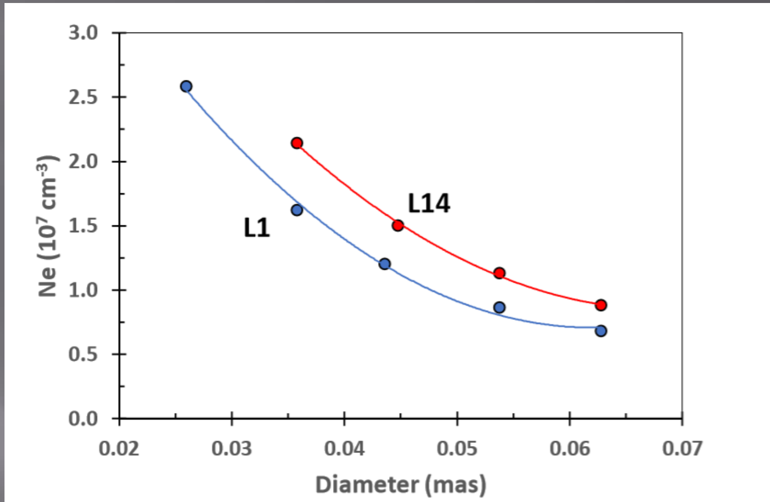
Raster map: velocity of the maximum line intensity.

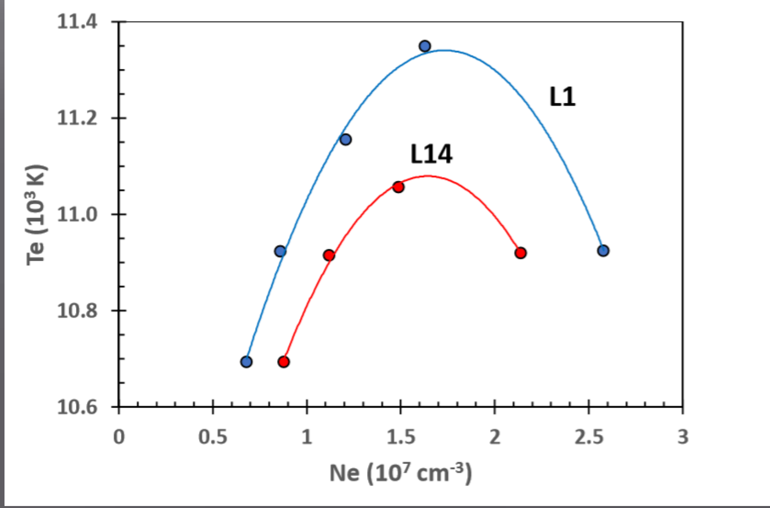


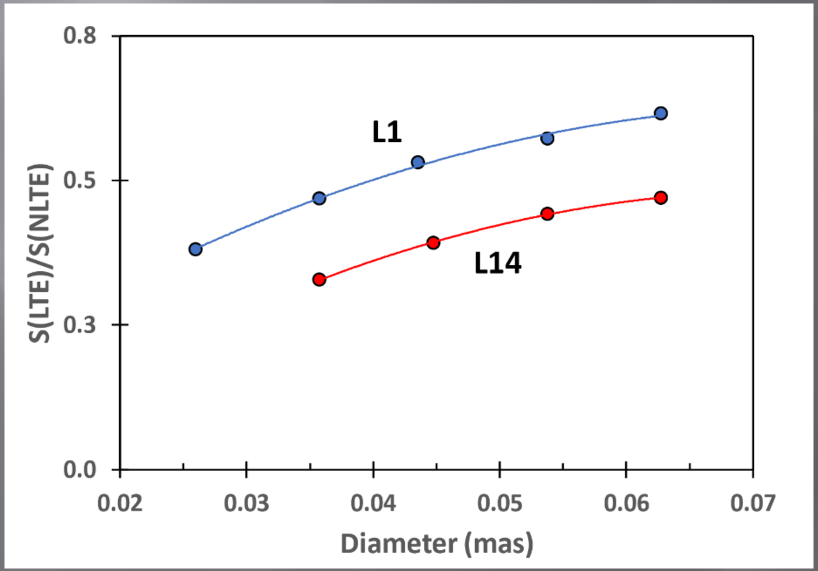
Profiles: integrated over circles of 0.1”

Physical conditions of the compact sources

- For a given value of the spherical source diameter (smaller than the HPBW) and for several values of Te, we determined the value of Ne that reproduced the continuum flux density, and determined the peak flux density of the H30α line.
- We then found the value of Te that correspond to the observed value of the peak flux density.







Targets for masers in radio recombination lines

Class of Region	Size (pc)	Density (cm^{-3})	Emis. Meas. ($pc\ cm^{-6}$)	Ionized Mass ($M_\odot$)
Hypercompact	$\lesssim 0.03$	$\gtrsim 10^6$	$\gtrsim 10^{10}$	$\sim 10^{-3}$
Ultracompact	$\lesssim 0.1$	$\gtrsim 10^4$	$\gtrsim 10^7$	$\sim 10^{-2}$
Compact	$\lesssim 0.5$	$\gtrsim 5 \times 10^3$	$\gtrsim 10^7$	~ 1
Classical	~ 10	~ 100	$\sim 10^2$	$\sim 10^5$
Giant	~ 100	~ 30	$\sim 5 \times 10^5$	10^3–10^6
Supergiant	>100	~ 10	$\sim 10^5$	10^6–10^8

Kurtz 2005, IAUS, 227, 111

Thank you