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The structure of the Proto-Planetary Nebula OH231.8+4.2 as revealed by VLTI & MERLIN interferometric Observations

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AGB Stars

- The AGB phase starts when the star has ceased the core helium burning phase. Then double-shell burning takes place. The star reaches its maximum mass-loss rate (up to 10^{-4} $M_{\odot}$/yr) when it enters the so-called 'thermal pulse phase' (TP-phase).

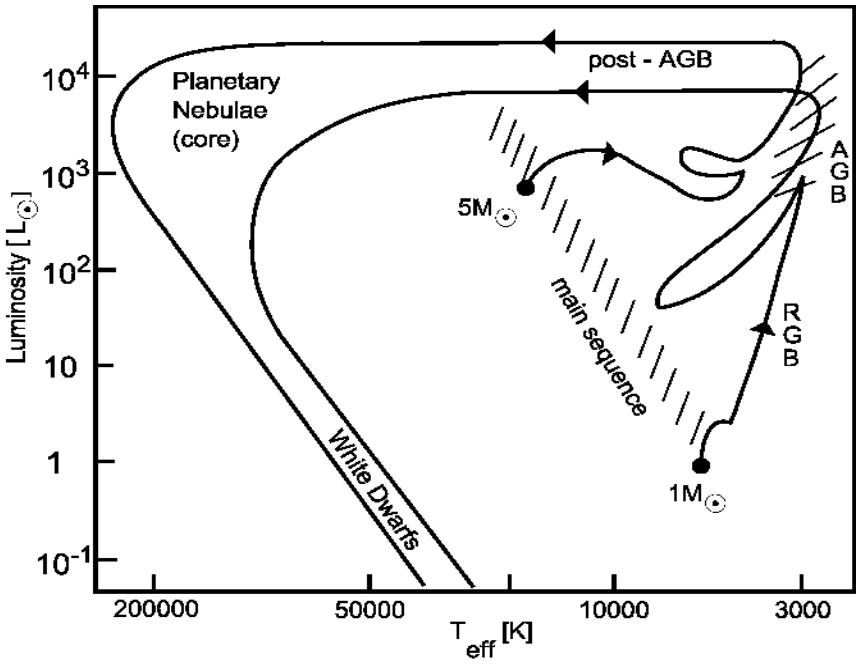


Fig 1 Engels (2004)

Schematic evolutionary tracks of stars with main-sequence masses of 1 and 5 $M_{\odot}$

Post-AGB Stars

- The post-AGB/ Proto-Planetary Nebula stage starts at the end of the ‘thermal pulse phase’ (TP-phase) where a 'fast wind' develops and stop at the ionisation of the nebula.

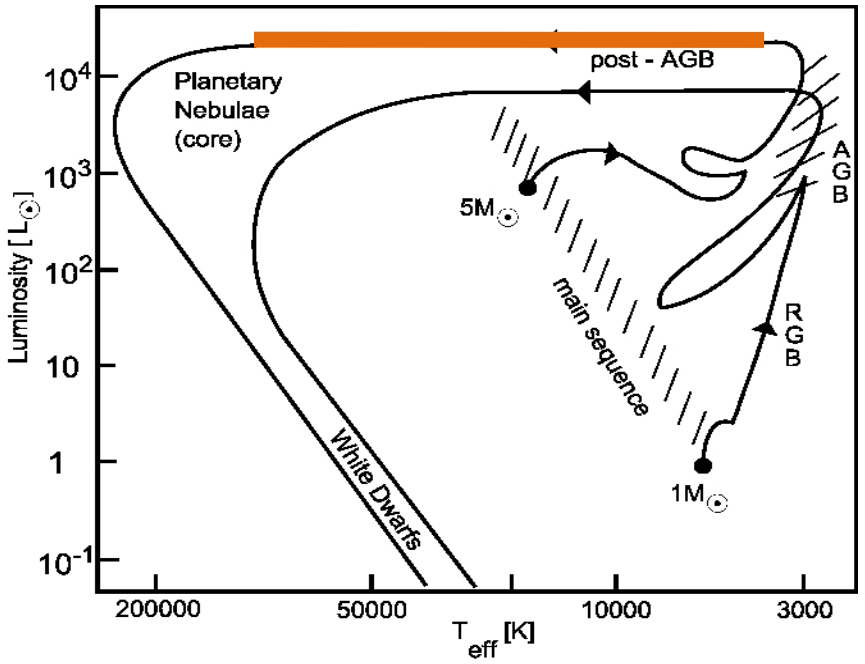
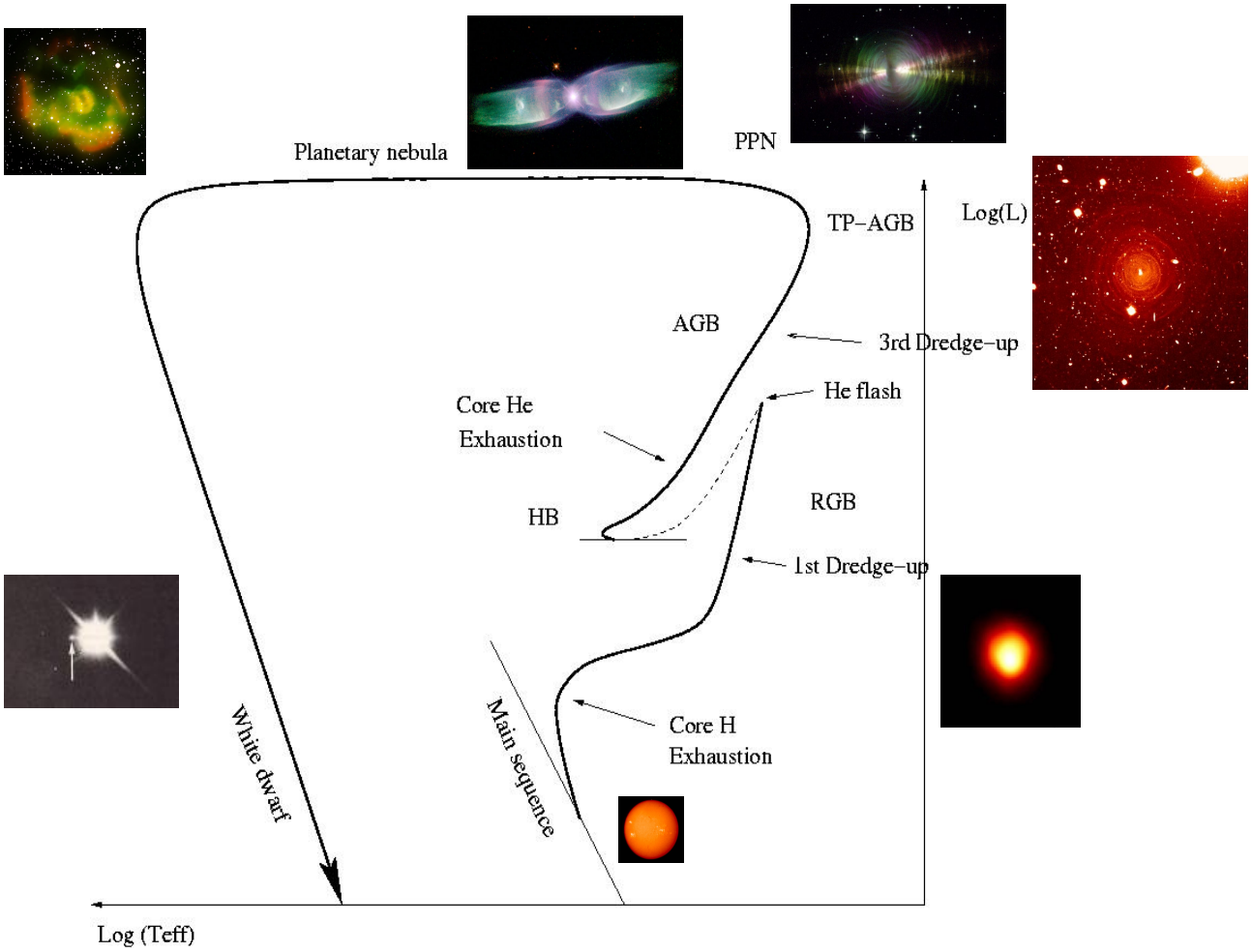


Fig 1 Engels (2004)

Schematic evolutionary tracks of stars with main-sequence masses of 1 and 5 $M_\odot$

Evolution of a low mass star



- Change of geometry somewhere between the tip of the AGB and the PN stage

Adapted from Lattanzio & Boothroyd (1997) (evolution of a 1 Solar mass star)

OH231.8+4.2

Prototype Bipolar Planetary Nebula

(Rotten-Egg / Calabash Nebula / IRAS 07399-1435)

- Intermediate-mass evolved star (>3$M_\odot$)

  TiO band detected towards central region ⇨ type M9 (Cohen 1981) & total molecular mass of 0.5-1 $M_\odot$

- distance: ~1.5 kpc *(located in the open cluster M46 – Jura & Morris 1985)*

- outflow strongly bipolar titled 40˚ to the plane of sight *(Kastner et al. 1992)*

  Bubble and shocked region detected within it (bujarrabal et al. 2002)

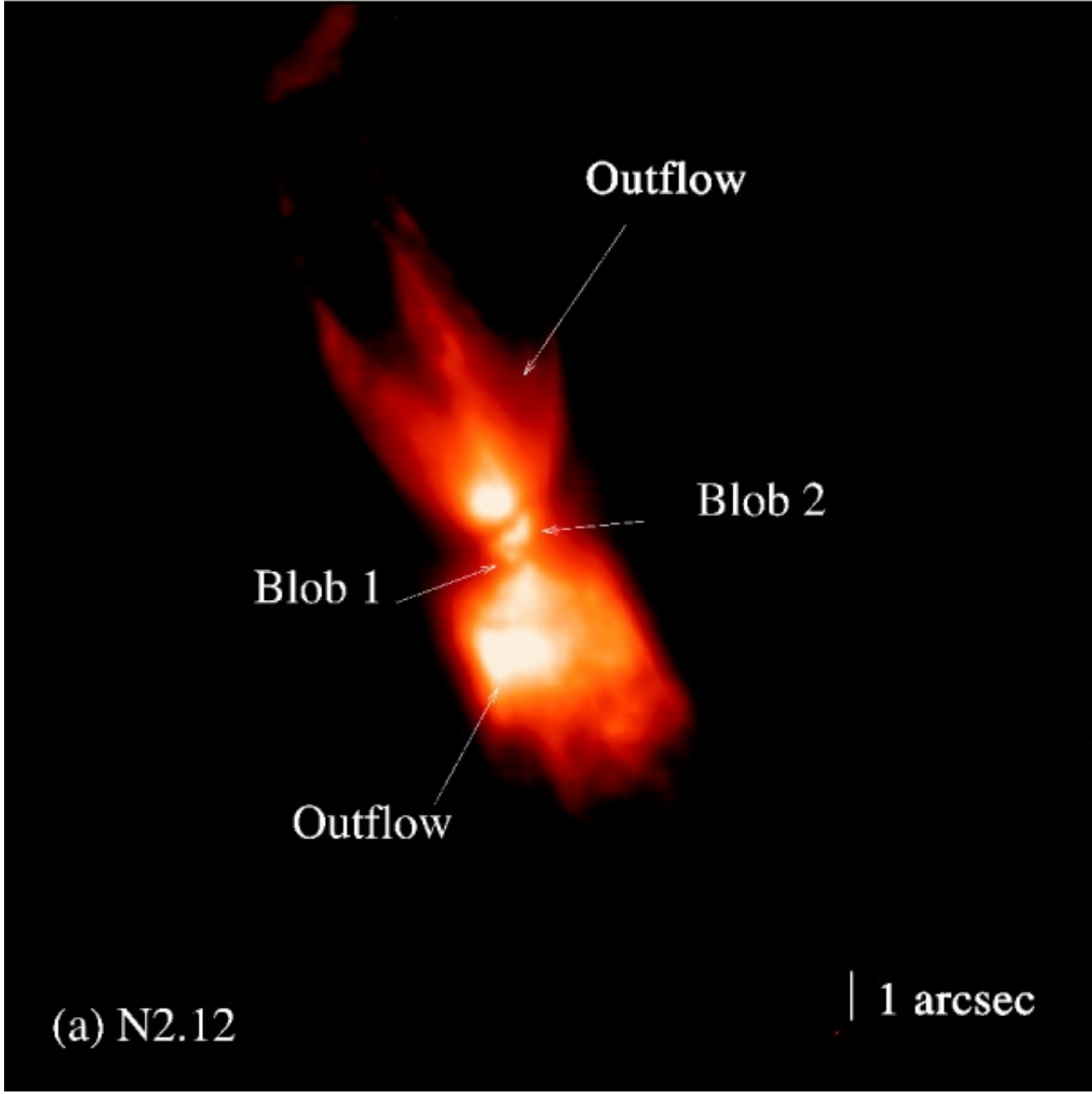
OH231.8+4.2

Prototype Bipolar Planetary Nebula

(Rotten-Egg / Calabash Nebula / IRAS 07399-1435)

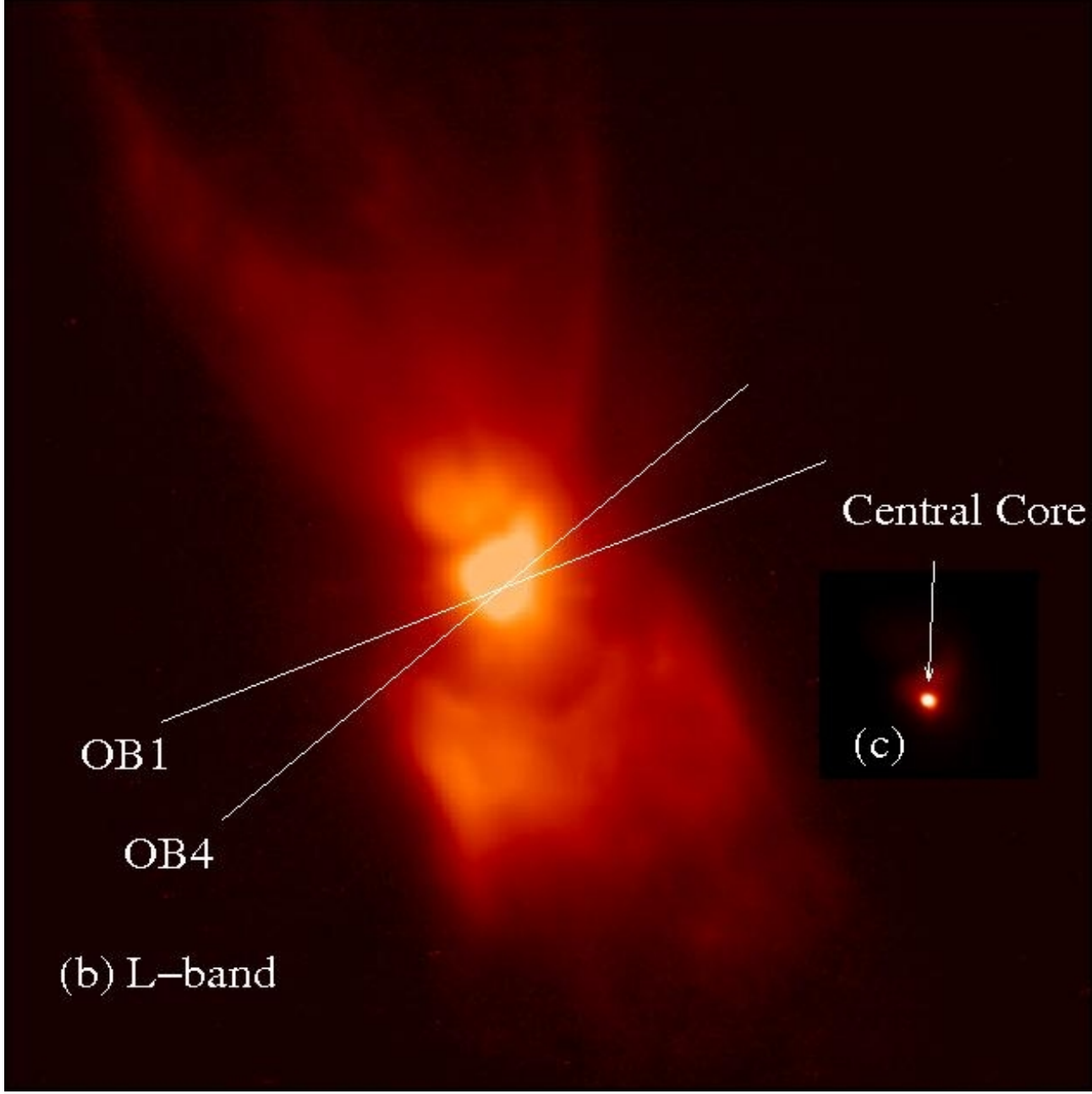
- Possible binary system *(Sanchez-Contreras et al. 2004)*
- $V_{star} \simeq +35$ km/s *(from CO)*
- $\Delta V_{OH} \simeq 100$ km/s & $\Delta V_{CO} \simeq 200$ km/s *(300 km/s deprojected)*
- Observed with the VLA in 1988 where a torus/disk-like structure + outflow material were detected in OH *(Zijlstra et al. 2001)*

- Near-infrared adaptive optics images taken with the camera NACO on the VLT in March 2004
- the outflow is clearly seen
- The central region is still obscured and consists of patchy cloud (Blobs)



(Matsuura et al. 2006)

- The L'band *(i.e., at 3.80 μm)* image
- **the outflow is much fainter**
- **The central region revealed a source** *(unresolved in the NACO image)* **with a diameter ~30-40mas** *(MIDI observations)*



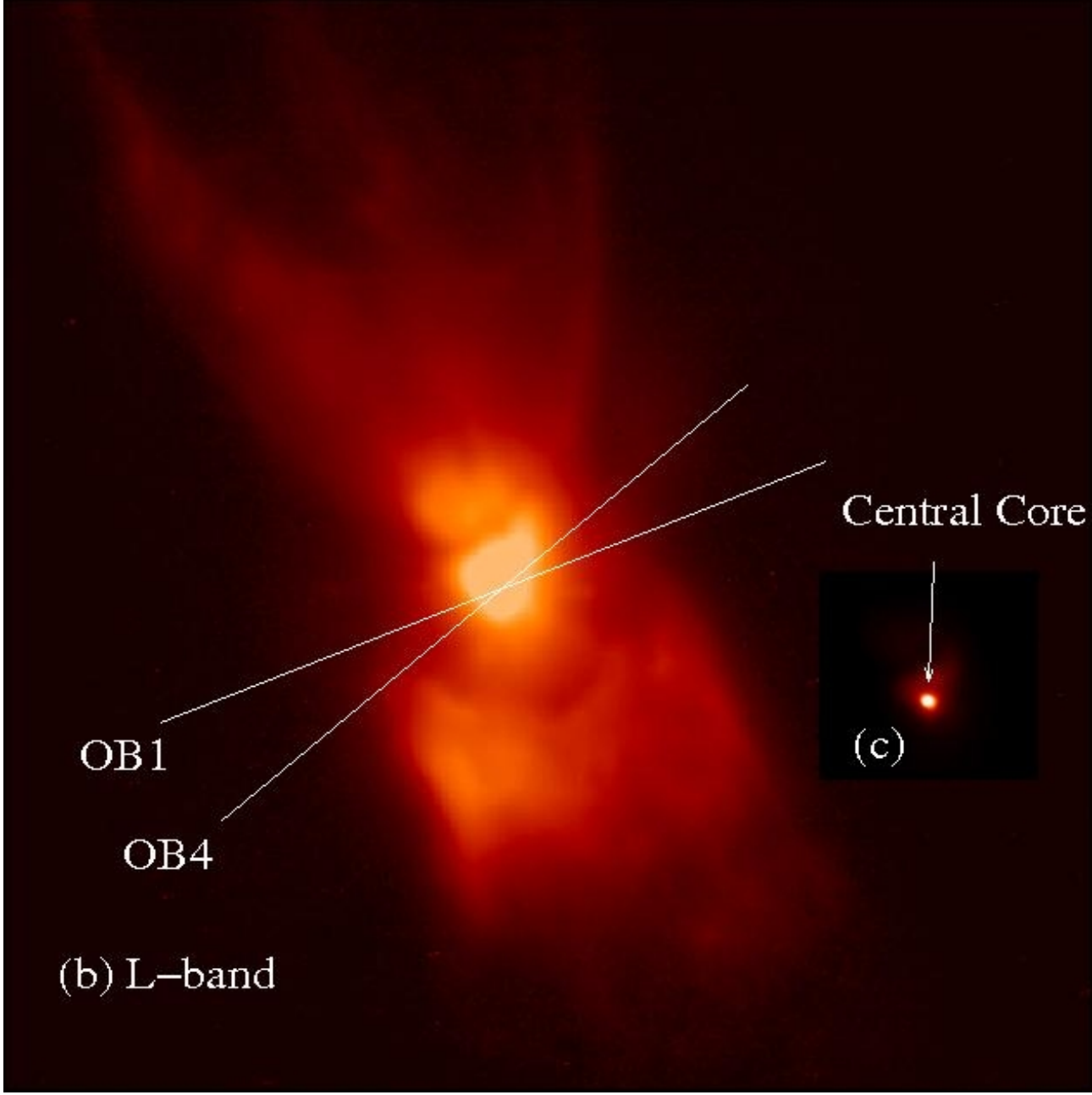
(Matsuura et al. 2006)

BUT

- Measurements only with baselines ~ perpendicular to the bipolar lobes

↓

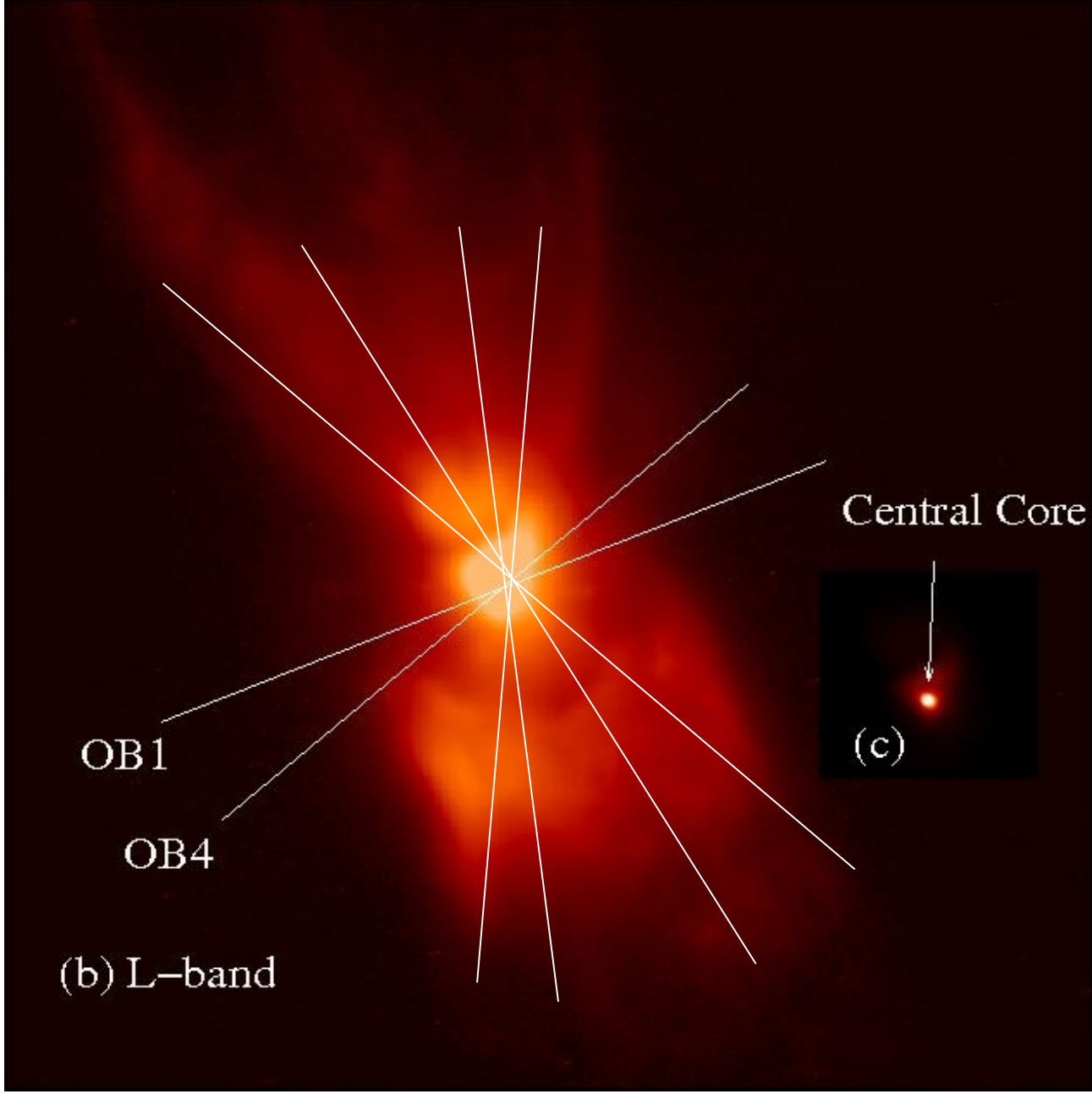
- Dusty structure size determined in just one direction



(Matsuura et al. 2006)

A disc or a shell ?

- New observations with MIDI (PI: Eric Lagadec) with 4 new baselines along the poles

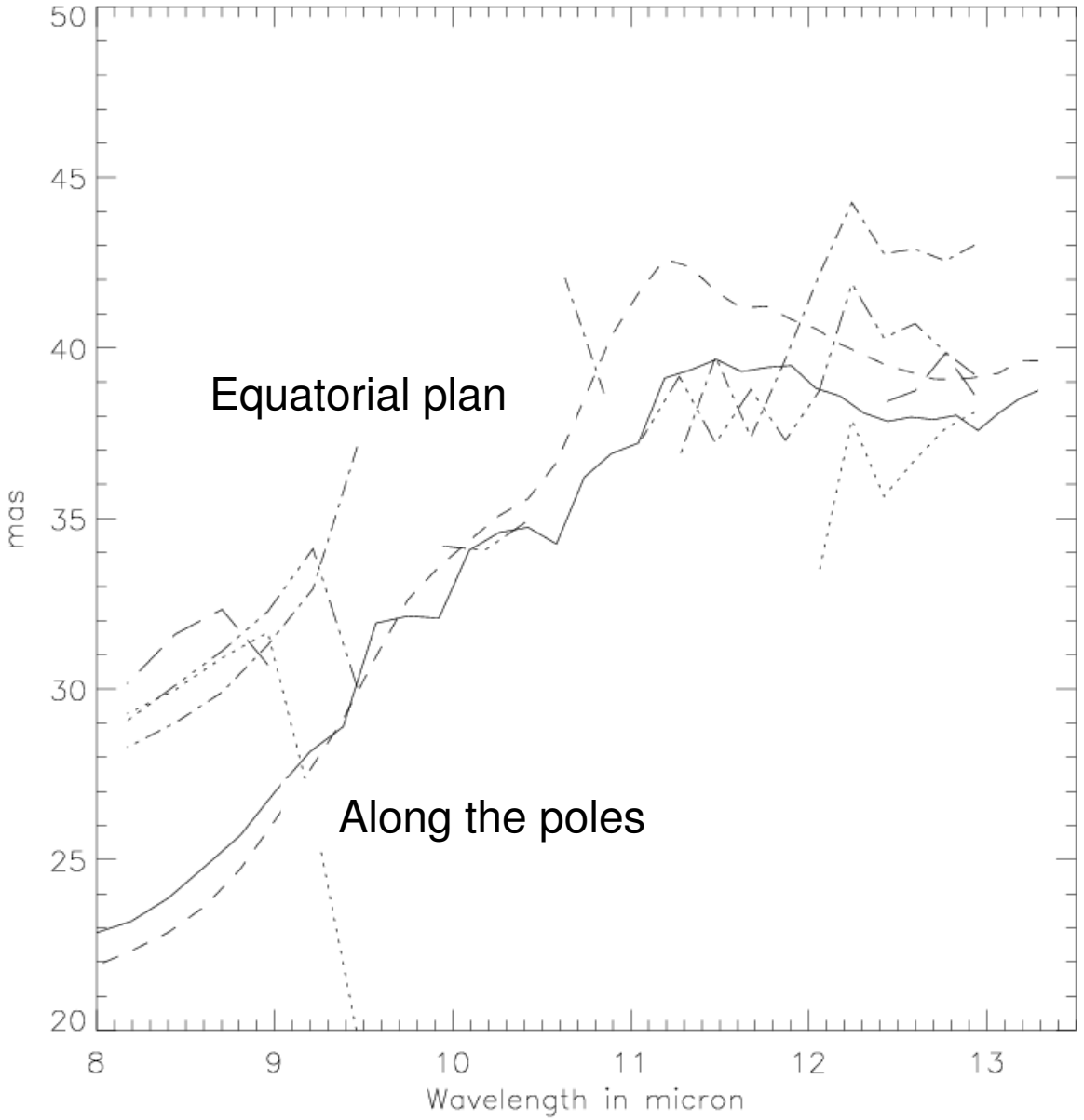


Gaussian fit of the visibilities

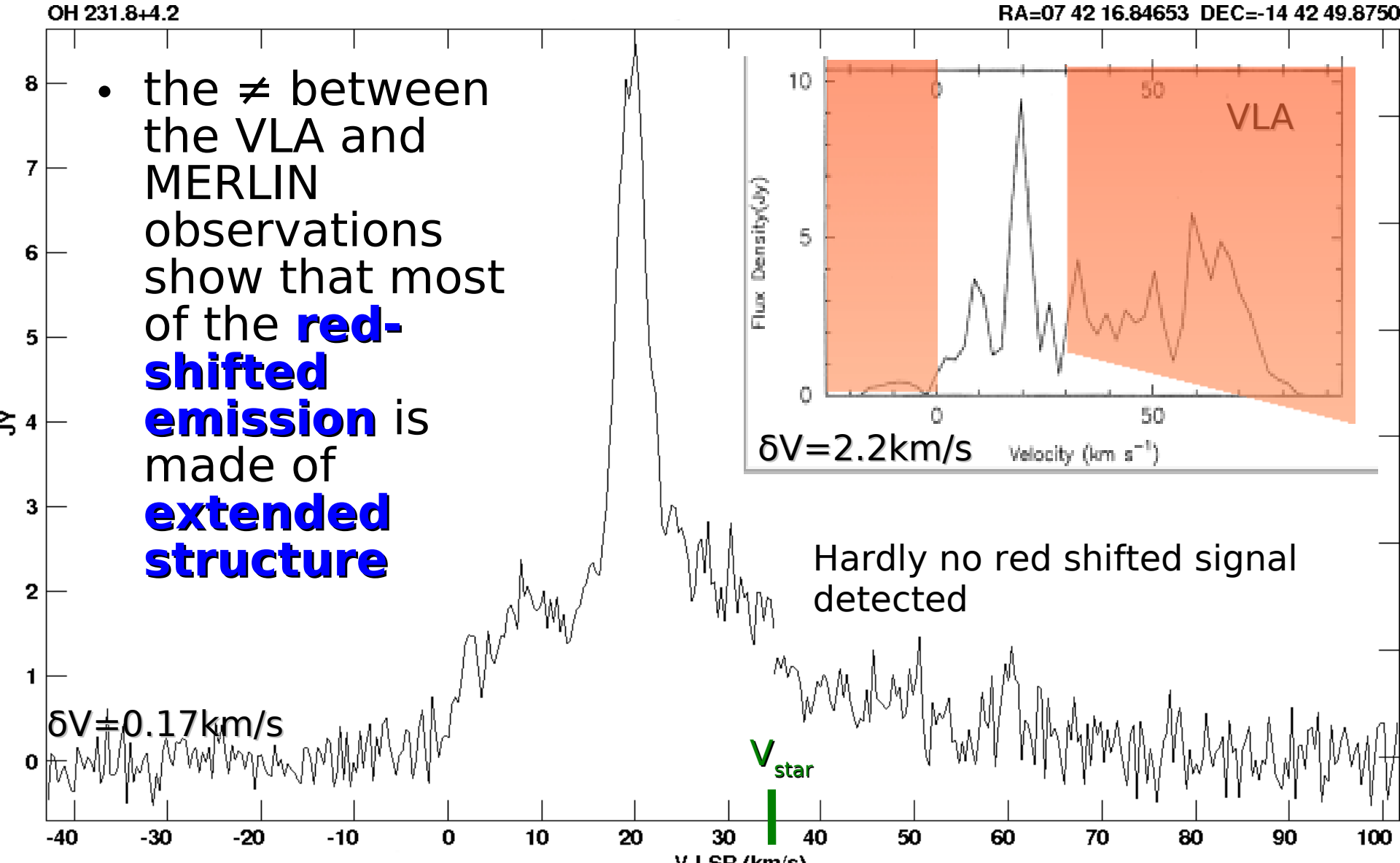
- Along the poles: $\varnothing_{8\mu m}$ ~ 22-23 mas *(33 AU @ 1.5kpc)*
- Equatorial plane: $\varnothing_{8\mu m}$ ~ 30 mas *(45 AU @ 1.5kpc)*
- & $\varnothing_{13\mu m}$ ~ 40 mas

↓

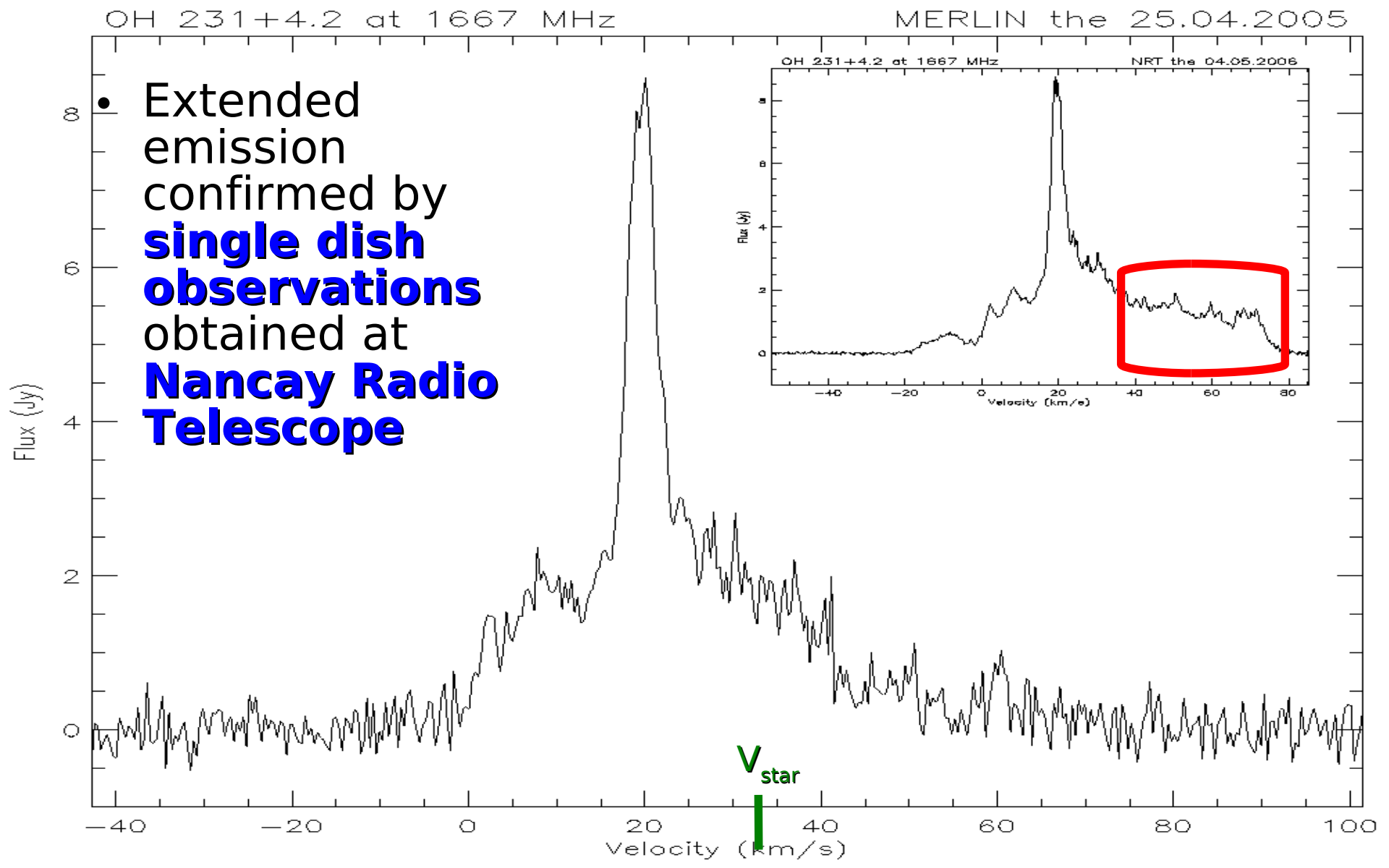
- Not a disc but rather a flattened shell *(Lagadec et al. 2007, submitted)*



MERLIN I Stokes Spectrum



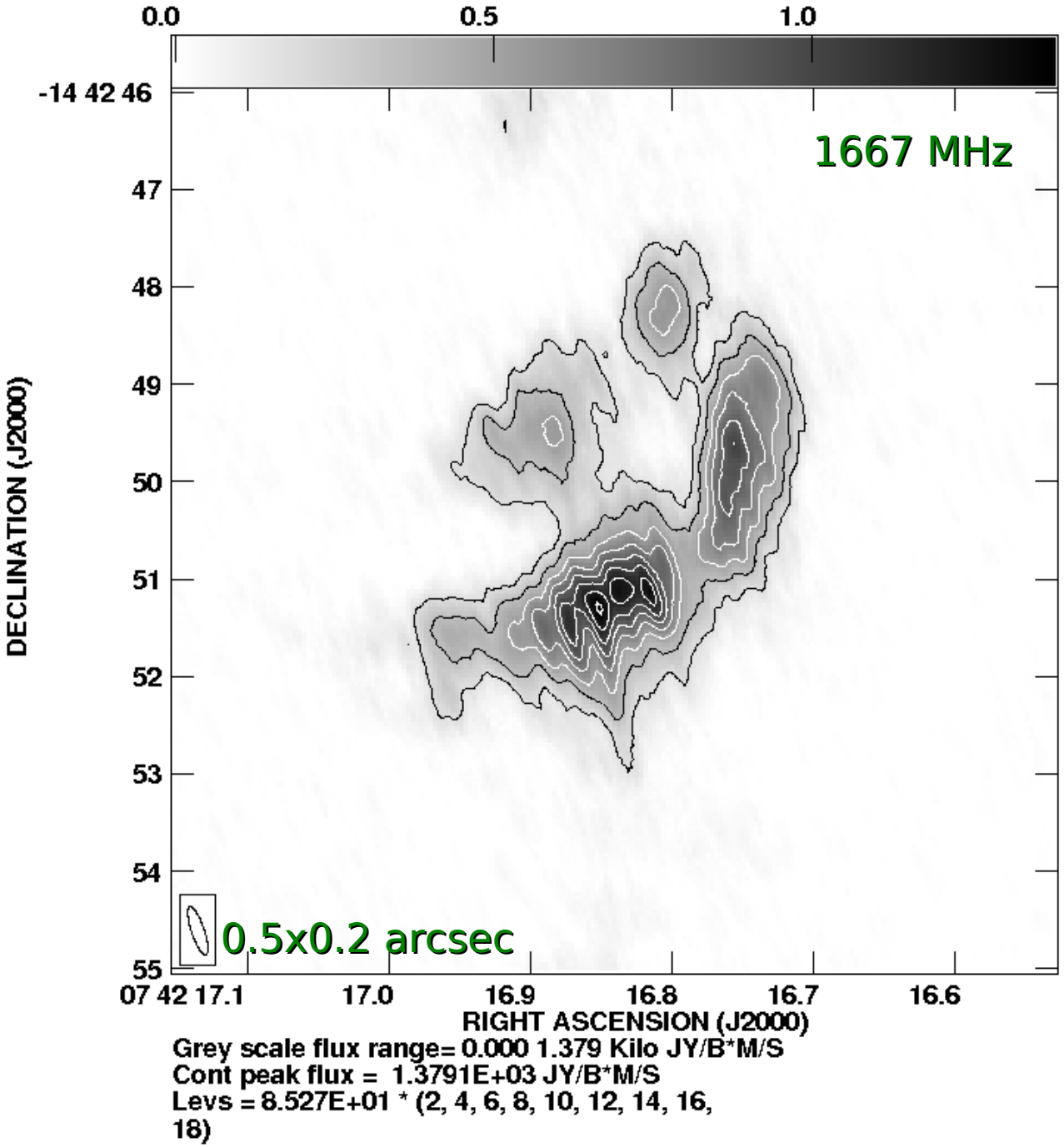
MERLIN I Stokes Spectrum



- Extended emission confirmed by **single dish observations** obtained at **Nancay Radio Telescope**

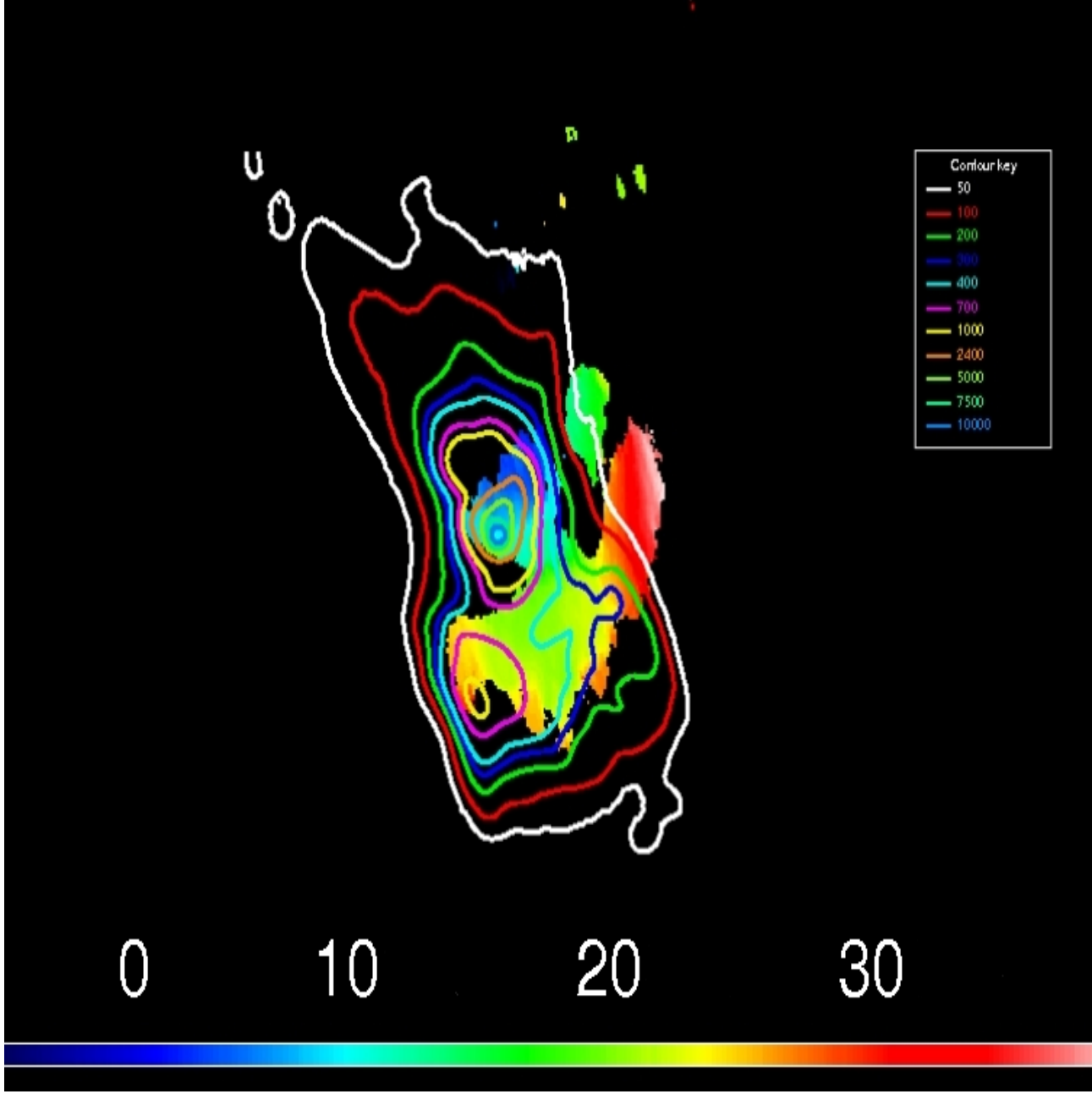
MERLIN Velocity-Integrated Image

over all the channels where signal has been detected



- OH-maser velocity map, aligned with the L’-band ISAAC contour image.
- Shows a **clear velocity gradient along the disk/torus like shape**:
- **“bluest”** emission being located in the **north**

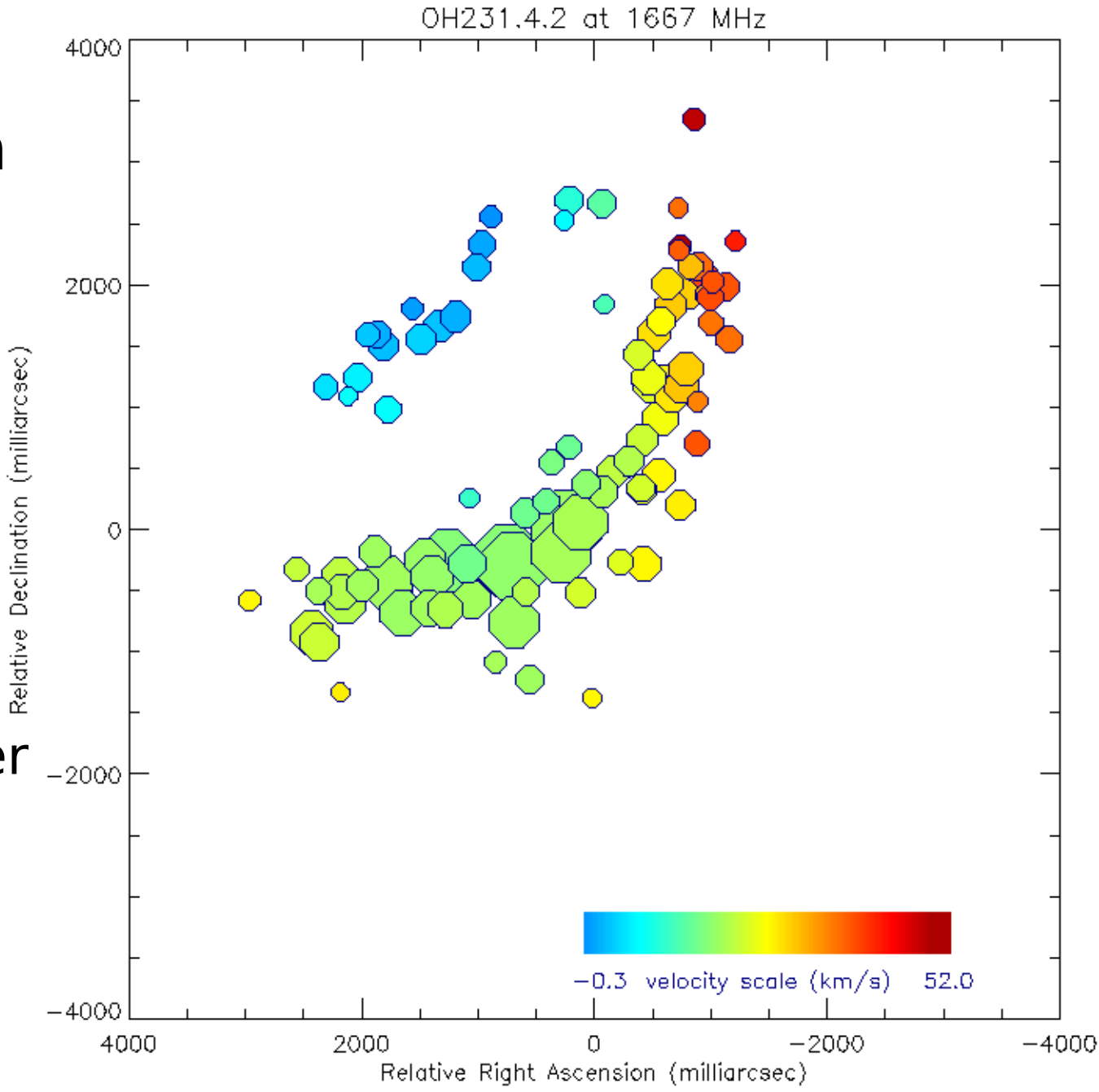
  while
- **“reddest”** being located in the **south**

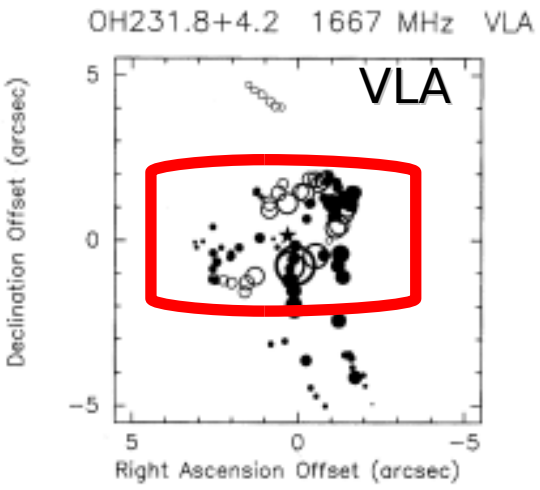


Maser spot distribution

Maser spot distribution criteria:

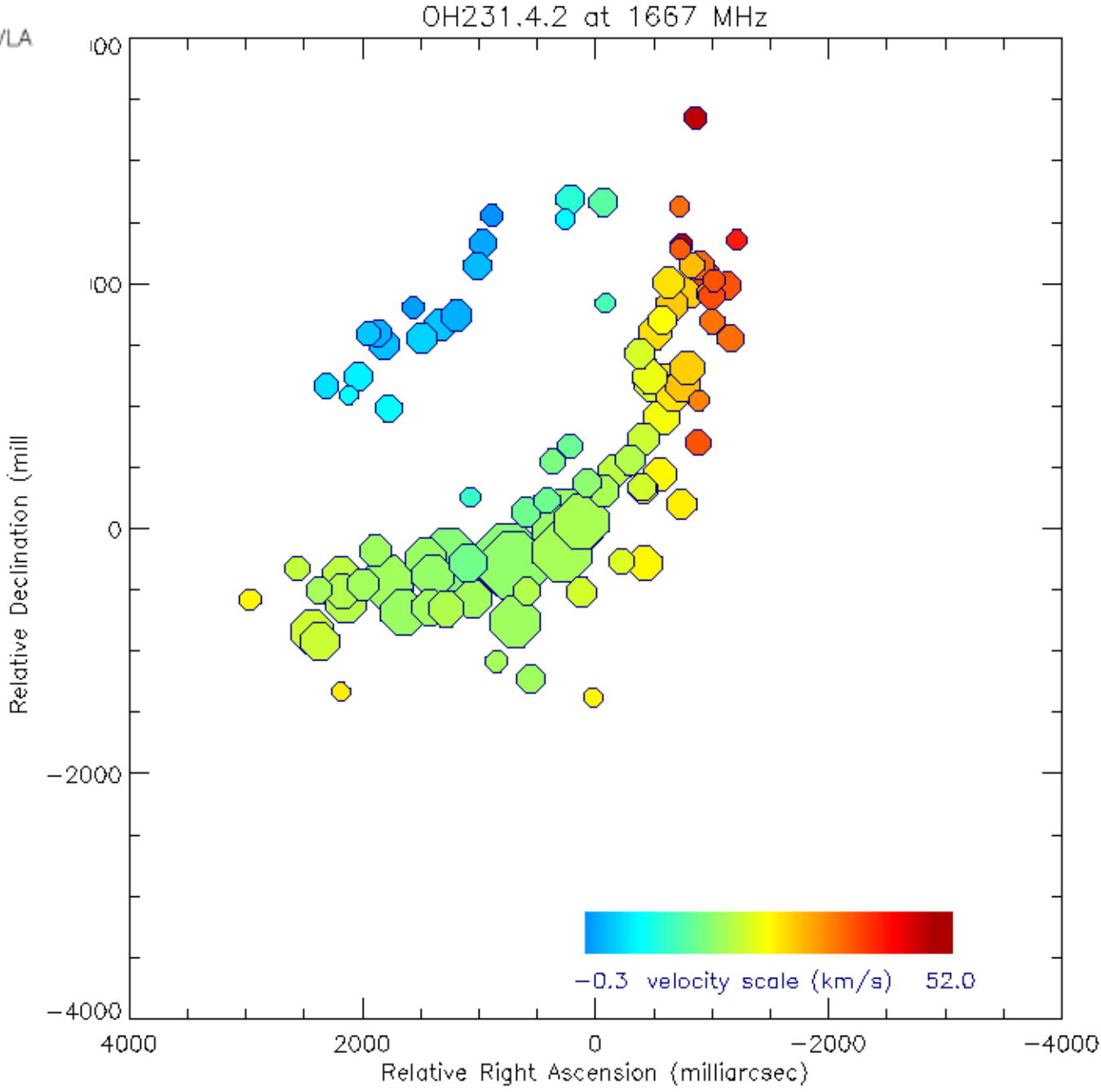
- 3 consecutive channels
- 1667 MHz maser component in Stokes I ≥ 3σ





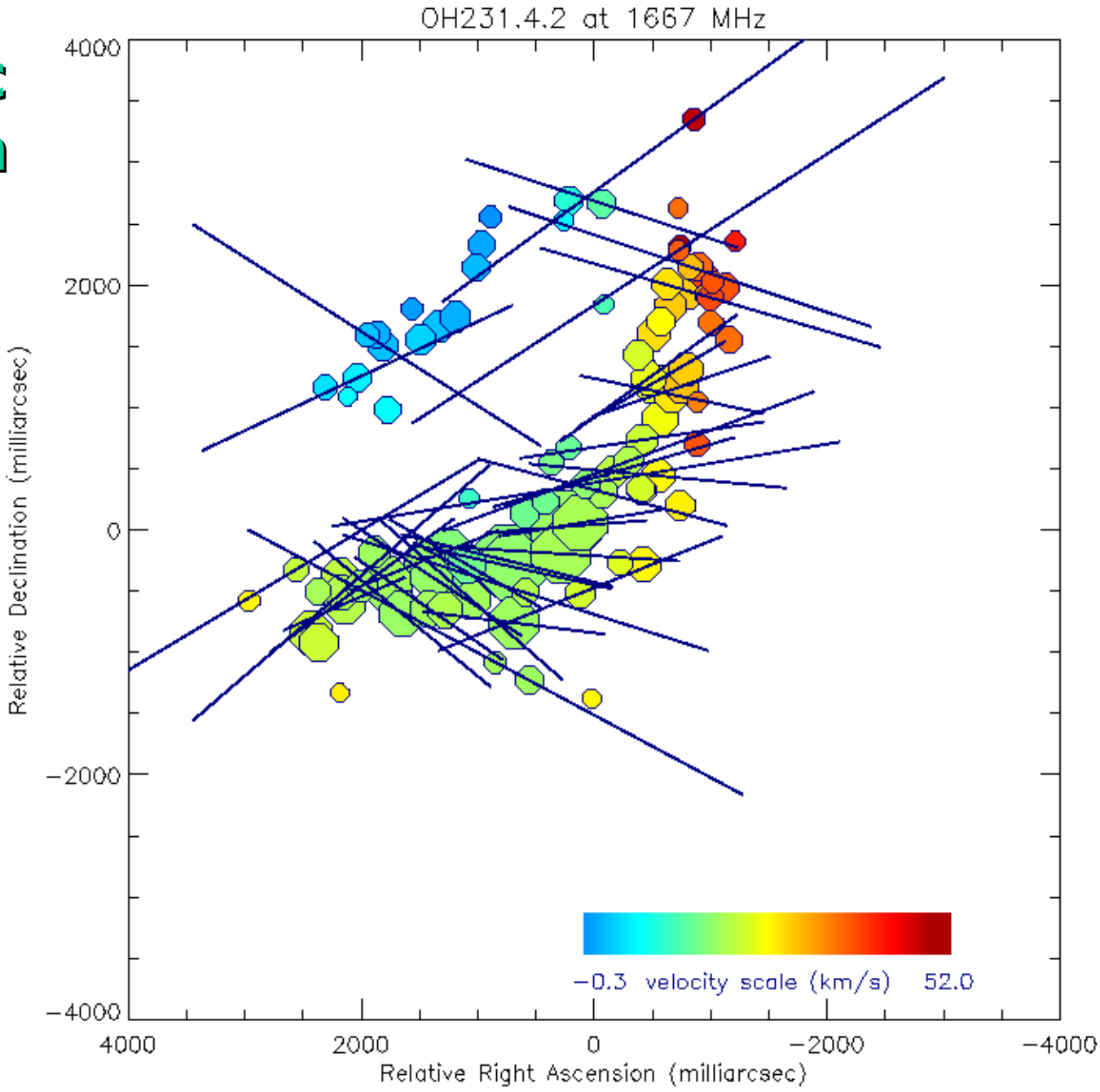
- The MERLIN observations allow us to isolate the central structure

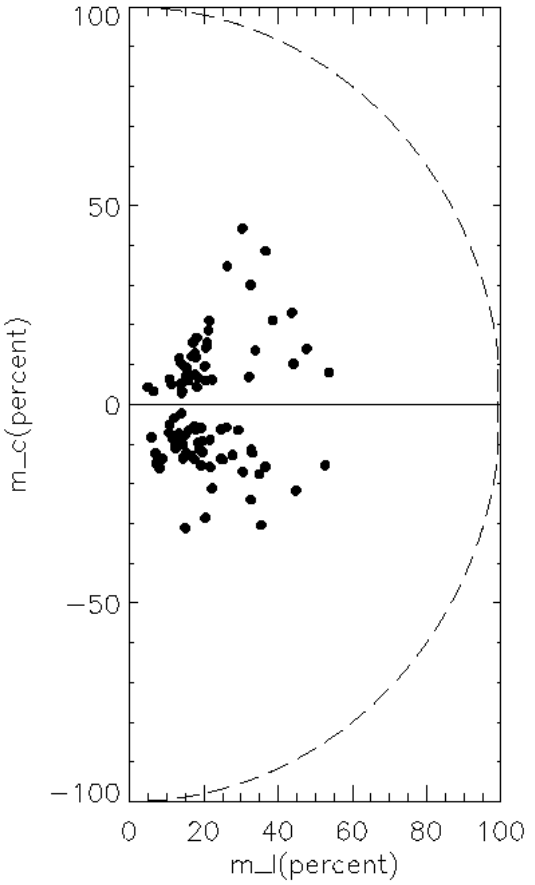
- **The velocity gradient is very well defined**

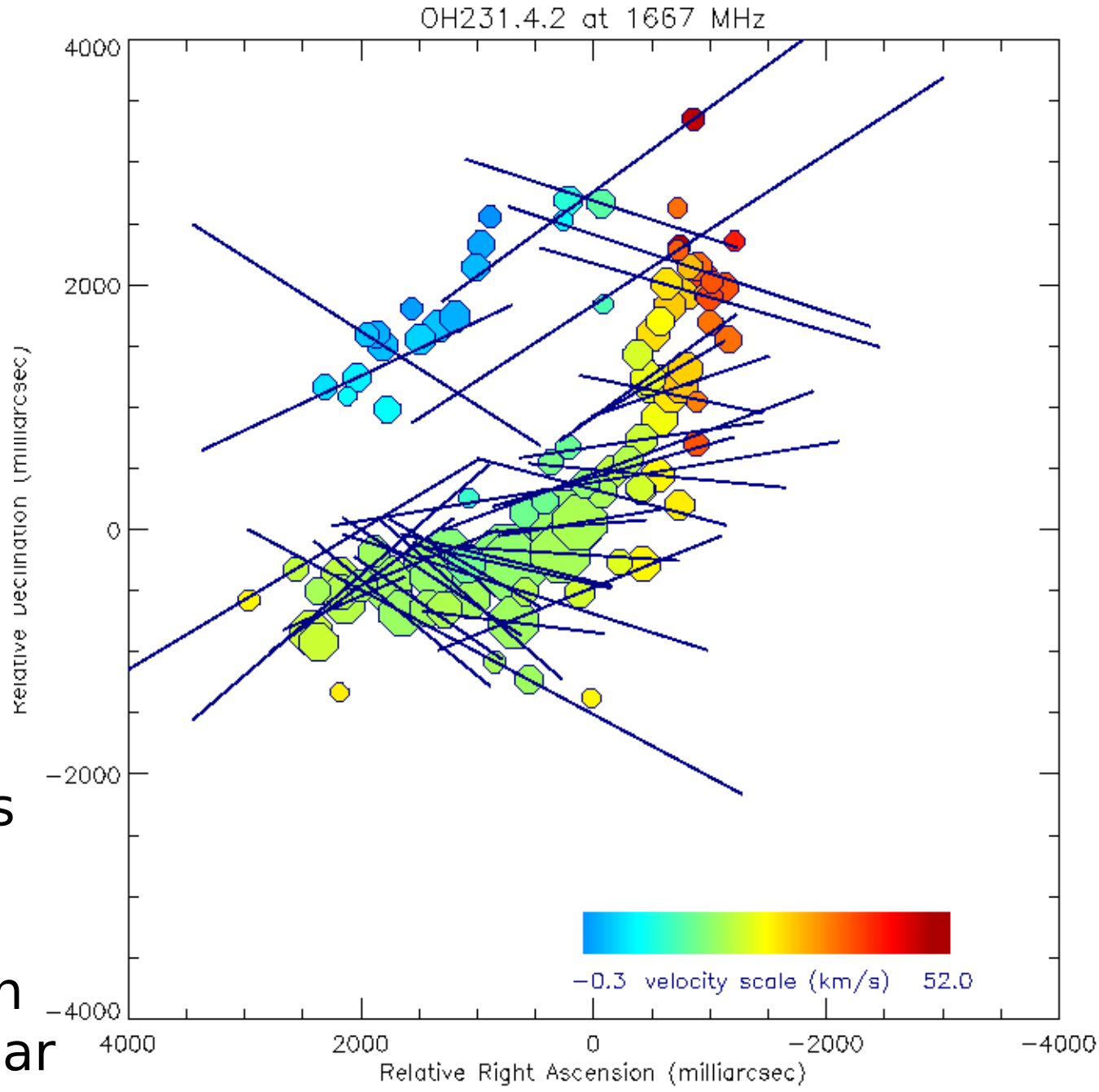


Polarimetric information

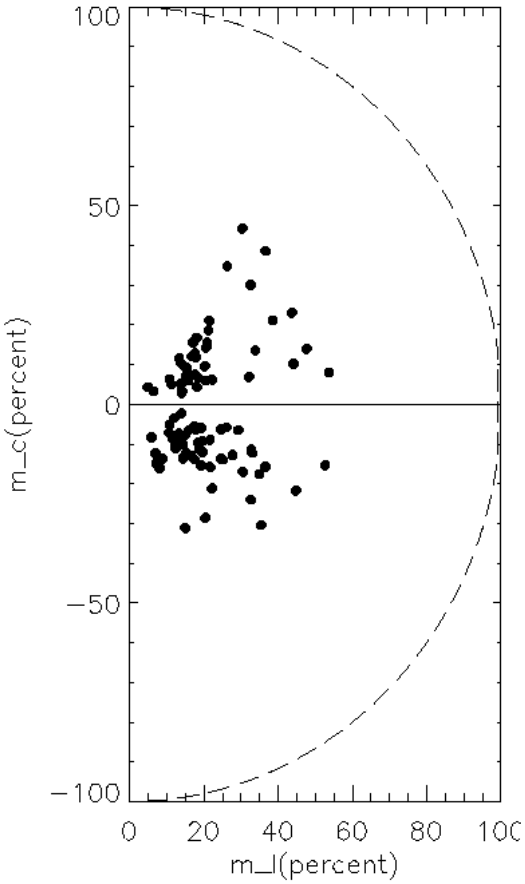
- P only shown if ≥3σ
- Indicates the direction of the **magnetic field** lines projected on the plane of the sky **"flaring out" of the disc/torus structure**.

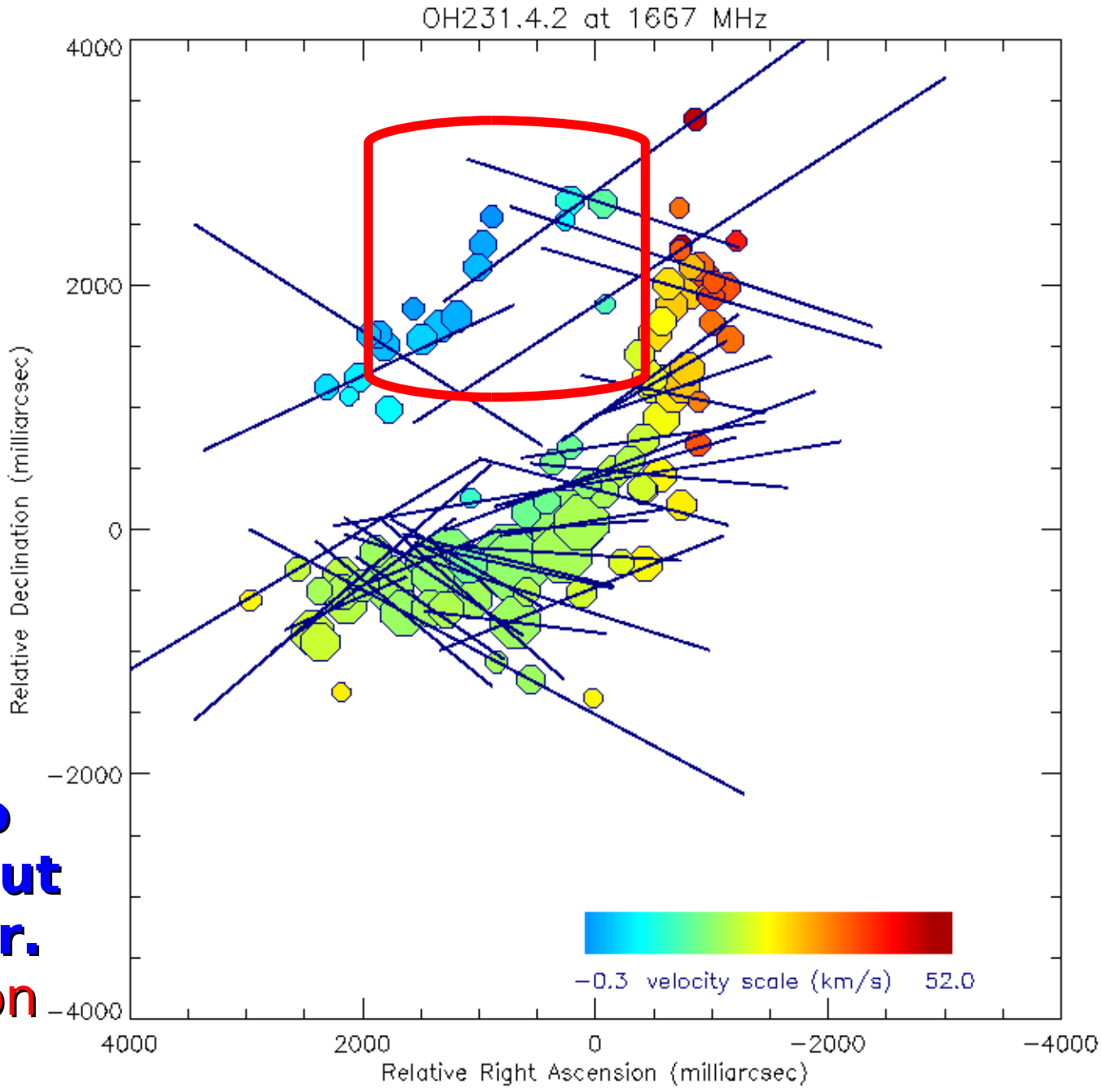






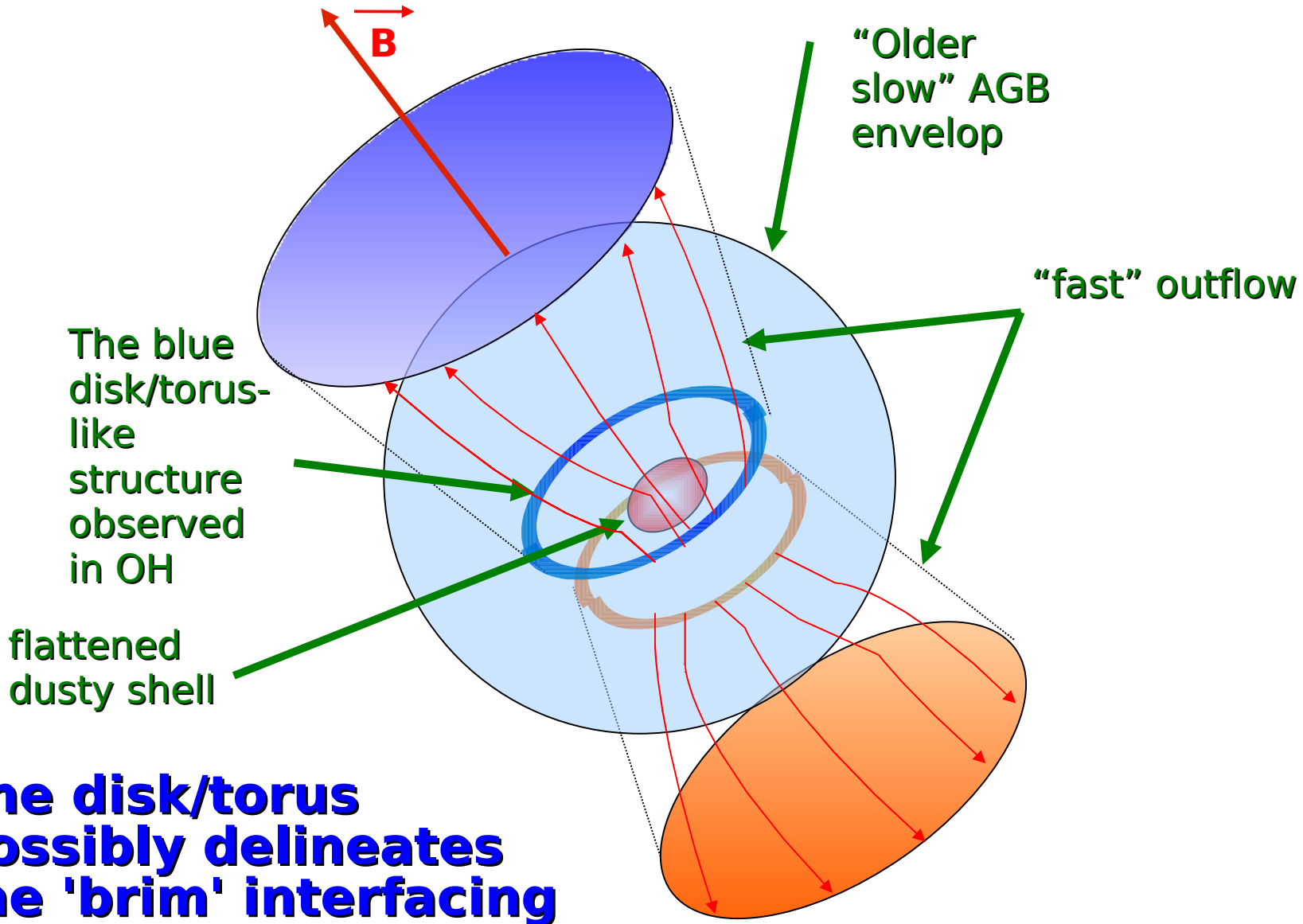
The maser spots show a high degree of polarisation both circular and linear





& there is a region with no linear polar. but only circ. polar.

indicative of B on the line of sight



The disk/torus possibly delineates the 'brim' interfacing the old AGB wind and the outflow

Summary

- The **VLTI observation** showed the presence of a **flattened dusty shell** at the centre of the system
- 1667 MHz emission detected by **MERLIN delineates accurately the disc/torus structure possible 'brim' interfacing the old AGB wind and the outflow**
- A **Clear gradient in the velocity field** is seen
- The polarimetric structure attests to a **well-organized magnetic field "flaring out" in the outflow direction**