An investigation of the morphology and kinematics the circumstellar envelope of the AGB star π[1] Gruis

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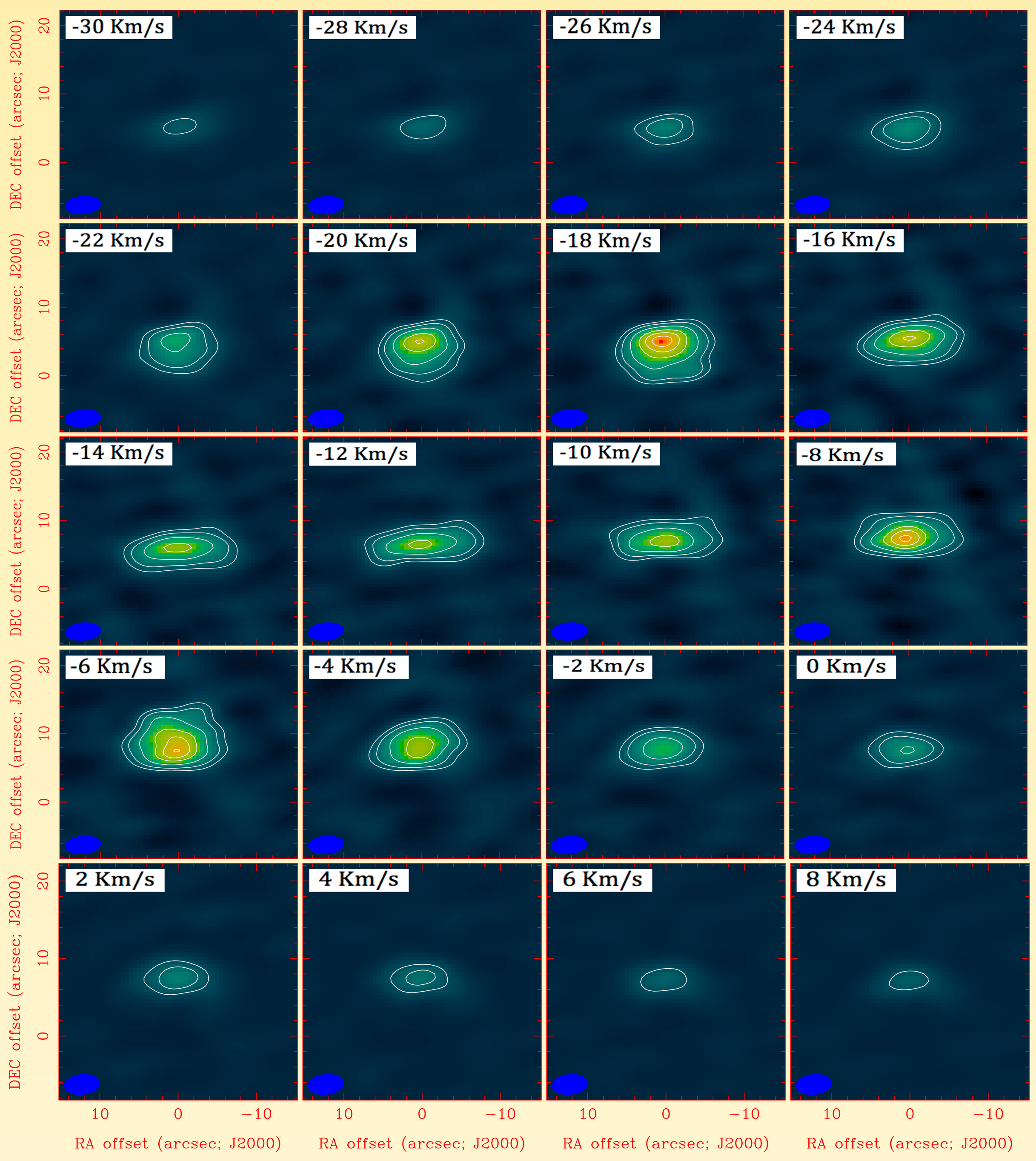
Abstract

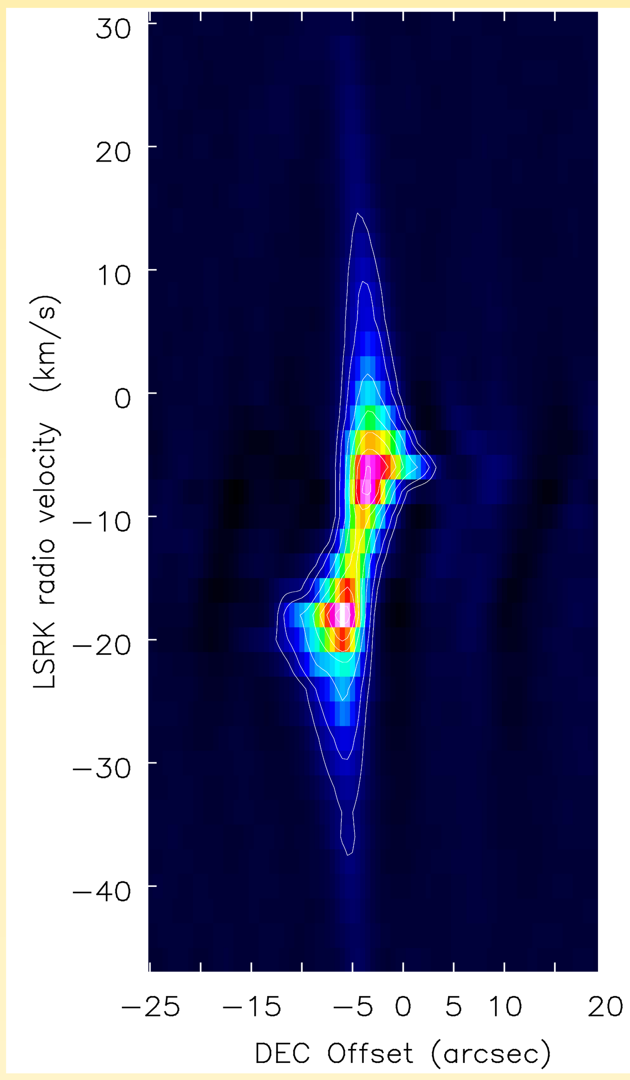
The S-type AGB star π[1] Gruis has a known companion at a separation of 400 AU. Previous observations of the circumstellar envelope (CSE) show strong deviations from spherical symmetry. We present our results from the analysis of ALMA-ACA and SMA observations of π[1] Gruis. The images of the rotational line emission from CO *J=2-1* and *3-2* provide good constraints for a model of the morphology and kinematics of the CSE. We model the source using SHAPEMOL (Santander-García. M et al. 2015) to derive the density and velocity distribution.

Observation

CO J = 2-1 and CO J = 3-2 emission of π[1] Gruis [α(J2000)= $22^h22^m44^s.2$, δ(J2000)=45^0 56′ 52″.6] were observed in 2004 with the SMA and in 2013 with the ALMA-ACA, respectively. The SMA observations were made with a 2 GHz bandwidth correlator and a 812.5 Khz channel separation over 256 channels. The ALMA-ACA observations consist of a three-point mosaic covering an area of 25"x25".

The observations have four spectral windows with a width of 2 GHz centered on 331, 333, 343, and 345 GHz. The resulting spectral resolution is about 0.5 km/s, but it has been binned to 2 km/s to improve sensitivity. The beam size for the ACA observations is 4.5"x2.5". We used CASA software to perform calibration and make the clean maps with high signal-to-noise ratio.





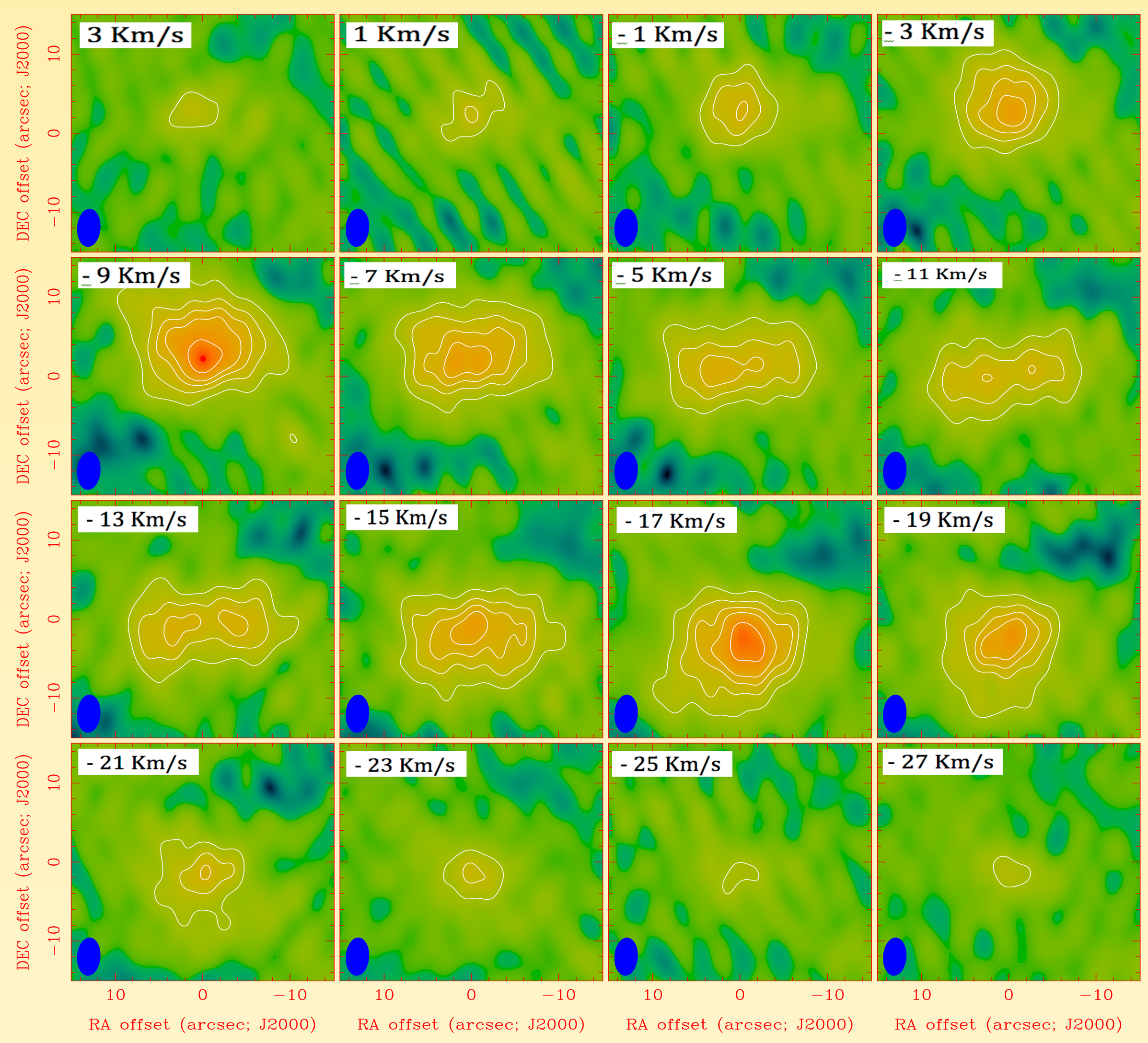


Fig. 1 – Intensity and contour maps for CO J = 3-2 (left), CO J = 2-1(right); and PV diagram of CO J = 3-2 (center). Channel velocities are indicated in the upper left corner. Contour levels are 3, 5, 9, 15, 20, 25 σ (σ=1Jy/ beam) for CO J = 3-2 and 2, 4, 6, 8, 12 σ (σ=0.75Jy/ beam) for CO J = 2-1; and 2, 4, 8, 12, 16, 20σ (σ=1Jy/ beam) for the PV diagram. The synthesized beam is shown in lower left corner of each panel.

A *SHAPEMOL* Model for the π[1] Gruis envelope

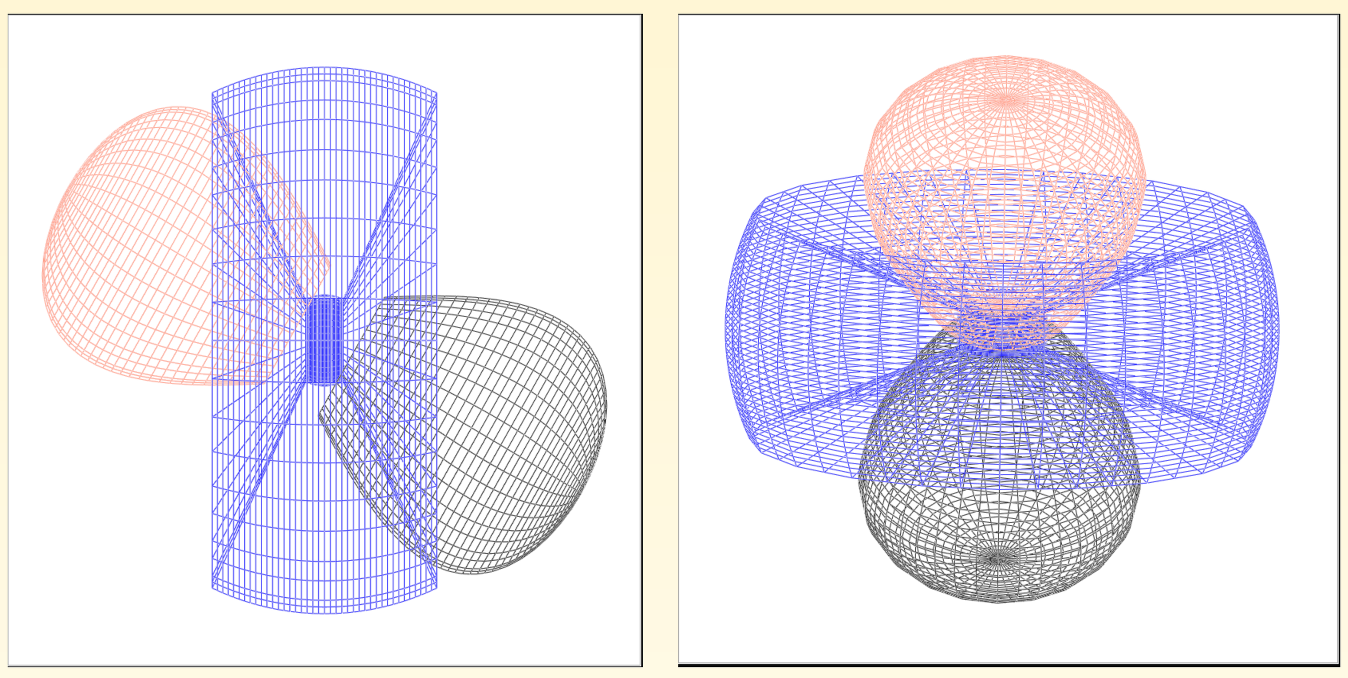


Fig. 2 – Sketches illustrate two components in the CSE of π[1] Gruis: low velocity expanding torus and high velocity bipolar outflow.

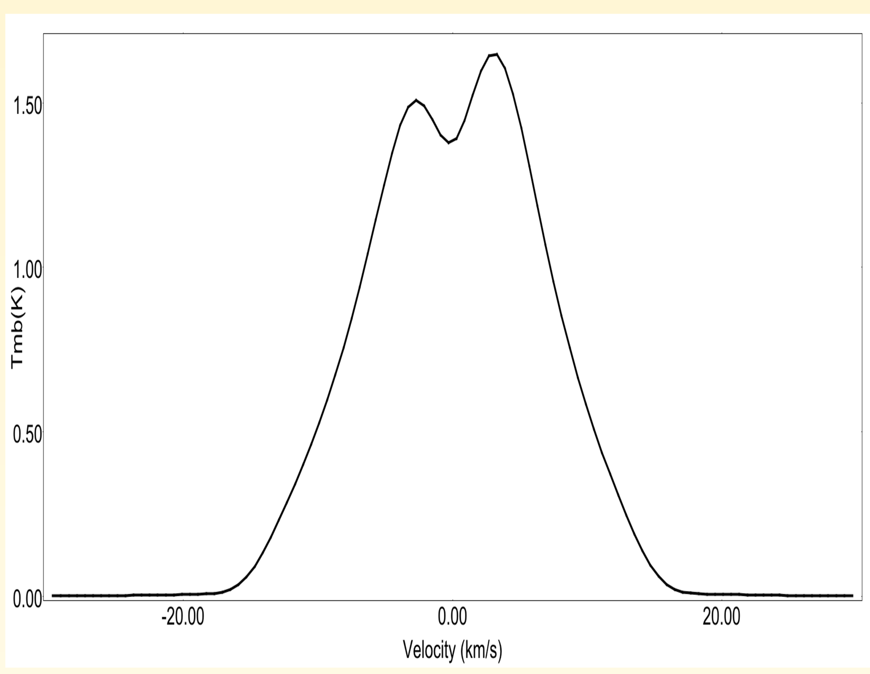


Fig. 3 – Line profile produced from the model with beam size of 30".

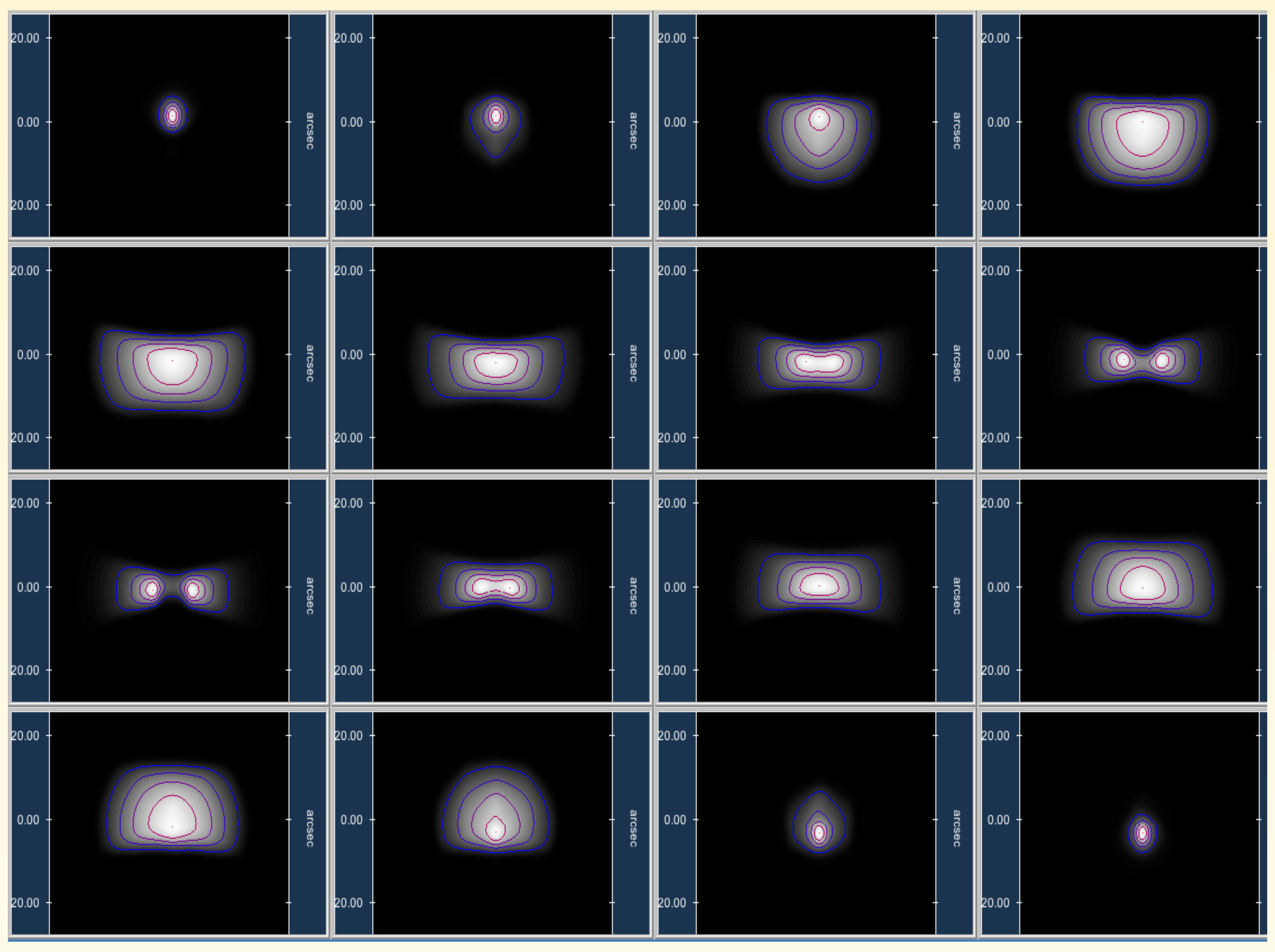


Fig. 4 – Intensity and contour Channel maps for CO J = 2 -1 from SHAPEMOL model

Parameter	Value		
Mass loss	$5.10^{-7}(r/3 \times 10^{15}\,cm)^{0.25}\,M_{sun}\,yr^{-1}$		(Chiu et al. 2006)
Density	$6.10^{11}\,(r/10^{15}\,cm)^{-1.75}\,m^{-3}$	(Torus)	
	$6.10^{10}\,(r/10^{15}\,cm)^{-1.75}\,m^{-3}$	(Outflow)	
Velocity	$15 \times (r/6.10^{16}\,cm)\,km/s$	(Torus)	
	$15 + 45(r/6.10^{16}\,cm)\,km/s$	(Outflow)	
Temperature	$300\,(r/1.3 \times 10^{15}\,cm)^{-0.7}\,K$		(Chiu et al. 2006)

Table 1. Input parameters for the model of π[1] Gruis envelope

Acknowledgements

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Conclusion

The observational results clearly show two separate components: slowly expanding and flared torus with velocity less than 15 km/s and high velocity bipolar outflow with velocity up to 60 km/s. Our best fit model for CO J = 2-1 emission roughly determines the velocity distribution and density for the CSE. Also, the model suggests the bipolar outflow is inclined relative to the torus. The angle of inclination is about 30^0. Further studies are needed before any firm conclusions regarding the morphology and kinematics of the CSE can be drawn.