Proceedings of the 7th European VLBI Network Symposium
Bachiller, R. Colomer, F., Desmurs, J.F., de Vicente, P. (eds.)
October 12th-15th 2004, Toledo, Spain

mm VLBA Observations of SiO masers: probing the close stellar environment of the PPN OH231.8+4.2

Desmurs, J.-F.[1], Sánchez Contreras, C.[2], Bujarrabal, V.[3], Alcolea, J.[1], and Colomer, F.[3]

[1] Observatorio Astronómico Nacional, c/Alfonso XII 3, 28014 Madrid, Spain
[2] California Institute of Technology, Astronomy Department, Pasadena, California, USA.
[3] OAN, Apartado 112, E-28803 Madrid, Spain

Abstract. We present milliarsecond-resolution maps of the SiO maser emission v=1 J=2–1 (3 mm) in the bipolar post-AGB nebula OH 231.8+4.2, and compare them with our previous observations of the v=2 J=1–0 line (7 mm). Our observations show that the SiO masers arise in several bright spots forming a structure elongated in a direction perpendicular to the symmetry axis of the nebula. This, and the complex velocity gradient observed, is consistent with the presence of an equatorial torus in rotation and with an infall of material towards the star.

1. Introduction

Planetary and Proto-Planetary Nebulae (PNe, PPNe) present conspicuous departures from spherical symmetry, including e.g. multiple lobes and jets. To explain their evolution from spherical AGB envelopes, several models have postulated the presence of dense rings or disks close to the central post-AGB stars as the agents of the mechanical collimation of the stellar wind. Existing observations reveal the presence of central disks in several PPNe, but their limited spatial resolution cannot unveil the very inner regions of the disks that are relevant for the processes mentioned above.

Our first VLBA observations of SiO masers in OH 231.8+4.2, carried out at 7 mm (v=2, J=1–0) in April 2000, revealed for the first time the structure and kinematics of the close stellar environment in a PPN (Sanchez Contreras et al., 2002). The SiO maser emission arises in several compact, bright spots forming a structure elongated in the direction perpendicular to the symmetry axis of the nebula. Such a distribution is consistent with an equatorial torus with a radius of ~ 6 AU around the central star. A complex velocity gradient was found along the torus, which suggests rotation and infall of material towards the star. The rotation and infalling velocities deduced are of the same order and range between ~ 7 and ~ 10 km s^{-1}. Such a distribution is remarkably different from that found in other late-type stars, where the masers form a roughly spherical ring-like chain of spots resulting from tangential maser amplification in a thin, spherical shell (Diamond et al., 1994, Desmurs et al., 2000).

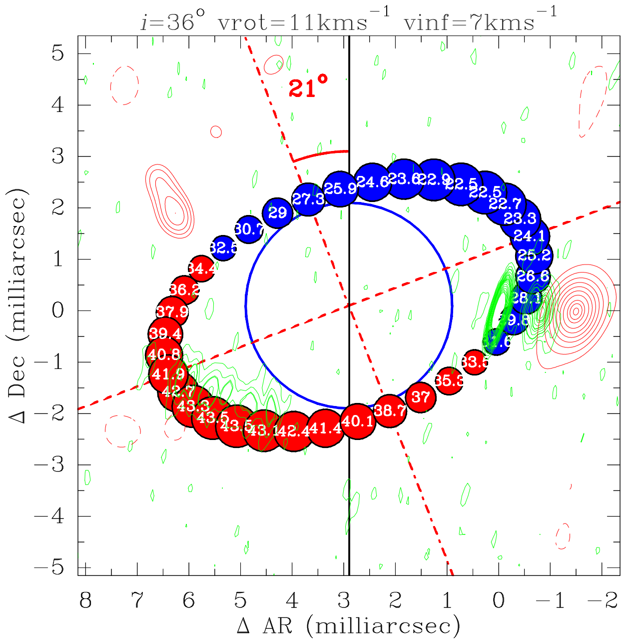

Fig. 1. Comparison of our first observations of the v=2, J=1–0 (7 mm) SiO maser transitions (grey scale+contours), with our new observations of the v=1, J=2–1 (3 mm) SiO maser (thick contours) and our model of a rotating/infalling torus in the OH 231.8+4.2 (grey & light grey circles; the velocity of the spots predicted by the model is indicated inside the circles — see Sanchez Contreras et al., 2002 for details).

2. Observations and Results

The new VLBA observations at 3 mm were observed on April 2002. The data were recorded in dual circular polarization over a bandwidth of 16 MHz, assuming a rest frequency of 86243.442 MHz for the v=1 J=2–1 SiO maser emission, for a final spectral resolution of about 0.1 km s^{-1}. We frequently observed several calibrators for band-pass and phase calibration; pointing was checked and corrected every less than half an hour. The data reduction followed the standard scheme for spectral line calibration data in AIPS. To improve the phase calibration solutions, we extensively map all the calibrators, and their brightness distribution were introduced and taken into account in the calibration process.

Our VLBA maps at 3 mm (Fig. 1) show two SiO maser spots that are globally aligned with those at 7 mm, i.e., they are roughly distributed orthogonally to the nebular symmetry axis. The velocities of the two maser spots observed at 3 mm are in good agreement with velocities observed at 7 mm. The spatial distribution and velocity structure of the SiO maser spots at 3 mm and 7 mm are consistent with a torus with radius $R \sim 6$ A.U., perpendicular to the nebular symmetry axis (inclined $\sim 36^o$ with respect to the plane of the sky). This torus-like structure is not totally traced by the maser spots. Such a spot distribution is expected, even for a homogeneous torus, if the maser is tangentially amplified. This amplification mechanism leads to the most intense maser features at the edges of the torus-like structure. Moreover, given the comparable size of the star and the maser emitting region, occultation by the star of the far side of the torus is very likely, which would partially explain the small number of detected spots.

In our opinion, the structure traced by the SiO maser emission in OH 231.8+4.2, compatible with a rotating+infalling torus very close to the central star, is unlikely an accretion disk. The dynamic is well reproduced by a simple model considering the presence of an inner torus in rotation and infall with a radius of ~ 5AU (R_{star} ~4.5 AU), which means very close to the surface of the star (Sanchez Contreras et al., 2002). In fact, the dramatic changes with time of the SiO v=2, J=1–0 profile suggest that the masers lie in a region with an unstable structure and/or kinematics, rather than in a stable accretion disk. Moreover, accretion disks are expected around the compact companion in a binary system and less likely around the mass-losing star.

Finally, it is worth mentioning that: (a) 3 mm maser spots are located further away from the central star than those at 7 mm, similarly to what has been recently found in AGB stars (see Soria-Ruiz et al., 2004); and (b) the rotation velocity measured in the torus of OH 231.8+4.2 is consistent with the values of the rotation velocity found in inner envelopes of several AGBs (NML Cyg : Boboltz & Marvel, 2000; TX CAM and IRC+10011: Desmurs et al., 2001, R Aqr : Hollis et al., 2001).

References

Boboltz, D. A. & Marvel, K. B., 2000, ApJ, 545, 149.

Desmurs, J.-F., Bujarrabal, V., Colomer, F., & Alcolea, J. 2000, A&A, 360, 189.

Desmurs, J.-F., V. Bujarrabal, F. Colomer & J. Alcolea, 2001, IAU Symposium 206, Eds. V. Migenes et al., p 278.

Hollis, J. M., Boboltz, D. A., Pedelty, J. A., White, S. M. & Forster, J. R. 2001, ApJ, 559, L37-L40.

Contreras, C., Desmurs, J.-F., Bujarrabal, V., Colomer, F., Alcolea, J., 2002, A&A, 385, L1-L4.

Soria-Ruiz R., Alcolea J., Colomer F., Bujarrabal V., Desmurs J.-F., Marvel, K.B. & Diamond, P.J., 2004, A&A, in press.

Marvel, B ., Diamond P.J., & Boboltz D., 2003, in ASP Conference Series (in press), Futur Direction in High Resolution Astronomy: The 10th Anniversary of the VLBA, ed J.D. Romney, M.J. Reid.