Proceedings of the 6th European VLBI Network Symposium
Ros, E., Porcas, R.W., Lobanov, A.P., & Zensus, J.A. (eds.)
June 25th-28th 2002, Bonn, Germany

The Relative Spatial Distribution of SiO Masers in AGB Stars at 43 and 86 GHz

J.-F. Desmurs[1], R. Soria-Ruiz[1], F. Colomer[1], K.B. Marvel[2], V. Bujarrabal[1], J. Alcolea[1], P. J. Diamond[3], D. Boboltz[4], and A. J. Kemball[5]

[1] Observatorio Astronómico Nacional, Apartado 1143, Alcalá de Henares, Spain
[2] American Astronomical Society, 2000 Florida Avenue NW Suite 400, Washington DC 20009
[3] MERLIN/VLBI National Facility, Jodrell Bank Observatory, Macclesfield, Cheshire SK11 9DL, UK
[4] US Naval Observatory, 3450 Massachusetts Avenue, NW, Washington, DC 20392-5420, US
[5] National Radio Astronomy Observatory, PO Box 0, Socorro NM 87801, US

Abstract. We present the first VLBI images of SiO masers in the circumstellar envelope of an S-type star obtained with the newly developed capabilities of the Very Long Baseline Array (VLBA) at 86 GHz. We combine these data with those obtained quasi simultaneously at 43 GHz. These observations provide information on the structure and dynamics of the innermost circumstellar shells, where the return of large quantities of stellar material to the interstellar medium starts. Despite of the fact that these are preliminary results, we report that the maser emission of the v=1 J=1–0 and J=2–1 present a very different emission distribution, being not coincident in most cases.

1. Introduction

SiO maser emission at 7 mm wavelength (v=1 and v=2, J=1–0 transition near 43 GHz) has been observed in AGB stars with very hight resolution by means of VLBI techniques, yielding important results in relation with their not yet well understood pumping mechanism. The 7 mm maser emission regions are found to be distributed in a number of spots forming a ring-like structure at about 2-3 stellar radii (Colomer et al., 1992; Diamond et al., 1994; Greenhill et al., 1995; Desmurs et al., 2000) which are assumed to be centered on the stellar position. This ring-like flux distribution arise naturally in the framework of the radiative pumping mechanism of SiO masers (see Bujarrabal et al. 1994), but may also be explained by a collisional modeling. Recent simultaneous observations of the v=1 and v=2, J=1–0 (see Desmurs et al. 2000) show that the v=1 and v=2 maser spots are often close, but appear systematically shifted by a few mas and are only rarely coincident; a result that would argue in favor of radiative pumping models.

In an attempt to pursue the comparison between the predictions of the different models and observational data, we have measured the relative spatial distribution of SiO maser emission between the J=1–0 and J=2–1 transitions. In that case, models using either radiative or collisional pumping predict "maser chains" across the excited vibrational states, in such a way that the inversion of the different-J transition in the same v state are mutually reinforced. Models predict that the rotational masers in the same vibrational state should appear under the same physical conditions and, therefore, that the 43 GHz and 86 GHz masers emission originate from the same condensations in the circumstellar envelope (CSE) (see Bujarrabal et al., 1994; Humphreys et al., 2002).

2. Observations and data analysis

We have performed quasi-simultaneous observations (separated only by few hours) of the J=1–0 v=1 and v=2 (at 7mm), J=2–1 v=1 and v=2 lines of ^{28}SiO, and the J=1–0 v=0 line of ^{29}SiO (at 3mm) with NRAO Very Long Baseline Array, on May 9th, 2001 of three AGB stars: TX Cam, R Cas and χ Cyg. This was possible with the new capabilities of the VLBA at 3 mm. The system was setup to record 4 MHz at 7 mm in dual polarization and 8 MHz at 3 mm in single polarization. The correlation was produced at the VLBA correlator in Socorro (NM, USA) providing 256 and 512 spectral channels respectively for a final spectral resolution of ∼0.1 and ∼0.05 km s^{-1}. The calibration was performed using the standard scheme in the Astronomical Image Processing System (AIPS) for spectral line experiments; the amplitude calibration was performed applying the template spectra method. In this paper, we report only on the first results we obtained for the source χ Cyg in the v=1, J=1–0 (at 43122.080 MHz see Fig 1) and v=1, J=2–1 (at 86243.442 MHz see Fig 2) lines. Maps of the two transitions were independently produced by solving the residual fringe-rates on the line source. This correction is determined by selecting a channel containing a simple feature with a simple structure and a high signal to noise ratio, that is used as phase reference for all other channels. This fixed the position of that maser spot as the map origin, in both cases.

3. Results and discussion

We produced the first VLBA maps with milliarcsecond resolution of the SiO maser emission from an S-type star, χ Cyg. We obtained maps of the transitions v=1, J=1–0 at 7 mm (see Fig 1) and of the v=1, J=2–1 at 3 mm (see

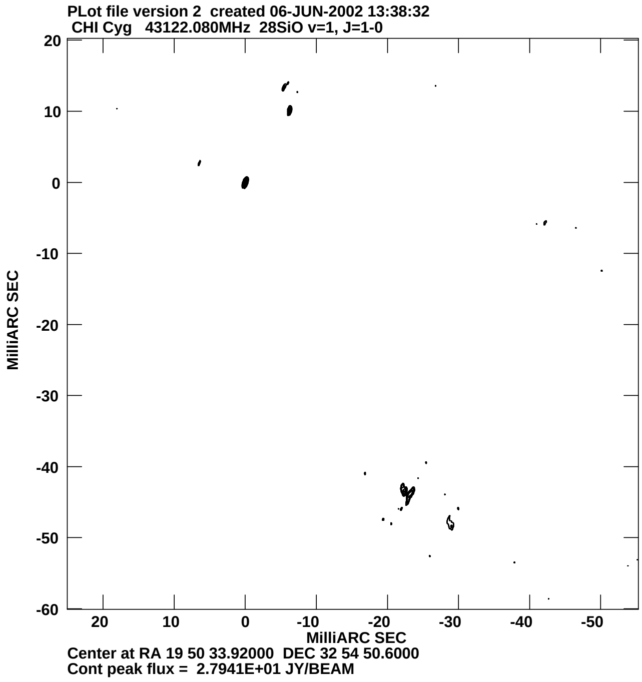

Fig. 1. Integrated intensity maps of the v=1, J=1–0 line (rest frequency 43122.080 MHz) of SiO masers towards χ Cyg. Contours are multiples by 10% of the peak flux (∼28 Jy). The resolution beam is 0.8x0.21 mas (PA=-12.4°).

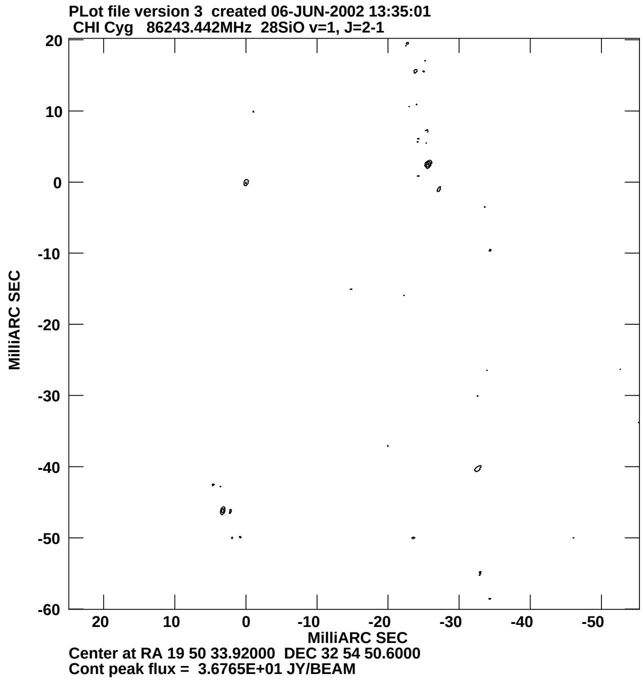

Fig. 2. Integrated intensity maps of the v=1, J=2–1 line (rest frequency 86243.442 MHz) of SiO masers towards χ Cyg. Contours are multiples by 10% of the peak flux (∼36 Jy). The resolution beam is 0.75x0.052 mas (PA=-15.8°).

Fig 2). The map size is approximately ∼80 by 80 mas. The Gaussian restoring beam has a FWHM of 0.8x0.2 mas (with a position angle PA=-12.4°) and 0.75x0.05 mas (with a position angle PA=-15.8°), respectively, for the data at 7 and 3 mm. Both figures are using the same scale to ease a direct comparison, but do not share spatial origin as explained before.

Our preliminary results shows that the SiO maser emission distribution in both transition occur more or less at a similar radii from the center. In particular, we observed that masers for v=1, J=2–1 (3 mm) arise from a ring-like structure, as it has been reported in several other AGB stars at 43 GHz (Diamond et al., 1994; Greenhill et al., 1995; Desmurs et al., 2000; Phillips et al., 2001). The radii of this ring structure is of the order of $\sim$ 28 mas which, adopting the Hipparcos distance (ESA 1997) of 106±15 pc, is equivalent to $4.5\,10^{13}$ cm.

One of the most surprisings result of these observations is that the emission distribution between the two lines is completely different. Whatever the chosen alignment, it is impossible to make coincident more than one maser spot at the same time. Even the regions emitting in one transition or the other are very different at large scale (see Figs 1 and 2). This is in complete contradiction with all theoretical predictions.

Our conclusions are only preliminary. But in the case that they would be confirmed by future observations and in other sources, this result would cast serious doubts on the present models of the SiO maser excitation.

References

Bujarrabal, V., 1994, A&A 285, 953

Colomer, F., Graham, D. A., Krichbaum, T. P., et al. A., Baudry, A., Booth, R. S., Gomez-Gonzalez, J., Alcolea, J., Daigne, G, 1992, A&A 254, L17

Diamond, P., Kemball, A. J., Junor, W., et al. 1994, ApJ, 430, L61

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

Greenhill, L. J, Colomer, F., Moran, J. M., et al. 1995, ApJ 449, 365

Humphreys, E.M.L., Gray, M.D., Yates, J.A., et al. 2002, A&A 386, 256

Phillips, R.B., Sivakoff, G.R., Lonsdale, C.J., Doeleman, S.S., 2001, AJ 122, 2674.