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Multiline Study with VLBI of SiO Masers in Evolved Stars

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Abstract. We present preliminary results of our observations of the 7 mm (v=1 and v=2 J=1-0) and 3 mm (v=1 J=2-1) SiO masers in the circumstellar envelopes of evolved stars. The 7mm masers were observed with the Very Large Baseline Array (VLBA) and the European VLBI Network (EVN), and the 3mm ones with the Coordinated Millimeter VLBI Array (CMVA). We find similarities between the maps, despite the non-coincidence in the location of most spots in the different 7 mm lines. The visibilities found for most compact spots are compatible with maser sources as small as 0.13 mas (or 0.023 AU at the distance of R Cas).

1. Introduction

The understanding of the origin and evolution of circumstellar envelopes around evolved stars depends critically on our knowledge of the processes involved in their innermost layers within a few stellar radii of the star. SiO maser emission can be used as a probe to investigate the physical conditions in those regions, unobservable by means of the thermal emission molecular lines. The regions where SiO arises are of particular interest as dust is formed there and the velocity field is a tracer of the dynamical processes occurring in the acceleration region of the molecular envelope. However, few attempts exist trying to relate the SiO maser emission spots at different frequencies with high spatial resolution. Our project studies how these emissions compare.

2. Observations

We have performed VLBI observations of the 7mm (v=1 and v=2 J=1-0) and 3mm (v=1 J=2-1) SiO masers with the VLBA, EVN, and CMVA. The 7mm data were taken simmultaneously, and very detailed maps have been produced that allow comparison of the spatial distributions and polarization of these masers (Desmurs et al. 2000).

On the other hand, quasi-simultaneous observations of the v=1 SiO masers at 7mm (with the EVN) and 3mm (with the CMVA) have been performed on the Mira-type star R Cas. Previous studies of these masers were not conclusive due to insufficient spatial resolution at 3mm (Colomer et al. 1996).

2.1. Preliminary Results and Discussion

Non spatial coincidence of the SiO masers spots in different transitions is found when comparing the $J = 1 - 0$ $v = 1$ and $v = 2$ lines at 43 GHz (Desmurs et al. 2000). These high quality VLBA data allow detailed mapping of the spatial distributions and polarization of the maser spots, and provide arguments that favor a scenario in which these SiO masers are pumped by radiative mechanisms: ring-like spatial distributions, tangential polarization, emission of the $v = 2$ masers closer to the central star than the $v = 1$ masers, etc.

A scenario of radiative pumping mechanism is described in Bujarrabal (1994). The calculations presented, summarized in Fig. 1, indicate that the conditions to pump the $v = 1$ and $v = 2$ $J = 1 - 0$ masers are systematically different. The expected maser distributions are in agreement with the maps in Desmurs et al. (2000).

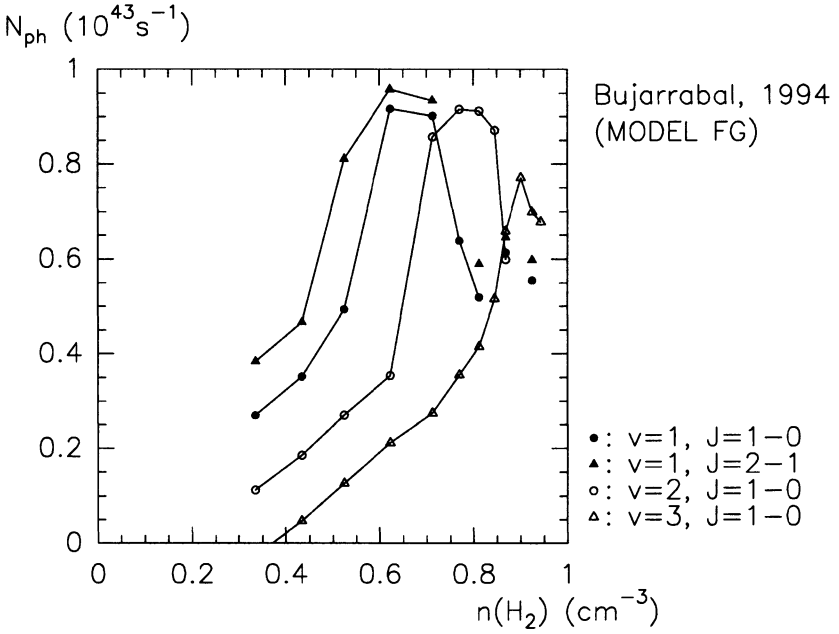

Figure 1. Expected SiO maser flux in Bujarrabal (1994) model.

The comparison of the SiO emission in different rotational transitions within a vibrational level, as it is the case of the $v = 1$ $J = 1 - 0$ line at 43 GHz versus the $v = 1$ $J = 2 - 1$ line at 86 GHz, is the goal of our second dataset. Figure 2 shows the cross-correlated SiO spectra towards R Cas obtained with the EVN at 7 mm wavelength. Despite the fact that several peaks can be clearly identified in the plots, the noise in these preliminary data is still too high to map other than the most intense features. Nevertheless, VLBA maps of this source show the existence of a ring-like distribution of these masers (Yi et al. 2000).

The case of 3mm SiO masers towards R Cas, as studied with the CMVA, is shown in Fig. 3. Previous interferometric maps of this source with the IRAM interferometer at Plateau de Bure (Colomer et al. 1996) were unconclusive,

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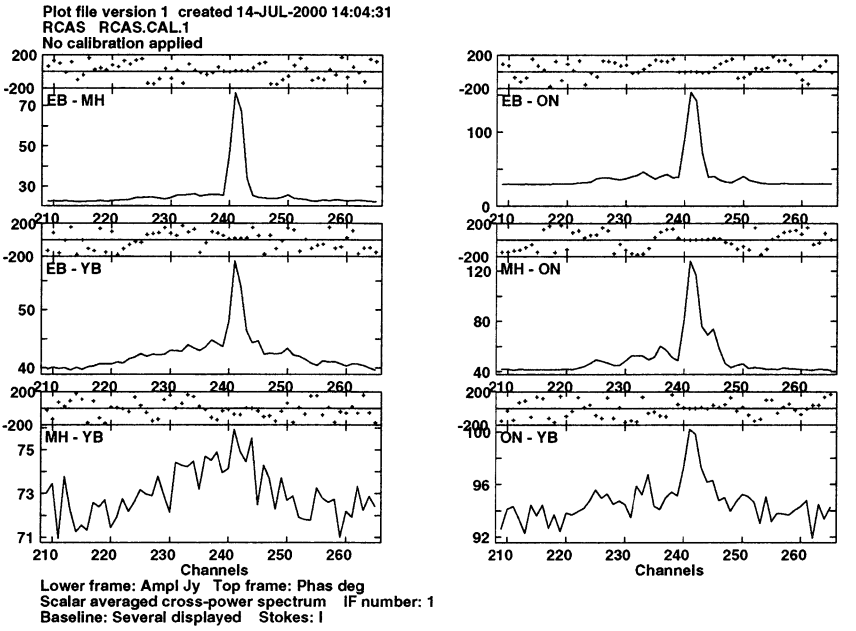

Figure 2. Cross-correlated spectra obtained on the $v = 1$ $J = 1 - 0$ maser line of SiO with the EVN

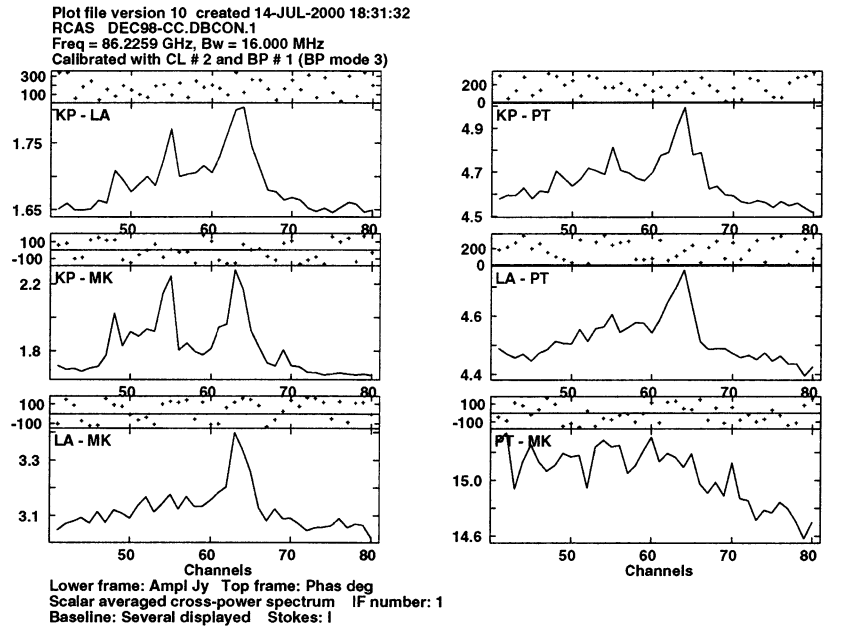

Figure 3. Cross-correlated spectra obtained on the $v = 1$ $J = 2 - 1$ maser line of SiO with the CMVA

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although complex spatial and velocity emission was found. The cross-correlated spectra demonstrate the existence of many and very compact SiO clumps, as small as 0.13 mas (or 0.023 AU at the distance of R Cas). A preliminary map displays however only a few spots, and even if the border of a ring-like structure is suggested, a deeper analysis is needed before any coincidence with the 7 mm masers can be claimed.

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