Astrophysical Masers and their Environments
Proceedings IAU Symposium No. 242, 2007
J.M. Chapman & W.A. Baan, eds.

doi:10.1017/S1743921307013282

SiO maser emission in oxygen AGB stars

R. Soria-Ruiz[1], F. Colomer[2], J. Alcolea[3], V. Bujarrabal[2], and J.-F. Desmurs[3]

[1]Joint Institute for VLBI in Europe, Postbus 2, 7990 AA Dwingeloo, The Netherlands
email: soria@jive.nl

[2]Observatorio Astronómico Nacional, Apartado 112, E-28803, Alcalá de Henares, Spain
[3]Observatorio Astronómico Nacional, Alfonso XII 3, E-28014, Madrid, Spain

Abstract. We present high resolution observations of SiO masers in the late-type star R Cas as part of a multi-line study of SiO circumstellar masers in oxygen-rich AGB stars. We used the NRAO Very Long Baseline Array (VLBA) to map the 43 GHz maser emission of ^{28}SiO. We study the relative spatial distribution of the different maser lines and discuss the relevance of line overlaps in the SiO pumping theory.

Keywords. technique: interferometric – stars: circumstellar matter – stars: AGB

1. Introduction

SiO maser emission is mainly detected in the circumstellar envelopes around evolved stars, which are formed due to the mass loss process occurring during the AGB phase. This emission is produced in the innermost shells of these envelopes, at a few stellar radii from the central star. It is well established that the SiO maser emission is distributed in ring structures composed of many compact spots with very high brightness temperatures, therefore being ideal targets for VLBI studies. Maser amplification is present in ^{28}SiO, ^{29}SiO and ^{30}SiO in many rotational lines extensively studied with single-dish telescopes. From these observations, we know the strong correlation between the SiO maser emission and the IR 8μm stellar radiation or its time variability (Pardo *et al.* 2004).

2. Observations and results

High resolution observations of the ^{28}SiO v=1 and v=2 J=1–0 maser transitions were carried out in January 2005 with the NRAO† VLBA in R Cas, obtaining an angular resolution of $\sim$0.17 *mas*. The calibration was done following the standard procedures for spectral line VLBI.

When comparing the two maps, the v=2 emission is produced in an inner part of the envelope and the spatial spot distribution is similar (see Fig. 1). This shift between the masing regions is consistent with previous results in other O-type stars (see e.g. Desmurs *et al.* 2000 and Soria-Ruiz *et al.* 2007) and in R Cas (Yi *et al.* 2006).

3. Discussion

Currently, two types of pumping mechanisms are considered as the primary mechanism responsible for the amplification: the stellar radiation at 8 μm in radiative models (Bujarrabal 1994), or the collisions with the H_2 molecules in the collisional models

† The National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

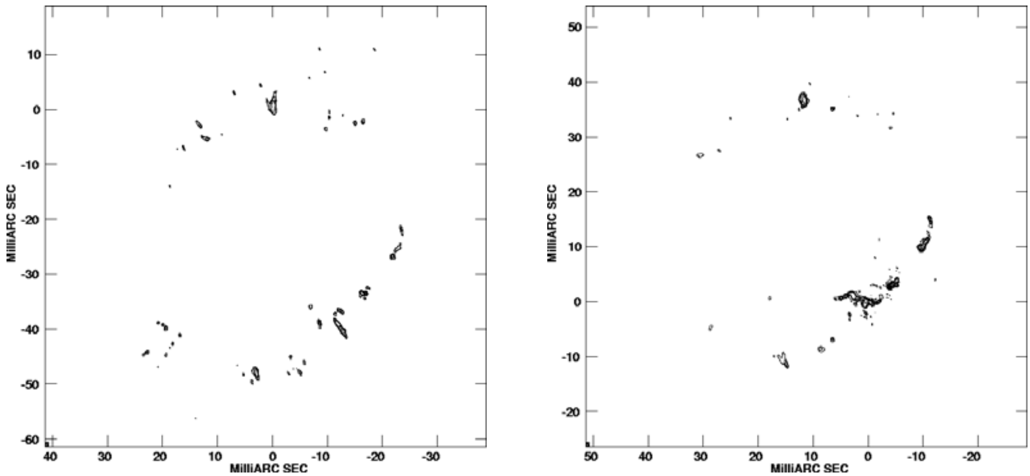

Figure 1. ^{28}SiO v=1 (left) and v=2 (right) J=1–0 maser emission in R Cas. The figure shows the integrated intensity maps in Jy beam^{-1} units. For the ^{28}SiO v=1 J=1–0 map, the peak intensity is 7.55 Jy beam^{-1} and the contour levels are -8, 8, 10, 20, 40 and 80% of the peak. For the ^{28}SiO v=2 J=1–0 map, the peak intensity is 6.20 Jy beam^{-1} and the contour levels are -3, 3, 6, 9, 18, 36 and 72% of the peak.

(Humphreys *et al.* 2002). In all cases, the inversion of the levels in the maser transition is produced when the Δv=1 de-excitation is opaque. Because of the nature of the inversion mechanism, the physical conditions for the arising of SiO masers within the same v-state are similar regardless of the model. They occur when the corresponding $v \rightarrow v$–1 lines become optically thick, in a similar way for the different J levels. On the contrary, for masers in different vibrationally excited estates, the conditions must be naturally different. For this reason, the emissions in the v=1 and v=2 vibrationally states, which are separated about 1800 K, are expected to be produced in different regions of the envelope. However, the v=1 and v=2 J=1–0 lines present relatively similar, although not identical, distributions, while that of the v=1 J=2–1 line (Soria-Ruiz *et al.* 2004) is clearly different; these results are obviously in contradiction with the theoretical predictions. On the other hand, further calculations of the excitation of the SiO molecule in AGB stars have shown that the conditions under which different maser transitions occur, change when the line overlap between infrared lines of H_2O and ^{28}SiO is introduced in the pumping models and could explain the observed relative distributions (Bujarrabal *et al.* 1996, Soria-Ruiz *et al.* 2004).

Finally, although our new maps support the relevance of line overlaps in the SiO maser pumping in O–rich shells, it would be desirable to perform similar studies in a larger sample including all types of long-period variable stars, namely, Mira-type, semi-regular and irregular variables, as well as supergiant stars.

References

Bujarrabal, V. 1994, *A&A*, 285, 953
Bujarrabal, V., Alcolea, J., Sánchez Contreras, C., *et al.* 1996, *A&A*, 314, 883
Desmurs, J.-F., Bujarrabal, V., Colomer, F., & Alcolea, J. 2000, *A&A*, 360, 189
Humphreys, E. M. L., Gray, M. D., Yates, J. A., *et al.* 2002, *A&A*, 386, 256
Pardo, J. R., Alcolea, J., Bujarrabal, V., *et al.* 2004, *A&A*, 424, 145
Soria-Ruiz, R., Alcolea, J., Colomer, F., *et al.* 2004, *A&A*, 426, 131
Soria-Ruiz, R., Alcolea, J., Colomer, F., *et al.* 2007, *A&A*, in press
Yi, J., Booth, R., & Conway, J., 8th European VLBI Network Symposium, Torun, 2006

https://doi.org/10.1017/S1743921307013282 Published online by Cambridge University Press