Cosmic Masers: Proper Motion toward the Next-Generation Large Projects
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Preliminary results on SiO maser emission from the AGB binary system: R Aqr.

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Abstract. Binary/multiple stellar systems are as abundant as single stars. They are very interesting cosmic laboratories as they are related to many astrophysical phenomena. In the case of AGB (and post-AGB) stars, binaries are the most likely explanation for the shaping of non spherical PNe, a long standing problem in stellar evolution. While many binaries are known in the PNe phase, there are few examples in the previous AGB phase. Hydrodynamical models of the binary interaction are available, but well known parameters for orbits are non-existent. We observed the AGB binary system R Aqr at 7 mm using the Global VLBI array in wide-band continuum and SiO masers. The strong SiO masers were used to self-calibrate the observations and pinpoint the location of the AGB component. We used the continuum to try to directly detect the WD companion or its close environments (non-thermal emission from accretion disks/jets). We present our preliminary results for R Aqr on the relative positions of the J=1−0 SiO masers (v=1) with respect to the white dwarf position. This opens a new way to determine orbits in binaries at the AGB phase and better study their role in late stellar evolution and PNe shaping.

Keywords. AGB, SiO masers

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1. Introduction

R Aqr is a symbiotic system consisting in a primary AGB star (a Mira-type variable star, a pulsating red giant star, R Aqr-A) and a WD secondary (R Aqr-B), as well as an ionized nebulae around the system, located at 200-300 pc. Our ALMA observations (Bujarrabal 2018) have revealed the strong shaping of the CSE by the companion, with the detection of a two-arm spiral in molecular gas. Based on the velocity variations of the primary we derived the parameters of the orbit (Gromadzki 2009). However, it was not till very recently that the two components were finally resolved by means of VLT (Schmid 2017) and ALMA observations (Bujarrabal 2018). Using these observations and additional spectroscopic data, we have recomputed the orbital parameters of the system, which now agree with the spiral structure seen in molecular gas. We recently published (Bujarrabal 2021) a comparison of our CO observations with hydrodynamical simulations of the system, but this is a delicate subject, as some of the orbital parameters still show large errors. This is mostly due to the lack of spatially resolved data, just four epochs, and the intrinsic uncertainties in spectroscopic data: R Aqr-A is a pulsating star, and the pulsation velocity is larger than the orbital velocity; this effect can be minimized by averaging data over full pulsation periods, but some errors remain. The best way to improve the situation is by adding more data points to the relative orbit, but this is difficult as the maximum separation in the sky of the two stars is just 50 mas, and the system is close to periastron (when a stronger interaction is expected) and conjunction;

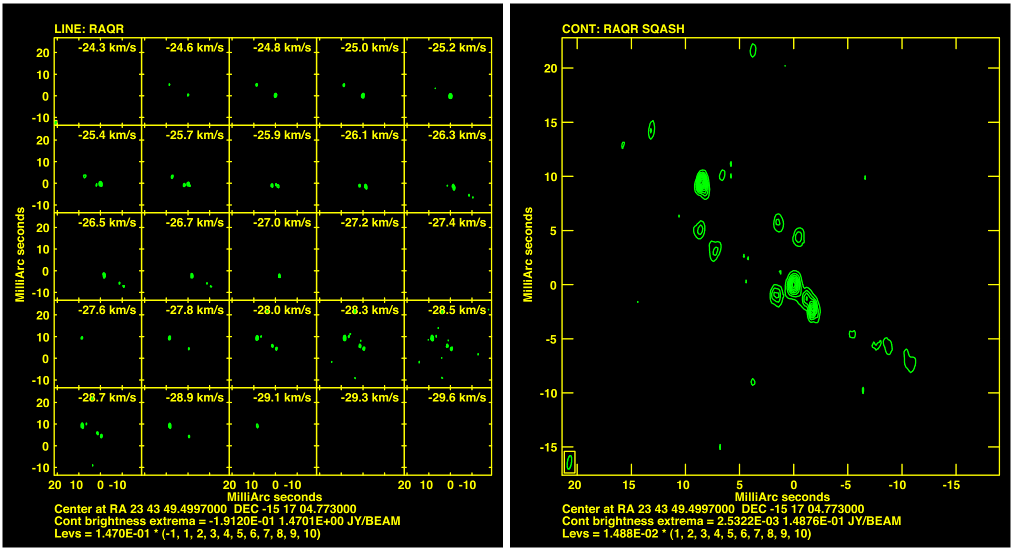

Figure 1. Global VLBI SiO v=1 J=1−0 maser emission maps at 43 GHz toward R Aqr: Left panel, channel maps of SiO emission between −24 and −30 km s^{-1}. Right panel: SiO integrated flux map.

in the next years the angular separation between the two components will be of 10-15 mas. Measuring such small separations is not an easy task even for the VLT or ALMA, while it will be very easy for a Global-VLBI experiment at 43 GHz.

2. Observations

We perform Global-VLBI observations of the R Aqr binary systems, both in spectral lines SiO v=1 J=1−0 maser at 43122.08 MHz assuming a source velocity with respect to the local standard of rest of −25 km s^{-1}, and broad band continuum in Q-band (7 mm). We recorded at maximum bit rate for maximum continuum sensitivity, in dual circular polarization, 8 sub-bands 32 MHz wide. The SiO maser pinpoints the location of the AGB component, while the continuum marks the position of the hot component in the system (the WD).

3. Preliminary results

On Figure 1, we present the synthesis image maps of the SiO v=1 J=1−0 maser emission toward R Aqr. The maps were generated following the standard line imaging and calibration techniques with the AIPS data reduction package. The synthesized resolution beam is about 1.0x0.4 mas in natural weighting. On the left panel, we show the channel maps of the SiO maser distribution. We search for emission across more than 25 km s^{-1} (from −15 km s^{-1} to −40 km s^{-1}) but we only find detections in the velocity range −24 km s^{-1} to −30 km s^{-1} (according to the predicted velocity curve). The maser peak flux ranges between 30 to 150 mJy/beam which means a brightness temperature of the order of ∼10 to 100 mega-K. On the right panel, we show the total integrated flux SiO emission map. We can notice that the maser spots do not show the typical ring distribution observed in AGB stars, also observed in this source by Cheulhong (2014). In contrast, it shows an elongated structure in the North-East to South-West direction; a similar structure was also found in the first epoch observed by Boboltz (1997). The continuum map is not shown as the data reduction is still under progress.

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References

Boboltz, D.A, Diamond, P.J and A. J. Kembal, A.J, 1997, *ApJ* 487, L147
Bujarrabal, V., Alcolea, J., Mikolajewska, J., *et al.* 2018, *A&A*, 616, L3.
Bujarrabal, V., Agúndez, M., Gómez-Garrido, M. *et al.* 2021, *A&A*, 651, A4
Cheulhong Min, Naoko Matsumoto, Mi Kyoung Kim, *et al.* 2014, *PASP*, 66, Issue 2, 38
Gromadzki, M., Mikolajewska, J., 2009, *A&A*, 495, 931
Schmid, H.M., Bazzon, A., Milli, J., *et al.* 2017, *A&A*, 602, A53.