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VLBI studies of SiO masers around VX Sagittarii

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Abstract. Observations of 43 GHz ^{28}SiO ($v = 1$, $J = 1$–0) masers in the circumstellar envelope of the M-type semi-regular variable star VX Sgr were performed using the VLBA at 3 epochs during 1999 April-May. By tracing 42 matched maser features appearing in all the three epochs, we determined the contraction of an SiO maser shell toward VX Sgr at a velocity of about 4 km s^{-1} at a distance of 1.7 kpc to VX Sgr. We also report on some preliminary results from our first epoch of simultaneous VLBA observations of three 7 mm SiO masers toward VX Sgr.

Keywords. circumstellar matter — masers — stars: individual (VX Sgr)

1. VLBA observations

In order to study the kinematics of the extended atmosphere around VX Sagittarii (VX Sgr), we observed the 43 GHz ^{28}SiO ($v = 1$ $J = 1$–0) maser emission toward VX Sgr at 3 epochs (1999 April 24, May 23 and May 31) using the Very Long Baseline Array (VLBA). Furthermore, recently we have been performing the simultaneous VLBA observations of three 7 mm SiO masers (^{28}SiO $v = 1$ $J = 1$–0 (43.122 GHz), ^{28}SiO $v = 2$ $J = 1$–0 (42.820 GHz), and ^{29}SiO $v = 0$ $J = 1$–0 (42.879 GHz)) toward VX Sgr at multiple epochs to test the pumping mechanism of SiO maser emission. Here, we will present some preliminary results from the first simultaneous observation of three 7 mm lines on 2006 July 16 as well as results from three-epoch observations in 1999. All data were correlated with the FX correlator in Socorro, New Mexico (USA). The correlator output data has a spectral resolution corresponding to a velocity resolution of 0.22 km s^{-1}.

2. Results and discussions

2.1. *Contraction of SiO maser shell observed in 1999 April-May*

By identifying 42 matched common maser features among all the three epochs in 1999, we were able to estimate their proper motions (left panel in Fig. 1). Analysis of the pairwise separation (right panel in Fig. 1) of the 42 matched features suggests a contraction of the SiO maser shell toward VX Sgr at a velocity of about 4 km s^{-1} at a distance of 1.7 kpc to VX Sgr. This contraction speed can be easily obtained through the gravitational infall. This is the first direct evidence for an inward motion of the SiO maser shell around a red supergiant variable star. Interestingly, the optical phase at which the SiO maser shell around the red supergiant contracts is nearly the same as that seen in Mira variables: VX Sgr (ϕ=0.75-0.80; Chen et al. 2006), R Aqr ($\phi = 0.78$-0.04; Boboltz, Diamond & Kemball 1997), TX Cam (ϕ=0.50-0.65; Diamond & Kemball 2003). This infers that the contraction of the SiO maser shell would occur during an optical stellar phase of 0.5-1, which agrees with the theoretical kinematical model results of Humphreys *et al.* (2002).

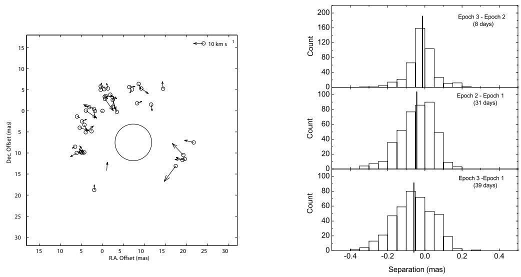

Figure 1. Left panel: The distribution of 42 proper motion vectors (Chen *et al.* 2007). Right panel: Histograms of pairwise component separations with bold line indicating the mean inward shift (Chen *et al.* 2006).

2.2. *Simultaneous observations of three 7 mm SiO masers on 2006 July 16*

The ^{29}SiO (v=0, J=1–0) maser emission was not detected, while two other 7 mm ^{28}SiO lines were clearly seen (left panel in Fig. 2). The fitted ring diameter of the ^{28}SiO (v=2, J=1–0) masers is smaller than that of the ^{28}SiO (v=1, J=1–0) masers (see right panel in Fig. 2), i.e., the ^{28}SiO (v=2, J=1–0) masers are a bit closer to the star. But this is still not adequate to constraint the dominant pumping mechanism for SiO maser emission, because both the radiative and the revised collisional pumping models can explain the systematically smaller radii for ^{28}SiO (v=2, J=1–0) masers. However, the modified collisional pumping model predicts an evolution of radii over the stellar pulsation period. Therefore, our on-going multi-epoch simultaneous VLBA observations of these lines will be critical to further distinguish between the two models.

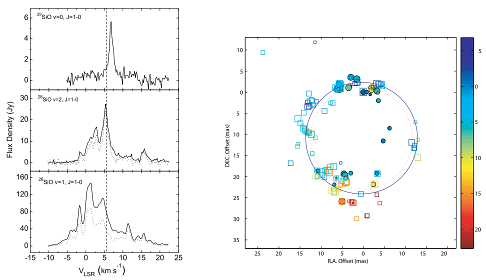

Figure 2. Left panel: The spectra of cross power imaged by VLBI (dotted line) and total power (solid line) obtained from MK antenna. Right panel: The distribution of ^{28}SiO maser features at v=2, J=1–0 transition (filled circle) aligned with that v=1, J=1–0 transition (open square).

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