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# Correlation of circumstellar SiO maser spot distribution with the stellar light curve

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**Abstract.** We have investigated the distributions of silicon monoxide (SiO) v = 2 and v = 3 $J = 1 \rightarrow 0$  masers around long-period variables (LPVs) in VLBI observations using the VLBI Exploration of Radio Astrometry (VERA) combined with the Nobeyama 45 m telescope. We find some examples of correlation of a maser spot distribution with the stellar light curve, which may provide a clue to elucidating the pumping mechanism of circumstellar SiO masers.

## 1. Introduction

There are three pumping models of circumstellar SiO masers: (1) stellar radiation pumping; (2) collisional pumping; (3) line overlapping [1, 2, 3]. The v = 3  $J = 1 \rightarrow 0$  SiO maser is expected as a unique probe to investigate the pumping mechanism of SiO molecules. According to the third model, the mid-infrared lines of H<sub>2</sub>O molecules will pump SiO molecules from the J = 0 rotation level at lower vibration(v) levels to the J = 1 level at higher v-level, resulting in spatial correlation between the v = 3 and v = 1/v = 2 SiO masers. Multi-epoch VLBI mapping of these masers throughout different stellar light curve phase may enable us to discriminate a predominant pumping mechanism. In fact, it is suggested that the relative distributions of the v = 2 and v = 3 masers with respect to the central star may change with correlation with light curve [4].

#### 2. Observations

We carried out VLBI observations of SiO v = 2 and v = 3  $J = 1 \rightarrow 0$  masers towards 12 LPVs (WX Psc, AP Lyn, U Ori, VY CMa, R Leo, RS Vir, W Hya, U Her, RU Her, V1111 Oph, V4120 Sgr, and T Cep) using four VERA 20 m telescopes and the 45 m telescope of Nobeyama Radio Observatory (NRO) on March 24–25 and May 21–22 in 2012.

#### 3. Results and Discussion

The v = 3 maser emission was detected toward 5 stars. We succeeded in superimposition of v = 2 and v = 3 maser maps toward WX Psc, R Leo, W Hya (Fig.1), and T Cep (Fig.2). In T Cep, v = 3 masers well correlate with v = 2 masers within a few mas and 1 km s<sup>-1</sup>, respectively. This result suggests that the H<sub>2</sub>O–SiO line overlapping is predominant in T Cep. For T Cep and W Hya, we investigated correlation between the distributions of the two maser lines with

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the stellar light curve. With the visible light curves provided by the American Association of Variable Star Observers (AAVSO), we find that good spatial correlation between the SiO v = 2 and v = 3 masers is found only at  $\phi \sim 0.2$ , when the near infrared radiation may be at a maximum [5, 6]. The sequence of the line overlapping mechanism is as follows: (1) the  $\sim 8\mu$ m emission increases at  $\phi \sim 0.2$ ; (2) SiO molecules are excited from v = 1 J = 0 to v = 2 J = 1 and from v = 2 J = 0 to v = 3 J = 1 by  $11_{6,6}$   $\nu 2=1 \rightarrow 12_{7,5}$   $\nu 2=0$  and  $5_{0,5}$   $\nu 2=2 \rightarrow 6_{3,4}$   $\nu 2=1$ , respectively; (3) the v = 3 masers increase around v = 2 masers. We speculate that the line overlapping mechanism may be predominant only at  $\phi \sim 0.2$  while the collisional pumping may be predominant in other phases.



Figure 1. Composite map of v = 2 (black) and v = 3 (gray) maser lines toward W Hya. A dashed circle is drawn so as to fit to the v = 2 maser distribution. The v = 3 masers do not have any spatial correlation with v = 2. Interestingly, some of the v = 3 masers are located further away from the central star than the v = 2 masers.



Figure 2. Same as Fig.1 but toward T Cep. These masers exhibit good correlation in position.

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