Comprehensive study of nearby stellar masers: W Hydrae

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Abstract

In this poster, we propose a comprehensive study of one of nearby long-period variable star, W Hya, on the basis of systematic VLBI monitoring observations of SiO v=1, 2, 3 (*J*=1-0) and H_2O maser emission with, especially VERA and KVN using unique capabilities of these arrays. This research plan will enable us to produce "stellar maser movies" that should fascinate astronomers interested in stellar mass loss, pulsation, shock wave propagation into a circumstellar envelope, and maser excitation as well as public people who have watched only movies of the Sun and unmoved sky. VLBI observaitons of W Hya are scientifically and technically feasible only by comnbining VERA and KVN. The expected quality of maser source images may be comparable to or slightly better than images taken with ALMA and EVLA, enabling to elucidate the transportation of stellar gas and dust from the stellar survace to the outer region of the circumstellar envelope.

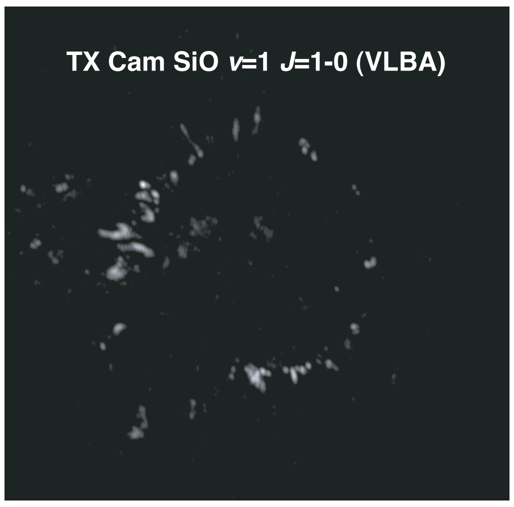

Figure 1. Only one "stellar maser movie" to date, obtained from 75-epochs VLBA observations (Diamond & Kemball 2003).

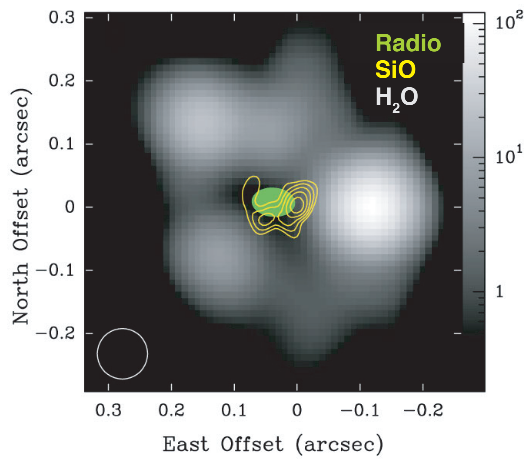

Figure 2. Superposition of VLA radio maps to investigate spatial correlation from the stellar surface to the circumstellar envelope (Reid & Menten (2007).

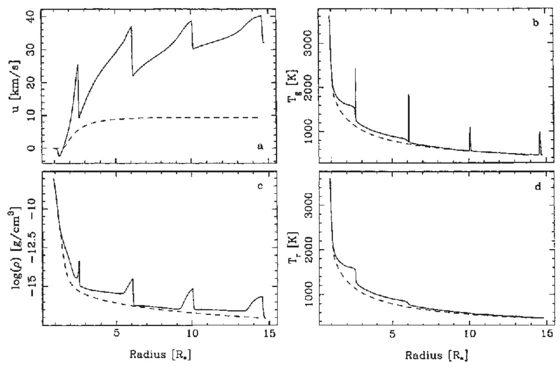

Figure 3. Theoretical model of dust-induced pulsation-driven shock waves moving outwards in to a circumstellar envelope (Hofner et al. 1995).

Motivation

○ Unique science through SiO maser movie: material ejection and contraction (including acceleration and inhomogeneity) around the surface of long-period variable stars such as Mira variables. (Figure 1)

○ From SiO to H_2O maser regions: tracing material floating, dust formationm and accelration in circumstellar envelope (CSE). (Figure 2)

○ Dust formation should enhance pulsation-driven shock waves that accelerates the outward flow in H_2O maser regions in a CSE (Figure 3). However, only a tentative confirmation was reported (Figure 4).

○ SiO maser excitation mechanism is a key issue to elucidate the dynamics of the inner CSE. It is difficult to unambiguously identify the pumping scheme if only v=1 and v=2 masers are mapped (Miyoshi et al. 1994, Yi et al. 2005). But if v=3 maser is mapped as well, it is possible (Figure 5). The v=3 maser can be mapped with VLBI (Figure 6).

Observation plan with VERA+KVN(+JVN/EAVN)

○ W Hya: Nearest (80 pc) SiO and H_2O maser star. VERA alone can measure annual parallaxes of AGB stars at > 100 pc (Nagagawa et al. 2008), but NOT for W Hya. These masers are well spatially resolved but suitable for VERA+KVN observations (Figure 7).

○ **Monthly monitoring** through the whole pulsation period (~400d) in order to detect a few pulsation-driven shock waves travelling into a CSE through H_2O maser acceleration (Figure 8).

○ **Simultaneous mapping of SiO v=1, v=2, v=3 and H_2O masers**, which may be possible only the combination of KJJVC and VERA+KVN with new wide-band backend system. (OCTAVIA/OCTADISK, Mark 5C).

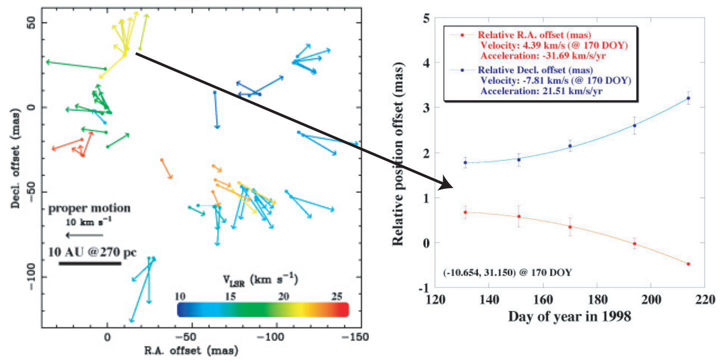

Figure 4. Possible detection of the passage of a pulsation-driven shock wave, which was traced by acceleration in H_2O maser motion in RT Virginis (Imai et al. 2003)

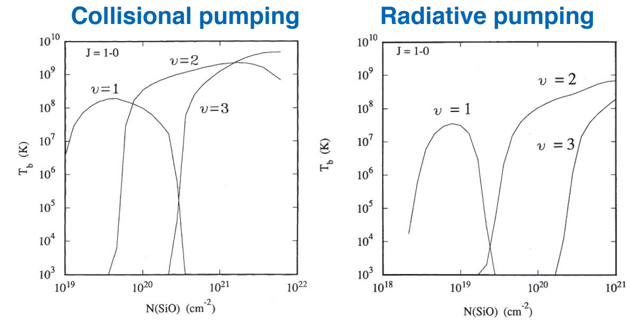

Figure 5. Two different theoretical models of SiO pumping mechanism based on different schemes; maser photon number against gas density (higher density region is closer to the stellar surface) (Locket & Elizur 1992).

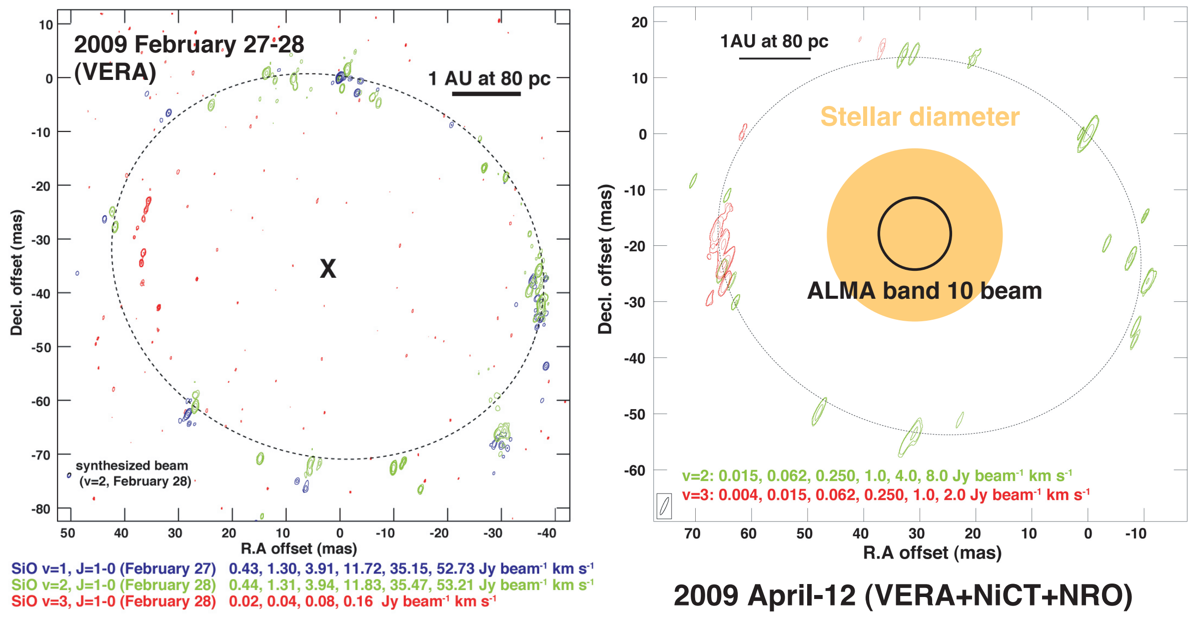

Figure 6. Superposition of SiO *J*=1-0 maser maps obtained with VERA and JVN (Imai et al. 2010). (Left panel) The maser emission regions of v=1 and v=2 are well correlated, while the v=3 emission has offsets from the v=1 and v=2 regions. (Right) one month later, the v=3 maser regions well coincide with the v=2 region. These indicate a possible switch of the maser pumping schemes.

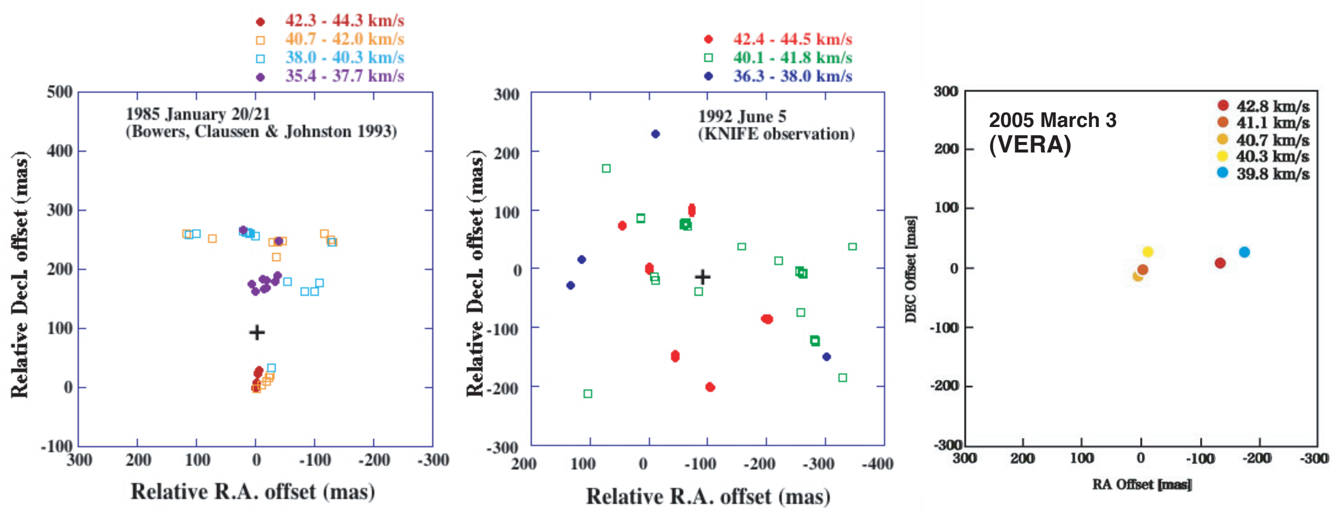

Figure 7. Various VLBI mapping of the W Hya H_2O masers. The difference in maser spot extension size between 1985 and 1993 should be intrinsic variation due to stellar pulsation, while that between VLA/KNIFE and VERA observations should be attributed to the difference in degrees of spatial resolution.

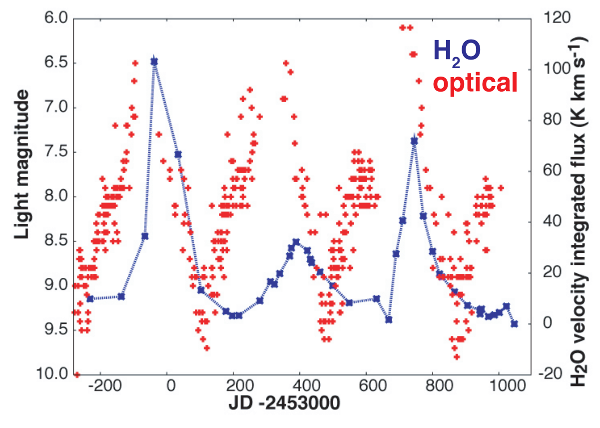

Figure 8. Periodic variation of H_2O flux in W Hydrae with correlation with the optcal light curve plus phase lag, indicating maser excitation by stellar pulsation and shock waves (Shintani et al. 2008)

Refereces

Diamond, P.J. & Kemball A.J., 2003, ApJ, 599, 1372
Locket, P., & Elitur, M. 1992, ApJ, 399, 704
Imai, H. et al. 2010, PASJ, 62, 431
Imai, H. et al. 2003, ApJ, 590, 460
Imai, H. et al. 1997, A&A, 317, L67
Kamohara R., et al., A&A, 510, 69
Matsumoto, N. et al. 2008, PASJ, 60, 1039
Miyoshi M. et al. 1994, Nature. 371, 395
Nakagawa et al. 2010, PASJ, 62, in press
Nakagawa et al. 2008, PASJ, 60, 1013
Reid, M.J., Menten, K.M., 2007, ApJ, 671, 2068
Shintani, M. Imai, H., et al. 2008, PASJ, 60, 1077
Soria-Ruiz, R., et al. 2004, A&A, 426, 131
Yi, J., et al. 2005, A&A, 432, 531