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Water and silicon-monoxide masers monitored towards the "water fountain" sources

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Abstract. We have investigated the evolution of 12 "water fountain" sources in real time in the accompanying H_2O and SiO masers through our FLASHING (Finest Legacy Acquisitions of SiO-/H_2O-maser Ignitions by Nobeyama Generation) project. It has been confirmed that these masers are excellent probes of new jet blob ejections, acceleration of the material supplied from the parental circumstellar envelope and entrained by the stellar jets yielding its deceleration. Possible periodic variations of the maser emission, reflecting properties of the central dying stars or binary systems, will be further investigated.

Keywords. masers, stars: AGB and post-AGB, stars: mass loss, stars: winds, outflows

1. Introduction

A "water fountain" source (WF) is classified as an H_2O maser source associated with a high velocity, collimated outflow or jet driven by a dying star in the transition of the AGB phase to the phase of a central star of a planetary nebula. Recent ALMA observations revealed that they are likely experiencing the "common envelope evolution" of low to intermediate-mass binary stars ($M_* \lesssim 4\,M_\odot$) with extremely high mass loss rates (up to $\dot{M}_* \sim 10^{-3}\,M_\odot \mathrm{yr}^{-1}$) for a very short period (<200 yr)(Khouri et al. 2021). Because of such a short-lived event, it has been expected to see spectral and morphological evolutions of the WFs in H_2O and SiO masers over a few decades. We have conducted monitoring observations of these maser sources in the FLASHING project using the Nobeyama 45 m telescope (see Table 1) and ATCA. These observations aim to monitor the spectral evolution of the masers, while interferometric follow-up observations with ATCA and KaVA (KVN and VERA Array) aim to find their morphological evolutions.

Table 1. Specification of the FLASHING observations. The H22 and H40/Z45 receivers have been used for the 22 GHz and 43 GHz bands to observe H_2O and SiO masers, respectively. The pairs of the H22–H40 and H22–Z45 receivers can be used to simultaneously observe these masers (Okada et al. 2020). The latter pair has been operational since 2022 March. The root-mean-square (rms) noise level of H22 will be reduced since 2022 November.

Obs. periods	2018 Dec.—2019 May 2020 Dec.—2021 April 2019 Dec.—2020 April 2021 Dec.—2022 March 2022 Nov.—2023 April (proposed)	
Targets	38 stars (12 WFs, 2 WFCs, 24 AGBs/post-AGBs)	
Receivers	H22 (K-band, RHCP+LHCP)	H40 (Q Band, LHCP) Z45 (Q-band VLP+HLP)
rms noise	σ_{TA}~0.06 Jy (➡ 0.04 Jy)	σ_{TA}~0.1 Jy (H40) σ_{TA}~0.05 Jy (Z45)
Spectral windows	4 x 2 (H22+H40) 2 x 2 + 2 (H22+Z45) Δv≈820 km/s	8 (H22+H40) 5 x 2 (H22+Z45) Δv≈420 km/s
Velocity resolution	0.4 km/s	0.2 km/s
Beam size	~74″ (FWHM, with KQ-optics)	~39″ (with KQ-optics)
Aperture efficiently	~61% (with KQ-optics)	~55% (with KQ-optics)

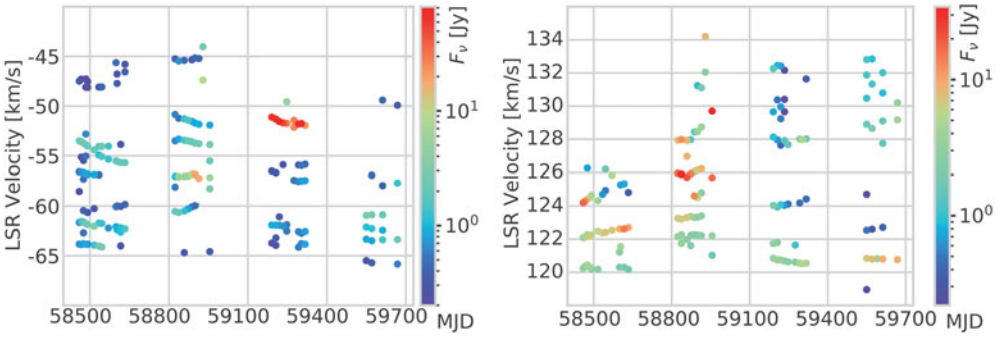

Figure 1. Peaks of H_2O maser spectra of W 43A taken with the NRO 45 m telescope. With respect to the systemic LSR velocity (~35 km s^{-1}), the drifts of the spectral peak velocities indicate further accelerations of the maser clumps, suggesting that the entrained material hosting the masers may be accelerated by the faster jet (~120 km s^{-1}).

2. Progress of the project

We have found new spectral peaks of H_2O masers breaking the records of the top speed of the WF jets by up to 130 km s^{-1} towards IRAS 18286−0959 (Imai et al. 2020) and IRAS 18043−2116 (Uscanga et al. 2022). Due to their too short lifetimes, it should be further investigated whether they exhibit rapid deceleration as predicted (Orosz et al. 2018). For both sources, comparing with the previous H_2O maser distributions (Walsh et al. 2009; Imai et al. 2013a,b) a growth of the maser jet with a very short dynamical timescale (~30 yr) also has been confirmed (Imai et al. 2020; Uscanga et al. 2022).

We also newly found SiO masers associated with IRAS 16552−3050 (Amada et al. 2022), the second case of SiO masers in WFs after W 43A. This was newly yielded by our development of the simultaneous two-band observation system equipped with the Nobeyama 45 m telescope (Okada et al. 2020).

Through the intensive monitoring observations, we have found systematic velocity drifts of H_2O masers in W 43A (see Figure 1). In W 43A, it is suggested that the faster jet traced by CO emission should accelerate the outflow formed in entrained material

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supplied from the parental circumstellar envelope (Tafoya et al. 2020). The observed maser accelerations support this suggestion.

Periodicity of the maser spectra is expected if the central stellar system is composed of a long period variable such as an OH/IR star (e.g., Imai et al. 2013b) or a binary system (Tafoya et al. 2020; Khouri et al. 2021). This will be confirmed after solving the complexity of the maser spectra affected by chaotic variation and the artificial periodicity due to time gaps of the monitoring program.

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