Discovery of Water Maser Superburst with Effelsberg and Toruń Radio Telescopes


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Abstract
On 7 September 2017, a new water-maser superburst with the flux density of up to 40,000 Jy that occurred in W49N at $V_{\text{LSR}} = -82$ km s$^{-1}$ was detected with the Effelsberg radio telescope during a regular monitoring and immediately confirmed by the Toruń 32-m radio telescope on 8 September 2017. This discovery triggered a monitoring programme with the global single-dish network established during the IAU Symposium 336 Astrophysical Masers: Unlocking the Mysteries of the Universe held in Cagliari (Sardinia), Italy, on 4–8 September 2017. Moreover, successful follow-up VLBI observations of water masers were carried out with KaVA, EVN, VLBA at 22 GHz. Here, we present the data from monitoring of this superburst by the Toruń radio telescope in both 22 GHz water masers and 6.7 GHz methanol masers. We also discuss the future collaboration between Effelsberg and Toruń.

Target
W49A is one of the most luminous ($>10^{10} L_o$) giant molecular clouds in the Milky Way. W49A harbors several embedded massive stellar clusters with stars as massive as 120 $M_o$ (Alves & Homeier 2003, Wu et al. 2014) and exhibits starburst-like phenomena (Peng et al., 2010). W49A is thus an ideal laboratory for studies of massive star formation. However, due to its large distance 11.1 $\pm$ 0.7 kpc (Zhang et al., 2013), the kinematics inside the cloud core are still poorly understood. Water maser emission is an important signpost for star-forming processes, i.e., tracing warm molecular gas behind shock waves driven mainly by energetic jets and winds from YSOs. Water maser emission at the central region of W49A (so called W49N) is one of the strongest water maser sources in the Galaxy. Its variability has been well studied since its discovery (Litvak 1971, Liljestrom & Gwinn 2000 and references therein). The dramatic variability of masers in short time scale is referred to ‘outbursts’. Even though the outburst process is still not fully understood, observations of outbursts would allow us to study both physics of masers as well as the physical conditions of star forming regions.

Monitoring Observations with Effelsberg
Following the report of a major outburst (~80,000 Jy) of the 22 GHz water maser emission in W49N by A. Tolmachev (The Astronomer’s Telegram, 28 January 2014), Kramer et al. started monthly monitoring of the 22 GHz transition with the Effelsberg 100-m radio telescope (and bimonthly observations starting from August 2016 – see Fig. 1). Even though the major outburst (2014) feature has faded away, they found that the site is still active with several high velocity outburst appearing mainly in blue wing during the last 2 years. Some features appear at extremely high velocities (up to $\pm 280$ km/s) and show rapid flux variations within 1–2 month period. These sub-year scale variability implies that the water masers could be excited by episodic shock propagations caused by a high-velocity protostellar jet. This regular monitoring programme has led to a discovery of a new H$_2$O maser outburst (up to 40,000 Jy) at $V_{\text{LSR}} = -82$ km s$^{-1}$ on 7 September 2018.

Observations in Toruń
Regular monitoring of W49N at 6.7 and 22 GHz was started with Toruń 32-m telescope on 8 September 2017 (just after outburst had been noticed in Effelsberg) and ended on 6 January 2018. Methanol maser emission at 6.7 GHz did not show any significant changes. The cadence of 22 GHz observations ranged from twice a day to one every 5 days. Our K-band receiver is characterized by SEDF $\sim 510$ Jy and noise temperature of 40 K. The observations were carried out using position switching method. The total on-source integration time for a single observation was 5 min. Two circularly polarized 16 MHz-wide bands were delivered to autocorrelator composed of four 4096-channel banks. Such frequently sampled monitoring showed that especially weaker components of the source are highly variable in time scales of days to weeks (Fig. 2). Figure 3 shows that W49N spectra obtained with the Effelsberg and Toruń telescopes are very comparable. Joint observations allowed to confirm linearity of Toruń K-band receiver in wide dynamic range and estimate antenna temperature to flux density conversion factor. Flux-density curves of bursting component and two others (for reference) obtained in Toruń thanks to application of conversion factor would be crucial for final calibration of our system.

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References

Figure 1: Effelsberg Spectra of the 22 GHz H$_2$O masers in W49N (Kramer et al 2018, Proceedings of the IAU symposium No. 336, in press).

Figure 2: Dynamic spectra of water maser in W49N taken with Toruń radio telescope. Left: full velocity range (16 MHz). Right: blue-shifted part with the outburst at $-82$ km s$^{-1}$

Figure 3: Flux density curves for bursting component and two others for reference. Data points in circles correspond to spock 8017 (ID = 24500) of joint Effelsberg and Toruń observation. Inset frame presents Ef and Tr spectra obtained at the same epoch.