Cosmic Masers: Proper Motion toward the Next-Generation Large Projects
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Torun methanol maser monitoring program

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Abstract. Since 2009, the Torun 32 m radio telescope has been used to monitor a sample of ∼140 sources of the 6.7 GHz methanol maser emission. In 2022, the sample was extended to about 250 targets. Approximately three-quarters show variability greater than 10% on timescales of a few weeks to several years. The most significant results are detecting a few flare events and discovering about a dozen periodic variables with periods ranging from a month to a few years. Here, we present the preliminary analysis of the properties of periodic masers.

Keywords. masers, radio lines: ISM, stars: formation

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1. Introduction

It is well known that the emission of class II 6.7 GHz methanol masers occurs in high-mass star-forming regions and is a powerful tool for studying processes during the early stage of star formation. One way to better understand star formation is to monitor maser line variability. A significant achievement in this field was the detection of maser outbursts caused by a rapid increase in the rate of accretion and the discovery of periodic sources. Up to now periodic variability of 6.7 GHz methanol masers were reported in 28 sources, excluding the recent detection of ∼1800 days quasi-periodic variations in Cep A (Durjasz *et al.* 2022). The periods range from 24 to 1260 days. Several mechanisms that explain the variety in flare profiles and periods have been hypothesized. Some models, such as the colliding wind binary model, consider seed photon flux changes as the driving mechanism (van der Walt 2011). Others consider the change in the pumping efficiency to be the main mechanism responsible for flares. The pump rate can vary due to periodic modulation of the accretion rate in binary systems (Araya *et al.* 2010) and spiral shocks (Parfenov & Sobolev 2014). Inayoshi *et al.* (2013) proposed the κ mechanism to explain high-mass star pulsation in the phase of high accretion. There is a claim that the orientation of the disc-outflow system in the plane of the sky might have a significant impact on observed flare profiles (Morgan *et al.* 2021).

2. Data and results

The Torun 32-m radio telescope has been monitoring a sample of ∼140 objects since 2009 (Szymczak *et al.* 2018) and 12 periodic sources were detected so far. In the last 5 years, we have discovered 7 objects; G24.148−0.009, G30.400−0.296, G33.641−0.228, G45.804−0.35 G49.043−1.079, G59.633−0.192 and G108.76−0.99 (Olech *et al.* 2019, 2022). We updated Table A3 from Olech *et al.* (2019) and performed a statistical analysis of parameters such as the period, timescale of variability (FWHM) and the ratio of rise to decay time ($R_{\rm rd}$) for 28 periodic maser sources. Histograms summarizing the results

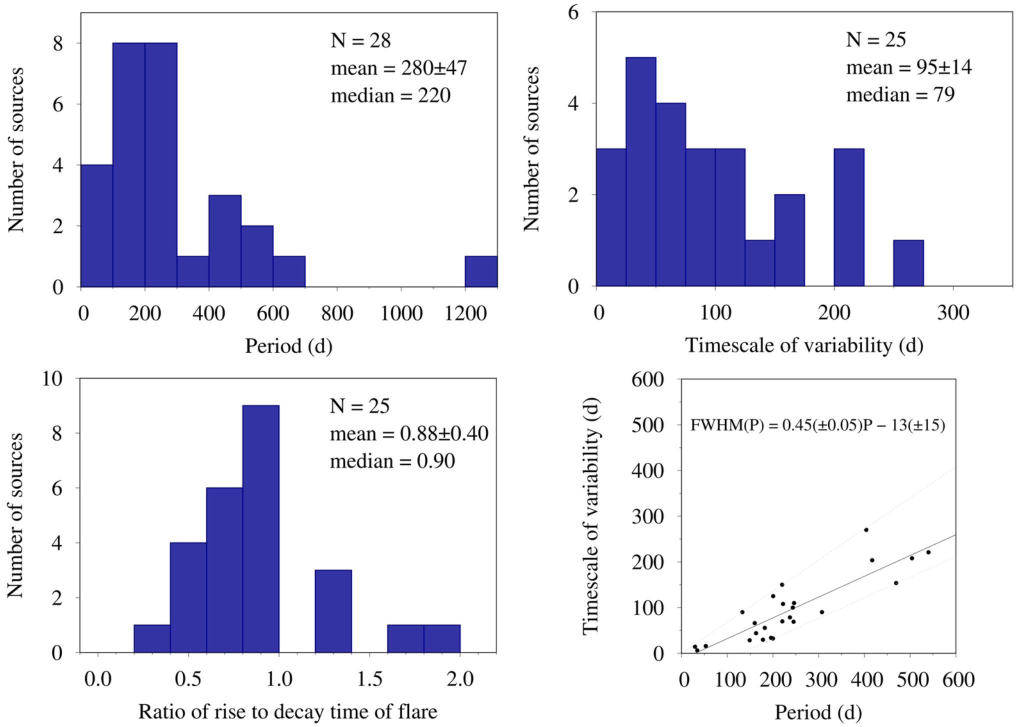

Figure 1. Distributions of selected variability parameters of known periodic sources from Table A3 in Olech *et al.* 2019 updated with new objects reported by Olech *et al.* (2022) and Tanabe *et al.* (2023).

and the average and median values are given in Fig. 1. The sources with a period in the range of 133−245 days are 57% (16/28) of the sample. For 64% (16/25) of the sources the FWHM ranges from 6.4 to 100 days. The profile of flare is asymmetric; for about 80% (20/25) of the sources $R_{\rm rd}$ is from 0.35 to 1.0. The ratio of FWHM to period can be a measure of the duty cycle. It is the smallest (0.16) in G75.76+0.34 and the largest (0.68) in G358.460−0.391. This suggests that the mechanisms that trigger periodic outbursts can be quite diverse.

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