*Cosmic Masers: Proper Motion toward the Next-Generation Large Projects*
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# Feature prospects of IRAS 20126+4104 maser studies

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**Abstract.** IRAS 20126+4104 is an extensively studied high-mass star-forming region with many astrophysical maser lines from methanol and water molecules. The brightest and highly variable is the 6.7 GHz methanol maser transition. We present follow-up studies on this target including the monitoring with the Irbene radio telescope with high-cadence data and European VLBI Network imaging extending the VLBI monitoring to 19 years. We also plan to study the target in the future based on its variability, both in the radio domain (EVN observations are planned for June 2023) and in infra-red with the 1 meter Kagoshima University Telescope operated by Amanogawa Galaxy Astronomy Research Center (AGARC).

**Keywords.** masers – stars, massive – instrumentation, interferometers – stars, formation – astrometry

## 1. Introduction

The formation of high-mass stars is still an actual topic in modern astrophysics. Accretion processes which allow protostar to evolve into a massive star are still debated. There are two most promising scenarios are: a global collapse or competitive accretion (e.g. Zinnecker 2007 as a review). Astronomical masers have emerged as a powerful tool to study the high-mass star-forming regions (HMSFRs), especially the 6.7 GHz methanol maser transition which is exclusively associated with early stages of massive star formation (Menten 1991).

IRAS 20126+4104, also known as G78.122+3.633, is well studied HMSFR: a protostar is estimated to be 7 $M_{\odot}$. with a Keplerian disk seen at several hundred GHz molecular lines with Pico Veleta telescope and Plateau de Bure interferometer (Cesaroni *et al.* 1997). The 22 GHz water masers are related to a jet, while the 6.7 GHz methanol masers are located in the disk (Moscadelli *et al.* 2011). The distance based on the parallax measurement is $1.64^{+0.30}_{-0.12}$ kpc (Reid *et al.* 2019). Single-dish monitoring suggested low and high activity periods of blue-shifted components relative to −6.1 km s$^{-1}$ line (Szymczak *et al.* 2018).

## 2. Further investigations

We selected this target for further monitoring using the Irbene radio telescopes. We have observed it every week since April 2017. Between August and October 2020. We have confirmed that a rapid variability of the spectral feature at the LSR velocity of

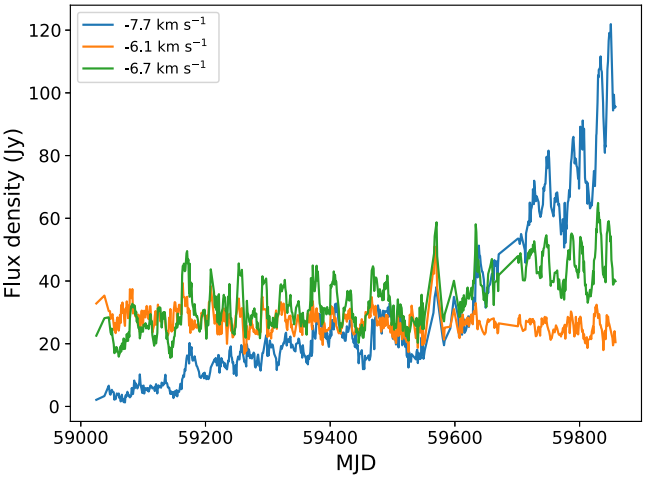


**Figure 1.** Time series of three IRAS 20126+4104 spectral components seen using the Irbene 16-m dish.

−7.7 km s$^{-1}$ (Figure 1). New image of the target obtained using EVN† extended the time-baseline of the VLBI monitoring presented by Moscadelli *et al.* (2011). With the use of proper motion studies, we confirmed a view that the maser emission from the western part tracks the gas lifted from the disc near the base of outflow/jet evidenced by the 22 GHz water masers. Overall source morphology over 19 years seems to be unchanged.

The 6.7 GHz methanol maser variability is related to the variation in infrared pumping radiation (e.g. Kobak *et al.* 2023). Therefore, we have initiated a feasibility study to monitor infrared flux fluctuations employing the Amanogawa Galaxy Astronomy Research Center (AGARC) with their 1-meter infrared telescope operated by the Kagoshima University in Japan. Preliminary data from the archive of WISE All-Sky Survey suggest fluctuations in the brightness of the infra-red emission, however, too rare observations were carried out so far and no detailed conclusions can be made.

We will also continue the Irbene methanol maser monitoring program on a daily cadence for IRAS 20126+4104. From June 2020 till May 2023, we obtained ca. 700 spectra using Irbene 16-m radio telescope. Note that some of the maser components will be still in the active phase as of 2023 June. There is a need to cooperate with other long-term monitoring programs (like from Torun and Ibaraki) and evaluate the properties of the variability. It will be important to search for any periodicity - both, long- and short-term. As one can notice in Figure 1. most of lines show short-term fluctuations, which is an interesting point, of investigation to search of possible periodicity.

IRAS 20126+4104 is still an interesting source for follow-up studies. This might answer several important questions: What mechanism is responsible for the activity of the blue-shifted methanol masers?, How do individual cloudlets evolve?, Do we have a correlation of infra-red emission with the maser transition? We aim to obtain a clear image of the ongoing scenario in IRAS 20126+4104.

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