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Preview look on: IRAS 20126+4104 6.7 GHz methanol maser cloudlet variations in 6 epochs spanning for 20 years

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Abstract. IRAS 20126+4104 is a well-studied high-mass star-forming region, known for its numerous astrophysical maser lines from methanol and water molecules. The bright 6.7 GHz methanol maser transition exhibits significant variability over both short and long-time scales.
We present follow-up studies on this target, including high-cadence monitoring with the Irbene radio telescope and imaging with the European VLBI Network (EVN), extending the monitoring at high angular resolution to almost 20 years. Preliminary results from the most recent EVN observation carried out in 2023, suggest that the relative movement of maser cloudlets are linear.

1. Introduction

The formation of high-mass stars remains a significant topic in modern astrophysics. The accretion processes that enable a protostar to evolve into a massive star are still debated. The two most promising scenarios are global collapse and competitive accretion (e.g. Zinnecker et al. (2007) as a review). On the scale of individual systems, it is still debated how the accretion disk exchanges angular momentum with the jet, allowing gas to fall towards the protostar. Astronomical masers have emerged as powerful tools for studying high-mass star-forming regions (HMSFRs), particularly the 6.7 GHz methanol maser transition, which is exclusively associated with the early stages of massive star formation (Menten et al. 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 (0.645±0.030 mas Moscadelli et al. 2011; Nagayama et al. 2015) 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). Aberfelds et al. (2023) showed that maser variability strongly correlates with their position when they combined long-term time series with the milliarcsecond (mas) accuracy positions and morphology results of a single maser cloudlets. More recently, analysis of the long-term monitoring time series obtained between 2000–2003 and 2009–2023 with the Hartebeesthoek and Torun radio telescopes has shown that all but one spectral feature varies with a period of 2520 days (ca. 7 years) (Szymczak et al. 2024). Additionally, the 6.7 GHz methanol maser flux variation shows a high correlation with NIR continuum emission measured six times over 20 years (Massi et al. 2023).

2. Observations

The most recent 10 hour EVN[1] observations of IRAS 20126+4104 were carried out on 2 June 2023 under the project code: EA067. Following nine stations successfully took part in these observations: Medicina, Tianma, Noto, Effelsberg, Torun, Onsala, Westerbork, Jodrell Bank nad Irbene. The phase−referencing technique was used with the cycle time of 105 s+225 s between a phase calibrator and a target. 3C345 was used as a fringe finder and a bandpass calibrator. We calibrated data with standard procedures using NRAO's Astronomical Image Processing System (AIPS), next, we imaged the spectral channels with the emission and measured the positions by fitting 2D Gaussian profiles as we did previously (Aberfelds et al. 2023).

3. Results and conclusions

The results are presented on Fig. 1. Single dish monitoring by Irbene station suggest a rapid variability of the spectral feature at the LSR velocity of −7.7 km s^{-1} and an overall flux increase of blue-shifted features. That agrees with the results of Szymczak et al. (2024). Overall source morphology over 19 years is unchanged (Fig. 1 here and

[1] The European VLBI Network is a joint facility of independent European, African, Asian, and North American radio astronomy institutes. Scientific results from data presented in this publication are derived from the following EVN project code: EA067

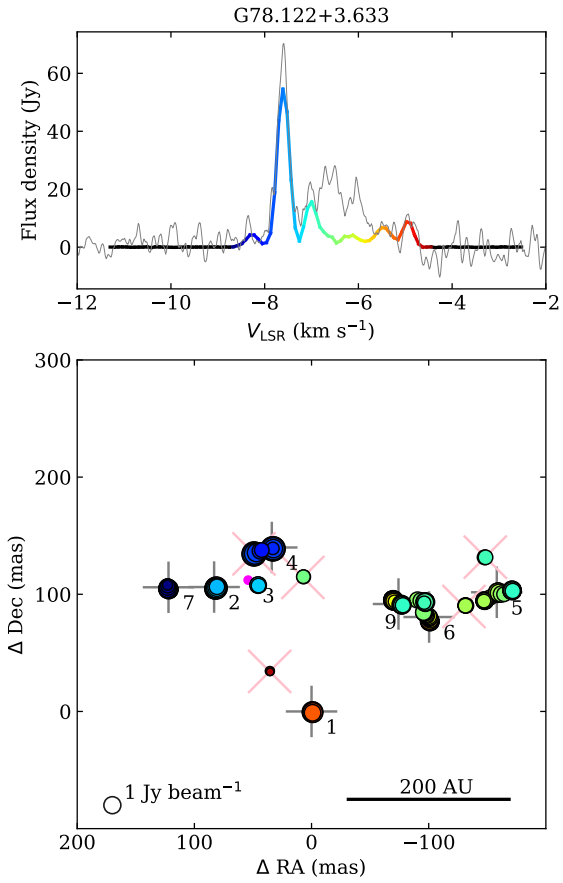

Fig. 1. Top: Maser spectra of IRAS 20126+4104 as obtained by the EVN (colour) and the 16 m Irbene radio telescope (a grey line) on 3 June 2023. Bottom: Distribution of methanol maser spots. The colours are related to the LSR velocities as in the spectrum. The spot size is proportional to the logarithm of its brightness. Grey crosses with numbers marks the long persistent maser cloudlets, new cloudlets are market with pink X-ies, the position of the cloudlets 3 from 2019 epoch is marked with a magenta point

Fig. 2. from Aberfelds et al. 2023). We note the following changes: a new bright cloudlet has appeared at the LSR velocity of −7.6 km s^{-1} and it lies close to the cloudlet at the LSR velocity of −7.7 km s^{-1} which is variable. In addition, the cloudlet 3 (see Fig. 1) shows a significant displacement relatively to 2019 data, in direction towards cloudlet 1.

In total, we have now six epochs of interferometric observations over almost 20 years and we can properly analyse a long-term evolution of single maser cloudlets and an overall structure variability. An example of simple analysis of projected distances between cloudlets is presented on Fig. 2. We calculated it as following: an angular distance projected on the sky between a pair of cloudlets is estimated relatively to the first epoch (i.e. 2004) for each pair for each epoch. Then, we subtract these values

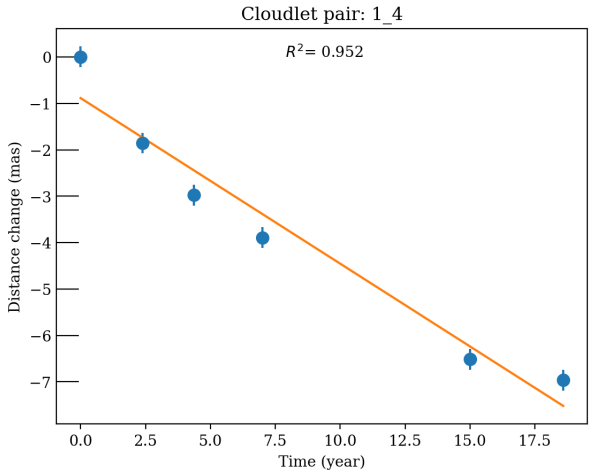

Fig. 2. Relative and projected distance change over years, between maser cloudlets 1 and 4. The orange line traces the best square fit.

from values calculated for the first epoch data. A negative value implicates that cloudlets are moving closer to each other with time. Next, we check the linear characteristics of these changes. We note that relative proper motions are linear for all pairs of cloudlets excluding pairs with the cloudlet 3.

In a summary, IRAS 20126+4104 shows rapid changes over a period of time 20 years in the large scale and also in a single cloudlet morphology together with the stability of the overall morphology of the jet-disc system. Results for blue-shifted cloudlets may indicate an intense response to long term variation in NIR flux, which may be caused by the eclipsing effect from a wobbling inner disk (Szymczak et al. 2024).

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