Milliarcsecond analysis of the 6.7 GHz methanol maser outburst in HMYSO G24.33

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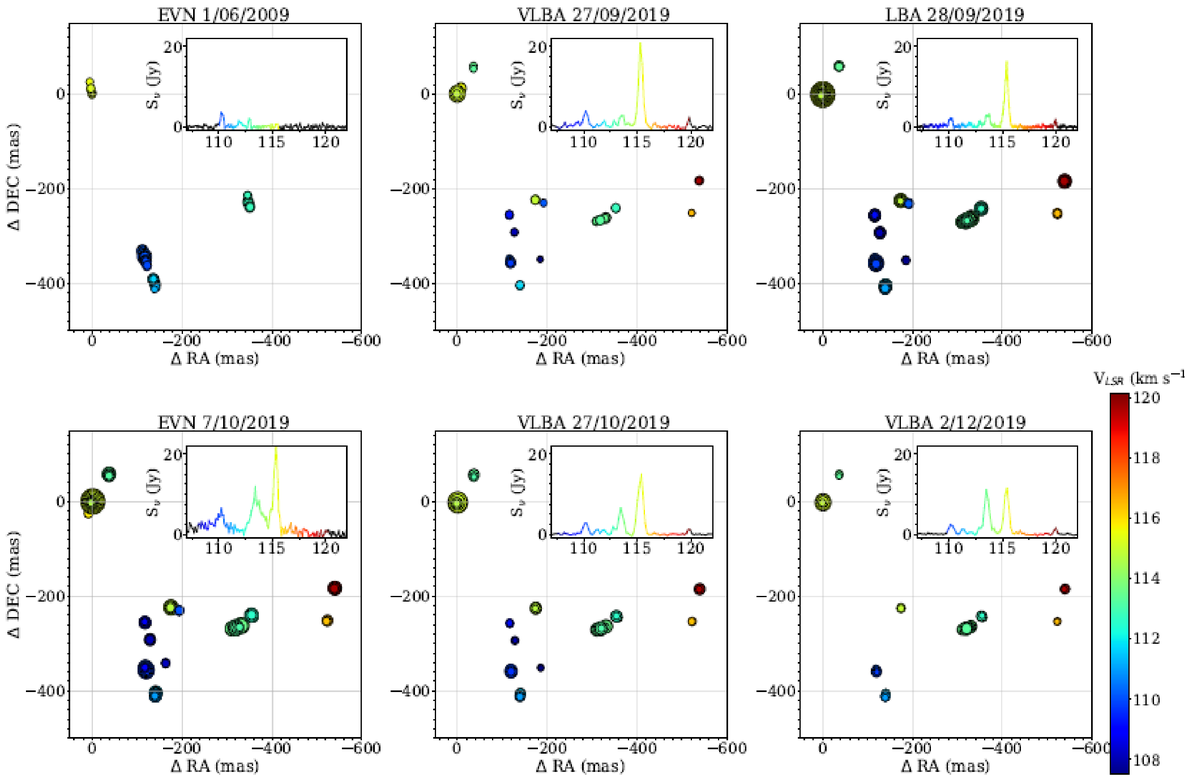
Abstract

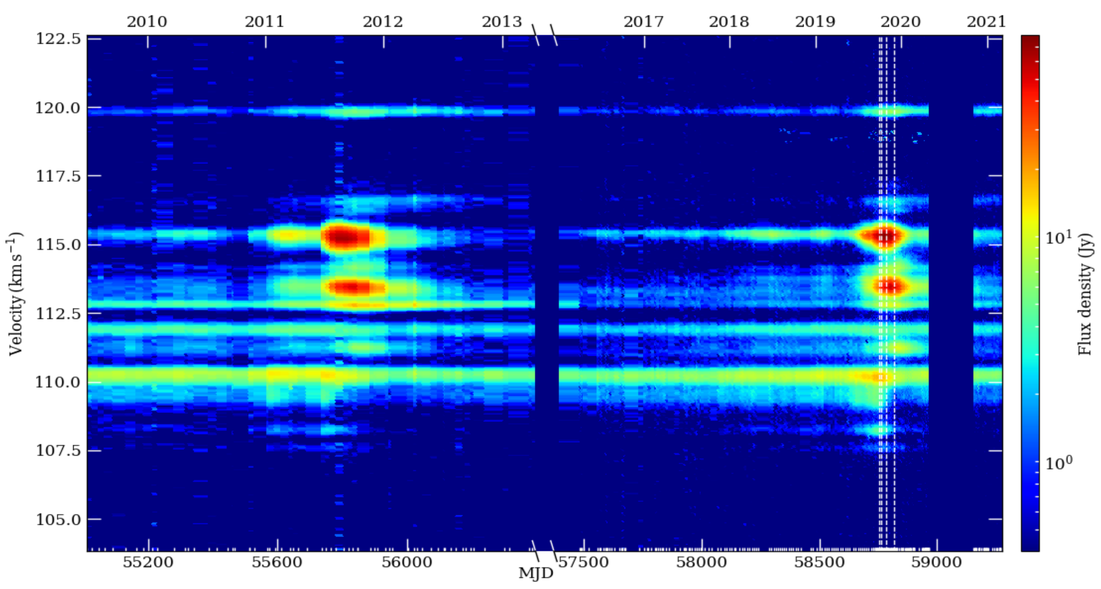
The outburst was detected in the high-mass star-forming region G24.329+0.145 at the 6.7 GHz methanol maser line under the monitoring program with the 32 m Torun dish (Wolak et al. 2019). The M2O collaboration has started multi-frequency and multi-epoch studies to analyze this rare episode, which can be provide a rapid increase a gas accretion on the disc. Using VLBA and EVN methanol maser lines (6.7and 12.2 GHz) and water maser (22 GHz). We present detailed studies of variability of single maser cloudlets and their distributions. These help to derive the physical conditions and kinematics in the target.



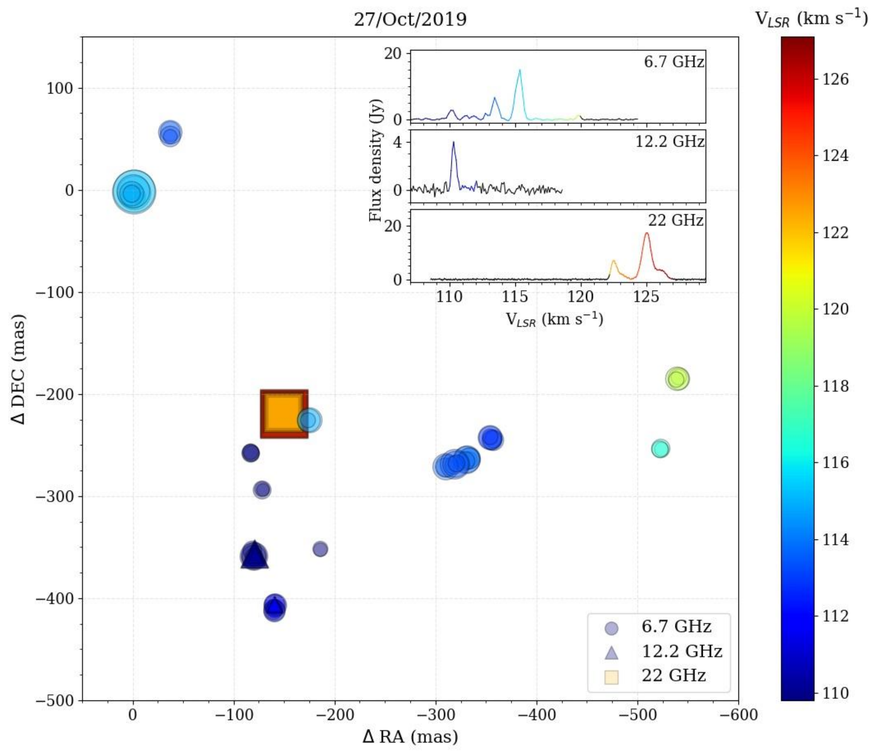
Distributions of the 6.7 GHz methanol maser spots as derived in all epochs of observations using EVN (2009) (included archival data from Bartkiewicz et al. (2016)), VLBA and LBA. The size of a circle is proportional to the square root of the intensity of a given spot. Its colour corresponds to the LSR velocity as indicated on the vertical bar and the inserted spectra.

The maser spots are spread over a large, ca. 0.6"×0.6", region corresponding to ca. 4320 AU×4320 AU. More complex morphology has appeared with the time evolution. We also note, that the overall three regions with the maser emission, detected in 2009, persisted for more than 10 yrs. However, no significant displacements were determined to enable us to derive kinematics of the massing regions.

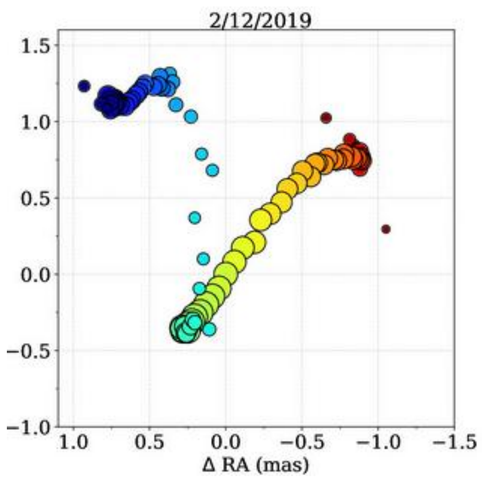
Single channel images of co-propagation of 6.7 and 12.2 GHz methanol masers as observed in VLBA E2. Contours present the 6.7 GHz methanol maser emission; the first contour correspond to 30 mJy/beam (3×σrms). The next contours are: 2, 4,8, 16, 32, 64, 128 times 3×σrms, respectively. The first negative contour is also presented, and the contour at the 90 % of the peak emission. Numbers on the top of each panel correspond to the LSR velocities of each spectral channel and the peak intensity of the 6.7 GHz methanol maser emission. The colour scale presents the 12.2 GHz methanol emission with ranges as indicated in the top of each map in Jy/beam. Co-propropagation of both methanol maser transitions was predicted in wide physical conditions, considering gas temperature and density by Cragg et al. (2002). It is interesting that the 12.2 GHz methanol maser transition is brighter than the 6.7 GHz line in same cases. Moreover, in same cases the 12 GHz appear without any 6.7 GHz counter-parts implying specific conditions.



Dynamic spectrum obtained from 32m Torun dish . The shapes of flare profiles of strong features are highly repeatable in the two events with peaks in 2011 and 2019. The major bursts of the strongest features of 113.4 and 115.3 km /s are preceded by low-amplitude, oscillations. In general, the shapes of low intensity features are less repeatable. The average flux density-weighted interval between the two flares is 2982±12 d.



The distributions and spectra of methanol and water maser transitions obtained using VLBA in E2. The circle, triangle, and square correspond to the 6.7 GHz, 12.2 GHz methanol, and 22.2 GHz water transitions, respectively. The symbol size is proportional to the square root of the maser intensity. The 6.7- and 12.2 GHz methanol lines are blue-shifted, the water line is red-shifted. The 12.2 GHz methanol masers appear at the smaller region, ca. 0.02"×0.06" (144 AU×432 AU) than 6.7 GHz., but we observe coincide between this two lines in the sky within 1.8 mas in RA and 1 mas in Dec. That is well within the position uncertainties of single maser spot at each transitions(Sect. 2). It is highly probable that the 6.7 and 12.2 GHz lines originate in the same gas volume.



The 22 GHz water masers are close, on the sky projection, to the methanol masers within 8 mas and are offset in the velocity domain by 8.4 km s−1. Water masers form two extended groups separated by ca. 1 mas (ca. 7.6 AU) from each other with clear velocity gradients from SE to NW. These gradients persisted for 66 day. ALMA 229.589 GHz thermal methanol line on the 1.3 mm dust continuum observations suggest that water maser could either the tracing the compact inner component of the bipolar outflow or a jet structure.