Cosmic Masers: Proper Motion toward the Next-Generation Large Projects
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Multi-scale observational study of G45.804−0.355 star-forming region

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Abstract. This is a multi-wavelength study to examine the G45.804−0.355 massive star-forming region (SFR) and its environs. Using MeerKAT with angular resolution (θ) of $8''$ at 1.28 GHz, we identify for the first time, a faint radio continuum emission core in G45.804−0.355. At 1.3 mm, ALMA observations ($\theta \sim 0\farcs7$) resolved the core into multiple dust continuum condensations including MM1 which was found to be the primary massive dust dense core in the region (mass $M_c \sim 54.3\,M_\odot$). The dust continuum shows an arm-like extended emission within which other dense cores are situated. The velocity gradient of the MM1 core indicates that the source is associated with a rotation gas motion. The red- and blue-shifted lobes overlap at the position of MM1. The compact morphology of the 4.5 μm IR emission, the presence of spiral arms and overlapping of the red- and blue-shifted lobes suggest a face-on geometry of G45.804−0.355.

Keywords. stars: formation, (ISM:) HII regions, ISM: jets and outflows, ISM: kinematics and dynamics, ISM: individual (AGAL045.804–00.356), instrumentation: interferometers

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1. Introduction

The molecular clouds in which massive young OB stars form have sizes varying from 2–15 pc for dark clouds, 0.3–3 pc for clumps and 0.03–0.2 pc for cores (Bergin & Tafalla 2007). Using molecular lines and various maser emission, we can probe the kinematics and physical properties of the environments where these massive young stellar objects (MYSOs) form. This study reports the millimetre and centimetre interferometric observations of the star-forming region, G45.804−0.355, which is a bright IR source. It is located at a parallax distance of ~ 7.3 kpc and has a clump luminosity of $\sim 1.9{\times}10^4\,L_\odot$, corresponding to a B0.5-spectral type star (Rivera-Ingraham *et al.* 2010). The IR source, G45.804−0.355 is associated with periodic 6.7 GHz methanol (CH_3OH) maser and an extended green object (EGO), giving an indication of ongoing star formation activities (Cyganowski *et al.* 2008; Olech *et al.* 2022).

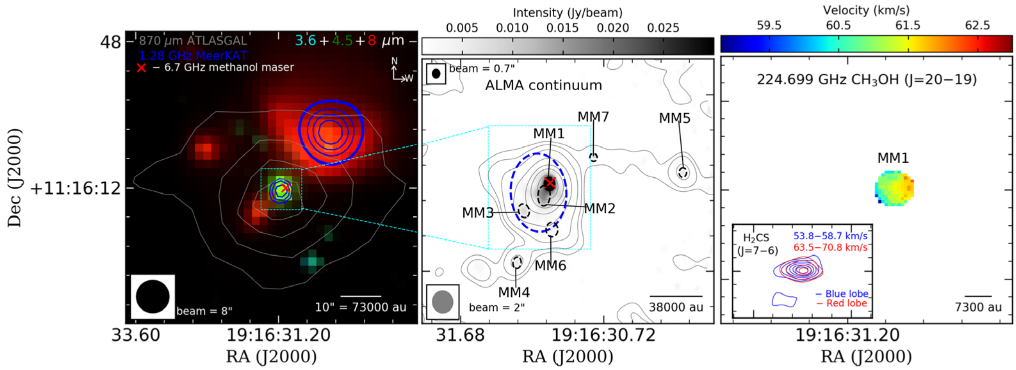

Figure 1. *Left*: IR Image of the G45.804−0.355 field overlaid with contours of ATLASGAL dust and 21 cm radio continuum emission. The black filled ellipse is the synthesized beam of MeerKAT. *Middle*: ALMA 1.3 mm continuum image, exhibiting multiple dust cores. The extended emission was achieved by convolving the dust image with a larger beam shown as a grey-filled ellipse ($2'' \times 1\rlap{.}''8$). The black-filled circle at the top left panel represents the ALMA synthesized beam. *Right*: First moment map and the velocity-integrated intensity map (insert) of MM1. The contours start from $3\times$ 11.9 μJy/beam for MeerKAT, $4\times$ 68 mJy/beam for ATLASGAL and $3\times$ 0.6 mJy/beam for the ALMA dust emission. Contours of the red and blue lobes start from 3σ, where σ is 14 mJy/beam km/s and 11 mJy/beam km/s for the red and blue lobes.

2. Observations

The radio continuum emission at 1.28 GHz ($\sim$21 cm) was observed in 2018 under the MeerKAT Galactic Plane Survey Legacy project (Goedhart *et al.* 2023, in prep.). The survey covered a wide field of view with each sky map covering $\sim 1°$. The continuum sensitivity was rms $\sim$ 10 μJy/beam and the angular resolution was $\theta \sim 8''$.

The data of dust continuum and molecular line emission at 1.3 mm were taken with ALMA in 2016 (project code 2015.1.01312.S, PI: Gary A. Fuller). The observed frequency range for the molecular line emission was between 224.2 GHz and 242.8 GHz. The angular resolution was $\theta \sim 0\rlap{.}''7$ and the velocity resolution was 1.41 km/s.

3. Results

The left panel of Figure 1 shows a faint ($S_\nu \sim 281 \pm 11\,\mu$Jy) 21 cm radio continuum emission coinciding with the 6.7 GHz methanol maser, the "fuzzy" green IR 4.5 μm emission and the sub-mm ATLASGAL dust continuum. The ALMA image shows a bright and massive central dust component (MM1). The integrated flux density and mass of MM1 are $S_\nu \sim$ 87 mJy and $M_c \sim 54.3\,M_\odot$, respectively. MM1 is surrounded by an extended emission which has an arm-like morphology and a physical size of 0.25 pc $\times$ 0.18 pc. The other sub-condensations (labelled MM2 – MM3) have masses ranging from $M_c \sim 35\,M_\odot$ to $1.5\,M_\odot$. The MM1 core is rich in thermal CH_3OH molecular lines and the moment one map reveals a rotating structure (see panel 3 of Figure 1). No separation is found between the blue and red-shifted lobe peaks.

4. Discussions and Conclusions

The high abundance of thermal methanol lines, spatially coincident radio continuum and the excess 4.5 μm, along with the association of 6.7 GHz methanol maser suggest the MM1 to be the main powering source hosting a central MYSO. Of all the identified cores, the MM1 core has the highest average-beamed column density ($\sim 3 \times 10^{22}$ cm^{-2}).

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The estimated luminosity function value is $2.18\times10^3\,L_\odot$, which corresponds to an early B-type star.

The MM1 core has excess 4.5 μm IR emission, which is a good indicator of outflowing gas. However, there is no separation between the peaks of the blue- and red-shifted lobes at the position of MM1. The velocity gradient reveals a rotating envelope with spiral arms around the MM1 core. Since the morphology of the IR emission at 4.5 μm is compact and not extended like regular EGOs, we suggest the G45.804−0.355 SFR to have a face-on geometry. This is confirmed by the presence of arms and the overlapping of the red- and blue-shifted lobes.

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