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Multi-Maser VLBI structure of the high-mass SFR G16.59-0.05

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In the following we summarize our results based on multi-epoch, phase referenced, Very Long Baseline Interferometry (VLBI) observations of maser associations towards the high-mass Star Forming Region (SFR) G16.59-0.05 . We observed H_2O 22.2 GHz (4 epochs) and OH 1.6 GHz (1 epoch) masers using the Very Long Baseline Array (VLBA), and 3 epochs of CH_3OH 6.7 GHz masers with the European VLBI Network (EVN). This source is part of a sample that we are studying aiming to better constraint the process of Massive Star Formation (MSF). Maser emission in high-mass SFRs is associated with the earliest evolutionary stages of massive star formation (e.g. [3]). In particular, different maser species appear to trace distinct environments (e.g. [6]). Using single-epoch VLBI observations it is possible to derive the absolute position and the line of sight (L.O.S.) velocity of the maser spots. Furthermore, multi-epoch VLBI experiments allow us to derive the proper motion of such spots, i.e. to determine the 3-D kinematics of the innermost gas around the associated Young Stellar Objects (YSOs). The synergy between interferometric observations of thermal lines and VLBI observations of maser transitions allows us to investigate the SFR environment on scales ranging from the parsec scale to a few AU.

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1. Introduction

The SFR G16.59-0.05 is located at a *near* kinematic distance of $\sim 4.7\ kpc$ and has a systemic velocity (V_{LSR}) of $\sim 59.9\ km\ s^{-1}$. The estimated large-scale clump mass is $> 1500 M_\odot$ [5], with a bolometric luminosity of $\sim 10^{4.3} L_\odot$ [1]. Thermal tracers show a multiple-outflow system emanating from a core detected in the mm and cm continuum emission. The axes of the more intense and better collimated outflows are directed northwest-southeast and northeast-southwest, with the red lobes towards north [2]. The peak position of the mm emission is displaced to the northwest with respect to both the cm emission [2] and the peak of the molecular emission [5], suggesting the presence of multiple YSOs. Molecular line emission has been used to trace the velocity field of the innermost hot (~ 130 K) and dense ($\rho > 10^6 - 10^7\ cm^{-3}$) gas. The millimeter continuum flux indicates the presence of a Hot Molecular Core (HMC) with a mass of $\sim 100 M_\odot$ [5].

2. Results

Our VLBI observations were succesful in mapping both water 22.2 GHz and methanol 6.7 GHz masers, which were previously observed at lower resolution by [4] using the VLA (C configuration) and [7] using the ATCA, respectively. The OH masers, previously imaged by [4] with the VLA A-B hybrid configuration, were not detected by us, probably due to insufficient sensitivity. We have measured 40 distinct centers of H_2O maser emission and 39 centers of CH_3OH maser emission. The maser intensities range from $\sim 0.10 - 65.5\ Jy\ beam^{-1}$, and from $\sim 0.06 - 20.6\ Jy\ beam^{-1}$, for water and methanol respectively. In correspondence with the maser emission area, the 7 mm continuum emission shows a double-lobe elongated along the northwest-southeast direction. The southeastern lobe coincides with the 1.3 cm peak and the methanol maser distribution (Fig. 1). Our measurements of water maser absolute velocities suggest that water masers may trace an expanding motion from the same object exciting the methanol masers. Accurate relative proper motion of the 6.7 GHz methanol masers have successfully been derived using 3 epochs of EVN observations. Comparing the CH_3OH and H_2O relative proper motions indicates that the two maser species trace distinct kinematic structures (Fig. 1). In particular, CH_3OH maser velocities relative to the maser emission barycenter, seem to trace rotation around this point, with amplitudes in the range $\sim 5 - 15\ km\ s^{-1}$. If we assume a keplerian-like rotation, the required central mass is consistent with the stellar mass estimated from the 1.3 cm continuum flux density, that is of order $\sim 20\ M_\odot$. For details and furhter discussion of these data we refer to Sanna et al. 2009, in prep.

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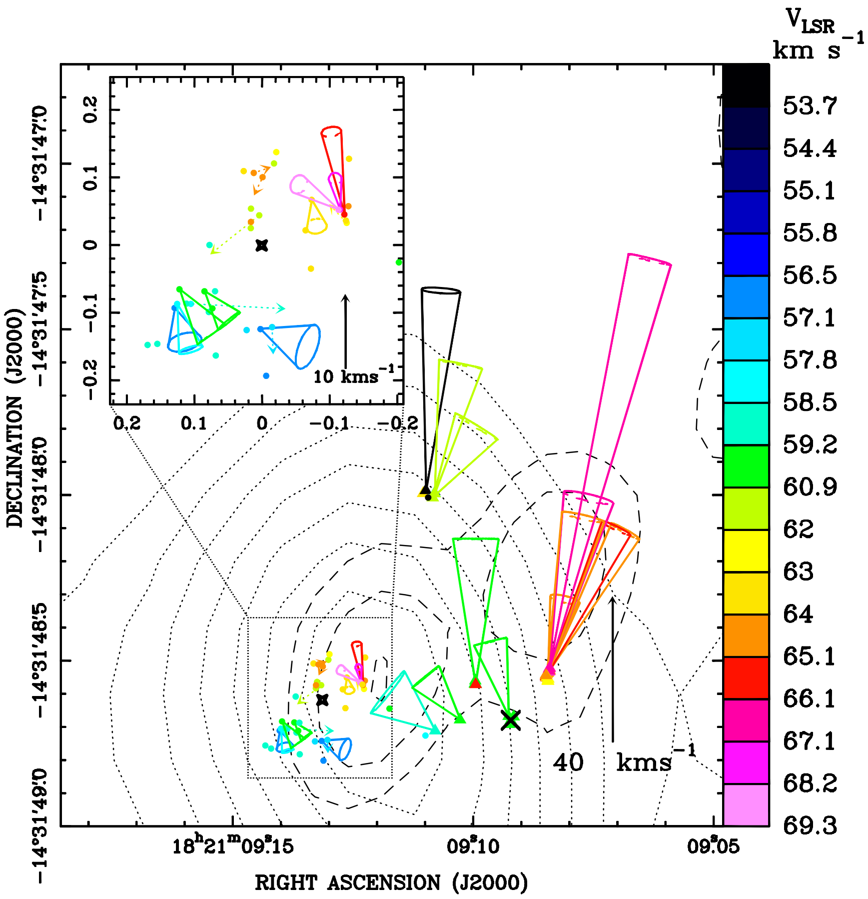

Figure 1: Comparison of absolute positions and relative velocities of methanol and water masers. Triangles (H_2O) and dots (CH_3OH) give the absolute positions of maser spots. Colours indicate the maser L.O.S. velocities with the green colour indicating the source LSR velocity. Coloured cones are used to show both the direction and the uncertainty (cone aperture) of the proper motion of the maser spots. The proper motion amplitude scale is given in the bottom right corner of the plot. Dotted arrows denote the most uncertain measurements. H_2O: relative proper motion are measured with respect to the crossed feature. CH_3OH: relative proper motion are calculated relative to the maser spots barycenter (*cross*). **Inset:** zoom of the methanol maser region, with position relative to the maser baryceter. Colour–L.O.S. velocity conversion code is the same as for the main panel. The proper motion amplitude scale is given in the bottom right corner of the inset. Dotted and dashed contours represent the 1.3 cm VLA and the 7 mm VLA continuum archival data, respectively (P.I.: Zapata).

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