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VLBI observations of H_20 and CH_3OH masers towards the high-mass YSO G16.59-0.06

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Introduction and outline

The Synergy between interferometric observations of thermal lines and Very Long Baseline Interferometry (VLBI) observations of maser transitions allows us to obtain a better understanding of the process of massive star formation. Using thermal line observations at high resolution, the kinematics of massive star forming regions (SFRs) can be traced on scales from 1000 AU to a few pc (at typical distances of a few kpc). Hence, jet/outflow or disk-like structures can be revealed and their physical properties derived (Cesaroni et al. 2007). Maser emissions in high-mass SFRs are associated to the earliest evolutionary stages of massive star formation (Beuther et al. 2002). In particular, different maser species appear to trace distinct environments (e.g. Moscadelli et al. 2005; Edris et al. 2005; Goddi et al. 2007). Using single-epoch VLBI observations it is possible to derive the absolute position and the line of sight velocity (L.O.S.) 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 YSO on scale of about 10 AU. Putting together the information obtained (i.e. gas temperature, density, and velocity field) from the aforementioned tracers, it is then possible to draw a detailed and self-consistent scenario of the environment and phenomena related to massive star formation.

In the following, we report preliminary results based on multi-epoch, phase referenced, VLBI observations of maser associations towards the candidate high-mass YSO G16.59-0.06 (Codella et al. 1997). We observed H_20 22.2 GHz (4 epochs) and OH 1.6 GHz (1 epoch) masers using the VLBA, and 2 epochs of CH_3OH 6.7 GHz masers with the EVN. Our observations have an angular resolution of the order of a few milliarcsec (1 mas ≡ 4.7 AU at the distance of G16.59-0.06), sufficient to investigate the innermost regions of the SFR.

The Star Forming Region G16.59-0.06

The SFR G16.59-0.06 is located at a distance of 4.7 kpc at the LSR velocity of 59.8 km s^{-1}. Furuya et al. (2007) observed molecular-line and continuum emission in G16.59-0.06 with the PdBI and OVRO interferometers. Fig.1 shows their detection of a ^{12}CO outflow centered on the 3mm continuum emission. The continuum emission flux density was used to estimate an Hot Molecular Core (HMC) mass of about 100 $M_{\odot}$. The peak position of the 3mm source is displaced by ~ 1''.4 to the northwest of the CH_3CN peak (Fig.2). The CH_3CN line emission has been used to trace the velocity field of the innermost gas, that is possibly describing a disk structure.

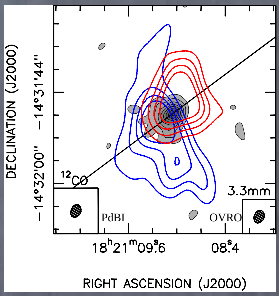

Fig.1: Overlay of the blue- and redshifted emission of ^{12}CO (1-0) with the 3mm image (grey scale). The solid line indicates the axis of the ^{12}CO outflow. Synthesized beams are shown in the bottom corners (Furuya et al. 2007).

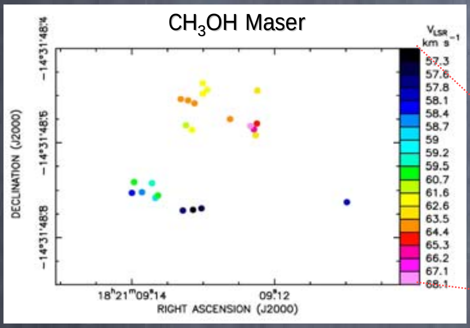

Fig.3: The absolute distribution of the CH_3OH maser spots (24 features) at the first EVN epoch (February 2006). Colours indicate the maser L.O.S. velocities, assuming a source LSR velocity of 59.8 km s^{-1}. Peak intensities range: 0.094 to 17.4 Jy $beam^{-1}$. EVN beam FWHM: 15 × 5 mas. Vel. res.: 0.08 km s^{-1} (BW 2MHz; correlator channels: 1024). With 3h of on-source integration, the away-from-signal rms on the channel maps was around 10 mJy $beam^{-1}$.

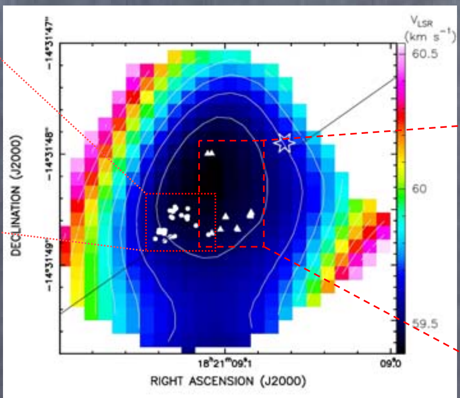

Fig.2: Velocity field (vel. res.: 1.63 km s^{1}) of the CH_3CN (5-4) line emission (K=3). The black line indicates the axis of the ^{12}CO outflow. Star: 3mm continuum peak. PdBI beam FWHM: 2''.46 × 1''.96 (Furuya et al. 2007). White circles and triangles: maser spots of CH_3OH and H_2O, respectively.

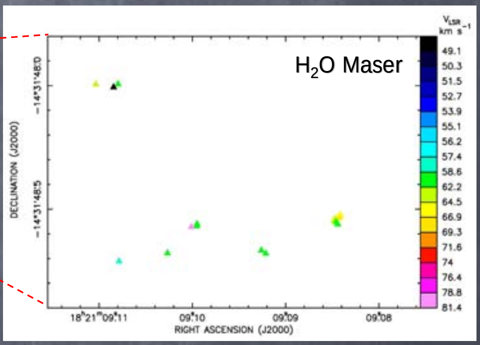

Fig.4: The absolute distribution of the H_2O maser spots (22 features) at the first VLBA epoch (April 2006). Colours indicate the maser L.O.S. velocities, assuming a source LSR velocity of 59.8 km s^{-1}. Peak intensities range: 0.076 to 25.23 Jy $beam^{-1}$. VLBA beam FWHM: 2 × 0.4 mas. Vel. res.: 0.2 km s^{-1} (BW 16 MHz; correlator channels 1024). With 3h of on-source integration, the away-from-signal rms of the channel maps was around 10 mJy $beam^{-1}$.

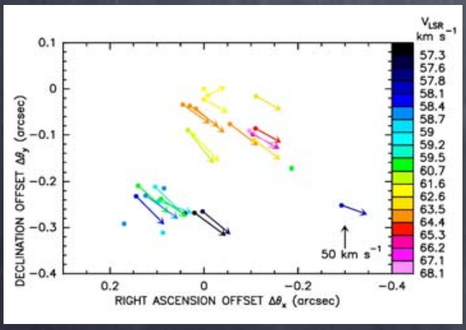

Fig.5: The relative proper motions of the CH_3OH maser spots derived from two EVN epochs (February 2006 – March 2007). Velocities are measured with respect to the feature with the largest Dec, that is the most intense (cross). There are 23 maser features persistent between the two epochs.

Preliminary results and discussion

CH_3OH masers: the blue- and redshifted spots are spatially grouped in two distinct regions, separated along a P.A. close to that of the ^{12}CO outflow axis (see Figs. 2 and 3). Also, the maser L.O.S. velocity distribution agrees with that of the ^{12}CO outflow lobes (see Fig.1). Using the two EVN epochs, we derived the relative proper motions of the 6.7 GHz features respect to the reference maser feature (Fig.5). Fig.5 shows that, respect to that feature, the others move concordly with a quite high velocity amplitude of ~ 90 km s^{-1}. Differences between relative proper motions are of ~ 10 km s^{-1}. There is no correlation between feature locations and intensities.

H_2O masers: they are distributed across a larger area than the CH_3OH spots, in two groups located both north (gI) and south (gII) of the CH_3CN peak. The group gII shows an elongated structure (with size of about 0.5 arcsec), while group gI is compact and contains only few features. Also in this case, no correlation between spot location and intensity is found.

Furuya et al. (2007) propose two scenarios both of which imply that the 3mm continuum and CH_3CN emission might arise from two distinct objects. Discussing the disk-outflow association they argue that, as the putative rotation axis appears to lie close to the L.O.S., while explaining the absence of velocity gradient in the CH_3CN, makes the detection of any rotational velocity trend difficult. Our observations show: I) both CH_3OH and H_2O masers distribute close to the CH_3CN peak, suggesting that both types of masers are likely associated to the same YSO; II) features of either maser species are spatially segregated in two contiguous but distinct regions, which indicates that the two maser emissions may trace different portions of gas (see also the poster from Goddi et al., where water and methanol masers appear to trace different kinematical structures in the high-mass YSOs AFGL 5142 and G24 A1). We postpone any interpretation of the kinematics of the gas traced by the masers until the absolute proper motions of the water masers are derived.

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