Associations of $H_2O$ and $CH_3OH$ masers at milli-arcsec angular resolution in two high-mass YSOs

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Introduction

Single-dish surveys of 6.7 GHz methanol and 22.2 GHz water masers in high-mass star forming regions (SFRs) have shown that both maser species trace the earliest evolutionary stages of the high-mass star forming process (outflows, hot molecular cores, and UC HII regions).

Very Long Baseline Interferometry (VLBI) multi-epoch observations have clarified that water masers originate from shocks associated with winds/jets ejected from the massive young stellar objects (YSOs). Instead, the birthplace of 6.7 GHz methanol masers is still debated and different environments have been proposed in several sources (Keplerian disks, jets, hot molecular cores, and UC HII regions).

Comparing the spatial-kinematic distribution of both maser species in the same YSO at high-angular resolution constrains the interpretation of the kinematic structures and the evolutionary stages traced by the masers. So far only a few studies have been performed in both maser types with sufficient angular resolution (e.g., the Driving YSOs of outflows, hot molecular cores, and UC HII regions.

Since a few years, we have been conducting a multi-epoch VLBI campaign of a sample of high-mass YSOs, where both the 6.7 GHz methanol and 22.2 GHz water masers are observed.

In this poster, we present the results obtained toward two high-mass YSOs: SH 2-255 IR and AFGL 5142.

Observations

AFGL 5142 (L = 4 x 10^7 L☉, D = 1.8 kpc)

AFGL 5142: X, K, Q-band continuum observations (Mar 05)

Sh 2-255 IR (L = 9 x 10^7 L☉, D = 2.5 kpc)

Observational results on the two sources

H₂O and CH₃OH maser variability from single-dish monitoring

The figures on the sides show the range of variation in the spectrum of H₂O masers from Medicina monitoring and CH₃OH masers from Hartebeesthoek monitoring [5], in AFGL 5142 and Sh 2-255 IR respectively. The dashed and dotted lines are the upper envelope and the lower envelope of the maser emission, respectively, calculated by finding the maximum and minimum at each velocity channel in the time interval 1999-2003.

In both sources, water masers have spectra changing completely over the years, whereas the methanol features remain at the same velocities. Water and methanol emissions differ also at clearly different ranges of LOS velocities.

The different degree of time variability between water and methanol masers and, mainly, the rather clear separation in LOS emission velocities, for both sources, suggest that they trace different kinematic structures in the same YSO.

AFGL 5142

The water masers show a bimodal spatial and LOS velocity distribution. Based on their 3D velocities, H₂O masers clearly trace extension from the YSO, supported by the 22 GHz continuum emission peak.

Two interpretations are possible:
1. They trace the innermost portion of the extended CO outflow “C” [2].
2. They trace the wide-angle disk wind at the base of the CO outflow “B” [2].

High-angular resolution observations in continuum might help to identify the driving YSOs of outflow “B” and “C”, and hence, discriminate between the two options.

Sh 2-255 IR

Water maser emission in Sh 2-255 IR consists of three main clusters of features (Aw, Bw, and Cw) distributed nearly along the axis of a H₂ ionized jet [1], water masers are possibly associated with the inner part of the jet. However, all the measured proper motions are not aligned along the jet axis but form large angles with it.

Two scenarios can be considered:
1. Precession of the jet axis.
2. Rotation around the jet (e.g. disk wind).

The data in hands do not allow us to discriminate unambiguously between the two scenarios.

AFGL 5142

Water maser emission in SH 2-255 IR appears to arise from two distinct areas, Groups A and B [1].

Sh 2-255 IR

The 6.7 GHz methanol maser emission appears to arise from two distinct areas, Groups A and B [1]. The present data are too scarce even to attempt a qualitative interpretation of their birthplace.

New multi-epoch EVN observations of the 6.7 GHz methanol masers are scheduled in order to determine their absolute positions and proper motions: they will help clarify the kinematic structures traced by both maser species toward this YSO.

Summary

Phase-reference VLBA multi-epoch observations of the 22.2 GHz water masers and EVN single-epoch observations of the 6.7 GHz methanol masers were conducted toward two high-mass YSOs in AFGL 5142 and Sh 2-255 IR.

With absolute positions as accurate as a few mas, our data reveal a true association of both CH₂O 6.7 GHz and H₂O 22.2 GHz masers with the same massive YSO in AFGL 5142: the two maser types can then trace a common stage in the evolution of a forming high-mass star.

Albeit associated with the same YSO, in AFGL 5142 water and methanol masers appear to trace different kinematic structures, in particular expansion at the base of a molecular outflow and infall in a molecular envelope, respectively.

References