Cosmic Masers - from OH to H_0
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10 years of 12.2 GHz methanol maser VLBI observations towards NGC 7538 IRS1 N: proper motions and maser saturation

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Abstract. We present the outcomes of the consistent analysis of 6 epochs of VLBA 12.2 GHz data obtained between 1995 and 2005 towards the known high-mass star formation reigon NGC7538 IRS1 N. Our analysis concentrates on the study of the main spectral/spatial feature, which is 20 VLBA synthesized beams in size with a distinct velocity gradient. We looked for proper motion signals relative to the central peak which, in an edge-on disc framework, is expected to be stationary. We also study the peak flux and the spatial brightness profile of the main maser feature searching for maser variability. Our results are twofold: we detect a clear proper motion signal of three spatial features (0.21, 0.1, 0.65 mas yr^{-1}) and conclude that these can be made consistent with previous modelling of a Keplerian disc seen edge-on around a high-mass protostar. We further detect a consistent decrease of the peak flux over the time-span 1995-2005 ($\sim$ 5.4 Jy yr^{-1}), confirmed when taking into account earlier data (1986, 1987) as well as by the 6.7 GHz maser emission. Also, the width of the spatial brightness profile of the main feature seems to decrease between 1995 and 2005 by some 50%. We consider these observables as clear signs of partial maser saturation.

Keywords. Star formation, high-mass stars, masers, methanol, saturation, proper motions

1. Introduction

The high-mass star formation region NGC 7538 hosts a number of IR sources, one of them (IRS1 N) showing a prominent methanol maser emitting at 6.7 and 12.2 GHz. The brightest spectral feature of that maser at both frequences has been modelled as a rotating dics seen edge-on (Minier *et al.* 1998, Pestalozzi *et al.* 2009), rotating around a 30 $M_\odot$ protostar. The structure shows an impressive morphological and dynamical coherence across 20 beams, which makes the hypothesis fairly strong. This idea has been challenged recently by e.g. De Buizer & Minier (2005) and Surcis *et al.* (2011).

The present contribution assumes the edge-on rotating disc scenario. Six epochs of VLBA data at 12.2 GHz, taken between 1995 and 2005 build the presented data set.

2. Results

Proper motion. This part of the study had the goal of obtaining an independent measurement of the mass of the central object. In fact, assuming the brightest point to be fix in space, all other distinguishable features followed across the observational epochs would move either away or toward the central peak. Outward motions were registered (see Fig. 2), for the three features away from the central peak, indicating that they must be on the far side of the disc. Their velocity can be made compatible with a central object between 5 and 120 $M_\odot$.

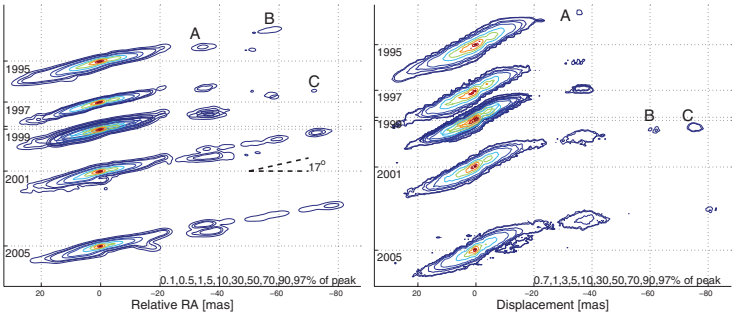

Figure 1. Velocity integrated data (left) and position-velocity diagrams (right) of the six VLBA epochs considered for the present work. Notice the three spatial features A, B, C for which proper motions relative to the central peak have been measured (see Fig. 2).

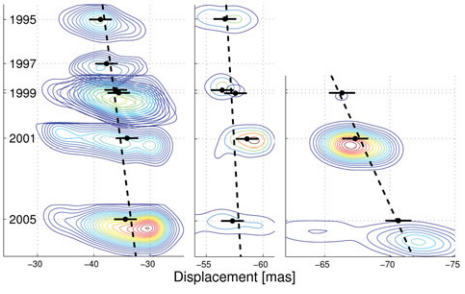

Figure 2. Centroid proper motion measurments (relative to central peak) of spatial features A, B and C indicated in Fig. 1. First contours are ar 10% of the peak with 5% spacing. The transversal velocities are 0.21, 0.1 and 0.65 mas yr^{-1} for A, B and C respectively, that can be made consistent with a central object between 5 and 120 $M_\odot$.

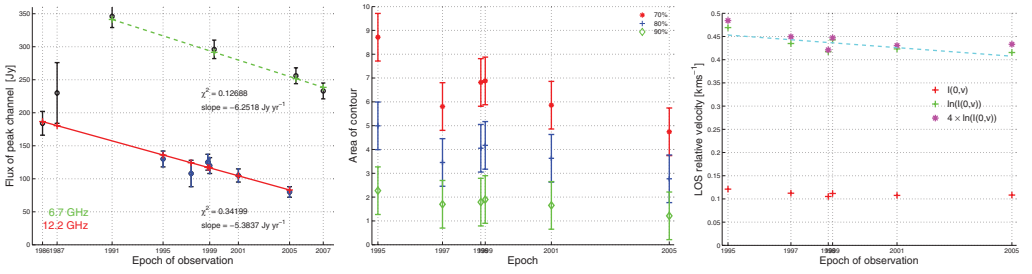

Figure 2. Three observables that have to be modelled with partial saturation along the amplification path. From left to right: peak flux decrease, spatial profile narrowing, spectral profile narrowing.

Variability. We register a constant decrease of the peak flux density of the brightest maser feature, that can be followed over 20 years, both at 12.2 and at 6.7 GHz. Also, we register a narrowing of the spatial and spectral profile (the latter is at the edge of detection, see Fig. 2). These three facts are not compatible with models of *un*saturated maser emission, and the only way to reconcile them with modelling is to introduce partial saturation: shortening of the unsaturated portion of the of amplification path makes it possible to obtain the three effects at once.

References

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