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Masers as probes of proto-planetary discs

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Abstract. Water maser emission from star forming regions has been monitored for several decades using the Puschino radio telescope, showing radial velocity variations consistent with material in Keplerian orbit around protostars. MERLIN and the EVN are now being used to image the 22 GHz emission on au scales and measure proper motions. This will distinguish discs from outflows, and provide an estimate of the central mass and possibly orbiting condensations.

1. Introduction

Masers are the brightest spectral lines found in star-forming regions. Recently, CH_3OH masers have shown clear evidence for Keplerian rotation in protostellar disks (Norris et al. 1998; Minier, Booth, & Conway 2000) A&A). H_2O masers have usually been associated with shocked outflows but protoplanetary discs may also produce suitable conditions. Since 1980 a joint LPI-SAI group has monitored about fifty 22-GHz H_2O maser sources using the Puschino radio telescope e.g. Lekht et al. (1993). A number of objects show a triplet of persistent spectral features with small velocity drifts which are sometimes correlated with brightness changes. Four possible models include accelerating outflows or Keplerian rotation. Intriguingly, if orbital motion is being observed, irregularities in Keplerian behaviour suggest discrete clumps. Can H_2O masers be used to trace matter as it condenses in a protostellar disk?

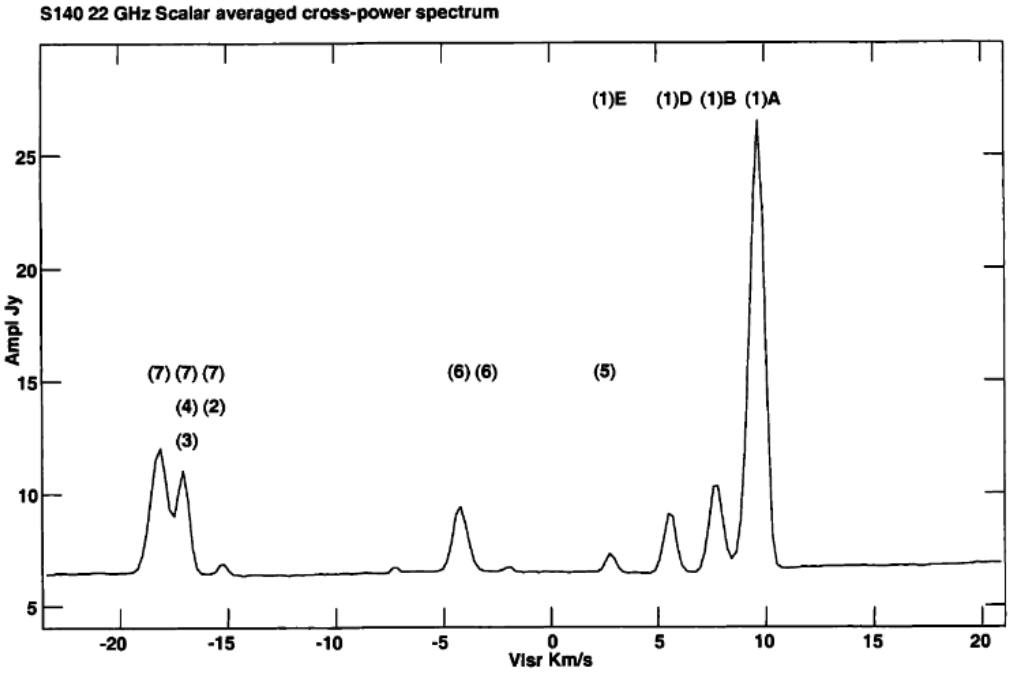

Figure 1. Velocity profile of S1240 observed with MERLIN in 1998.

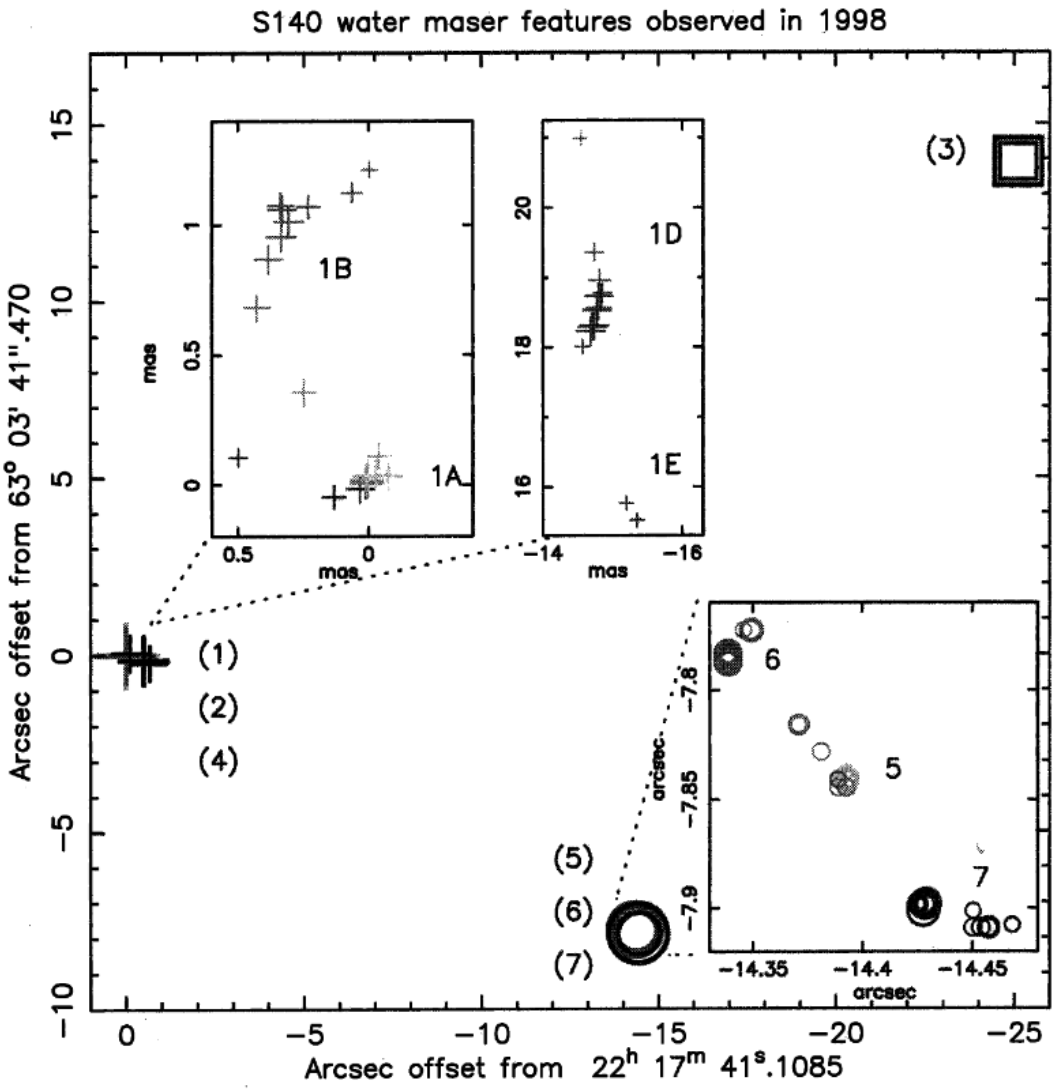

Figure 2. Location of H_2O masers, labeled as in Fig. 1

2. Observations

MERLIN [1] has milli-arcsec (mas) resolution at 22 GHz in 0.1 km s^{-1} velocity channels. An absolute position accuracy of 10 mas can be achieved. A series of observations of five nearby sources started in 1998 to measure H_2O maser clump size and distribution and proper motions. This will distinguish rotation from outflow in a few years. Other sources (at greater distances, requiring higher resolution) are being observed by the European VLBI Network.

3. Preliminary Results

The first epoch of MERLIN observations showed that some velocity peaks are blends of emission from separate maser sources up to 50″ apart, but each spatial region is distinct and covers less than an arcsec with a complex but non-random velocity structure. For example S140 has a maximum 22-GHz spectral peak separation of $\sim$ 25 km s^{-1} (Fig. 1). Lekht et al. (1993) fitted models to the spectral variations which suggested the masers emanate from fragments ≥ 1 au in diameter, orbiting at 25 – 80 AU from the central star, mass $5M_{\odot}$. Imaging (Fig. 2) shows several separate regions which could be associated with distinct protostars; for example the region **5-6-7** has a 20 km s^{-1} velocity range and an angular radius of 75 mas, or 60 AU at a distance of 0.8 pc, which could be fitted by a similar perturbed Keplerian model around a lower mass star. Individual AU-scale clouds are resolved with a velocity extent of $\sim$ 1 km s^{-1}.

4. The Future

This single epoch of radio data shows sub-AU structure of water vapour clouds, and modelling will constrain the local temperature, density and other conditions. Comparison with later data may also reveal condensations in protoplanetary discs, but in any case gas dynamics close to the star will be better understood when this project is complete. Increasing the sensitivity of MERLIN and upgrading the correlator will make these observations much easier.

References

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[1] MERLIN is the UK national radio astronomy facility operated by the University of Manchester at Jodrell Bank Observatory on behalf of PPARC