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Methanol Masers—Are They in Circumstellar Disks?

R. P. Norris
CSIRO Australia Telescope National Facility, Epping, NSW 2121, Australia

C. J. Phillips & S. P. Ellingsen
University of Tasmania, Hobart, Australia

Abstract. Since the discovery of the 12.2 and 6.7 GHz methanol maser lines, these masers have been studied in great detail. Even in the earliest studies, it appeared that in some fraction of the sources, the maser spots were arranged in lines. This contrasts with the well-studied OH and water masers, in which the masers tended to be clustered almost randomly around a compact H II region. Here I describe recent work to investigate the hypothesis that these lines represent edge-on circumstellar disks.

1. Introduction

Since the discovery by Batrla et al. (1987) of the 12.2 GHz methanol maser line, and the discovery by Menten (1991) of the 6.7 GHz methanol maser, these masers have been studied in great detail. In the first major set of synthesis maps of 6.7 GHz masers published (Norris et al. 1993), 11 out of the 17 maser sources had maser spots distributed along a line, often with a velocity gradient along them. Norris et al. considered the various ways in which such a line might be formed (a jet, a shock front, or an edge-on disk) and concluded that these lines were most probably edge-on circumstellar disks. If this hypothesis is true, then it predicts that (a) the lines should be across a diameter of the star or its surrounding H II region, rather than being radial or tangential, (b) a derived Keplerian mass should correspond to the O,B stars presumed to be energizing these masers, (c) the masers should show proper motions appropriate to Keplerian rotation. In addition, if the large number of edge-on disks is a result of selection effects, then (d) the fraction of lines in a sample of masers should decrease with flux density.

This paper, much of which is based on Chris Phillips' Ph.D. project, is a progress report on the tests of these predictions.

2. Observations

We have taken a sample of 30 methanol maser sources, and studied each of them in detail using a variety of techniques, including VLBI (with the Australian Long Baseline Array at 6.7 and 12.2 GHz), synthesis imaging of the continuum and maser lines (using the Australia Telescope Compact Array), millimetre observations of the dense molecular gas expected in these disks (using the Australia Telescope Mopra Antenna), and infrared observations (using the Anglo-Australian Telescope).

3. Results

In some cases the line of masers bisects the compact H II region as predicted by the edge-on disk hypothesis, although some sources show a more complex structure. In several we have detected compact cores of molecular gas, such as HC3N.

The masers do not, however, show the beautiful Keplerian curve demonstrated by the water megamasers in NGC 4258, as discussed elsewhere in these proceedings, and we attribute this primarily to the higher ratio of turbulent velocity to rotational velocity in these sources.

Of the 43 methanol maser source now studied in detail, 12 are linear (compared to 7 out of 17 for the strongest sources studied by Norris et al. [1993]), two are curved, and the rest are complex or double. 22 of these are associated with a detectable compact H II region.

Of these 22,

- 14 are at the center of H II region, or slightly offset
- 4 are at the edge of H II region
- 4 are offset from the H II region

4. Conclusion

These preliminary results suggest that predictions (a), (b), and (d) of the circumstellar disk hypothesis are generally confirmed, while the proper motion test of prediction (c) is still in progress. These results, while broadly supporting the disk hypothesis, also indicate that, in some sources, additional complexity exists, which we must still understand.

References

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