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VLA Imaging of Class I Methanol Masers at 7 mm with Angular Resolution 0″.2

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Abstract. Eight Class I methanol masers were imaged at 44 GHz with A–configuration of the VLA providing angular resolution 0″.2. The images show a distribution of unresolved maser spots forming pairs in simple structure sources, and a distribution of pair clusters in complex sources. We found that the maser pairs are associated with hot, dense gas cores of sub-stellar masses. In complex sources the cores were found over the whole extent of the host molecular clouds.

1. Introduction

Class I methanol masers are peculiar objects found in star forming regions, but are not connected with compact H II region, OH masers, or IR sources, as is the case for Class II methanol masers. This classification of the methanol masers was introduced by Menten (1991). The Class I methanol masers were never studied with a sufficiently high angular resolution, so that their angular size, structure, and exact position are not known. Here we report on VLA observations of Class I methanol masers in the transition $7_0 - 6_{-1}$ A^+ at 44.069 GHz with angular resolution 0″.2

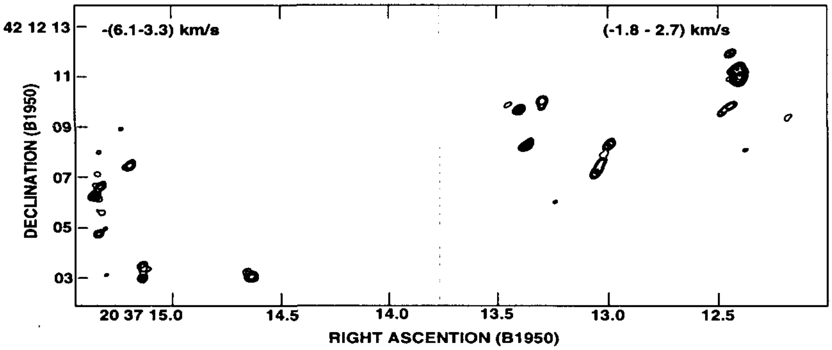

Figure 1. Velocity integrated map of the 44 GHz methanol maser DR21(OH). The two regions (western and eastern) separated by dashed line correspond to the velocity intervals shown at the top. Note that the eastern and western groups of maser spots are plotted with different contour levels. The strongest component at the radial velocity 0.3 km s^{-1} is located at the extreme east side of the eastern ellipse.

2. Observation and Data Reduction

We used inner 10 (and later 13) of the 27 VLA antennas equipped with 7 mm receivers, in both the D– and A–configurations. The synthesized beam was $0''.2$ in A–configuration. The NRAO AIPS package was used for data reduction. The images were produced with the strongest spectral feature taken as a phase reference. Following sources were mapped: OMC 2, NGC 2264, NGC 6334 I(N), M8E, L379, W33 Met, DR21(OH) and DR21 West. As an example we discuss here DR21(OH). This is the most complex source in the sample (Fig. 1). At least 17 components distributed over an area of $45'' \times 12''$ in extent were identified. There are two elliptically shaped regions of maser components. The western region is red shifted by $\approx$5.5 km s^{-1} relative to the eastern region. The two ellipses seem to be formed by small clusters with two or three components in a cluster. The maser component distribution is consistent with the 95 GHz map of Plambeck & Menten (1990) if the difference in angular resolution is taken into account.

The individual maser spots are not resolved by the VLA beam. The lower limit to the brightness temperature is from 2.8×10^5 K for NGC 2264 to 1.6×10^8 K, 1.0×10^8 K, and 4.5×10^7 K for NGC 6334 I(N), L379, and W33, respectively.

3. Discussion

The inferred morphology of Class I methanol masers reveals a hierarchical structure. The sources in one group have narrow spectra and small angular extent corresponding to the linear separation from 0.006 pc to 0.04 pc. If the pairs of components are gravitationally bound, then the linear separation and the velocity difference correspond to a central mass between 0.1 $M_\odot$ and 0.7 $M_\odot$. This range of sub–stellar masses probably refers to the mass of a gas core connected with the maser pairs in each source. The estimate of the gas density inferred from the mass is between 10^5 and 2×10^7 cm^{-3}. One may speculate that Class I methanol masers are connected with dense gas cores formed in the parent molecular cloud.

The methanol masers of the second group with large velocity separation and linear extent from 0.3 pc to 0.7 pc are composed of small clusters similar to the maser of the masers of the first group. The masses associated with the clusters are of the same order, while the mass needed to hold the whole association of maser components is between 500 $M_\odot$ and 2400 $M_\odot$ for different sources, and is typical of the mass of giant molecular clouds. The density estimates inferred for these clouds is between 2×10^5 cm^{-3} and 2×10^6 cm^{-3}.

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References

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