Mapping Class I Methanol Masers in the DR21 Region

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Introduction

Masers are used in astronomy as probes for conditions in interstellar clouds. They can be used to study temperatures, densities, magnetic fields, and outflows. Methanol masers are divided into two groups: Class I and Class II. Class I masers are usually found in massive star forming regions, and are believed to be formed by collisional pumping due to shocks. The two Class I maser transitions (36 and 95 GHz) have been used in these studies.

Observations

Using the Sapejuk Very Large Array (SVLRA) in Searcys, NM, we observed the 36 1H13CO+ GHz 3 – 3, 3-2, 2-1 transition line of methanol masers in three areas of the massive star forming region DR21. The three areas observed were DR21OH, DR21N, and DR21W. Data were taken with the SVLRA in D configuration. Over the data was cleaned and processed using AIPS, each maser detection was examined and fitted with Gaussian parameters across the bandwidth. The masers spots were plotted on velocity maps against known masers in other regions of our galaxy.

DR21OH

This source had no interstellar maps of other transitions in which our data could be compared, through Prane v 2008 paper indicates a strong methanol emission line in the 44GHz transition. The pattern here shows no clear organization. The spots on the eastern side is a large cluster of low-intensity (0.15-1.02 Jy) blue-shifted masers, while the western spots is a rough line of brighter, redshifted masers (not dotted line). There is also a single very bright, blue-shifted maser just north of this line. Similar to the low-intensity masers, these spots also show extended emission. Several of these spots are within a region of high column density, which is most likely an indication of multiple maser sources that cannot be resolved with the observations.

DR21N

Our 36 GHz detections are plotted against 44 GHz detections (Bourke and Pratap, in preparation). Notice the double or triple structure present in each transition overlaid on a figure. The “spikes” are most likely tracing an outflow and the source is probably a young massive stellar object near the center. The arc-like patterns suggest bow-shock origins.

Zeeman Splitting and Evidence for a Different Pumping Mechanism

Zeeman splitting is used to detect the magnetic field within a region, Sarma and Menten (1990) detected the Zeeman for 36 GHz masers in 2005. Following these methods, we also made use of the effect to report a magnetic field in one of our sources. The magnetic field measurement is obtained by examining the Stokes V spectrum as a function of Stokes I, where

\[ V = q - p \]

The value of the offset, \( q \) minus the scaled offset, is plotted as a histogram against the best fit of the scaled derivatives of Stokes I. A line-of-sight magnetic field can be obtained with the fit parameter \( b \) via the equation

\[ b = \frac{2.15 \times 10^{-20} \times V}{I} \]

where \( z \) is the Zeeman splitting factor and \( I \) is the line of sight magnetic field. Using the same values for \( z \) as Sarma and Menten (1.7 Hz G), we detected a magnetic field of 28.09 ± 22.23 G, which is a 2.3 times stronger than that detected by Sarma and Menten. Because a region’s density is roughly proportional to the square of its magnetic field, this measurement lowers the lower density limit from \( 10^4 \) cm\(^{-3} \) (Crutcher, 1999).

Class I masers are expected to be found in regions of up to \( 10^6 \) cm\(^{-3} \).

Pumping Mechanisms

The currently accepted mechanism for Class I masers excitation is collisional pumping followed by radiative decay. When the molecules are collisionally excited, they spontaneously decay into an intermediate energy state. This creates the population inversion. However, this is enough to occur in regions of lower density than our data for DR21W.

An alternative to collisional pumping is collision-collision pumping, as proposed by Strelnitski (1993). In this pumping scheme, species with two different temperatures collide with the cooler species causes the excitation, and collisions with the cooler species would cause the energy sink back to the intermediate level, creating a population inverting. This scheme has no density limits, and could be right for this mechanism within outflows, where Class I masers are generally found.

Remarks

In several places, the 36 GHz masers align with masers detected in other transitions. In DR21W, the masers in all transitions follow the same outflow pattern with similar velocities. However, 44 GHz masers also appear scattered in the north and south while the 36 GHz masers appear to the south. The differences in conditions required for different maser transitions is still under investigation.

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