The Zeeman Effect in the 44 GHz Class I Methanol Maser Line toward DR21W

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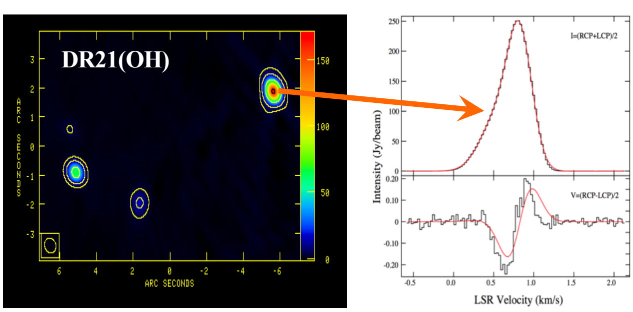
Abstract

As part of our long term effort to measure magnetic fields in star forming regions, we report the detection of the Zeeman effect in the 44 GHz Class I methanol maser line toward the star forming region DR21W. The 44 GHz methanol masers in this source occur in a ~3″ linear structure that runs from northwest to southeast, with two dominant maser spots at each end. Toward the maser at the northwestern end, we find a significant Zeeman detection of −23.4 ± 3.2 Hz. If we use the Zeeman splitting factor of z = −0.92 Hz/mG from Lankhaar et al. (2018), then this yields a line-of-sight magnetic field of 25 mG. Such fields of tens of milligauss are consistent with Class I methanol masers occurring in high density regions with n ~$10^{7\text{-}8}$ cm^{-3}. We also give a brief overview of past Zeeman effect detections in 44 GHz Class I methanol masers (e.g., Sarma & Momjian 2011; Momjian & Sarma 2017) in light of the recently measured Zeeman splitting factors.

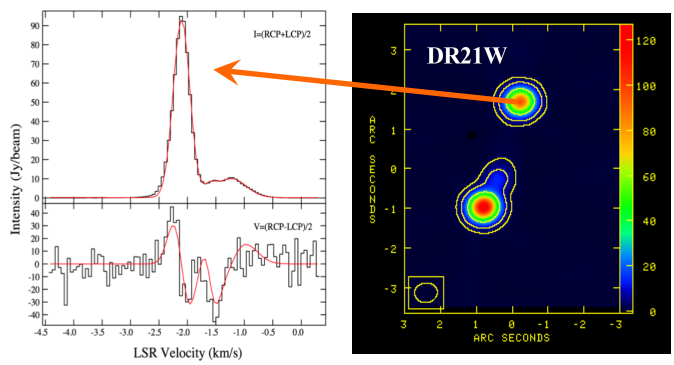
Introduction

- High mass stars form in densely populated environments. Masers, being intense point sources, allow us to study high mass star forming regions at high spatial resolution.
- Class I methanol masers usually form in outflows where collisional shocks not only create enhanced methanol abundances, but also pump the Class I maser transitions.
- Magnetic fields likely play an important role in the star formation process, but the exact nature of their role is still not understood, primarily due to the scarcity of observational data.
- We are engaged in a long-term effort to measure magnetic fields in star forming regions. Part of this effort involves the detection of the Zeeman effect in Class I methanol maser transitions such as the 44 GHz line. The Zeeman effect remains the most direct method for measuring magnetic fields in star forming regions.



Observations and Analysis

- We observed the 44 GHz Class I methanol maser line with the Karl G. Jansky Very Large Array in dual polarization mode.
- The Zeeman effect is usually measured by fitting the Stokes V profile to the derivative of the Stokes I profile, with the fit parameter equal to zB_{los}, where z is the Zeeman splitting factor and B_{los} is the line-of-sight magnetic field. We have benefited immensely from the new tasks XGAUS and ZEMAN in AIPS which allow for the simultaneous fitting of multiple maser components with different magnetic field values.



Results and Discussion

- The 44 GHz Class I methanol masers toward DR21W occur in a ~3″ linear structure running northwest to southeast (right panel above). Our detection of a significant Zeeman effect is in the maser at the northwestern end of this linear structure toward which we have found that zB_{los} = −23.4 ± 3.2 Hz.
- If we use z = −0.920 Hz/mG from Lankhaar et al. (2018), then our detection in DR21W gives a line-of-sight magnetic field B_{los} = 25 mG.
- Fields on the order of tens of mG are expected in regions hosting Class I masers, where the particle density is ~$10^{7\text{-}8}$ cm^{-3}. Thus, using z = −0.920 Hz/mG, the detected B_{los} toward OMC-2 from Sarma & Momjian (2011) would be 20 mG, and that for DR21(OH) from Momjian & Sarma (2017) would be 58 mG (left panel).
- If the magnetic field in shocked regions is amplified in proportion to the gas density, then our detected value of 25 mG in DR21W suggests that the magnetic field in the pre-shocked gas should be 0.1-0.8 mG. Although there are no direct measurements in the pre-shocked gas in DR21W, Falgarone et al. (2008) measured fields of 0.36 and 0.71 mG about 3.5′ away via the Zeeman effect in thermal lines of CN.
- Our detected field in DR21W indicates that the magnetic energy density in these shocked regions is of the same order as the kinetic energy density, implying that the magnetic field is important to the dynamics of this region. In the future, we plan to make many more measurements to amass a larger collection of magnetic field values in diverse environments.