Periodic Radio Emission from the M7 Dwarf 2MASS J13142039+1320011: Implications for the Magnetic Field Topology

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We present multi-epoch radio and optical observations of the M7 dwarf 2MASS J13142039+1320011. We detect a ~1 mJy source at 1.43, 4.86, 8.46 and 22.5 GHz, making it the most luminous radio emission over the widest frequency range detected from an ultracool dwarf to date. A 10 hr VLA observation reveals that the radio emission varies sinusoidally with a period of 3.89+/-0.05 hr, and an amplitude of ~30% at 4.86 GHz and ~20% at 8.46 GHz. The periodicity is also seen in circular polarization, where at 4.86 GHz the polarization reverses helicity from left- to right-handed in phase with the total intensity. An archival detection in the FIRST survey indicates that the radio emission has been stable for at least a decade. We also detect periodic photometric variability in several optical filters with a period of 3.79 hr, and measure a rotation velocity of vsini=45+/-5 km/s, in good agreement with the radio and optical periods. The period and rotation velocity allow us to place a lower limit on the radius of the source of >0.12 R_sun, about 30% larger than theoretical expectations. The properties of the radio emission can be explained with a simple model of a magnetic dipole mis-aligned relative to the stellar rotation axis, with the sinusoidal variations and helicity reversal due to the rotation of the magnetic poles relative to our line of sight. The long-term stability of the radio emission indicates that the magnetic field (and hence the dynamo) is stable on a much longer timescale than the convective turn-over time of ~0.2 yr. If the radio emission is due to the electron cyclotron maser process, the inferred magnetic field strength reaches at least 8 kG.

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