THE ARECIBO SEARCH FOR RADIO FLARES FROM THE COOLEST BROWN DWARFS

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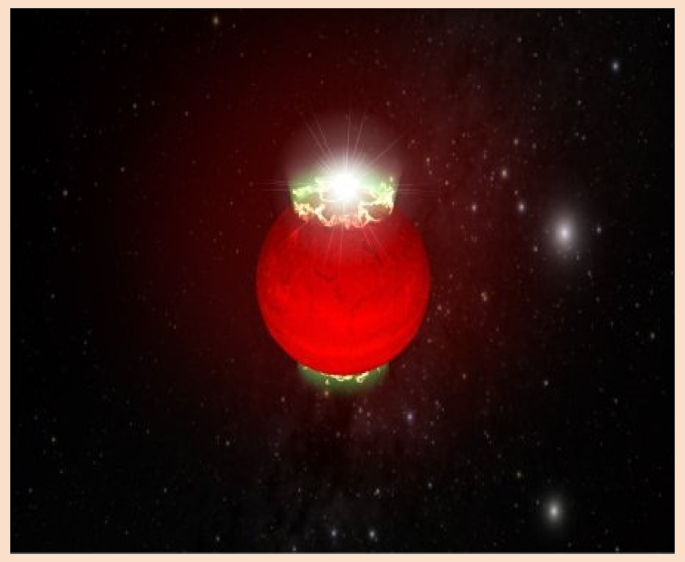
Abstract

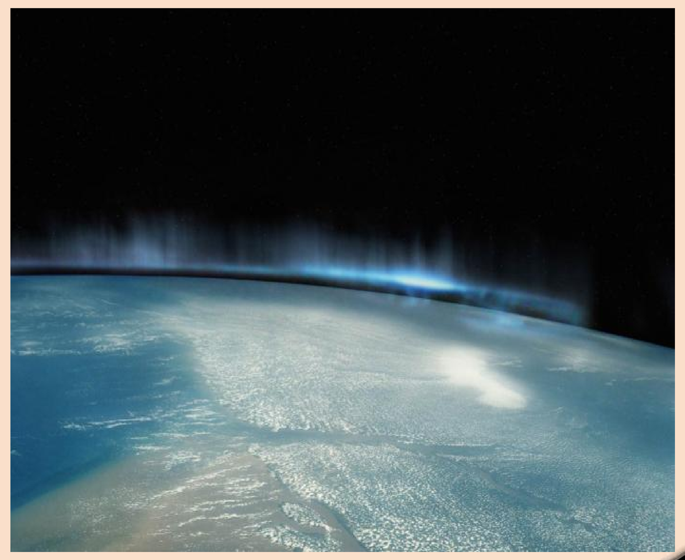
We present the results of a survey of 34 brown dwarfs for flaring radio emission, conducted with the 305-m Arecibo radio telescope at a center frequency of 4.75 GHz using the broadband, fast-sampled Mock spectrometer. We launched this search to study the magnetic field properties of objects cooler than spectral type L3.5, the coolest brown dwarf detected prior to our survey. In addition, we attempted to detect flaring radio emission from the young exoplanetary system HR 8799, guided by the theoretical work indicating that hot, massive exoplanets may have strong magnetic fields capable of generating radio emission at GHz frequencies. Such a detection would provide an exciting alternative to the unsuccessful low radio frequency searches for the emission from exoplanets orbiting middle-aged, solar type stars.

During the course of this survey, we have identified two new radio-flaring ultracool dwarfs: the L1 dwarf J1439+19 and the T6.5 dwarf J1047+21 (Route & Wolszczan 2012). Our detection of J1047+21 dramatically extends the temperature range over which brown dwarfs appear to be at least sporadic radio-emitters, from ~1900 K (L3.5) down to ~900 K (T6.5). This discovery suggests that the magnetic fields of a number of ultracool dwarfs, and plausibly, hot, massive exoplanets may be studied in this fashion, although the detection of radio emission from exoplanets still remains elusive.

Motivation

- Objects beyond spectral type M7 (ultracool dwarfs) are believed to be fully convective and exhibit steadily declining magnetic activity, evidenced by little or no observable emission of Hα and X-rays
- However, a handful of sources have been found to be strong bursting emitters of nonthermal radio emission that indicates the presence of kilo-Gauss strength magnetic fields.
- Two emission mechanisms have been suggested to account for this radio emission: gyrosynchrotron radiation and the electron cyclotron maser instability (ECMI).
- Prior to this search, no object cooler than spectral type L3.5 was shown to flare in the radio.
- But in the Solar System, the Earth (AKR), Jupiter, and Saturn (SKR) all emit radio waves via the ECMI mechanism. This radio emission is related to aurorae in the planetary ionospheres.
- The Sun and other stars emit a number of types of radiation in the radio, some of which are bursts analogous to those observed in the planets.
- Our goal is to detect radio emission from ultracool dwarfs in general, with the anticipation of detecting emission from sources colder than L3.5, and so bridge the gap in our understanding of the magnetism of objects between M7 dwarfs, Solar System planets, and exoplanets.





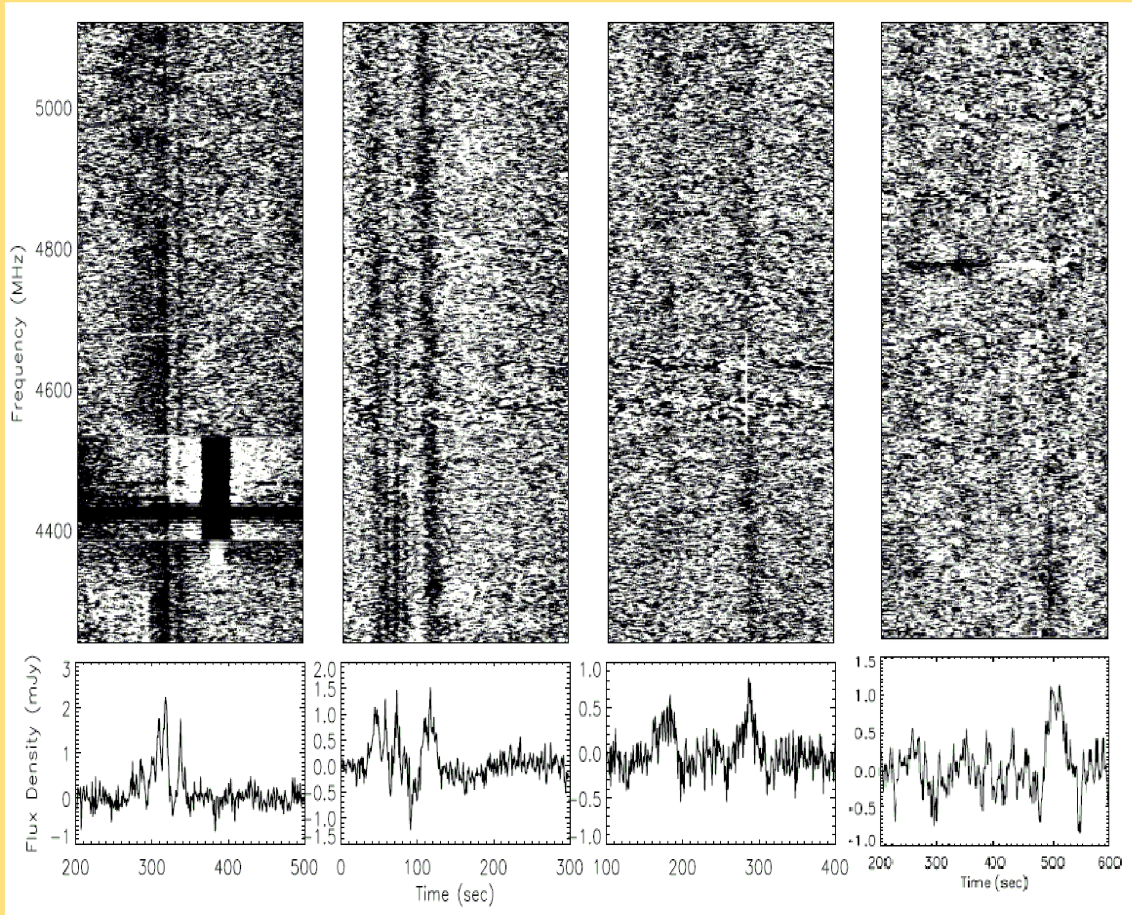
Observations

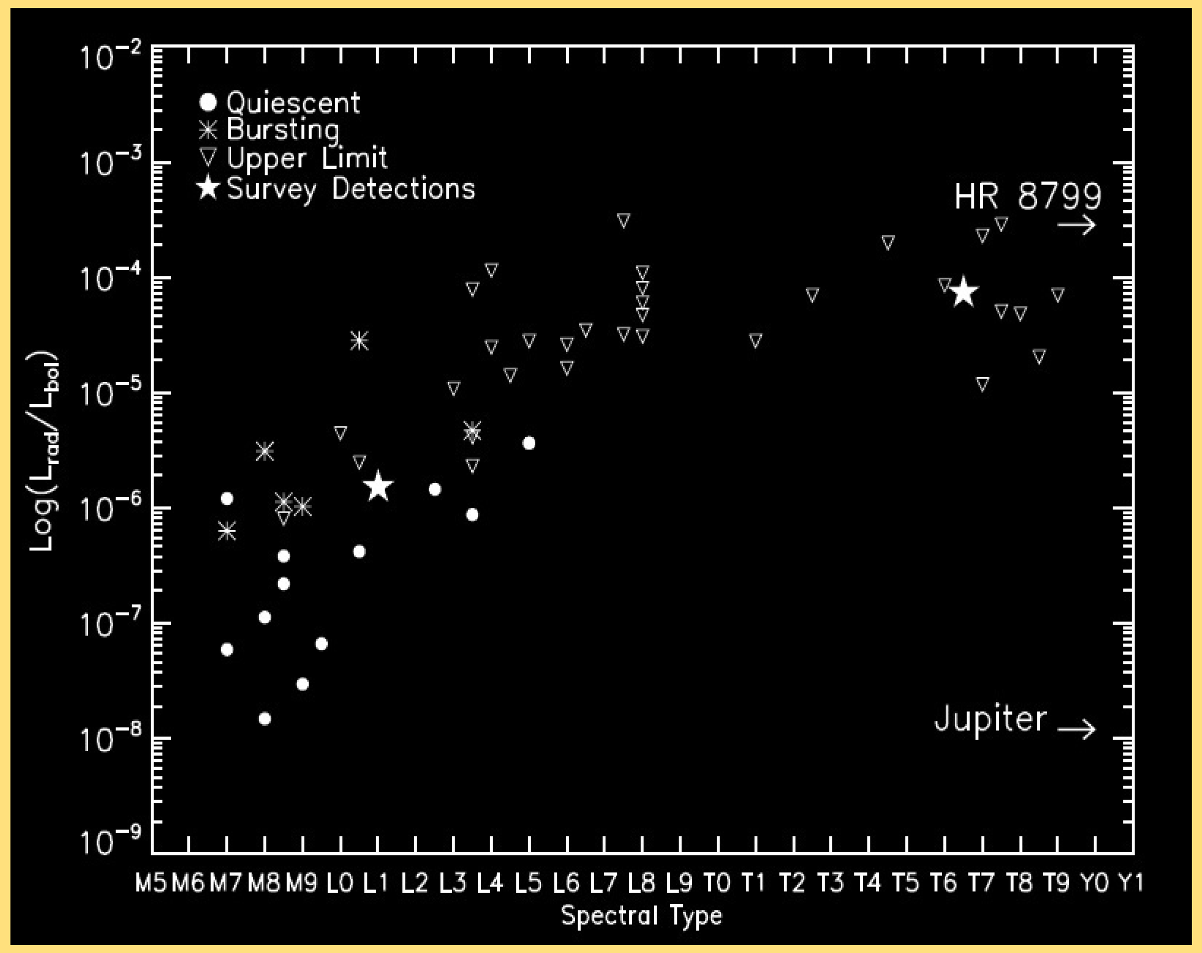
All observations were conducted with the 305-m Arecibo Radio Telescope, using the C-band receiver centered at 4.75 GHz and the Mock FFT spectrometer. This spectrometer offers a 1.1 GHz bandpass and the simultaneous determination of all four Stokes parameters, with 21 kHz frequency resolution and 0.1 s time resolution.

As Arecibo is a fixed-dish system, our targets were restricted to having declinations 0 to +38 degrees. We also desired targets that were located < 50 pc from Earth, and later spectral types were preferred to earlier ones. Additionally, we searched for bursting radio emission from the HR 8799 system, as theoretical work by Reiners & Christensen (2010) indicated that these hot, young, massive planets may possess kG strength magnetic fields.

Results

This survey detected two new radio flaring sources, the T6.5 dwarf J1047+21 (Route & Wolszczan 2012) and the L1 dwarf J1439+19. J1047+21 has a temperature of ~900K and is located at a distance of 10.3 pc (Vrba et al. 2004). Detected flares were measured on three separate occasions (left three panels), with the first two showing high brightness temperature (>10^{10} K), highly circularly polarized (>70%) bursts, with the third burst being weaker. J1439+19 has a distance of 14.4 pc and a temperature of ~2270 K (Dahn et al. 2002). Its single detected flare has a polarization fraction >90% and a high brightness temperature of 2x10^{10} K. Both sources have magnetic field strengths of ~ 1.5 kG. The characteristics of the flares observed for these two sources are consistent with the electron cyclotron maser instability being the emission mechanism.





No other burst events are discovered, not even from HR 8799. The detection limits determined for all sources are reported in the table below and summarized in the graph (above right).

Object	Spectral Type	Distance (pc)	4466 MHz 3σ (mJy)	Bolometric Luminosity (log solar units)	Luminosity (log solar units)	Luminosity (log Jovian radio units)	Log Radio Lum/Bol Lum.
J00325937+1410371	L8	33.18	1.101	-4.55	-8.773	6.656	-4.223
J0036159+182110	L3.5	8.76	1.179	-4.51	-9.900	6.791	-5.390
J0039191+211516	T7.5	11.11	1.14	-5.41	-9.708	6.759	-4.298
J01514155+1244300	T1	21.4	1.262	-4.54	-9.094	6.747	-4.554
J02074284+0000564	T4.5	28.69	3.135	-4.74	-8.445	7.078	-3.705
J0326137+295015	L3.5	32.26	1.293	-4.62	-8.727	6.722	-4.107
J03284265+2302051	L8	30.18	1.044	-4.55	-8.878	6.644	-4.328
J03454316+2540233	L0	26.95	1.206	-3.56	-8.914	6.710	-5.354
J07003664+3157266	L3.5	12.2	1.455	-3.88	-9.521	6.848	-5.641
J07271824+1710012	T8	9.08	1.101	-5.58	-9.898	6.761	-4.318
J07464256+2000321	L0.5	12.21	1.392	-3.93	-9.539	6.831	-5.609
J08251958+2115521	L7.5	10.66	1.242	-5.21	-9.707	6.797	-4.497
J0850359+105716	L6	25.58	1.302	-4.34	-8.926	6.744	-4.586
J085911+101017	T7	26.36	1.29	-5.26	-8.904	6.738	-3.644
J09121469+1459396	L8	20.48	1.473	-4.55	-9.065	6.811	-4.515
J09373487+2931409	T7	6.14	1.227	-5.26	-10.191	6.834	-4.931
J10475385+2124234	T6.5	10.56	1.218	-5.35	-9.723	6.790	-4.373
J11122567+3548131	L4.5	21.72	1.473	-4.16	-9.014	6.806	-4.854
J11463449+223053	L3	27.17	1.146	-3.96	-8.929	6.689	-4.969
J115739+092201	T2.5	29	1.674	-4.55	-8.708	6.832	-4.158
J1238285+095351	T8.5	20	1.026	-5.58	-9.243	6.671	-3.663
J131508+082627	T7.5	23.4	1.464	-5.41	-8.952	6.798	-3.542
J1328550+211449	L5	32.26	1.158	-4.22	-8.775	6.679	-4.555
J133553+113005	T9	10.3	1.242	-5.58	-9.737	6.799	-4.157
J14243909+0917104	L4	31.55	1.617	-4.04	-8.650	6.811	-4.610
J1439284+192915	L1	14.37	1.257	-3.67	-9.442	6.778	-5.772
J144601+0024519	L6	22	1.098	-4.34	-9.131	6.690	-4.791
J15232263+3014562	L8	18.62	1.211	-5.27	-9.233	6.742	-3.963
J16241436+0029158	T6	11	3.474	-5.16	-9.233	7.200	-4.073
J16322911+1904407	L8	15.24	1.217	-5.31	-9.405	6.760	-4.095
J1711457+223204	L6.5	30.2	1.109	-4.39	-8.851	6.667	-4.461
J1841086+311727	L4	42.43	3.696	-4.09	-8.033	7.106	-3.943
J21011544+1756586	L7.5	47	3.172	-4.5	-8.011	7.037	-3.511
HR 8799	7, 10, 10 M_J	39.4	1.044	-5.1	-8.647	6.621	-3.547
TVLM-513	M8.5	10.5	1.347	-3.59	-9.685	6.830	-6.095

Monte Carlo simulations based on our results and those from other surveys suggest that the ultracool dwarf radio-flaring population is significantly larger than observed, with the main obstacle to discovering new sources being restrictions on observing time, which reduce chances to detect sporadic events.

M.R. acknowledges support from the Center for Exoplanets and Habitable Worlds, the Zaccheus Daniel Fellowship, and the Soffen Memorial Fund Travel Grant. The Center for Exoplanets and Habitable Worlds is supported by the Pennsylvania State University, and the Eberly College of Science.

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Image Credits

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Earth's aurora: NASA ISS
Arecibo Observatory at dusk: Cornell University