

Searching for flaring ultracool dwarfs with the MWA

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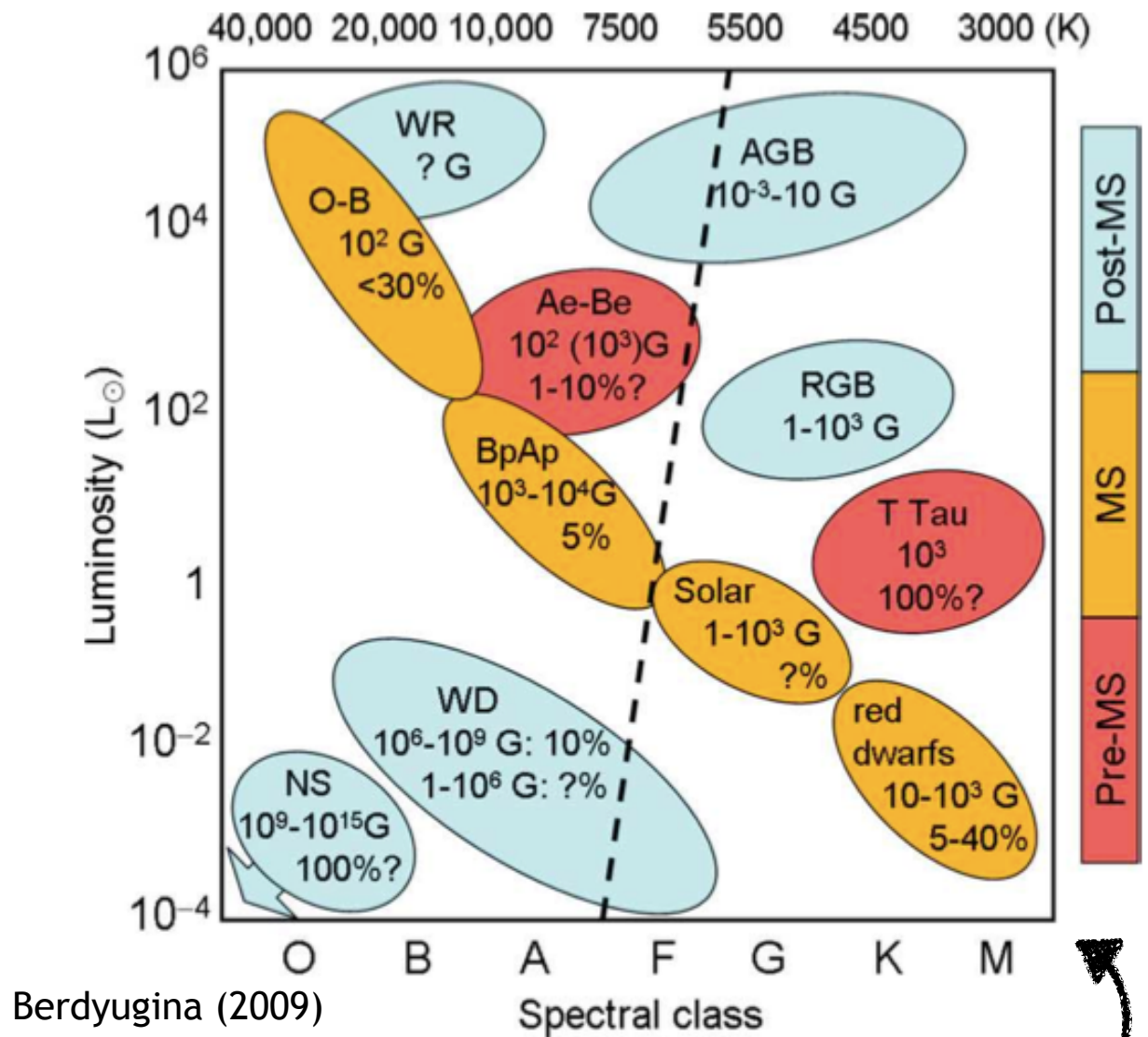




Stellar magnetic fields are ubiquitous:

- ➔ Magnetic fields are found throughout the Hertzsprung-Russell diagram.
- ➔ Fields thought to play important roles in evolution.

Ultracool Dwarfs (UCDs) = the lowest mass stars and brown dwarfs



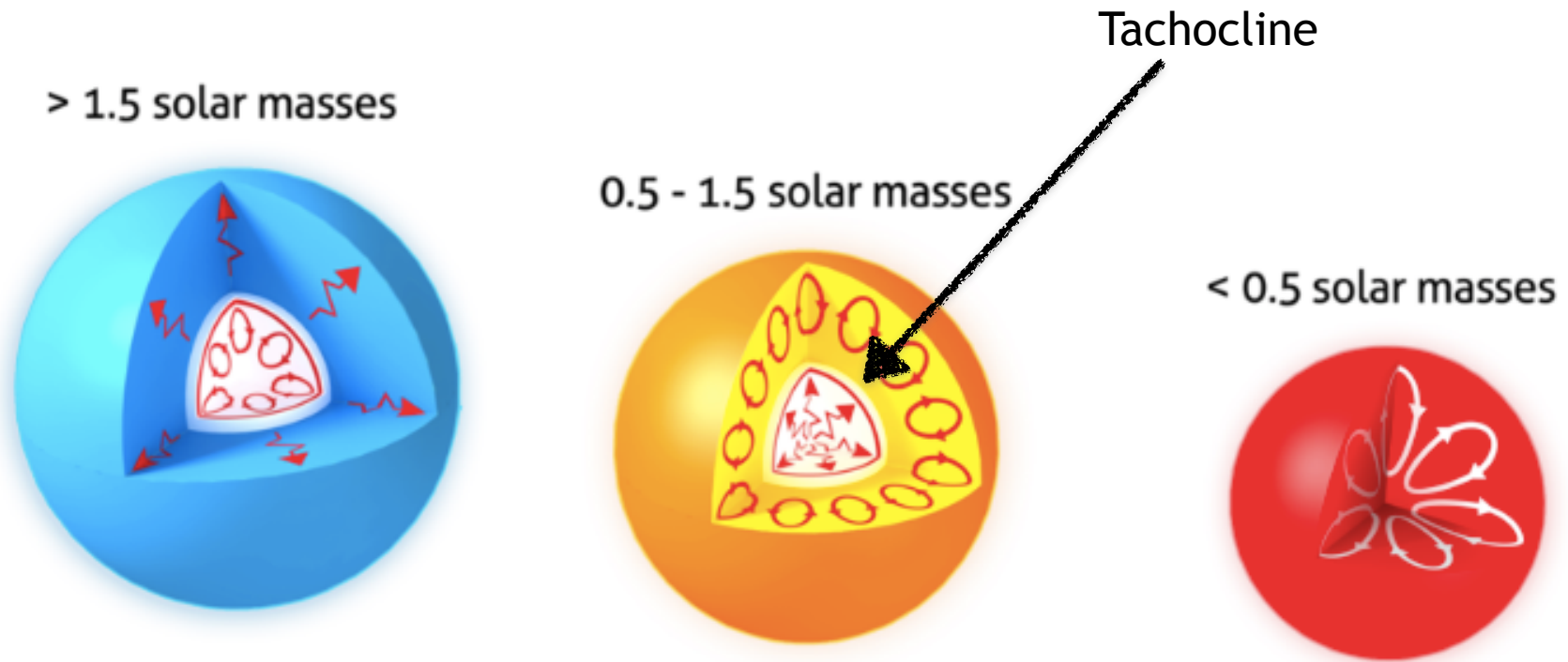
UCDs > M7



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UCDs are fully convective:

Note: Solar dynamo depends crucially on the “tachocline” interface layer between the radiative and convective zones.



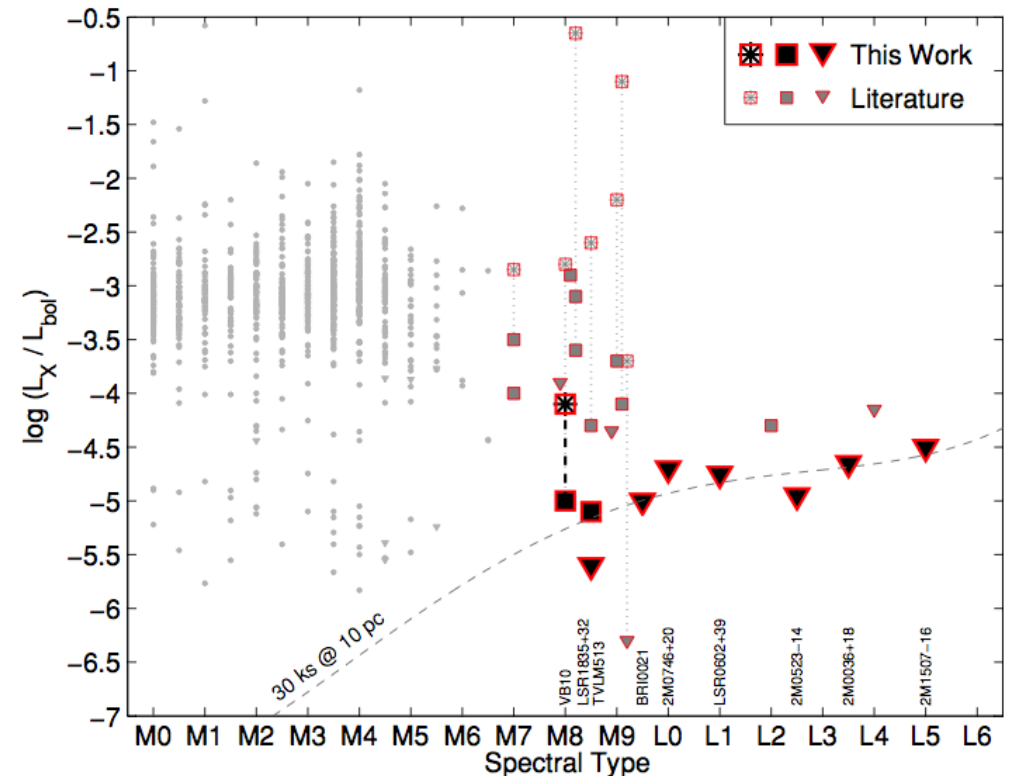
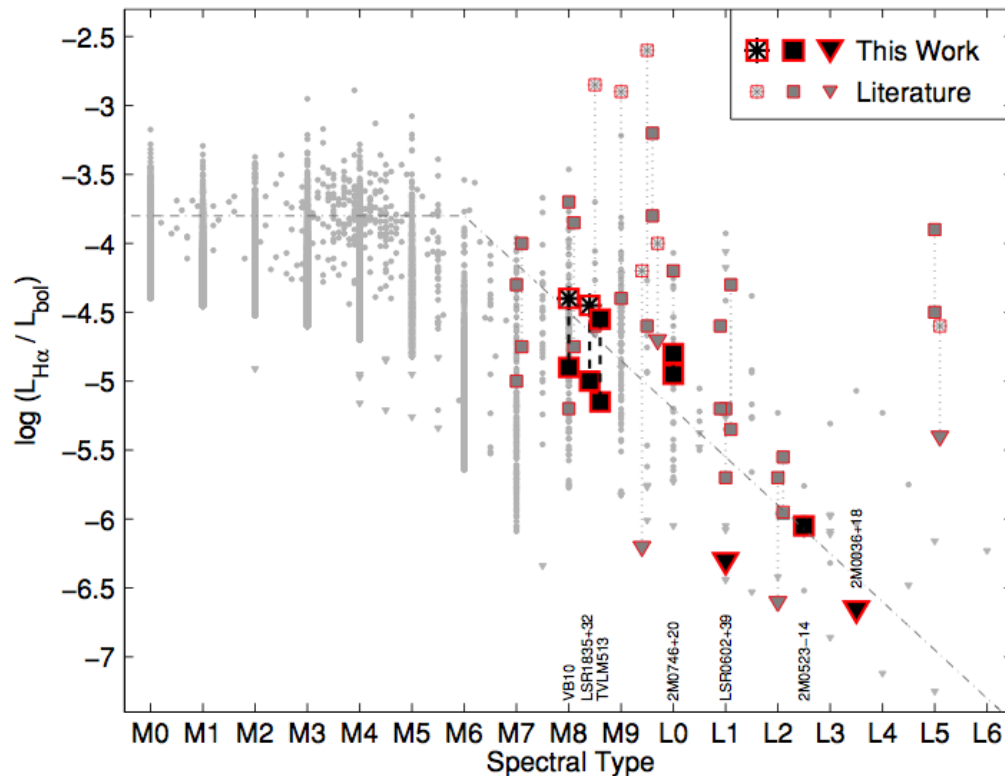
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UCD fields challenge solar dynamo theories!

Optical & X-ray show a drop in activity past type M7:

➡ Associated with decrease in plasma heating

Berger et al. 2010

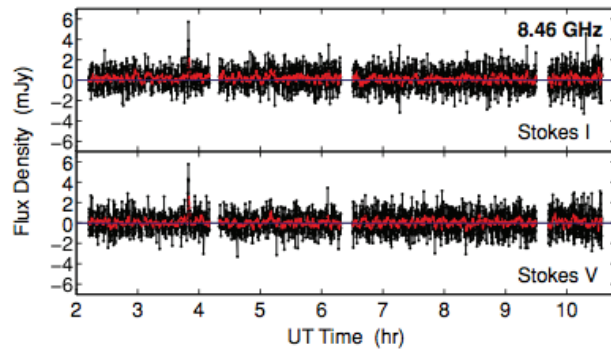


➡ Does not imply a drop in magnetic activity.

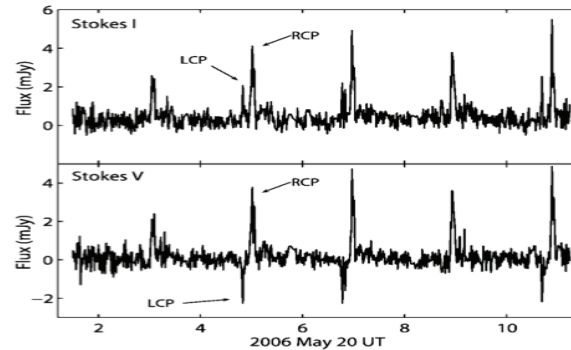


Radio Emission Characteristics:

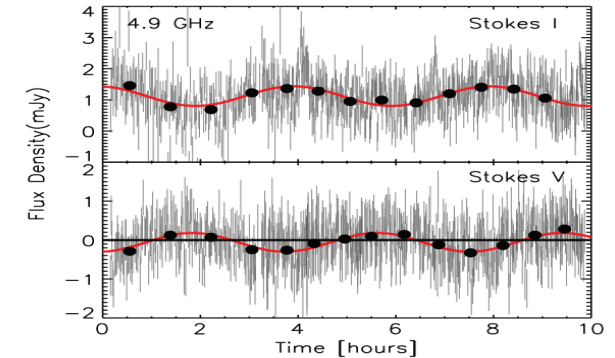
(A) 2M J0746+20 (Berger et al. 2009)



(B) TVLM 513-46 (Hallinan et al. 2008)



(C) J1314+1320 (McLean et al. 2011)



Three types of emission:

1. Quiescent emission showing no variability
2. Periodic emission on same timescales as rotation period
3. Isolated radio flares



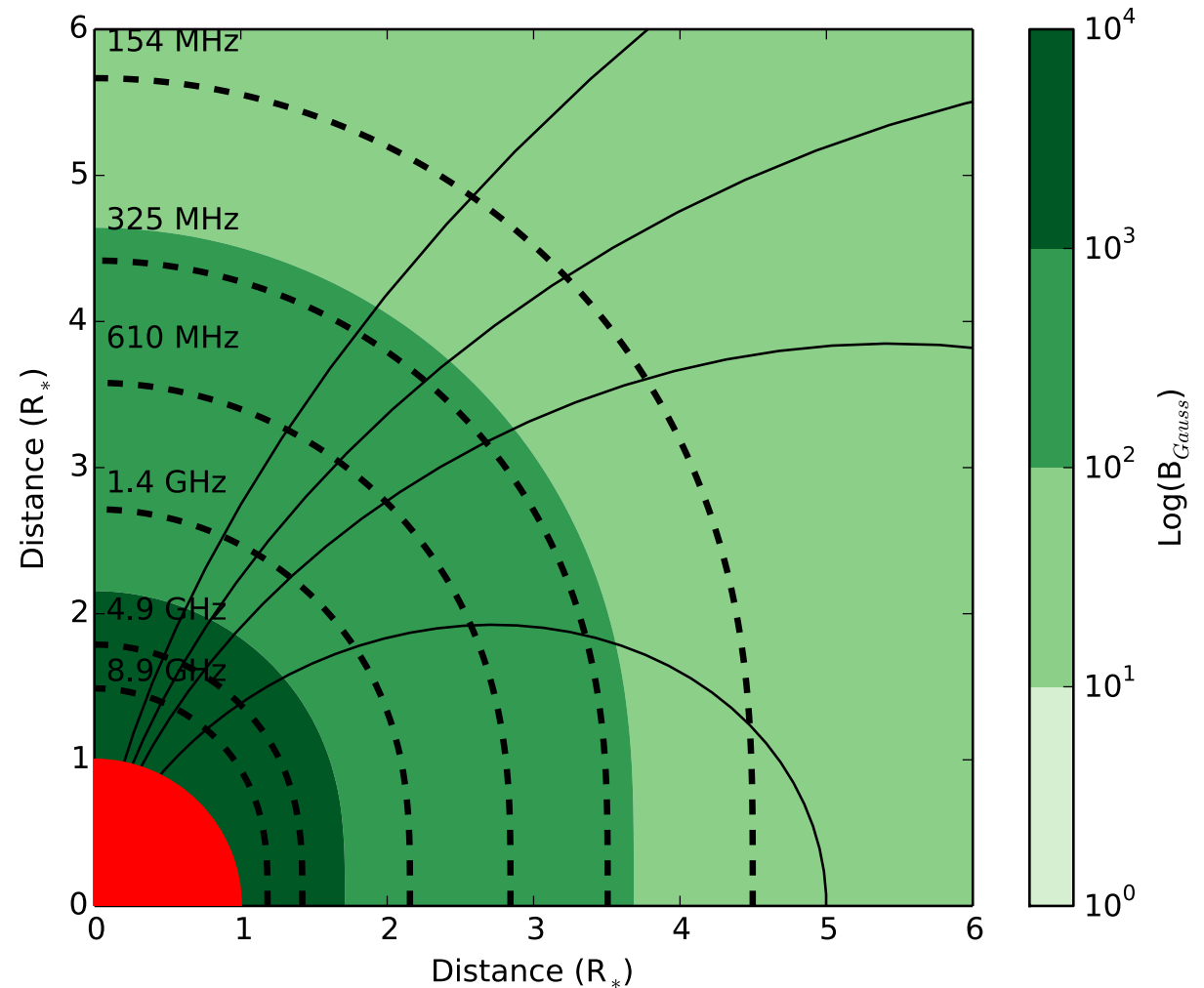
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Source of UCD Radio Emission:

Bright, circularly polarised,
short duration bursts strongly
indicate electron cyclotron
maser emission:

$$\nu_{\text{gyro}} = (B) \text{ 2.8 MHz}$$

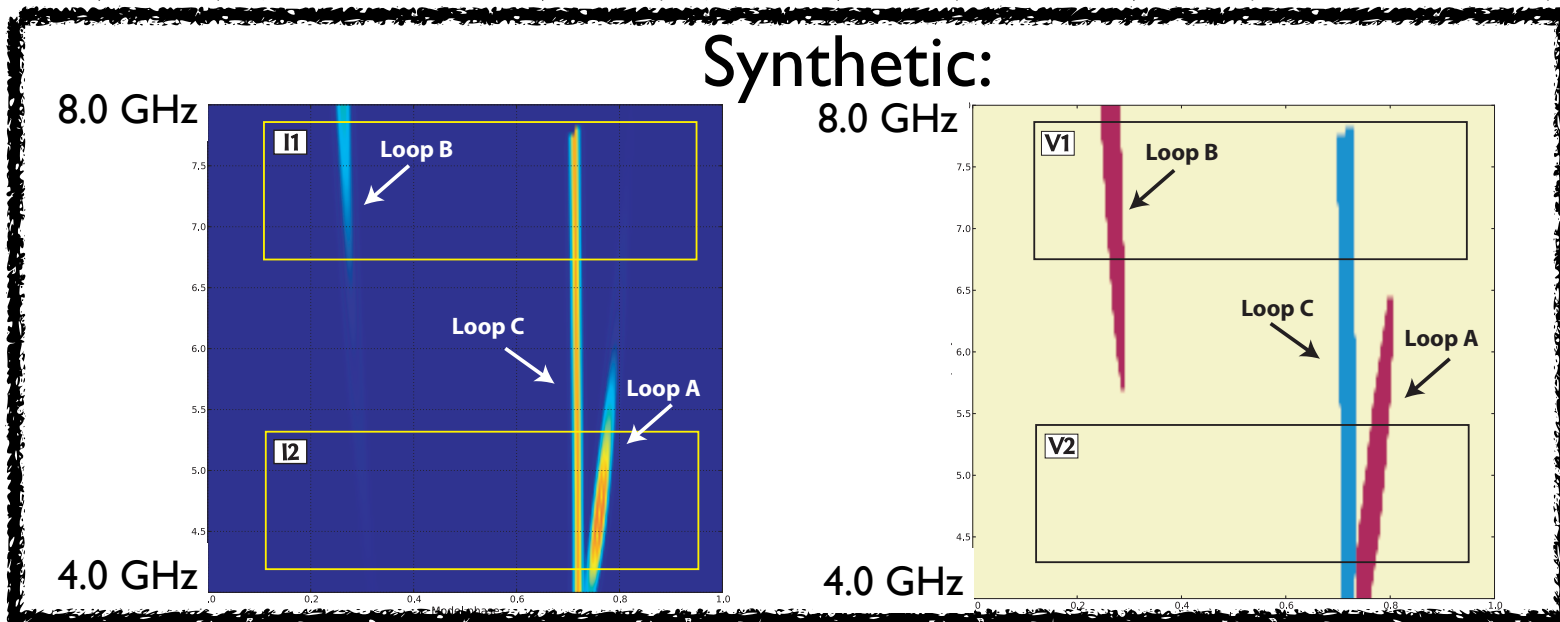
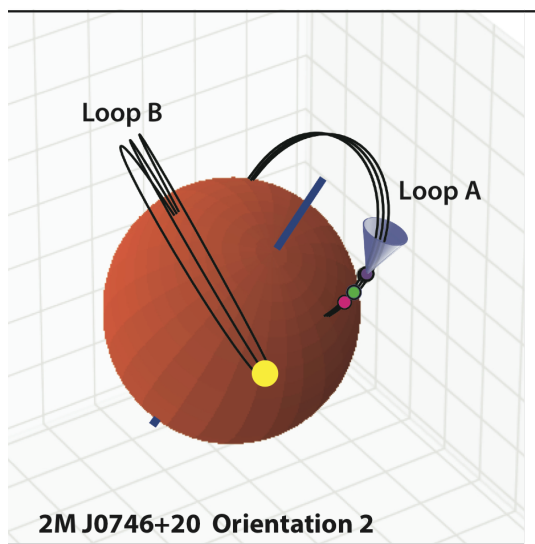
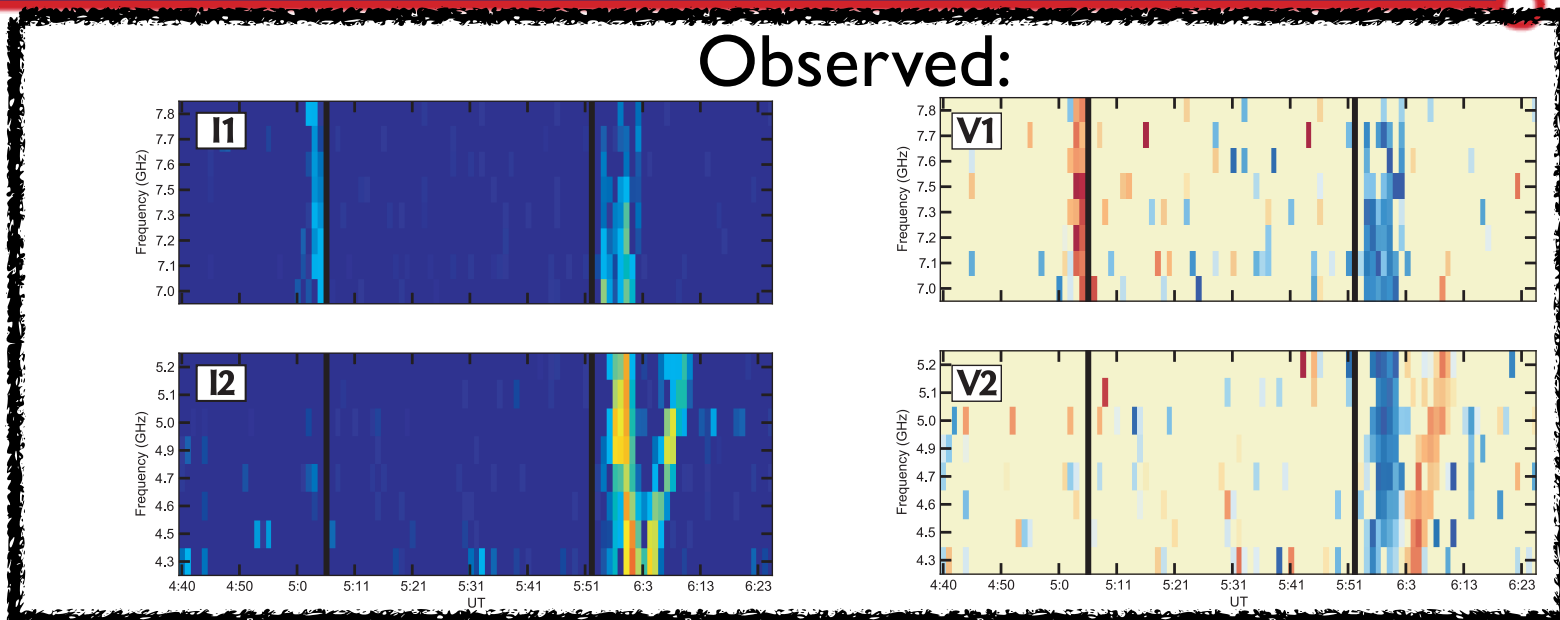
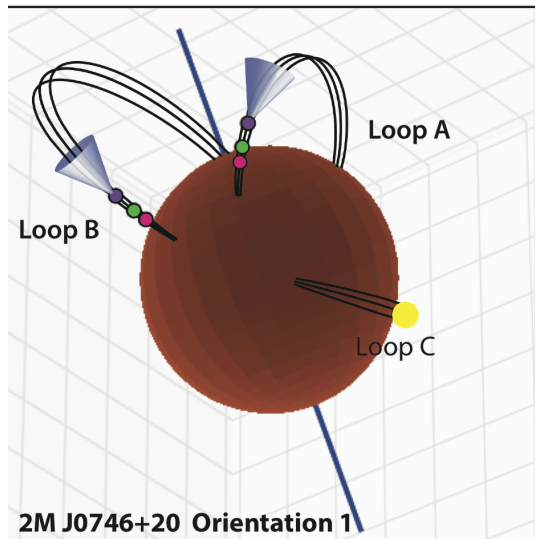
Beaming + Gyrofrequency
mapping leads to
geometrical constraints on
source region.





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UCD Field Orientation:





- Previous targeted Surveys @ 4 GHz and 8 GHz
 - ➡ Using VLA, Arecibo, ATCA
 - ➡ ~ 7% detection rate; currently 17 known radio loud sources
- Widefield, low-frequency surveys:
 - ➡ Objects with weaker fields (10-100 Gauss) emit in Murchison Widefield Array (MWA) frequency range (80-300 MHz)



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Sampling Outer Magnetosphere:

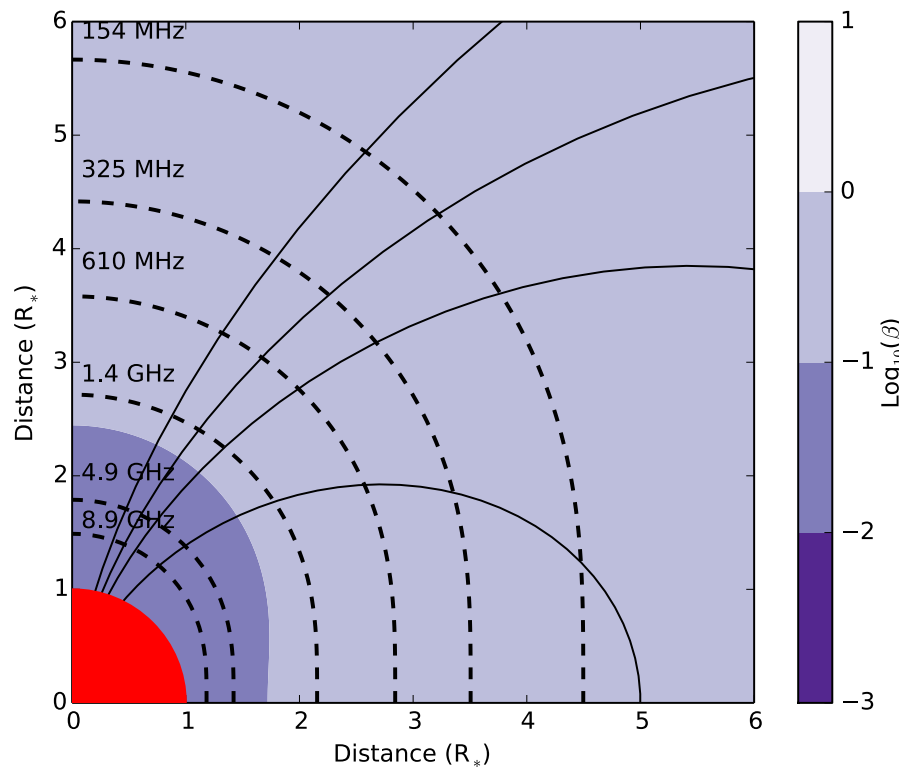
Sources with known radio emission @ 4 GHz and 8 GHz:

➡ Further constrain source plasma conditions:

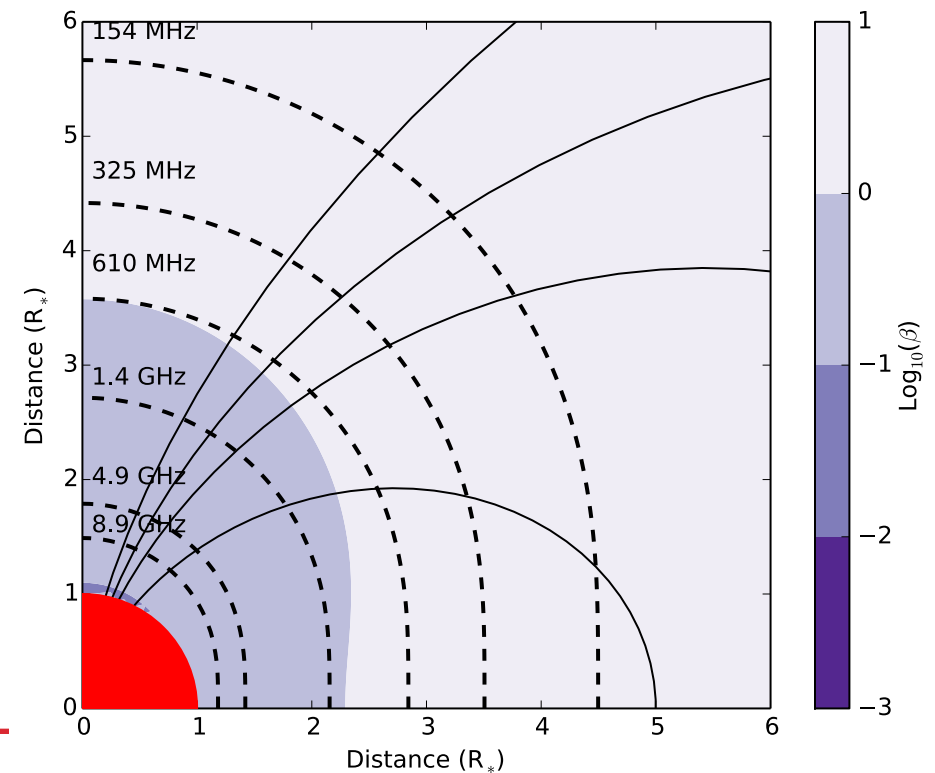
$$\beta = v_{pe}/v_{gyro}$$

$$\beta = (9 \text{ kHz } (n_e)^{1/2}) / (2.8 \text{ MHz } B) < 1$$

$B_0 = 5 \text{ kG}, N_0 = 1.e9 \text{ cm}^{-3}$



$B_0 = 5 \text{ kG}, N_0 = 1.e10 \text{ cm}^{-3}$





UCD Search Setup:

- MWA Transient Survey dataset (MWATS; PI M. Bell)
 - ➡ 154 MHz observations 1 night each month for 1 year (2013-2014)
 - ➡ 2 min snapshots at declinations: $\delta = +1.6^\circ, -26.7^\circ, -55^\circ$
 - ➡ Snapshots stacked for each sources
- Catalog of 418 sources with spectral type $> M7$
 - ➡ Nearby sources (< 20 pc)
 - ➡ 193 with radio limits at 5GHz

No detections in snapshots or mosaics

MWA Stokes I Comparison for Radio Loud UCDs:

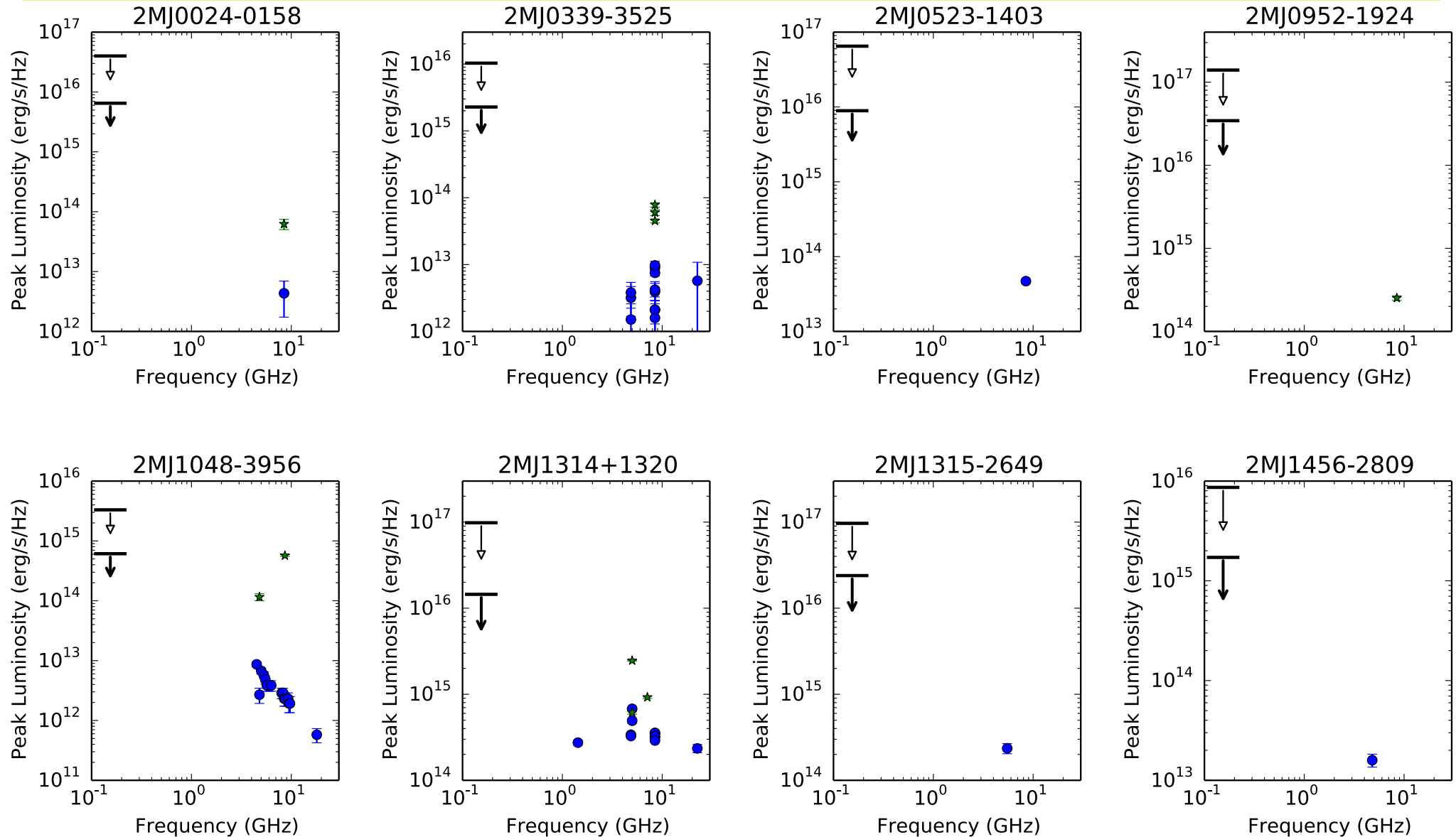
➡ MWA Stack

➡ MWA Snapshot

● Literature Quiescent



★ Literature Flare



MWA Stokes V Comparison for Radio Loud UCDs:



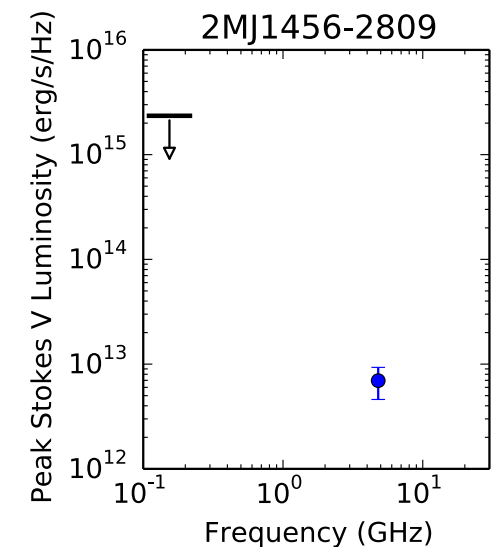
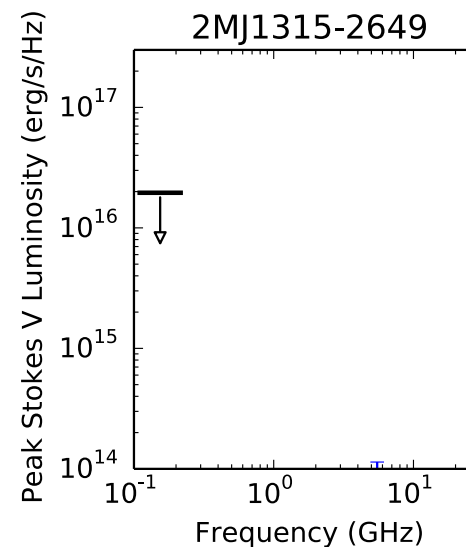
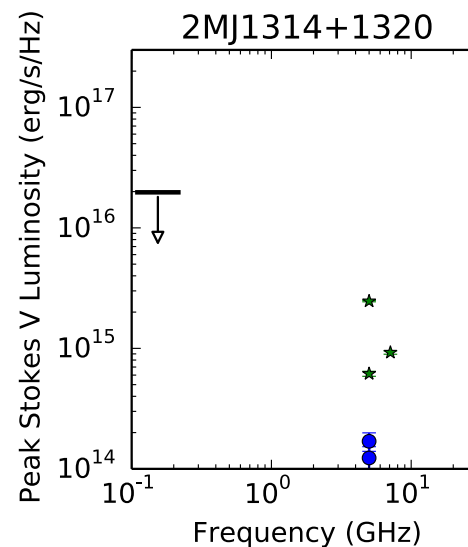
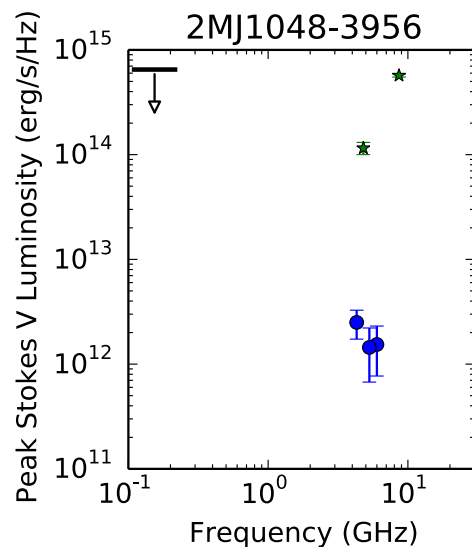
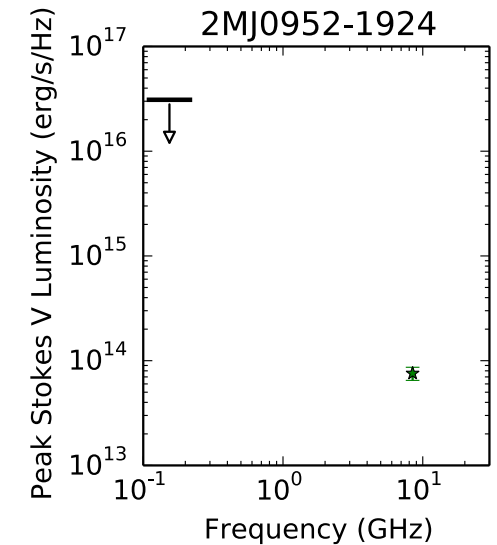
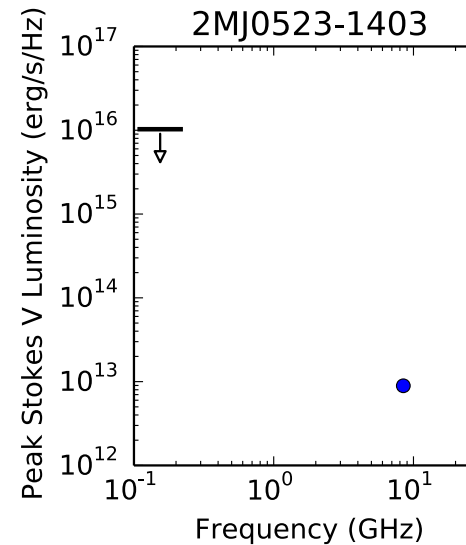
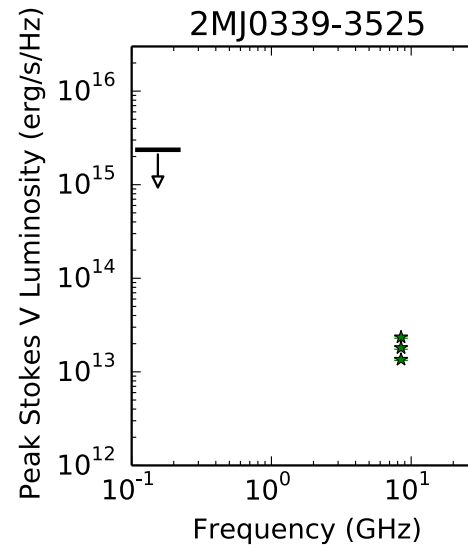
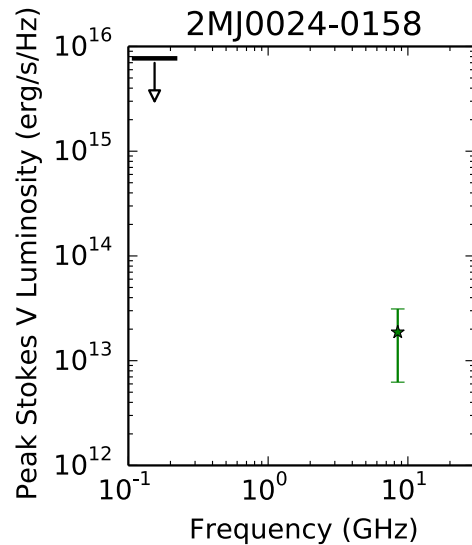
MWA Snapshot



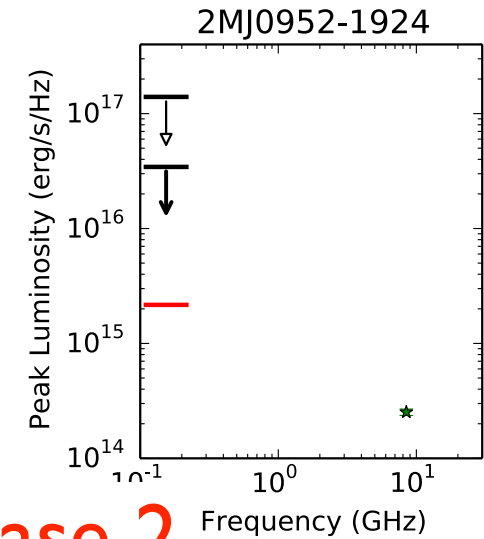
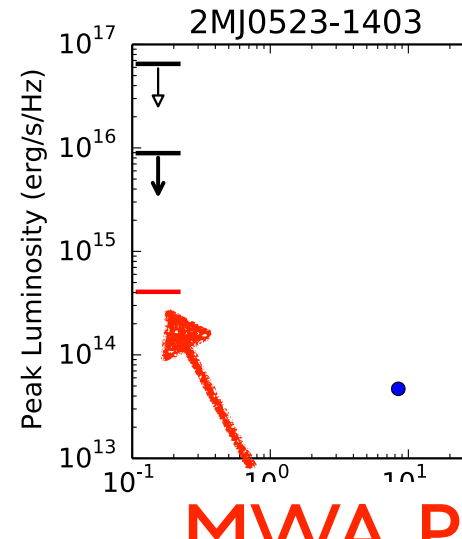
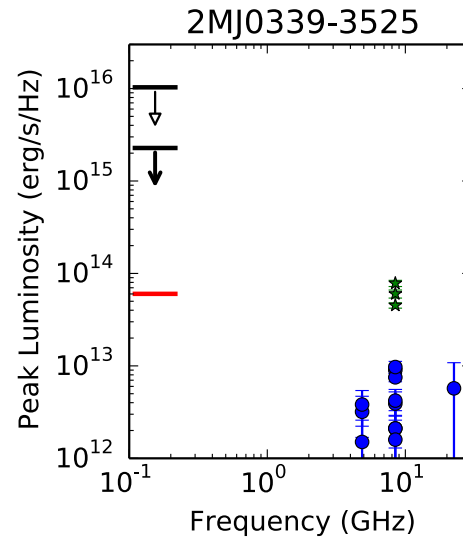
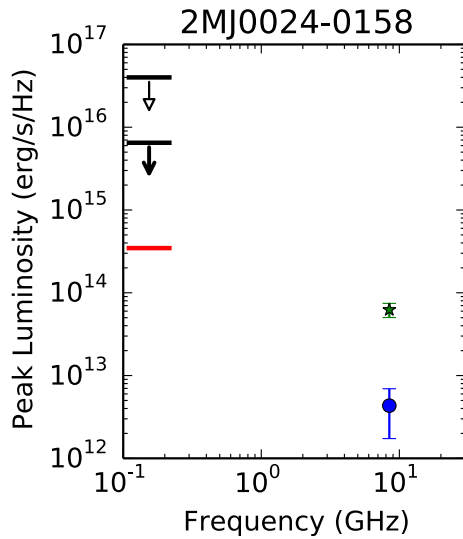
Literature Quiescent



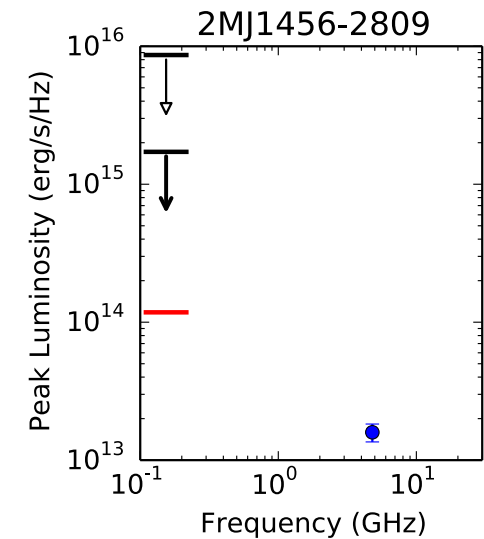
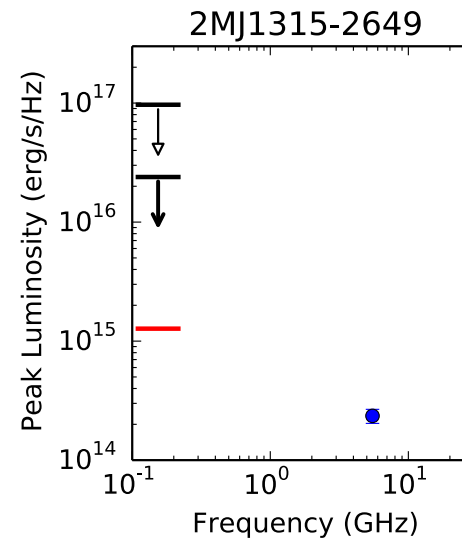
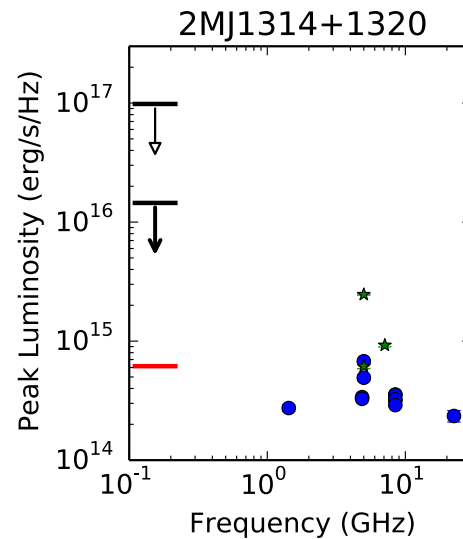
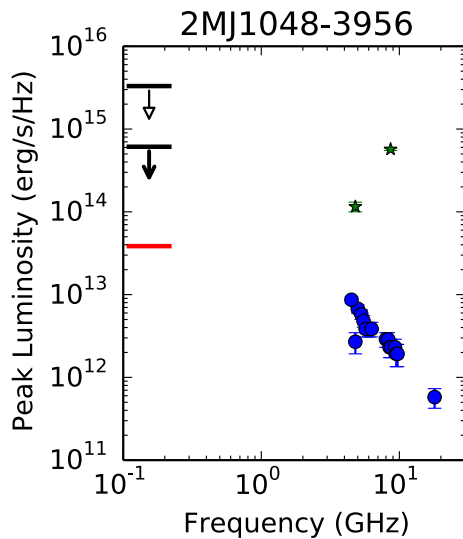
Literature Flare



MWA Phase 2 Stokes I Comparison:



MWA Phase 2





Summary:

1. Ultracool dwarfs generate and sustain strong magnetic fields through non-solar dynamo process.
2. $\sim 7\%$ of UCDs have radio emission at 4 and 8 GHz — frequency/time structure of pulsed emission constrains magnetic geometry.
3. The MWA place further constraints on known radio loud UCDs + build catalog of detections.
4. Current MWA sensitivity too low to detect sources in Stokes I; may be able to detect brightest pulses in Stokes V.
5. Phase 2 MWA sensitivity may be enough to detect brightest radio loud UCDs.



Future Work:

1. **ATCA Targeted Surveys of UCDs:**

- a. Completed survey of 15 UCDs at 5.5 and 9.0 GHz — detected new UCD only at 4 GHz.
- b. Follow up at 1 - 3 GHz to answer the following questions:
 - What fraction of UCDs have emission < 4 GHz?
 - For UCDs with observed radio emission, where does the spectrum of the quiescent emission turn over?

2. **Other stars with coherent flares in MWATS:**

- a. Magnetic A stars — coherent flares @ 600 MHz ~10 mJy level
- b. Close Binary (RS CVns) — coherent flares @ 300 MHz ~100 mJy level

3. **MWA search for Exoplanets:**

- a. Target young stellar associations — young, magnetically active Jupiters around high mass loss stars
- b. 40 hr @ 154 MHz of Upper Scorpius Association