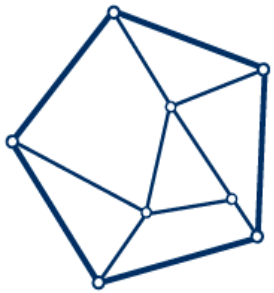
Chasing Low Frequency Radio Bursts from Magnetically Active Stars

Christene Lynch (U. Sydney/CAASTRO)

Collaborators:
Tara Murphy (U. Sydney/CAASTRO)
David Kaplan (U. Wisconsin-Milwaukee)
Cleo Loi (Cambridge)
Martin Bell (CSIRO/CAASTRO)



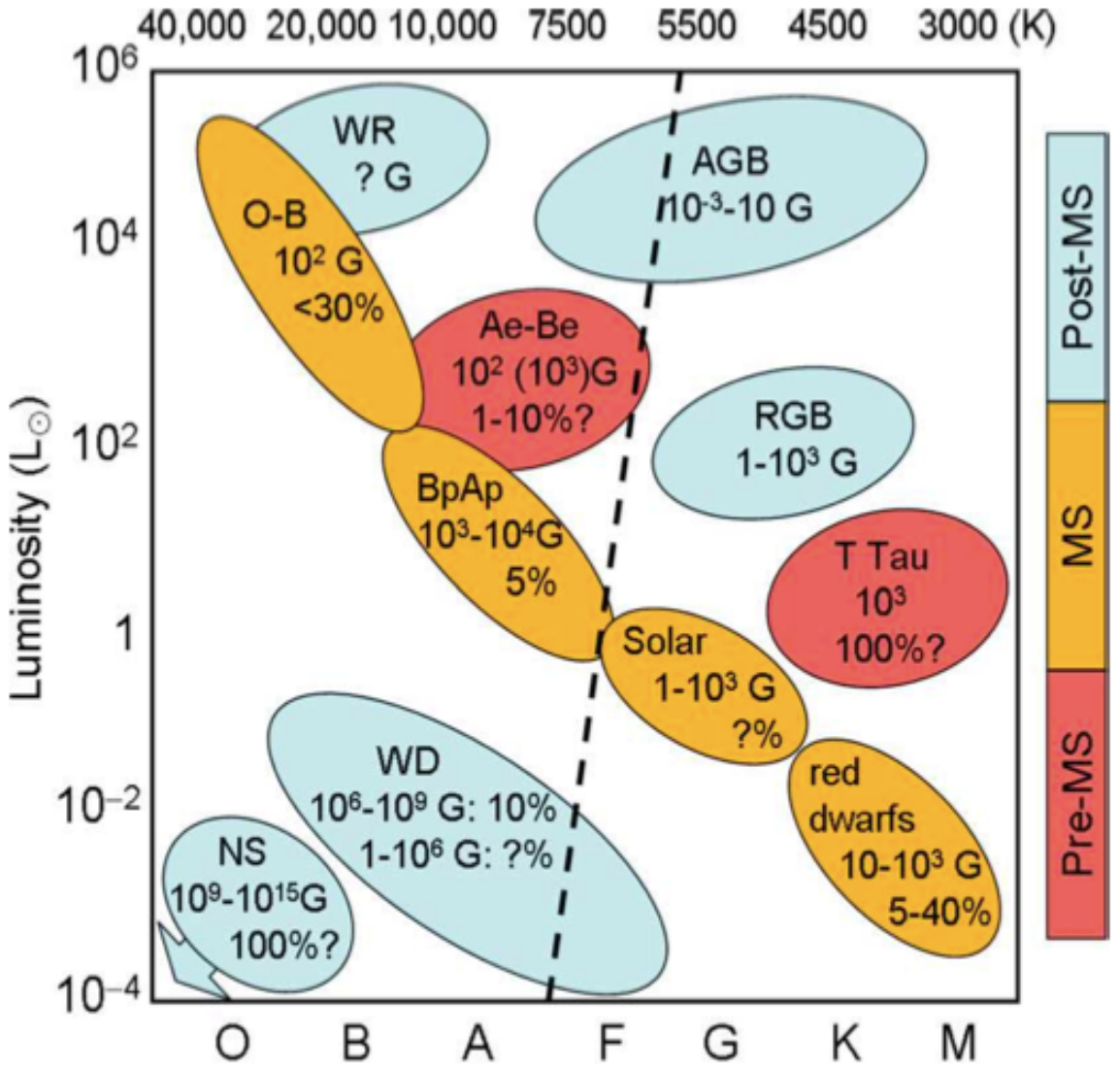
CAASTRO
ARC CENTRE OF EXCELLENCE FOR ALL-SKY ASTROPHYSICS

THE UNIVERSITY OF SYDNEY

Stellar magnetic fields are ubiquitou

➡ Magnetic fields are found throughout the Hertzsprung-Russell diagram.

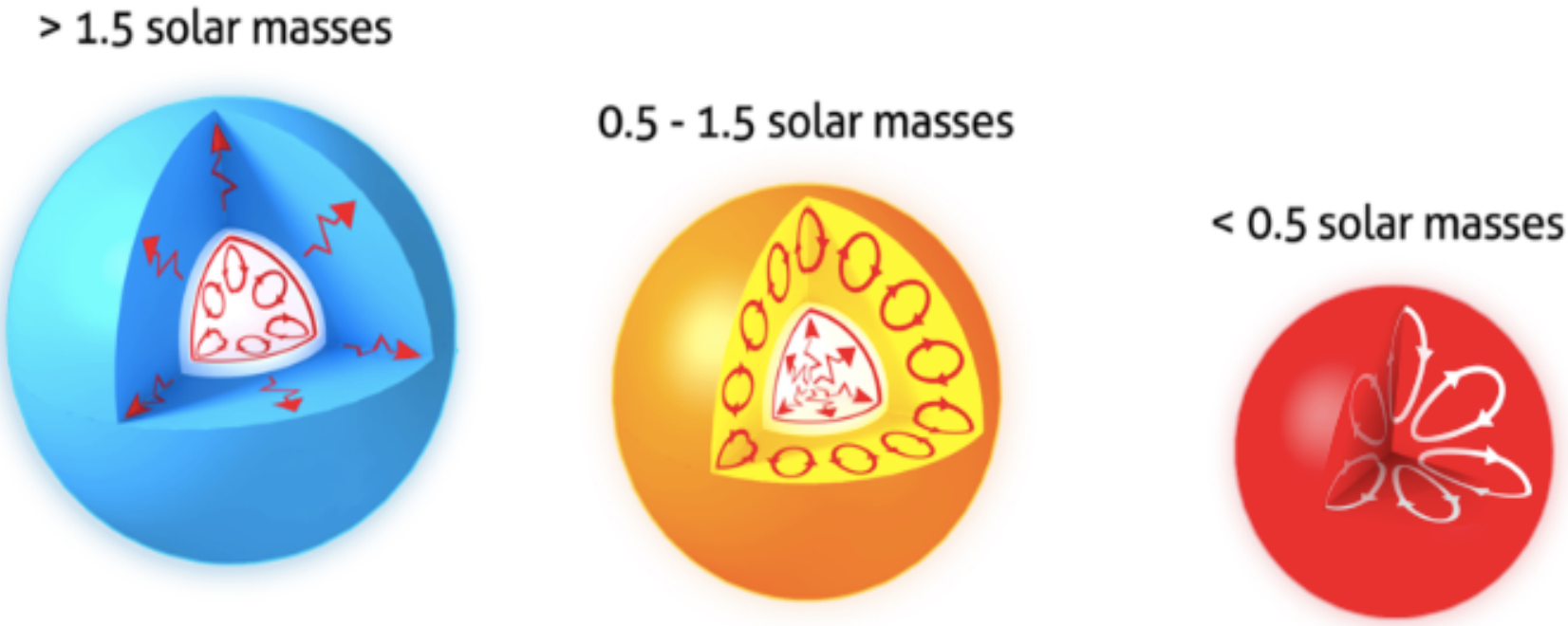
➡ Fields thought to play important roles in evolution.



Berdyugina (2009)

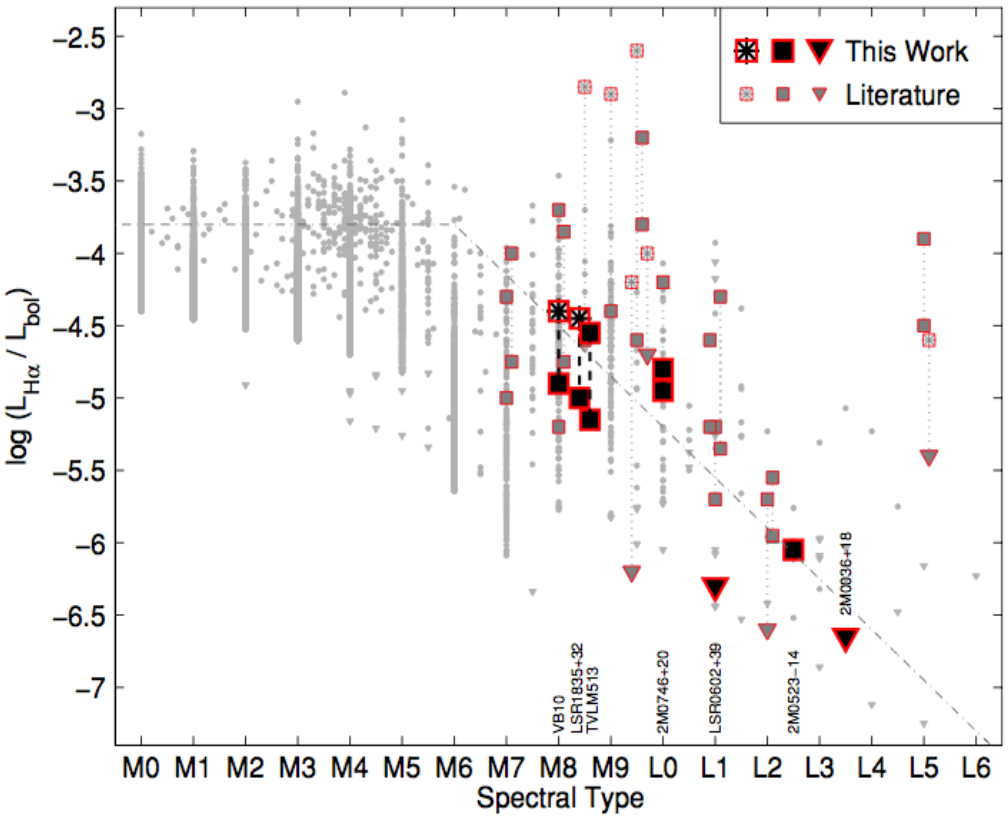
Challenging Solar Dynamo Models:

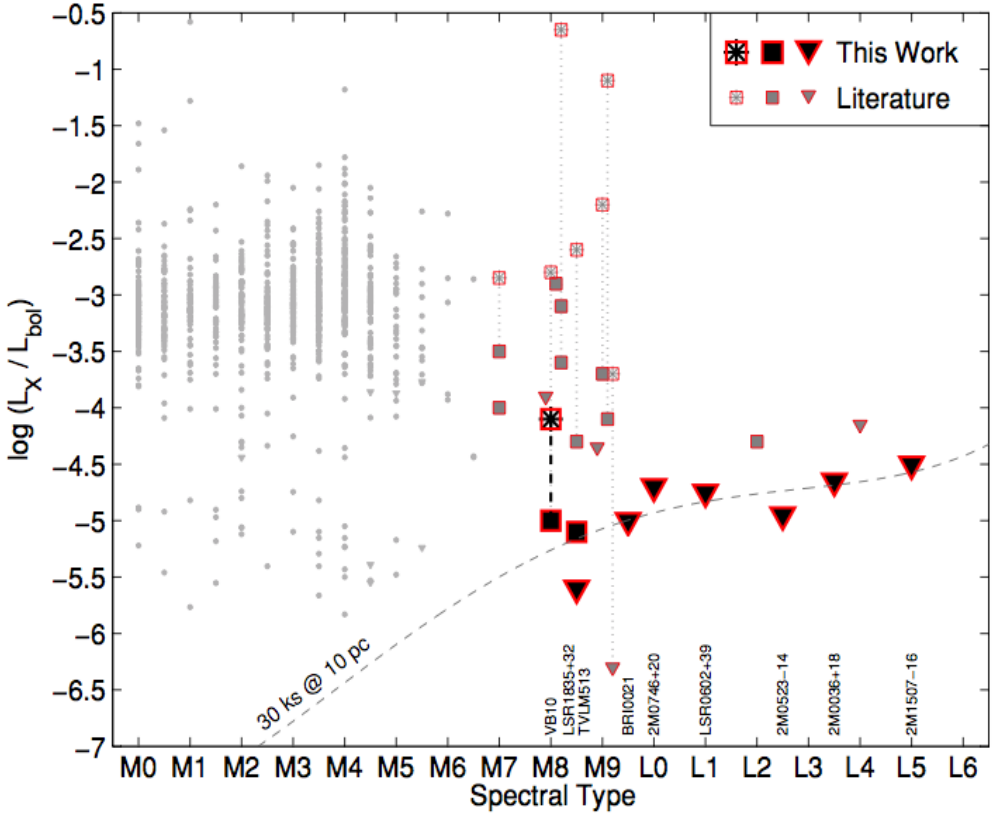
Solar dynamo depends on the interface layer between the radiate and convective zones.



Sun.org - www.sun.org, released under CC-BY-SA 3.0

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



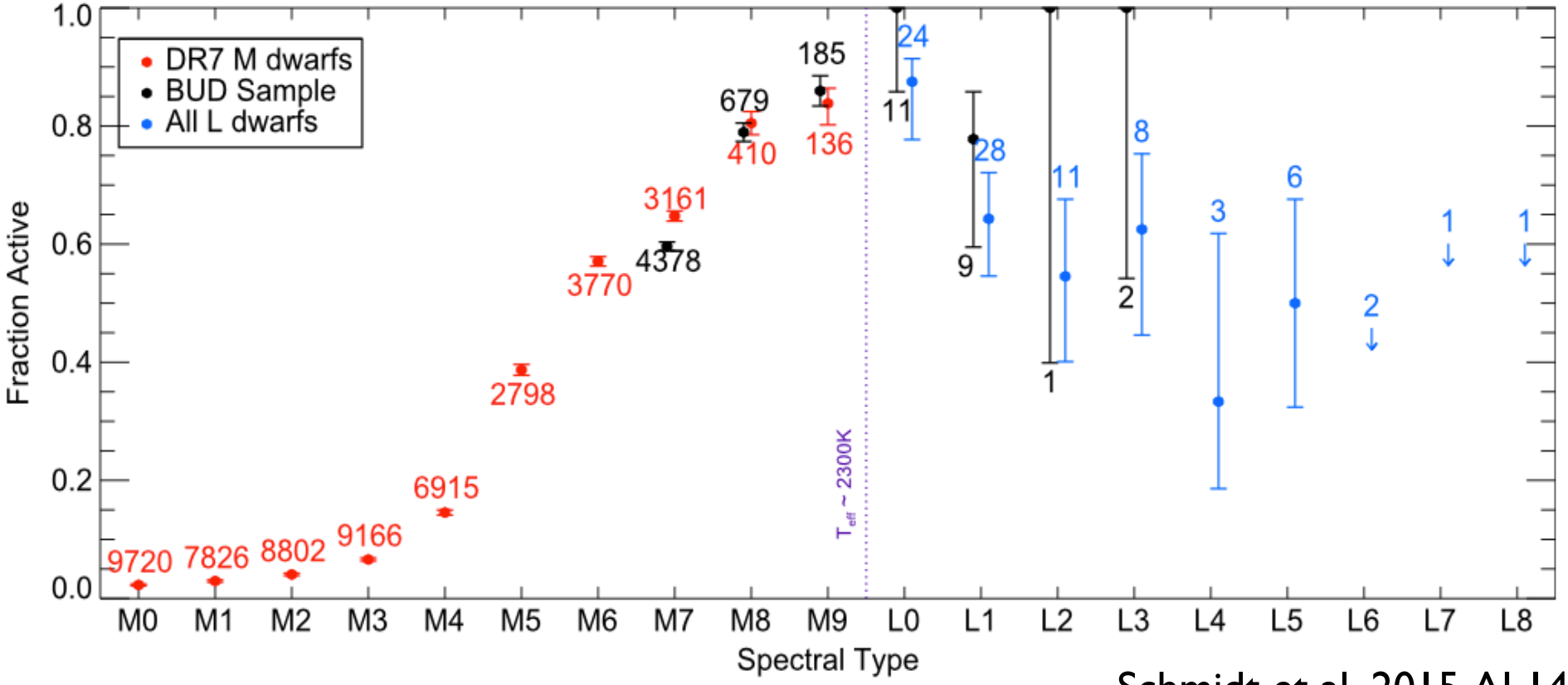


➡Associated with decrease in plasma heating

➡Does not imply a drop in magnetic activity.

Berger et al. 2010 ApJ 70

Number of Active Objects as traced in Hα:



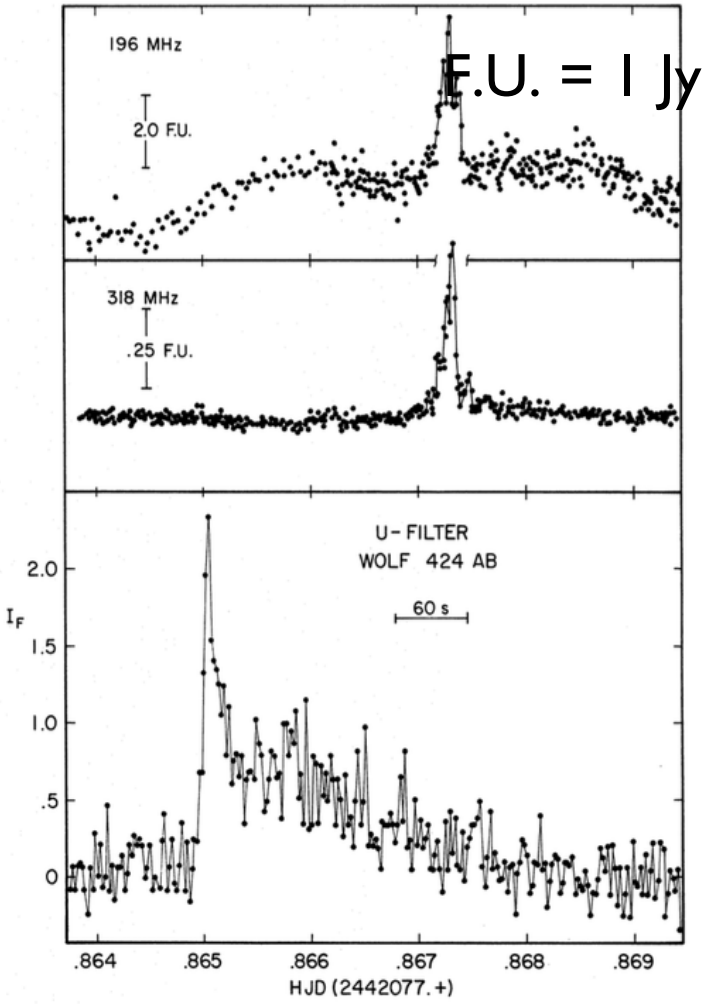
Schmidt et al. 2015 AJ 149

Fraction of active dwarfs peaks in early-L dwarfs

Radio Emission Characteristics:

M0-M6

Wolf 424

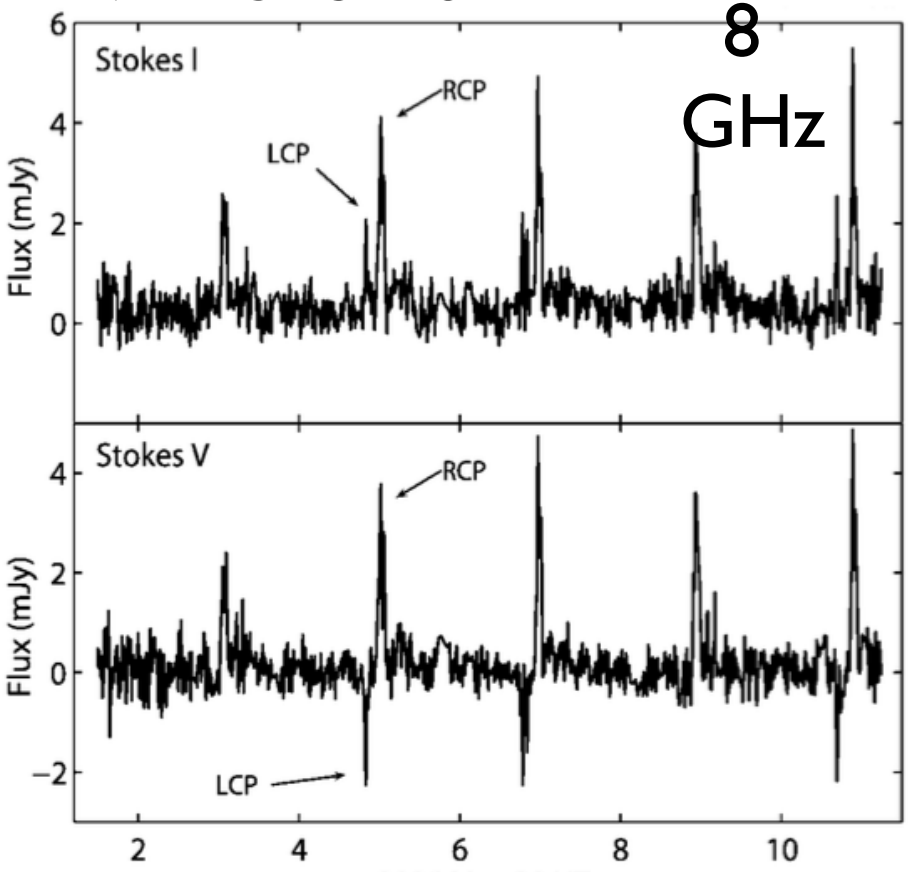


F.U. = 1 Jy

Spangler et al. 1976, ApJ 203

>M7:

TVLM513-46



8 GHz

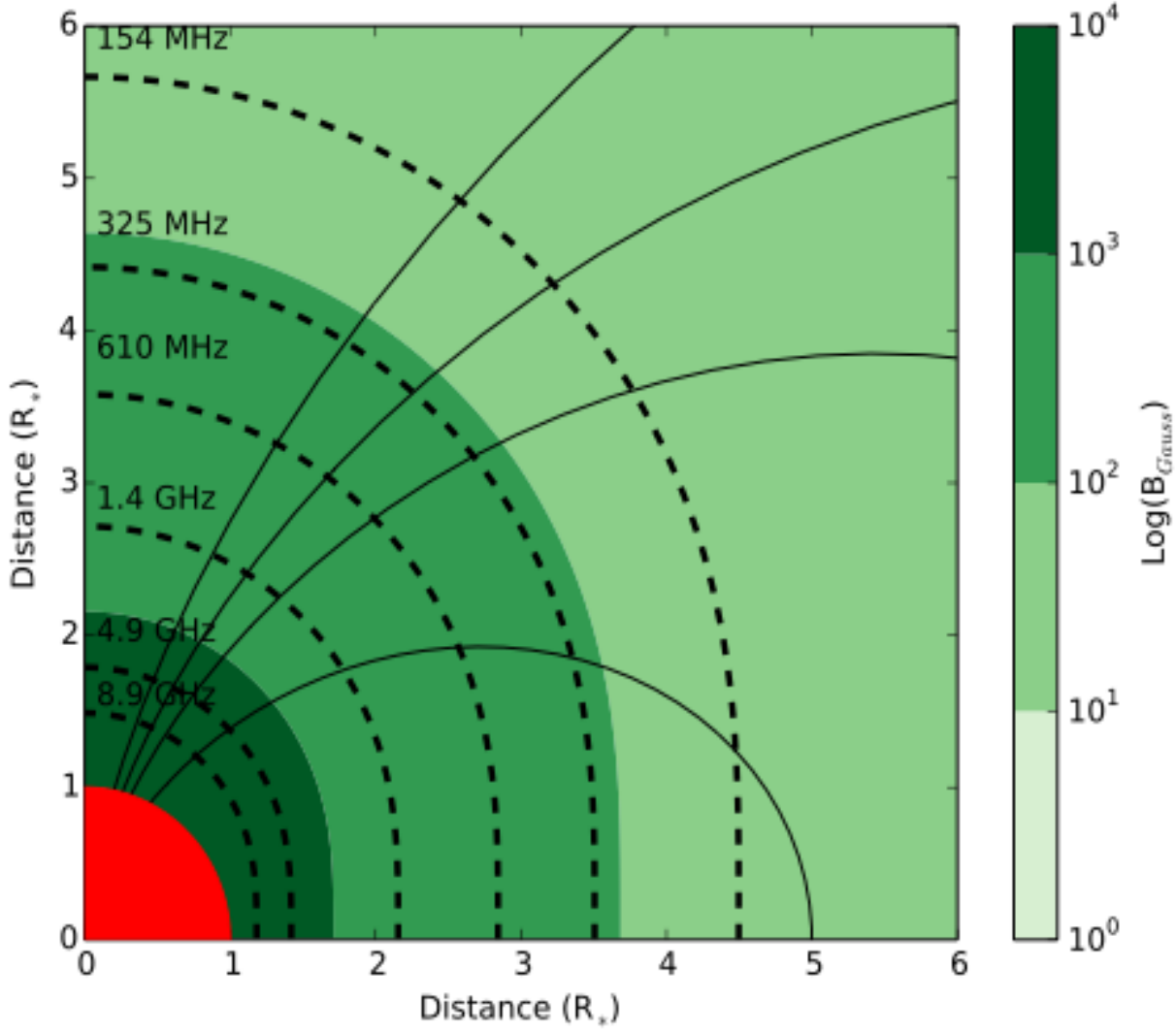
Hallinan et al. 2007 ApJ 663

Ultracool Dwarf Flare Emissi

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

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

Beaming + Gyro-frequency mapping leads to geometrical constraints on source region.



Previous targeted Surveys:

- M0 – M6 Spectral Types:

Catalog building:

➡1970-80's 80 - 400 MHz surveys; after 1980's 1-4 GHz

➡~40% have radio flares; flare rates 0.02 - 0.8 hour^(-1)

- >M7 spectral types:
  - ➡ Focused on 4-8 GHz
  - ➡ ~ 7% detection rate; currently 16 known radio loud sources

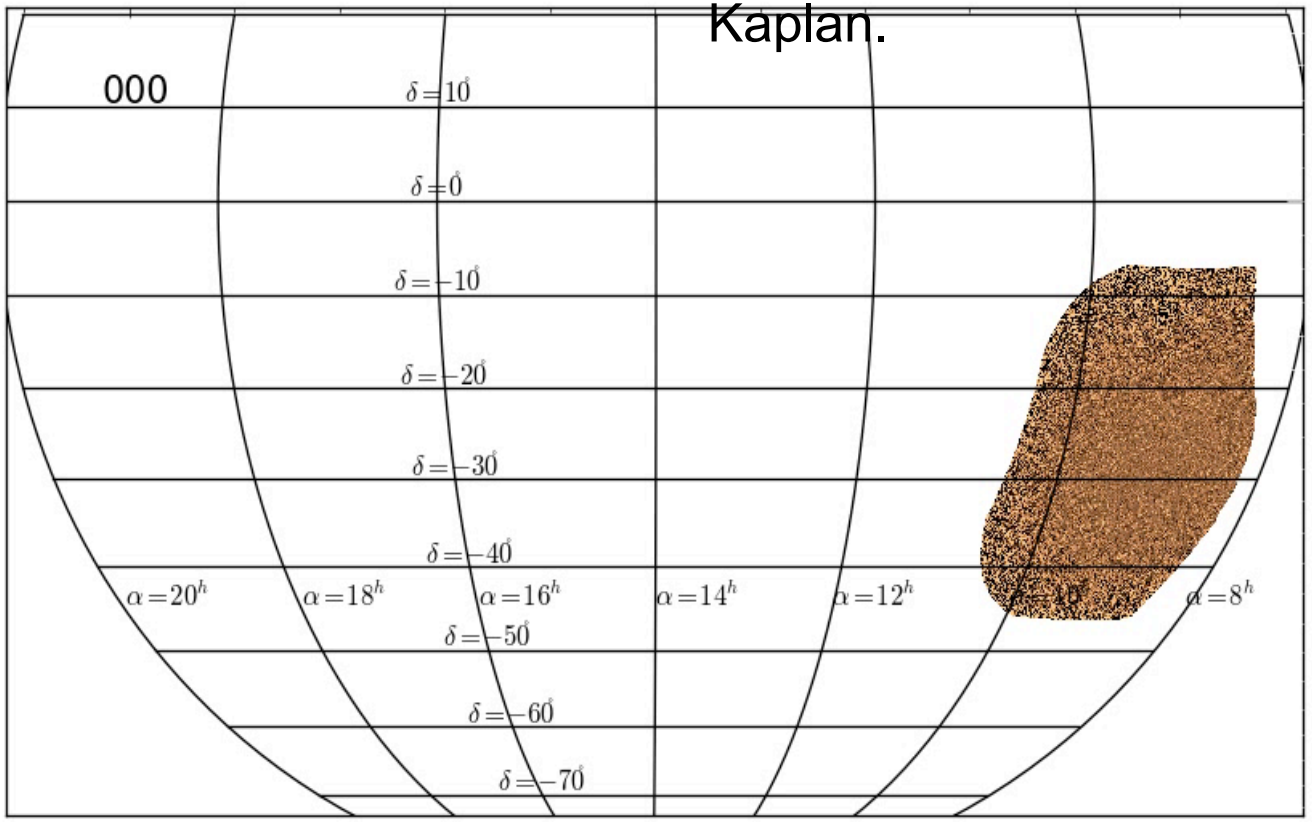
Widefield, low-frequency surveys:

➡ Weak fields (10-100 Gauss) emit in Murchison Widefield Array (MWA) frequency range (80-300 MHz)

MWA Transients Survey (PI Martin Bell):

Frequency: 154 MHz
Method: Drift scans at δ= +1.6, -26 and -55
Survey area: *Entire Southern hemisphere*.
Cadence: One night per month.
Integration time: 2 min per snapshot.
Survey length: Two years (but ongoing); only 1st year reduced

Movie courtesy of D. Kaplan.



Many Projects!

➡ Image plane pulsar search (Bell et al. *in prep*)

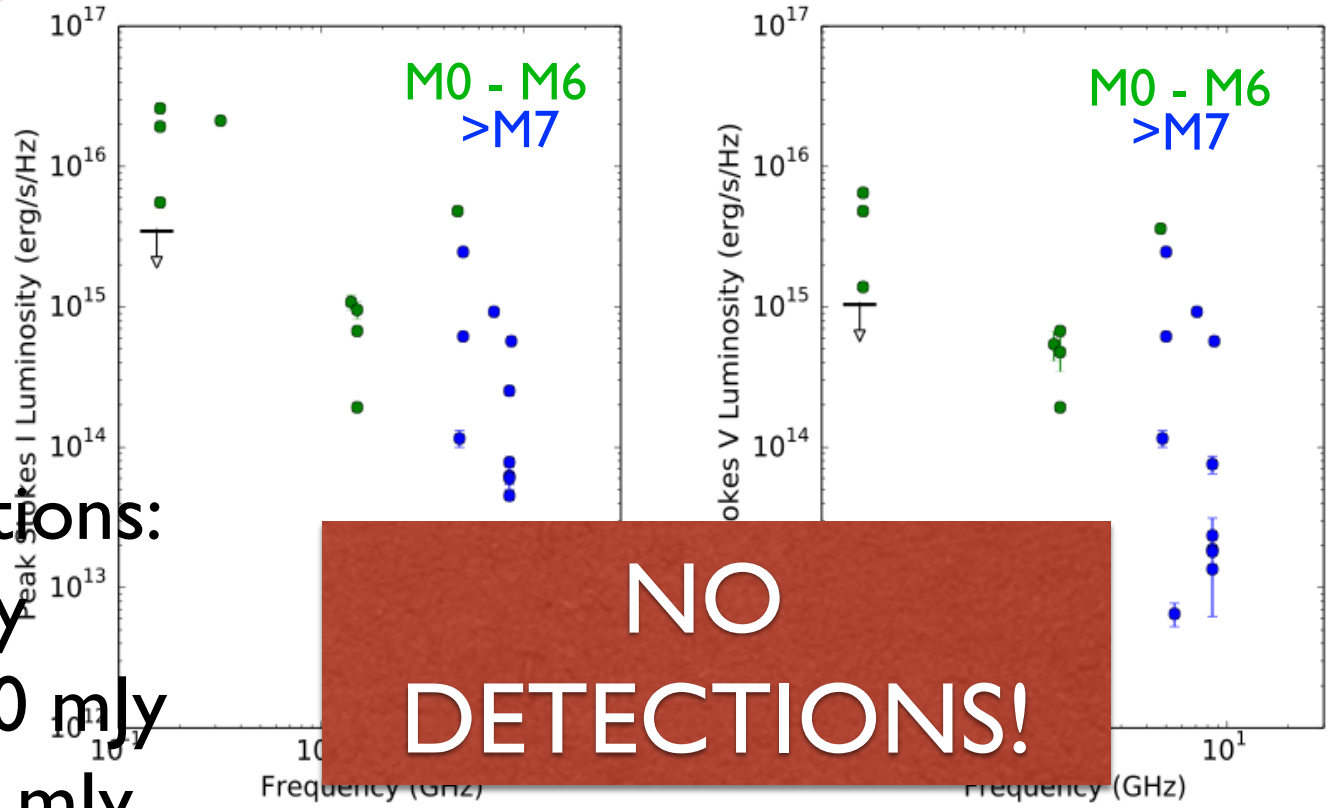
➡ Characterizing Ionosphere (Loi et al. 2015 MNRAS 453)

➡ Limits on southern hemisphere exoplanets (Murphy

Search for 154 MHz Stellar Flares:

Catalog of candidate sources:

- 700 M0-M9.5, 100 >M9.5
- Distances <20 pc; closest source @ 2 pc



NO DETECTIONS!

Reasons for non-detections:

1. Sensitivity of survey
   - Stokes I 3σ = 170 mJy
   - Stokes V 3σ = 30 mJy
2. Time coverage: average time on source ~2 hours
   - ➡ Use rest of MWATS data for targeted searches
3. In-activity of sources
   - ➡ Triggered observations from *Swift* Burst Alerts

Rates of 154 MHz Stellar Flares:

- Upper limit to occurrence of flares brighter than Stokes V upper limit from closest member of our catalog: $L_{154\ MHz}$ = 1.e15 ergs s^{-1} Hz^{-1}

- Assume probability of burst is Poisson distribution:

$$P(n|T\mu) = \frac{e^{-T\mu}(T\mu)^n}{n!}$$

for *n* flares in [illegible]vation given a flare rate of μ.

- 95% confidence l[illegible]

$$\mu = \frac{-\ln(0.95)}{T\ f\Omega}$$

$f\Omega$ = fraction of stellar surface the flare emission is concentrated.

- Assume source region similar to that of GHz flares ⇒ $f\Omega$~0.05 and note T=150 min: $\mu \leq 0.4$ hour^{-1}

Summary:

1. Lowest mass stars and brown dwarfs generate and sustain strong magnetic fields.

2. Magnetic features produce short-duration, circularly polarized coherent bursts — frequency/time structure of bursts can be used to constrain field configuration and strength.

3. Low frequency widefield telescopes (like MWA) can be used to build catalog of sources with known radio bursts.

4. Fitting the position of 800 known M dwarfs & brown dwarfs, we made no detections in the first year of the MWA Transient Survey

5. Non-detections may be due to sensitivity (brown dwarfs) or time coverage (only 2 hours), or inactivity of sources.