



university of
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Radio-emitting engines in M dwarfs

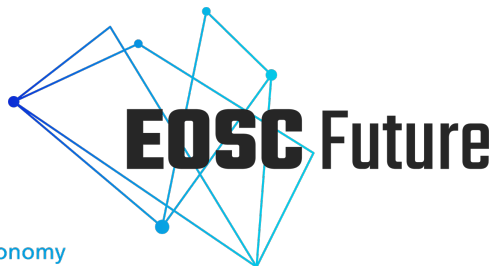
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Supervisors: Harish Vedantham, Joe Callingham, Léon Koopmans

Cool Stars 21 Brown Dwarf, Toulouse

ASTRON

Netherlands Institute for Radio Astronomy



4 July 2022



Why study stars in radio?

- Plasma oscillation & charges in magnetic fields all emits in radio wave
⇒ Excellent probe of plasma dynamics and magnetic field!
- Allow us to study coronae of stars & magnetospheres of exoplanets



1. *Impact of stellar plasma on exoplanets*
2. *Coronal heating mechanism*
3. *Magnetic field strength of exoplanets*

Engine

What is powering the radio emission of these objects?

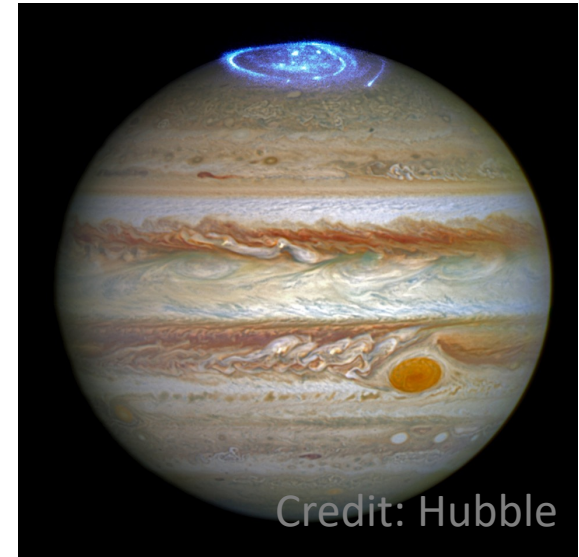
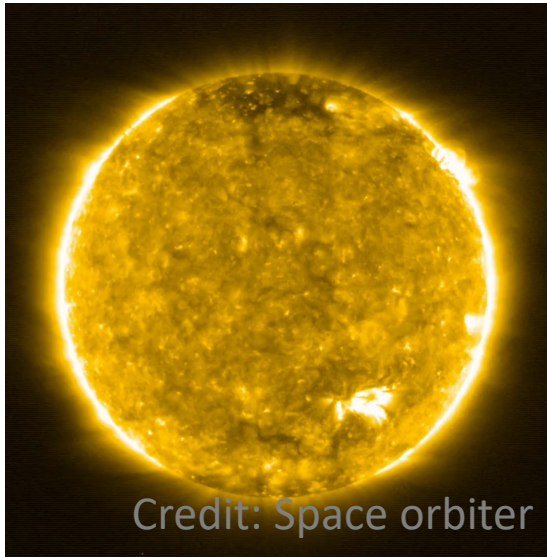
Sun-like

vs

Jupiter-like

- *Flares*
- *Nanoflares*

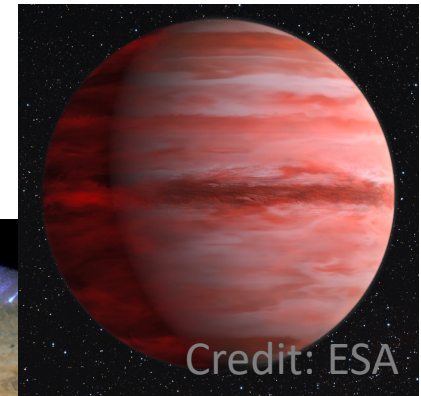
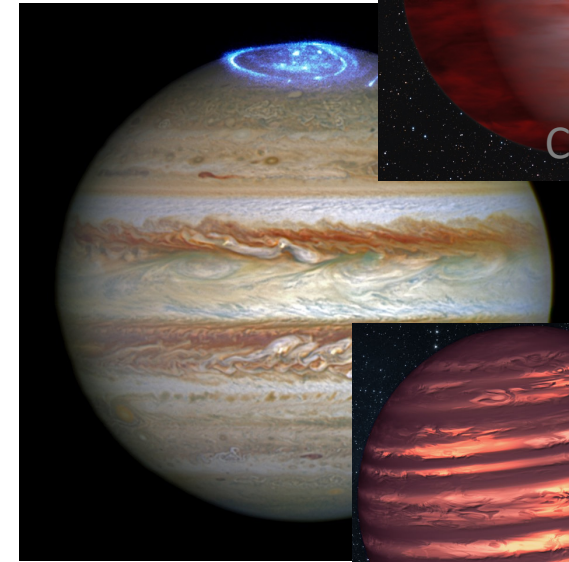
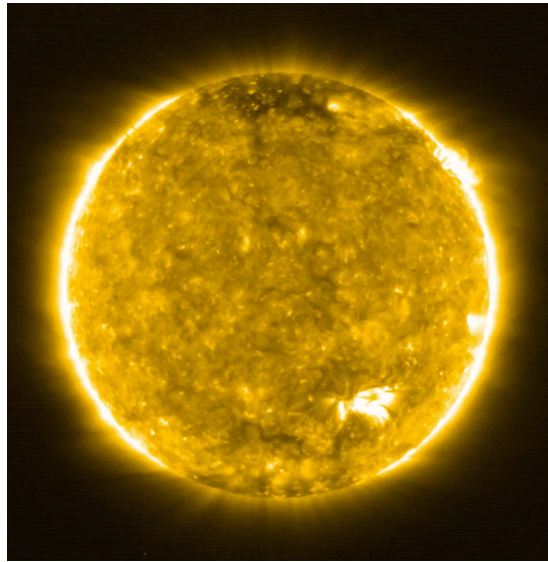
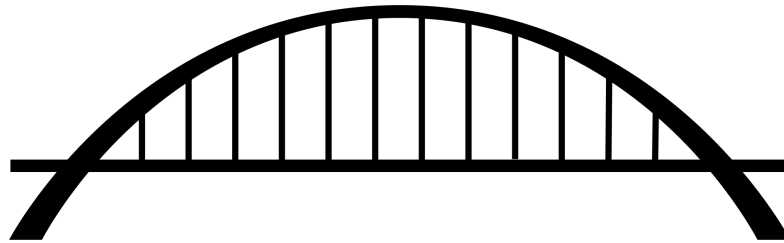
- *Magnetosphere*
- *Dynamo*



A bridge



M dwarfs!



Advantages of LOFAR

- Low frequency (10 to 240 MHz)

⇒ > 1 mJy source cannot be due to synchrotron radiation

$$S_\nu \propto \nu^2 T_b \Omega$$

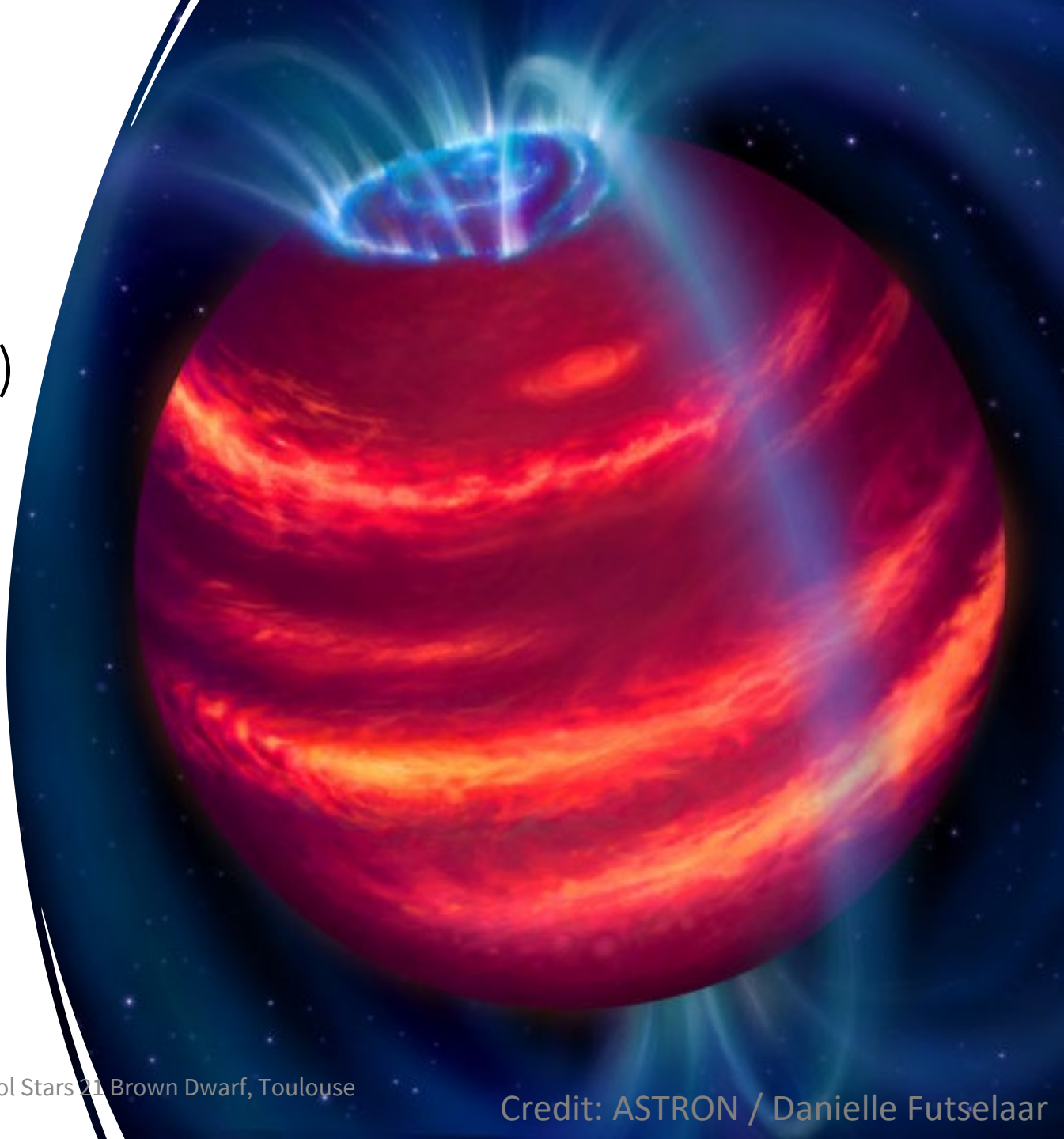
- Stokes-V ⇒ highly circularly polarised sources

Therefore, incoherent emission!



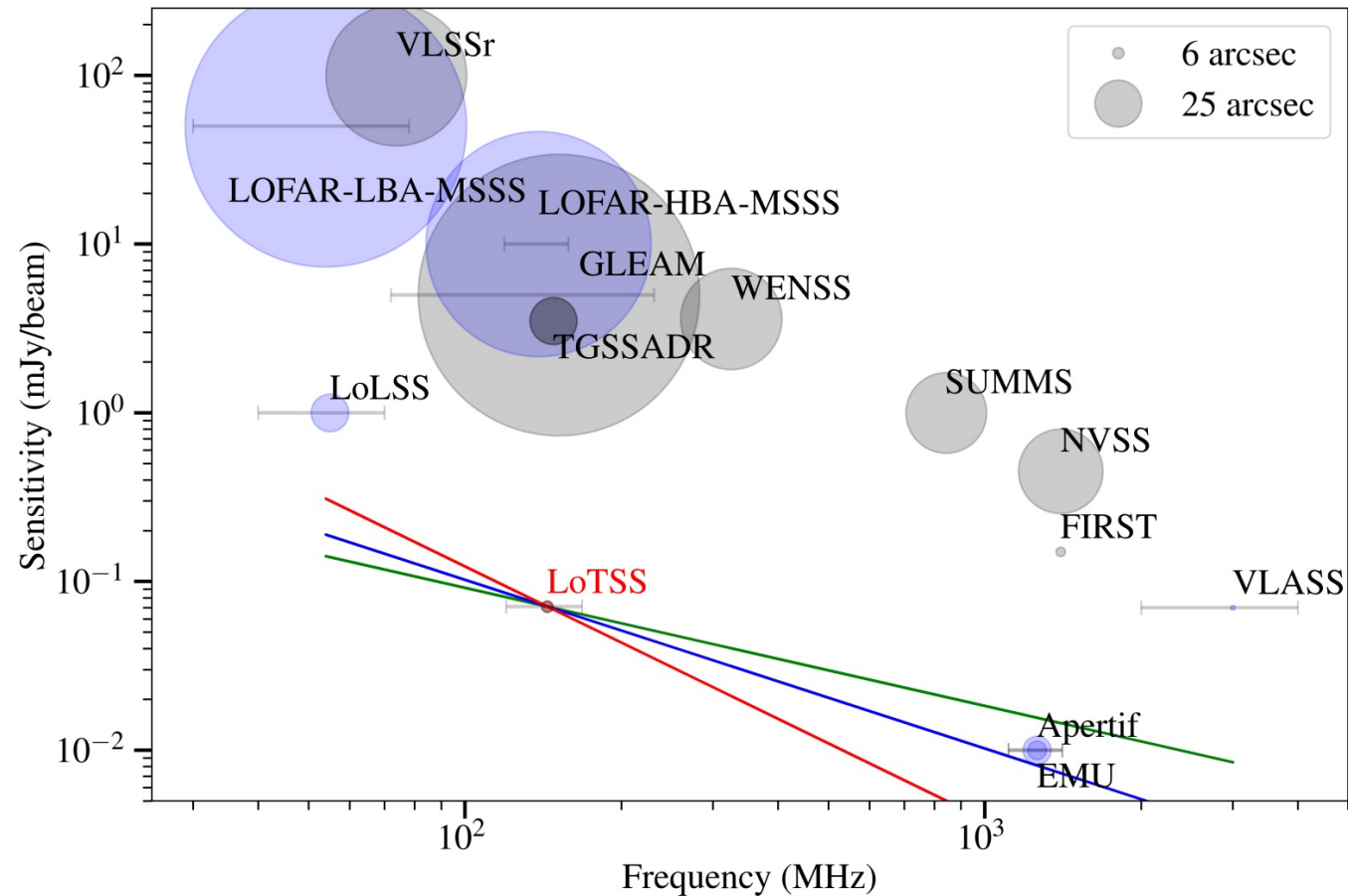
Radio-emitting BDs

- Found 2 BDs with LOFAR
(Vedantham et al., 2020 & 2022)
- Both highly circular polarised
⇒ Auroral emission!
- Both ~T6 dwarfs
⇒ Coincidence?



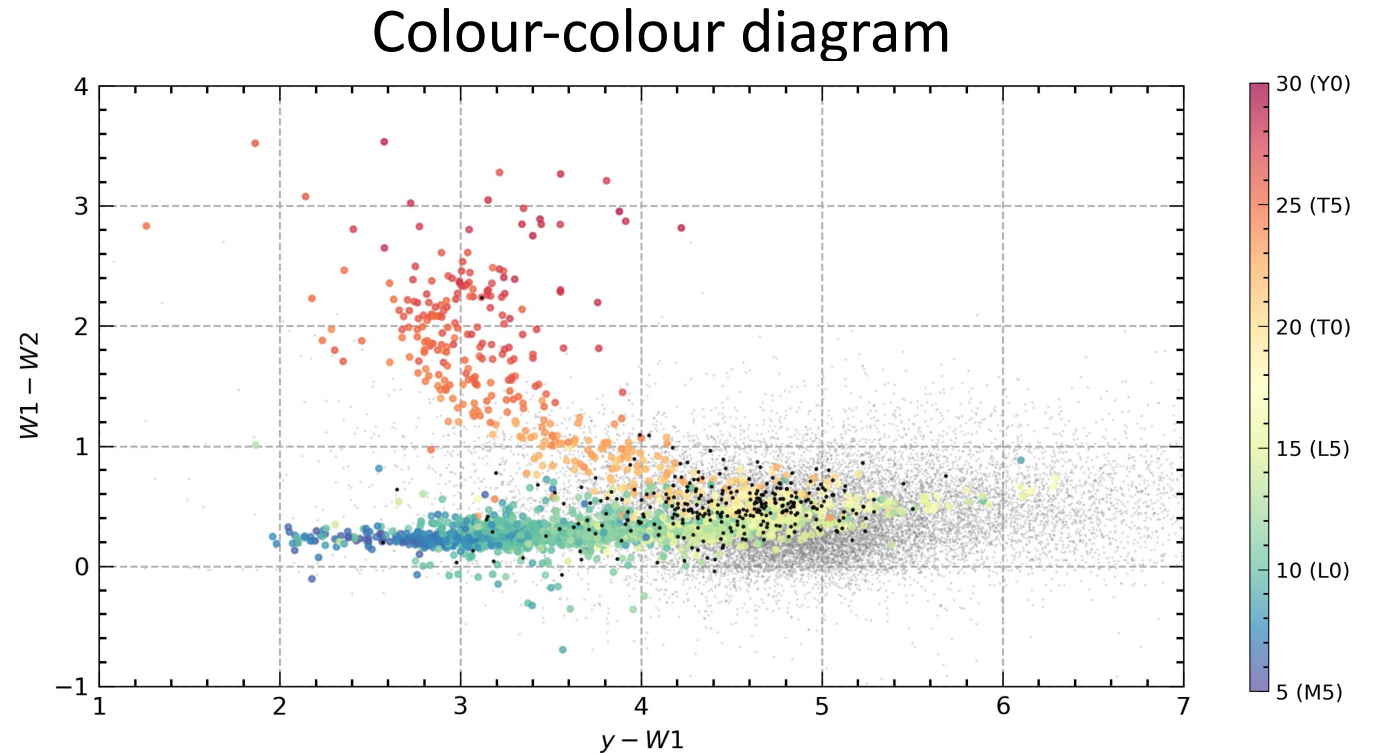
LoTSS (LOFAR Two-Meter Sky Survey)

- *largest radio sky survey ever conducted (by source counts)*
- DR2: 4.4 million sources
in 27% of Northern Sky!
- Likely coherent emissions



Challenges

- Most sources are extragalactic ☹️



Source density

Max. separation

$$N_{false} \propto N_s N_{s'} \theta^2$$


- Chance-coincidence associations!

Solution: LoTSS Stokes-V + Gaia!

- LoTSS Stokes-V: ~6k sources (Callingham et al., in prep.)
- Circularly polarised sources \Rightarrow coherent emission

- $\mathcal{O}(\gtrsim 4)$ less dense than LoTSS Stokes-I
 \Rightarrow No more false matches ☺

Source density Max. separation


$$N_{false} \propto N_s N_{s'} \theta^2$$

Gaia Catalogue of Nearby Stars (GCNS)

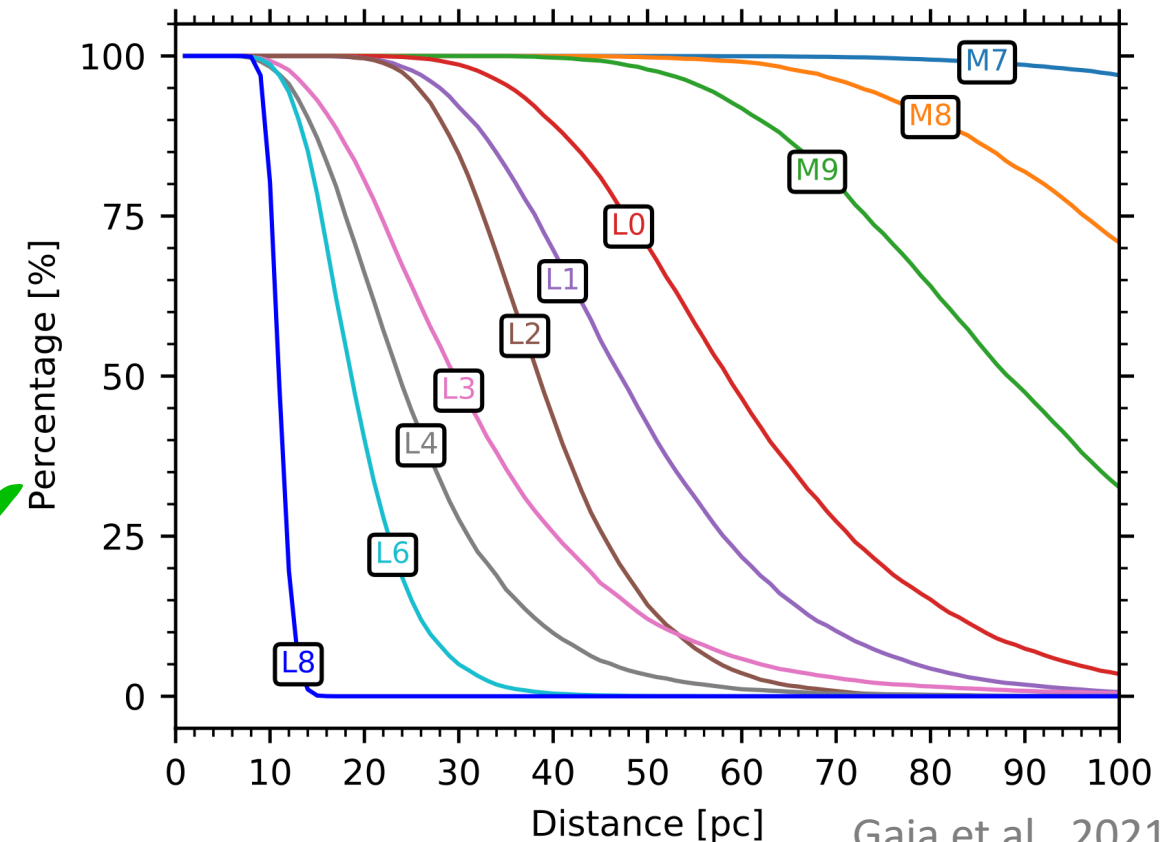
- 331k sources, ~40k within 50pc
- Accurate proper motions

⇒ Stokes-I x GCNS within 50pc ✓

- Complete to late M within 50pc

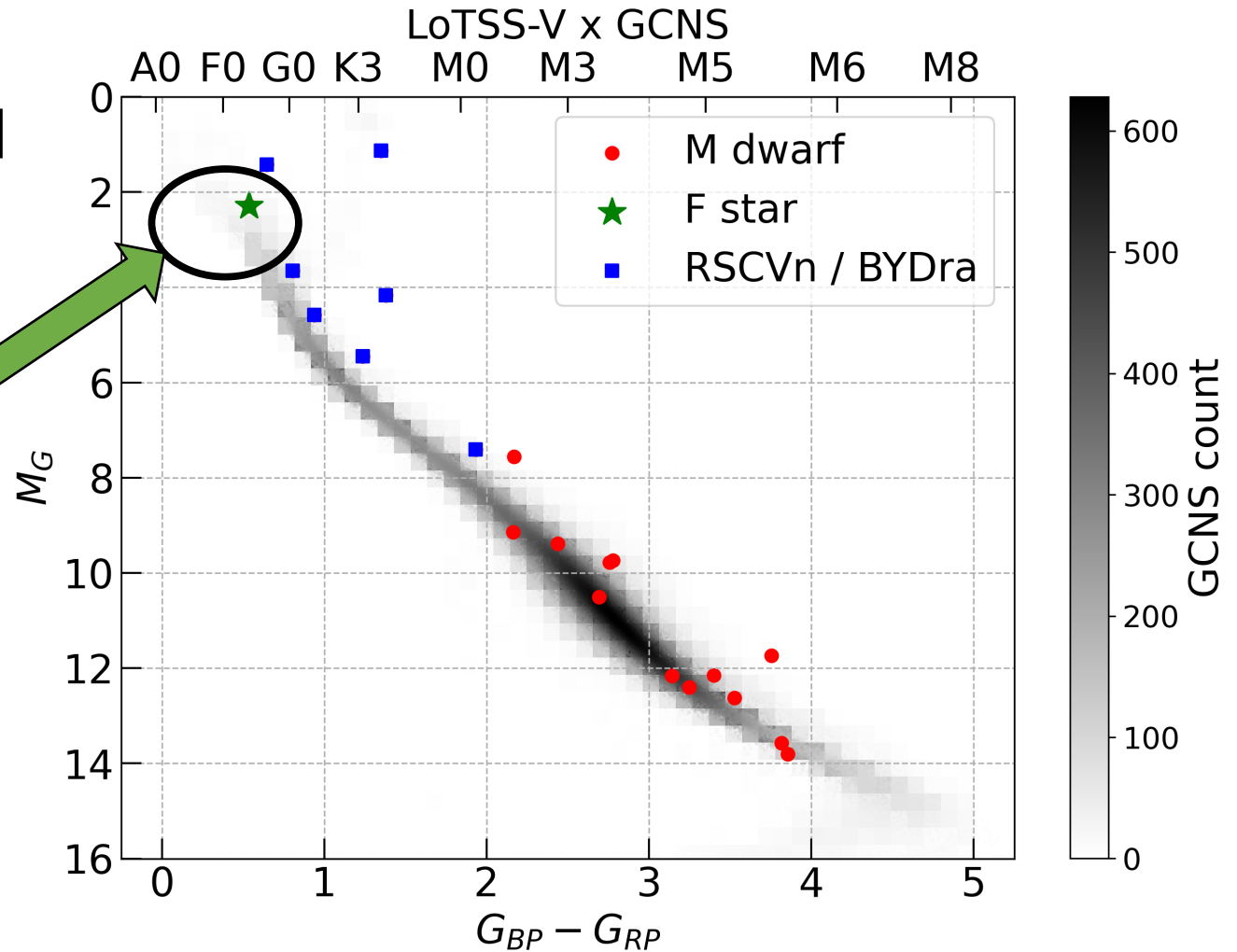
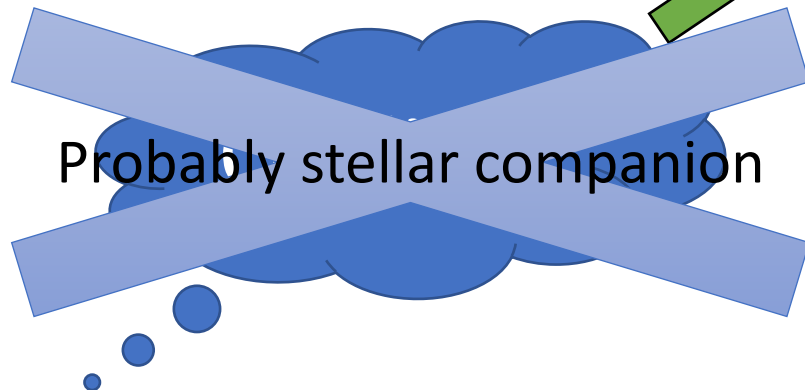
⇒ Look for trends in spectral type ✓

GCNS Completeness per spectral type



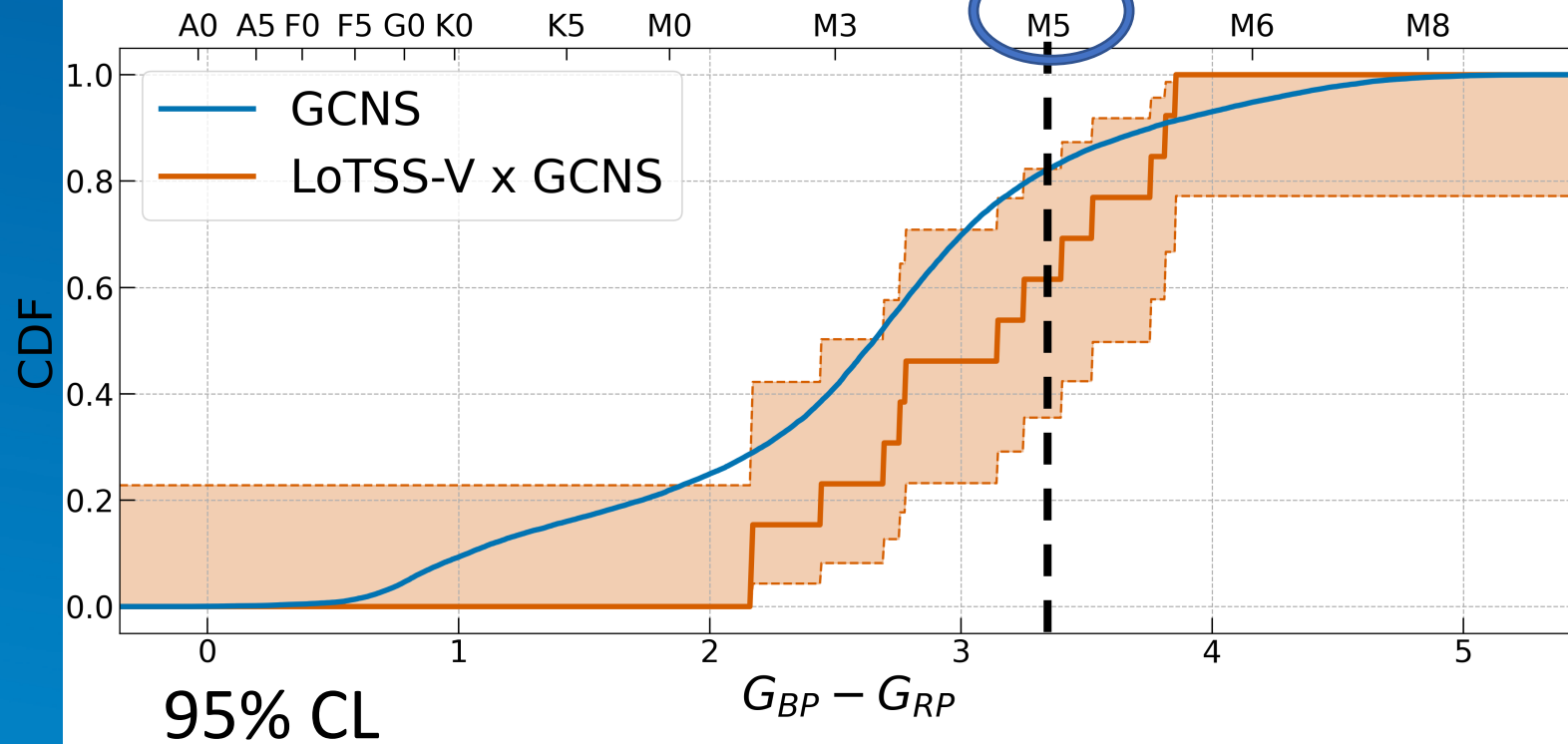
Results

- 21 matches
- All highly (~40-100%) polarised

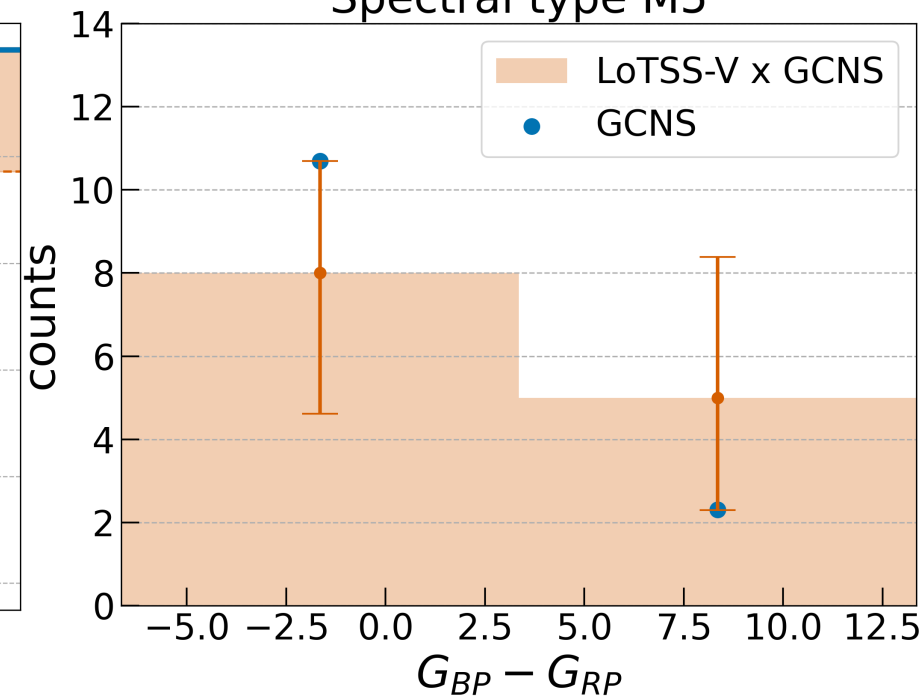


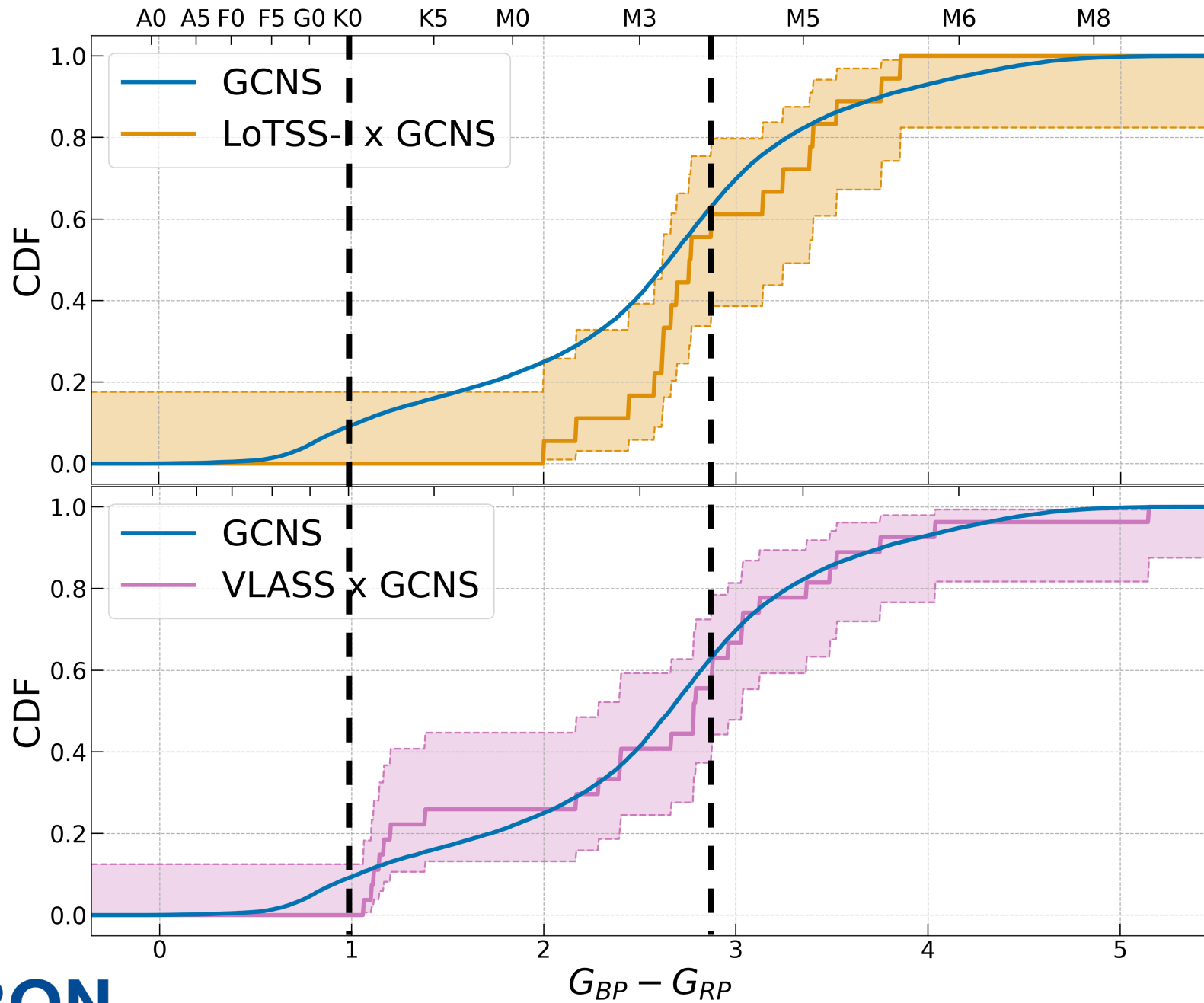
Looking for transition

Cumulative distribution function



Spectral type M5



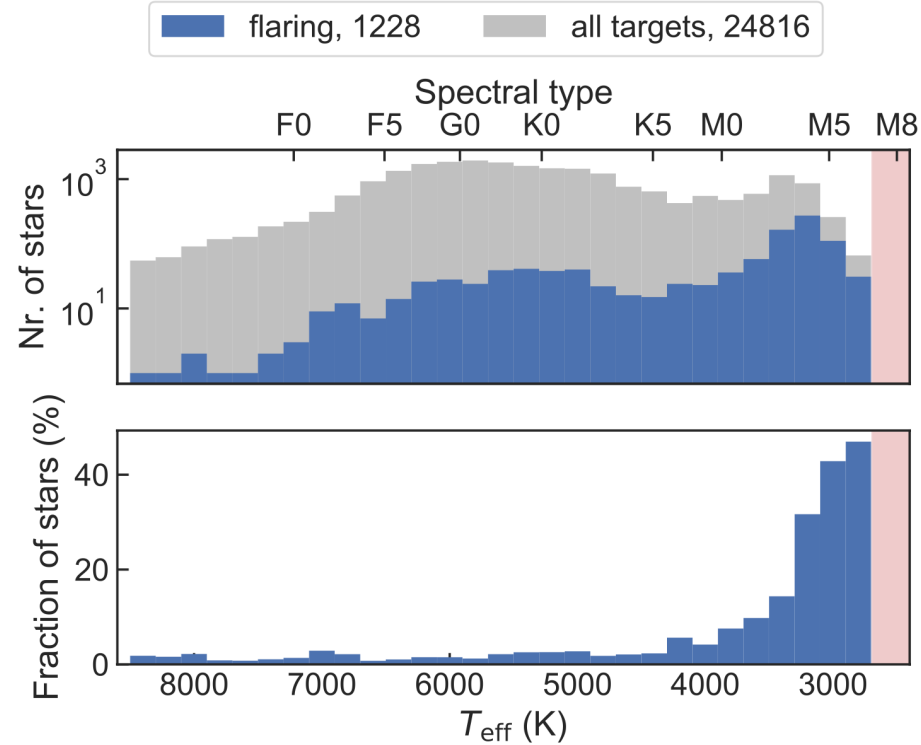


LoTSS: 120-168 MHz

VLASS: 2-4 GHz

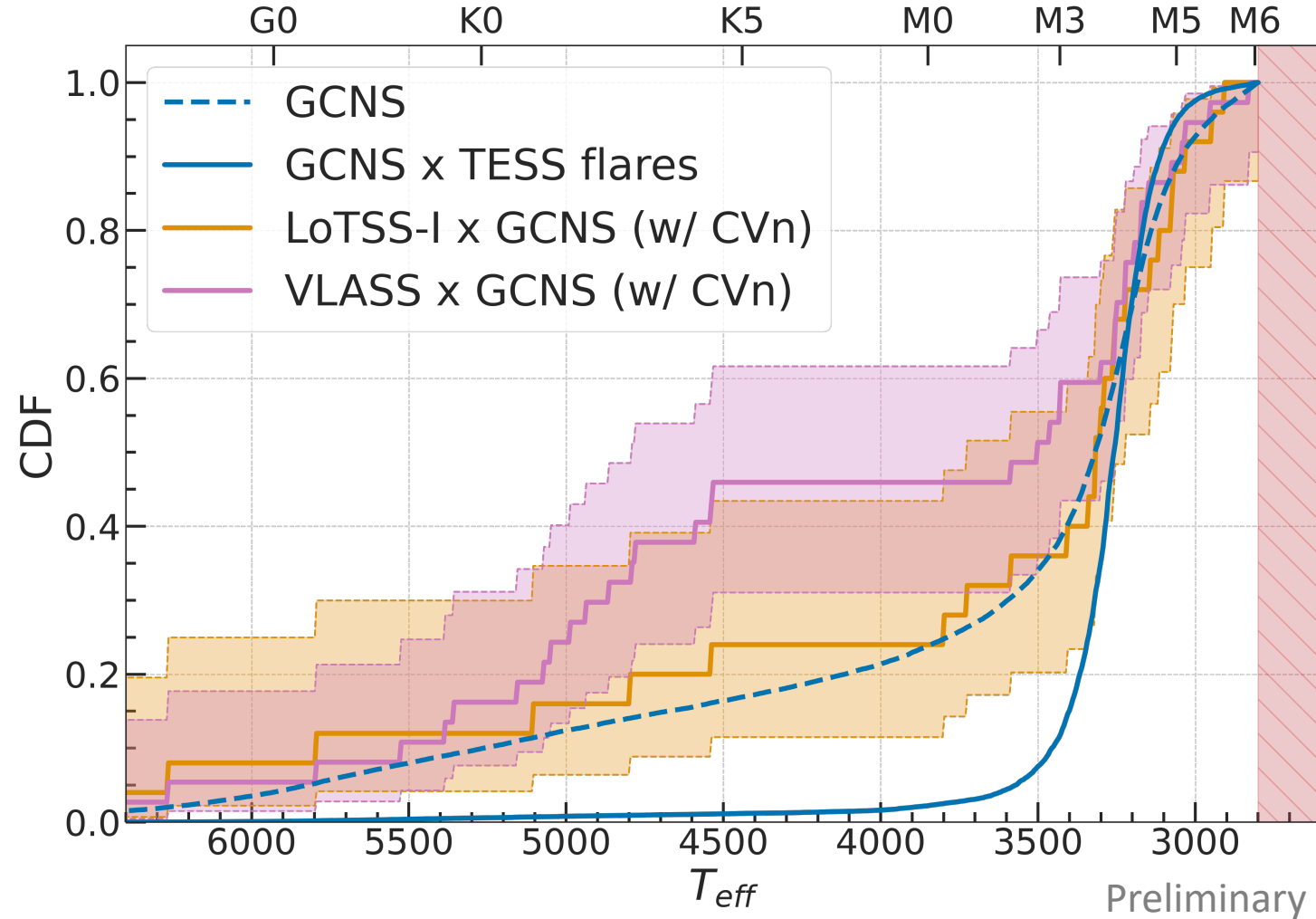
Preliminary

CDF with flares



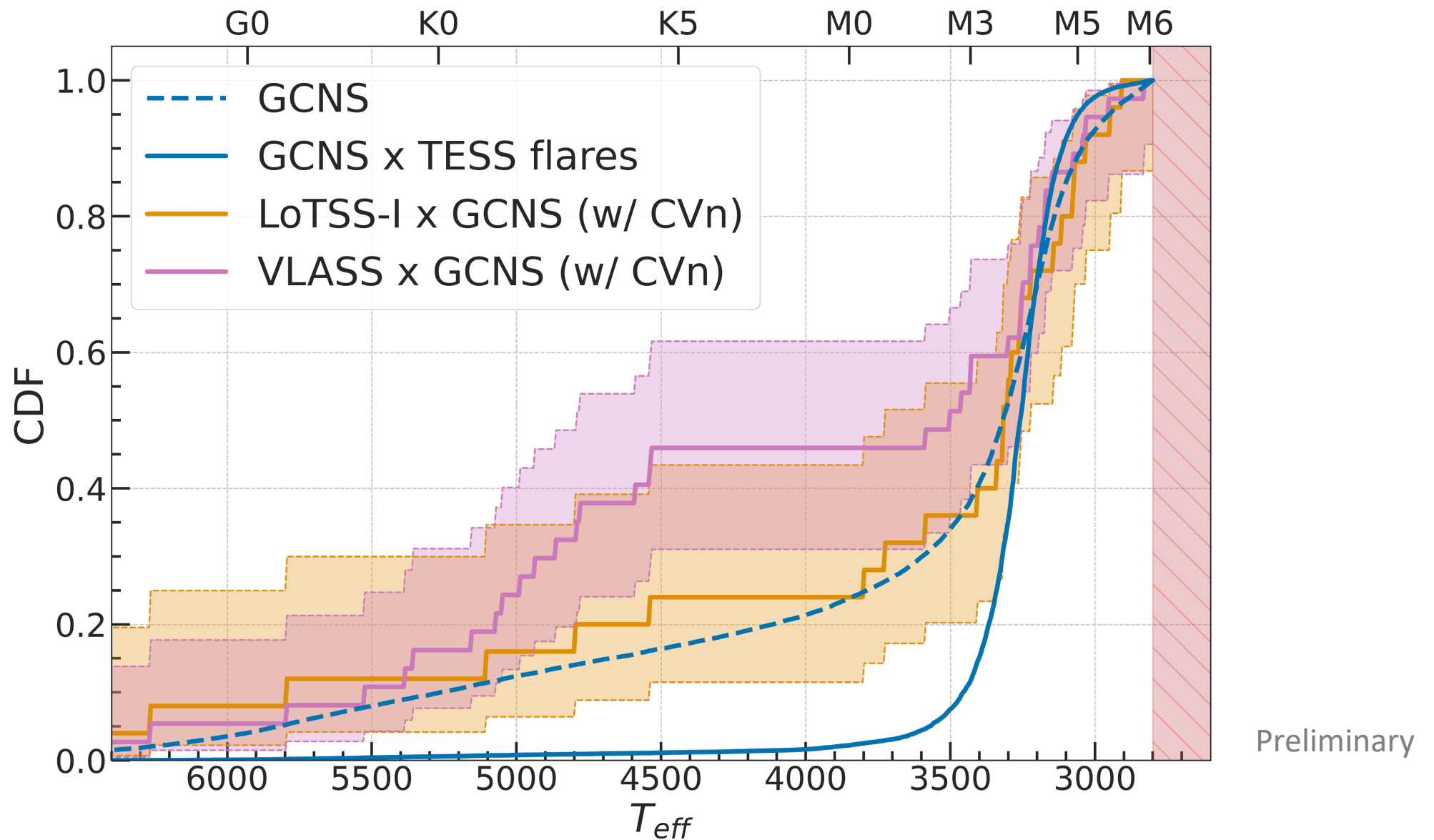
Günther et al., 2020

Cumulative distribution function



Preliminary

Both surveys inconsistent with flares!



Flares not related to stellar radio emission?!

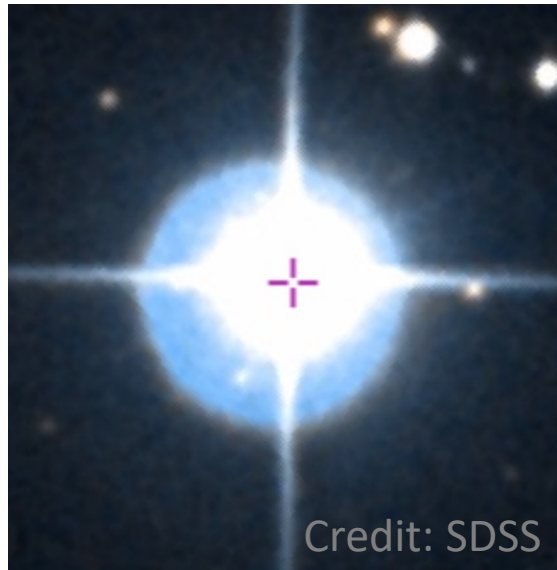
Conclusion

- Radio allows probing of coronae/magnetospheres of coolest stars
- Matched LoTSS Stokes-I/V (or VLASS) to GCNS
- No conclusive evidence for transition in M dwarfs
- **Flares not related to stellar radio emission?!**
(More investigation needed)

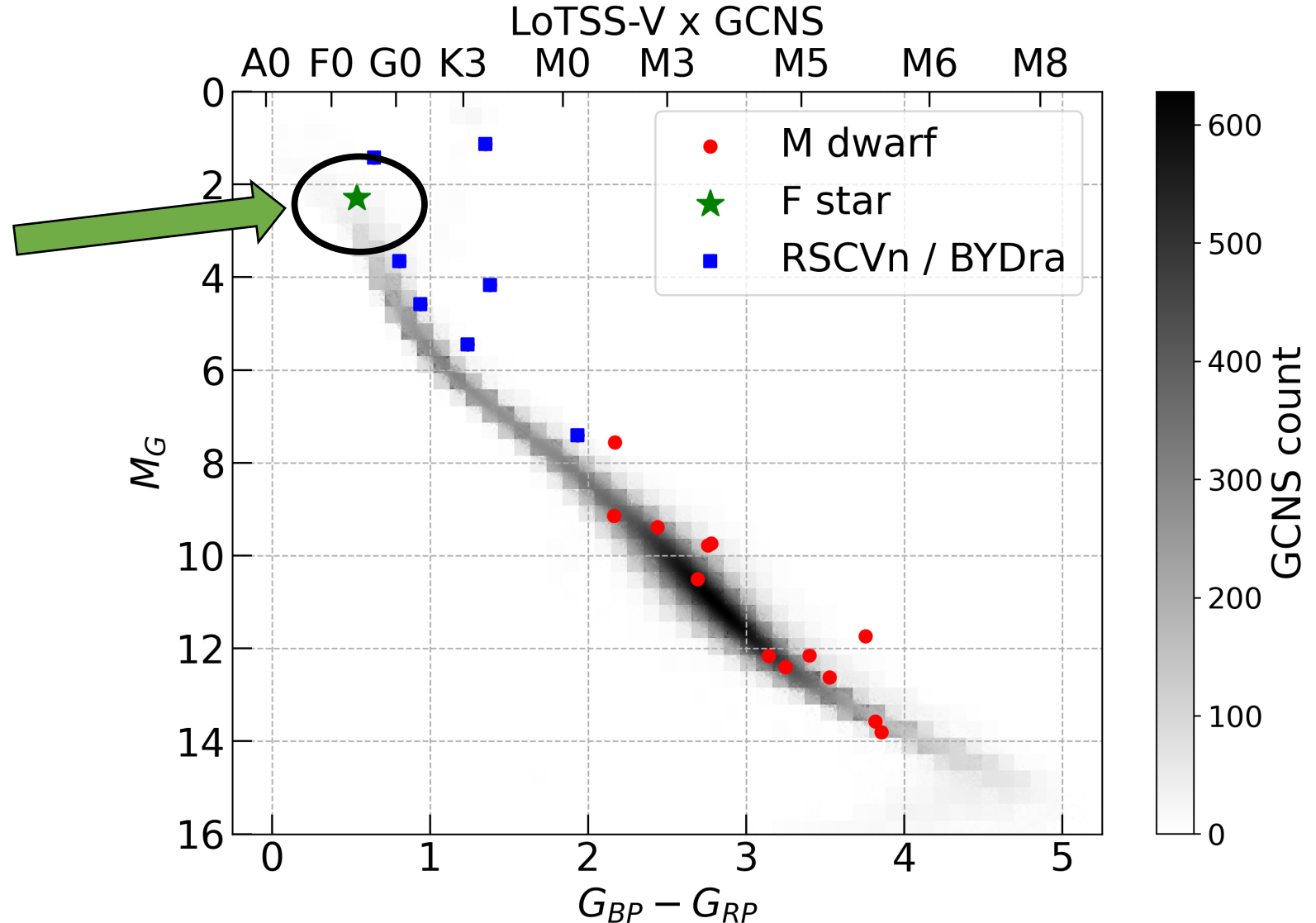


Remember?

- F stars are not known to be radio bright

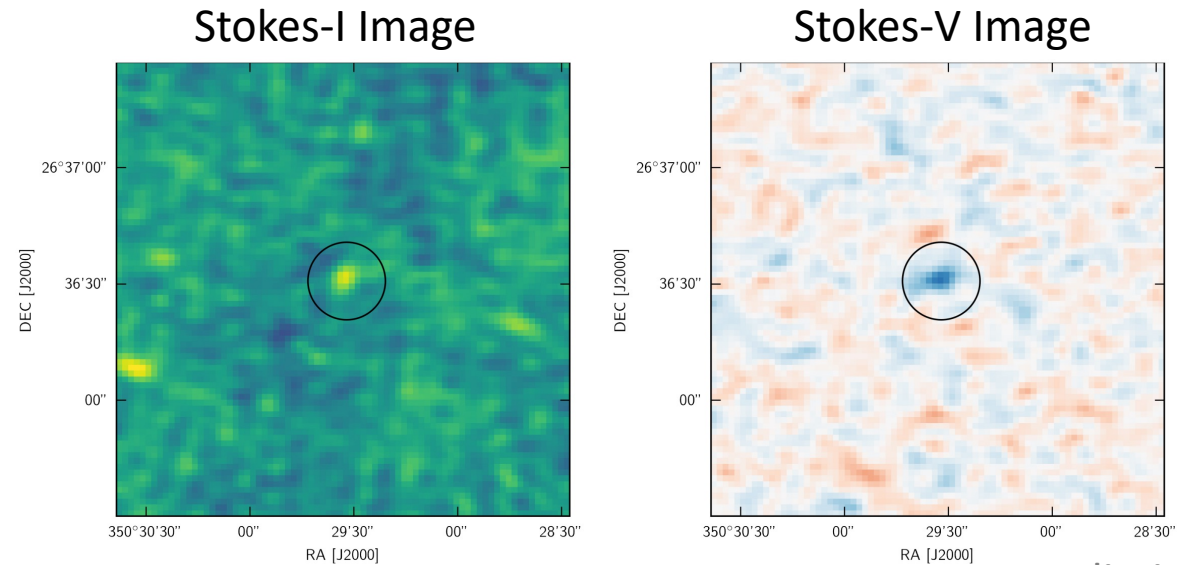


HD 220242: an F5 star



Oddity: HD 220242

- ≈ 2 mJy in Stokes-V, $\approx 100\%$ CP



Preliminary

- Lack of double-line emission/excess radial velocity (Nordström et al., 2004)

⇒ Not RSCVn

- Hipparcos-Gaia PM anomaly (Kervella et al., 2019)

⇒ Tangential acceleration

Possible BD companion?!

Appendix: X-ray vs Radio Luminosity

