Stars and exoplanets at low frequencies

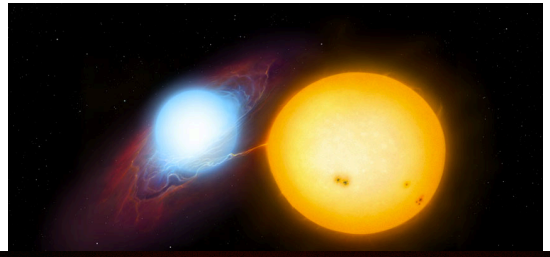
ASTRON

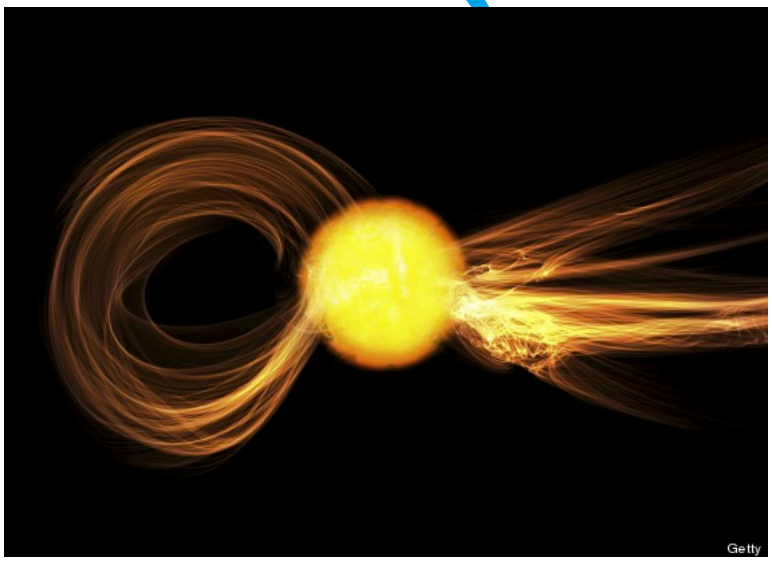
Joe Callingham, Harish Vedantham, Tim Shimwell, Cyril Tasse et al.

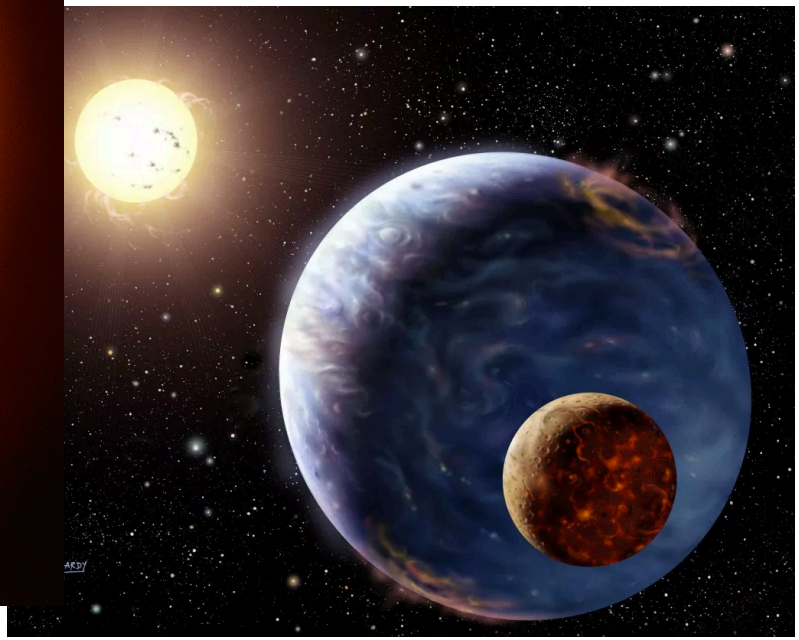
LOFAR Users Meeting, Leiden, NL

21st of May, 2019

Radio stars: What do we expect to see?







Callingham et al., Nature Astro., (2019)

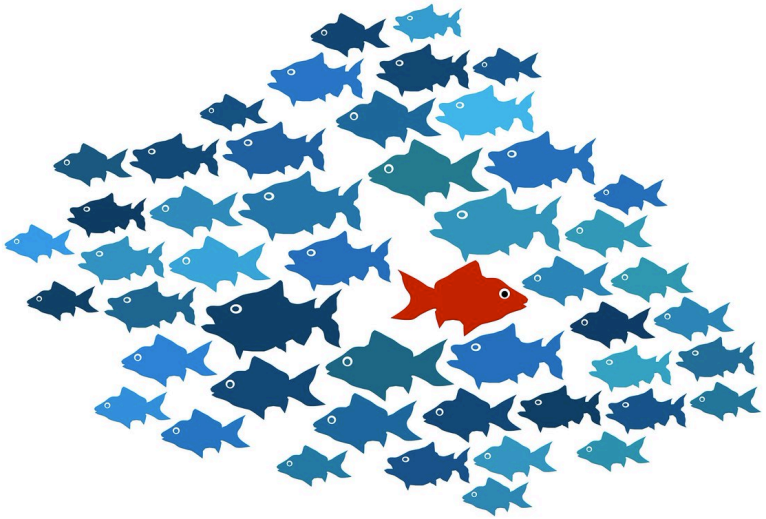
Detection technique

1. Blind Stokes V source finding in low resolution (20”) images (excluding near >100 mJy sources) of 4 sigma sources

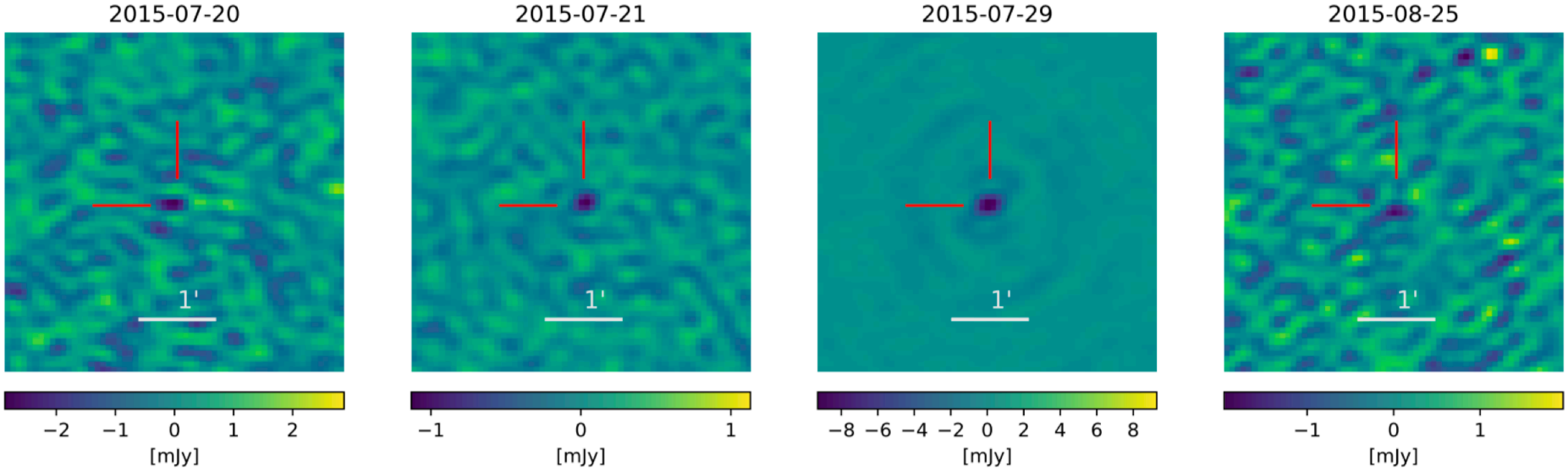
2. Association with Stokes I source (within 5” of Stokes V) to minimise statistical fluctuations

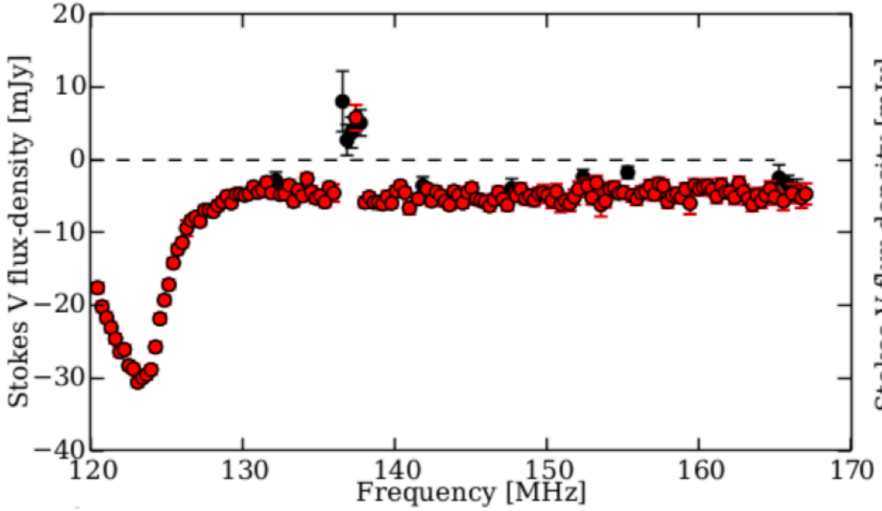
3. Association with a Gaia source that has a parallax / parallax_error >= 3

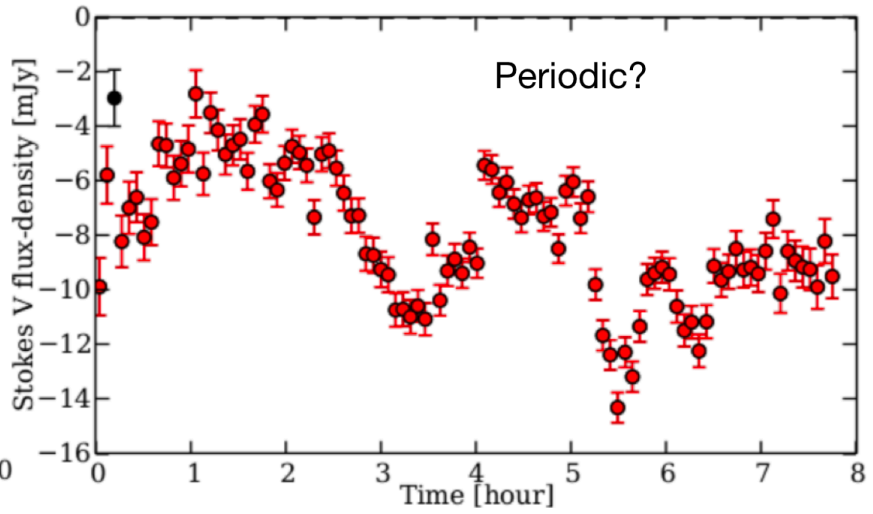
4. Bonus: time variability – AGN variability at low-frequencies quite low (Bell et al. 2018)



The low-frequency population

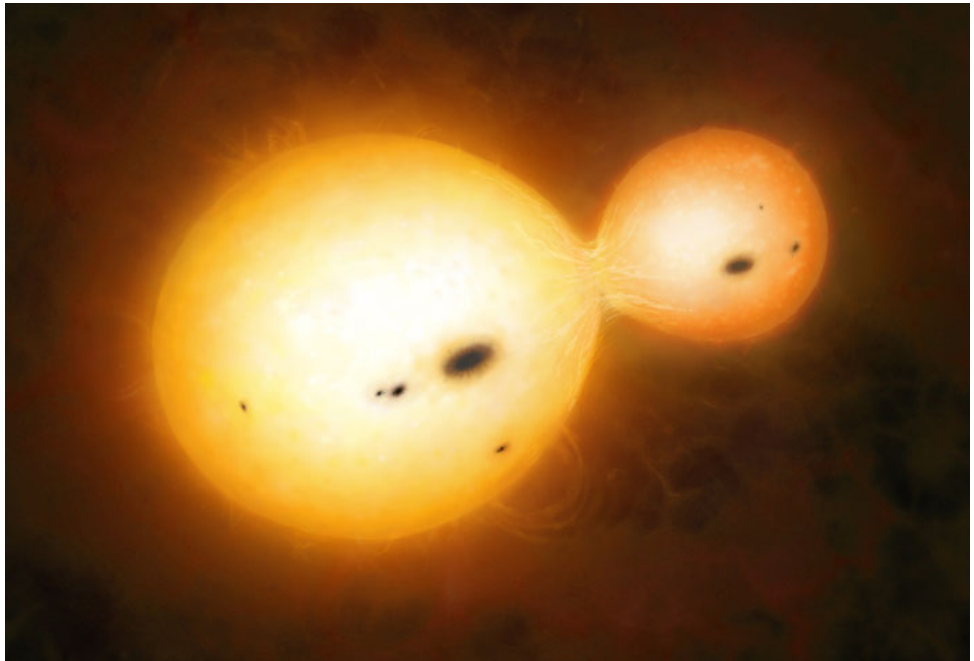




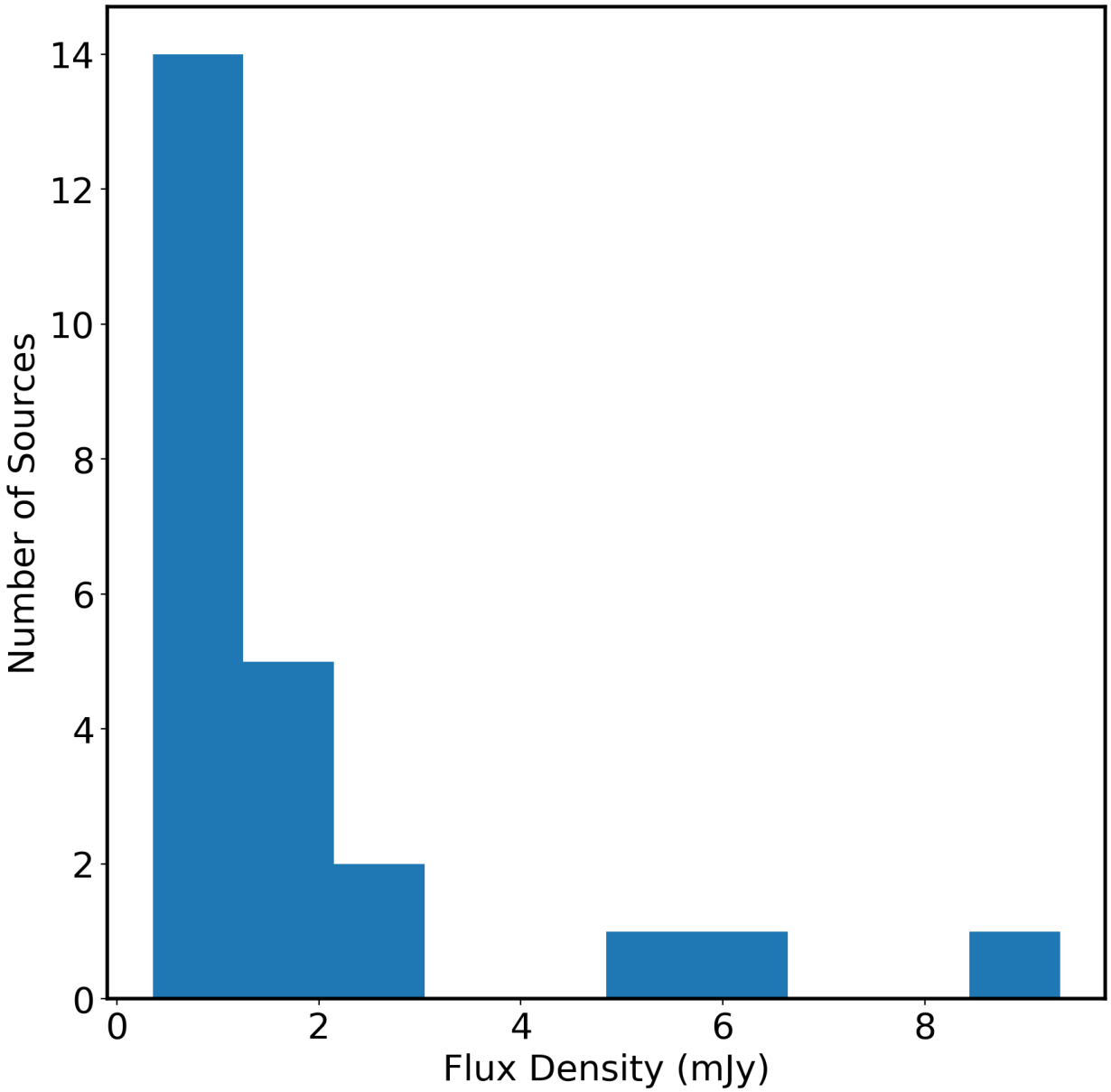


New Population

Type	Number
RS CVn	12
Flare Stars (dMe)	4
‘Active’ M dwarfs	7
Quiescent M dwarfs	3
Contact binary	1
Millisecond Pulsars	2 (3?)

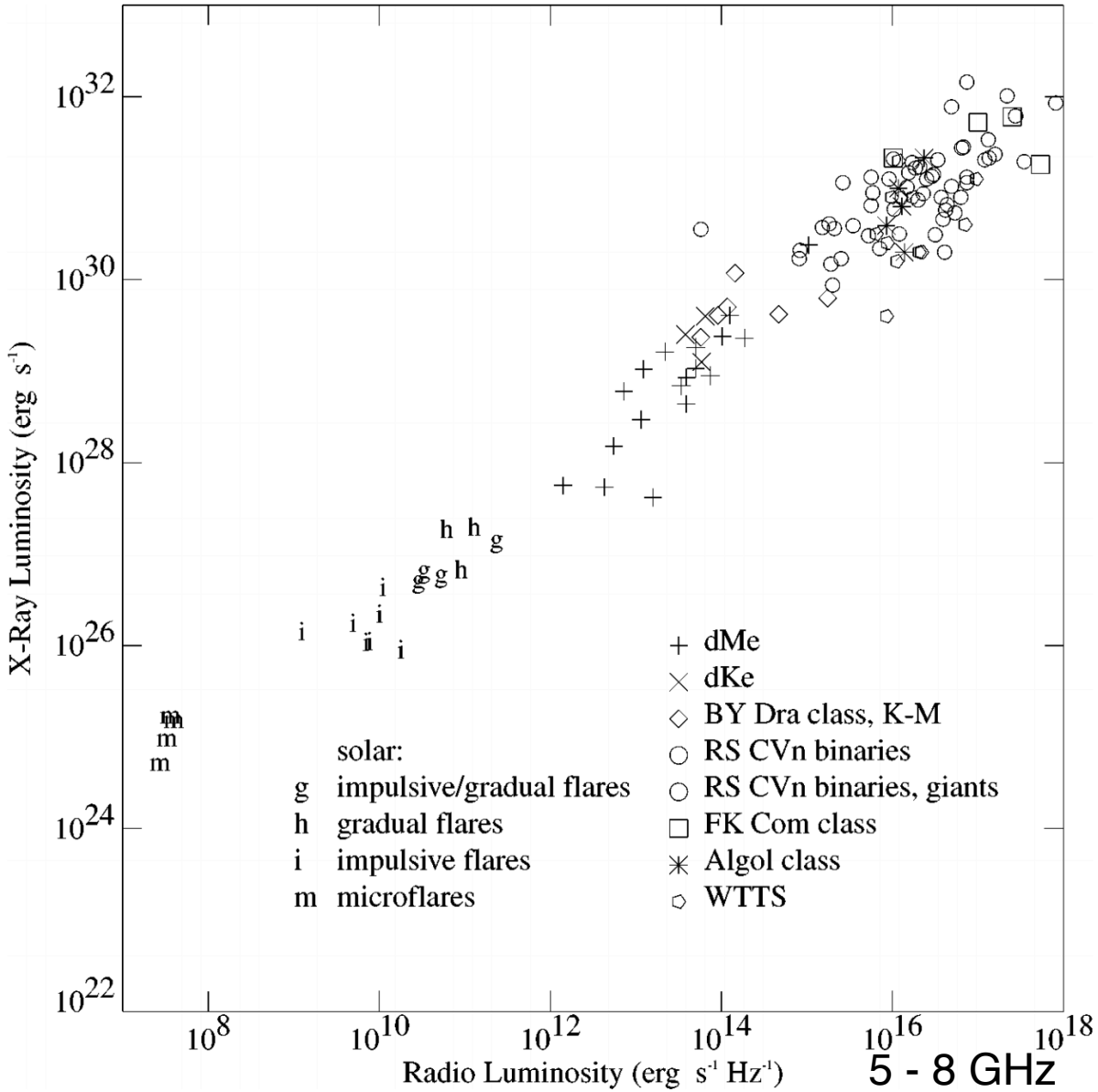


Why have these not been seen before?

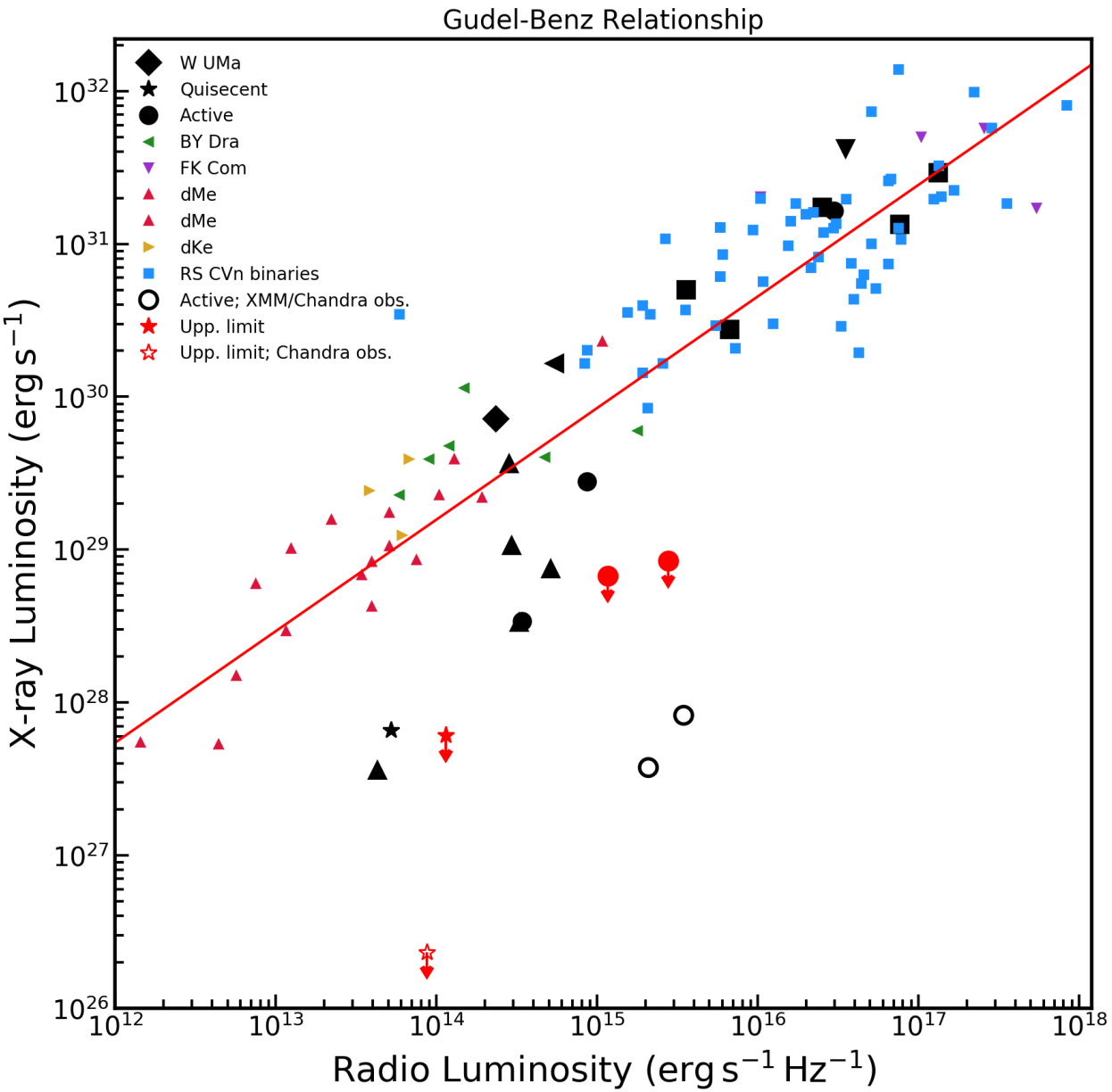


Gudel-Benz relationship

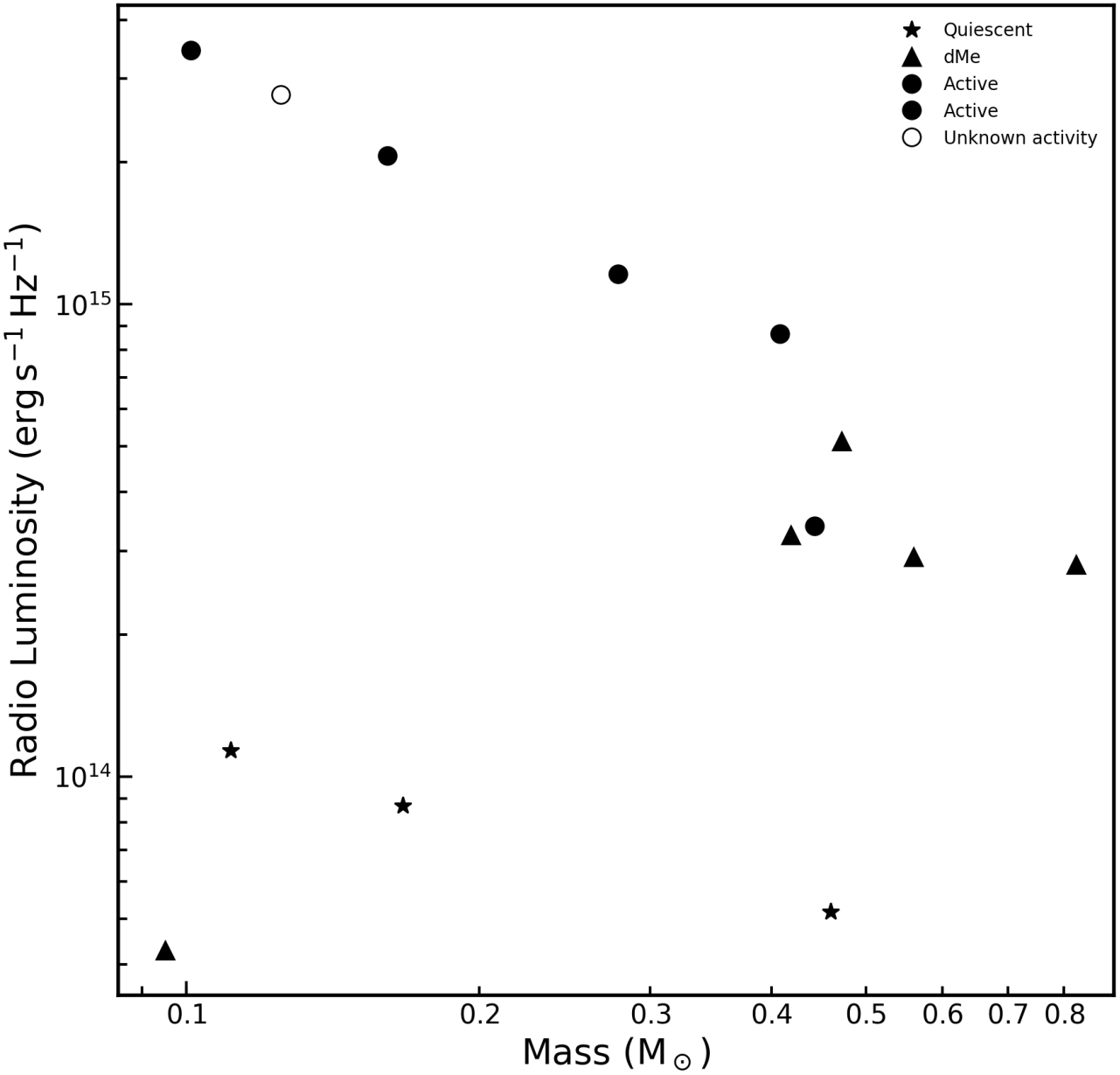
- X-rays trace dense, hot (MK) plasma trapped in closed coronal magnetic loops
- GHz radio probe non-thermal accelerated electrons in open or closed coronal loops (gyrosynchrotron)
- Accepted fact that if radio emission is not gyrosynchrotron, we should see a deviation from this relationship



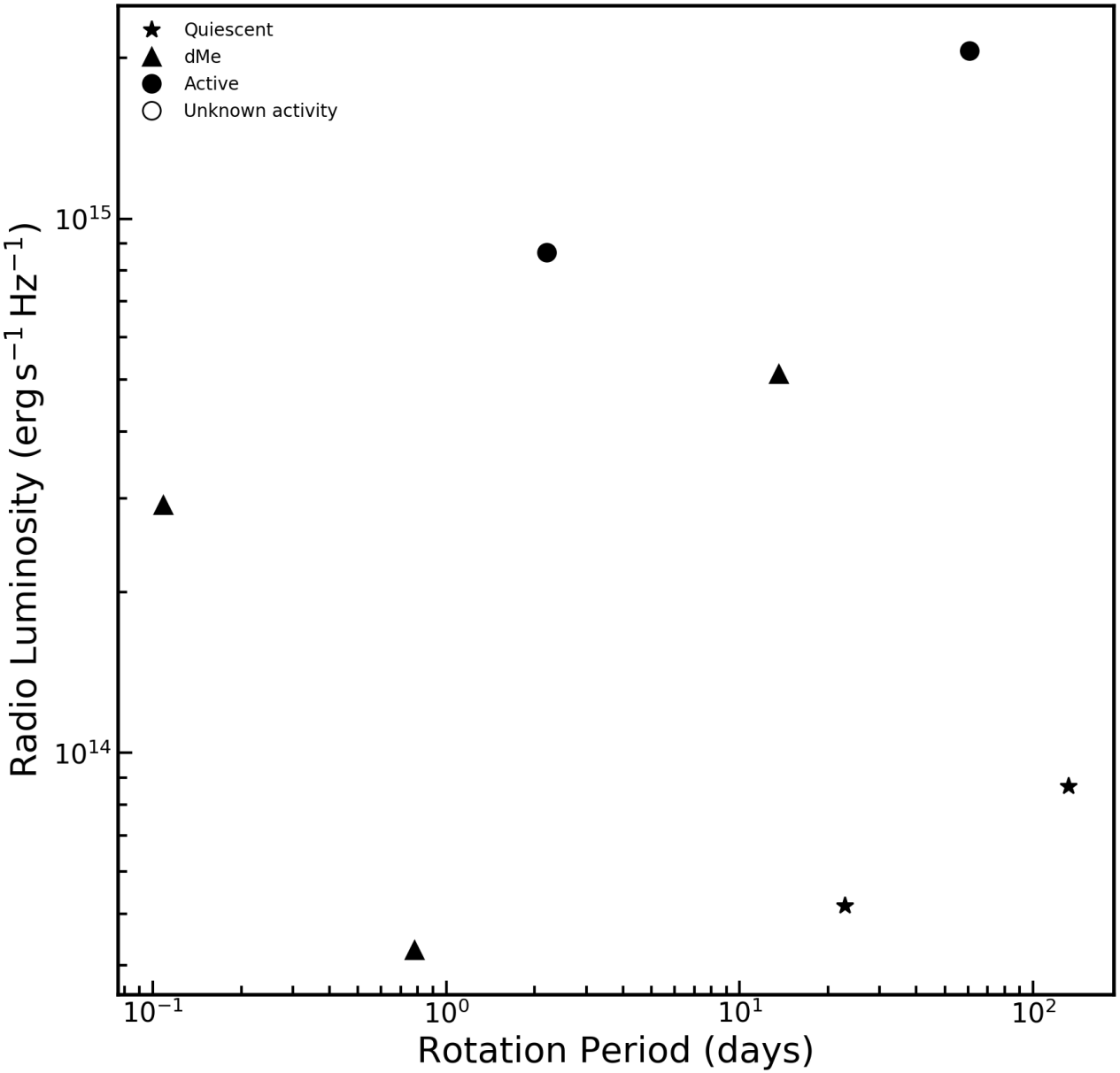
Gudel-Benz relationship



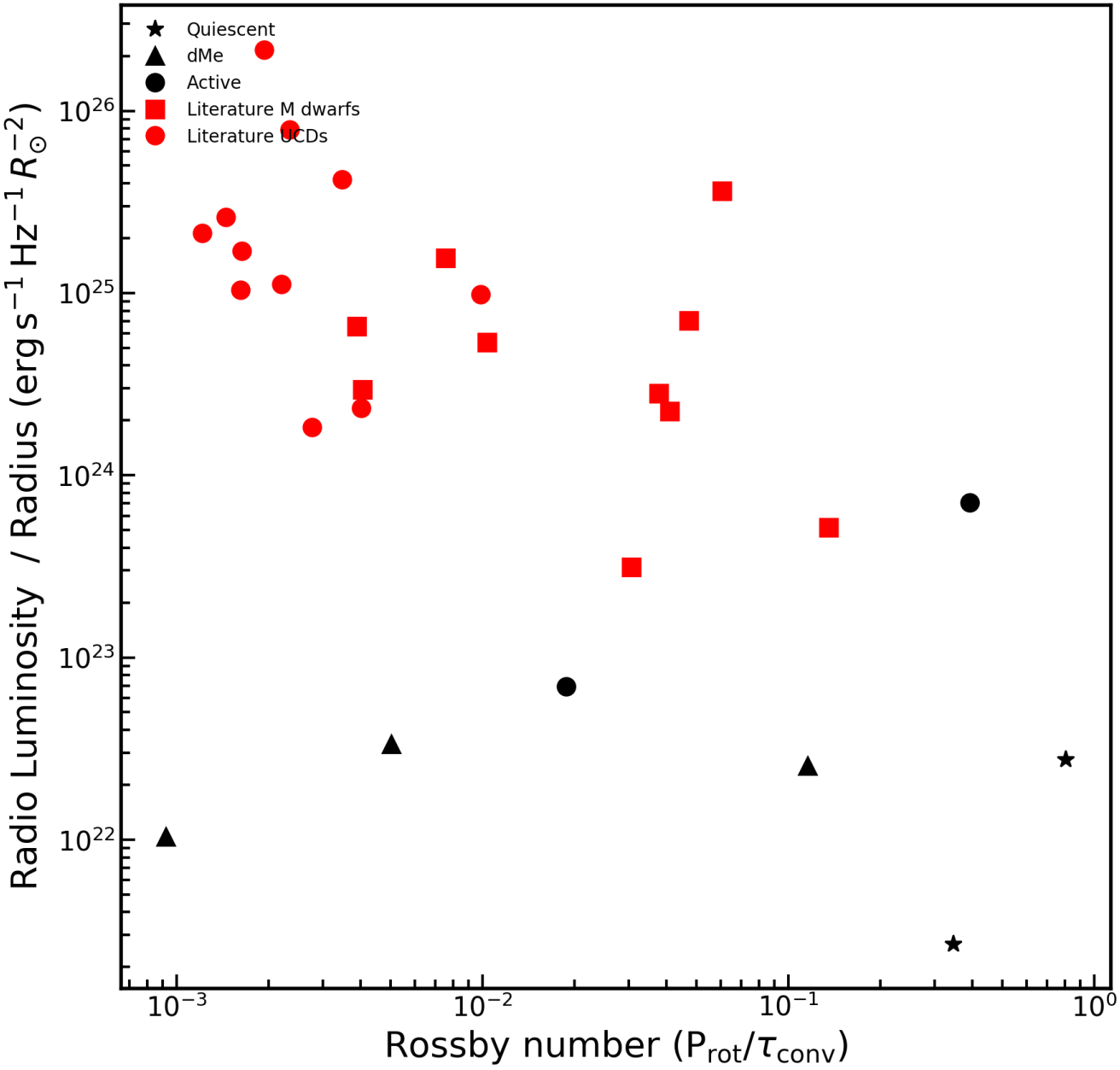
Mass Dependence



Periodicity



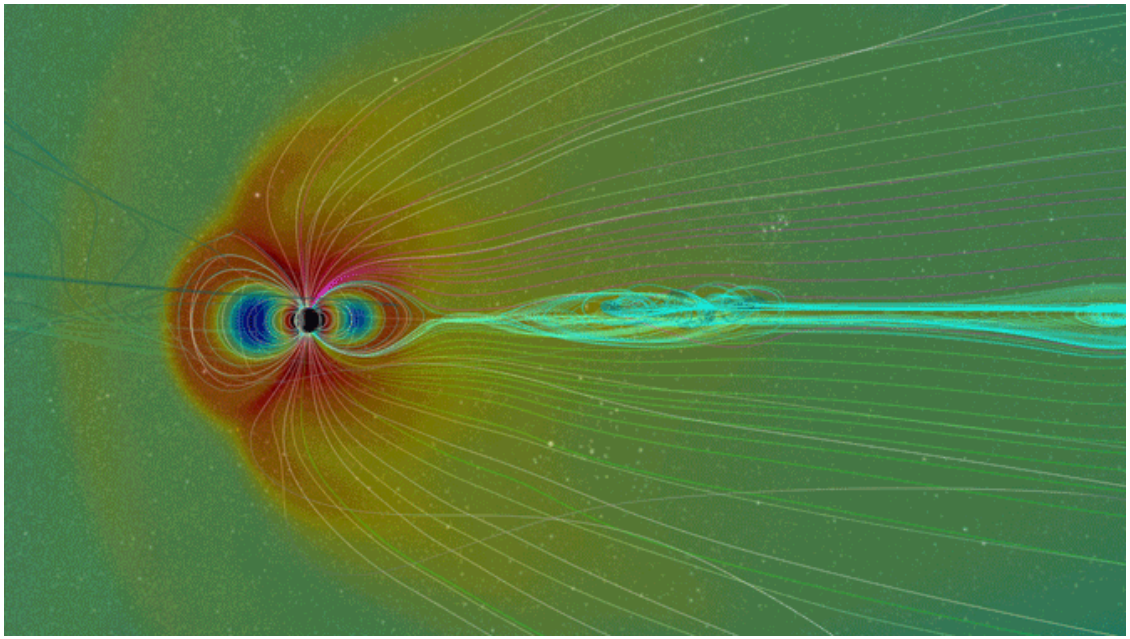
Rossby Number



Current activities and future plans

ASTRON

- ~180 hours approved in LOFAR Cycle 11 to target all stars <6 pc and above a declination +30 deg.
- TESS+LOFAR Proposal awarded 100 hours – constrain CMEs
- Dedicated RV follow-up program in the near-IR in the US
- First detection of stellar system with known super-Earth in ~10 day orbit in Elais-N1 field



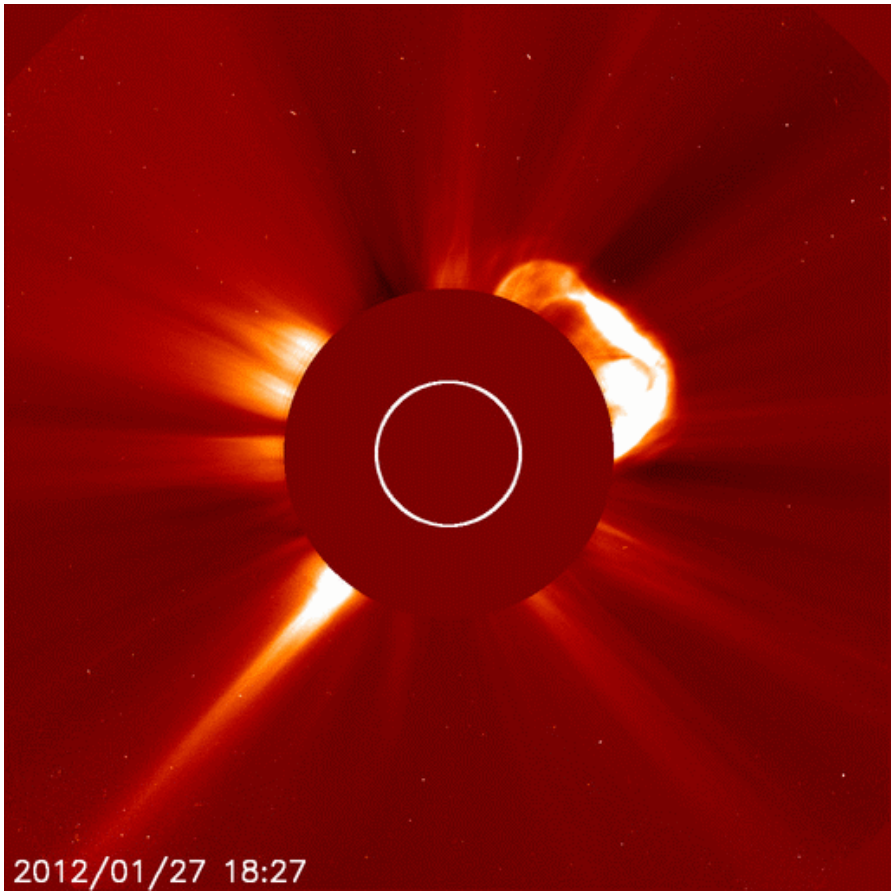
Conclusions

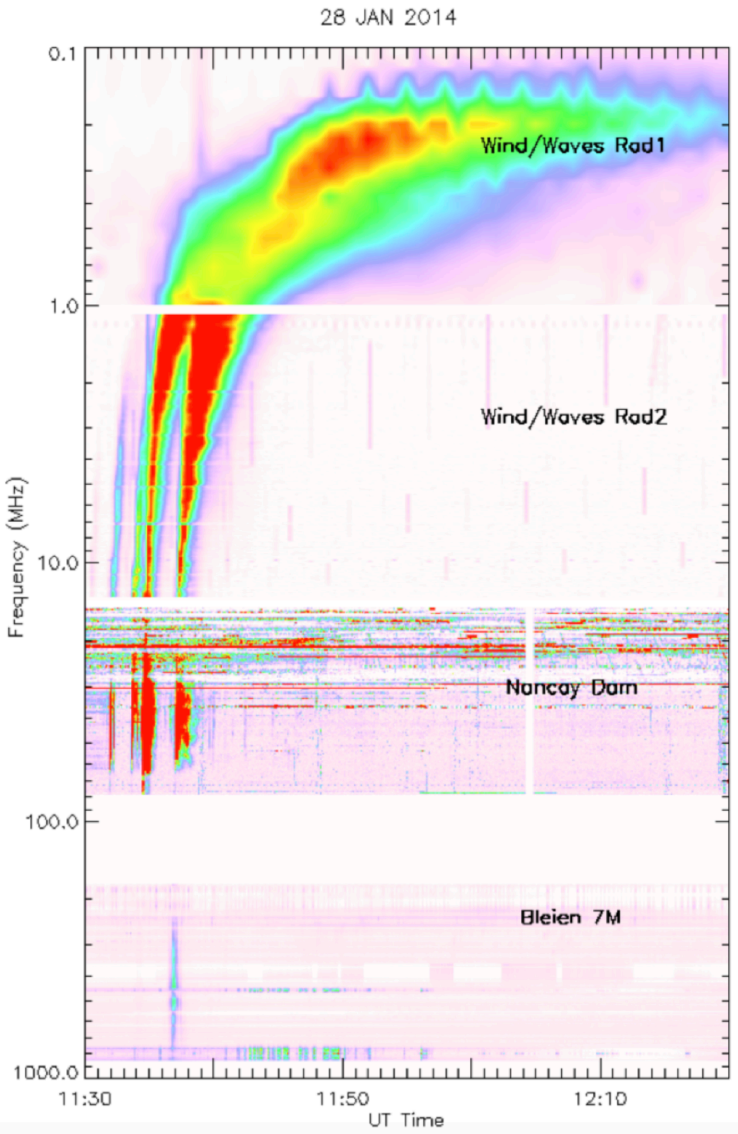
ASTRON

- First detections of stellar systems represents the tip of the nearby radio star iceberg – not what we expected (most auroral in nature, not flares)

- We are really in a new parameter space, where discoveries imply our understanding of emission from stellar coronae (as extrapolated from the Sun) is incorrect or we are seeing a different source of emission

What does the Sun say?



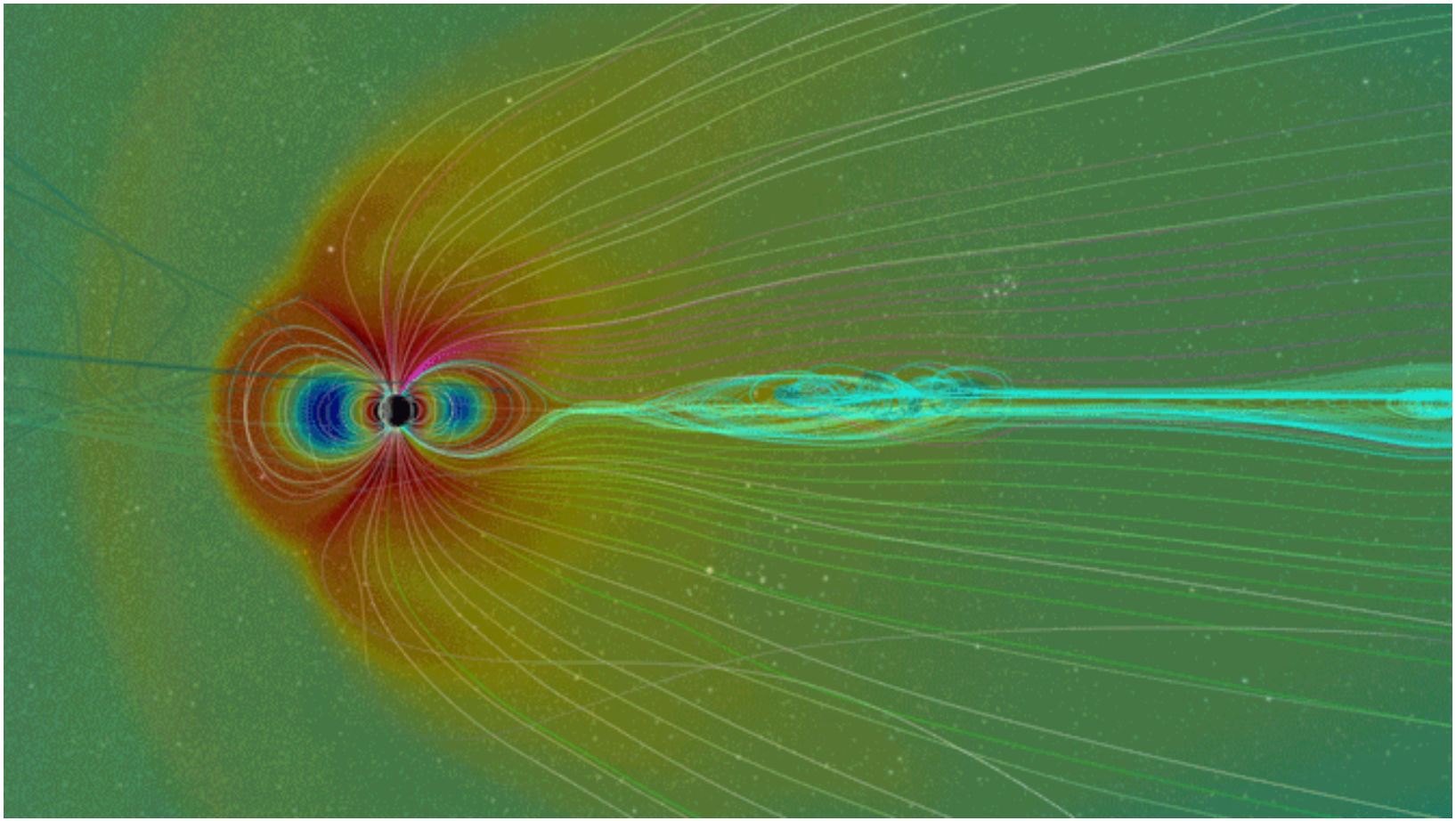


Constraints:

Plasma density profile
Magnetic field (limit)
CME ejecta mass
CME speed

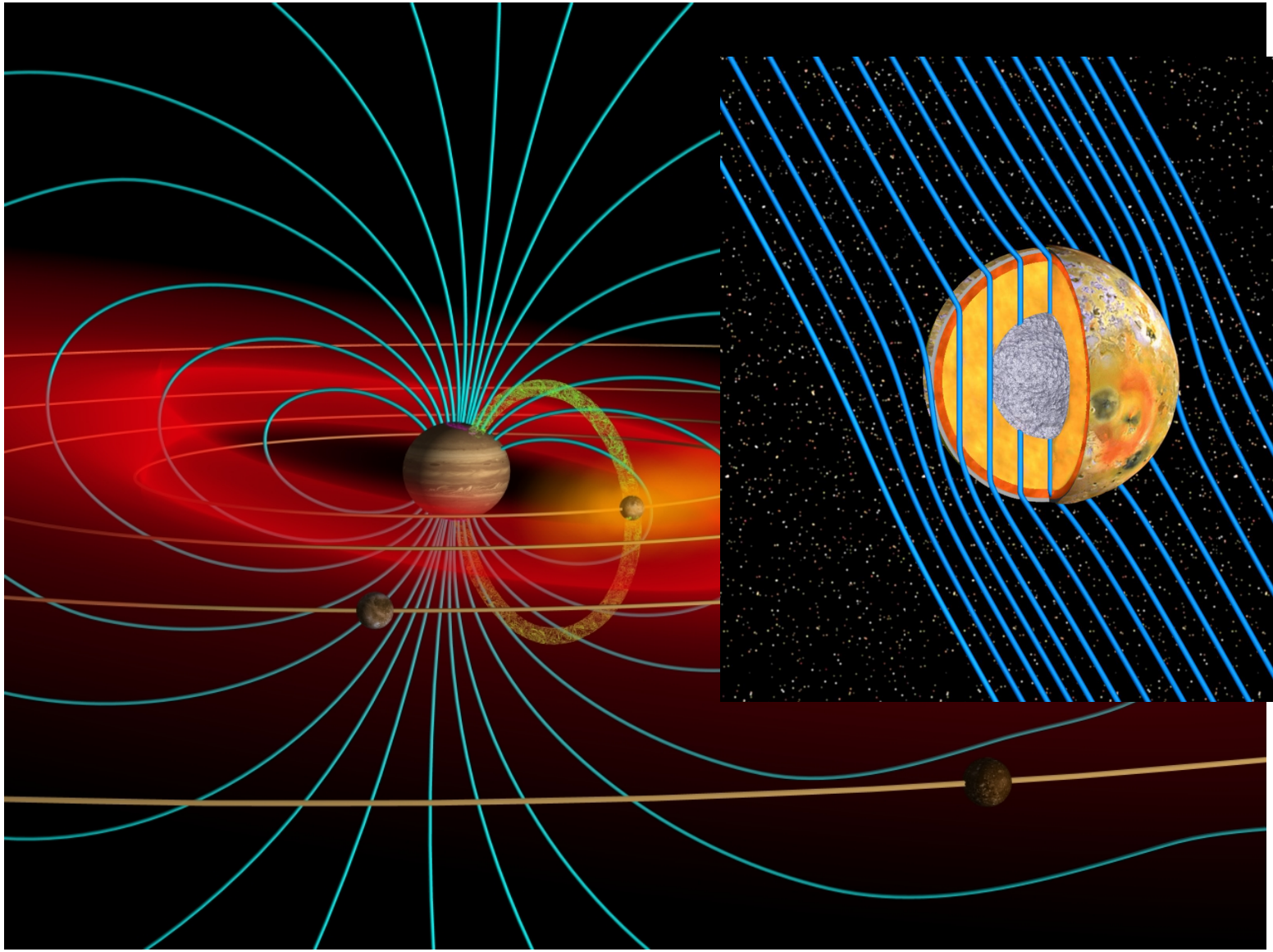
Carrington Event

ASTRON

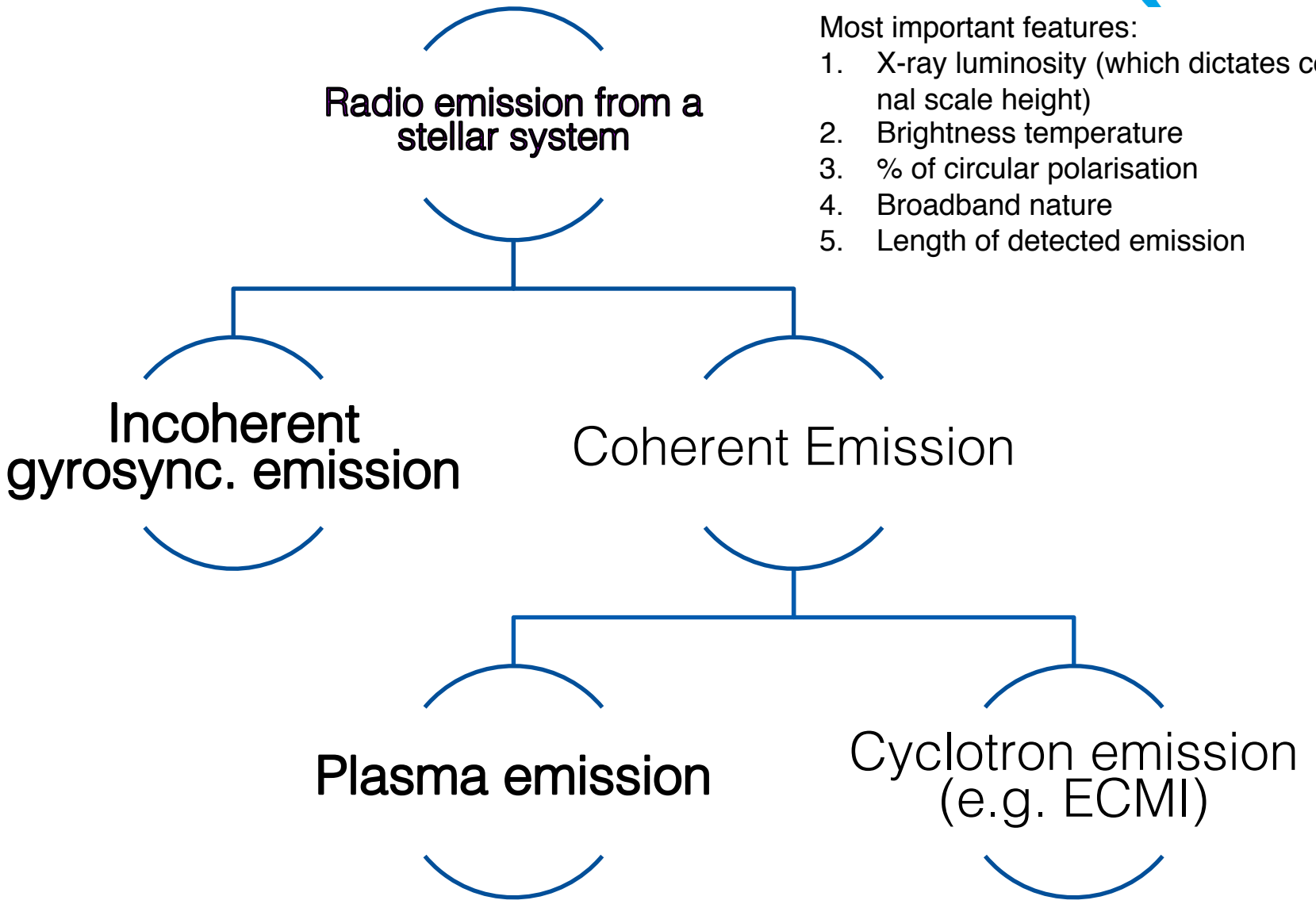


Faraday induction in space

ASTRON



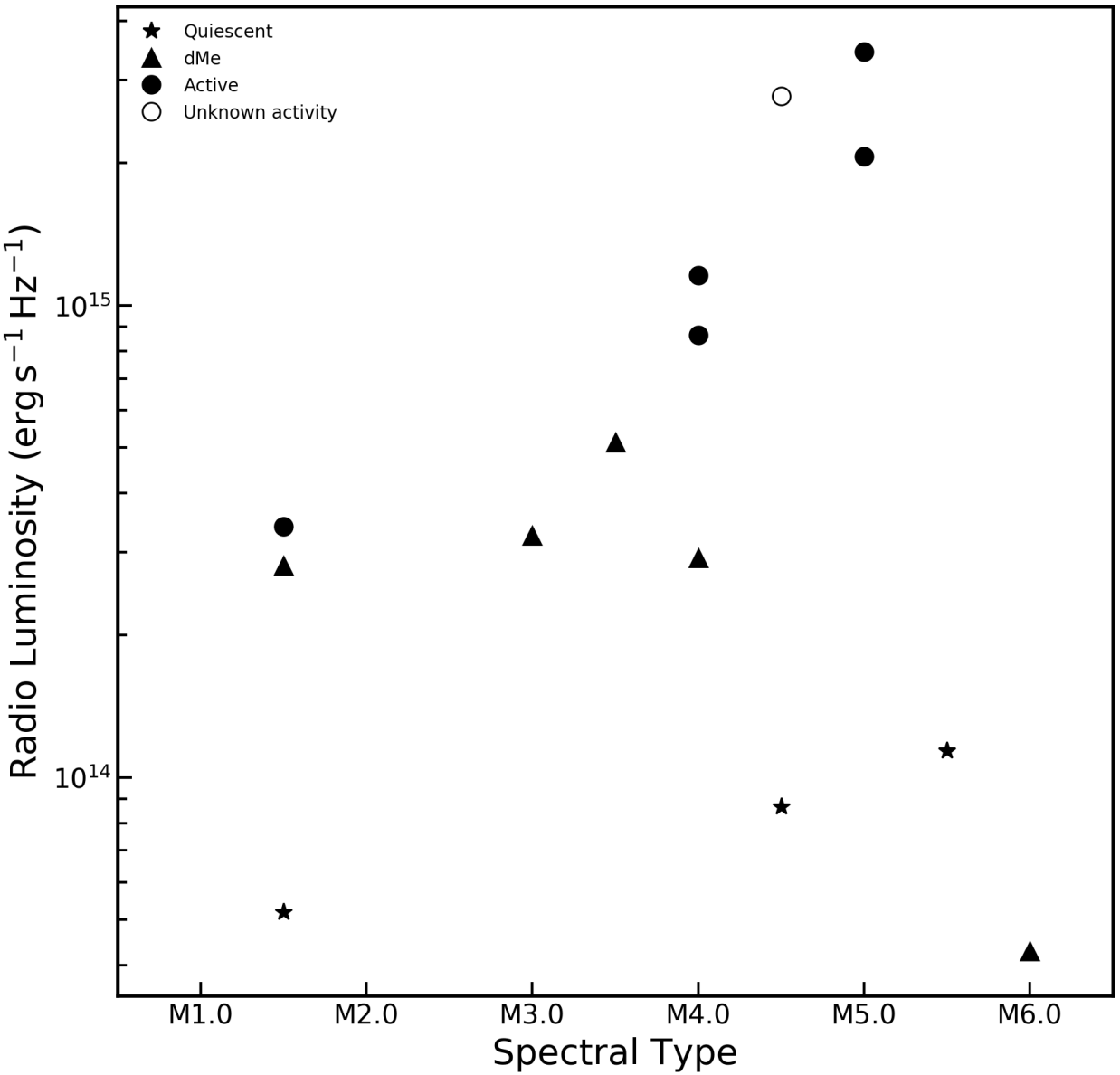
Interpretation of emission



Most important features:

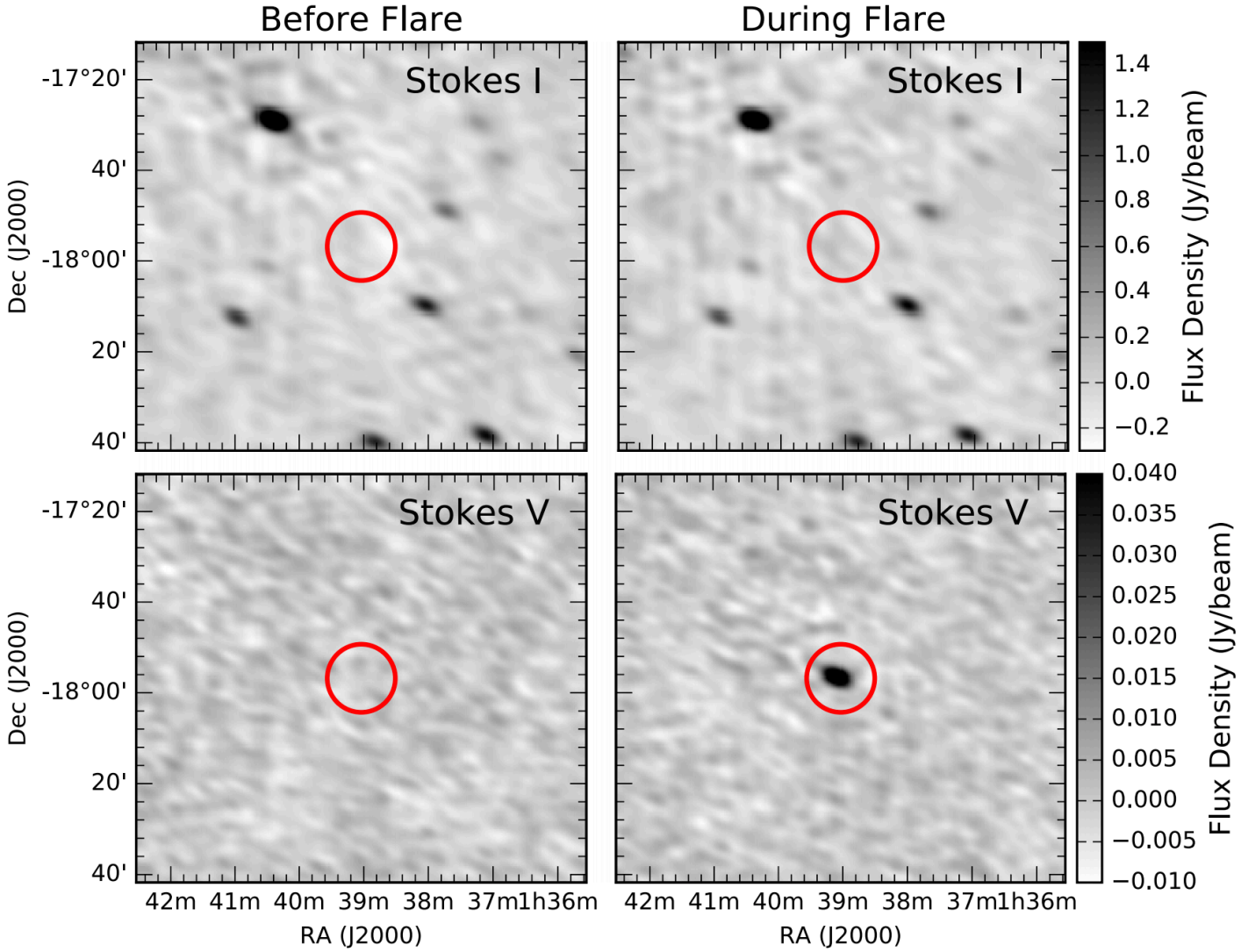
1. X-ray luminosity (which dictates coronal scale height)
2. Brightness temperature
3. % of circular polarisation
4. Broadband nature
5. Length of detected emission

Spectral Class



What has come before?

- Only UV Ceti has been observed at low-frequencies with an interferometer (Lynch et al. 2017)



LoTSS sensitivity, resolution, and time on sky