Faint, Highly-Polarized Flares from UV Ceti with the MWA

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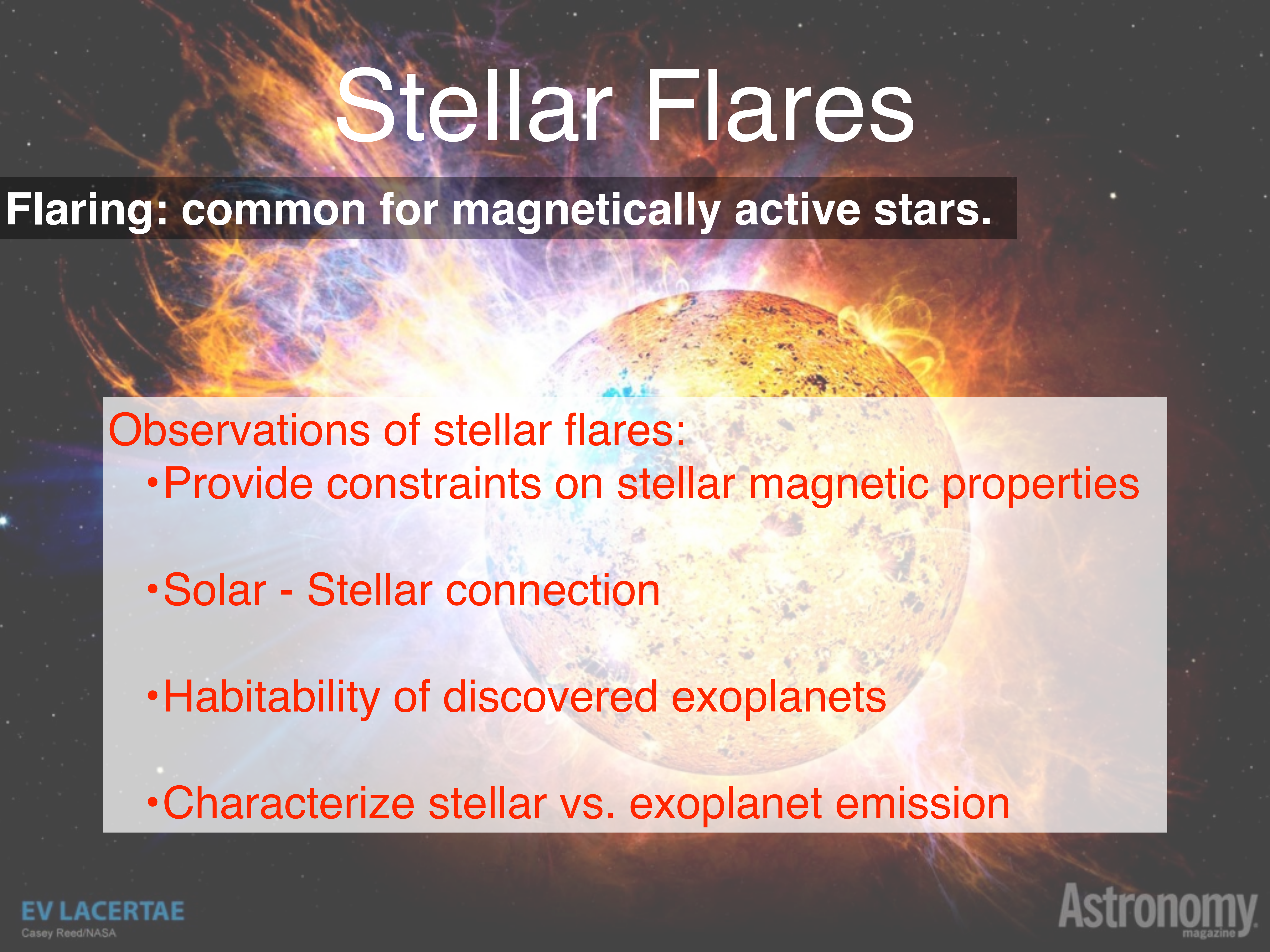
Lynch et al. 2017, ApJL, 836, 30

Stellar Flares

Flaring: common for magnetically active stars.

Observations of stellar flares:

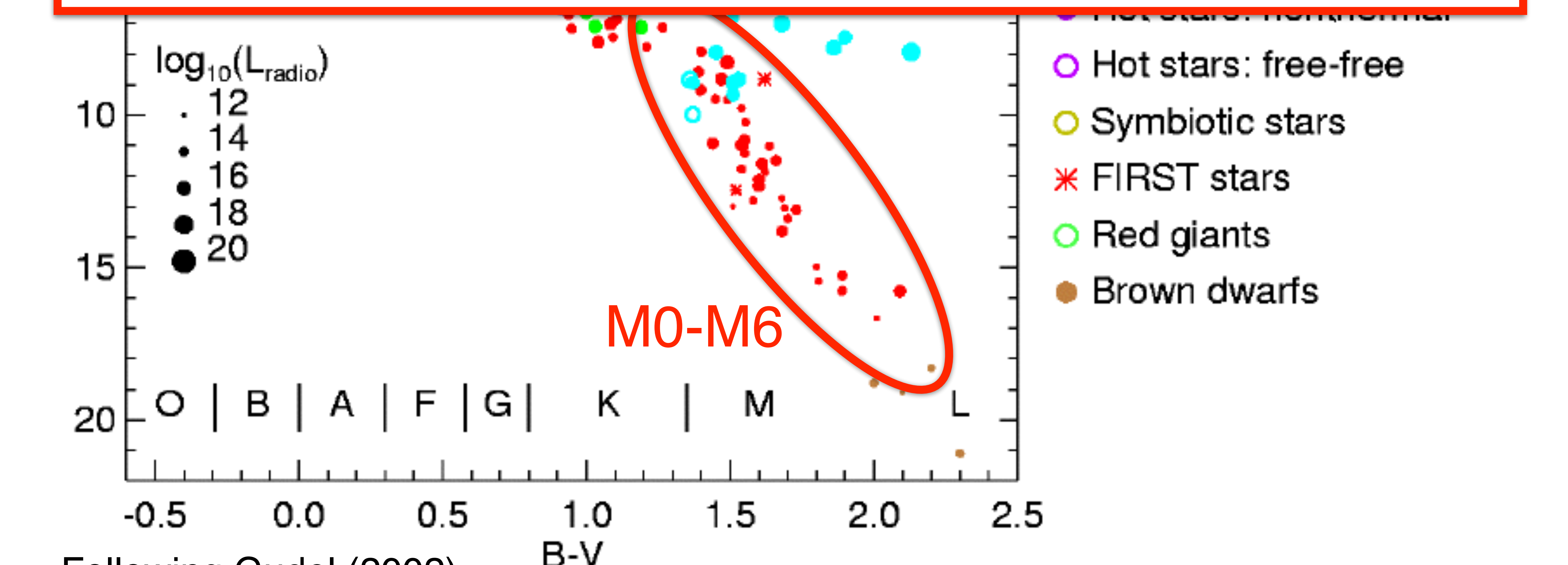
- Provide constraints on stellar magnetic properties
- Solar - Stellar connection
- Habitability of discovered exoplanets
- Characterize stellar vs. exoplanet emission



Radio H-R Diagram: Radio Luminosities

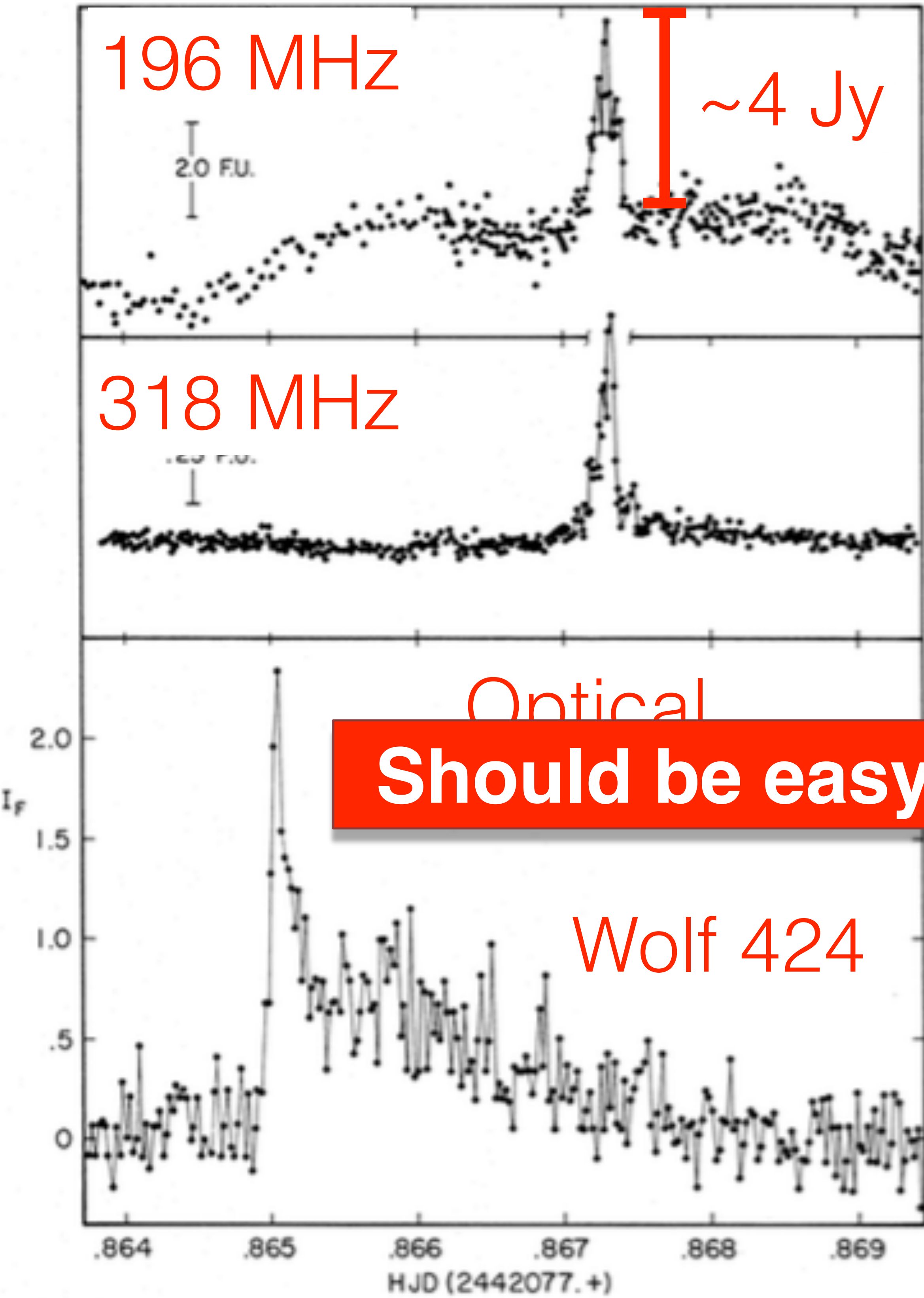
M dwarfs:

- Dominant stars in Galaxy (~70%)
  - Some of the nearest exoplanets (e.g., Proxima Cen)
- Magnetically active, B~2-4 kG ($B_\odot$~10 G)
  - Much higher filling factor than for Sun
- Radio emission from magnetically-confined coronae
- >10^6x radio emission compared to Sun, increase w/ spectral type



Following Gudel (2002)

Low-Freq Flares



Spangler et al. (1976)

Early single dish observations (1960's - 1980's) measured:

- Flare rates = 0.03 - 0.8 flares/hour
- Duration = 0.5 - 3 hours
- Intensities = 0.8 - 20 Jy
- High fractional circular polarization (>70%)

Should be easy to find in blind surveys

Z CMi at 408 MHz:

1. Davis et al. (1978, Nature)
2. Kundu et al. (1988, ApJ)

Total number of sources with m-wave emission = 11

Recent Blind Surveys

Non-detections in long-duration, widefield surveys for transients:

- Tingay+ ('16): Kepler K2 field, 5.9 hours, 5σ ~ 0.5 Jy
- Rowlinson+ ('16): 100 hrs of MWA EoR field, 5σ ~ 0.235 Jy
- NB: expect: up 0.1-1 flare/hour, peak~1 Jy

➡ 2375 M dwarfs within 25 pc expected (Winters+ '15)

➡ 70 nearby M dwarf stars per MWA pointing

➡ < 2% have detectable 100 - 200 MHz flare emission

Where are all the flare stars?

Try targeted observations to assess behavior

UV Ceti Observations

UV Ceti:

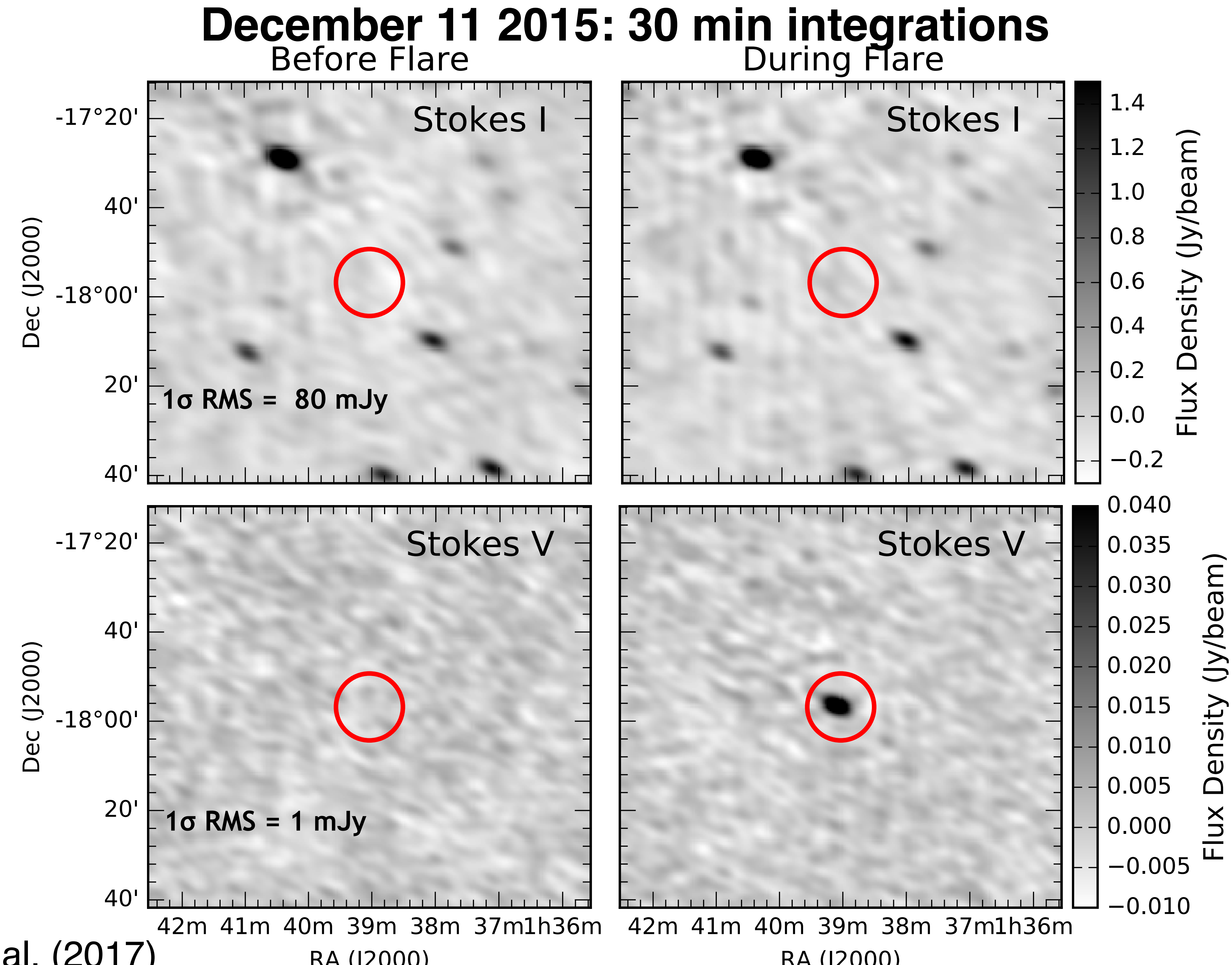
- Binary system (P_b=26 yr) — both exhibit radio flares
- Spectral types = M5.5 (BL Cet) + M6 (UV Cet)
- BL Cet P_{rot}=5.86 hr; UV Cet P_{rot}= 5.45 hr
- Distance = 2.7 pc

- Total observation time = 8.8 hours — split over 4 days in Dec 2015

- Frequency = 154 MHz

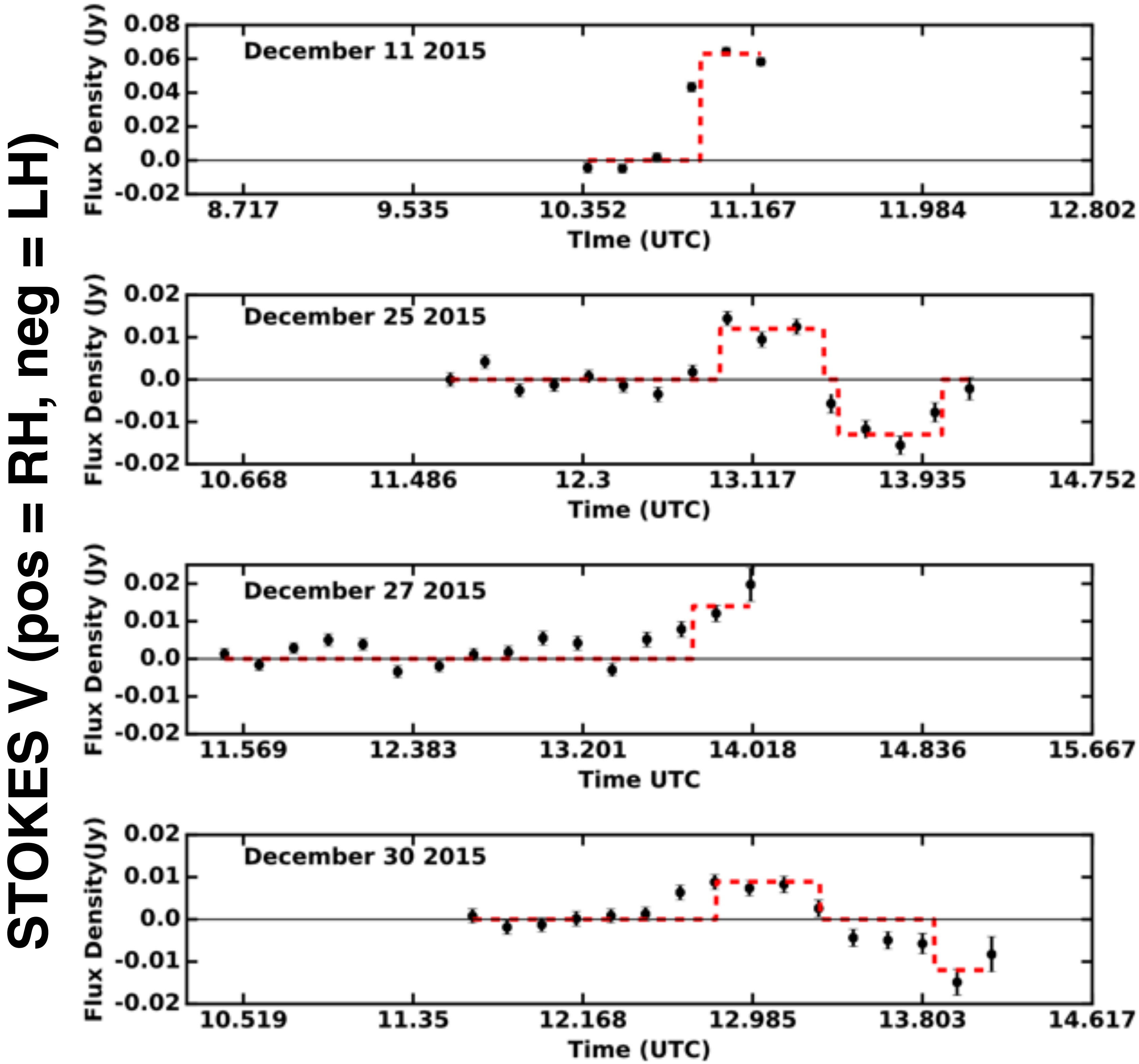
- Focus on Stokes V (circular polarization): noise in Stokes I dominated by confusion (factor of 80 higher!)

Faint, Polarized Flares



Lynch et al. (2017)

Light Curves



- 4 flares total
- Peak flux densities ~0.1 Jy
- Duration ~30min
  - Possibly followed by flare of opposite sign(?)
- Modest evidence for periodicity:
  - P=5.45 h @ 95% confidence
  - Rotation?

Emission Type

Brightness Temperature: $$S_\nu = 2k_B T_b \left(\frac{\nu}{c}\right)^2 \left(\frac{l}{d}\right)^2$$

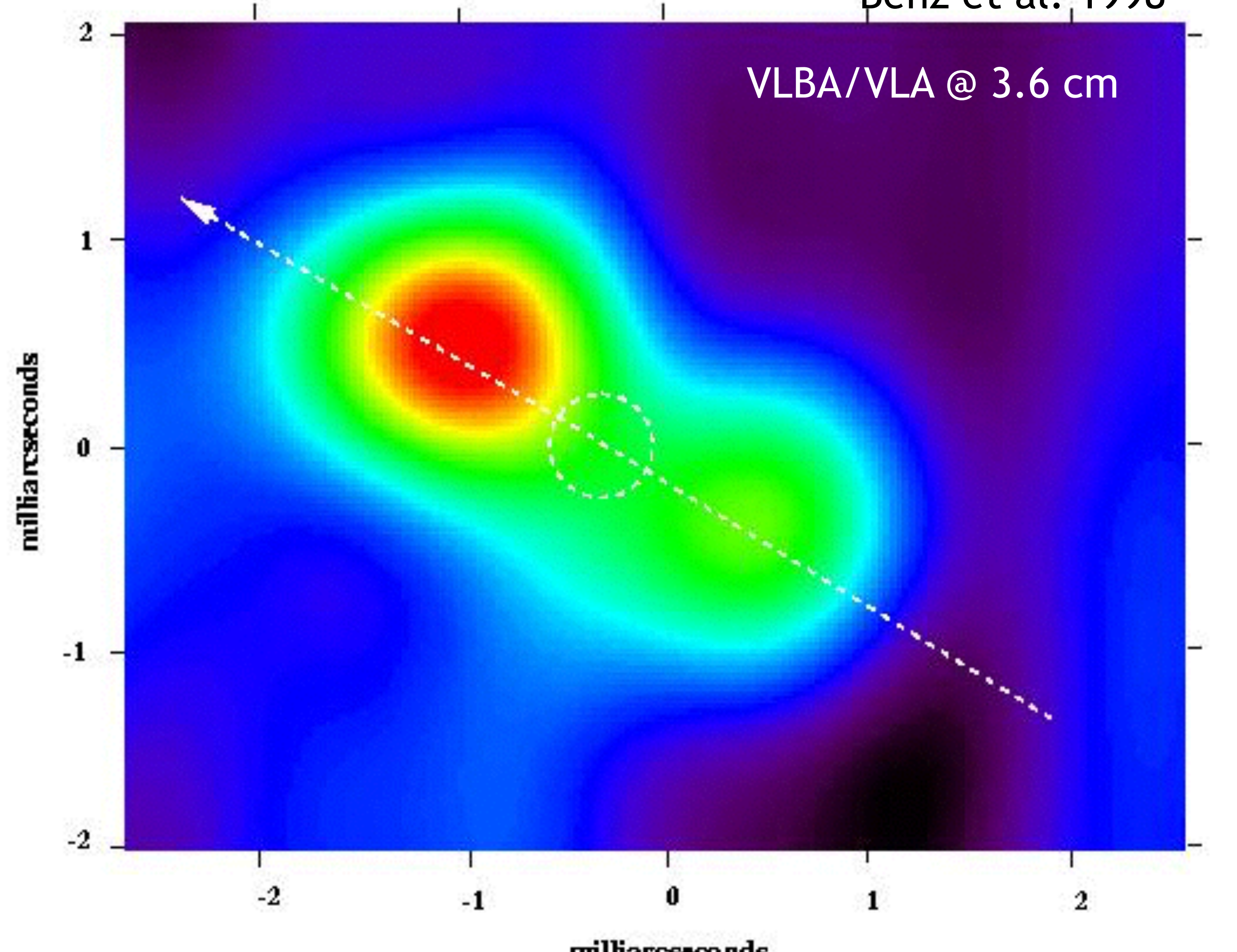
A. Source size constrained by assuming periodic persistent source:

- $l = \Delta t\, v\sin(i) \sim 10^9$ cm
- $T_b \sim 10^{14}$ K

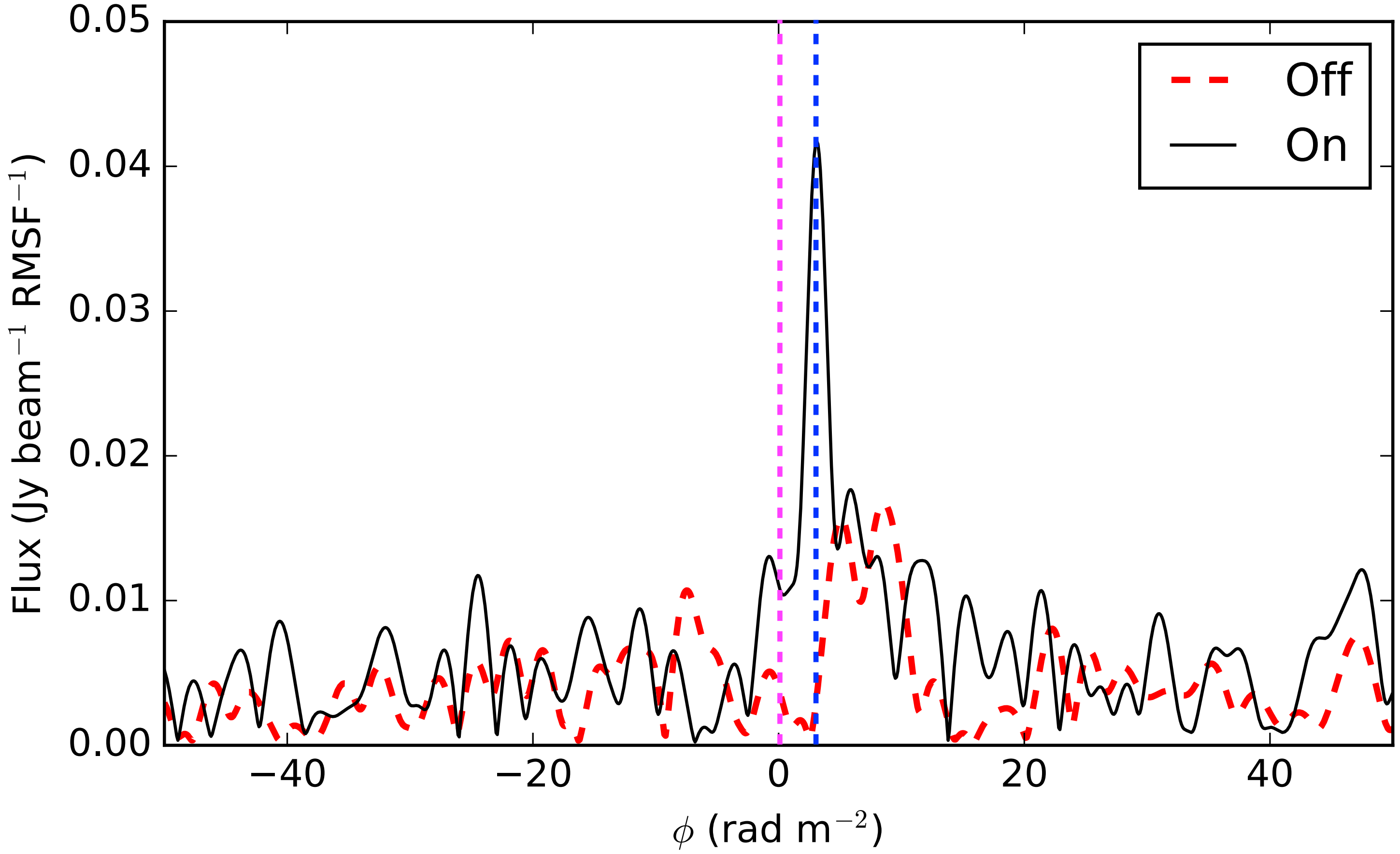
B. Source size constrained by VLBA:

- $l \sim 10^{10}$ cm ($\sim 0.14\, R_\odot$)
- $T_b \sim 10^{13}$ K

Benz et al. 1998



Emission Type



Polarization:

A. Circular: Both right & left handed; >27%

B. Linear: >18%; $\phi = +3$ rad m^{-2}; Faraday rotation ~12 rad

→ **Elliptically Polarized** → **Electron cyclotron maser**

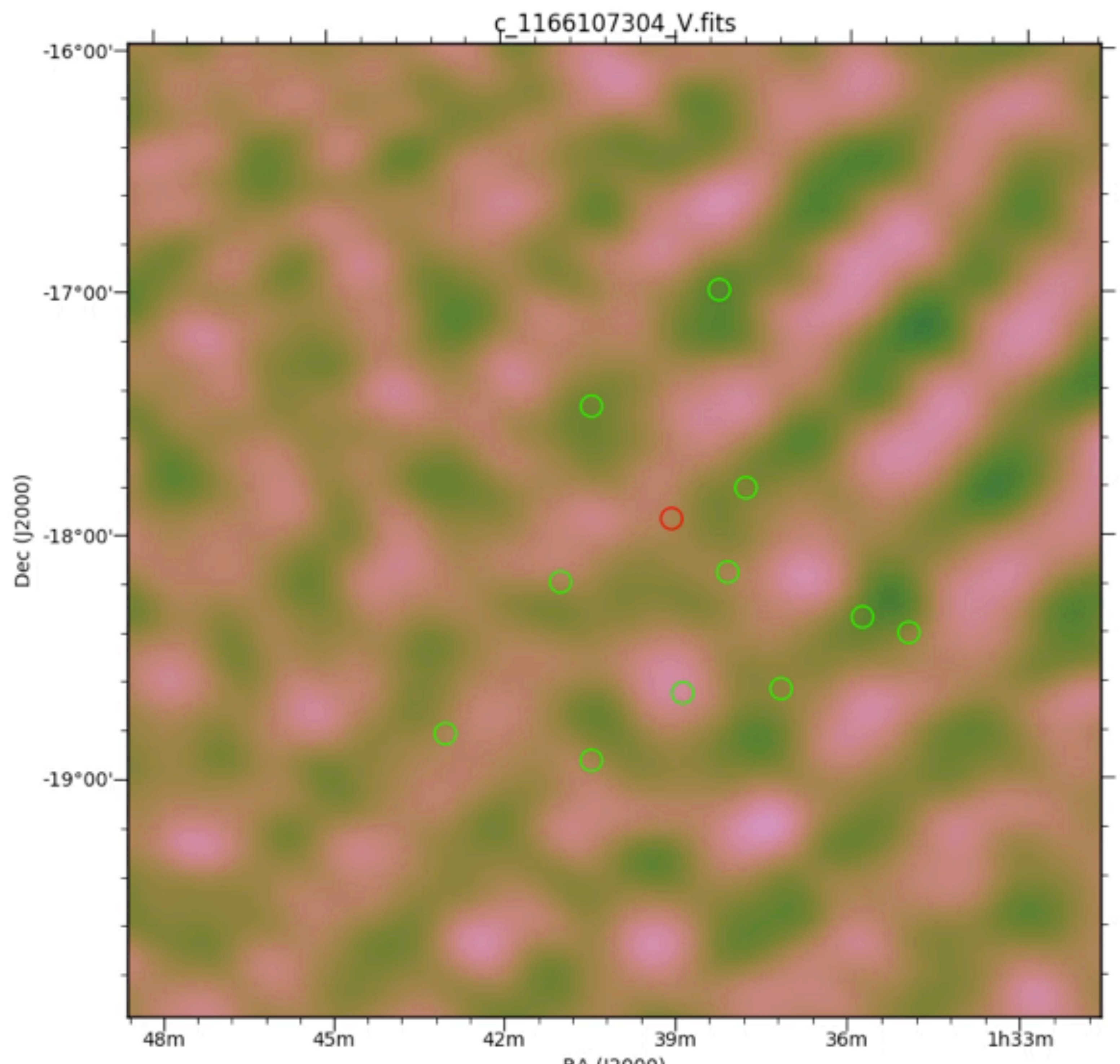
$\nu_{obs} = (B)$ 2.8 MHz → B = 28 G

$\nu_{pe}^2/\nu_{ce}^2 \ll 1$ → $n_e \lesssim 7 \times 10^7$ cm^{-3}

Follow-up @ 154 MHz

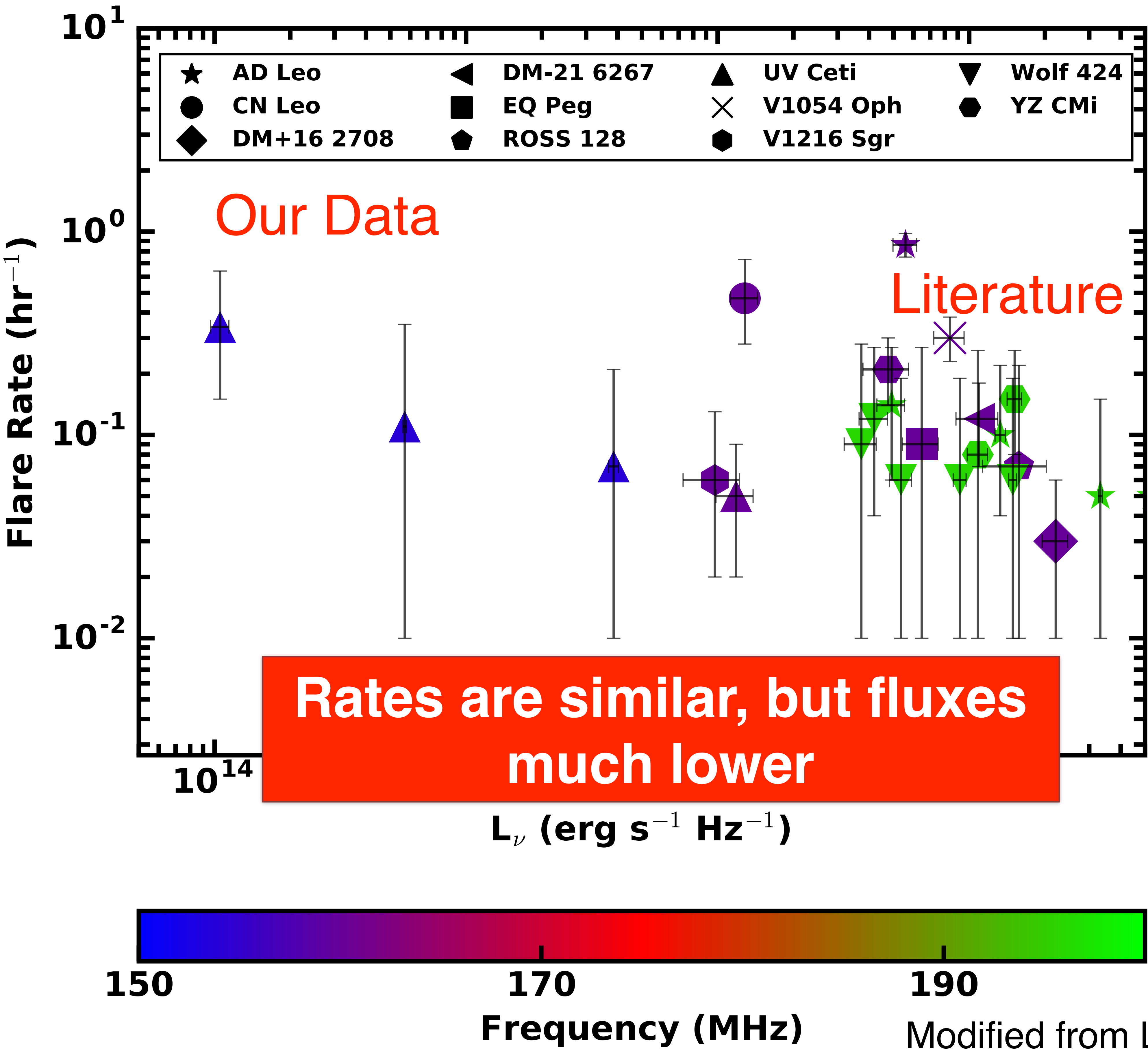
15 hours follow-up observations of UV Ceti w/ compact (Hex) array:

- 5σ sensitivity ~ 0.1 Jy
- Detect single flare
- S~ 0.4 Jy (7x brighter); lasts ~4 min (10x shorter)



Preliminary!

Flare Rates



Modified from Lynch et al. (2017)

Summary

1. Frequencies < 5GHz: M dwarfs flares dominated by coherent bursts. Infer *B,* local plasma properties. Assess habitability

2. Previous observations suggest M dwarf flares easy to detect @ 150 MHz — but blind surveys do not find them

3. Targeted observation of UV Ceti reveal:
   - Low-intensity, periodic flares (30 min) — electron cyclotron maser

   - Bright, short duration flare: **similar flares would be detectable within Rowlinson et al. (2016)!**

4. Flare distribution not well constrained — need more detections

6. With better detections can constrain physical environment, assess habitability, determine rotation properties, …