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# Radio Search for Extrasolar Coronal Mass Ejections and Energetic Particle Events

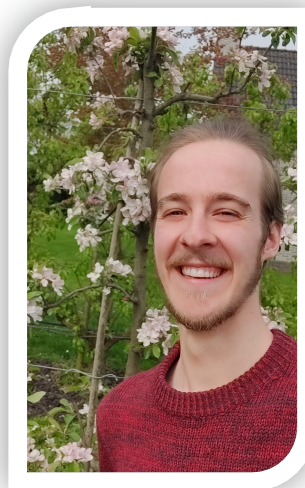
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David Konijn

Radio Stars 2024

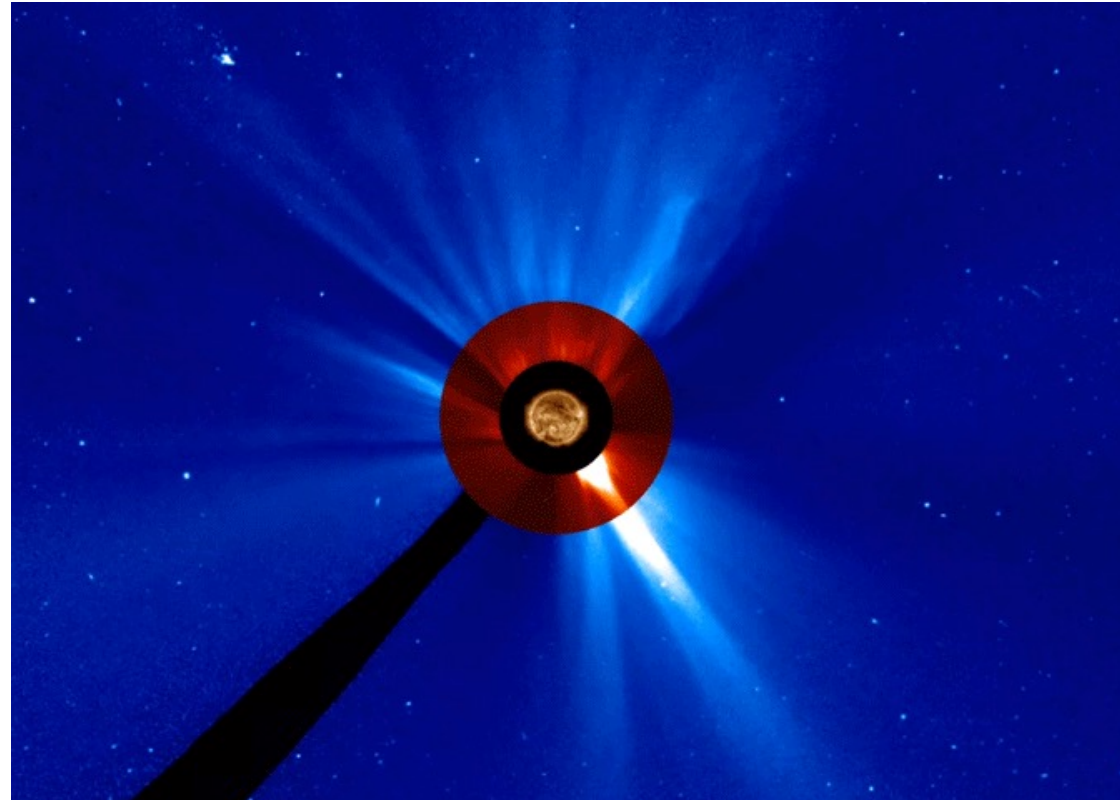
Harish Vedantham  
Joe Callingham

 **erc** 190136710; P.I. H. Vedantham





# Coronal Mass Ejections & Energetic Particle Events



LASCO coronagraph (370-700nm); Brueckner et al. 1995



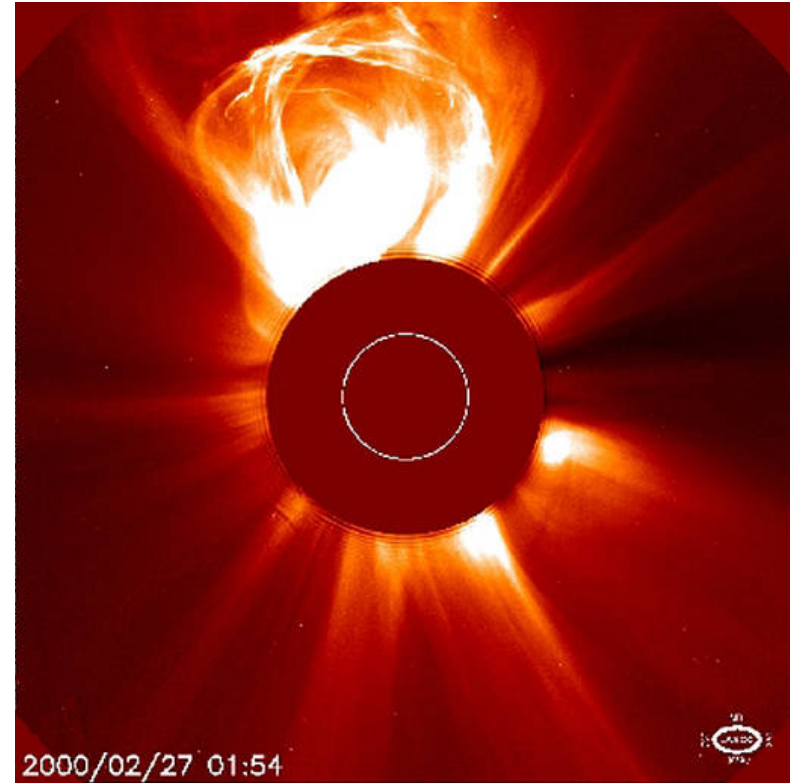
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# Eruptive Solar Flares



Painted by Frederic Edwin Church 1865



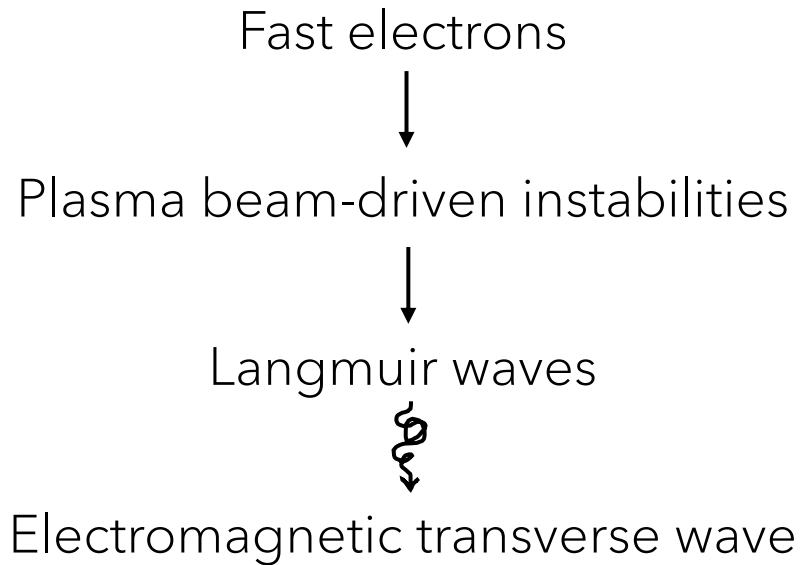
LASCO coronagraph (370-700nm); Brueckner et al. 1995



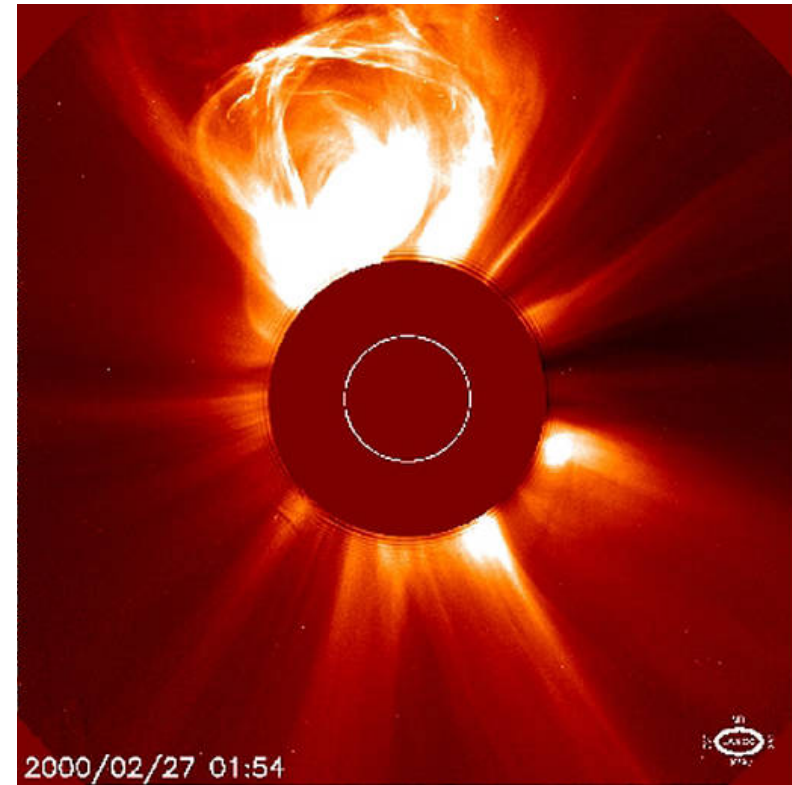
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# Plasma Emission



$$\nu_p = \left( \frac{n_e e^2}{\pi m_e} \right)^{1/2} \approx 9 n_e^{1/2} \text{ kHz}$$



LASCO coronagraph (370-700nm); Brueckner et al. 1995



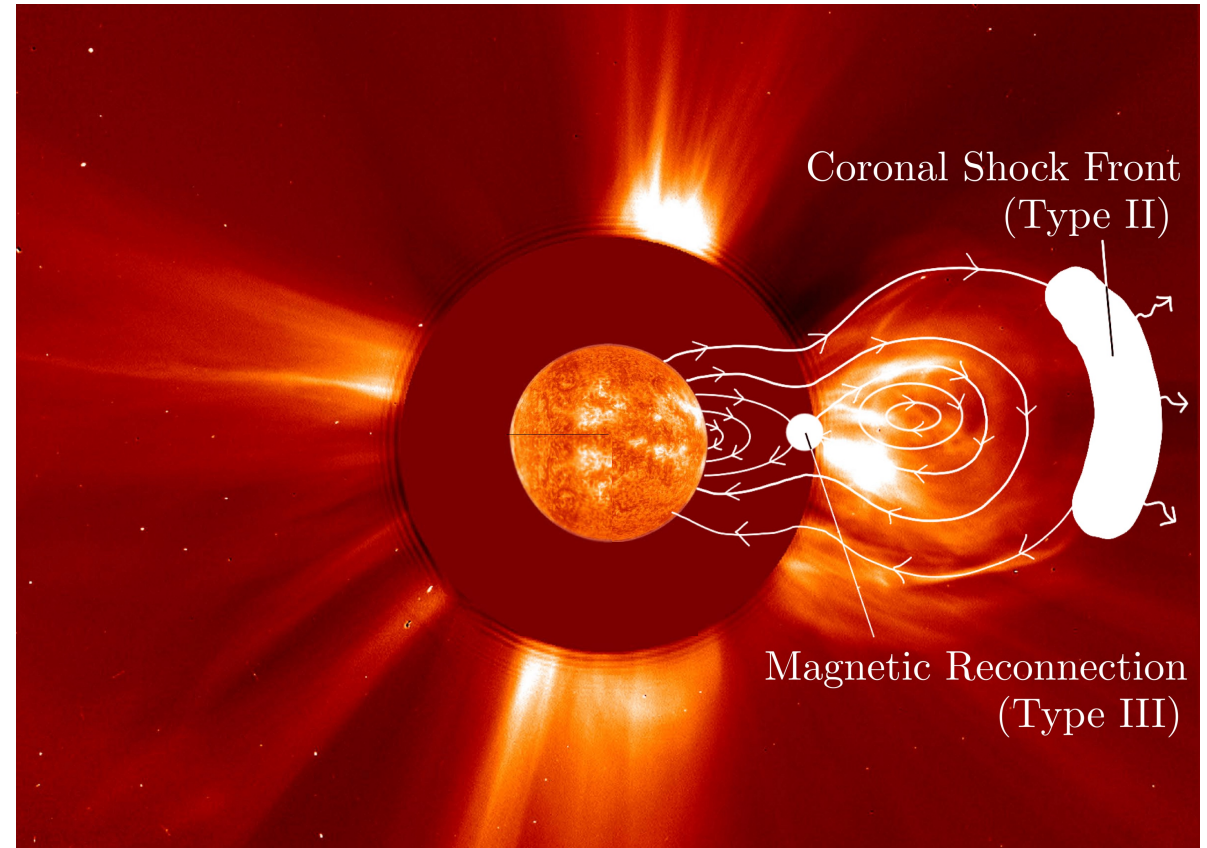
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# Eruptive Solar Flares

- Type II: Accelerated electrons at forefront of shock
- Type III: Accelerated electrons on open field lines



LASCO coronagraph (370-700nm); Bruekner et al. 1995;  
Extreme ultraviolet imaging telescope (17-30nm); Delaboudiniere et al. 1995

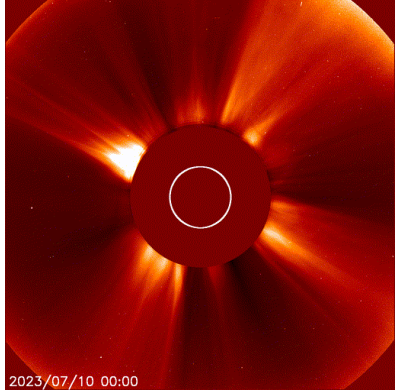


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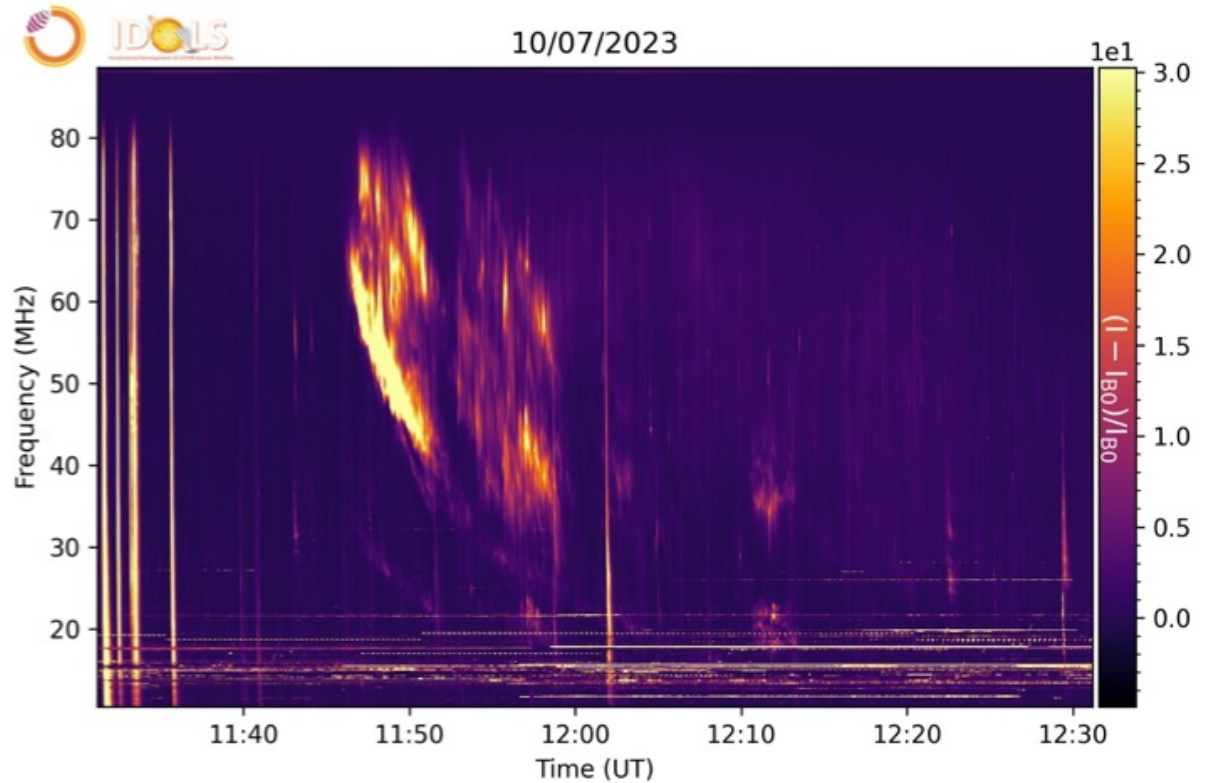


# Type II and Type III Solar Flares



2023/07/10 00:00  
LASCO coronagraph (370-700nm); Brueckner et al. 1995

- Type II: Several minutes
- Type III: Several seconds
- Type II: 0.5 MHz/s (at 150 MHz)
- Type III: 10-100 MHz/s (at 150 MHz)
- Both: Harmonic pairs
- Kundu & Shevgaonkar 1988;  
Jackson et al. 1990;  
Boiko et al. 2012;  
Crosley et al. 2016;  
Crosley & Osten 2018;  
Villadsen & Hallinan 2019;  
Callingham et al. 2021



The Low Frequency Array (10-90 MHz); Van Haarlem et al. (2013)  
Image credits: Zucca et al. (2023)



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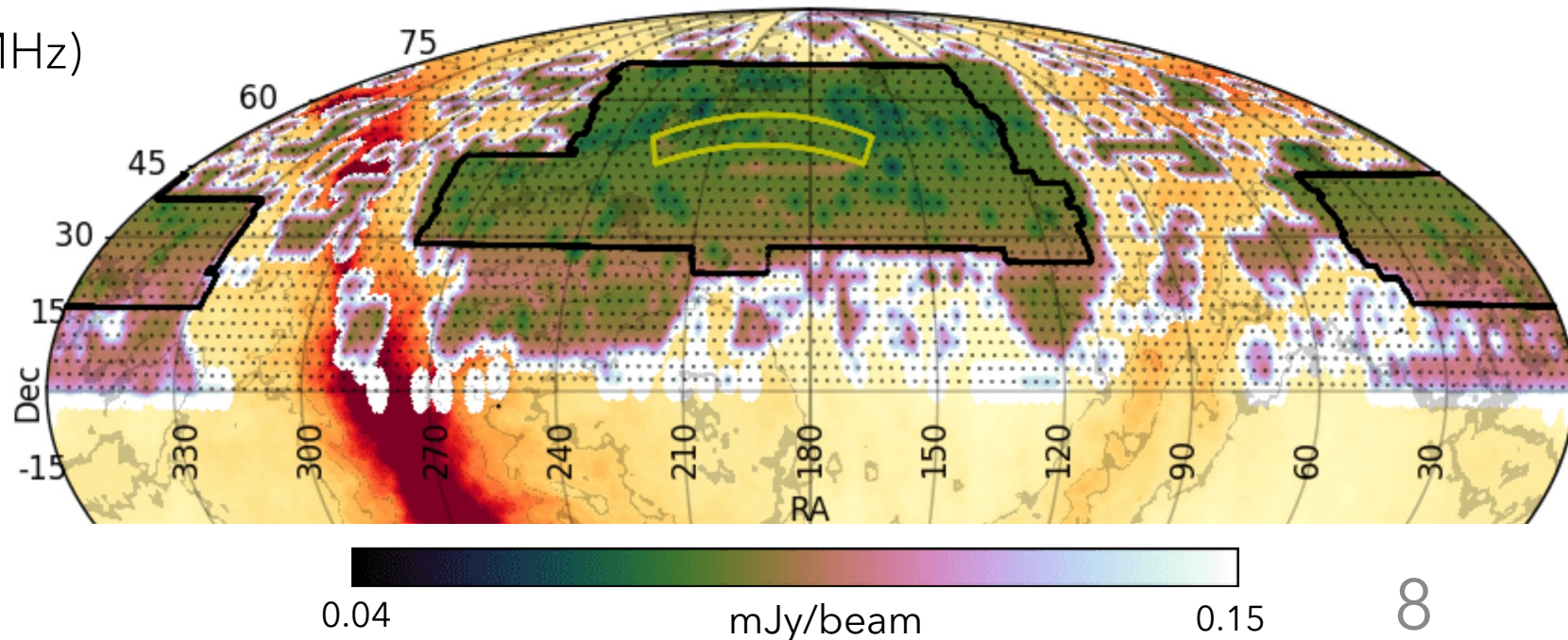


# Low-Frequency Array Two-metre Sky Survey (LoTSS)

Shimwell et al. (2019)



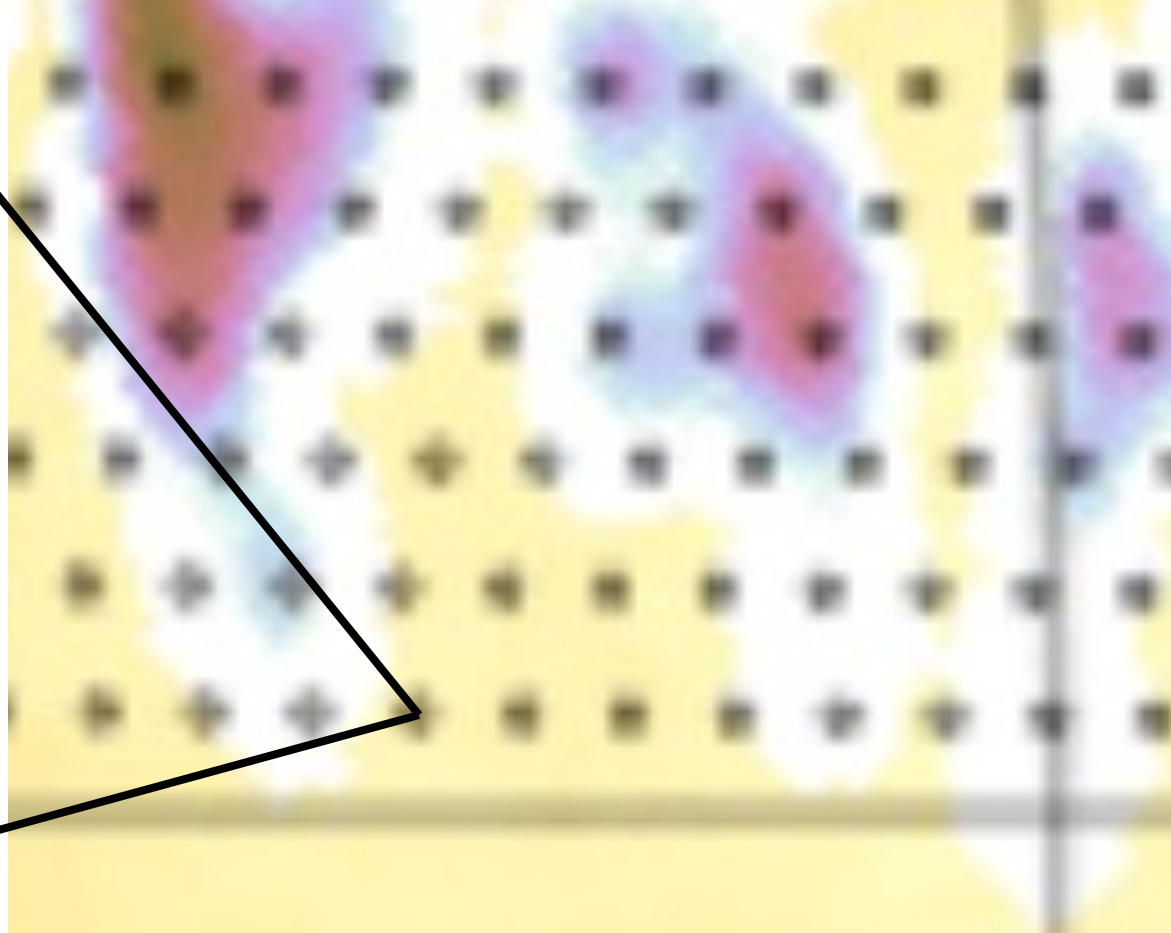
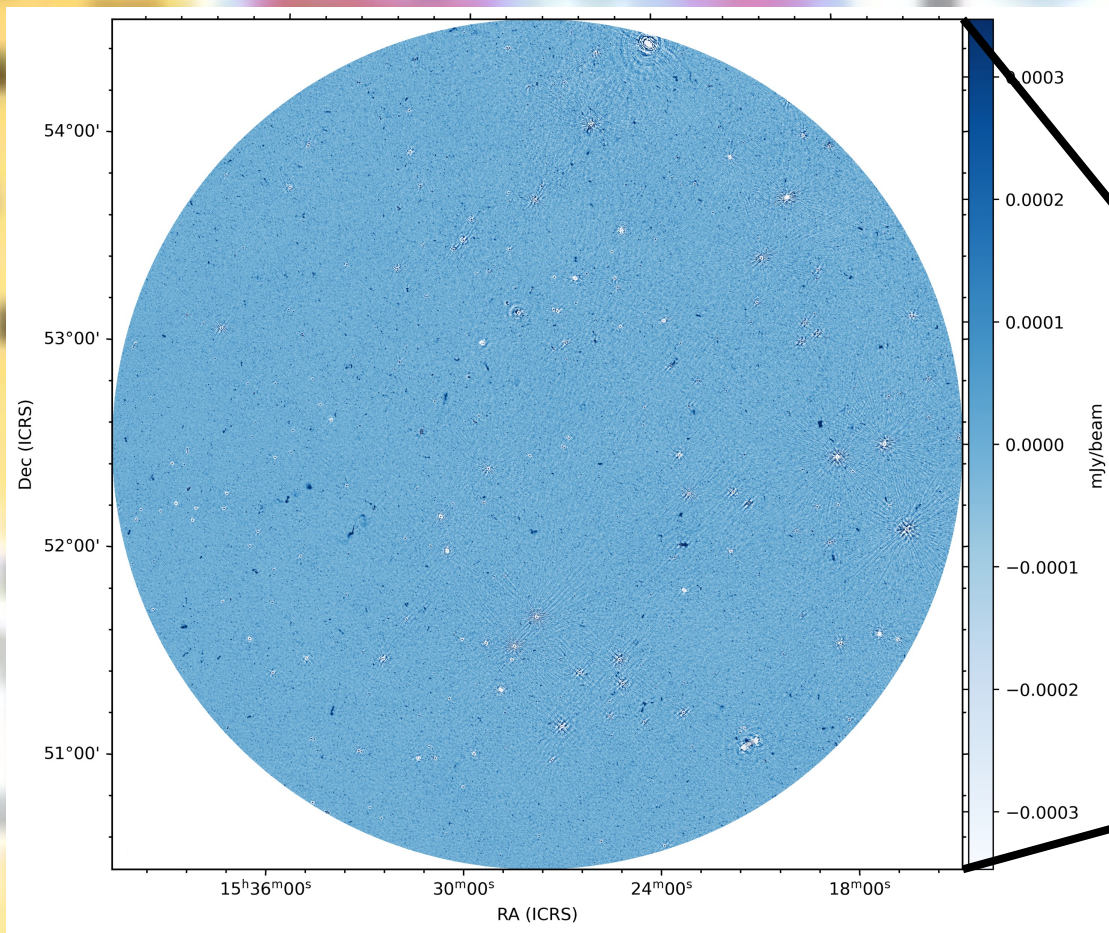
- Deep ( $83 \mu\text{Jy}/\text{beam}$ )
- Wide-field ( $6035 \text{ deg}^2$ ) (!)
- High-resolution ( $6''$ )
- Low-frequency (120-168 MHz)
  
- 3168 pointings
- 5 million sources



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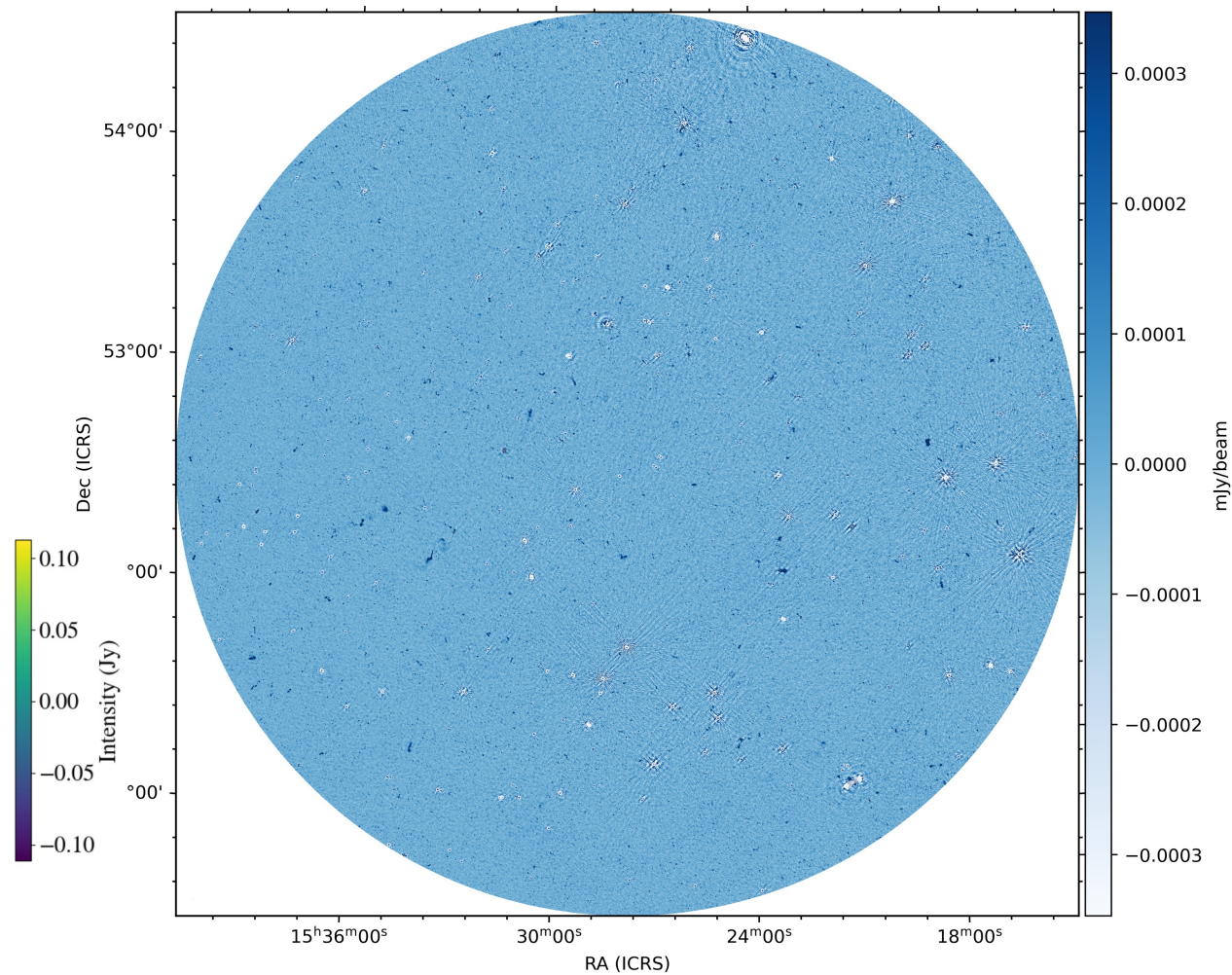
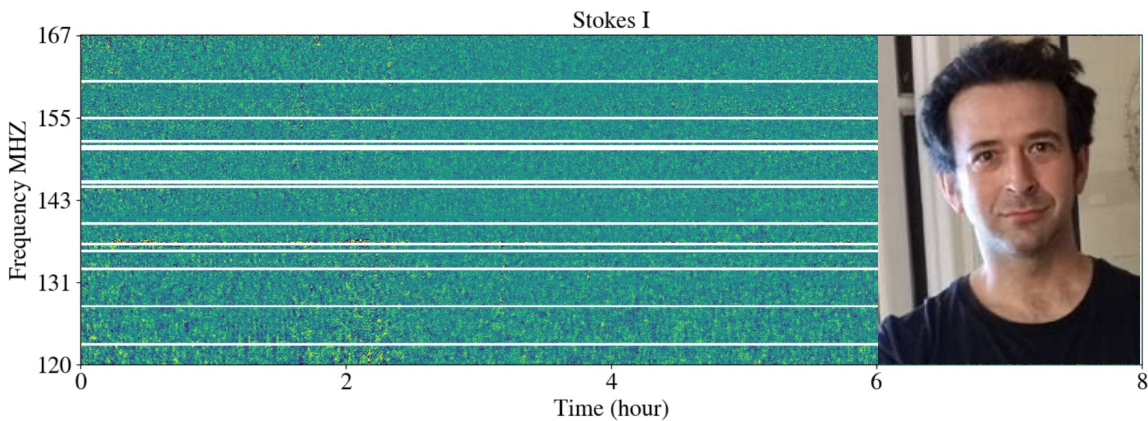






# Low-Frequency Array Two-metre Sky Survey (LoTSS)

- Each star < 100 pc at 8-second time resolution (Courtesy of Cyril Tasse)
- ~250,000 sources
- ~200 years of data at 8 seconds time resolution

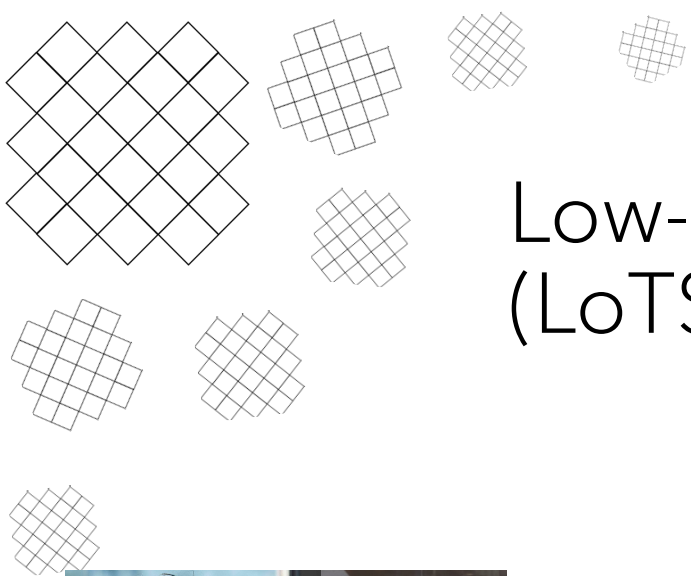


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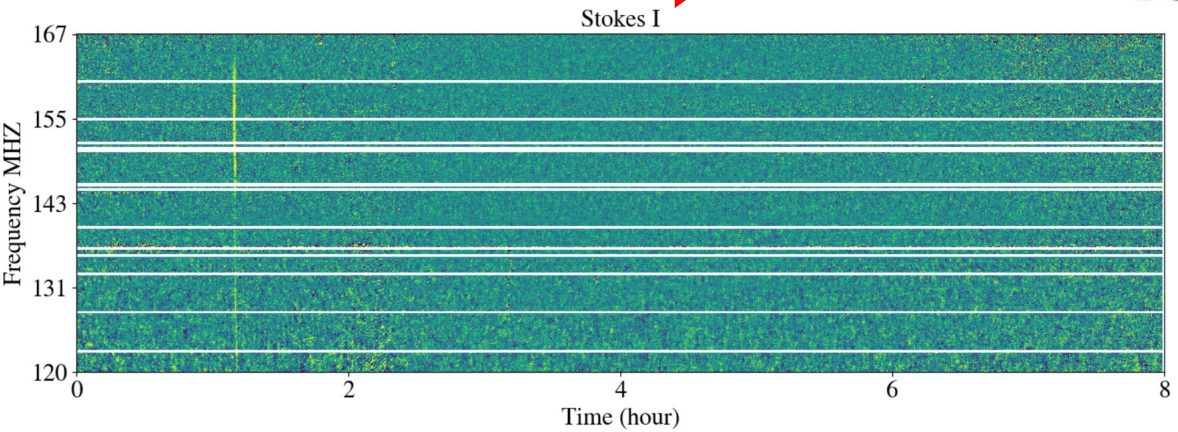
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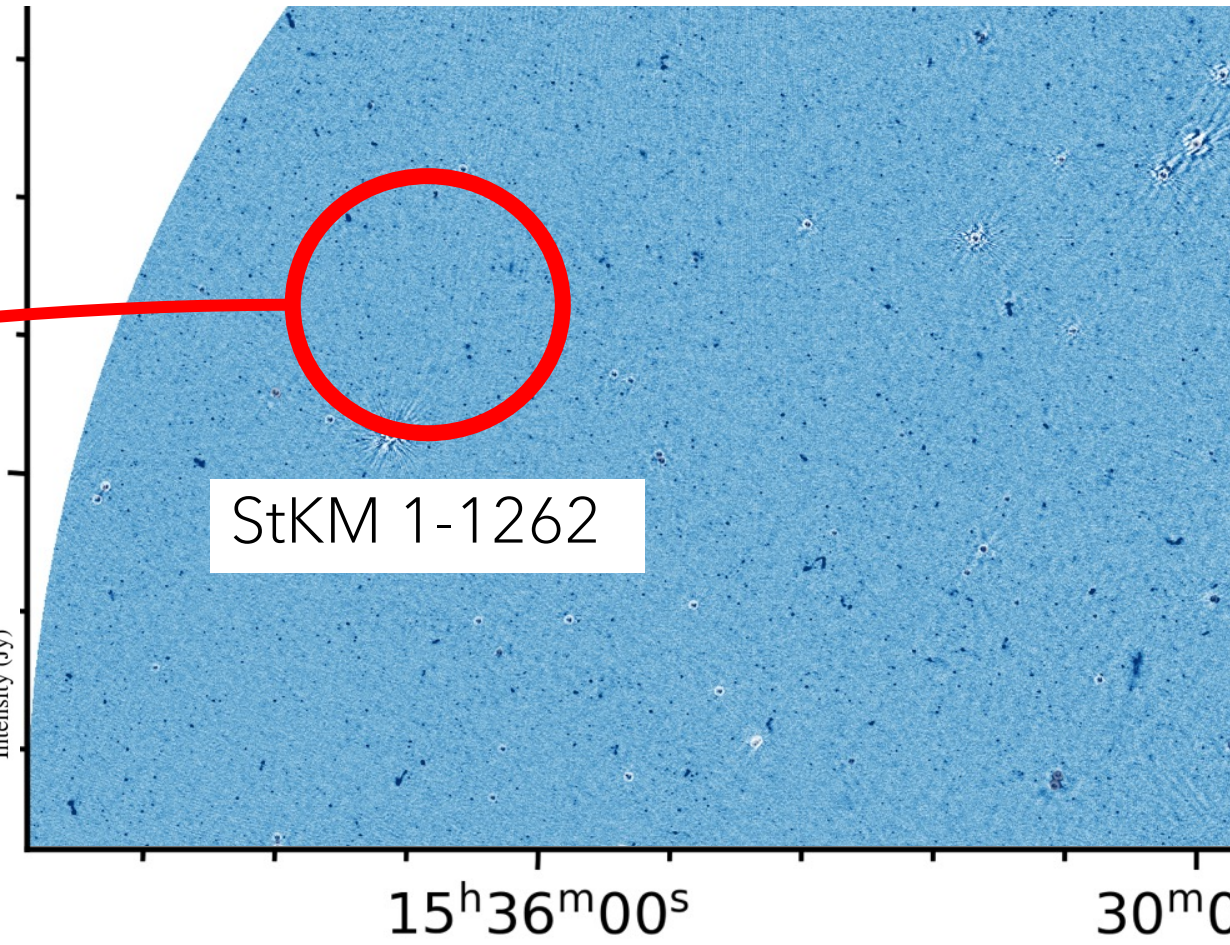
# Low-Frequency Array Two-metre Sky Survey (LoTSS)



Joe Callingham & Roos Keers



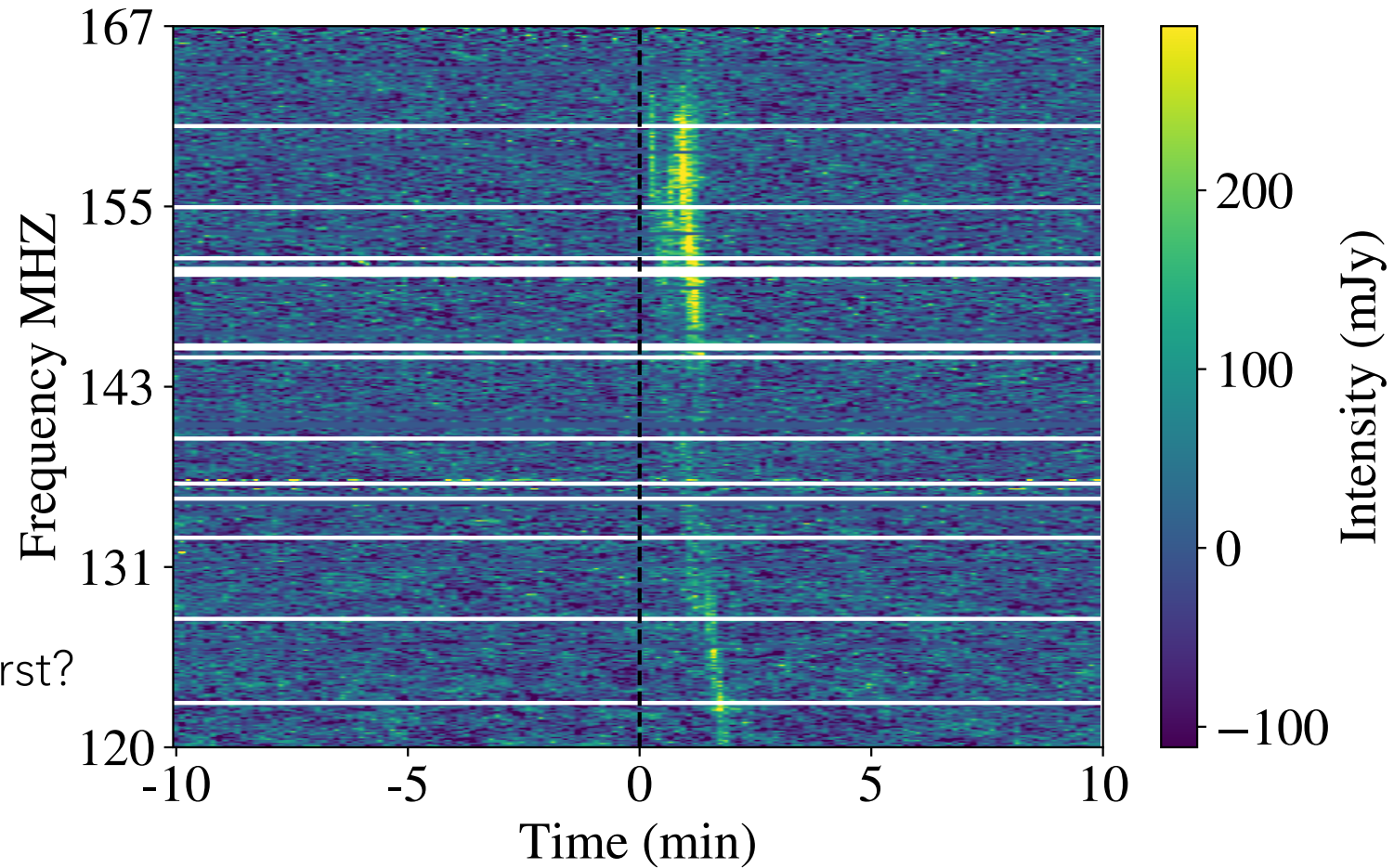
53°00'





# Unknown Stellar Radio Burst...

- Drift-rate =  $-0.35$  MHz/s
- Circularly polarized = 90%
- Bright
- Analogous to Solar Type II Radio Burst?

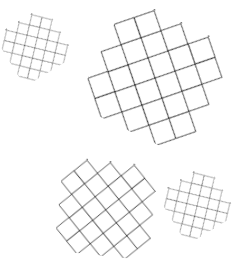
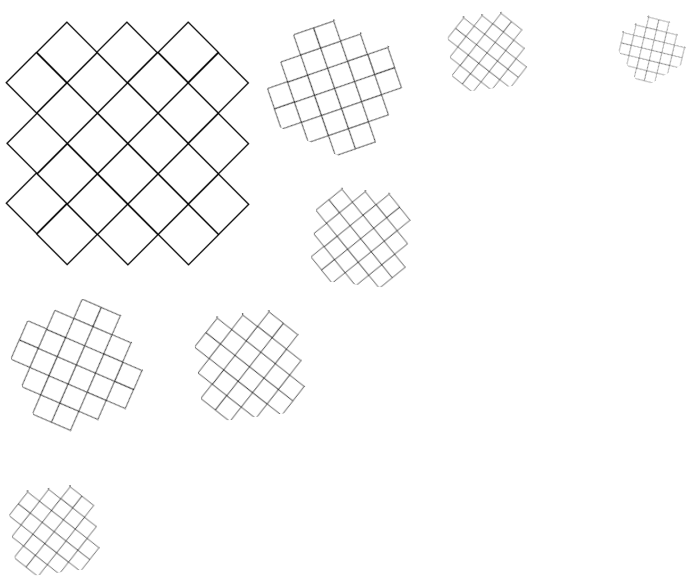


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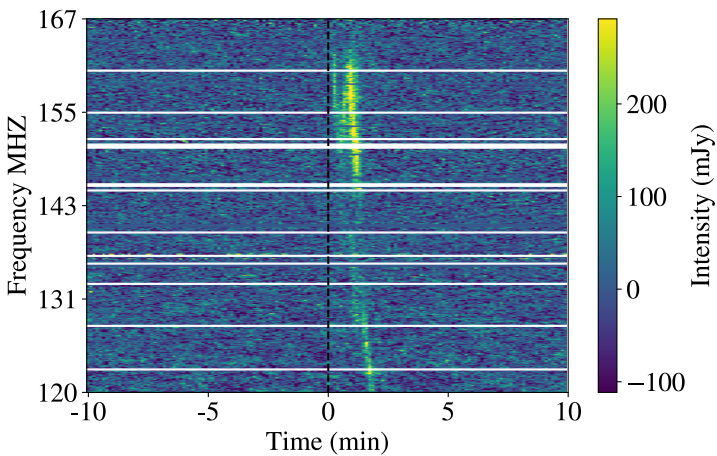


Maybe?



Yes, Type II!

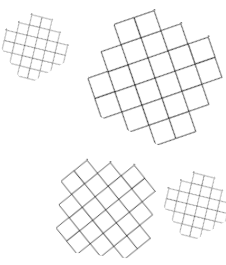
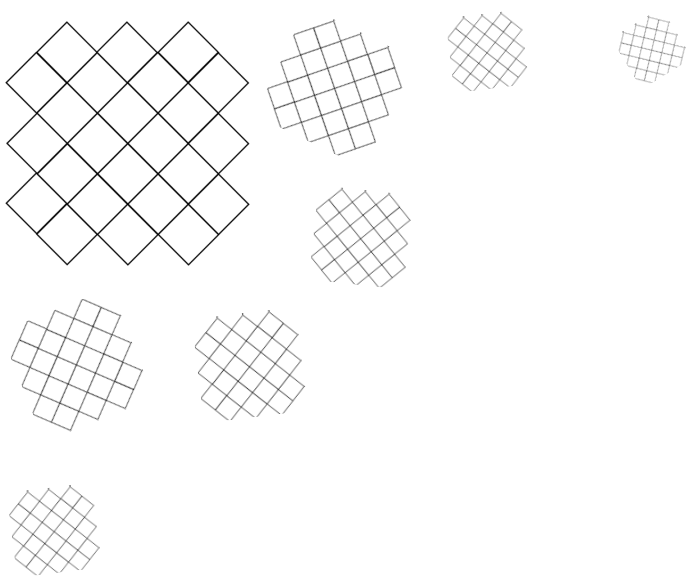
- Drifts
- Substructure (Herringbones)
- Frequencies
- Ejection speed =  $\sim 10^3$  km/s
- Solar-equivalent rarity = 1.5% (Gopalswamy et al. 2009)



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# Maybe?

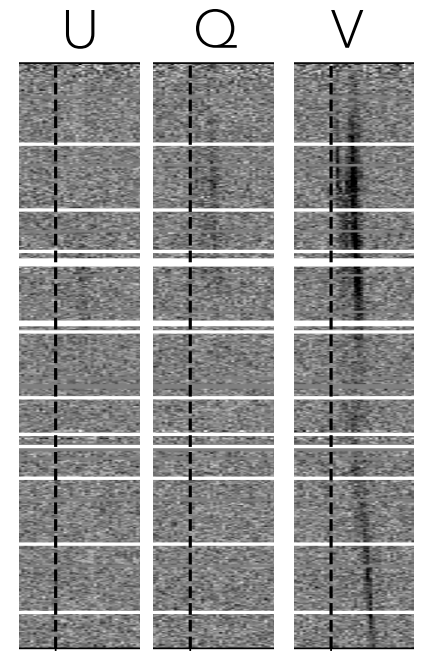
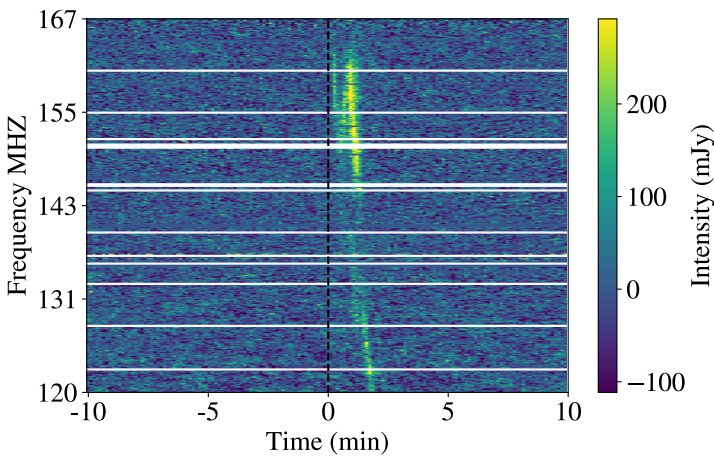


Yes, Type II!

- Drifts
- Substructure (Herringbones)
- Frequencies
- Ejection speed =  $\sim 10^3$  km/s
- Solar-equivalent rarity = 1.5% (Gopalswamy et al. 2009)

Difficulties...

- Where is the Harmonic?
- High circ. polarization?
- Linearly polarized?



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# What about Type III bursts?

- Reprocess all 8-sec. dynamic spectra at 1-sec time resolution
- Vedantham et al. (2020):  
Solar empirical data + semi quantitative theoretical estimates  
=  $\geq 10^1$  Type III bursts (at  $10\sigma$ )

$$S \propto E_{\text{flare}}$$

- Transiting Exoplanet Survey Satellite (TESS)

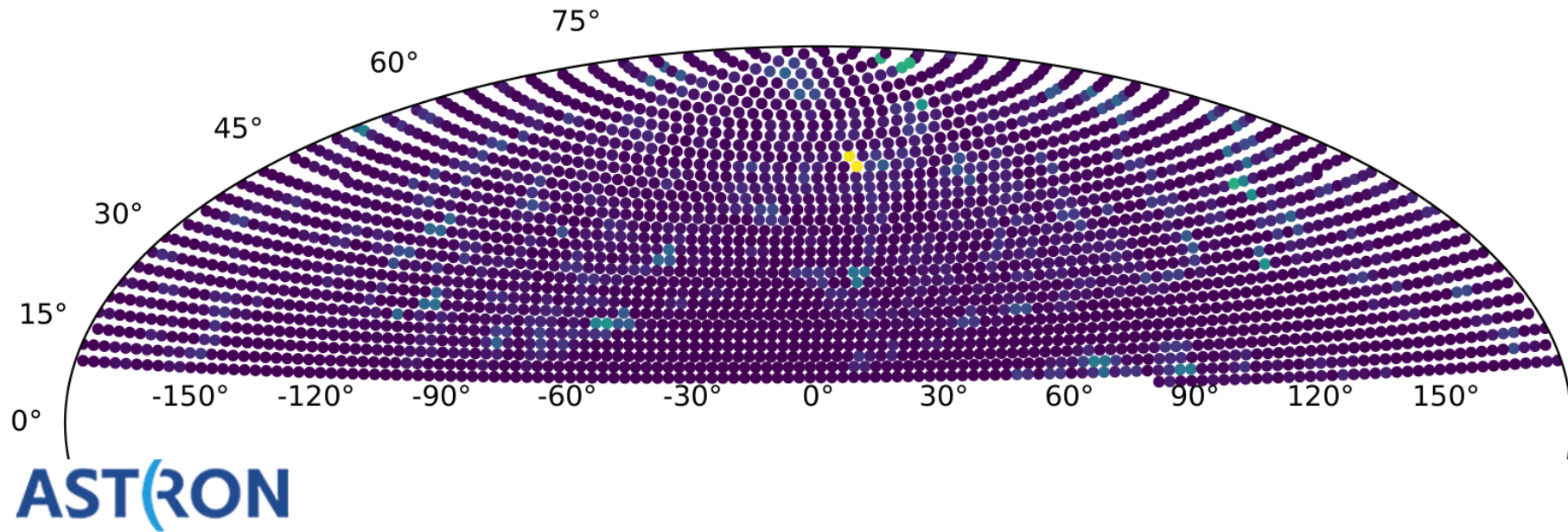


Estimated Type III burst rate per star



# What about Type III bursts?

- Estimated 39.70 extrasolar  $10\sigma$  Type III bursts in all of LoTSS



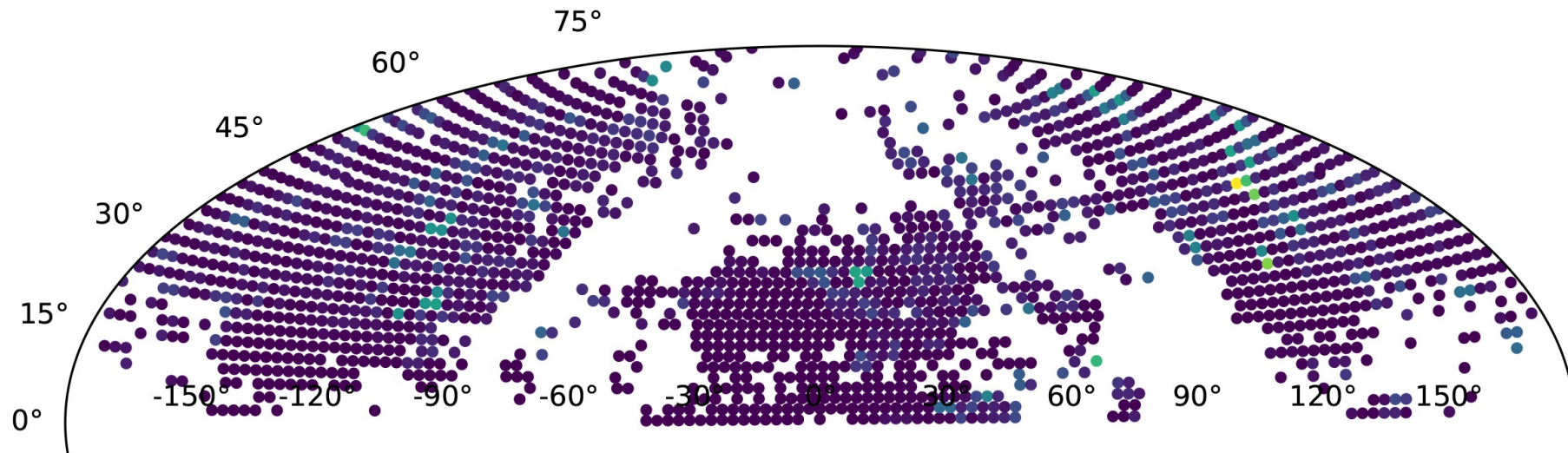
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# What about Type III bursts?

- Estimated 22.53 extrasolar  $10\sigma$  Type III bursts in current LoTSS



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# Summary

- Start the extensive search through **years** of data at an 8-second time resolution.
- **First ever** stellar radio burst **analogous** to a Type II burst indicative of a stellar CME.
- Rate prediction of stellar Type III bursts in LoTSS pointings, totalling **39.70** Type III bursts (**22.53** in current LoTSS).

