

# Flaring stars from four years of the SPT-3G transient survey



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The Transient and Variable Universe  
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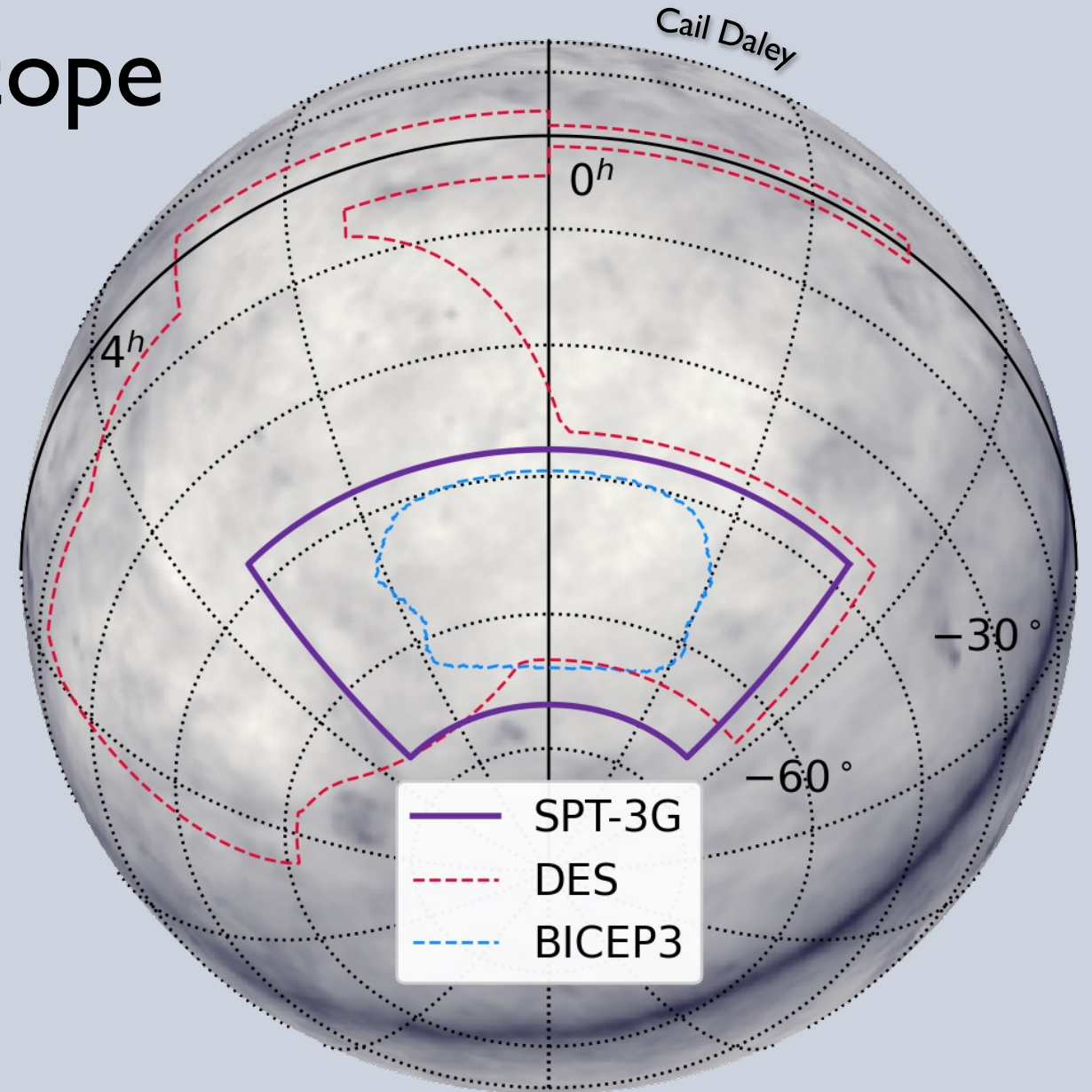
# The South Pole Telescope

SPT-3G: third generation camera

- 95/150/220 GHz
- 1.6'/1.2'/1' beam
- 1500 deg<sup>2</sup> field
- ~2 deg field of view

Observing strategy

- 4 subfields observed
- 2-hour observations in each subfield
- 100 second single scans at constant elevation
  - roughly 30 minutes for a location in the sky to be completely seen



# Not just the CMB

Asteroids – Paul Chichura

AGN – John Hood

Long duration – Kedar Phadke

Short duration extragalactic – Sam Guns

Galactic plane – Yujie Wan

Static point sources – Melanie Archipley

Presenting this week!

Point source list used  
for transient maps

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Methods built on Guns+21

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# The search

## Map making

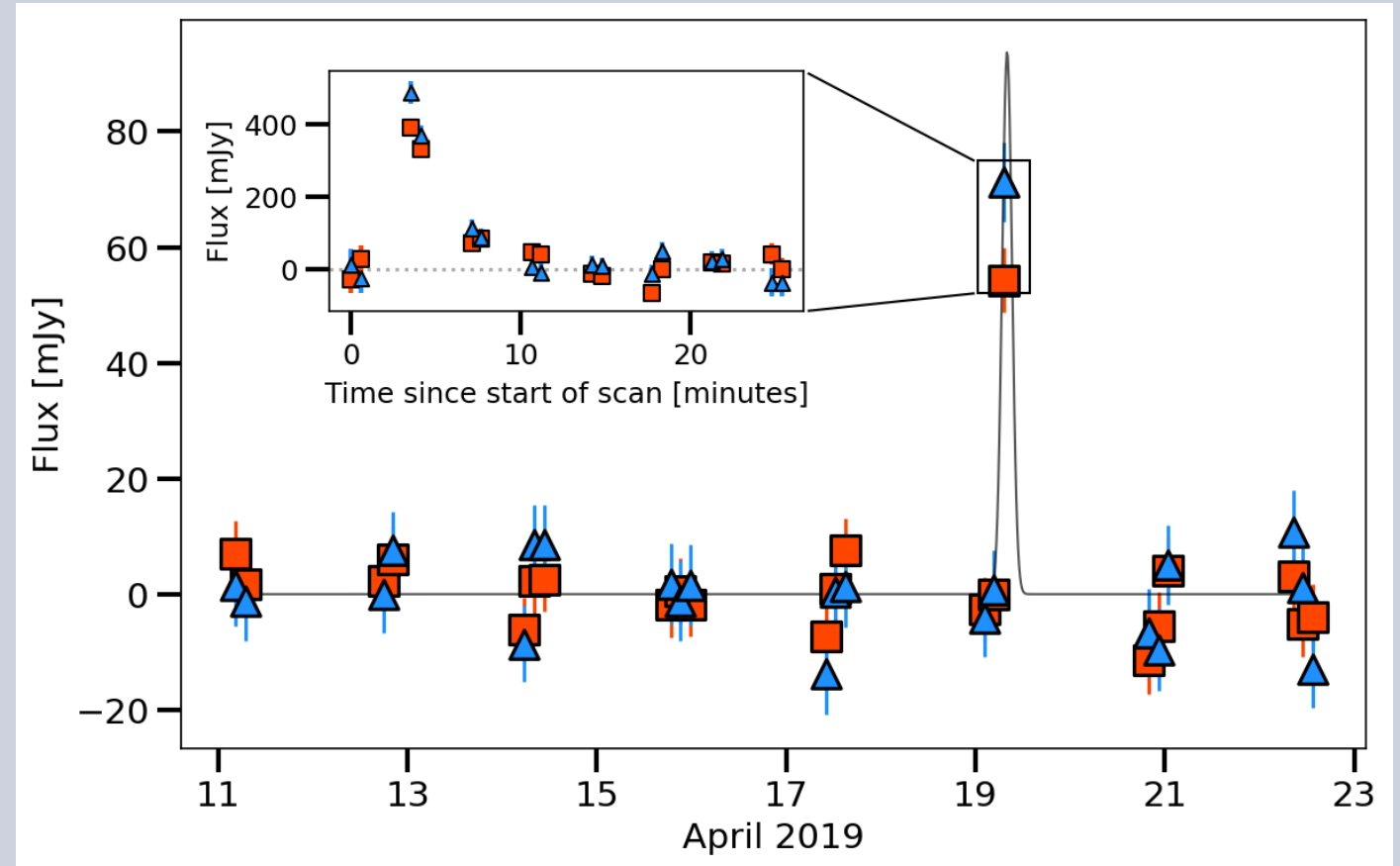
- Multiple step filtering process
- $3\sigma$  cut (95/150 GHz) on pixels
- ~300,000 candidate pixels

## Transient events

- Test statistic (TS): 2-band (95/150 GHz) detection
- 12-day lightcurves
- **Short duration:** <10 day fit
- **High significance:** >45 TS ( $\sim 5\sigma$ )

## Candidate events

- Removal of balloons/glitches/etc.
- Ends with 111 candidates



$$\text{TS} = 2\ln\mathcal{L}(\widehat{S}_{95}, \widehat{S}_{150}, \widehat{t}_0, \widehat{w}) - 2\ln\mathcal{L}(0) + 2\ln\left(\frac{\widehat{w}}{12\text{days}}\right)$$

(For detection purposes only! Not parameter estimation)

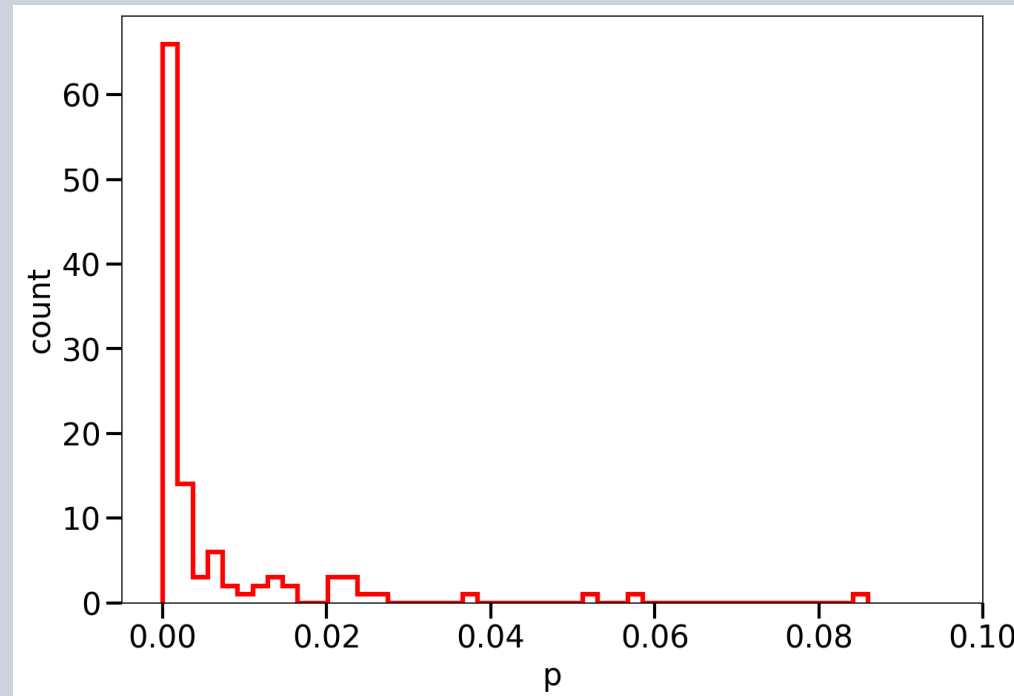
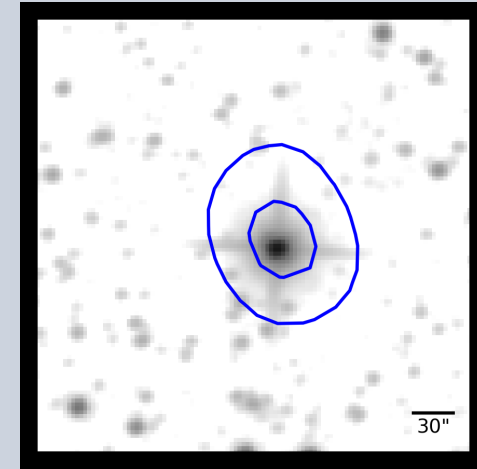
# The search

## Matching to Gaia

- Excluding Gaia QSO/galaxies
- Considers separation and brightness of candidate source to event
- CDF created from 400,000 random points
- One-to-one mapping interpolated over

$$\Lambda = \ln \left( \mathcal{B} \frac{N_{total}}{N(> S)} \right)$$

$$\mathcal{B} = \exp \left[ -\frac{1}{2} \left( \left( \frac{\Delta_{RA}}{\sigma_{RA}} \right)^2 + \left( \frac{\Delta_{Dec}}{\sigma_{Dec}} \right)^2 \right) \right]$$

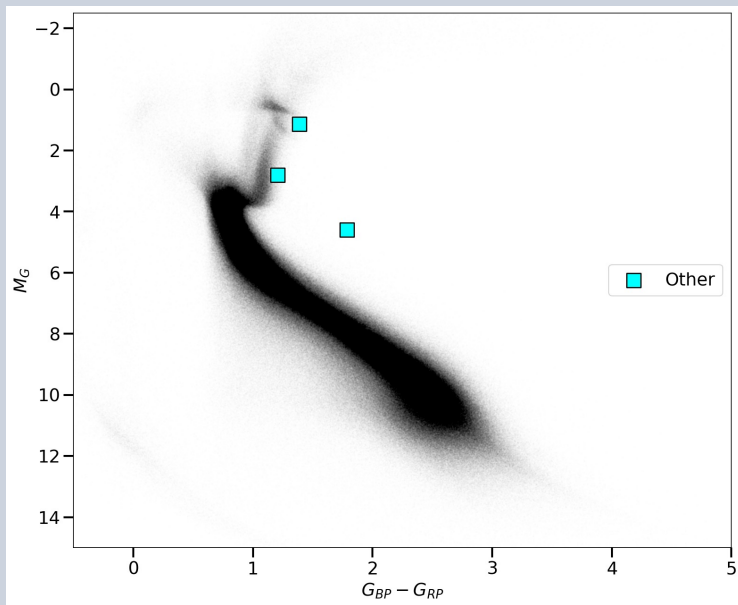


$$p(\Lambda) = 1 - CDF(\Lambda)$$

Tandoi+23 in prep

# The stars

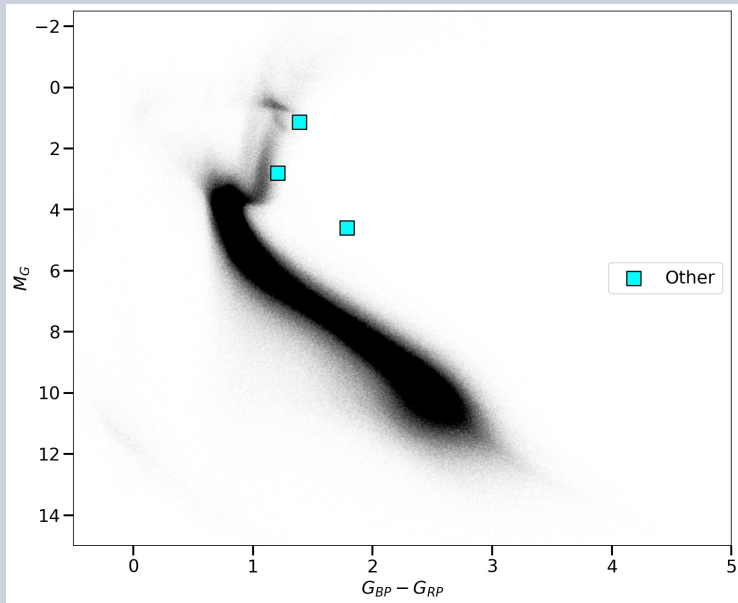
Pre-2018



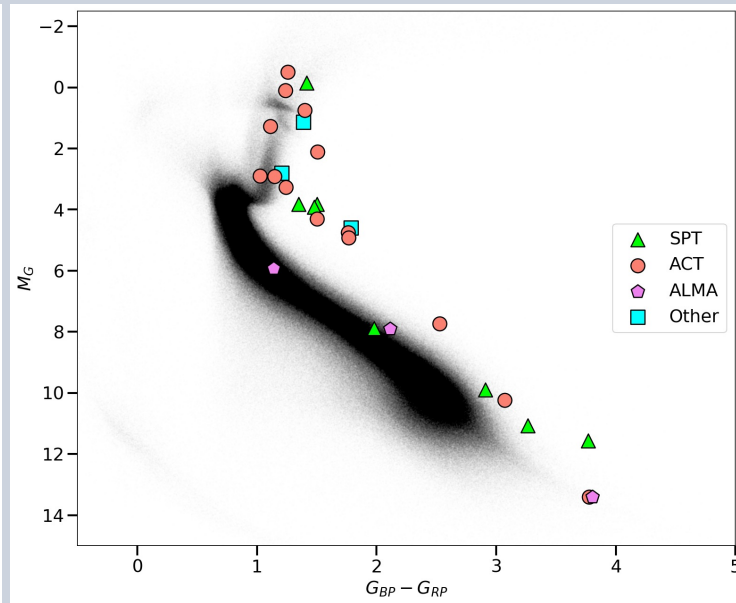
Beasley & Bastian 98  
Bower 03  
Brown & Brown 06  
Umemoto 09  
Mairs 19

# The stars

Pre-2018



2018 - 2023



Beasley & Bastian 98  
 Bower 03  
 Brown & Brown 06  
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 Mairs 19

- ▲ SPT Guns 21 — 8
- ACT Naess 20, Li 23 — 14
- ◆ ALMA MacGregor 18/20/21, Burton 23 — 3

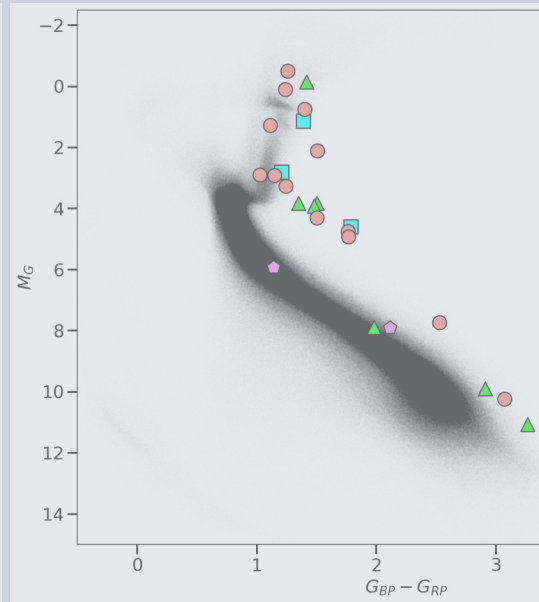
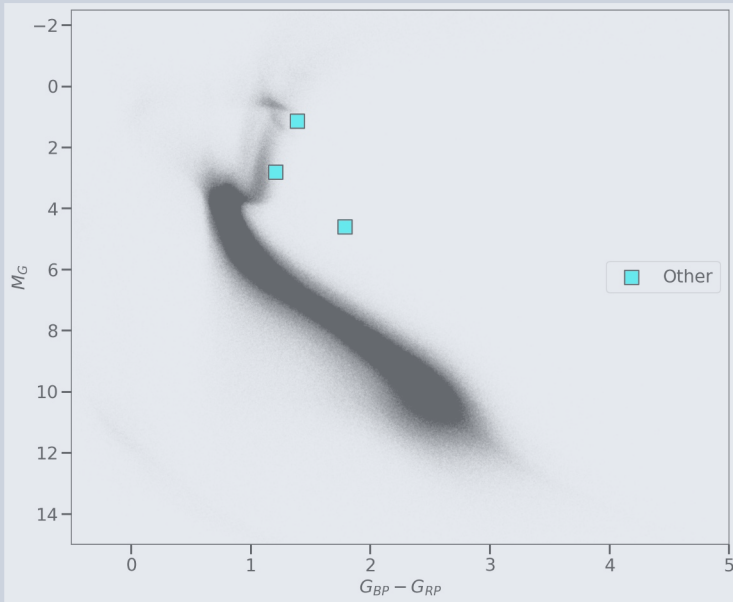


# The stars

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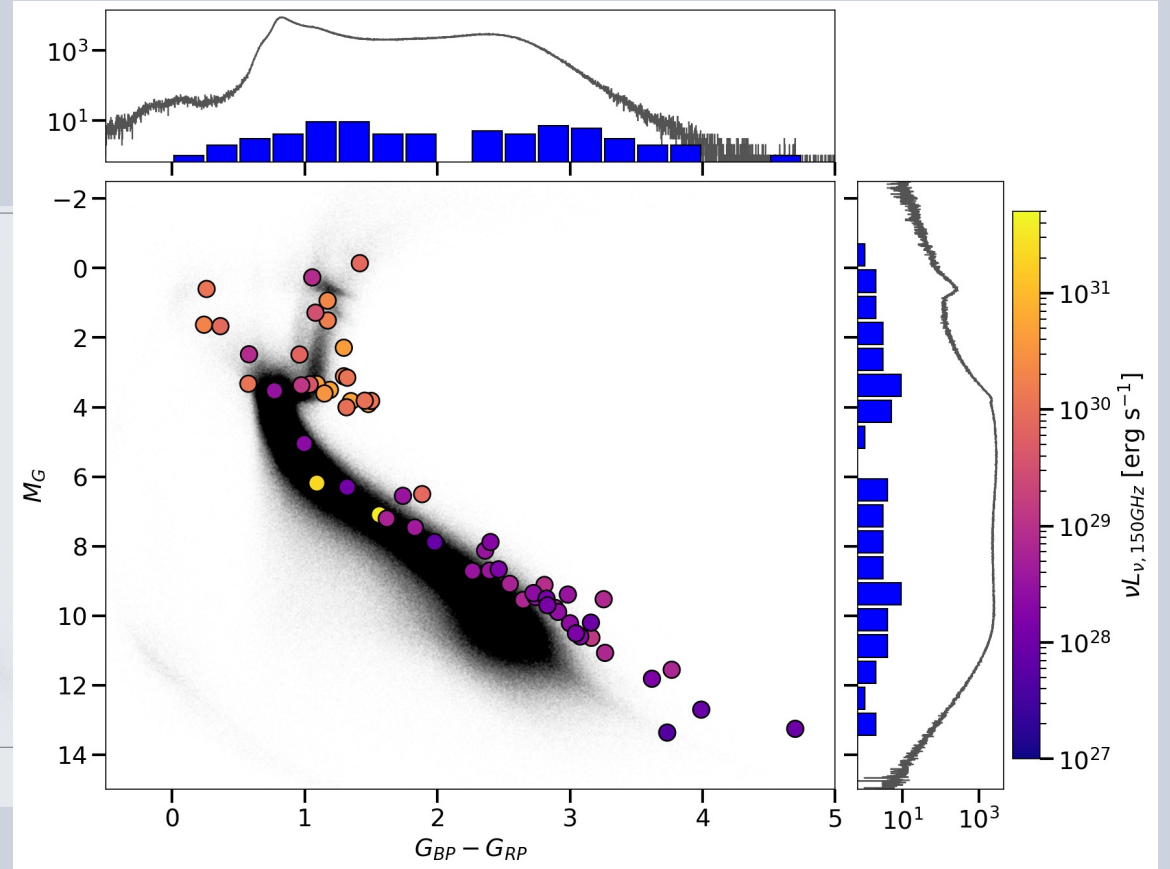
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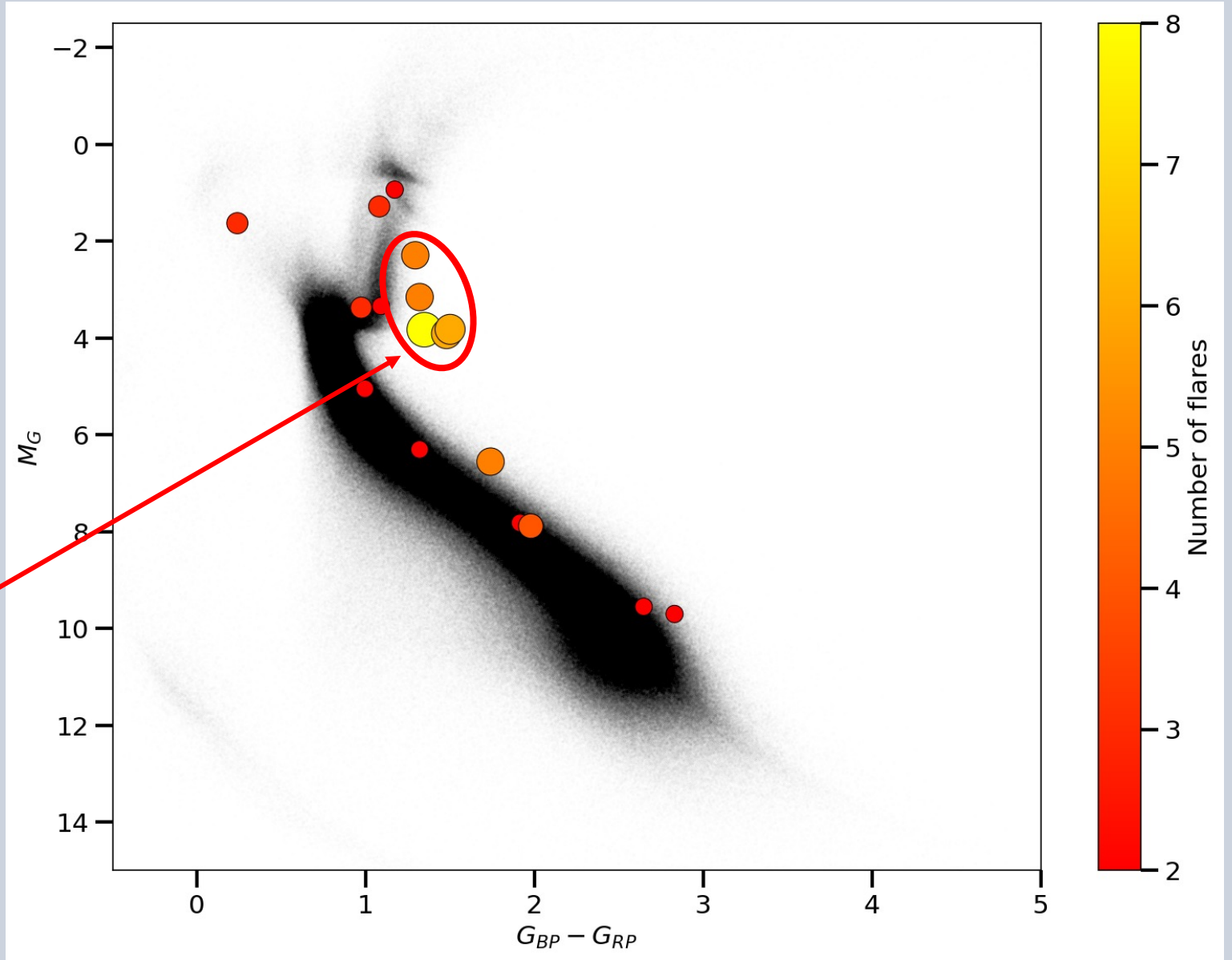
- 66 stars
- III flaring events

# The stars

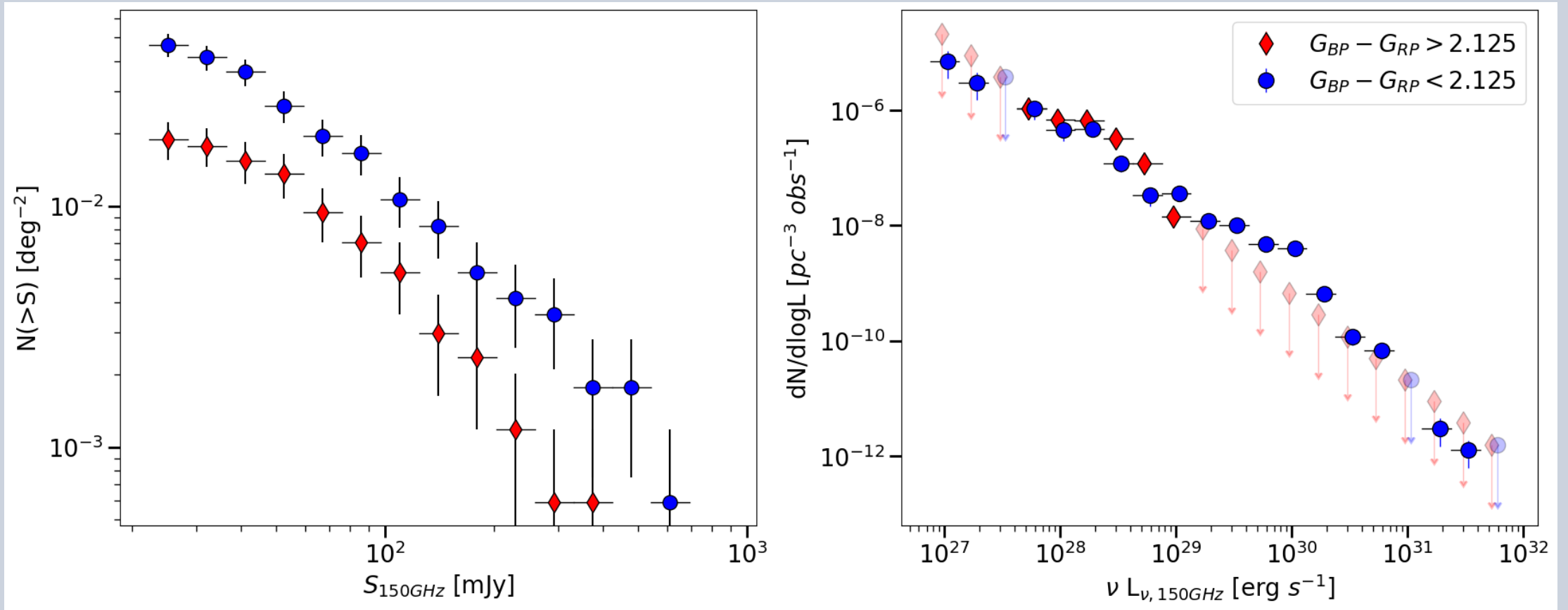
17 stars with multiple flares

62 multi-flares observed

30 flares from 5 giants



# The flares

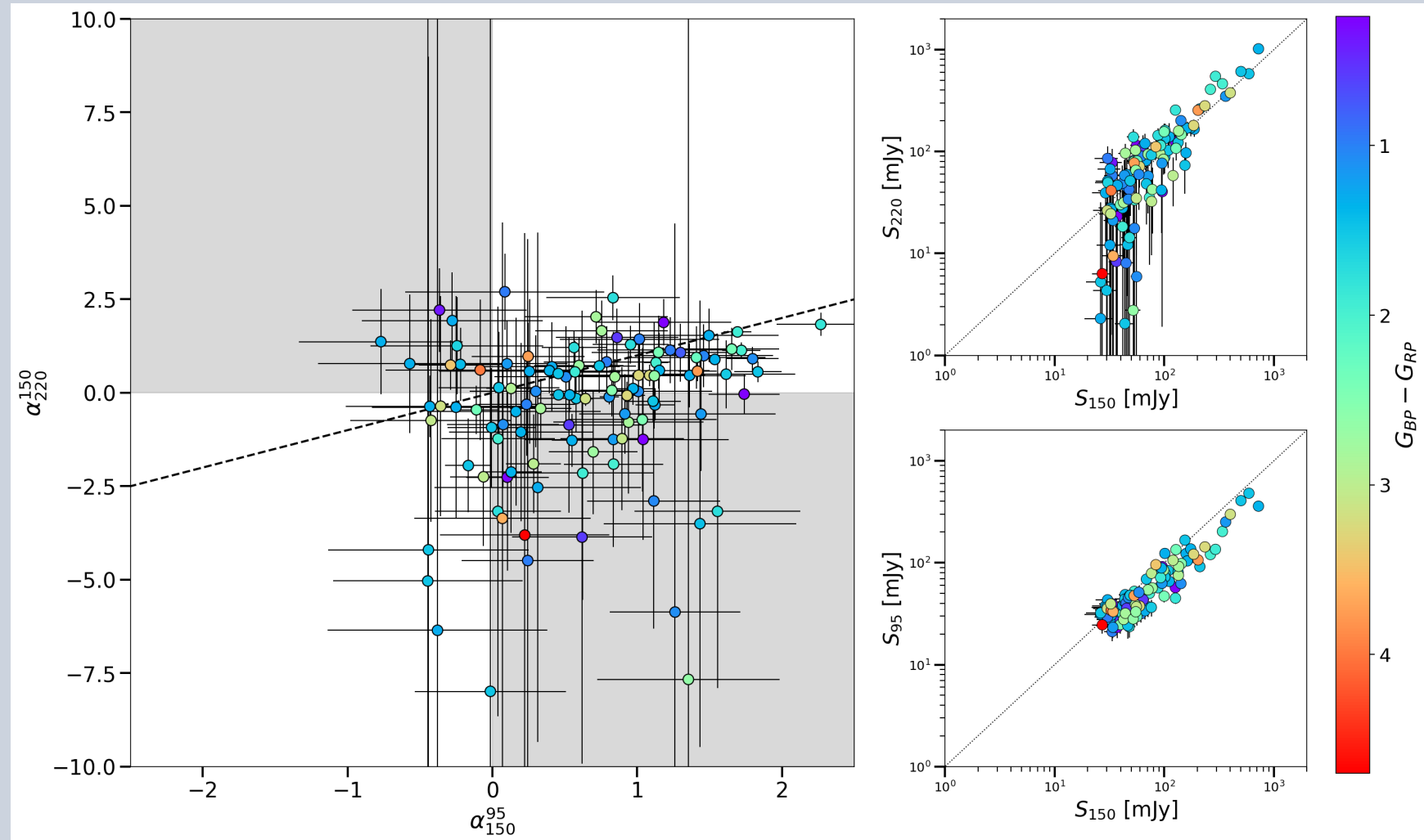


Tandai+23 in prep

# The flares

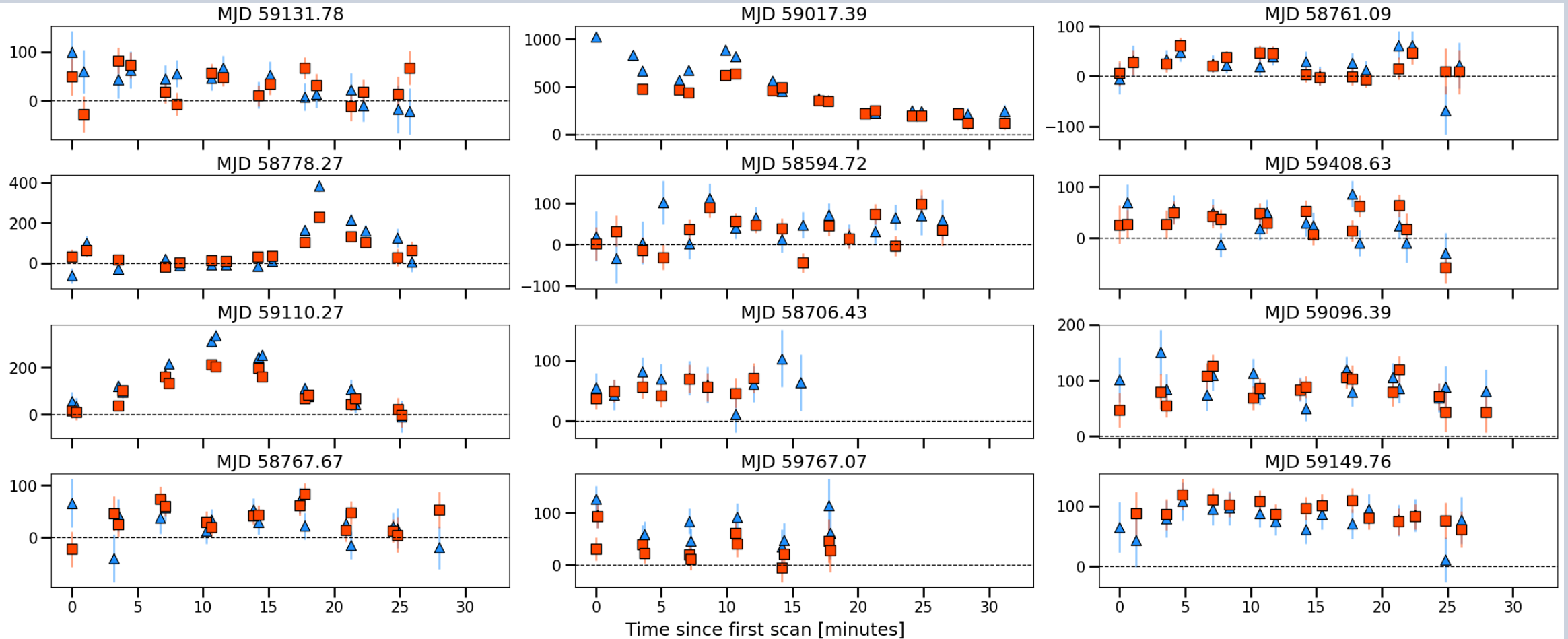
$$\alpha(v_1 - v_2) = \frac{\log(S_1/S_2)}{\log(v_1/v_2)}$$

- mm-wave assumed to track particle acceleration in early phase, synchrotron in origin
- Rising spectra in 95/150... not entirely expected
- Precedent exists! "THz flares"  
– solar flares with rising spectra at 212/405 GHz observed (Krucker+11)
- Optically thick synchrotron with extreme parameters



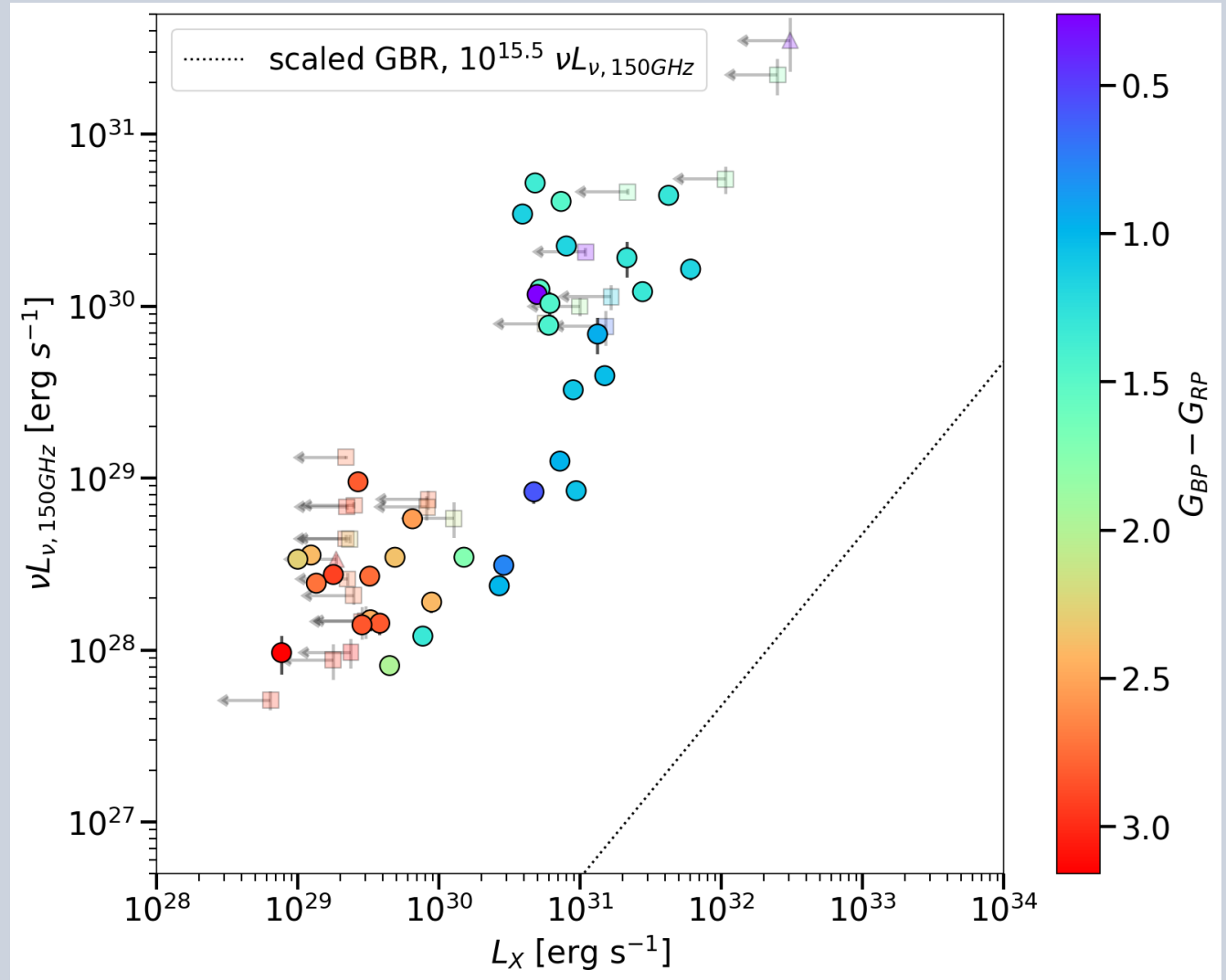
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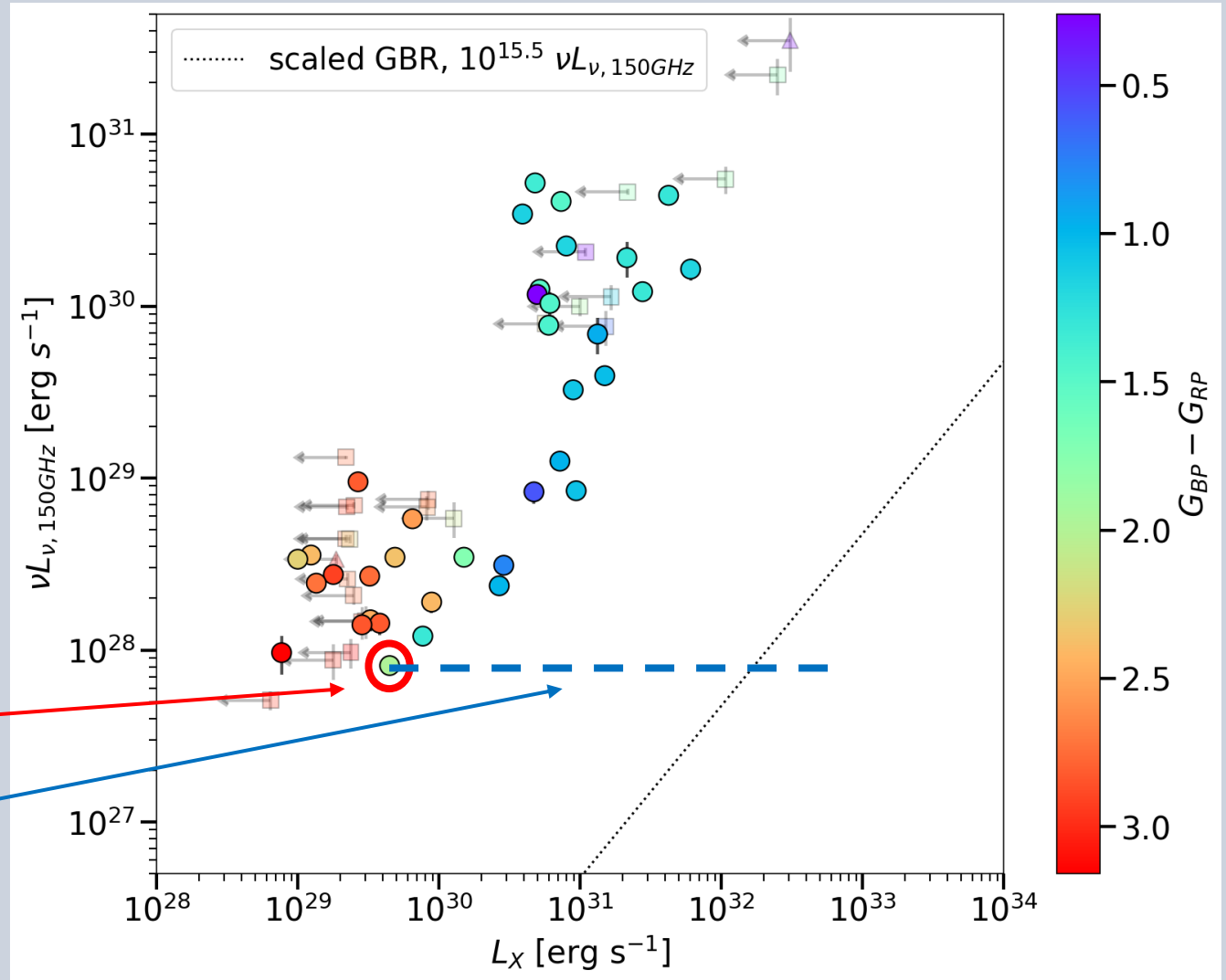
# X-ray sources

- Gaia stars cross matched to 2RXS (Freund+22)
- Güdel-Benz relation: empirical linear relation between 5 GHz (particle acceleration) and soft X-ray (coronal heating)
- No simultaneous SPT/X-ray flaring, but....



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- **CC Eri** previously seen flaring by Swift at an increase of **~1900** times more luminous than quiescence



# Conclusions

- Huge increase in number of mm-wave flaring stars observed
- Polarization, multi-wavelength useful for emission mechanism
- Multi-wavelength currently work in progress. TESS re-visiting SPT sector soon! ASAS-SN, Swift, ASKAP, etc.
- What stars are we seeing? RS CVn, eclipsing binaries, what else?