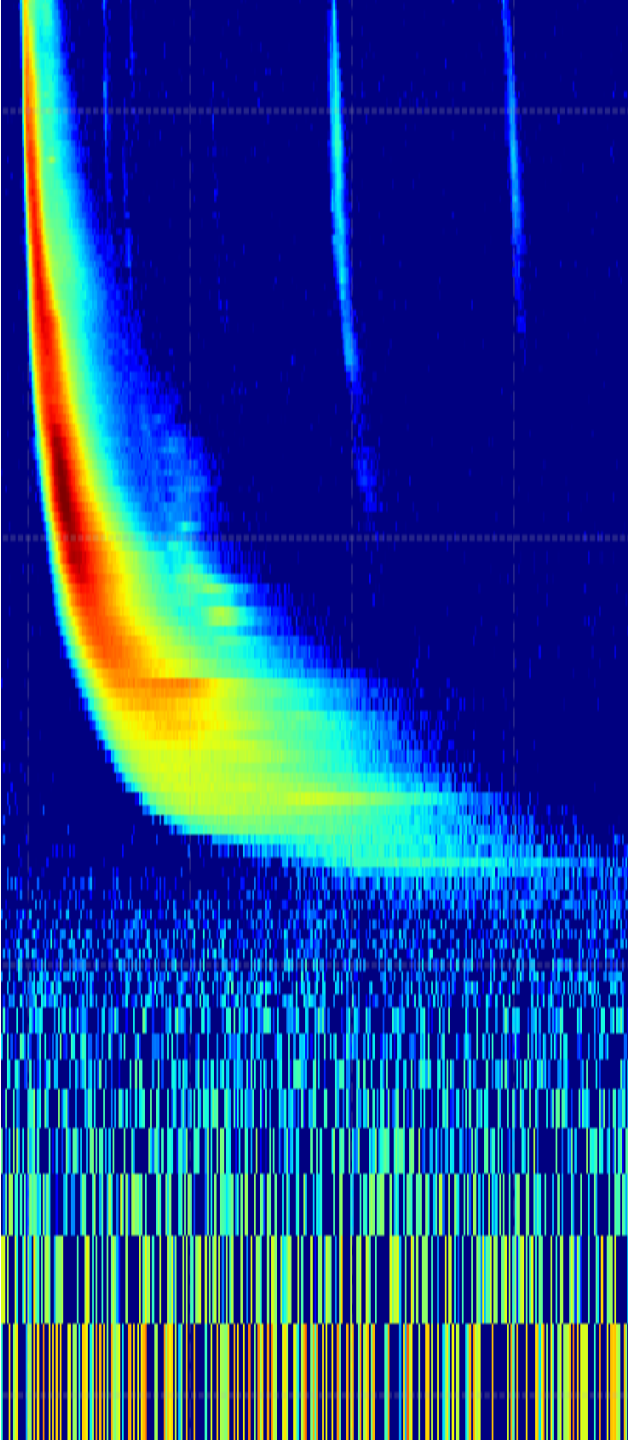


Fluctuations in Solar Type III Radio Bursts Spectra: Observations with PSP and SolO

Panisara Thepthong[1] , Matthieu Kretzschmar[1] , Milan Maksimovic[2] , Katerina Pesini[2,3]

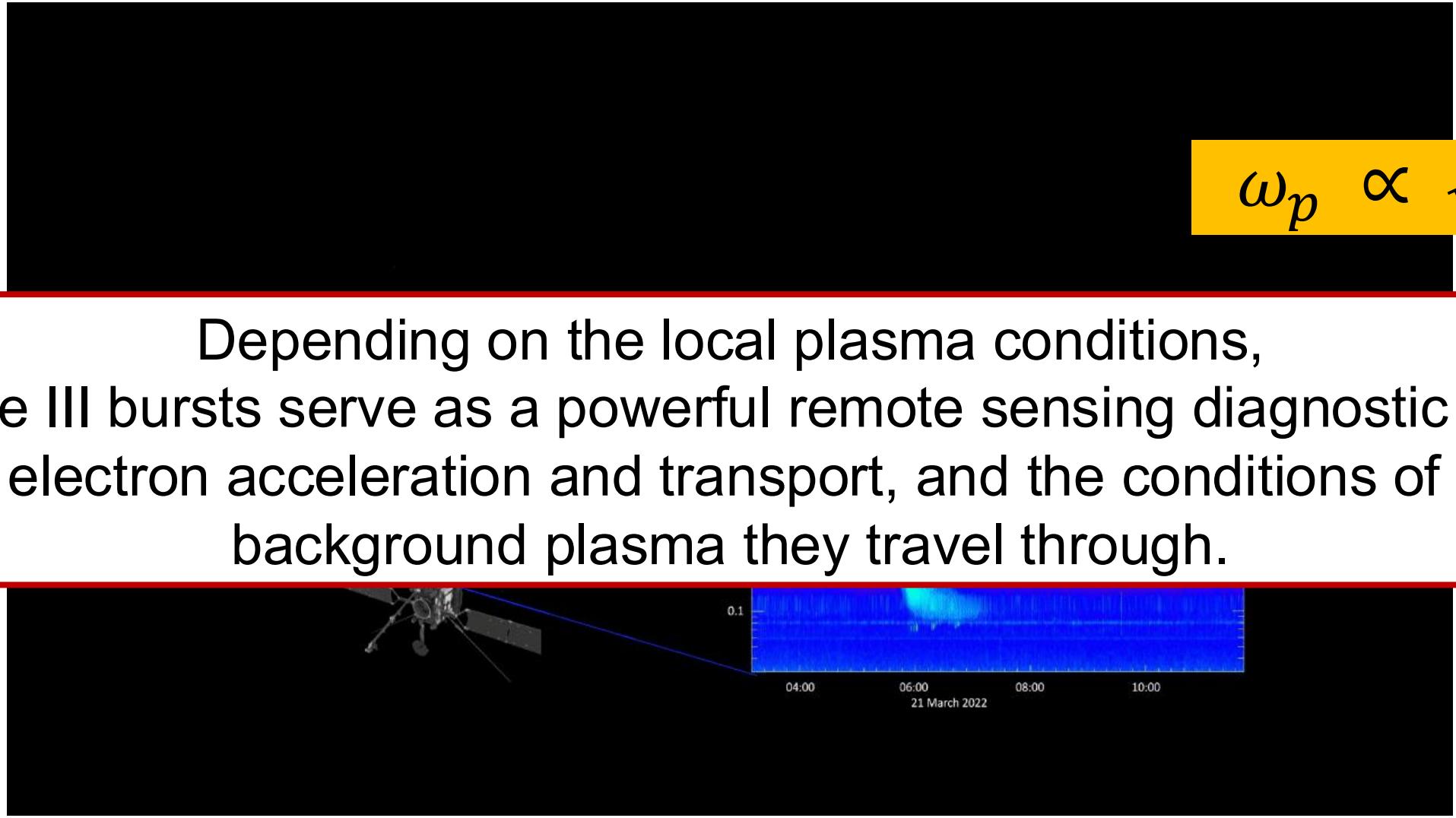
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Type III Radio Bursts

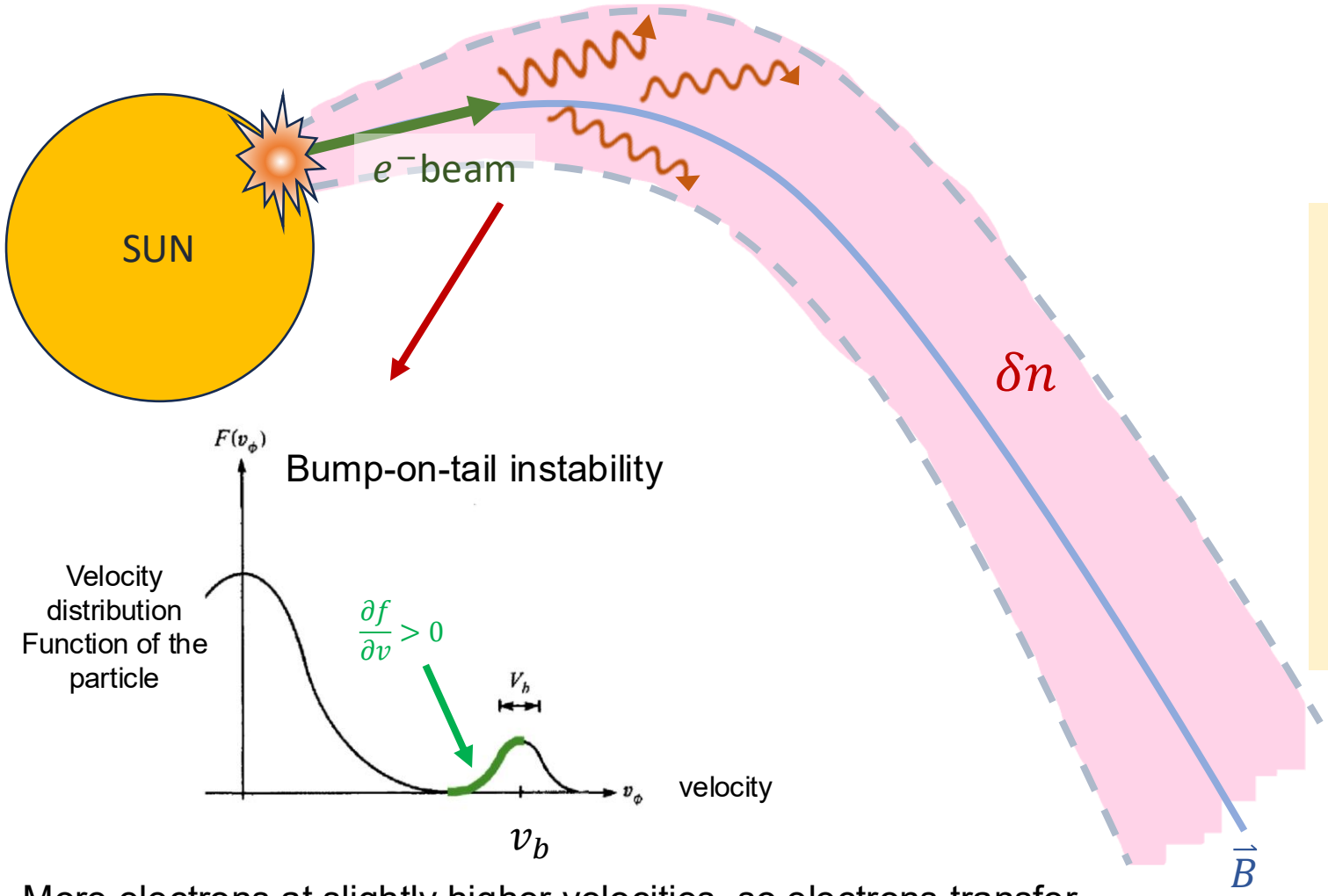
$$\omega_p \propto \sqrt{n_e}$$

Depending on the local plasma conditions,
Type III bursts serve as a powerful remote sensing diagnostic tool for electron acceleration and transport, and the conditions of the background plasma they travel through.



Credit : https://www.esa.int/Science_Exploration/Space_Science/Solar_Orbiter/Catch_solar_bursts_in_new_citizen_science_project

Generation Mechanisms



More electrons at slightly higher velocities, so electrons transfer energy to electrostatic plasma waves rather than damping them. This produces exponential growth of **Langmuir waves (electrostatic waves).** (Lin et al. 1981, Dulk 2000, Reid & Ratcliffe 20214)

Langmuir waves have to convert into electromagnetic (EM) waves near the local plasma frequency

Nonlinear processes

Ion scattering & 3 wave decay $\mathcal{L} \rightarrow \mathcal{L}' + S$

Coalesence $\mathcal{L} + \mathcal{L}'$

Fundamental Emission (ω_p)

Harmonic Emission ($2\omega_p$)

Plasma is homogeneous

Linear mode conversion (LMC)

Random density fluctuations (δn)

EM Emission

(e.g., Ginzburg & Zhelezniakov 1958, Robinson et al. 1993, Krafft et al. 2013, Volokitin & Krafft 2018)

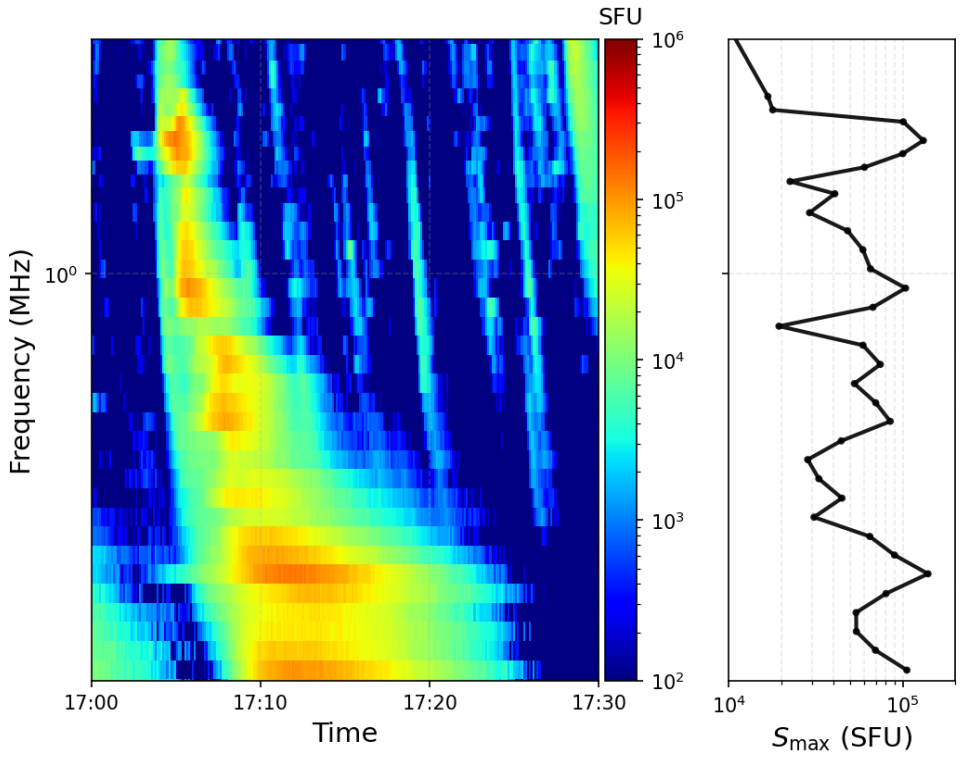
Density Fluctuations (δn)

- Small variations of plasma density around its average value, caused by turbulence or instabilities.

- The presence of δn not only enables the escape of EM radiation, but also strongly influences the evolution of Langmuir turbulence, leading to the formation of localized and spatially clumped wave structures.

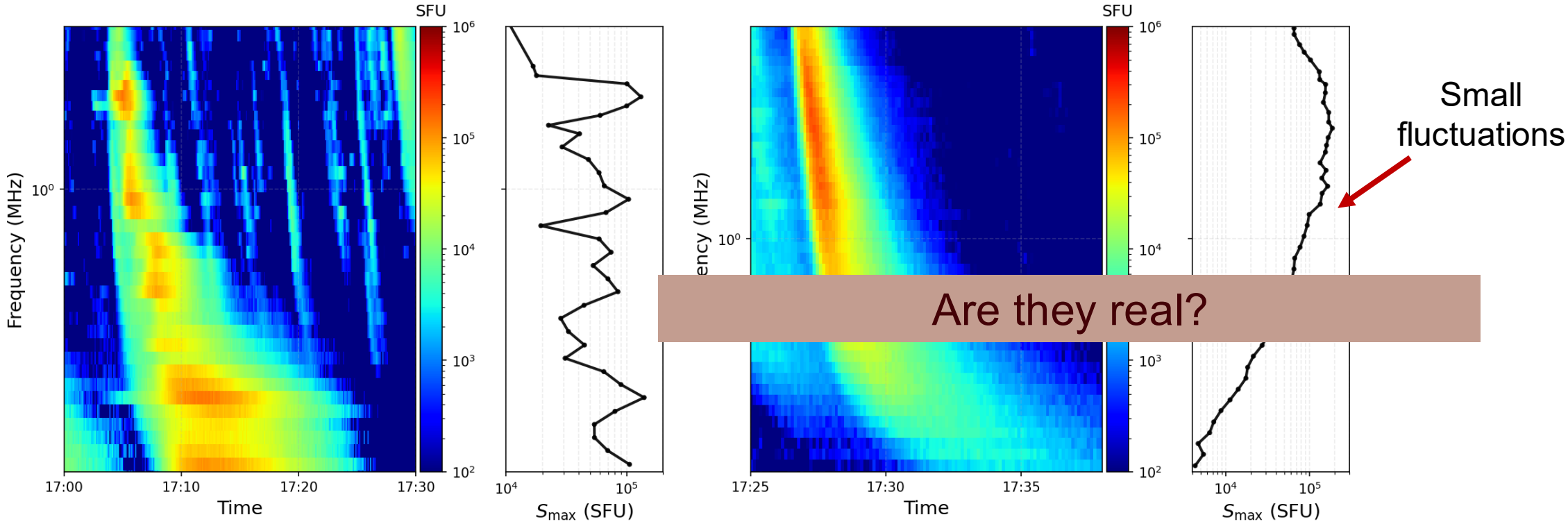
  - These processes producing highly irregular and intermittent burst structures.

Structured Type III Bursts



- Fine Structures
- Type IIIb bursts
- Striae (substructure)

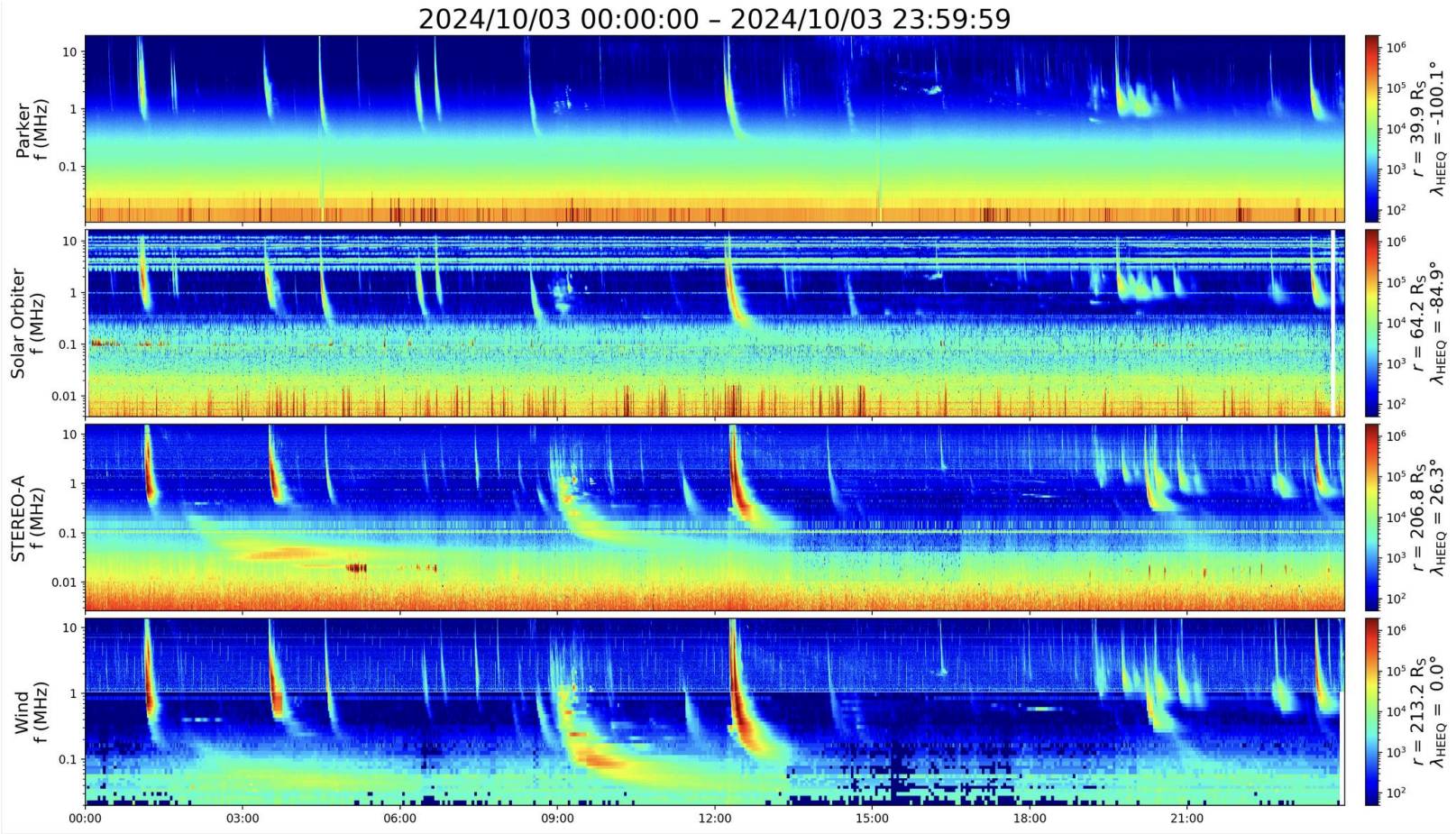
Fluctuations in Type III bursts



- Exhibit fine-scale features within their dynamic spectra, while maintaining the same drifting behaviour as normal type III bursts.

- Associated with the presence of **‘density fluctuations’** at different distances from the Sun (e.g., Chen et al. 2018, Krafft et al. 2022; Jebaraj et al. 2023, Krupar et al. 2025).

Multi-spacecraft

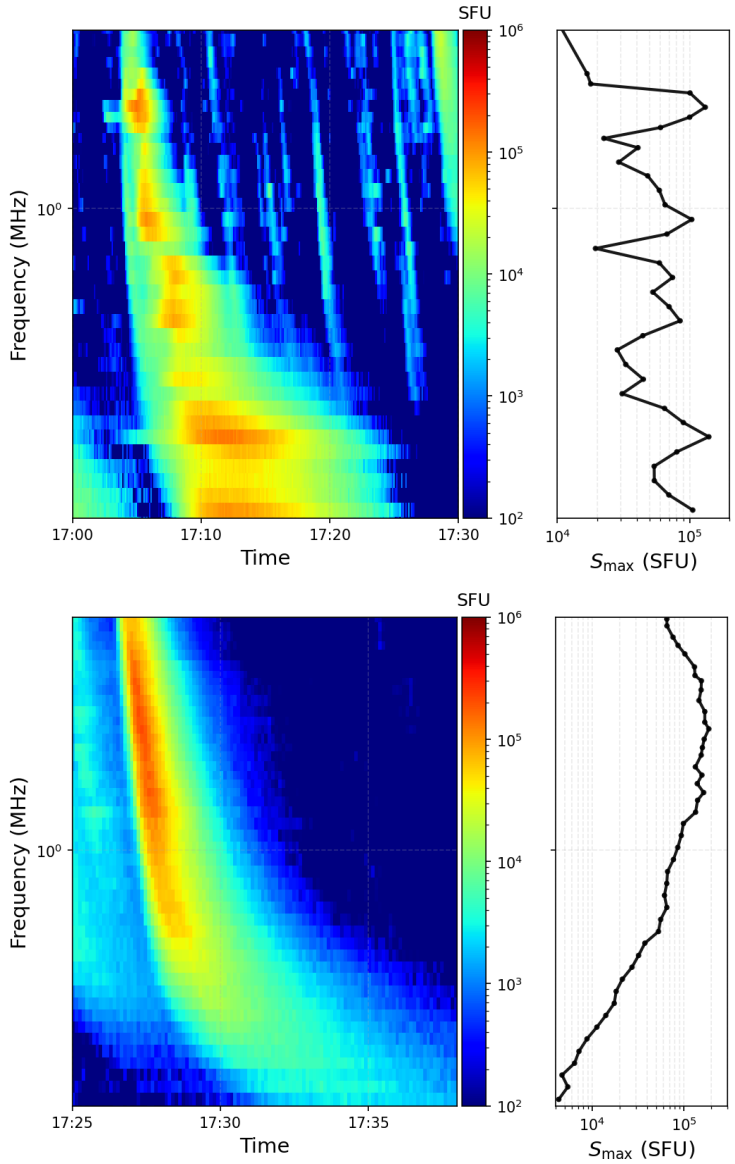


https://parker.gsfc.nasa.gov/crocs.html

Possible Mechanism for Type III busts sprea

- High Luminosity and Wide Beaming Anisotropic
  (Badman et al. 2022, Bonin et al. 2014)
- Scattering by Density Fluctuations
  (Chen et al. 2023, Musset et al. 2022, Reid & Kontar 2021, Kontar et al. 2019)
- Refraction by large-scale density gradients
  (Badman et al. 2022, Bonin et al. 2014)
- Perpendicular transport in the Interplanetary Medium
  (Dresing et al. 2014)

Main Objectives



What can we learn from type III radio burst fluctuations?

- How do these features evolve with radial distance and the spacecraft's observing viewpoint?
- Are the fluctuations driven by a local effect near the emission source region?
- Do large and small fluctuations share the same underlying emission mechanisms?
- Are they associated with density fluctuations?

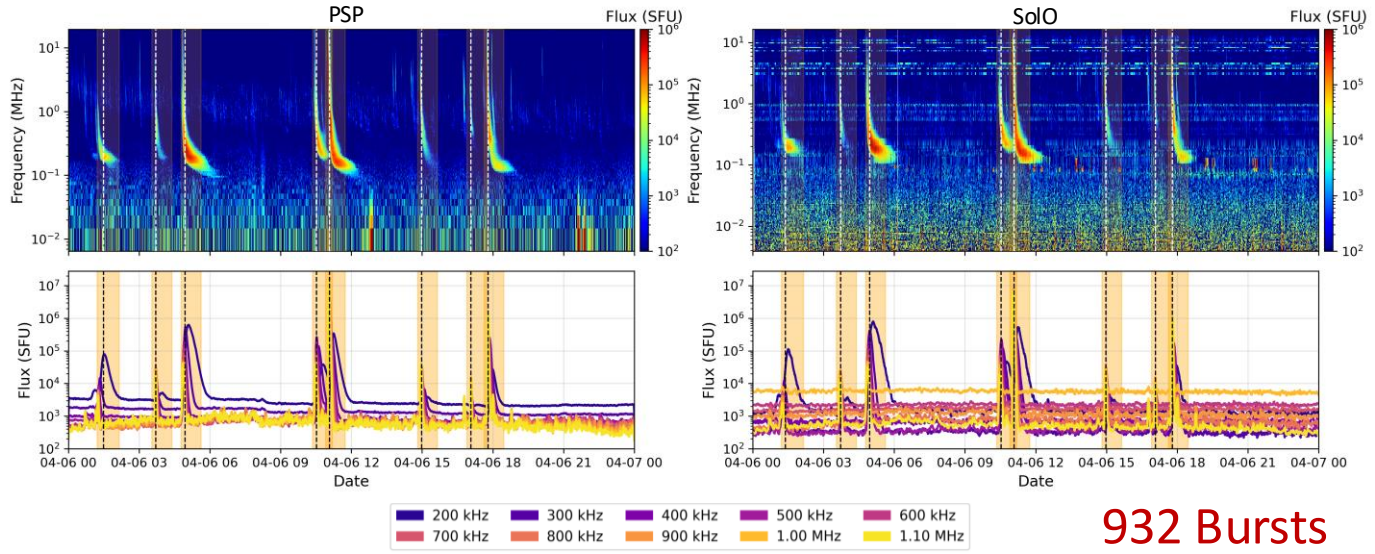
Data and Analysis Method

Data & Processing

PSP : FIELDS L3 | SolO : RPW L3
Interval: 2023 - 2024

The data processing steps were as follows:

1. Background Subtraction ($S_{obs} = S_{burst} + S_{bg}$)
2. Type III Burst Detection
   : using enhancement in time profile at each frequency
3. Cross-Spacecraft Event Selection
   : observed by both PSP and SolO ($\Delta t_{obs} < 10$ mins)

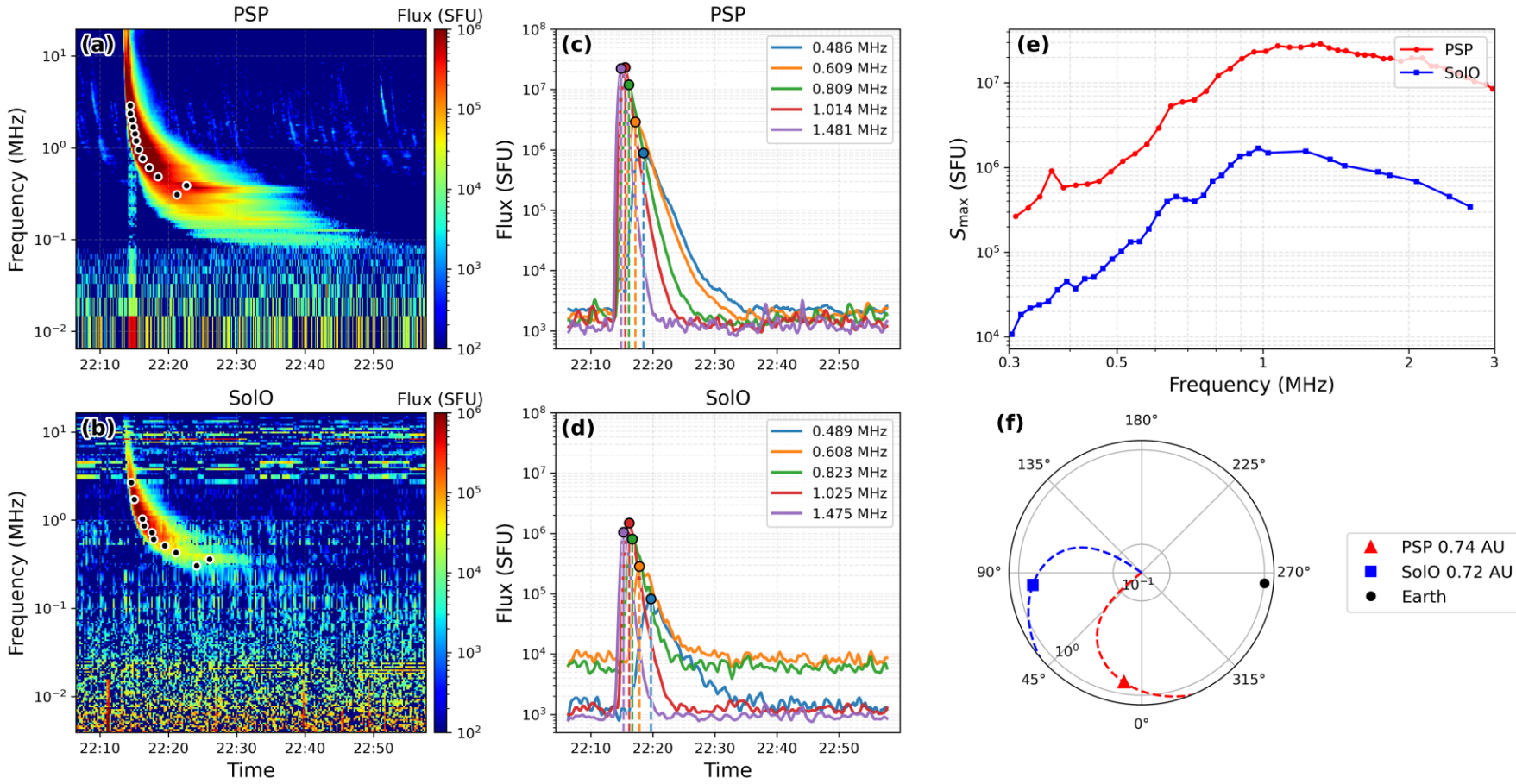


932 Bursts

Data and Analysis Method

Data & Processing

Maximum flux S_{max}

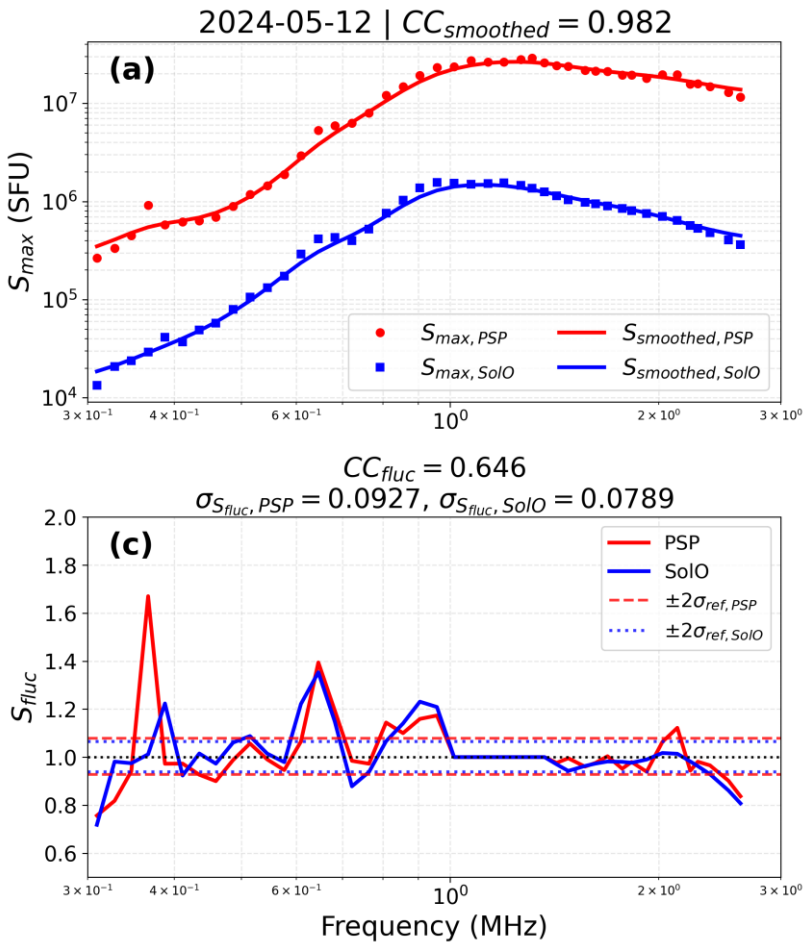


Data and Analysis Method

Data & Processing

Maximum flux S_{max}

Fluctuations S_{fluc}



$$S_{fluc} = \frac{S_{max}}{S_{smoothed}}$$

The cross-correlation coefficient $CC_{smoothed}$ was computed to confirm that they observed the same Type III burst.

Only events with a $CC_{smoothed}$ > 0.8 are retained for further analysis. (668 events)

σ_{ref} from the smallest fluctuations event

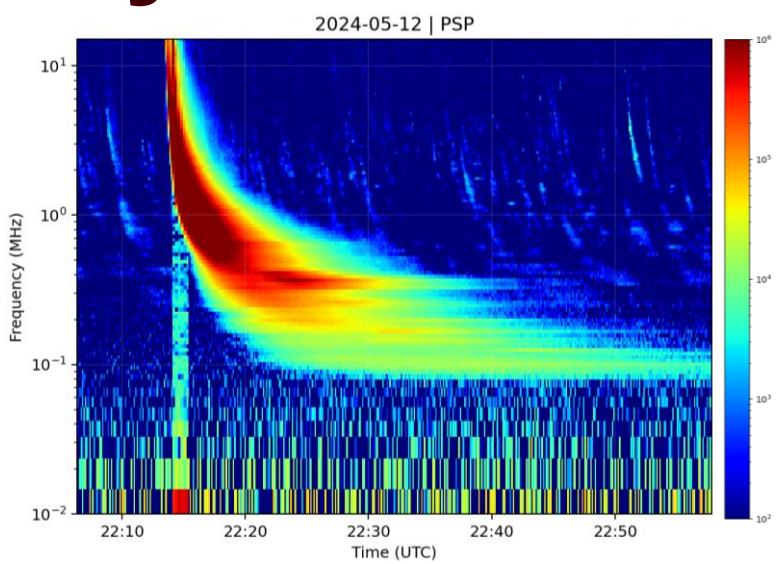
- Points > $2\sigma_{ref}$: Fluctuations

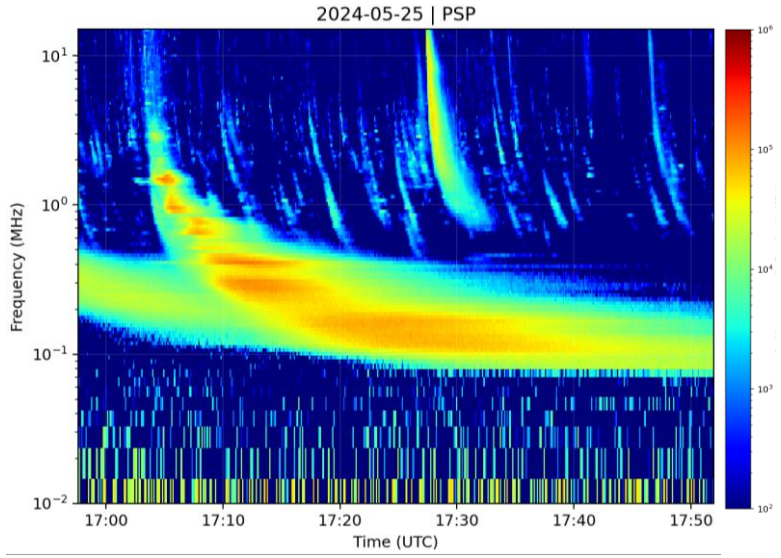
Data and Analysis Method

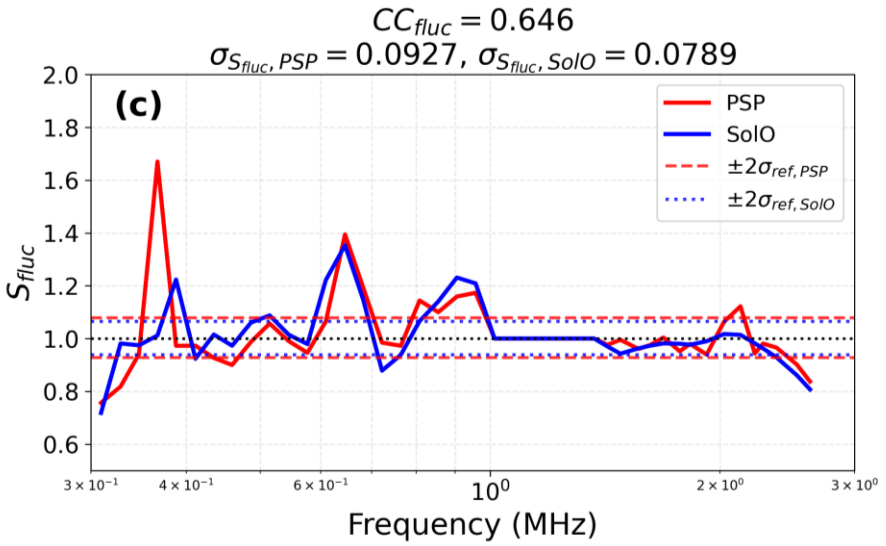
Data & Processing

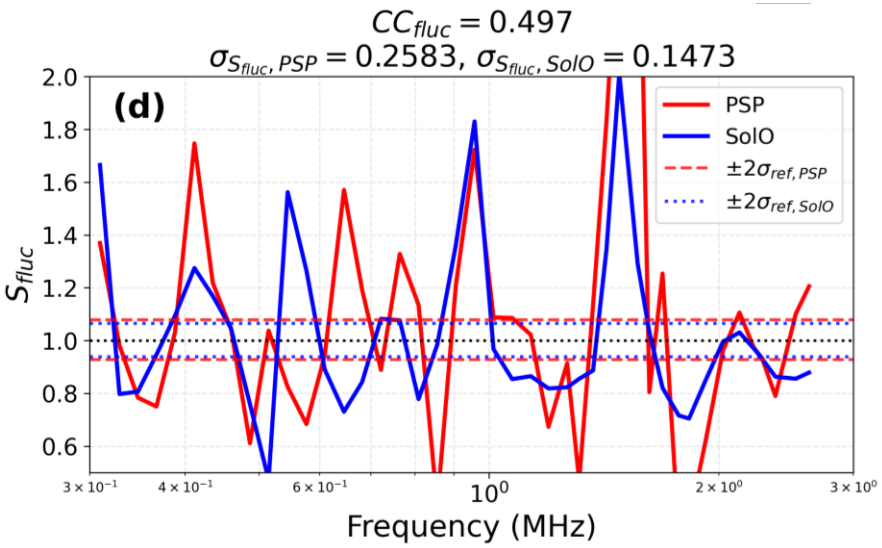
Maximum flux $S_{\max}$

Fluctuations S_{fluc}

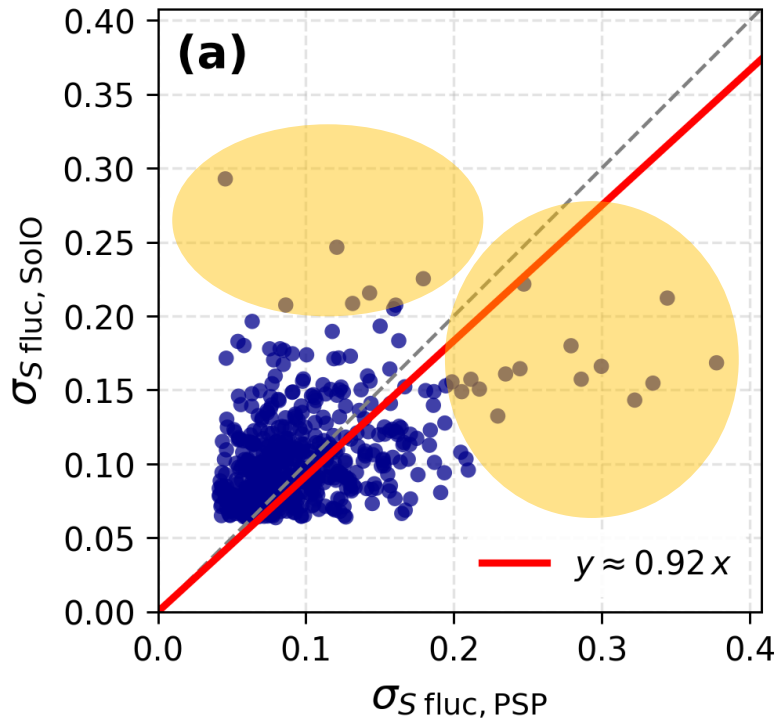


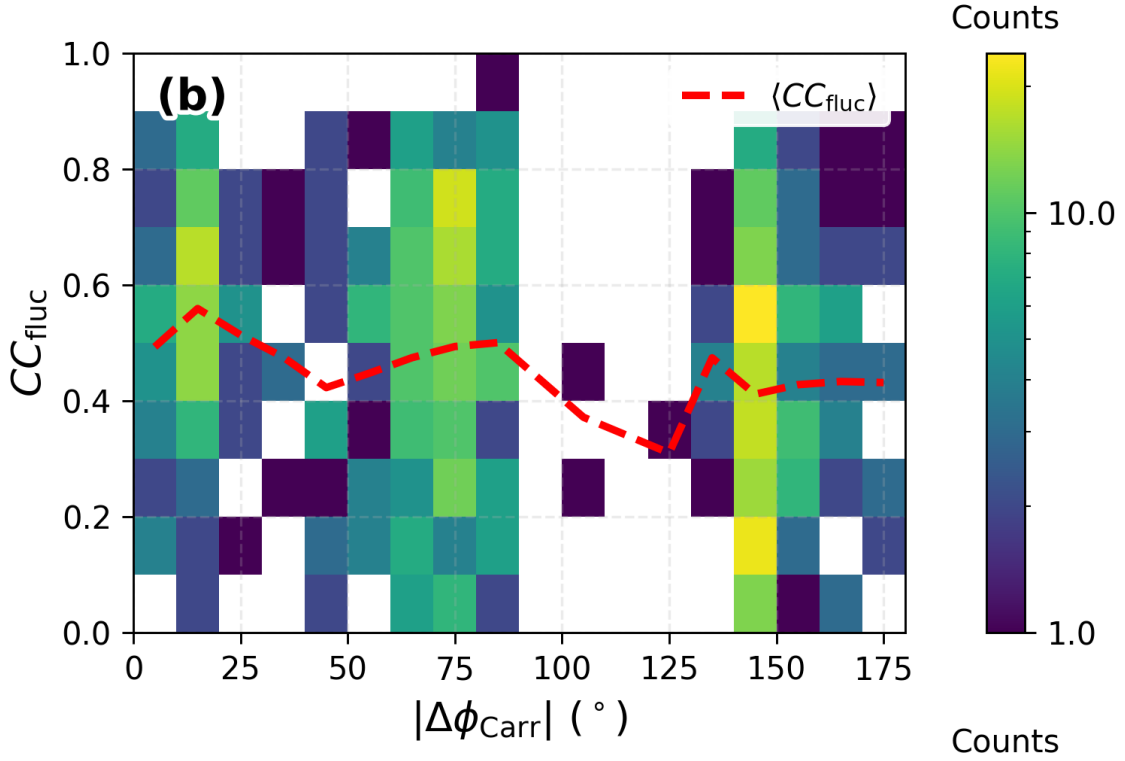






Fluctuations Correlation: PSP vs. SolO





From observations, events with $\sigma_{S_{fluc}} > 0.2$ are associated with the occurrence of striae.

We classified them as an event with strong fluctuations.

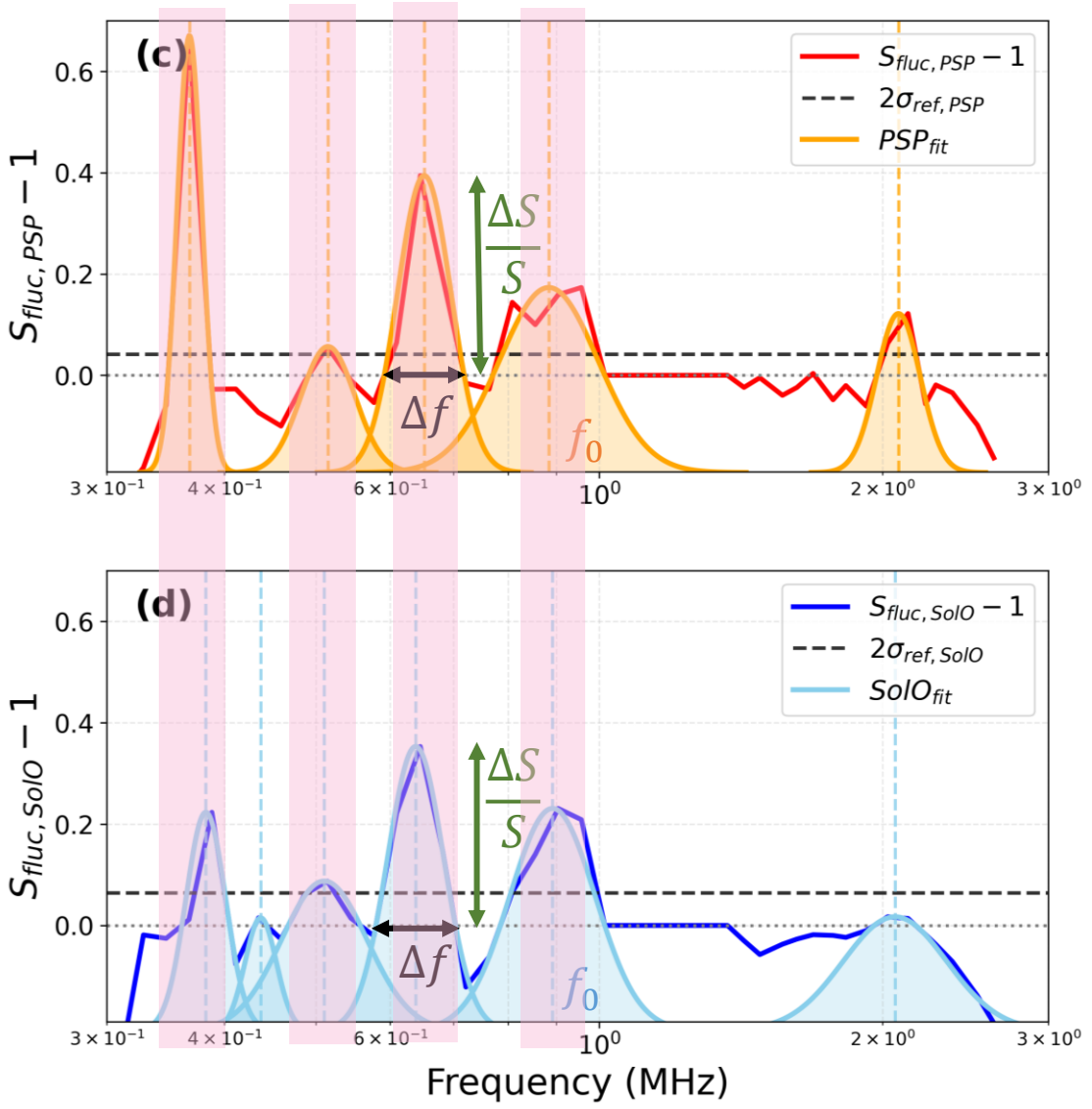
No clear dependence of the fluctuations on the angular separation is observed.

Individual Fluctuations

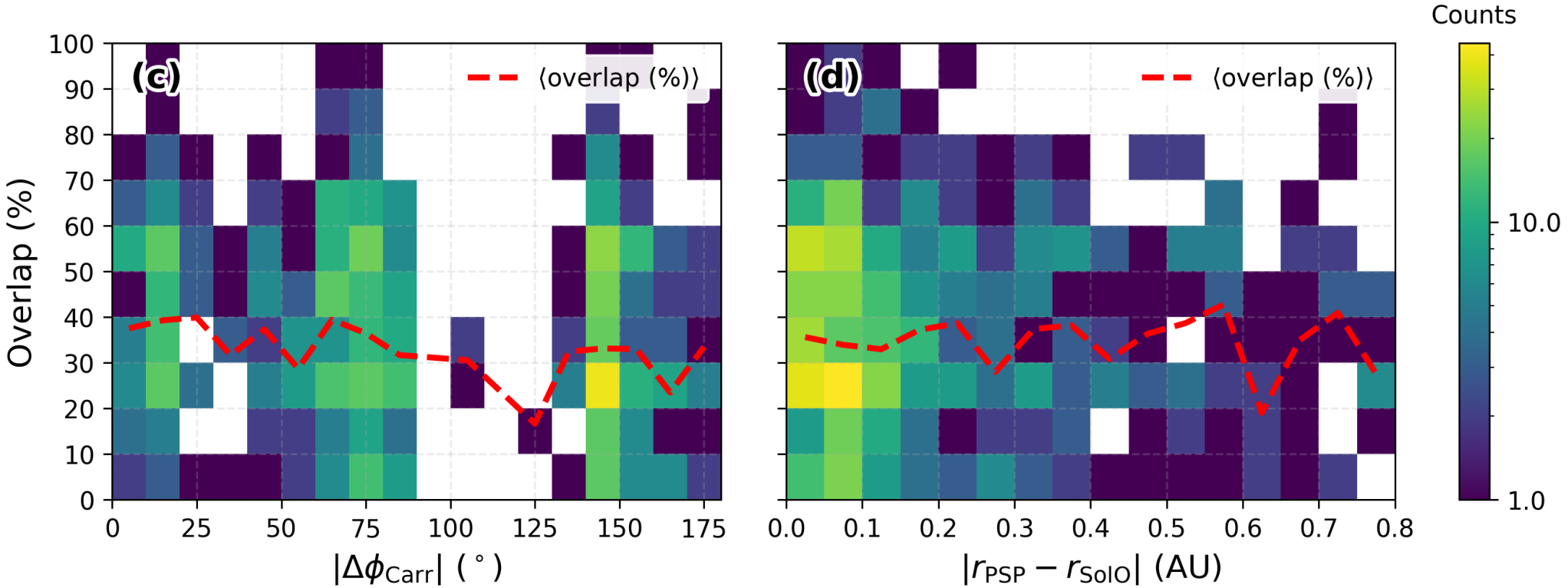
Individual fluctuation was identified using zero-crossing boundaries, and the Gaussian fit was applied to the positive peak. (same method use in Krupar et al. 2025)

- The relative amplitude; $\Delta S/S$
- The frequency bandwidth; Δf
- Centre of the observed peak; f_0

Overlapped %
when the f_0 from an individual fluctuation from one spacecraft falls within the Δf bandwidth of the other spacecraft.



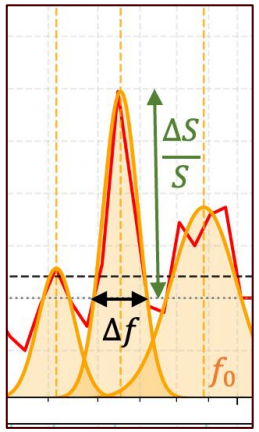
Overlapped (%)

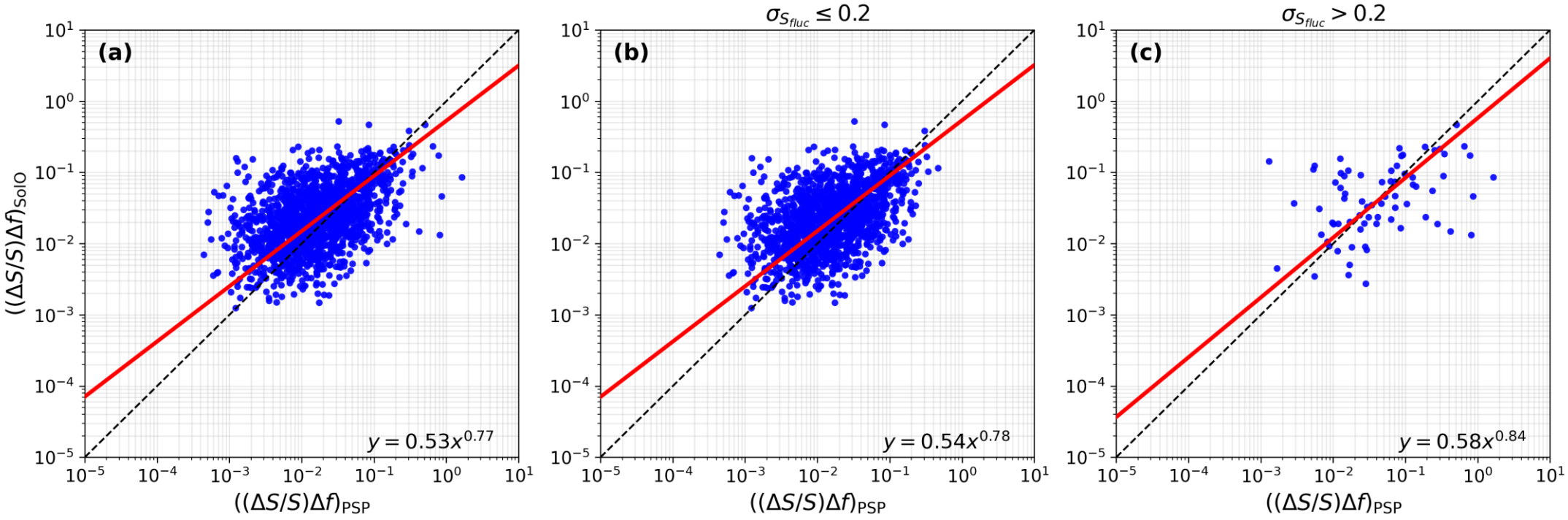


Both spacecraft may still sample comparable spectral features despite being located at different heliocentric distances.

- Krupar et al. 2024: There's no significant radial variation in type III radio burst properties (below 0.24 AU).

Relative size : $(\Delta S/S)\Delta f$





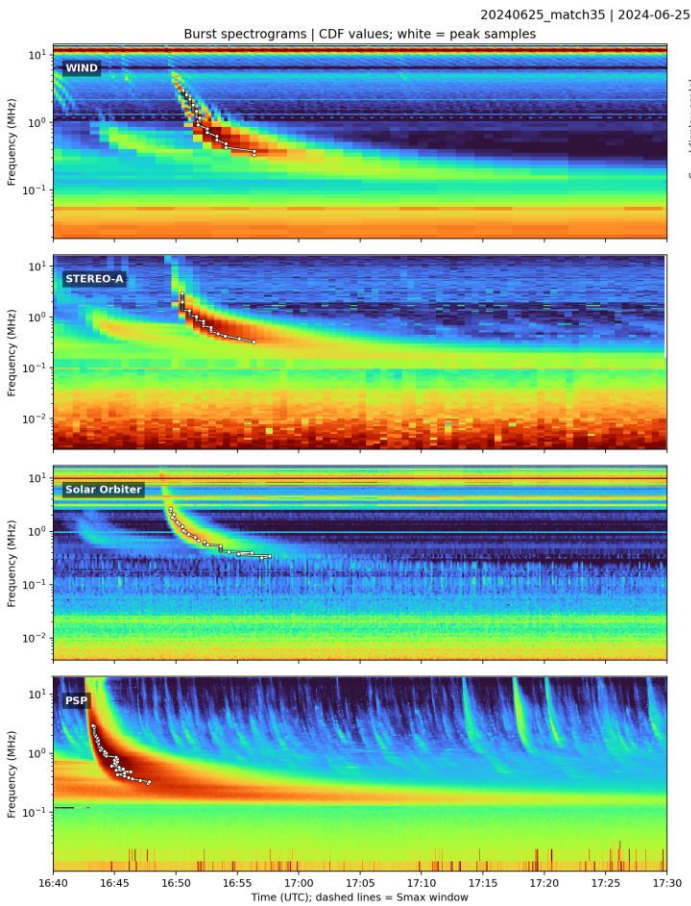
The relative sizes of individual type III fluctuations observed with PSP and SolO agree well, with similar trends for both small and large fluctuations.

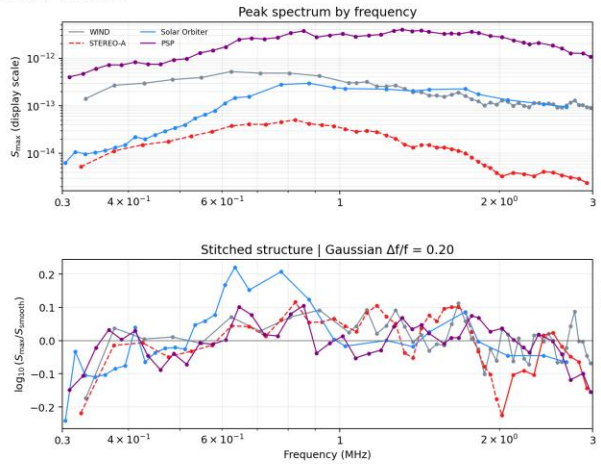
Conclusions

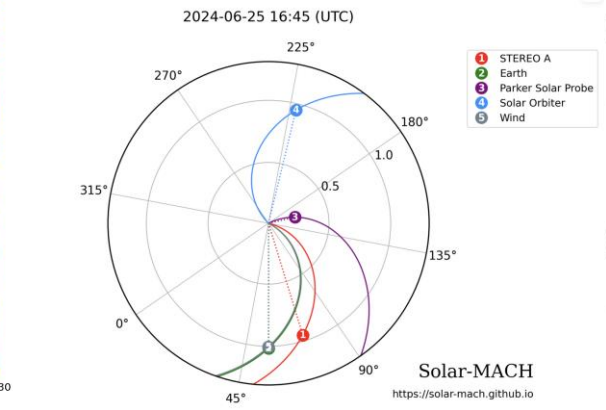
- Small spectral fluctuations are real
  - PSP and SolO independently observe similar fluctuation patterns.
  - Not instrumental noise.
  - The data are consistent with a continuum, rather than two distinct populations between small and large fluctuations

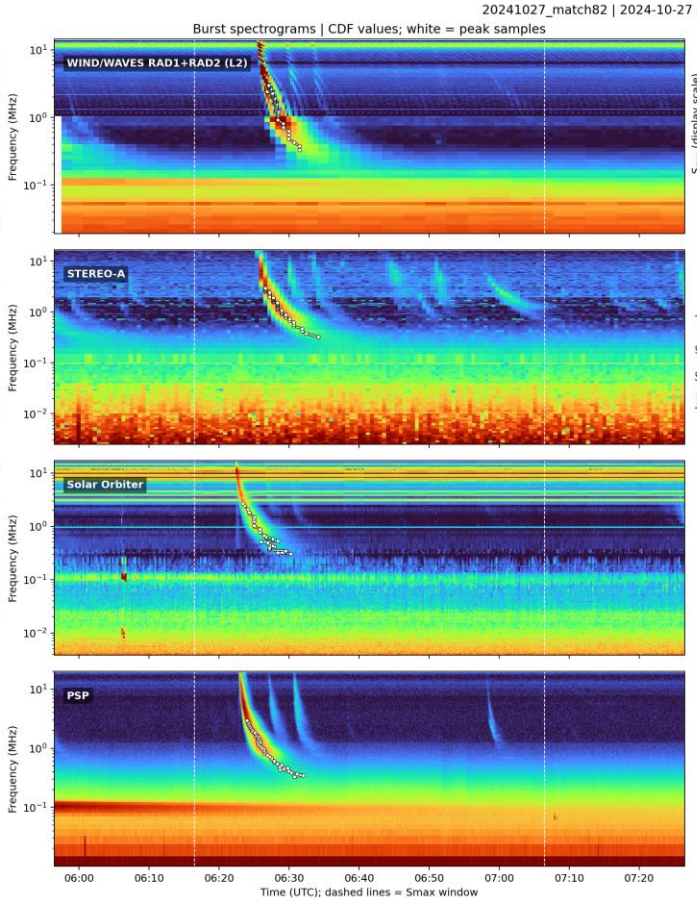
- Fluctuations are preserved across spacecraft viewpoints
  - The similarity in fluctuations does not clearly decrease with radial distance or heliolongitude separation.
  - This suggests that the structures are imprinted within or near the radio source region.

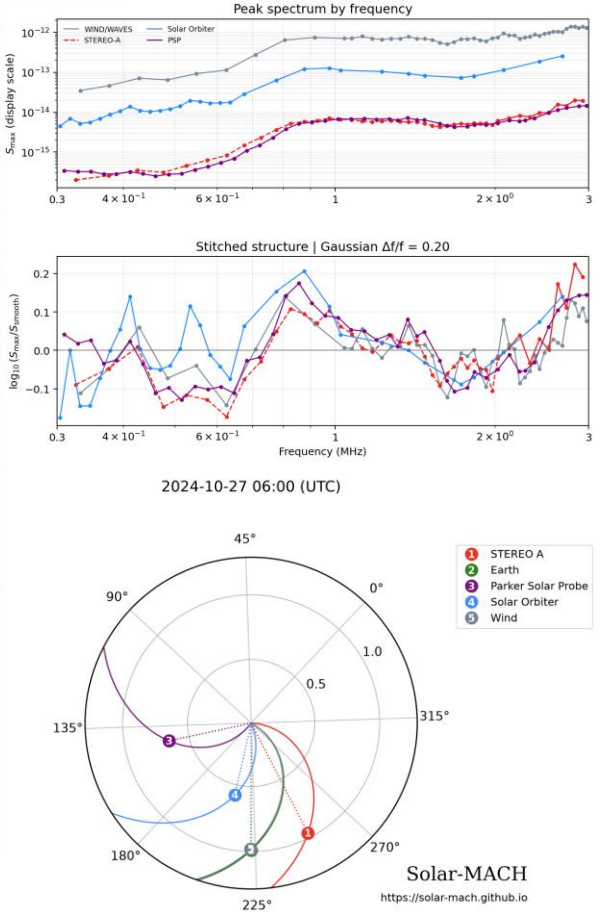
Ongoing work
WIND and STEREO-A





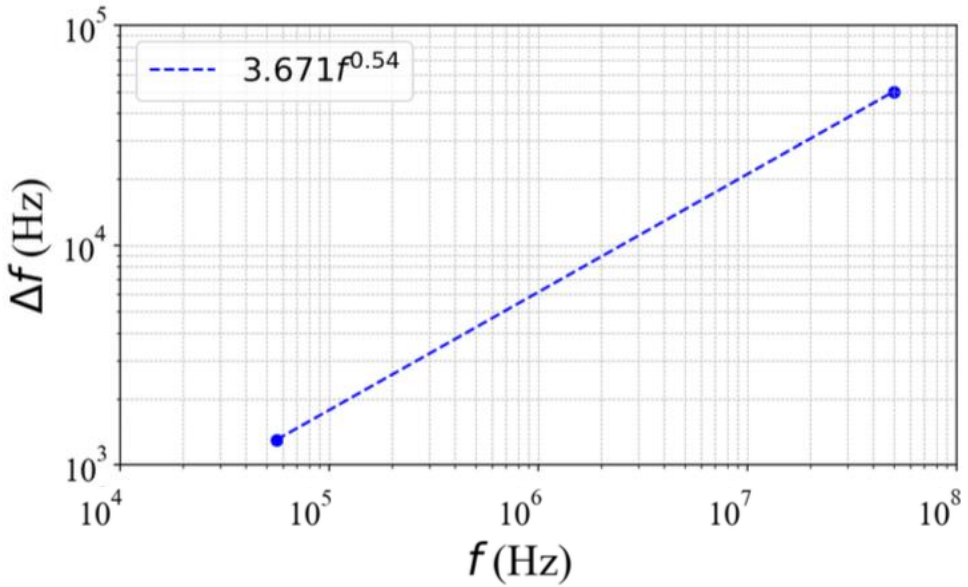




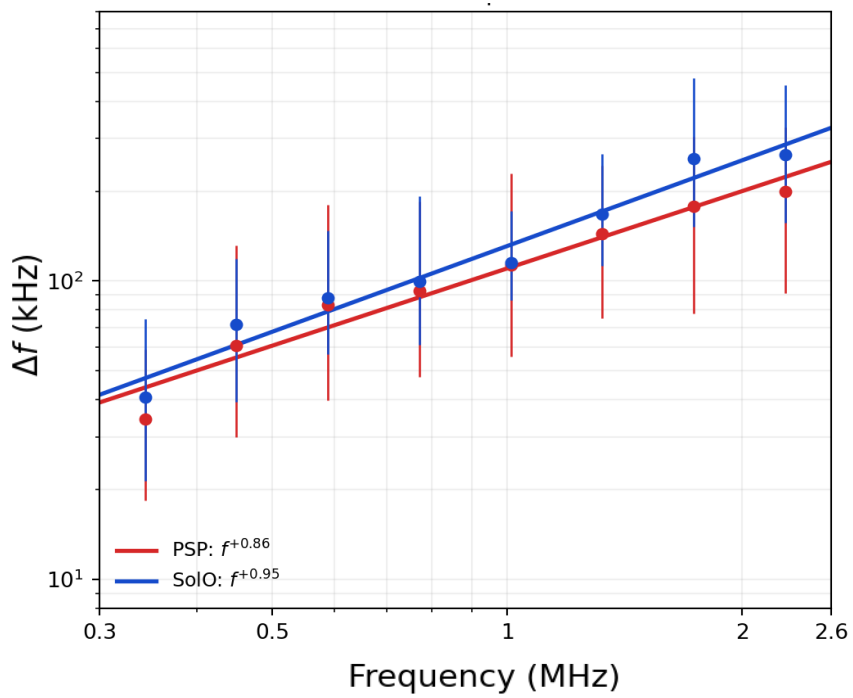


Ongoing work

- Toward the generation mechanism of spectral fluctuations
  - Is it possible to identify the generation mechanism of small and large fluctuations in Type III bursts?
  - Are they associated with density fluctuations?



Krupar et al. 2025



Thank you for your attention