The impact of the observer's position on solar radio observations

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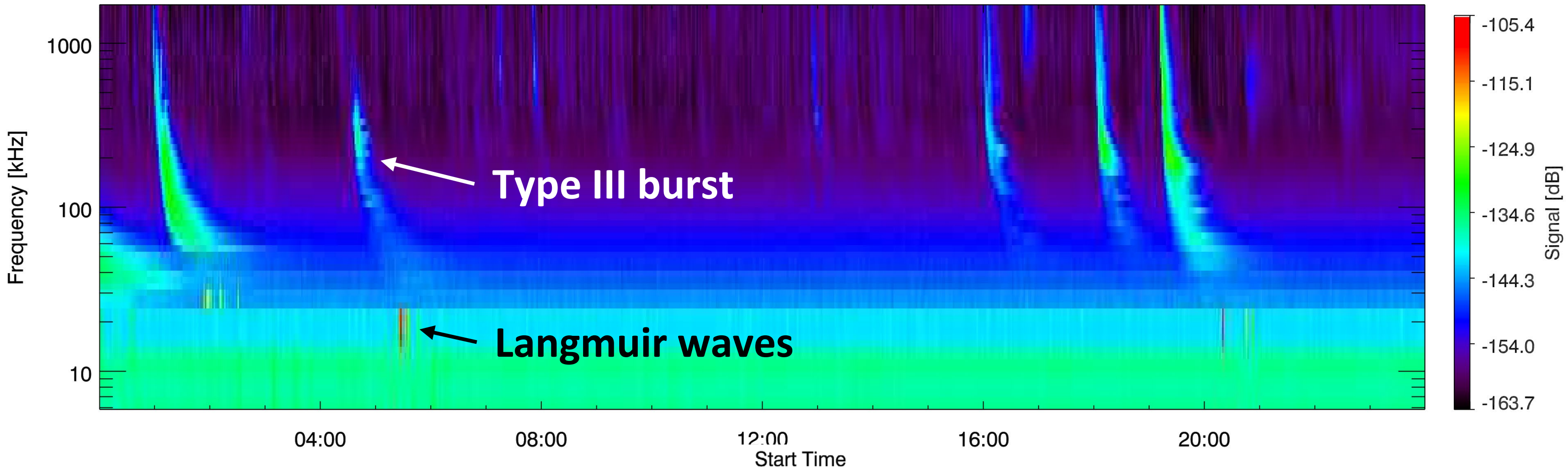
Spectroscopic Properties

Type III bursts:

- radio photons excited by electrons accelerated along open magnetic fields
- sometimes observed with associated Langmuir waves



Observed spectroscopic properties:

- signal amplitude (peak)
- duration
- delay time
- **rise time**
- **decay time**

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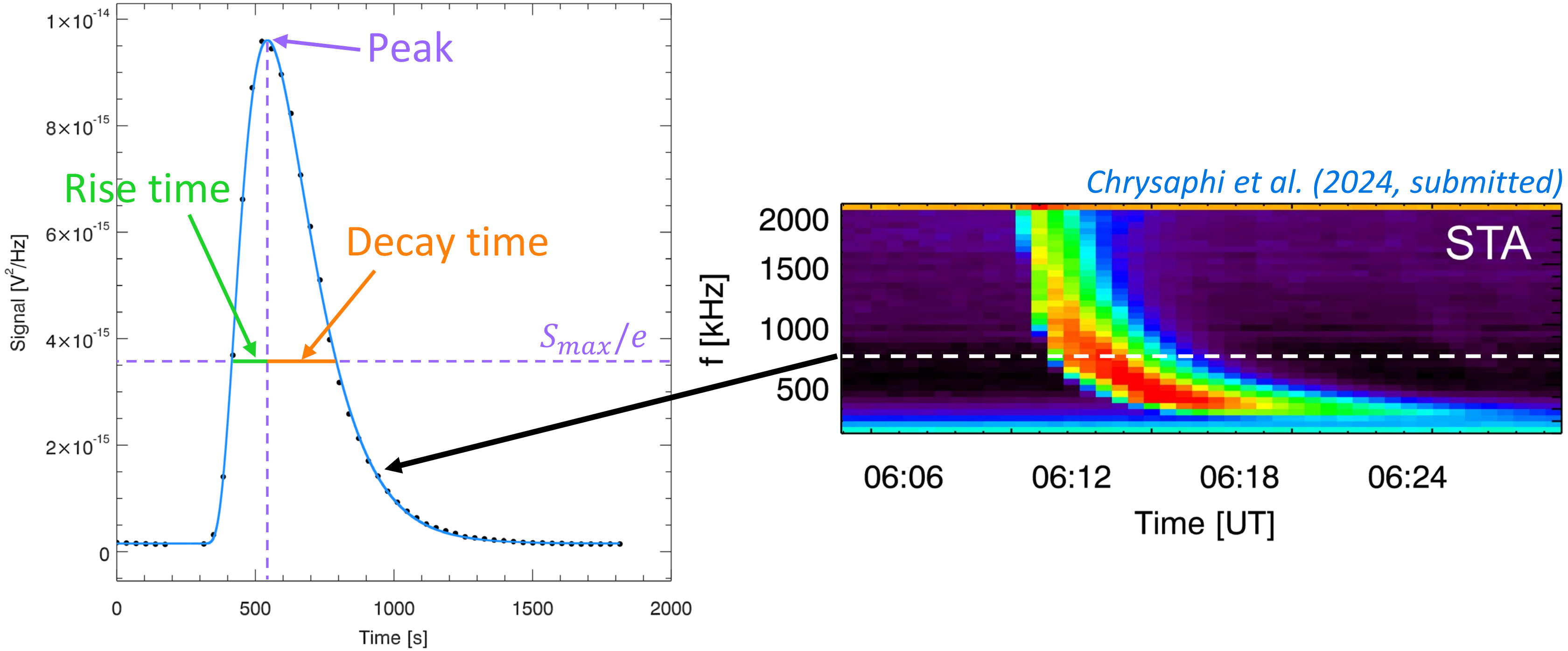

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Radio-wave Propagation Effects

Density inhomogeneities in the heliosphere **affect the propagation of photons**

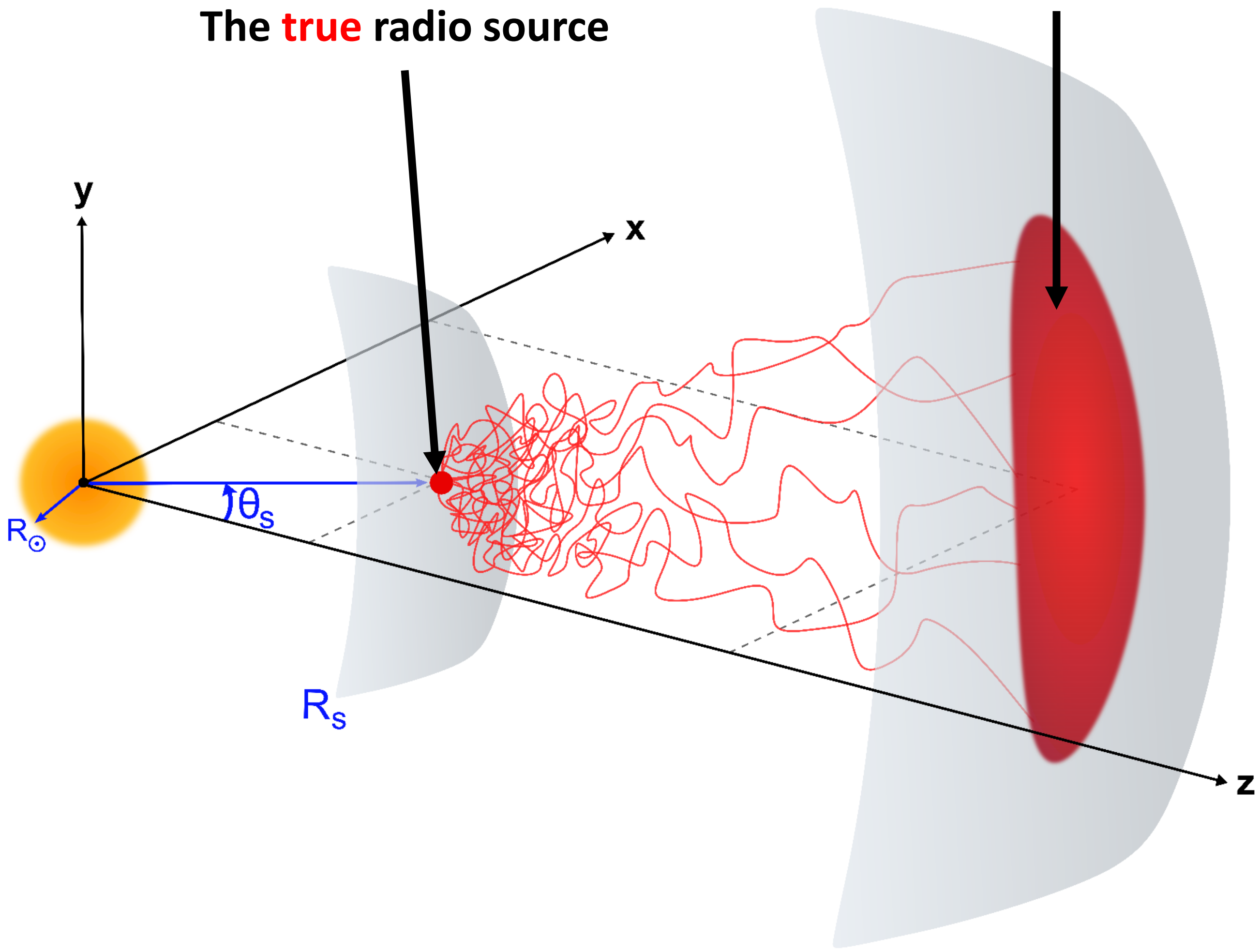
- photons can be scattered, refracted, absorbed
- Important when observed $f \approx f_{pe}$
- frequency-dependent ⟹ lower frequencies are affected more

Scattering dominates the observed properties

- source sizes appear larger
- source positions appear shifted

Density inhomogeneities are anisotropic

⟹ scattering is also **anisotropic**



Kontar et al. 2019, ApJ, 884, 122

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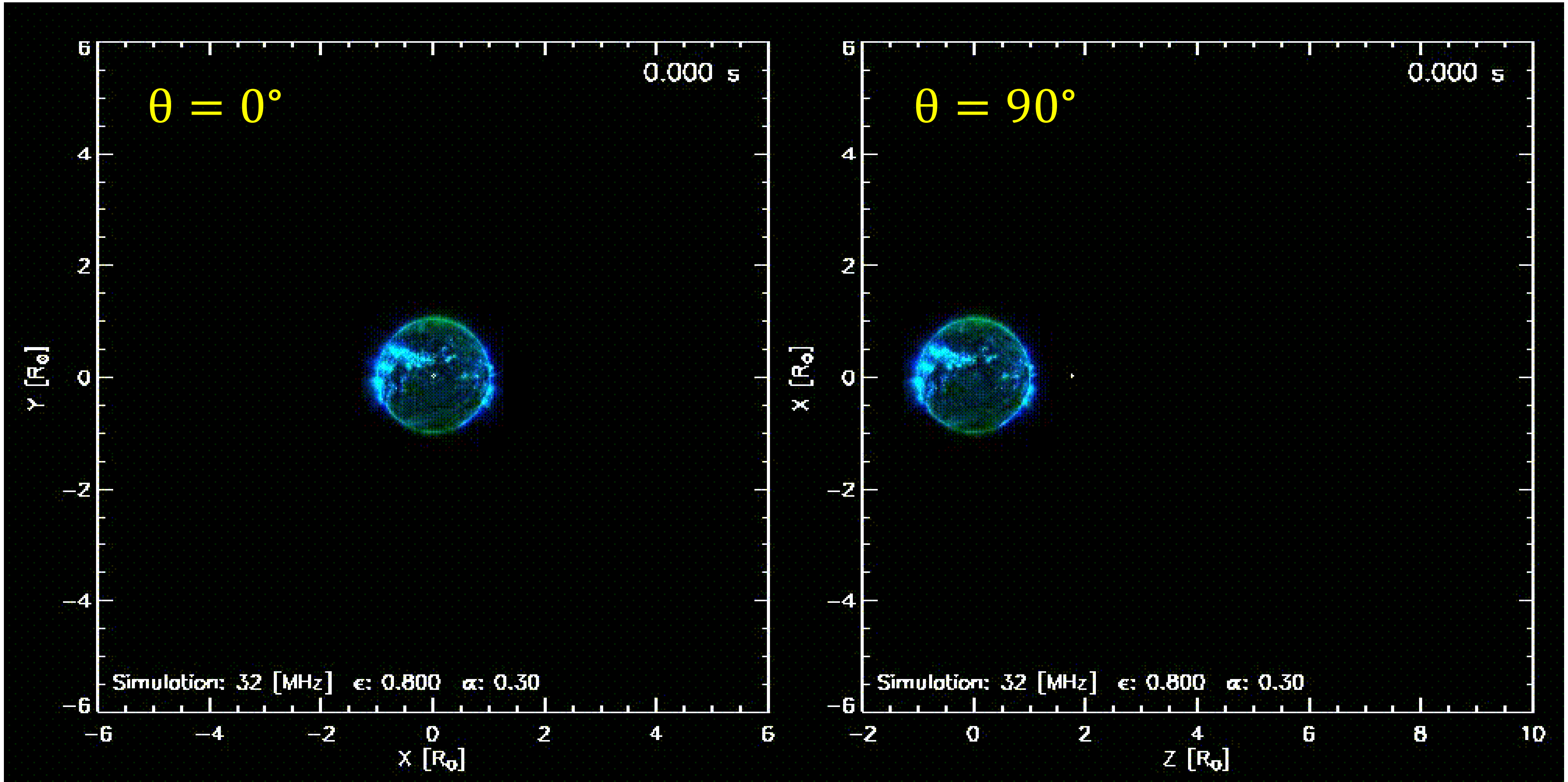
Anisotropic Scattering

- Anisotropic scattering means that photon propagation is **directional** (mushroom-like shape)
  ⟹ **observer's position is important (for source size, position, and flux)**

The animation can be found at this CESRA nugget: Chrysaphi et al. (Nov. 2019), Figure 1



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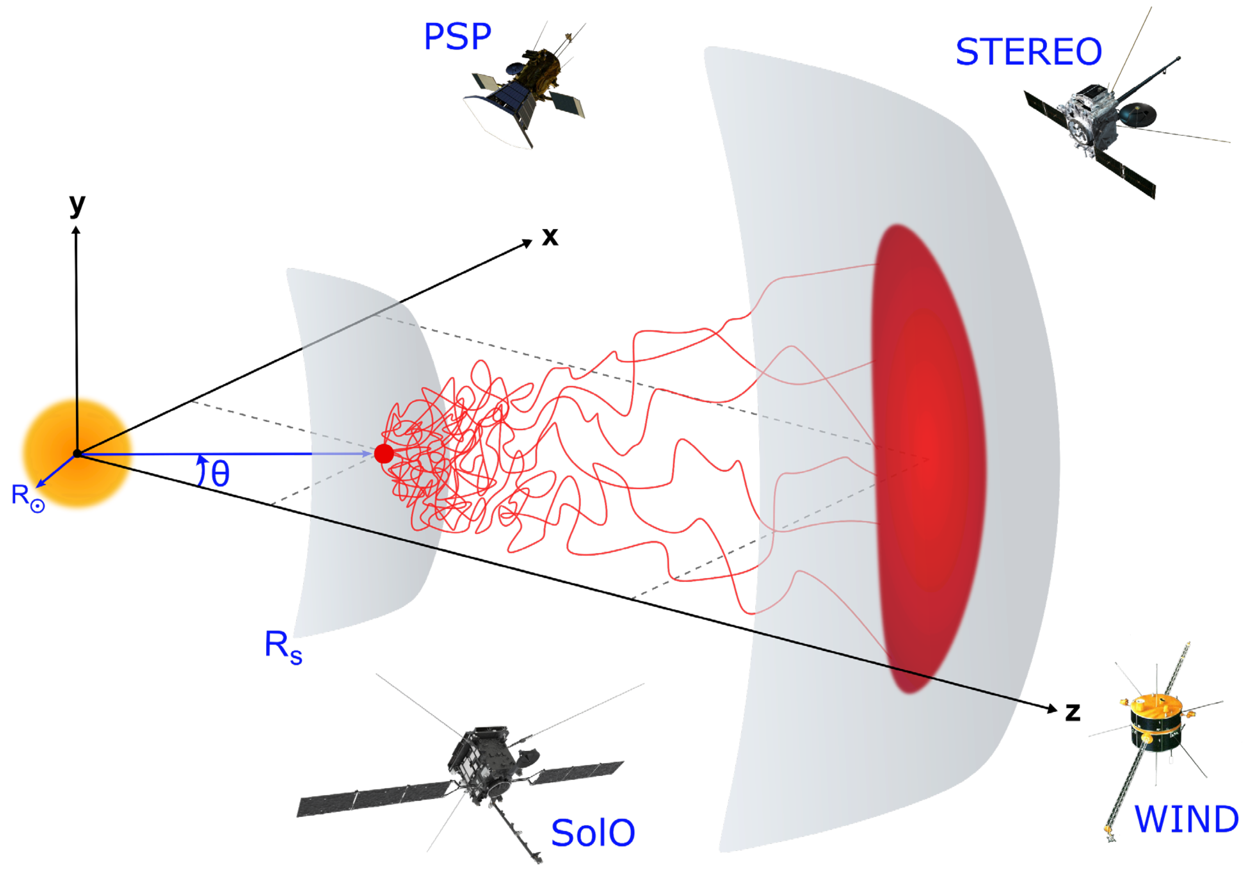
Decay Time

Is the decay time also affected by the observer's position?



Why examine the decay time?

- Decay time **defined by scattering**
- Used as **proxy for estimating level of density fluctuations** $\frac{\delta n}{n}$
- If dependent on angular separation, measurements will need correction

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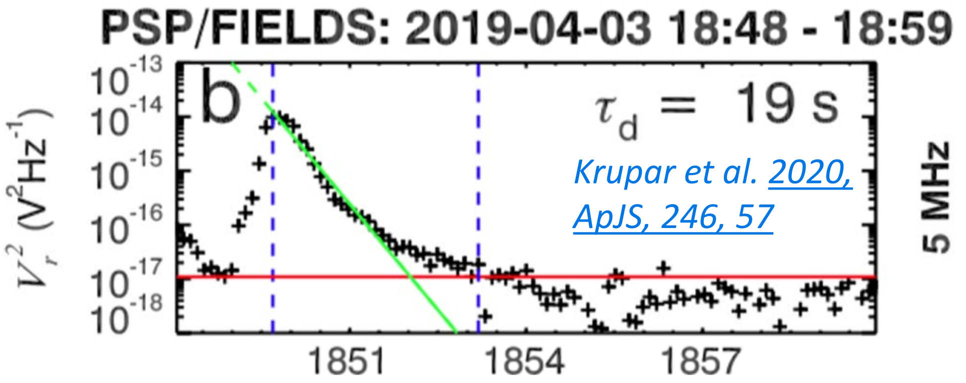
Fitting the entire light curve

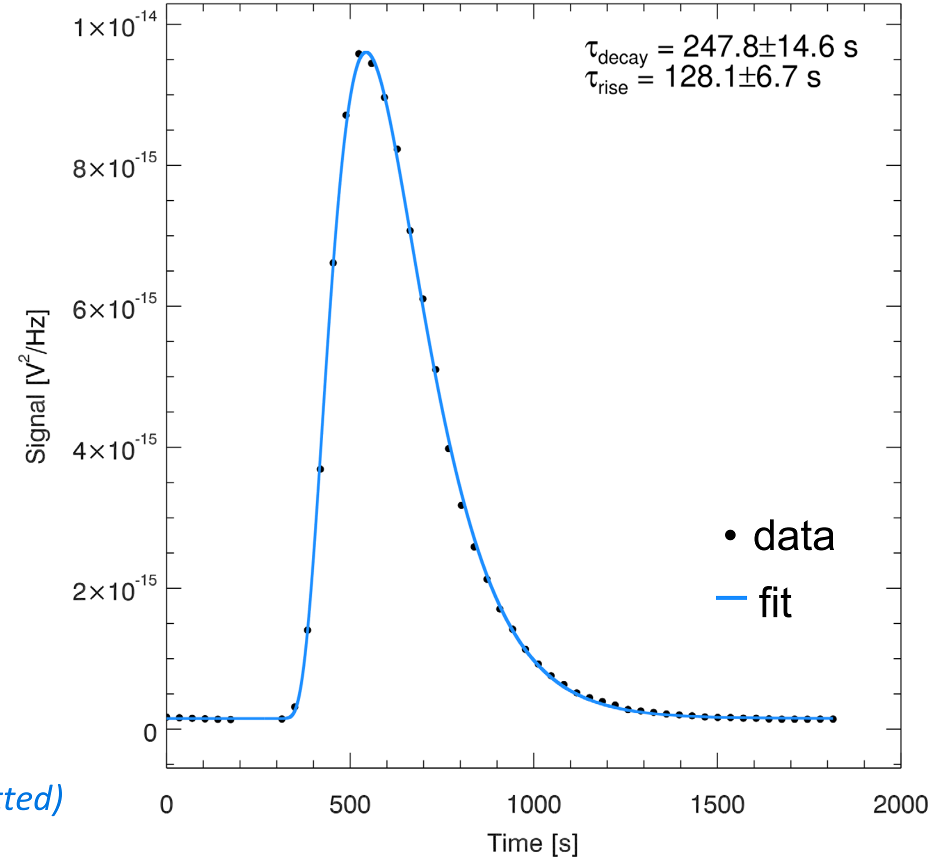
Previous Decay Time Estimations:

- Approximated using a single exponential fit to the decay phase
- Not always a good characterisation
- Peak time not described



We fit the **entire light curve** **with a single function**, providing an improved estimation of the **decay time**, and a simultaneous estimation of the **rise time and peak flux**:

$$f = \left[A\exp\left(-\frac{\tau_1}{t_i - t_{off}} - \frac{t_i - t_{off}}{\tau_2}\right) + C\right] \times H(t, t_{off})$$



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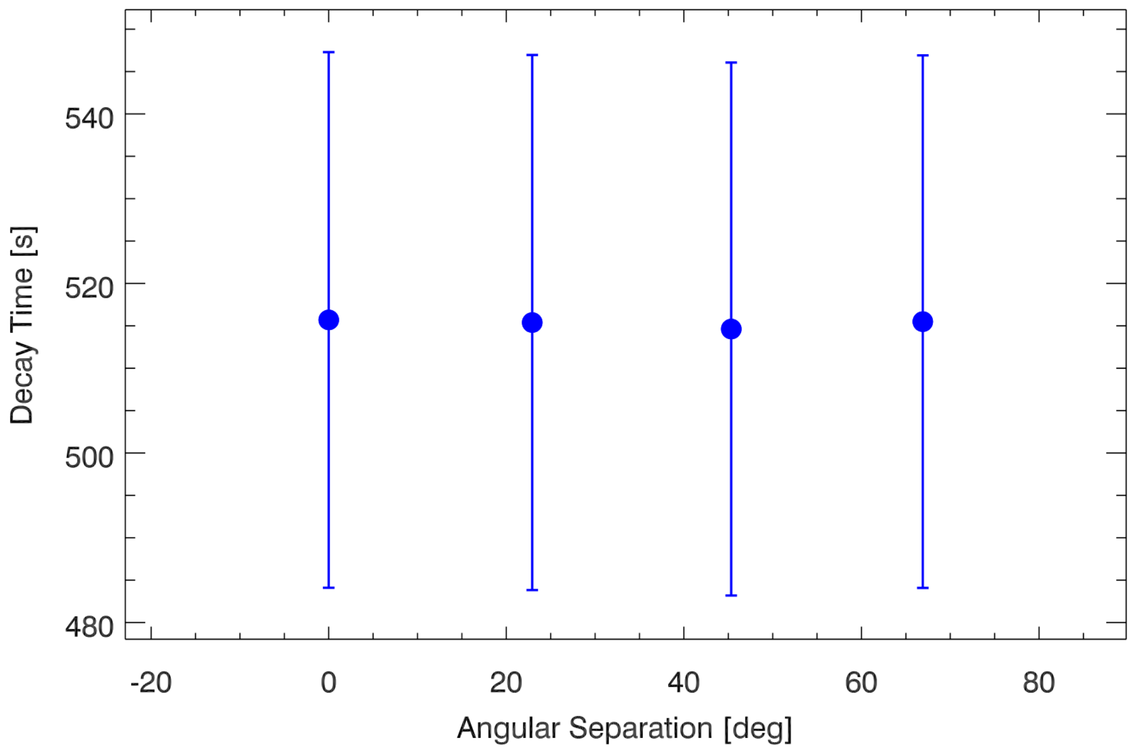
Simulations Prediction



- Used state-of-the-art 3D ray-tracing simulations accounting for anisotropy *(Kontar et al. 2019, ApJ, 884, 122)*
- **Prediction: No dependency** of the decay time on the observer's position

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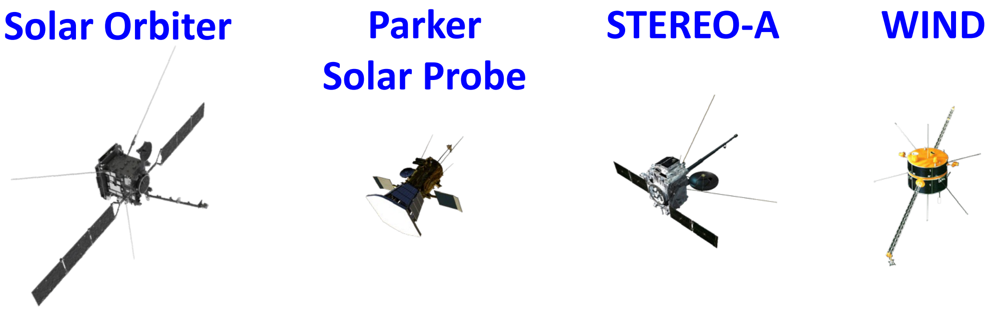
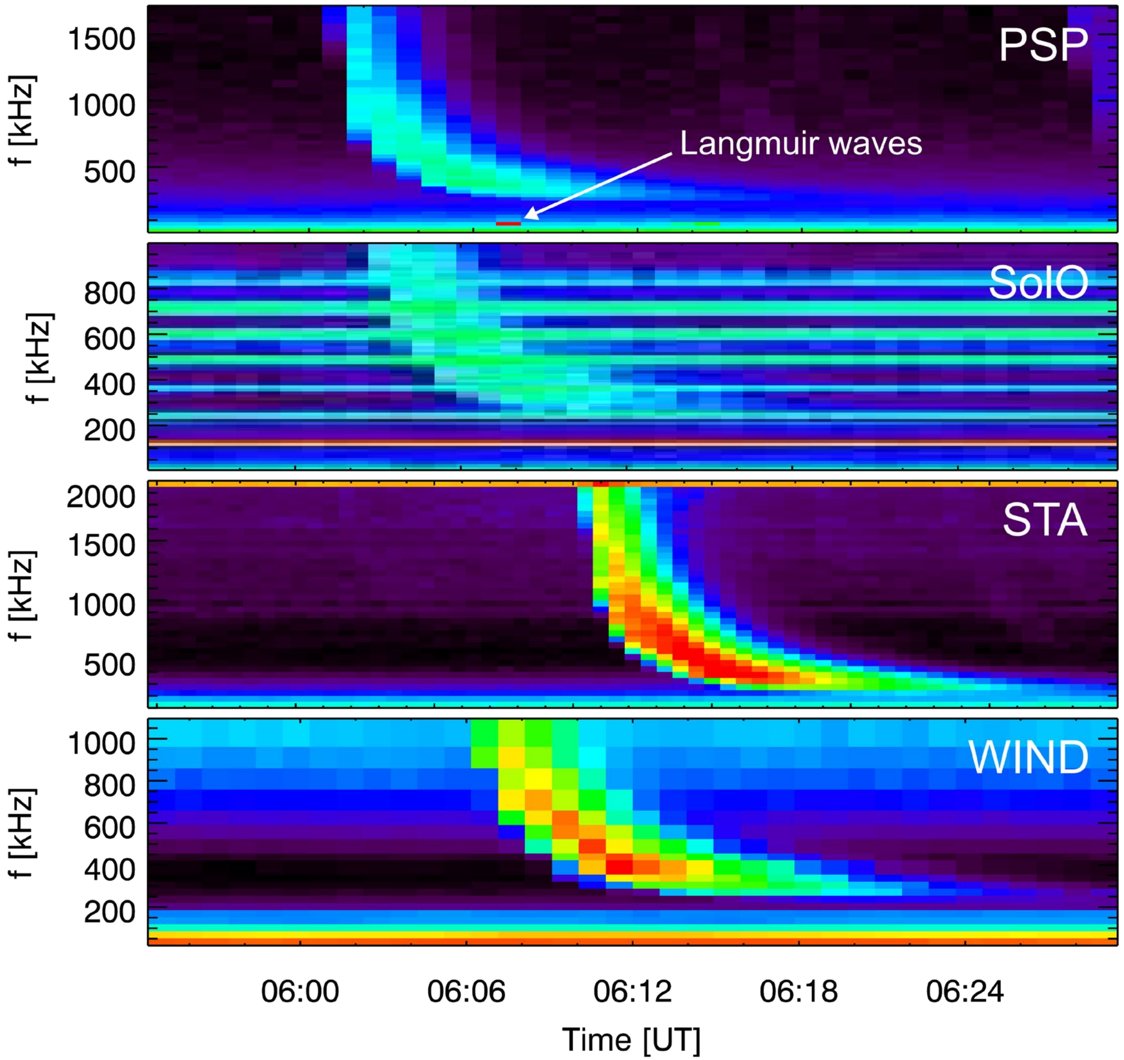
Multi-vantage observations

- Multi-vantage observations of interplanetary Type III bursts

- Used data from:



- **Langmuir waves** observed by one of the spacecraft



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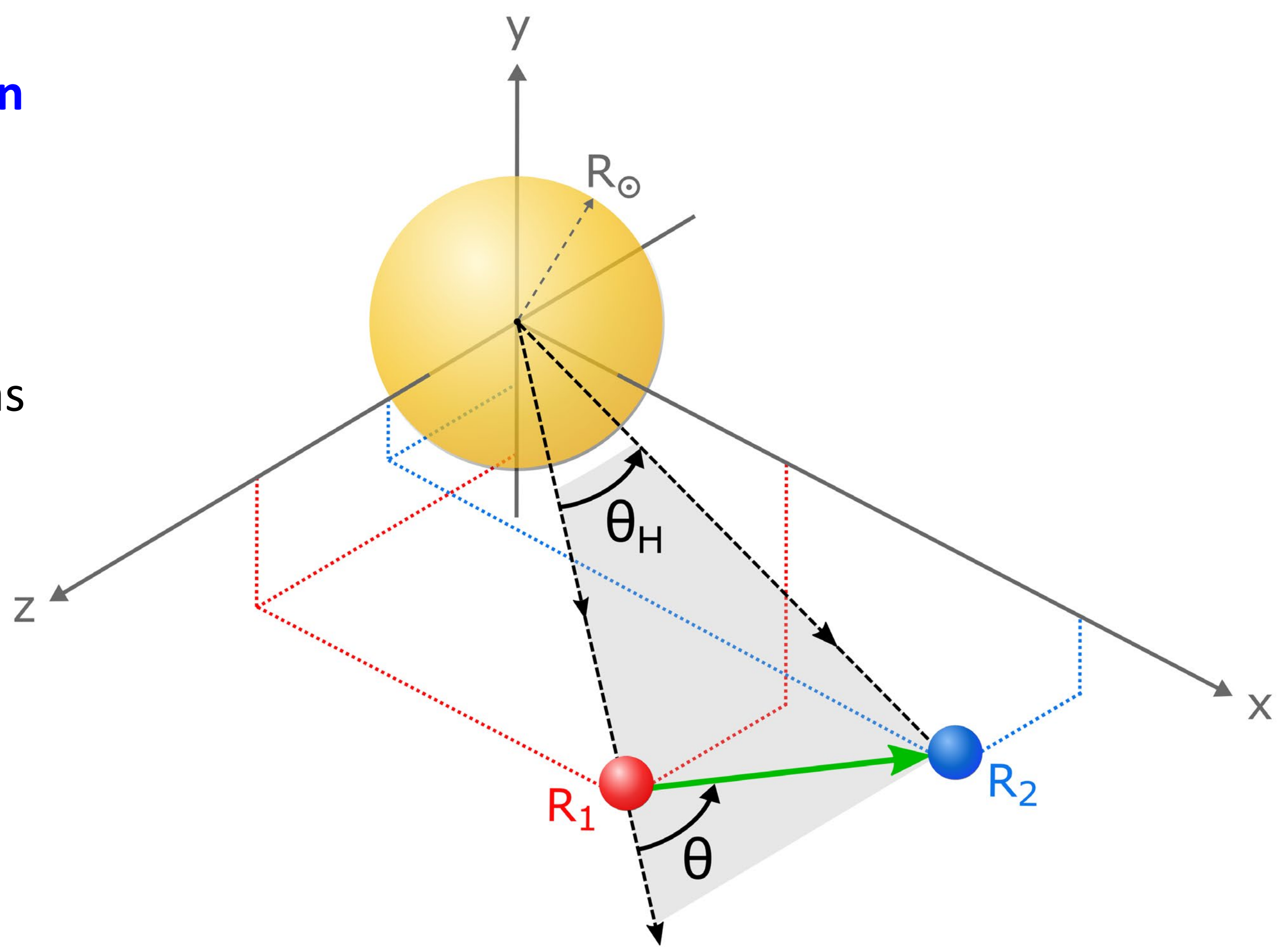
Angular separation calculation

- **Langmuir waves** observed by one of the spacecraft
  ⟹ spacecraft location **taken as radio source location**

- (3D) angular separation **θ** calculated in the **plane of the two spacecraft**, with the Sun-source axis taken as the origin

- Considered the **Euclidean distance** between the source and spacecraft



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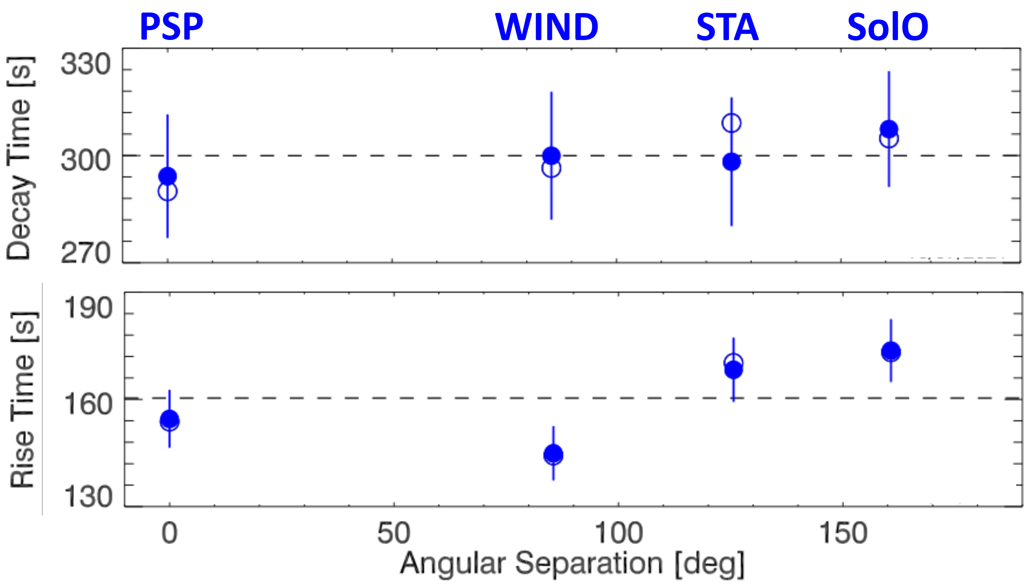
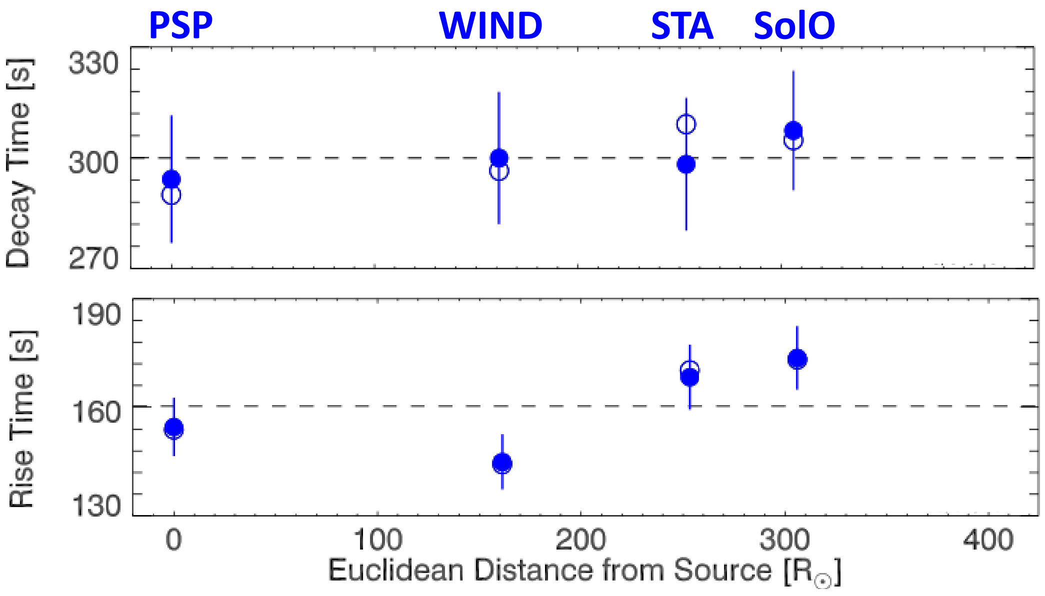
Decay and Rise time

As a function of angular separation from source:



As a function of Euclidean distance from source:



* Figures shown are for one of the Type III bursts analysed

- Corrected for scattering-induced broadening due to frequency differences between spacecraft
- **Result:** **No systematic trend** between measurements at comparable frequencies

$\Longrightarrow$ **Decay- and Rise-time measurements are independent of the observer's position**

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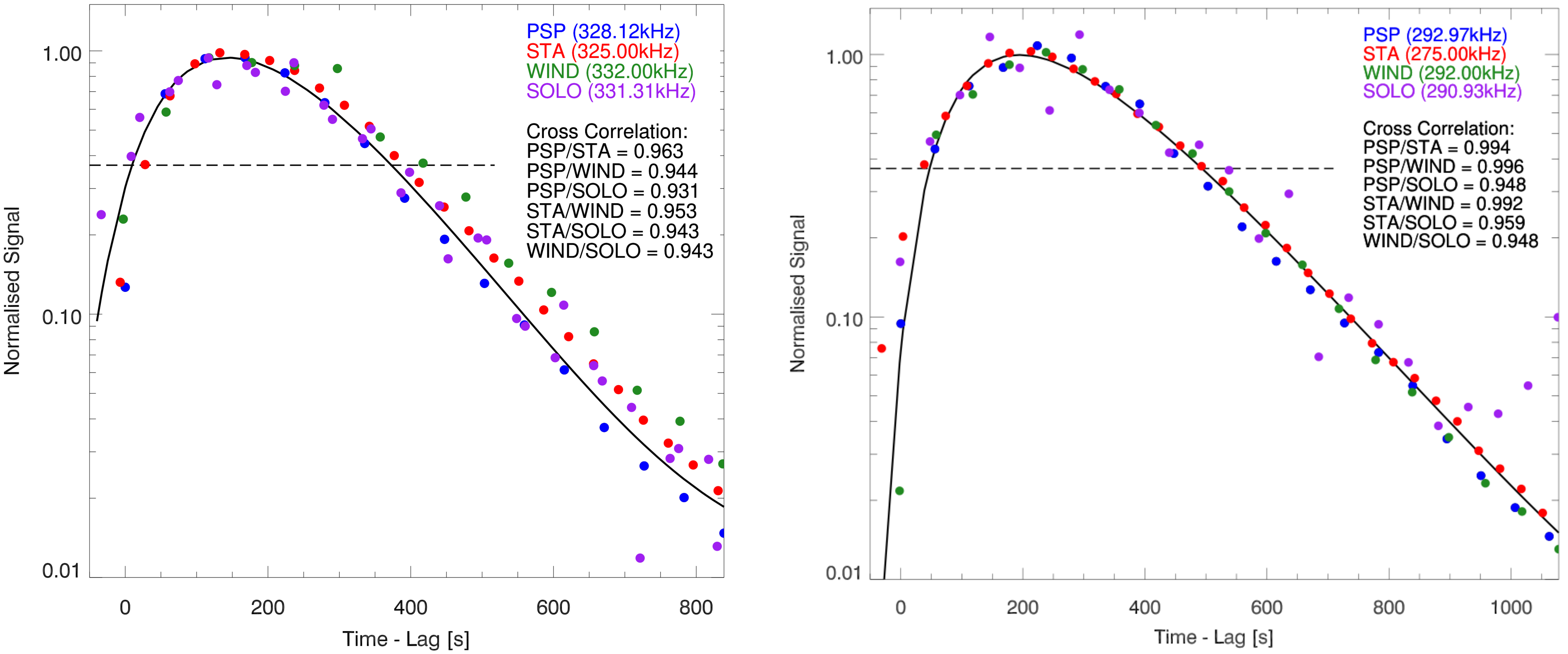
Direct comparison



- Similar time profiles despite that recorded frequencies are not identical

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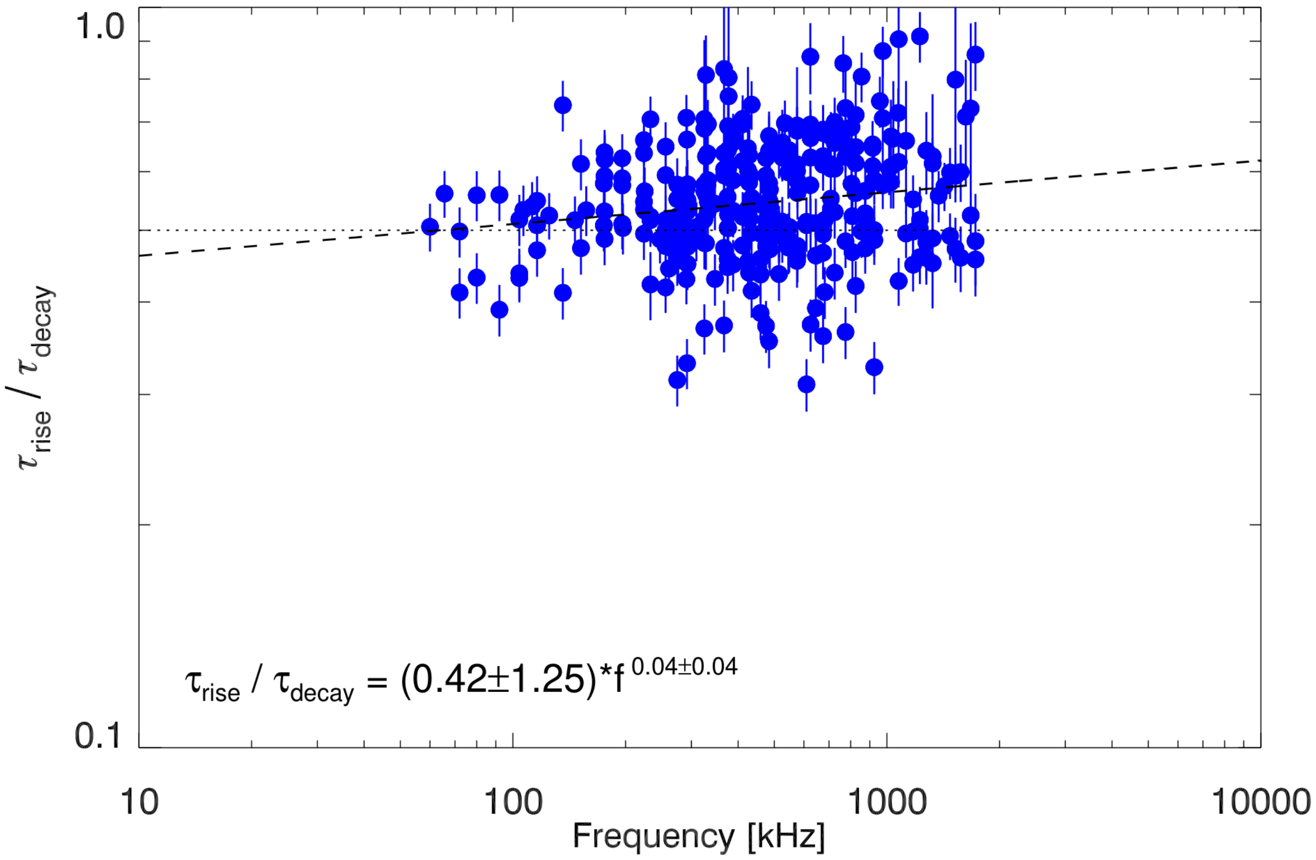
Rise-to-decay time ratio vs Frequency



- $\tau_r/\tau_d \propto f^{\,0.04\pm0.04}$ (obtained for 0.06 – 1.73 MHz)
- Compared datasets covering frequencies from 0.06 – 130 MHz (4 decades), finding similar τ_r/τ_d
- **Result:** No frequency dependency

⟹ **Rise time is affected by scattering effects in a proportionate manner to the decay time**

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Summary

Improved Methodology

⟹ **more physically meaningful**

1. Used 3+ vantage points
2. Fitted entirety of light profiles with single function
3. Accounted for errors in rise and decay time estimations
4. Considered 3D locations of spacecraft
5. Calculated θ from the source (not heliocentric)
6. Calculated Euclidean distance (not just radial)
7. Corrected for differences between spacecrafts' recorded frequencies
8. Evaluated results in 3 separate ways

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Conclusions

- **Scattering is anisotropic**, leading to highly-directional emissions ⟹ **consider observer's position**
- Decay & Rise time: **No systematic trend** between measurements at various observer separations
  - ⟹ only measurements that can be trusted irrespective of the observer's location
  - ⟹ do not require a correction
- **Rise phase of radio bursts does not grow exponentially**
- Rise-to-decay time ratio: **No frequency dependency**
  - ⟹ **Scattering contributes significantly to rise phase**

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