PNST, May 2022.

The angular dependence of spectroscopic solar radio measurements using multi-spacecraft observations

Nicolina Chrysaphi[1,2]

M. Maksimovic[1], E. Kontar[2], A. Vecchio[3,1], X. Chen[2], and K. Pesini[3]

[1]LESIA, Observatoire de Paris, Université PSL, CNRS, Sorbonne Université, Université de Paris, 5 place Jules Janssen, 92195 Meudon, France
[2]School of Physics & Astronomy, University of Glasgow, Glasgow, G12 8QQ, UK
[3]Radboud Radio Lab, Department of Astrophysics, Radboud University Nijmegen, The Netherlands

ORCID.org

cnes CENTRE NATIONAL D'ÉTUDES SPATIALES | LESIA l'Observatoire de Paris | PSL | Laboratoire d'Études Spatiales et d'Instrumentation en Astrophysique | University of Glasgow | Science & Technology Facilities Council

Solar radio emissions

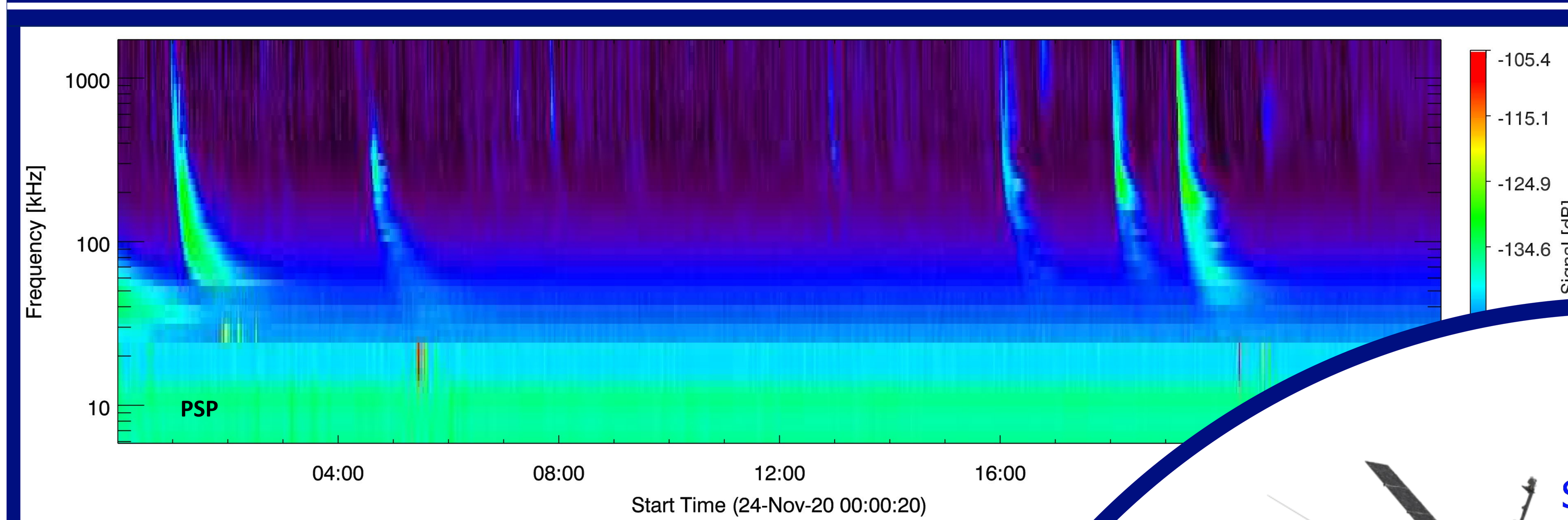

Fig. 1 Multiple Type III bursts and their Langmuir waves observed by PSP in a single day.

- Solar eruptive events can excite emissions of radio photons [1–3]
- These intense and sporadic solar emissions are called **radio bursts**
- Emitted at frequencies close to the local electron plasma frequency of the heliosphere ($f \approx f_{pe}$)
- Most frequently-observed emissions are called **Type III bursts** (short-lived and broadband)

Radio-wave propagation effects

- Photons interact with density inhomogeneities in the solar corona when $f \approx f_{pe}$ $\Longrightarrow$ "radio-wave propagation effects" (scattering, refraction, and absorption)
- These radio-wave propagation effects **distort the intrinsic properties** of the radio sources, like the source size, position, delay time, and decay time (see Fig. 3; [1–6]).
- Propagation effects are **frequency-dependent** ($\propto 1/f$) $\Longrightarrow$ lower frequencies are affected more [2,4]
  - **Scattering dominates** over other radio-wave propagation effects [2–4]

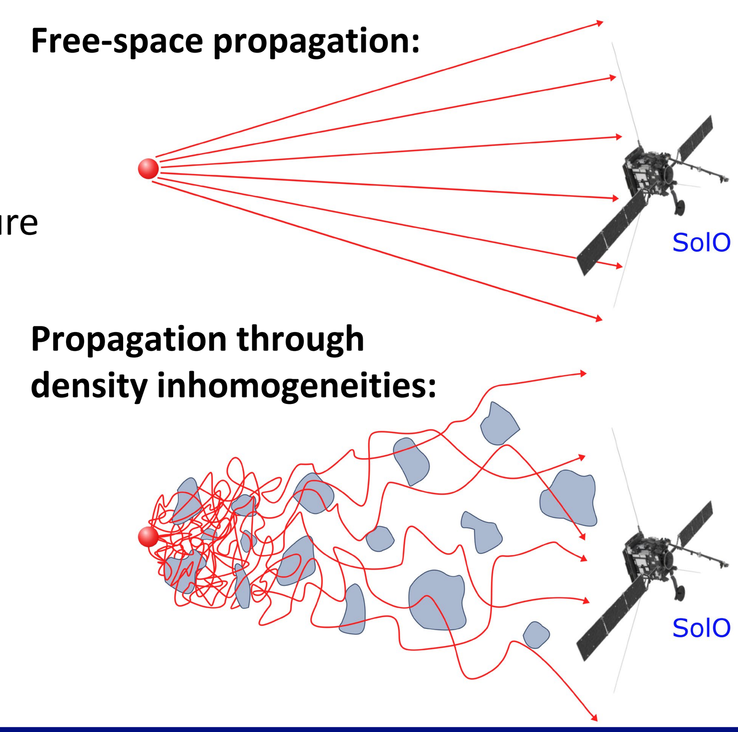

Fig. 2 Photon propagation through free-space vs density inhomogeneities (figure adapted from [6]).

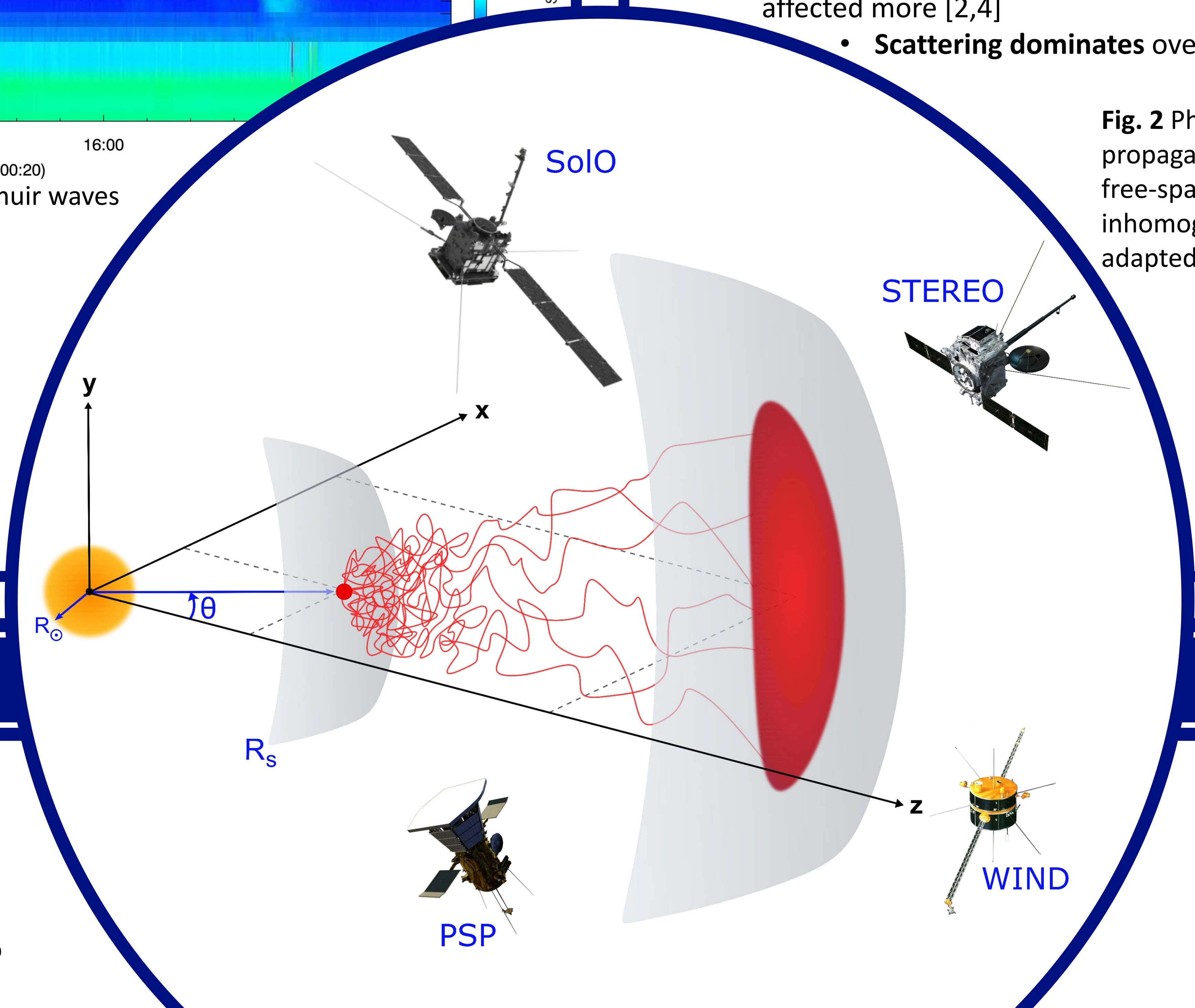

Fig. 3 Multi-spacecraft observations allow for the examination of the dependence of spectroscopic measurements on the observer's position (figure adapted from [4]).

Decay time vs Viewing angle

- **Question:** Do spectroscopic measurements (like the decay time) **differ depending on the position** of observer?
- **Investigation methods:**
  - Simulate the decay times vs viewing angles
  - Use observations from multi-vantage points to examine the behaviour
- **Simulation results: No dependence** is predicted.

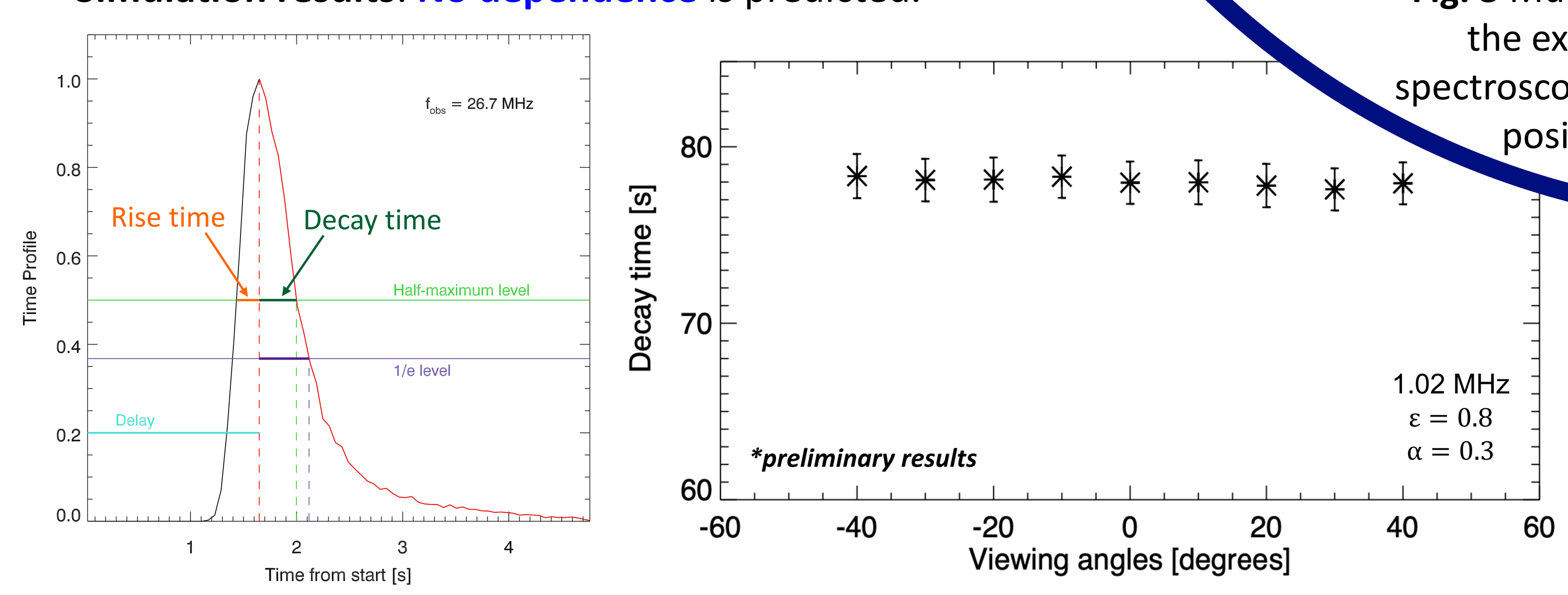

Fig. 4 Left: Annotated light curve. Right: Simulated decay times vs viewing angle (defined with respect to the Sun-Earth direction, as shown in Fig. 3).

Fitting the entire light curve

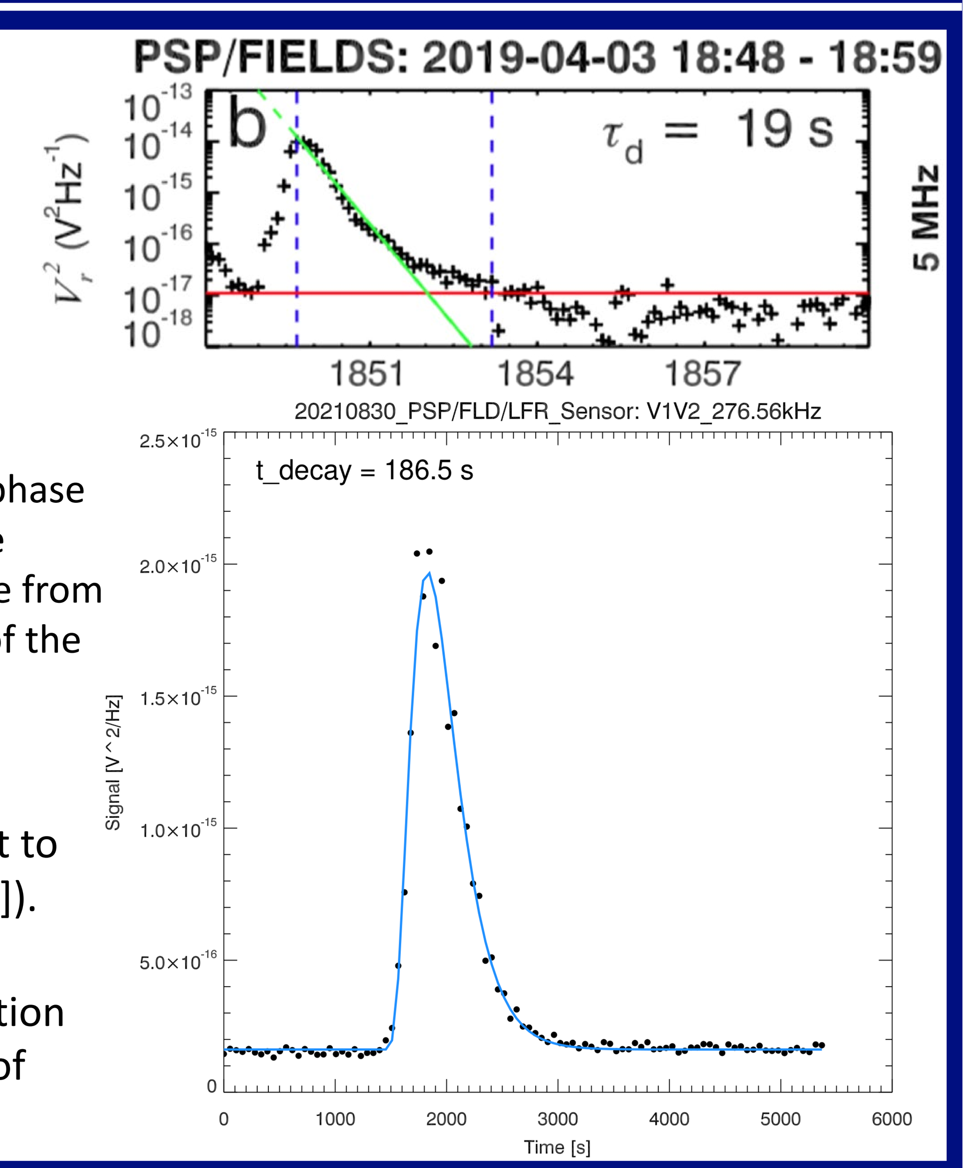

Fig. 5 Top: Decay phase fitted with a single exponential (figure from [7]). Bottom: Fit of the entire light curve.

- In the literature, the decay time has been approximated using a single exponential fit to the decay phase of the light curves (e.g. [7]).
- We fit the entire light curve **with a single function**, allowing for an improved estimation of the **decay time**, but also an estimation of the **rise time**.

Observational Results

- The observed decay time (i.e. the duration of the decay phase) of a radio burst at each frequency is dictated by radio-wave scattering [4,7].
- Scattering simulations do not predict a dependence of the decay time of a single burst on the observer's location (Fig. 4).
- Measurements from **4 different spacecraft** were used to compare the simulations' prediction to observations:
  - Solar Orbiter (SolO)
  - Parker Solar Probe (PSP)
  - WIND
  - STEREO

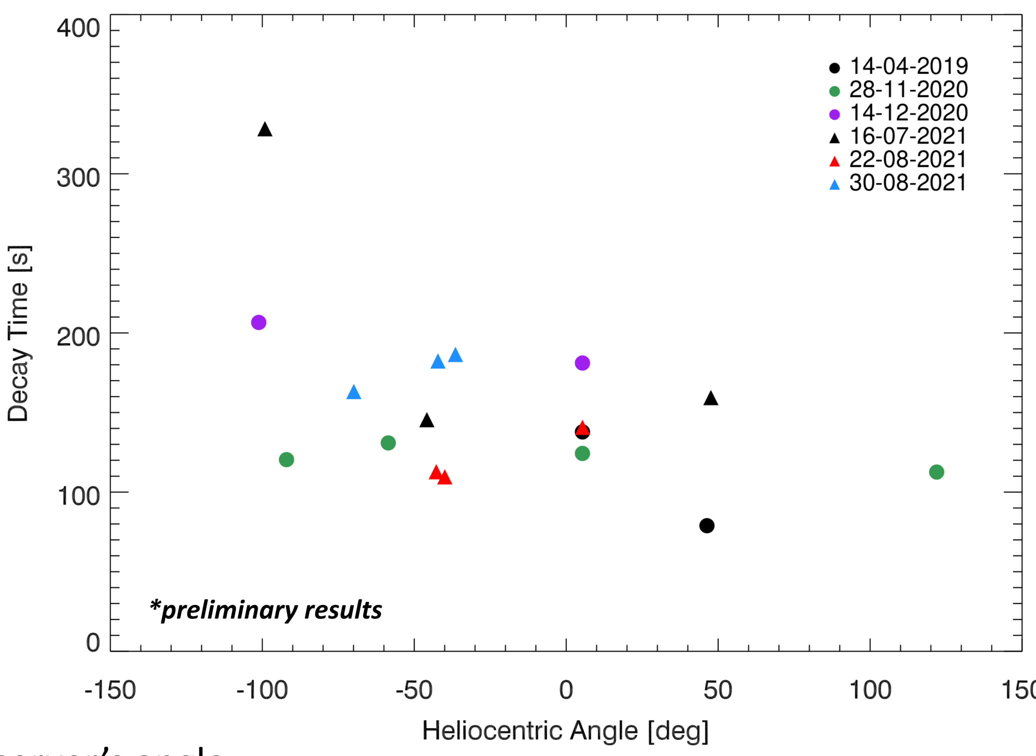

Fig. 6 Decay times as a function of the observer's angle, estimated for several radio bursts using data from 4 spacecraft.

Conclusions

- In **agreement** with the simulations, **no dependence** of the decay time of a single burst (at a comparable frequency) is observed with respect to the position of the detector.
- The delay time (i.e. the photons' arrival) and peak flux are the only spectroscopic properties dependent on the observation's location.
- **Key takeaways:**
  Measurements of decay time between different spacecraft do not need to be corrected.

References

[1] Kontar et al. 2017, NatCo, 8, 1515
[2] Chrysaphi et al. 2018, ApJ, 868, 79
[3] Kuznetsov et al. 2020, ApJ, 898, 94
[4] Kontar et al. 2019, ApJ, 884, 122
[5] Chen et al. 2020, ApJ, 905, 43
[6] Chrysaphi 2021, PhD thesis, U. of Glasgow
[7] Krupar et al. 2020, ApJS, 246, 57

nicolina.chrysaphi@obspm.fr

With thanks to CNES for its financial support.