Coronal Plasma Density Mapping through Radio and In-Situ Observations, and Modeling with EUHFORIA

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Introduction

Our study combines novel in-situ and radio observations with state-of-the-art modeling techniques. Here's an overview:

- Coronal Density Mapping Challenges: Up to now, limited in-situ data at close to the Sun distances makes mapping of the coronal plasma characteristics very hard.
- Innovative Approach: Employing radio observations and novel Parker Solar Probe observations, we can validate both radio observations and solar wind models such as EUHFORIA.
- Radio Triangulation: Using direction finding data space data (STEREO and WIND) and radio triangulation for estimating 3D positions of radio sources.
- Modeling: Solar wind characteristics as modeled by EUHFORIA, are compared with PSP in-situ observations and plasma density obtained from radio.
- Key Finding: Modelled density at PSP positions was underestimated. Changing the PFSS source surface height decreases the discrepancy between the observations and modelled result. Radio densities show significant overestimation, which could be particularity of type III propagation path.

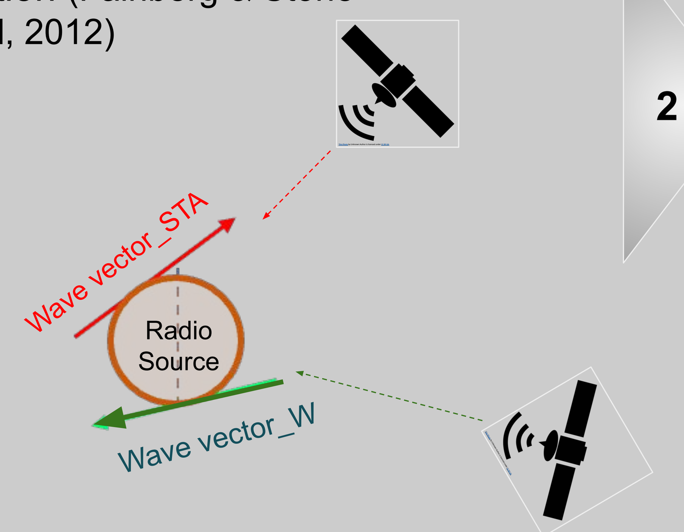
Methodology

1 Estimating radio source positions: Radio Triangulation (Fainberg & Stone 1974, Krupar et al, 2012)

Shortest Distance between the wave vectors

↓

Radio Source



2 Estimating densities from radio observations:

The relation between the electron density and plasma frequency is given by,

$$f_p = 9\times10^{-3}\sqrt{n}\ \text{MHz}$$

With the estimated radio source positions we can map the densities obtained with radio observations.

3 EUHFORIA (EUropean Heliospheric FORecasting Information Asset; J. Pomoell & S. Poedts, 2018): Simulations at PSP and radio sources

EUHFORIA

Coronal Domain (up to 0.1 AU) + Inner Heliospheric Domain (0.1 AU to 2 AU)

4 Comparison of results:

Radio Observations

+

EUHFORIA Simulations at (Radio sources & PSP position)

+

Parker Solar Probe in-situ Observations

Results

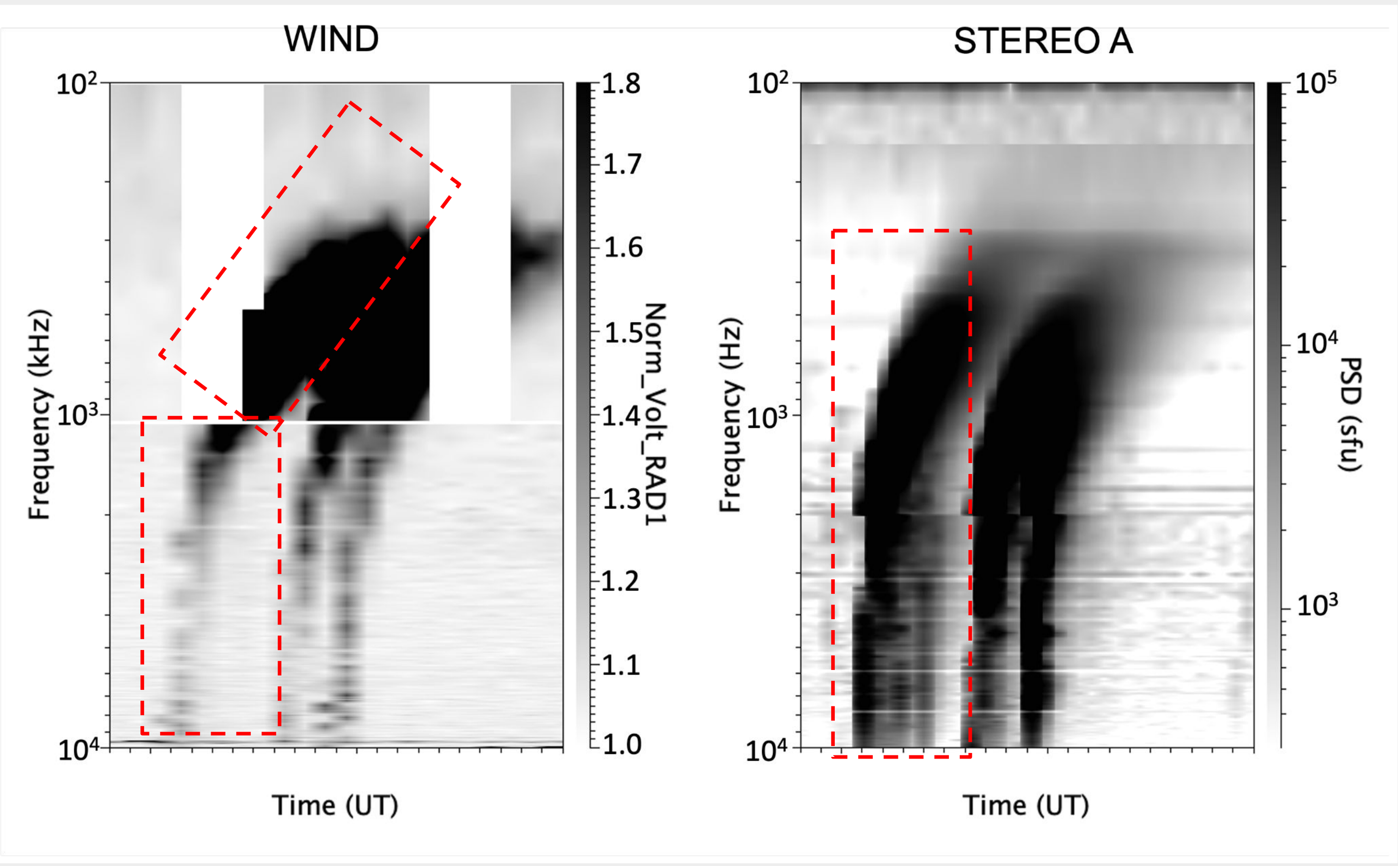


Fig. 1: The dynamic spectra show the type III radio bursts, signatures of fast electron beams propagating along open or quasi open magnetic field lines, observed on 05 April 2019 at ~ 01: 20 UT.

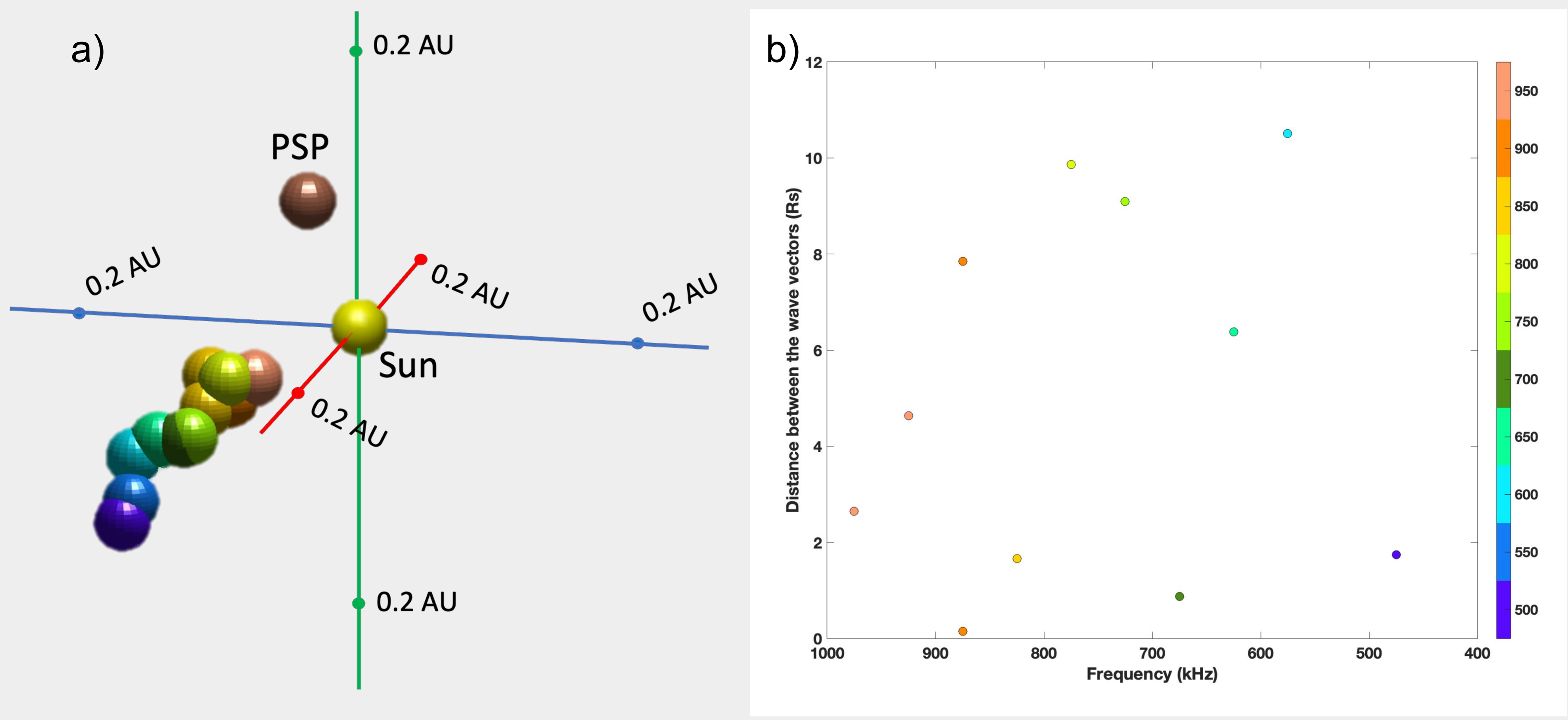


Fig. 2: a) The estimated radio source positions for the marked type III burst in Fig. 1.
b) Distance between the wave vectors for the same type III burst. The colours scale is same for both of the plots.

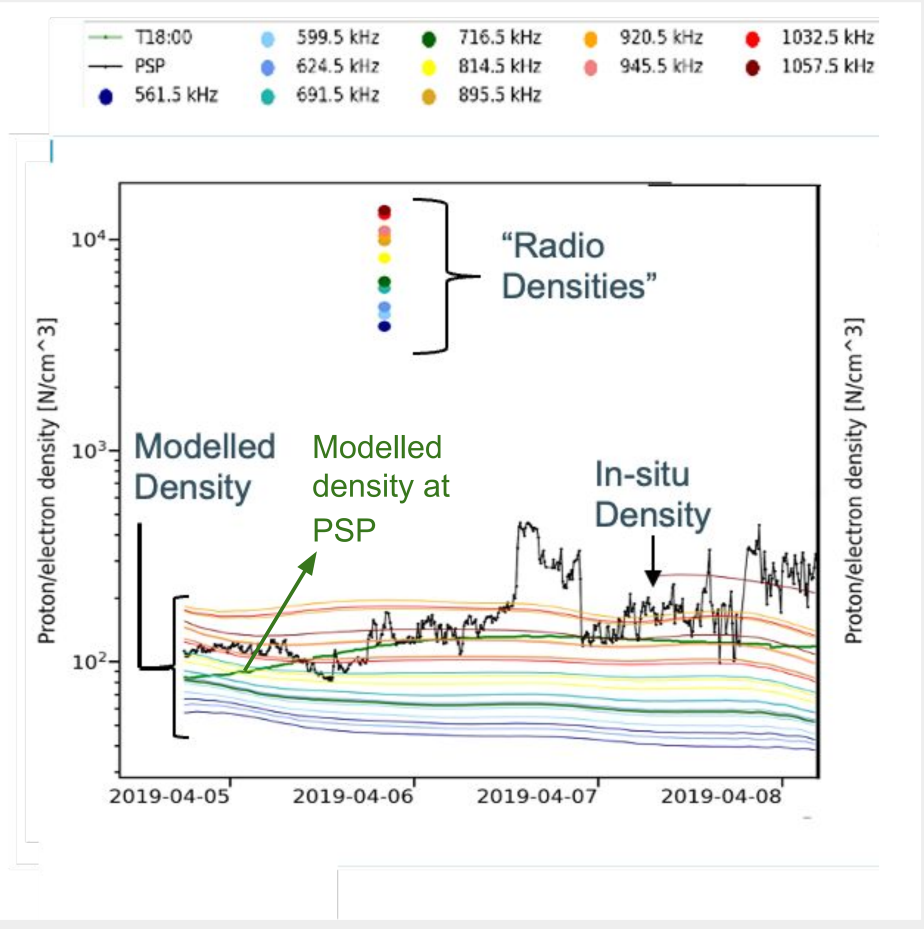


Fig. 3: Comparison of the density obtained from radio and in situ observations with the modeling results from EUHFORIA:

- Large difference is observed between the densities obtained from radio and in situ observations.
- Also, first modelling results at PSP position show underestimation in comparison to the in situ density from PSP.
- The simulations with modified PFSS source surface radius 2.6, 2.7, 2.8, 2.9 and 3.0 Rs, provided better results for 2.9 and 3.0 Rs (shown here).

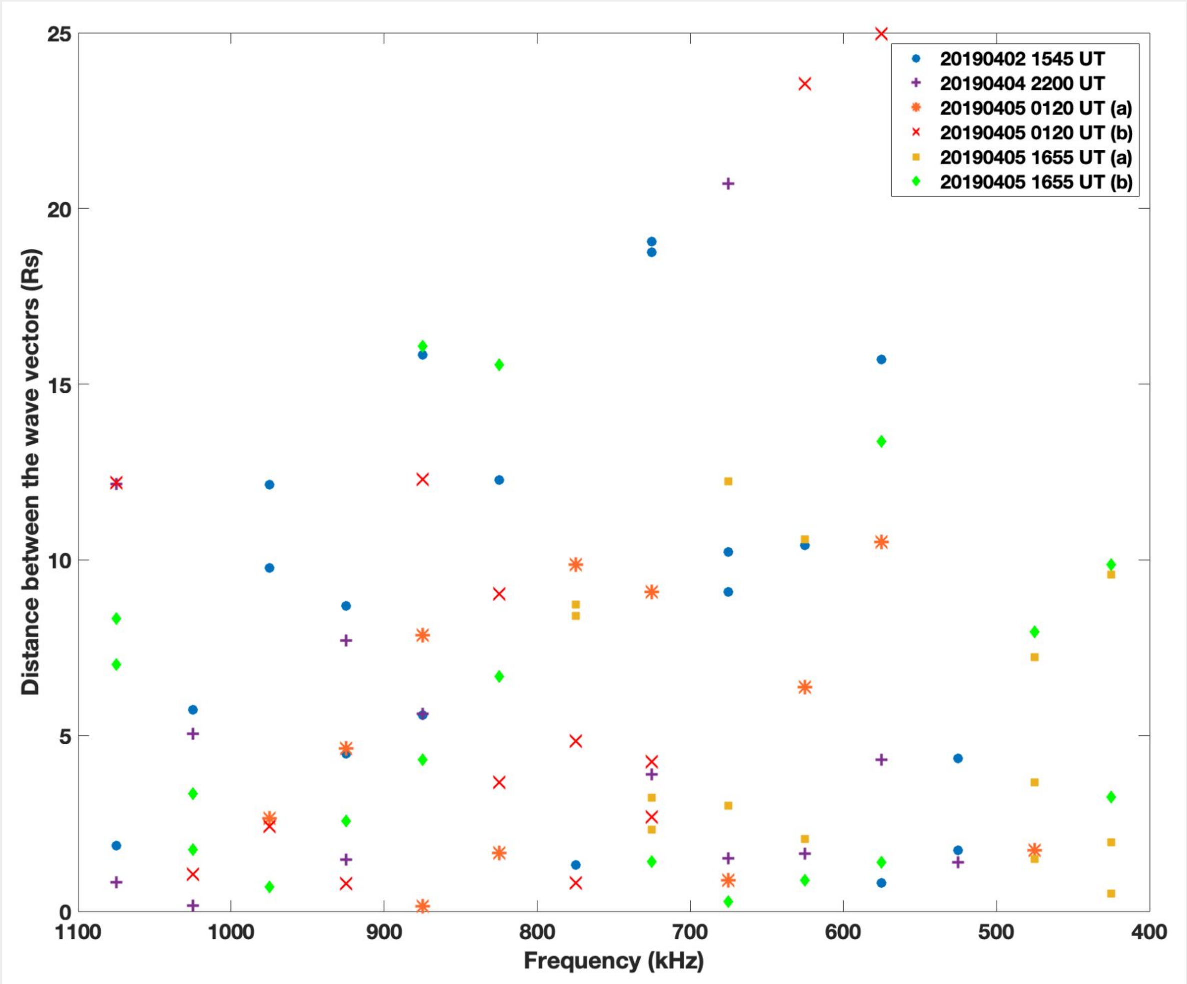


Fig. 4: Distance between the wave vectors for 6 type III radio bursts observed during the second PSP perihelion provides indication on the sizes of the type III radio sources.
The distances between the wave vectors do not show any variation with respect to the frequency at which they were estimated. We obtained distances in the range of 0.5 - 25 Rs.
This result indicates that the scattering effects are not very dominant. (Deshpande et. al, in preparation)

Conclusions

- We studied number of type III bursts observed during the second Parker Solar Probe perihelion.
- The results for the type III burst observed on 05 April 2019 at 01:20 UT are shown here.
- The radio source positions obtained using radio triangulation provided us the density profiles along the burst propagation path.
- The distance between the wave vectors did not show any regular behaviour with respect to the frequency. This result indicates that the scattering effects are not very dominant.
- The in-situ densities from the PSP were then compared with the densities obtained from radio observation. Rather large discrepancies between the two densities were obtained. This result might have been induced with large distance between the PSP and radio source positions.
- The density at radio source positions modelled with EUHFORIA was underestimated in comparison with the observed densities.
- To decrease the discrepancy between observed and modelled density, we performed simulation with larger PFSS source surface radius 2.6, 2.7, 2.8, 2.9 and 3.0 Rs than default set up of EUHFORIA. Using 2.9 and 3.0 Rs provided us better modelling results.

Future Work

- Study of type III bursts propagating closer to the PSP in order to facilitate more direct comparison between the densities obtained from radio observations, modelling and in situ PSP observations.
- Modeling at different positions in between PSP and radio source positions to better understand the spatial variation in the solar wind electron density.

References

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