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First imaging evidence of fundamental-harmonic Type III radio burst pair in the interplanetary space

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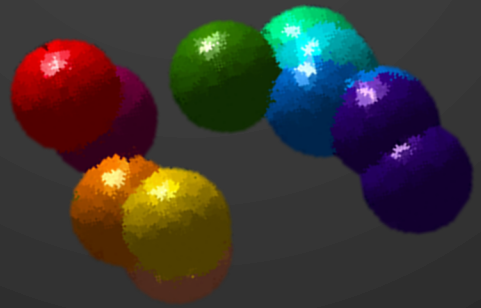


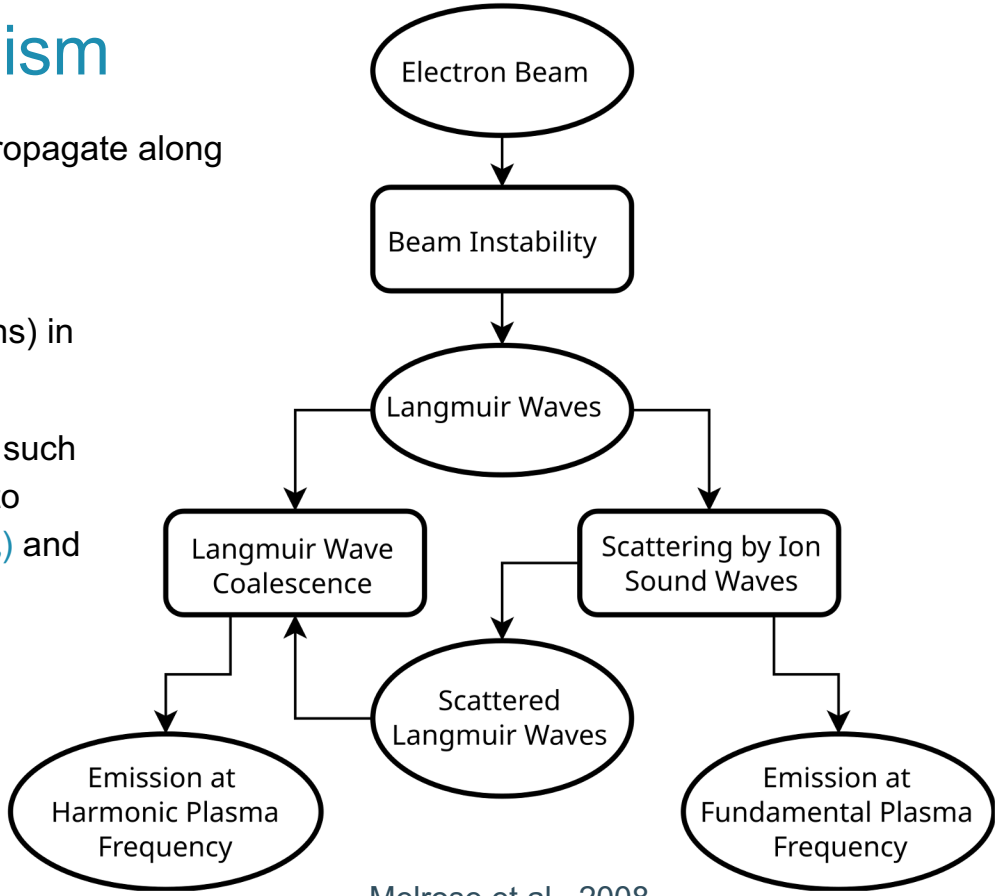
Plasma Emission Mechanism

- Electron beams accelerated close to the Sun propagate along open magnetic field lines into the heliosphere.

- They excite Langmuir waves (plasma oscillations) in the ambient solar wind plasma.
- Langmuir waves undergo nonlinear processes, such as wave–wave interactions, converting them into radio emission at the local plasma frequency (f_p) and its harmonic ($2f_p$).

- The emitted radio waves are observed as fast drifting bursts from high to low frequencies, reflecting the decreasing plasma density with distance from the Sun.

Type III radio bursts



Melrose et al., 2008

Fundamental-Harmonic (FN-H) problem

Metric vs. Kilometric behavior of type III radio bursts:

- In the metric frequency range, they occur in sequences of fast subsequent bursts.
- In the decimetric to kilometric range, typically only one or a few closely spaced bursts are observed.

➢ Complex propagation and generation mechanisms.

Challenges in identification of fundamental & harmonic:

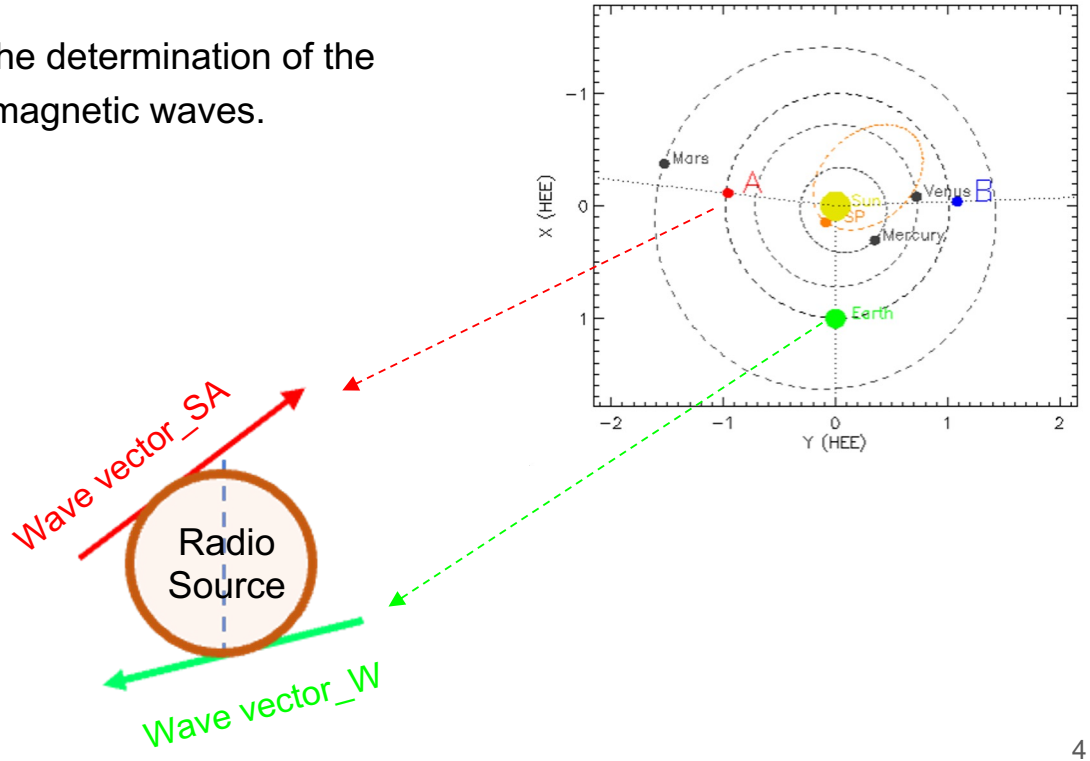
- Even for isolated type III bursts distinguishing fundamental or harmonic component is difficult.
- Propagation effects and the beam broadening in the corona & inner heliosphere complicate the interpretation, limiting understanding of radio source characteristics.

Insights from Parker Solar Probe (PSP):

- High-resolution PSP observations in the interplanetary range confirm that so-called "isolated" type III bursts typically include both fundamental and harmonic components (Jebaraj et al., 2023).
- This provides new evidence refining our understanding of type III burst structure and origin.

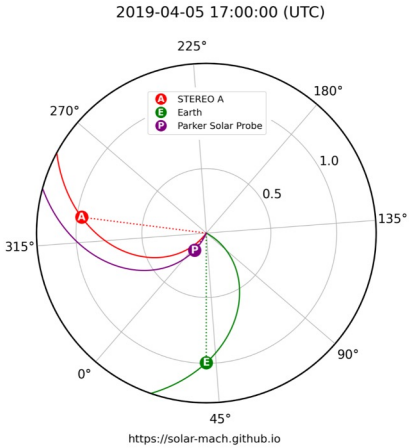
Radio Triangulation

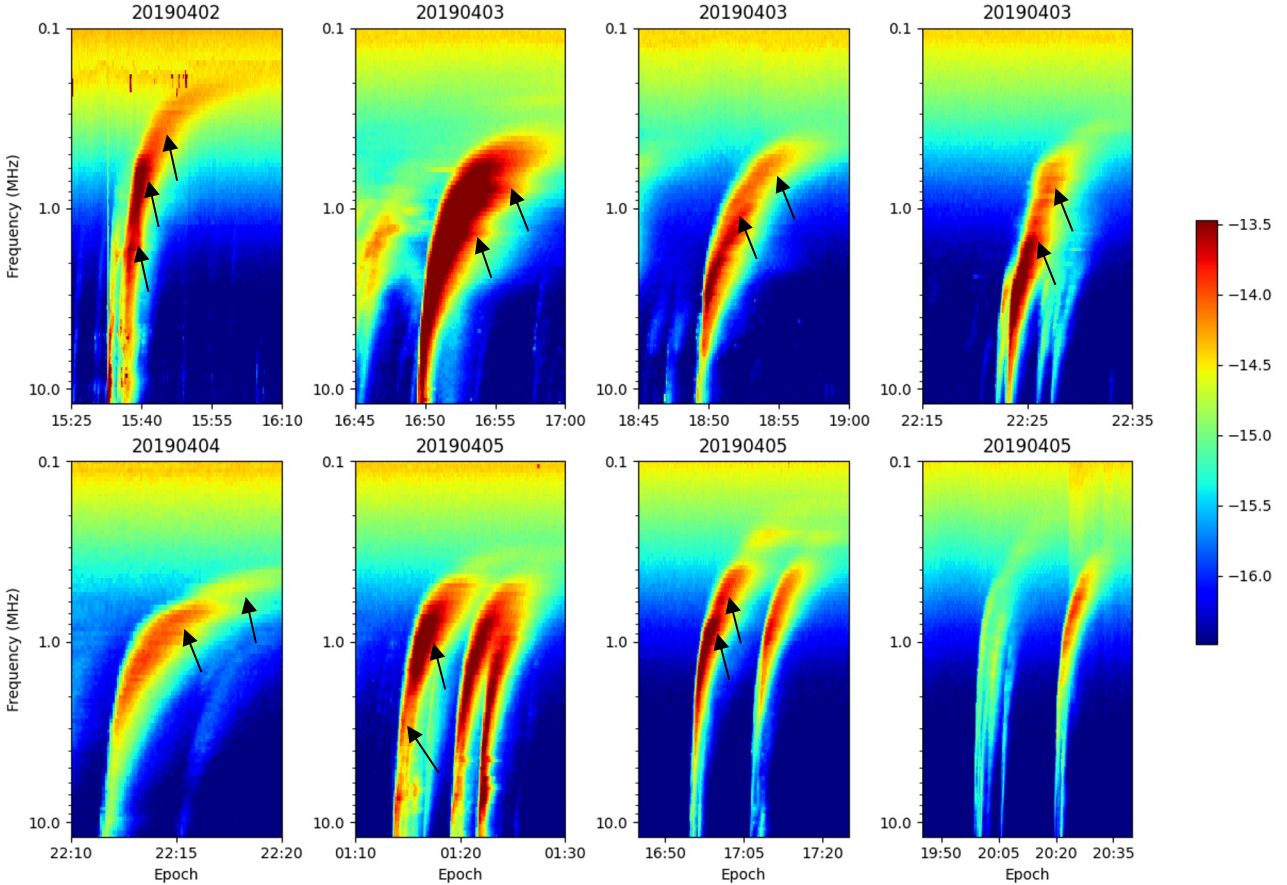
- Direction-finding techniques enable the determination of the direction of arrival of incident electromagnetic waves.
- The wave vectors obtained from direction-finding observations from two or more spacecrafts allow us to locate the source position of the radio emission.
- We define the radio source position as the region between the shortest distance between these two wave vectors.



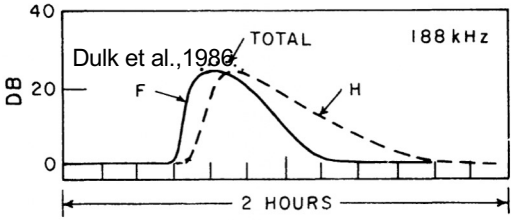
Analysis

- We studied 11 type III radio bursts observed during second PSP perihelion.
- High time resolution (7s) PSP data shows presence of multiple type III bursts & indicate possible FN-H pair.

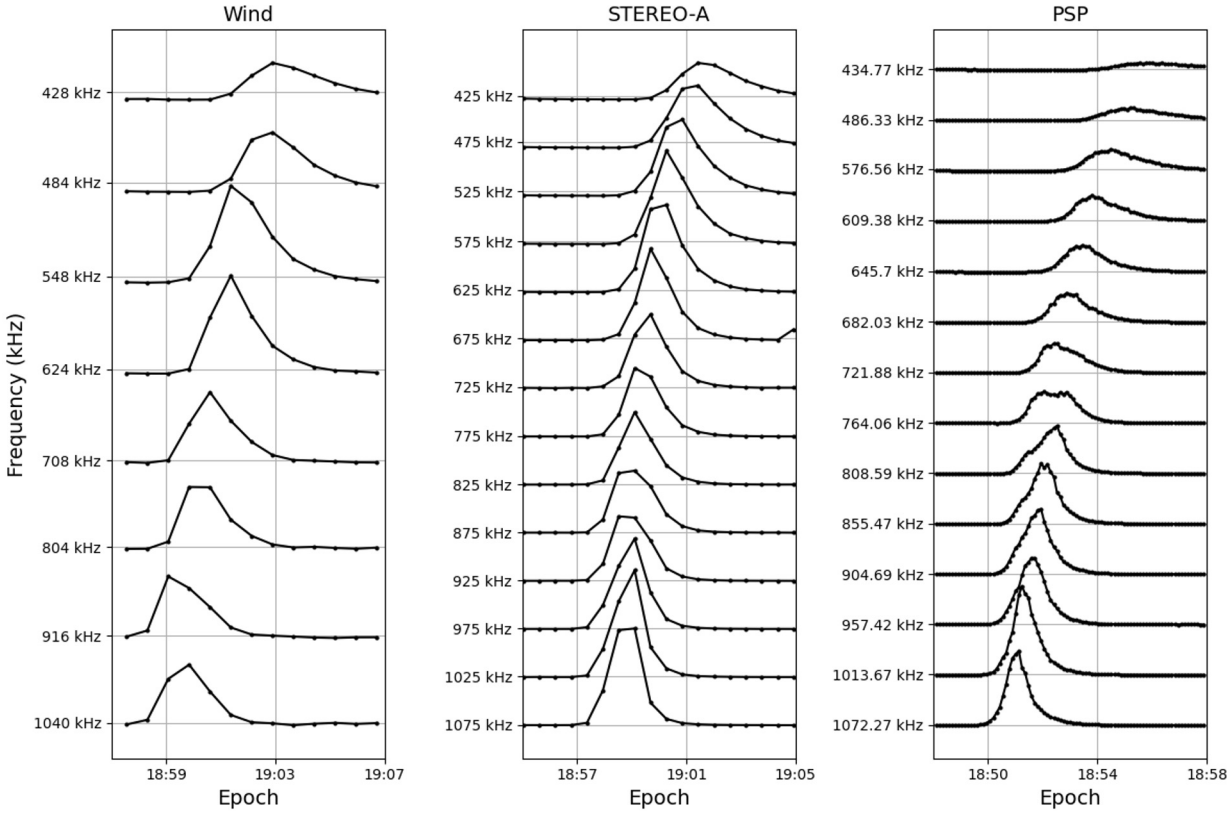




Time Profiles

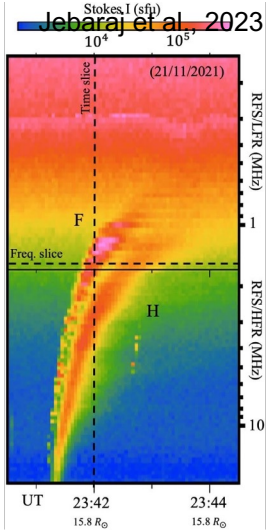


- Dulk et al. showed sharp rise & slow decay indicate FN and H, respectively.
- Our profiles appear more symmetric in comparison.
- PSP high-resolution data reveals more than one type III bursts within a single profile.
- Suggests potential identification of overlapping FN–H components.

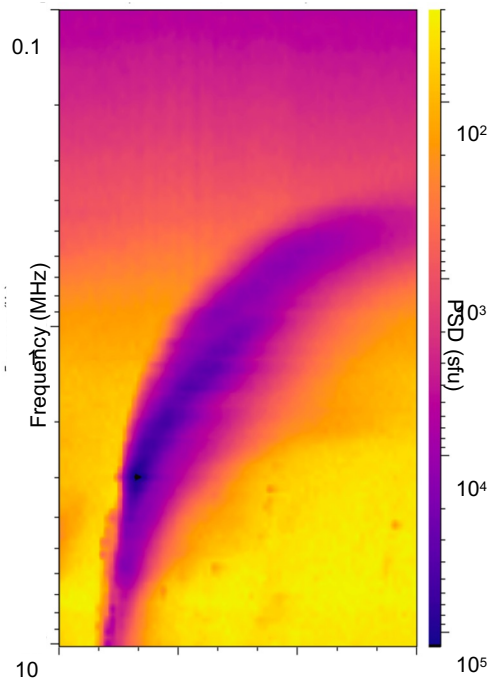


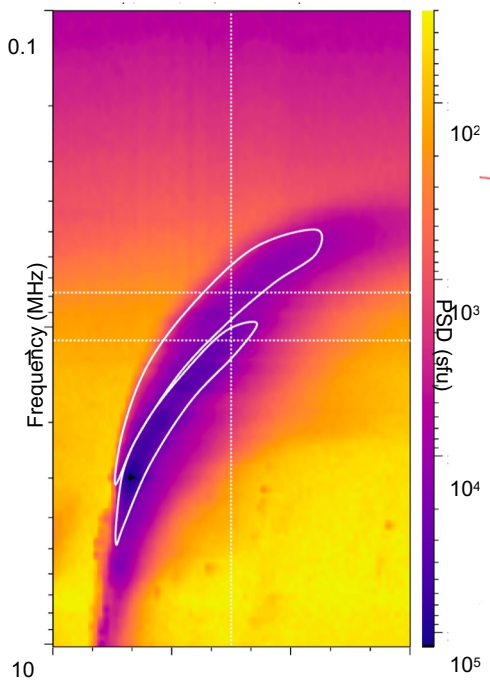
Dynamic Spectra of fundamental-harmonic pair

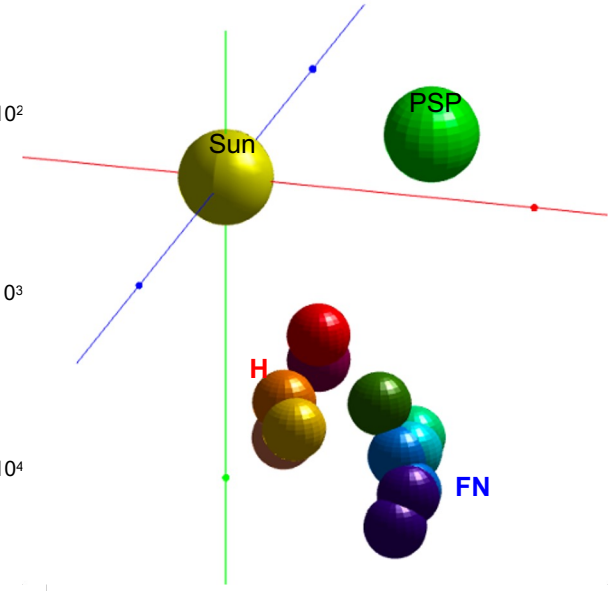
- High time resolution (7s) PSP data shows presence of multiple type III bursts & indicate possible FN-H pair.



Jebaraj et al., 2023





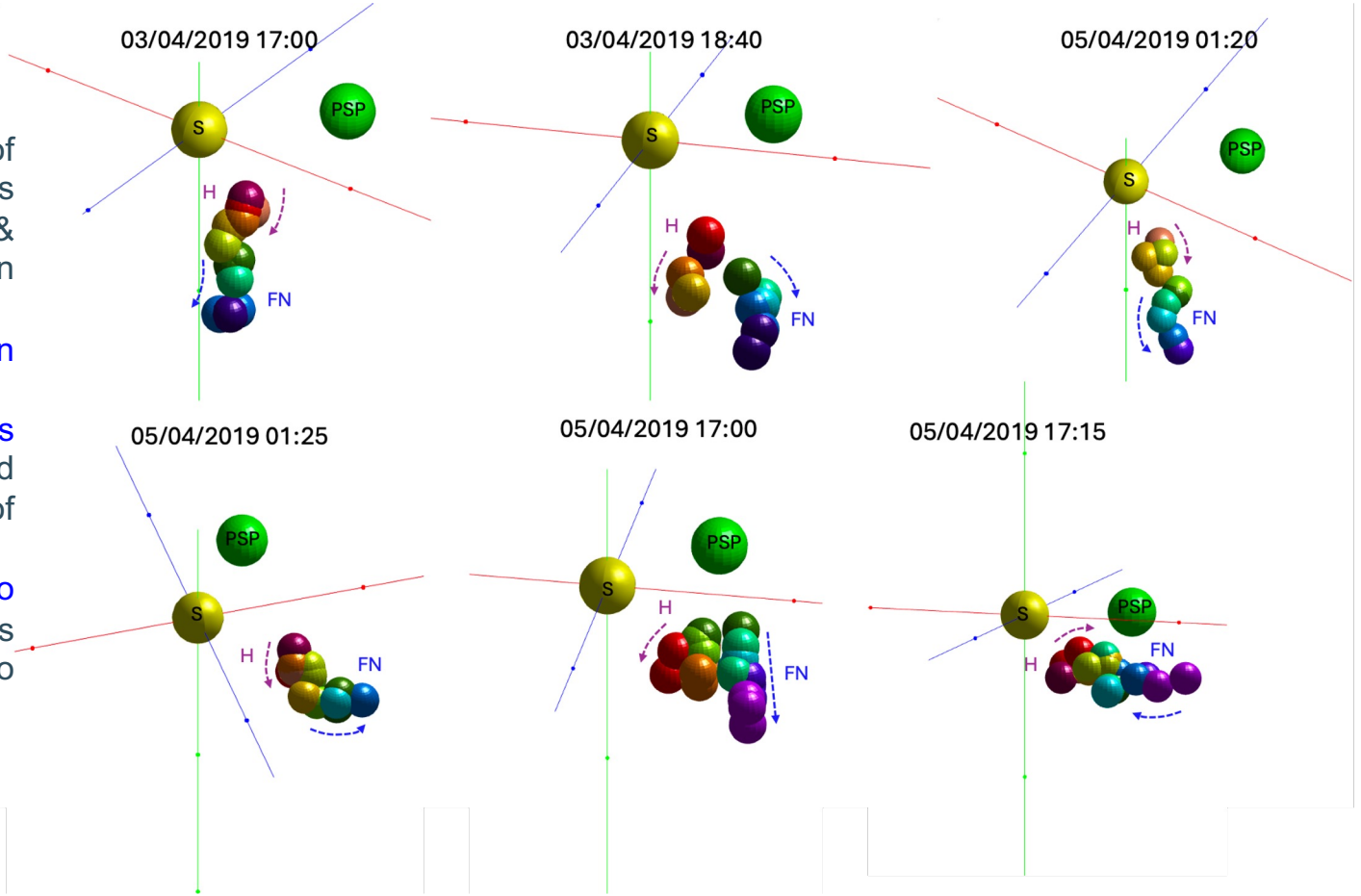


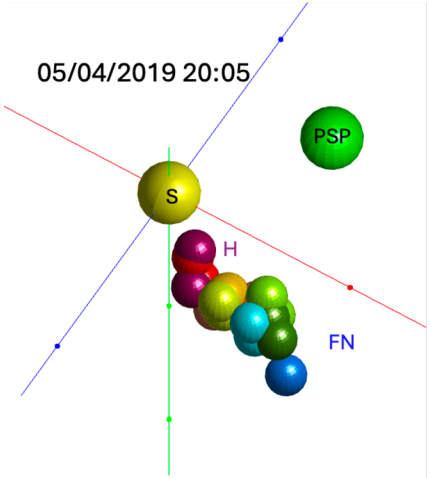
- Radio triangulation of “isolated” type IIIs observed by Wind & STEREO-A often show;

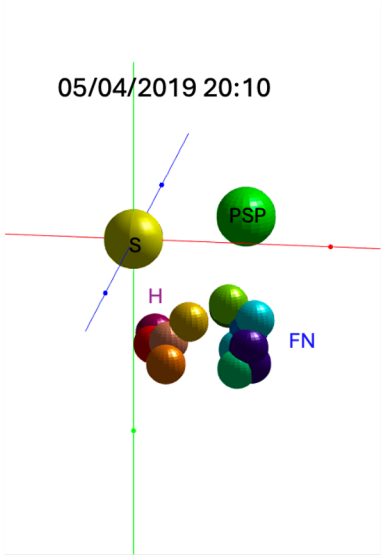
a) kink in the propagation path, and sometimes

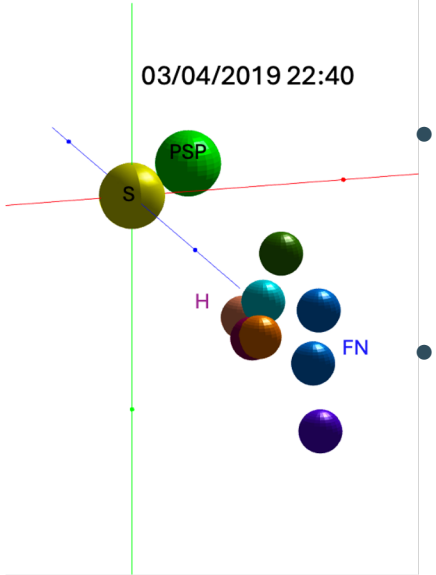
b) two different lanes separating high- and low-frequency part of the burst

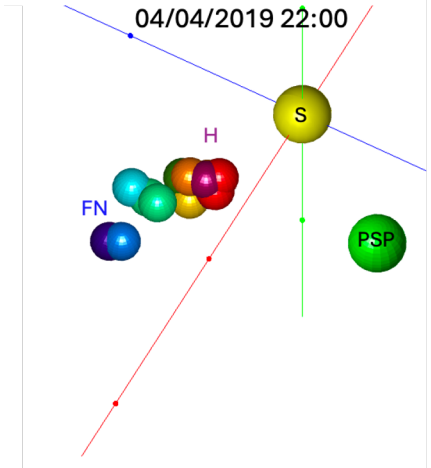
c) overlapping of two distinguishable parts when observed in two lanes.









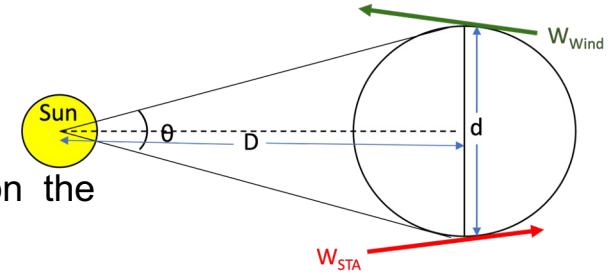


- Observed radio source behavior indicate the presence of a fundamental-harmonic emission pair.
- Scattering effects, intrinsic to radio wave propagation, differ for fundamental and harmonic components.

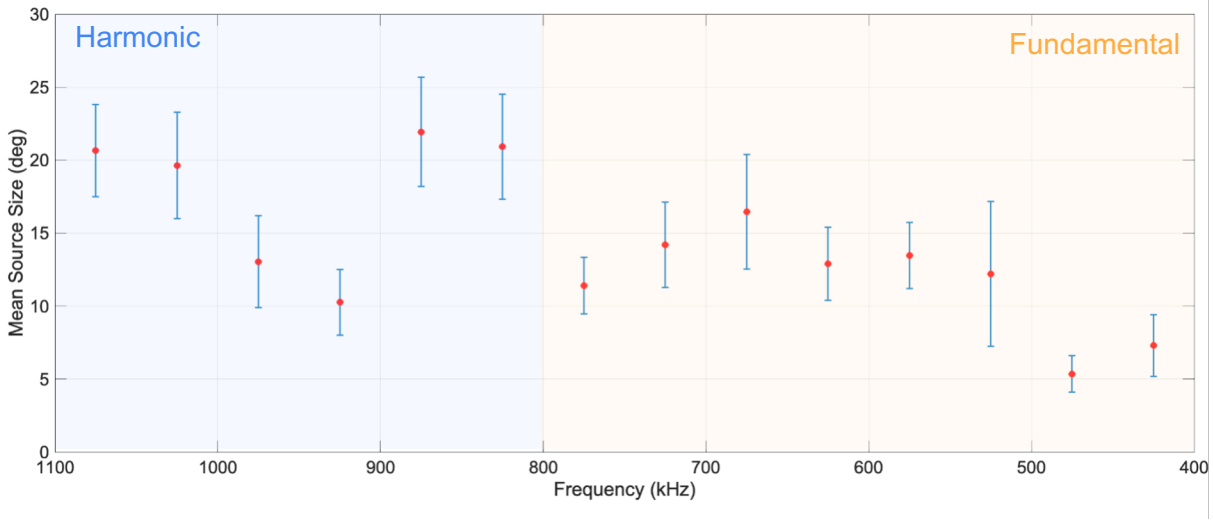
➢ Radio source positions may shift in any directions depending on ambient plasma density structures.

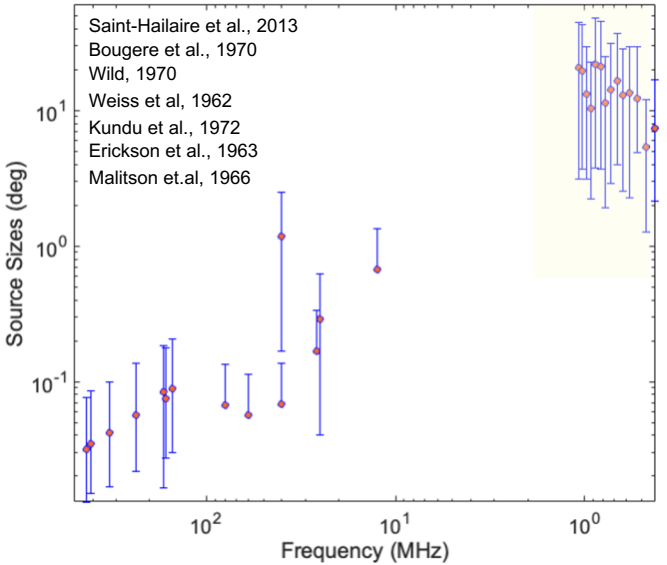
➢ The positional shifts could provide observational evidence supporting FN-H pairing in radio bursts.

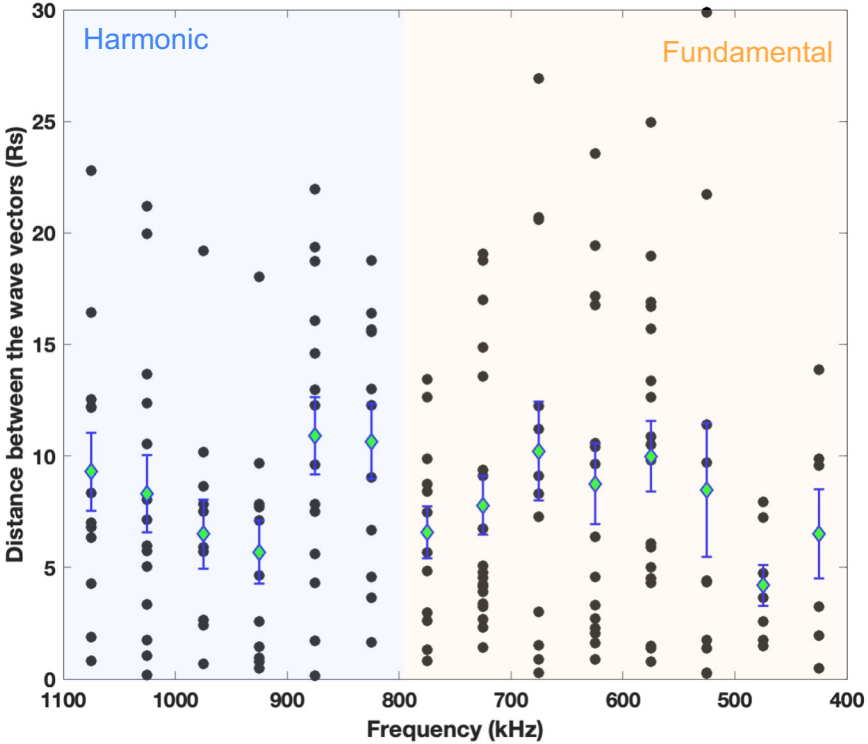
Source Sizes

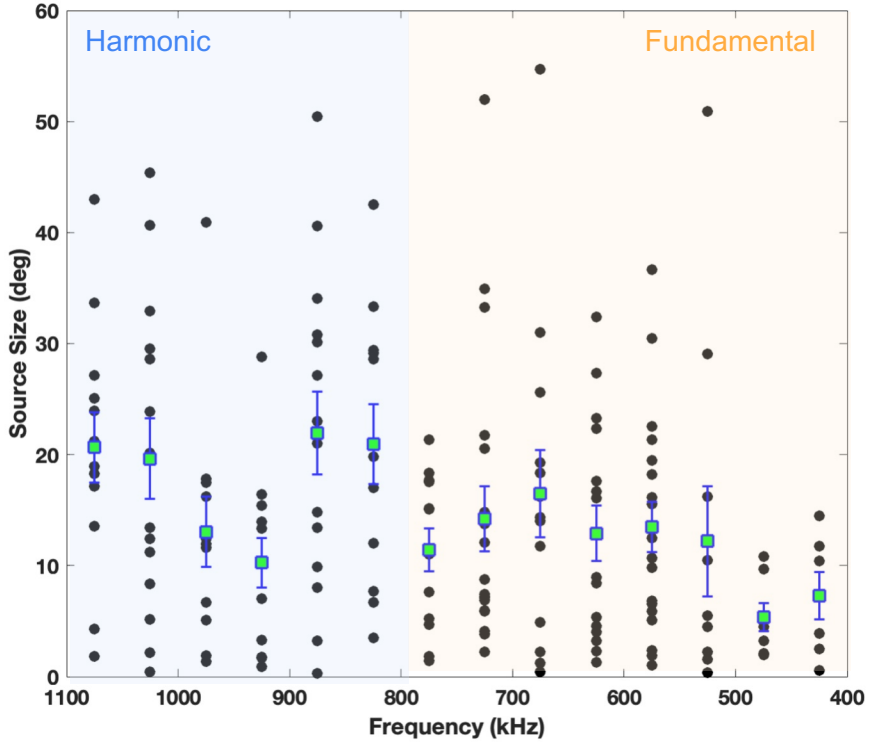


- Distance between the wave vectors *d* provides indication on the sizes of the type III radio sources.
- Source sizes are larger for harmonic than fundamental emission source sizes.






Harmonic
Fundamental
Distance between the wave vectors (Rs)
Frequency (kHz)
0
5
10
15
20
25
30
1100
1000
900
800
700
600
500
400


Harmonic
Fundamental
Source Size (deg)
Frequency (kHz)
0
10
20
30
40
50
60
1100
1000
900
800
700
600
500
400

Conclusions

- We present for the first time evidence of type III fundamental-harmonic pair in the interplanetary range through imaging.

- It is still difficult to identify Fundamental-harmonic pair in the dynamic spectra due to the beam broadening and their close proximity.

- Kink or two lanes in the propagation path of the “isolated” burst indicates the presence of possible fundamental-harmonic pair.

- Source sizes are larger for harmonic than fundamental emission source sizes.

Questions?

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