STEREO Science Highlight

Tracking a Beam of Electrons from the Low Solar Corona into Interplanetary Space with the Low Frequency Array, Parker Solar Probe and 1 au Spacecraft

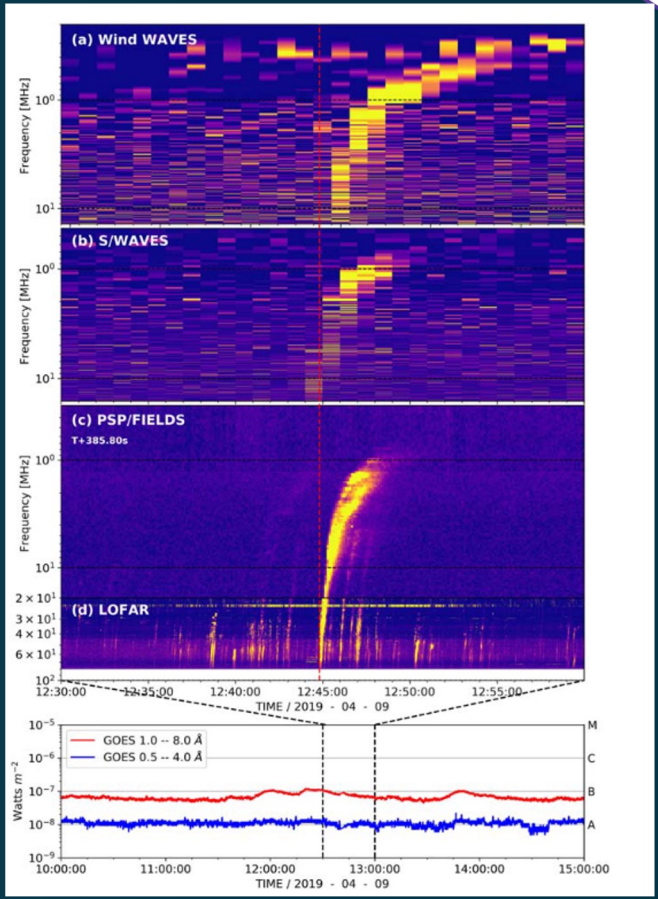
Badman, Carley, Canizares et al. (2022), ApJ **938** 95, DOI: 10.3847/1538-4357/ac90c2

Background

- **Objective:** Use a type III radio burst as a remote observation of heliospheric plasma from the Sun to 1 AU.

- **Background:** Type III radio bursts are one of the most luminous radio emitting phenomena in the solar system. They are caused by energetic beams of electrons injected by eruptions on the Sun onto interplanetary field lines. They are readily observed all around the heliosphere and travel at mildly relativistic speeds.

- **Goal :** By making use of multi-spacecraft observations of these events we can constrain the electron beams path through space and in so doing investigate the source that produced it and the plasma properties along the path it took. *There is currently no other way to determine these quantities over an extended region of the heliosphere.*



Above: Badman et al. 2022 Figure 2. A single type III radio burst observed by Wind/WAVES, STEREO-A/WAVES, Parker Solar Probe and LOFA (a-d)

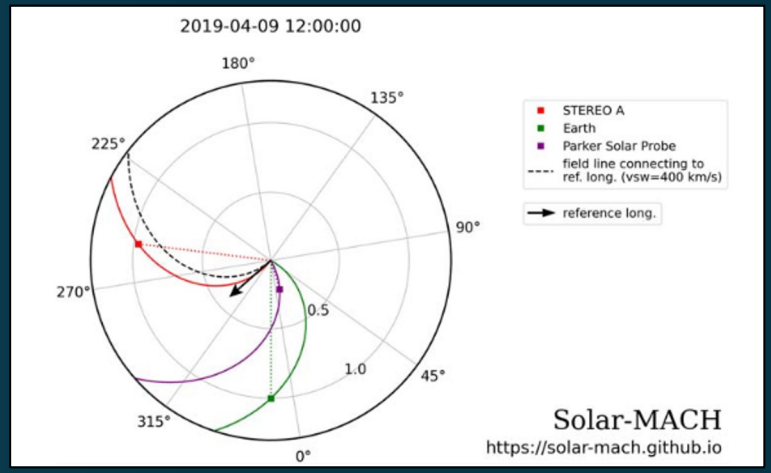
Analysis

- A multi-spacecraft, multi-instrument endeavor:
  - STEREO-A : All *in situ* suites! (IMPACT, PLASTIC, WAVES)
  - Wind : WAVES
  - Parker Solar Probe : FIELDS Radio Frequency Spectrometer (RFS)
  - The Low Frequency Array (LOFAR)
  - Potential Field Source Surface modeling - pfsspy

- LOFAR - Solar radio burst imaging using ground based interferometry use to image the burst in the corona

- PSP/RFS, Wind/WAVES, STEREO/WAVES - Used in Time Delay of Arrival analysis (a new method established in paper) to localize the burst in the heliosphere.

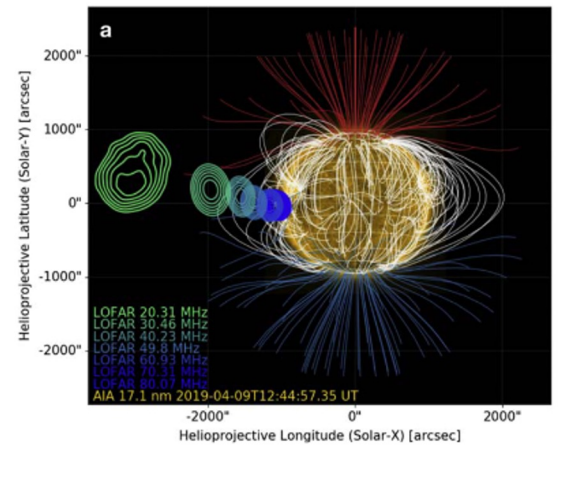
- IMPACT/PLASTIC - In situ data and interpretation used to determine the imprint of the burst in situ at STEREO-A at 1 AU



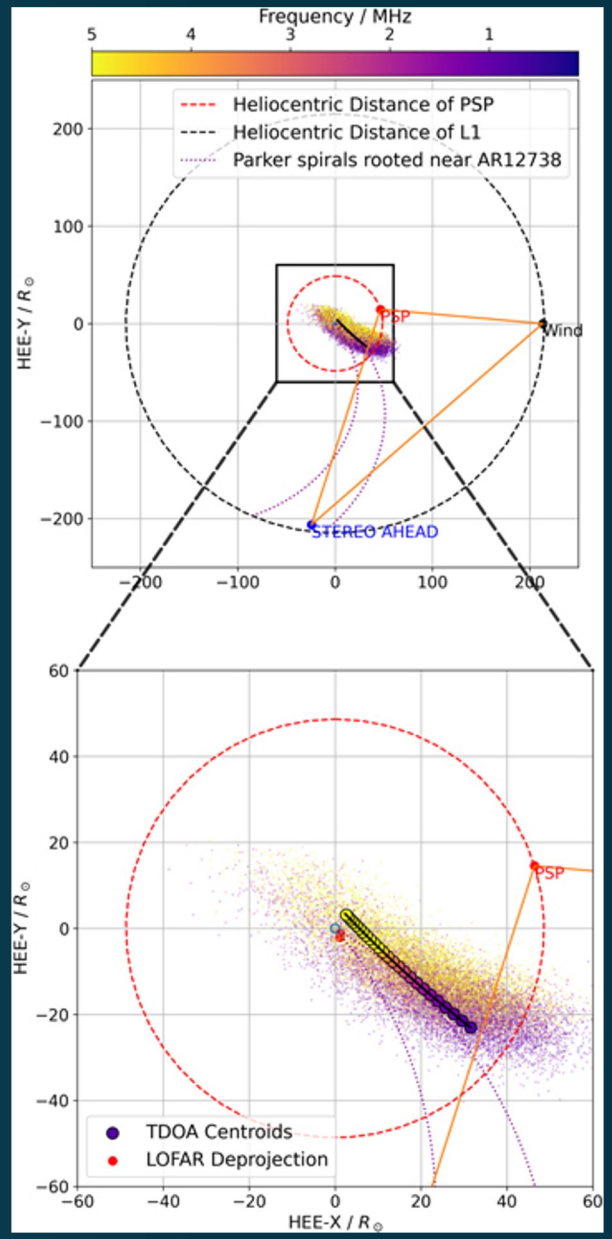
Above: Badman et al. Figure 2. Relative positions of the observing instruments in the ecliptic plane on the date of the burst's occurrence

Findings

- **Result:** We retrieve the path of an individual electron beam from its injection at the corona out to an in situ detection at STEREO-A
- **What it means :** We proved the concept of a novel multi-spacecraft technique to retrieve this information, associated the burst with a source region (without a flare), and found its path through space.
- **Lessons Learned :** More powerful inferences about phenomena like Type IIIs can be made when combining multiple instruments and observation methods.



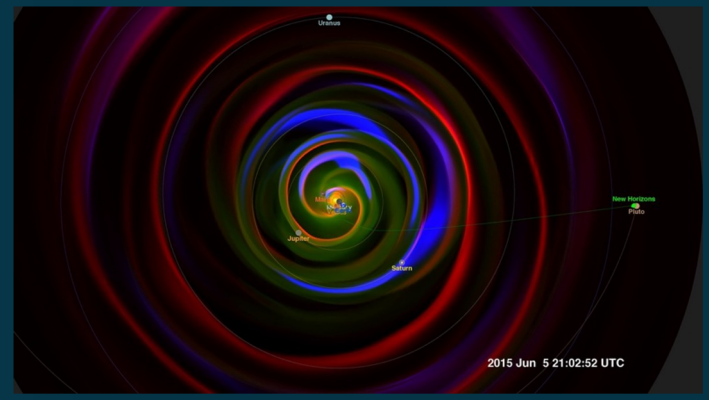
Left: Badman et al. 2022 Figure 5a LOFAR images the burst escaping a source active region (AR 12738) along open magnetic field lines.



Right: Badman et al. 2022 Figure 6 Localization of the Type III radio burst in space as it propagates out from the Sun, dropping from high frequency (bright colors) to low frequency (dark colors). The interplanetary location is consistent with where LOFAR sees it escaping in the corona.

Impacts

- Broader impacts
  - The new method helps us determine the large scale structure of the heliosphere. Specifically, what are its plasma properties, which, in turn, affect the path space weather events like coronal mass ejections (CMEs) and solar energetic particle (SEP) events take from the Sun to the Earth.
  - This study shows a novel way of using an energetic electron beam escaping the corona to make progress towards measuring this kind of structure, which does not otherwise emit signatures that can be directly observed.
- Scientific Community
  - Our reproducible methods can be used and improved to make similar measurements and reach robust actual determination of, for example, magnetic field lines and density structure in the heliosphere.
  - The analysis codes for the time delay of arrival methods are publicly available on GitHub : https://github.com/STBadman/Radio-Public
- General public
  - This process ultimately will contribute to accurate models of the inner heliosphere, which will in turn aid in future space weather prediction to protect Earth and human assets in space from the effects of the Sun.



Above: Large scale heliospheric structure. It can be modeled but not directly observed. The paths type III radio bursts take can uncover this structure. *Credits: NASA Scientific Visualization Studio*

Publication Information

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Samuel T. Badman[1,2] , Eoin Carley[3] , Luis Alberto Cañizares[3,4] , Nina Dresing[5] , Lan K. Jian[6] , David Lario[6],

Peter T. Gallagher[3] , Juan C. Martínez Oliveros[1], Marc Pulupa[1] , and Stuart D. Bale[1]

[1] University of California, Berkeley
[2] Harvard-Smithsonian Center for Astrophysics
[3] Dublin Institute for Advanced Studies
[4] Trinity College Dublin
[5] University of Turku
[6] NASA Goddard Space Flight Center