Fine Structures of Type III Radio Bursts

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1. Introduction

Type III radio bursts are generated as a result of beam-plasma interactions throughout the heliosphere, signifying electron energy deposition, and providing details about the local plasma they are generated in [1]. **The aim** of this study is to collect time series of electric ($\vec{E}$) and magnetic ($\vec{B}$) fields during Langmuir wave bursts from Parker Solar Probe (PSP) and Solar Orbiter (SolO), comparing their properties with electron velocity distributions, in an attempt to better understand the mechanisms that govern this electromagnetic (EM) emission.

Type III radio burst example:

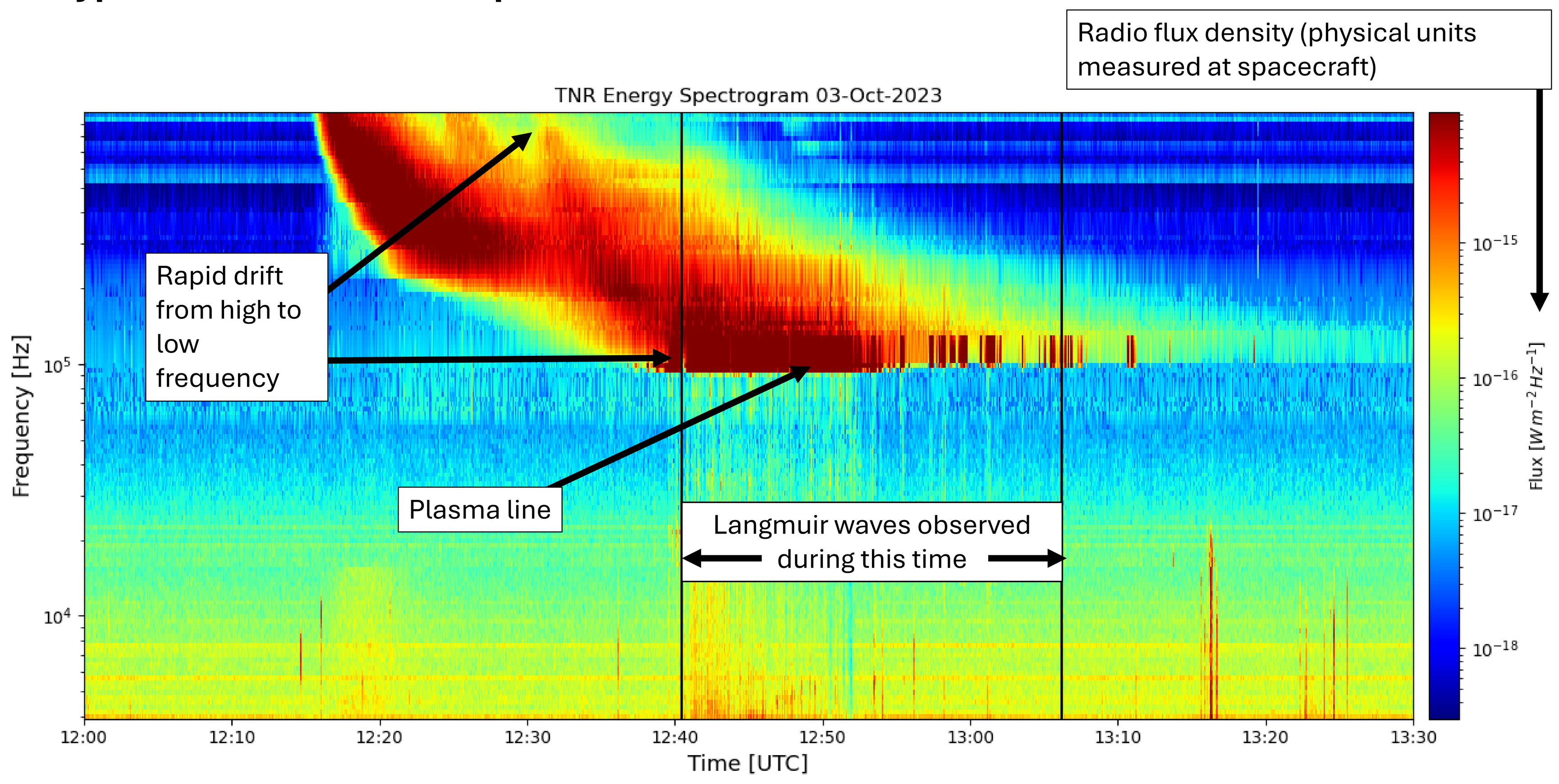

Figure 1. Typical type III radio burst from SolO Radio Plasma Waves (RPW) instrument; bright short burst of radio emission, classified by high to low frequency drift rate, observed around the plasma frequency (f_p) or one of it's harmonics (~$2f_p$). Plasma line enhancements are indications of Langmuir wave generation.

Generation:

- Energetic electrons released during an eruptive solar event, e.g. solar flare, are accelerated along magnetic field lines into the corona and solar wind.
- Faster moving e^- outpace slower ones growing electrostatic Langmuir waves (bump-on-tail instability) that non-linearly convert into EM emission [2].
- Conversion due to either scattering, causing the decay of a Langmuir wave into an EM so-called Z-mode wave and ion acoustic wave [1], or through density fluctuations [3].

→ **What mechanisms cause mode conversion from electrostatic to electromagnetic waves?**
→ **Does this relate/impact e^- peak flux energy and velocity spectrums?**

2. Recent Observations

Slow-extraordinary/Z-mode waves

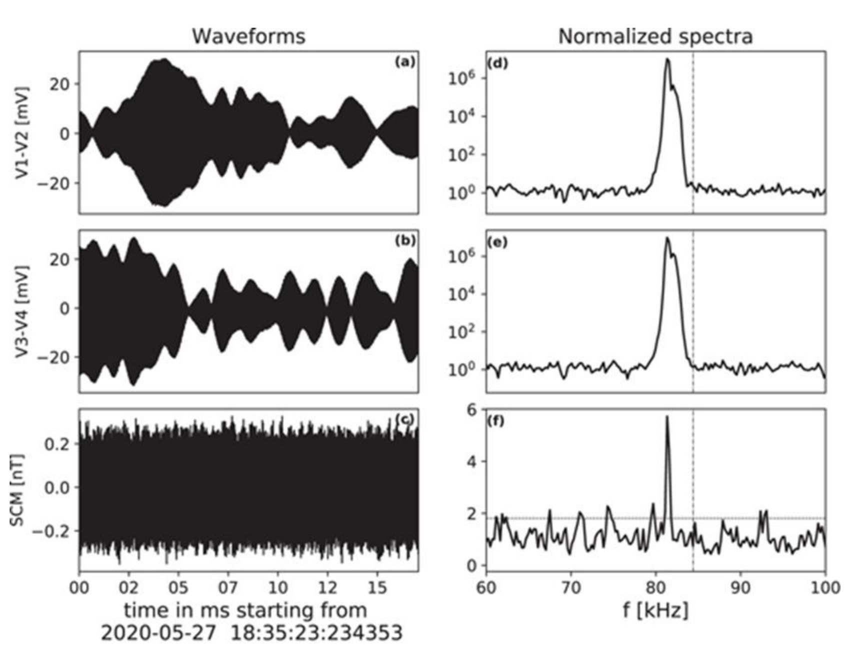

Figure 2. Results from [3]: **Left:** Raw waveforms from dipolar $\vec{E}$ -fields (top two) and $\vec{B}$ -field (bottom). **Right:** normalised PSDs corresponding to waveforms. Top two double peak, incident and reflected Langmuir waves, and B signature (bottom) coinciding with first peak.

- At ~ f_p, Langmuir/Z-modes can be transformed into ordinary as well as fast and slow EM extraordinary modes.
- B component of Langmuir/Z-mode waves inferred through elliptically/circularly polarized electric field vectors but no detections [3].
- First direct measurement of B using PSP in 2022.
- Event corresponded to strong density fluctuations and Type III Burst.

Beam-Plasma Interactions

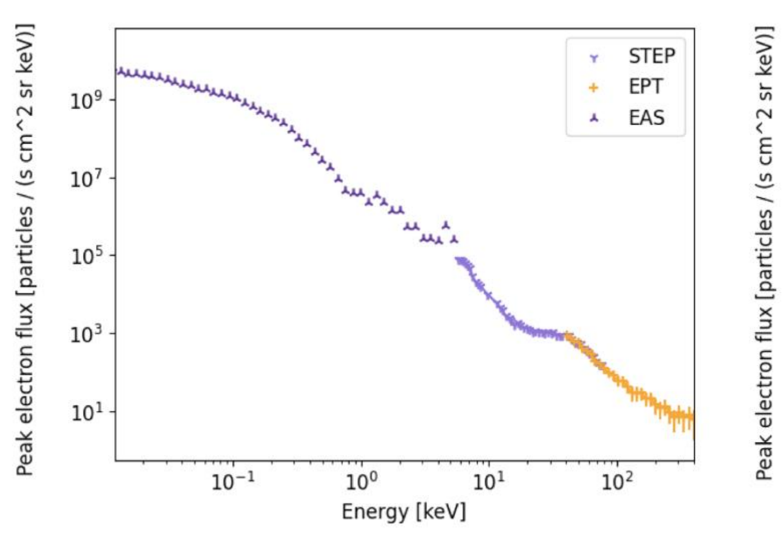

Figure 3. Results from [4]: Triple power law electron flux featuring breaks at 35keV ('knee') and 13keV ('ankle'). The 'knee; corresponds to peak Langmuir wave growth for this event and the 'ankle' in line with electron velocity diffusion.

- 'Bump-on-tail' instability means positive gradient in e^- velocity space and Langmuir waves can grow.
- This plateaus, as slower e^- reabsorb the initial energy lost to wave growth, and diffuse in velocity [2].
- Velocity spectrum and breaks in e^- peak flux energy measured directly.
- Appear to be as a result of beam-plasma interactions [4 and references therein] but exact mechanisms are not known.

3. Results

Event Search

Events of interest properties:

- Type III solar radio burst,
- Strong Langmuir waves/plasma line,
- Clear magnetic component,
- Well-aligned electron beam (suitable pitch-angle coverage).

Example Event

Using SolO RPW data, an event search was carried out between 2023-2025. Out of 30 that displayed a clear magnetic component, 4 met the rest of the above criteria, one of which from 03-10-2023 is given as an example here.

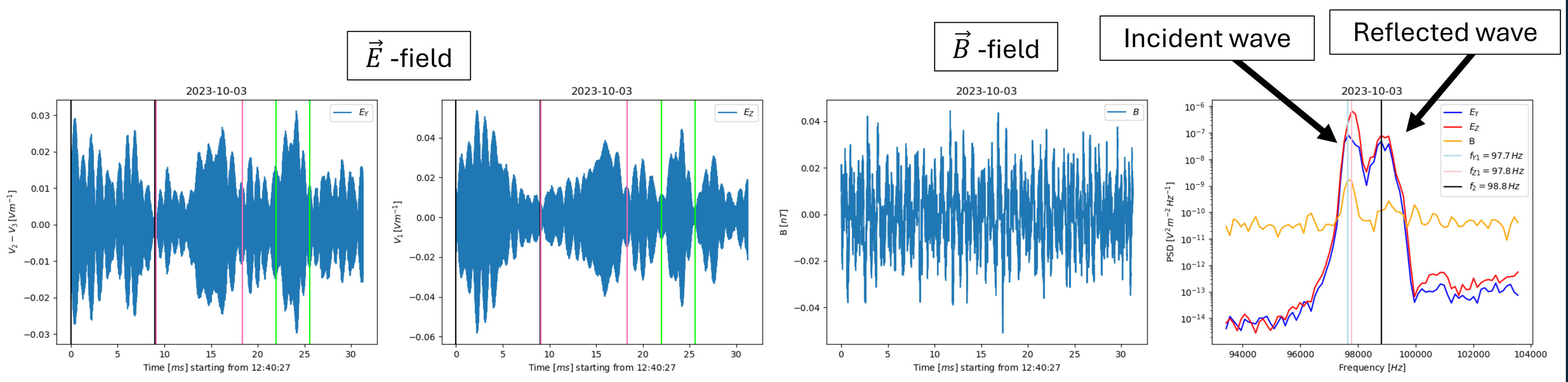

Figure 4. From left to right: Electric field measured in the E_y and E_z directions (calibrated to the spacecraft reference frame SRF), coloured lines correspond to hodogram intervals in Fig. 5. Next magnetic field measurement and finally PSD of all three waveforms. Labelled are the peak frequencies in both the incident and reflected wave for both E_y and E_z.

- Beginning of event taken from Langmuir wave generation start time.
- Event duration from 12:40:27 – 13:06:13, produced 33 snapshots (like above) total.
- Waves vary from double to single peak and not all have a B component.
  → Plot hodograms to check for circular/elliptical polarization.

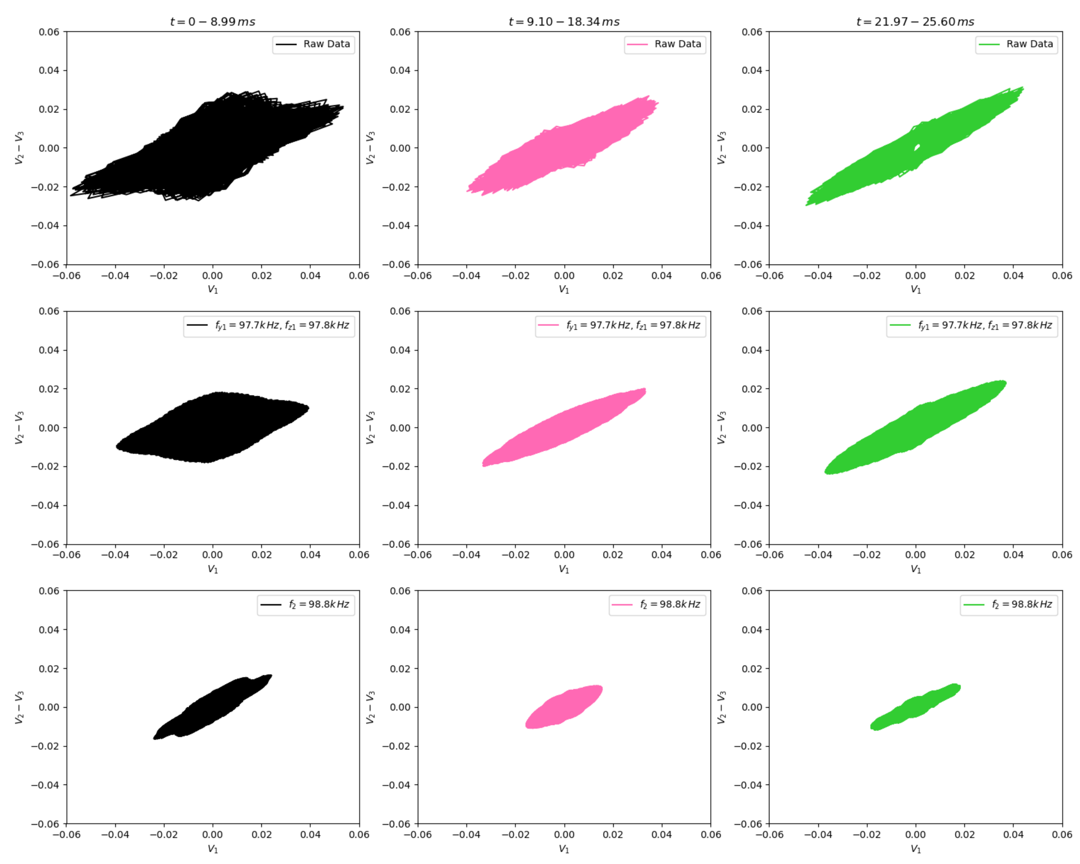

Figure 5. Hodograms plotted for E_z against E_y for three separate time intervals corresponding to coloured lines plotted on E_y, E_z in Fig. 4. Top row contains raw data signal, middle row are waves corresponding to incident wave frequencies and bottom to the reflected frequency.

- For resolvable double peaks two frequencies are defined.
- Electric field waveforms can be decomposed into two sinusoids.
- E_z and E_y plotted against one another, one wave frequency at a time, for different waveform time intervals.
  → Even for times with weaker/no B-signature elliptical polarization was observed.

4. Future Work

1. Full event analysis of current 4 best candidates:
   - Analyse hodograms alongside background B field directions
   - Look at pitch angle coverage, how does this impact interpretation of e^- beam?
   - Beam-plasma interactions; from e^- velocity distribution and flux spectrum, can Z-mode EM wave generation mechanisms be inferred?
   - What impact do density fluctuations have on this analysis?
2. Complete the search for suitable events for remaining SolO data and include PSP.

References

- [1] Reid, H. *et al* 2014 *Res. Astron. Astrophys.* **14** 773
- [2] Lorfing, C.Y. *et al* 2023 *Sol Phys* 298, 52
- [3] A. Larosa, A. *et al* 2022 *ApJ* **927** 95
- [4] Lorfing, C.Y. *et al* 2023 *ApJ* **959** 128

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