Langmuir-Slow Extraordinary Mode Magnetic Signature Observations with Parker Solar Probe

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- Langmuir-Slow waves in extraordinary mode (L-SE) have been regularly observed in the solar wind and in the Earth's electron shock since the early days of space exploration. These waves are closely related to the plasma emission mechanism for type III and II radio emissions.

- The generally accepted scenario is that the L-SE waves are converted to free propagating electromagnetic emission at the plasma frequency.

- However, the details of the mode conversion are still hotly debated today.

- The existence of a magnetic component for these L-SE waves had been predicted but never actually observed.

- Thanks to Parker Solar Probe, this magnetic component has been observed for the first time (Figure 1 at right), providing important constraints on the generation mechanisms of these waves.

Figure 1. Observation of a magnetic signature in a L-SE wave. On the left, from top to bottom: waveform of the potential difference of the PSP antennas 1 and 2; waveform of the search-coil magnetometer high frequency coil. On the right, their corresponding normalized power spectral densities. The vertical dashed line indicates the location of the plasma frequency as evaluated from the quasi-thermal noise observations. Source: Larosa, A., Dudok de Wit, T., Krasnoselskikh, et al. 2022, ApJ, 95.
Details of Observations and Analysis

• The magnetic signatures were observed in an inhomogeneous plasma environment and were preceded by a type III radio burst. These events were associated with strong electric fields. An electron beam was present, as expected (see Figure 2, next slide).

• The link between the magnetic signature, the electric field and the refractive index of the waves can be obtained from the linearised Vlasov-Maxwell system as shown in reference 1.

• In Fourier space, the amplitude of the magnetic part of the L-SE is directly proportional to the amplitude of the electric field and inversely proportional to the refractive index. Therefore, a decrease in the refractive index increases the amplitude of the magnetic part of the waves and increases the chances of observing it above the noise level. The refractive index reaches its minimum value when the waves are reflected due to density inhomogeneities.

• The reflection of Langmuir waves by density fluctuations can lead to the conversion of electrostatic energy into electromagnetic energy and explain the formation of type III bursts (see reference 3). Therefore, observations of the magnetic signatures of extraordinary Langmuir-Slow modes and their link to density fluctuations are extremely relevant to the problem of plasma emission.

• The mechanisms of transformation of electrostatic waves into SE and ordinary waves are both related to density fluctuations.
Figure 2. General view of the plasma conditions on May 27, 2020. From top to bottom: the magnetic field from the MAG fluxgate magnetometer; spectrogram of the V1-V2 dipole voltage from RFS (with color bar at the top); peak frequency of the L-SE bursts observed by the TDS instrument; energetic electron counts from the EPI-Lo particle detector. All the acronyms refer to Parker Solar Probe instruments.
Conclusions

• The Parker Solar Probe mission has allowed us to observe for the first time the magnetic signatures of extraordinary Langmuir-Slow modes that are generated by electron beams in the solar wind.

• Density fluctuations undoubtedly play an important role in this phenomenon. However, a key element had been missing until now: the details of the interaction between the beam and the plasma.

• Insights about this effect, from an observational point of view, can be found in reference 2. The next step (in progress) is to study the interaction by means of Vlasov-Maxwell simulations.

References

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