Supplementary Information

Revealing an Unexpectedly Low Electron Injection Threshold via Reinforced Shock Acceleration

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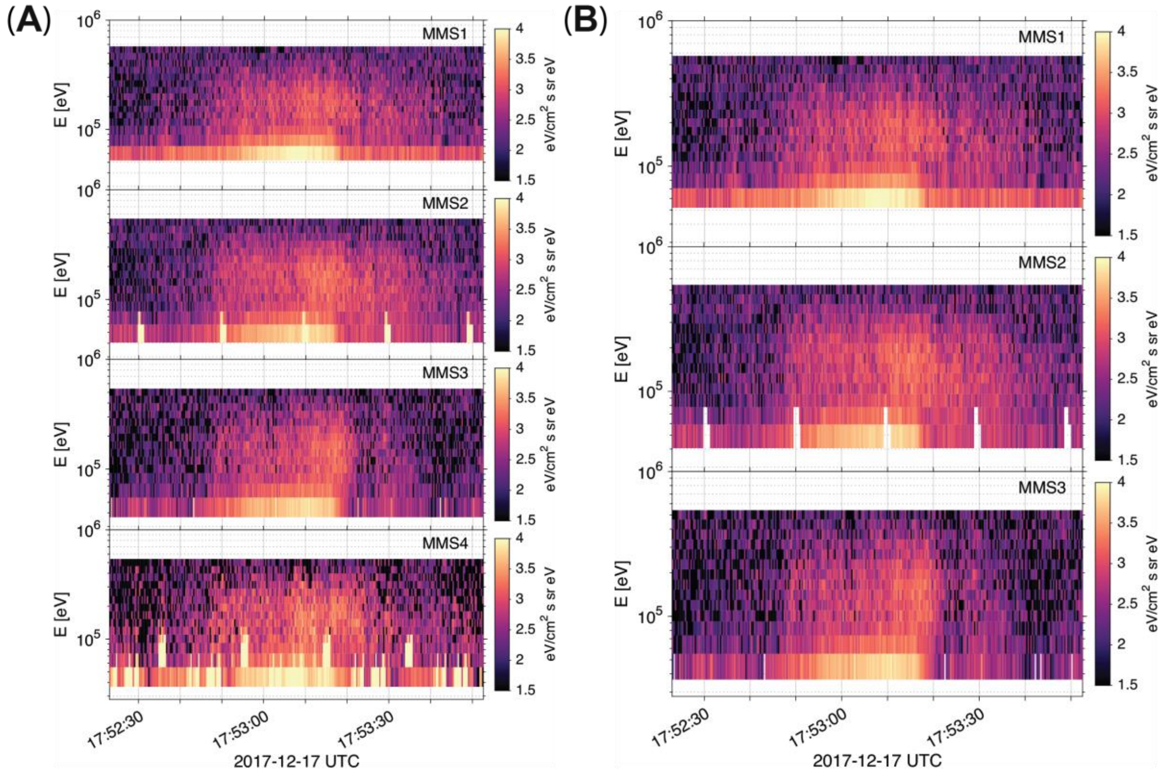
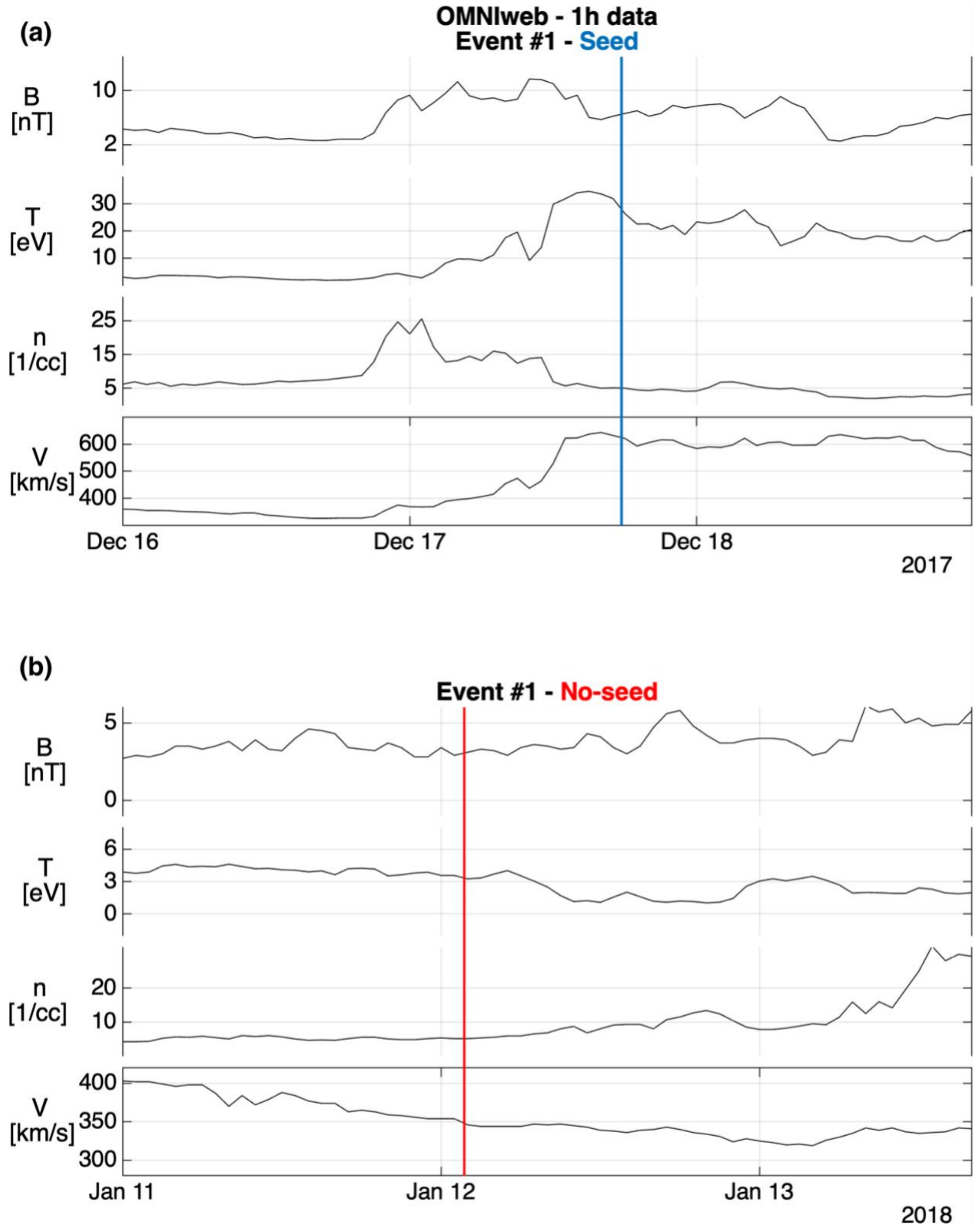
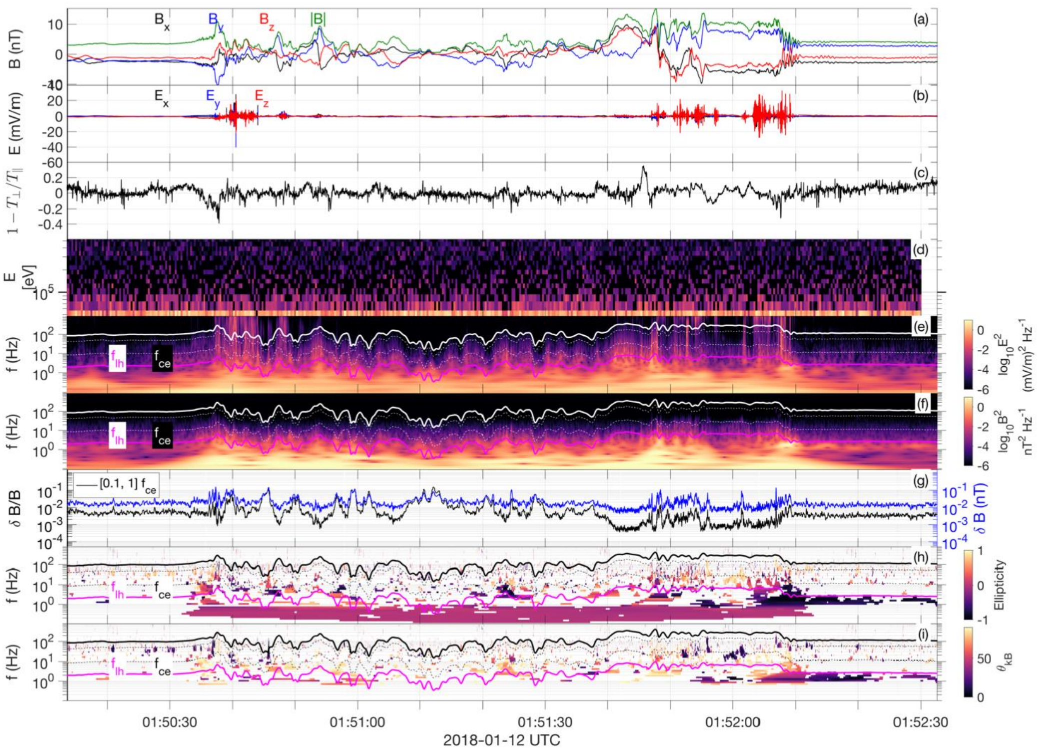


Supplementary Fig. 1: Raw FEEPS measurements along with cleaned post-processed products. The data to the left (A) show electron differential energy flux from MMS1-4 obtained from the FEEPS instrument in burst resolution. The data to the right (B) are the cleaned data from MMS1-3 that were used in the main manuscript for the generation of the combined spectrum shown in Fig. 1.



Supplementary Fig. 2: Global properties of the solar wind conditions for two events. (a) shows the conditions for the main seeded event, while (b) shows the conditions for the #1 non-seeded one (according to the numbering described in the method section and Fig. 3). From top to bottom, magnetic field absolute value, ion temperature, plasma density, and ion velocity. The vertical lines indicate the time that each foreshock transient was registered at close to earth orbit using MMS. Looking at the global solar wind conditions, we clearly see not only the fast and slow solar wind conditions, but also the fact that the main event is clearly associated to a high-speed stream occurring after the change from slow solar wind (<400 km/s) to fast solar wind (>400 km/s). On the other hand, the non-seeded event is associated with a totally different solar wind profile of less variable, slow speed conditions.



Supplementary Fig. 3: Overview plot of the non-seeded event #1. (a) magnetic field components and magnitude in GSE coordinates, (b) electric field components and magnitude in GSE coordinates, (c) electron temperature anisotropy, (d) high-energy (FEEPS) differential electron spectra (e) electric field power spectra, (f) magnetic field power spectra, (g) ΔB/B and ΔB timeseries filtered between 0.1 and 1 electron cyclotron frequency (h) ellipticity showing the polarization of the magnetic field power spectra, and (i) wave propagation angle. Electron cyclotron frequency and lower hybrid frequency lines are also shown with line plots on panels (d) to (i). As shown here, while this foreshock transient is well-formed, the lack of strong electromagnetic activity and seed population resulted in FEEPS measurements (panel d) to essentially measure background noise.