

Supplementary Material for "Shock-Induced Radiation Belt Dynamics: Simultaneous Observations of 'One-Kick' Acceleration and Ultralow Frequency Modulation"

1 SUPPLEMENTARY FIGURE

Here, we employ wavelet analysis to achieve a more quantitative description of the electric and magnetic fields observed by the Van Allen Probes.

Panels A-D, I-J, a-d, and i-j are identical to the corresponding panels in Figure 3 in the manuscript. The y-axes representing the wavelet periods (Panels E-H, K-L, e-h, and k-l) are identical to those in Figure 4 in the manuscript. The z-axes representing the wavelet amplitude (i.e. the axes of the colorbars) are identical for RBSP-A and RBSP-B.

As shown in the right column, RBSP-B observed a $\sim 90 s$ wave almost immediately after the shock arrival (from $\sim 23:00$ to $\sim 23:10$ UT). Particularly, for the wave magnetic field, the GSE-y component presented the largest amplitude (Panel g). Since the spacecraft was located near the equator (|MLAT| < 15), the background magnetic field was mainly in the GSE-z direction, perpendicular to the dominant component of the wave magnetic field. Therefore, the ULF wave directly triggered by the IPS impingement, as observed by RBSP-B immediately after the IPS arrival, was dominated by the transverse component.

In contrast to the clear ULF signatures in the RBSP-B observations, the electric and magnetic fields observed by RBSP-A (left column) exhibited more complicated features. If focused on the time interval between 23:00 and 23:10 UT, there was no significant patterns along the horizontal dotted line of 90 s (Panels E-H and K-L), which means that the transverse ULF wave observed by RBSP-B was not recorded by RBSP-A. There indeed appeared some green patterns along the 90 s lines between \sim 23:05 to \sim 23:15 (Panels E, G, and H), but they differed from the wave observed by RBSP-B where B_t did not oscillate. The fluctuations in the magnetic field magnitude indicated that a compressional wave was generated after the shock arrival. Moreover, the pattern along the 90 s line in Panel F turned from green to red around 23:10 UT. At roughly the same time, strong ULF waves appeared in the electric field observations (Panels K and L). One possible explanation for these features is that the compressional wave converted into transverse wave and further intensified after the mode conversion. However, we leave the wave mode conversion and its effects on the energetic particles for future investigations.



Figure S1. Wavelet analysis of electromagnetic fields. Van Allen Probe A observations of (A) magnetic field magnitude, (B)-(D) x,y, and z components of the magnetic field vector in the geocentric solar elliptic (GSE) coordinates, (E)-(H) magnetic field wavelet amplitudes, (I)(J) y and z components of the electric field in the modified-GSE coordinates, and (K)(L) electric field wavelet amplitudes. (a)-(h) Van Allen Probe B observations and the corresponding wavelet amplitudes in the same format as Panels A-H. For magnetic fields, the International Geomagnetic Reference Field (IGRF) is subtracted. The vertical dashed lines mark the IPS arrival (23:00 UT) and the horizontal dotted lines mark the period of 90 s.