Prompt Energization of Relativistic and Highly Relativistic Electrons During A Substorm Interval

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Abstract

On 17 March 2013, a large magnetic storm significantly depleted the multi-MeV radiation belt. We present multi-instrument observations from the Van Allen Probes spacecraft Radiation Belt Storm Probe A and Radiation Belt Storm Probe B at ~6 Re in the midnight sector magnetosphere and from ground-based ionospheric sensors during a substorm dipolarization followed by rapid reenergization of multi-MeV electrons [1]. A 50% increase in magnetic field magnitude occurred simultaneously with dramatic increases in 100 keV electron fluxes and a 100 times increase in VLF wave intensity. Chorus is excited following the injection of low-energy (1–30 keV) plasma sheet electrons into the inner magnetosphere [2]. During the 17 March substorm injection, cold plasma that had circulated into the nightside magnetosphere from the dayside ionosphere - plasmasphere contributed to an energetic (50 keV) electron population involved in chorus-mode wave amplification [3].

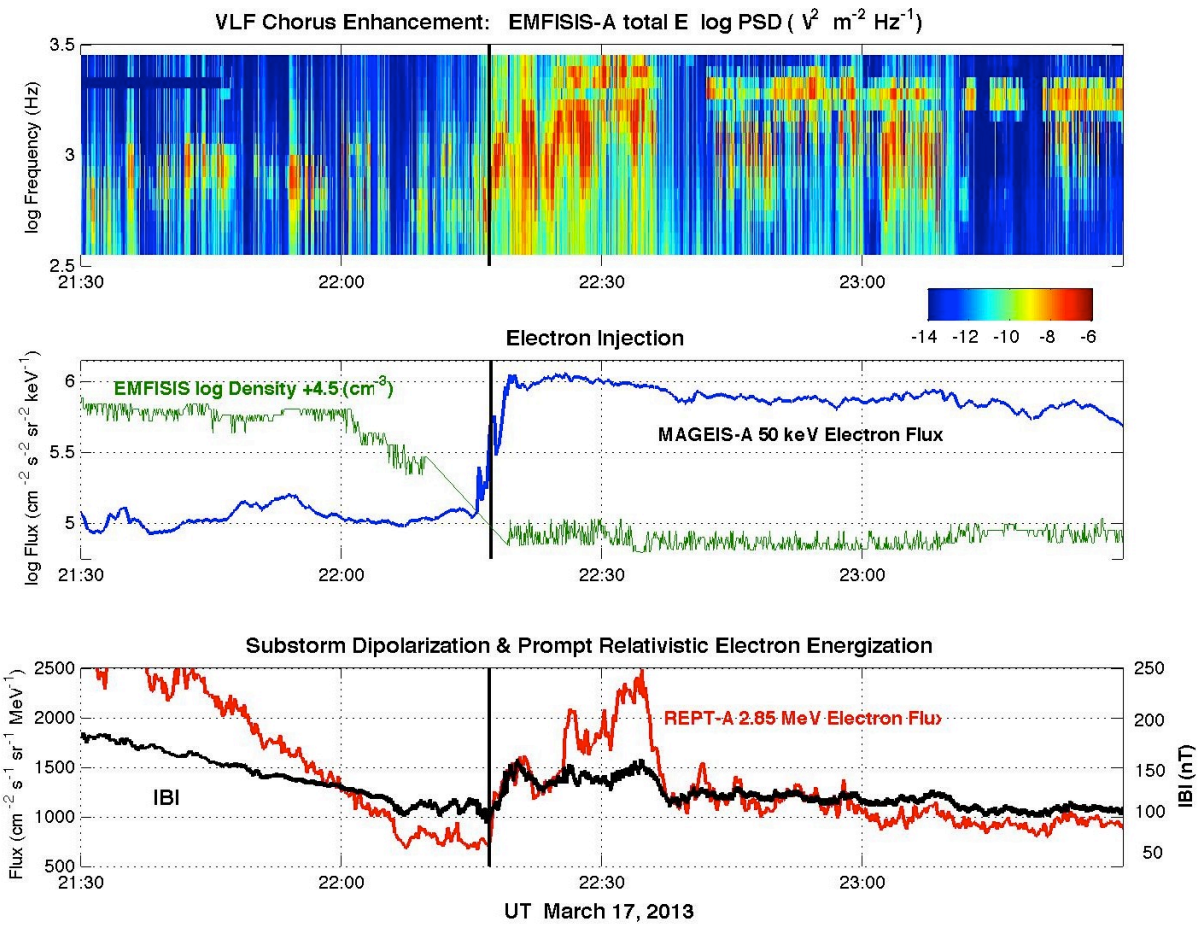

Figure 1. Multi-instrument RBSP-A observations at L* ~ 4.5 near apogee in the midnight sector are shown for the March 17, 2013 event. Substorm onset is seen in the sharp magnetic field depolarization signature at ~22:15 UT (black). This is accompanied by 1) dropout of the enhanced cold plasma density (green) redistributed to the nightside; 2) injection of 50 keV electrons (blue); 3) 100x enhancement of chorus wave power seen in the wave power spectral data shown in the top panel; 4) prompt enhancement of MeV electron flux (red).

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The high-energy tail (>100 keV) of the injected electrons and the intense VLF waves provide a seed population and energy source for subsequent radiation belt energization. The observed electron flux behavior is striking in its large increases over short intervals. As seen by RBSP-A at L* ~ 4.5 highly relativistic (>2MeV) electron fluxes increased immediately at the time of the substorm injection and strong chorus enhancement. At RBSP-B, at apogee at substorm onset, observed in the ~5 h separation between L* = 4.0 crossings, 3.60 MeV highly relativistic electron fluxes increased by a factor of 56, while 4.50 MeV flux increased by an even larger factor of 95.

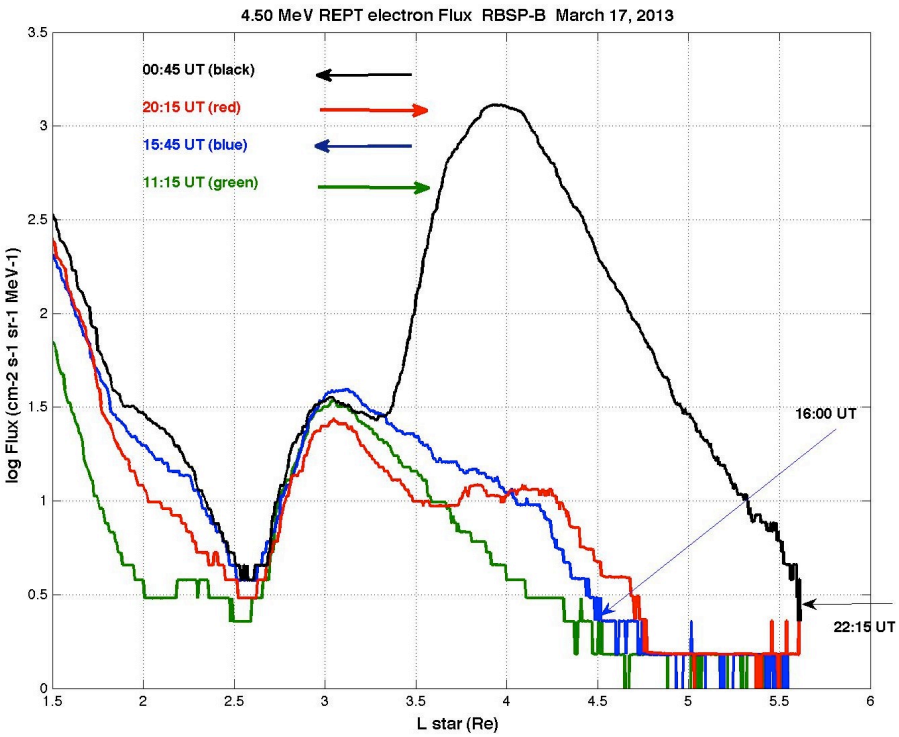

Figure2. Four consecutive Lstar (L*) profiles of 4.5 MeV electron flux as observed by RBSP-B are shown. (Highy energetic particles rapidly circle the Earth (~100 s) on trajectories of constant L*.) Relativistic electrons near L*~4 increased slightly during an initial substorm at 16:00 UT during the blue inbound pass. The subsequent red outbound pass observed little further significant flux enhancement. The 22:15 UT substorm onset occurred exactly at apogee for RBSP-B (maximum L*) and the black inbound pass shows the prompt transition to the post-substorm flux profile with 100x flux increase at L*~4 Re.

The 17 March multipoint observations indicate the significant role that substorm processes can play in creating a seed population of 100 keV electrons and VLF chorus wave enhancements that can lead to a prompt energization of relativistic and highly relativistic electrons in the region outside the plasmapause.

References

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