

Supplementary Information for "On the Confinement of Ultrarelativistic Electron Remnant Belts to Low L-shells"

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Introduction

This supporting information file includes Tables S1 and S2 providing the times and characteristics of the 18 remnant belts of ultra-relativistic electrons of 2012-2017 considered in the manuscript, and Figure S1 showing EMIC and chorus waves observed by the Van Allen Probes during the 2013-04-24 event. Table S1 shows the minimum plasmapause position L_{pp} inferred from Van Allen Probes upper-hybrid resonance (HFR) or spacecraft potential (EFW) measurements (Kurth et al., 2015; Kletzing et al., 2013; Li et al., 2015), the minimum 8-hour-averaged (in MLT) L_{pp} obtained from test particle simulations from Goldstein et al. (2014), and the minimum $L_{pp}(Dst, MLT)$ obtained from the statistical empirical model in equation (3) from O'Brien and Moldwin (2003) based on minimum Dst during the 24 hours preceding the end of the dropout. Table S2 shows the minimum LCDS location during or just before the dropout period estimated using the LANL* code (Yu et al., 2012) with the T96 (Tsyganenko, 1995) and TS05 (Tsyganenko and Sitnov, 2005) magnetic field models for 90° electrons, the upper edge of the 4-MeV electron remnant belts, the maximum 2-hour ULF wave power measured on ground stations MEA-TRAP or PGEO-DOB, and the multi-MeV electron PSD gradient shape obtained from Van Allen Probes measurements. The data files of ULF wave power as a function of time for the different pairs of stations are provided in accompanying *date-power-new+* dat files. LANL* LCDS calculations for the considered periods are provided in *Lmax-date-Txx* txt files for T96 and T05 magnetic field models (xx in file name indicating the UT hour of start and LCDS being calculated in steps of 5 min). The electron PSD profiles obtained from the Van Allen Probes during/nearby each event are provided in the *PSD-VanAllenProbes* PDF file.

Table S1. Date of event; times (UT) of Min(LCDS) and 4 MeV electron flux dropout; minimum L_{pp} inferred from Van Allen Probes upper-hybrid resonance (HFR) or spacecraft potential (EFW) measurements in the 20-to-13 MLT sector during the considered dropout period (asterisks indicate L_{pp} values obtained just outside this MLT sector that agree with simulations from Goldstein et al. (2014) at the same MLT, confirming the simulations); minimum 8-hour-averaged (in MLT) L_{pp} obtained from test particle simulations from Goldstein et al. (2014); minimum $L_{pp}(Dst, MLT)$ obtained from the statistical empirical model in Equation (3) from O'Brien and Moldwin (2003) based on the minimum Dst during the 24 hours preceding the end of the dropout; maximum Kp during the dropout period. The minimum L_{pp} values used in the paper are indicated in bold.

Remnant Belt Events of 2012-2017 - minimum L_{pp} and maximum Kp					
Date	Min(LCDS), Drop (UT)	Min[Lpp,VAP]	Min[Lpp,G]	Min[Lpp,OM]	Max(Kp)
2012-09-03	13, 10-15		2.7	3.0	5.7
2013-03-17	8, 4-12	2.54	2.7	2.8	6.7
2013-04-24	3, 1-5	3.6	3.5	3.8	3.0
2013-05-01	13, 14-18	2.7	2.8	2.95	4.7
2013-10-02	5, 1-8	3.2	2.4	3.0	7.7
2013-11-09	5, 3-8	< 4*	2.7	3.0	5.0
2016-01-20	9, 9-12		2.75	2.95	4.7
2016-06-05	13, 19-24	3.24		3.6	5.3
2016-11-24	13, 13-21	3.6		3.4	4.7
2016-12-07	18, 18-22	4.68		4.1	3.0
2016-12-21	15, 12-17	3.48		3.4	6.0
2017-06-16	7, 5-10			5.0	4.0
2017-07-16	10, 10-13	< 5.9*	2.9	3.05	5.7
2017-08-04	10, 8-13			3.75	4.3
2017-08-17	11, 12-15			3.75	4.7
2017-09-27	7, 5-11	3.95	3.4	3.6	4.7
2017-10-11	4, 2-6			3.70	4.7
2017-11-07	8, 7-12			3.33	4.7

Table S2. Date, times (UT) of Min(LCDS) and 4 MeV electron flux dropout, minimum L_{LCDS} , upper edge $\max(L)$ of the remnant belt of 4 MeV electron flux, maximum 2-hour ULF wave power (nT^2) measured at $L \sim 3.9$ and 4.6 . Last column: minimum sign of outward gradient of $\text{PSD}(L^*)$ from $L^* \geq \max(L)$ up to $L^* \sim \min(L_{LCDS})$ before or after dropout for $\mu \simeq 2500$ and $\simeq 4000$ MeV/G at lowest available $K = 0.04$ or $0.1 G^{1/2}R_E$ (+ and $-$ correspond to PSD increase/decrease by a factor ≥ 2 , and 0 to a quasi-plateau with factor < 2 oscillations). Next in last column: minimum final to initial PSD ratio R over $3.6 < L^* < 5$ and $\text{Min}(L^*)$ of PSD peak or start of plateau during two consecutive Van Allen Probes orbits comprising the dropout. Only events without strong oscillations of 4 MeV electron flux at $L \sim 4.0 - 4.5$ after the dropout are considered in the last column.

Remnant Belt Events in 2012-2017 – other parameters						
Date	Min(LCDS), Drop(UT)	L_{LCDS}	$\text{Max}(L)$	P_{ULF} 3.9	P_{ULF} 4.6	$(\partial \text{PSD} / \partial L^*)$, R, $\text{Min}(L^*)$
2012-09-03	12, 10-15	3.9	3.5	846	3153	
2013-03-17	8, 4-12	3.9	3.4	1857	993	0, 0, 0.05, 4.6-3.8
2013-04-24	3, 1-5	5.15	4.1	5.2	70	–, –, 0.3, 4.0-4.0
2013-05-01	13, 14-18	5.05	3.8	57	446	
2013-10-02	5, 2-8	3.5	3.4	527	1585	+, 0, 0.2, 3.5
2013-11-09	5, 3-8	4.6	3.8	33	435	–, –, 0.5, 4.4-4.0
2016-01-20	9, 9-12	4.4	3.5	241	3396	–, –, 0.03, 4.0
2016-06-05	13, 19-24	4.3	3.7	381	156	
2016-11-24	13, 13-21	4.9	3.8	123	3526	
2016-12-07	18, 18-22	5.3	3.8	32	37	–, –, 0.25, 4.5-4.7
2016-12-21	15, 12-17	5.25	3.5	508	1617	–, 0, 0.7, 4.6-4.6
2017-06-16	7, 5-10	4.7	4.15	62	84	
2017-07-16	12, 10-13	3.5	3.4	448	6172	0, 0, 0.5, 4.4-4.2
2017-08-04	10, 8-13	4.8	4.6	140	2843	–, –, 0.15, 4.3-4.3
2017-08-17	11, 12-15	5.6	4.1	232	2132	–, –, 0.6, 4.5-4.2
2017-09-27	7, 5-11	5.2	3.8	89	344	0, 0, 0.1, 4.1-4.2
2017-10-11	4, 2-6	6.0	4.2	61	188	–, –, 0.2, 4.1-3.8
2017-11-07	10, 7-13	4.5	3.5	375	5350	0, 0, 0.02, 3.9

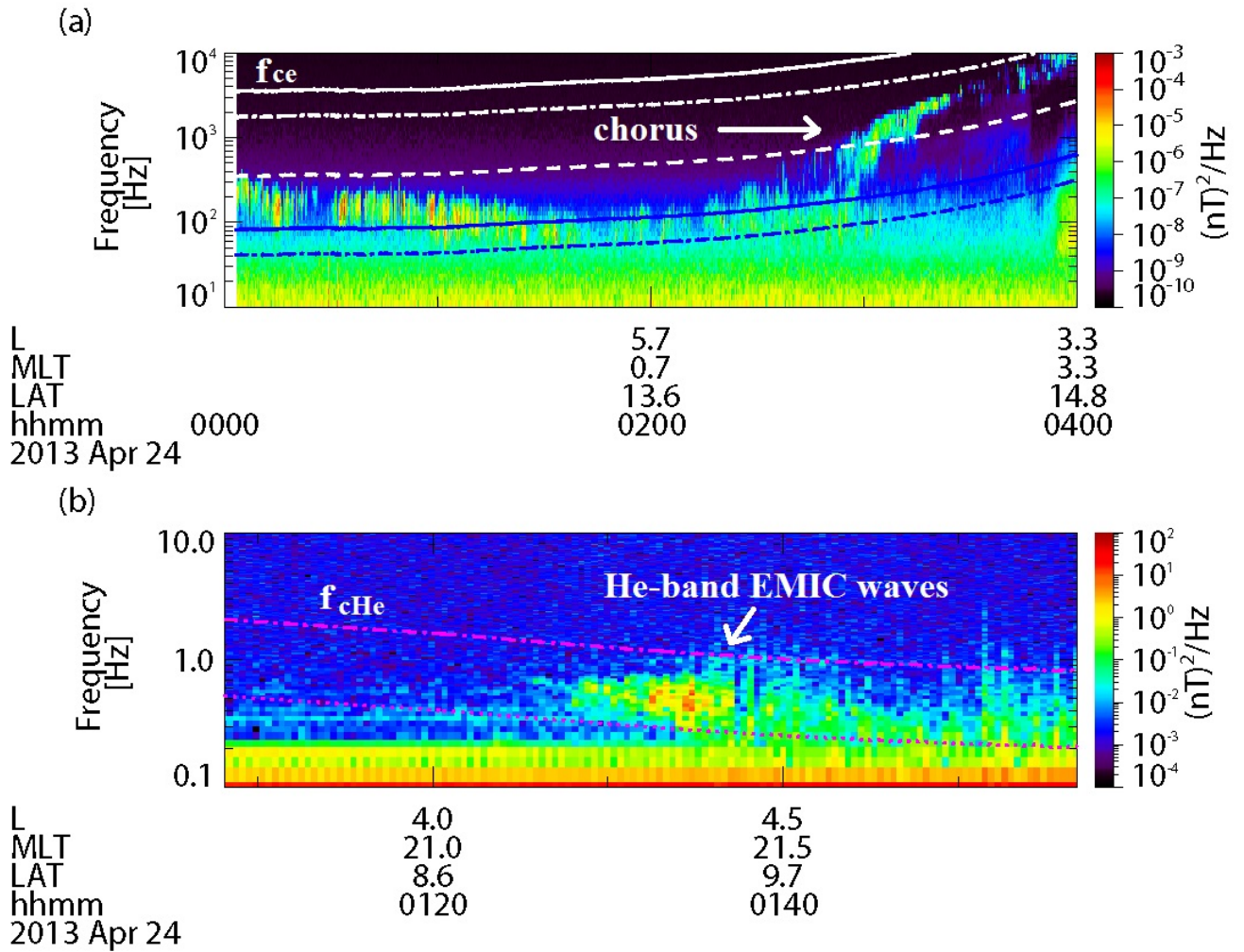


Figure S1. Intense lower-band chorus waves (panel a) and Helium-band EMIC waves (panel b) observed nearly simultaneously by Van Allen Probes A and B at $L = 4.3$ between 1:35 UT and 3:10 UT during the 2013-04-24 dropout event.