Effects of Solar Wind Parameters on the Location of Tail Reconnection

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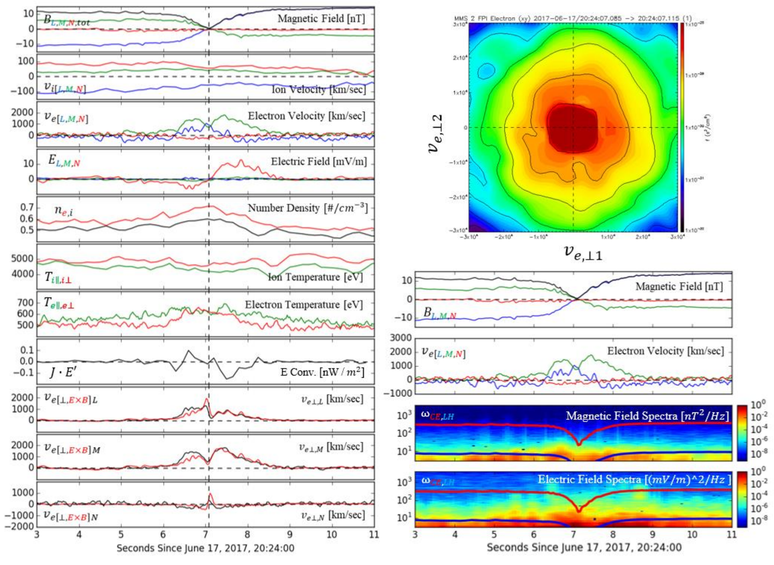
1. Abstract

The Earth's magnetotail contains a current sheet separating the anti-Sunward field of the southern lobe from the sunward-pointing northern lobe. Herein, we report tail current sheets that are supported by only electron currents. We examine one electron-only current sheet in detail, and briefly discuss ten others. Three current sheets are interpreted in terms of the time-evolution of reconnection onset. These current sheets show evidence of parallel electron heating, perpendicular ion heating, and current sheet expansion. These features are consistent with electron and ion behavior during traditional "electron-ion" reconnection. Ground-based and in-situ data show that electron-ion reconnection occurs shortly after each "pre-ion reconnection" electron-only reconnection event. This suggests that electron-only reconnection can act as a precursor to electron-ion reconnection. We note that five events occur shortly after a period of electron-ion reconnection, which suggests that electron-only reconnection is more than merely a precursor to ion reconnection.

2. Electron-Only Reconnection

Recently, using the high time and spatial resolution of the Magnetosphere Multiscale (MMS) Mission, several observers have reported a phenomenon dubbed "electron-only" reconnection in various magnetic environments [Phan et al., 2018, Wang et al., 2018, Stawarz et al., 2019]. These observations meet every observational criterion for an EDR except the ion response one might expect in traditional magnetic reconnection [Phan et al., 2018]. Two mechanisms have been proposed for this process: low frequency, high amplitude waves (specifically below the lower hybrid frequency) [Vega et al., 2020, Wang et al., 2018], and the current sheet having a small length (in the L direction) to width (in the M direction) ratio [Mallett, 2019, Pyakurel et al., 2019]. However, due to few observations and the disparate nature and rarity of "electron-only" reconnection, a consensus on their origin or nature has not yet been established.



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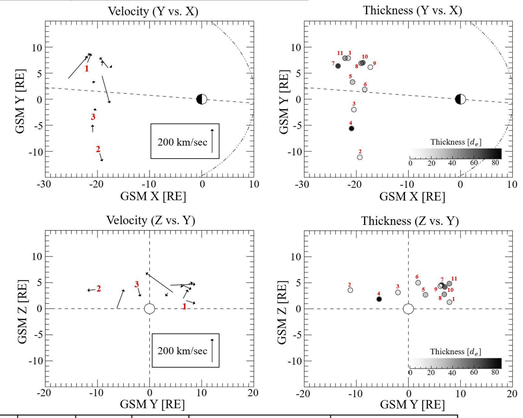
3. Electron-Only Time Evolution

Electron-Only Reconnection Criteria

We used four criteria to find electron-only reconnection events:

1. Current Sheet Crossing ($B_L = 0$)
2. Absolute B_{tot} minimum
3. Lack of ion exhaust jets ($v_{iL} < v_{iA}$, no v_{iL} reversal)
4. Super-Alfvenic electron exhaust jets ($v_{eL} > v_{iA}$)
5. Lack of significant T_i response
6. Significant T_e energization
7. Positive $J \cdot E'$
8. Deviation of $v_{e\perp}$ from $v_{E\times B}$

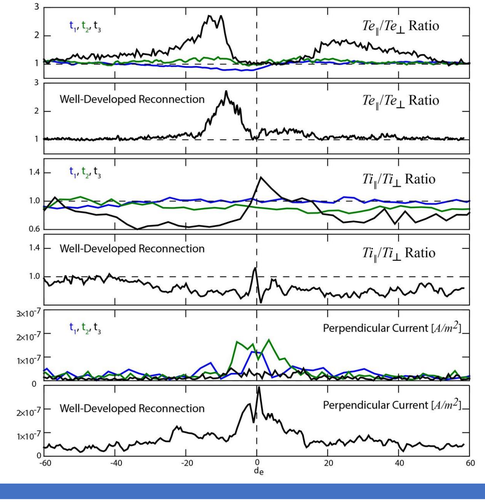


#	Time Interval	X	Y	Z	Thick. (km,d_e)	Vel. (km/sec)
1	*7-20-17/09:59-10*	*0.36*	***0.88***	*-0.29*	*77, 9.3*	*77*
2	*6-17-17/20:24-25*	*0.18*	***-0.93***	*-0.33*	*69, 10*	*69*
3	*6-19-17/09:43-44*	*0.08*	*0.24*	***-0.97***	*219, 14.6*	*73*
4	6-13-17/21:09-10	-0.01	0.35	**0.94**	860, 86	172
5	7-06-17/05:38-39	0.08	-0.57	**-0.82**	186, 29	31
6	7-24-17/13:04-05	0.22	**-0.79**	0.57	294, 21	294
7	7-26-17/17:39-40	0.65	**0.75**	0.03	852, 72	284
8	8-07-17/11:04-05	0.07	0.47	**0.88**	410, 39	82
9	7-23-18/15:04-05	0.41	-0.34	**0.84**	100, 8.4	10
10	7-26-18/13:05-06	-0.58	**0.73**	-0.36	720, 60	120
11	8-01-18/12:58-59	0.35	**0.87**	0.35	190, 40	38

Time Evolution

We now use three "pre-ion reconnection" electron-only events **(Event #1 (t_1), Event #2 (t_2) [Wang et al., 2018], and Event #3 (t_3) [Yu et al., 2019], italicized in Table 1)** and one EDR crossing during well-developed reconnection observed by MMS in the near-Earth magnetotail to describe the evolution of electron-only reconnection during "electron-ion" reconnection onset. **Features of a traditional EDR crossing were taken from MMS observations of the interval 08-10-2017/12:18-19 [Li et al., 2019, Zhou et al., 2019].**

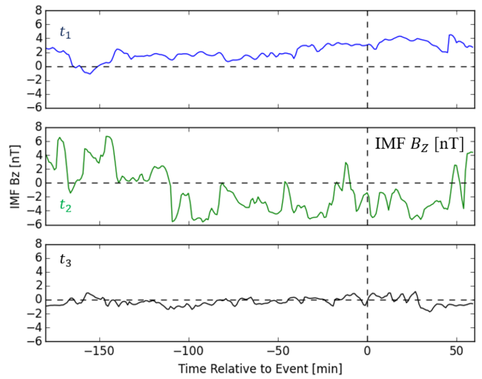
Events #1-3 display a transition from a relatively undisturbed current sheet to a well-developed, reconnecting current sheet. The thinnest current sheet displays weak perpendicular electron heating and no ion heating. However, as the process develops, $T_{e,\parallel}$ and $T_{i,\perp}$ increase with respect to $T_{e,\perp}$ and $T_{i,\parallel}$. The current sheet thickness and E_N also increase. Eventually, the temperature anisotropy and current sheet thickness of "electron-only" reconnection become consistent with the thickness and anisotropy of well-developed reconnection in the near-Earth magnetotail.



4. Solar Wind/Ground Conditions

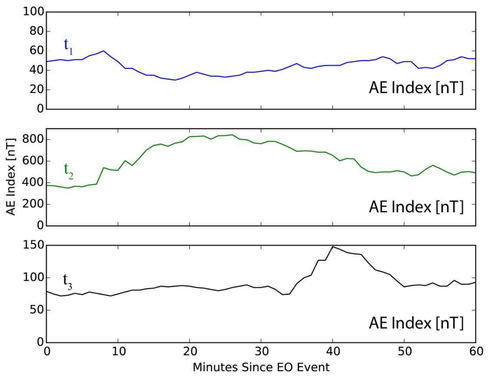
IMF B_Z

To investigate solar wind features, we propagated WIND satellite data to the Earth's magnetopause [Lai et al., 2019]. We observe southward IMF B_z turning less than one hour prior to four of five events (Events #2-5), suggesting that magnetic flux was being carried to the nightside during these intervals.



AE Index

We then examined AE index and DST index data from the World Data Center for Geomagnetism in Kyoto over the 6 hours prior to and following each "pre-ion reconnection" observation. The AE index was perturbed significantly within 60 minutes after three of our five "pre-ion reconnection" observations (Events #2,3,5).



5. Conclusions

In this study, MMS observed 11 events of "electron-only" reconnection, characterized by a B_L reversal, B_{tot} minimum, super-Alfvenic v_{eL}, lack of ion response, electron heating, positive J·E', deviation of $v_{e\perp}$ from $v_{E\times B}$. Five events occurred prior to traditional reconnection, five events occurred after traditional reconnection, and one occurred with no traditional reconnection signature before or after the event. The thicknesses of these current sheets vary from sub-ion scale to ion scale. Isolating three "pre-ion reconnection" electron-only events, we find that electron-only reconnection develops in time into traditional "electron-ion" reconnection with an increase in parallel electron heating and perpendicular ion heating. This anisotropy eventually reaches the scale seen in well-developed reconnection regions. Over time, these current sheets also increase in thickness. These events' durations suggest that this process develops on a timescale that well exceeds 10 seconds. These events also occur less than 60 minutes after southward IMF B_Z turning and prior to geomagnetic response. Our findings provide evidence that electron-only reconnection occurs in a transient fashion and can contribute to the onset of traditional magnetic reconnection in Earth's magnetotail.

References/Acknowledgements

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