Observations of Ion Diffusion Regions in the Geomagnetic Tail

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Abstract

We present analysis of two Ion Diffusion Regions (IDRs) in the geomagnetic tail, as observed by the Magnetospheric Multiscale Mission (MMS). Analysis of each event is centered around discussion of parameters commonly associated with IDRs such as enhanced electric field magnitude, guiding center expansion parameter, and ion velocity. Characteristic values for these parameters are determined, as well as other common attributes of IDRs, and used to develop a searching algorithm to automate identification of possible IDRs for closer inspection. Preliminary results of applying this algorithm to *in situ* MMS observations are also presented

Methodology

The search for Ion Diffusion Regions is taken in three stages. The first stage looks for correlated reversals in B_N and ion V_L, taken to mean occurring $\leq$3 minutes apart. The second stage looks for $|\vec{E}| \geq 10mV$ and a guiding center expansion parameter $\delta_i \geq 1.0$, both coinciding with the reversal in B_N. The third stage looks for Hall $\vec{E}$ and $\vec{B}$ in the neighborhood of the reversal in B_N, again taken to be within 3 minutes. To maintain consistency with previous studies, GSM coordinates have been used throughout this study.

References

— Muzamil, F. (2017) "A Study of Reconnection Poleward of Cusp: Cluster and Polar". PhD Thesis. UNH Physics. Durham, NH

— Scudder, J.D., R.D. Holdaway, R. Glassberg, S.L. Rodriguez. (2008) "Electron diffusion region and thermal demagnetization". *JGR. 113.* A10208

— Alexandrova, A., R. Nakamura, V.S. Semenov, T.K.M. Nakamura (2015) "Motion of reconnection region in the Earths magnetotail". *Geophys. Res. Lett. 42.* 46854693.

Selection Rules

Stage 1	
B_z(GSM) Reversal	$\pm 1nT$
V_x(GSM) Reversal	$\pm 100\frac{km}{s}$
Separation	$\leq 180s$
Stage 2	At B_z Reversal:
$\lvert\vec{E}\rvert$	$\geq 10\frac{mV}{m}$
δ_i	≥ 1.0
Stage 3	Within Stage 2 Region:
Hall $\vec{E}_n$	DC Offset $\geq 2mV$
Hall $\vec{B}_m$	$\geq$ 2 Quadrants
Total Stage 1	75
Total Stage 1+2	27
Total Stage 1+2+3	6

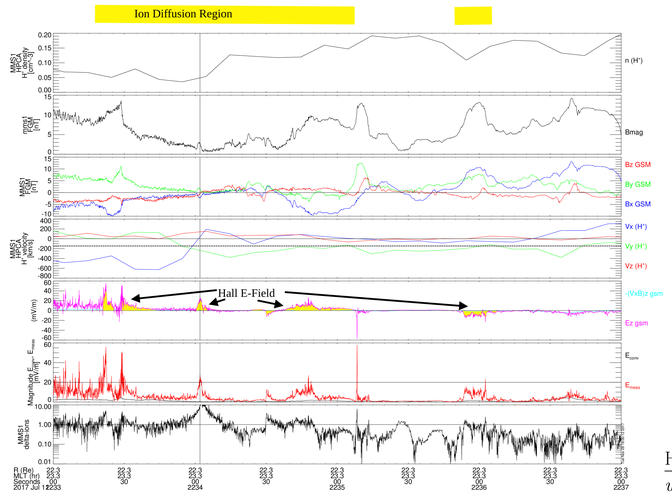
IDR Search Criteria *The above are the selection rules used to define the search algorithm bounds for identifying Ion Diffusion Region candidates. Included is the total number of events which satisfy these criteria during the period from May 01, 2017 to July 20, 2017.*

Identified IDRs
(2017-05-01 $\rightarrow$ 2017-07-20)

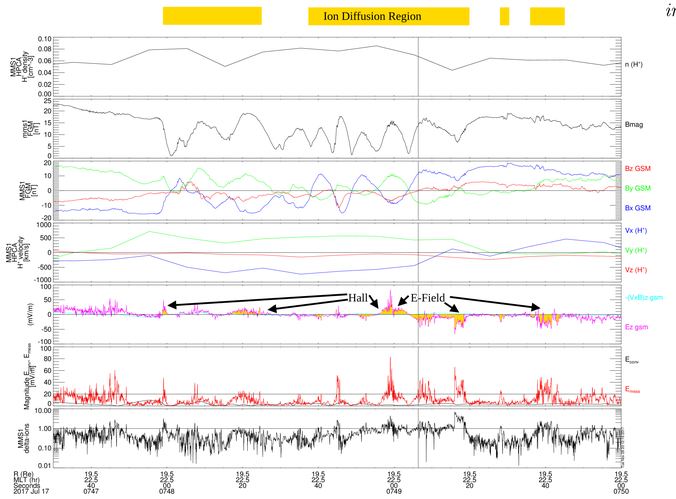
yyyy-mm-dd/tttt UT	B_z	V_x	Δt	$\lvert\vec{E}\rvert$	δ_i
2017-06-17/2024	$\frac{+5nT}{-3nT}$	$\frac{+150\frac{km}{s}}{-150\frac{km}{s}}$	$47s$	$12\frac{mV}{m}$	3.3
2017-06-19/0943	$\frac{-3nT}{+4nT}$	$\frac{-550\frac{km}{s}}{+450\frac{km}{s}}$	$19s$	$30\frac{mV}{m}$	3.8
2017-07-03/0527	$\frac{+6nT}{-8nT}$	$\frac{+200\frac{km}{s}}{-200\frac{km}{s}}$	$5s$	$67\frac{mV}{m}$	12.
2017-07-06/1547	$\frac{-3nT}{+6nT}$	$\frac{-750\frac{km}{s}}{+900\frac{km}{s}}$	$35s$	$20\frac{mV}{m}$	2.5
2017-07-11/2234	$\frac{-4nT}{+3nT}$	$\frac{-600\frac{km}{s}}{+200\frac{km}{s}}$	$< 1s$	$28\frac{mV}{m}$	15.
2017-07-17/0749	$\frac{-7nT}{+6nT}$	$\frac{-750\frac{km}{s}}{+450\frac{km}{s}}$	$7s$	$29\frac{mV}{m}$	1.8

Preliminary Results *The table above shows the six Ion Diffusion Region encounters by MMS1 during the period beginning May 01, 2017 and ending July 20, 2017, as identified by the criteria outlined before.*

2017-07-11/2234 UT - Time Series

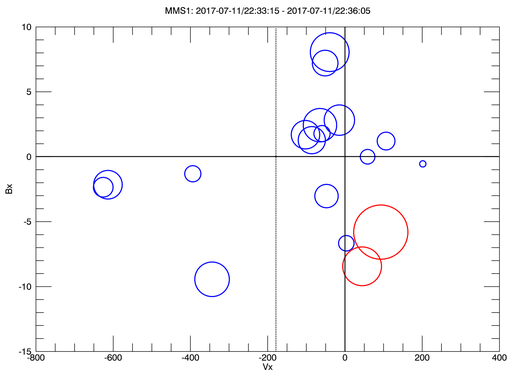


2017-07-17/0749 UT - Time Series



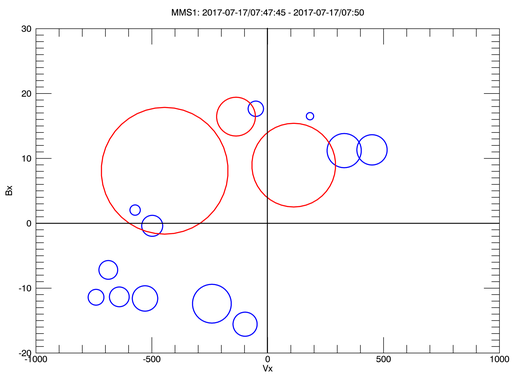
Time Series Data: *These time series data from MMS1 include HPCA H^+ density as a proxy for overall ion density, FGM magnetic field data, HPCA H^+ velocity as a proxy for overall ion velocity, EDP electric field data in the GSM $\hat{z}$ direction as well as $|\vec{E}|$, and the calculated guiding center expansion parameter. Vertical lines are included to indicate B_z reversal. Hall $\vec{E}$ are highlighted in the E_z plots. Dashed lines represent approximate correction for motion of the X-line in GSM_x.*

2017-07-11/2234 UT - Hall $\vec{B}$



Hall $\vec{B}$ Analysis: *The abscissa of each plot is the ion velocity which is used as a proxy for the $\hat{L}$ direction, while the ordinate axis is B_x which is used as a proxy for the $\hat{N}$ direction. Lines are provided at $B_x = 0$ and at the estimated GSM_x velocity of the X-point. Colored circles represent Hall magnetic field (B_y) values, with positive values in blue, negative values in red, and magnitude proportional to the area of each circle. Dashed lines represent approximate correction for motion of the X-line in GSM_x.*

2017-07-17/0749 UT - Hall $\vec{B}$



Note: *The July 17th event above represents a subset of identified IDRs for which calculation of the X-line velocity is difficult. In this case while a positive X-line velocity in GSM_x can be inferred on the basis of the correlation of B_z and V_{ion} reversals, it is not conclusive and a value for the X-line velocity has not been included here.*

Conclusions

- Used a stepwise approach for IDR identification
- Identified 6 IDRs encountered by MMS1 between May 01 and July 20, 2017
- B_m measurements in most of these show predicted quadrupole Hall $\vec{B}$ in 3/4 quadrants, as expected in quasi-symmetric tail reconnection
- Code to automate this process is in development

Future Work

IDL code to automate application of the search algorithm is under development and can currently test for stages one and two. Our goal in developing this code is to automate the flagging of likely IDRs which include flow reversals for later analysis by a human to determine if Hall fields are present. While our algorithm does not, presently, provide flagging for IDR candidates *without* ion flow reversals, further development and refinements will be possible after the current iteration reaches production maturity.

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