Velocity Structure of Dipolarization Events

Tyler J. Metivier[1], Hiroshi Matsui[1], Charles J. Farrugia[1], Roy B. Torbert[1,2]

[1] University of New Hampshire, Space Science Center
[2] Southwest Research Institute

Introduction

We present 3 case studies and a brief statistical analysis on dipolarization events found with MMS from the magnetotail to the inner magnetosphere. Electric fields, bulk velocities, and structure velocities are compared. Overall, we find that the plasma associated with dipolarization events often have characteristics of a Hall fluid in the magnetotail and the transition region. Flow diversion is found in the transition region and in the inner magnetosphere compared to the primarily earthward flow in the tail.

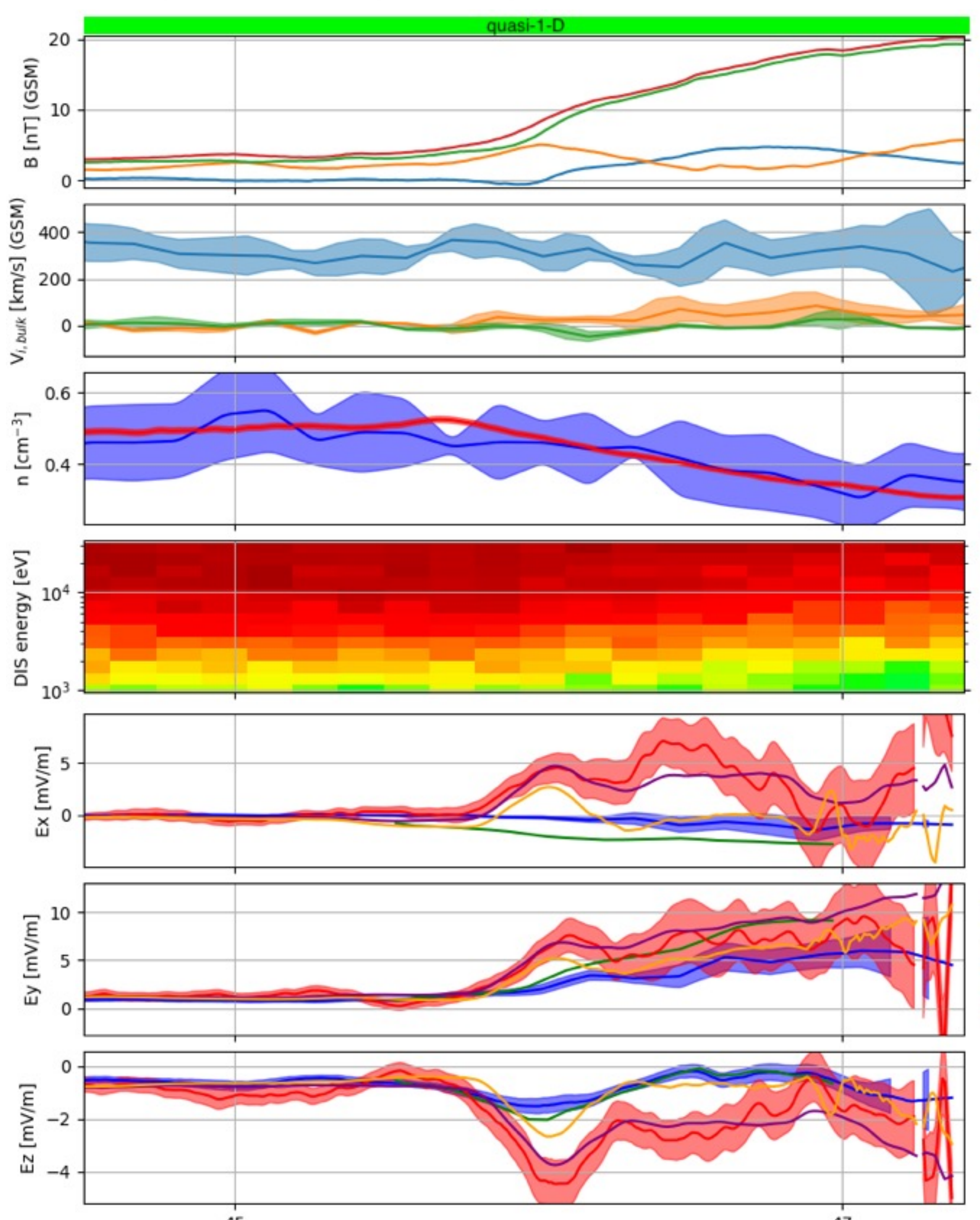

Fig. 1

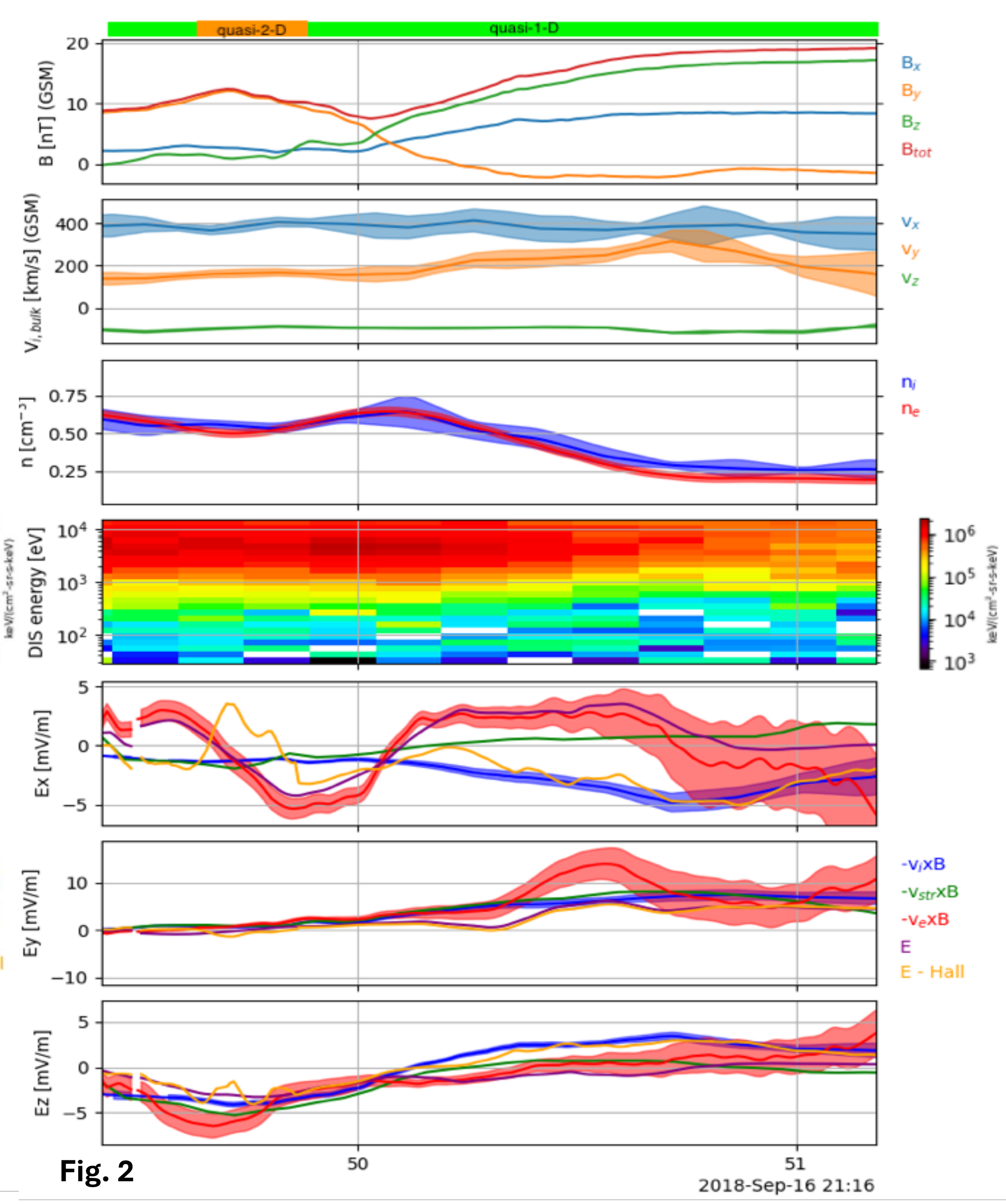

Fig. 2

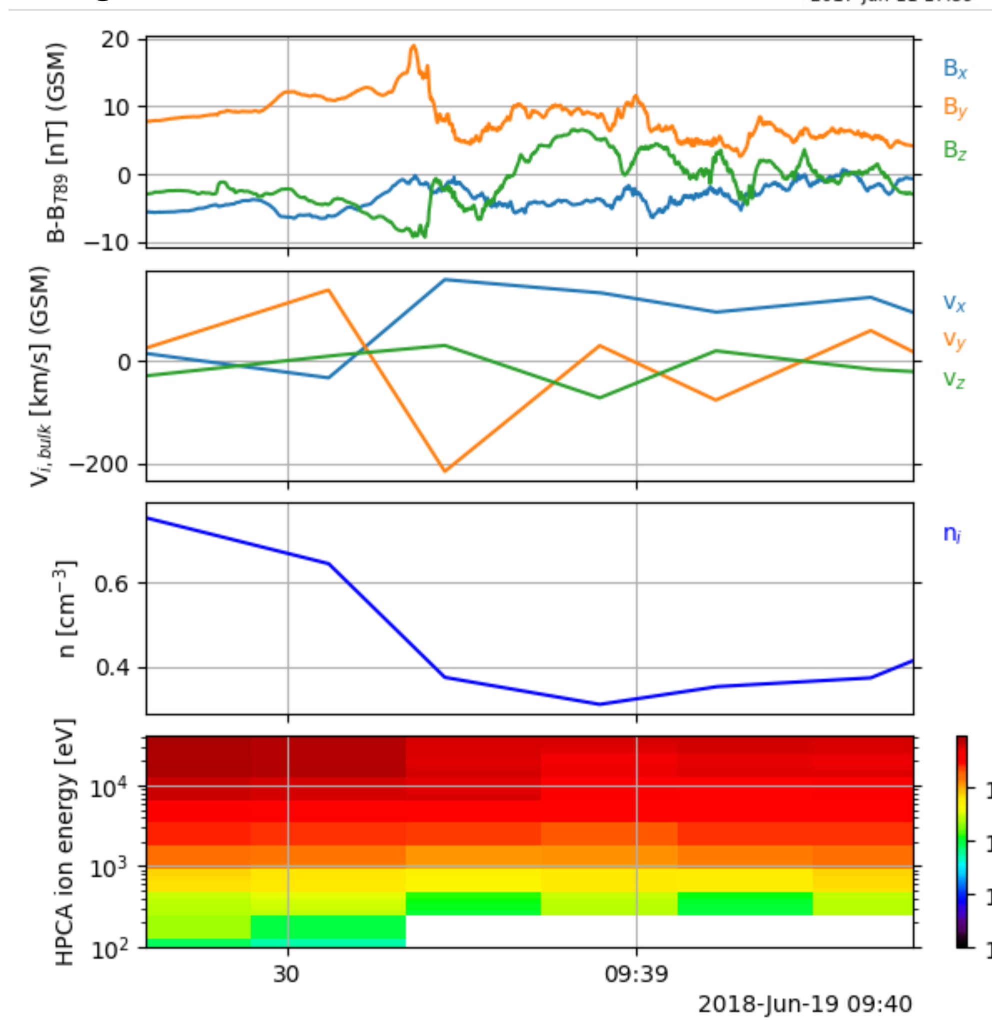

Fig. 3

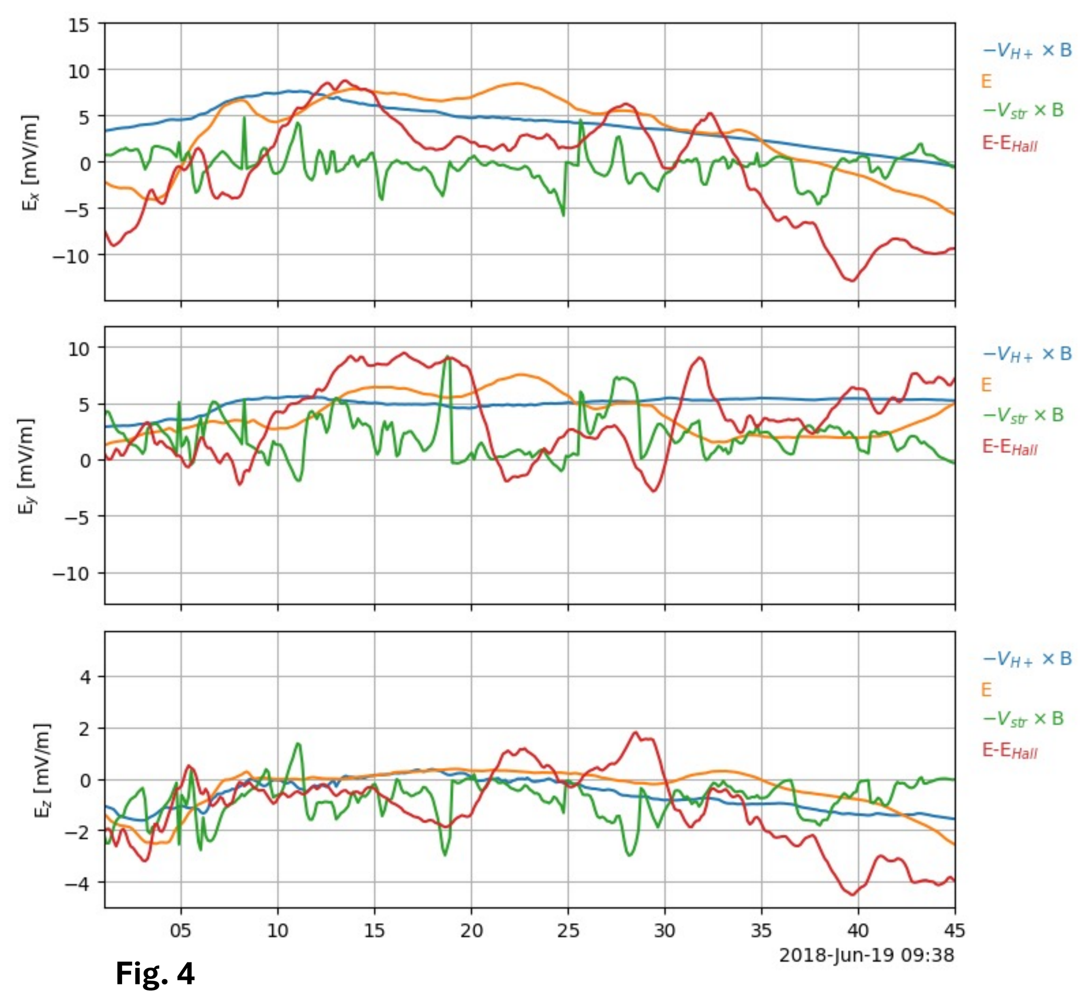

Fig. 4

Magnetotail and Transition Region Events

Figures 1 and 2 (top left) show a dipolarization fronts (DF) 25 R_E and 18 R_E downtail. The DF in Fig. 1 is entirely 1-D and the bulk ion flow is directed earthward. The DF in Fig. 2 is largely 1-D, with slight quasi-2-D characteristics during the first half of the event (corresponding with the B_Y fluctuation). A clear density decrease can be seen alongside the arrival of both fronts. In Fig. 2, the bulk ion velocity is mainly earthward, with a duskward component that rises and falls. Both figures show that the Hall electric field is mainly in the X_{GSM} direction and $E - E_{Hall}$ follows $-\mathbf{v}_i \times \mathbf{B}$ closely. In the Y_{GSM} and Z_{GSM} directions, $-\mathbf{v}_i \times \mathbf{B}$, $-\mathbf{v}_e \times \mathbf{B}$, $-\mathbf{v}_{str} \times \mathbf{B}$, and the E field are all quite similar. For these events, electrons remain frozen-in while ions are decoupled by the Hall field.

Inner Magnetosphere Events

Figure 5 (directly below) shows a series of dipolarization events in the inner magnetosphere from roughly 7 to 8 R_E. Fig. 5 also shows the electron spectrogram (FEEPS) and two proton spectrograms (EIS) showcasing injection signatures along with each event. Fig. 3 shows the third dipolarization event seen in Figure 5, along with HPCA bulk ion velocity, ion number density, and ion energy spectrogram. The HPCA ion data shown in Fig. 3 is at lower energies than the FEEPS/EIS data and shows the that lower energy ions decrease on arrival of the dipolarization event (while the flux of higher energy ions and electrons increase). The bulk ion velocity shows a predominantly earthward flow, along with a diversion from duskward to dawnward flow. Fig. 4 shows the electric field alongside $-\mathbf{v}_{str} \times \mathbf{B}$, $-\mathbf{v}_{H+} \times \mathbf{B}$, and $E - E_{Hall}$. While there is Hall field, the protons largely follow the E field.

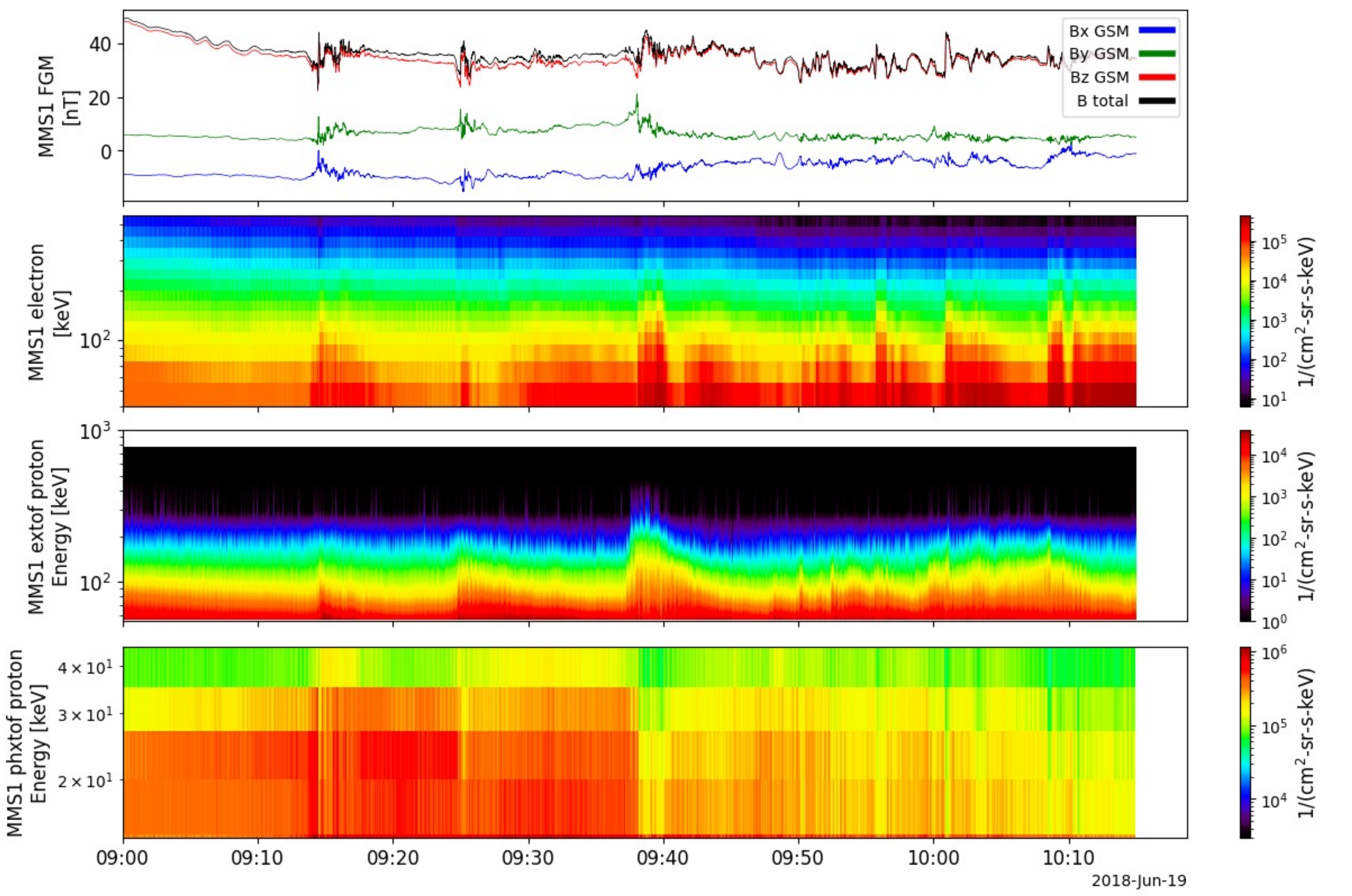

Fig. 5

Statistics

Only DFs are used for statistics (time from minimum to maximum B_Z). Figure 6 shows the median bulk ion velocity projected onto the normal direction (and normalized) and the median structure velocity for each DF in the magnetotail and transition region. There is a linear correlation between the two quantities, with median($\mathbf{v}_{str}$), being slightly larger on average. Fig. 7 shows the Y_{GSM} component of median($\mathbf{v}_{str}$), median($\mathbf{v}_{i,bulk}$), and median($\mathbf{v}_{e,bulk}$) compared to the Y_{GSM} position (with trendlines shown for each). For all quantities, there is a linear correlation with larger dawnward velocities on the dawnside and larger duskward velocities on the duskside. The linear fits for $\mathbf{v}_{i,bulk}$ and $\mathbf{v}_{str}$ are very similar. Finally, Fig. 8 shows histograms of the median($\mathbf{v}_{i,bulk}$) and median($\mathbf{v}_{e,bulk}$) shown for each direction. The left column in Fig. 8 shows the magnetotail cases (X_{GSM} < -12 R_E) and right column shows the transition region events (-9 R_E > X_{GSM} > -12 R_E). From the magnetotail to the transition region, there is an overall decrease in velocities in the X direction and an increase in the Y direction. For both cases, electrons have slightly more dawnward velocities, and the ions have slightly more duskward-oriented velocities. This could be due to the presence of Hall fields, causing ions and electrons to drift in opposite directions.

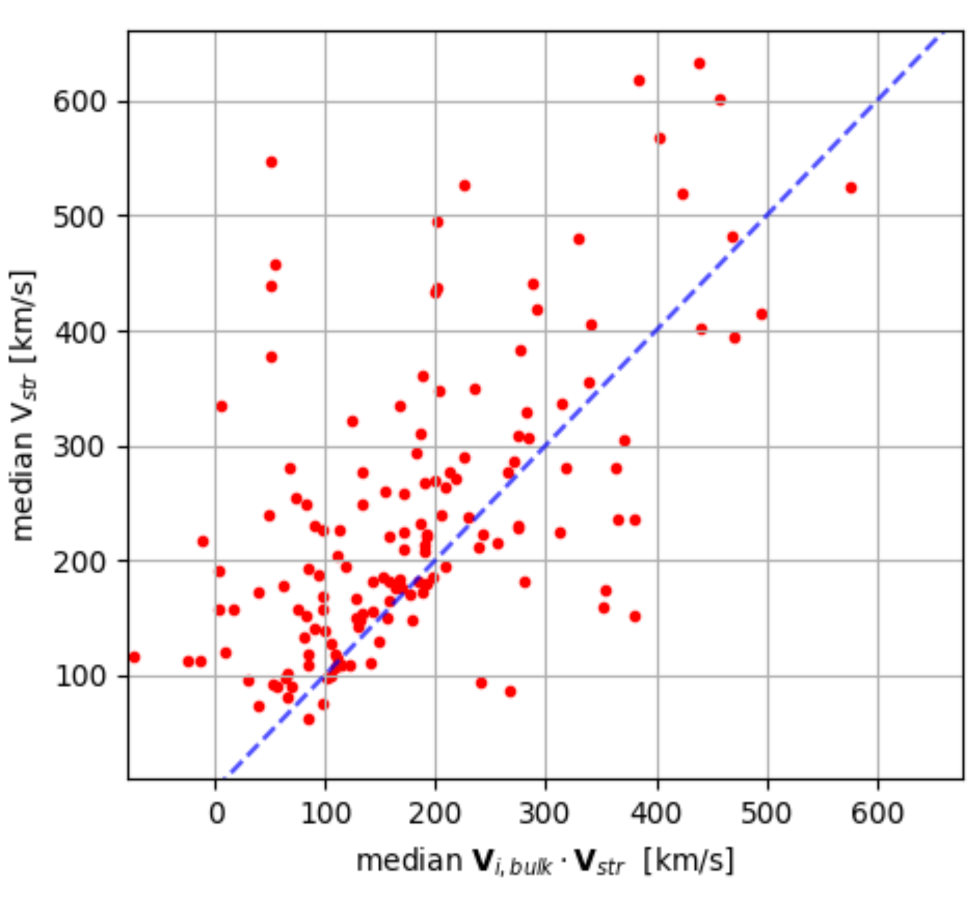

Fig. 6

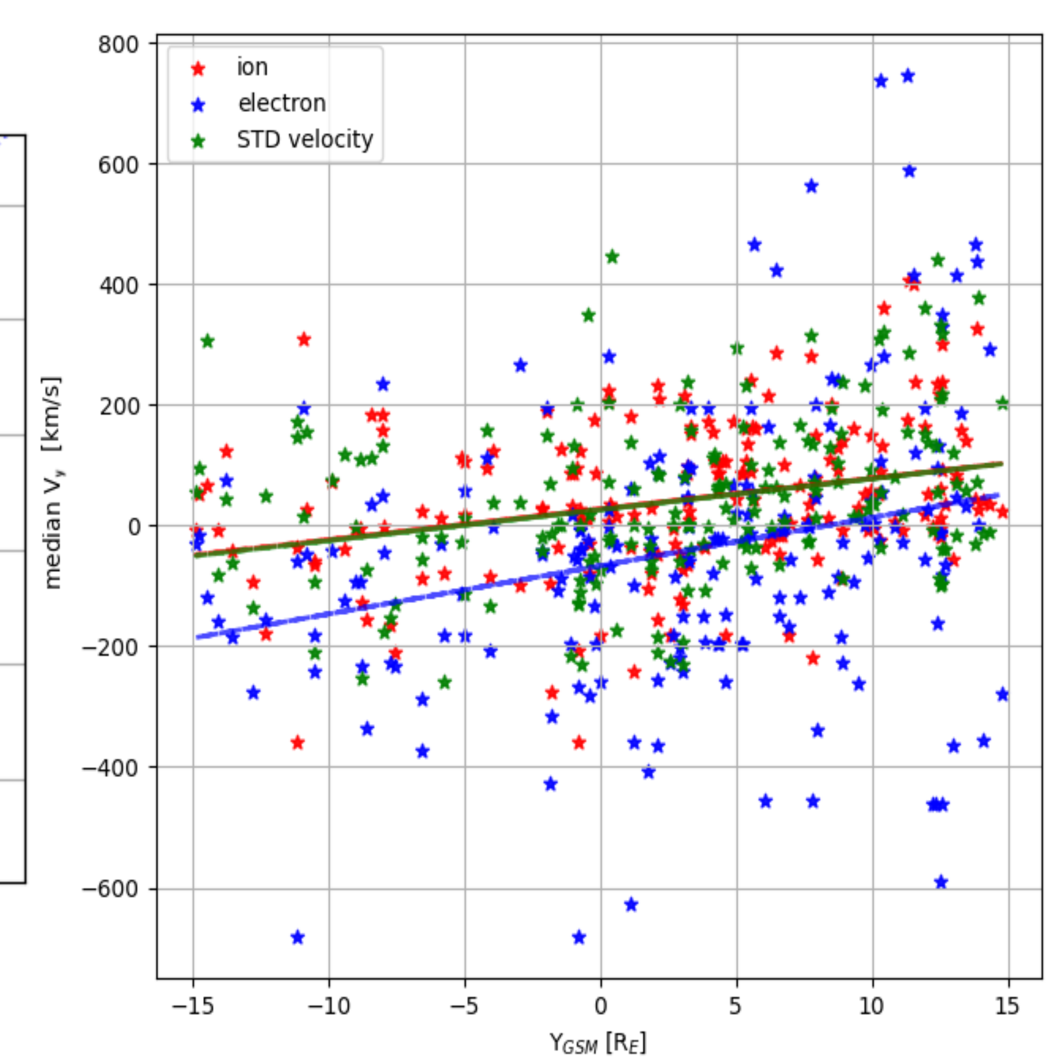

Fig. 7

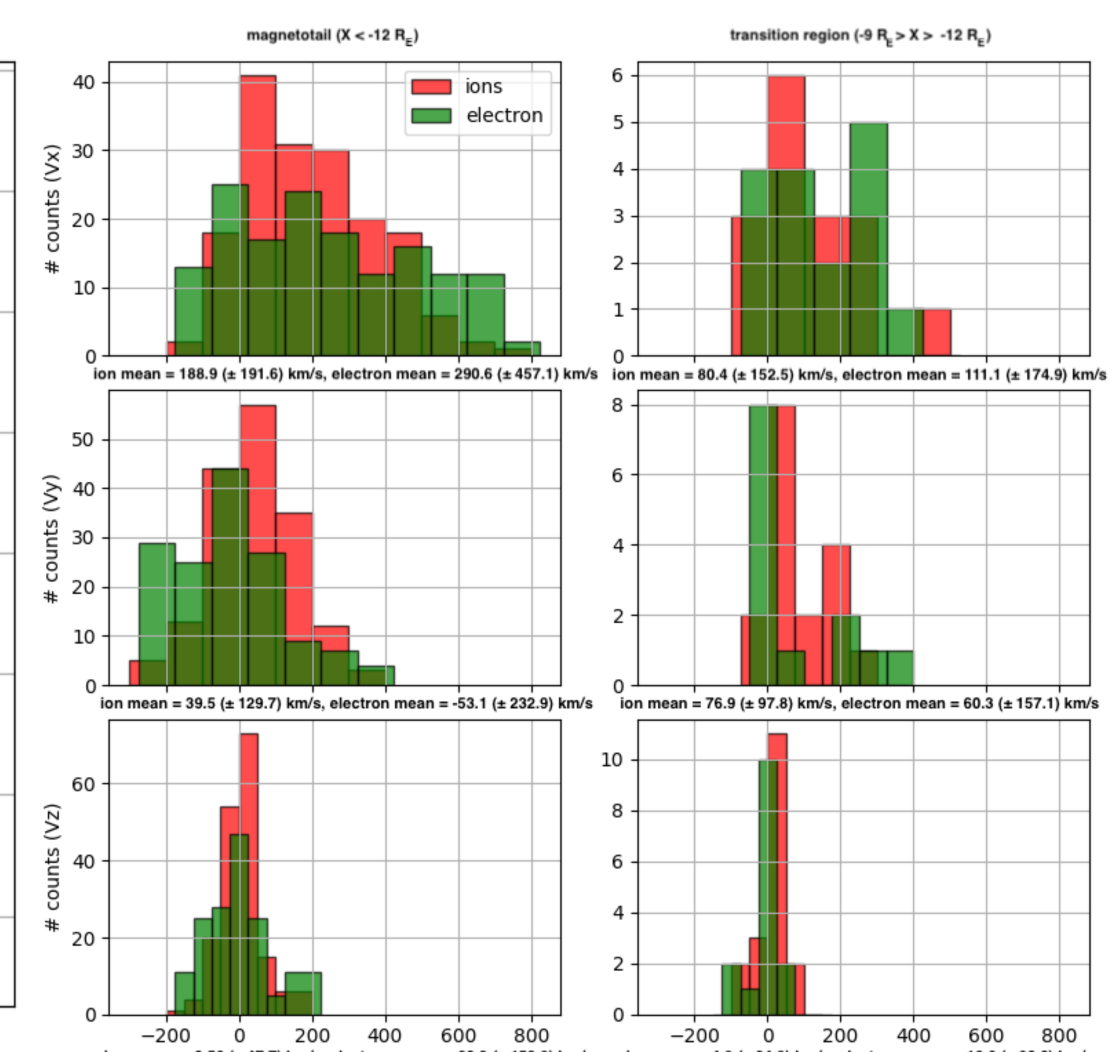

Fig. 8

tyler.metivier@unh.edu

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