



Energy Partition and Conservation Near Electron Diffusion Regions During Magnetic Reconnection

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Abstract

The conversion of energy stored in magnetic fields to other forms during magnetic reconnection is one of the primary topics of focus that the Magnetospheric Multiscale (MMS) mission aims to study. Inflowing magnetic energy is released into the exhaust in the form of plasma heating, bulk flows, and Poynting flux, the latter of which may be further divided into frequency bands that separate large scale, quasi-static structures from various wave phenomena. In close encounters where the x-point lies within or close to the tetrahedron formed by the four MMS spacecraft, the terms in Poynting's theorem, the statement of energy conservation in electrodynamics, can be evaluated. These methods are used on multiple events when MMS encountered the electron diffusion region (EDR). A better understanding of the relative contributions to various energy fluxes as well as the relative contributions to the terms in Poynting's theorem may help shed light on the processes that lead to energy dissipation during magnetic reconnection.

Outflow Energy Flux

Energy flux subdivided into kinetic energy flux, enthalpy flux, and Poynting flux in the outflow directions ($\pm z$ GSE for dayside, $\pm x$ GSE in the tail). Kinetic and Enthalpy fluxes are further separated based on particle species s .

$$\vec{K}_{out} = \left(\frac{1}{2} m_s n_s v_{out}^2 \right) \vec{v}_{out}$$

$$\vec{H}_{out} = \left(\frac{3}{2} n_s k T_s + P_s \right) \vec{v}_{out} = \frac{3}{2} P_s \vec{v}_{out}$$

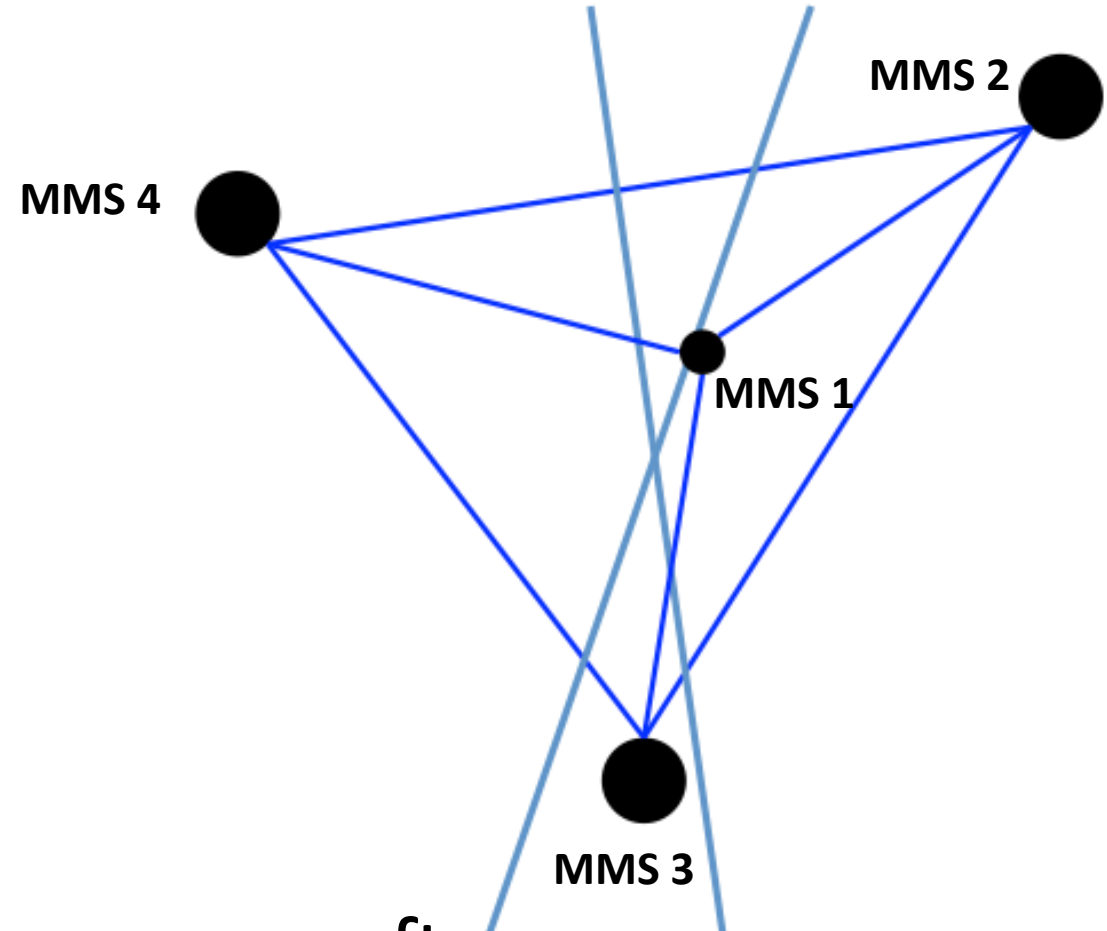
$$\vec{S}_{out} = \frac{1}{\mu_0} (\vec{E} \times \vec{B})_{out}$$

Poynting's Theorem

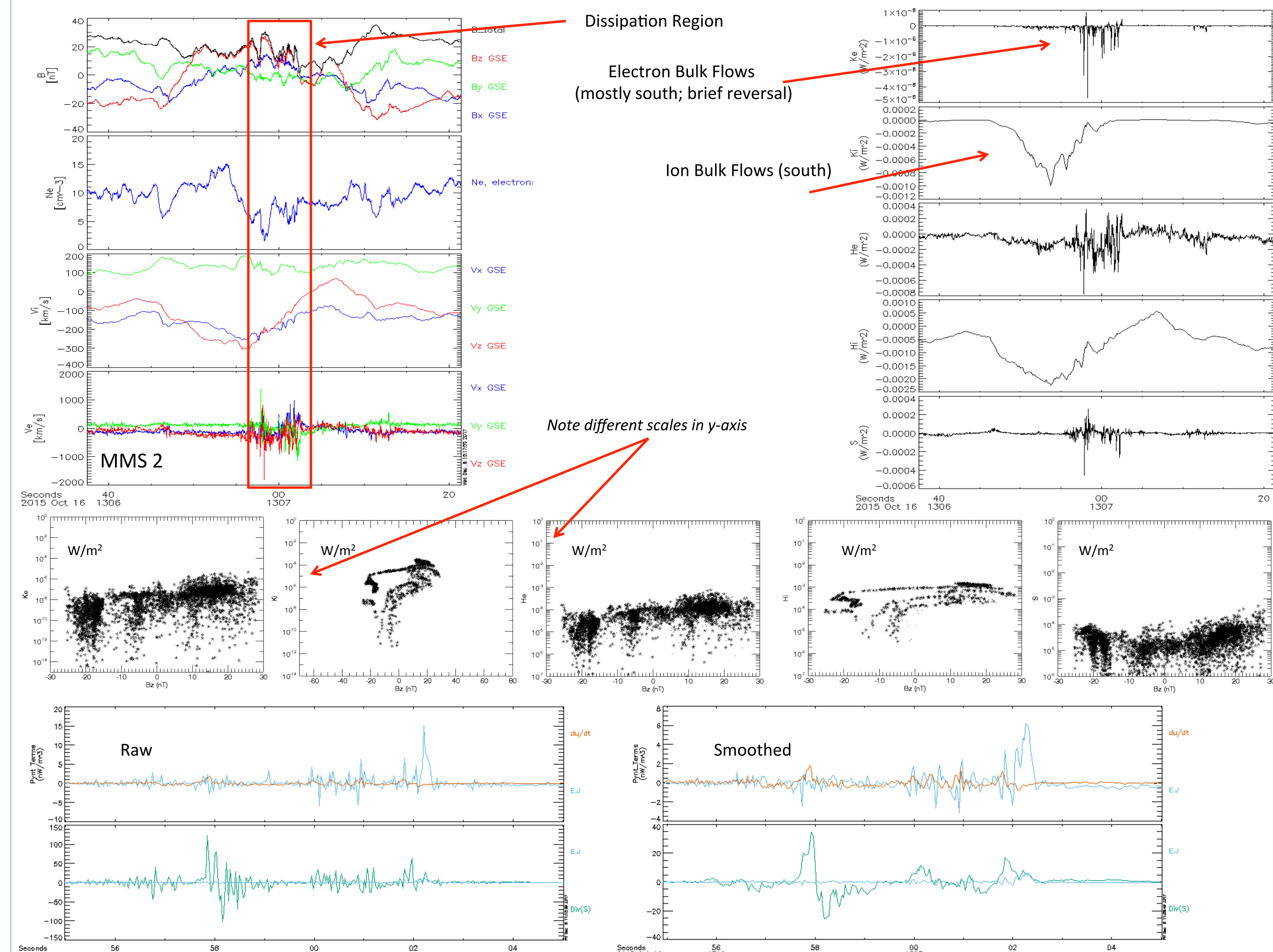
$$\frac{\partial u}{\partial t} + \nabla \cdot \vec{S} = -\vec{j} \cdot \vec{E}'$$

$$u = \frac{\epsilon_0}{2} E^2 + \frac{1}{2\mu_0} B^2$$

- Conservation of energy within a volume
- All quantities taken as an average over the four spacecraft
- Steady state $\rightarrow du/dt = 0$
- Ideally, all contributions should balance out

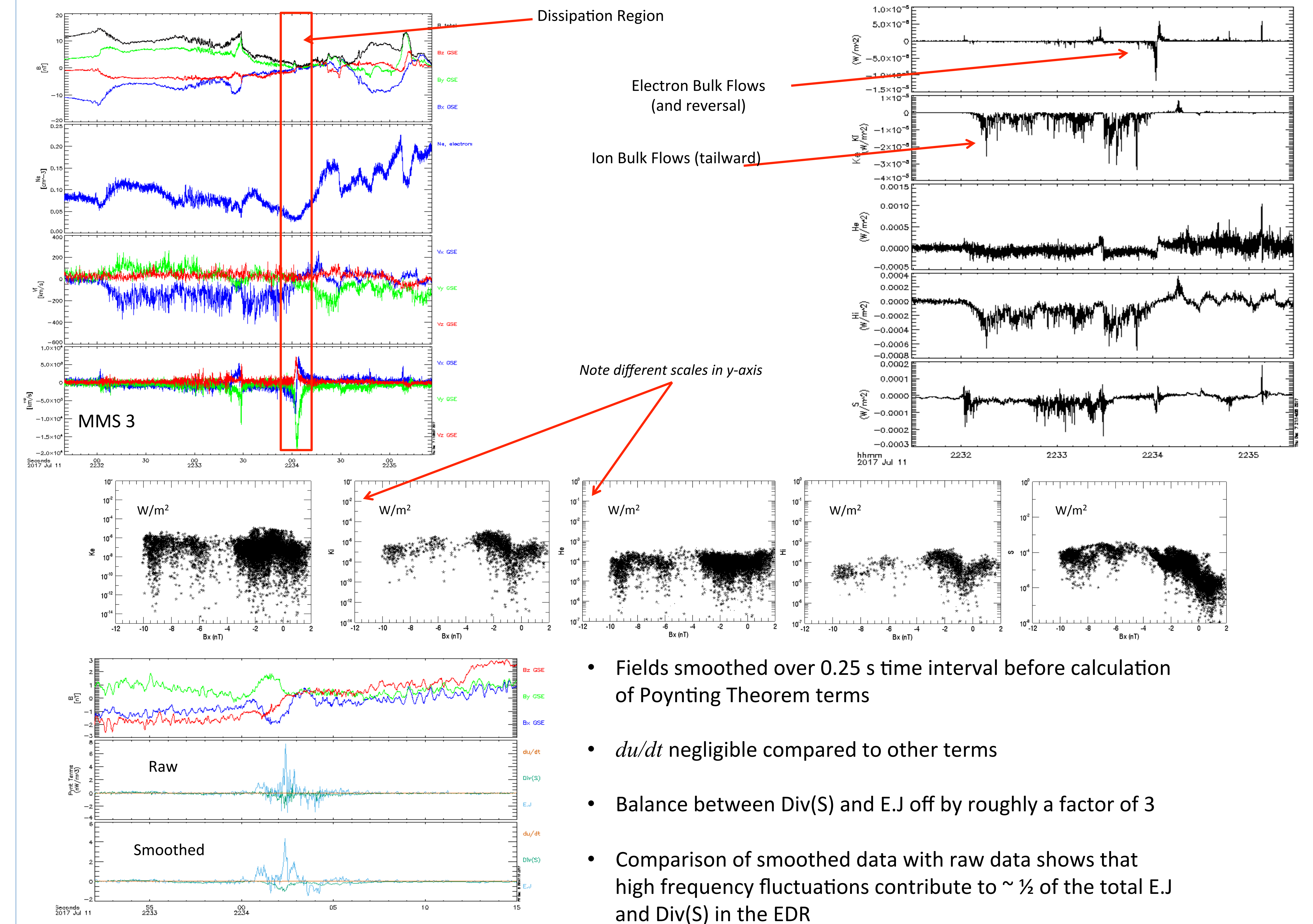


Magnetopause Event: October 16th, 2015



- Fields smoothed over 0.25 s time interval before calculation of Poynting terms
- Large imbalance between Div(S) and E.J by an order of magnitude
- Comparison of smoothed data with raw data shows that high frequency fluctuations account for $\sim 1/2$ of E.J and Div(S)

Magnetotail Event: July 11th, 2017



- Fields smoothed over 0.25 s time interval before calculation of Poynting Theorem terms
- du/dt negligible compared to other terms
- Balance between Div(S) and E.J off by roughly a factor of 3
- Comparison of smoothed data with raw data shows that high frequency fluctuations contribute to $\sim 1/2$ of the total E.J and Div(S) in the EDR

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Conclusions

- Energy flux partitioning and scales similar in both cases, however the lower density in the magnetotail suggests the energy flux per particle is much higher
- Large imbalance in Poynting's theorem at the magnetopause likely due to scale sizes smaller than the spacecraft separation.
- In the magnetotail where scale sizes are much larger, imbalance is much smaller, but still present
- Field fluctuations below 0.25 seconds contribute $\sim 40 - 60\%$ of the total E.J and Div(S) near the EDR in both cases