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Observation of non-gyrotropic electron distribution across the electron diffusion region in the magnetotail reconnection

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Reference: Li et al., GRL 2019

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Introduction

- Based on accurate measurements of electron velocity distribution function from MMS, *Burch et al.*(2016b) first reported the crescent-shaped electron distribution in the plane perpendicular to the magnetic field in close proximity to an EDR at the magnetopause, which was predicted as one distinct EDR feature in asymmetric reconnection simulations (*Hesse et al.*, 2014; *Hesse et al.*, 2016; *Bessho et al.*, 2016; *Bessho et al.*, 2017; *Lapenta et al.*, 2017; *Cassak et al.*, 2017; *Shay et al.*, 2016).
- A few mechanisms were proposed to interpret such distribution, such as meandering (cusp-like) electron orbits (*Hesse et al.*, 2014; *Lapenta et al.*, 2017; Shay et al., 2016) and a drift-kinetic model (*Egedal et al.*, 2016).
- The crescent-shaped electron distribution was detected in the EDR of a symmetric reconnection in the magnetotail as well (*Torbert et al.*, 2018; Zhou et al., 2019), as predicted by numerical simulations (e.g. *Bessho et al.*, 2018).

- In this letter, we present a complete EDR crossing in the magnetotail, which was reported recently by *Zhou et al.*(2019). Thus, the evolution of electron velocity distribution functions (VDFs) across the EDR can be investigated in detail.

Observation

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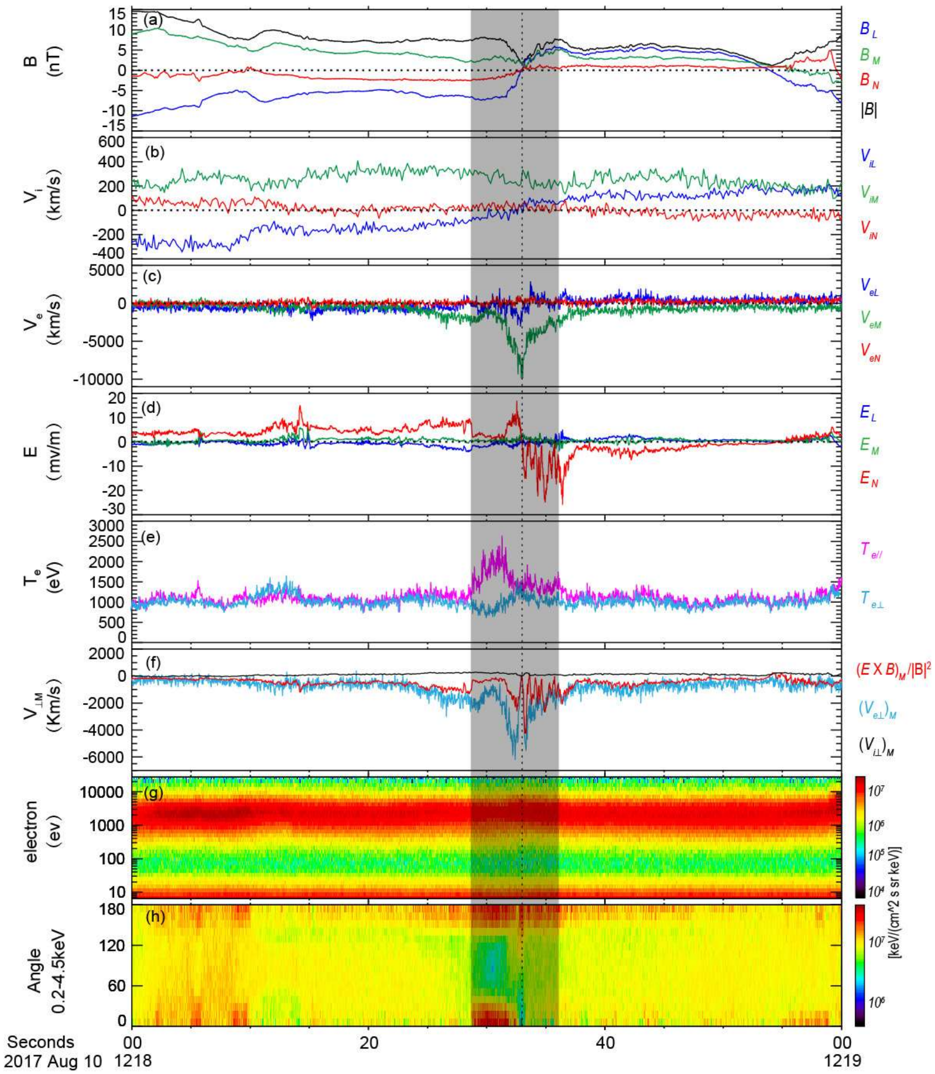
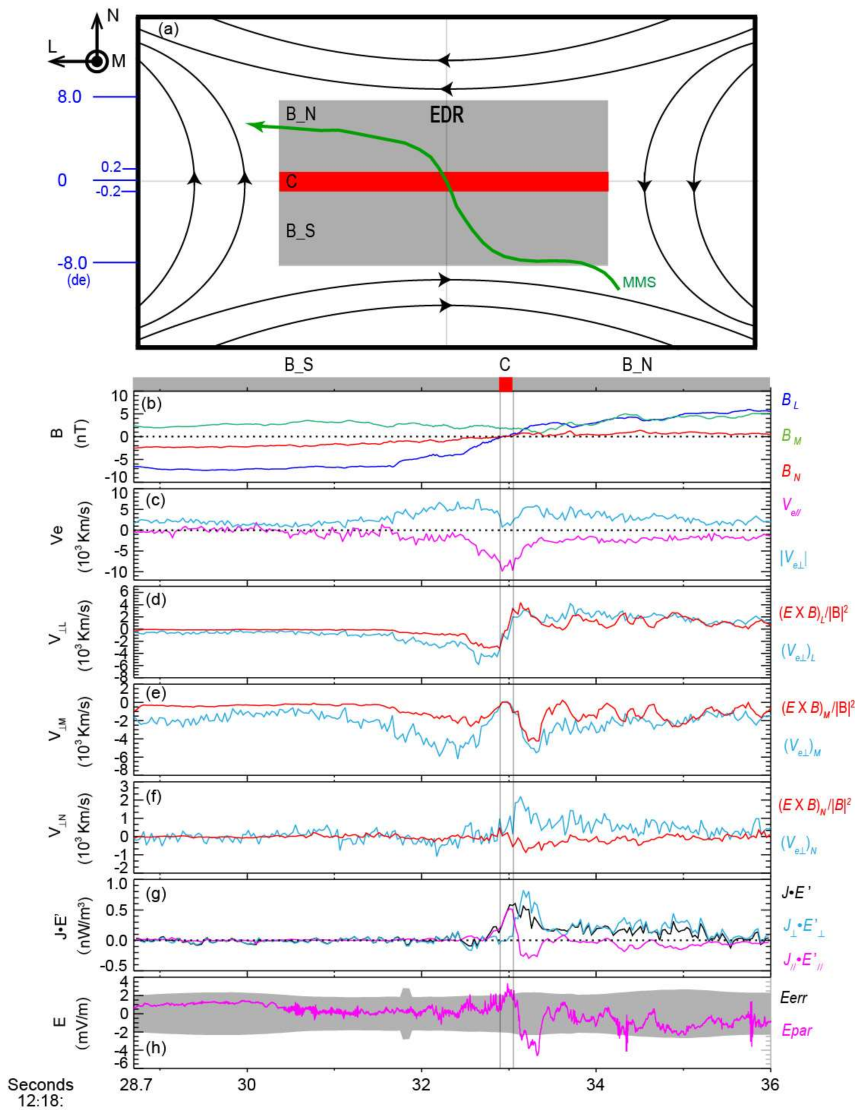


An overview of the reconnection at the magnetotail. LMN coordinates (relative to the GSE):

L = [0.9617,-0.1762, -0.2099],
M = [0.2522, 0.8686, 0.4266],
N = [0.1071, -0.4632, 0.8798].

The shadow area is identified as electron diffusion region. Confirmed by the reversal of B_L, V_{iL} and E_N, the intense V_{eM}, anisotropic T_e, and the difference between the E with $VeXB$.

Observation



The details of the EDR.

The half-thickness of EDR was 8 d_e.

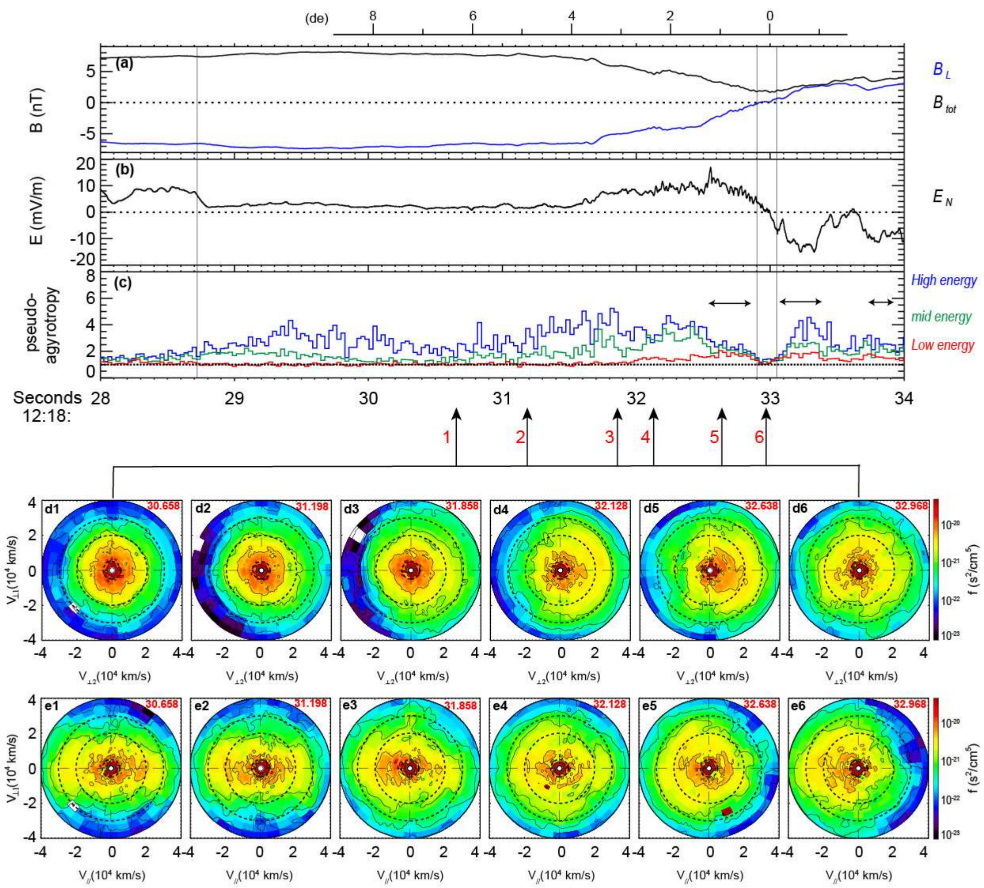
The fine sub-structures were observed in the narrow electron diffusion region. In the center of the EDR (red area), $T_{e\parallel} \simeq T_{e\perp}$, $V_{e\perp} \simeq (E \times B)/B^2$ and the electron VDFs displayed nearly gyrotropic in perpendicular plane (shown in next slide).

Reconnection rate:

$$R = \frac{E_M}{v_{iA}B_0} \approx 0.19 \sim \frac{v_{in}}{v_{iA}} \approx 0.15$$

(Where $E_M = E_{para}$, and V_{in} in the rest velocity frame of the current sheet)

Observation



Pseudo-agyrotropy:

$$\frac{\int_{v_{\perp 2}>0} f dv_{\perp 1} dv_{\perp 2}}{\int_{v_{\perp 2}<0} f dv_{\perp 1} dv_{\perp 2}}$$

The relationship between electron VDFs with both energy of electrons and the distance from the mid-plane.

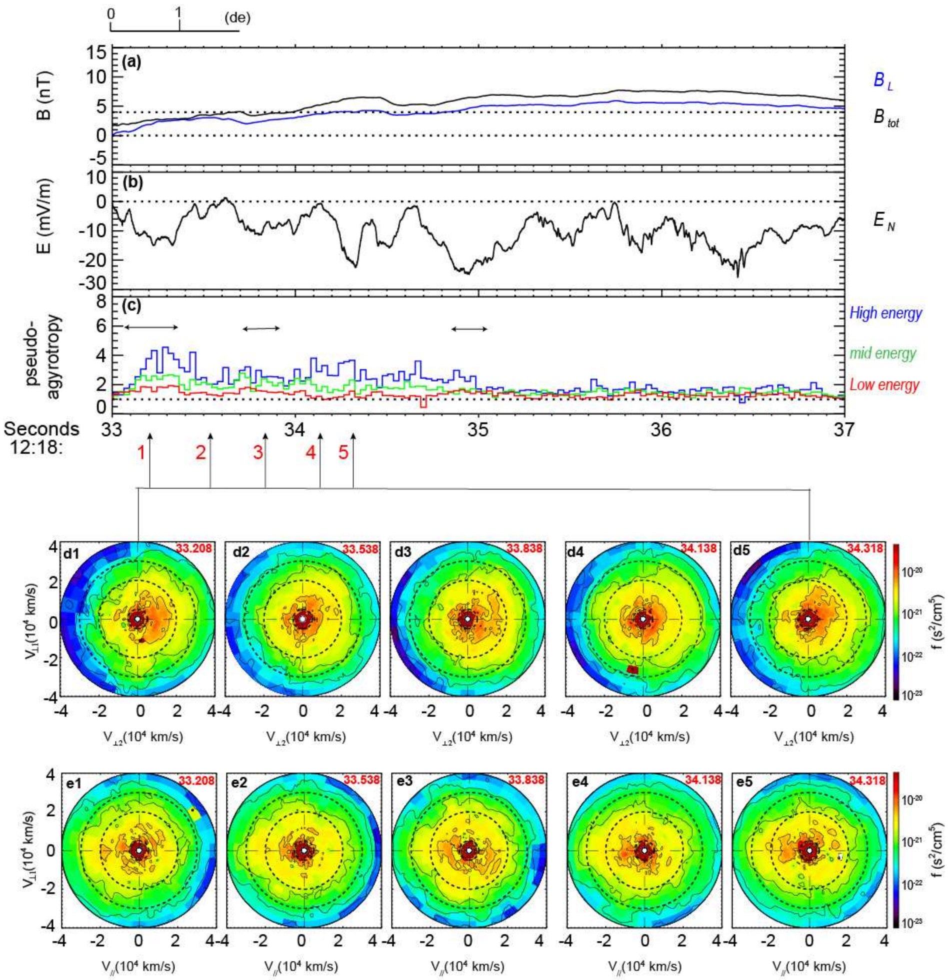
The energy range was divided into three segments: the high-energy ($3-4\times10^4\ km/s$), medium energy ($2-3\times10^4\ km/s$), low-energy ($0.5-2\times10^4\ km/s$).

The non-gyrotropic electron distribution could be observed ~8.0 d_e away from the EDR mid-plane for the high-energy electrons, appeared at ~ 5.9 d_e away from the EDR mid-plane for the medium-energy electrons, and confined to be within ~ 3.0 d_e away from the mid-plane for the low-energy electrons.

At the right center part of the EDR, the electrons displayed the gyrotropic distribution (Fig. d6).

The variable *Pseudo-agyrotropy* (defined on the left) shows the same change (panel c).

Observation



The relationship between electron VDFs with Hall electric field E_N.

It is clear that electron non-gyrotropic distribution was strongly affected by E_N. The non-gyrotropic and crescent distributions became clear when the E_N is large (Fig. d1, d3, d5)

Conclusion

1. The electron non-gyrotropic distribution depended on the energy and the normal distance from the mid-plane of the electron diffusion region
2. The electron crescent distributions were caused by the meandering motion and the Hall electric field together
3. The fine sub-structures were observed in the narrow electron diffusion region

Thank you for reading