Magnetic Islands and Energetic Electrons in the Reconnection Diffusion Region: Cluster Observation

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Outline

1. Introduction
2. Observation
3. Conclusion

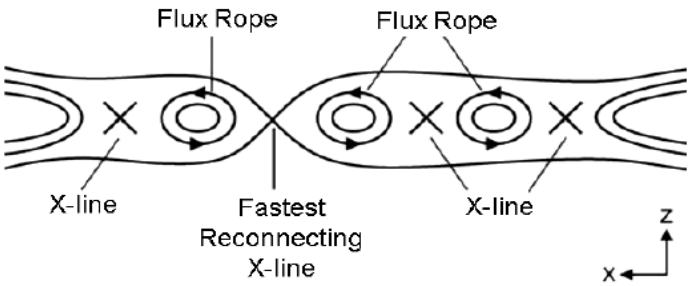
1. Introduction

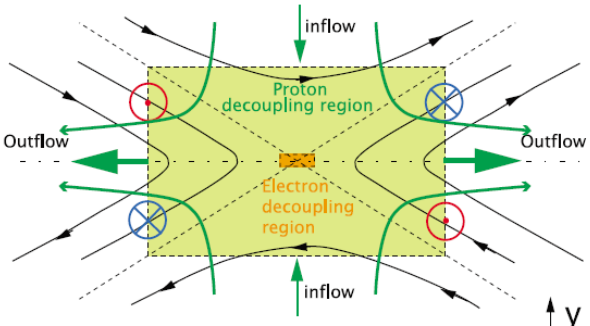
Magnetic reconnection is a fundamental plasma process during which magnetic energy is converted into kinetic and thermal energy, and it is always accompanied with changes of magnetic topological structures.

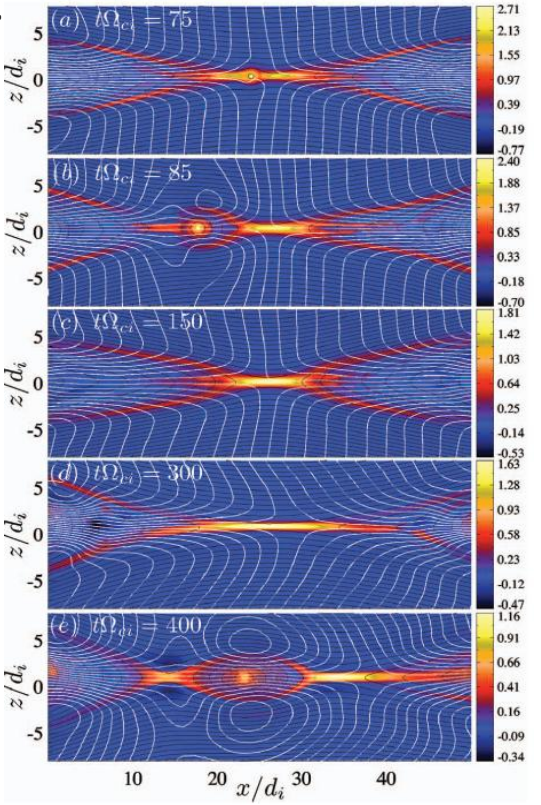
It's known that the diffusion region consists of two scale structures, i.e. ion diffusion region (with scale on the order of ion inertial length) and electron diffusion region (with scale on the order of electron inertial length), due to the decoupling of ion and electrons from magnetic field lines [*Priest and Forbes*, 2000].

The magnetic islands or flue ropes (both named as magnetic island as bellow) can be formed by multiple X-lines reconnection [e.g. *Lee et al.*, 1985; *Deng et al.*, 2004; *Slavin et al.*, 2003].

Recent kinetic simulation shows that the secondary island can be formed in diffusion region due to the unstable tearing mode with or without guide field [*Daughton et al.*, 2006; *Drake et al.*, 2006b].

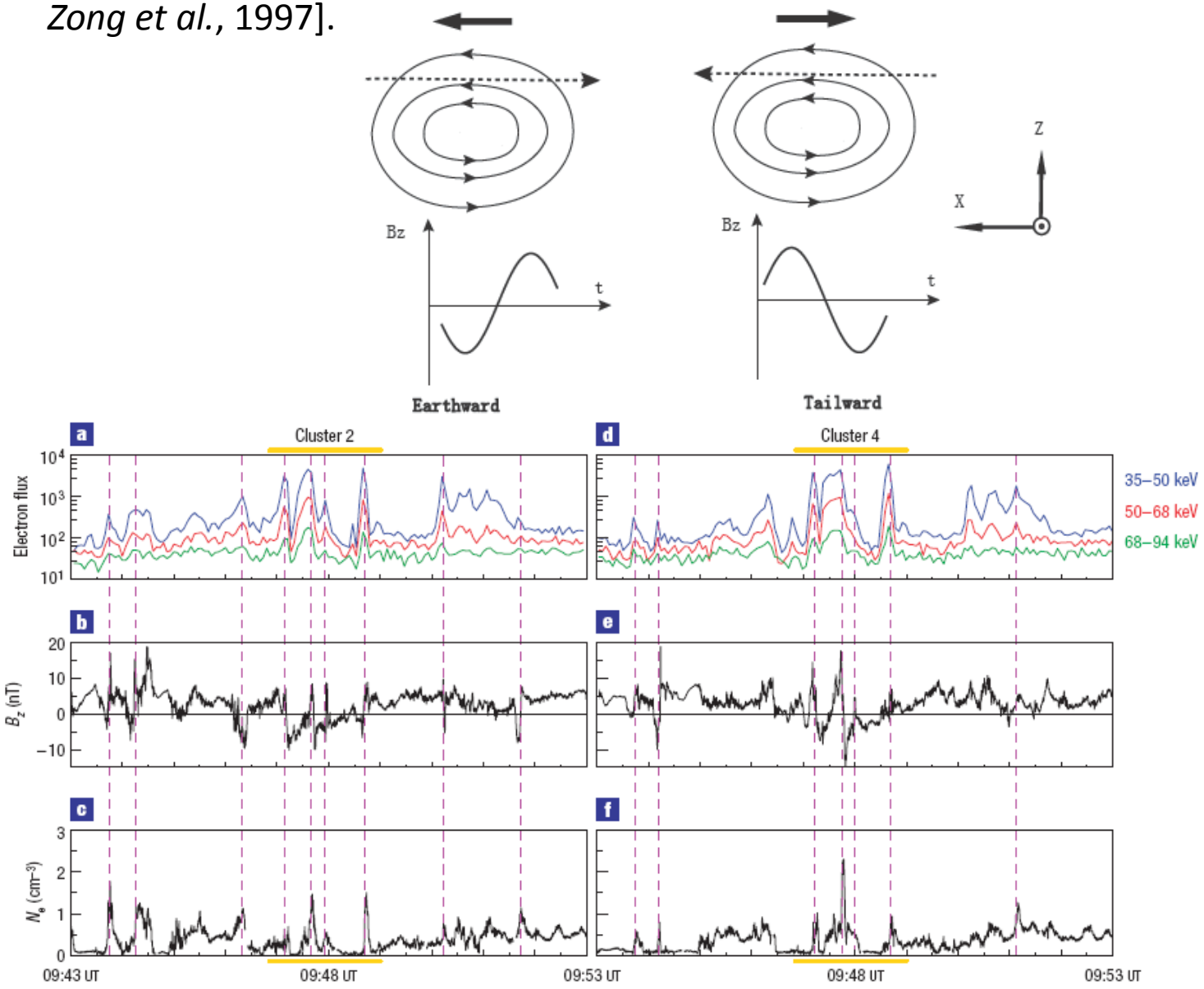






Daughton et al., 2006

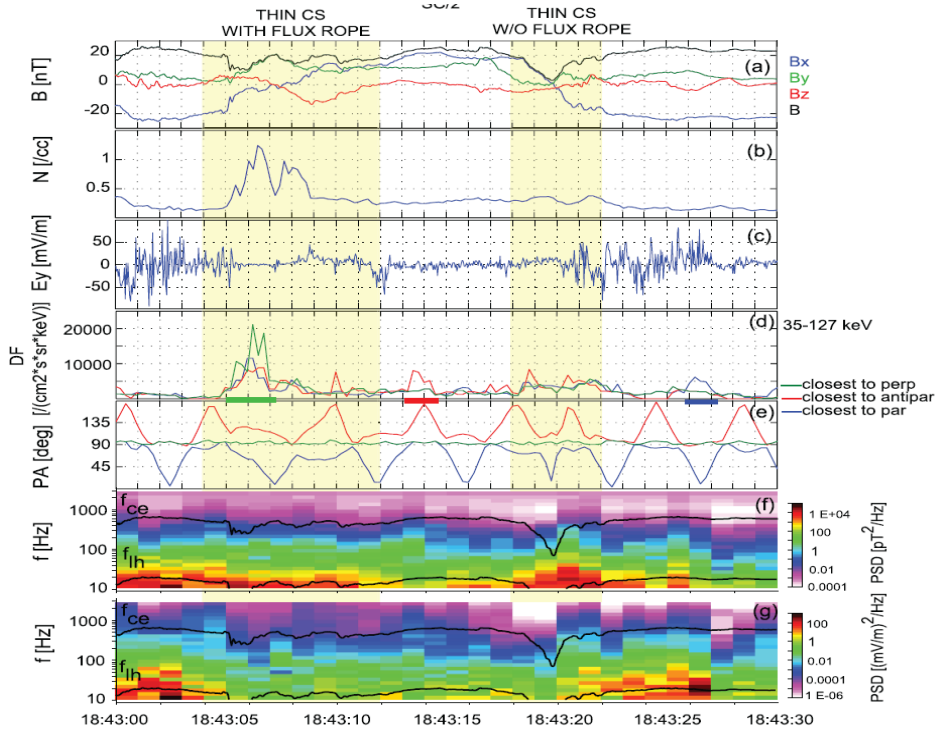
Magnetic islands have been observed in or near the diffusion region in the Earth's magnetopause and magnetotail [*Chen et al.*, 2008; *Retinò et al.*, 2008; *Øieroset et a.*, 2011], and also detected far away from the reconnection site [*Slavin et al.*, 2003; *Zong et al.*, 1997].



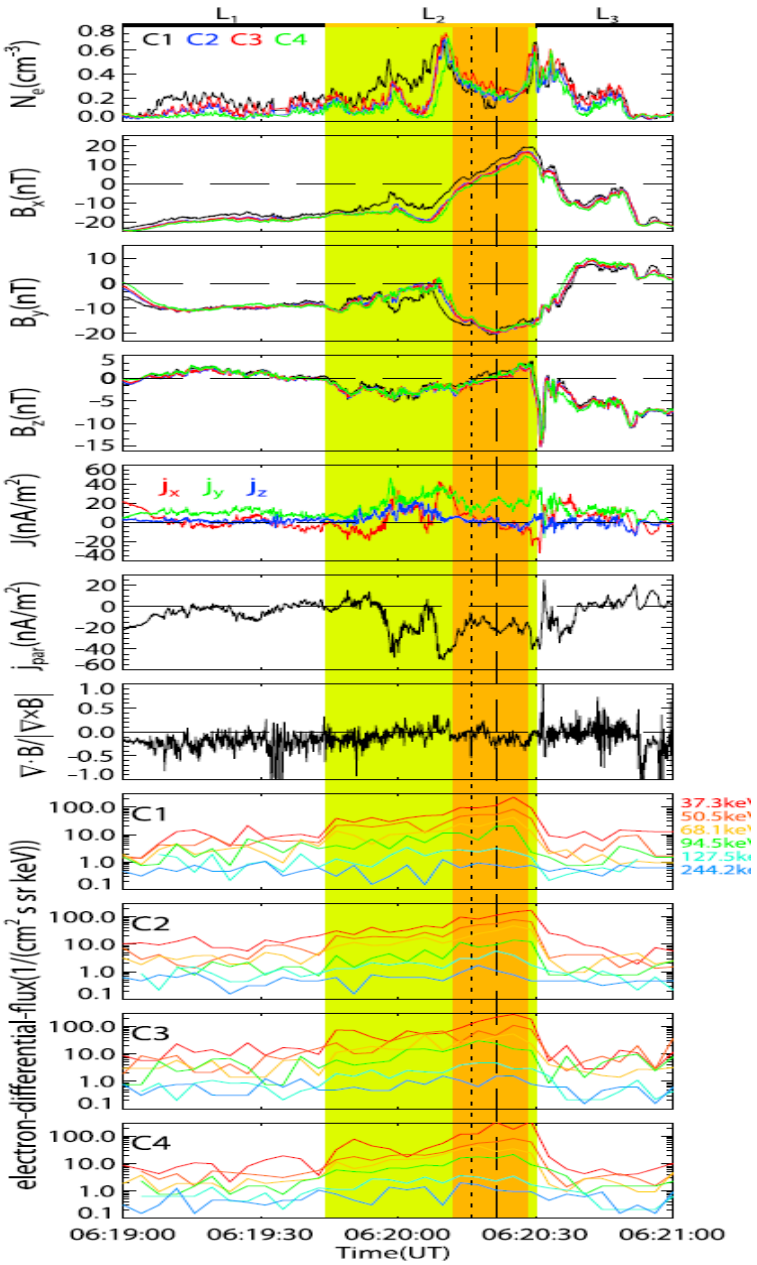
Chen et al., 2008

In addition, the secondary islands were observed near the diffusion region [*Eastwood et al.*, 2007] and in the diffusion region [*Teh et al.*, 2010; *Wang et al.*, 2010].

Magnetic islands or secondary islands are closely related with electron acceleration during reconnection.



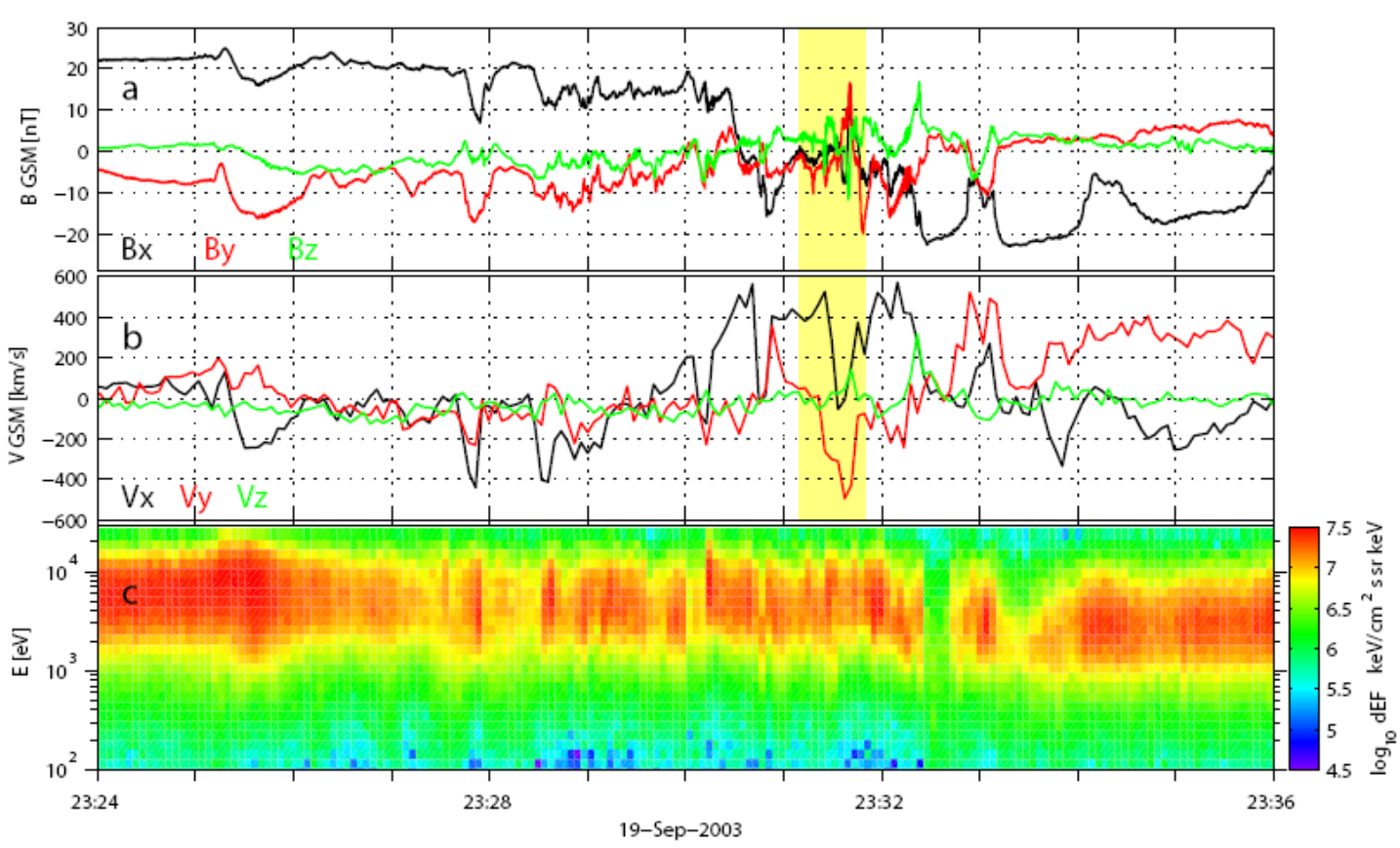
Retinò et al., 2008

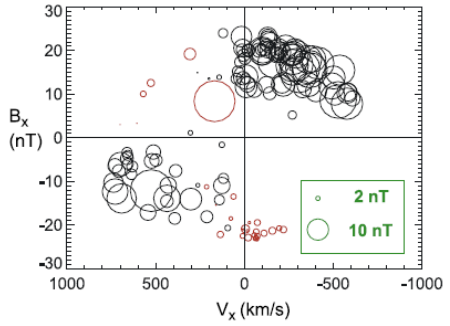


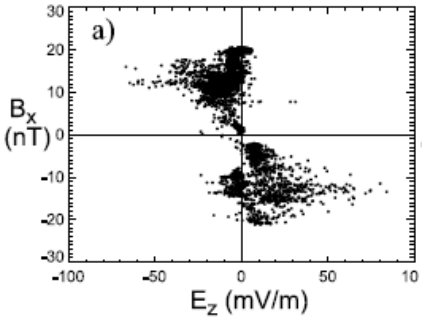
Wang et al., 2010

2. Observation

Figure 1





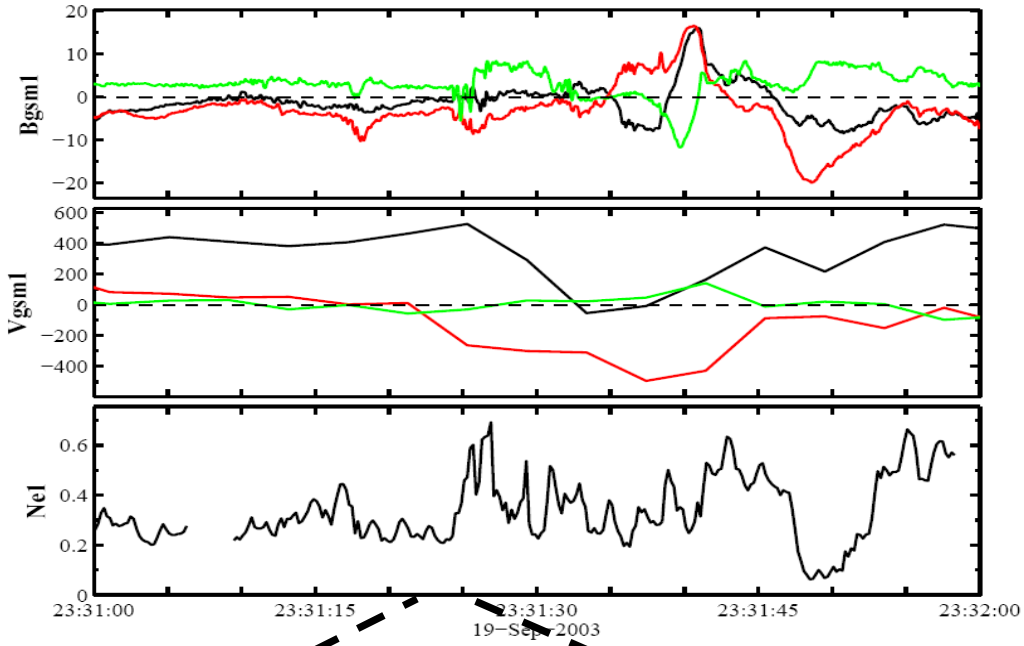


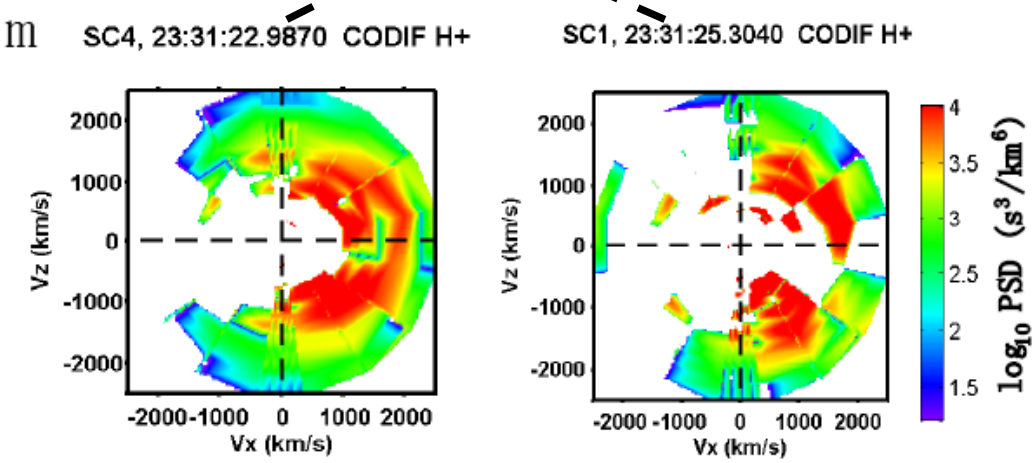
Borg et al. [2006]

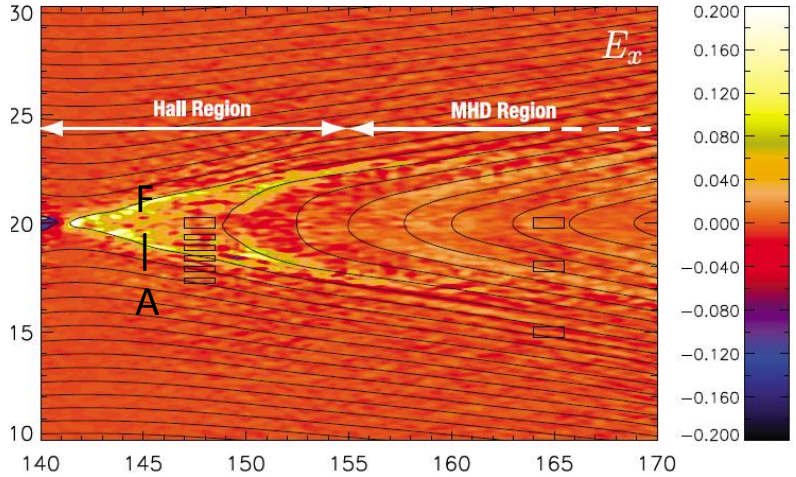
The Cluster observations during the time period from 23:24 UT to 23:36 UT on19 September 2003 is identified as a reconnection event [*Borg et al.*, 2006].

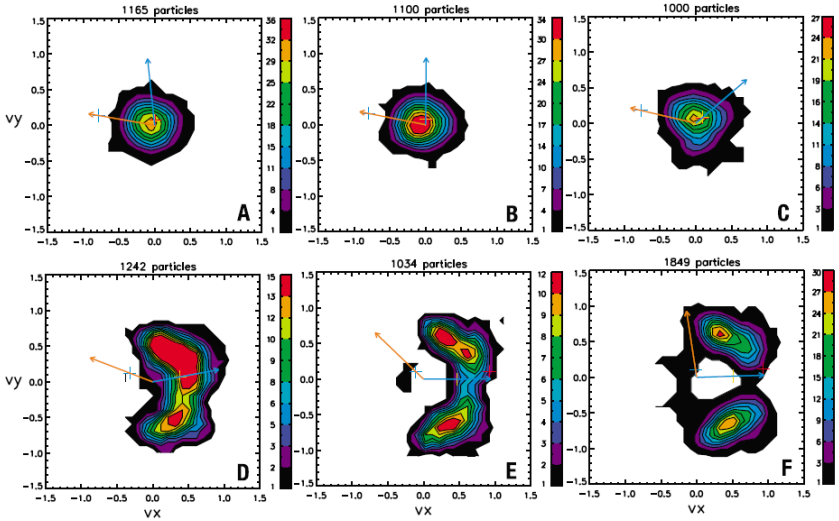
Borg et al. [2006] identified a diffusion region during the interval of 23:25:15 UT - 23:34:00 UT that manifests by quadrupolar structure of out-of-plane magnetic fields and bipolar Hall electric fields pointing toward current sheet in the normal direction.

Figure 2





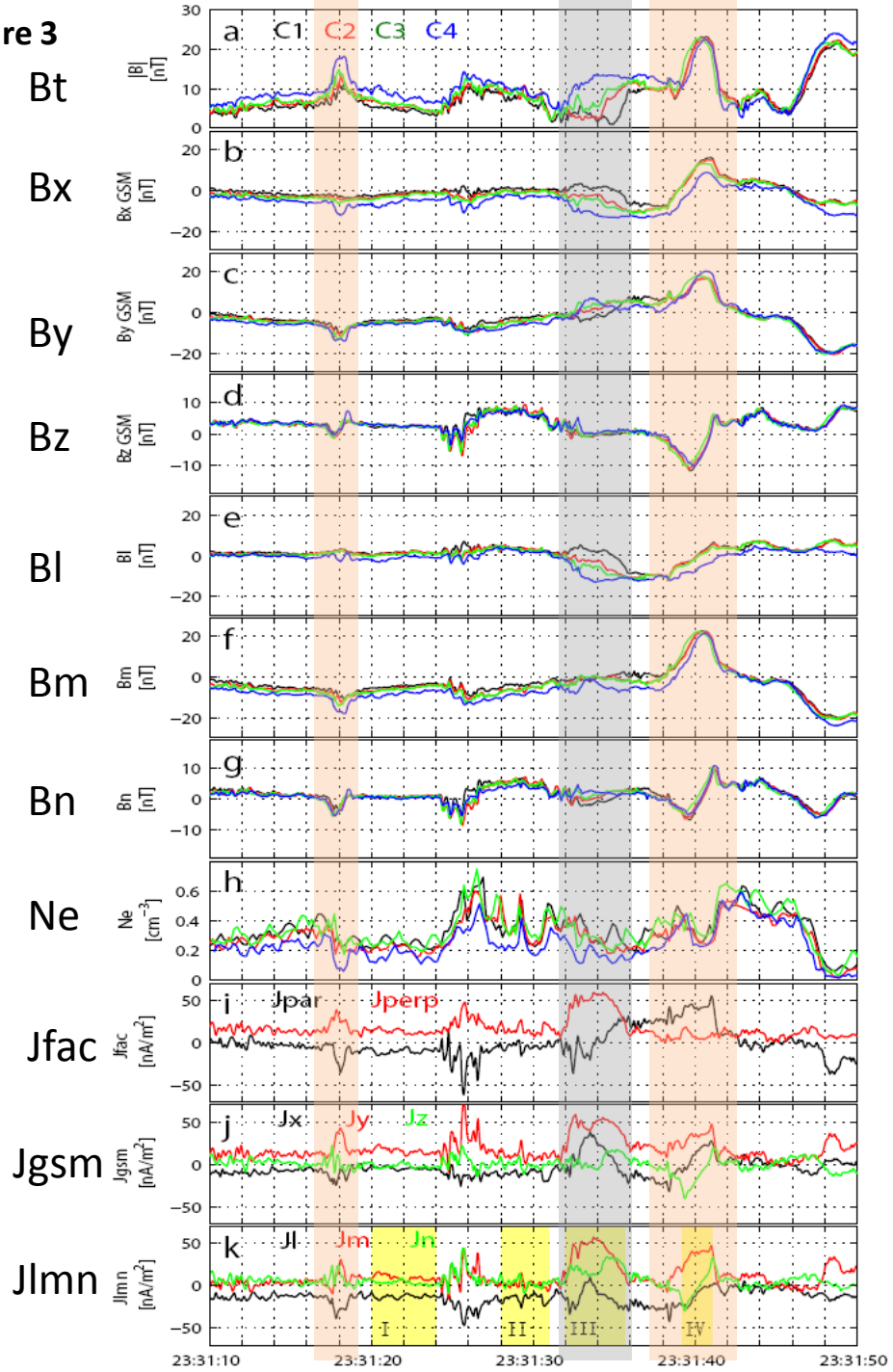




Aunai et al., 2011

Strong evidence for diffusion region!

Figure 3



Bt peak

By peak

Bipolar structures

Core field: Bm peak

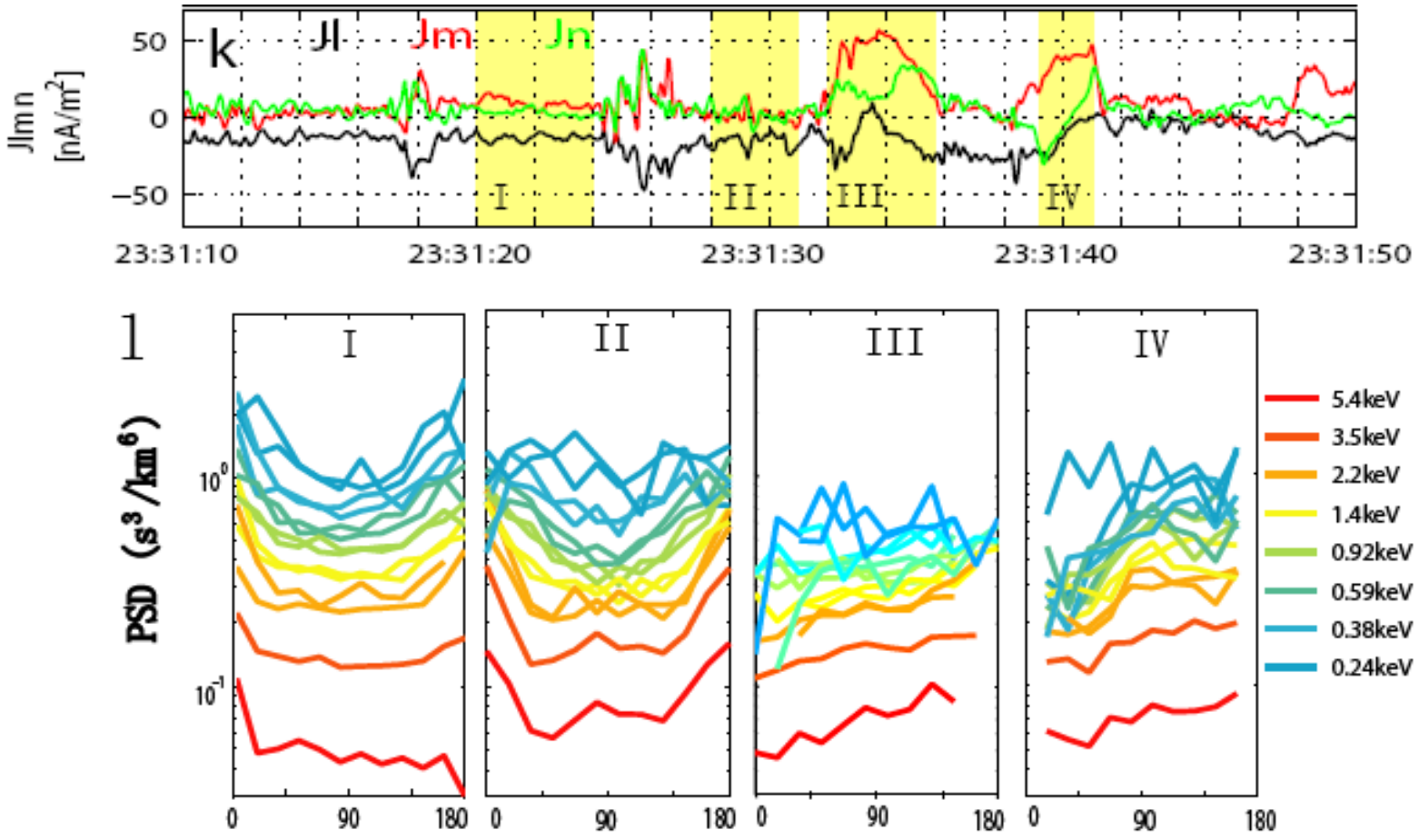
Bipolar structures

Density dip

Large parallel current,
un-neglectable perpendicular current

Large axial current

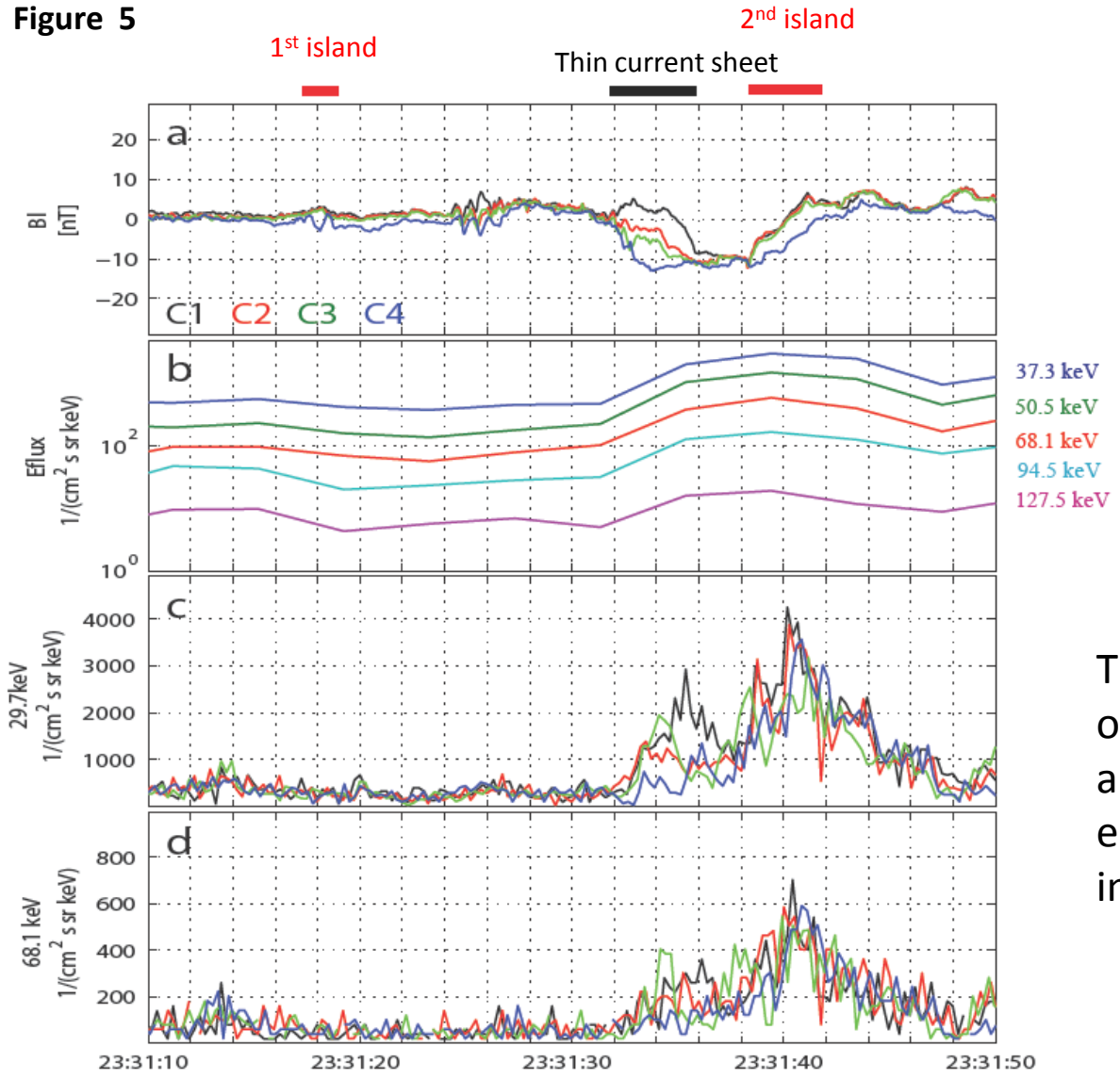
Figure 4



Field-aligned bidirectional distribution, i.e. intensification of the PSD at 0° and 180° in the thick current sheet.

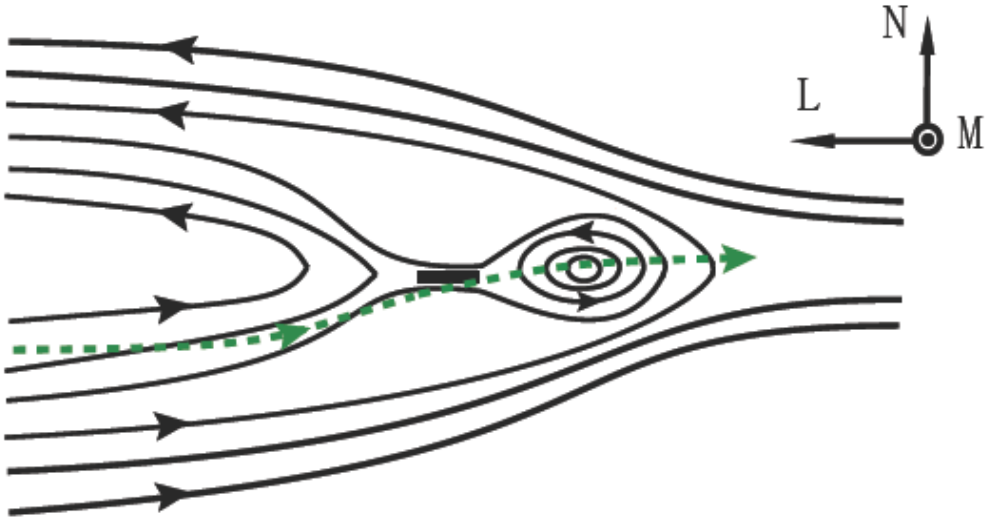
Anti-parallel direction in the thin current sheet and magnetic island.

Figure 5



The energetic electrons are only observed in the thin current sheet and the second magnetic island especially the highest enhancement in the density dip.

Figure 6



The black bar is the thin current sheet.

The green dashed line shows the Cluster trajectory.

For the most energetic electrons with ε=127 keV in the magnetic of edge (core region) of island of the magnetic field strength *B* ~10 (22) nT, the gyroradius is ρ_{ce} ~ 120 (56) km which is much smaller than the estimated width of island and consistent with the trapping condition. Thus, the electrons can be trapped and accelerated in the magnetic island [*Oka et al.*, 2010].

In addition, the electrons may be accelerated by betatron acceleration since there is strong peak of magnetic field in the magnetic island

Combining the observations of energetic electrons in the adjacent thin current sheet and magnetic island (where the energetic electron fluxes inside magnetic island are about two times in the thin current sheet, which is consistent with the variation of the total magnetic field δB/B ~2), we propose two-step acceleration for the observed energetic electrons that the electrons are fist accelerated in the thin current sheet, and then trapped in the magnetic island and further accelerated by betatron acceleration.

3. Conclusion

We observe two magnetic islands and thin current sheet embedded plasma flow in the diffusion region used the Cluster observations.

There are density dips in the core region of islands. Intense current density is observed in the islands which is dominant by parallel current density and has large axis orientation component. The un-neglectable perpendicular current indicates that the islands are not “force-free” configuration.

The energetic electrons are only observed in the thin current sheet and the second magnetic island especially the highest enhancement in the density dip.

These energetic electrons may be first accelerated in the thin current sheet, and then trapped and further accelerated in the magnetic island by betatron acceleration.

Many Thanks !