Cluster Encounter of the Reconnection Hall Plane

Y.Liu[1] (yhliu@atlas.sr.unh.edu), L. M. Kistler[1], H. Karimabadi[2], C. G. Mouikis[1], V. Roytershteyn[2], S. Wang[1], B. Klecker[3], I. Dandouras[4]

[1]Space Science Center, University of New Hampshire, Durham, NH 03824, USA

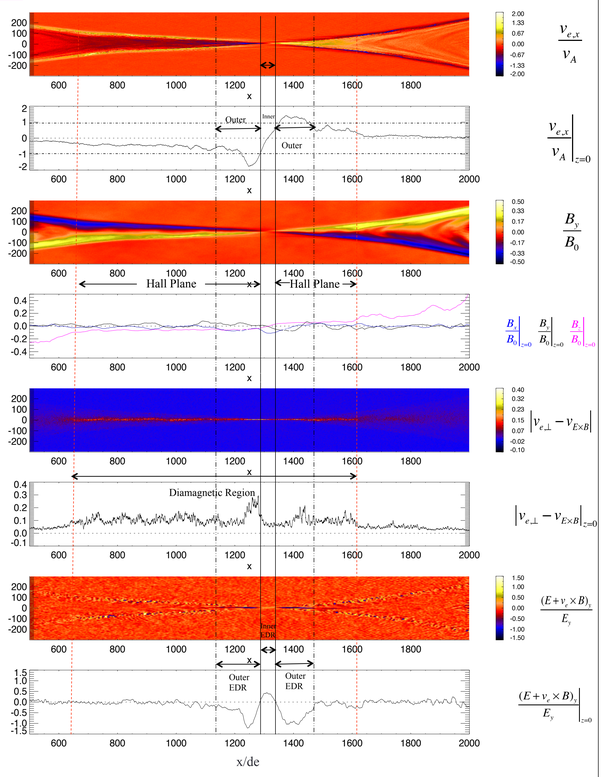
[2]University of California at San Diego, CA 92093, USA

[3]Max-Planck-Institut für extraterrestrische Physik, Garching, Germany [4]CESR, Avenue du Colonel Roche, 31028 Toulouse Cédex 4, France

Abstract

Recent PIC simulations of magnetic reconnection show the multi-scale structure of electron diffusion region (EDR). The inner EDR is energy dissipation region and the outer EDR contains the super-alfven jets. The extension of EDR may produce a thin hall plane, where the magnetic fields are mainly in plane. In 2002 Aug 21st, Cluster crossed magnetotail reconnection site. With the Cluster measured real parameters and including the flushing-in effect of O+ from lobes, a 2.5D PIC simulation is performed. By comparing the multi-spacecraft magnetic field, electron and ion data with the simulation, we deduced the spacecraft trajectory in reconnection frame and show that Cluster has a parallel passage of the hall plane. The simulation data along the deduced trajectory shows a surprising agreement with observation. Utilizing the hall field passage, we also measured the reconnection rate.

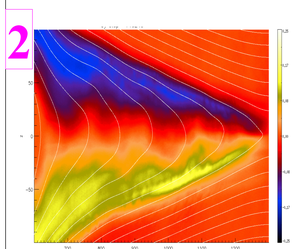
1 Multi-scale Structure of EDR



Figures 1: PIC simulation of Aug 21st, 2002 reconnection event.

- EDR contains inner and outer regions: the inner EDR shows positive non-ideal electric field and the outer EDR contains negative non-ideal electric field and the super Alfvenic flow jet.
- The Hall field flip in a very thin region (Hall plane) and extends ~ 1000 de (140 di).
- The electrons don't drift with magnetic field line in electron diamagnetic region and the length of this region is about the scale of Hall plane, but not the length of outer EDR.

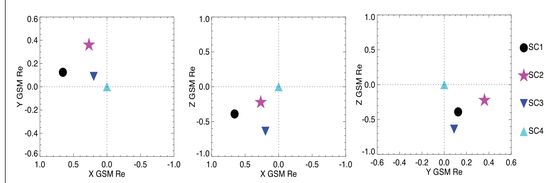
2



Figures 2: Zoomed-in Hall plane.

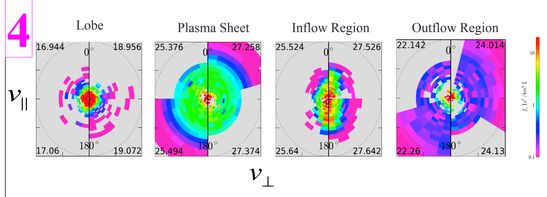
The color indicates the out of plane magnetic field and the contour line indicates the in-plane magnetic field line.

3 Auxiliary



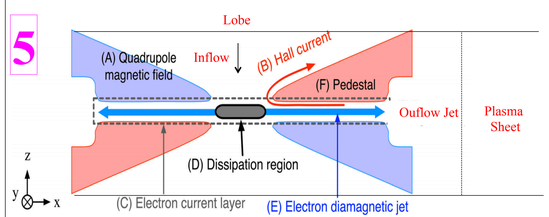
Figures 3: Cluster locations in GSM coordinate with SC4 as reference. From north hemisphere to south hemisphere : C4, C2, C1, C3

4



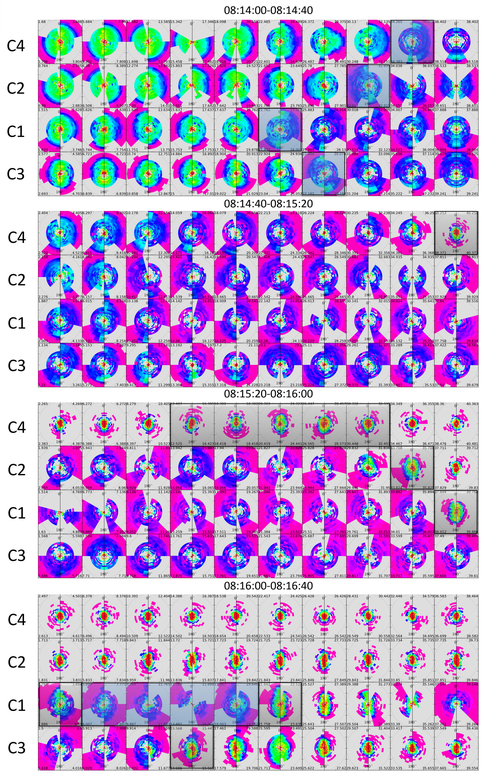
Figures 4: Cluster PEACE electron distribution functions as an indication of SC position in reconnection frame

5



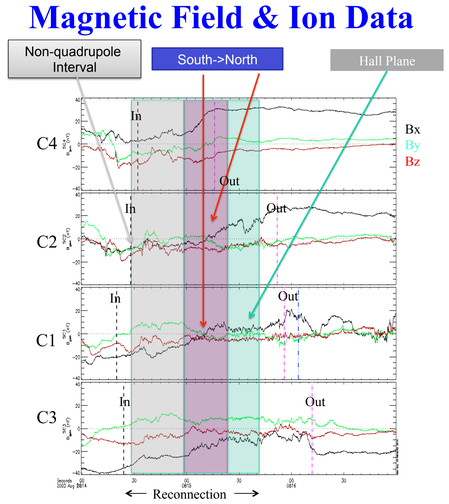
Figures 5: Cartoon of magnetic reconnection, edited from Zenitani et al., 2011, POP

6 Electron Distribution



Figures 6: Electron Distrubtion Functions
The grey opaque marks the entry of inflow region and the blue opaque marks the entry of outflow region.

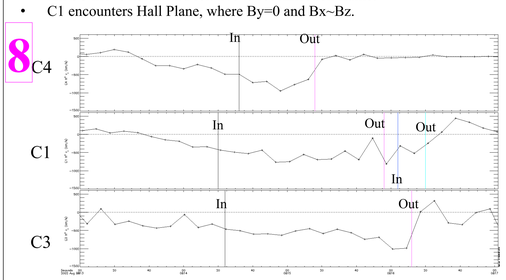
7 Magnetic Field & Ion Data



Figures 7: Magnetic Field Data

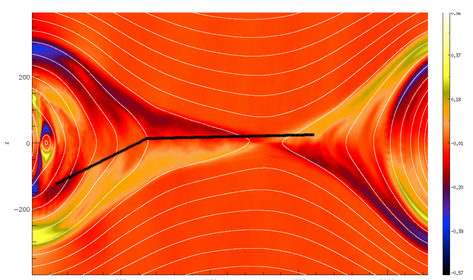
- C2 passed through a non-quadrupole region.
- All SC move northward relative to reconnection frame.
- C1 encounters Hall Plane, where By=0 and Bx~Bz.

8



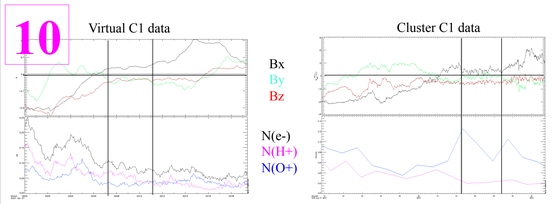
Figures 8: CODIF measured H+ x component of velocity.

9 Data Model Comparison



Figures 9: Simulation Magnetic Field Data. The black line marks the deduced virtual C1 orbit in reconnection frame.

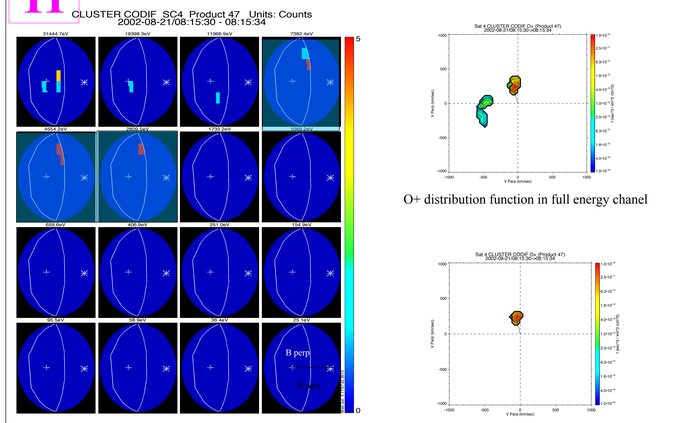
10



Figures 10: Comparison between virtual spacecraft data in simulation and Cluster measured data.

I. The magnetic field data shows a very well agreement in the main trend.
II. At the Hall Plane, the By component in simulation shows non-zero values.
III. The proton density decreases as the approach of X point, which is observed both in simulation and observation.
IV. At the Hall Plane, the O+ density is higher than the H+ density in observation.

11 Reconnection Rate



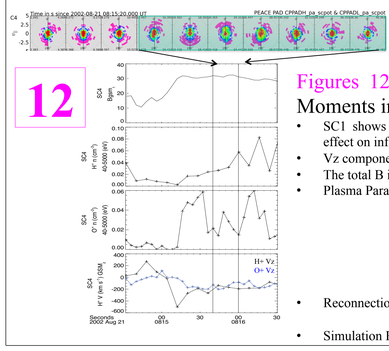
CODIF globe plot of O+ in each energy chanel

O+ distribution function in full energy chanel

O+ distribution function in selected energy channel

Figures 11: We show an example of calibrating ion moments calculation during SC1 in hall plane and SC4 in inflow region. With careful calibrations, the inflow velocity can be measured.

12



Figures 12: Recalculated SC4 CODIF Ion Moments in Lobe

- SC1 shows parallel passage of Hall Plane, thus tail flapping effect on inflow velocity measurement is neglected.
- Vz component for H+ and O+ agrees very well.
- The total B is almost the asymptotic magnetic field strength.
- Plasma Parameters:

$B_T \sim 31.6(nT)$

$n(H^+) \sim 0.024(cm^{-3})$

$n(O^+) \sim 0.026(cm^{-3})$

$v_{in} \sim 180(km/s)$

$v_{Alfven} = 1076(km/s)$

- Reconnection rate can be calculated: $R = v_{in} / v_{Alfven} = 0.17$
- Simulation Reconnection Rate: 0.17

Appendix: Coordinate System in Observation

MVA does not work during this interval, but we find GSM coordinate can describe this event best.

13

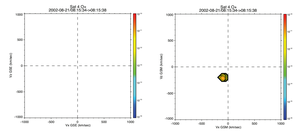


Figure 13: O+ distribution function in GSE/GSM X-Z plane within energy range [0,8e3] eV. We found that the GSM coordinate can catch the inflow O+ beam very well.

Summary

- The length of hall plane is about the scale of electron diamagnetic region length but not the scale of outer EDR length.
- We use simulation and observation data to deduce Cluster orbit in reconnection frame and show the spacecraft's parallel passage of hall plane.
- We found O+ is the dominant ion specie in the hall plane.
- Utilizing the deduced scenario, we manage to measure the reconnection rate, which is about 0.17 .

Reference

Karimabadi et al (2007), GRL, Doi: 10.1029/2007gl030306

Chen et al (2008), JGR, Doi: 10.1029/2008ja013385

Karimabadi et al (2011), Planetary and Space Science, Doi: 10.1016/j.pss.2010.07.014

Acknowledgements

Work at UNH was supported by NASA under **NNX07AF54G**, **NNX11AB65G** and **NNX10AQ42G**.