Simultaneous Observations of a FTE on Jan. 4, 2005 with Cluster and TC1

Chinese Double Star-Cluster Science Team
Outline

- Spacecraft Locations & Interplanetary Condition
- MP Crossing
- FTE signatures
- Event Analyses
- Summary
On Jan 4, 2005, TC-1 & Cluster were traversing, respectively, inbound and outbound across the duskside northern MP boundary.
Orbit of Cluster & TC1, TC2

Spacecraft locations
Spacecraft Locations

- C 4:   (3.91, 12.03, 5.01) \( R_E \) (GSE)
- TC-1: (4.33, 12.50, 1.93) \( R_E \) (GSE)

\[ \Delta X \sim 0.42 \, R_E, \quad \Delta Y \sim 0.47 \, R_E, \quad \Delta Z \sim 3.08 \, R_E \]
GEOTAIL Magnetic Field

GEOTAIL: Near Earth Solar wind
X ~ 19.6 Re
Y ~ 2.8 Re
Z ~ 3.8 Re

~ 07:00 IMF $B_z$ changed from Positive to negative
Solar Wind Condition

$V_x \sim 685 \text{ km/3}$
From 06:30 to 07:10 UT, TC1 and Cluster both stayed in the MSP boundary region.

At ~07:10, MP moved inward, both TC1 & Cluster traversed across the MP into the MSH.
Pitch angle spectrum of electrons from PEACE /C1

MP crossing
Just prior to the MP crossing, Cluster/RAPID saw a field-aligned bi-directional electrons in the MSP boundary layer.
HT analysis indicates that the MP was an open boundary.
Cluster observed a few FTEs in the MSH after the MP crossing.
TC-1 observed a couple of FTEs in the MSH after the MP crossing.
Why we choose this 2?

Cluster TC-1

~07:13:20

FTE-Cluster

ΔT≈110 s

~07:15:10

FTE-TC1
3-D Distribution of Thermal Ions in FTE

3-D distributions of thermal ions for both TC-1 and Cluster FTEs were very similar.
## HT Velocities

<table>
<thead>
<tr>
<th></th>
<th>velocity components (km/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TC1</td>
<td>-313.86, 269.94, 137.88</td>
</tr>
<tr>
<td>Cluster/SC1</td>
<td>-379.22, 270.50, 82.49</td>
</tr>
<tr>
<td>Cluster/SC3</td>
<td>-370.44, 274.22, 54.82</td>
</tr>
<tr>
<td>Cluster/SC4</td>
<td>-316.47, 237.22, 67.54</td>
</tr>
</tbody>
</table>

**All HT velocities derived are similar**

The larger components are $V_x$ and $V_y$. 
3-D Distribution of Thermal Ions in FTE

The larger components are $V_x$ and $V_y$. 

TC-1/HIA at 07:15:05
CS3/HIA at 07:13:14
Cowley-Owen-Cooling Model (Cooling et al., 2001) Calculation

Derived HT velocity is consistent with model calculation that the FTEs were produced via time-dependent MR near the equator.
Reconstruction of Flux Ropes
(By Solving Grad-Shafranov equation (Sonnerup, 2004))

Strong axis-aligned core field

<table>
<thead>
<tr>
<th>spacecraft</th>
<th>A (-0.05)</th>
<th>A (-0.06)</th>
<th>A (-0.07)</th>
<th>A (-0.08)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TC-1</td>
<td>1.541E+006</td>
<td>1.156E+006</td>
<td>8.916E+005</td>
<td>6.196E+005</td>
</tr>
<tr>
<td>SC1</td>
<td>1.276E+006</td>
<td>1.071E+006</td>
<td>8.869E+005</td>
<td>6.244E+005</td>
</tr>
</tbody>
</table>

Magnetic fluxes contained in two flux ropes are approximately equal
Both flux ropes had prominent axis-aligned magnetic field component.
## Scale Size of the Cross-Section of Two Flux Ropes

\[ L \sim |(V_{HT} \times e)| \times \Delta t \]

<table>
<thead>
<tr>
<th></th>
<th>TC1</th>
<th>Cluster/SC1</th>
<th>Cluster/SC3</th>
<th>Cluster/SC4</th>
</tr>
</thead>
<tbody>
<tr>
<td>R_{E}</td>
<td>2.10</td>
<td>2.28 R_{E}</td>
<td>2.27 R_{E}</td>
<td>1.94 R_{E}</td>
</tr>
</tbody>
</table>

The scale-sizes of the cross-section of TC-1 and Cluster flux rope are also similar.
### Orientation of Flux Rope

<table>
<thead>
<tr>
<th>Methods</th>
<th>TC-1</th>
<th>Cluster</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMVA (a)</td>
<td>-0.4411, 0.0713, 0.8946</td>
<td>-0.5060, 0.4970, 0.7050</td>
</tr>
<tr>
<td>BMVA (b)</td>
<td>—</td>
<td>-0.2407, 0.4280, 0.8711</td>
</tr>
<tr>
<td>GS</td>
<td>-0.4040, 0.2190, 0.8880</td>
<td>-0.5450, 0.1710, 0.8210</td>
</tr>
<tr>
<td>Angel from IMF</td>
<td>73°</td>
<td>50°</td>
</tr>
</tbody>
</table>

Flux rope orientation of two flux ropes were similar. The axis of flux rope observed by Cluster was somewhat closer to the ambient B field.
$V_{HT} = (-380,270,82) \text{km/s}$

$V_{HT,N} = (-186,78.9,-187.6) \text{km/s}$

$d = 7181.7 \text{km} = 1.14 \text{RE}$
Leading edge: C2, C3, C1, C4

TC1 & Cluster Observation_050104_BNC

Trailing: C3, C2, C1, C4
2005-01-05 07:10 UT
Leading edge: C2, C3, C1, C4

Trailing edge: C3, C2, C1, C4
Summary

The coordinated measurements of Cluster and Double Star have given the possibility to study flux tube evolution along the magnetopause with five-point measurements: first giving accurate, quantitative estimate of the orientation, motion and characteristics of the open flux rope at Cluster and second relating this measurement to an adjacent location at TC-1. We can see the structures of FTEs at small scales within the Cluster tetrahedron, as well as the large-scale evolution with Cluster and Double Star. The 04 01 2005 event manifests a close conjunction FTE of Cluster and TC-1. More work is underway to expand on the context and controlling parameters of this event.
谢谢！
Result of GS (TC1)
Result of GS (Cluster)