

# Oxygen motion in the Magnetotail of Earth

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Reconnection with  
multiple ion populations

**Mars**

Complex magnetic field  
topology and mixed  
plasma

Tail  
observation

Harada et al.  
Accepted GRL  
2015

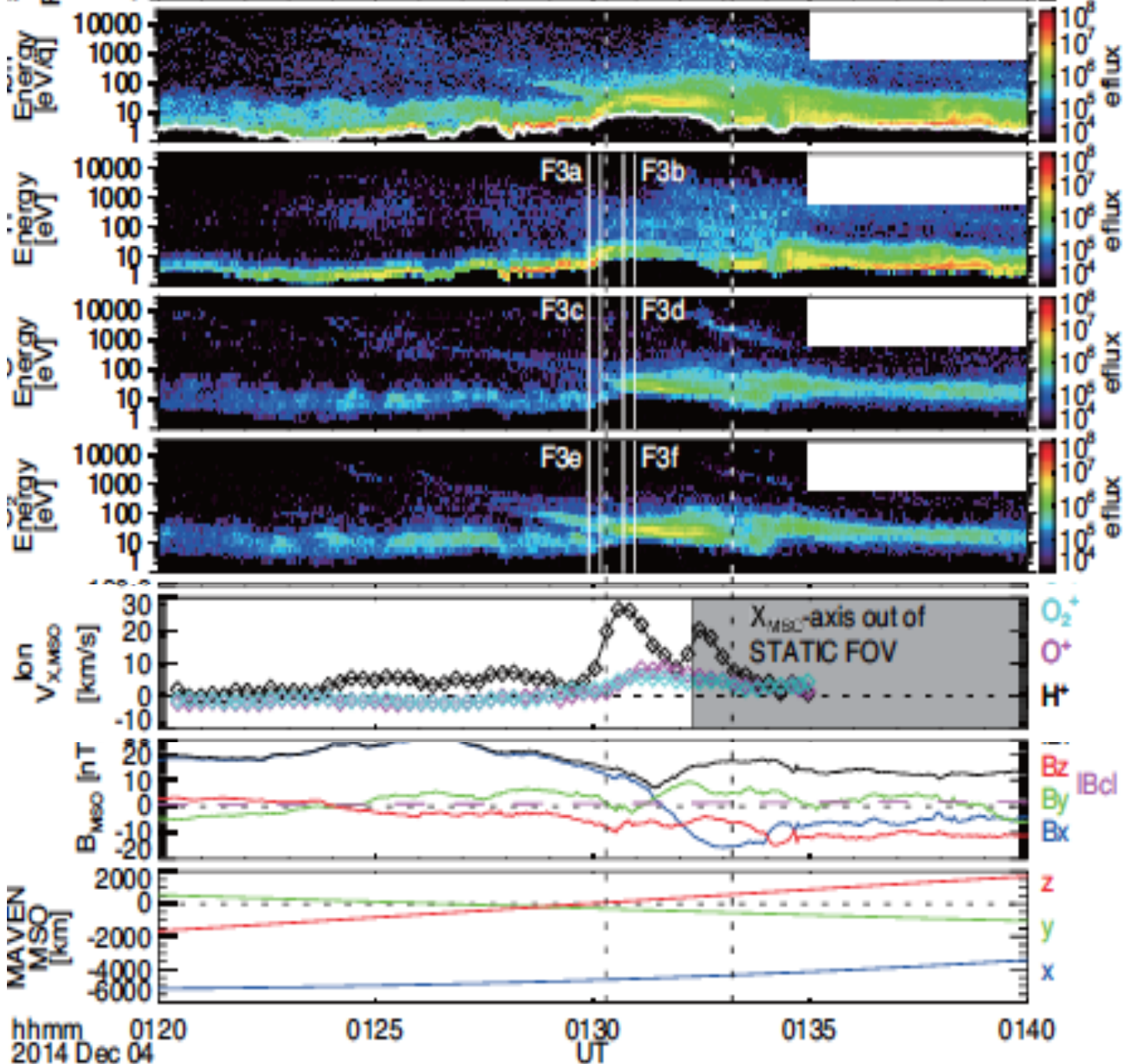
All

$H^+$

$O^+$

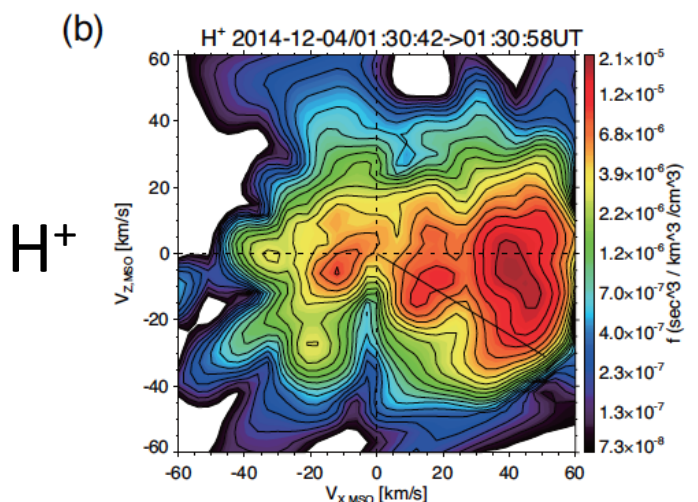
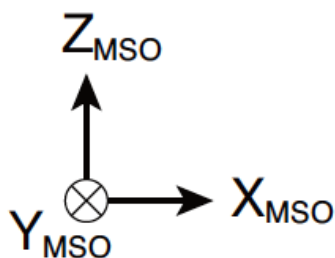
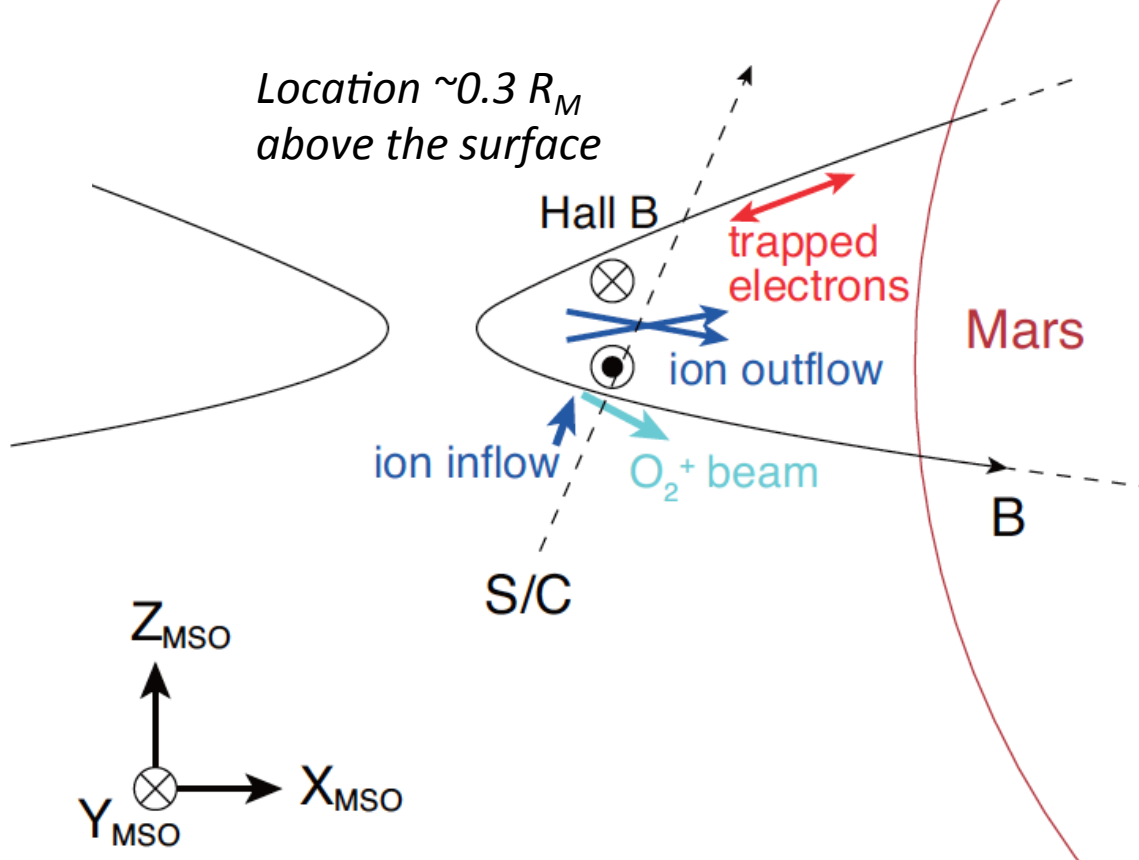
$O_2^+$

MAG

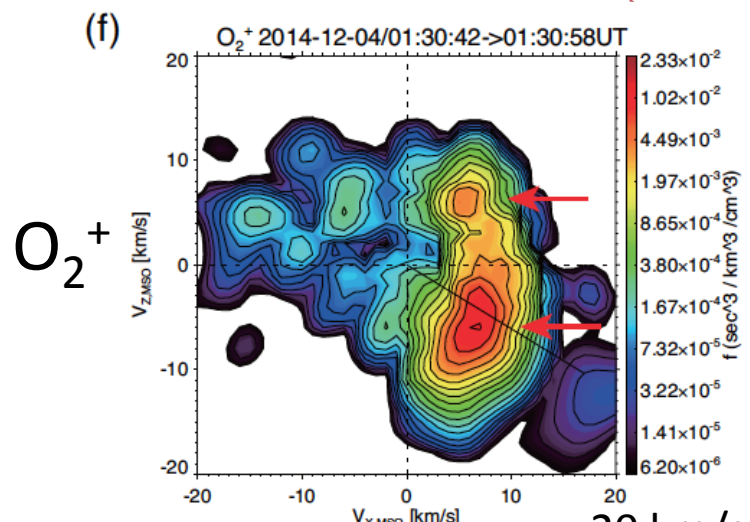


# Closed and open field lines identified using electrons

Harada et al.  
Accepted to  
GRL 2015



60 km/s



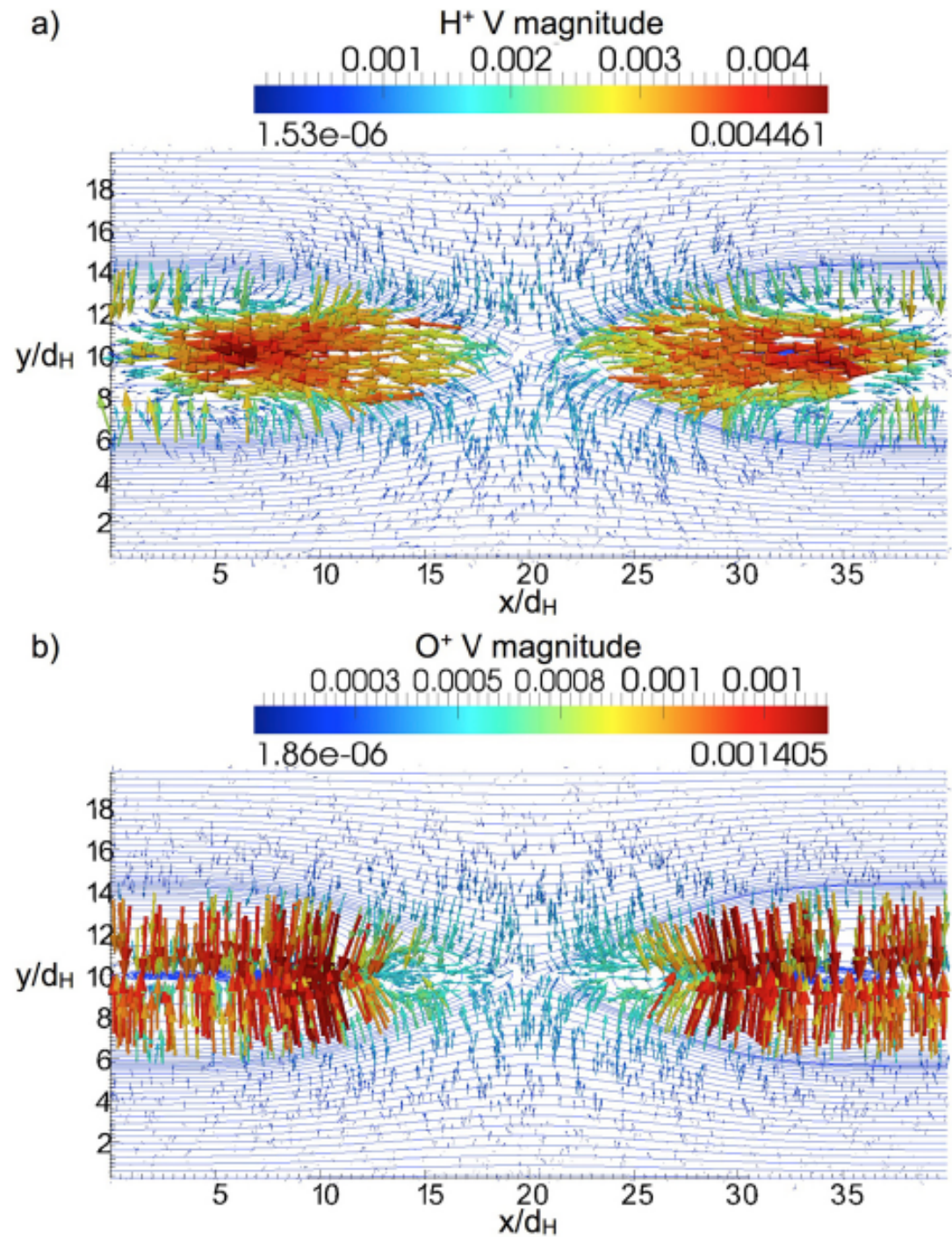
20 km/s

# Oxygen – Proton Reconnection in Harris sheet

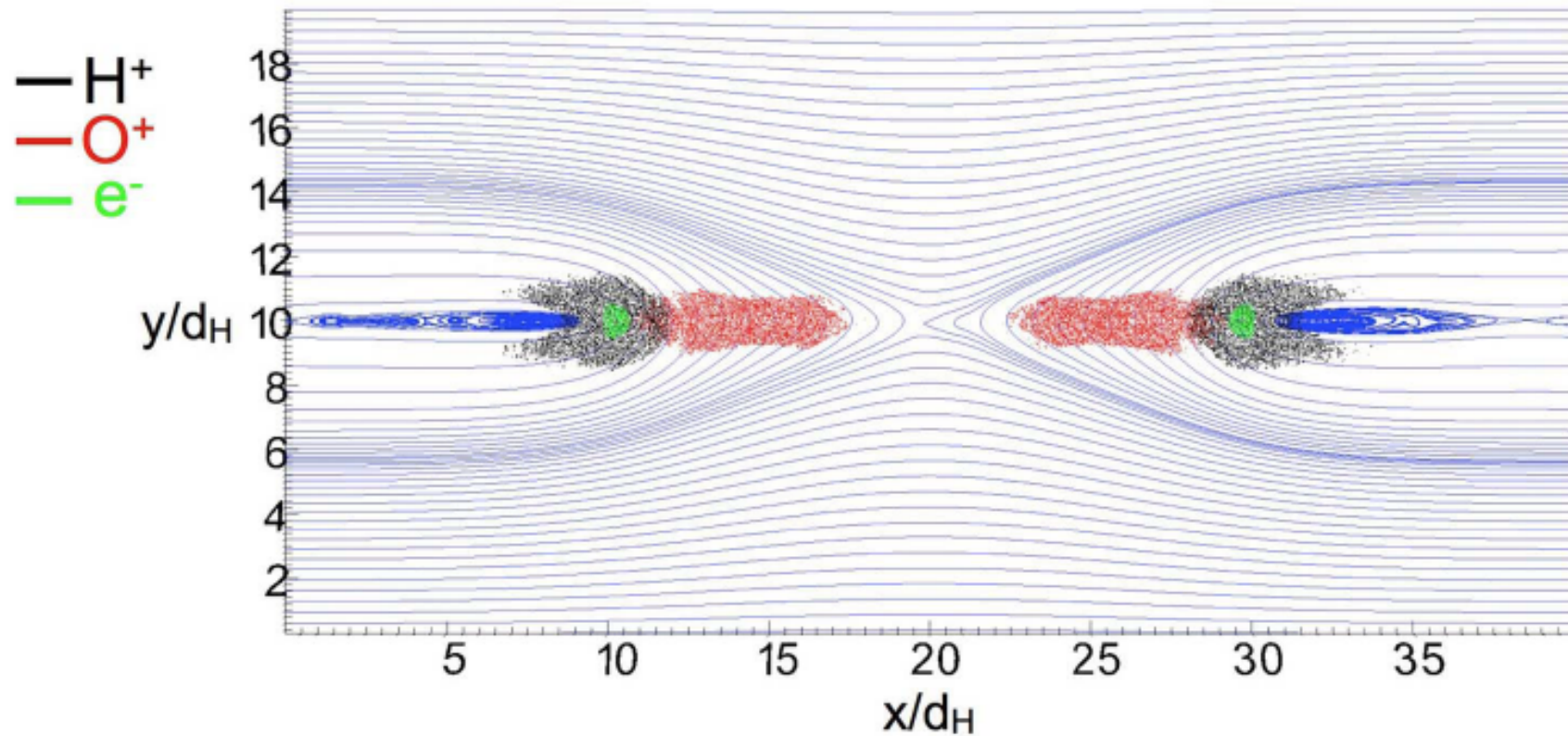


Gyro radius effects  
results in different  
paths

Markidis et al 2011



The two ion populations peak densities  
are at different locations



Markidis et al 2011

Why interested in  $O^+$  -  $H^+$  reconnection?

Reconnection is usually suggested as causing fast earthward flows in the magnetotail

At **low** speeds  $O^+$  and  $H^+$  flow together based on observations

At **high** speeds  $O^+$  and  $H^+$  flow not together based on observations

This will impact the plasma return flow in the magnetosphere circulation. This can change the mass density in the return flow impacting the response time to solar wind drivers.

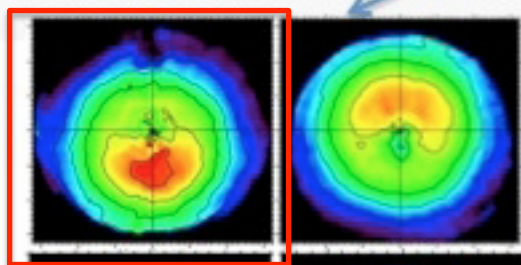
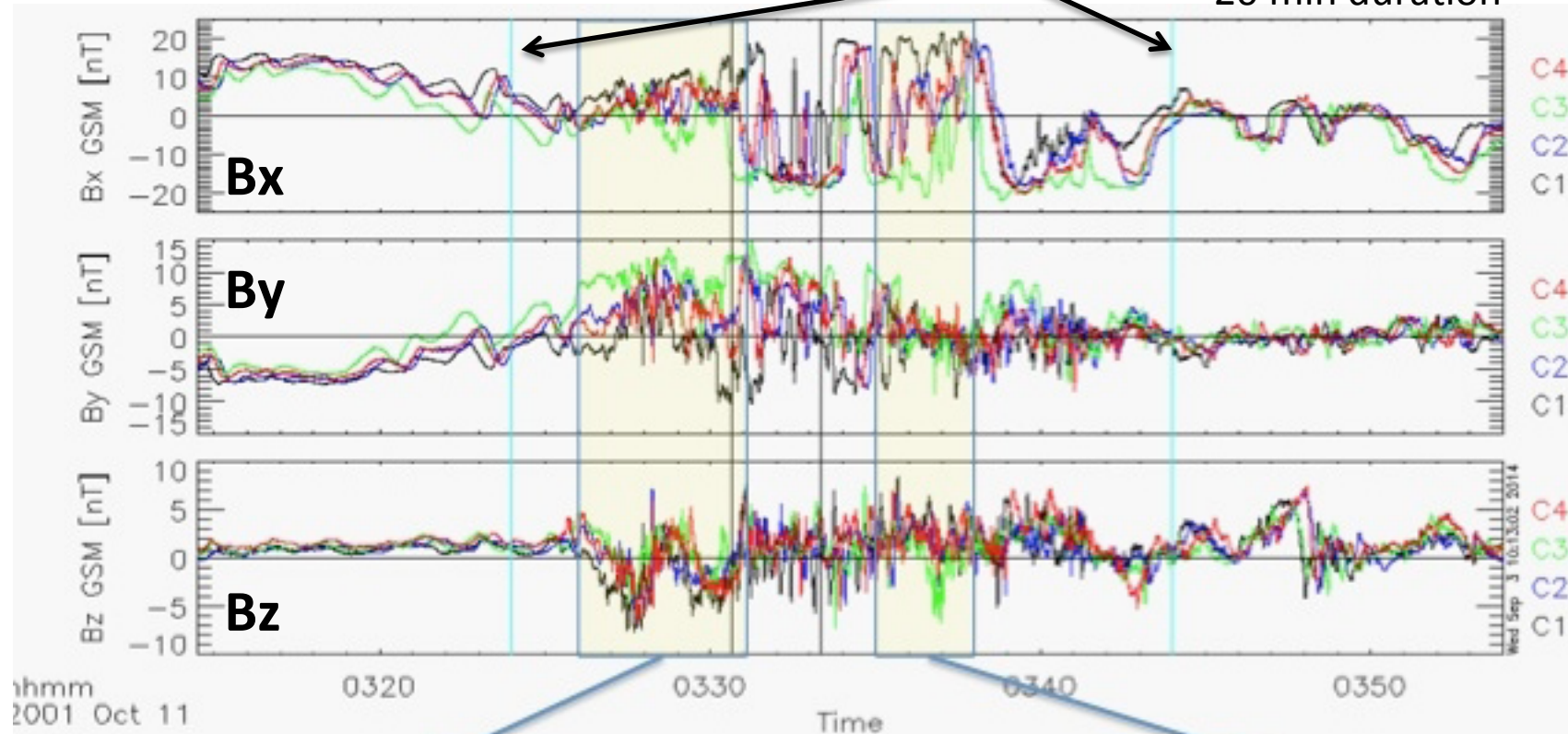


# Cluster observation Reconnection event

Østgaard et al. 2009; Eastwood et al. 2010; and Borg et al 2012

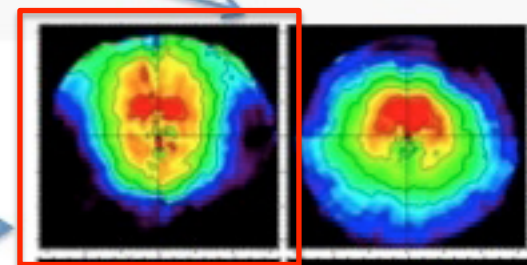
Magnetic equator (i.e. small  $B_{\text{tot}}$ )  
~20 min duration

~18  $R_E$



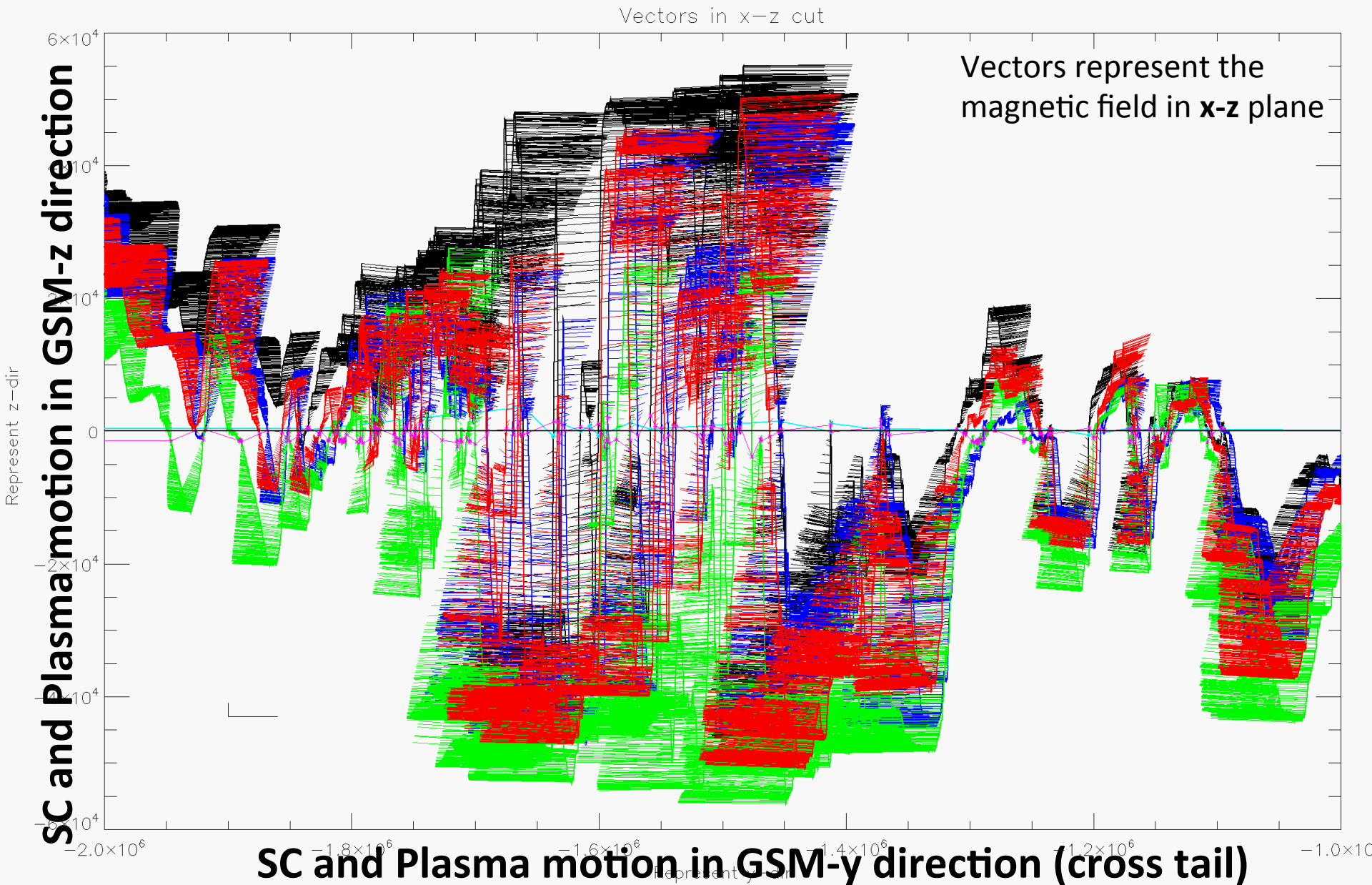
+3200 km/s  
Para  
 $H^+$   
Perp1

+3200 km/s  
Perp2  
 $H^+$   
Perp1

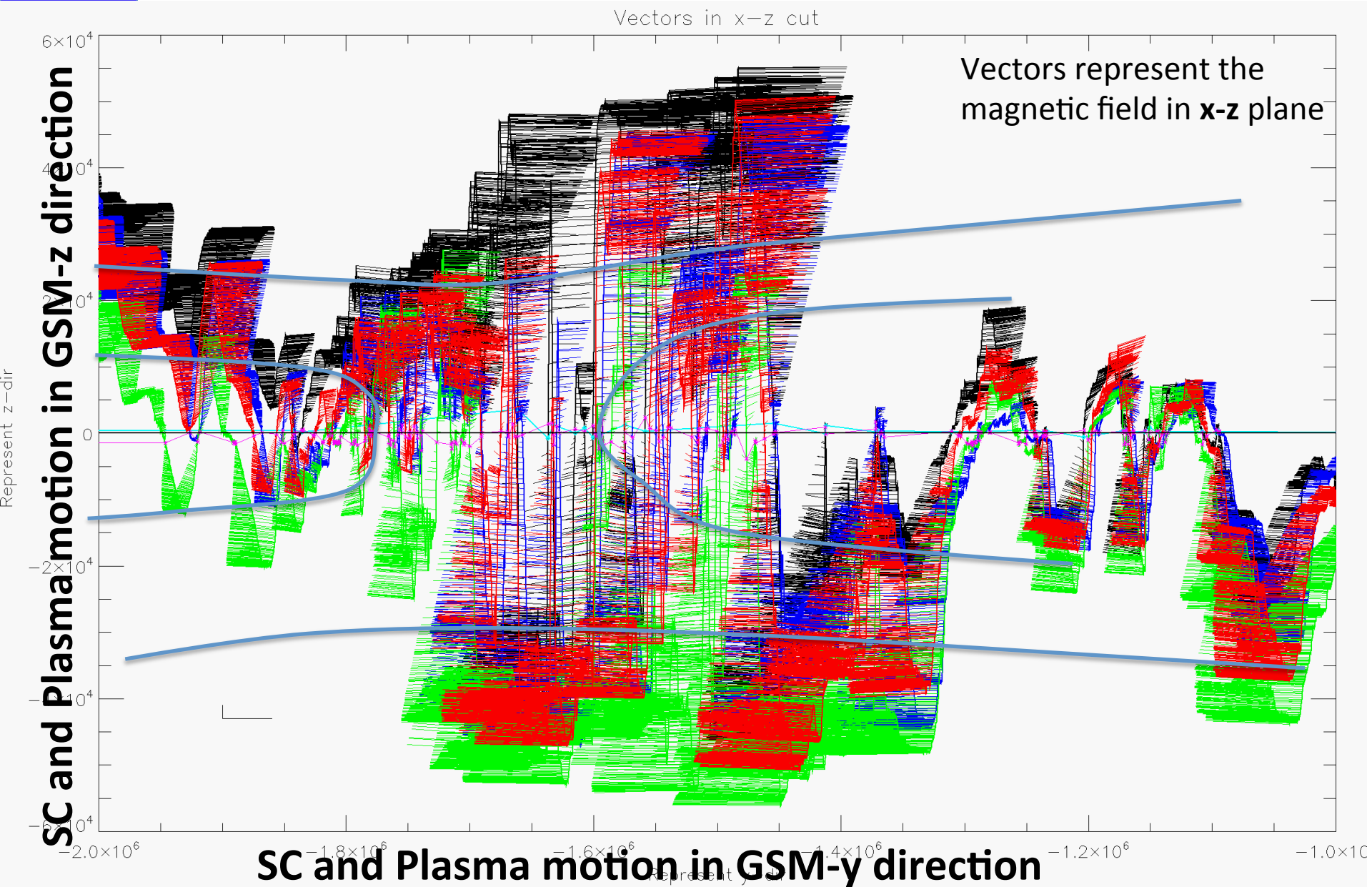


# Cluster Magnetic field observations:

Based on location, a constant 'yz' motion, and vertical speed proportional to  $B_x$



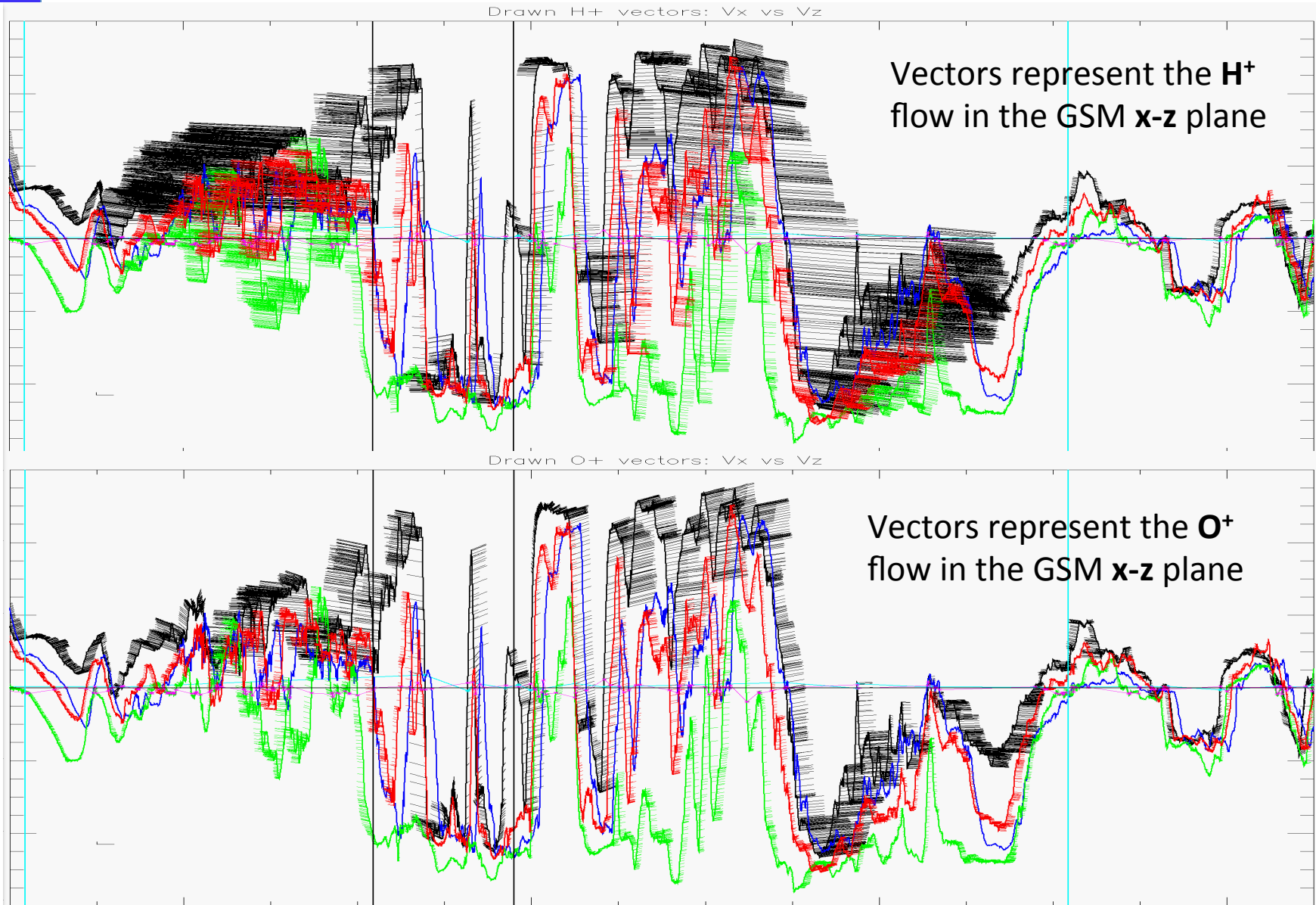
# Cluster Magnetic field observations in the assumed frame of reconnection





# Cluster Magnetic field observations in the assumed frame of reconnection

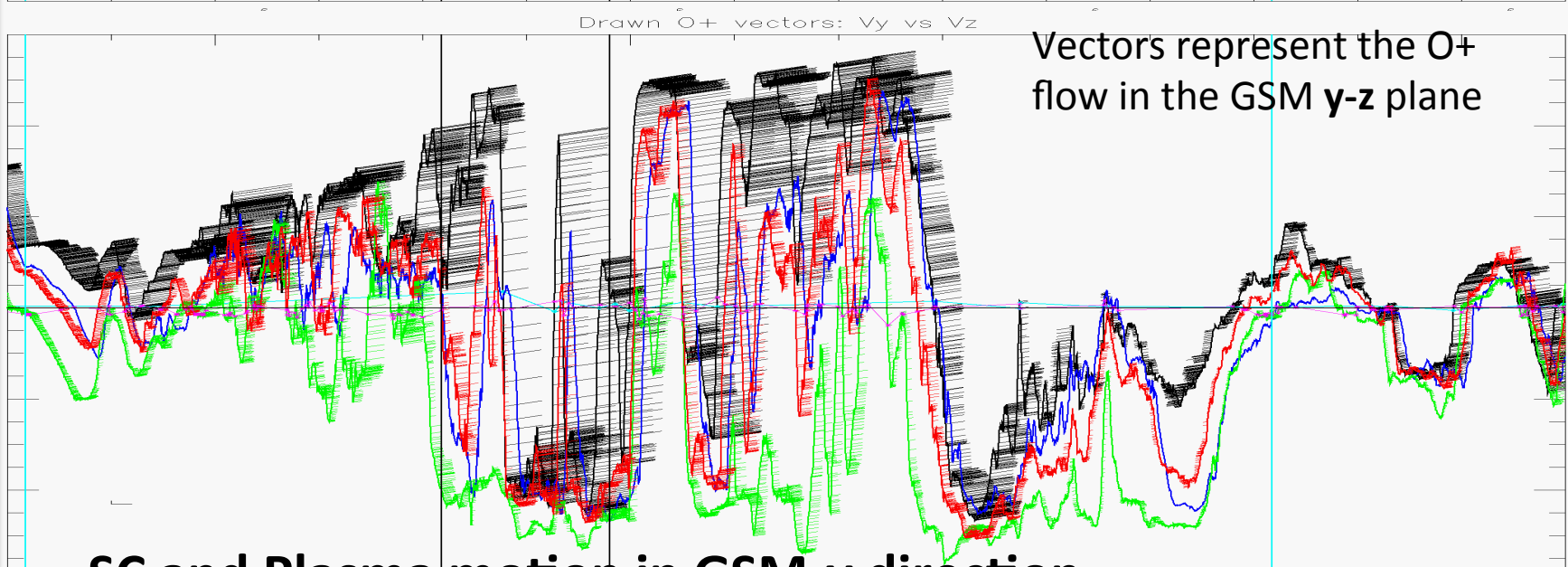
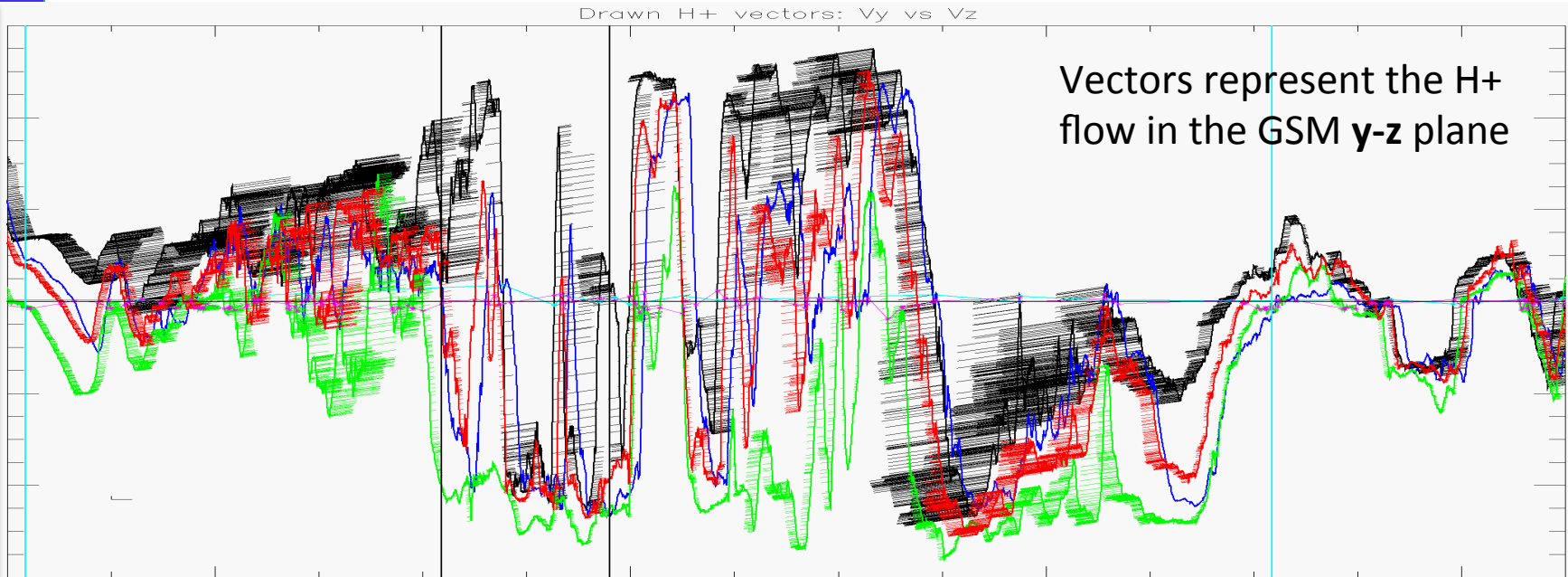
SC and Plasma motion in GSM-z direction



SC and Plasma motion in GSM-y direction

# Cluster Magnetic field observations in the assumed frame of reconnection

SC and Plasma motion in GSM-z direction

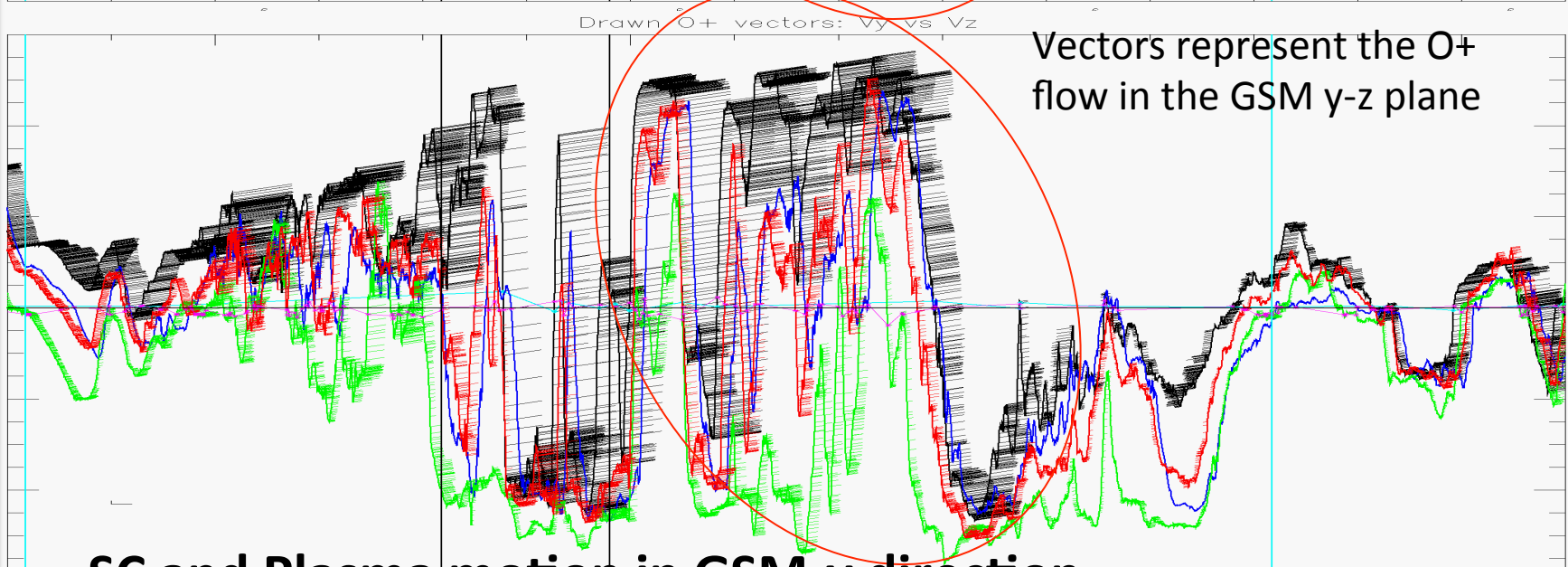
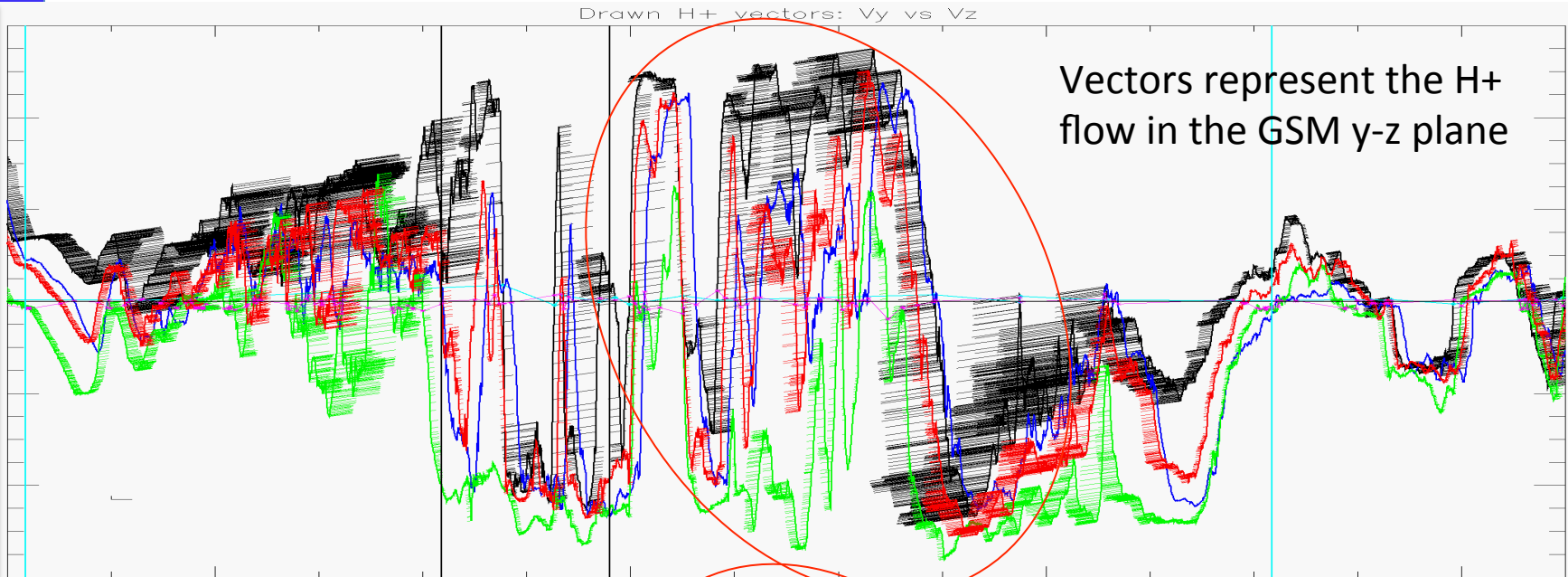


SC and Plasma motion in GSM-y direction



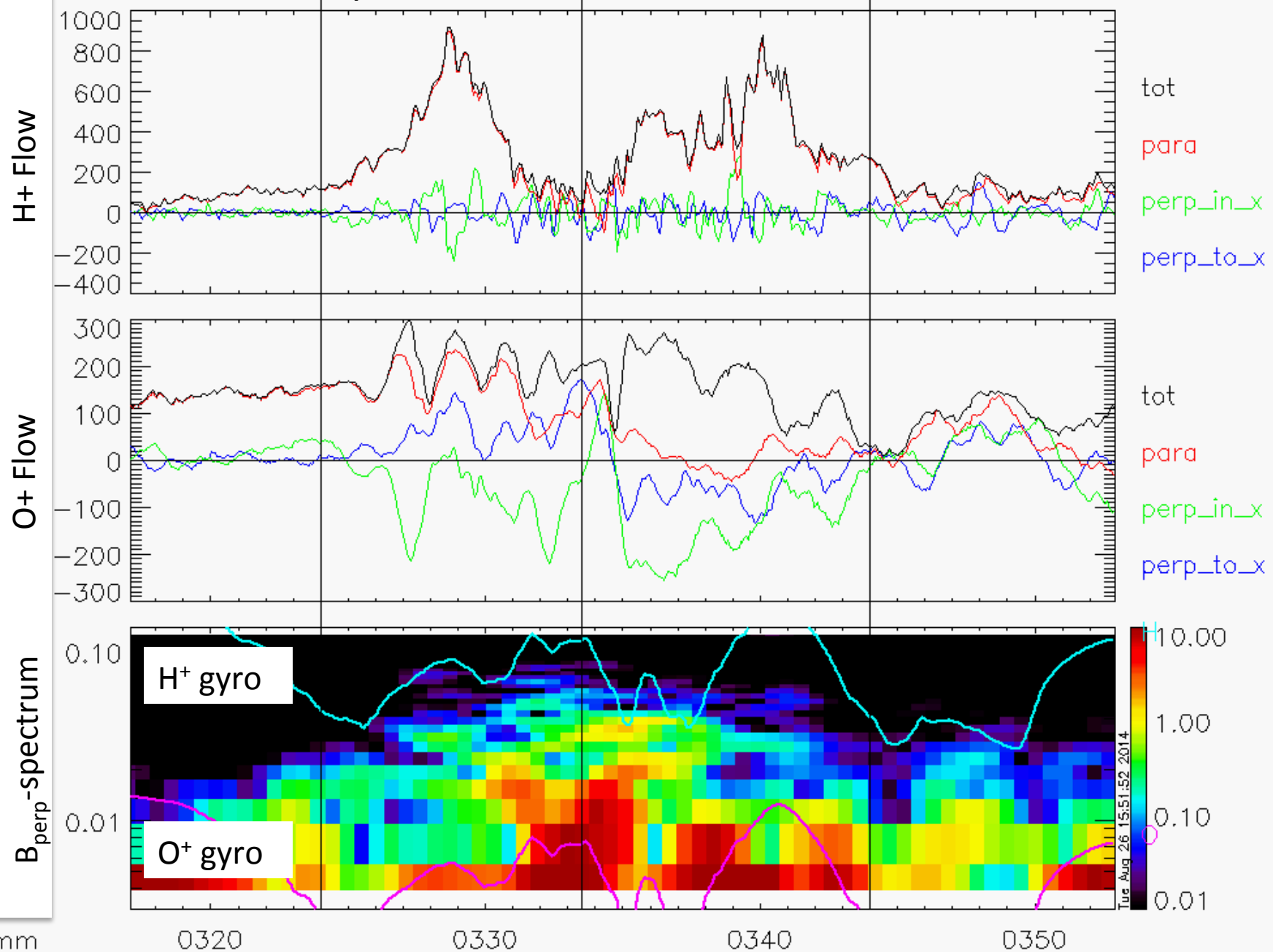
# In SC Frame $H^+$ and $O^+$ Moves in Opposite Direction

SC and Plasma motion in GSM-z direction



SC and Plasma motion in GSM-y direction

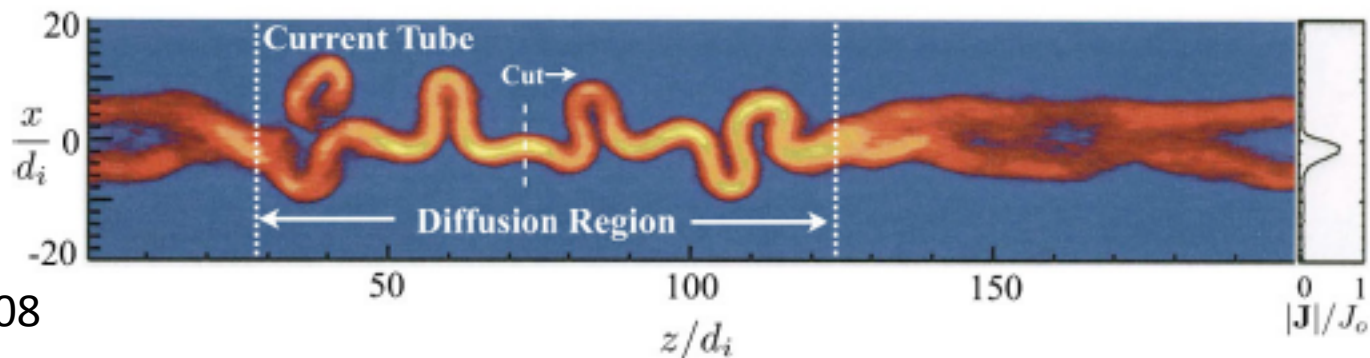
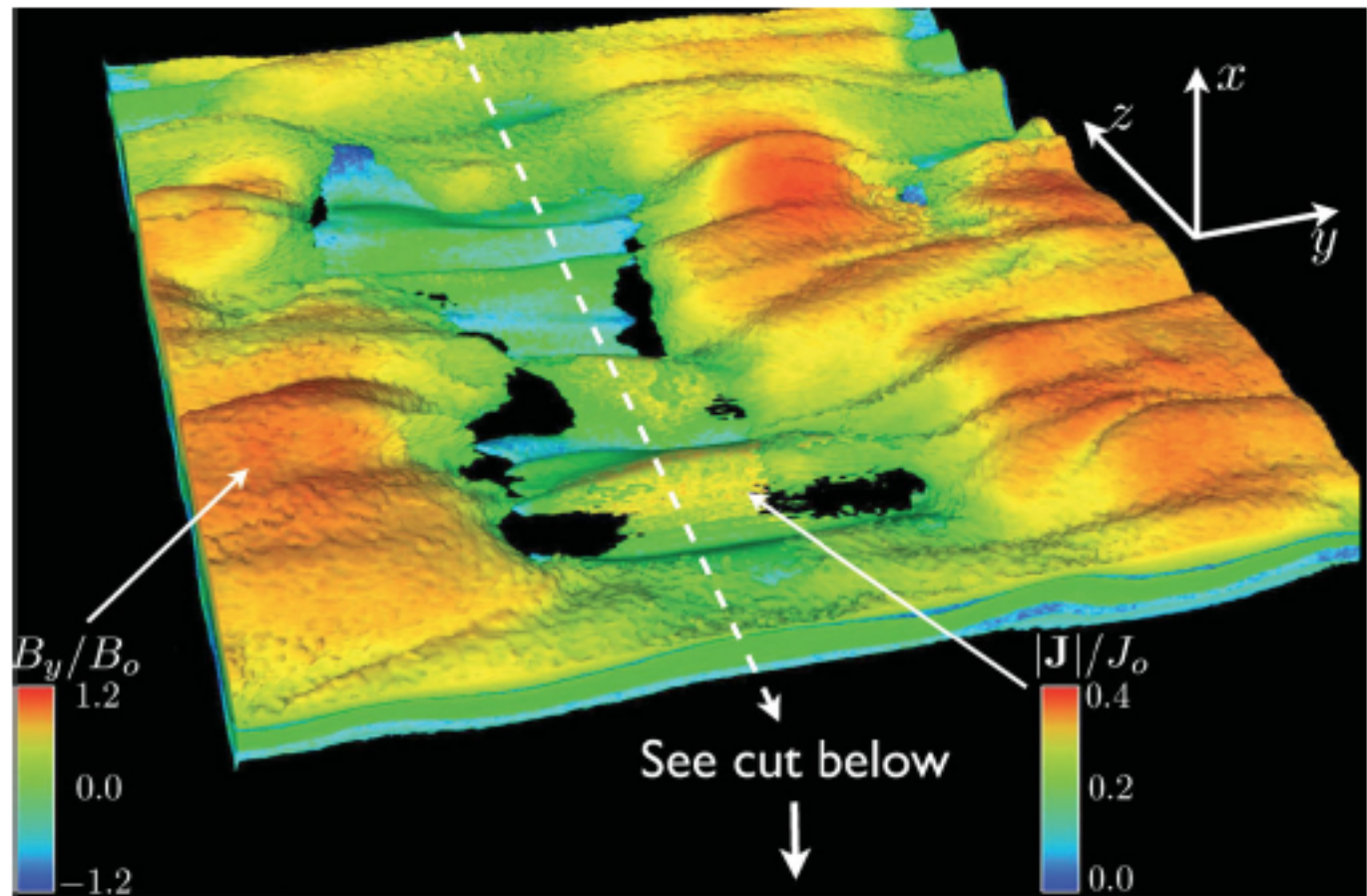
# Flows presented in $H^+$ flow coordinate



# Simulations

# Simulations using electron-positron plasmas

Secondary  
kinking



Yin et al. 2008

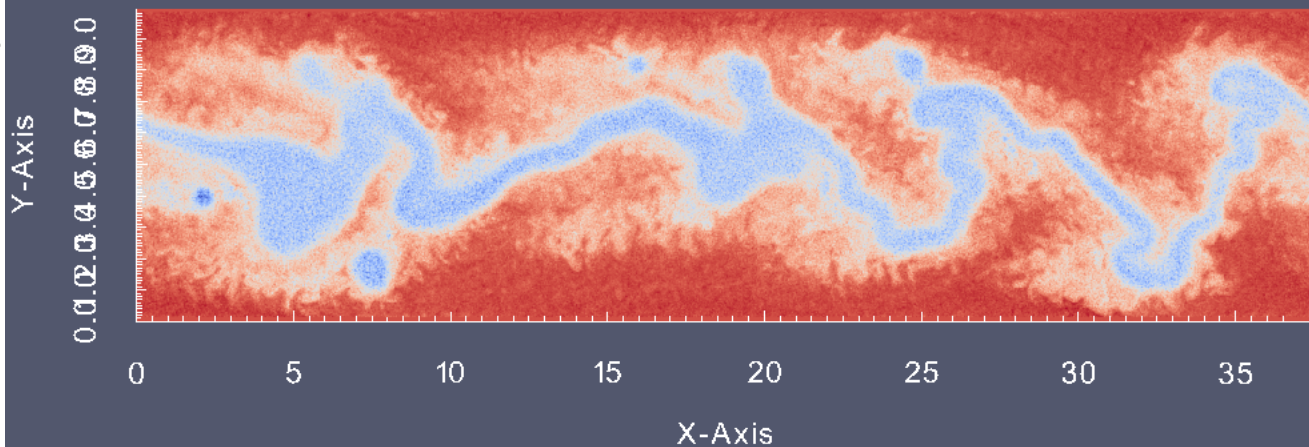


iPIC3D

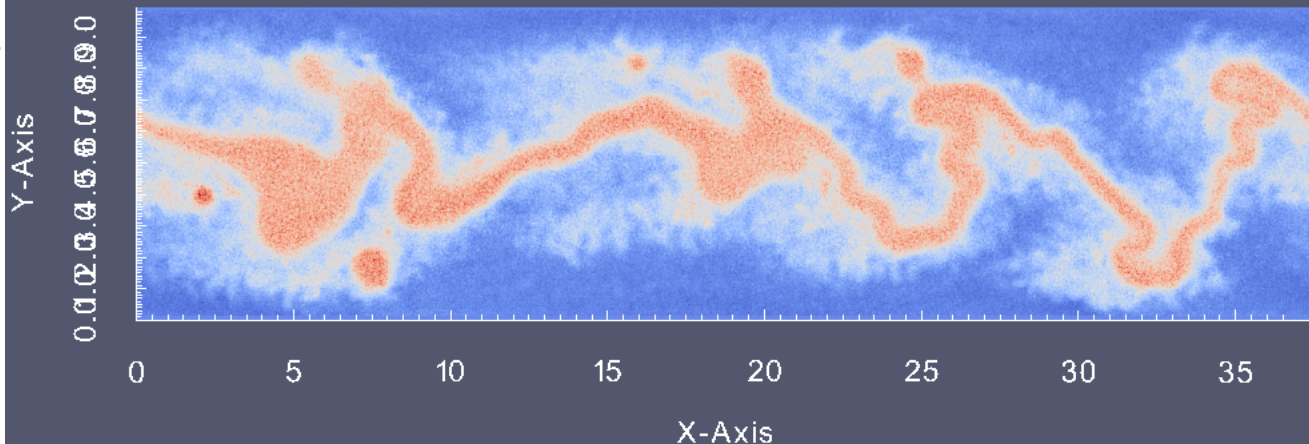
2D simulation  
of LHDI, cross  
tail simulation  
with protons  
and oxygen

Tail  
oscillations  
can  
decouple  
oxygen from  
the plasma  
sheet and  
create  
detached  
flux tubes

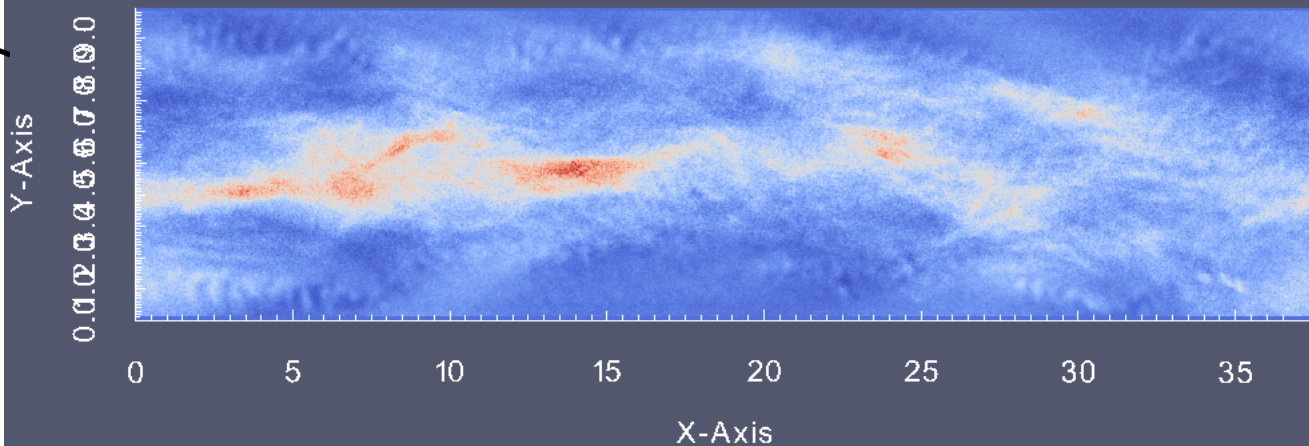
$e^+$  density



$H^+$  density



$O^+$  density





## Summary

Space plasma's often have multiple ion populations this will impact reconnection

Few studies has investigated in reconnection with multiple ion populations

The cross tail flow that could be driven by reconnection in the magnetotail can drive LHDI resulting in decoupling of the two ion populations