Effect Of Magnetic Reconnection Over The Space Environment Of The Earth

LIÈGE université

Jessy Matar
PhD Supervisor: Benoit Hubert

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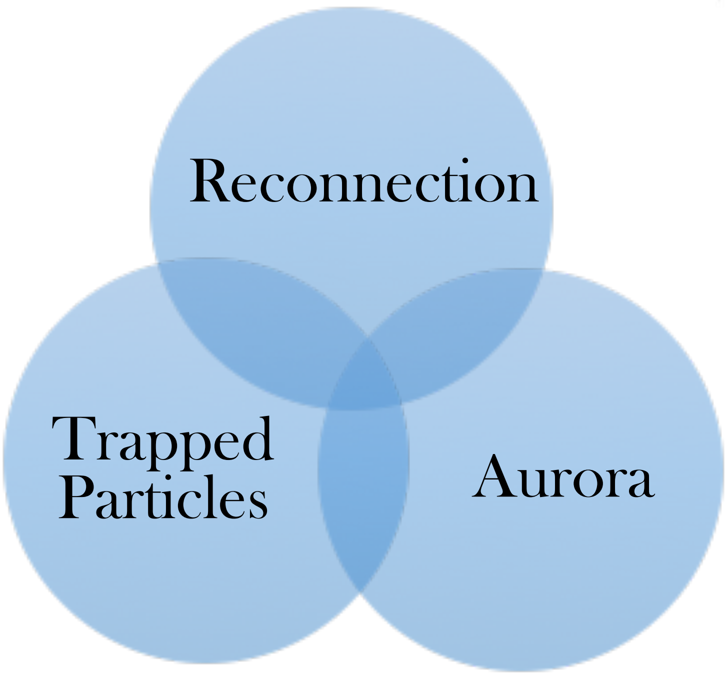
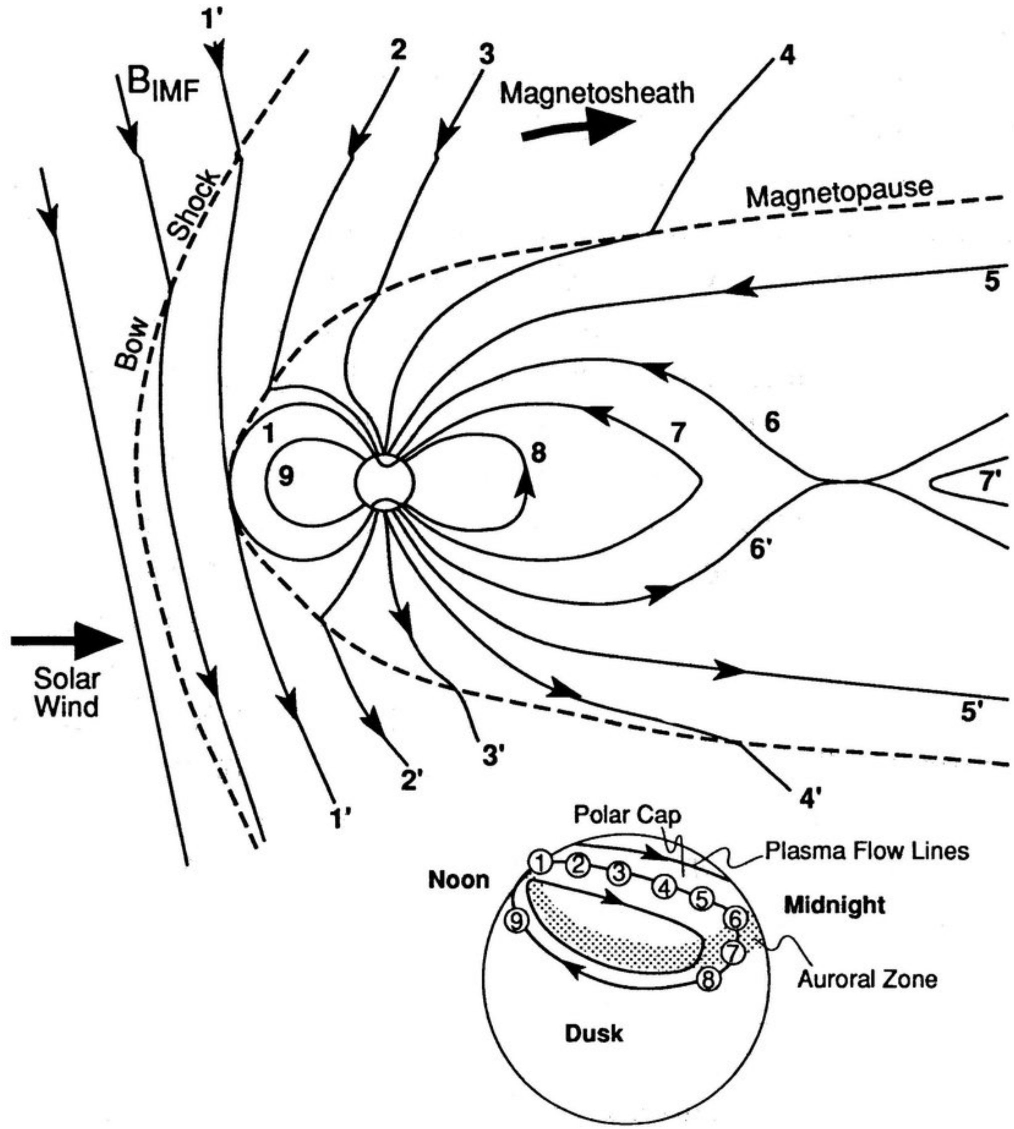
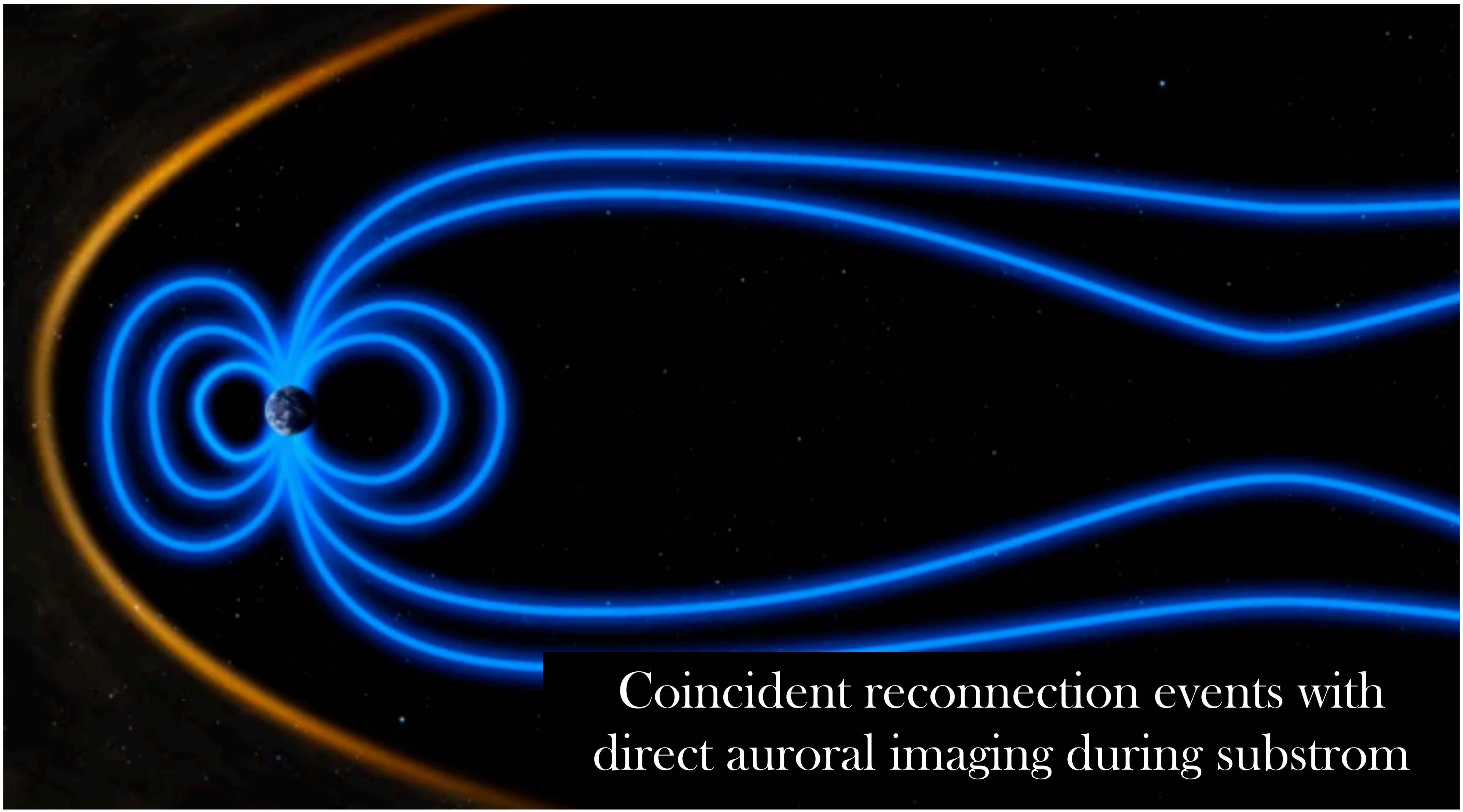
Motivation

Dungey Cycle





Motivation



Coincident reconnection events with direct auroral imaging during substrom

Data Instruments

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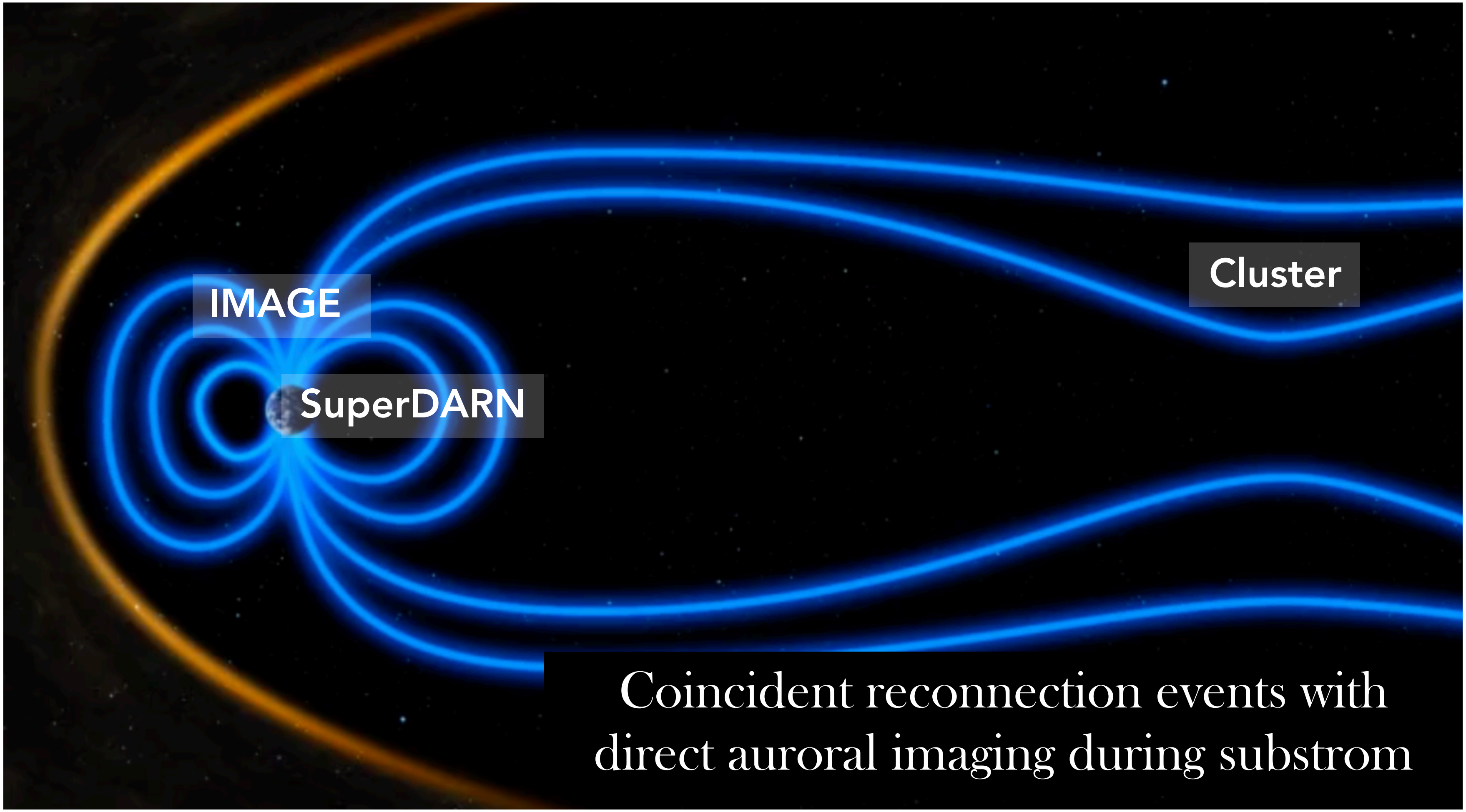

Coincident reconnection events with direct auroral imaging during substrom

Data Instruments

Selection of events:

- ✔ Good auroral images from IMAGE
- ✔ B and V measurements during reconnection from Cluster
- ✔ Convection measurements from SuperDARN

22 August 2001

15 September 2001

Analysis *Reconnection Case Studies*

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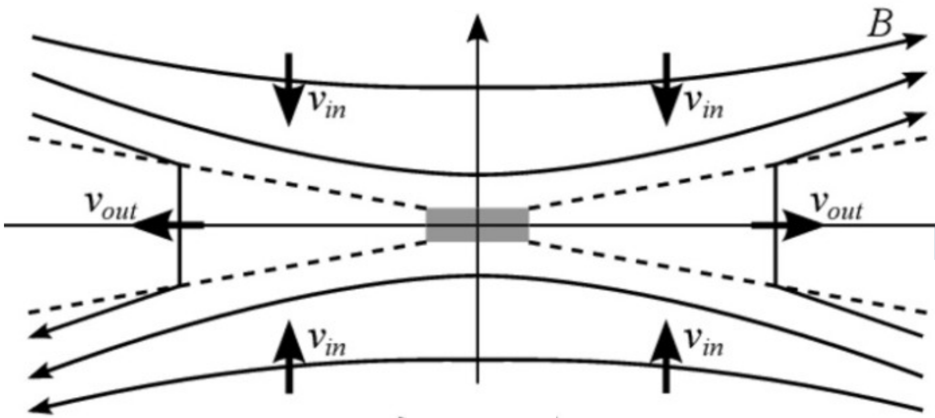
Cluster Inflow Region

15 September 2001



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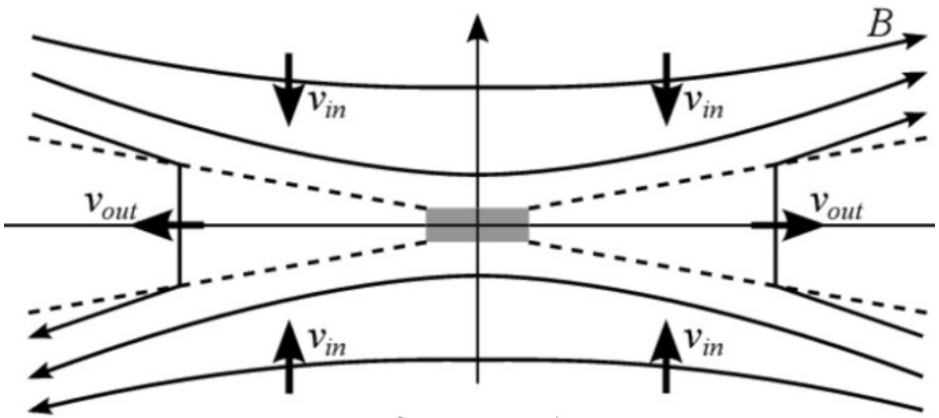

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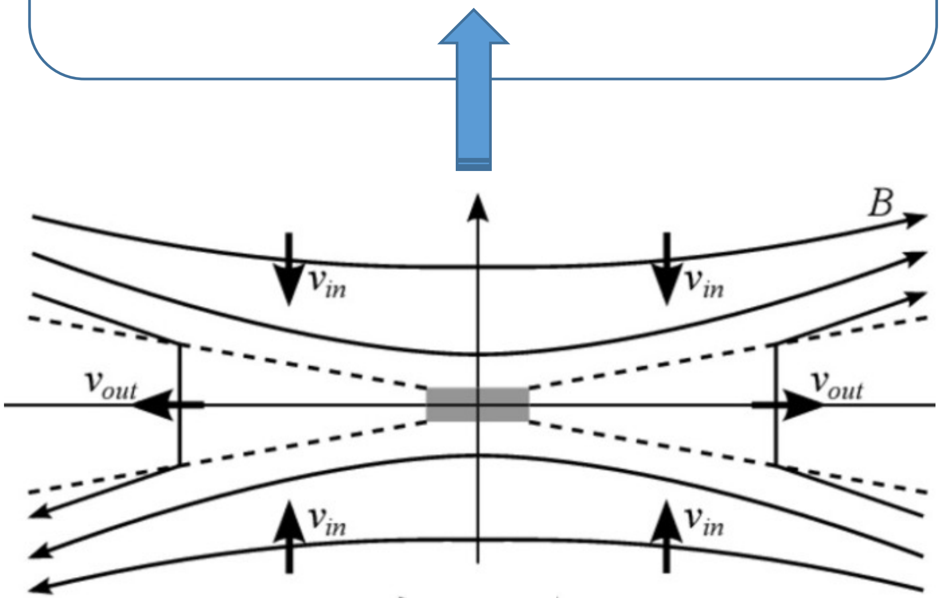

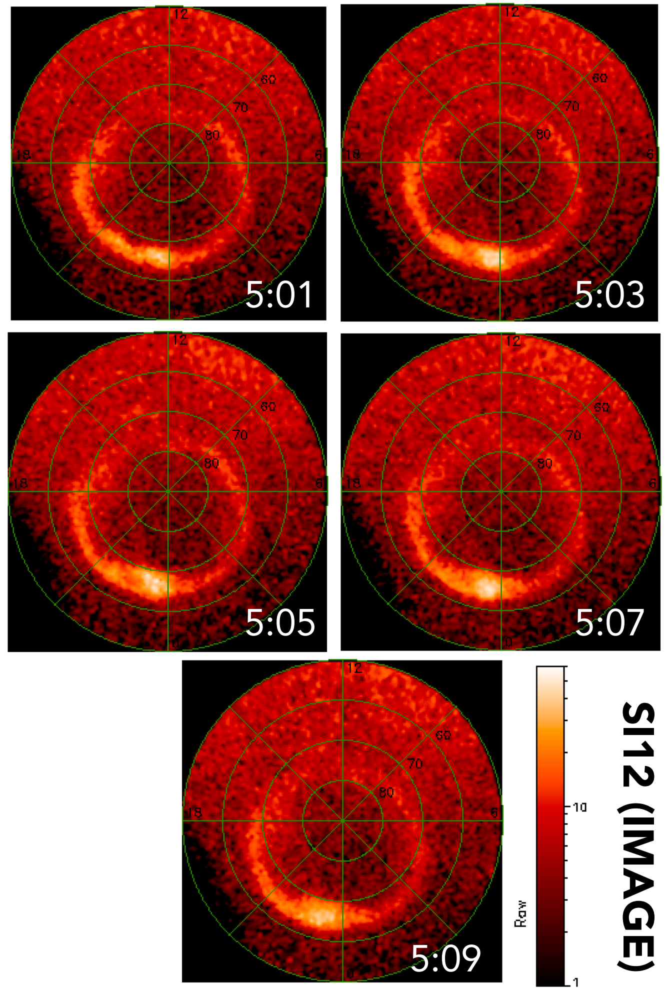

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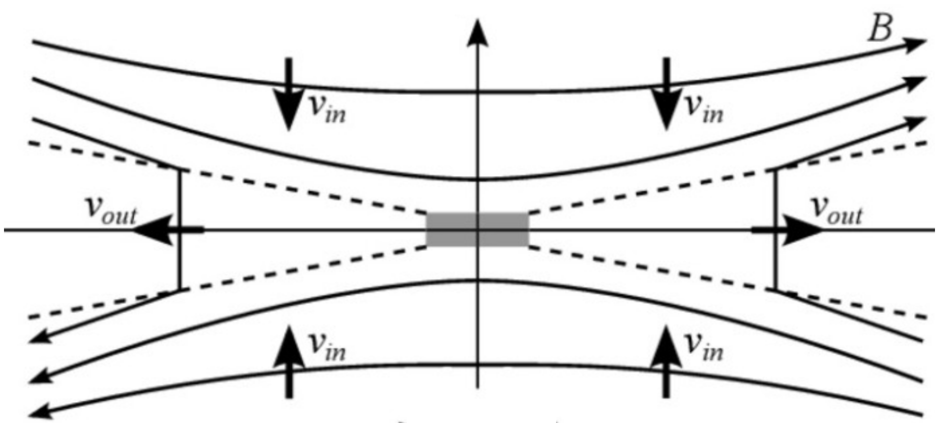
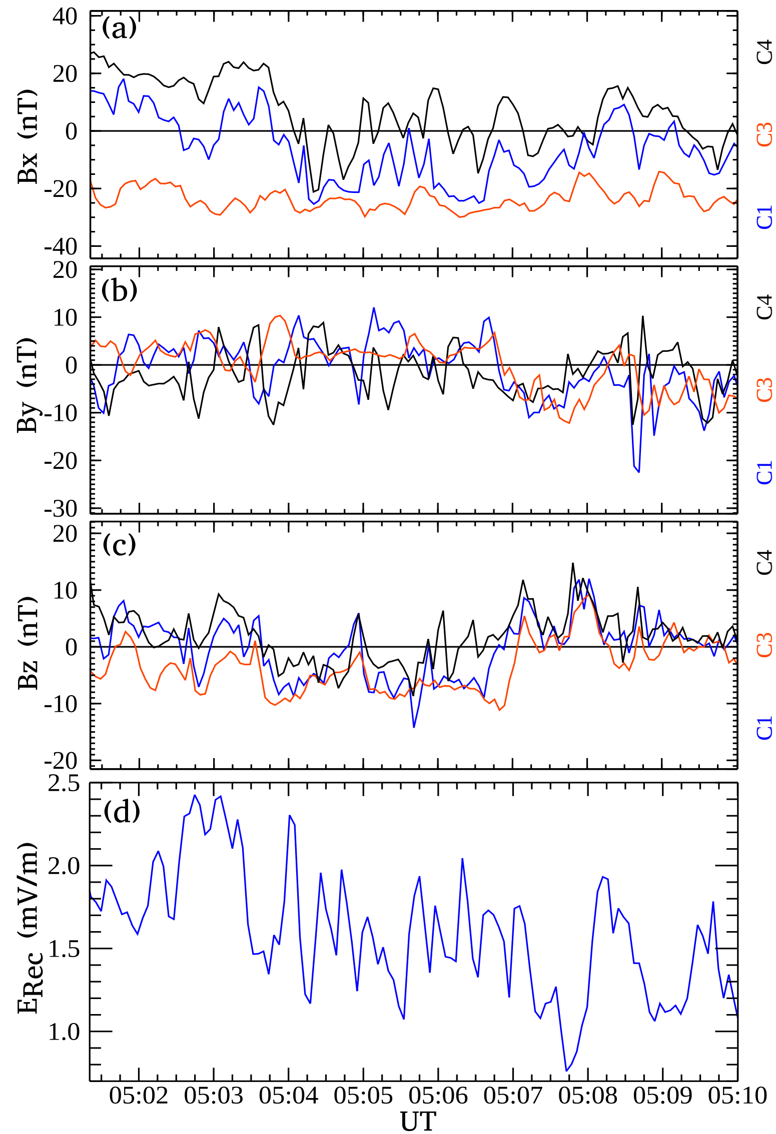


$$E = V_{In} B_{In}$$

* V_{In} *(Xiao et al. 2007)* * $B_{In} = B_x$



Analysis *Reconnection Case Studies*

Cluster Inflow Region

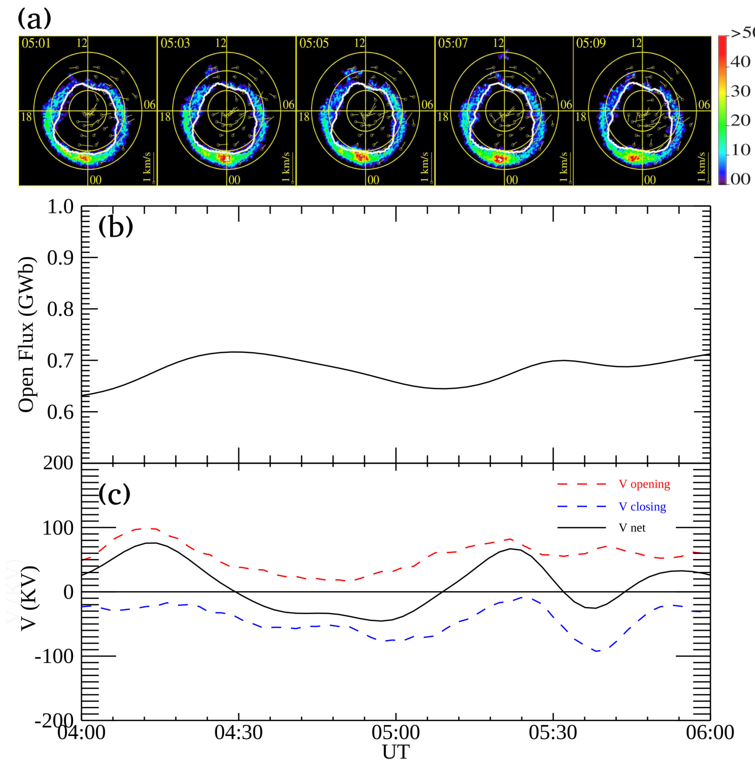
15 September 2001

Reconnection Voltage

CLUSTER

$$V_{Rec} = E\,L_y$$

IMAGE



Reliable boundary determination!
Φ, $V_{Reconnection}$ and E
In application of Faraday's Law
SI 12 (IMAGE) + SuperDARN

(Method from Hubert et al. 2006)

Analysis *Reconnection Case Studies*

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Cluster **Inflow** Region

15 September 2001

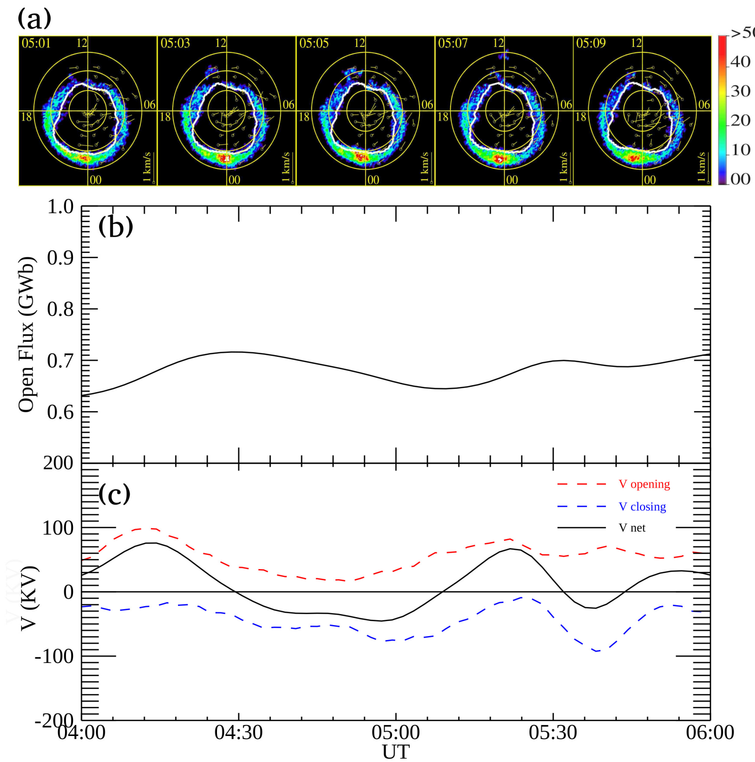
Reconnection Voltage

CLUSTER

$$V_{Rec} = E\,L_y$$

$$L_y\ ??$$

IMAGE



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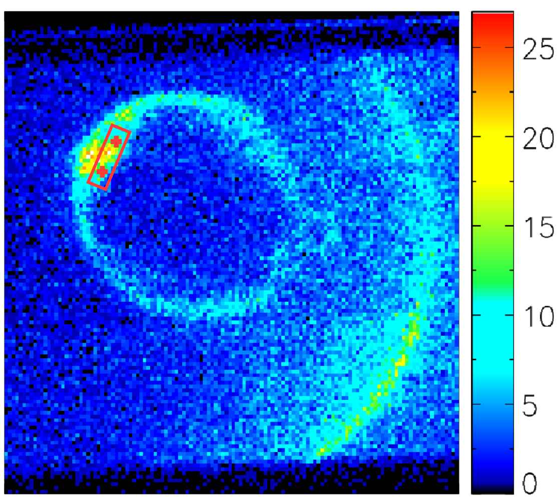
L_y ??

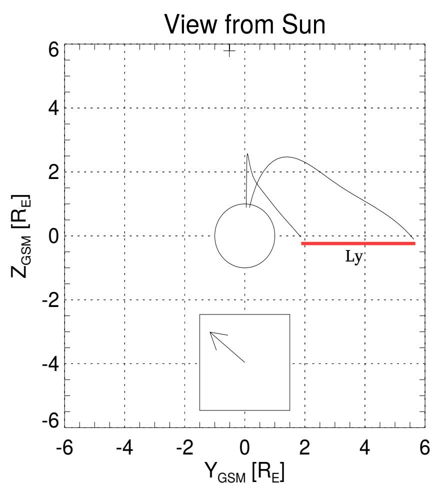
Mapping Tail ⇌ Ionosphere

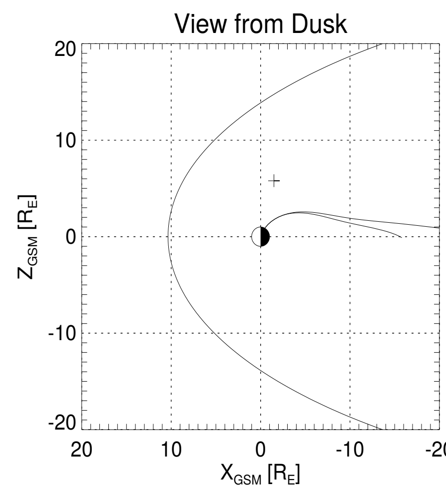
Tsyganenko 96

Steps

1. From Cluster to the ionosphere ⟹ MLT
2. From the O/C boundary to the tail ⟹ L_y







Reconnection site $L_y \approx 3.76\ R_E$

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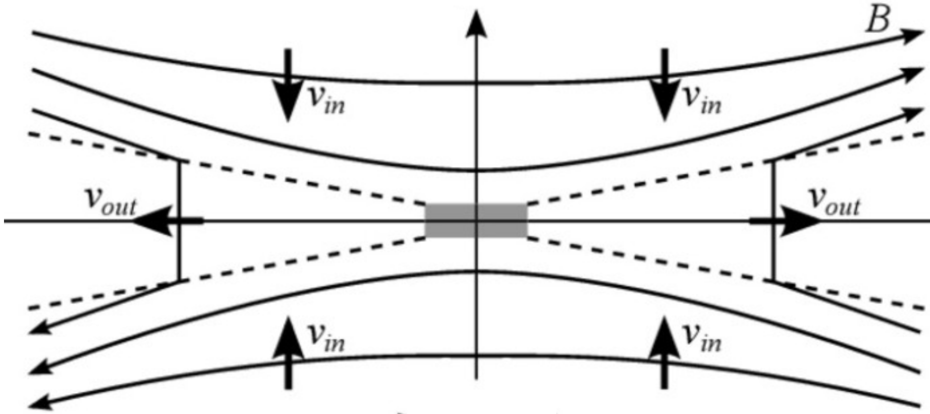

Cluster Outflow Region

22 August 2001

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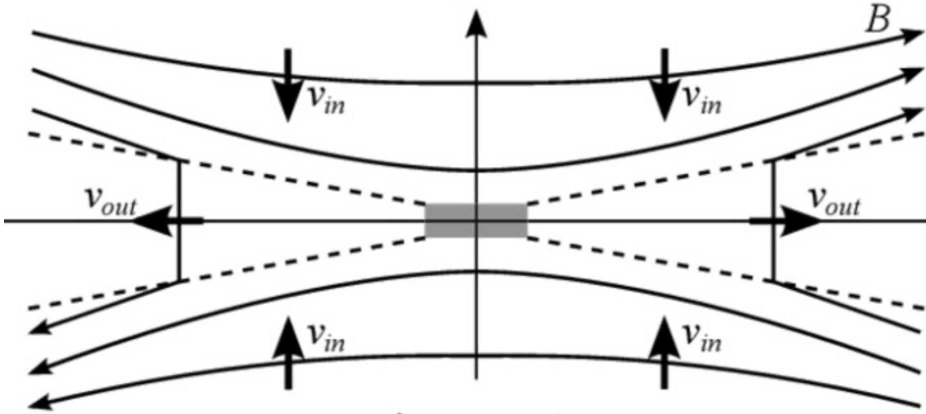
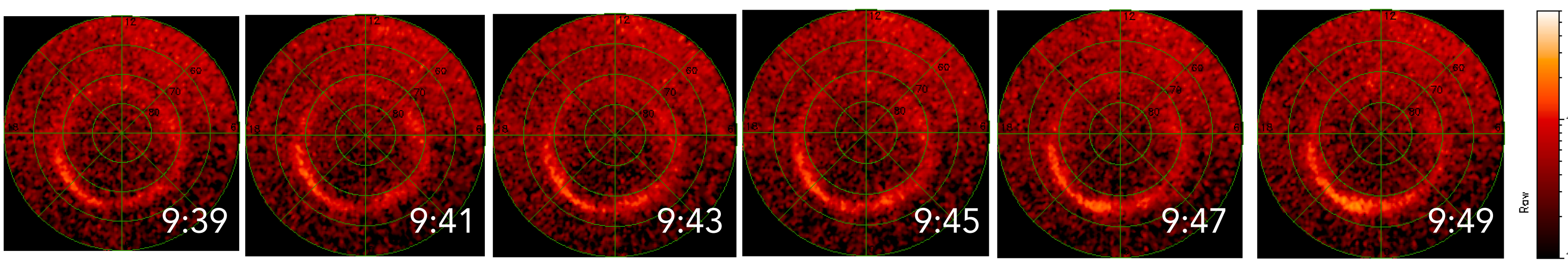


Cluster Outflow Region

22 August 2001



SI12 (IMAGE)

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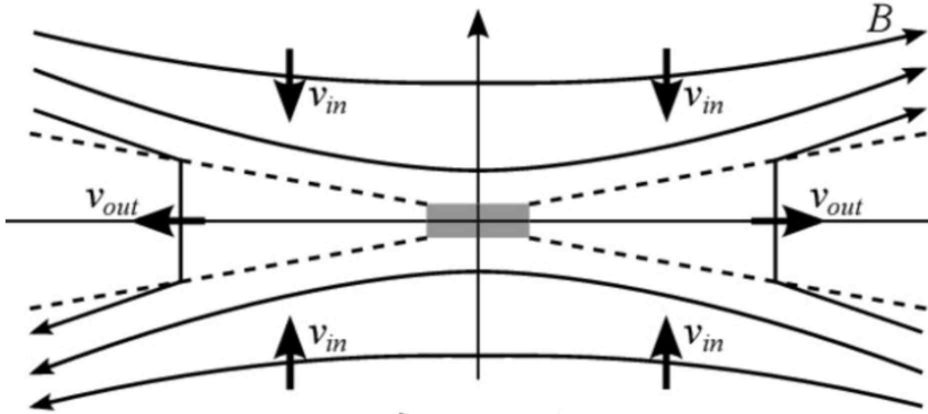

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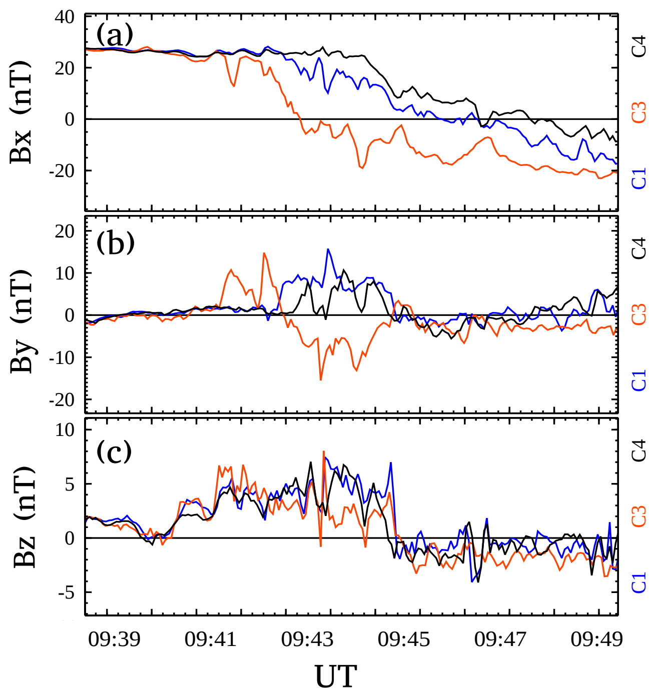

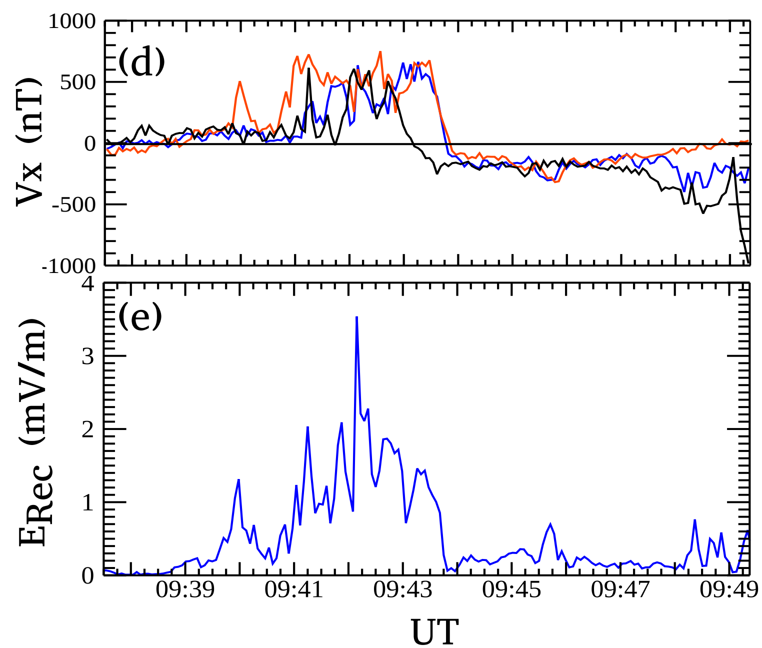

$$E = U_{Out} B_{Out}$$

$^*U_{Out} = V_x$

$^*B_{Out} = B_z$

Analysis *Reconnection Case Studies*

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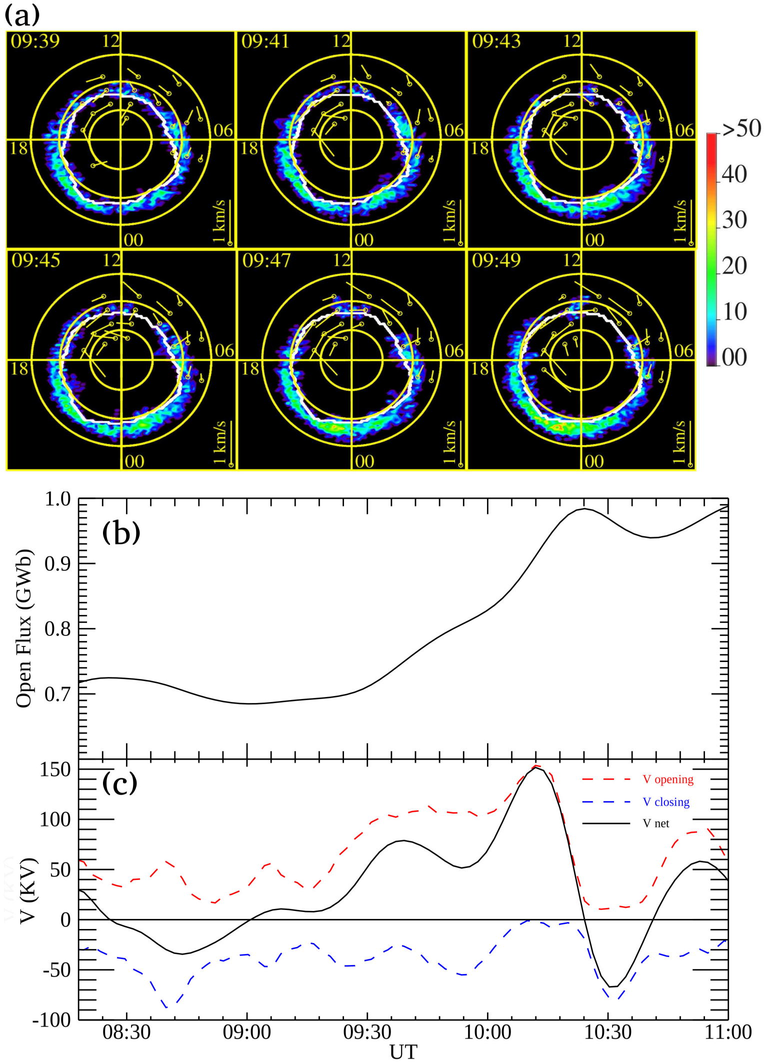
IMAGE



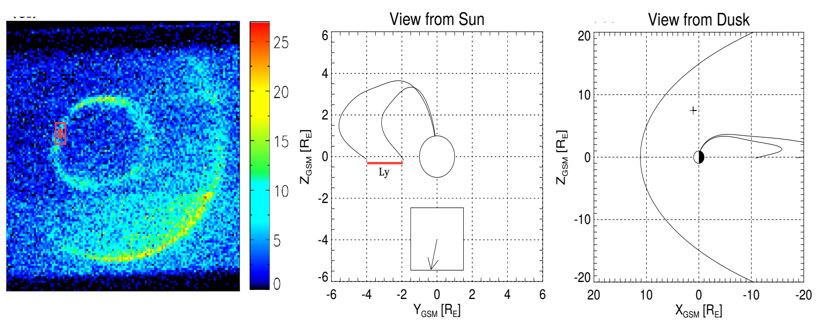
Cluster Outflow Region

22 August 2001

Reconnection Voltage

CLUSTER

$$V_{Rec} = E\, L_y$$



Reconnection site $L_y \approx 1.90\ R_E$

Analysis

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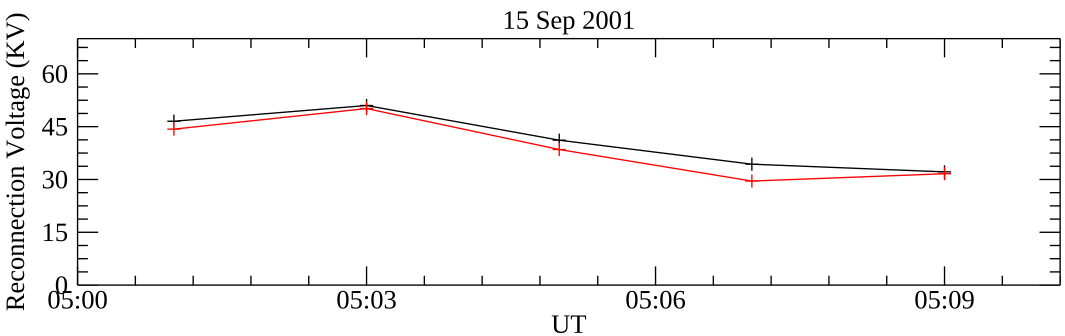
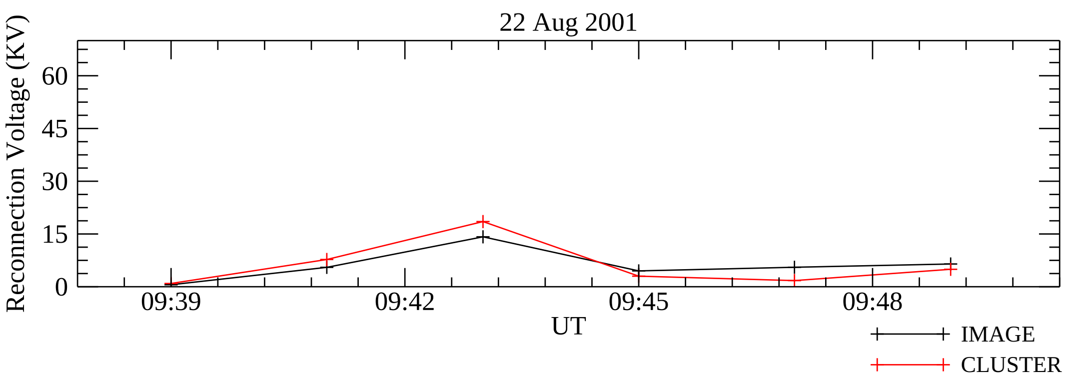
Reconnection Voltages

Cluster/IMAGE



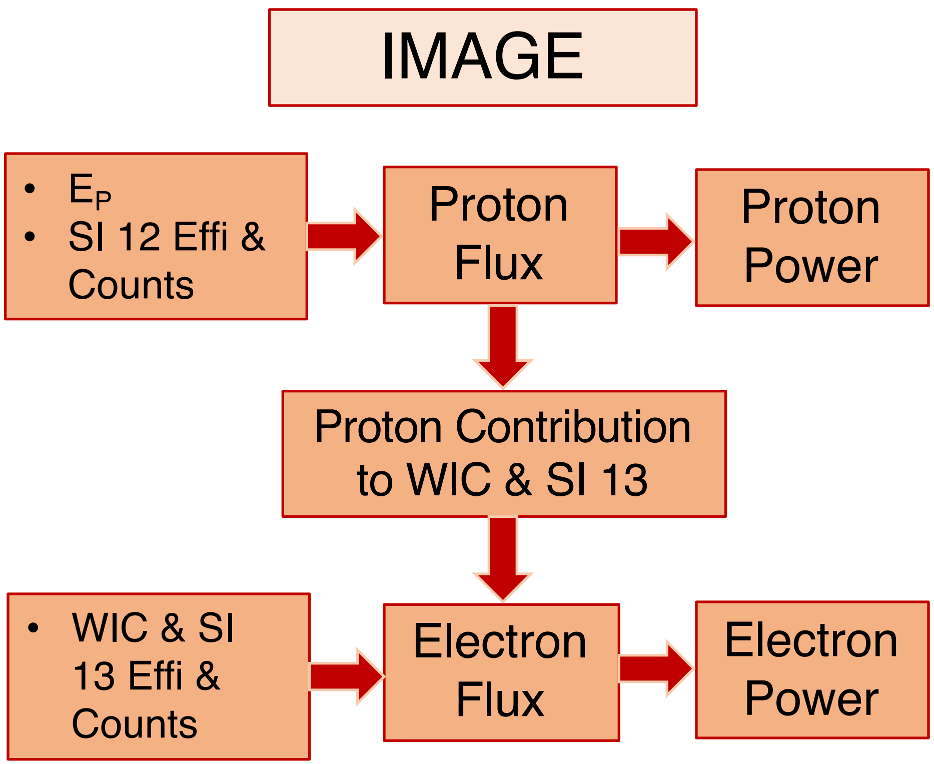
Nearly perfect match!



Analysis

Energy Circulation

Cluster/IMAGE



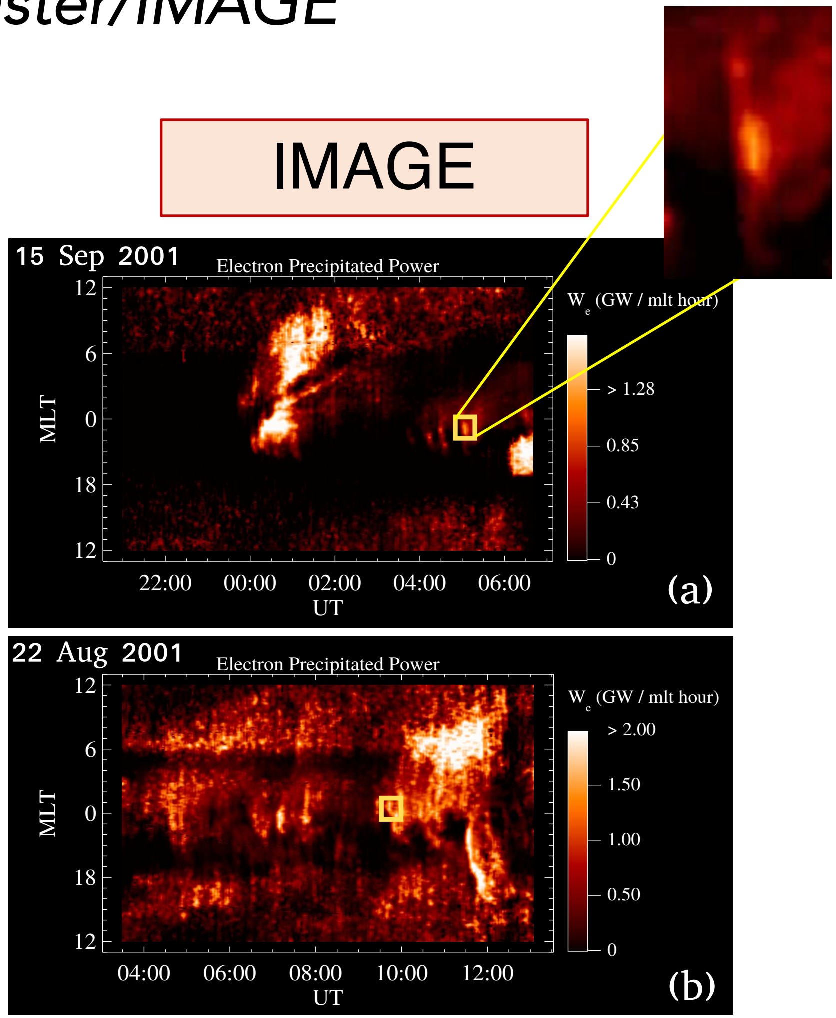
(Hubert et al. 2002)

Analysis

Energy Circulation

Cluster/IMAGE

IMAGE



Analysis

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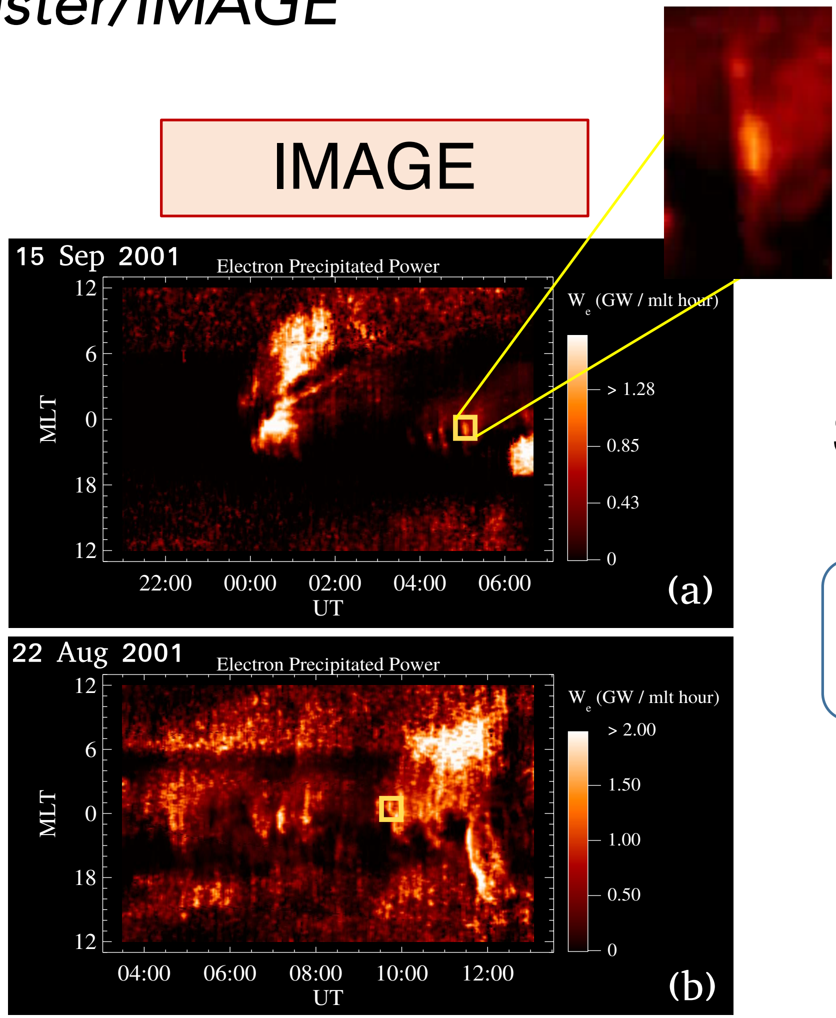
Energy Circulation

Cluster/IMAGE

IMAGE



CLUSTER

$$S_{In} = \frac{(V_{In} B_{In}{}^{2})}{\mu_0} \; ; \quad S_{Out} = \frac{(V_{Out} B_{Out}{}^{2})}{\mu_0}$$

$$W_{Released} = S_{In} L_y L_x - S_{Out} L_y L_z$$

(in GWatt)

Analysis

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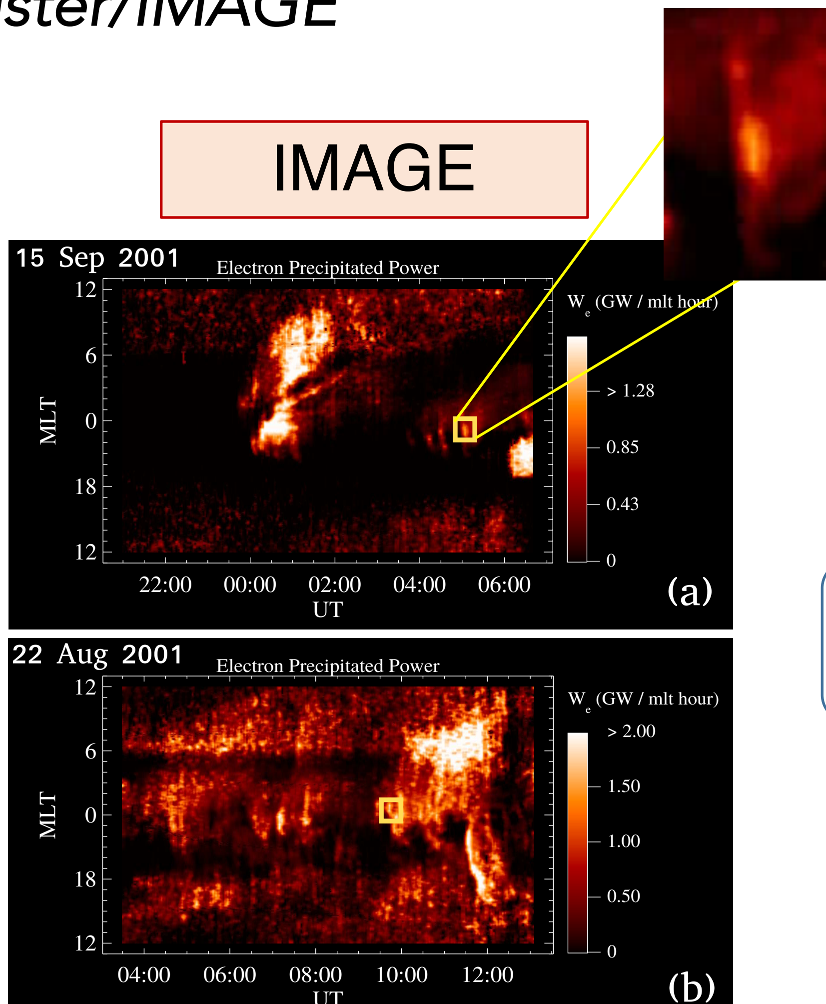
Energy Circulation

Cluster/IMAGE

IMAGE



CLUSTER

$$S_{In} = \frac{(V_{In} B_{In}{}^2)}{\mu_0} \; ; \quad S_{Out} = \frac{(V_{Out} B_{Out}{}^2)}{\mu_0}$$

$$\boxed{W_{Released} = S_{In}\, L_y\, L_x \cancel{- S_{Out}\, L_y\, L_z}}$$

(in GWatt)

Distance
Earth-Reconnection site

>>

Analysis

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Energy Circulation

Cluster/IMAGE

	Time	W_{In}	W_{Out}	$W_{CLUSTER}$	W_{IMAGE}
15 Sep 2001	5:01	64.827	0.329	32.249	3.297
	5:03	83.051	0.218	41.417	3.406
	5:05	43.034	0.587	21.223	4.071
	5:07	25.146	0.322	12.412	2.432
	5:09	26.328	0.234	13.152	3.415
22 Aug 2001	9:39	43.748	0.052	21.848	1.801
	9:41	111.947	0.337	55.805	3.178
	9:43	115.223	0.357	57.433	4.412
	9:45	42.438	0.048	21.195	5.154
	9:47	27.425	0.020	13.702	2.483
	9:49	47.060	0.060	23.500	3.193

$$W_{Cluster} = (W_{In} - W_{Out})/2$$

Sweet-Parker mechanism converts ½ of the electromagnetic energy into kinetic energy

Analysis

Energy Circulation

Cluster/IMAGE

	Time	W_{In}	W_{Out}	$W_{CLUSTER}$	W_{IMAGE}
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$$W_{Cluster} = (W_{In} - W_{Out})/2$$

Sweet-Parker mechanism converts ½ of the electromagnetic energy into kinetic energy

10-20% of the energy dissipated to aurora

Discussion

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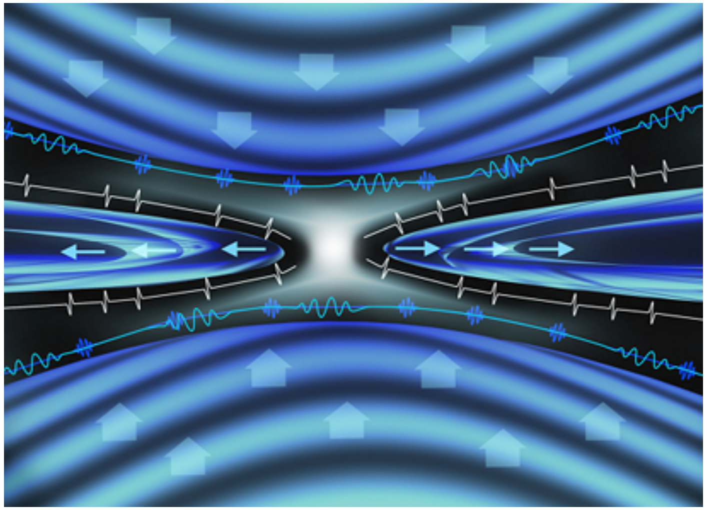
Plasma enters the reconnection site where it is accelerated to speeds of the order of V_A and escapes through the flanks, while the field topology is reconfigured.

Assumptions:

- **Symmetry** with respect to the reconnection site



- The **voltage** computed across 2 points on the OCB between which E is almost constant, is equal to the voltage computed across 2 points at the reconnection site

- **T96 mapping model** quite reliable as the tail-ionosphere mapping pointed at an MLT close to the intensification of the aurora relating reconnection to the bright spot

Conclusion

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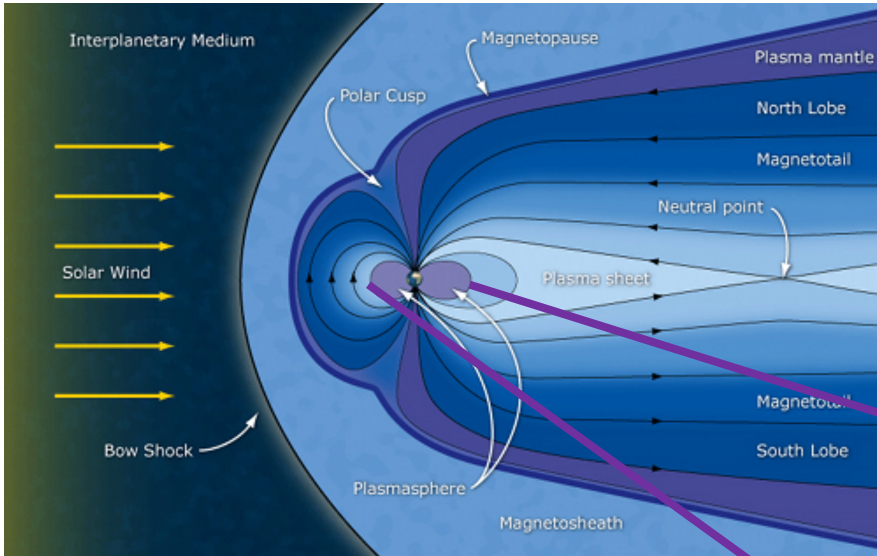
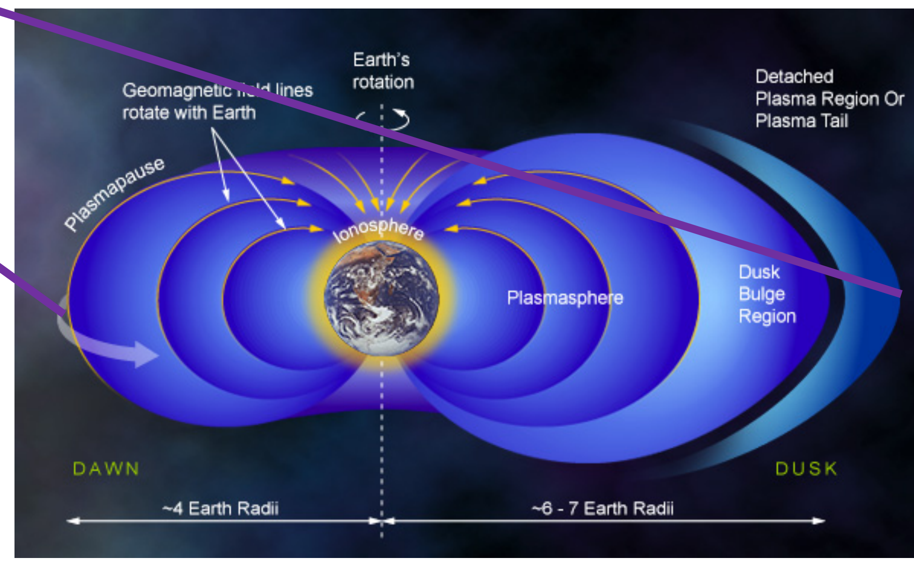
- Global auroral images are compared to reconnection measurements in the magnetotail
- Direct correspondence between the nightside reconnection rates and the aurora / Reconnection voltages estimated match nearly perfectly!
- The match tells that we are comparing two directly related phenomena
- Nightside energy dissipated into the aurora is estimated to be between 10-20% and the rest is contribution from other processes

Submitted to JGR: Space Physics

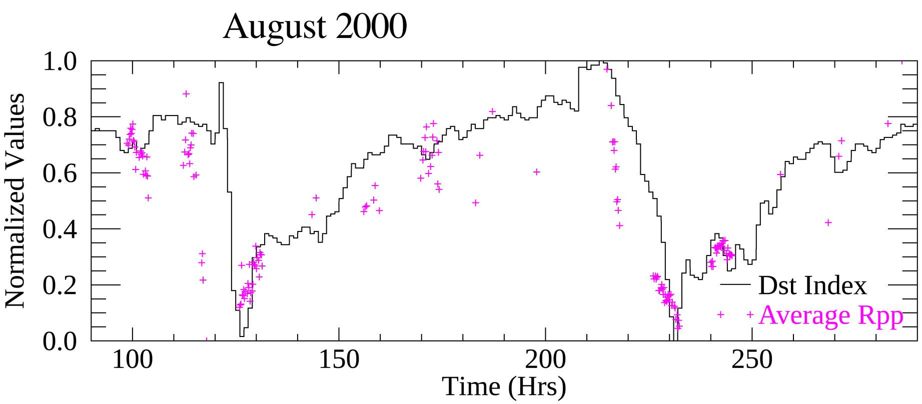
Project 1

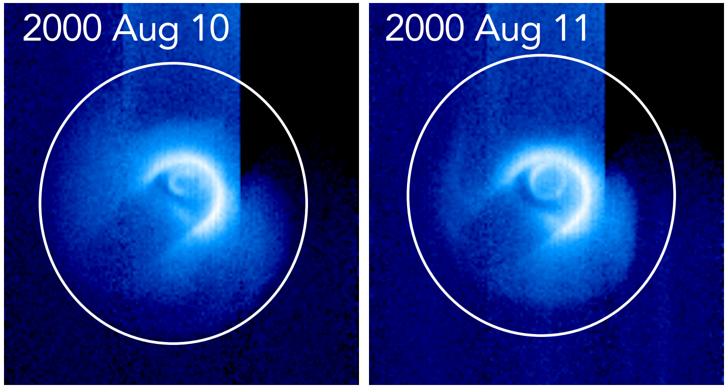


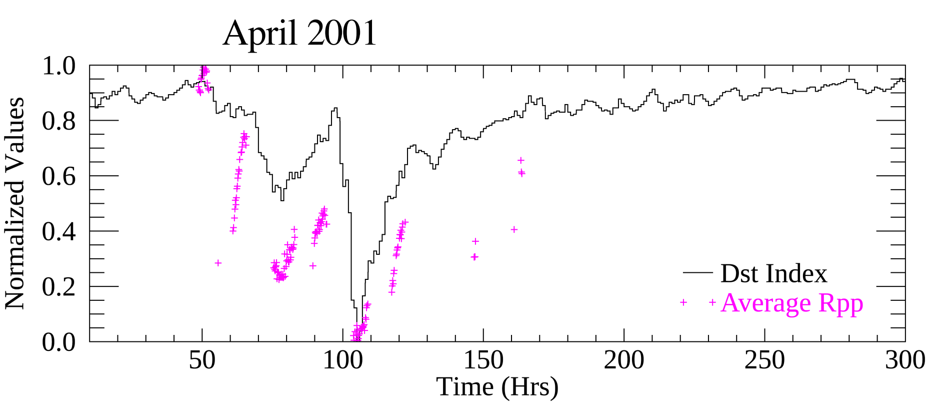
Project 2

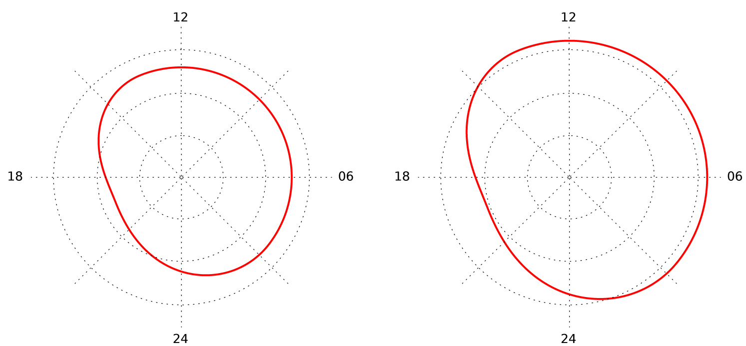


Trapped Particle Response During Storms









Effect Of Magnetic Reconnection Over The Space Environment Of The Earth

Thank you

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V_{Rec} IMAGE Calculation

$\Rightarrow$ Creation of polar ionospheric convection $\vec{E_i}$ = - $\vec{u_i} \times \vec{B}$
Faraday's Law of Induction:

$$\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} \quad \Phi = \int_S \vec{B}.\vec{n} d\sigma \quad \frac{d\Phi}{dt} = -\oint \vec{E}.d\vec{l} = V$$

$$\vec{E} = \vec{E_i} + \vec{\nu} \times \vec{B}$$

$\Rightarrow$ Retrieve open magnetic flux and reconnection voltages from SuperDARN + SI 12