

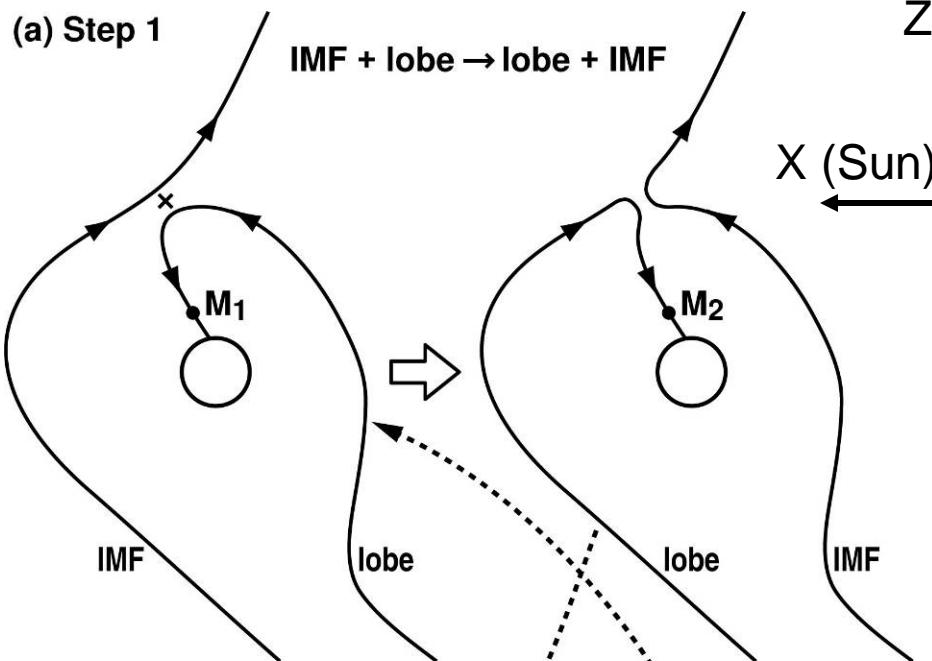
惑星間空間磁場北向き時の交換型 リコネクションによる対流

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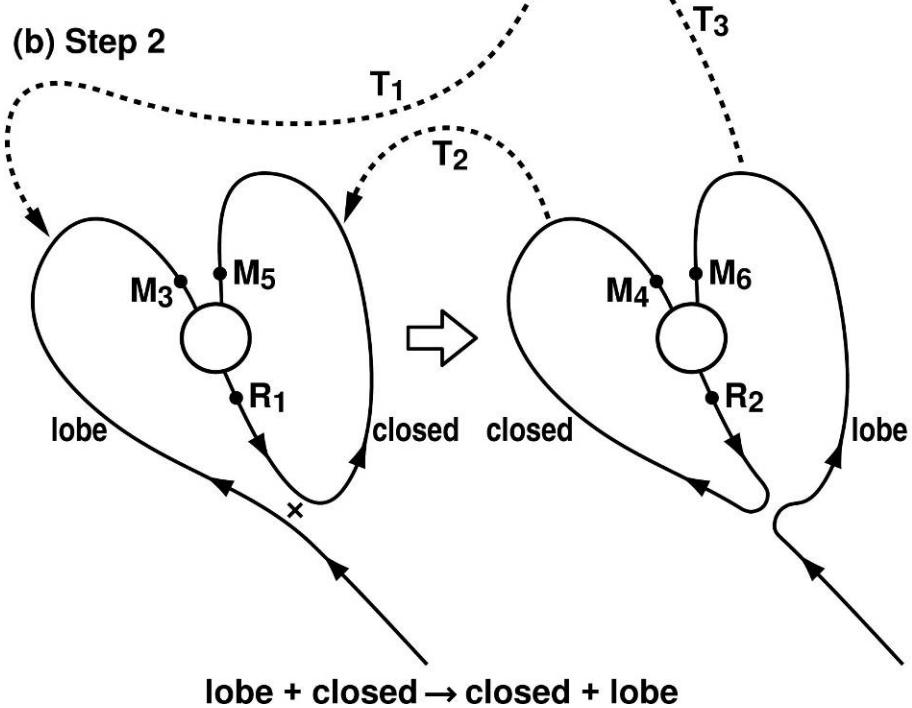
1. 九州大学
2. 気象大学校

Interchange cycle

(a) Step 1



(b) Step 2

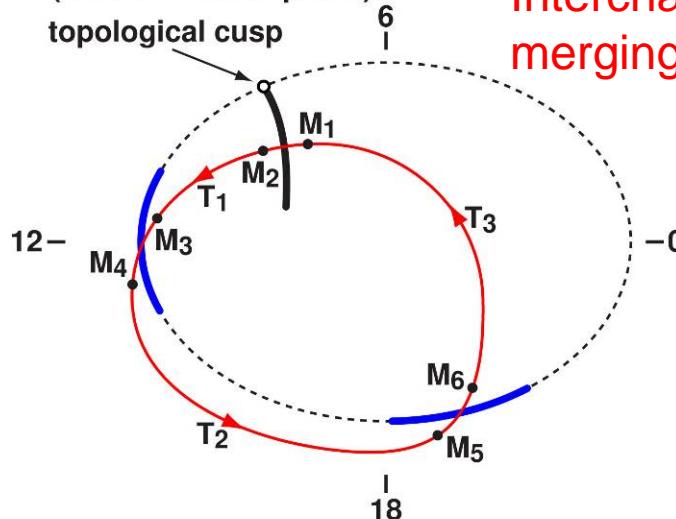


X (Sun)

Z (north)

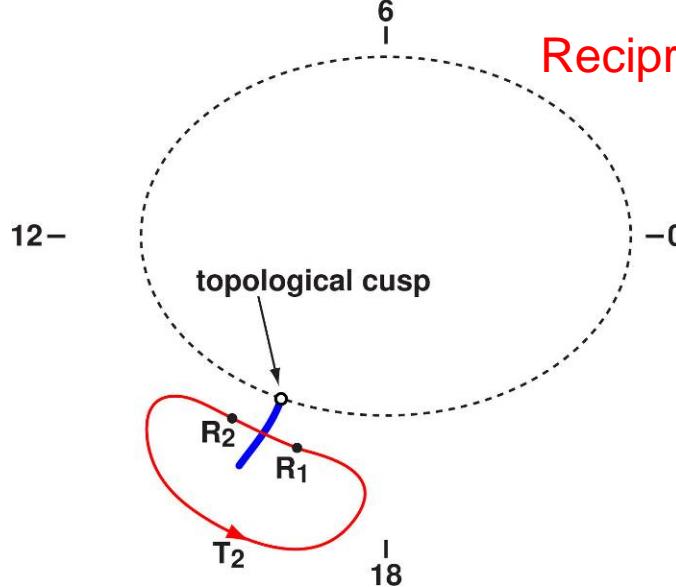
(a) Hemisphere of IMF-lobe reconnection
(Northern Hemisphere)
topological cusp

Interchange-type
merging cell



(b) Hemisphere of lobe-closed reconnection
(Southern Hemisphere)

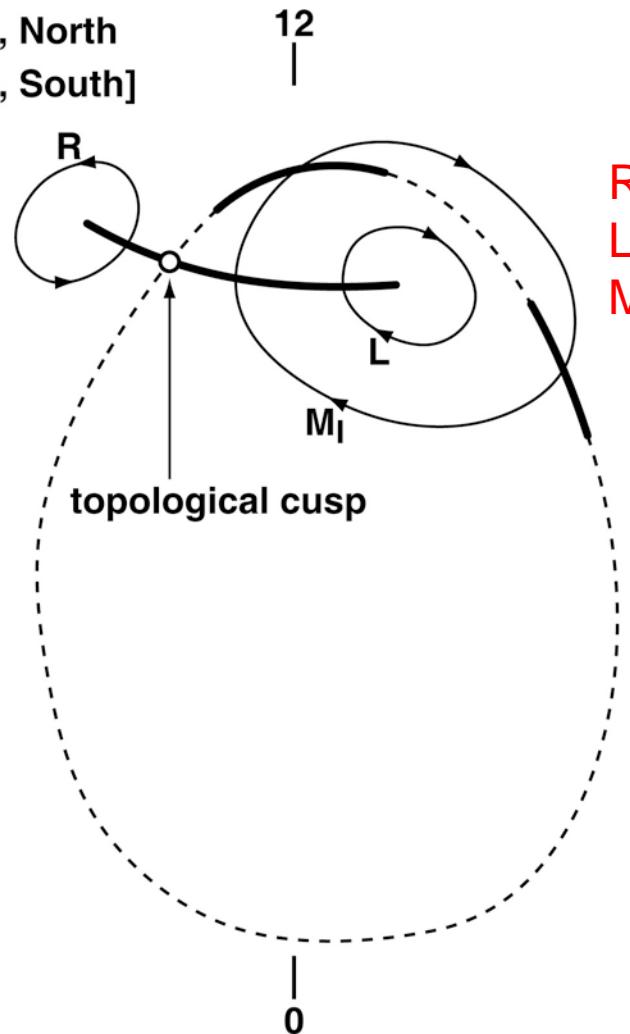
Reciprocal cell



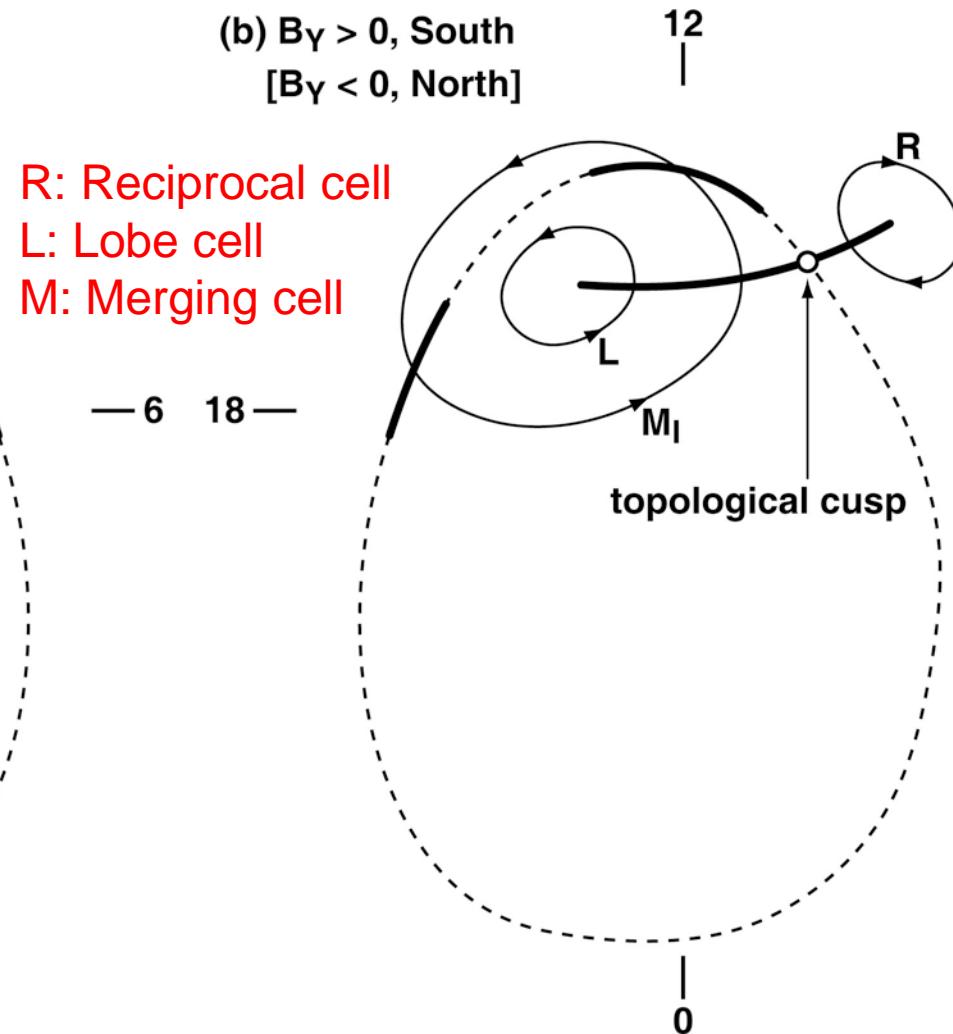
Interchange cycleの一帰結: 電離圏対流 ($\theta_{\text{IMF}} \sim 20^\circ$ の場合)

Expected ionospheric convection at $\theta_{\text{IMF}} \sim 20^\circ$

(a) $B_Y > 0$, North
[$B_Y < 0$, South]



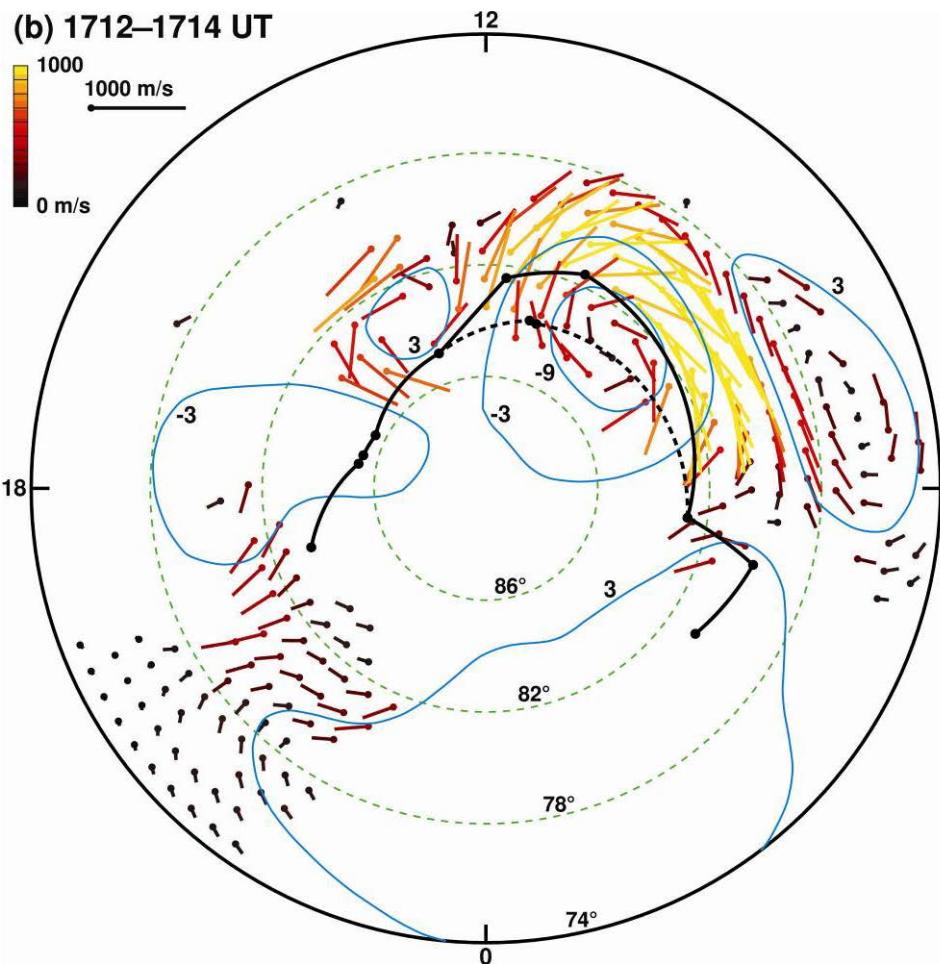
(b) $B_Y > 0$, South
[$B_Y < 0$, North]



R: Reciprocal cell
L: Lobe cell
M: Merging cell

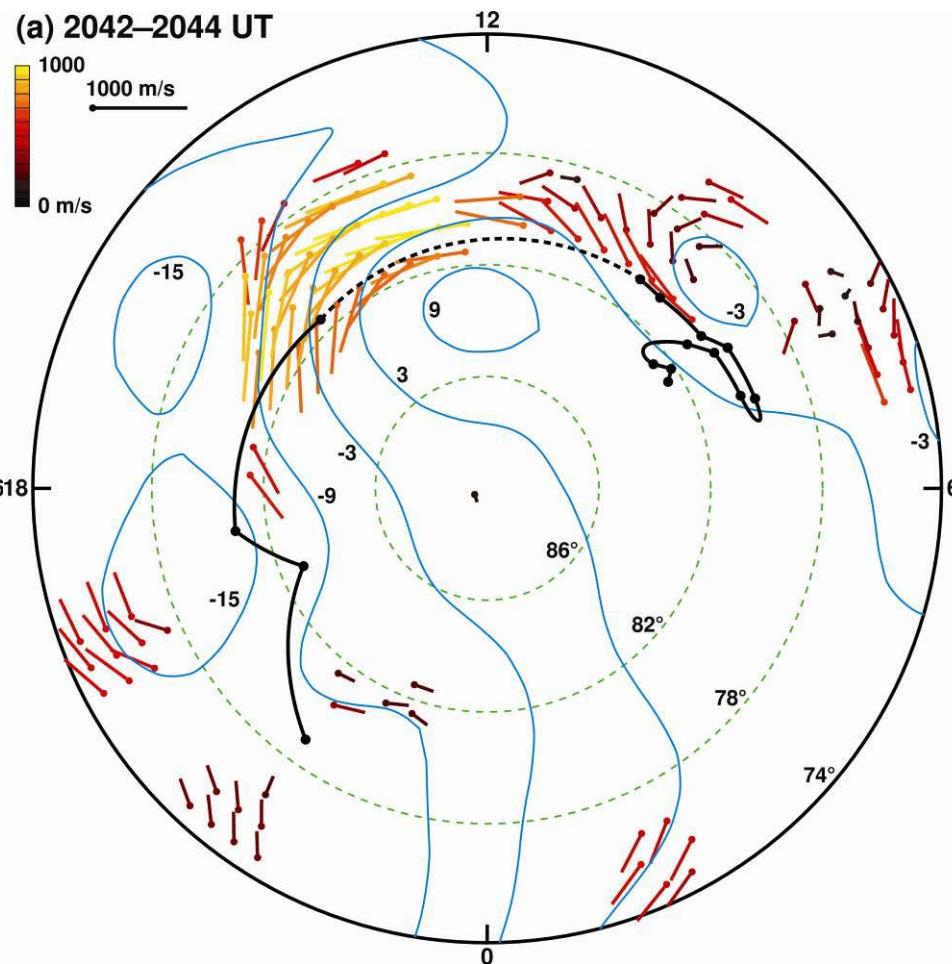
Interchange cycleを支持する観測

IMF $B_Y < 0$ 北半球



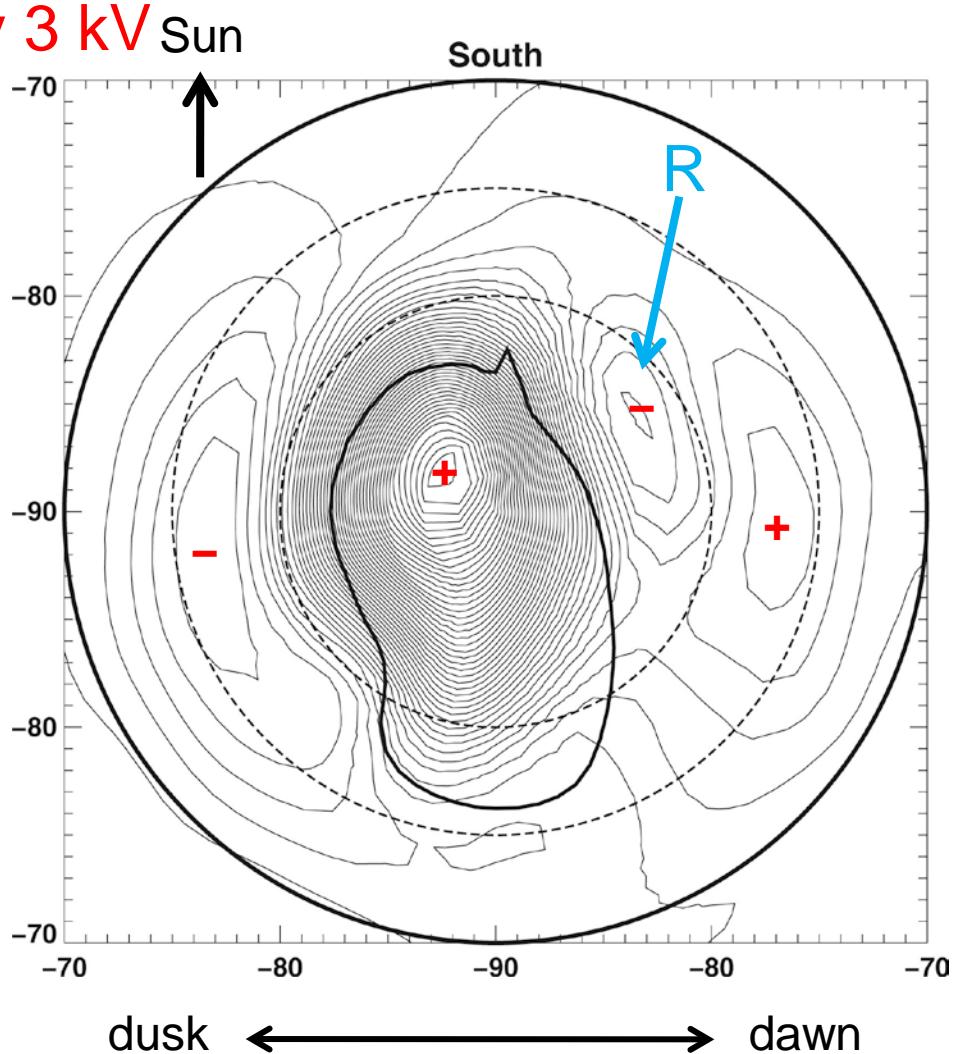
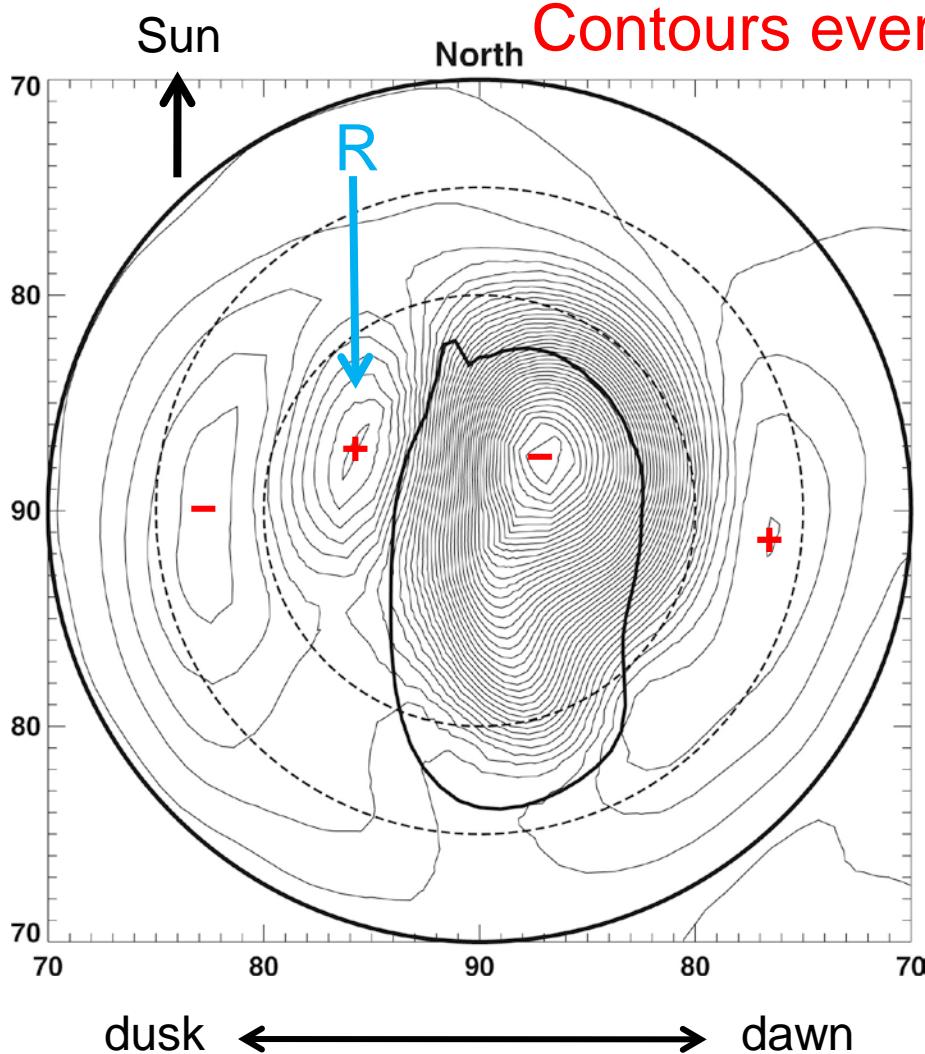
22 March 2008

IMF $B_Y > 0$ 北半球



8 March 2008

Reproduction of reciprocal cells in MHD modeling



$B_{\text{IMF}} = 5 \text{ nT}$, $\theta_{\text{IMF}} = 20^\circ$ ($B_Y > 0$)

$V_{\text{SW}} = 350 \text{ km/s}$, $N_{\text{SW}} = 5 \text{ #/cc}$, $T_{\text{SW}} = 50,000 \text{ K}$

Reconnection in 3D

A necessary and sufficient condition for a general magnetic reconnection (Schindler et al., 1988):

$$\int E_{\Box} ds \neq 0 \quad \text{Integration along a field line}$$

Reconnection rate $R_{rec} \propto E_{\Box}$

In MHD modeling, E_{\Box} is useful to identify the reconnection mode.

Direct proof of interchange cycle: Field-aligned electric field on separatrices

Field-aligned electric field calculation

- Normalized electric resistivity

$$\bar{\eta} = \frac{\eta}{\mu_0 L_0 v_0} \quad \mu_0 = 4\pi \times 10^{-7} \text{ H/m}$$
$$L_0 = 6370 \text{ km} \quad v_0 = 53.2 \text{ km/s}$$

- Model resistivity

$$\bar{\eta} = \bar{\eta}_m + \bar{\eta}_n \quad \bar{\eta}_n: \text{numerical resistivity}$$

$$\bar{\eta}_m = 0.001 \frac{(J/J_0)^2}{(B/B_0)^2 + 0.003^2} \approx \frac{0.001}{(\Delta l/L_0)^2}$$

$$B_0 = 10 \text{ nT}$$

$$J_0 = 1.26 \text{ nA/m}^2$$

$$\bar{\eta}_m \square \bar{\eta}_n$$

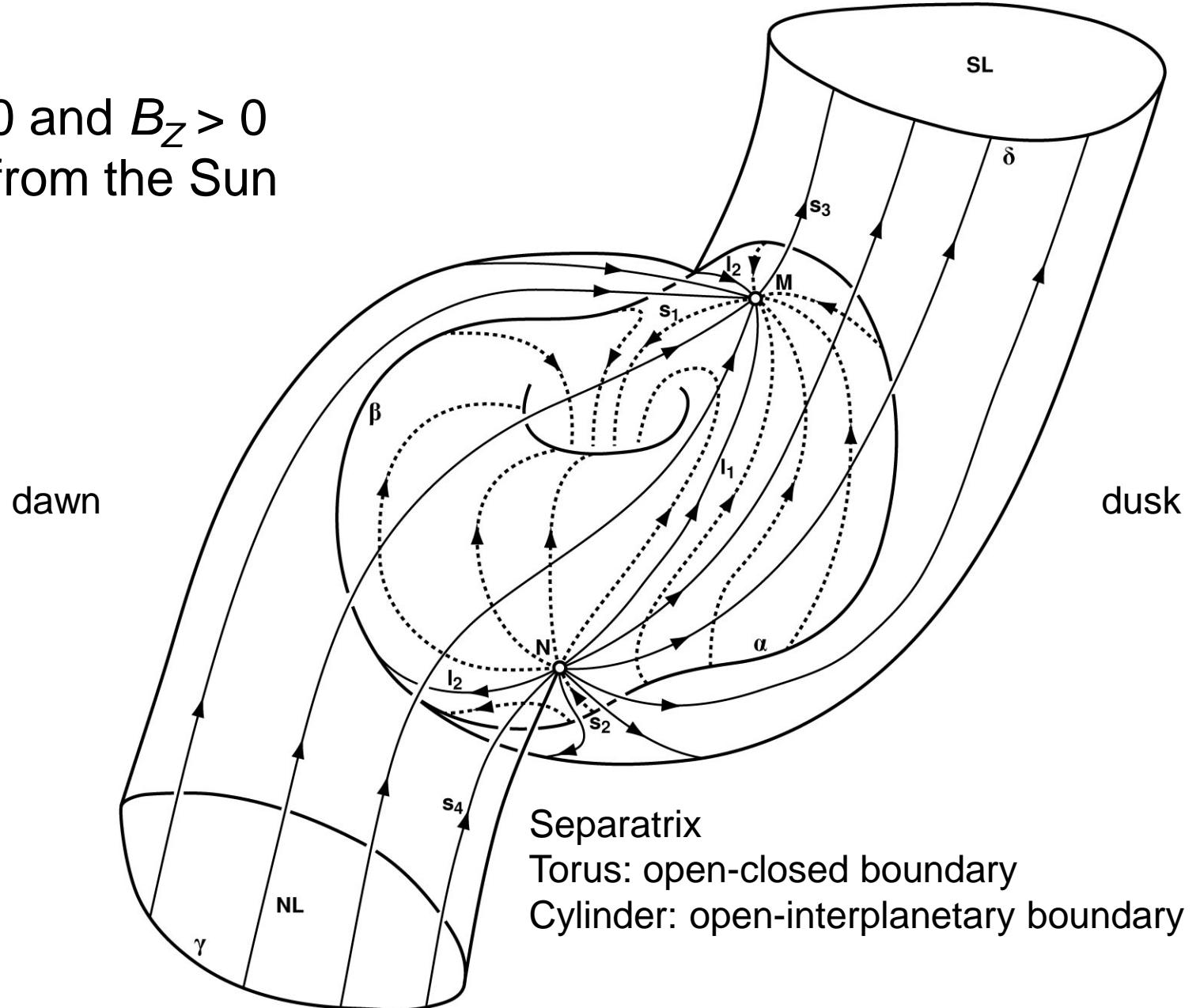
- Ohm's law

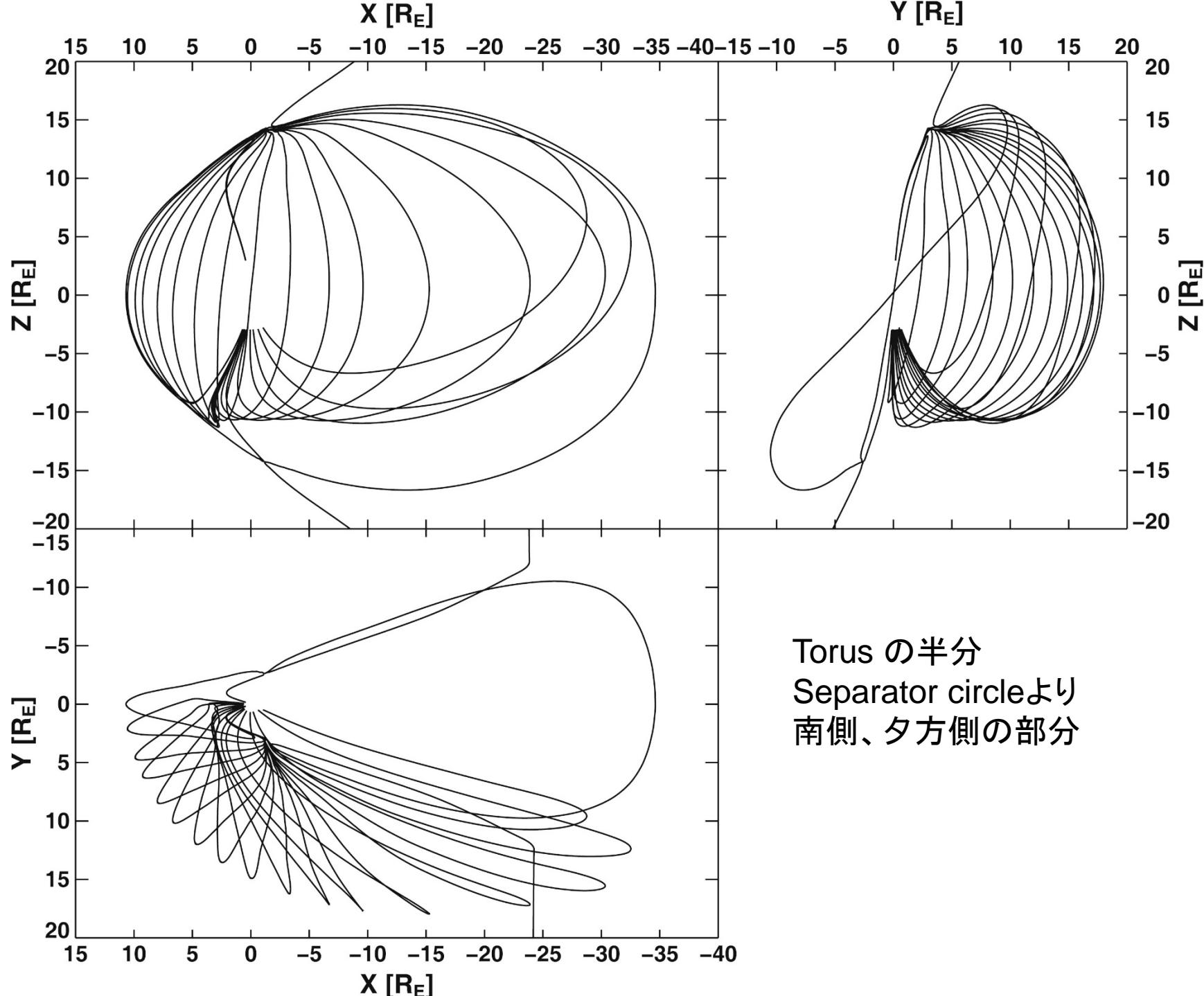
$$\mathbf{E} + \mathbf{v} \times \mathbf{B} = \eta \mathbf{J}$$

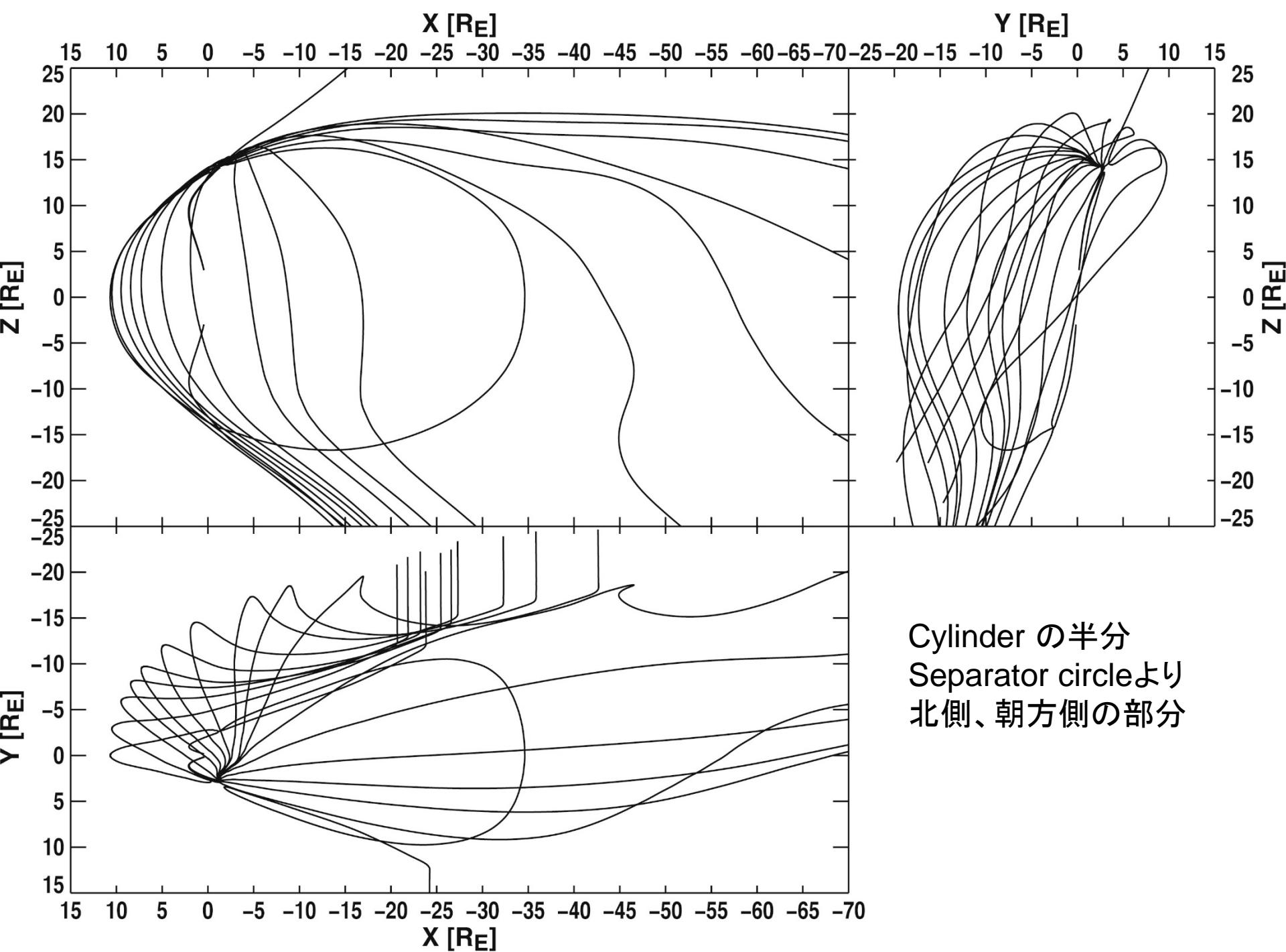
$$E_{\square} = \eta J_{\square}$$

The “2 null – 2 separator” topological structure

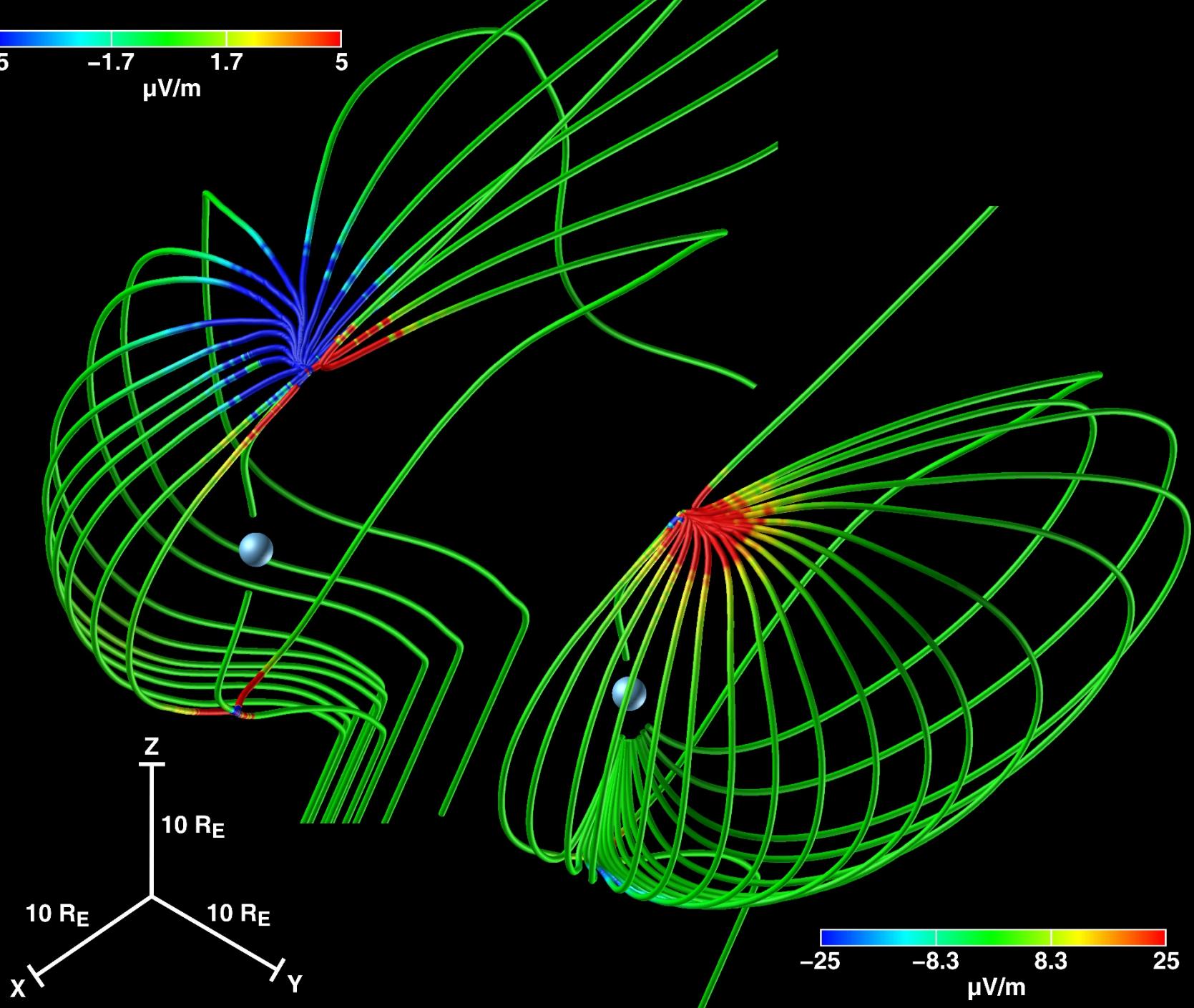
$B_Y > 0$ and $B_Z > 0$
view from the Sun





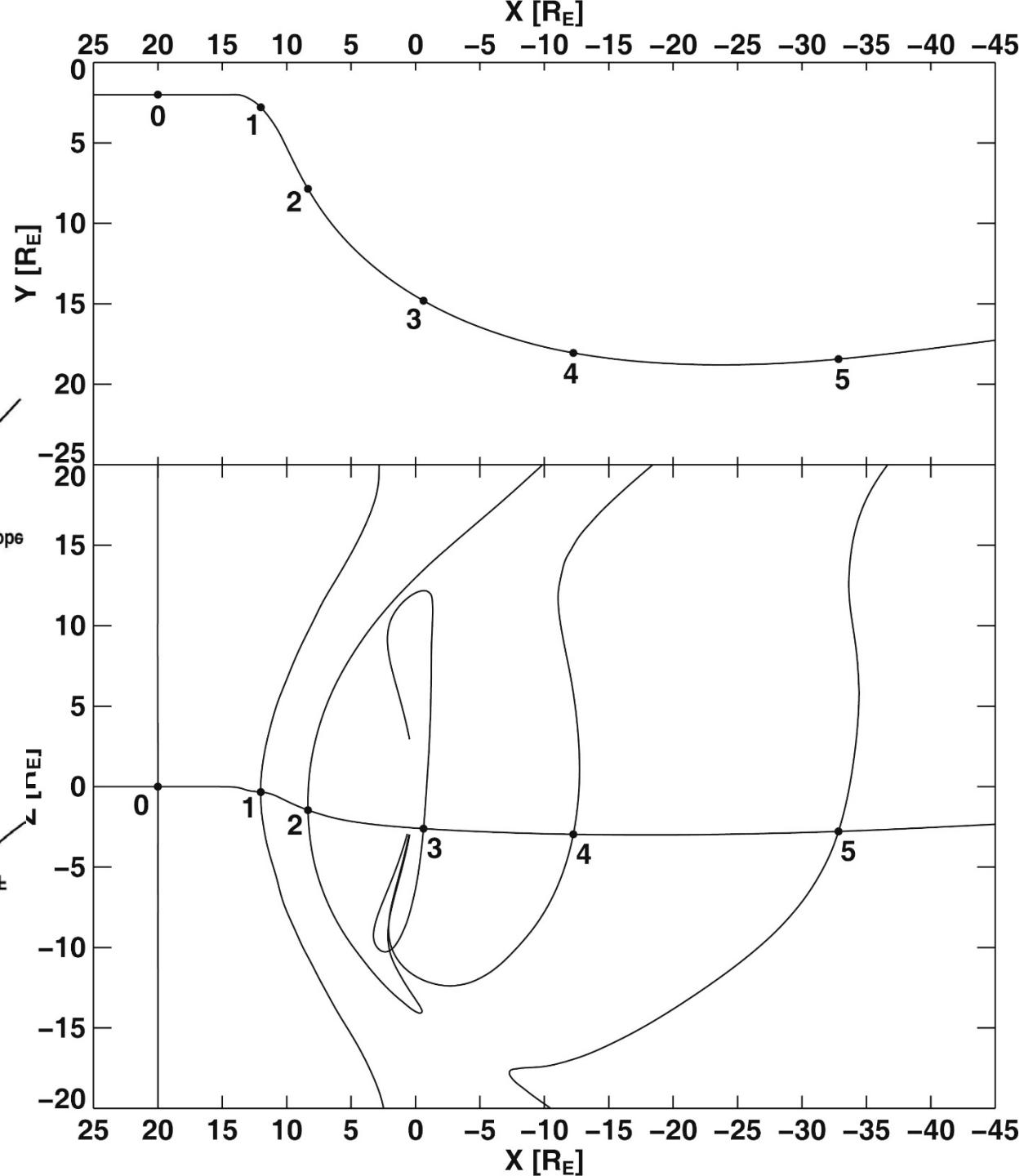
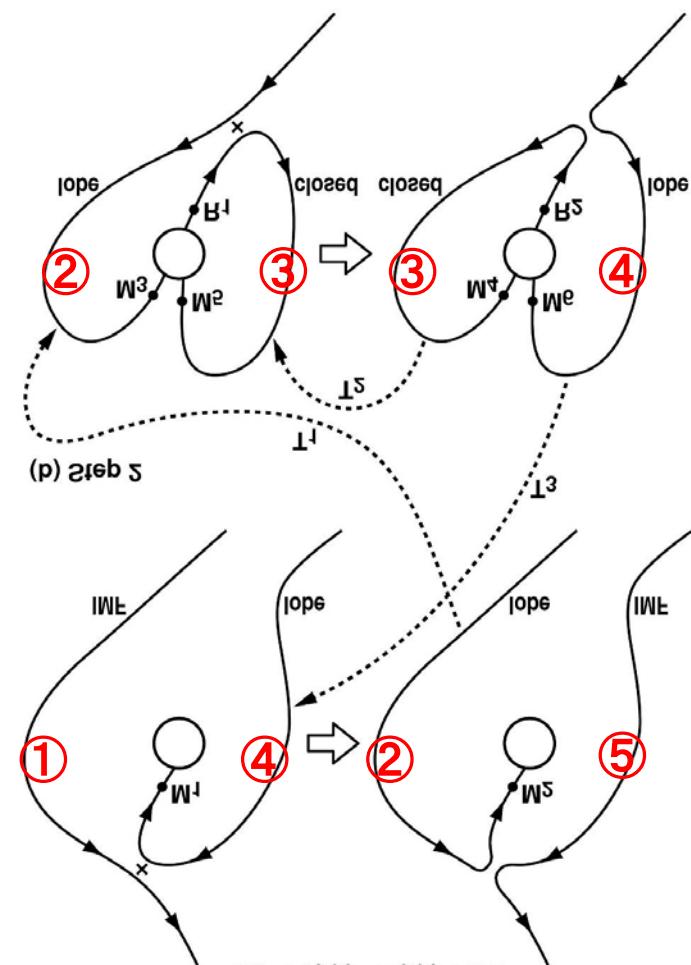


Cylinder の半分
Separator circleより
北側、朝方側の部分



Interchange cycle の間接的証拠2

$(X, Y, Z) = (20, 2, 0)$ を通る流線
に沿って磁力線トポロジーの変化を追ってみると



結論

- Interchange cycleはMHDモデルで確実に再現されており、現実の磁気圏でも起こっている可能性が高い。