サブストームのトポロジー

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Magnetic Topology inducing the substorm

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Now, the substorm can be reproduced by the global simulation, and the mechanism of the substorm has become clear without including estimations. Although the growth phase is a strengthening of convection, flow does not reach the center of the plasma sheet, but becomes reflux toward the dayside passing through the surface of the plasma sheet. In this flow pattern, shear motion induces the quiet arc. The thinning is due to the sweeping out of magnetic flux from the inner edge of the plasma sheet by convection. It is not due to the increase in lobe pressure.

Seeing most globally, the onset is a change in convective path. This change is a state transition of convection system. After the transition, flow passes through the center of the plasma sheet, reaches the inner magnetosphere, and returns toward the dayside from there. The transient tip is observed as the dipolarization front. The state transition is a change in force balance. The BBF and the injection are parts of the change in force balance. Injection at transient stage forms a compact pressure regime which acts as the near Earth dynamo and generates an onset current system. The dipolarization corresponding to the injection is an increase of magnetic tension, but not a decrease. In the expansion phase, the ionospheric Hall current generates polarization and forms the WTS (westward traveling surge).

A large question left is the NENL formation process. What occurs if we inspect the NENL formation correctly? To do this, the null-separator structure is required. Under the northward IMF (interplanetary magnetic field), there are two nulls near the cusp of both hemispheres, forming the 2 null 2 separator structure. The deformation process from the 2 null 2 separator structure to the NENL formation is a key of substorm topology. It can be understood through three phases.

Phase 1: After a southward turning of the IMF, old 2 nulls retreat tailward, and new 2 nulls corresponding to the southward IMF are formed on the day side in the low latitude region. From new nulls, null lines extend along the frank magnetopause to old nulls.

Phase 2: The plasma sheet reconnection (also the early stage of the lobe reconnection) proceeds in the remnant tail structure formed under the northward IMF. In this structure, the retreating nulls change the configuration of the tail magnetic field to form a By outstanding structure in the plasma sheet just behind the dipole magnetic field. Strange to say, this deformation involves intersecting cross of magnetic fields. Similarly, retreating nulls generate magnetic field lines connecting themselves and the midnight inner mganetosphere. At the midnight reconnection point, a mixing occurs between different magnetic field lines through the By component. This process leads to the formation of the core By.

Phase 3: When By dominated magnetic fields of the plasma sheet is swept out downtail as the plasmoid, outer layers on the northern and southern sides contact to make the near earth tail shift to the state of the lobe reconnection. The midnight reconnection point is expanded to a line, and strong tension is activated in the x direction.

サブストームでの NENL の形成過程を調べる。サブストームのトポロジーを反並行リコネクションで理解するのは、誤りであろう。正しくは、ヌルーセパレーター構造の発展により理解する必要がある。これは、以下のような 3 段階で理解できる。

第 1 段階：北向き IMF では、両半球のカスプ付近にヌルがあり、２ヌル２セパレーター構造がある。IMF 南転後は、これらのヌルは反太陽方向に後退する。昼側には新たに南向き IMF に対応したヌルができる。

第 2 段階：旧ヌルの後退によって、テイルの磁場構造が変形される。これはヌルで磁場の結合が変えられるためである。双極子磁場のすぐ後方には、By が卓越する領域ができる。この構造には、交差磁場を含む。またヌルと真夜中を結ぶ磁場ができる。プラズマシートリコネクションは、北向き IMF でできた構造の残存中で起こる。真夜中で、By 成分の卓越により、磁場の繋ぎ変わりが発生する。

第 3 段階：By の卓越した構造がコアー By となりプラズモイドとして掃き出される。その後、南北のローブ磁場が接近し、NENL の状態ができる。リコネクションは点から線に拡大する。