Interaction between the skeletal magnetic field and plasma dynamics in the solar wind-magnetosphere system under the northward IMF condition

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When plasmas in the magnetosphere and solar wind are taken away, the magnetic field becomes a superposition of the Earth's dipole magnetic field and the homogeneous interplanetary magnetic field (IMF). Furthermore, this superposed magnetic field is stable. Consequently, this magnetic field can be regarded as the skeletal field of the solar wind-magnetosphere system. Figure 1 shows the skeletal magnetic field in the northwestward IMF condition. (This figure is a modified one from that of Lau and Finn (1990).) Both the last closed field lines extending to the northern hemisphere and field lines on the boundary between IMF and the open field lines radiate out from the null point B where the magnetic field intensity is 0. The two surfaces formed by bundles of the field lines are called Σ_B. At the same time, the last closed field lines from the southern hemisphere as well as all field lines on the boundary between IMF and open field lines converge on the null point A (this surface is called Σ_A). The separators are special field lines connecting two null points. The bundle of the last closed field lines forms a torus. At the same time, the torus is divided into two parts of Σ_A and Σ_B by the separators. On the other hand, the open field-IMF boundary becomes cylinders extending parallel (Σ_B) and antiparallel (Σ_A) to IMF, and two cylinders touch each other on the separator.

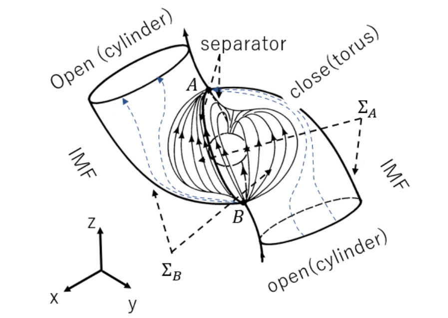

Figure 1 Schematic illustration of the skeletal magnetic field in the solar wind-magnetosphere system for the northward IMF condition.

The structure of the real magnetosphere is determined by the interaction between this skeletal magnetic field and solar wind plasmas. It is noted that the topology of the magnetic field does not change during the deformation [Siscoe, 1988]. We investigated how the skeletal magnetic field structure is deformed due to the plasma dynamics. The main results are schematically summarized in Figure 2. The characteristic features obtained from this figure and other resources (not shown here) are as follows.

1) The shape of the torus near the Earth reflects that of the skeletal structure (the inner torus). Whereas, the torus has a thin elliptic cross-section and extends long toward the tail on the night side (the outer torus). The inclination of the elliptical cross-section of the outer torus is almost along the equatorial plane near the Earth and becomes close to the IMF direction in the outer part of the outer torus. The demarcation between the inner and outer tori is located near r ~ 15Re. The outer torus seems to correspond to the plasma sheet when IMF is northward. The length of the outer torus depends on the solar wind parameters including IMF direction, intensity, and dynamic pressure. The mechanism of this dependence is a future issue.
2) The cylinder is laid down along the anti-sunward direction in the magnetotail. This deformation is caused by the plasma current flowing in and around the magnetosphere. In the inner region of r less than about 15Re, the current passing the equatorial region flows around the Earth in the equatorial plane. On the

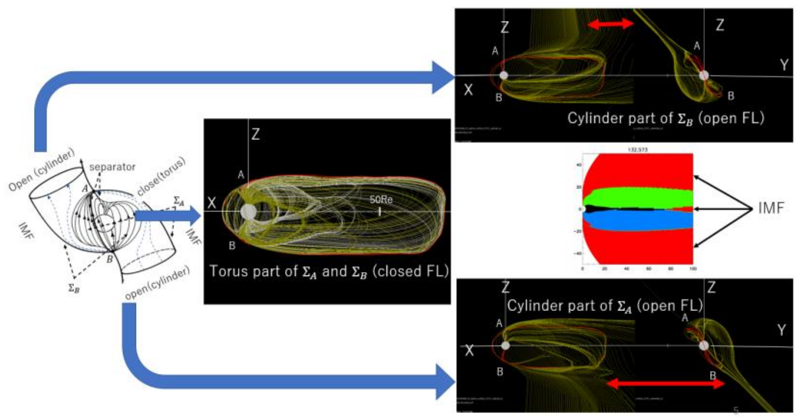

Figure 2 Schematic diagram of deformation of the skeletal magnetic field structure by the solar wind plasma in the northward IMF condition under the condition of IMF=(0,-4.3nT,4.3nT), Vx=372km/sec and SW density=10/cc. (left) skeletal structure, (centter) deformed torus, (top right and bottom right) deformed cylinder parts of Σ_B and Σ_A, respectively, (center right) distribution of magnetic field regimes in the meridian plane (red: IMF, black: closed, green: open from northerh hemisphere, blue: open from southern hemisphere)

other hand, the current passing the equatorial plane goes to the magnetopause ("magnetopause" is defined as the region with a steep spatial gradient of the pressure toward the outside) and flows around the magnetotail. However, the current does not draw the perfect theta curve because the magnetopause current does not pass the slot region ("slot" is explained next). The circular windows of the cylinder of the skeletal field structure are deformed a narrow slot extending long along the tail. The over-draping magnetic field lines appear in the null point regions. It is noted that the skeletal magnetic field already has such an over-draping field near the null point. The slot is derived from the transport of these over-draping magnetic fields toward the tail. This result proves that the topology of the magnetic field lines does not change during the deformation of the skeletal magnetic field due to plasmas. (There are many physical implications of the relation between the slot and the reconnection. This is also a future issue.)

3) We notice that the IMF intrudes in the outermost region in the nightside equatorial plane. The two cylinders originally extended in opposite directions. Even if the solar wind plasma causes the two cylinders to topple sideways, the two cylinders will move apart at a distance from the Earth, reflecting the natural tendency of cylinders to extend in opposite directions. In this way, the IMF region appears on the equatorial plane of the outermost region.

The concept of the skeletal magnetic field of the solar wind-magnetosphere system is so important when we understand magnetospheric physical processes. In particular, we should note that the skeletal magnetic field does not have magnetic tension because this magnetic field structure is not associated with electric current. Furthermore, it is also indicated that the magnetic field configuration of the reconnection is established in the region around the null point in the skeletal magnetic field configuration. The magnetic tension is caused by the deformation of the magnetic field structure due to the interaction between the skeletal magnetic field and the plasmas. This topic will be discussed in the next time.

References

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