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A Study of IMF's Penetration into the Earth's Magnetotail and Magnetic Flux Rope via Global MHD Simulations

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It is well known that the By component observed in the Earth's magnetotail, both in the tail lobe and in the plasma sheet, often show good correspondence with the By of the IMF observed in the upstream region of the Earth. It is believed that the IMF 'sinks into' or 'penetrates' the Earth's magnetosphere. However, the process how the IMF sinks into the mageototail is still unclear. We performed 3-D global MHD simulations to study the mechanism for the IMF to penetrate the Earth's magnetotail. We first performed several global MHD simulations using simple IMF models as input parameters; with no By component in the IMF. In the both cases with $Bz > 0$ and $Bz < 0$, no penetration of the IMF By component was found in the magnetotail. We then performed simulations with southward IMF (By is non-zero) to study magnetospheric dynamics such as IMF's penetration into magnetosphere and generation of magnetic flux ropes. In this presentation, we discuss the interaction between IMF By and penetration into magnetosphere via 3-D Global MHD simulation and 3-D visualization. We also propose a new model of 3-D structure of magnetic flux ropes. In this study, we use an MHD code developed by Tanaka [1994] that adopts an unstructured grid system to study the interaction between IMF and magnetosphere. We used real observational data (observed by ACE satellite at the upstream region of the Earth) as input parameters for the 3-D MHD simulations. In both cases with $Bz > 0$ and $Bz < 0$, Bz components in the magnetotail (both in the lobe region and in the plasma sheet) were found. What was more interesting is the time-dependent changes of the By components observed in the magnetotail. We found that By components in the plasma sheet are well synchronized with the change of those in the IMF. It also found that magnetic flux ropes in the magnetotail is generated and propagated to tailward. An inclination of Magnetic field lines at both ends of flux rope expanded to tailward, is good correspondence with the By of the IMF. Using a virtual reality system, we carefully examined how the configurations of dayside boundary magnetic filed lines of the IMF develop in time. We found in the 3-D virtual space that there are two-step reconnections for the IMF to penetrate the magnetotail. At the first step reconnection, which takes place at the nose of the magnetosphere, the IMF magnetic field lines are reconnected with the Earth magnetic fields, as shown in left figure. The 'open' field lines, which are generated by the first step reconnections,

are draped in the anti-sunward direction, to encounter the close magnetic field lines at the flank region. There occurs the second step reconnection both at the dawn side and dusk side of the magnetotail, as shown right figure. Since the two open magnetic field lines are again reconnected at the magnetotail flank, finally the magnetic field lines, the both side of which are connected with the IMF, show up. We analyzed 3-D structures of magnetic flux ropes in the magnetotial on 11/12/2003 00:47:57-01:46:57 UT by using a virtual reality system and various types of 3-D visualization techniques such as iso-surface, particle trace, and so on. As a result, we can classify found a reverse of By components and loop current system at the frank edge of magnetic flux ropes. In this study, we performed 3-D global MHD simulations to study interaction between IMF By and magnetospheric dynamics such as IMF penetrations into the magnetosphere and generation of magnetic flux rope. As a result, we found that By components both in the plasma sheet and tail region often show good correspondence with IMF By. We found 2-step reconnection and magnetic flux ropes in the magnetotail, when IMF is southward. We also proposed a new model of 3-D structures of magnetic flux ropes.