論文の内容の要旨

Study of plasma transport near the magnetopause

（磁気圏境界面付近におけるプラズマ輸送の研究）

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Understanding the plasma transport process in space is a crucial issue in plasma physics. In terms of magnetospheric physics, it is important not only for understanding the formation and maintenance of magnetosphere but also for space weather forecast. It is widely known that transport of magnetosheath plasma into the magnetosphere across the magnetopause becomes efficient under northward IMF conditions. This transport makes not only the low-latitude boundary layer (LLBL) just inside the magnetopause at low-latitudes, but also the cold-dense plasma sheet in the nightside magnetosphere. When the cold-dense plasma of magnetosheath-origin is transferred deep into the magnetosphere, the stronger geomagnetic storm is induced. Although several transport processes have been suggested, their relative importance was poorly understood.

The goal of this study is to unveil the mechanism of plasma transport across the magnetopause and in the magnetosphere under northward IMF conditions. Although several transport processes have been suggested, their relative importance is still not completely understood. Especially, the contribution of the following two transport processes near the magnetopause is poorly understood: one is plasma transport across the magnetopause induced by kinetic Alfvén wave (KAW) turbulence, and the other is plasma transport from the magnetopause toward the Earth induced by eddy turbulence as is the case in an ordinary (Navier-Stokes) fluid. This is because there is no definite observational evidence for their operation in space. In this dissertation, I challenge to demonstrate their evidence by inspecting characteristic particle signatures with the use of multipoint observations

from the THEMIS spacecraft and by making comparisons between the observed signatures and the theoretical predictions. On the basis of obtained results and previous knowledge, I aim at drawing a transparent picture of plasma transport under northward IMF conditions.

The main body of this dissertation is organized as follows. In Chapter 3, I start by developing the theory of plasma transport induced via KAW turbulence. The KAW-induced transport is shown to be a selective transport depending on particle's energy and surrounding environment. Focusing attention on its selective nature, I propose a new data analysis method to identify the operation of the KAW-induced transport on the basis of in situ plasma particle data. In Chapter 4, I perform an event study of THEMIS observations applying the proposed method. From the analysis of ion distribution functions obtained in both sides of the magnetopause, the characteristic ion signatures which are fairly consistent with the KAW-induced selective transport are found. Other transport processes are shown to be unable to explain the observed signatures. This study is first to show that KAW turbulence can indeed transfer magnetosheath plasma into the magnetosphere across the magnetopause. In Chapter 5, I perform a statistical study of THEMIS observations using the same method in order to understand the contribution of the KAW-induced transport to the LLBL formation. By estimating the amount of ions transferred across the magnetopause from simultaneous multipoint observations, it is shown that the KAW-induced transport is not a major process for the formation of the outer part of the dayside LLBL. New implications for the KAW-induced transport process and another transport process are provided. In Chapter 6, I perform an event study of THEMIS observations in order to verify the plasma eddy diffusion in the magnetosphere. The spatial and time scales of the transport signatures detected from simultaneous multipoint observations are shown to be in good quantitative agreement with the numbers of the eddy diffusion coefficients. Other transport processes are shown to be unable to explain the observed signatures. This study is first to show the operation of plasma eddy diffusion. In Chapter 7, plasma transport under northward IMF conditions is discussed on the basis of the results obtained in Chapter 3, 4, 5, and 6 and previous knowledge. Key issues to be addressed toward further understanding of plasma transport in space are pointed out. In Chapter 8, a general conclusion is presented.

New knowledge acquired in this dissertation is as follows: (1) collision-less space plasma is subject to cross-field diffusion in KAW turbulence; (2) the KAW-induced transport is selective transport and may be effective for limited intervals when the magnetopause satisfies the specific conditions; (3) collision-less space plasma is subject to eddy diffusion as is the case in an ordinary fluid, which can transfer plasma of magnetosheath origin in the magnetosphere.