論文内容の要旨

論文題目　Escape of Atmospheric Ions and Creation of Large-Scale Magnetic Structures around Mars
(火星周辺の大気イオン流出と大規模磁場構造の形成)

氏名　　久保田　康文

This dissertation mainly discusses the physical processes of the interaction between the solar wind and the Martian ionosphere, specifically the escape mechanisms of ionospheric ions and the structure of the Martian tail. Mars does not possess a significant global intrinsic magnetic field, and hence the solar wind directly interacts with the Martian ionosphere. The Phobos-2 spacecraft and recently Mars Express spacecraft observed the Martian tail and estimated ion escape flux. These observations indicate that heavy ions including O^+, O_2^+ and CO_2^+ escape from Mars and form a plasma tail with a ray structure. Because the heavy ions such as O_2^+ and CO_2^+ are produced in low-altitude regions of the Martian ionosphere, escape mechanisms are required to work against gravity. In this dissertation, we try to clarify the following problems using MHD simulations. (1) The global structure of magnetic field and plasma around Mars, particularly the characteristics of flows that transport planetary ions from day side to night side. (2) The total amount of ion escape flux, particularly its dependence on the solar wind total pressure and IMF.

In order to solve these problems, we construct a 3D MHD model for the Mars environment, including all the chemical and physical processes which would be important in the interaction processes. We discuss our simulation models and numerical

methods in Chapter 2.

In Chapter 3, we start with the discussion of the background chemical equilibrium state of the Martian ionosphere which works as a basis for the discussion of physical processes. Particularly, the vertical structure of the sub-solar ionosphere is discussed including the photochemistry and vertical convection. We will demonstrate that the vertical convection in the dayside ionosphere is strongly dependent on the solar wind total pressure.

In Chapter 4, we discuss the simulation results obtained in the case of a solar wind not accompanied by IMF. The flow structure obtained for this extreme case is much different from the finite IMF case discussed later in other Chapters, and gives us hints to interpret the mechanisms operating in the more standard case of finite IMF. Guided by the importance of stream line topology in considering ion escape fluxes, we introduce an evaluation method of total ion escape flux by integrating over "open" stream lines. We will show that the solar wind total pressure controls the topology of stream lines and eventually the total escape rates. We show that O_2^+ and CO_2^+ ions escape little while the total O^+ escape flux increases almost linearly with the density of the solar wind if the wind is not accompanied by IMF.

In Chapter 5, we discuss the results of our simulation for the standard set of solar wind parameters including standard magnitude of IMF. We show that O_2^+ and CO_2^+ ions produced in the low-altitude regions of the day side ionosphere do escape in this case. The reason for this is discussed and the role played by magnetic tension in the ion transport along the meridian plane is emphasized. We show that a characteristic form of central ray is produced along the x-axis within the tail by the ions transported from the day side by the action of magnetic tension.

In Chapter 6, we discuss the total amount of escape flux for each ion species and its dependence on the solar wind total pressure. The total amount of escape flux is obtained by the open-line integration method, just like in the case of zero IMF. It is found that the escape flux increases linearly with the solar wind pressure for O^+, but the dependence of O_2^+ and CO_2^+ escape rate on the solar wind pressure is more gentle than that of O^+. We interpret this result in terms of the stronger magnetic control over O_2^+ and CO_2^+ ions than on O^+ ions. The absolute values of escape flux are consistent with the observed values for each ion species. The detailed mechanisms of escape, in terms of source locations and transport path, are discussed for each ion species emphasizing the importance of relative locations of "open" stream lines and the source regions.

Finally we summarize our results in Chapter 7 and give comments on the past history of atmospheric escape from Mars.