

Ion Energization Associated With the Interaction Between the Solar Wind and the High-Latitude Magnetosphere

Haruto Koike

This thesis investigates the characteristics of ion energization through the interactions between the solar wind and the high-latitude magnetosphere, with a particular focus on the role of reconnection between the magnetic field lines in the lobe region of the magnetosphere and the interplanetary magnetic field (IMF), i.e., lobe reconnection.

Chapter 1 provides an overview of the magnetosphere, including the lobe, the cusp, and the magnetosheath, and explains the unsolved issues that are addressed in this thesis.

Chapter 2 describes the datasets and instruments used in the analyses presented in the subsequent chapters.

Chapter 3 investigates how the energies and number flux of ions precipitating from lobe reconnection into the altitudes of about 800 km are controlled by the magnetosheath plasma near the reconnection site. A statistical analysis of ion data from the DMSP satellites revealed a positive correlation between the energy of precipitating ions and the estimated tailward flow speed in the magnetosheath near the lobe reconnection site. This result suggests that the ion outflow jet from lobe reconnection is enhanced as the nearby magnetosheath flow speed increases. This finding provides an explanation for a previously unsolved issue —why the brightness of the so-called cusp proton auroral spot for northward IMF correlates better with the solar wind dynamic pressure than with the solar wind number density.

Chapter 4 aims to verify the aforementioned relationship using in-situ observations of lobe reconnection and to clarify the role of magnetosheath flow in the ion energization associated with lobe reconnection. The flow that creates velocity shear in the reconnection region is referred to as shear flow. We investigated how shear flow around the lobe reconnection site affects the velocity and heating of the outflow jet from reconnection. The analysis revealed that when reconnection occurs under conditions of faster shear flow, the resulting outflow jet is faster and ion heating in the outflow region is more enhanced. Furthermore, we found that the hybrid asymmetric Alfvén speed—

determined by the ion density and magnetic field strength on both the magnetosheath and lobe sides—is a key parameter controlling ion energization during lobe reconnection.

Chapter 5 focuses on an event of the high-energy (~ 20 keV) oxygen ions detected near the high-latitude magnetopause, aiming to understand the role of the outflow jet from lobe reconnection in the generation of the high-energy oxygen ions. The oxygen ions originate from the Earth's atmosphere and reach the high-latitude magnetopause by flowing outward along the Earth's magnetic field lines. The detailed analysis of their energies and velocity distribution functions revealed that the oxygen ions were non-adiabatically accelerated through the pickup process both in the lobe reconnection jet and in the magnetosheath flow. To demonstrate that such high energies can be achieved in the magnetosheath under the observed electromagnetic field conditions, a test particle simulation was performed. The simulation successfully reproduced the observed energy increase of the oxygen ions, supporting the proposed double-pickup acceleration mechanism.

Chapter 6 summarizes the findings of this thesis and presents the general conclusions. The findings of this thesis provide a new perspective on the ion energization process associated with the outflow jet from lobe reconnection in the situation of the counterstreaming flow in the magnetosheath.