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Mass and charge dependent characteristics of Earth's magnetospheric plasma

Kunihiro Keika [1], Masahiro Hoshino[1], Kanako Seki[1], Takanobu Amano[1], Satoshi Kasahara[1], Shoichiro Yokota[2], Masahito Nosé[3], Yoshizumi Miyoshi[4], Iku Shinohara[5]

1. Graduate School of Science, The University of Tokyo, 2. Graduate School of Science, Osaka University, 3. World Data Center for Geomagnetism, Kyoto University, 4. Institute for Space-Earth Environmental Research, Nagoya University, 5. Institute of Space and Astronautical Science Aerospace Exploration Agency

e-mail: keika@eps.s.u-tokyo.ac.jp

The Earth's magnetosphere is populated by plasma of solar wind origin and those from the Earth's upper atmosphere. The major species are electron and proton, with He++ in the solar wind and He+ and O+ in the ionosphere being the second major species. This paper is focused on a global view of magnetospheric plasma dynamics, that is, transport of these plasma to the magnetotail, heating and acceleration in the plasma sheet, and acceleration during the course of fast transport into the inner magnetosphere.

Plasma transported to the magnetotail can be heated up to 0.1 – 1.0 keV in temperature in the plasma sheet. Part of the energetic plasma is then transported earthward, approaching to the region where the magnetic field is stronger and dominated by the Earth's dipole field. The transport can occur with a high speed (>a few 100 km/s) during a short period (<a few tens of minutes). The fast flow is interpreted as a plasma jet due to the magnetic reconnection which occurs in the central plasma sheet. The magnetic field is piled up at the flow front, observed as a sharp magnetic field increase in an order of seconds, called a dipolarization front. The fast flow slows down as it approaches to the dipole field.

During the course of such transport, O+ ions can be also accelerated up to >100 keV in kinetic energy. It has been observationally confirmed that the energetic O+ population makes a significant contribution to the plasma pressure in the Earth's inner magnetosphere (e.g., Keika et al., 2013), in response to the arrival of solar wind structures such as coronal mass ejections and corotating interacting regions. The O+ pressure frequently becomes comparable to and sometimes dominates the H+ pressure. Observations have also shown that energy spectra at high energies (>10 keV) differ between H+ and O+, indicating processes that are selective or effective in accelerating O+ ions. However, it remains an open question what mechanism(s)/process(es) play the dominant role in selective/effective O+ pressure enhancements.

This paper introduces previous studies related to O+ dynamics in the Earth's magnetosphere, and also present recent studies using data from the Arase spacecraft. We examine spatial variations of the contribution from H+ and O+ to plasma pressure during the pressure development phase (i.e., the main phase of a geomagnetic storm). We primarily use H+ and O+ data from the MEP-i instrument (Yokota et al., 2017) on board Arase. MEP-i measures energetic ions with energies of 9-180 keV/q; ion mass-per-charge is derived from energy and velocity measurements by an electrostatic analyzer and the time-of-flight system, respectively. Arase observed six magnetic storms with the Dst index minimum smaller than -50 nT during the first year of the mission.

The results are summarized as follows. The pressure ratio between O+ and H+ was between 0.1 and 1. The O+/H+ ratio increased as increasing total pressure for some cases, while did not for the other cases. The contributing energy, which is an energy range that makes the dominant contribution to total pressure, depends on the radial distance from Earth. In the inner magnetosphere, the contributing energy was a few tens of keV. Around the geosynchronous orbit or further tailward, on the other hand, a wider energy range made an important contribution. The contributing energy also depends on mass, being higher (50-100 keV/q) for O+ than H+ (10-80 keV/q). The results suggest that plasma pressure in the inner magnetosphere is dominated by relatively low-energy ions (<50 keV) that were adiabatically transported by enhanced convection. In the outer part near the transition region (from the stretched magnetic field configuration to the dipole-like field), pressure is contributed mostly from higher-energy ions (>80 keV) generated by mass-dependent acceleration during the course of transport from the plasma sheet.

References

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