Investigation of the source of cold O+ beams in the plasma mantle: PSD comparison between GEOTAIL and FAST using Liouville's theorem

*Kanako Seki[1] , Richard C. Elphic [1], Michelle F. Thomsen [1]
John Bonnell [1], Masafumi Hirahara [2], Toshio Terasawa [3]
Toshifumi Mukai [4]

Los Alamos National Lab.[1], Rikkyo Univ.[2], Univ. of Tokyo[3], ISAS[4]

From 2130 UT on April 7 to 735 UT on April 8, 1998, the Geotail spacecraft observed high energy (～5 keV) cold O+ beams (COBs) flowing tailward together with He+ and H+ in the northern dusk plasma mantle at X__GSM～-21 Re. During the interval, the interplanetary magnetic field (IMF) By and Bz were almost steadily negative, and the FAST satellite passed across the dayside northern pole from dawn to dusk six times at altitudes of 1200-3400 km, observing several types of ion precipitation. The COB energy observed by GEOTAIL in the tail plasma mantle was in a range from 3 to 10 keV. This energy is much higher than the typical energy of cusp/cleft originating ions which are traditionally considered to feed the near-Earth lobe plasma, and investigation of energization and supply mechanisms of these high- energy COBs has been one of outstanding problems in the magnetospheric physics. Based on the statistical properties of COBs in the lobe/mantle regions observed up to X__GSM=-210 Re by GEOTAIL, Seki et al. [JGR, p4477, 1998] have discussed possible supply scenarios of these high-energy COBs to the magnetotail and came to the conclusion that there seem to be three surviving candidates. One of the candidates is to consider the equatorially trapped O+ ions in the closed flux tubes in the dayside magnetosphere as a source of COBs in the magnetotail. Once the Earth's magnetic field is reconnected with the IMF at the dayside magnetopause, equatorially trapped O+ will be mixed with sheath ions from the opposite side, get energized around reconnection site, then injected into the high-latitude ionosphere, undergo magnetic mirror reflection, and finally be transported into the tail lobe/mantle, as the reconnected flux tube is dragged tailward. In this event, FAST is observing a part of the injected O+ ions into the dayside high-latitude ionosphere. Thus we can investigate the validity of the scenario by comparing O+ observations in the two different regions.

FAST observed ion precipitation in a wide range of MLT and ILAT of the dayside polar magnetosphere, which typically had isotropic distributions except for a loss cone in the upward going direction and sometimes contained heavy ions such as He++, He+, and O+ in addition to the major H+ component. This ion precipitation with a single loss cone can be roughly classified into two groups. One is the high-energy ion precipitation in relatively low latitude and flanks in which O+ contribution is significant, and another is the intense cusp-type precipitation sometimes with dispersed-energy signature in which the He++ flux increases. A remarkable point is that these two types of ion precipitation coexist in the orbits skimming near the dayside separatrix around the cusp. In other words, there exist flux tubes which contain the magnetosheath-originated plasma together with plasma of dayside plasma sheet (or low energy tail of ring current) origin. These observations confirm the existence of O+ precipitation in the cusp which have been potentially expected by previous O+ observations in the dayside magnetosphere, but had not yet been confirmed.

For comparison of the FAST and GEOTAIL data, we have compared phase space densities (PSDs) of O+ at typical COB energies utilizing Liouville's theorem. The results can be summarized as follows: 1. O+ precipitation in relatively high-latitude energy-dispersion regions have too low energy to supply COBs in the plasma mantle. 2. O+ PSDs in the high-energy precipitation region on closed flux tubes is comparable to those of COBs observed by GEOTAIL. 3. In the regions where the magnetosheath and dayside magnetospheric plasmas are precipitating together, PSD of precipitating O+ is typically smaller than, but sometimes enhanced up to comparable values to that of COBs. These results suggest that O+ population in the dayside magnetosphere on closed flux tubes is adequate in quantity to supply COBs in the lobe/mantle. However, the smaller O+ PSDs on the open flux tubes than in the closed ones suggest the importance of ion dynamics in the dayside reconnection process. Namely, how much O+ originally on closed flux tubes can be remain in the magnetosphere when these flux tubes are reconnected with IMF at the dayside magnetopause will be a key issue for further discussions.