Origin of energetic ion events upstream of the Earth's bow shock and in the magnetosheath

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In order to identify origin (i.e., where ions were accelerated) of energetic ion ($¥ge$ 50 keV) events upstream of the Earth's bow shock and in the magnetosheath, we investigated energetic ion events observed by the energetic particles and ion composition (EPIC) instrument on board the Geotail spacecraft from 1995 to 2001. We analyzed geomagnetic activity dependence of occurrence probability and spatial distribution of the energetic ion events, by using the SYM-H index which is essentially the same as the Dst index. The events were observed more frequently in the dawnside upstream region and in the duskside magnetosheath when geomagnetic activity was high (SYM-H $¥le$ -30 nT). Heavy ions such as nitrogen and oxygen ions during the events were also examined. Heavy ion flux was enhanced in almost all the events. We calculated the percentage of low-charge-state heavy ions (P_LCS) in each event and classified energetic ion events into three groups: High-Charge-State (HCS) events (P_LCS $¥le$ 25%), Intermediate (IM) events (25% $¥lt$ P_LCS $¥lt$ 75%), Low-Charge-State (LCS) events (P_LCS $¥ge$ 75%). The HCS and LCS events can be regarded as solar wind and magnetospheric origin, respectively. The IM events can be considered to include both ions of solar wind origin and ions of magnetospheric origin. Occurrence probability of the HCS, IM, and LCS events was 30%, 45%, and 25%, respectively. The HCS events were frequently observed in the dawnside upstream region. The IM events occurred both in the dawnside upstream region and in the magnetosheath around noon. Most of the LCS events were observed in the duskside magnetosheath. The IM and LCS events occurred more frequently in geomagnetically disturbed conditions (SYM-H $¥le$ -30nT) than in quiet conditions (SYM-H $¥ge$ 0nT). We conclude that magnetospheric ions are leaking out from the duskside magnetopause and traveling toward the dawnside upstream region when geomagnetic activity is high in particular. It is suggested that ions of magnetospheric origin can be mixed with solar wind ions on the way to the dawnside upstream region. Solar wind acceleration is likely to occur at the quasi-parallel bow shock.