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Study of occurrence processes of the Jovian substorm-like events: Examination of an internal drive hypothesis

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The observations of the Galileo revealed that there were quasi-periodic flow bursts of energetic particles and the characteristic variation of the north-south component of magnetic field implying magnetic reconnections in the Jovian magnetosphere. Galileo also observed quasi-periodic variation of spectral indexes of energetic ions (slope of the energy spectra in a log-log plot). These imply periodic thinning and thickening of the plasma sheet with a repetition period of 2.5 - 4 days. The signatures of these events were similar to the terrestrial substorm, so they are called "substorm-like events".

In the preceding studies (Kronberg et al., 2007; Woch et al., 1998), their generation processes are proposed as follows based on a hypothesis of plasma mass-loading in the Jovian magnetotail region. First, the magnetotail is stretched because of the large centrifugal force by the rapid rotation and heavy ions. Second, a reconnection occurs and a plasmoid is released. Third, the magnetic field configuration returns to the initial (non-stretched) state, at the sometime the magnetotail stretching starts again and the cycle repeats to make the periodicity.

In this study, we have examined the plasma mass-loading hypothesis by investigating the plasma density inside the plasma sheet by using the data obtained by the Plasma Wave Subsystems (PWS), Energetic Particle Detector (EPD) and Magnetometer(MAG) on-board the Galileo.

At first, we estimated the local electron density by using the plasma frequency. To estimate the occurrence frequency of the substorm-like events, we used two methods; One is to use north-south component of the magnetic field as devised by Vogt et al. (2010) (MAG event). The other is to use narrowband KilOMetric radiation (nKOM) as a signature of the occurrence of the event (nKOM event) to make up the expected azimuthal occurrence restriction of the MAG event. We identified 172 MAG events and 69 nKOM events from the 9 Galileo orbits for 1996-1999. As a result, there was a positive correlation between the local electron density and the occurrence frequency of the events. This result strongly suggests that the substorm-like events tend to occur when the plasma loaded to the Jovian magnetotail region is large.

Second, we estimated the plasma mass-loading rate by using the calculation method proposed by Kronberg et al. (2007). We selected two events for the G2 and the G8 orbits. In order to estimate the mass-loading rate, we also estimated the half-thickness of the current sheet. As a result, the mass-loading rate for the G2 orbit was larger than that of G8. On the other hand, the occurrence frequency and the electron density in the G2 orbit were also larger than those of the G8. This result suggests that the large plasma mass-loading rate causes increase of the plasma loaded to the Jovian magnetotail region, and also increase of the occurrence frequency of the substorm-like event.

We discussed the long-term correlation between the variations of the occurrence frequency of the event and the Io torus activity. It is confirmed that there was a positive correlation between the intensity variations of [SII] optical emission of Io torus derived by Nozawa et al.(2005) and the occurrence frequency variations of the events for 1997-1999. This result implies that the occurrence of the event is controlled by variations of Io torus. On the other hand, there was no or very weak correlation between the high solar wind dynamic pressure state and the occurrence frequency of the events. And there were not any clear peaks near the characteristic reputation period of the events on the Fourier spectrum of the solar wind pressure. These results indicate the periodic occurrence of the substorm-like event cannot be explained only by the variations of the solar wind pressure.

We conclude that the plasma mass-loading hypothesis could explain the driving mechanism of the substorm-like event.

Keywords: Jupiter, Jovian magnetosphere, magnetospheric dynamics, substorm, plasma density, Galileo