博士論文

Studies on variation characteristics of the Jovian synchrotron radiation

(木星シンクロトロン放射の強度変動特性の研究)

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Abstract

The JSR is a radio wave emitted from the relativistic electrons in the Jovian radiation belt at a frequency range between about several tens MHz and 22 GHz, which has information of dynamics of high energy particles and electromagnetic disturbances in the Jovian inner magnetosphere.

A steady observation of the JSR has been started at a frequency of 2295 MHz since 1971. From this observation, It had been recognized that the JSR flux varies with time scale of more than 10 years. However, recently, several research groups have confirmed existence of the variations with the time scales of days to weeks. Now, the existence of the JSR flux short-term variation is determinant.

The observations of the JSR flux at high frequencies, such as 1.5 and 2.3 GHz, have been made with both long and short-term. On the other hand, the JSR flux observation at lower frequencies have not been generally made except in some campaigns such as the SL9 impacts to Jupiter. This is mainly because the intensity of galactic background radiation is dozens of times higher than that of the JSR at low frequencies, and the evaluation of the background confusion is not easy. As a result, variation characteristics at high frequencies have been cleared to some extent by many observations particularly at 1.5 and 2.3 GHz, but the variation characteristics at low frequencies below 1 GHz have been little known yet.

In this thesis, we focus on low frequency characteristics of the JSR. An observation of the JSR gives information on the electron flux variation at the energy corresponding to the frequency. Therefore, the lack of the JSR observations at low frequencies has obstructed our understanding on the dynamics and energetic of relativistic particles in the Jovian radiation belt. We therefore purpose to elucidate characteristics of the JSR flux variation

at a frequency of 327 MHz and reveal unknown dynamics of several MeV electrons.

The regular observations of the JSR have been made at a frequency of 327MHz since 1994 by using parabolic cylinder antennas at the Kiso and Fuji observation sites of the Solar Terrestrial Environment Laboratory (STEL), Nagoya University. These systems have some instrumental advantages for the observation of the JSR; i.e., high sensitivity and narrow beam width. However, the observed JSR flux includes apparent variation due to inevitable system gain and receiver temperature variations of the radio receiving system.

On the JSR flux observations using the STEL systems at 327 MHz, we have taken account of the followings to derive the JSR flux as accurate as possible: 1)elimination of large galactic background noise (BG) and 2)evaluation for the variations of system gain and temperature. Concerning the first term, we have made two step observations to derive the JSR flux; at the first step we observed Jupiter, and at the next step we observed the same celestial position again after Jupiter's movement. By subtraction of the both observation data, we could derive the only JSR flux. Concerning the second term, we have made quasi-simultaneous observations for Jupiter and a reference calibration source using the fast beam switching function of the STEL systems. By using the two data sets for Jupiter and the reference calibration source, we could eliminate effect of system temperature variation and evaluate system gain variation. The observation using the STEL system gives the JSR flux as a relative value to the flux of a reference calibration source. In order to derive absolute flux of JSR, we have estimated absolute flux of the reference calibration source using the IPRT, Tohoku University which enables to derive absolute radio flux with the self-calibration function for the system gain and temperature. Thus, we could derive absolute JSR flux successfully.

From this analysis, we can obtain characteristics of short-term and long-term JSR flux variations. Characteristics of the short-term variations and their expected causalities are summarized as follows.

- The JSR flux shows large amplitude variations of $2 \sim 9$ Jy typically and varies $2 \sim 3$ Jy within a few days.

- These amplitude variations are much larger than those at 2295 MHz for the same observation terms. This difference of JSR flux variations between high and low frequencies can't be explained by the simple radial diffusion process. To explain the difference, it may be needed to consider other acceleration mechanisms that have energy dependence of relativistic electron.

- It has been suggested that the JSR short-term flux variation is related to solar F10.7 flux at 2295 MHz. However, it seems that the relation between the JSR flux and solar F10.7 flux variations isn't obvious at 327 MHz particularly at low F10.7 flux, and this is the same for solar wind variations. This result suggests that some causalities other than solar / solar wind variations generate the large and rapid flux variations of several MeV electrons radiating the JSR at 327 MHz.

- An event with rapid and unusual enhancements of JSR flux intensity was confirmed on July 15, 1998 (JST). The flux was about 9 times larger than usual JSR flux values and the duration was less than 2 days. A conceivable cause of this enhancement is a local particle acceleration/ dissipation occurred only in the innermost part of the radiation belts. Though such processes have not been confirmed yet, an investigation of expected localized variable radiation regions might be one of the future observation targets.

The characteristics of long-term variations are also derived for 1994 - 2005. The characteristics of the long-term variations and their expected causalities are summarized as follows.

- Yearly average fluxes roughly show a decreasing trend from 1994 to 1998 and an increasing trend from 1999 to 2004. The JSR flux observations at 2295 MHz for 1994 - 2001 also indicated similar trends to those at 327 MHz. A simple correlation analysis between the JSR flux and solar F10.7 / solar wind parameters infers that the both factors influence on the JSR flux variations at least when either factor is intense enough to cause the variations.

- There was one clear difference in the long-term trend for 1994 - 1998 between the observation results at 327 MHz and 2295 MHz: the flux of 327 MHz increased while the flux of 2295 MHz decreased in 1996.

One possible explanation of the difference is as follows. The variation features at low and high frequencies infer that some enhanced particle accelerations affecting for relativistic electrons with a wide energy range might occur between the 1995 and 1996 observation periods, and the difference might be caused by the energy dependent loss process, such as the synchrotron radiation loss.

In this study, we indicated possibilities of existence of an acceleration mechanism which depends on the energy of relativistic electrons and a loss mechanism which causes the rapid JSR flux decrease within a few days. To confirm the existence of this acceleration mechanism, we need to observe the JSR flux spectrum because difference the frequency of JSR flux reflects the difference of contributed electron energy. Moreover, to confirm the existence this loss mechanism, a steady observation with the time resolution of within 1 day at a wide frequency range is needed. We expect future progress of study of the Jovian radiation belt by these observations and model simulations.