Short-term variation phenomena in Jupiter's radiation belt: Their relation with the magnetospheric events

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ABSTRACT

Rapid variation of relativistic electrons in Jupiter's radiation is newly identified with the time scale of a day or less by the observation of Jupiter's synchrotron radiation at 327MHz. The Galileo Jupiter orbiter data shows the rapid variation has some relation with the magnetic reconfiguration events in the outer magnetosphere, however, does not show the existence of local electron energization at the region. This fact implies that some rapid electron acceleration processes exist at somewhere between the outer and deep inner magnetosphere.

1. Introduction

It is known that Jupiter has a radiation belt filled with relativistic particles like the Earth, though the flux and energy of the particles are much larger. The relativistic particles are trapped by Jupiter's intense magnetic field and emanate synchrotron radiation. Thus the radio emission (hereafter we call it JSR) has information on dynamics of Jupiter's deep inner magnetosphere. The Tohoku University group has started regular observations since 1990's and revealed that JSR has short term variations with the time scale of several days[1] and such the short term variations are general in several hundreds MHz[2,3]. The characteristic time scale of several days has not been explained by previous understandings for Jupiter's radiation belt particles; i.e., the characteristic time scale of representative source process is about two years for the case of radial diffusion[4] and that of loss process is more than 10 days as the shortest case for the interaction with Jupiter's moons[5]. To interpret this problem, Miyoshi et al. (1999)[1], Bhardwaj et al. (2009)[6] and Tsuchiya et al. (2011)[3] showed that the time scale meets with the enhanced radial diffusion for the relativistic particles caused by the solar UV/EUV heating to Jupiter's upper atmosphere which was originally proposed by Brice and McDonough (1973)[7].

On the other hand, JSR sometimes shows more rapid flux variations (RFV) by more than several tens % whose characteristic time scale is a day or less. It is quite difficult to explain its physical processes by present theories even though the enhanced radial diffusion mentioned above. This phenomena recalls the fast particle acceleration and transport in the earth's magnetosphere during substorm events. It is already confirmed that there are substorm like recurrent disturbances occur also in Jupiter's magnetosphere [8,9,10] with the repetition period of 2 – 6 days, however, it has not been revealed well whether the phenomena reach into and affect the deep inner region. In this paper, we show characteristics of the RFV events in JSR and discuss the relationship between the RFV events and substorm like recurrent disturbances.

2. Data and Analyses

In order to reveal unknown dynamics of the RFV events in JSR, we have tried to investigate relationship between the RFV events and electromagnetic phenomena in Jupiter's magnetosphere. For searching the RFV events, we have used the JSR monitoring data at 327MHz observed using the radio telescope at the Kiso observatory of STE Lab, Nagoya University, which is usually utilized for observing solar wind by measuring interplanetary scintillation phenomena. The JSR at 327 is generated by the relativistic electrons with the energy of around 6MeV in the radiation belt. The Tohoku university group has made daily JSR monitor for a few to several months a year since 1994. The observation and data reduction methods are denoted by Misawa and Morioka (2000)[2] and Nomura et al. (2007)[11]. On the other hand, in situ plasma and magnetic field data observed by the Galileo Jupiter orbiter have been used for examining condition of the Jovian magnetosphere. We have analyzed the JSR and Galileo data for 1997 in particular, when both data were obtained simultaneously for relatively longer periods than the other years.

3. Results

The daily JSR variations and their relation with the magnetic field are shown in Fig.1. In the figure, the solar 10.7cm radio flux expected at Jupiter's position (F10.7) and solar wind dynamic pressure expected on Jupiter for the same period are also shown for examining the solar effect on the RFV events. F10.7 is known as a good proxy of solar UV/EUV activity. The date for the F10.7 data The data of the solar wind dynamic pressure on Jupiter are estimated using the 1D MHD method[12] and provided by courtesy of C. Tao. As seen from Fig.1, the RFV events have no significant relation with the solar and solar wind variations, therefore it is concluded that

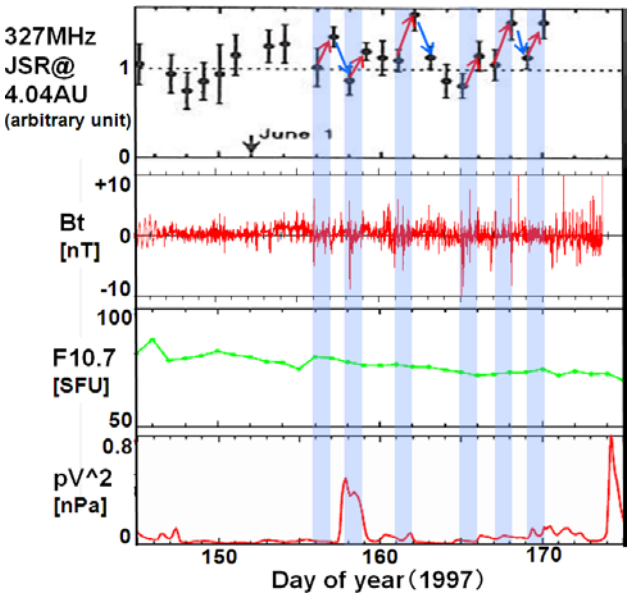

Fig. 1 Daily JSR flux in May-June, 1997 (top panel) and the relation with Jupiter's magnetic field variations in B_θ (2nd panel), solar F10.7 expected at Jupiter's position (3rd panel) and solar wind dynamic pressure expected on Jupiter (bottom panel). The hatched areas denote the period when the RFV events occurred. Galileo moved from 90 to 40R_J in 1 to 4h LT for 145–175 days in 1997.

solar and solar wind variations did not directly cause the RFV events. On the other hand, five-sixth RFV events showed some relation with the magnetic field variations in B_θ, the north-south component. This result implies that the RFV events occurred almost simultaneously with Jupiter's global magnetic field reconfiguration[13] interpreted as substorm like events.

4. Discussions and Conclusions

The observational results shown in Fig.1 strongly suggest that the RFV events, that is rapid variations of relativistic particles in Jupiter's deep inner magnetosphere, were caused by some inner processes relating to the substorm like events. Then, a remaining question is where and how the relativistic particles for the RFV events are generated. As the first step for the investigation, we examined energetic electron flux in the outer magnetosphere where the substorm like events occurred. In Fig. 2, the electron flux values for E>2MeV and E>11MeV observed by Galileo for the periods of the RFV event occurrence. There is almost no systematic correlation between occurrences of the RFV events and energetic electron flux enhancements. This implies that the energetic electrons for the RFV events were not generated in the outer magnetosphere, but could be generated in the more inner regions. In Jupiter's inner magnetospheres, the relatively similar time scale particle variation events with the RFV events have been reported, that is, the injection events[14]. The relationship between the injection events and substorm like events has not

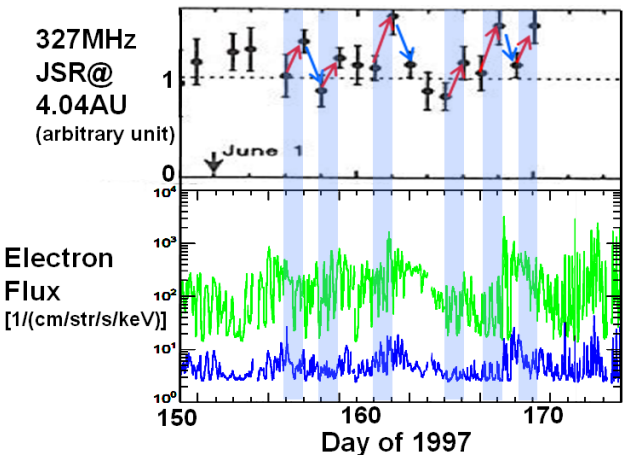

Fig. 2 The relation of RFV events identified in May-June, 1997 (top panel) and energetic electron flux in Jupiter's magnetosphere observed by Galileo (bottom panel). The electron fluxes for E>2MeV and E>11MeV are represented in green and blue colors, respectively.

been known well yet. The further observational studies are needed for revealing the relationship among the RFV events, substorm like events and injection events and investigating the particle rapid acceleration processes relating outer to inner magnetospheres of Jupiter. The JUNO Jupiter exploration planned after 2016 is one of the desirable opportunities for further observations. The coordinated Jupiter observations planned from the late 2013 to 2014 is also a good opportunity, in which the auroras by the HST satellite and ground-based infrared telescopes, torus emissions by the Japanese SPRINT-A satellite launched in Aug. 2013, and the radiation belt radio imaging by the GMRT interferometer have been listed so far. These upcoming projects would be expected to bring new insights for the remaining question.

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