修士論文

Effect of the solar UV/EUV heating on the intensity and spatial distribution of Jupiter's synchrotron radiation

(太陽紫外線の超高層大気加熱による木星シンクロトロン放射の強度・空間分布への影響)

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Jupiter's synchrotron radiation (JSR) is the emission from relativistic electrons in the strong magnetic field of the inner magnetosphere, and it is the most effective probe for remote sensing of Jupiter's radiation belt from the Earth. Although JSR has been thought to be stable for a long time, recent intensive observations for JSR reveal short term variations of JSR with the time scale of days to weeks.

Brice and McDonough [1973] proposed a scenario for the short term variations (hereafter the B-M scenario); i.e, the solar UV/EUV heating for Jupiter's upper atmosphere drives neutral wind perturbations and then the induced dynamo electric field leads to enhancement of radial diffusion. If such a process occurs at Jupiter, brightness distribution of JSR is also expected to change. That is, it is suggested that the induced dynamo electric field produces dawn-dusk electric potential difference and dawn-dusk asymmetry in electron spatial distribution. Then dawn-dusk asymmetry of the brightness distribution is produced.

Previous studies confirmed the existence of the short term variations in total flux density and its variation corresponds to the solar UV/EUV variations (Miyoshi et al.[1999], Tsuchiya et al. [2010]). However, the effect of solar UV/EUV heating on the brightness distribution of JSR has not been confirmed. Hence, the purpose of this study is to confirm the solar UV/EUV heating effect on total flux density and brightness distribution simultaneously, so as to evaluate the B-M scenario. In order to accomplish this purpose, we have made radio imaging analysis using the National Radio Astronomy Observatory (NRAO) archived data with the Very Large Array (VLA) obtained in 2000. We derived the total flux density and the dawn-dusk peak emission ratio of JSR and examined their relationship to the variation of the solar UV/EUV flux. From the VLA data analysis, following results were shown.

1. Total flux density variations occurred corresponding to the solar UV/EUV variations.
2. The dawn-dusk ratio was larger than unity almost every day.
3. Variations of the dawn-dusk ratio did not correspond to the solar UV/EUV flux.

First result supports the B-M scenario, so dawn-dusk ratio would change in accordance with the scenario. When we

see the dawn-dusk ratio at the long term view (a week order), second result also supports the B-M scenario. This result suggests the existence of the diurnal wind system. However, from the third result, we cannot simply explain the observed variation feature of the dawn-dusk ratio by the solar UV/EUV heating. There is a possibility that variations related to the solar UV/EUV were masked by other processes which dominated in the variations of the dawn-dusk ratio on the short time scale (day-order). Thus, the contribution of the solar UV/EUV heating effect is different between long term and short term aspects of the dawn-dusk ratio.

In order to explain the long term and short term variation features of the dawn-dusk ratio, we discuss the effect of the candidates which causes for the variation of the dawn-dusk ratio; i.e., solar UV/EUV heating, geometric effect and the convection electric field. From the data adapted from Kloosterman et al. [2005], it is found that the dawn-dusk ratio has D_E (Jovicentric declination of the Earth) dependence and always exceeds unity at all of the data. This does not meet with the expected geometrical effect by D_E. Thus, the other effects are needed to cause the dawn-dusk asymmetries. Next, we estimate the diurnal wind velocity from the observed dawn-dusk ratio by using the model brightness distribution of JSR. We construct the equatorial brightness distribution model and obtain the relation between the dawn-dusk ratio and neutral wind velocity. Estimated neutral wind velocity is 46 ± 11 m/s, which reasonably corresponds to the numerical simulation of Jupiter's upper atmosphere Tao et al. [2008]. It was therefore suggested that the steady dawn-dusk asymmetry is caused by steady diurnal wind system and its wind velocity is expected to be several tens m/s. As the result, the fluctuation of the convection electric field and the electric field strength proposed by Smith et al. [2011] was enough to cause the observed variations of the dawn-dusk ratio. In addition to that, some magnetospheric parameters suggest the enhancement of magnetospheric activity. Hence, there is a possibility that the convection electric field could affect the dawn-dusk ratio and become the major factor for the dawn-dusk ratio variation.

Finally, we conclude that variation of the total flux density and long term dawn-dusk asymmetry can be explained by the B-M scenario. Short term variation of the dawn-dusk ratio cannot be simply explained by the solar UV/EUV heating only. This implies that the solar UV/EUV heating effect on the dawn-dusk ratio is relatively small and is masked by other processes. One of the possible explanations for the short term variations of the dawn-dusk ratio is variations of the convection electric field driven by tailward outflow of plasma in Jupiter's magnetosphere.

The further confirmation of causalities of the short term variations is deferred to future studies in both observations and modeling analyses. For example, we can obtain the information on temperature of upper atmosphere by coordinated observation of infrared and radio telescope. Developing more reliable brightness distribution model can make more detail comparison with observed radio image. In addition, as we show the effect of global convection electric field, comprehensive study regarding to Jupiter's magnetosphere is needed to reveal the detailed characteristics of JSR.