Roles of Io's volcanic activity on Jupiter's inner magnetosphere
(木星内部磁気圏に於けるイオの火山活動の役割)

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Io is the most volcanically active body in the solar system. Io's atmosphere consists of volcanic gas, and this volcanic gas continuously escapes from Io into Jupiter's inner magnetosphere. Jupiter's inner magnetosphere is therefore occupied by plasma which consists of heavy ions (e.g., S+, S++, S+++, O+, O++, and O+++). Magnetospheric environment of Jupiter is very different from that of the earth because its magnetospheric plasma has its origin almost only in the solar wind. It is well-known that magnetospheric phenomena of the earth like magnetic storms are actually triggered or controlled by the solar wind or solar activity. Influence of the solar wind on Jupiter's magnetosphere is also known to exist. However, Io's contribution on Jupiter's magnetospheric change has not investigated well while we know Jupiter's inner magnetosphere is filled with Iogenic plasma. In this study, we tried to reveal this outstanding issue.

Jupiter's sodium nebula, extending over several hundreds of Jovian radii, is a result of atmospheric escape of sodium atoms from Io through the Io plasma torus. Sodium atoms forming the nebula have large velocities so that they can escape from the strong gravitational field of Jupiter. It is believed nowadays that pick-up of NaCl+ in Io's ionosphere by Jupiter's co-rotating magnetic field, and their subsequent dissociative recombination with an electron in Io plasma torus is a primary source of producing these fast neutral sodium atoms. Volcanic eruptions are only likely sources of NaCl gas on Io because of its sublimation temperature. This volcanically supplied NaCl gas is rapidly ionized and becomes ionospheric ions on Io's dayside hemisphere, then they go to the Io plasma torus. Lifetime of NaCl+ ions in the Io plasma torus is 10 hours. In addition, the sodium nebula consists of neutral particles that are not under control of any electric or magnetic force. Hence, its brightness seems to reflect faithfully Io's volcanic supply. We have been making ground-based observations of Jupiter's sodium nebula in the past decade. Its D-line brightness changed year by year. In addition, we found two short enhancements which lasted several days in 2003 and 2007, respectively.

An imaging observation of [SII] 673.1 nm emission from the Io plasma torus was also made around the enhancement of the sodium nebula seen in 2003. During this enhancement, [SII] 673.1 nm brightness and the ion temperature (scale height) along Jupiter’s magnetic fields did not show any significant change, but magnetic flux tube content of S+ ion was calculated from the [SII] 673.1 nm brightness and the scale height, and an increase of the ion flux tube content was clearly identified. Thus, an increase of supplied plasma from Io seems to be reflected in both plasma density and ion temperature. We conclude that Io’s volcanic enhancement with a duration time of a few days can change Jupiter’s inner magnetospheric environment in aspects of both ion density and temperature.

We could successfully obtained activities of Jupiter’s radio emissions called DAM and HOM, which are believed to be related to Jupiter’s aurora emissions, using data from the WIND spacecraft around the enhancement of the Jupiter’s sodium nebula in 2007. Most of the radio signals are not contaminated by solar radio or earth’s auroral radio emissions around this period. Activities of both DAM and HOM seemed to become lower after the sodium nebula enhancement with respect to both emission power and occurrence. In addition, Jupiter’s aurora named Io’s footprint aurora which appears on the footprint of Io’s flux tube on Jupiter became unstable after the enhancement of the sodium nebula. This may indicate Io’s volcanic enhancements weaken Jupiter’s magnetospheric activities temporally. However, this is an insight obtained from only a single event. More events should be studied in the future to obtaine more detailed insights.

Our past study had been made with an assumption that Io’s volcanic activity can be inferred from brightness of the Jupiter’s sodium nebula. However, several issues, like an exact beginning time of volcanic enhancement or temperature that volcanoes can attain, cannot be solved only from the sodium nebula. We hence made groundbased observations of Io’s volcanic activity using a 1-m telescope at the University of Tokyo Atacama Observatory, Chile in November, 2009 in a wavelength range of middle infrared. Observations of the Io’s volcanic activity in past studies have been made in near infrared because thermal radiation of Io’s volcanoes has its peak in that wavelength. However, the observations for Io’s volcanic activity have two serious problems. One is that this type observation can be made only when Io is in Jupiter’s shadow because solar radiation has a strong flux in near infrared. The other problem is that Io’s rotational and orbital period are synchronized, so we can observe only

Io’s Jupiter-facing hemisphere. On the other hand, the solar flux is negligibly-small compared to the thermal emission of Io in mid infrared, but decline of volcanic radiation at middle infrared from near infrared is not as large as that of solar radiation. Our observations for Io’s volcanic activity were made at wavelengths of 8.9 and 12.2 microns. In addition to results of the mid infrared observation, a decreasing trend of Io’s volcanic activity was also seen in the observation results of Jupiter’s sodium nebula around the end of 2009. This indicates that observations of Io’s volcanic activity in mid infrared have a certain accuracy.

We established methods for observing Jupiter’s magnetospheric phenomena and Io’s volcanic activities, and found Io’s volcanic activity has some effects on Jupiter’s magnetosphere to some extent through the present study. Especially, Io’s control of plasma abundance in Jupiter’s inner magnetosphere was shown clearly. It is expected that insights relations among Jupiter’s magnetospheric phenomena and Io’s volcanoes are developed in an orderly sequence by means of making these observations simultaneously. These observations will also support strongly future missions (e.g.; Sprint-A, Juno) of which target is Jupiter.