Ganymede's magnetic footprint brightness and location in respond to main emission

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Abstract. Jupiter's aurora features have been observed by the Hubble space telescope (HST) for over two decades. One of the auroral features, Ganymede's magnetic footprint, appears close to the main emission and is sometimes embedded in the main emission. The latter case causes difficulty in identifying Ganymede's magnetic footprint from in the main emission. The FUV aurora images were taken by Advanced Camera for Surveys (ACS) onboard the HST. The fluctuations of Ganymede's footprint brightness over time will be analyzed. Moreover, the correlation between the brightness and locations of the main emission and Ganymede's magnetic footprint will be analyzed to characterize the connection between ionospheric phenomena and the magnetospheric dynamics. Since the main emission is very bright in comparison with the footprint, therefore, the variation of the main emission can affect the Ganymede's magnetic footprint. Furthermore, the expansion of the main emission is consistent with the location shift of Ganymede's magnetic footprint in equatorward direction. The brightness and location of the main emission can be influenced by the plasma variation in Jupiter's magnetosphere which is affected partly by the volcanic eruption on Io and solar wind dynamic pressure. The variation of Ganymede magnetic footprint's brightness and location in respond to the main emission could be an important indicator of the magnetospheric variation under the influences of internal and external factors.

1. Introduction

Jupiter's aurora is mainly divided into three parts which are main emission, polar emission, and satellites' magnetic footprints (figure 1). This work focuses on the location shifts of main emission and Ganymede's magnetic footprint. Jupiter's magnetosphere contains plasma which is mainly from a volcanic eruption on Io. Charged particles inside the magnetosphere travel along Jupiter's magnetic field lines into Jupiter's ionosphere. These charged particles interact with Jupiter's atmospheric particles resulting in atmospheric particles emitting the auroral emissions.

The satellite magnetic footprints are connected to the magnetohydrodynamic interactions near the satellites which are embedded in Jupiter's magnetosphere. Due to the interactions, charged particles near the satellites are carried from the vicinity of the satellites along the magnetic flux tubes toward Jupiter's ionosphere causing the auroral magnetic footprints.

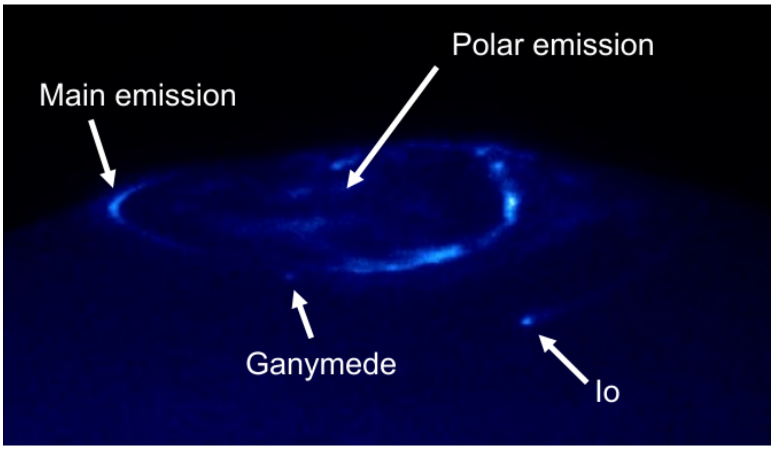

Figure 1. Jupiter's auroral components in northern hemisphere detected on day of year (DOY) 052 or 21 February 2007 by ACS instrument onboard Hubble Space Telescope.

From previous work [1, 2], Galileo observation revealed a region of high energy electron at distance between 20 - 30R_J ($1R_J$ = ~71492 km) in Jupiter's magnetosphere. On the other hand, Ganymede orbits at distance about 15R_J from Jupiter in Jupiter's middle magnetosphere. Figure 2 shows the stretching of the magnetic field lines in the middle magnetosphere which is influenced by strong variation of plasma. As a result, the magnetic field stretching affects Ganymede magnetic footprint locations in Jupiter's ionosphere to shift in poleward or equatorward directions depending on the plasma condition near the satellite. Ganymede's magnetic footprint typically appears close to the main emission. Therefore, the simultaneous shifts of the main emission and Ganymede's magnetic footprint locations could be used to identify the variation of plasma and magnetic field structure inside Jupiter's magnetosphere.

This work presents the location shifts of the main emission and Ganymede's magnetic footprint from the center of main emission. The center of main emission in northern hemisphere is at 74° latitude and 185° longitude [3]. From previous work [4], the expansion of main emission can be influenced by the plasma variation in Jupiter's magnetosphere which is affected partly by volcanic eruption on Io. Moreover, the structure of the main emission is affected by the solar wind dynamic pressure [5]. Therefore, in this work, the influence of both volcanic materials and solar wind dynamic pressure on the locations of main emission and Ganymede's magnetic footprint will be studied. The structure of the main emission was analyzed with the average path [5] to investigate the effect of solar wind property. The fluctuations of solar wind property could affect Jupiter's magnetic field structure. In the case of compression, the magnetic field lines can be compressed closer to Jupiter resulting in the shift of the main emission in poleward direction. This result could be implied to the shift of Ganymede magnetic footprint as well.

2. Data analysis

Jupiter's FUV images in this study were obtained by Hubble Space Telescope (HST) in 2007, using Solar blind camera (SBC) from the Advanced Camera for Survey (ACS) (115 -170 nm). The reduction process and auroral brightness conversion are based on pipeline routine from

Boston University [6, 7]. The brightness of Ganymed's magnetic footprint is presented in kilo-Rayleighs (1 kR = 10^9 photons cm^{-2} s^{-1}). The polar projection and location of the main emission were analyzed with (Interactive Data Language) IDL and Python software.

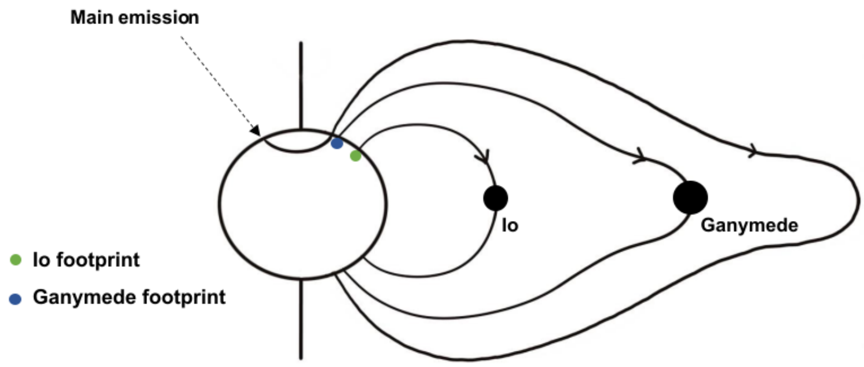

Figure 2. Sketch of the cross section through the inner and middle magnetosphere of Jupiter. Jupiter's magnetic field lines are represented by the solid lines with arrows. Io orbits in the inner magnetosphere ($\sim 6R_J$), while Ganymede orbits in the middle magnetosphere ($\sim 15R_J$). Adapted from figure 1 in Cowley and Bunce [8].

3. Result and discussion

Polar projections of Jupiter's aurora (figure 3) show the structures of main emission and the locations of Ganymede's magnetic footprint from the average path [5] (red dash line). The main emission structure is close to the average path at longitude beyond ∼180°. However, at longitude ∼150°-160°, the main emissions observed on DOY 052 and DOY 059 shift from the average path with similar distance (figure 3a and 3b). In the bottom panels, the main emission observed on DOY 068 shifts more further toward the equator in comparison with the data on DOY 053. Moreover, the shifted of Ganymede's magnetic footprint in equatorward direction is also detected on DOY 068.

The polar projection showed the similar feature on DOY 052 and DOY 059 (figure 3a and 3b). The solar wind propagation model showed that the solar wind dynamic pressure decreased slightly from DOY 052 to DOY 059 [6]. The New Horizons spacecraft observations revealed that, during February 2007, there were continuous volcanic eruptions on Io [9]. As a result, Jupiter's main emission and Ganymede's magnetic footprint located at similar locations while comparing data from DOY 059 with DOY 052.

The main emission had a noticeable change at longitude ∼150°-160° on DOY 053 from DOY 068 (figure 3c and 3d). Between these two events, the main emission expanded in equatorward direction with maximum shift of ∼1.6° at longitude ∼150° on DOY 068 in comparison to the shift observed on DOY 053. Based on the propagating solar wind model [6], the solar wind dynamic pressure increased on DOY 053. The high solar wind dynamic pressure should correspond with the location shift of the main emission in polweard direction on DOY 053 in comparison to the main emission location in DOY 068. For the comparison, the expansion of the main emission is consistent with the location shift of Ganymede's magnetic footprint. Table 1 shows that the location of Ganymede's magnetic footprint shifted by ∼0.6° in equatorward direction at similar longitude on DOY 068 in comparison to the footprint observed on DOY 053. The equatorward shift on DOY 068 could correspond with the increase of plasma sheet density in Jupiter's magnetosphere due to accumulated volcanic materials from Io [9]. The increase in plasma density causes the stretching of the magnetic field lines away from Jupiter. Thus, the locations of main emission and Ganymede's footprint are shifted in equatorward direction on DOY 068.

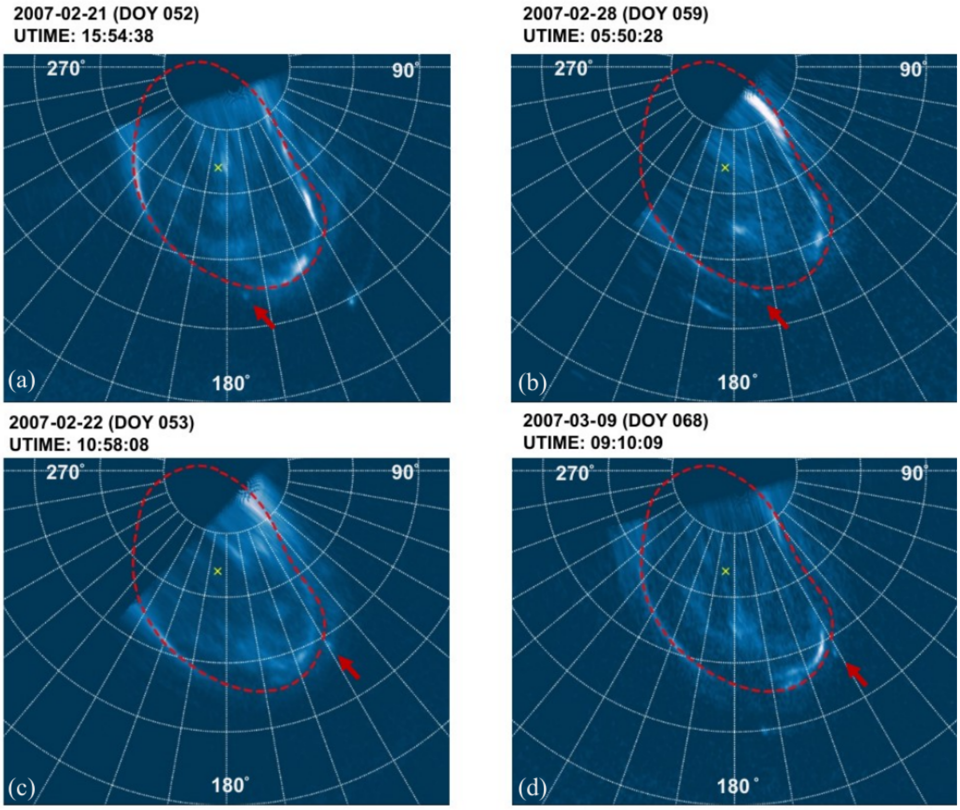

Figure 3. Polar projections show the variations of Jupiter's auroral structures, observed in 2007 between DOY 052 and 059 (a and b) and between DOY 053 and 068 (c and d). The statistical position of main emission is represented by red dashed line [5]. The center of Jupiter's main emission is represented by yellow cross. The red arrows point at Ganymede's magnetic footprint.

Table 1 shows that Ganymede's magnetic footprint brightness on DOY 052 is ~71.6 kR greater than the brightness on DOY 059. However, Ganymede's magnetic footprint brightness on DOY 053 is approximately the same as the footprint brightness observed on DOY 068. It must be noted that Ganymede's magnetic footprint appears close to the main emission. Since the main emission is very bright in comparison with the Ganymede's magnetic footprint. Thus, the variation of location and brightness of the main emission could affect the analysis of Ganymede's magnetic footprint brightness. Moreover, the brightness of Ganymede's magnetic footprint is related to the plasma density around the moon. The plasma density in Jupiter's magnetosphere increase mainly from Io volcanic materials. Therefore, the detail interpretation of Ganymede's magnetic footprint brightness will be studied in corresponding with the location shift and the brightness variation of the main emission in the future.

4. Conclusion

Jupiter's main emission could be affected by both internal (Io volcanic materials) and external (solar wind dynamic pressure) factors. During the solar wind compression, Jupiter's magnetopause is compressed resulting in the poleward shift of the main emission and Ganymede's magnetic footprint. The increasing of plasma from volcanic eruption on Io affects the structure of

Table 1. The comparison of main emission (ME) and Ganymede's magnetic footprint (GFP) locations from the center of Jupiter's aurora [3] observed in 2007 between DOY 052 and 059 and between DOY 053 and 068.

DOY	GFP	ME location(∼150°-160°)	Brightness of GFP(kR)
052-059	Similar location	Similar location	71.6(052), 38.0(059)
053-068	∼0.6° equatorward	∼0.5°-1.6° equatorward	80.6(053), 71.6(068)

Jupiter's magnetic field, especially in the inner magnetosphere. While other factors are needed to be considered, both volcanic materials from Io and solar wind dynamic pressure strongly influence the structure of magnetosphere, causing the magnetic field and plasma fluctuations. Consequently, the modulation of main emission and Ganymede's magnetic footprint locations were detected and should be investigated in detail.

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