Auroral bright spot in Jupiter's active region in corresponding to solar wind dynamic

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Abstract. Jupiter's polar emission has brightness whose behavior appears to be unstable. This work focuses on the bright spot in active region which is a section of Jupiter's polar emission. Images of the aurora were taken by Advanced Camera for Surveys (ACS) onboard the Hubble Space Telescope (HST). Previously, two bright spots, which were found on 13^{th} May 2007, were suggested to be fixed on locations described by system III longitude. The bright spot's origin in equatorial plane was proposed to be at distance 80-90 Jovian radii and probably associated with the solar wind properties. This study analyzes additional data on May 2007 to study long-term variation of brightness and locations of bright spots. The newly modified magnetosphere-ionosphere mapping based on VIP4 and VIPAL model is used to locate the origin of bright spot in magnetosphere. Furthermore, the Michigan Solar Wind Model or MsWim is also used to study the variation of solar wind dynamic pressure during the time of bright spot's observation. We found that the bright spots appear in similar locations which correspond to similar origins in magnetosphere. In addition, the solar wind dynamic pressure should probably affect the bright spot's variation.

1. Introduction

Jupiter's aurora are phenomena which can be found around the pole in both Jupiter's northern and southern hemispheres. Aurora emissions are displayed when accelerated particles moving along magnetic field lines precipitate into Jupiter's ionosphere and impact atmospheric particles. Jupiter's auroras are separated into three components based on their locations, origins, and variation behaviors. The main emission is the brightest and most permanent feature. Its shape appears like an oval around the pole. Previous works suggested that the main emission is generally mapped to radial distance at around 20-30 Jovian radii (R_J), which is the location in middle magnetosphere [1]. This implies that the main emission is driven by internal process inside Jupiter's magnetosphere. Satellite magnetic footprints are another auroral feature whose auroral particles are associated with Jupiter's satellites, i.e. Io, Europa, and Ganymede. The footprint features are located at lower latitude than that for the main emission. Since the satellites are considered to be at particular distance inside Jupiter's magnetosphere, these satellites magnetic footprints are very useful as constraints for magnetic mapping models between Jupiter's ionosphere and inner magnetosphere [2].

The last features locating in higher latitude above main emission are called Jupiter's polar emissions. Their brightness quite varies and their origins are still unclear. The polar auroras are generally purposed to have connections with the outer magnetosphere, which may have some relation with the solar wind. The polar emissions are also divided into three sub regions; dark, swirl, and active regions [3]. Dark region is located in the dawn sector above the main emission. The dark region is dark in UV with a crescent shape that can extend and compress because of Jupiter's rotation but fixed with local time [4]. Swirl region, which consists of many details and behaviors, locates poleward from the active and dark region. Active region is very dynamic. Its most observable features are flares, bright spots, and arc-like features. Vogt et al. (2011) [2] suggested that the active region can be mapped from its position in Jupiter's ionosphere to the region beyond the dayside magnetopause. Pallier and Prangé (2001)[5] proposed that bright spots, an occasionally observable feature in active region, do not appear at any fixed location in system III longitude but often appear close to the local magnetic noon or 12 magnetic local time (MLT). Furthermore, bright spot probably be the signature of the polar cusp, at which the magnetic field lines were considered to be related to solar wind.

We analyze data of Jupiter's aurora images taken on May 2007 in order to study the bright spot's behaviors. Furthermore, we also investigate their origins in magnetosphere using Jupiter Ionosphere/Magnetosphere Online Mapping Tool based on flux equivalent calculation by Vogt et al. (2011 and 2015)[2, 6]. The results will be used to determine relation between bright spots and solar wind properties, which are based on simulated solar wind propagation by the Michigan Solar Wind Model (mSWiM) developed at University of Michigan [7].

2. Data Analysis

Images of Jupiter's aurora were observed by Advanced Camera for Surveys (ACS) camera onboard Hubble Space Telescope (HST). Data were taken about 45 minutes a day during 11^{th} May 2007 until 31^{st} May 2007, represented by day of year (DOY) 131 to 151 using F125LP longpass filter. The exposure time for each image was 100s (with 40s interval). Details on reduction processes were discussed by Wannawichian et al. (2010) [8]. The system III longitudes of bright spots in Jupiter's auroral images were evaluated using Interactive Data Language (IDL). Bright spots location was mapped from ionosphere to magnetosphere using the newly modified Jupiter Ionosphere/Magnetosphere Online Mapping Tool, based on VIP4 and VIPAL models [2, 6]. Finally, the solar wind dynamic pressure obtained from the Michigan Solar Wind Model or mSWiM was used to examine the role of solar wind in bright spot's activities.

3. Result and discussion

From all data of Jupiter's aurora in May 2007, eight bright spots were seen as shown in Table 1. The bright spots were labeled by letter *a* to *h*. Two bright spots were occasionally found in the same DOY. At DOY13, bright spots *b* was seen about 23 minutes after the appearence of bright spot *a*, also with bright spot *h*, which was found about 30 minutes after the appearance of bright spot *g* at DOY151. The positions of bright spots in Jupiter's ionosphere described by latitudes and longitudes in system III longitudes were analyzed using IDL program. The latitudes and longitudes of bright spots were found varying within 10 degrees. Next, the Jupiter Ionosphere/Magnetosphere Online Mapping Tool was used to map position of bright spots from ionosphere to magnetosphere based on flux equivalent calculated by VIP4, VIPAL, and GAM internal magnetic field models. The results showed that the origins of bright spots were located at radial distances more than 70 R_J. Moreover, their positions were mostly found in local time that considered to be daytime. However, some origins of bright spots were examined to be beyond 150 Jovian radii or beyond the dayside magnetopause. These distances were considered to be at the close-open field lines boundary. The result implies that the origins of bright spots could directly connect to the solar wind. It can be related to Jovian polar cusp as Vogt et al. (2011) [2] and Pallier and Prangé (2003) [5] suggested previously.

Table 1. Bright spots characteristics obtaining from IDL and Jupiter ionosphere/magnetosphere online mapping tool in corresponding to bright spot detections.

Bright spot	UT (DOY)	Latitude	Longitude	Position in magnetosphere		
				Model	Radial distance (R_J)	Local Time (Hr)
a	133.708	63.133	175.010		**B**	**B**
b	133.724	61.939	173.257	VIP4	85.516	10.836
c	136.648	61.668	177.912	VIP4	70.235	11.698
				VIPAL	85.675	11.849
d	137.854	64.320	177.247		**B**	**B**
e	138.724	62.872	168.530	VIP4	91.429	14.534
f	143.635	63.332	178.978		**B**	**B**
g	151.487	66.354	171.436		**B**	**B**
h	151.510	64.185	166.342	GAM	145.22	18.836

Note: The position in magnetosphere obtained from the Jupiter Ionosphere/Magnetosphere Online Mapping Tool are based on VIP4, GAM, and VIPAL magnetic field models. **B** refers to mapped location beyond 150 Jovian radii or beyond the dayside magnetopause. Occasionally, bright spot can be mapped to position in magnetosphere by some models while others give prediction to **B**. In this case, we showed only predictions that are not **B**.

Furthermore, the variation of solar wind properties, which are the solar wind number density, the solar wind dynamic pressure, and the solar wind magnetic field, from MsWim were compared during the time of auroral observations, represented by Figure 1 for the interval between 10^{th} May 2007 and 9^{th} June 2007. Vertical lines labeled by letters $a - h$ correspond to bright spots $a - h$ in Table 1. The results show that some bright spots occurred during the same time that the solar wind properties varied. The sample spots, which can be explicitly seen, are bright spots *a* and *b* during the solar wind increasing and *c*-*e* close to the solar wind decreasing. However, there are bight spots which were observed during the quiet time of solar wind propagation. This result could be related to Clarke et al. (2009) [9] who suggested that the mSWiM model had some uncertainty in time propagation. It should be noted that the bright spots may be affect by other dynamics as well.

4. Conclusion

In this study, we detected eight bright emission spots which were found in Jupiter's auroral images observed during May 2007. The bright spots seems to have unstable behavior. The latitudes and longitudes are varied within 10 degrees. The origins in magnetosphere were determined, based on VIP4, VIPAL, and GAM internal magnetic field models, to be at radial distances more than 70 R_J, while the local times were mostly considered to be daytime. The origins possibly locate in the outer magnetosphere, which can be related to Jovian polar cusp and affected by the solar wind. However, bright spots occasionally occurred while the solar wind was in quiet state. The uncertainty in solar wind propagation and the roles from other dynamics in bright spot emissions should be taken into consideration in more detail.

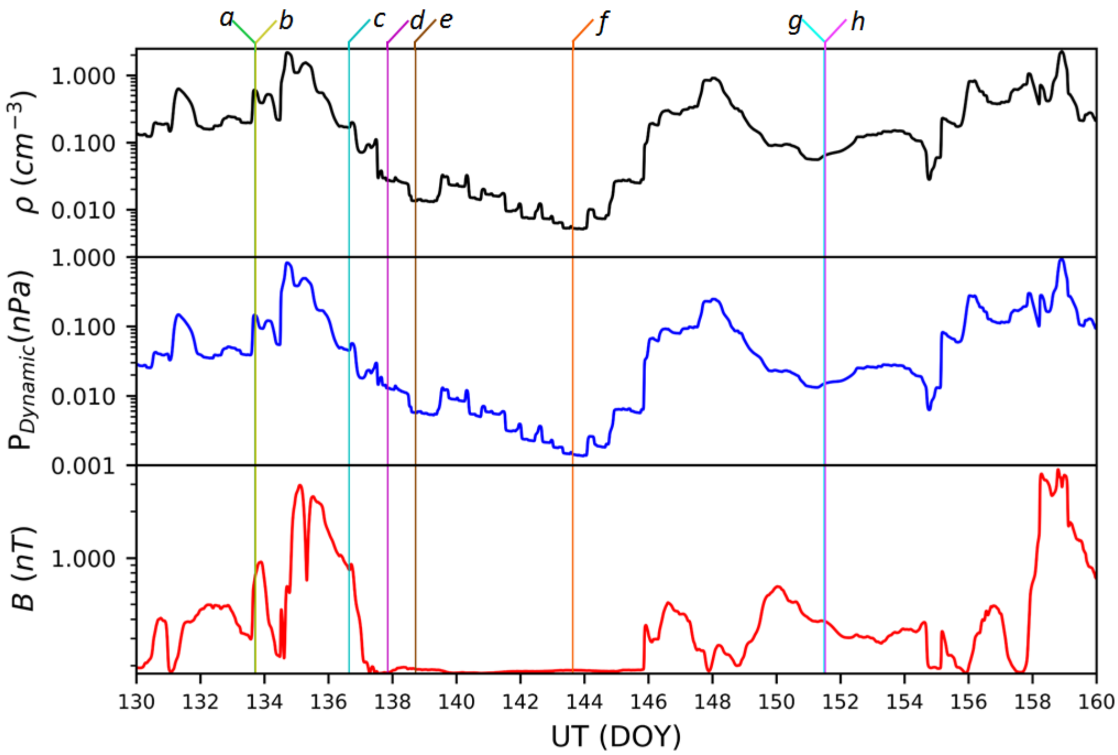

Figure 1. The detections of bright spots (vertical lines) in comparison with the solar wind propagation, including solar wind number density (top), solar wind dynamic pressure (middle), and solar wind magnetic field strength (bottom) at Jupiter from 10^{th} May 2007 to 9^{th} June 2007.

Acknowledgement

We would like to acknowledge Marissa Vogt from Boston University for the permission to use Jupiter Ionosphere/ Magnetosphere Online Mapping Tool. We also thank K.C. Hansen and B. Zieger for their Michigan Solar Wind Model. This work is based on observation with the NASA/ESA Hubble Space Telescope, obtained at the Space Telescope Science Institute, which is operated by AURA, Incorporated, for NASA. The research was supported by National Astronomical Research Institute of Thailand (NARIT) and Graduate School Chiang Mai University. Haewsantati was partially supported by Science Achievement Scholarship of Thailand (SAST).

References

[1] Clarke J T, Grodent D, Cowley S W H, Bunce E J, Zarka P, Connerney J E P and Satoh T 2004 *Jupiter: The Planet, Satellites, and Magnetosphere* (Cambridge University Press) chap 26, pp 639–670
[2] Vogt M F, Kivelson M G, Khurana K K, Walker R J, Bonfond B, Grodent D and Radioti A 2011 *J. Geophys. Res.* **116** A03220
[3] Grodent D, Clarke J T, Waite J H, Cowley S W H, GéRard J C and Kim J 2003 *J. Geophys. Res.* **108** 1366
[4] Grodent D 2015 *Space Sci Rev.* **187** 23–50
[5] Pallier L and Prangé R 2001 *Planet. Space Sci.* **49** 1159–1173
[6] Vogt M F, Bunce E J, Kivelson M G, Khurana K K, Walker R J, Radioti A, Bonfond B and Grodent D 2015 *J. Geophys. Res.* **120** 2584–2599
[7] Zieger B and Hansen K C 2008 *J. Geophys. Res.* **113** A08107
[8] Wannawichian S, Clarke J T and Nichols J D 2010 *J. Geophys. Res.* **115** A02206
[9] Clarke J T *et al.* 2009 *J. Geophys. Res.* **114** A05210