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Key Points:

- Observations at Saturn of an isolated high-latitude auroral spot located in the prenoon sector and associated with the cusp
- Pulsations in the cusp aurora brightness with 60–70 min periodicity, as well as in electron flux and magnetic field data
- Pulsed dayside magnetopause reconnection is suggested to produce the cusp auroral brightening and the pulsations in the electron flux

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Pulsations of the polar cusp aurora at Saturn

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Abstract The magnetospheric cusp is a region connecting the interplanetary environment to the ionosphere and enabling solar wind particles to reach the ionosphere. We report the detection of several isolated high-latitude auroral emissions with the Ultraviolet Imaging Spectrograph of the Cassini spacecraft. We suggest that these auroral spots, located in the dawn-to-noon sector and poleward of the main emission, are the ionospheric signatures of the magnetospheric cusp, in agreement with some previous observations with the Hubble Space Telescope. The high-latitude cusp auroral signature has been associated with high-latitude lobe reconnection in the presence of a southward interplanetary magnetic field. The occurrence rate of the polar cusp aurora suggests that lobe reconnection is frequent at Saturn. Several auroral imaging sequences reveal a quasiperiodic brightening of the polar cusp aurora with a period in the range of 60 to 70 min. Similar pulsations in the energetic electron fluxes and in the azimuthal component of the magnetic field are simultaneously observed by Cassini instruments, suggesting the presence of field-aligned currents. Pulsed dayside magnetopause reconnection is a likely common triggering process for the cusp auroral brightenings at Saturn and the quasiperiodic pulsations in the high-latitude energetic electron fluxes.

1. Introduction

The topology of the planetary magnetic field includes a funnel-shaped region in the high-latitude dayside magnetosphere inclined toward the direction of the Sun. This magnetospheric region, so-called cusp, is an entrance for the magnetosheath plasma which can reach the ionosphere of the planet [e.g., *Smith and Lockwood*, 1996; *Cargill et al.*, 2005]. The cusp can be associated with dayside magnetic reconnection between the planetary and the interplanetary magnetic field (IMF). The reconnection process opens closed magnetospheric field lines, allowing solar wind particles to flow into the cusp along open field lines. These open field lines map to the dayside high-latitude ionosphere, poleward of planetary closed field lines. The location of the reconnection depends on the orientation of the IMF B_z component. At Earth's magnetosphere, in the presence of a southward IMF, a reconnection occurs at low-latitude magnetopause, where the planetary magnetic field is antiparallel to the IMF. This low-latitude reconnection opens the closed planetary field lines. In the case of northward IMF conditions, the closed magnetospheric field lines are parallel with the interplanetary magnetic field contrary to the open field lines of the magnetotail lobe which are antiparallel. Therefore, reconnection occurs at higher latitudes between the IMF and the lobe field lines [*Onsager and Fuselier*, 1994].

The particles energized by dayside reconnection and flowing inside the cusp leave a signature in the ionosphere in the form of auroral emissions. At Earth, a bright auroral spot near local noon at latitudes higher than the dayside auroral oval has been interpreted as the signature of the high-latitude reconnection with northward IMF [*Milan et al.*, 2000a; *Frey et al.*, 2002]. The location of the cusp auroral feature, prenoon or postnoon, depends on the sign of the IMF B_y component. When the IMF turns southward, the signature of the low-latitude reconnection is related to the polar cap boundary and the cusp footprint merges with the dayside auroral oval [*Fuselier et al.*, 2002]. Furthermore, the dayside magnetopause reconnection at Earth can be occasionally pulsed, producing flux transfer events [*Russell and Elphic*, 1978; *Wild et al.*, 2001].

At Saturn, the first observational evidence of the cusp auroral emission has been achieved using images acquired with the Hubble Space Telescope (HST) [*Gérard et al.*, 2004]. As is the case at the Earth, the cusp footprint can present two distinct morphologies, depending on the orientation of the IMF: a bright spot near local noon and poleward of the main emission and a brightening along the main oval in the prenoon sector. Saturn's main auroral oval emission is generally suggested to be associated with the shear flows present at the boundary between open and closed magnetic field lines [e.g., *Bunce et al.*, 2008]. However, recent studies showed that the open-closed field line boundary (OCFLB) lies 1-2° poleward of the upward field-aligned currents associated with the main oval in the nightside [*Jinks et al.*, 2014; *Talboys et al.*, 2011] and dawnside [*Meredith et al.*, 2014; *Belenkaya et al.*, 2014].

Bunce et al. [2005] calculated that the energy fluxes of unaccelerated particles precipitating into the cusp are not sufficient to produce UV aurora at the intensities which are observed. However, they argued that the cusp aurora is associated with reconnection at the dayside magnetopause, possibly pulsed. In presence of northward IMF (corresponding to southward IMF for the Earth since Saturn and the Earth have oppositely aligned magnetospheric fields), pulsed reconnection at the low-latitude dayside magnetopause creates pulsed twin vortical flows in the magnetosphere and ionosphere close to the OCFLB. Centered in these vortices, field-aligned currents cause the brightening of the main oval at noon. For southward IMF conditions at Saturn and high-latitude lobe reconnection, the twin vortical flows, reversed in sense compared to the previous case, and the associated and reversed field-aligned currents are located poleward of the OCFLB. For both northward and southward IMF, the sign of the IMF B_y component determines if the cusp footprint appears in the prenoon or postnoon sector. This conceptual model of *Bunce et al.* [2005] is supported by HST observations of the UV aurora coupled with measurements of the solar wind properties and the IMF by Cassini during its approach to Saturn [*Gérard et al.*, 2005].

Other examples of high-latitude cusp emission associated with lobe reconnection are reported by *Meredith et al.* [2014] on HST images and by *Mitchell et al.* [2016] on a sequence of images taken with the Cassini UV imaging spectrograph (UVIS). In their study, *Mitchell et al.* [2016] reported a periodic brightening of an isolated auroral emission poleward of the main emission and speculated that it could be a cusp auroral signature. The brightness pulsations were characterized by a period of around 1 h, in phase with fluctuations in energetic electron fluxes, magnetic field angles, and auroral hiss power.

The dayside reconnection process at the Kronian low-latitude magnetopause in the presence of northward IMF can evolve in bursts of reconnection, resulting in poleward deviation of the main auroral emission, so-called bifurcation, in the noon-to-dusk sector [*Radioti et al.*, 2011; *Badman et al.*, 2013]. The flux transfer events in the Earth's magnetosphere produce a similar auroral signature in the postnoon ionosphere [*Milan et al.*, 2000b; *Sandholt and Farrugia*, 2007]. Bifurcations can exhibit multiple brightenings at Saturn [*Radioti et al.*, 2013; *Mitchell et al.*, 2016]. These consecutive brightenings are a possible consequence of multiple reconnection along the same flux tube [*Radioti et al.*, 2013] as it is also suggested for the Earth [*Fasel et al.*, 1993]. In case the bifurcations at Saturn are related to closed field lines due to shear flow in the magnetodisk, *Radioti et al.* [2013] suggested that the multiple auroral brightenings could be alternatively explained by bouncing of Alfvén waves on closed field lines [*Kan et al.*, 1996]. Regarding the cusp auroral emission, it is unclear how bursty magnetopause reconnection triggers the recurrent brightenings reported by *Mitchell et al.* [2016]. Furthermore, the occurrence rate and the link of the pulsed behavior of the cusp aurora with periodic pulsations in in situ measurements have never been established, as the single case study of *Mitchell et al.* [2016] offers no statistical insights.

The current study focuses on Cassini observations of a polar auroral spot located poleward of the main emission, which we suggest to be related to the cusp region. Using the large set of auroral imaging sequences acquired with the Ultraviolet Imaging Spectrograph (UVIS), we present several examples of quasiperiodic 1 h brightenings of the polar cusp aurora. Hence, we are able to determine the typical location and periodicity of the pulsed cusp spot and to investigate its occurrence rate. We also present simultaneous Cassini energetic particles and magnetic field measurements which exhibit similar periodic fluctuations.

2. Observation of an Isolated Polar Auroral Emission

In this work we present auroral images acquired with the UVIS spectrograph on board the spacecraft Cassini. Using the FUV channel (111–191 nm) of UVIS [*Esposito et al.*, 2004], the auroral region was scanned by the narrow low-resolution slit which provides 64 spatial pixels of 1 mrad (along the slit) by 1.5 mrad (across the slit). For all the UVIS observations presented here, the spacecraft Cassini was sufficiently distant from Saturn so that the whole auroral region was included in one single scan. Due to the delay time induced by the scanning through the auroral region, the rows of the obtained images were not recorded at the same time. Therefore, the term "pseudoimage" is generally used to refer to the UVIS images. The pseudoimages are projected on a polar plane following the method described by *Grodent et al.* [2011] and assuming that the auroral emissions

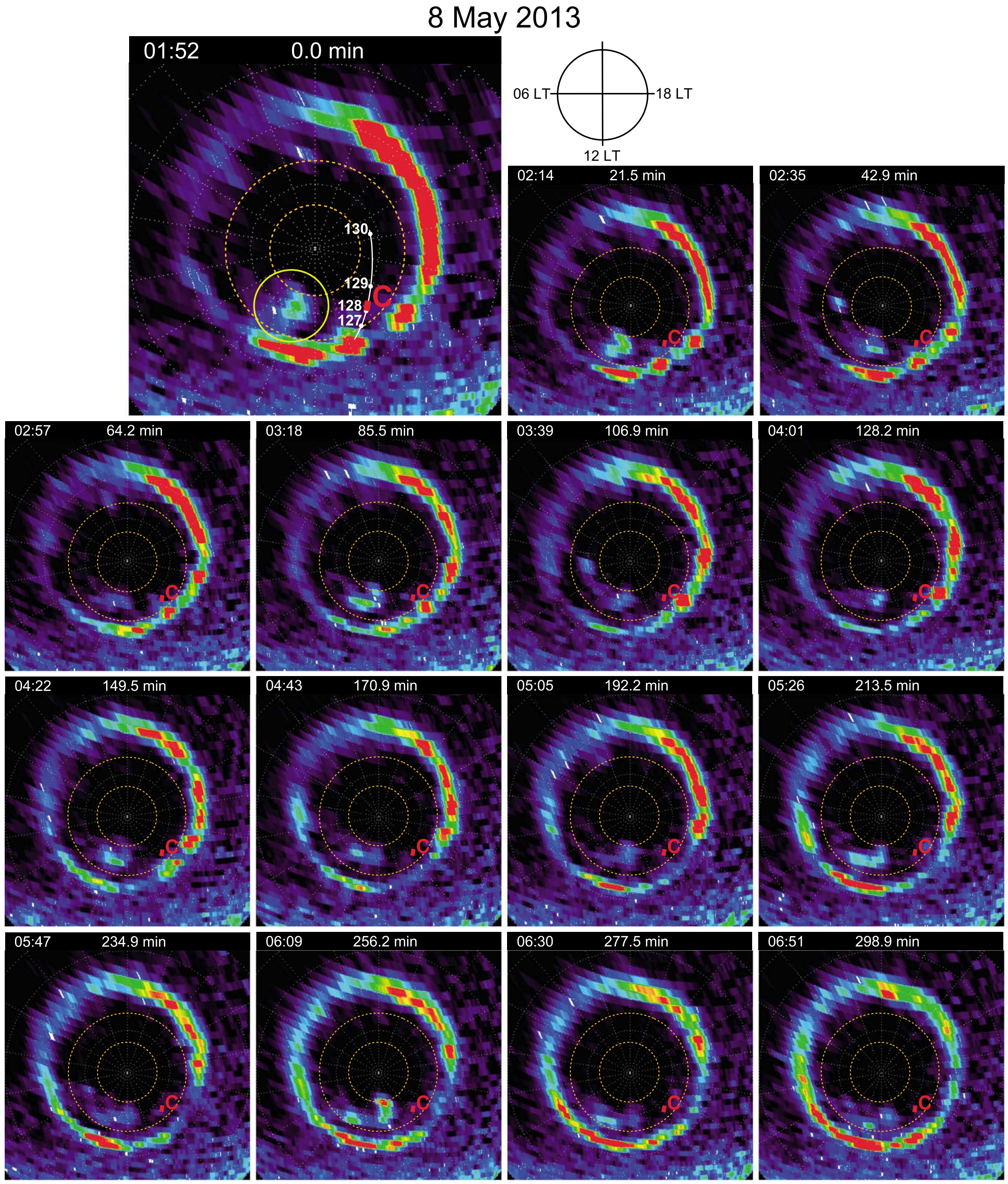

Figure 1. Sequence of polar projections of UVIS pseudoimages of the south FUV aurora, taken on 8 May 2013 (DOY 128) from 01:52 UT to 07:12 UT. The direction of the Sun (12 LT) is toward the bottom of the images and dusk (18 LT) to the right. The start of acquisition time in UT is given on the top of each frame as well as the elapsed time since the start of the sequence. On the first frame, the magnetically mapped Cassini trajectory is drawn in white for the period of 4 days around the UVIS sequence and the red part, close to the letter "C," corresponds to the period covered by the UVIS sequence. The cusp emission discussed in the text is surrounded by a yellow circle in the first frame. Dashed orange circles indicate the colatitude 7° and 14°, colatitude range used for the keogram in Figure 2.

peak at 1100 km above the surface of Saturn, in agreement with the observations by *Gérard et al.* [2009]. The projection procedure does not preserve photometry such that the brightness indicated on the following figures may only be used as a proxy.

We present in Figure 1 a sequence of 15 polar projections of UVIS pseudoimages of the southern UV auroral emissions acquired on day 128 of 2013 (8 May). The projections are displayed as seen from above the north pole through the planet, with the direction of the Sun toward the bottom. The sequence starts at 01:52 UT and ends at 07:12 UT (end of the acquisition of the last image). Each image was recorded every ~21.5 min,

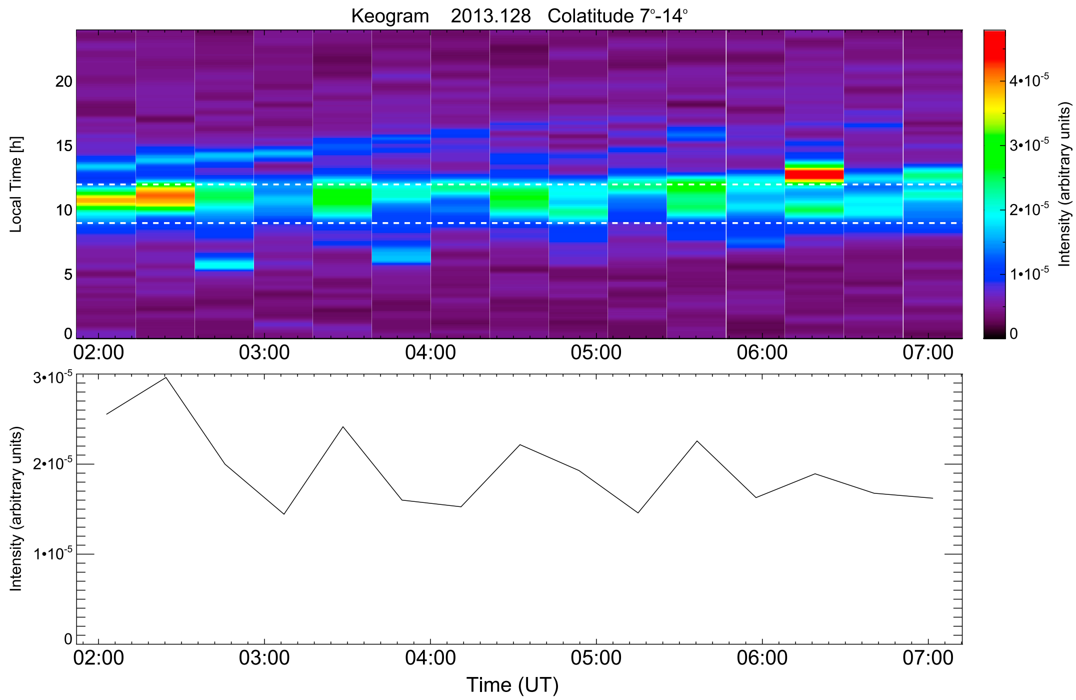

Figure 2. (top) Keogram of intensity for the UVIS image sequence of 8 May 2013, as function of time and local time, built by averaging the brightness between 7 and 14° colatitude. (bottom) Intensity average of the keogram between 9 and 12 LT (dashed lines drawn on the keogram).

and the whole sequence lasts for 320 min. The starting acquisition time is indicated at the top of each frame, as well as the elapsed time since the start of the sequence. During the sequence, the planetocentric latitude of Cassini changes from −39.9° to −42.6° and its altitude above the surface of the planet slightly decreases from 19.7 R_S to 19.1 R_S. The trajectory of Cassini, during 2 days before and after the UVIS sequence, has been magnetically mapped to the ionosphere using the internal field model of *Dougherty et al.* [2005] combined with the ring current model of *Bunce et al.* [2007]. We considered a magnetopause standoff distance of 22 R_S and a current sheet half thickness of 2.5 R_S. The magnetic footprint of the spacecraft is drawn in white on the first frame which is enlarged. The red part, close to the letter "C" and reproduced on each frame, corresponds to the time interval of the sequence.

The main auroral oval is easily distinguishable. A few degrees poleward of the main emission, a bright spot (circled in yellow on the first frame) is visible just before local noon. During the observations, the polar auroral spot remains fixed in local time while its extension and its brightness evolves.

To follow the evolution of brightness of the isolated polar auroral emission, we built a keogram which is shown in Figure 2 (top). The keogram gives the averaged brightness of the auroral emissions between 7° and 14° colatitude (dashed circles drawn on each frame of Figure 1) for each local time and each image of the UVIS sequence. Hence, the keogram allows tracking the local time position and the brightness of the emissions over time. In the keogram presented in Figure 2, the high-latitude spot corresponds to the emission fixed around 1030 LT. This emission exhibits pulsations in brightness. A bright emission is visible in the keogram as well as in Figure 1 at 06:09 UT and at 13 LT. This spot is located higher in latitude and later in local time than the high-latitude emission discussed in this work and has not been considered here.

Figure 2 (bottom) gives the averaged intensity between 9 and 12 LT, the local time sector where the high-latitude spot is observed. The brightness curve reveals that the auroral spot pulses. Its brightness peaks every three UVIS images, which corresponds to a periodicity of ∼65 min. The exact periodicity cannot be inferred due to the acquisition duration of each single UVIS pseudoimage (21.5 min). However, it should be noted that the inferred frequency of the brightening is smaller than the Nyquist frequency of the brightness sampling.

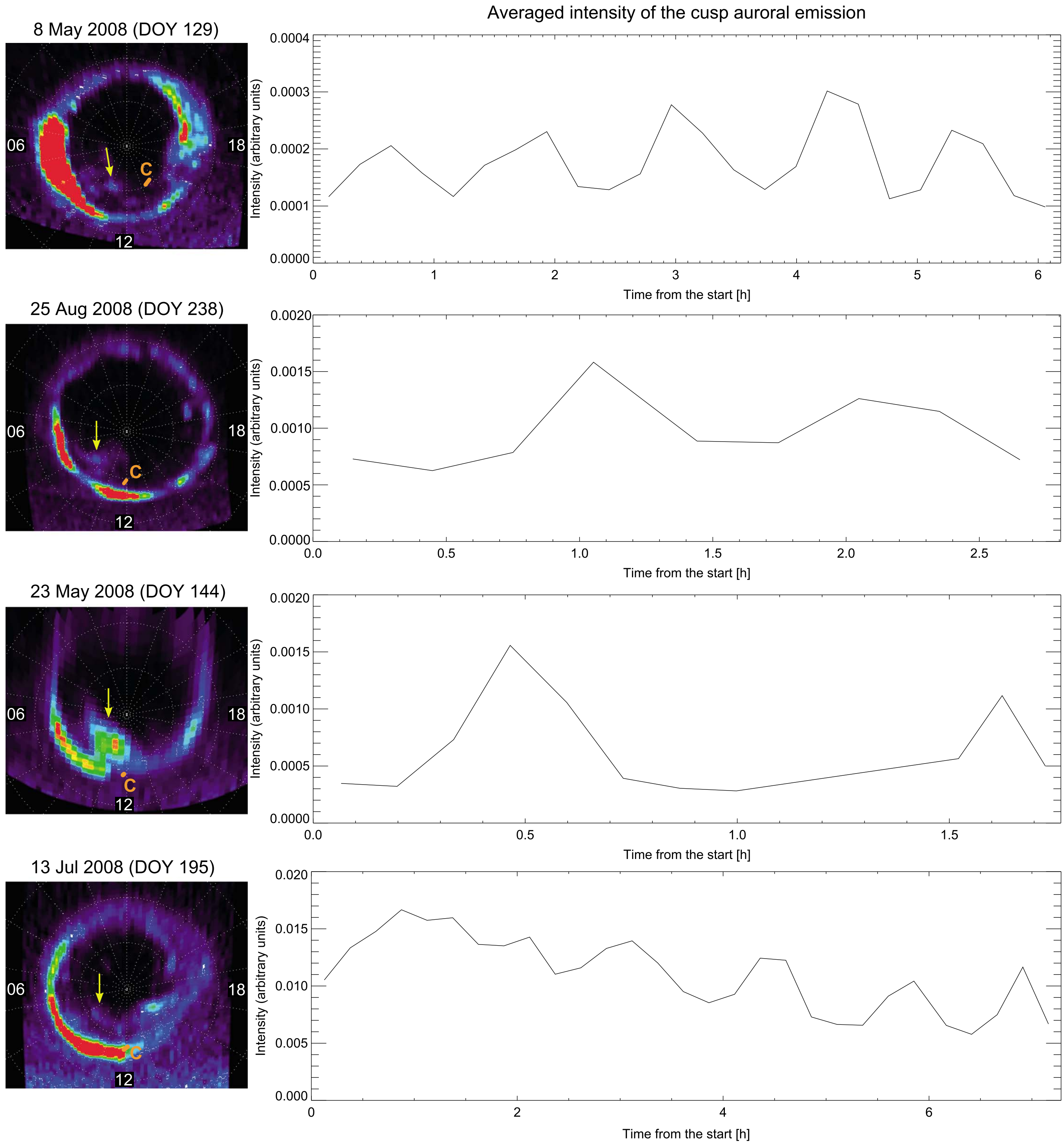

Figure 3. Four examples of UVIS observations of pulsating isolated polar emissions in the northern hemisphere. (left column) Snapshots of the observation sequences with the polar auroral spot indicated by a yellow arrow. The magnetically mapped position of Cassini is indicated with an orange line, close to the letter "C." (right column) Brightness of the polar auroral spot along the sequence.

We searched other examples of pulsating high-latitude spot emission. Over 15 sequences of UVIS auroral images having an appropriate temporal resolution and duration, four sequences exhibit an isolated polar auroral emission in addition to the sequence previously presented. In all the sequences, the brightness of the auroral spot pulses. That corresponds to an occurrence probability of this isolated polar emission of 29.6% for the northern aurora images (taking into account the total duration of the 15 UVIS sequences) and 22.7% for the southern aurora. A snapshot of each of the four sequences is given in Figure 3, as well as the evolution of the brightness of the auroral spot, derived by means of a keogram like for the sequence 128/2013. The high-latitude isolated spot is located in the prenoon sector poleward of the main emission, between 79° and 87° of latitude, and its brightness pulses like the sequence presented in Figure 1. In the long UVIS observation sequence on day 129 of 2008, the pulsations of the auroral spot brightness are quasiperiodic as already reported by *Mitchell et al.* [2016], with a periodicity of around 70 min. On day 238 of 2008, UVIS observations of the auroral emissions lasted less than 3 h. Within this observation time, the auroral spot intensity peaks twice, ∼60 min apart. In the example on day 144 of 2008, two brightenings of the high-latitude spot are observed, separated by ∼70 min. During this aurora observation, the polar spot is connected to the main emission and its peak intensity is as high as the main emission intensity. Finally, on day 195 of 2008, the isolated polar emission appears after 2.5 h of observations and the intensity starts pulsating. At the same time, a bifurcation is rotating in the dusk sector. Hence, the brightening periodicity of the auroral spot is ranging from 60 to 70 min for all the sequences. It should be noted that the four UVIS sequences presented in Figure 3 have an acquisition duration of each individual image shorter than in the sequence on day 128 of 2013 (Figure 1), providing a better sampling of the cusp aurora brightness.

3. In Situ Measurements During Auroral Observations

While the auroral emissions were observed by the UVIS spectrograph on board Cassini, the spacecraft was crossing magnetic field lines connected to the auroral region and was collecting measurements of the plasma and magnetic field environments. In the multiinstrument study achieved by *Mitchell et al.* [2016], it is noteworthy that fluctuations in the in situ measurements were detected simultaneously with the auroral pulsations despite Cassini not being located directly on the field lines connected to the pulsed aurora. For this reason, we present in this section the measurements of the magnetic field and the electron intensities during the interval of the UVIS auroral imaging.

The Low-Energy Magnetospheric Measurement System detector of the Magnetospheric Imaging Instrument (MIMI/LEMMS) [*Krimigis et al.*, 2004] on board Cassini measures the electron fluxes from 18 keV to energies greater than 10 MeV. The flux measurements in seven LEMMS electron channels are reproduced in Figure 4a from day 127 of 2008 at 00 UT till day 128 at 12 UT. The time interval that the UVIS sequence covers in Figure 1 is indicated in the upper part of the figure. The energy passbands of the LEMMS channels are indicated on the left. Figure 4b displays the measurement of the azimuthal component (B_ϕ) of the magnetic field by the Cassini magnetometer [*Dougherty et al.*, 2004]. Finally, the local pitch angle for the electrons of E-channels is given in Figure 4c. The pitch angle of the C-channel electrons is obtained by subtracting the E-channels pitch angle from 180°.

During the UVIS acquisition time, some pulsations are observed in the electron fluxes at energies from 18 keV to beyond 200 keV. A spectral analysis reveals that the interpulse period is 60 min, which is close to the periodicity of the isolated polar auroral emission brightenings. The energy of the primary electrons producing Saturn's H_2 aurora is estimated to be in the range of 5–30 keV [*Gérard et al.*, 2004, 2009; *Lamy et al.*, 2013], corresponding to the C0 and C2 channels. However, during this time interval, LEMMS was oriented perpendicular to the field so that the detected pulsed electrons cannot be directly connected to the pulsed polar auroral spot. Furthermore, the magnetically mapped position of Cassini position (shown in Figure 1) indicates that the spacecraft is not crossing the flux tubes connected to the cusp aurora. At the same period, the azimuthal component of the magnetic field exhibits sharp changes with a periodicity of 60 min too. These perturbations in B_ϕ are possibly the signatures of field-aligned currents crossed by Cassini. Indeed, due to Ampère's Law, a field-aligned current produces a perturbation in the azimuthal direction of the magnetic field [*Bunce et al.*, 2008; *Talboys et al.*, 2009]. It should be noted that the field-aligned currents mentioned here are not the main FAC associated with the main auroral oval emission. Furthermore, if electrons carrying these currents are moving to the ionosphere, they are not precipitating in the isolated polar auroral emission, as shown by the magnetic ionospheric projection of Cassini in Figure 1.

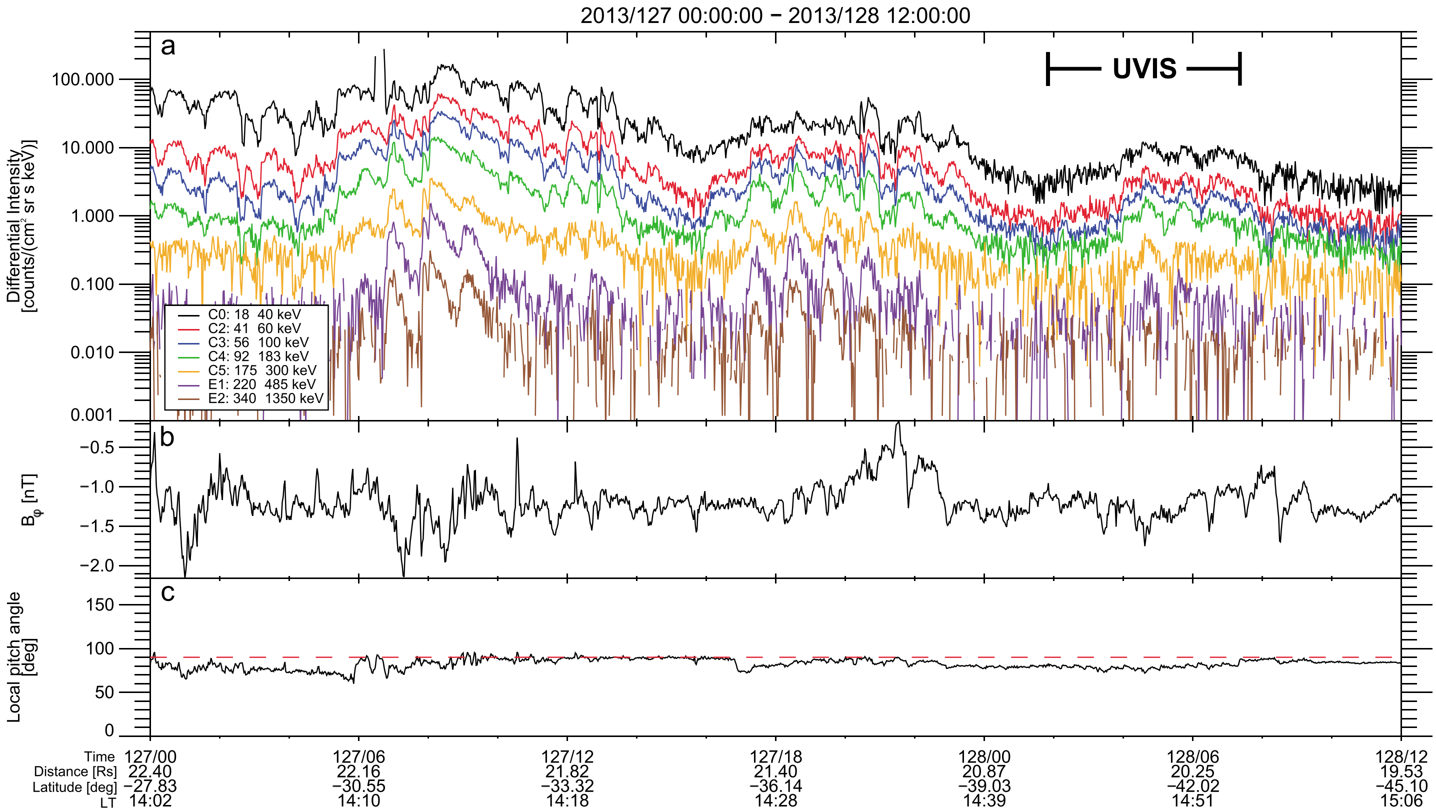

Figure 4. Cassini in situ observations on days 127 and 128 of 2013. Time series plots of (a) the differential intensities of electrons from different Cassini/LEMMS channels between 18 and 1350 keV, (b) the azimuthal component of the magnetic field measured with Cassini/MAG, and (c) the local pitch angle of the LEMMS High Energy Telescope. The time interval corresponding to the UVIS observation sequence presented in Figure 1 is indicated.

Previous to the UVIS observation, Cassini/LEMMS detected several other enhancements in the electron fluxes. In Figure 4, they can be divided in two separate sets of pulsations. The first set starts on day 127 at 05 UT and ends at 11 UT, while the second set extends from 16 UT to 24 UT. The averaged interpulse period is 74 and 63 min for the first and the second set of pulsations, respectively. These pulsations in the energetic electron fluxes are common and observed globally in Saturn's magnetosphere [*Roussos et al.*, 2016; *Palmaerts et al.*, 2016].

Similar quasiperiodic fluctuations of ∼1 h in the electron fluxes and B_ϕ measurements are also observed by Cassini during the other UVIS observing sequences shown in Figure 3. Figure 5 displays in situ magnetospheric data with a similar structure as in Figure 4 for days 237 and 238 of 2008. Structured variations in the electron fluxes are observed during UVIS auroral imaging. Some ∼1 h pulsations are also identified before the UVIS sequence. Simultaneously, the magnetic field azimuthal component presents clear signatures of field-aligned currents with a periodicity of 58 min. However, similarly to the 128/2013 sequence, the detected electrons are perpendicular to the field and the mapped position of Cassini is not located directly in the isolated high-latitude auroral emission. On day 237 of 2008, starting at 16 UT, a quasiperiodic 1 h electron pulsed event precedes the UVIS observation of the pulsed polar auroral emission. Regarding the UVIS sequence 129/2008, ∼1 h fluctuations in electron and magnetic field measurements have been reported by *Mitchell et al.* [2016]. Some pulsations are also distinguishable in LEMMS measurements for the sequence 144/2008, but gaps in LEMMS and MAG data do not allow a reliable analysis.

4. Discussion

Using Cassini/UVIS auroral imaging, we report observations in both hemispheres of an isolated auroral emission located in the dawn-to-noon sector and poleward of the main auroral oval emission. Except on day 144 of 2008 (Figure 3), the latitude separation between this polar auroral spot and the main emission exceeds the typical offset of 1–2° between the open-closed field line boundary and the main emission [*Jinks et al.*, 2014].

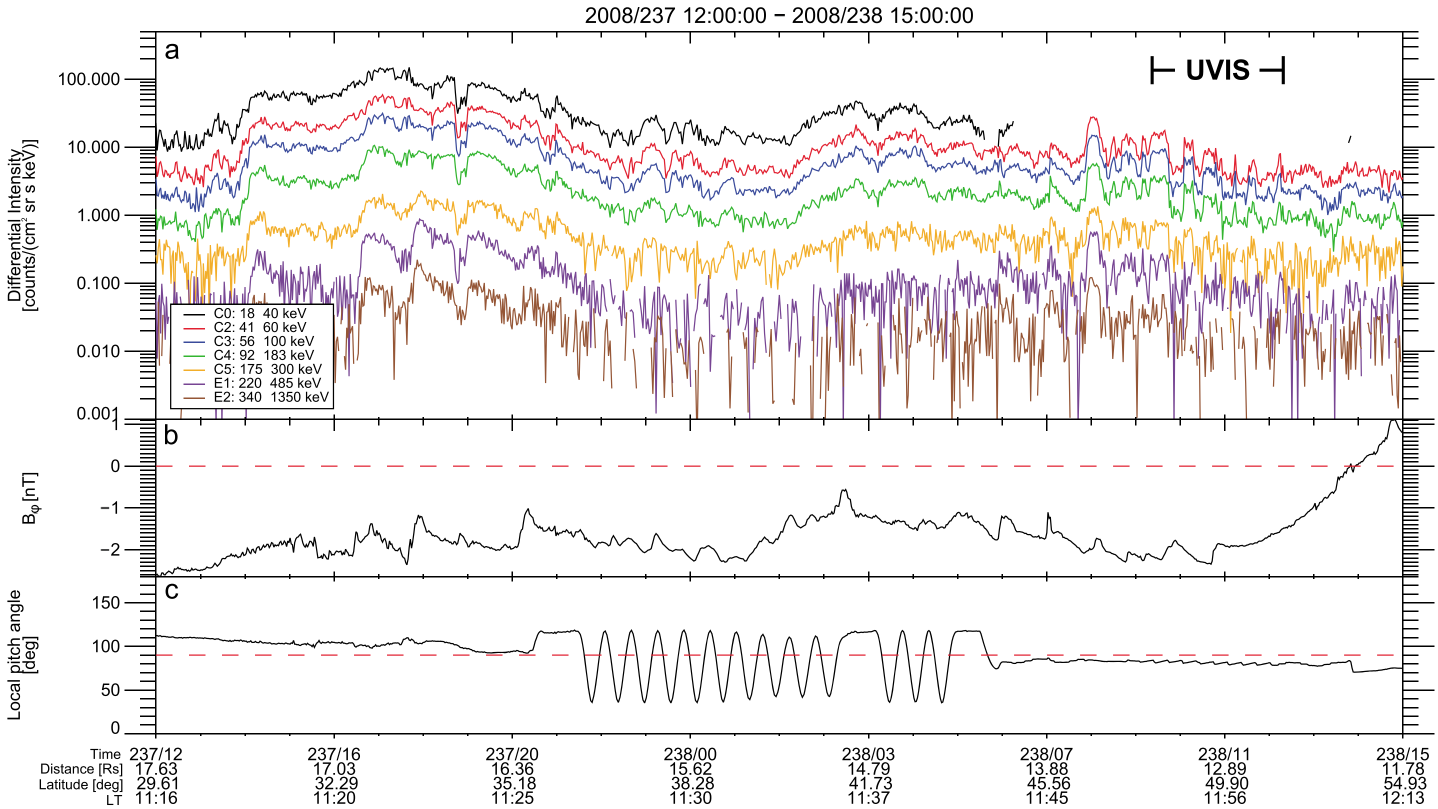

Figure 5. Cassini in situ observations on days 237 and 238 of 2008. Time series plots of (a) the differential intensities of electrons from different Cassini/LEMMS channels between 18 and 1350 keV, (b) the azimuthal component of the magnetic field measured with Cassini/MAG, and (c) the local pitch angle of the LEMMS High Energy Telescope. The time interval corresponding to the UVIS observation sequence presented in Figure 3 is indicated.

Its position fixed in local time and poleward of the open-closed field line boundary indicates that this auroral feature is connected to open field lines. For the above reasons we suggest that this polar auroral spot is the footprint of the magnetospheric cusp. Similar isolated auroral emissions have been previously observed in the same ionospheric region on HST auroral images [*Gérard et al.*, 2004, 2005; *Grodent*, 2015]. *Gérard et al.* [2005] argued that this polar auroral spot is the auroral signature of the cusp. The conceptual model developed by *Bunce et al.* [2005] supports this idea. In that model, high-latitude lobe reconnection at the magnetopause with southward IMF conditions results in particle precipitation poleward of the OCFLB near local noon.

The existence of reconnection at the magnetopause depends on the plasma β (ratio of thermal to magnetic pressure) conditions surrounding the magnetopause. *Masters et al.* [2012] showed that the typical plasma β in Saturn's magnetosheath is high, while observations at Earth [*Trenchi*, 2008] and theory [*Swisdak et al.*, 2003, 2010] suggest that reconnection is favored with low plasma β conditions and small β gradient across the magnetopause. Hence, dayside magnetopause reconnection is thought to be less common at Saturn than at Earth. However, magnetopause dynamics at Saturn can differ from the terrestrial magnetopause. For instance, unlike at Earth, the IMF orientation does not strongly influence the thickness of Saturn's low-latitude boundary layer [*Masters et al.*, 2011] nor the magnetopause location [*Lai et al.*, 2012]. Our investigation of the auroral signature of the cusp at high latitude indicates that its occurrence probability is 29.6% in the northern hemisphere and 22.7% in the southern hemisphere. Therefore, the high-latitude magnetopause reconnection in the lobe may be more frequent than previously thought. This conclusion supports the findings of *Arridge et al.* [2016] arguing that Saturn's cusp is active under a range of upstream conditions. Models of Saturn's magnetopause reconnection reveal also that reconnection is more likely to occur at higher latitudes [*Desroche et al.*, 2013; *Fuselier et al.*, 2014].

With the UVIS observations, we can follow the evolution of the polar cusp auroral spot and analyze its brightness variations. We show several examples of quasiperiodic brightenings of the cusp emission, with a periodicity ranging from 60 to 70 min. Quasiperiodic ~1 h enhancements in electron fluxes at energies from

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Table 1. Occurrence Probability of the Polar Cusp Emission in the UVIS Auroral Images and of the ~1 h Pulsations in the MIMI/LEMMS Energetic Electron Fluxes in the Magnetospheric Region, Within 20 R_S From the Planet and Mapping Into the Ionosphere in the Cusp Emission Region (06–12 LT and 79–87° in Latitude)[a]

	Magnetopause Standoff Distance	Northern Hemisphere (%)	Southern Hemisphere (%)
Polar cusp emission		29.6	22.7
Pulsations in	18 R_S	21.6	21.8
energetic	22 R_S	27.0	23.5
electron fluxes	27 R_S	36.6	25.3

[a]Using the internal magnetic field model of *Dougherty et al.* [2005] combined with the ring current model developed by *Bunce et al.* [2007].

18 keV to beyond 200 keV and in the azimuthal component of the magnetic field are observed simultaneously to the pulsating cusp emission (Figures 4 and 5). Although this energy range includes the energy of the primary electrons producing Saturn's aurorae [*Gérard et al.*, 2004, 2009; *Lamy et al.*, 2013], the detected particles are not in the field-aligned direction and the electron pulsations do not magnetically map to the cusp emission. Hence, any direct relation with the cusp spot cannot be evaluated. However, ~1 h fluctuations in charged particle fluxes, in the azimuthal magnetic field component, as well as in the broadband electromagnetic plasma waves are known phenomena in Saturn's magnetosphere [e.g., *Mitchell et al.*, 2009, 2016; *Badman et al.*, 2012; *Palmaerts et al.*, 2016]. Some of these quasiperiodic fluctuations have been related to downward field-aligned current layers connected to the auroral zone. In particular, in situ measurements of electron intensities displayed in Figures 4 and 5 include different examples of quasiperiodic 1 h pulsations in the electron fluxes. These quasiperiodic injections of electrons, mainly observed at high energies (from 100 keV to several MeV), occur in Saturn's outer magnetosphere over a wide range of latitudes and local times and at all pitch angles simultaneously, as revealed by two long-term surveys of these events [*Roussos et al.*, 2016; *Palmaerts et al.*, 2016]. Pulsed magnetopause reconnection is invoked as a triggering process for all the quasiperiodic electron injections in the dayside magnetosphere.

In their survey based on 720 electron pulsed events identified over 10 years of Cassini/LEMMS observations, *Palmaerts et al.* [2016] found an averaged interpulse period of 68 ± 10 min, similar to the periodicities appearing in the cusp aurora brightness. Some of the quasiperiodic ~68 min electron pulsations are observed at high magnetospheric latitudes ($|\varphi| > 40°$) between 05 and 12 LT. These high-latitude events are all observed within 20 R_S from the planet and are characterized by a pulsed signal that may extend at least up to 6 MeV. We investigated the occurrence probability of these high-latitude dawnside electron pulsations in order to compare with the observation frequency of the cusp auroral spot. For that purpose, we considered, for both hemispheres separately, the residence time of Cassini in the magnetospheric region mapping to the ionosphere in the area where the polar cusp aurora is observed, i.e., between 06 and 12 LT and between 79 and 87° of latitude (in absolute value). This region was restricted to 20 R_S away from the planet since no electron pulsations are detected further at these high magnetospheric latitudes. We used the previously mentioned magnetic field model of *Dougherty et al.* [2005] combined with the ring current model of *Bunce et al.* [2007] to perform the mapping, considering three different representative standoff distances of the magnetopause (18, 22, and 27 R_S). The occurrence probabilities of the pulsed electron events in the magnetospheric region mapping to the cusp aurora zone are listed in Table 1: electron pulsations occur from 21 to 25% of the time in the southern hemisphere and between 21 and 37% in the northern hemisphere. Thus, the occurrence probability of the dawn electron pulsed events located at high latitudes and mapping in the cusp aurora area is similar to the observation frequency of the cusp emission on the UVIS images. This result supports the idea of a common triggering process for both pulsed phenomena.

The mapping of the dawnside electron pulsed events observed at high latitudes has been performed by *Roussos et al.* [2016] using the magnetic field model of *Khurana et al.* [2006] which includes open field lines. The mapping indicates that these high-latitude dawn events reside on open field lines. This result was obtained considering a low and a very high solar wind dynamic pressure for the mapping, indicating that it is independent of the solar wind conditions. Furthermore, their ionospheric footprint is located in the prenoon sector at very high latitudes, poleward of the statistical boundaries of the main emission, thus in the auroral region where the high-latitude cusp footprint is observed. Since the mapping to the ionosphere of the high-latitude dawnside electron events starts from high spacecraft latitudes and at a very close distance from the planet, it is dominated by the internal dipole field and it is weakly dependent on the magnetospheric model and its configuration. For this reason, the mapping is reliable. The observation of the pulsating cusp emission validates that ∼1 h pulsations can reside on open field lines.

The quasiperiodic brightenings in the cusp auroral emission reported in this study support the idea of a pulsed reconnection process at the high-latitude dayside magnetopause, in the lobe region. At Earth, pulsed dayside magnetopause reconnection produces flux transfer events (FTE) and pulsed flows at the ionosphere [*Russell and Elphic*, 1978; *Provan et al.*, 1998; *Wild et al.*, 2001]. It should be noted that contrary to the polar cusp aurora at Saturn. associated with high-latitude lobe reconnection, FTEs at Earth are resulting from reconnection at lower latitudes between the IMF and closed planetary field lines. Nevertheless, a connection between periodic fluctuations in the Earth's low-latitude magnetopause reconnection rate and fluctuations in the proton cusp aurora with a similar periodicity has been highlighted by *Fuselier et al.* [2007]. The characteristic timescale at Earth between FTE and therefore between reconnection pulses is 8 min, but it can vary between 1 and 30 min [*Kuo et al.*, 1995]. A flux transfer event has been recently detected at Saturn's low-latitude dayside magnetopause [*Jasinski et al.*, 2016]. However, FTEs at Saturn are not frequent as revealed by the fruitless search for FTEs carried out by *Lai et al.* [2012]. The rarity of FTEs can be explained by plasma β conditions in the vicinity of Saturn's magnetopause which limit the reconnection rate [*Masters et al.*, 2012].

Nevertheless, the bursty behavior of the reconnection at Saturn's dayside magnetopause has been inferred from in situ data while Cassini was crossing the cusp region [*Jasinski et al.*, 2014; *Arridge et al.*, 2016]. Furthermore, the auroral bifurcations of the main emission, which present also multiple brightenings, provide another auroral evidence [*Radioti et al.*, 2011, 2013; *Badman et al.*, 2013]. During the UVIS observing sequence on day 129 of 2008, mentioned in Figure 3 and thoroughly described by *Mitchell et al.* [2016], brightenings are simultaneously observed in the bifurcation and in the cusp emission. The brightening period is nearly identical for both emissions, but the phase of the bifurcation pulsations leads the cusp pulsations by ∼18 min. *Mitchell et al.* [2016] argued that the delay may reveal the existence of a pressure pulse or a wave traveling across the polar cap propagating the pulsations from the bifurcation region to the cusp.

5. Summary

This study reports several Cassini/UVIS observations of an isolated high-latitude auroral emission, located in the prenoon sector poleward of the main emission. We suggest that this auroral spot is related to the magnetospheric cusp and associated with high-latitude magnetopause reconnection in the lobe region. The occurrence probability of the polar cusp aurora (around 25%) suggests that lobe reconnection occurs frequently at Saturn. The UVIS observations reveal quasiperiodic brightening of the auroral spot. The brightening periodicity is in the range from 60 to 70 min, similar to other fluctuations observed in the energetic electron fluxes and the magnetic field measurements in the outer magnetosphere. Simultaneously to the pulsed cusp aurora observation, ∼1 h pulsations in the electron intensities are detected by Cassini, indicating a triggering process probably common for both pulsed phenomena. The triggering process is suggested to be a pulsed magnetic reconnection at the high-latitude dayside magnetopause.

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