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Key Points:
- The auroral emission at Saturn as it rotates from midnight to dusk via noon occasionally is blocked near noon
- The blockage of the emission near noon is often accompanied by dayside magnetopause reconnection
- The auroral blockage could be related to flow shear variations or/and to fast rotating flux tubes which experience a blockage at noon

Correspondence to:
A. Radioti,
a.radioti@ulg.ac.be

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Stagnation of Saturn's auroral emission at noon

A. Radioti[1], D. Grodent[1], J.-C. Gérard[1], D. J. Southwood[2,3], E. Chané[3], B. Bonfond[1], and W. Pryor[4]

[1]Laboratoire de Physique Atmosphérique et Planétaire, Institut d'Astrophysique et de Géophysique, Université de Liège, Liège, Belgium, [2]Space and Atmospheric Physics, Imperial College London, London, UK, [3]Centre for mathematical Plasma Astrophysics, KU Leuven, Leuven, Belgium, [4]Science Department, Central Arizona College, Coolidge, Arizona, USA

Abstract Auroral emissions serve as a powerful tool to investigate the magnetospheric processes at Saturn. Solar wind and internally driven processes largely control Saturn's auroral morphology. The main auroral emission at Saturn is suggested to be connected with the magnetosphere-solar wind interaction, through the flow shear related to rotational dynamics. Dawn auroral enhancements are associated with intense field-aligned currents generated by hot tenuous plasma carried toward the planet in fast moving flux tubes as they return from tail reconnection site to the dayside. In this work we demonstrate, based on Cassini auroral observations, that the main auroral emission at Saturn, as it rotates from midnight to dusk via noon, occasionally stagnates near noon over a couple of hours. In half of the sequences examined, the auroral emission is blocked close to noon, while in three out of four cases, the blockage of the auroral emission is accompanied with signatures of dayside reconnection. We discuss some possible interpretations of the auroral "blockage" near noon. According to the first one, it could be related to local time variations of the flow shear close to noon. Auroral local time variations are also suggested to be initiated by radial transport process. Alternatively, the auroral blockage at noon could be associated with a plasma circulation theory, according to which tenuously populated closed flux tubes as they return from the nightside to the morning sector experience a blockage in the equatorial plane and they cannot rotate beyond noon.

1. Introduction

Auroral observations are a useful tool to study the magnetospheric processes as they provide a "global picture" of the magnetosphere at all local times at once. The main auroral emission at Saturn is suggested to be related to the shear in the rotational flow which is present in the boundary between open and closed field lines [*Bunce et al.*, 2008]. The difference in the plasma angular velocity between open field lines that subcorotate and closed field lines that near rigidly corotate with the planet generates strong field-aligned currents, which give rise to the auroral emissions. The morphology of the main auroral emission at Saturn is largely controlled by solar wind and internally driven processes. Both processes are suggested to play an essential role in the magnetospheric dynamics at Saturn [e.g., *Jackman et al.*, 2011]. *Cowley et al.* [2004] suggested that the magnetospheric circulation pattern at Saturn is composed by two separate cycles: the solar wind driven Dungey cycle and the internally driven Vasyliūnas cycle. The Dungey cycle [*Dungey*, 1961] begins with reconnection at the subsolar magnetopause which opens closed magnetic field lines, allowing solar wind plasma to enter the magnetosphere. The newly open flux tubes are then transported to the magnetotail and eventually reconnect. The newly closed field lines in the tail convect along the flanks back to the dayside. During the internally driven Vasyliūnas cycle [*Vasyliūnas*, 1983] the rapid rotation of the planet in combination with the mass loading of flux tubes which is fed by internal plasma sources (Enceladus and Saturn's rings) eventually leads to reconnection of distended flux tubes in the magnetotail and to the ejection of plasmoids. In addition to the aforementioned cycles (Dungey and Vasyliūnas) the viscous interaction of the solar wind with the planetary magnetosphere is another process, which probably influences Saturn's magnetosphere, involving small-scale magnetic reconnection [*Delamere and Bagenal*, 2013].

Magnetic field reconnection in the dayside and reconnection in the nightside tail largely influence the morphology of Saturn's aurora [*Cowley et al.*, 2004; *Badman et al.*, 2014]. Near noon bright UV emissions at Saturn are related to reconnection which takes place at the dayside of the magnetopause [*Gérard et al.*, 2005; *Bunce et al.*, 2005]. Additionally, the circular-like shape of the auroral emission at Saturn is occasionally distorted close to noon. Poleward arc bifurcations appear in the 11 to 18 h magnetic local time sector, which are interpreted as evidence of dayside reconnection events [*Radioti et al.*, 2011, 2013a; *Badman et al.*, 2012; *Meredith et al.*, 2014]. Overall, the auroral emission is observed to consist of arc-like features which rotate with the planet at ∼65% of the rigid corotation velocity [*Grodent et al.*, 2005]. The dawn auroral region is an interesting sector which often displays particular patterns. The midnight to noon sector via dawn occasionally displays bright auroral enhancements and poleward expansions associated with reconnection in the nightside [*Mitchell et al.*, 2009; *Jackman et al.*, 2013; *Nichols et al.*, 2014; *Radioti et al.*, 2014, 2016; *Badman et al.*, 2015]. The aurora brightens in the dawn region as hot tenuous plasma carried toward the planet in fast moving flux tubes returns from tail reconnection site to the dayside. These fast moving flux tubes may generate intense field-aligned currents which lead to auroral brightening [*Cowley et al.*, 2005; *Jia et al.*, 2012]. Additionally, dawn auroral emissions have been reported to form auroral spirals which are suggested to be associated with hot dynamic populations and create strong velocity gradients regions [*Radioti et al.*, 2015].

In the following, we present three auroral sequences all captured by the FUV channel (111–191 nm) of the UVIS (Ultraviolet Imaging Spectrograph) instrument [*Esposito et al.*, 2004] on board Cassini obtained between 2008 and 2013. We examine the behavior of the auroral emission as it moves from dawn to dusk via noon and we report for the first time that the main auroral emission occasionally stagnates close to noon.

2. Observations of Blockage of the Auroral Emission Near Noon

Figure 1 shows a sequence of Saturn's northern aurora obtained with Cassini/UVIS on day of year (DOY) 195, 2008. We constructed the projections by combining slit scans, which provide 64 spatial pixels of 1 mrad (along the slit) by 1.5 mrad (across the slit), following the method described by *Grodent et al.* [2011]. The limb brightening effect is limited, because of the relatively high subspacecraft latitude, and therefore, no correction was applied. The subspacecraft planetocentric latitude increased from 32° to 39° and the spacecraft altitude decreased from 13.5 to 11.5 R_S between the start of the first image and the end of the last one. A solid yellow line is plotted on top of the projection to indicate the noon meridian. For simplicity we only show here every second image of the whole sequence. The complete data set was presented by *Radioti et al.* [2011] and was shown to provide auroral evidence of dayside magnetopause reconnection. The auroral emission is observed to move to lower latitudes, which is seen as evidence of opening of flux, while at the same time auroral arcs (auroral bifurcations) between 11 and 18 LT bend toward the pole. The auroral bifurcations are indicated by the red arrows in Figure 1 and are related to auroral signatures of dayside reconnection [*Radioti et al.*, 2011].

In the present study we analyze the same auroral data set in order to report an auroral behavior at Saturn, "the blockage of the auroral emission close to noon," that has never been discussed before. A bright and long (5 h local time) arc of the main auroral emission is observed in the dawn region to move toward noon (12 LT is indicated with a yellow mark in Figure 1). The front of the dawn emission at the beginning of the sequence is observed at ∼9 LT, and it moves to noon within 2 h (first five panels of Figure 1). Once it arrives at noon, the front of the emission remains stagnant for the next 4 h, until the end of the sequence. At the same time auroral signatures of dayside reconnection are observed during the 7 h sequence. They are taking the form of auroral bifurcations (highlighted with red arrows in Figure 1), accompanied with a gradual expansion of the whole main emission to lower latitudes. The "bifurcation" features get very bright toward the end of the sequence (1016 UT). Similar brightness enhancements of the bifurcations are reported in *Radioti et al.* [2013a] and *Mitchell et al.* [2016] and were suggested to be related to magnetopause reconnection. In the afternoon sector, apart from the appearance of the bifurcations, consequent small fractions of the emission seem to get detached from the noon barrier (yellow line) and move toward dusk. Yellow circles (a–c) follow the patchy emissions as they move toward dusk. Dusk transient features have also been observed by *Meredith et al.* [2013] and were related to open flux tubes. The auroral patches observed here are possibly not the same as the dusk transients reported by [*Meredith et al.*, 2013] as the latter appear at later local times (between 14 and 15 LT) and do not seem to get detached from noon.

Blockage of the auroral emission near noon coinciding with signatures of low latitude dayside magnetopause reconnection is also observed during other auroral sequences, such as the one on 2008 DOY 129 presented by *Mitchell et al.* [2009, 2016] and the one on 2008 DOY 201 by *Badman et al.* [2013], even though the authors did not describe this phenomenon.

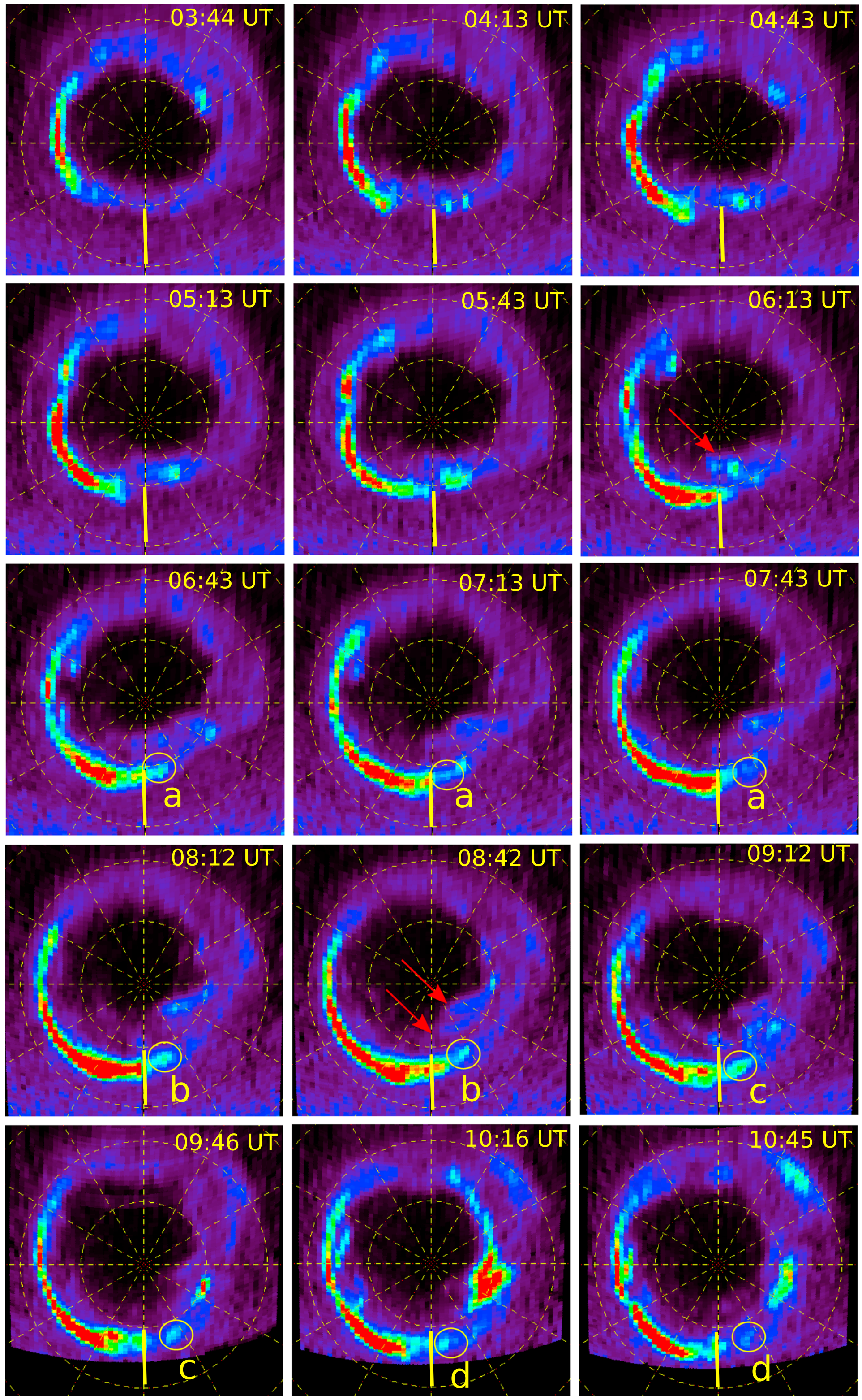

Figure 1. A sequence of polar projections of Saturn's northern aurora obtained with the FUV channel of UVIS on board Cassini. This sequence illustrates an example of the auroral emission being blocked near noon. The first image starts at 03:44 UT and the last one at 10:45 UT on DOY 195, 2008. Noon is to the bottom and dusk to the right. The grid shows latitudes at intervals of 10° and meridians of 30°. The yellow line indicates noon. The circles contain small "blobs" of emission which pass through the noon boundary. The red arrows point out to the bifurcations features discussed in *Radioti et al.* [2011]. The whole sequence is presented in *Radioti et al.* [2011].

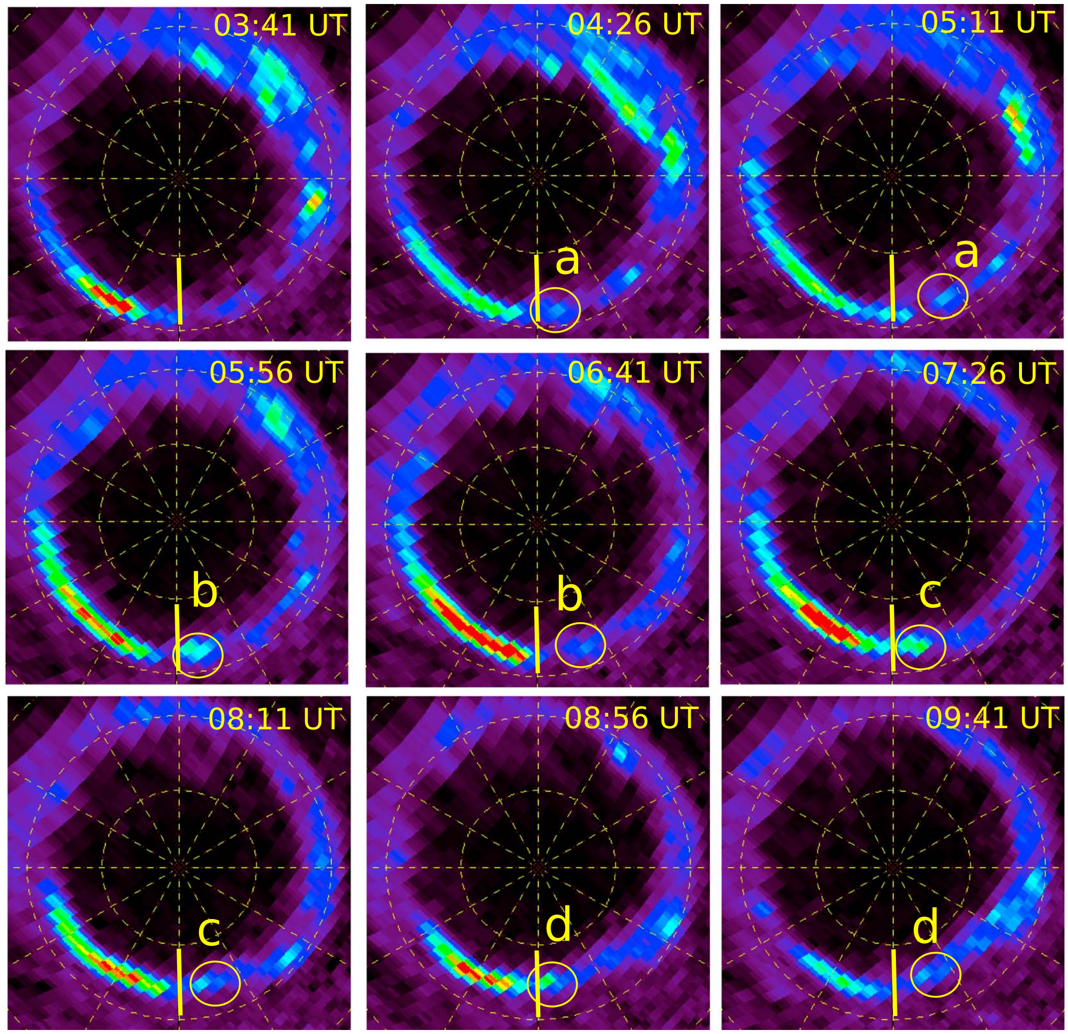

Figure 2. A sequence of polar projections of Saturn's southern aurora obtained with the FUV channel of UVIS on board Cassini. This sequence illustrates an example of the auroral emission being blocked near noon. The first image starts at 03:41 UT and the last one at 09:41 UT on DOY 109, 2013. Only every second image of the sequence is shown. The format is the same as in Figure 1.

Figure 2 presents a 6 h auroral observation of Saturn's aurora in the southern hemisphere obtained with the Cassini/UVIS instrument on DOY 109, 2013, in the same format as in Figure 1. Again, we only display every second image of this sequence. The subspacecraft planetocentric southern latitude increased from 37° to 40° and the spacecraft altitude decreased from 19.1 to 18.3 R_S between the start of the first image and the end of the last one. The auroral emission is observed to be blocked near noon. However, observations were not available before the beginning of this sequence in order to conclude that the front of the emission was rotating before it stagnates, contrary to the sequence in Figure 1. Four small fractions of the emission are observed to escape noon (yellow circles: a–d) and move to dusk. No clear auroral evidence of reconnection in the dayside and opening of magnetic flux is observed until the end of this sequence.

Finally, we present a third case in Figure 3. The subspacecraft planetocentric latitude increased from 43° to 46° and the spacecraft altitude decreased from 19.1 to 18.3 R_S between the start of the first image and the end of the last one. In this sequence the main emission moves from dawn to dusk via noon, without being blocked at noon. Noon does not seem to serve as a barrier, which "blocks" the emission like in the first two sequences. However, the auroral emission gets thinner after passing noon. This sequence also reveals a high-latitude emission in the prenoon sector, which is indicated by the arrow in Figure 3 (projection taken at 0956 UT). Such isolated poleward emissions near noon have been previously related to high-latitude

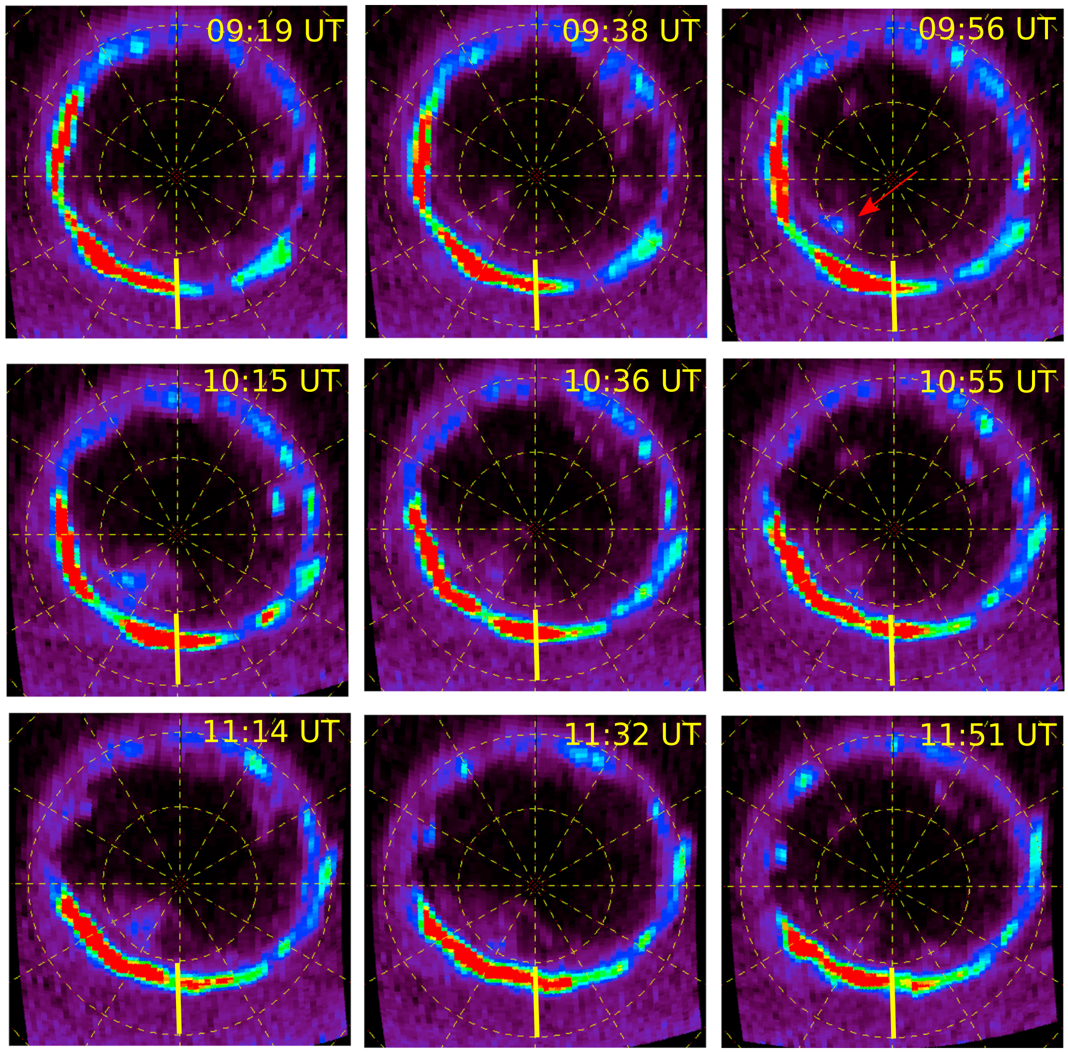

Figure 3. A sequence of polar projections of Saturn's northern aurora obtained with the FUV channel of UVIS on board Cassini. During this sequence the auroral emission circulates from dawn to dusk via noon without being blocked. The first image starts at 09:19 UT and the last one at 11:51 UT on DOY 238, 2008. The same format as Figure 1.

reconnection (lobe reconnection), occurring during intervals of southward IMF orientation [*Bunce et al.*, 2005; *Gérard et al.*, 2005; *Palmaerts et al.*, 2016]. A couple of other auroral observations do exist during which the main auroral emission is not blocked near noon at the magnetopause, without evidence of high-latitude reconnection. The interested reader can find them in *Radioti et al.* [2015] (2008 DOY 197) and *Radioti et al.* [2013b] (2008 DOY 334).

In order to quantify the frequency of the blockage of the auroral emission at noon, we performed some statistics. We analyzed all the available auroral data set which fulfills two conditions: (i) consist of at least six images and (ii) there is emission in the midnight to noon sector via dawn which during the sequence reaches noon. Sequences of low resolution which did not allow us to draw conclusions and the blockage/unblockage was not certain, were not considered in the analysis. This statistical analyses demonstrated that in four out of eight cases the auroral emission is blocked close to noon. In three out of these four cases the blockage of the auroral emission is accompanied by signatures of dayside reconnection and only in one out of four it is not (sequence presented in Figure 2). In the four out of eight cases where the emission at noon is not blocked, two cases show evidence of high-latitude reconnection (lobe reconnection).

In the following section we discuss two possible interpretations for the observed behavior of the auroral emissions close to noon.

3. On the Origin of the "Blocked" Auroral Emissions Near Noon

3.1. Local Time Variations of the Flow Shear

The main auroral emission at Saturn is suggested to be connected with magnetosphere-solar wind interaction, through the flow shear related to rotational dynamics across the boundary of open closed field lines [*Bunce et al.*, 2008]. The difference in the plasma angular velocity between open (at high latitudes) and closed field lines (at low latitude) generates strong field-aligned currents. Temporal or local time variations in the rotational flow shear could account for changes in the brightness of the main auroral emission. Particularly, the existence of a region of strong flow shear at prenoon and weak shear at the early afternoon sector will result in weak or nonexistent field-aligned currents and absence of bright auroral emission in the early afternoon sector.

Asymmetries of field and plasma properties in the dawn-dusk magnetosphere of Saturn have been recently discussed by *Jia and Kivelson* [2016]. The authors suggest that in the morning sector the field is stretched due to pressure gradient and centripetal terms resulting to a thin plasma sheet compared to a thick one in the afternoon sector. They also argue that the plasma rotates faster from dawn to noon than from noon to dusk in good agreement with the local time dependence of observed plasma radial velocities [*Wilson et al.*, 2013]. Considering that the open field lines strongly subcorotate with respect to the planet at all local times, the aforementioned observed and simulated local time dependences of the magnetospheric plasma velocities could point out to weak shear in the early afternoon sector. The weak shear in the early afternoon sector will lead to dimming or absence of the main emission in that sector. Such a flow shear pattern could account for the bright auroral emissions in the dawn sector and dim in the post noon sector. It should be noted that this possibility could account for auroral variations fixed in local time. In the cases where the front of main emission is observed to rotate from dawn to dusk via noon and be blocked at noon (Figure 1), local time changes in the shear could partially contribute without being the main driver.

3.2. Local Time Variations Initiated by Radial Transport Process

Local time asymmetries in the giant magnetospheres are also discussed in the concept of a flux circulation model [*Delamere et al.*, 2015], based on the radial transport of plasma which originates in the inner magnetosphere. According to magnetic flux conservation, outward net mass transport (lost to the solar wind) requires a balanced inward transport process. The authors studied the bend forward configuration, which is tied to rapid inward motion of mostly depleted flux tubes following reconnection. They found a strong local time dependence of the bend forward configuration, localized in the postnoon sector and suggested that much of the flux-conserving reconnection occurs in the subsolar and dusk sector. They proposed that reconnection is operating primarily on closed field lines and suggested significant small-scale structures for the returning flux channels in contrast to a global scale X line. Based on their theory, *Delamere et al.* [2015] discussed the auroral dawn-dusk asymmetries and proposed that the auroral emissions occur on closed field lines and that the local time variations in the auroral region could be related to the radial transport process. The authors suggested that dawn-dusk asymmetric features, such as the auroral forms in the dusk sector (bifurcations) shown in Figure 1 and in *Radioti et al.* [2011], could be generated by enhanced radial inflows large events, which are required for magnetic flux circulation.

3.3. Plasma Circulation Pattern

Alternatively, intense field-aligned currents, which are generated by fast moving flux tubes returning from tail reconnection site to the dayside occasionally brighten the aurora in the dawn region [i.e., *Mitchell et al.*, 2009; *Jia et al.*, 2012; *Nichols et al.*, 2014; *Radioti et al.*, 2014, 2016; *Badman et al.*, 2015]. Thus, a possible explanation for the observed auroral blockage at noon could be associated with the plasma circulation theory recently proposed by *Southwood and Chané* [2016]. The authors suggest that the tenuously populated closed flux tubes of the Dungey cycle, as they return from the nightside to the morning sector, experience a blockage close to the equatorial plane and cannot rotate beyond noon. The blockage at noon results from the combination of (1) the compressed field and the heavy material on flux tubes at lower magnetic latitudes and (2) the pressure of the sheath/solar wind on its outer flank (Figure 4a). The return flux tubes of Dungey cycle as they are depleted do not have enough force to push the magnetopause outward. According to the simulations by *Southwood and Chané* [2016] the plasma in the returning Dungey flow is being pushed along the field away from the equator because of the combination of solar wind pressure at noon, the denser tubes closer to the planet (from the Vasyliūnas regime) and the resulting flow blockage. The authors also argue that in that case reconnection takes place off the equator. Plasma β — ratio of plasma to magnetic pressure — is lower in that

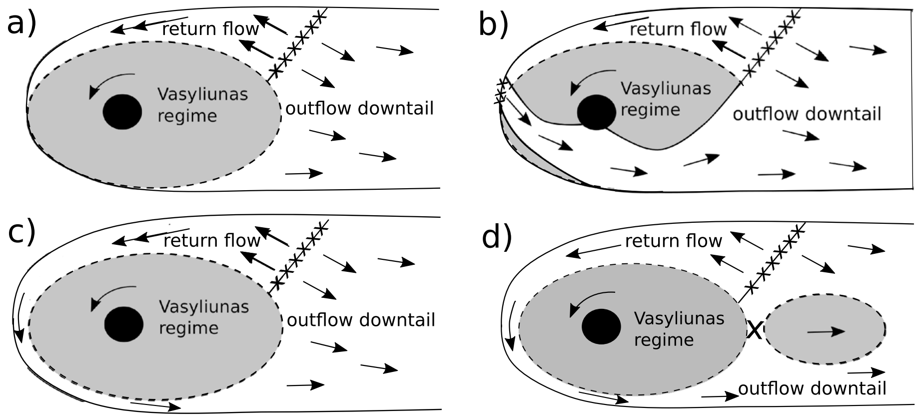

Figure 4. Illustration of the plasma flow for four magnetospheric configurations of Saturn's magnetosphere. The Sun is directed to the left. The grey area is the region dominated by the Vasyliūnas regime populated with heavy and dense material confined in the equator. The return flow of closed low density flux tubes is indicated in the morning sector, and the outflow down tail region is also indicated. (a) Equatorial view. Equatorial magnetospheric configuration showing that the return flow is blocked at the equatorial plane near noon between the heavy flux tubes from the Vasyliūnas regime at lower magnetic latitudes and the pressure of the sheath/solar wind on its outer flank. (b) Polar view. A projection showing the entire Dungey flow. The returning flow is pushed along the field away from the equator and reconnection takes place off the equator, where plasma β is lower. Solar wind material enters at high latitude. The open flux tubes stay off the equator until they reach the nightside. Figures 4a and 4b are adapted from *Southwood and Chané* [2016]. (c) Decreasing solar wind pressure results in the magnetopause to move further out to larger distances from the planet. The passage between the magnetopause and the Vasyliūnas regime is now possible and the blocked plasma can move from dawn to dusk via noon. (d) Internally driven tail reconnection (on closed field lines) is initiated and the Vasyliūnas regime is more relaxed. The passage between the magnetopause and the region dominated by the Vasyliūnas regime is now possible and the blocked plasma moves from dawn to dusk via noon.

region and reconnection is easier to sustain [*Masters et al.*, 2012]. When reconnection occurs, the newly open tubes which are connected to northern or southern ionospheres are no longer blocked by the heavy material near the nose. Once open, the tubes are able to move through noon by passing over the heavy material, which is confined in the equatorial plane (Figure 4b). The Dungey flow is no longer prevented from the equatorial pressure blockage, and the flux tubes will move past noon. The open flux tubes will stay off the equator until they reach the nightside. Figures 4a and 4b illustrate the theory proposed by *Southwood and Chané* [2016] on equatorial and polar view, respectively. This scenario could be a possible explanation of our auroral observations in Figure 1 which show blockage of the auroral emission at noon followed by auroral signatures of dayside reconnection. *Southwood and Chané* [2016] also discuss high-latitude circulation of flux tubes in the absence of reconnection, which could explain less frequent (one out of four) auroral sequences during which the blockage of the emission at noon is not accompanied with signatures of magnetopause dayside reconnection as shown in Figure 2. Also, MHD simulations performed with the model of *Chané et al.* [2013, 2017] predict a similar blockage near noon at Jupiter.

However, there is not additional known observational evidence which supports or contradicts the scenario of *Southwood and Chané* [2016]. The present auroral observations, though, provide supportive evidence to their theory. It should be noted that auroral observations are the "TV screen" of the whole magnetosphere as they provide a picture of the magnetospheric processes at all local times at once. The auroral observations reported here show evidence of the auroral blockage close to noon and at the same time dayside reconnection signatures (Figure 1). We also demonstrate in the auroral sequences that the blockage does not occur all the time; thus, instantaneous Cassini magnetospheric measurements even taken close to the planet and in the prenoon sector would not be that conclusive.

Figure 3 presents a case where the aurora is not blocked near noon. If we assume that the auroral blockage at noon is explained by the plasma circulation theory [*Southwood and Chané*, 2016], then cases of absence of the auroral blockage might be explained by changes in the magnetopause distance from the planet. The distribution of the standoff distance for Saturn is suggested to be described by a "bimodal" model, namely, the sum of two normal distributions with different means at ~22 and ~27 planetary radii [*Achilleos et al.*, 2008]. One of the main parameters in determining the magnetopause standoff distance is the solar wind dynamic pressure [*Arridge et al.*, 2006]. *Jackman et al.* [2004] used solar wind data (from Cassini magnetometer) close to Saturn and considered the interplanetary magnetic field as a proxy for compressions and rarefactions in the solar wind. The authors suggested that the interplanetary medium was in a compressed (high solar wind pressure) state around 20% of the time and in a lower solar wind pressure state otherwise. However, it should be noted that the results from the study by *Jackman et al.* [2004] may not be applicable to all epochs, because the authors considered IMF magnitude only during the declining phase of the solar cycle. During intervals of low solar wind pressure the magnetopause moves further out to larger distances from the planet, resulting to an uncompressed magnetopause. The flux tubes are not blocked at noon anymore and can move to dusk via a narrow channel. This configuration is illustrated in Figure 4c. The narrow passage between the magnetopause and the region of heavy flux tubes related to the Vasyliūnas regime in the afternoon sector is in accordance with the thinning of the auroral emission as it passes through noon. Additionally, *Achilleos et al.* [2008] considered internal processes at Saturn and studied how they influence the size of the magnetopause. They suggested that the observed bimodal distribution in magnetopause standoff distance could be explained by the effect of internal mass loading and loss from the magnetodisk. The authors proposed that both variability in mass loading as well as very rapid mass loss would influence the magnetopause standoff distance at Saturn. Also, *Pilkington et al.* [2015] recently showed that at constant solar wind dynamic pressure the magnetopause can change up to 10–15 Saturn radius, which corresponds to relatively "plasma loaded" or "plasma-depleted" states, defined in terms of the internal suprathermal plasma pressure. We suggest that ejection of heavy material down tail due to internally driven reconnection would relax the Vasyliūnas regime leaving space for the flux to circulate in the dayside. This configuration is illustrated in Figure 4d.

4. Summary and Conclusions

In this work we demonstrate that the auroral emission at Saturn as it rotates from midnight to dusk via noon, occasionally stagnates near noon for a couple of hours. In particular, the first sequence (Figure 1) shows that the main auroral emission in the dawn region moves toward noon and once it arrives there remains stagnant until the end of the sequence, while small parcels escape and make their way to dusk. In that sequence there is also auroral evidence of dayside magnetopause reconnection. The auroral emission in the prenoon sector, which is displayed in the second sequence (Figure 2), is observed to be blocked near noon. However, as observations were not available before the beginning of this sequence, we cannot conclude that the emission was rotating before it stagnated. Finally, in the third sequence the auroral emission is not blocked; however, after its passage from noon it gets thinner. In half of the cases examined the auroral emission is observed to be blocked near noon, while in three out of four sequences the blockage of the auroral emission is accompanied with signatures of dayside reconnection. In this work we discussed a couple of possible interpretations to explain our auroral observations, which are summarized below. It should be also noted that they are not exclusive and both of them could contribute to the observed auroral behavior.

The main auroral emission at Saturn is suggested to be driven by field-aligned currents generated by the difference in the plasma angular velocity between open and closed field lines. Thus, the auroral blockage at noon could be an evidence of a major local time variation of the flow shear close to noon. Studies of field and plasma properties in the magnetosphere of Saturn suggest that the plasma rotates faster from dawn to noon than from noon to dusk [*Jia and Kivelson*, 2016; *Wilson et al.*, 2013]. These local time dependences of the plasma velocities point out to a weaker shear in the afternoon sector, which in turn would lead to dimming or absence of the main auroral emission. This possibility should be considered for local time fixed variations of the main emission. Local time variations of the auroral emission are also suggested to be related to radial transport process [*Delamere et al.*, 2015]. Based on a flux circulation model, the authors suggested that much of the flux-conserving reconnection occurs in the subsolar and dusk sector, which would result in dawn-dusk auroral asymmetries.

Alternatively, the auroral emission in the dawn sector occasionally brightens due to intense field-aligned currents, which are generated by fast moving flux tubes returning from tail reconnection site to the dayside. Thus, the auroral blockage at noon could be related to tenuously populated closed flux tubes, which as they return from the nightside to the morning sector experience a blockage in the equatorial plane and are unable to rotate beyond noon (Figure 4a), according to the theory of *Southwood and Chané* [2016]. The blockage at noon results from the combination of the compressed field and the heavy material on flux tubes at lower magnetic latitudes and the pressure of the sheath/solar wind on its outer flank. The theory also suggests that reconnection takes places off the equator and once reconnection has occurred, newly open tubes can move through noon by passing over the equatorial confined heavy material (Figure 4b). This is in accordance with our observations that show that in three out of four sequences the auroral blockage is followed by auroral signatures of dayside reconnection. However, as indicated by our observations, the flux is not always blocked near noon (third case). Such cases might be explained by intervals of decreasing solar wind pressure during which the magnetopause moves further out to larger distances from the planet (Figure 4c). We suggest that internal processes play also an important role in "unblocking" the circulation of flux near noon. Very rapid mass loss processes, following internally driven reconnection, relax the Vasyliūnas regime leaving space for the flux to circulate in the dayside (Figure 4d).

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