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Saturn's Auroral Field-Aligned Currents: Observations from the Northern Hemisphere Dawn Sector During Cassini's Grand Finale

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Introduction

The Cassini mission's final year at Saturn saw it return to high-latitude auroral field lines. These orbits' local time (LT) coverage in the northern hemisphere allows for a comparison of the auroral field-aligned currents in the dawn and noon LT sectors. Below we show an ionospheric projection of these typical orbits. With the black trajectory at dawn and blue near noon.

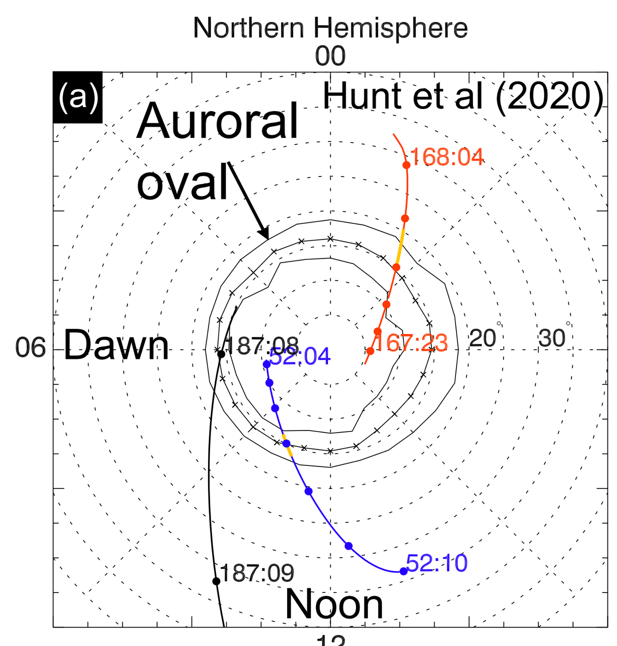

Figure 1

Previous studies of Saturn's auroral field-aligned currents have shown the presence of a quasi-static axisymmetric current system and rotating current systems associated with Saturn's ~10.7 hr Planetary Period Oscillations (PPOs) [Hunt et al. 2014]. It has been previously proposed that in the dawn sector there could a stronger non-PPO current due to solar wind interactions and return flows from tail reconnection.

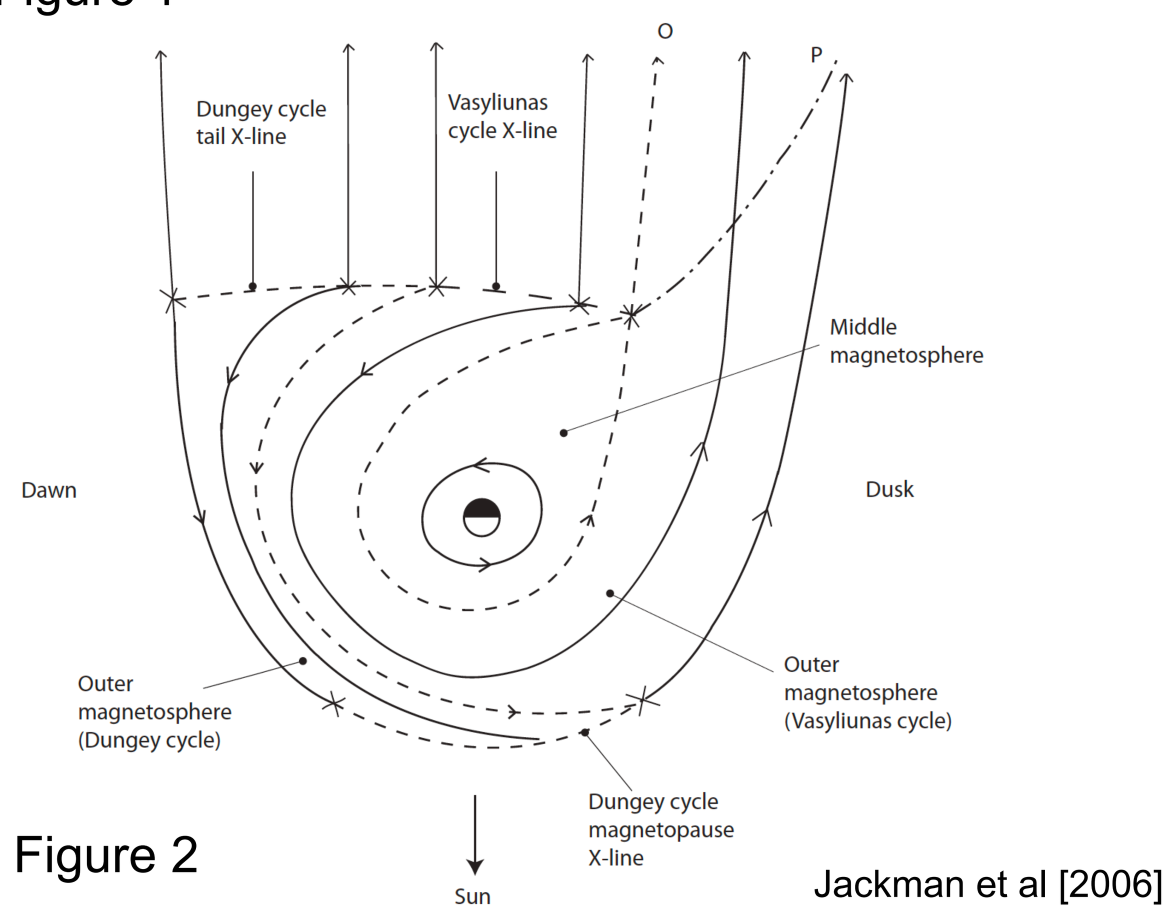

Figure 2

Above we show a sketch of the equatorial plasma flows during both the Dungey and Vasyliunas cycles. The combination of these result in a possibly enhanced flow in the dawn sector. Thus increased field-aligned currents within this LT sector.

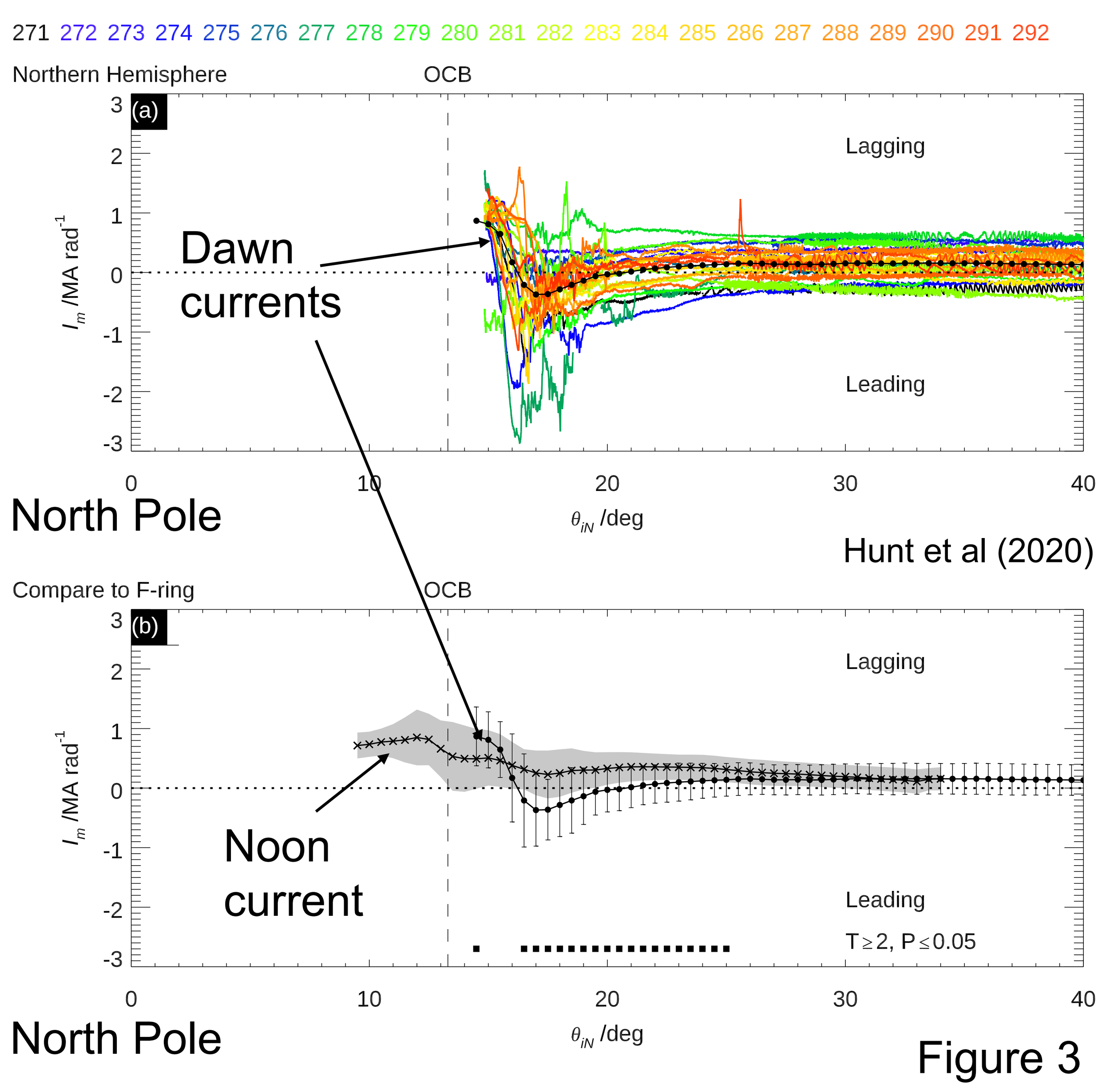

Figure 3

Conclusions

We separate the planetary period oscillation (PPO) currents from non-PPO currents and determined their current sheet properties at dawn and noon

Comparing the dawn and noon observations **we show the non-PPO upward current is stronger at dawn compared to near noon**

We determine a proxy for the precipitating electron power and show that the dawn non-PPO upward current electron power is ~1.9 times higher than at noon

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Data

Between November 2016 to September 2017 Cassini performed 42 orbits through the northern auroral regions, 20 at noon and 22 at dawn.

Figure 3a shows the 22 dawn horizonal meridional current profiles as a function of northern ionospheric colatitude. These are calculated from azimuthal magnetic field data by the application Ampere's law. Figure 3b shows a comparison between dawn and noon.

The main statistical difference is in the negative gradient of the mean profiles which corresponds to the main auroral upward current and the negative I_m values indicative of leading azimuthal field structure [Provan et al. 2019].

Results

Figure 3 shows a clear difference between the dawn and noon currents observed during 2016/17. In particular, with the main auroral field-aligned current. To explore this further we identified the main field-aligned current sheets in each pass. Sheet 2 is the main auroral upward current and sheet 3 is a downward current equatorward of that. Figure 4 shows box plots of the main parameters of the current sheets, current across sheet, position, width and current density.

There is considerably more current across the main auroral current at dawn compared to noon. Moreover, the position is shift between dawn and noon. This agrees with an offset of the auroral oval [Lamy et al. 2018].

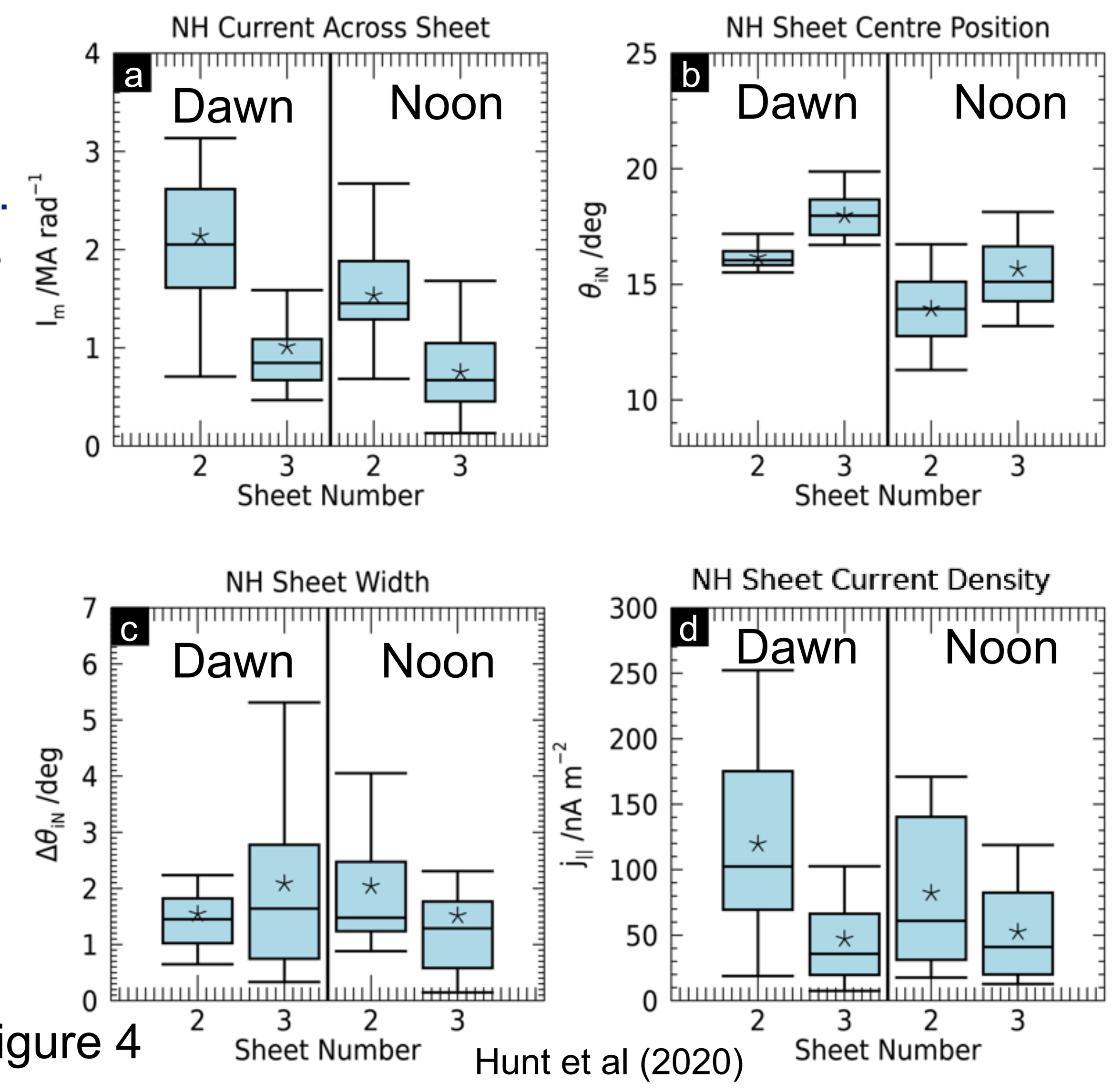

Figure 4

Combining the sheet current and width we calculate the current density. The mean (∗) and median (line) are ~ double at dawn compared to noon.

Discussion

Organising the sheets' boundaries by the PPO phase we can separate the non-PPO and PPO currents. The main difference again comes from the non-PPO current as shown in Figure 5a.

Following Hunt et al. [2016] we calculate a proxy for the precipitating electron power, $P = \frac{\Delta I_m^2}{\sin(\theta_i)\Delta\theta_i}$.

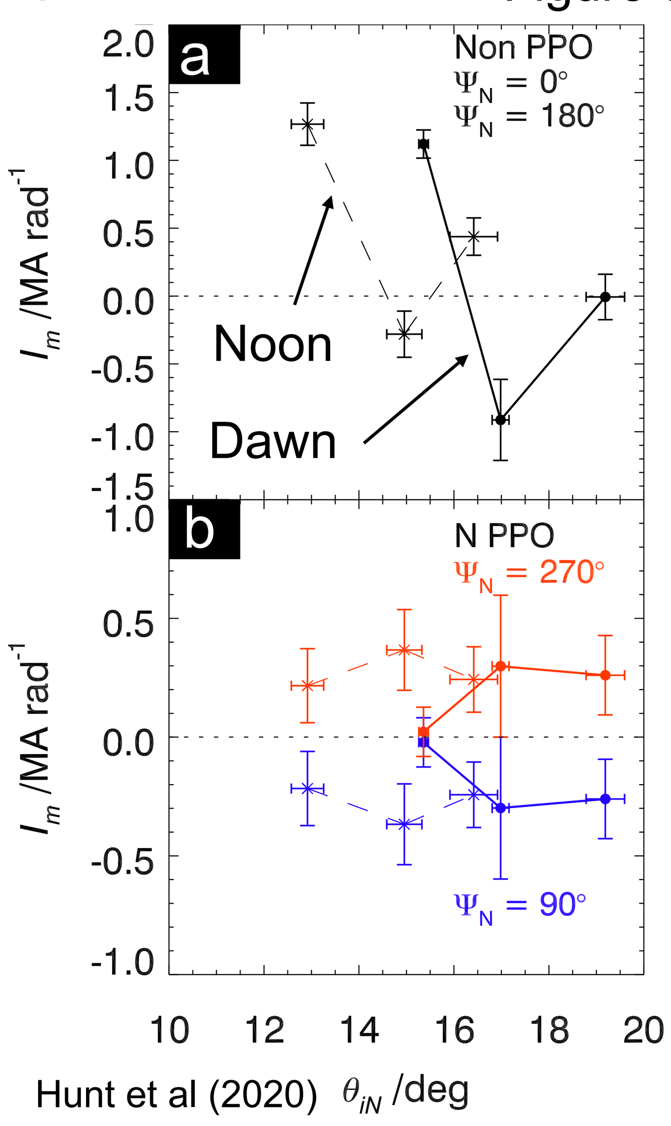

Figure 5

Applying this equation to the main upward current sheet of the non-PPO currents **we find that this proxy is ~1.9 times greater at dawn than noon.**

The implication of this is that the non-PPO upward current at dawn is on average stronger than noon. This coupled with a possibly hotter/more tenuous plasma due to tail reconnection events could lead to more intense/powerful transient dawn auroral features observed at Saturn.

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REFERENCES

Hunt et al. (2014) doi:10.1002/2014JA020506
Jackman, C. M., & Cowley, S. W. H. (2006) doi:10.5194/angeo-24-1029-2006
Provan et al. (2019) doi:10.1029/2019JA026800
Lamy et al. (2018) doi:10.1029/2018GL078211
Hunt et al. (2016) doi:10.1002/2016JA022712
Hunt et al. (2020) doi:10.1029/2019JA027683 – work shown in this poster!