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The response of Saturn’s dawn field-aligned currents to magnetospheric conditions during the Proximal Orbits

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1. Introduction

The Proximal orbits of the Cassini spacecraft during 2017 have given us the opportunity to examine the auroral field-aligned currents in the northern hemisphere dawn sector in relation to Saturn’s general magnetospheric conditions.

Bradley et al. (2020) reported that Saturn’s magnetospheric response to solar wind compressions was determined by the relative phases of the magnetic planetary period oscillations (PPOs), with major magnetospheric storm responses observed during PPO antiphase conditions.

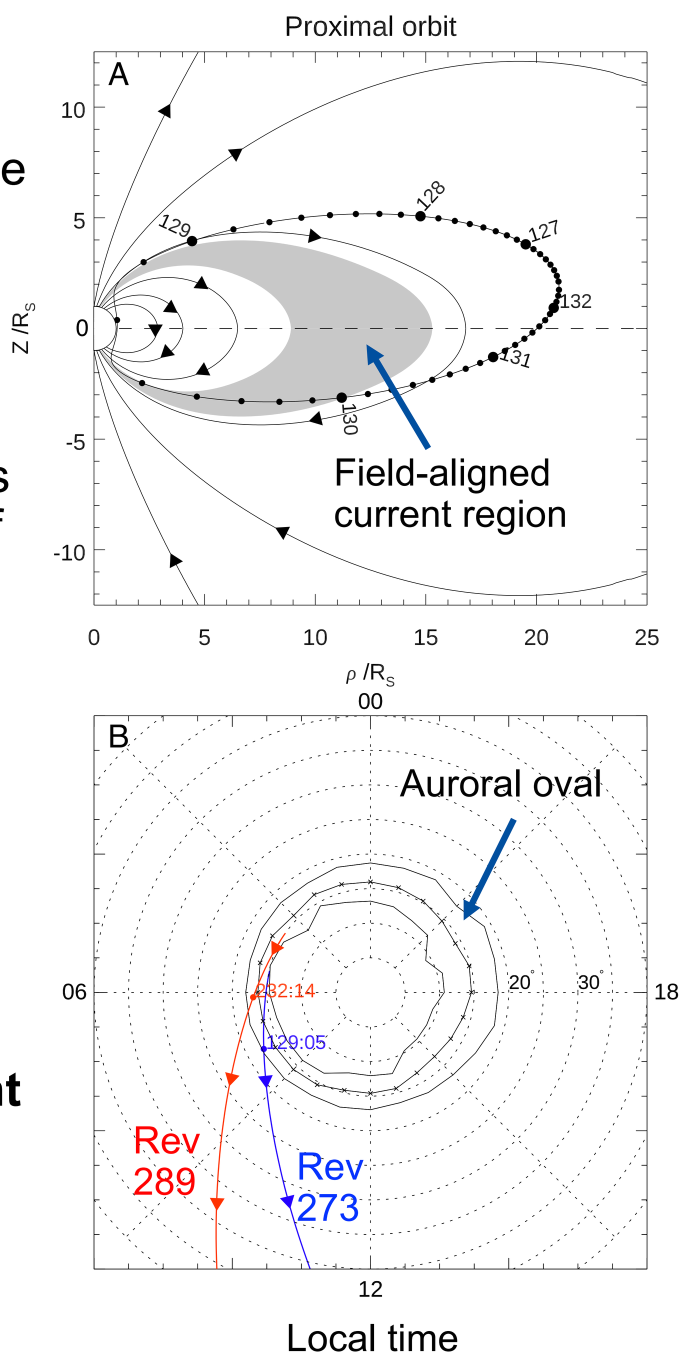
Provan et al (2021) found evidence of a partial ring current on the nightside during compressions of Saturn’s magnetosphere when the PPOs were in near antiphase. They found this by fitting a ring current model to magnetometer data ±1 day about periapsis with a short gap at periapsis. This partial ring current may close partly via field-aligned currents in the dawn-dusk sectors. In the case of Saturn this would be a downward current, into the ionosphere, at dawn.

2. Data and Background

In this study we use the final set of orbits from the Cassini mission, known as the Proximal orbits. The typical geometry is shown on the right.

The bottom panel shows the magnetic footprint of Cassini as it passed above the dawn auroral oval and through the sheets of field-aligned current.

Here we combine observations of the northern hemisphere dawn FACs (Hunt+ 2020), total ring current (Provan+ 2021) and magnetospheric compression from Bradley+ (2020).



3. Example Orbits

To begin with we compare the magnetic field observations of the field-aligned currents with plasma data.

Top panels: Ionospheric meridional current, I_m, derived from the azimuthal magnetic field via Ampère's law (Hunt et al 2020). Gradients are the FACs.

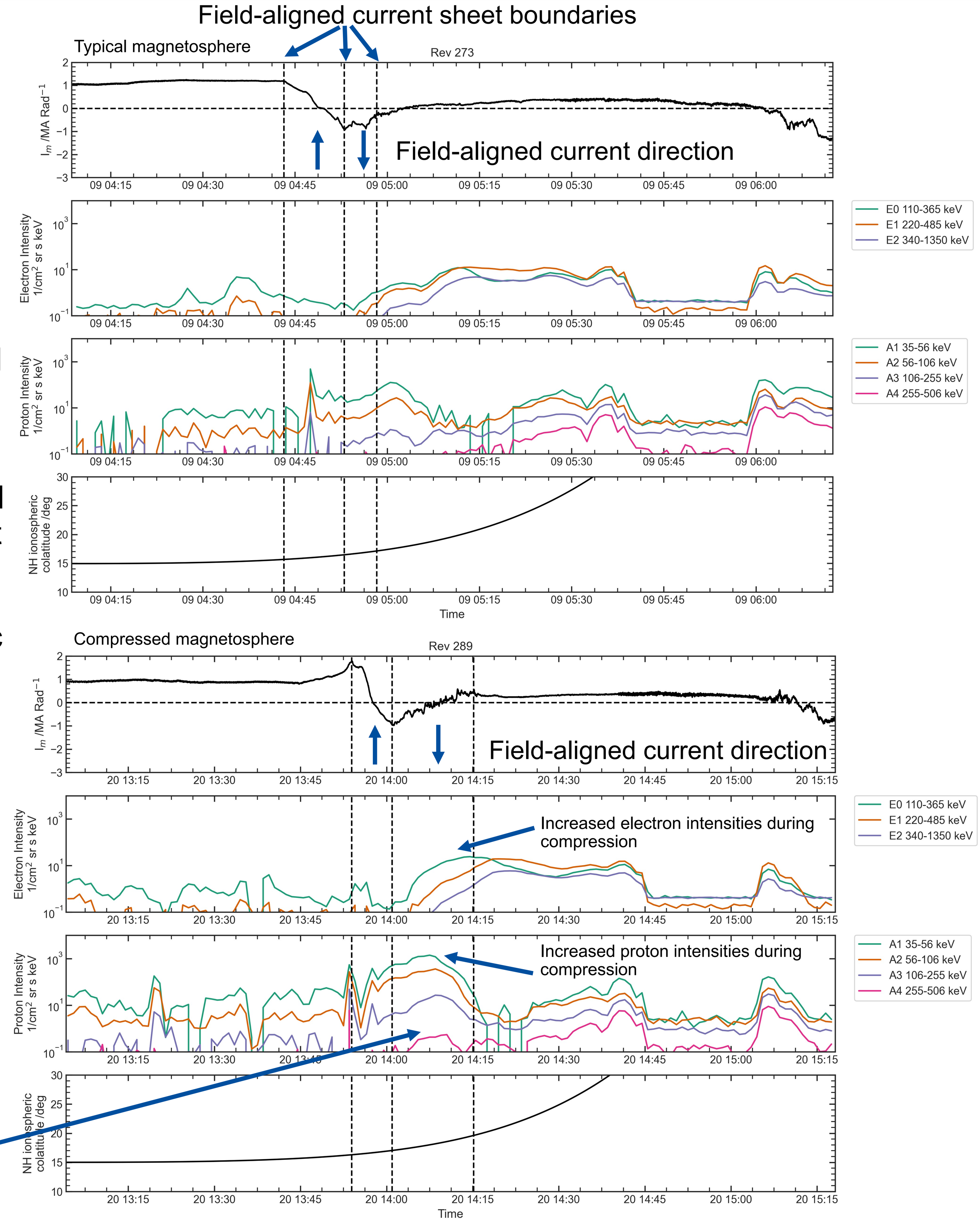
Middle panels: The electron and proton intensities across different energy channels from LEMMS.

Bottom panels: The ionospheric colatitude of Cassini’s magnetic footprint.

Here we compare a typical and compressed magnetosphere.

In the **case of a compressed magnetosphere, there is an increase in the plasma intensities within an increased downward current sheet**.

In particular, **there is an increase in the higher energy protons**, 255-506 keV (pink line).

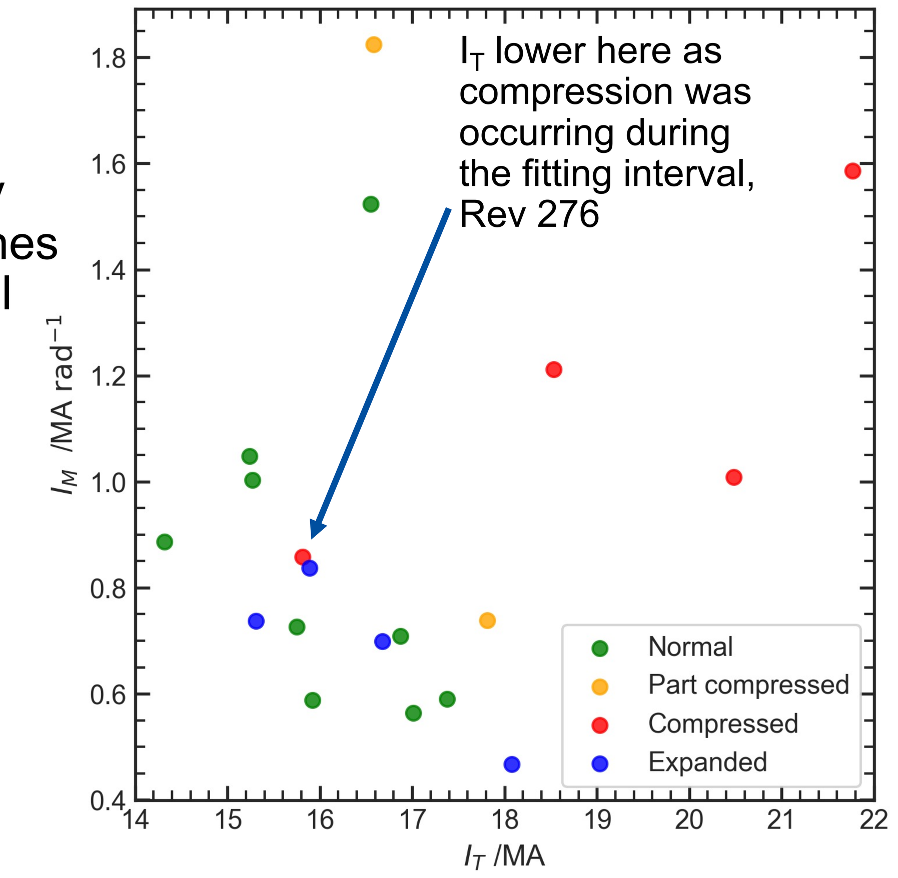


4. Comparison of Downward FAC and Total Ring Current

On the right we show the downward current, I_m, measurements from Hunt et al (2020), this is determined by the difference in I_m between the second and third dashed lines (see above). We plot these as a function of ring current total current, I_T from Provan et al (2021). The points are colour-coded by magnetospheric state from Bradley et al (2020).

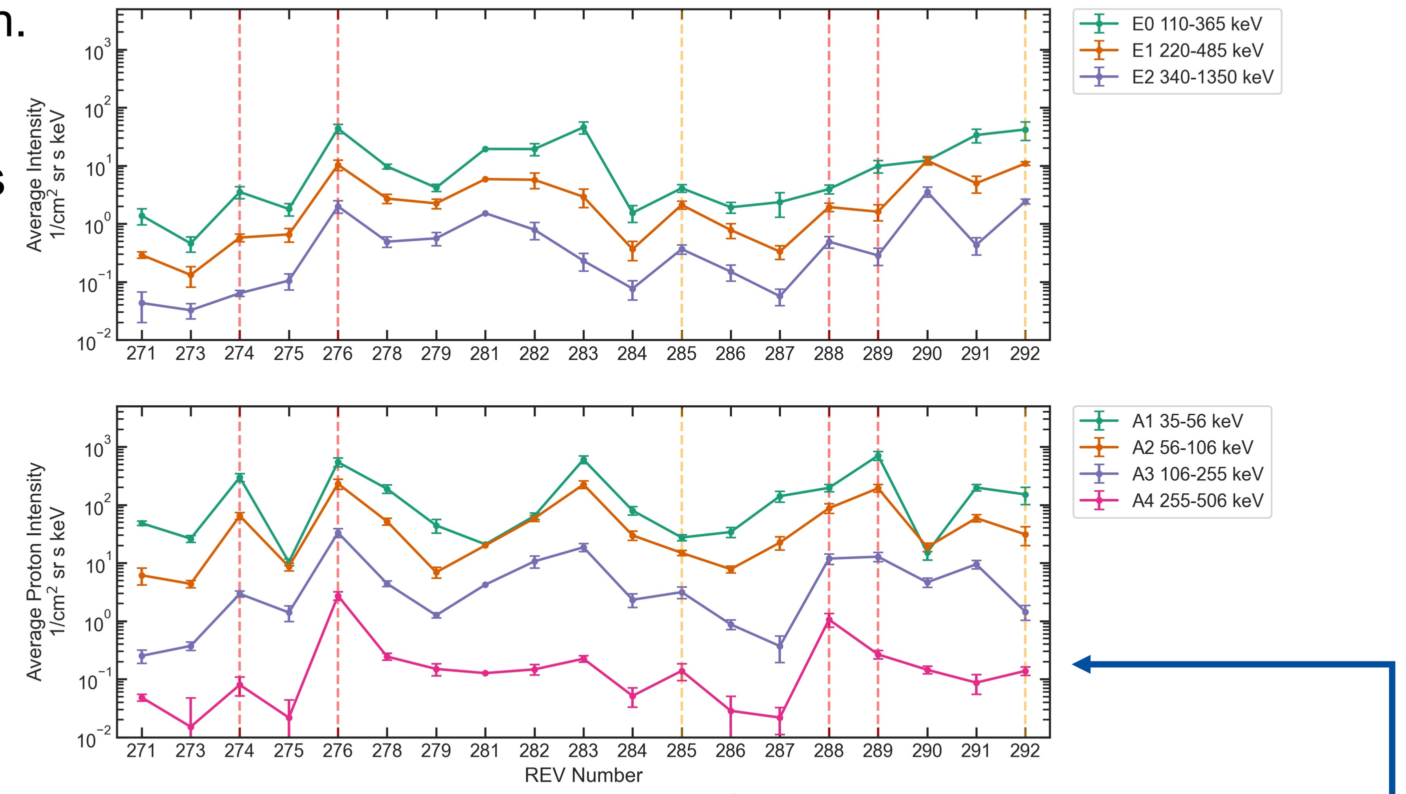
We can see that for a compressed magnetosphere there is typically a stronger downward current and higher total ring current. Compared to the opposite response for the expanded/normal cases.

This is indicative of an additional downward current during compression events, which likely forms the closure current of the partial ring current at dawn.



5. Average Plasma Measurements with Downward FAC Sheet

To explore the plasma populations further we averaged the LEMMS proton and electron intensities within the downward current sheet for each orbit that we have identified such a sheet. The results of this are shown below. The vertical dashed red line mark compression events. Errors are standard error of the mean.



These plots show the orbit to orbit variability of the plasma populations within the downward current sheet. **What is noticeable is the increases within the proton channels during compressions, especially in the higher energy protons, shown here by the pink line in the bottom panel.**

This increase in hotter protons supports the following hypothesis. That during a compression event of Saturn’s magnetosphere, reconnection occurs in the nightside tail. This in turn injects hot plasma leading to the formation of a partial ring current and an increased I_T. Then **as the hot plasma rotates through the dawn sector, as previously reported, an increased downward current occurs to close the partial ring current. This response is akin to an Earth-like region 2 current within Saturn’s magnetosphere**. Previously, an increase in current density from the equatorial plane at dawn was report by Martin, C. J., & Arridge, C. S. (2019).

6. Conclusions

Combining data from three studies; **Hunt et al. (2020), Bradley et al. (2020) and Provan et al. (2021)** we have shown there is an **increase in the dawn downward field-aligned current** during **compression events.** This is a **response to increasing total current** within the ring current, due to injected plasma and a partial ring current forming on the nightside.

We have shown **that typically there is an increase in the proton intensities within the downward current sheet during compression events**. This is especially **noticeable in the higher energy protons >255 keV.**

We conclude that these observations **provide the first evidence for an additional downward current within Saturn’s dawn auroral region akin to the Earth’s region 2 current.**

Work presented here is in prep and will be soon submitted

References : Hunt et al. 2020 https://doi.org/10.1029/2019JA027683 Bradley et al. 2020 https://doi.org/10.1029/2020JA027907 Martin, C. J., & Arridge, C. S. (2019) https://doi.org/10.1029/2018JA025970 Provan et al. 2021 https://doi.org/10.1029/2020JA028605