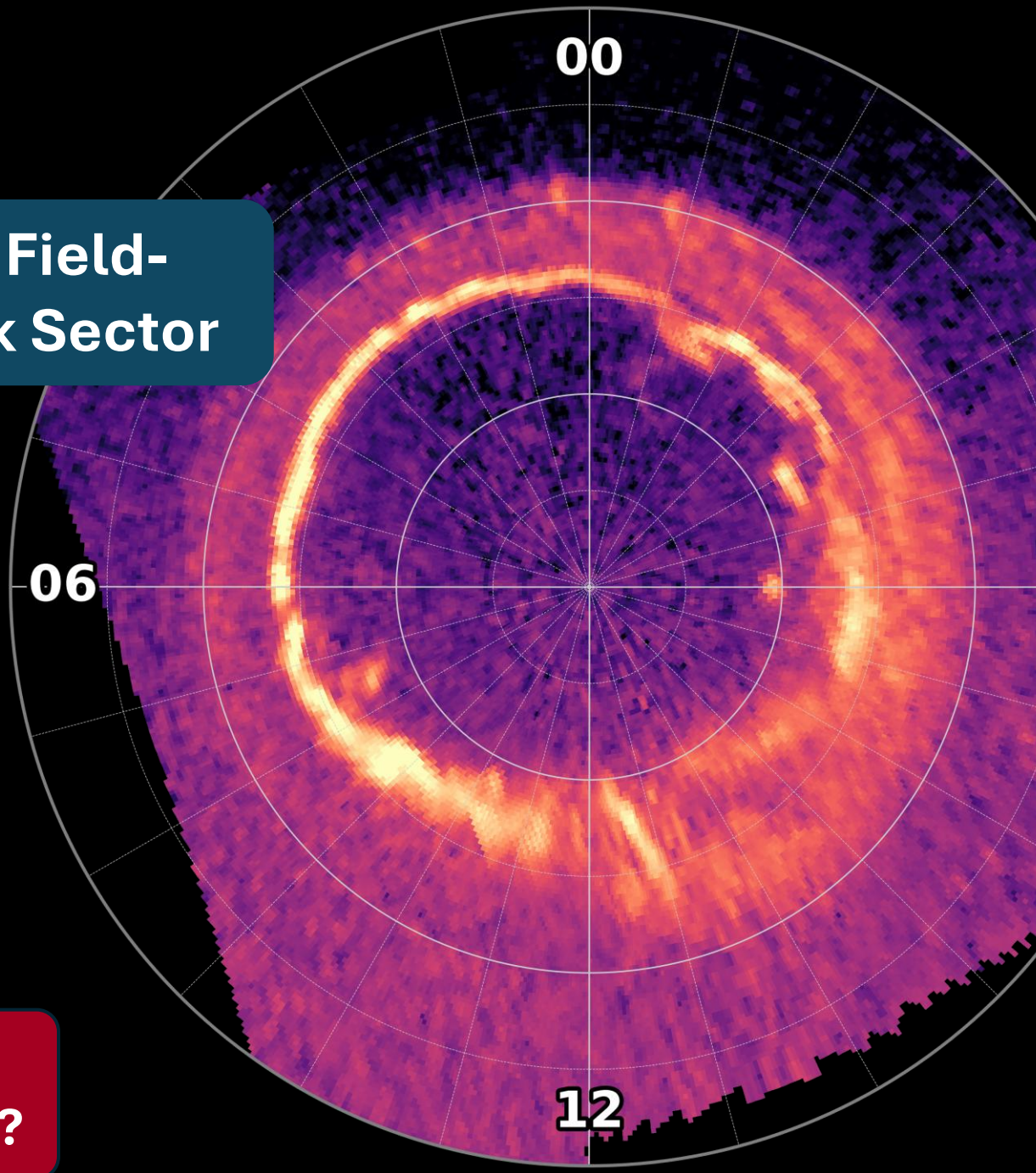
Structure and Behaviour of Saturn's Field-Aligned Currents in the Southern Dusk Sector

Sam Farr[1], Sarah Badman[1], Licia Ray[1], Gabrielle Provan[2], Stan Cowley[2]

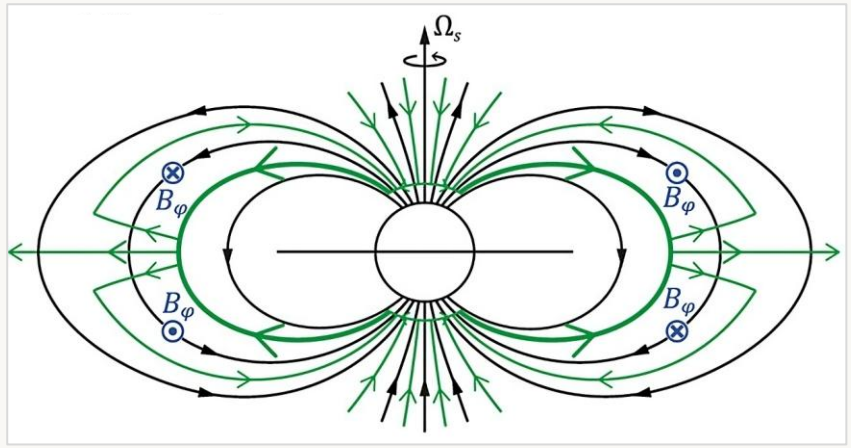
[1]Lancaster University [2]University of Leicester



Why is dusk so diffuse and variable? What's the response to internal and external drivers?

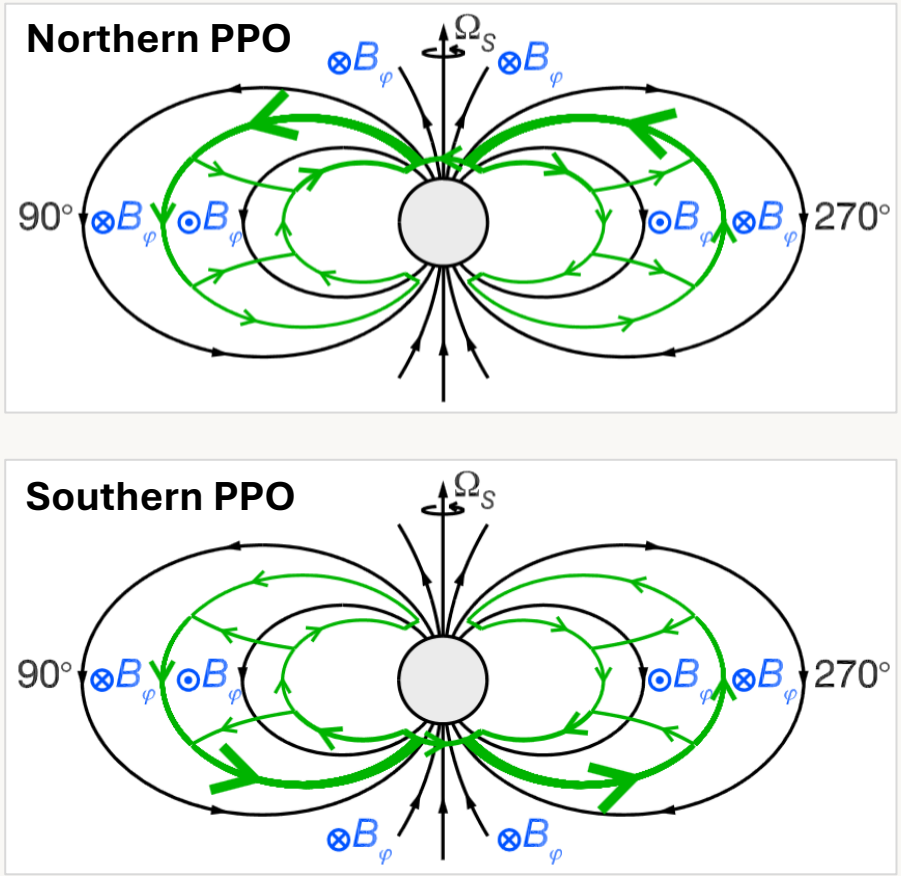
Saturn's Main FAC Systems

Subcorotation:



- FAC structure driven by flow shear in plasma
- Axially symmetric within ~8Rs

Planetary Period Oscillation Systems:



(Hunt et al., 2014)

- Axially asymmetric
- Rotating with periods of 10.8hrs (north) and 10.7hrs (south)

s.farr1@lancaster.ac.uk

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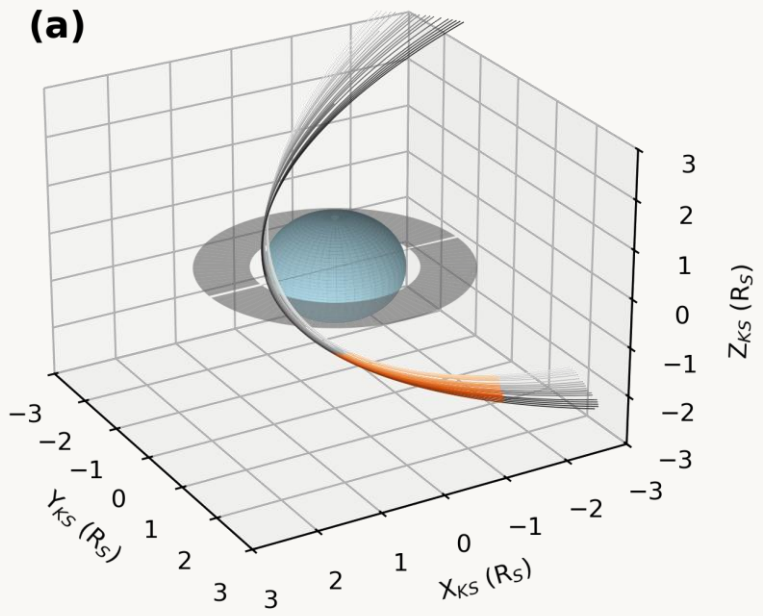
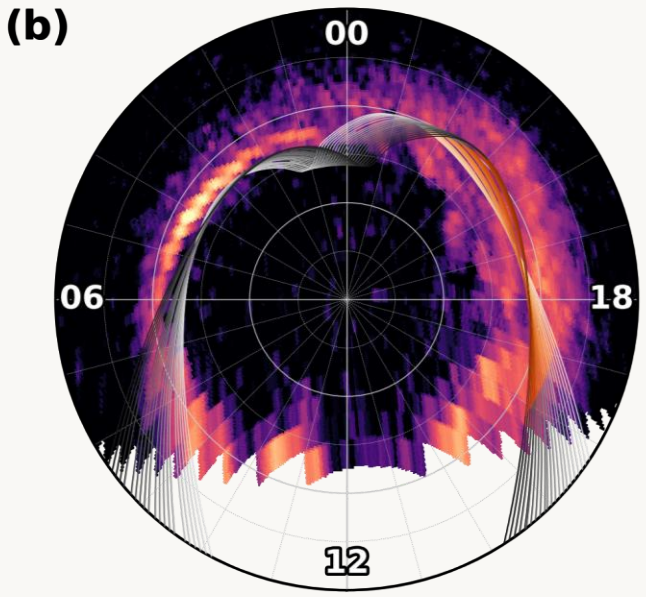
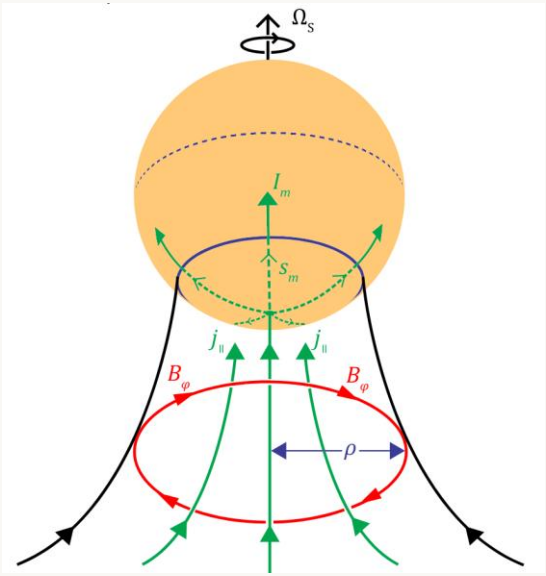
Cassini's Proximal Orbits





- Dataset from the final 22 orbits of Cassini, referred to as the 'Proximal' or 'Grand Finale' orbits
- Each orbit is similar in trajectory, inbound/outbound passes in northern/southern hemispheres respectively
- Data segment sweeps through FAC regions covering 16-22hr LT over ~2 hours (orange lines)
- Dawn FAC crossing published (Hunt et al., 2020)

Ionospheric Current Calculation

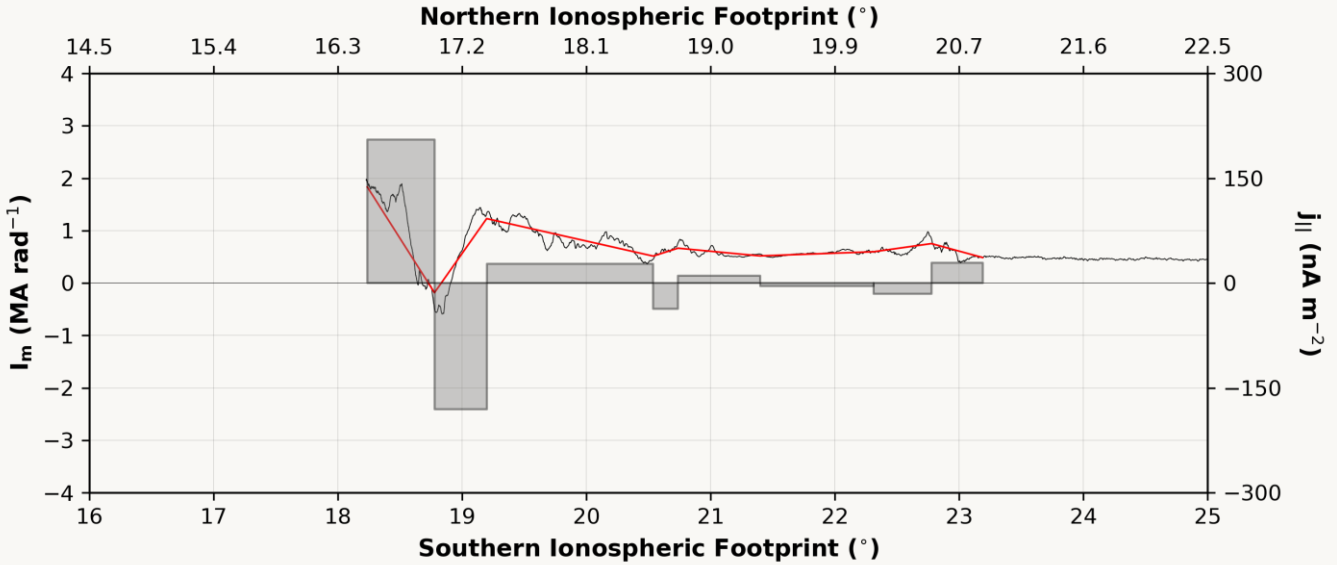


(Hunt et al., 2014)

- Using Ampère's law, we determine the **ionospheric meridional current**:

$$I_m = -\frac{\rho B_\varphi}{\mu_0}$$

- Gradients indicate FAC presence

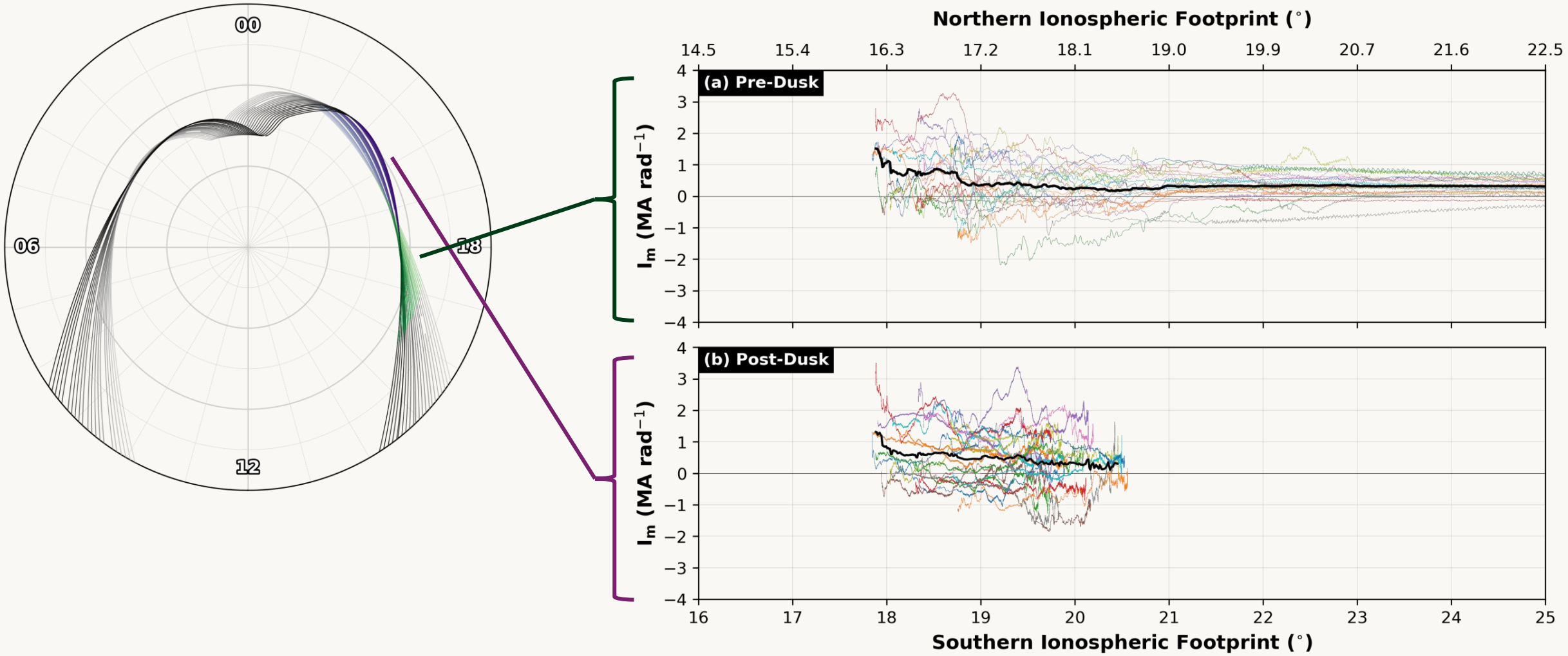


- Algorithm developed to automatically determine current sheets from Cassini MAG B_ϕ measurements (red line)

- **Current density** (grey boxes) determined via:

$$j_{||} = \frac{\Delta I_m}{R_i^2 \sin(\theta_i)\Delta\theta_i}$$

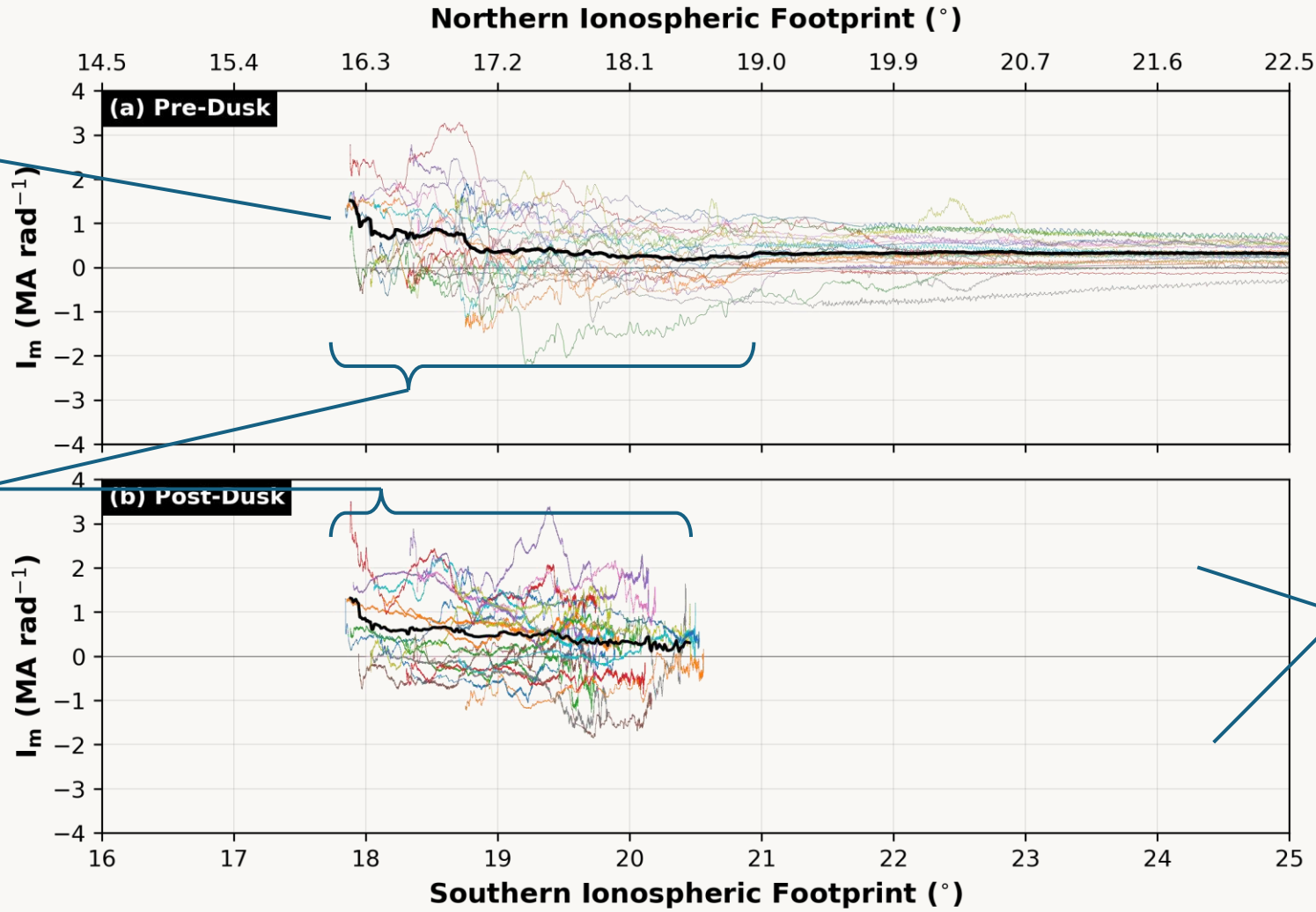
Splitting Dataset into Two LT Sectors



Ionospheric Current Profiles

Poleward limit imposed by orbital trajectory

Orbit-to-orbit variability 18° - 21°



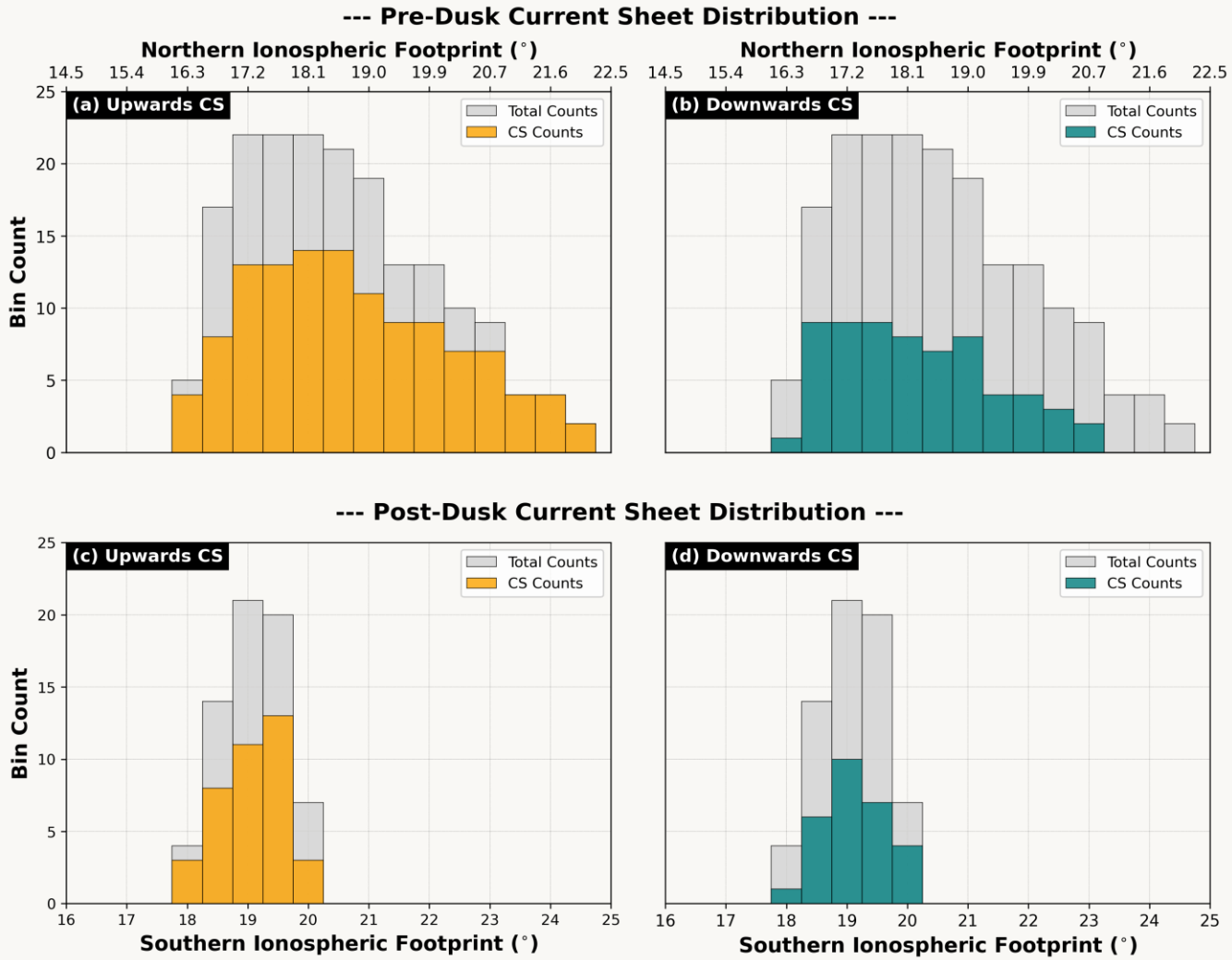
Decreasing average I_m profile suggests broad upwards FAC

+ve I_m indicates lagging B-field, -ve indicates leading

FAC Position Distribution

Upwards and downwards field-aligned currents are identified by the algorithm for all 22 orbits.

- Pre-dusk: upwards FACs 2.1x more frequently observed across a wider colatitude range
- Post-dusk: upwards FACs 1.6x more frequent, reduced colatitude range



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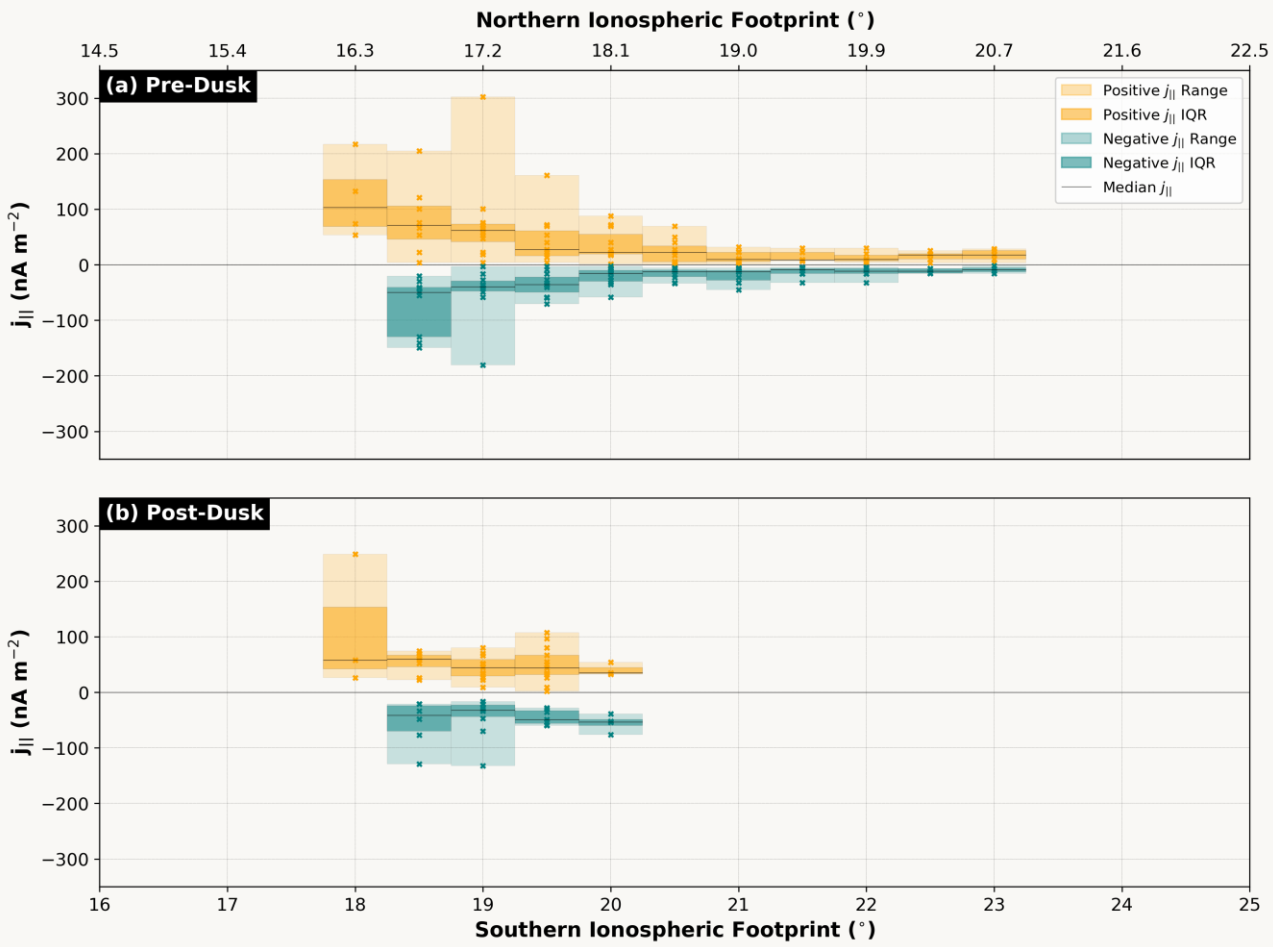
FAC Magnitude Distribution



- Current magnitudes increase polewards of 19.5° pre-dusk, flatter profile post-dusk
- Pre-dusk: upward currents have higher magnitude than downwards currents closest to the pole (<19.5°)
- Post-dusk: upward and downward currents have similar magnitudes at all colatitudes

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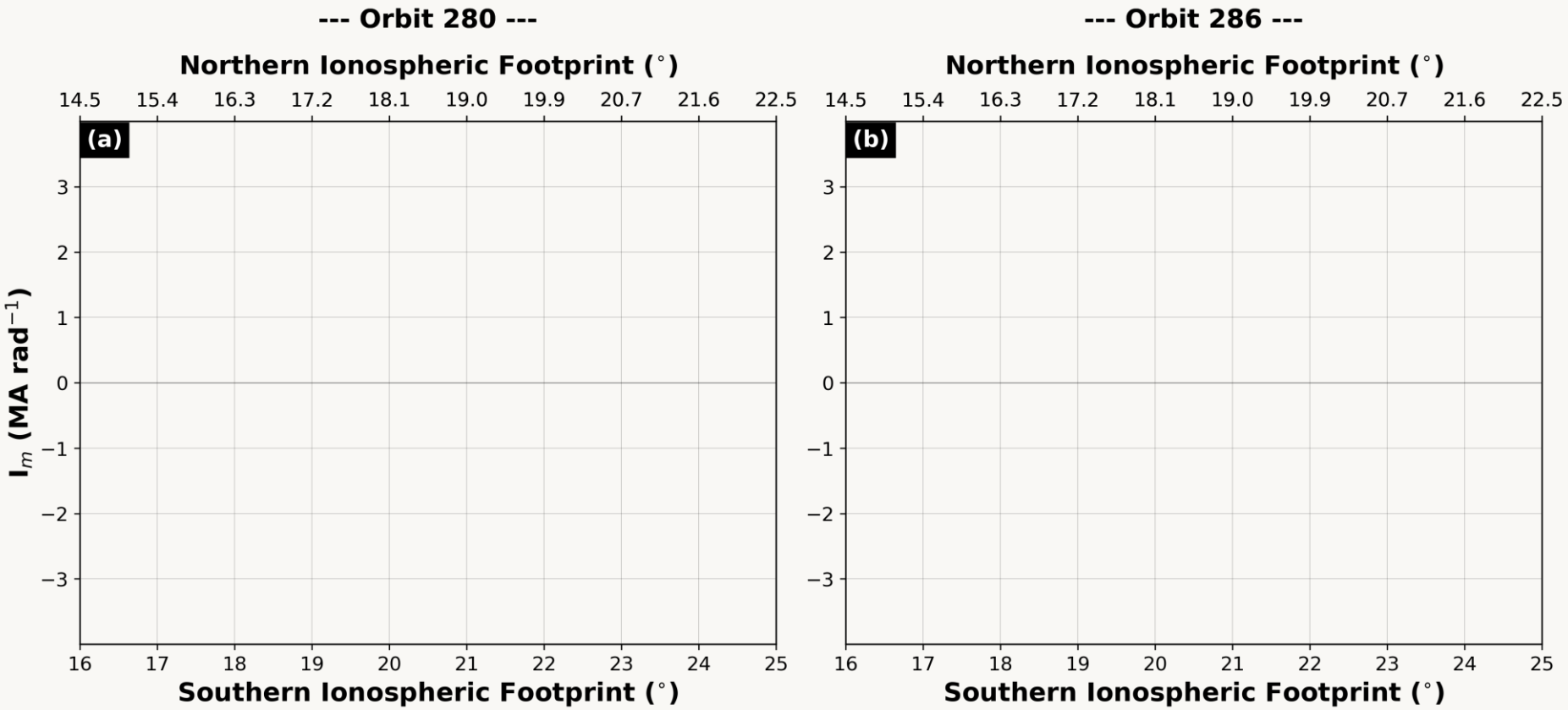
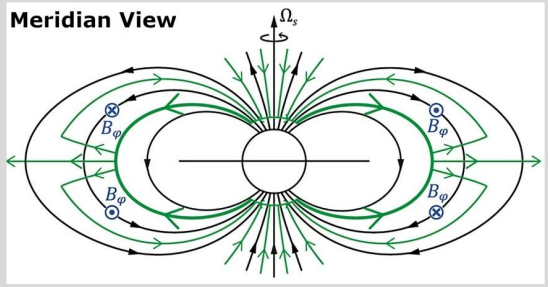
Modelling Current Contribution

Developed an empirical model for PPO-driven variability in I_m, using Provan et al., 2018 PPO phase models



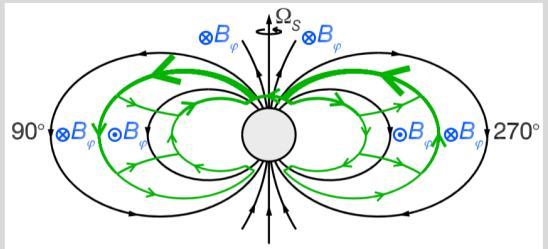
FAC Structure Reminder

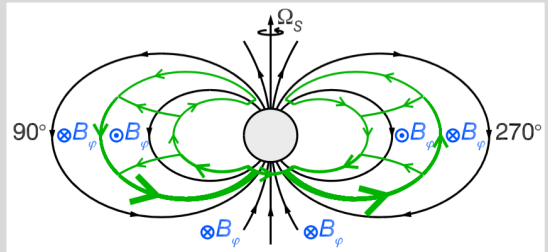
Subcorotation:



Bradley et al., 2018

PPOs (North/South):





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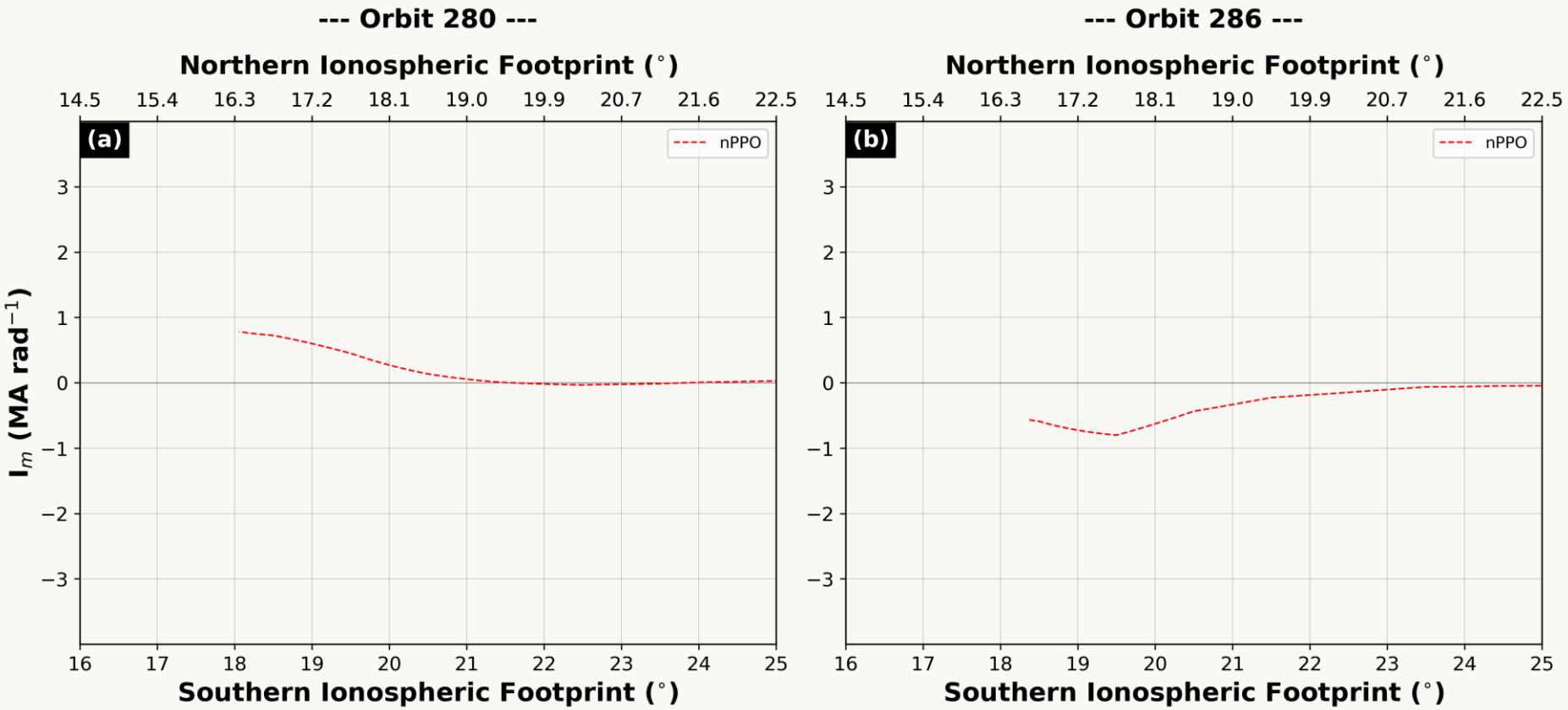

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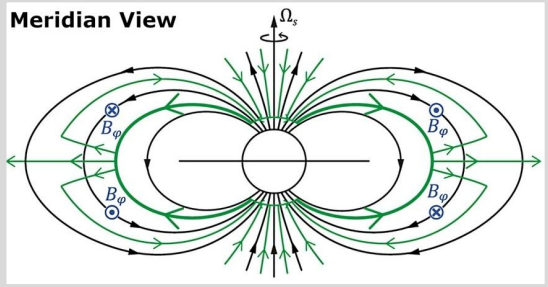

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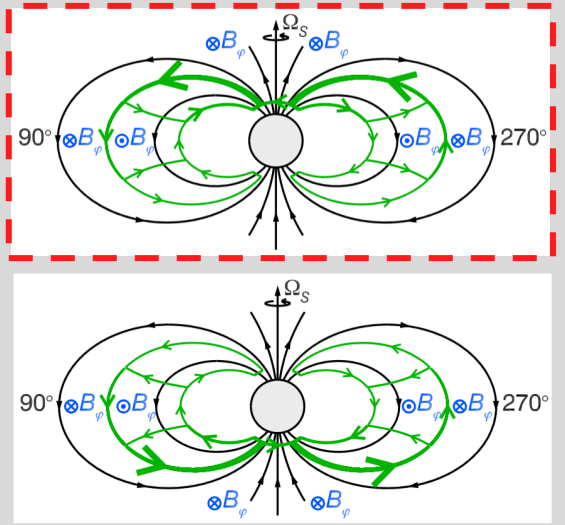

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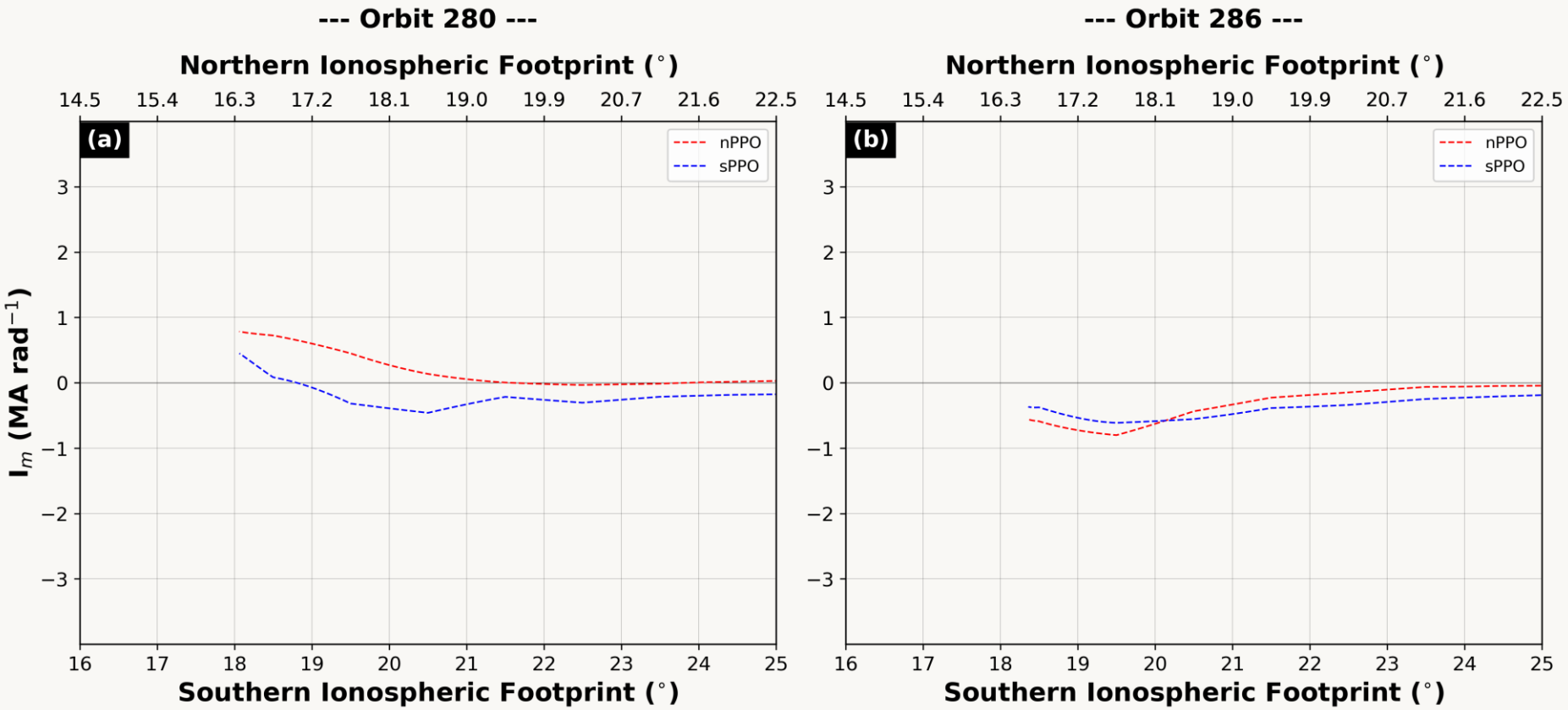

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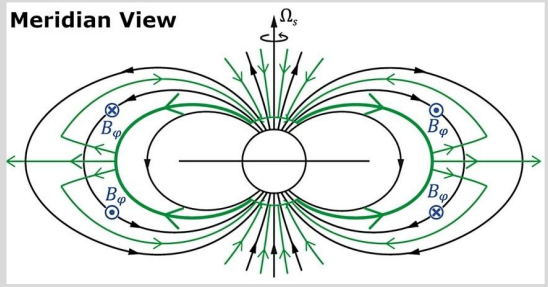

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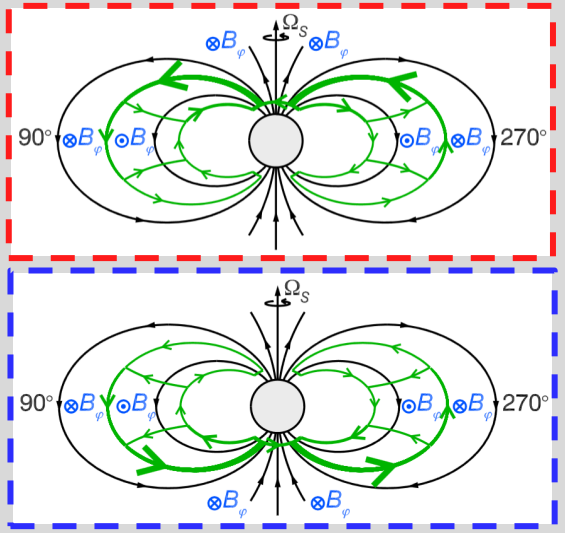

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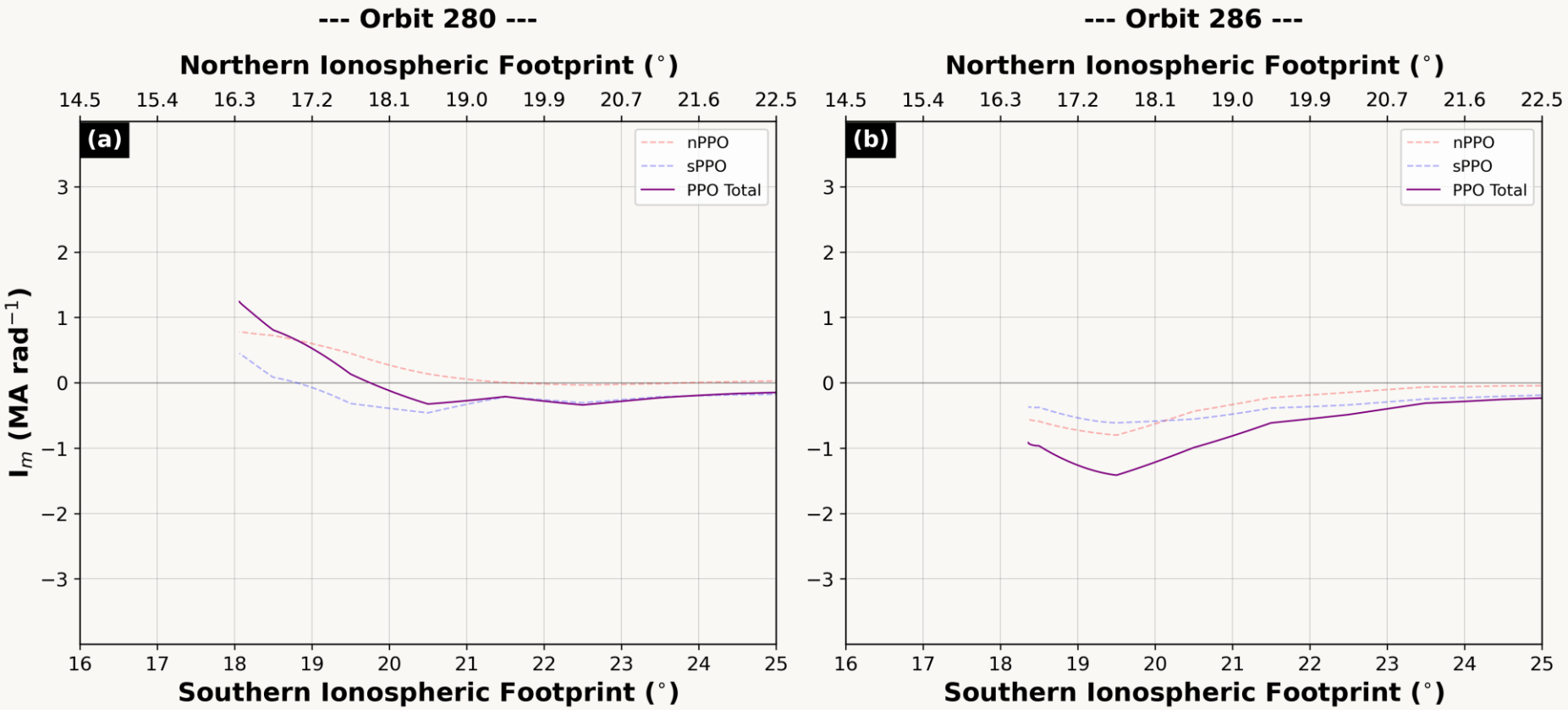

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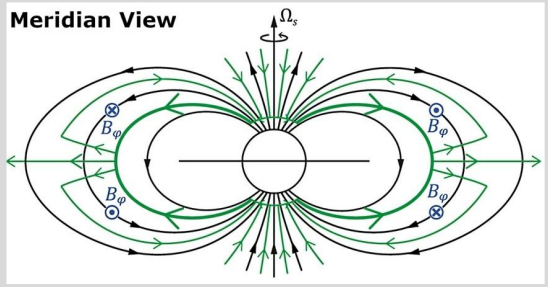

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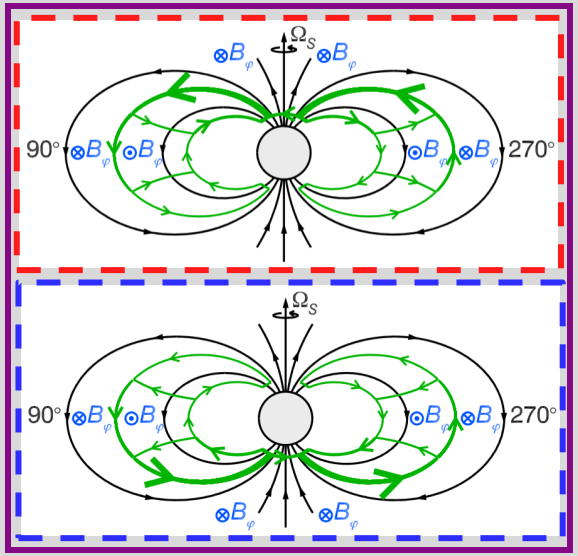

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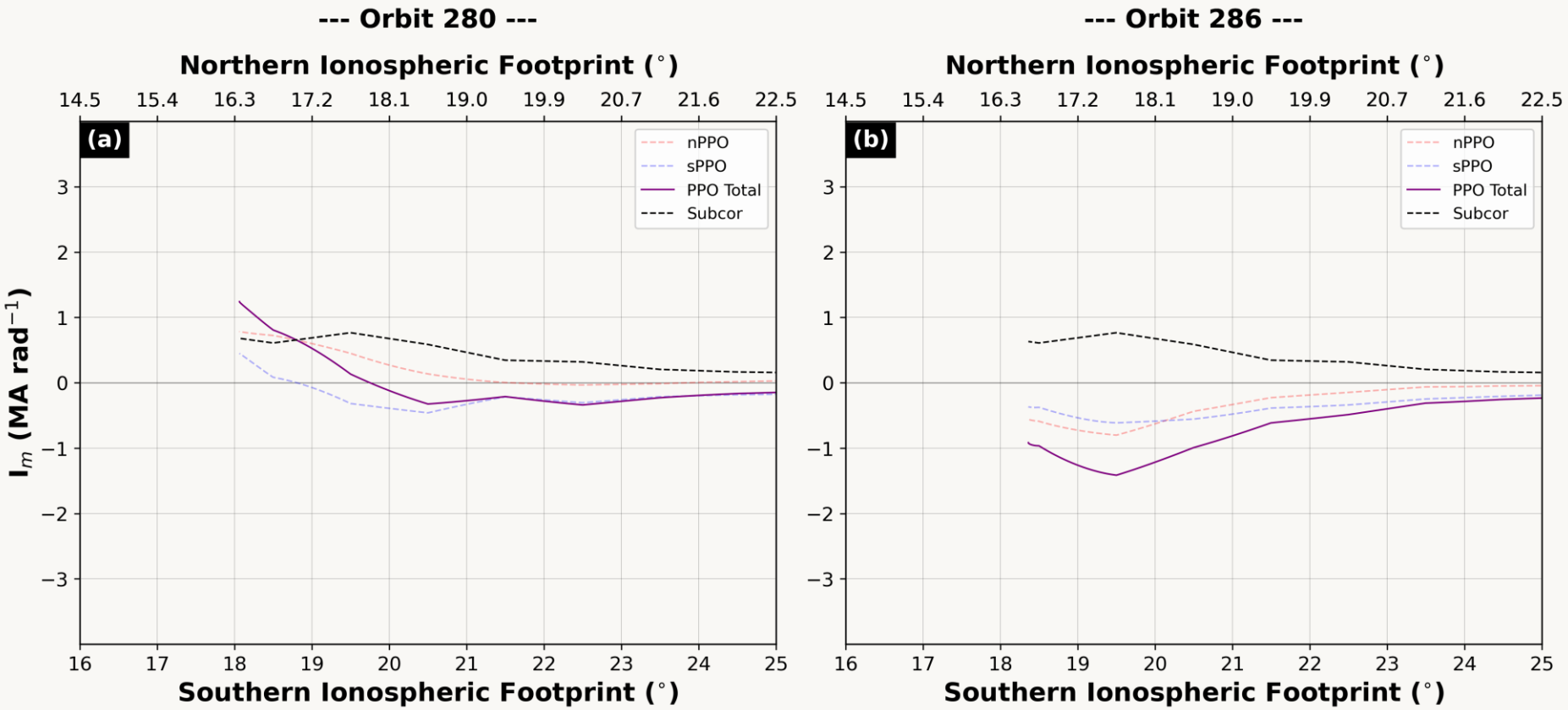

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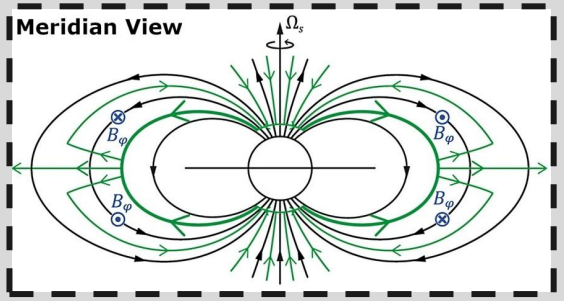

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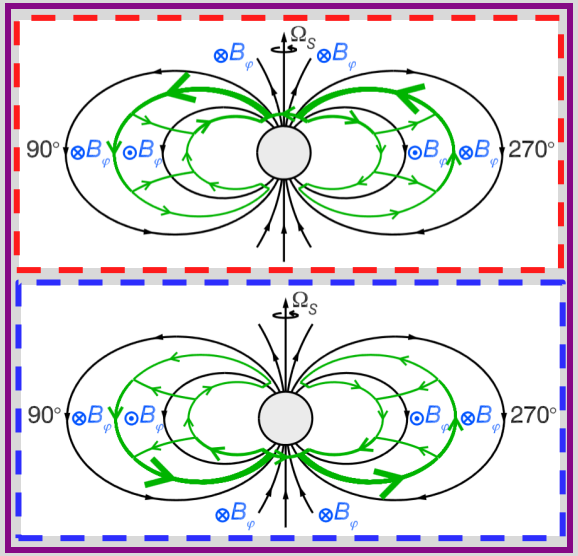

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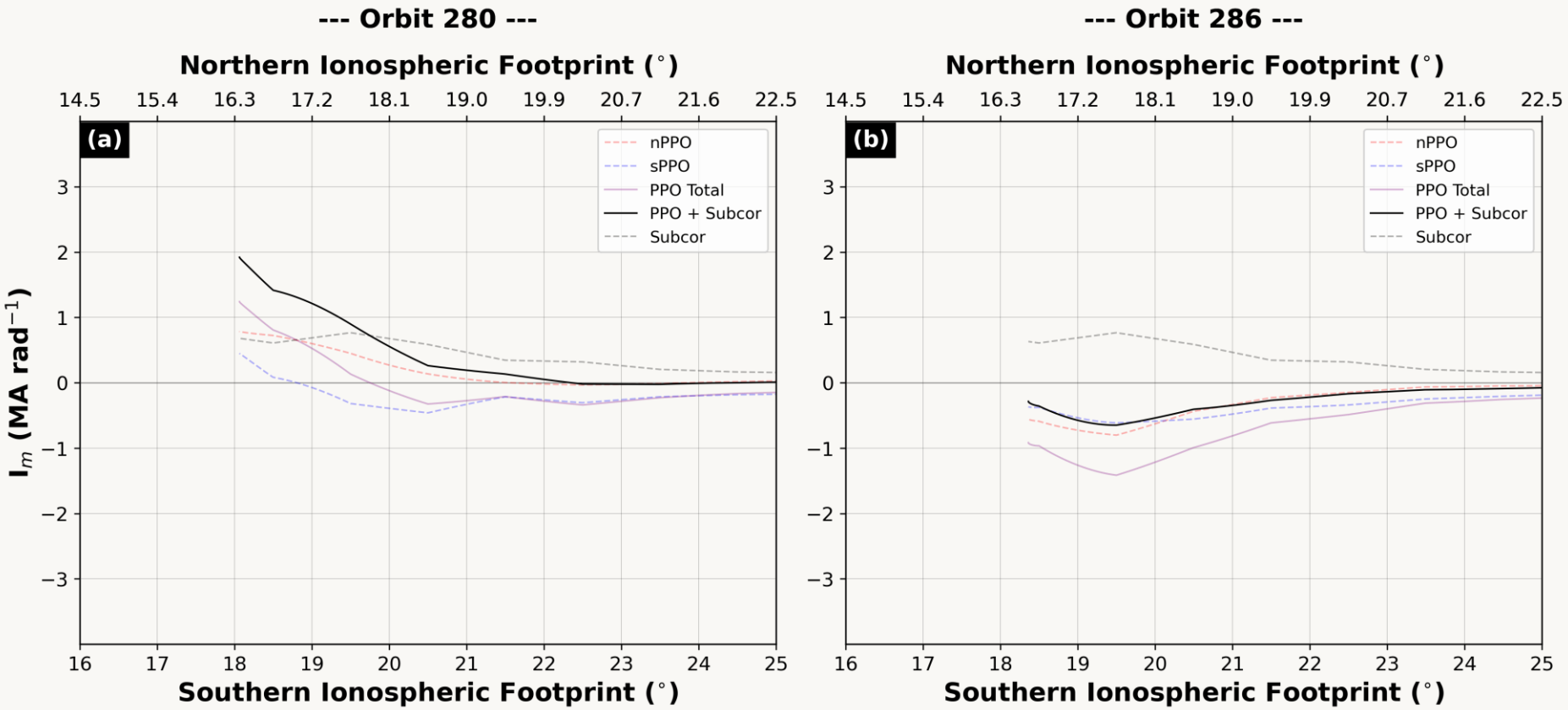

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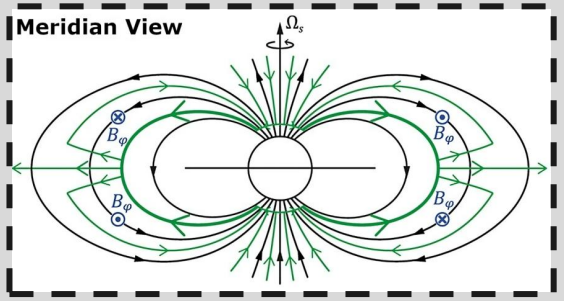

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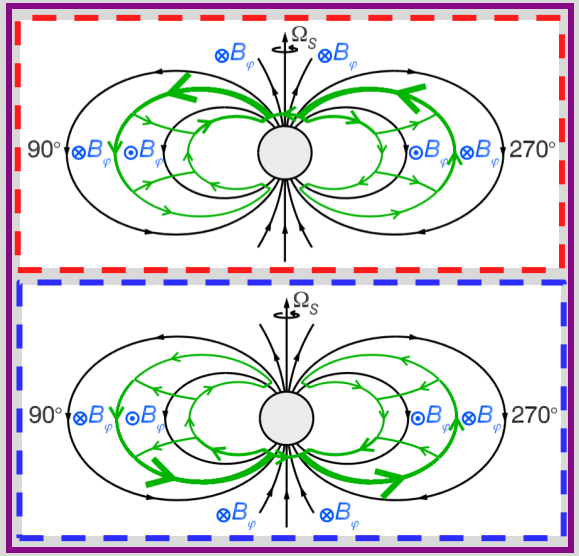

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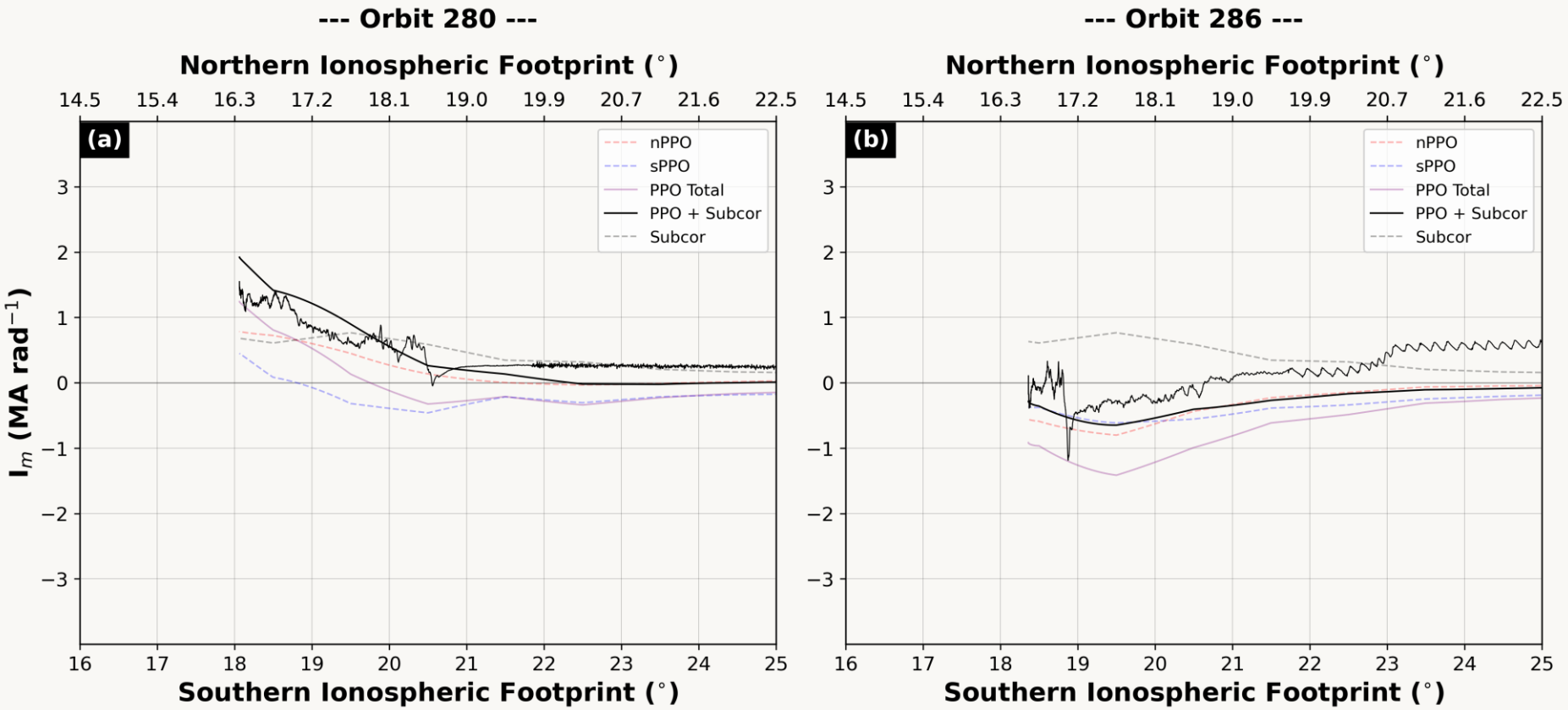

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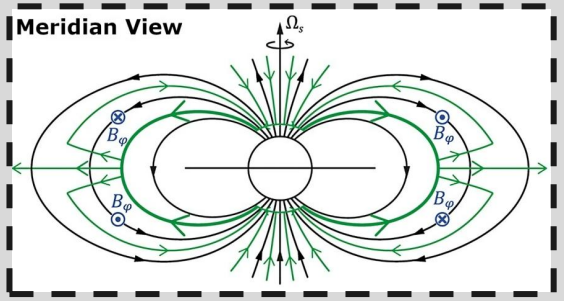

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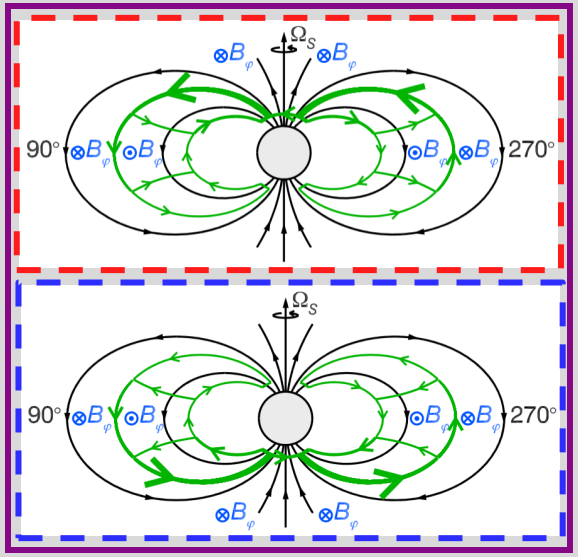

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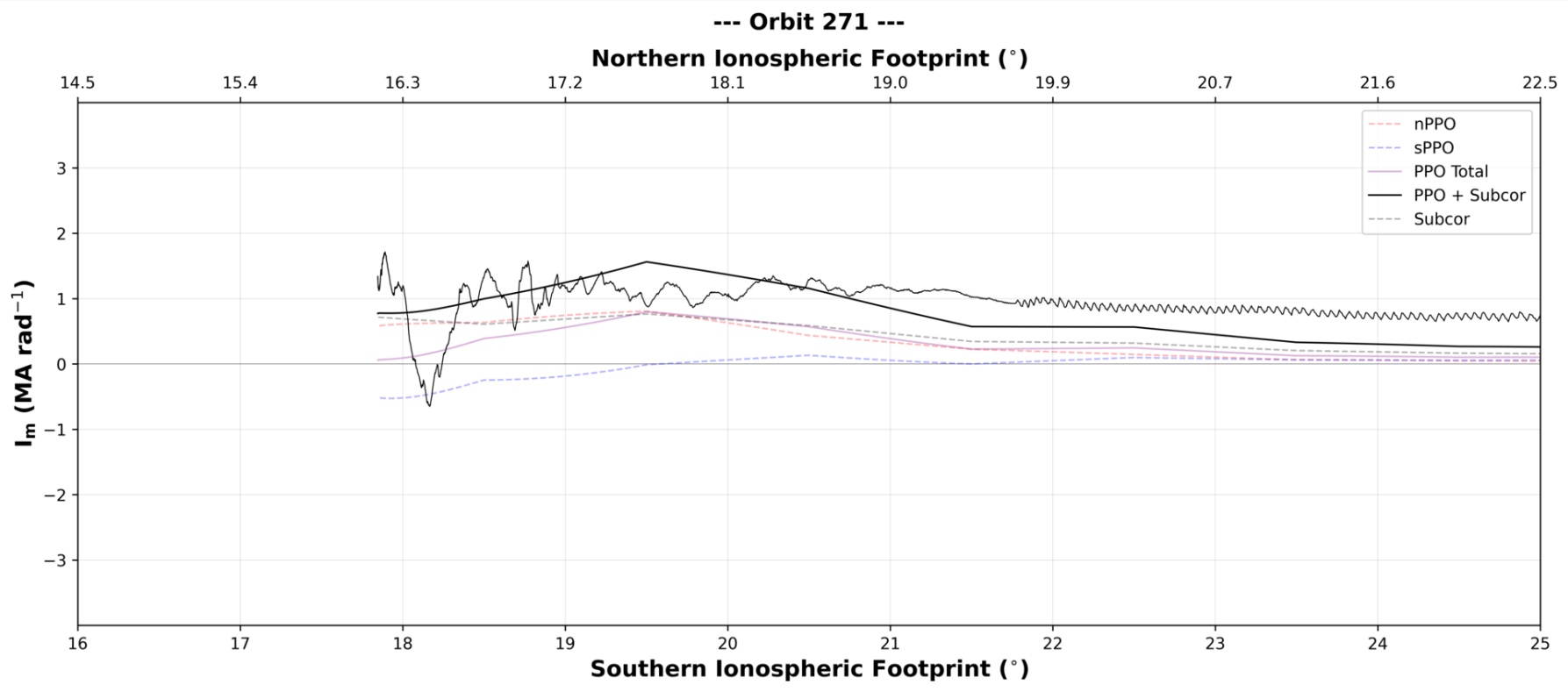

- Model doesn't consistently fit, small-scale variability not PPO driven
- Comparable peak location and magnitude contributions from PPO systems and subcorotation:
  - nPPO - 0.9 MA rad^{-1} at 19.5°
  - sPPO - 0.8 MA rad^{-1} at 20.5°
  - Subcorotation - 0.8 MA rad^{-1} at 19.5°

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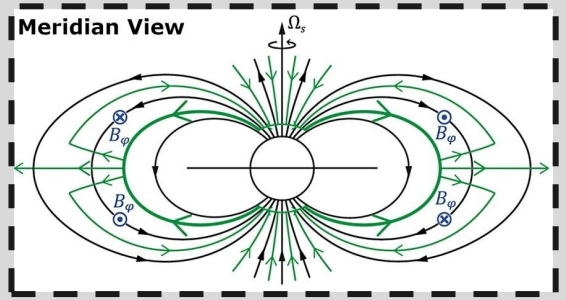

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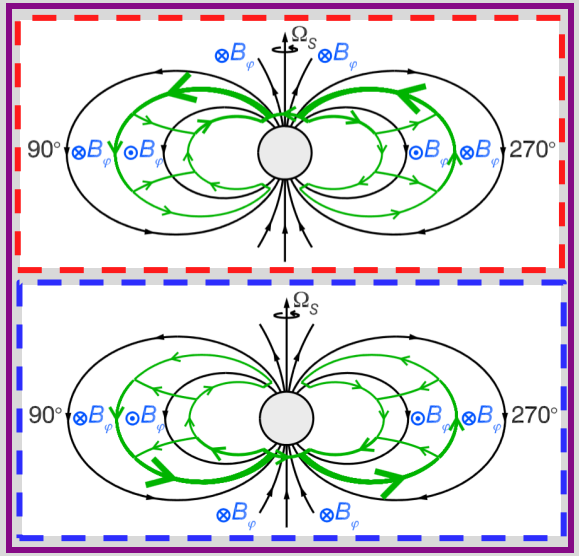
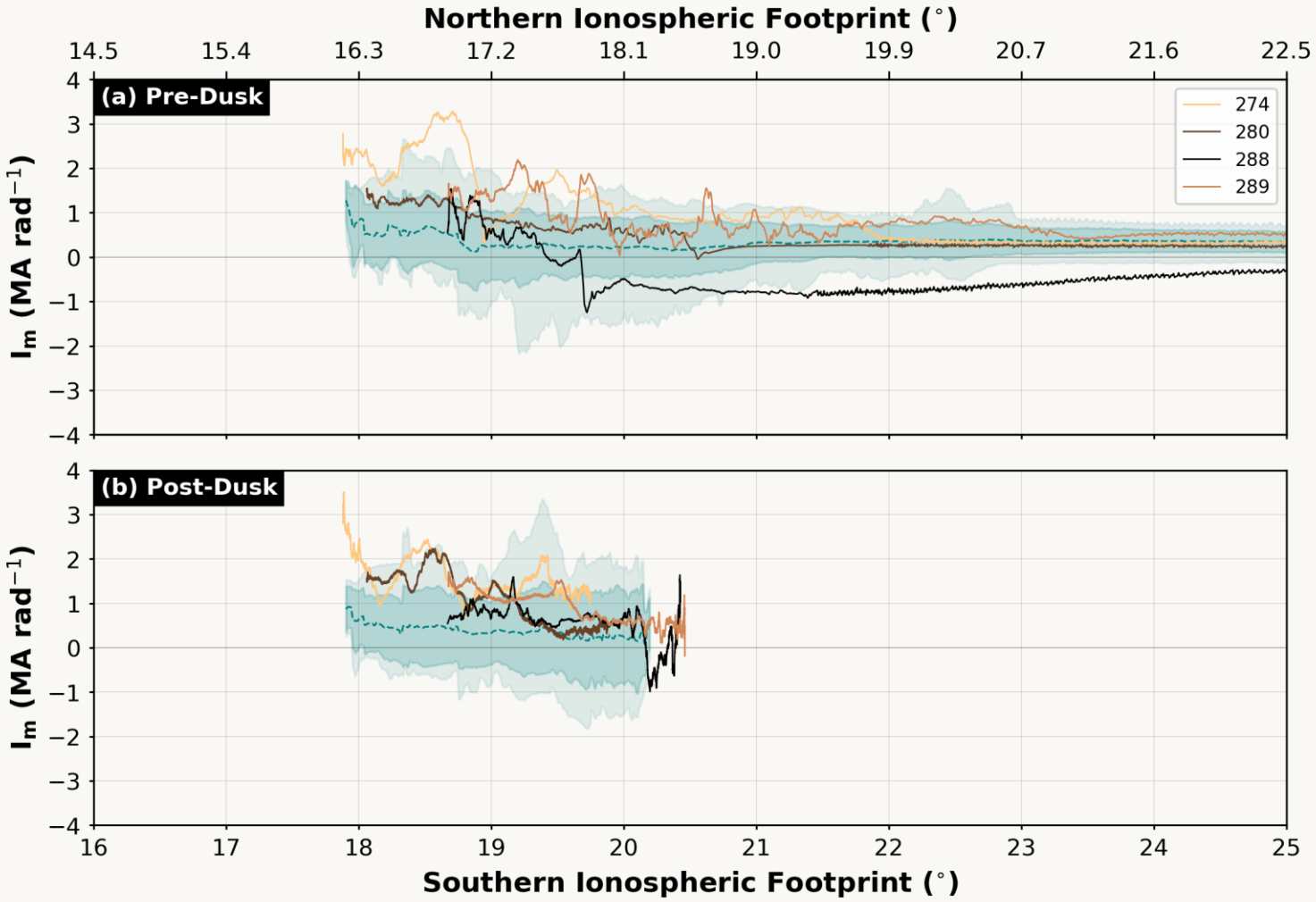


Hunt et al., 2014

FAC Response to Compression Events



Orbits during compression events (determined by Bradley et al., 2020) isolated.

Orbit	Time between compression onset and observation (hrs) ±2
274	17
289	25
280	54
288	84

- Orbits 274, 289 - High I_m and strong filamentation (up to ~|500| nAm^{-2}) reducing with time after compression onset
- Orbit 288 - Negative (leading) profile suggests super-rotating plasma flow
- All profiles broadly upwards FAC 18 - 20°, current densities 30-80 nAm^{-2}

Conclusions

1. Broad and filamented current sheets observed in southern dusk sector, consistent with UV auroral structures.

2. North/south PPO systems contribute similar amounts of FACs to the southern hemisphere and have same peak magnitude and location as the sub-corotation currents.

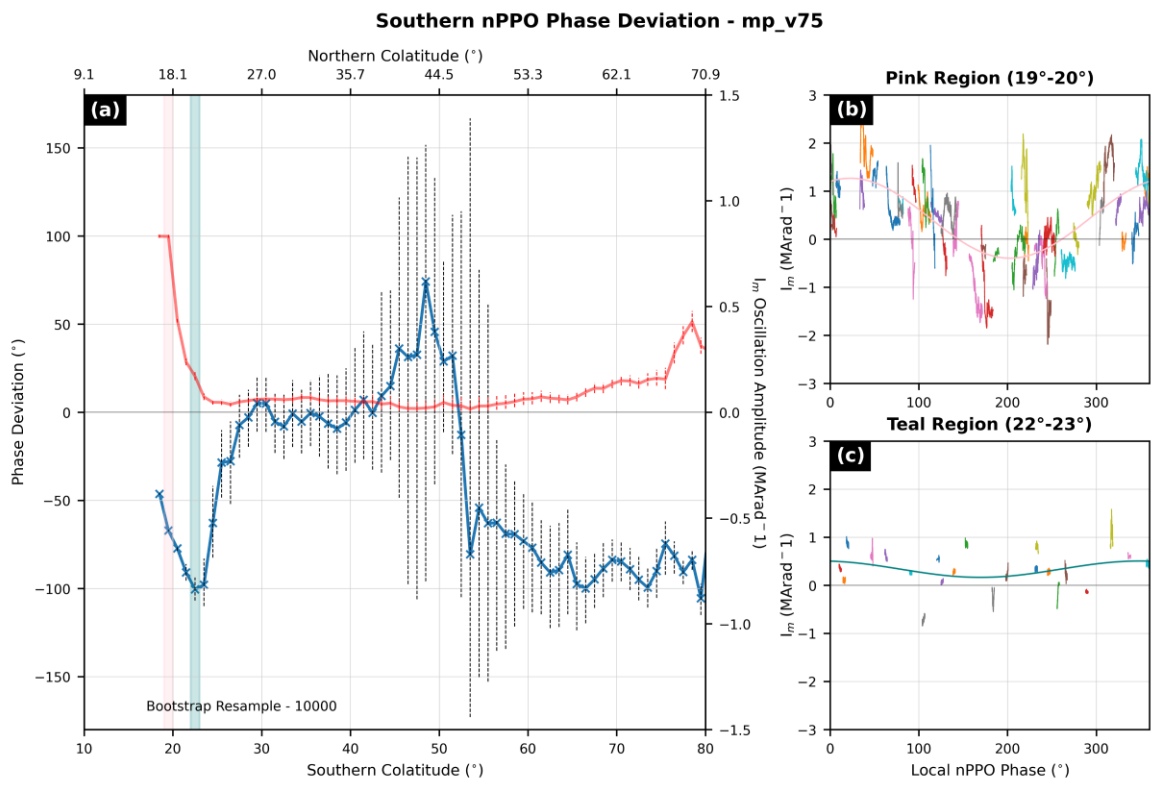
3. Derived average sub-corotation current profile suggests weaker poleward FACs than at northern dawn, possibly due to weaker flow shears.

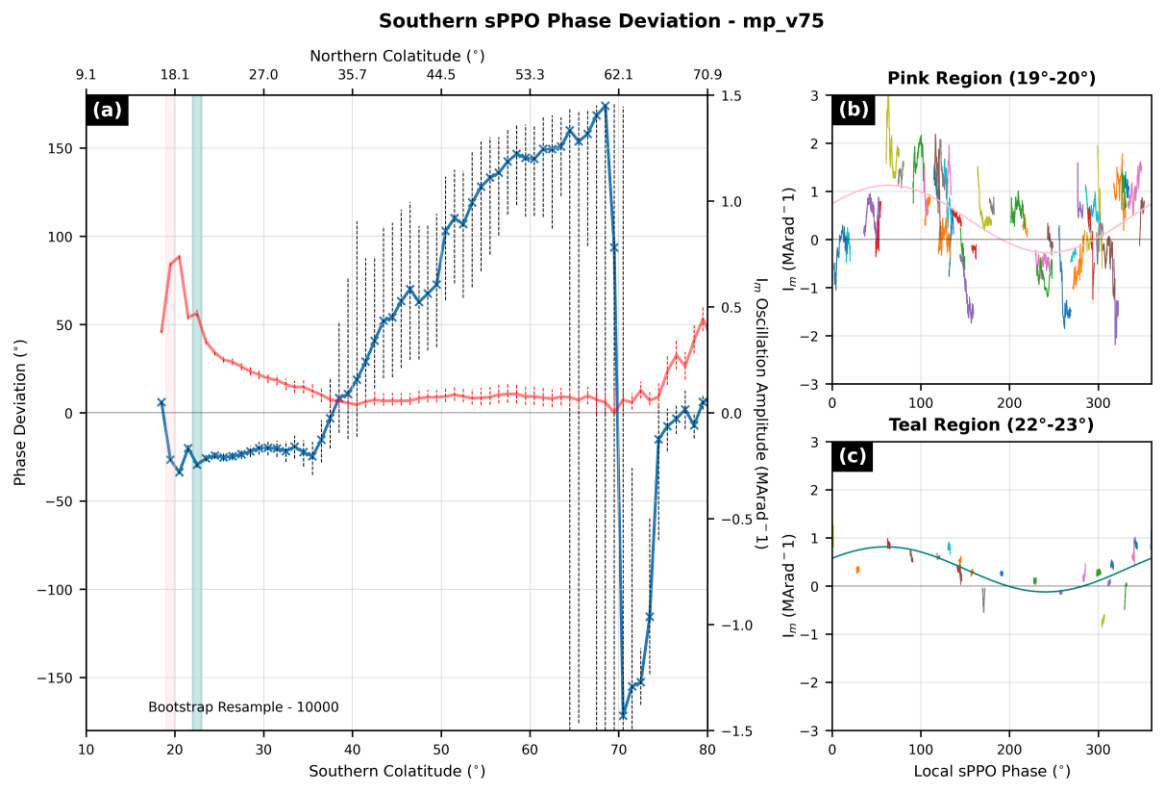
4. Upward FACs more common and stronger magnitude than downward at dusk, may be related to a nightside partial ring current.

5. Ionospheric currents and filamentation are enhanced during compressions. Super-corotation is observed in final pass.

s.farr1@lancaster.ac.uk

Backup 1: PPO Phase Deviation & Magnitude





Backup 2: UVIS-MAG plots