Satellite observations of topside equatorial spread *F*

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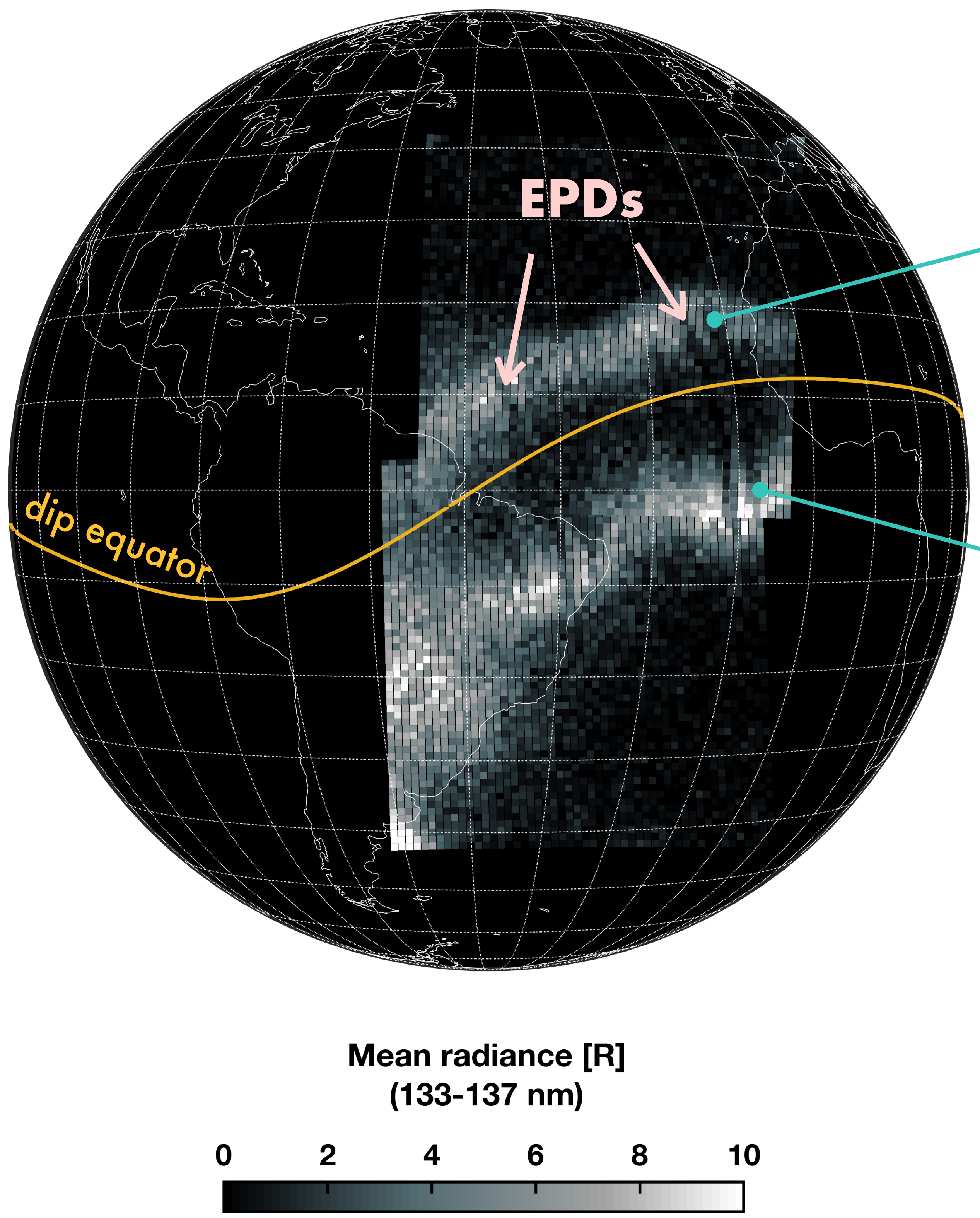
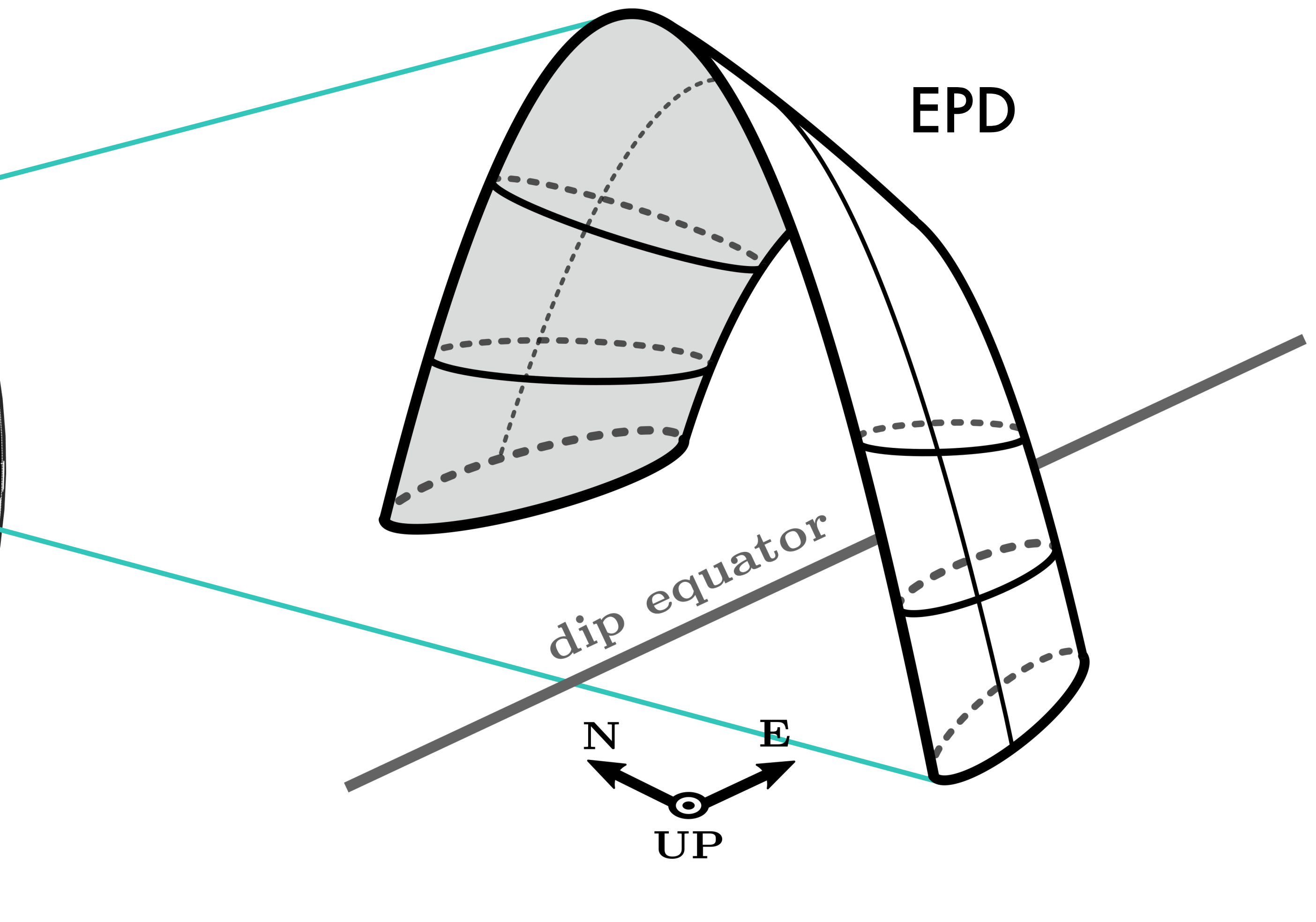
60th Anniversary Jicamarca Radio Observatory, 25 - 27 July, 2022, Lima, Peru.

Topside equatorial spread *F*:
a.k.a. equatorial plasma depletions (**EPDs**)

- Post-sunset phenomenon.
- Aligned with the geomagnetic field.
- Extent aprox. within ±20° of mag-lat., from about 200 km up to 2000 km.

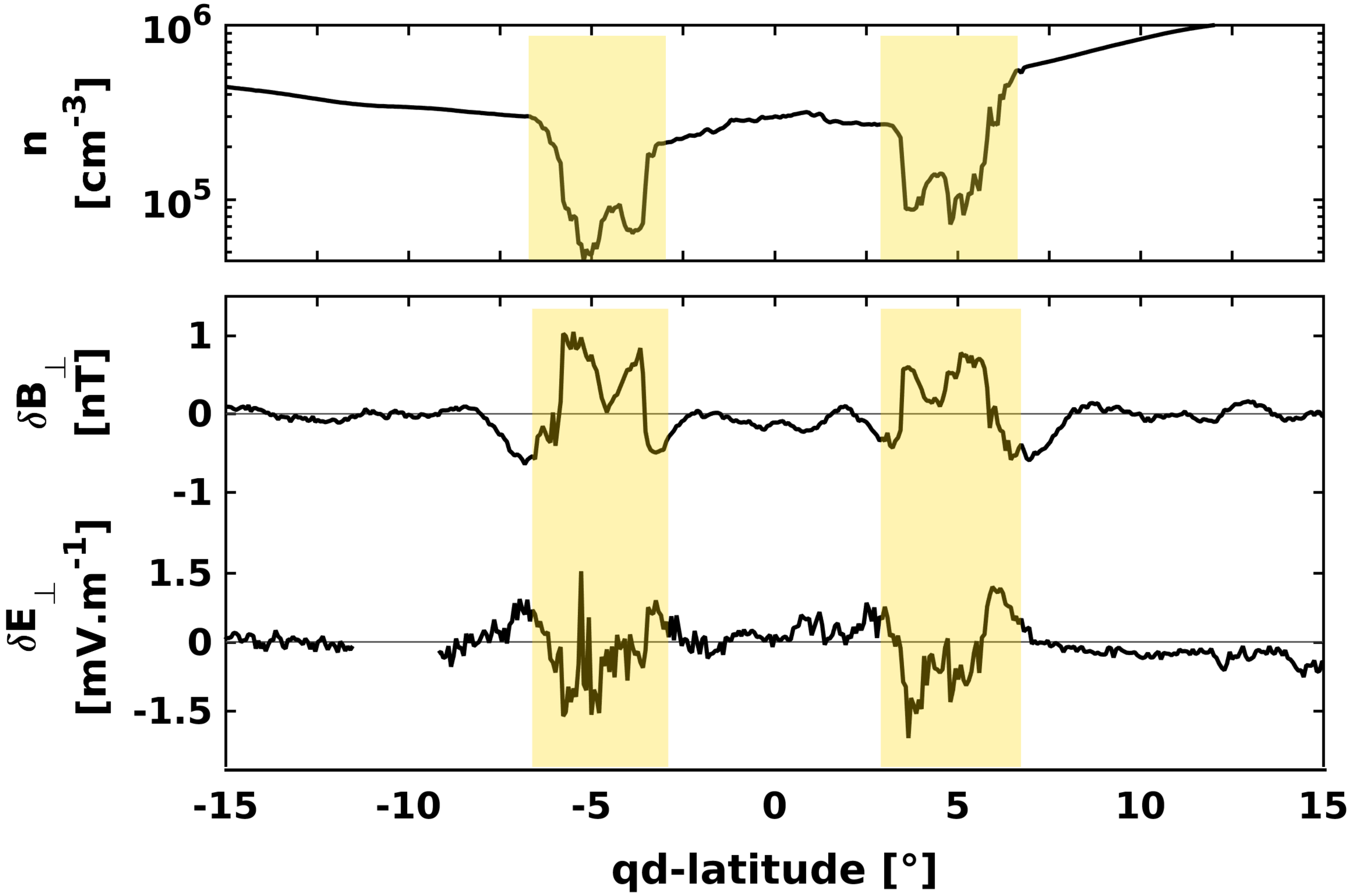
Far-ultraviolet image from GOLD
at about 22:30 UT

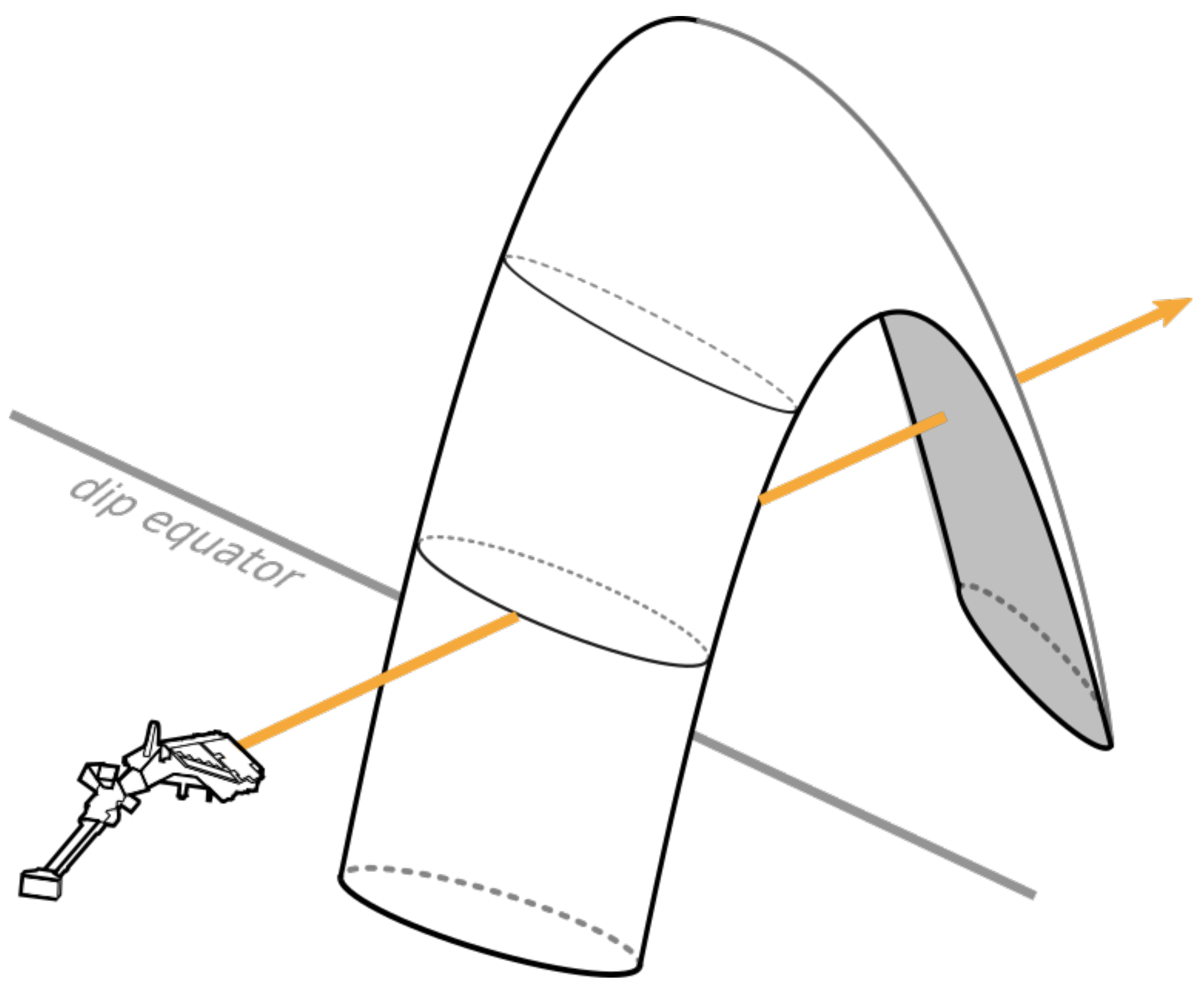




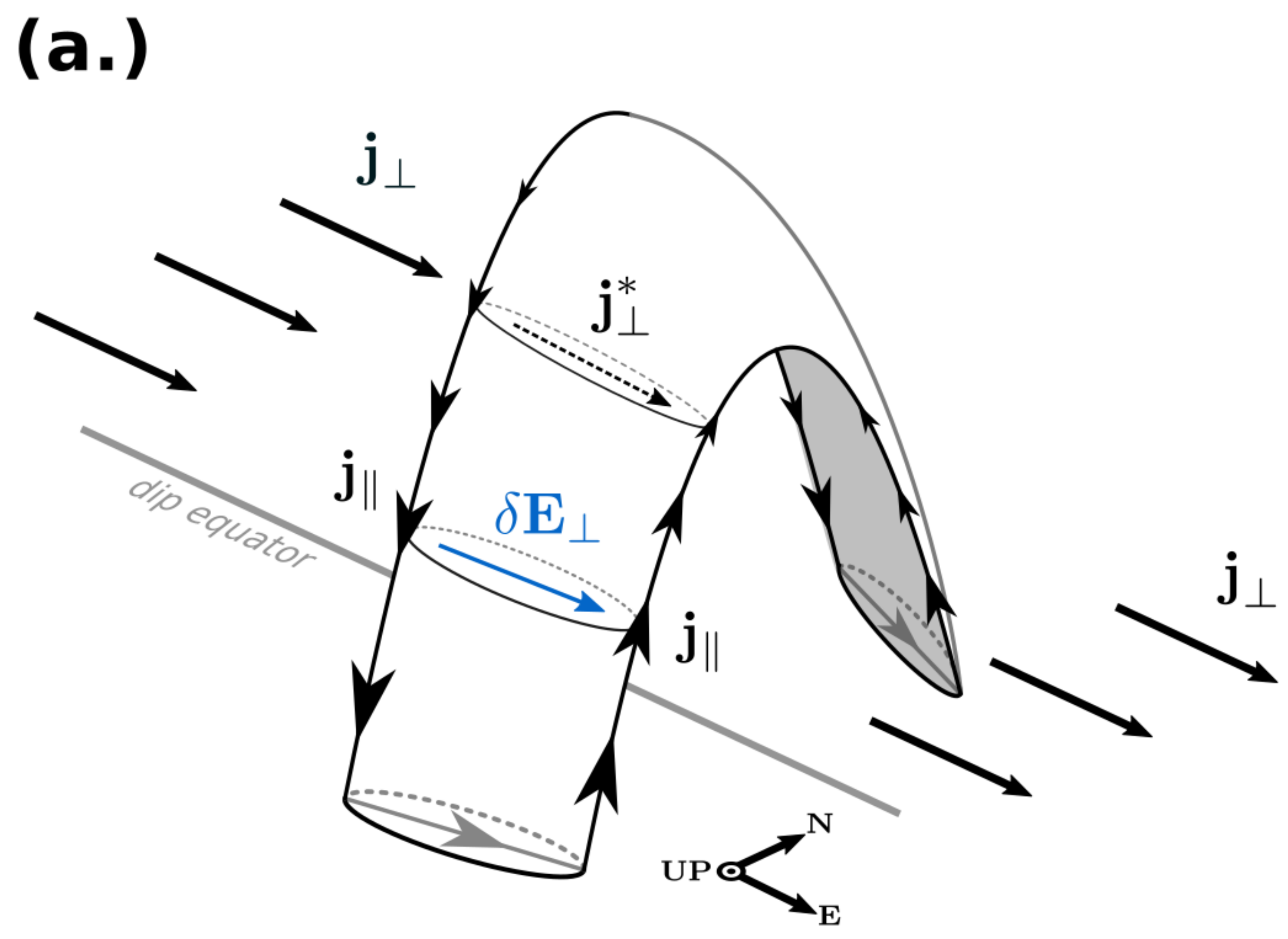
density-depleted magnetic flux tube

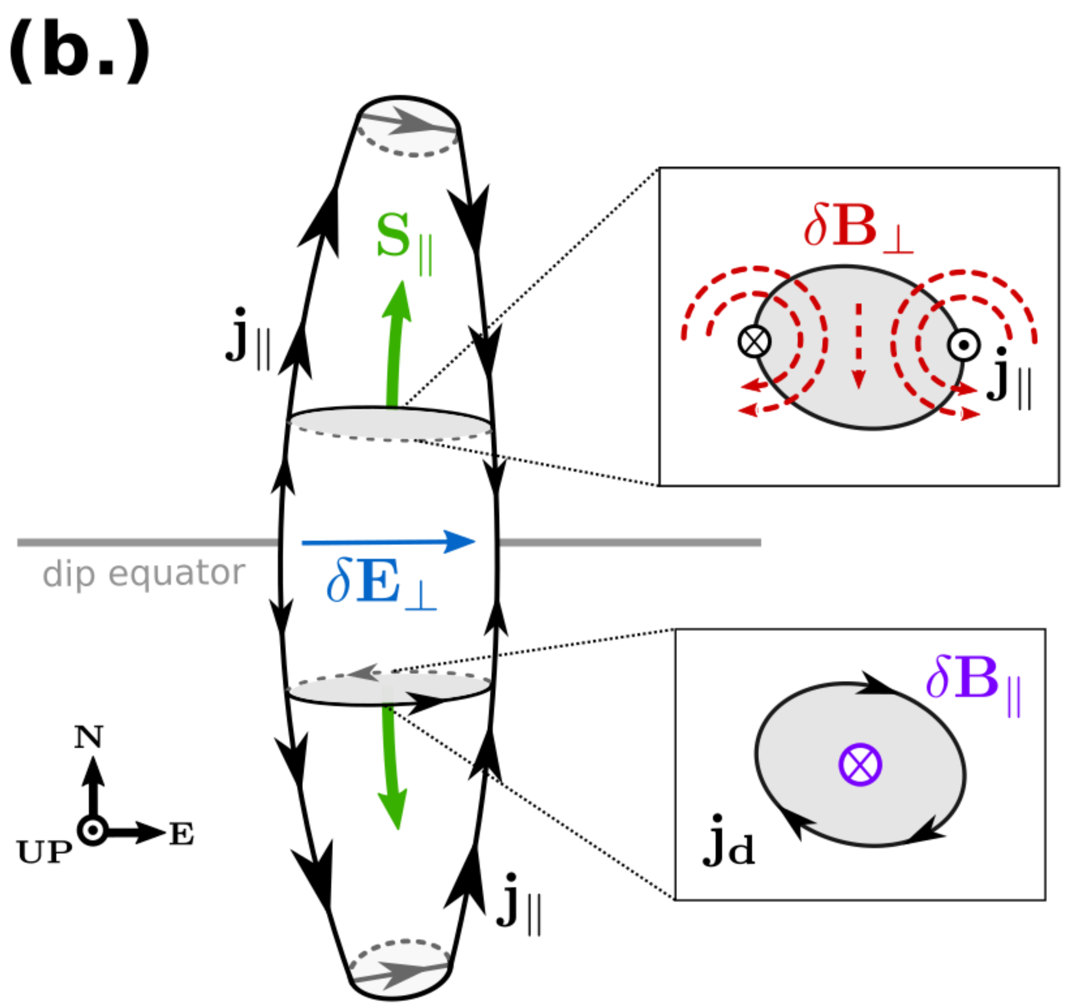
EPD observed by a polar-orbiting satellite





Electric and magnetic characteristics of EPDs





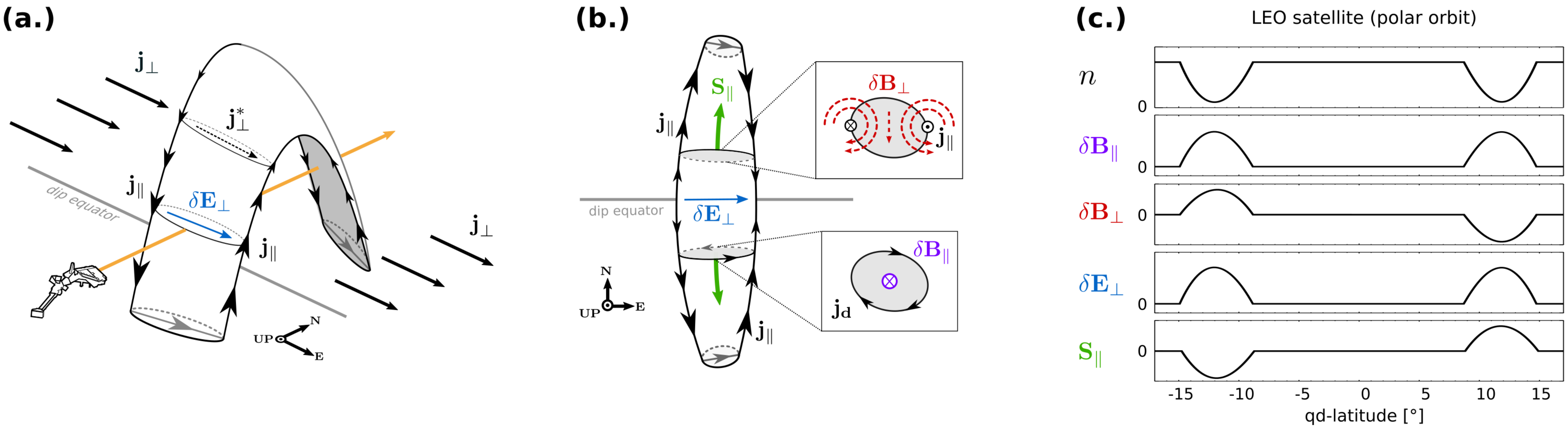
$$\mathbf{j}_\perp = nM\left(\frac{\mathbf{g}\times\mathbf{B}}{B^2}\right) + \sigma_P(\mathbf{E}_\perp + \mathbf{U}\times\mathbf{B})$$

$$\mathbf{j}_\parallel = \frac{1}{\mu_0}\left(\frac{\partial B_y}{\partial x} - \frac{\partial B_x}{\partial y}\right)$$

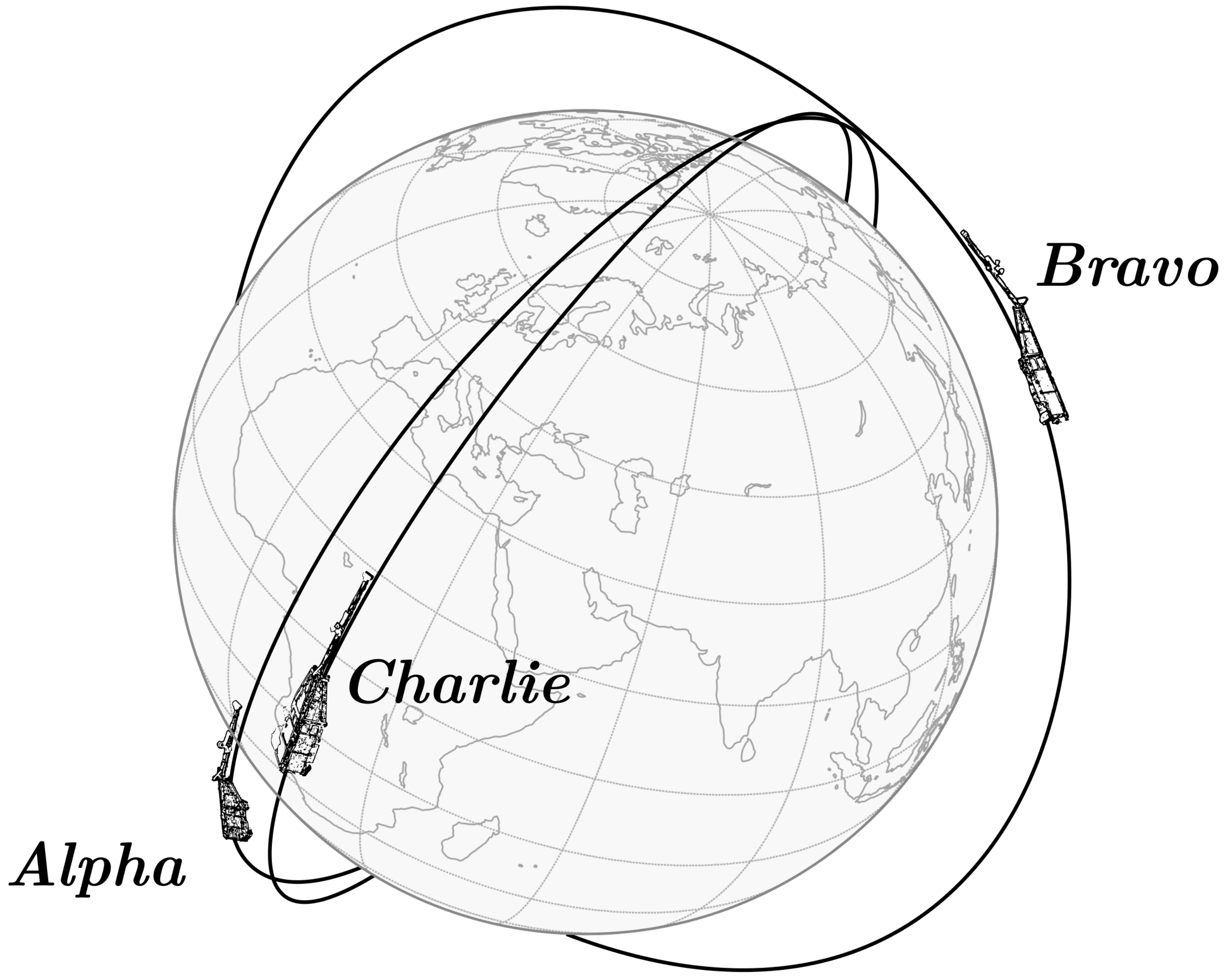
$$\mathbf{j_d} = -\frac{\nabla p\times\mathbf{B}}{B^2}$$

$$\mathbf{S}_\parallel = \frac{1}{\mu_0}(\delta\mathbf{E}_\perp\times\delta\mathbf{B}_\perp)$$

Expected observations from a polar-orbiting satellite



This talk presents observations gathered by the ESA *Swarm* constellation mission



Lifetime: Since November 2013.

Orbits: Near-circular polar,
Alpha & *Charlie* (ca. 450 km); *Bravo* (ca. 510 km).

Instruments:

Vector field and absolute scalar magnetometers
Langmuir probes
Thermo ion imager
Accelerometer
GPS receiver

Geophysical Research Letters

On the direction of the Poynting flux associated with equatorial plasma depletions as derived from *Swarm*

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Interhemispheric field-aligned currents at the edges of equatorial plasma depletions

Juan Rodríguez-Zuluaga[1,2] & Claudia Stolle[1,2]

Rodríguez-Zuluaga *et al.*
Earth, Planets and Space
https://doi.org/10.1186/s40623-022-01679-2

Earth, Planets and Space

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Topside equatorial spread *F*-related field-aligned Poynting flux: observations and simulations

J. Rodríguez-Zuluaga[1*], C. Stolle[2], D. Hysell[3] and D. J. Knudsen[4]

JGR Space Physics

On the Balance Between Plasma and Magnetic Pressure Across Equatorial Plasma Depletions

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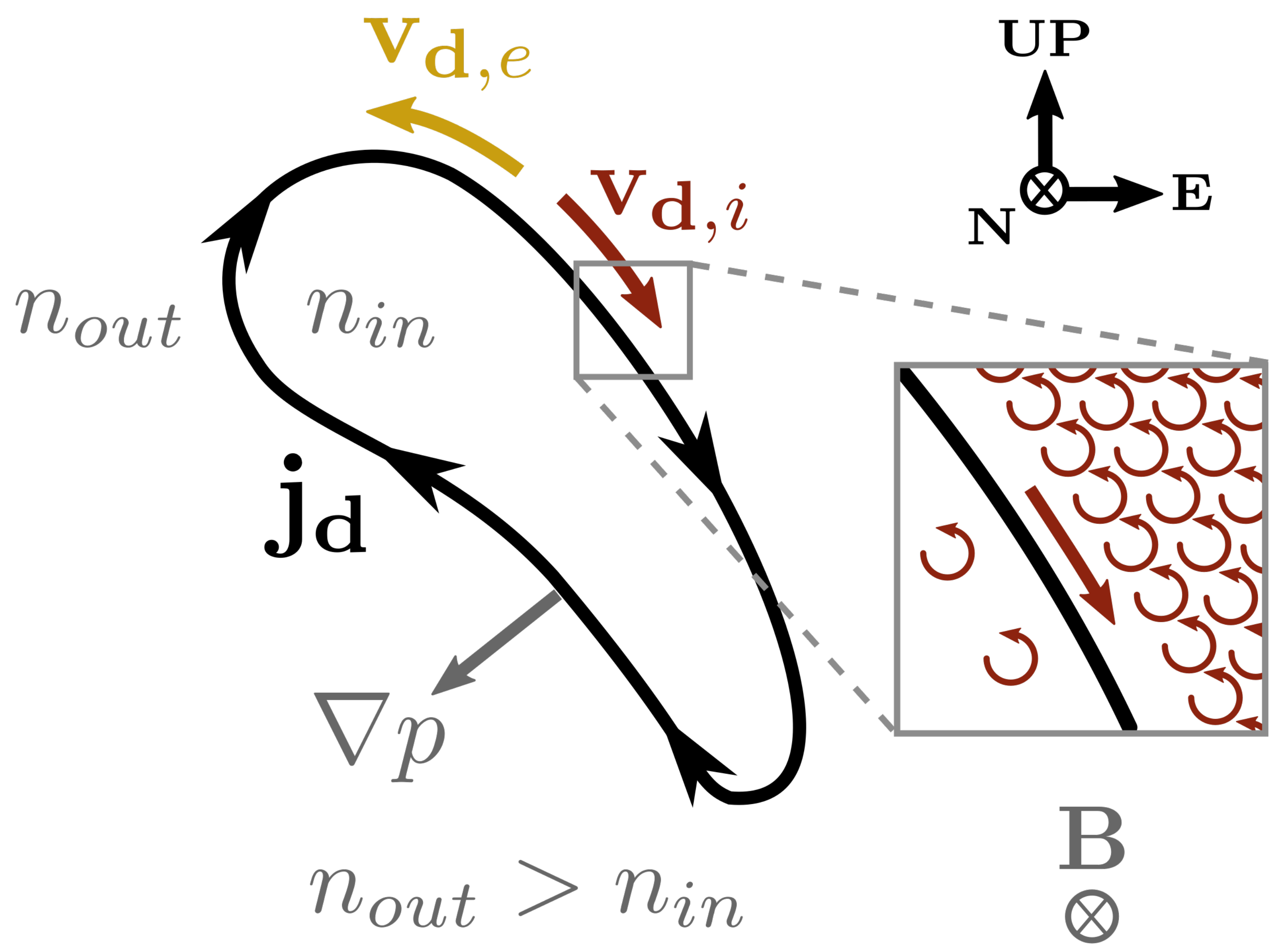
Plasma and magnetic pressure balance



$$\mathbf{V}_{\mathbf{d},j} = -\frac{\nabla p_j \times \mathbf{B}}{q_j n_j B^2} \qquad \mathbf{j_d} = -\frac{\nabla p \times \mathbf{B}}{B^2}$$

$$\frac{(B-b)^2}{2\mu_0} + kn(T_e + T_i) = constant$$

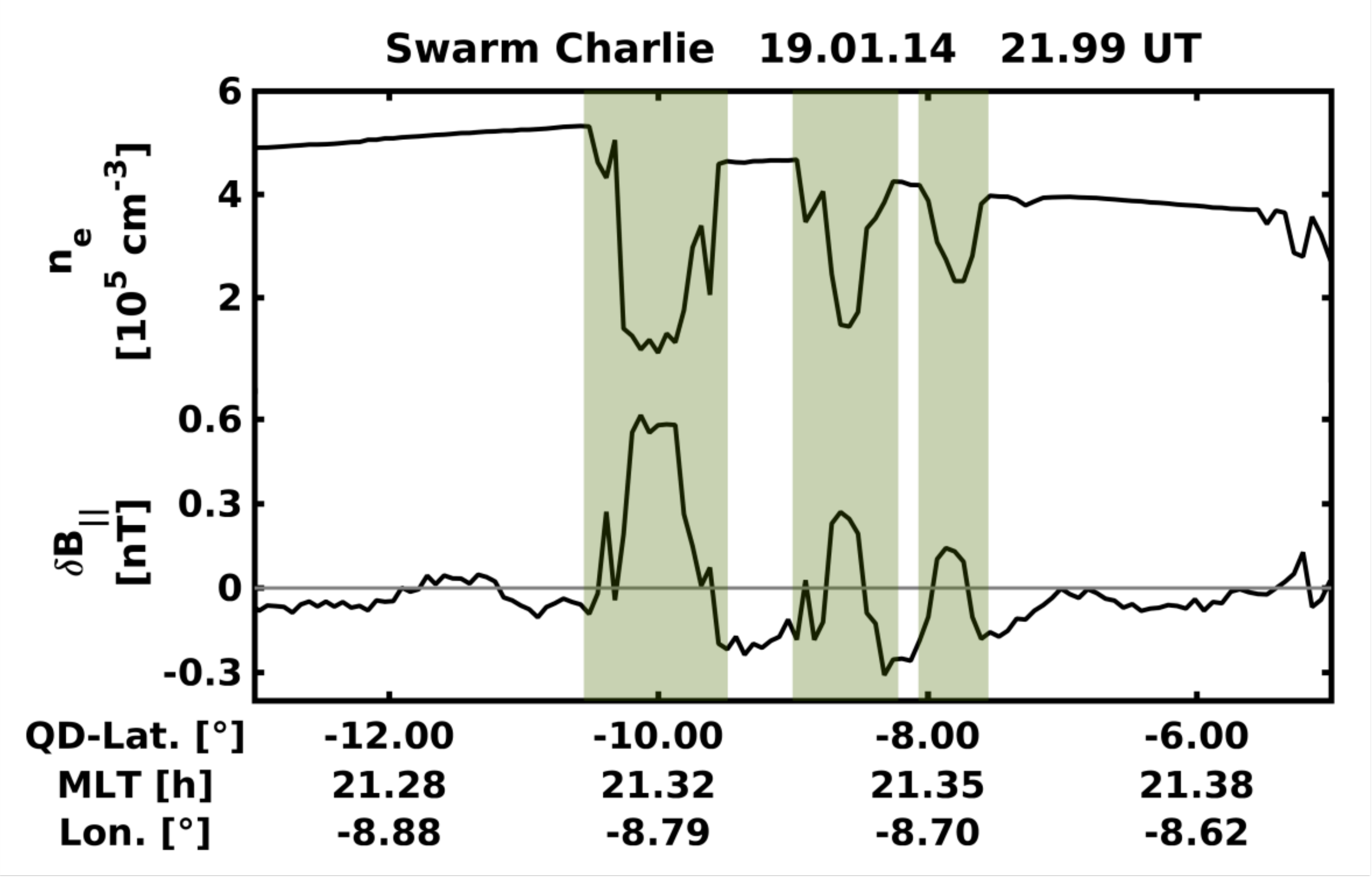
$$b = kn(T_e + T_i)\frac{\mu_0}{B}$$

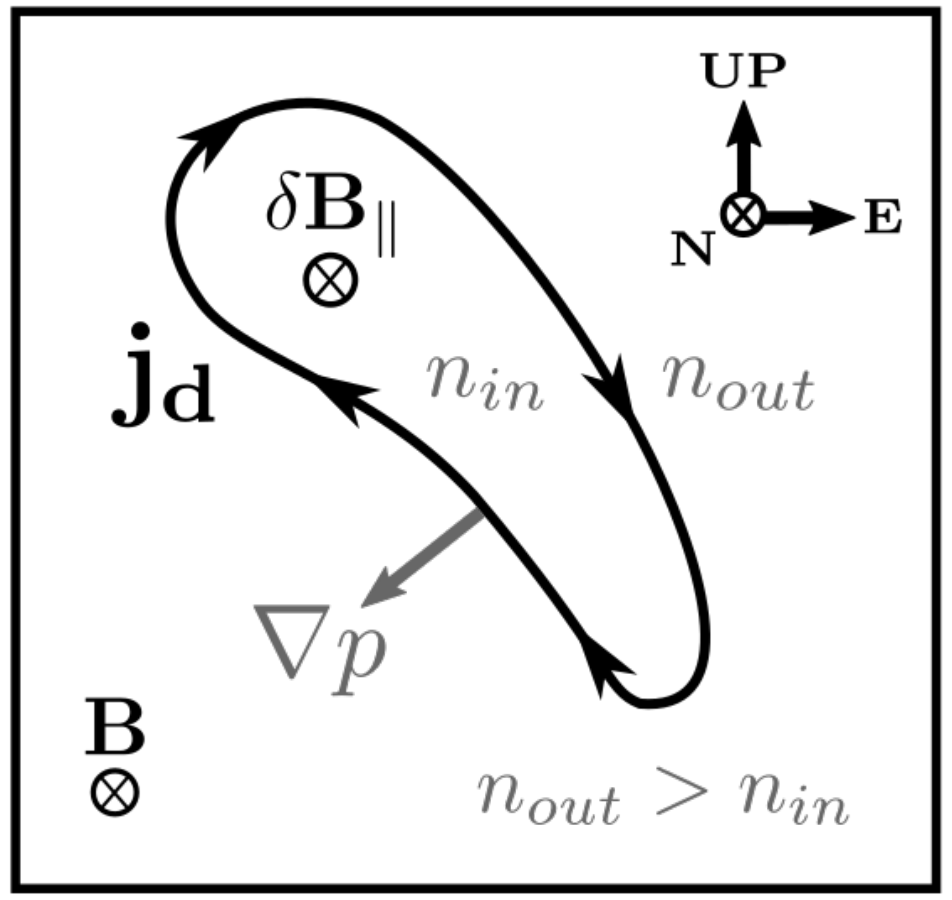
Diamagnetic effect (b)

Plasma pressure gradient is assumed to be driven by density variations mostly.

$$\nabla p = kT\,\nabla n$$

Typical observations of low-pressure EPDs (high magnetic pressure)

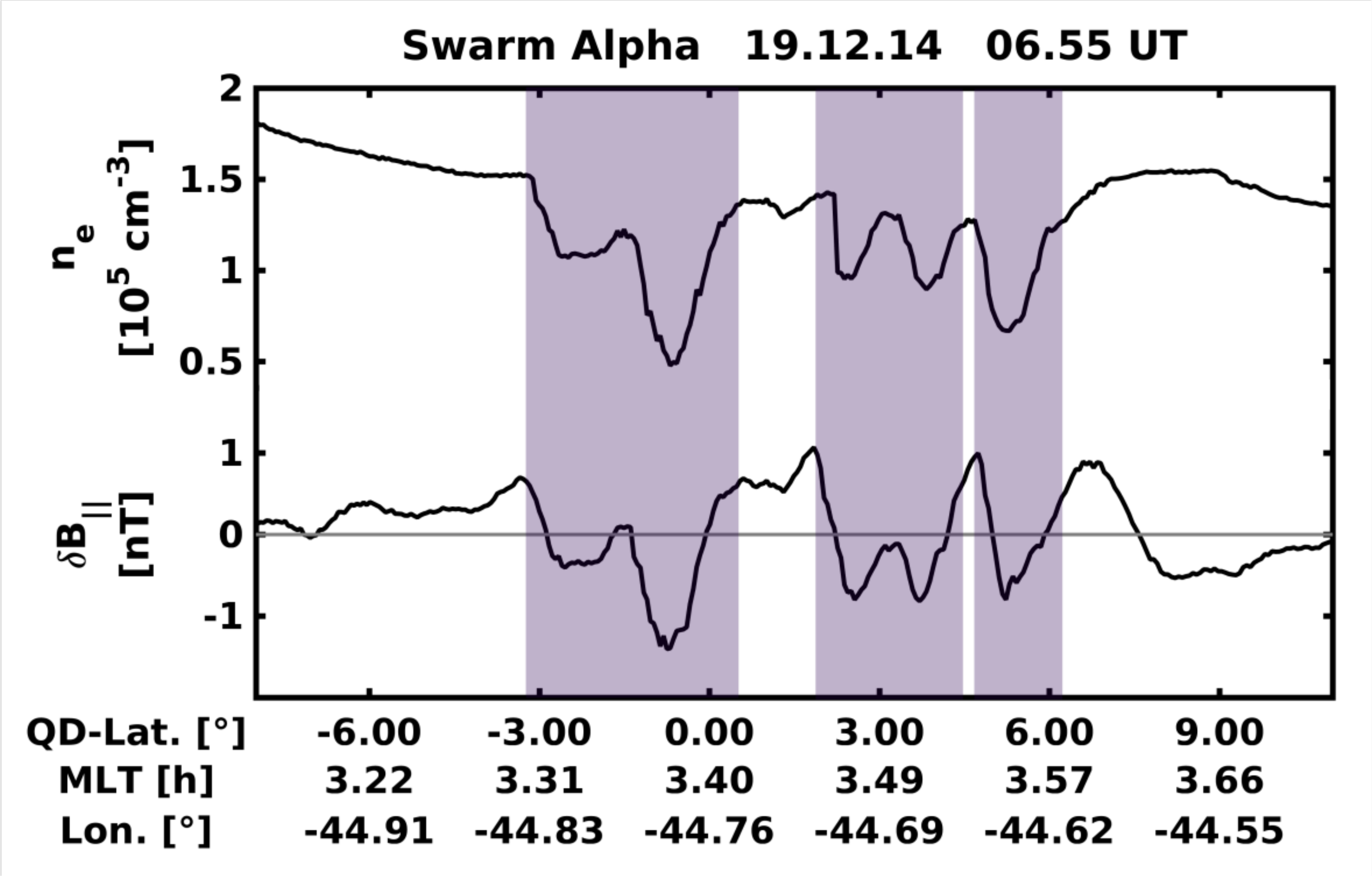


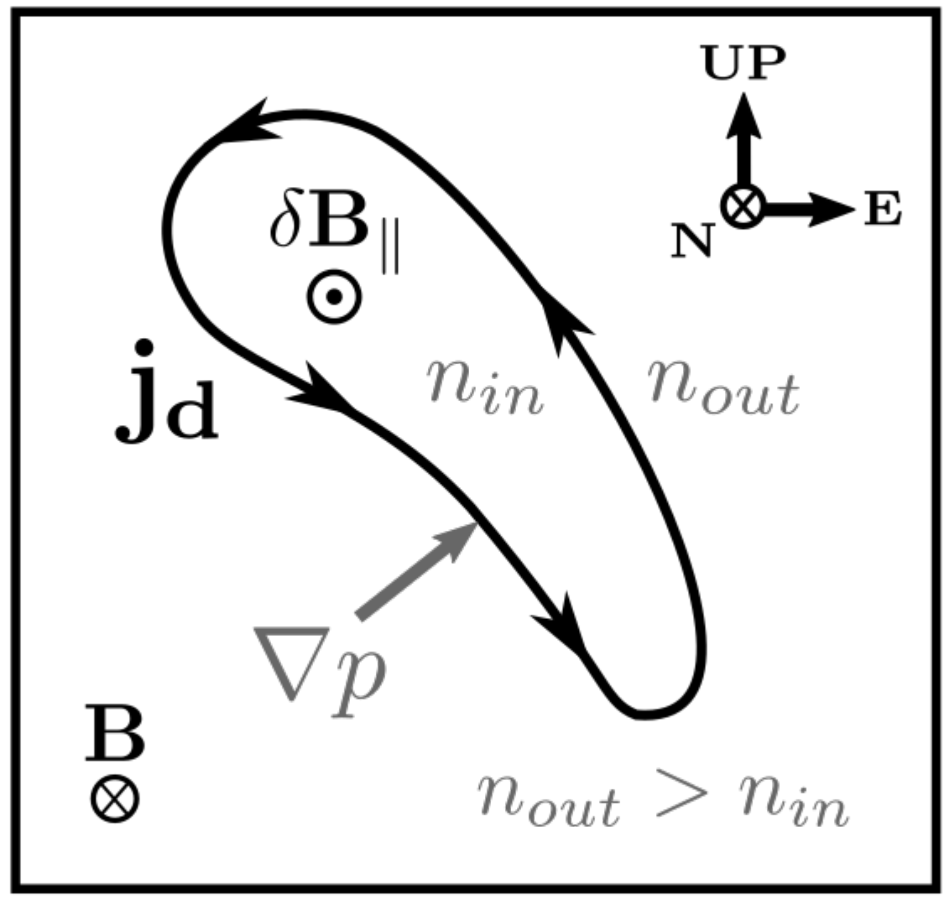


Low-pressure EPD

$$\mathbf{j_d} = -\frac{\nabla p \times \mathbf{B}}{B^2} \qquad \nabla p = kT\,\nabla n$$

EPDs with low magnetic pressure - high pressure EPDs (?)

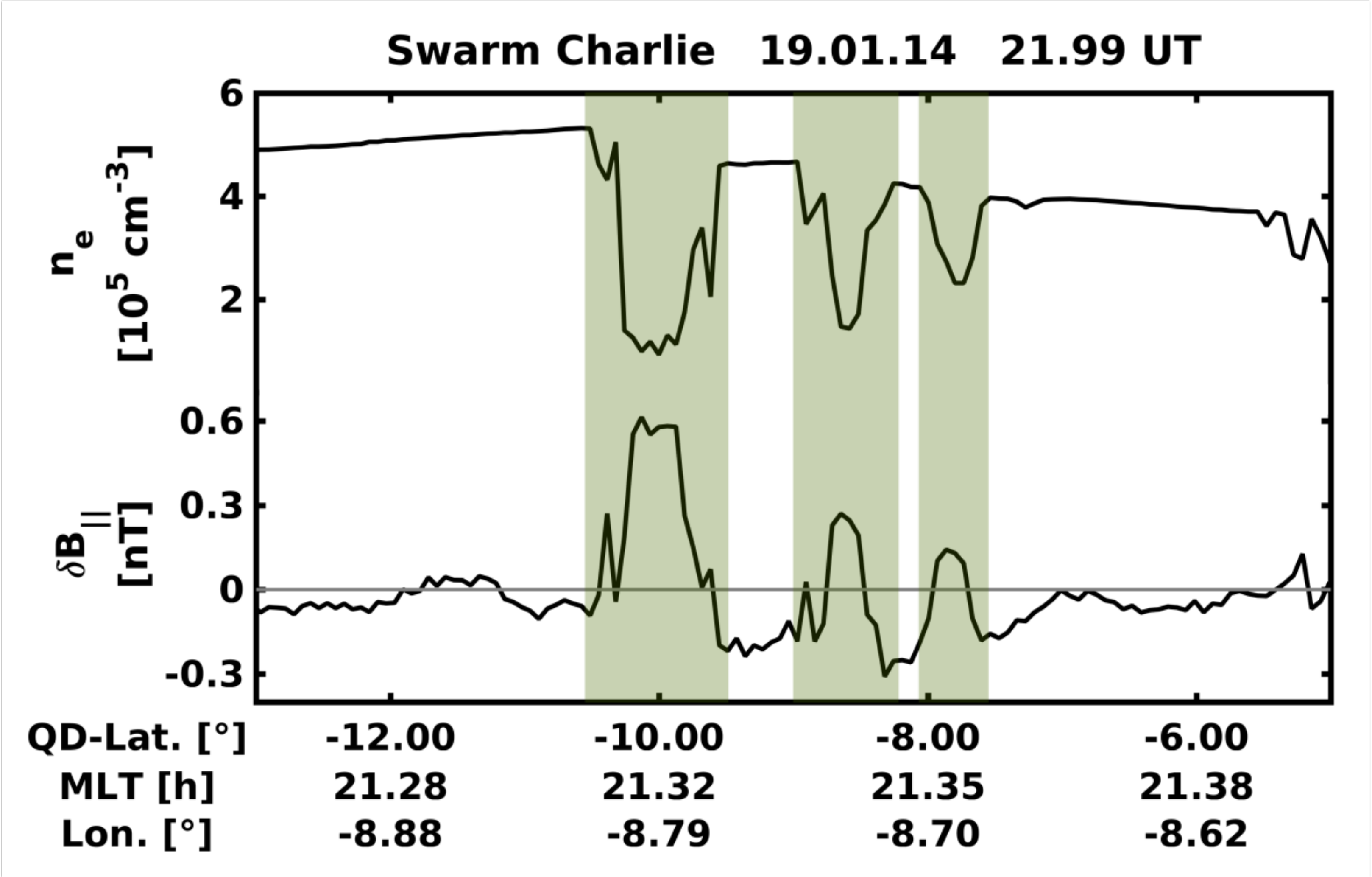


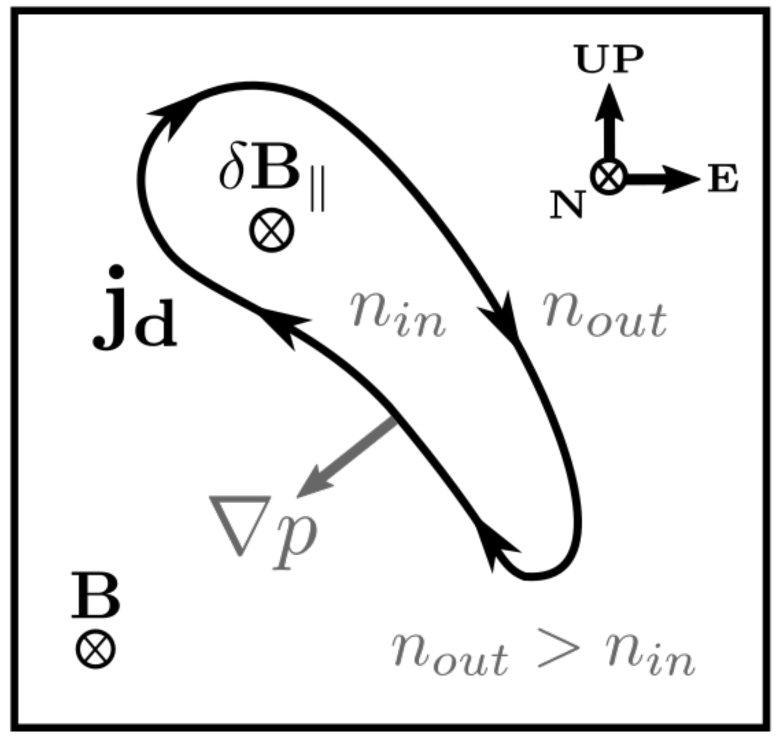


High-pressure EPD

$$\mathbf{j_d} = -\frac{\nabla p \times \mathbf{B}}{B^2} \qquad \nabla p = k\nabla(nT)$$

Looking at the role of plasma temperature



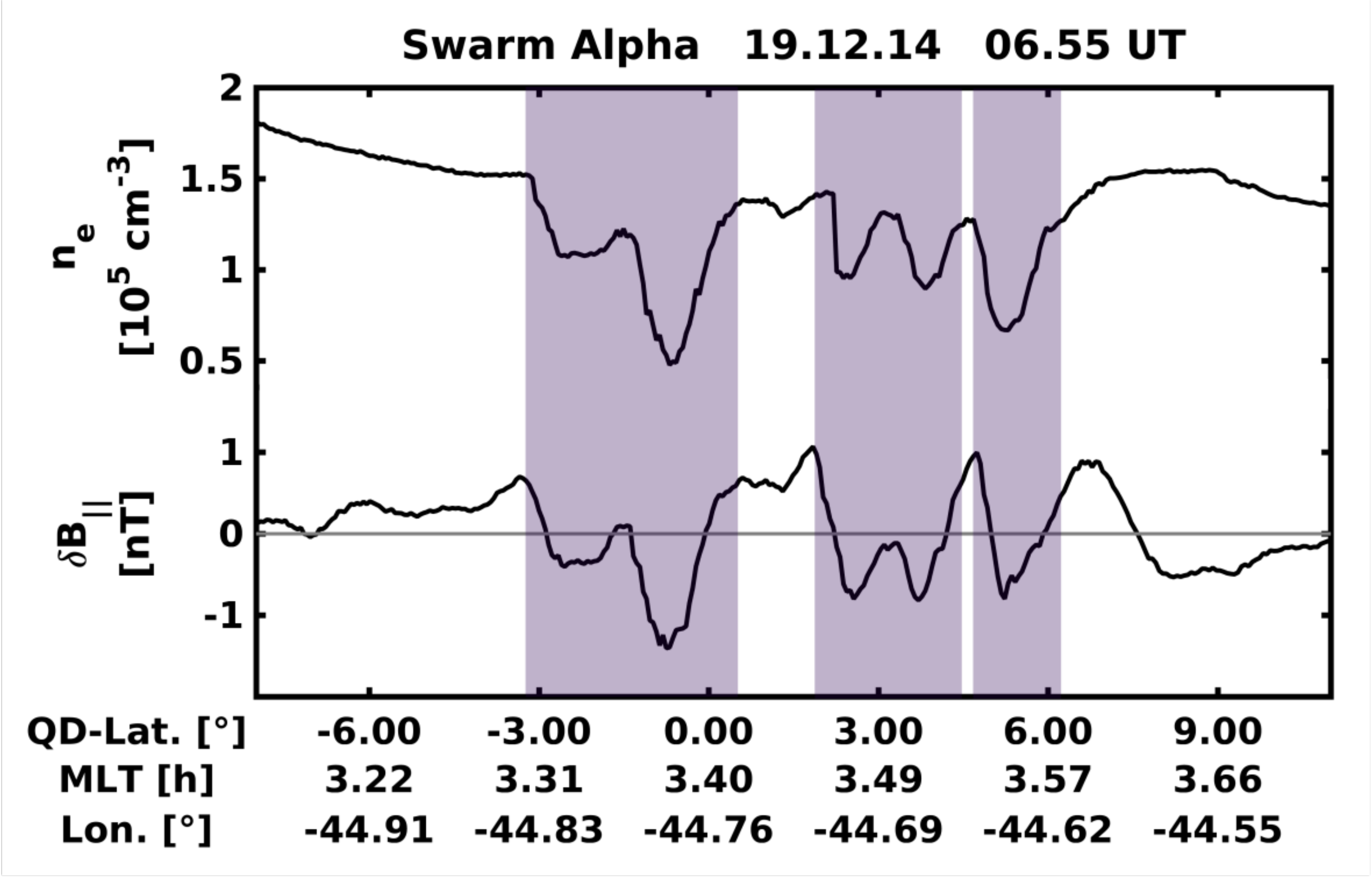


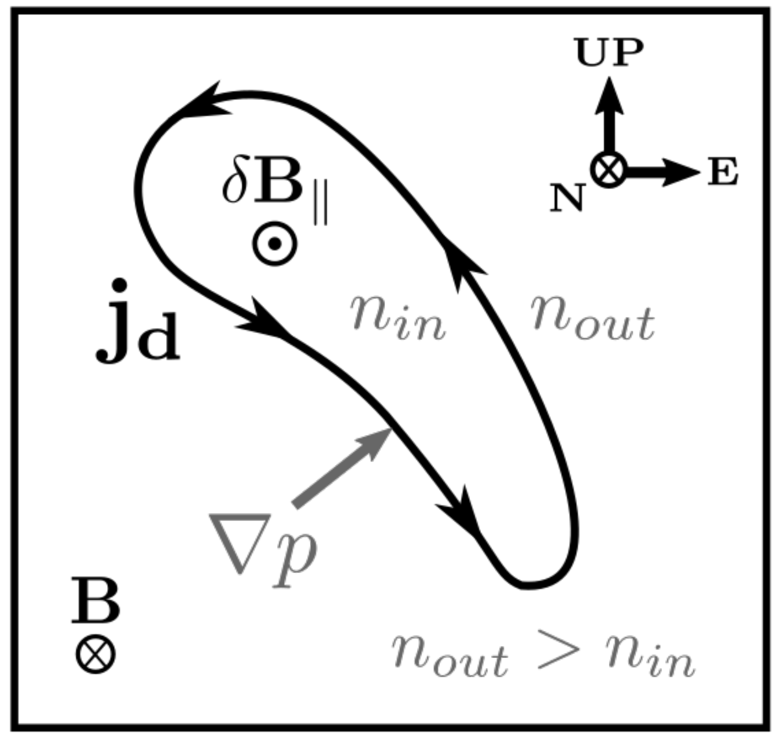
Low-pressure EPD

$$\nabla p = \nabla(nkT) = k\,(T\nabla n + n\nabla T)$$

$$T_{in} \leq T_{out}$$

$$T_{in} > T_{out} \quad \& \quad |T\nabla n| > |n\nabla T|$$





High-pressure EPD

$$T_{in} > T_{out} \quad \& \quad |T\nabla n| < |n\nabla T|$$

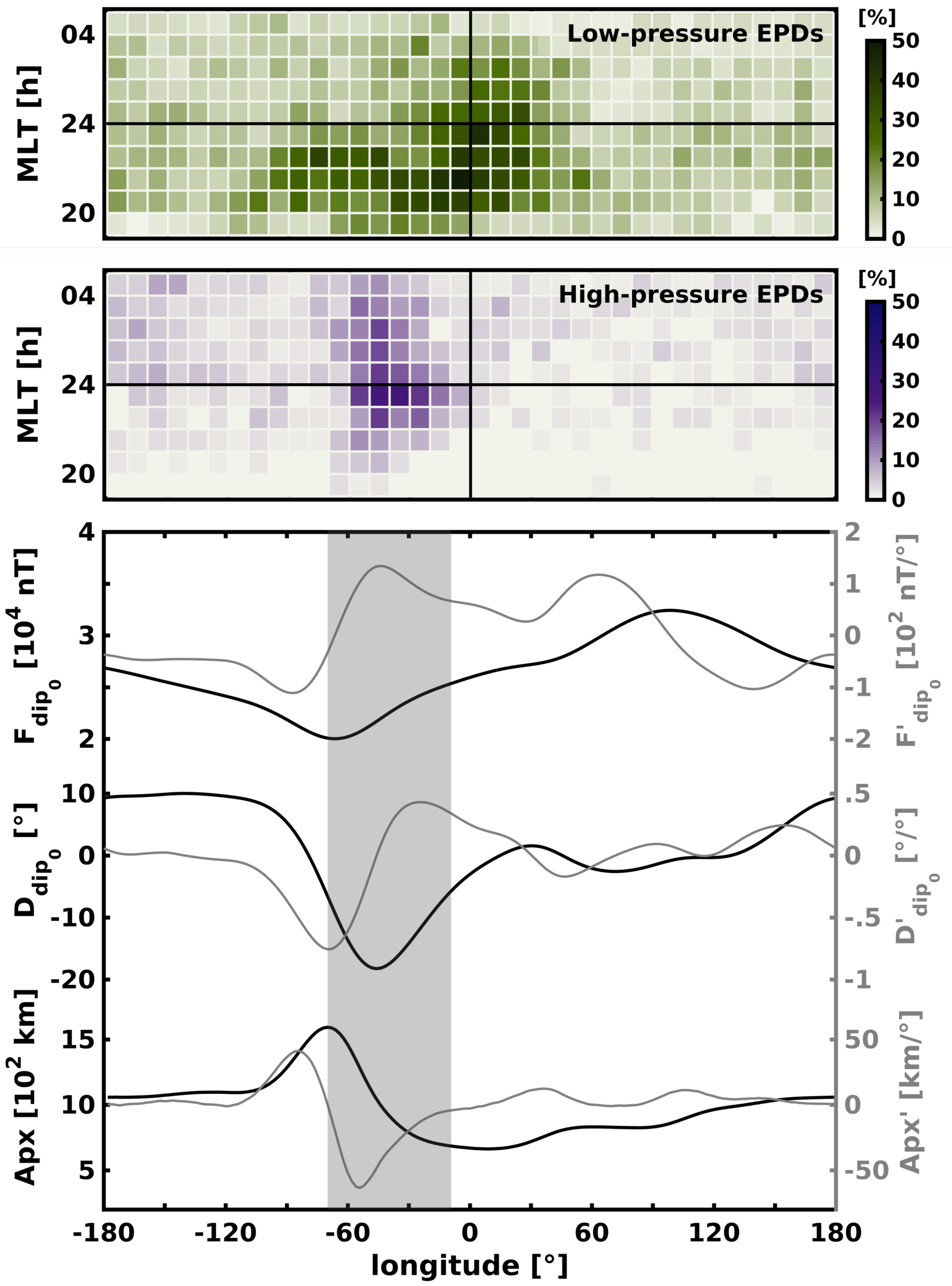
$$T_{\text{in}} > \frac{n_{\text{out}}}{n_{\text{in}}} T_{\text{out}}$$

Observations show a median of 1.96
(95% bootstrap confidence interval of 1.92–2.00)

Longitudinal and local time dependence:

81.7% of EPDs detected present low-pressure and 18.3% are high-pressure EPDs.

No seasonal and no geomagnetic activity dependence was found in the occurrence of high-pressure EPDs.



<u>Questions:</u>

What does the location of high-pressure EPDs tell us about possible heating mechanisms? (if so)

How can numerical simulations contribute to understanding these observations?

Conclusions

1. For low-pressure EPDs, the plasma pressure gradient is mostly dominated by variations of the plasma density. Changes in the plasma temperature are not expected to play a significant role. On the contrary, variations of the plasma temperature are significant for high-pressure EPDs.

2. Among all the EPDs detected, 18.3% correspond to high-pressure EPDs and 81.7% to low-pressure EPDs

3. High-pressure EPDs occur at the American/Atlantic sector mainly, between about 70°W and 10°W, corresponding to 54% of the total number of high-pressure EPDs detected. A preference in magnetic local time is found around midnight and postmidnight hours.

4. High-pressure EPDs are apparently characterized by temperatures as high as twice the ambient plasma temperature.

5. Based on the location of the highest occurrence rate of high-pressure EPDs (i.e., near the SAA), we suggest the main heating mechanism to be due to particle precipitation from the radiation belts.