UNIVERSITY OF HELSINKI

Connecting the geoelectric field to its magnetospheric sources in a global hybrid-Vlasov simulation

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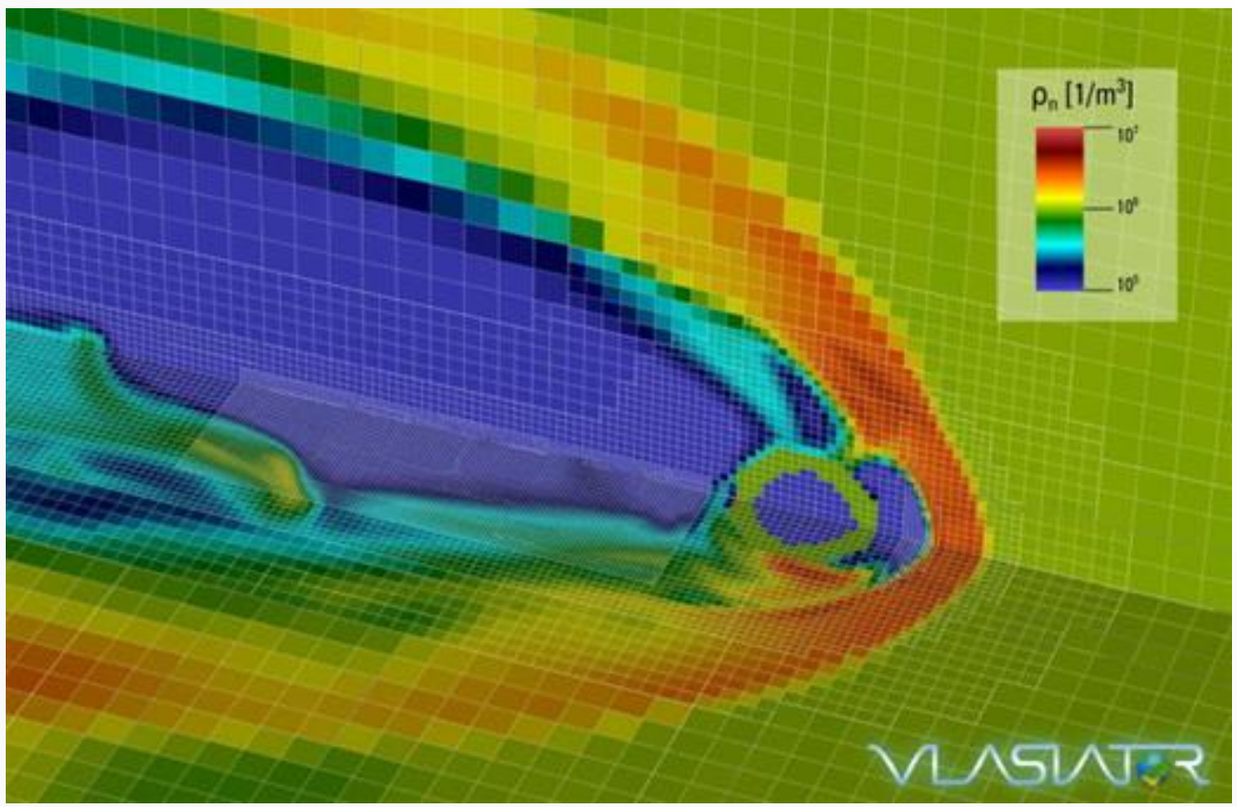
and the VLASIATOR Team

AGU Fall Meeting 2024

Vlasiator Simulations

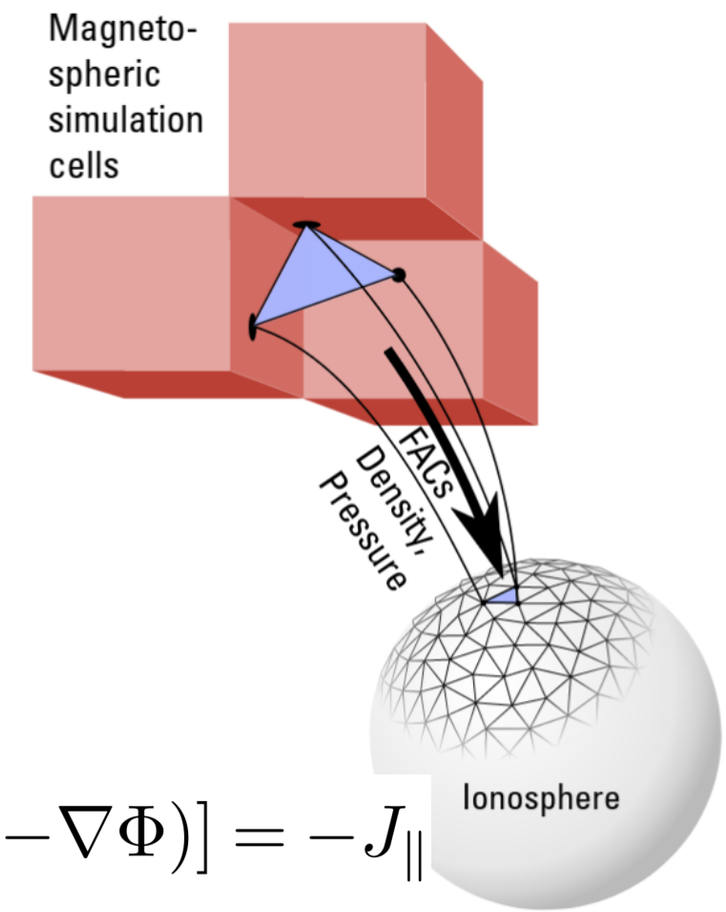
3D spatial domain



Hybrid-Vlasov (Kinetic p$^+$)

*U. **Ganse** et al, 2023*

Coupled ionosphere



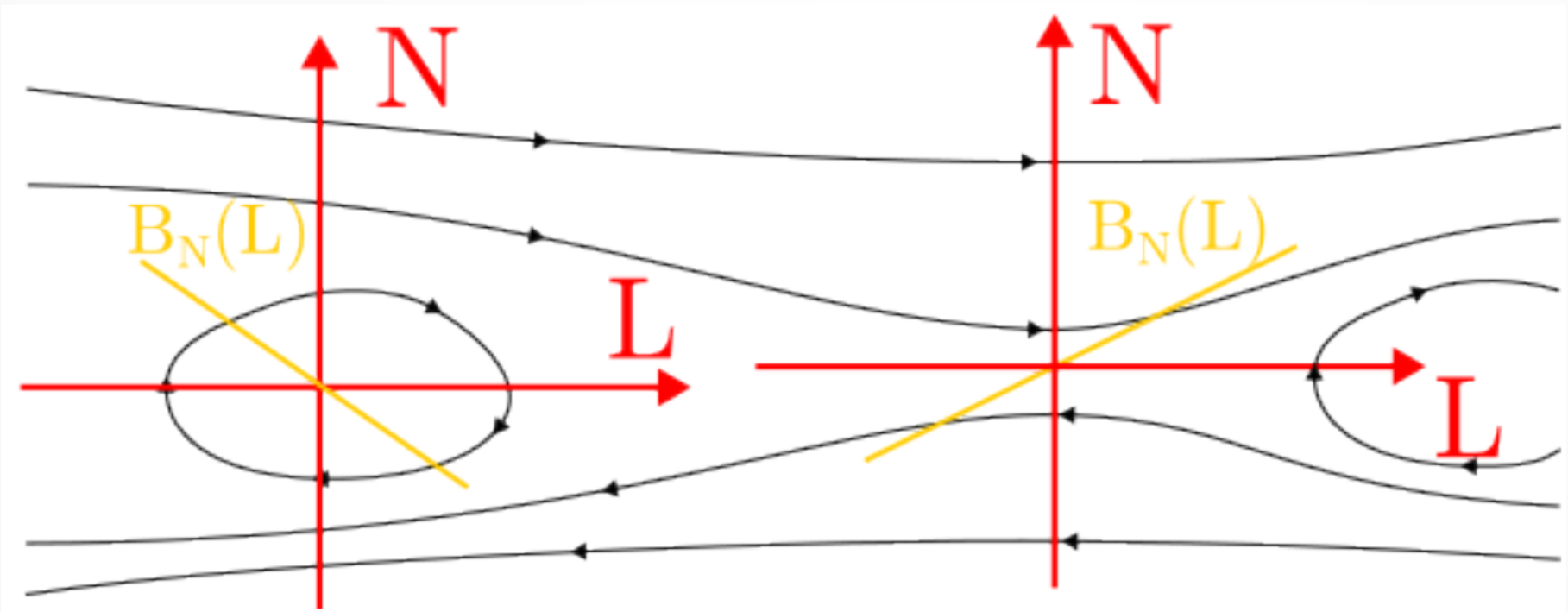
$$\nabla \cdot [\boldsymbol{\Sigma} \cdot (-\nabla \Phi)] = -J_{\parallel}$$

Electrostatic

*U. **Ganse** et al, 2024* [2]

X- and O-line identification

- In **LMN** coordinate system, $B_L = B_N = 0$
- sign(dB_N/dL) determines topology



*M. **Alho** et al, 2024*

“O-lines”:
$dB_N/dL < 0$

“X-lines”:
$dB_N/dL > 0$

X- and O-line identification

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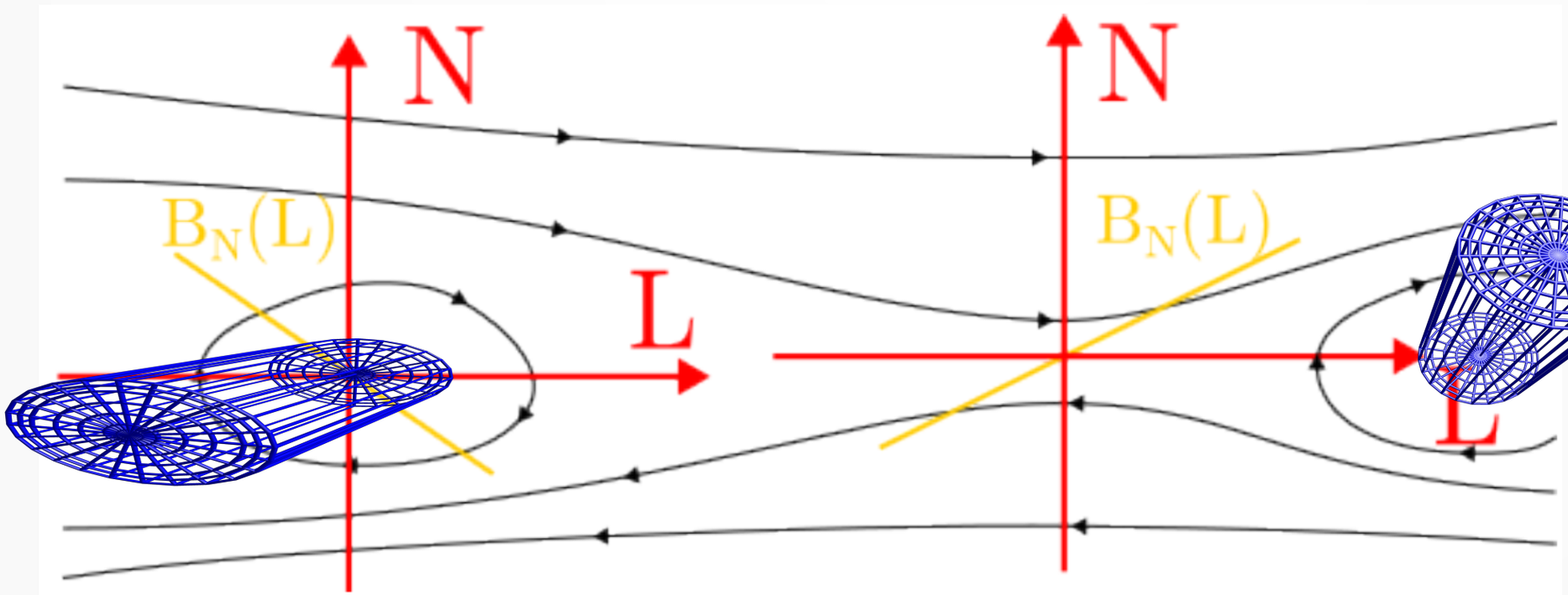


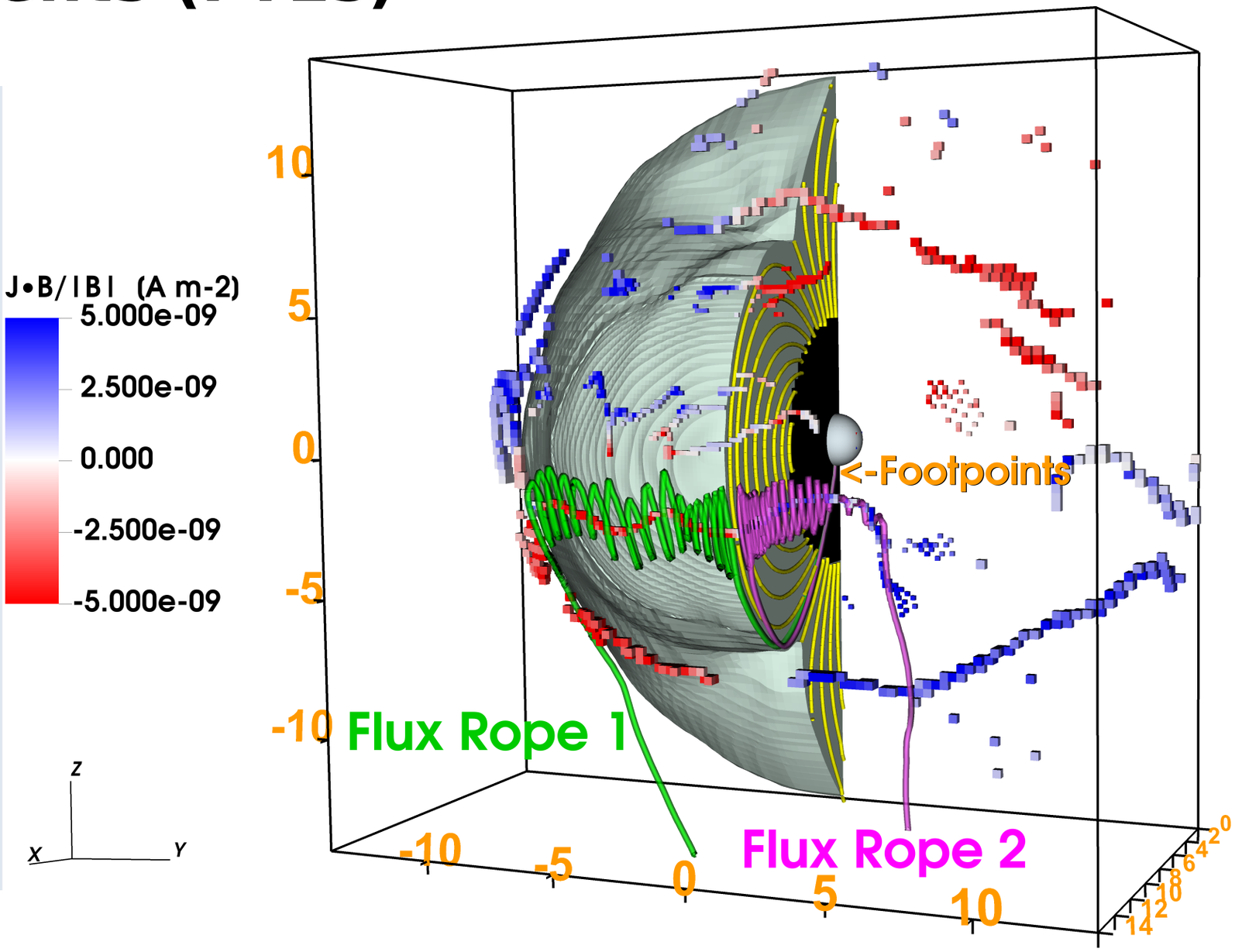
M. ***Alho*** *et al, 2024*

“O-lines”:
$dB_N/dL < 0$

“X-lines”:
$dB_N/dL > 0$

Flux Transfer Events (FTEs)

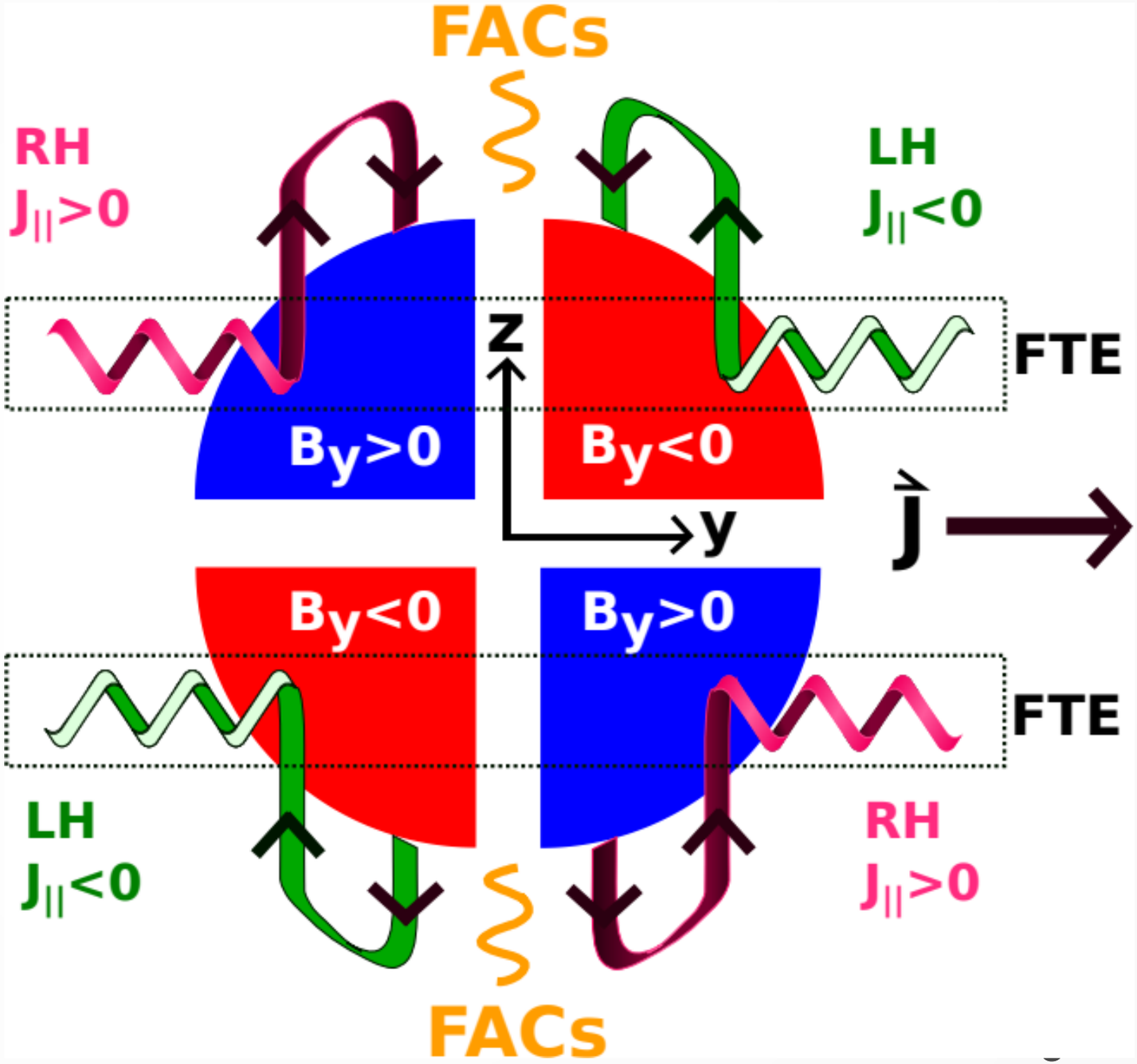
- FTE O-lines appear near equator, migrate to poles
- FTEs split into **multiple flux ropes**, at $J_{||}$ (red-blue) junctions!
- Flux ropes rooted at cusp footpoints



- FTE $J_{||}$ (~B_y) and handedness (RH or LH) organized into **4 quadrants in y-z plane**
- B_y pattern same as Earth's dipole
- Note: IMF constant, **strictly southward** and aligned with Earth's dipole

SW driving parameters

B	[0, 0, **-5**] nT
v_{sw}	750 km/s
n	1 cm^{-3}

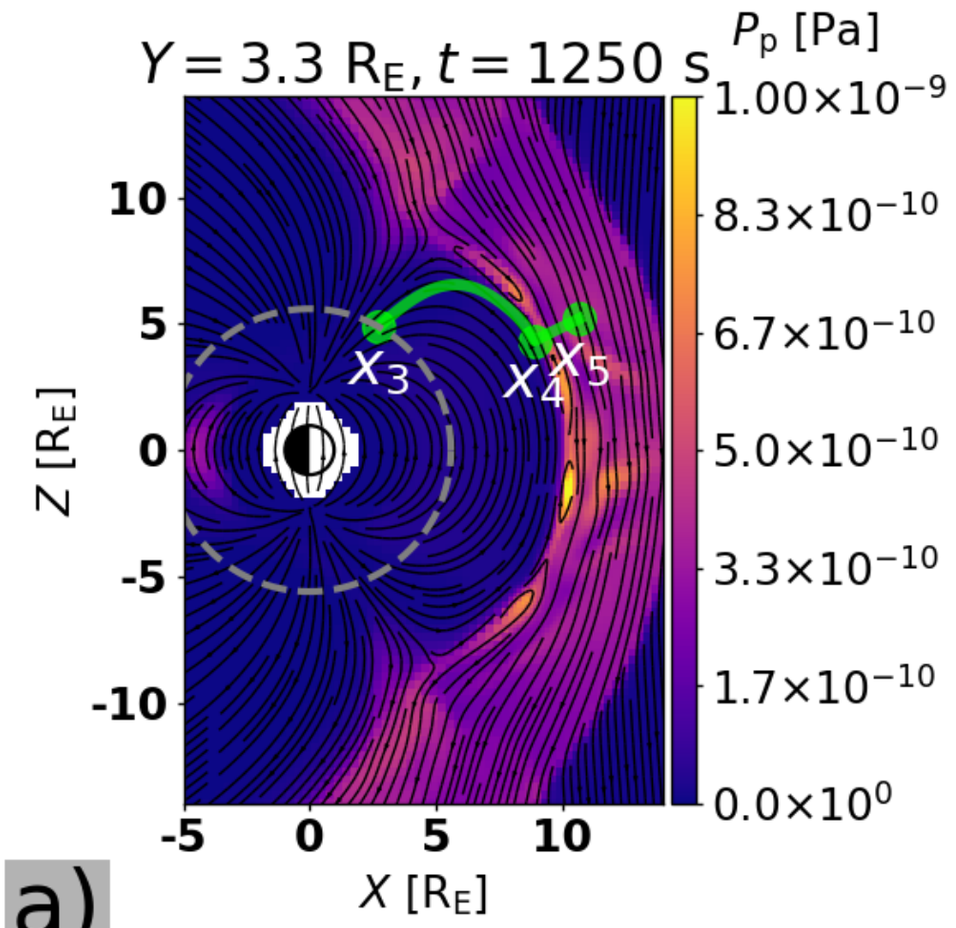


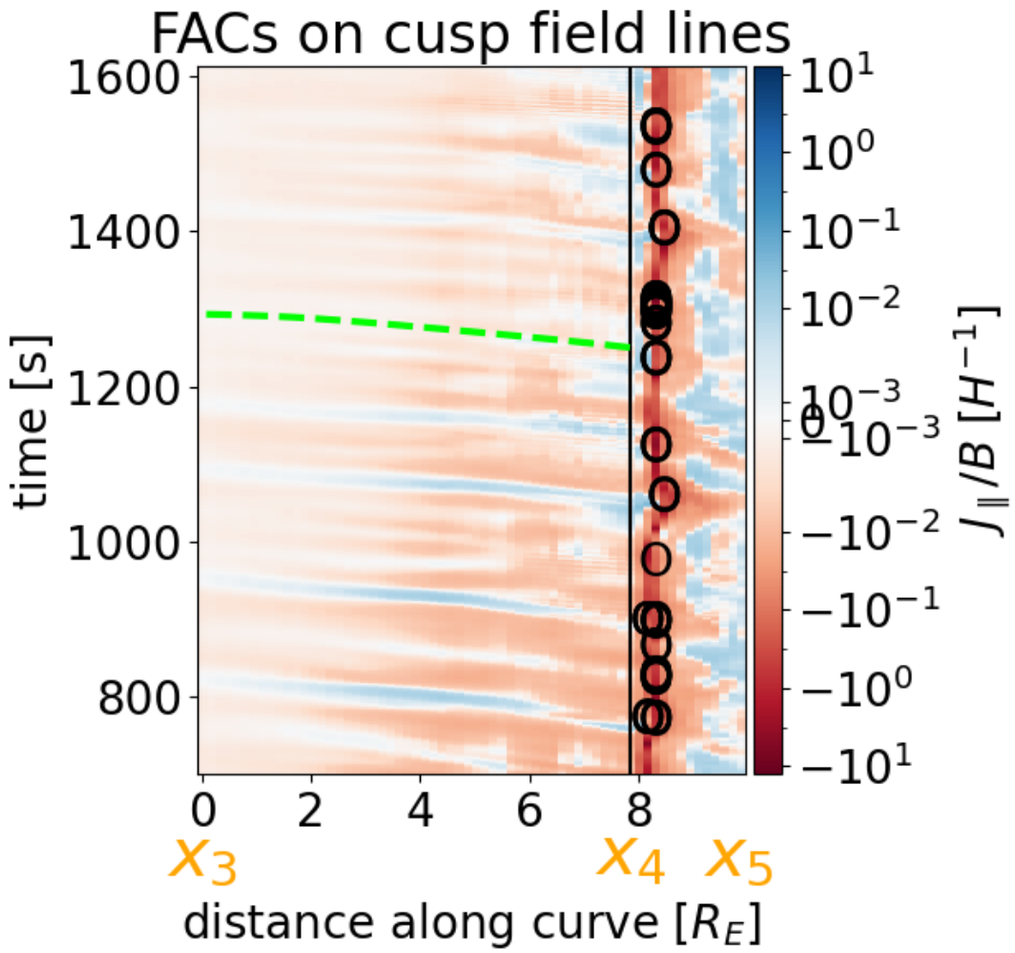
Green curve:

- B-field trace ($\mathbf{x_3 \rightarrow x_4}$)
- Radial segment ($\mathbf{x_4 \rightarrow x_5}$)

Keogram along x_3-x_4-x_5:

- FACs correlate with O-lines
- Travel at Alfven speed





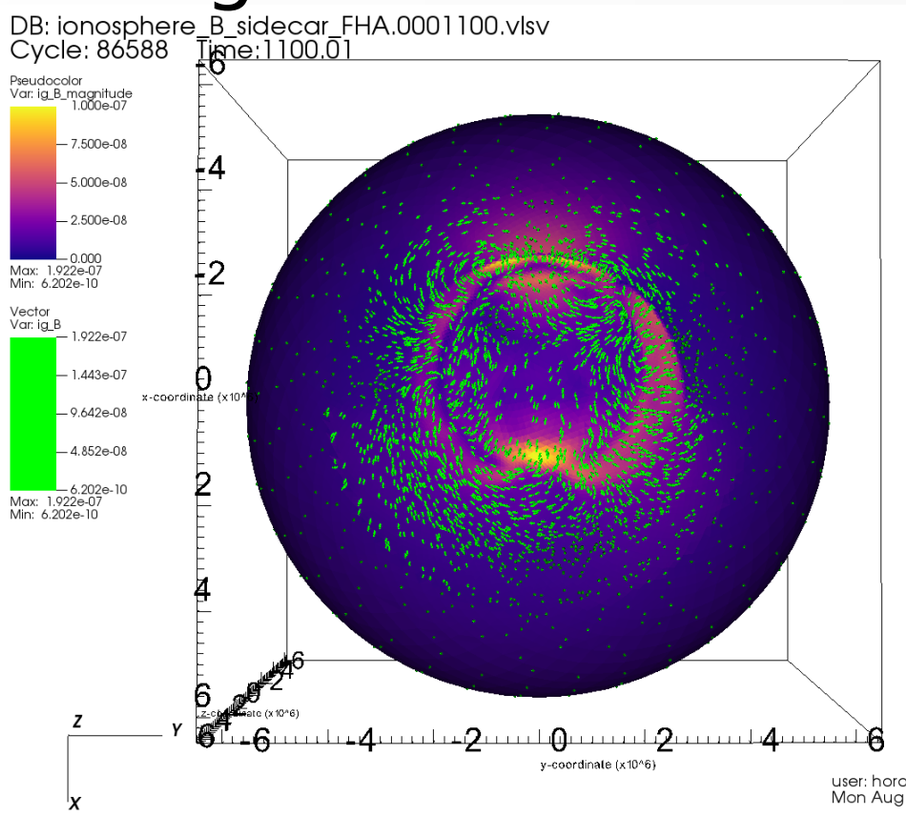
Ground electromagnetic field

Ground magnetic field

B(**r**) from Biot-Savart law:

$$\mathbf{B}(\mathbf{r}) = \frac{\mu_0}{4\pi} \iiint_V \frac{(\mathbf{J}\, dV) \times \mathbf{r}'}{|\mathbf{r}'|^3}$$

ground **B**-field



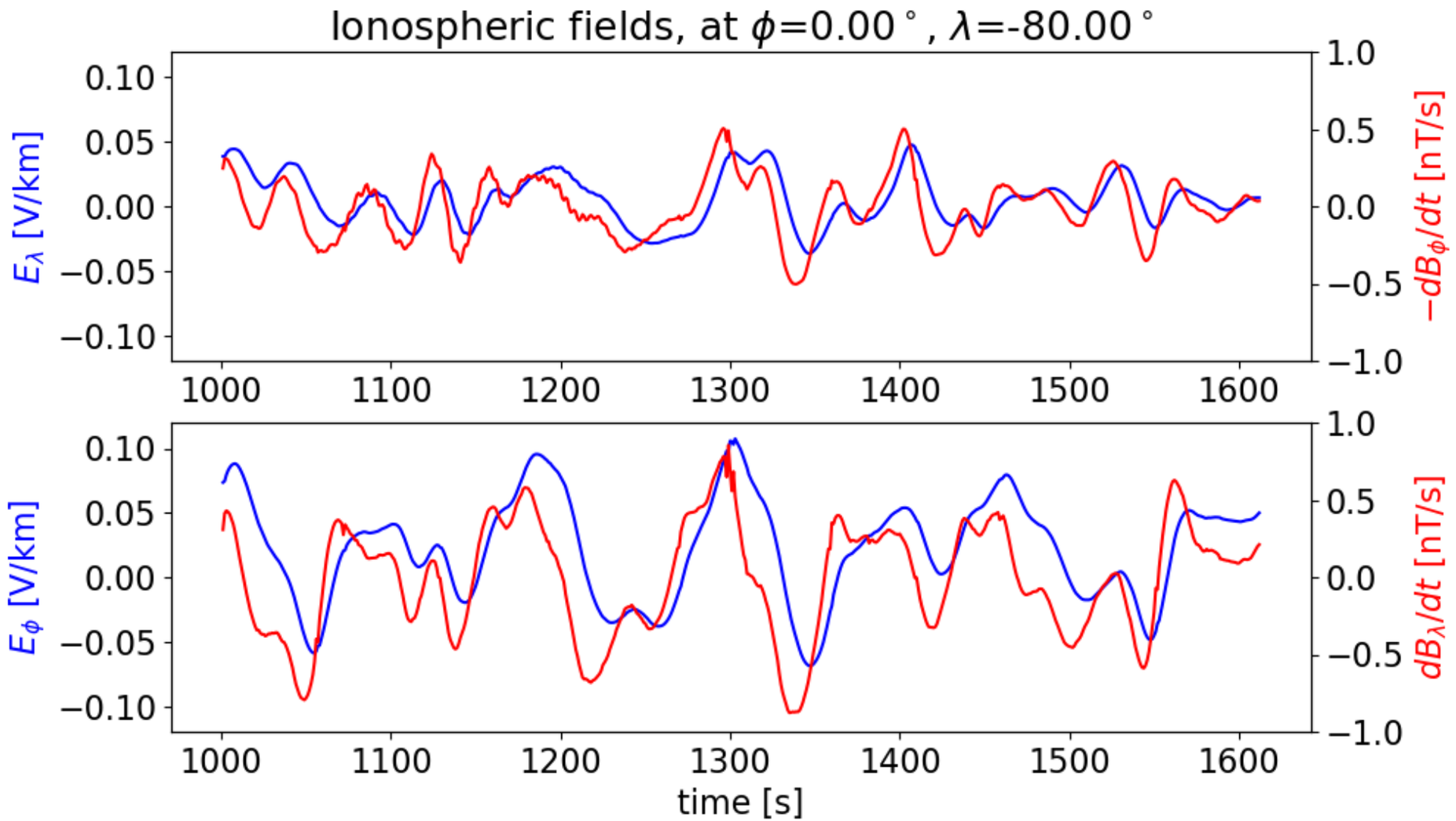
Geoelectric field

$E_y(t)$, $E_x(t)$ from Cagniard (1953):

$$E_y(t) = -\frac{1}{\sqrt{\pi \mu_0 \sigma}} \int_0^\infty \frac{dB_x(t-t')}{dt'} \frac{1}{\sqrt{t'}}\, dt'$$

$\sigma = 10^{-3}$ S/m

Geoelectric Field



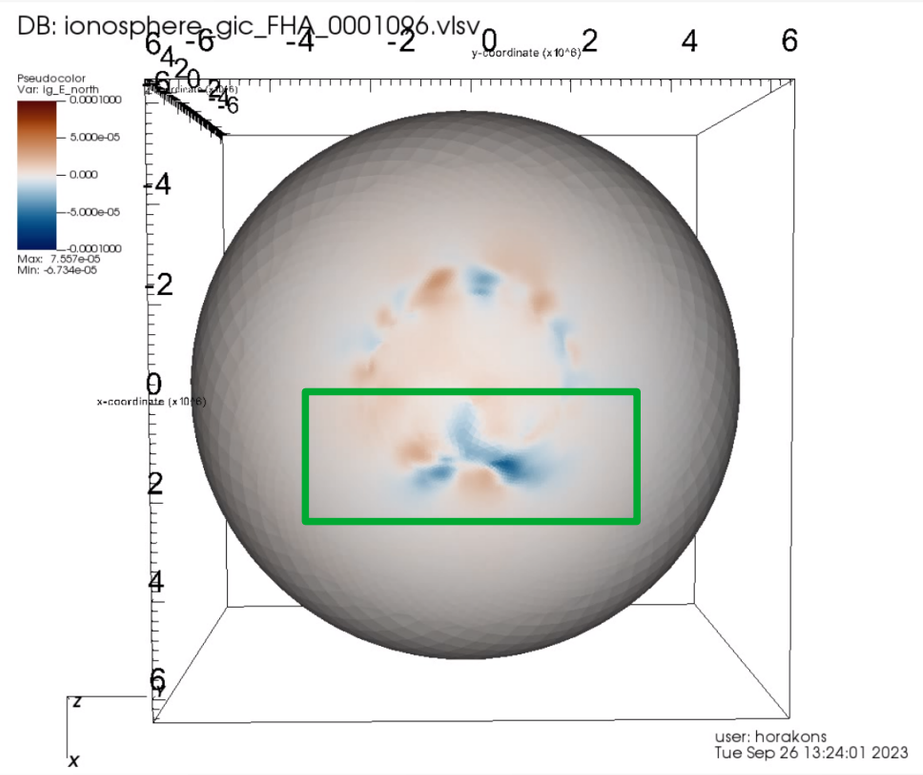
$E_\lambda \leftrightarrow -dB_\varphi/dt$ correlation

$E_\varphi \leftrightarrow dB_\lambda/dt$ correlation

φ: longitude (east), λ: latitude (north)

CONCLUSIONS

- **Vlasiator's new ionosphere** improves physical realism and enables the study of space weather.
- FTEs can be made of **multiple flux ropes!** Split where $J_{||}$ changes sign
- Field-aligned currents associated with O-line passage near the magnetopause



Next step: the cusp!

Paper in preparation

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