But what about the dawn-dusk asymmetry?
Two Electric fields govern particle drift outside of the ring current

1) Solar Wind Induced Electric Field

- Maintains current sheet that supports the tail
- Off equator – \( E \times (B_x) \)

\[
v = \frac{E \times B}{B^2}
\]

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**Diagram:***

- **Drift off equator**
  - \( E \times \pm B_x \)
  - N: \( B_x \)
  - S: \( B_x \)

- **Drift in equator**
  - Equipotentials

**Equipotentials**

- **Maintains current sheet that supports the tail**
- Off equator – \( E \times (B_x) \)
2) Corotation Induced Electric Field

\[ E_c = - (\omega \times r) \times B_{dip} \]

\[ B = B_0 \frac{R_E^3}{r^3} \left( -2 \sin \lambda \hat{r} + \cos \lambda \hat{\lambda} \right) \quad \text{Dipole formula} \]

\[ \omega \times r = \omega r \mathbf{z} \times \mathbf{r} = \omega r (\sin \lambda \hat{r} + \cos \lambda \hat{\lambda}) \times \mathbf{r} \]

\[ = \omega r \cos \lambda \phi \]

\[ E_c \approx -\omega B_0 \frac{R_E^3}{r^3} \cos \lambda \left( -2 \sin \lambda \hat{\lambda} + \cos \lambda \mathbf{r} \right) \]

At the equator (\lambda = 0), \( E_c \) is radially inward
Dusk Bulge
2 drifts merge

Null Point
\[ E_{\text{vxB}} = -E_{\text{wrxrB}} \]
\[ v = \frac{E \times B}{B^2} \]

Plasma Streamlines

Plasmopause where co-rotation breaks down
Currents and Aurora

\[ \lambda = \frac{\pi}{2} - \theta \]

\[ r = r_0 \cos^2 \lambda \]

\[ B_{dip}(r, \lambda) = \frac{\mu_0 M}{4\pi r} (1 + 3 \sin^2 \lambda)^{\frac{1}{2}} \]
Birkland Currents
Region 1 vs Region 2 polar currents
From drift motions
Region 1 Current – Convection of the fieldlines

\[ E = -v \times B \]
Cross-tail Current

\[ J = \sigma E \]

Chapman-Ferraro Current

Magnetopause

\[ \mathbf{v} = \frac{\mathbf{E} \times \mathbf{B}_z}{B^2} \]

Cross-tail Current

\[ J = \sigma E \]
Region 2 currents

ions  electrons
\( \nabla B \) and Curvature

LLBL (lower magnetopause)
Region 1 vs Region 2 polar currents

From drift motions
Chapman-Ferraro Current

Current Sheet Electric Field

Interplanetary magnetic field
Tail current

Plasma mantle
Magnetic tail

Plasma sheet 1
Neutral sheet current

Plasma sheet 2
Field aligned current

Ring current

Magnetopause current
Solar wind

Magnetopause

Gradient and Curvature Drifts