CURRENTS

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(in planetary magnetospheres)

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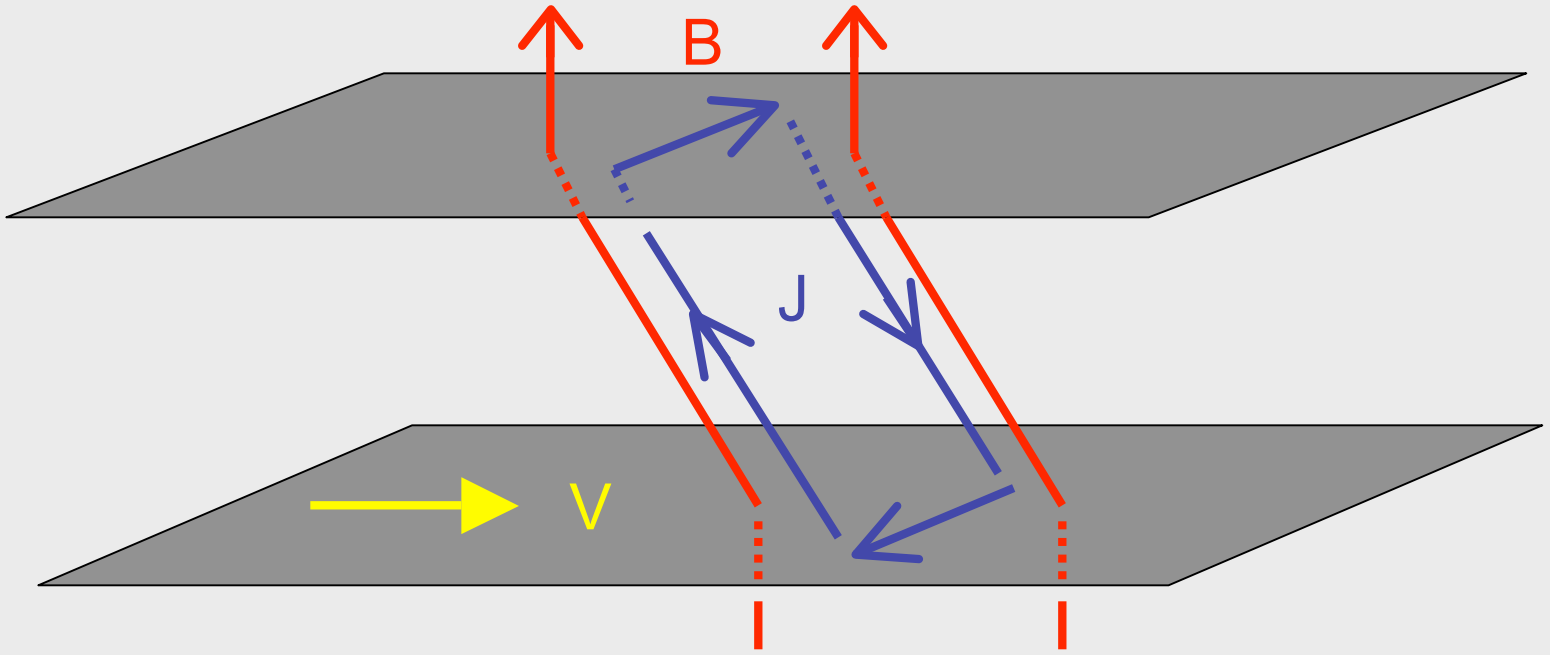
Five distinct **types** of current in planetary magnetospheres:

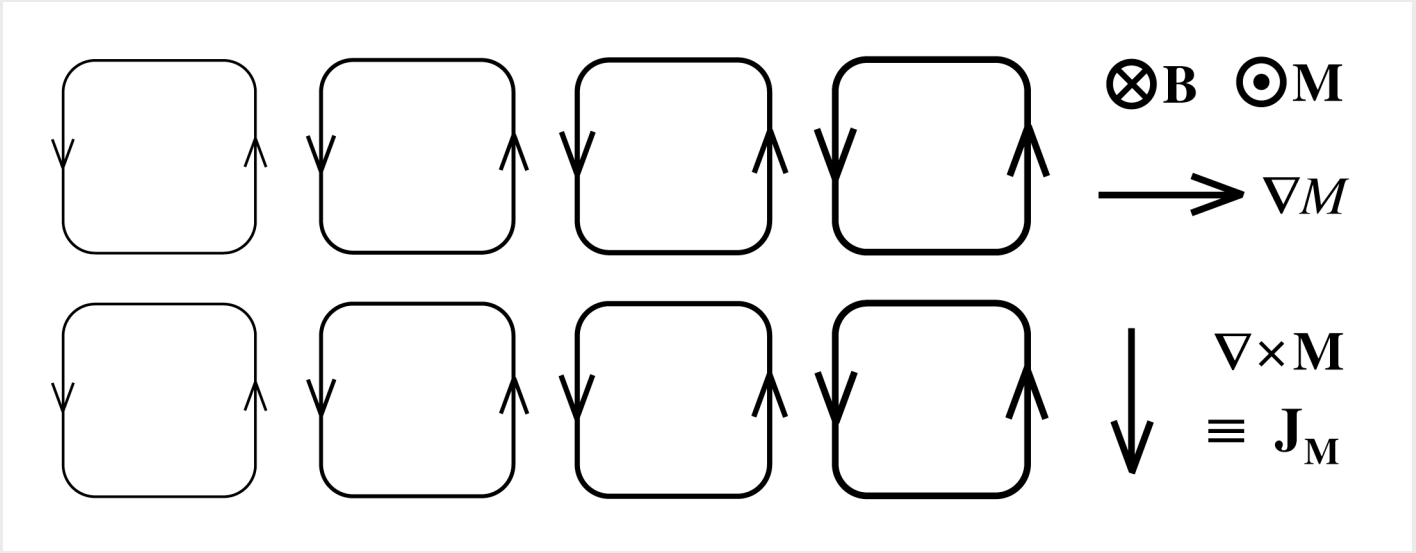
- Perpendicular (to **B**)
  - Magnetization
  - Drift
  - Conduction (Pedersen + Hall)
- Parallel (to **B**)
  - Upward
  - Downward

Perpendicular currents provide the magnetic force **JxB**.

Parallel currents, although they don't contribute *locally* to **JxB**, provide current linkage, and hence mechanical coupling, between different parts of a magnetic flux tube.



Magnetization Current: $\mathbf{M} \equiv -(p_{\perp}/B^2)\mathbf{B}$



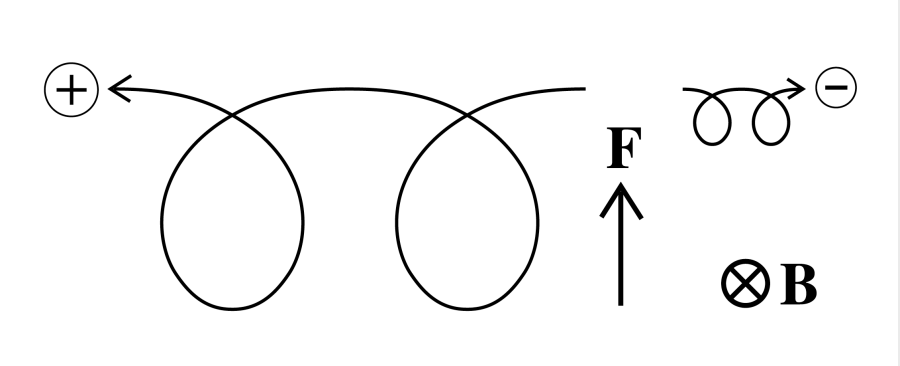
Note that $\nabla_{\perp} \cdot \mathbf{J}_M \equiv 0$.

$\Rightarrow$ $\mathbf{J}_M$ cannot couple to a parallel current.

Drift Current:

$$\mathbf{J}_d = \sum_i n_i q_i \mathbf{v}_{di}$$

where $$\mathbf{v}_{di} = \frac{\mathbf{F} \times \mathbf{B}}{q_i B^2}$$



F = qE ⇒ **ExB drift (no current; q's cancel).**

F = -∇B ⇒ **Gradient drift current.**

F = -*mv*$_{||}^2$κ ⇒ **Curvature drift current.**

F = *m*ω^{2}r ⇒ **Centrifugal drift current.**

F = -*m*dv**/d*t*** ⇒ **Acceleration drift current.**

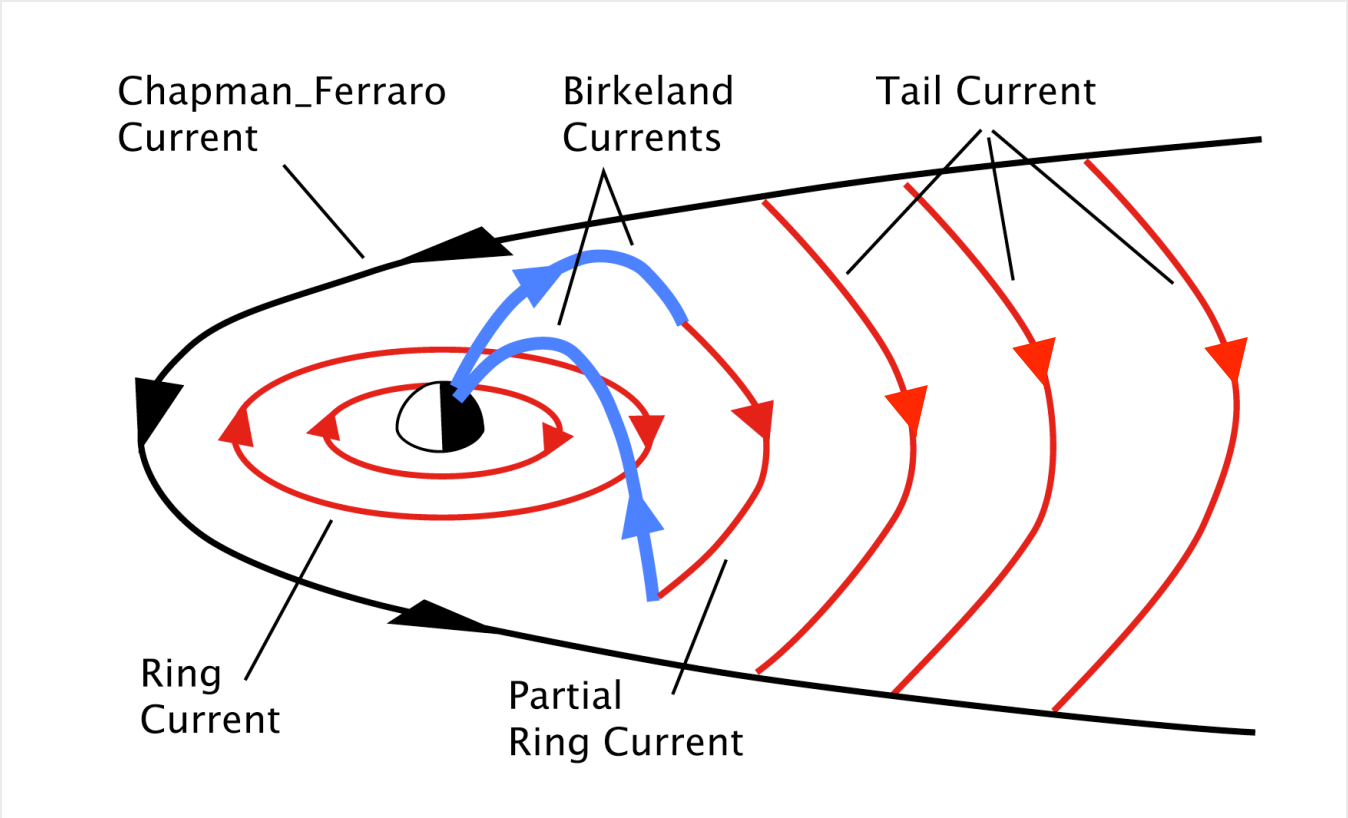
A divergence of any of these drift currents represents a source of *Birkeland* (magnetic-field-aligned) currents $j_{||}$ that couple the motion of magnetospheric plasma to the planet's ionosphere.

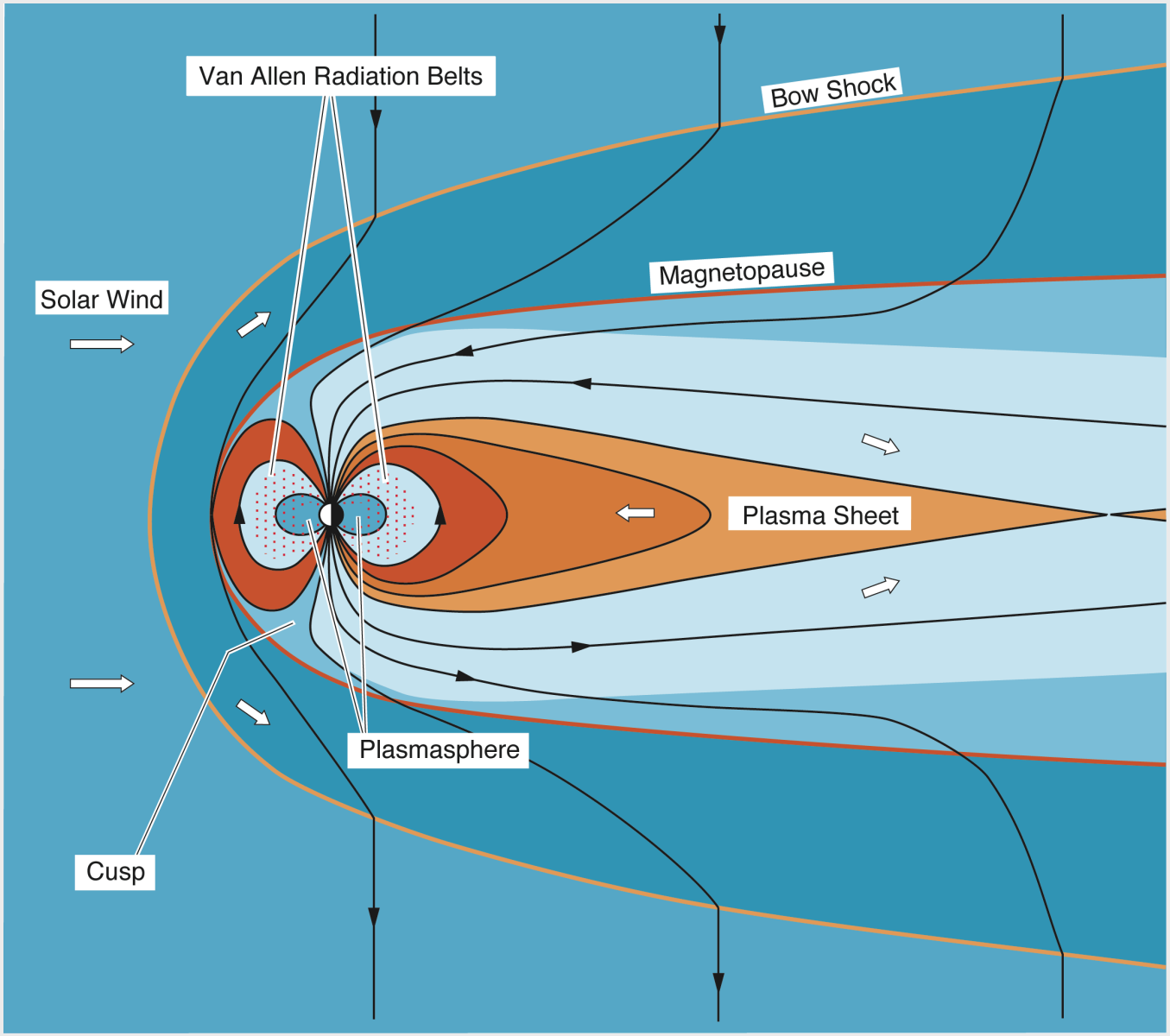
The *acceleration drift current* dominates in regions of high-speed flow (boundary layers, magnetotail).

The *gradient-curvature drift current* dominates in Earth's inner magnetosphere/ring current region.

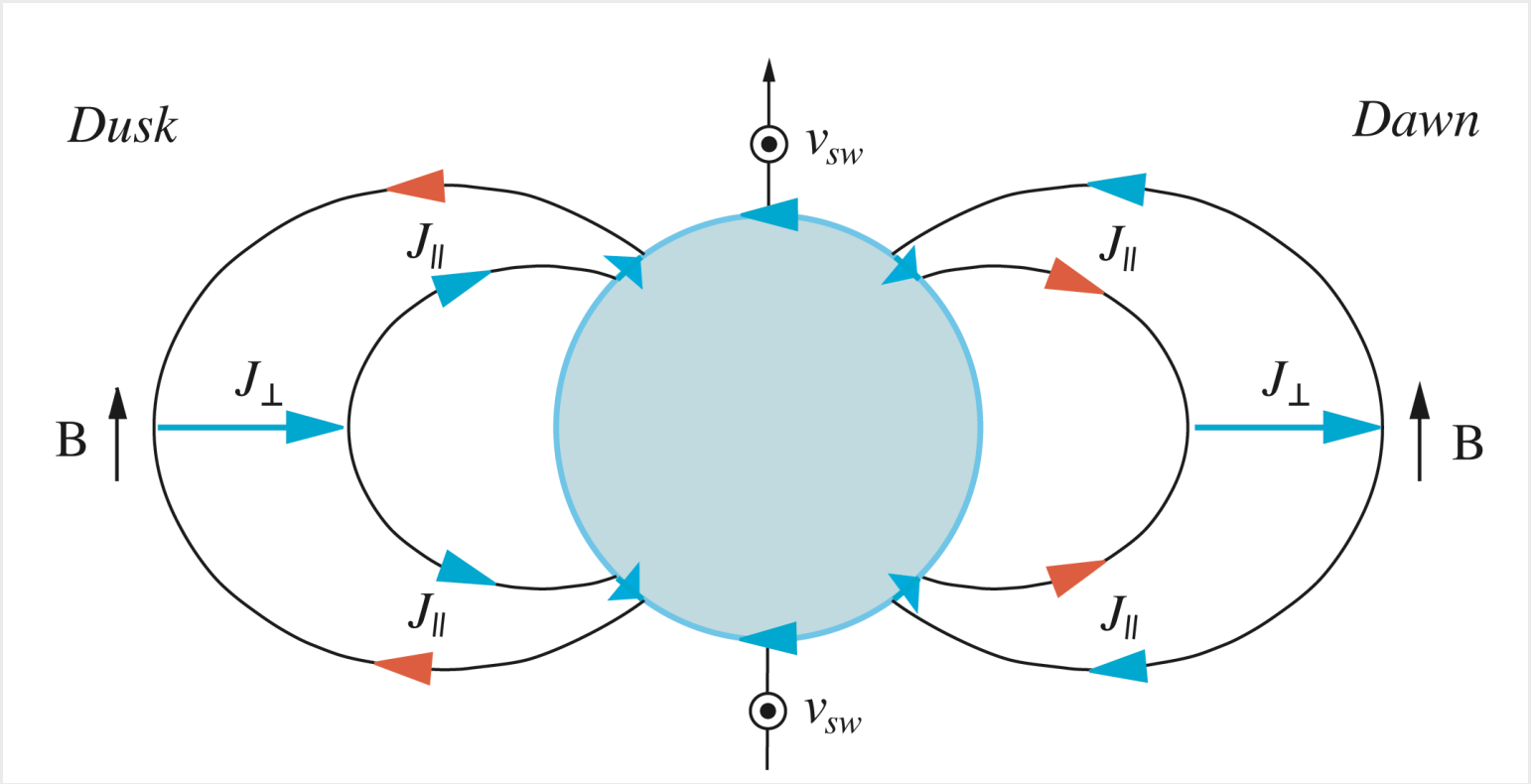
The *centrifugal drift current* dominates in the rapidly rotating magnetospheres of Jupiter and Saturn.

Earth's partial ring current is the classic example of magnetosphere-ionosphere coupling involving a diverging gradient-curvature drift current:



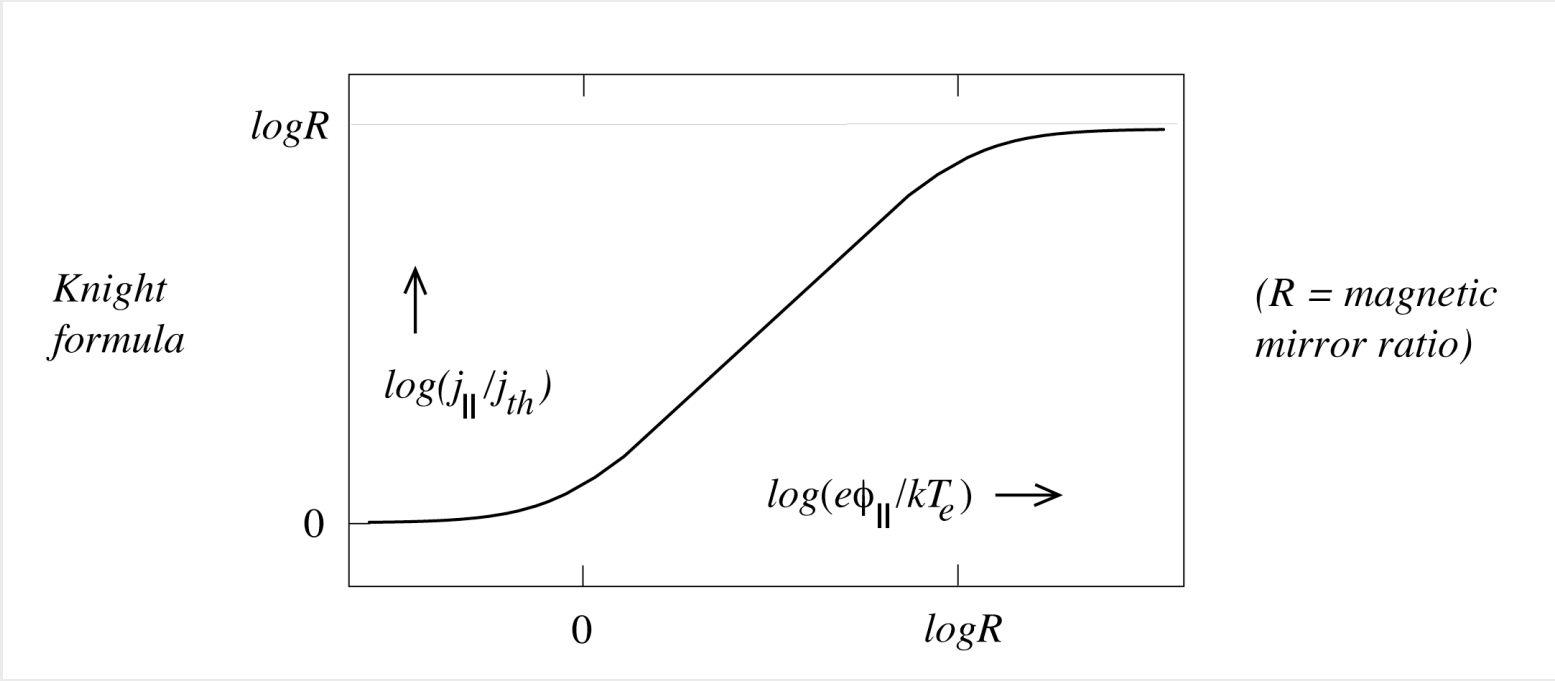

Van Allen Radiation Belts
Bow Shock
Magnetopause
Solar Wind
Plasma Sheet
Plasmasphere
Cusp

Magnetosphere-ionosphere coupling currents in the dawn-dusk meridian plane at Earth:



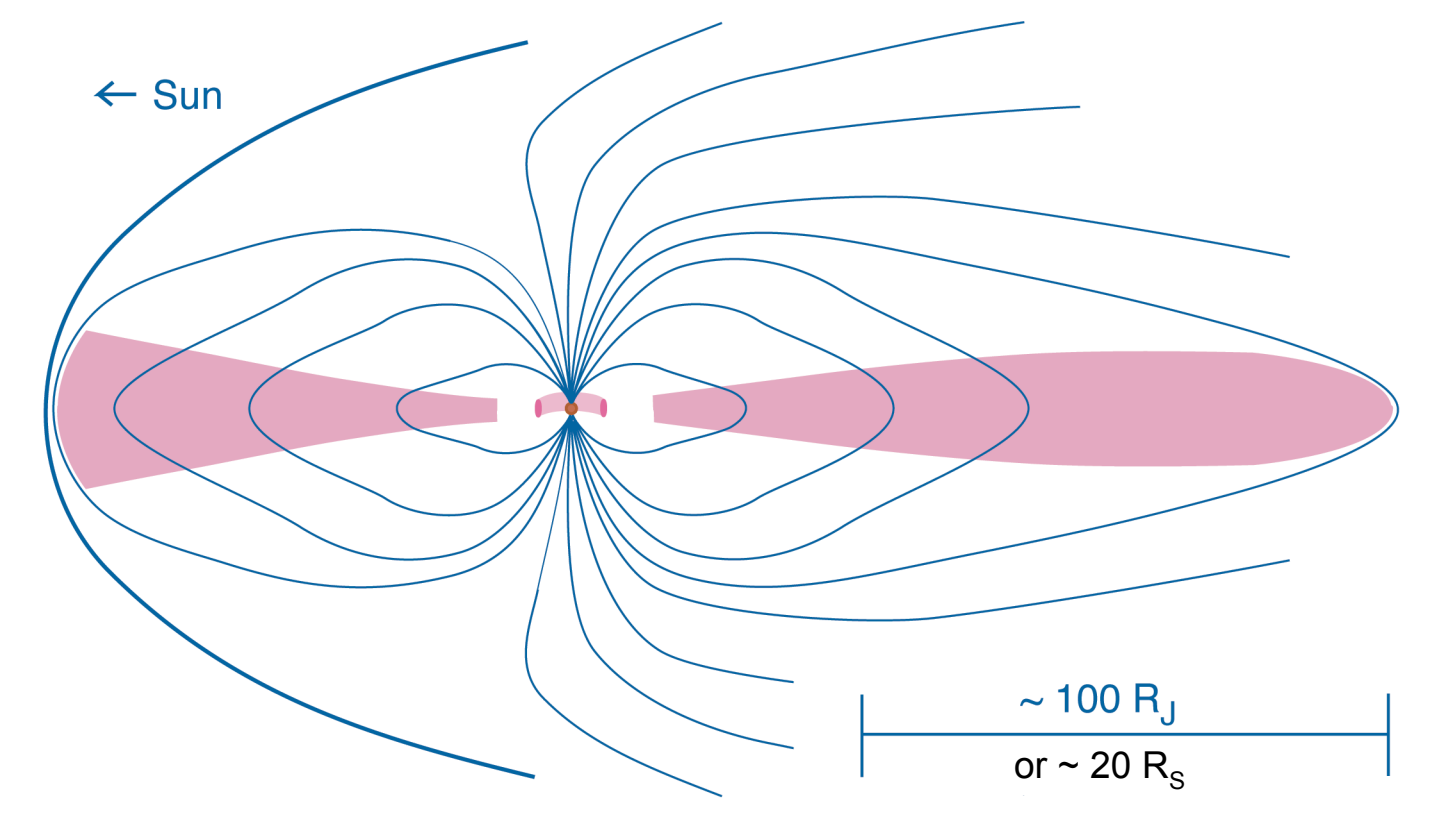
Upward $j_{||}$ produces the brightest aurora. Why?

Because $j_{||}$ is carried by electrons, and the ionosphere has a much larger thermal electron flux than the magnetosphere [Knight, 1970]:



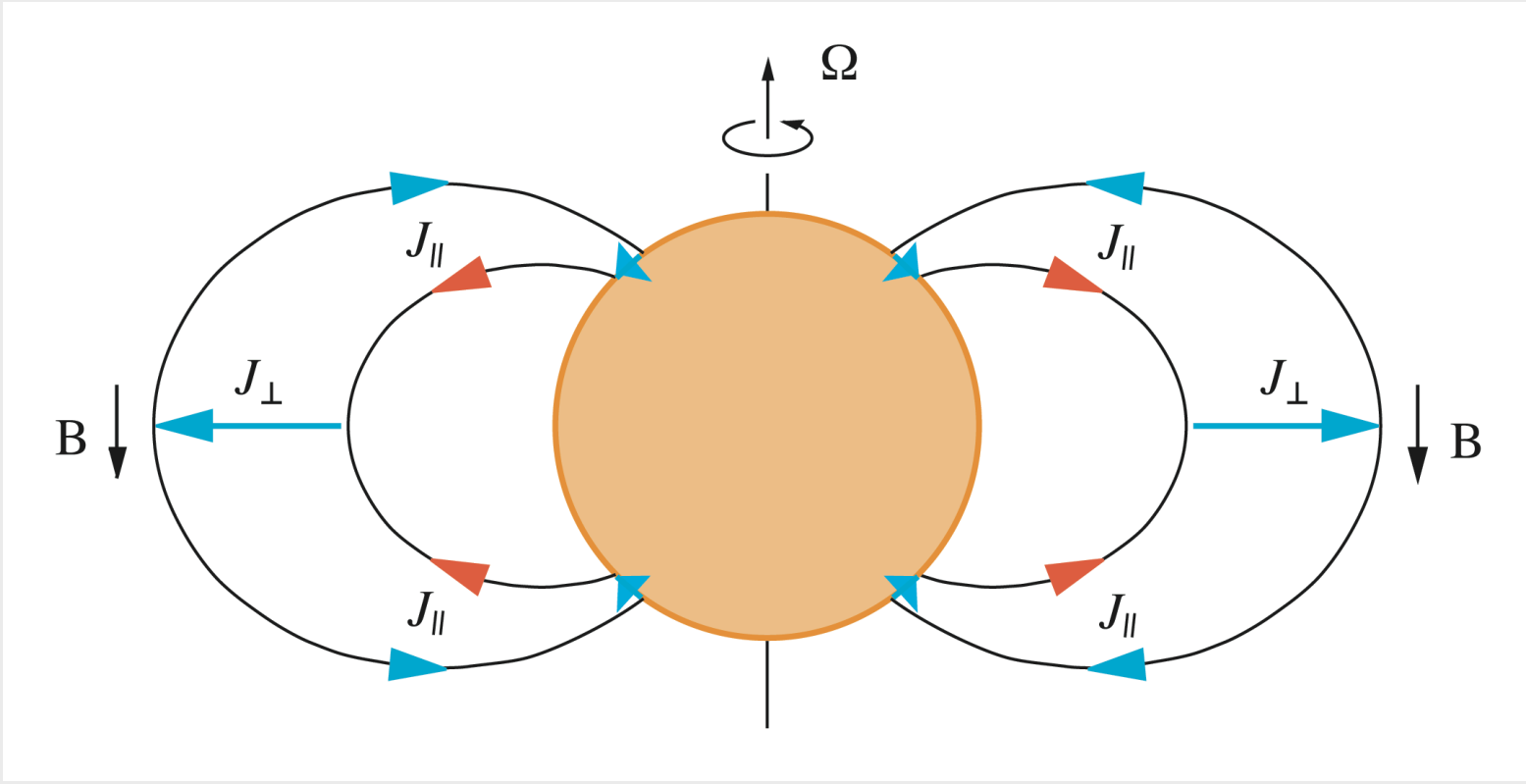
Upward $j_{||}$ requires a downward electron flux, which requires $\phi_{||}$ to overcome the magnetic mirror force.

Jupiter and Saturn have similar current systems, but their ring currents ("magnetodiscs") include the centrifugal drift current:

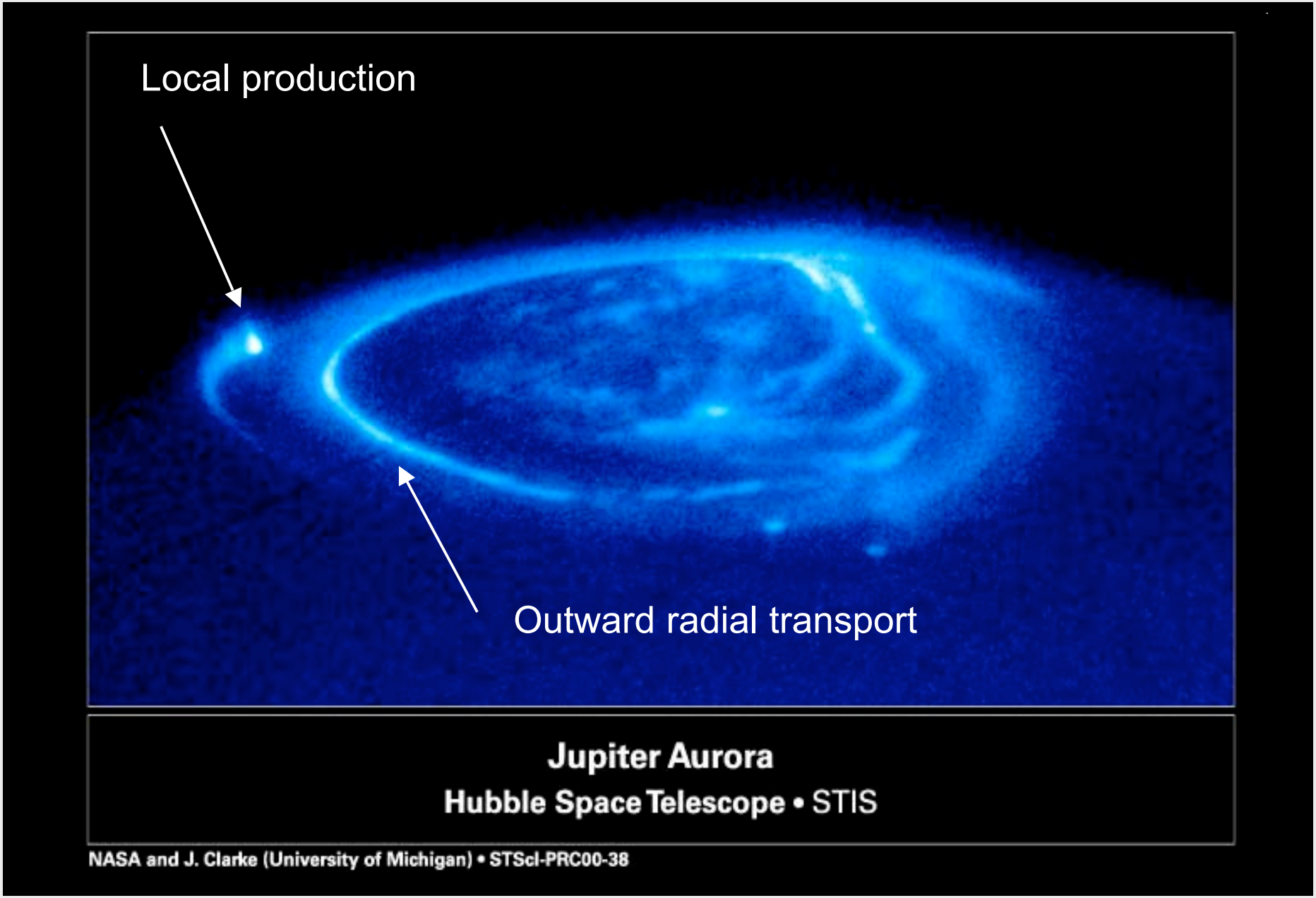


They also have auroral ovals, but for a different reason.

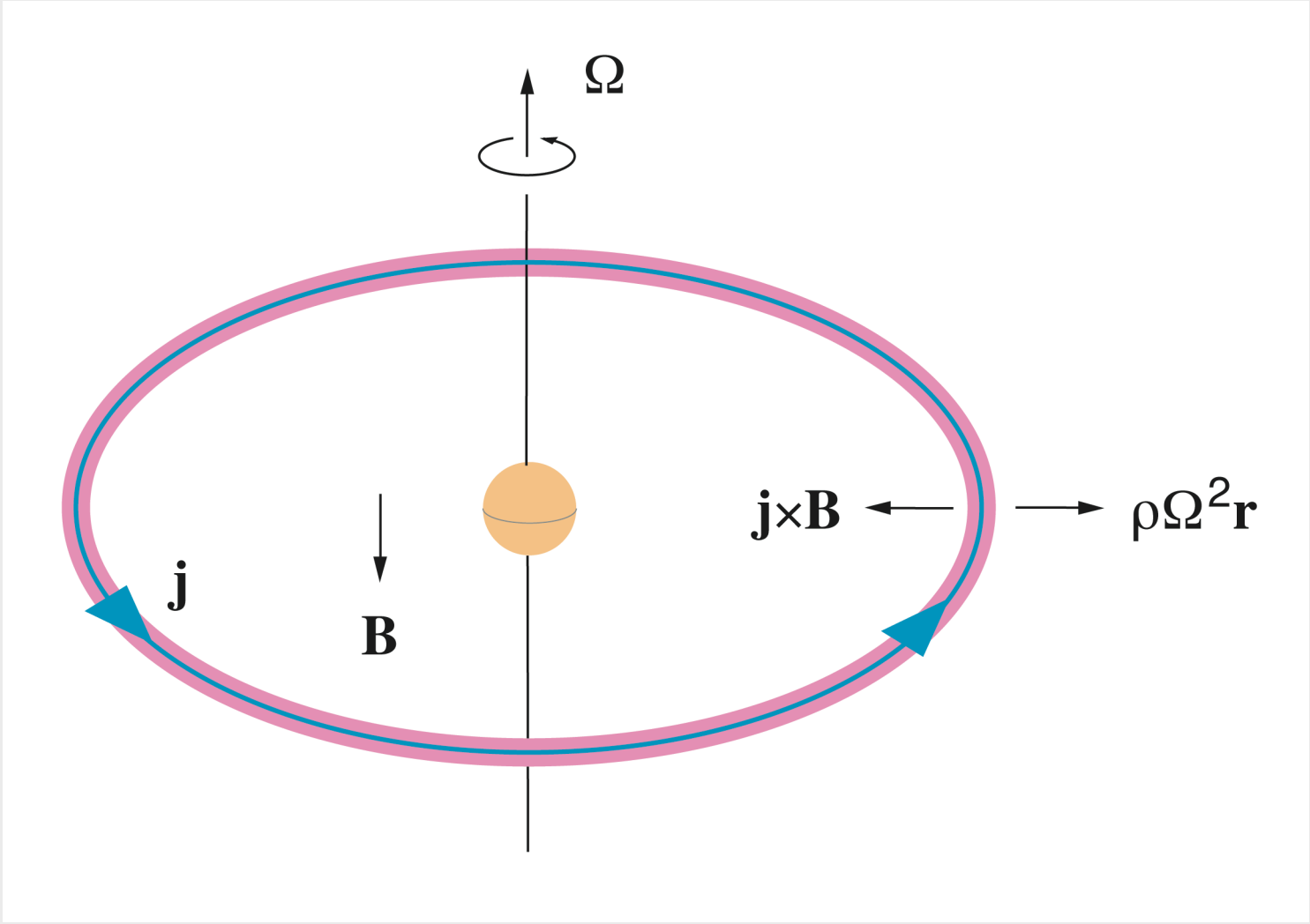
The auroral ovals of Jupiter and (probably) Saturn result from their attempts to keep their magnetospheres corotating with the planet:

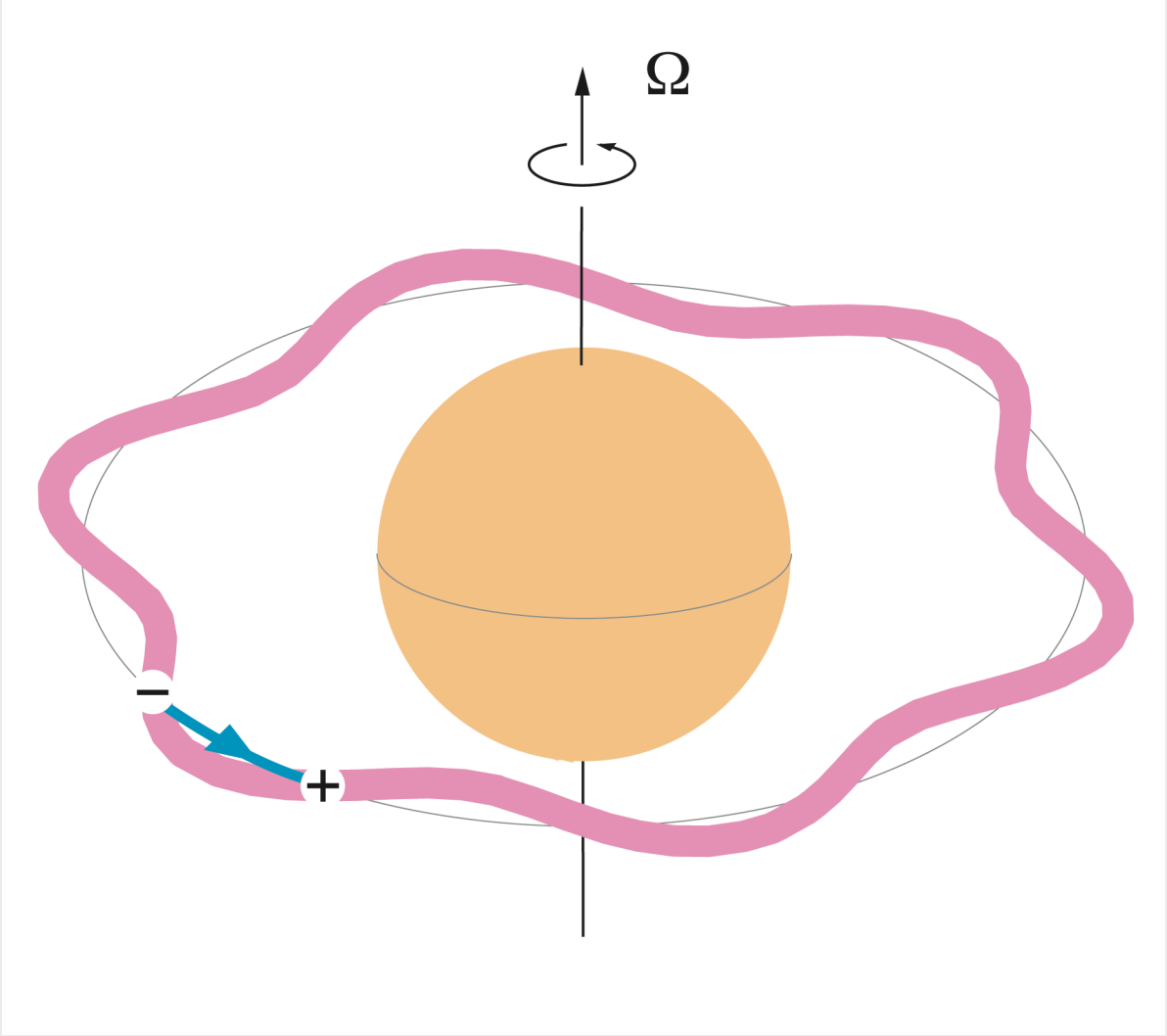


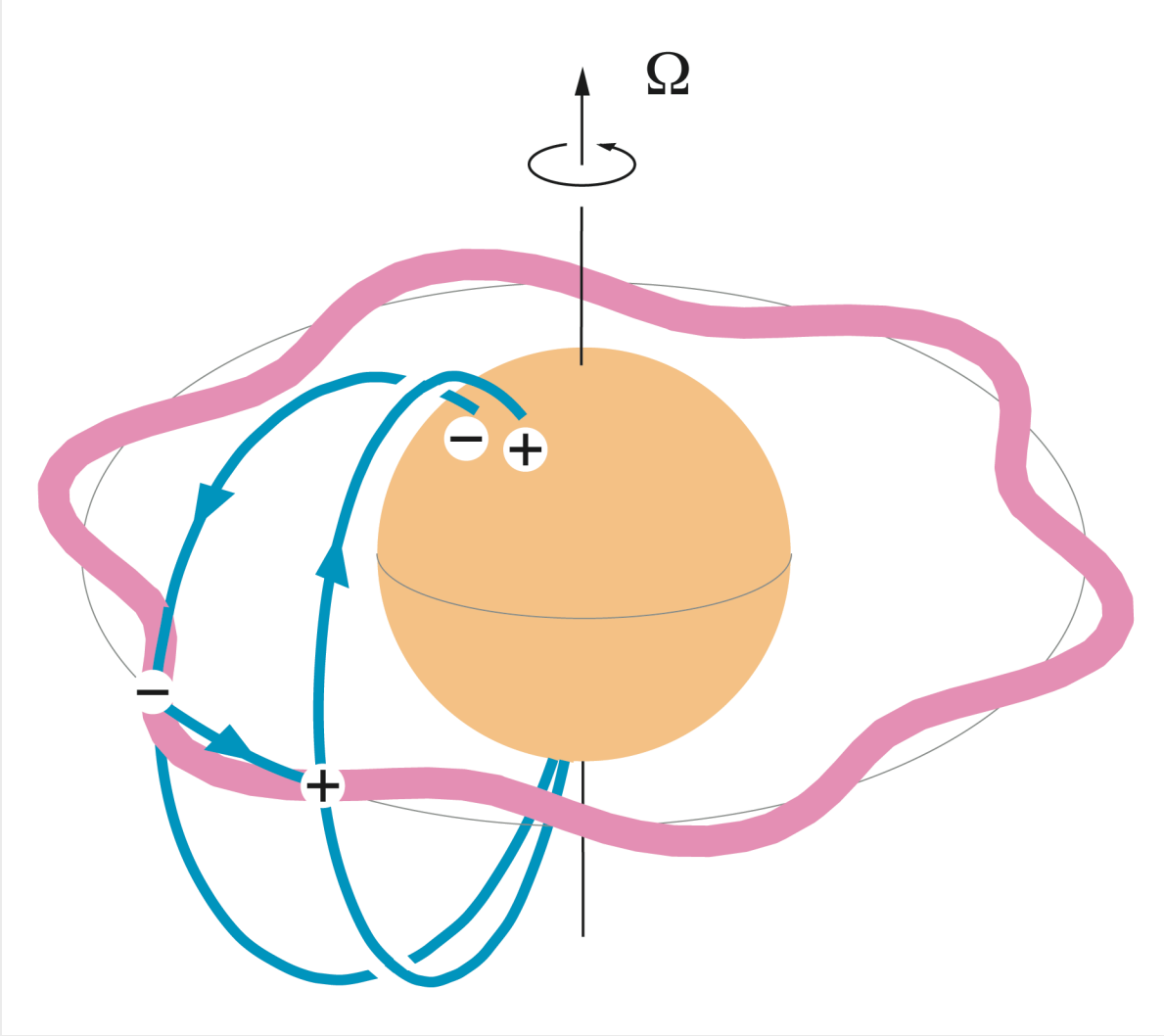
But, as at Earth, upward $j_{||}$ ⇒ bright aurora.

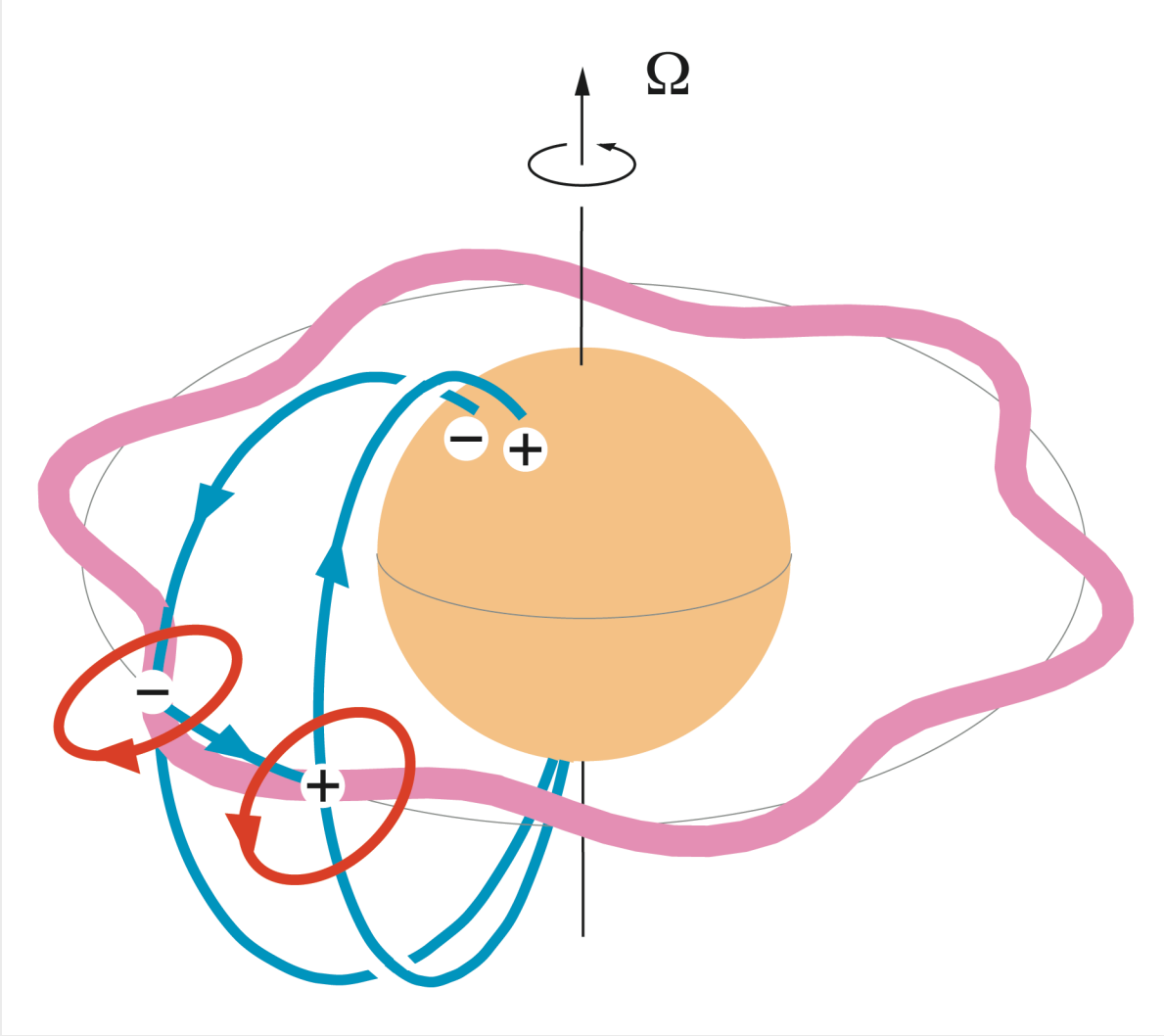

Local production
Outward radial transport
Jupiter Aurora
Hubble Space Telescope • STIS
NASA and J. Clarke (University of Michigan) • STScI-PRC00-38

The centrifugal interchange instability:




Ω
−
+


Ω
−
+
−
+


Ω
−
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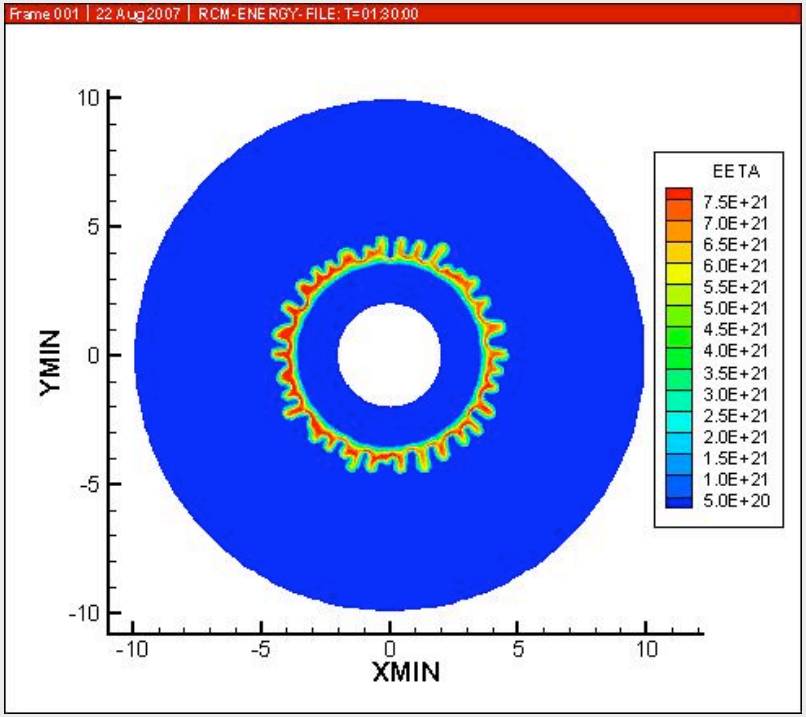
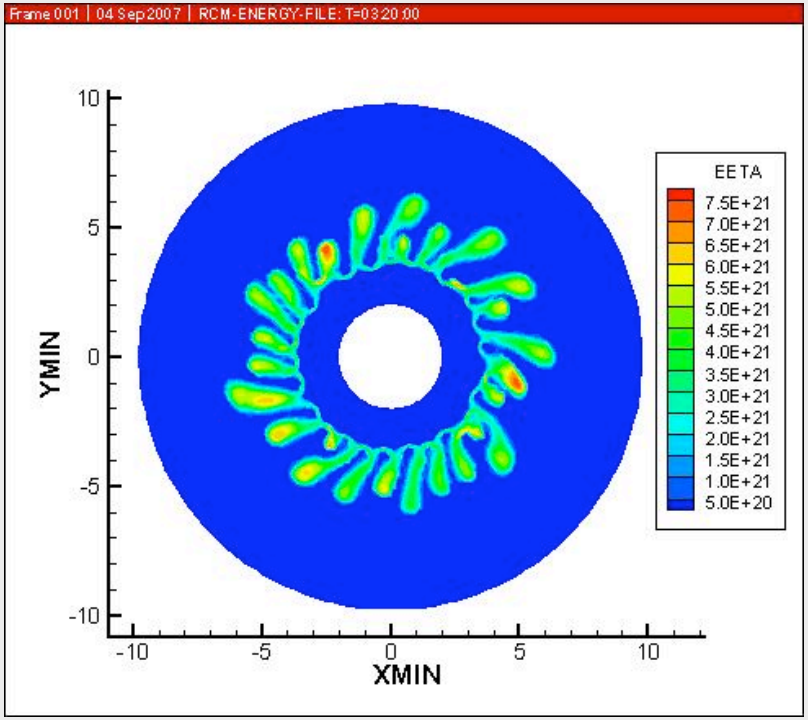
A Saturn simulation with the Rice Convection Model:





Discussion: