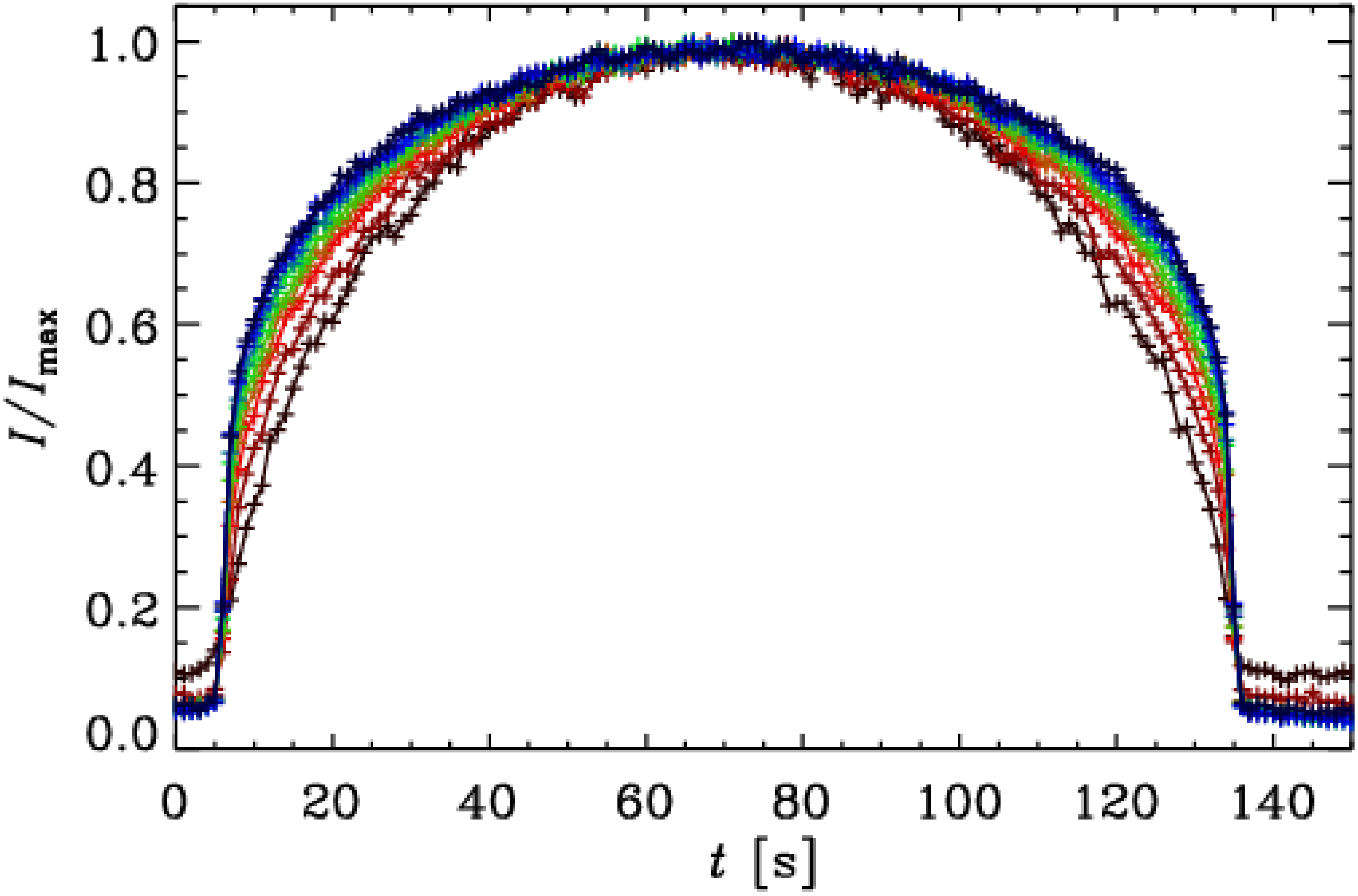
Lecture 34

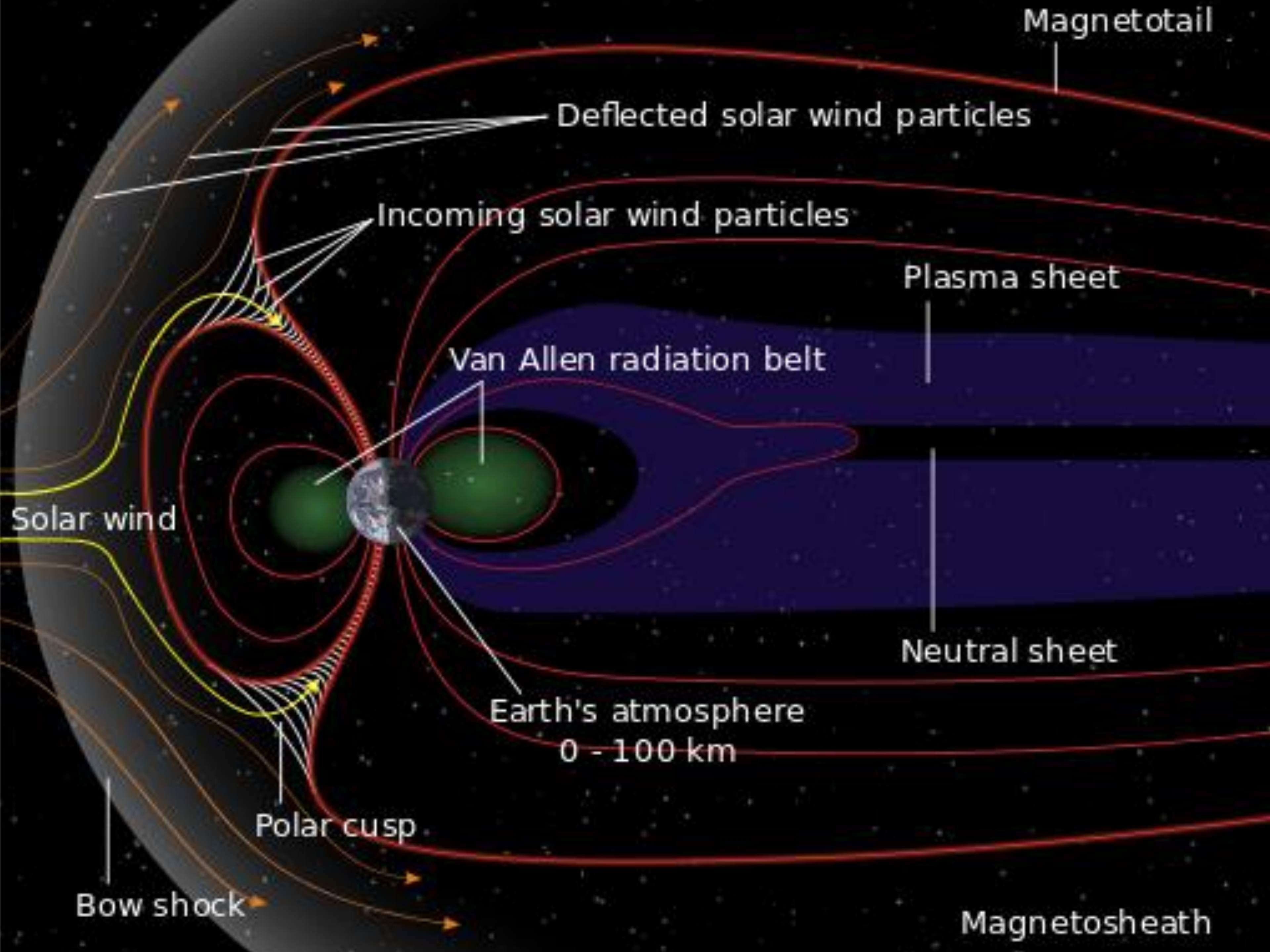
- Electric field in tail
- ExB drift
- Different plasma regimes

Letting sun pass by

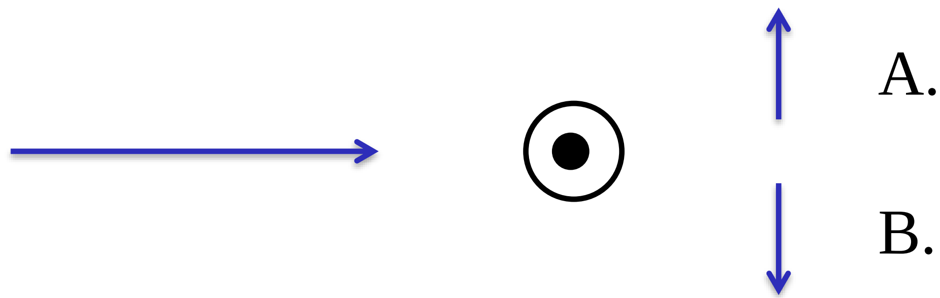


Last time…

- Earth magnetic field
  - Outer core (liquid iron)
- Magnetosphere
- Rare collisions
  - σ high, η low, ν large, Pr_M large
- Current systems

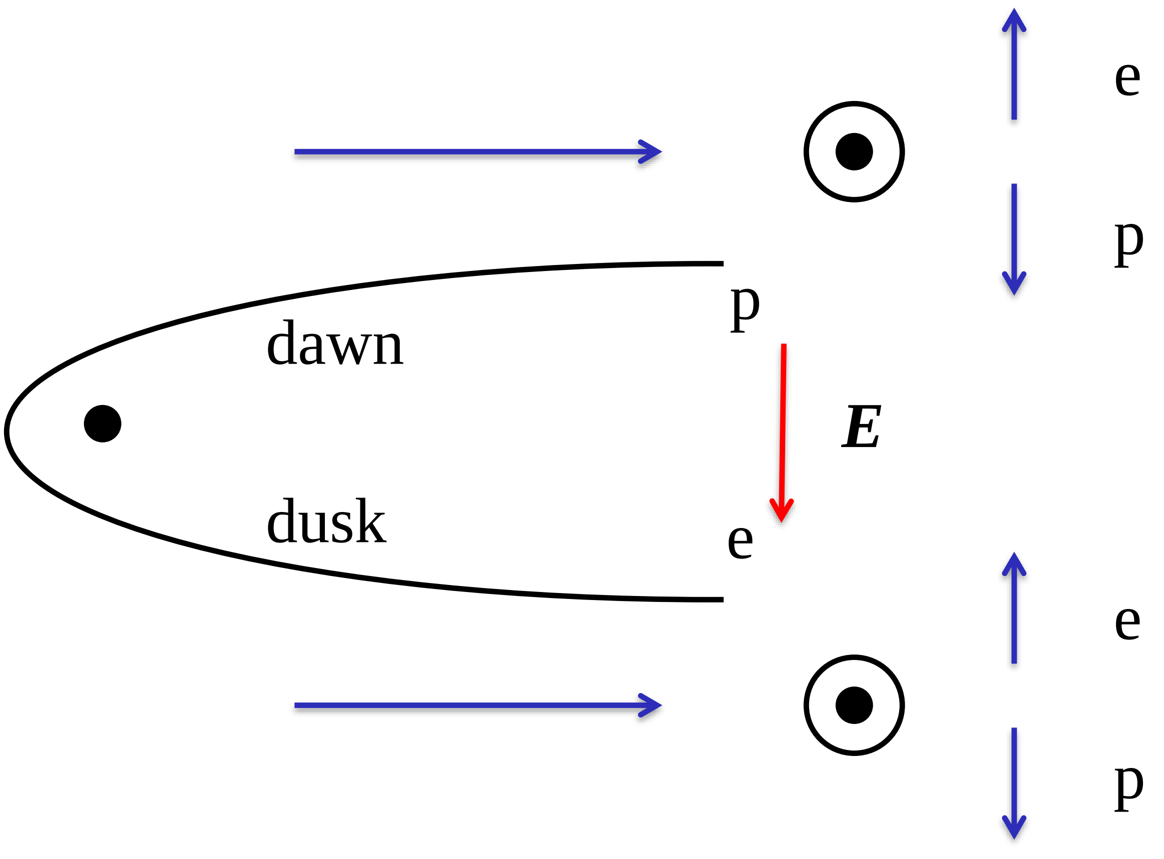

Magnetotail
Deflected solar wind particles
Incoming solar wind particles
Plasma sheet
Van Allen radiation belt
Solar wind
Neutral sheet
Earth's atmosphere
0 - 100 km
Polar cusp
Bow shock
Magnetosheath

Deflection of proton



$$m\frac{d\mathbf{u}}{dt} = q\mathbf{u}\times\mathbf{B}$$

Cross-tail electric field



Lect.10: Lorentz force

$$\left(\mathbf{J}\times\mathbf{B}\right)_i = \left(\tfrac{1}{\mu_0}\left(\nabla\times\mathbf{B}\right)\times\mathbf{B}\right)_i = ?$$

use

$$\varepsilon_{ijk}\varepsilon_{klm} = \delta_{il}\delta_{jm} - \delta_{im}\delta_{jl}$$

apply

$$\left(\mathbf{B}\times\left(\nabla\times\mathbf{B}\right)\right)_i = \varepsilon_{ijk}B_j\varepsilon_{klm}\partial_l B_m$$

$$= \left(\delta_{il}\delta_{jm} - \delta_{im}\delta_{jl}\right)B_j\partial_l B_m$$

$$= B_j\partial_i B_j - B_j\partial_j B_i$$

$$= \partial_i\left(\tfrac{1}{2}\mathbf{B}^2\right) - \left(\mathbf{B}\cdot\nabla\right)B_i$$

E x B drift

$$\mathbf{J} = \underbrace{\sigma}_{\to\infty}\underbrace{\left(\mathbf{E} + \mathbf{u}\times\mathbf{B}\right)}_{\to 0}$$

Solve for u

$$0 = \mathbf{E}\times\mathbf{B} + \left(\mathbf{u}\times\mathbf{B}\right)\times\mathbf{B}$$

$$\left[\mathbf{E}\times\mathbf{B}\right]_i = -\left[\left(\mathbf{u}\times\mathbf{B}\right)\times\mathbf{B}\right]_i = \left[\mathbf{B}\times\left(\mathbf{u}\times\mathbf{B}\right)\right]_i = \varepsilon_{ijk}B_j\varepsilon_{klm}u_lB_m$$

apply

$$\varepsilon_{ijk}\varepsilon_{klm} = \delta_{il}\delta_{jm} - \delta_{im}\delta_{jl}$$

E cross B drift

$$-\left[\left(\mathbf{u}\times\mathbf{B}\right)\times\mathbf{B}\right]_i=\left[\mathbf{B}\times\left(\mathbf{u}\times\mathbf{B}\right)\right]_i=\varepsilon_{ijk}B_j\varepsilon_{klm}u_lB_m$$

$$=\left(\delta_{il}\delta_{jm}-\delta_{im}\delta_{jl}\right)B_ju_lB_m$$

apply

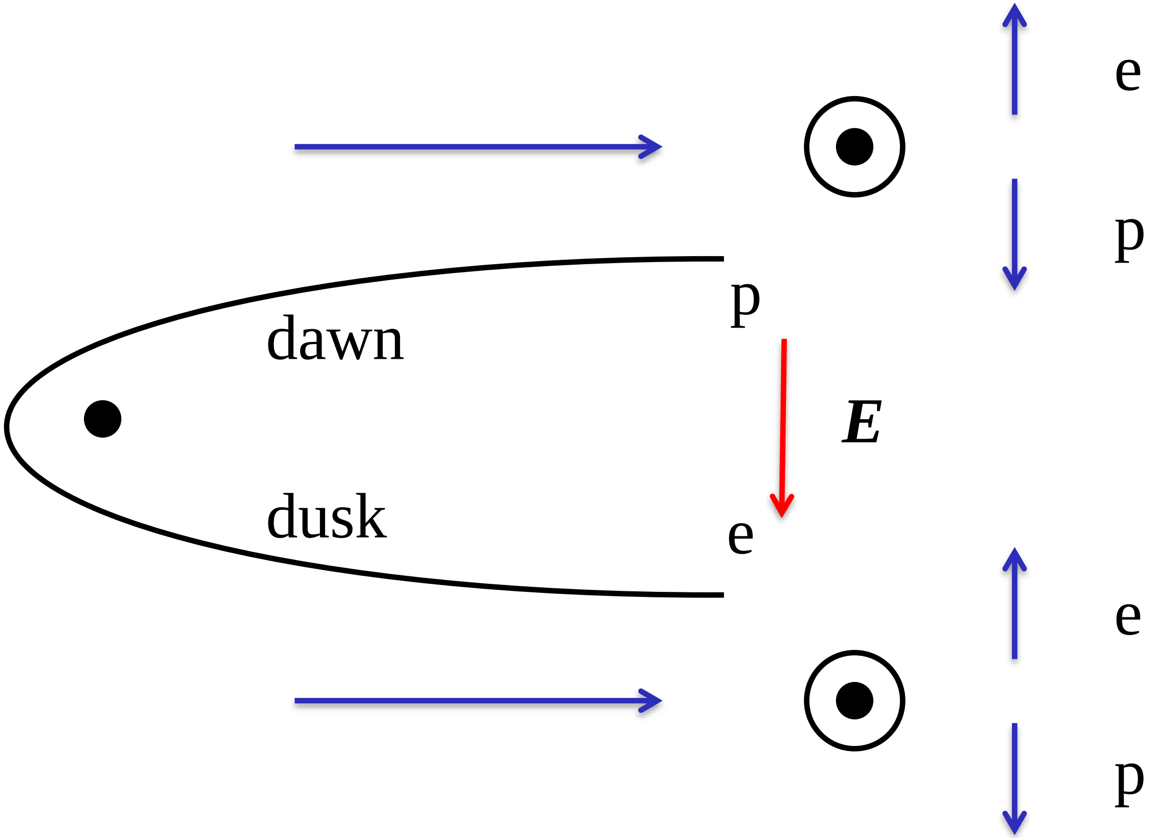
$$=B_ju_iB_j-B_ju_jB_i$$

$$=u_i\mathbf{B}^2-\mathbf{B}\cdot\mathbf{u}\,B_i$$

So, if u &B perp

$$\mathbf{u}=\mathbf{E}\times\mathbf{B}/\mathbf{B}^2$$

ExB drift

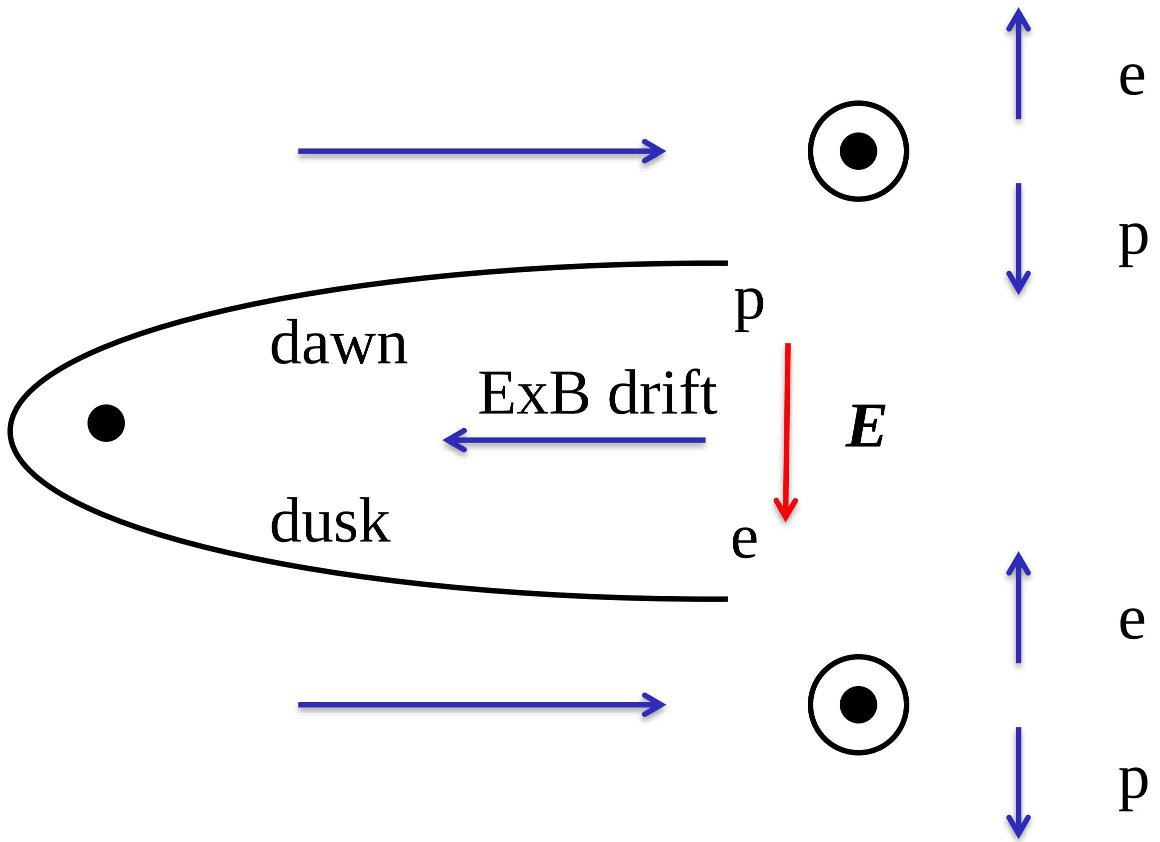


Flow:

A. to left

B. to right

ExB drift toward Earth



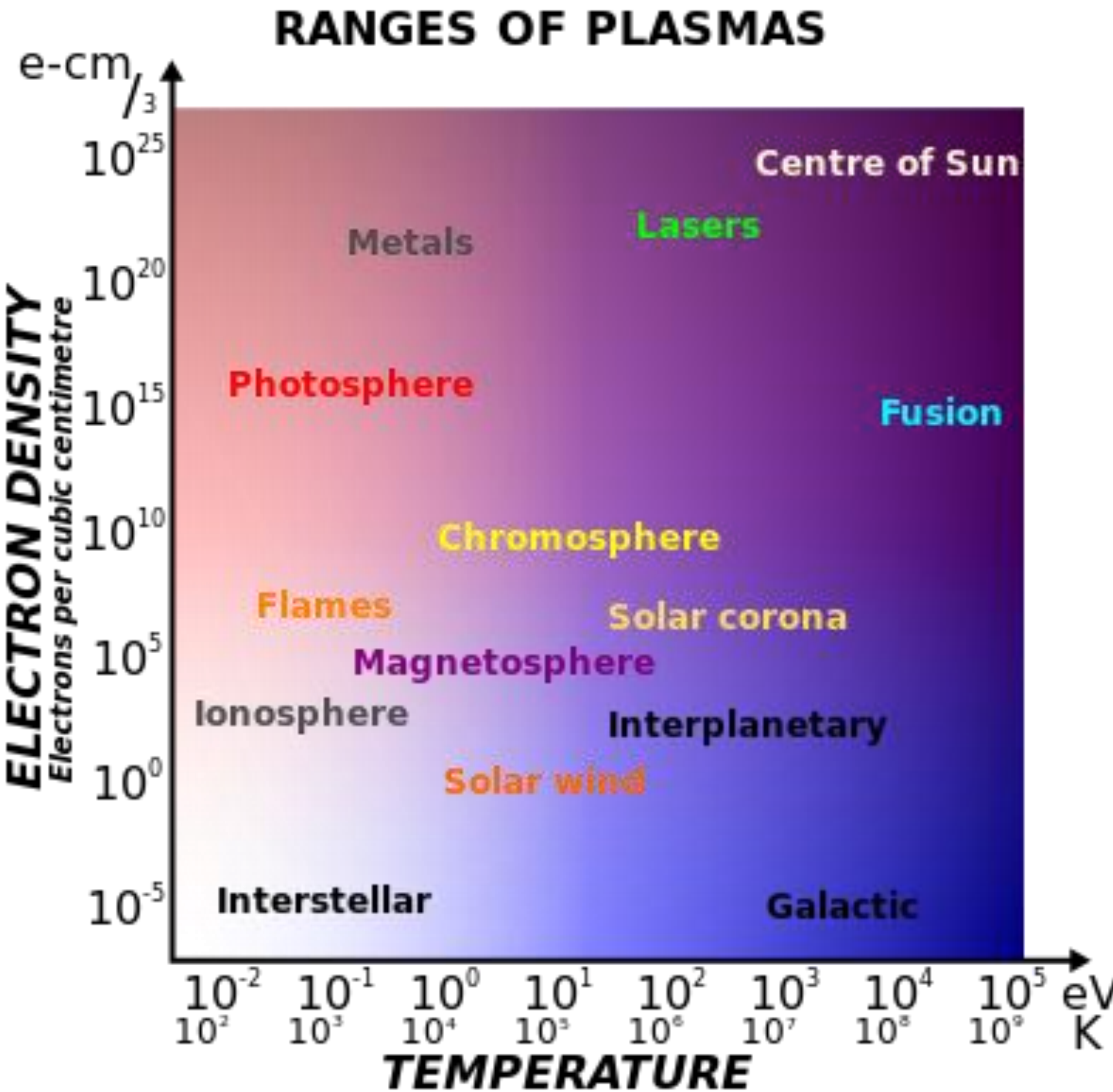
Flow:

A. to left

B. to right

Plasma Characteristics & behaviors

Knipp's book pp. 244-247



What we learned today

- Electric field in tail
- ExB drift
  - Vector algebra with double cross product
  - Interaction with Earth's corotating plasma
  - Kelvin-Helmholtz instability
- Different plasma regimes
  - Neutral Earth's atmosphere: n_e low, E low