Magnetic Curvature Analysis
on Reconnection Related Structures at Earth’s Magnetopause

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Curvature vector and the radius of curvature
Definition and the physical interpretation

• $\vec{k} = \vec{b} \cdot \nabla \vec{b}$
  The curvature vector can demonstrate the direction towards which the magnetic field lines curve.

• $R_c = \frac{1}{|\vec{b} \cdot \nabla \vec{b}|}$
  The radius of curvature can demonstrate the strength of the field line curving; the smaller is the $R_c$, the stronger is the curving.

• The curvature vector will reverse in the normal direction crossing a Harris current sheet ($B_0 \tanh(x/L)$) with a constant normal $B_n$. $L$ is the current sheet half-width.

• At the center of this kind of current sheet: the ratio of the $R_c$ to one type of particle’s gyro radius can be approximated by: $\left( \frac{B_n}{B_0^2} \right) \frac{L}{\rho_s}$ [Buchner and Zelenyi, 1989]; this ratio can be a proxy of the current sheet thickness relative to a certain type of particle’s kinetic scale.
Application 1: Radius of curvature can be a quantitative indicator of the proximity of the x-line with small guide field

- Far away from the x-line, when the particles are well guided by the magnetic field
  \[ R_c \gg R_{gyro} \]

- Near the reconnection line in the ion diffusion region, ions are decoupled while electrons remain magnetized
  \[ R_c \sim R_{i,gyro} \]

- Closer to the x-line, in the electron diffusion region
  \[ R_c \lesssim R_{e,gyro} \]
Application 2: Curvature features around the current sheet between two interlinked flux tubes

Schematic plot of two interlinked tubes

- When a spacecraft crosses the interface of the interlinked flux tubes, it will see significantly increased curvature.
- The curvature vector switches its direction across the current sheet.
- The increased curvature force helps to balance the sum of magnetic and plasma thermal pressure.

Figure 2 of [Oieroset et al., 2019]