THE KELVIN-HELMHOLTZ INSTABILITY AT EARTH'S MAGNETOPAUSE

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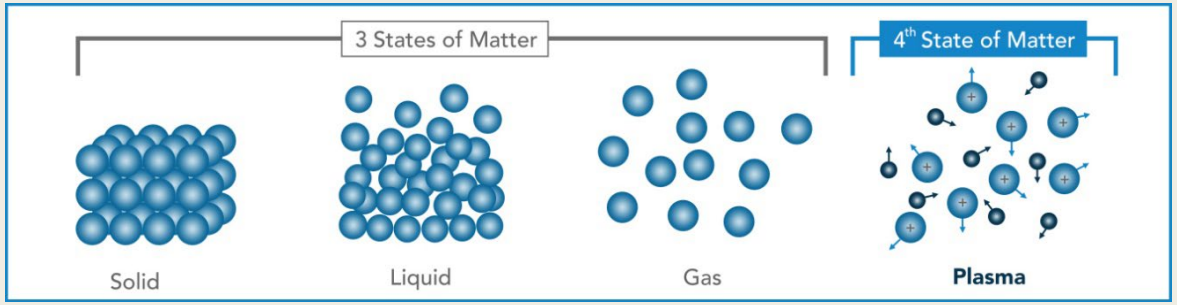
Plasma

- The 4th state of matter besides solid, liquid and gas
- Ionized and electrically conducting gas consisting of ions, free electrons and neutral particles
- Mass ratio between ions / electrons is 1836
  → different scales in a plasma for different species

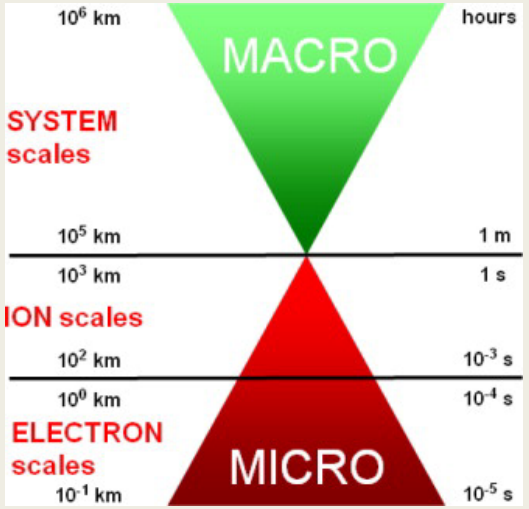
$$r_{C,s} = \frac{m_s v_\perp}{|q|B}$$

$$\nu_s = \frac{qB}{2\pi m_s}$$

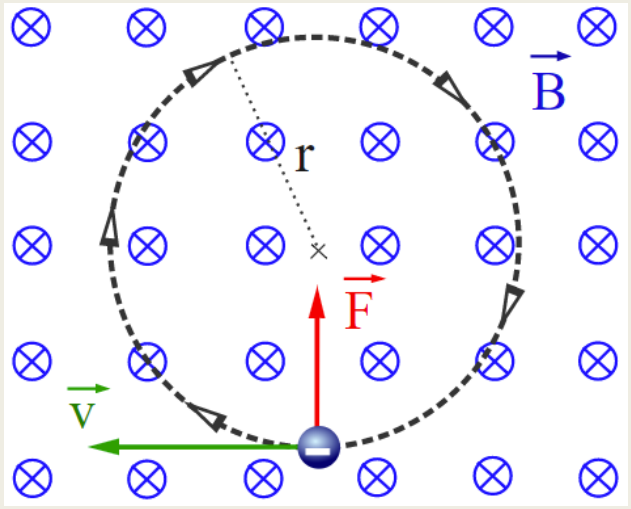
- Spacecraft mission to study electron scale



(Plasma Basics – GAOTON (gaotontech.com))



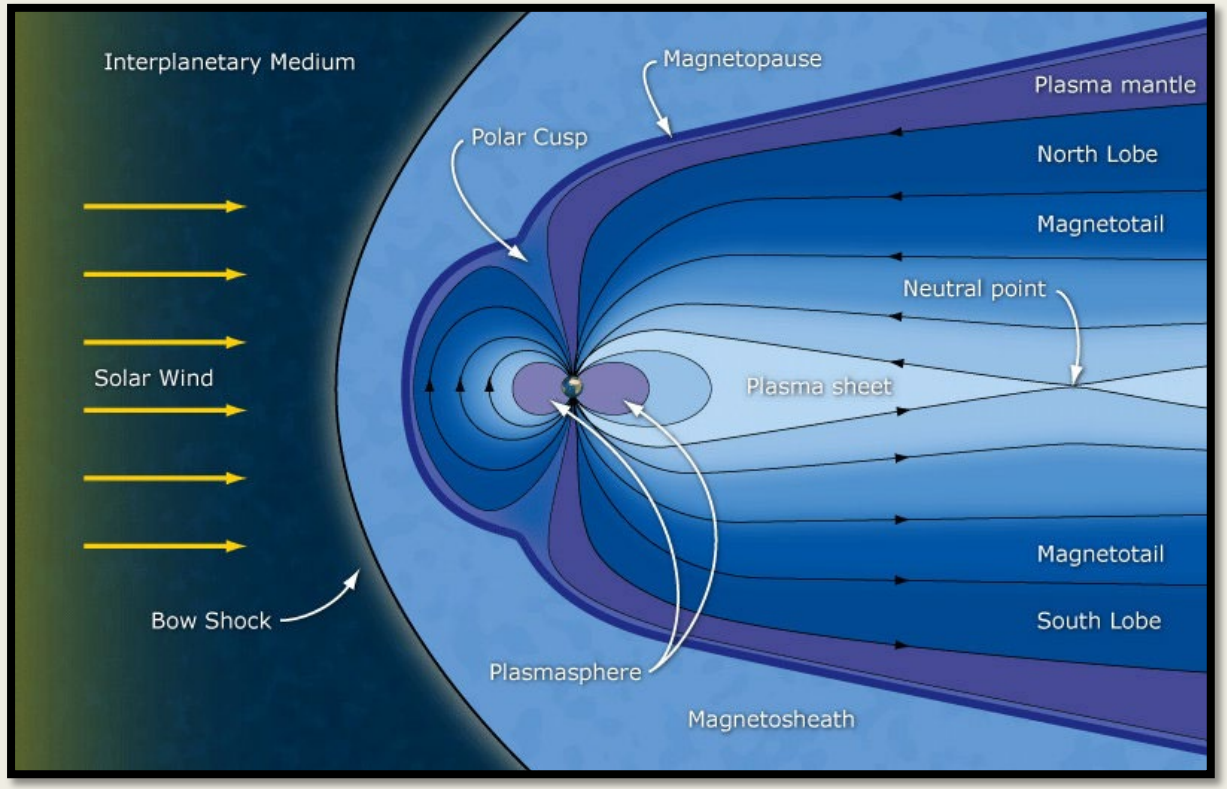
(G. Lapenta, 2012)



(Wikipedia, Larmor-Radius, 2022)

Earth‘s magnetopause

- Incoming solar wind
- Deflected around Earth‘s magnetic dipole field
- Frozen-in condition
- Magnetopause boundary layer
- Magnetosheath / Magnetosphere



(N. A. Case, 2014)

Earth‘s magnetopause

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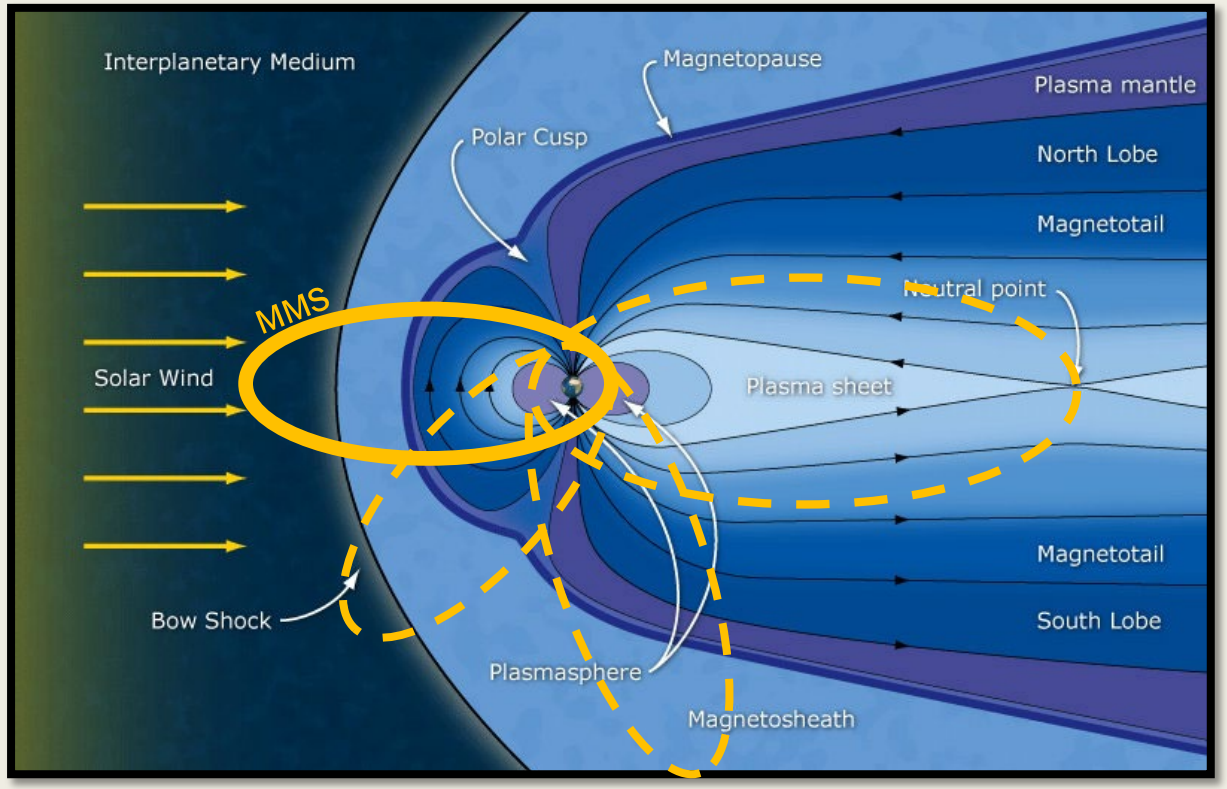
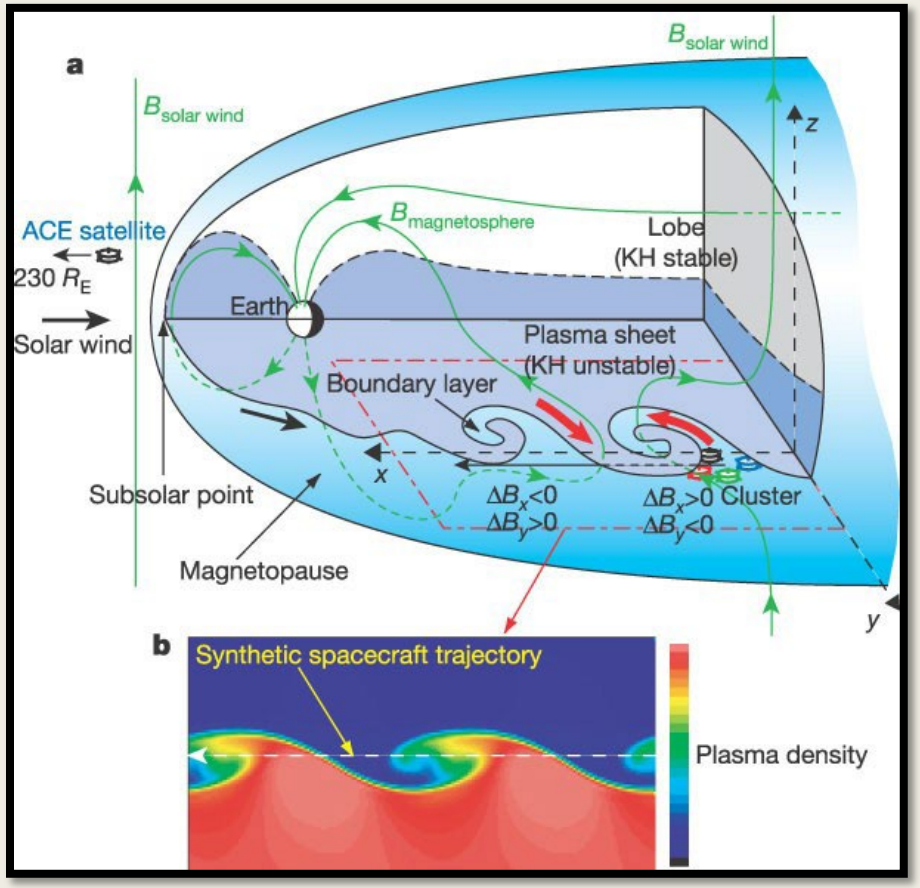
- Magnetospheric Multiscale (MMS)
  - *4 s/c in tetrahedral formation*
  - *measuring electric and magnetic fields and particle data*



(N. A. Case, 2014)

Kelvin-Helmholtz instability

- Velocity shear between magnetosheath and magnetosphere
- Sinusoidal waves develop into vortices
- Plasma mixing
- Difference in occurence of KHI between southward & northward IMF
- Why?



(H. Hasegawa, 2004)

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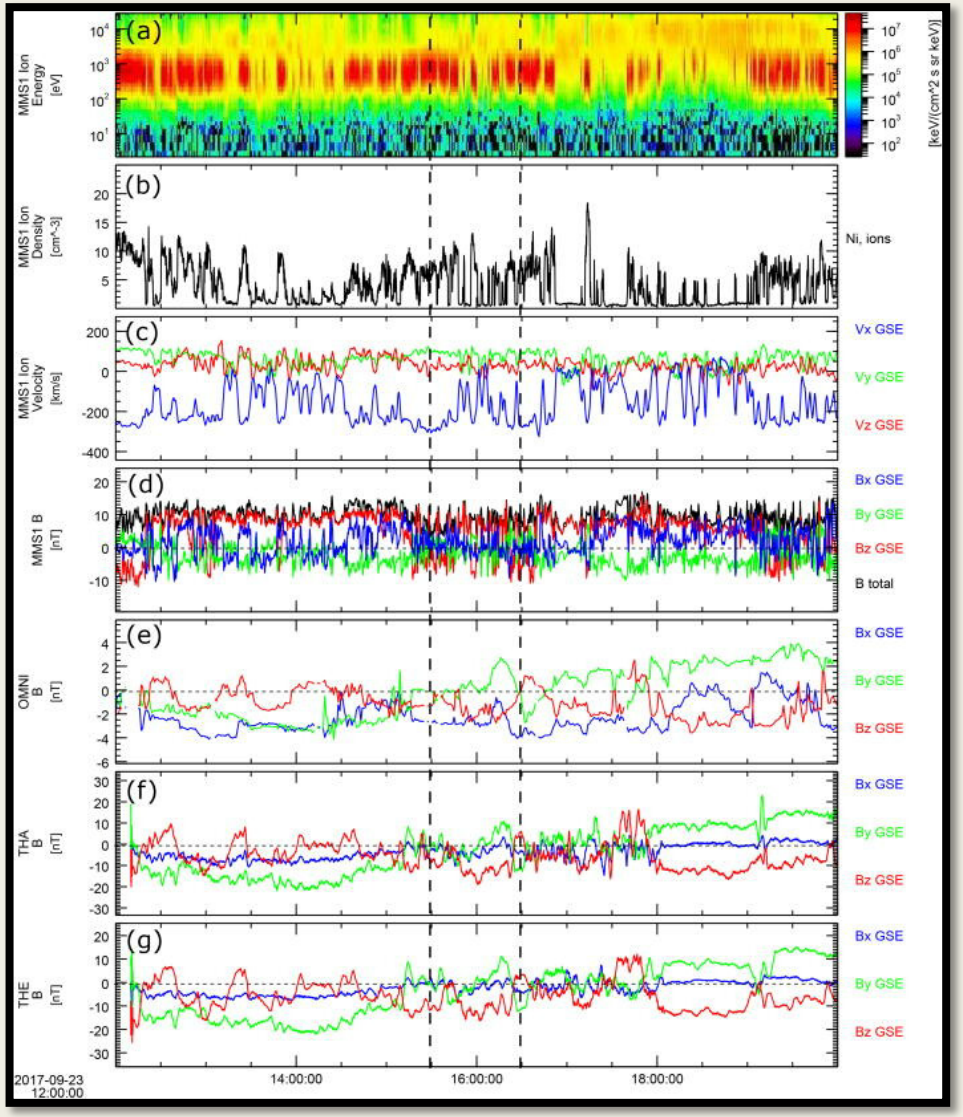
→ Study the KHI during southward IMF conditions from in-situ and simulation data [Blasl et al., 2022; Nakamura et al., 2022]



(K. A. Blasl, 2022)

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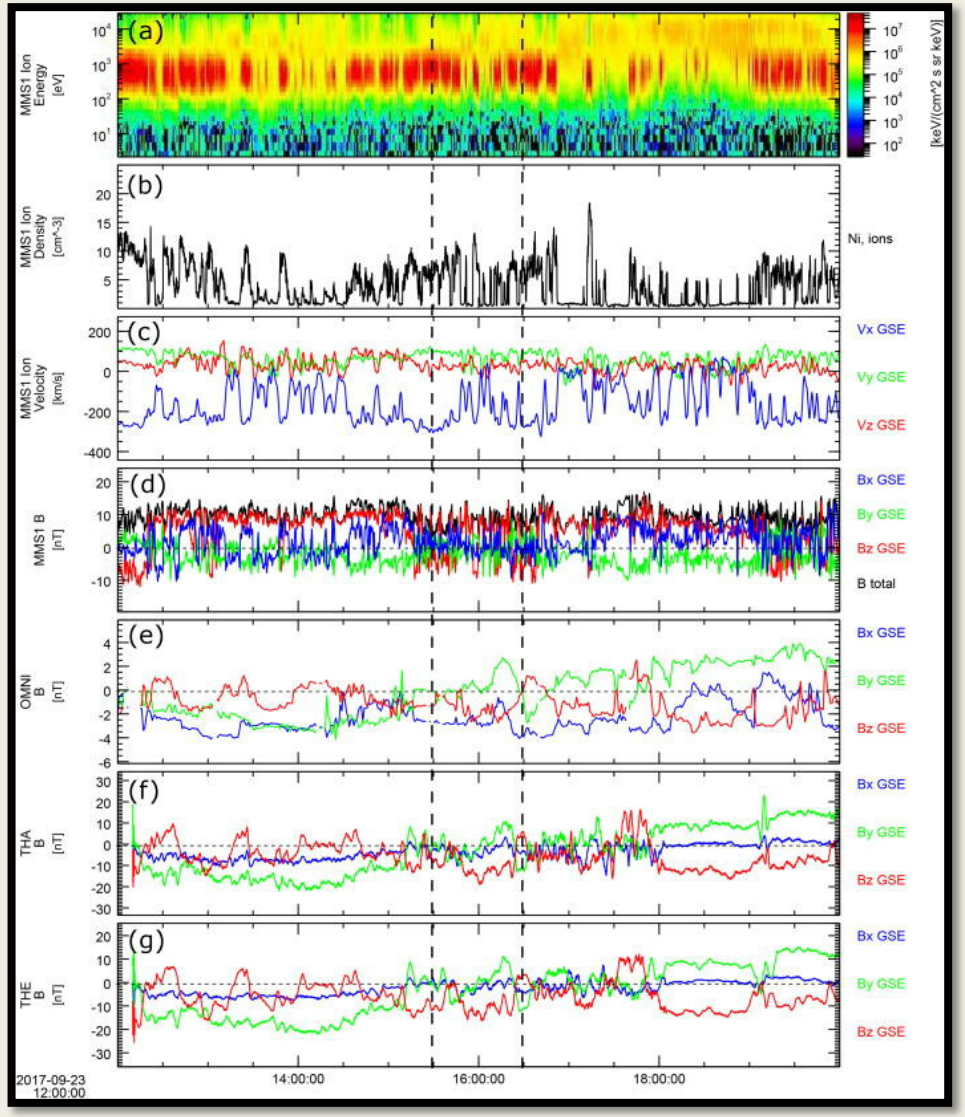
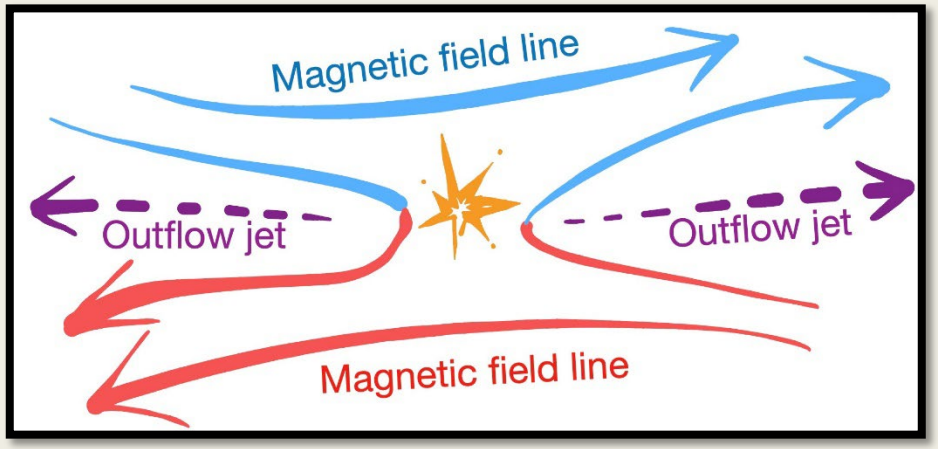
→ Study the KHI during southward IMF conditions from in-situ and simulation data
→ <u>Study related plasma effects</u>



(K. A. Blasl, 2022)

(Vortex-induced) reconnection

- Topological change of magnetic field lines
- Intense release of magnetic energy into kinetic energy
- Particles accelerated and heated
- Below ion scales only electrons get accelerated → electron-only reconnection



(Dartmouth College, 2022)

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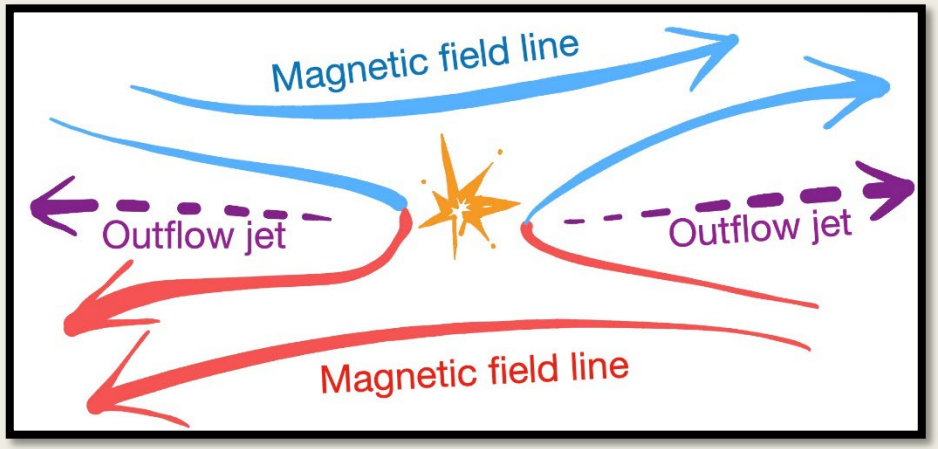

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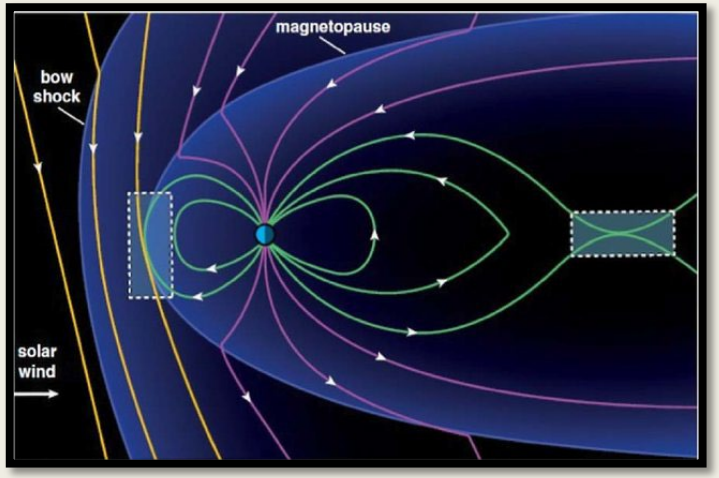
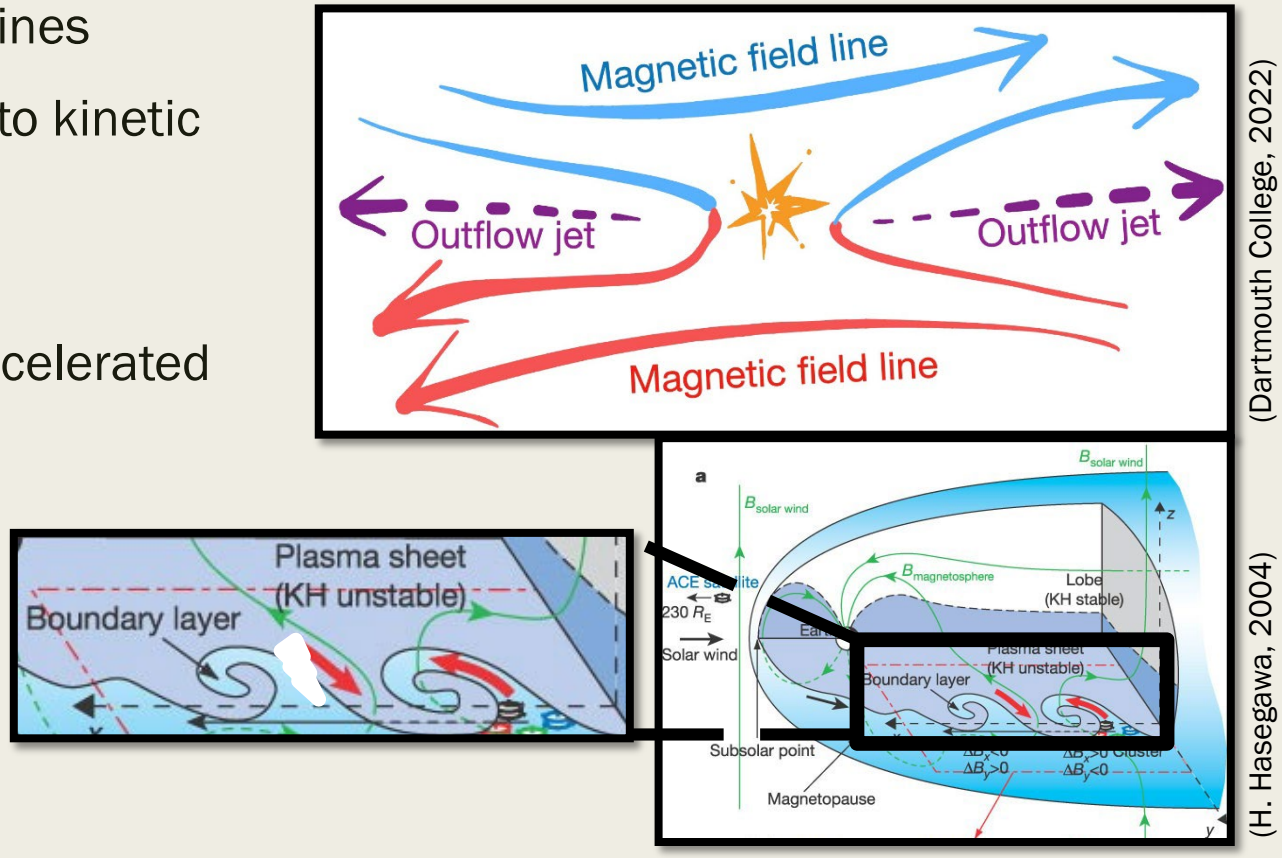


(L. Baldis, 2020)

(Vortex-induced) reconnection

- Topological change of magnetic field lines
- Intense release of magnetic energy into kinetic energy
- Particles accelerated and heated
- Below ion scales only electrons get accelerated → electron-only reconnection
- At dayside and nightside
- At Kelvin-Helmholtz vortices (Vortex-induced reconnection)

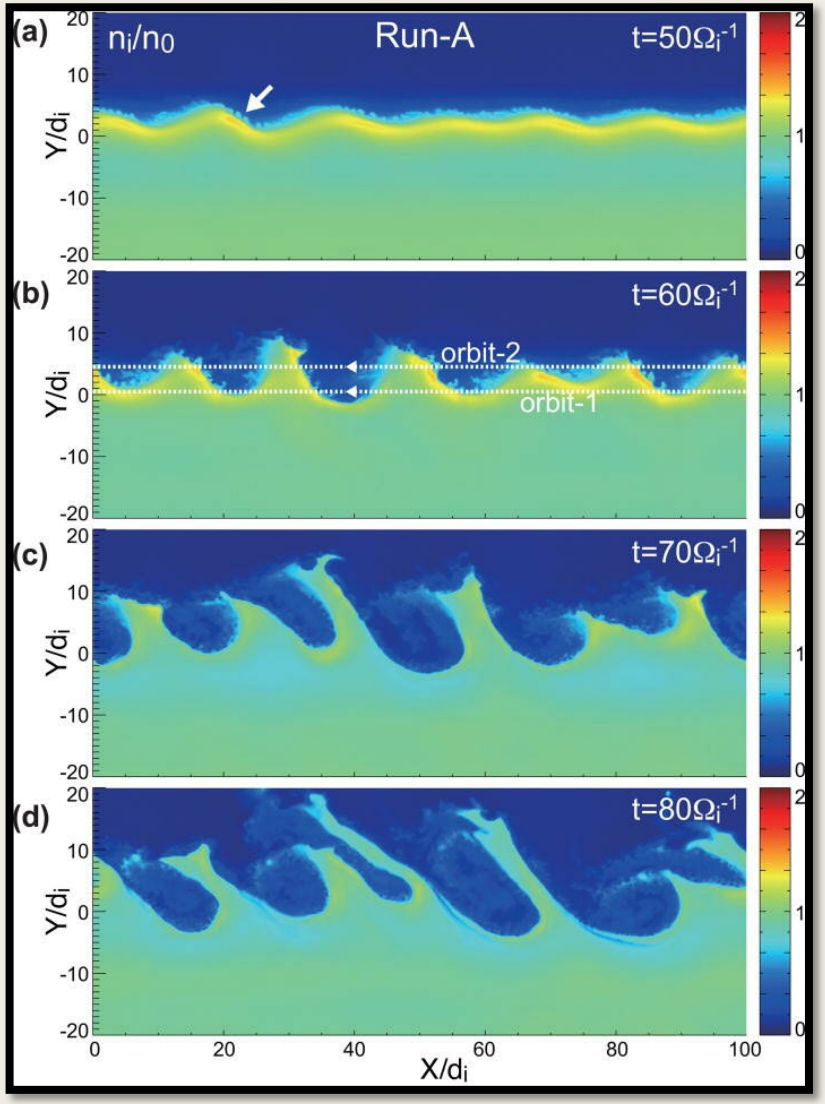


(Dartmouth College, 2022)

(H. Hasegawa, 2004)

Secondary instabilities

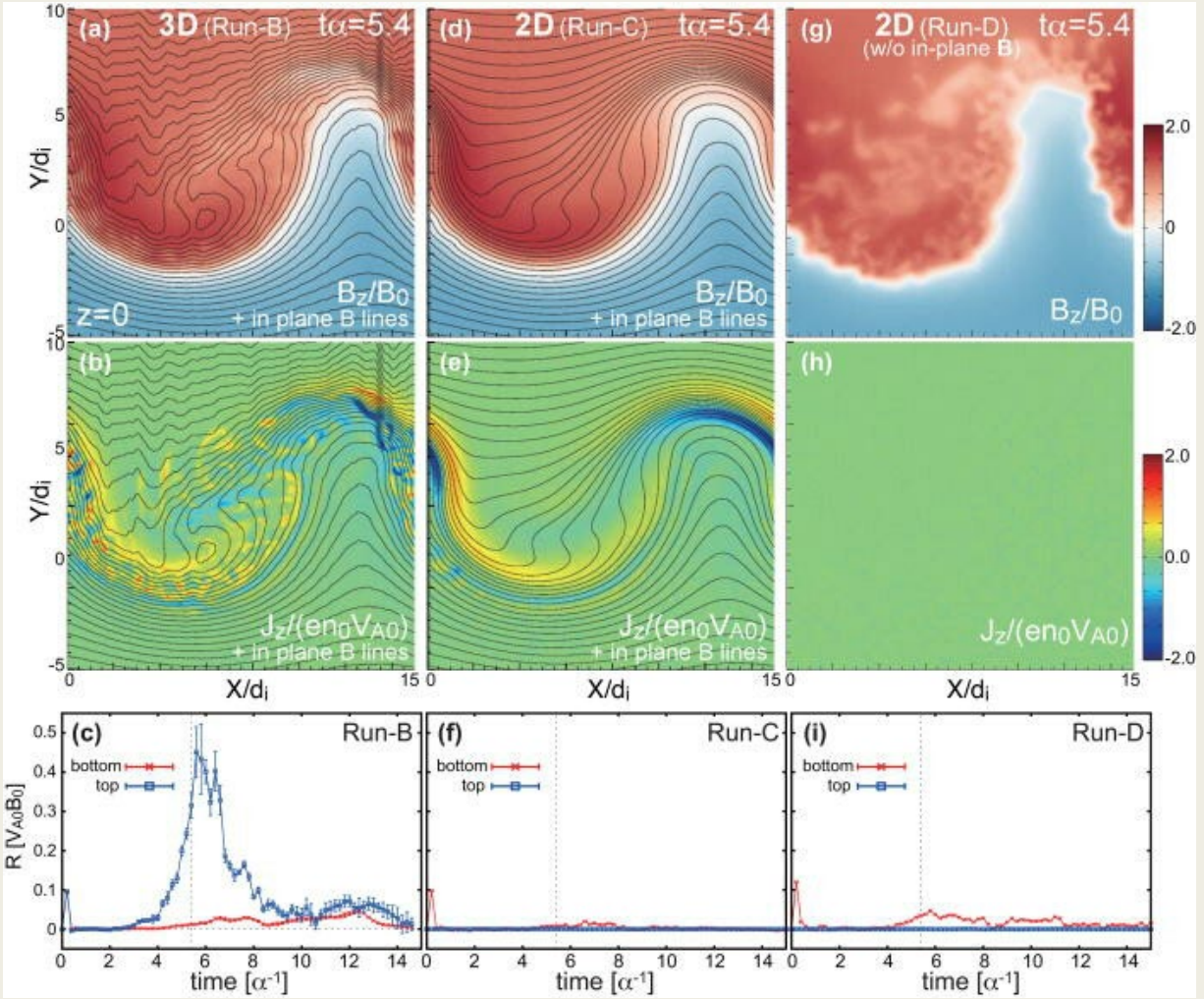
- Study with simulations (MHD, hybrid, kinetic)
- Vortex-induced reconnection
- Lower Hybrid Drift Instability → plasma mixing
- Rayleigh-Taylor Instability → vortex deformation
- Lead to differences in evolution and observational probability



(Nakamura et al., 2022)

Cross-process & Cross-scale

- **Idea: Electron-scale reconnection formed by the Kelvin-Helmholtz wave-induced lower hybrid waves**
- System-scale to electron-scale (cross-scale)
- KHI, LHDI, reconnection (cross-process)
- During observations we also see spatial and temporal evolution on electron scale → MMS



(Nakamura et al., 2022)

Summary & Outlook

- The KHI can effectively transport mass and energy across magnetospheric boundary layers
- Multi-scale and multi-process studies necessary to understand the KHI

- Combine different scales and processes and study their interplay
- Study the energy transfer across magnetospheric boundary layers in a systematic way

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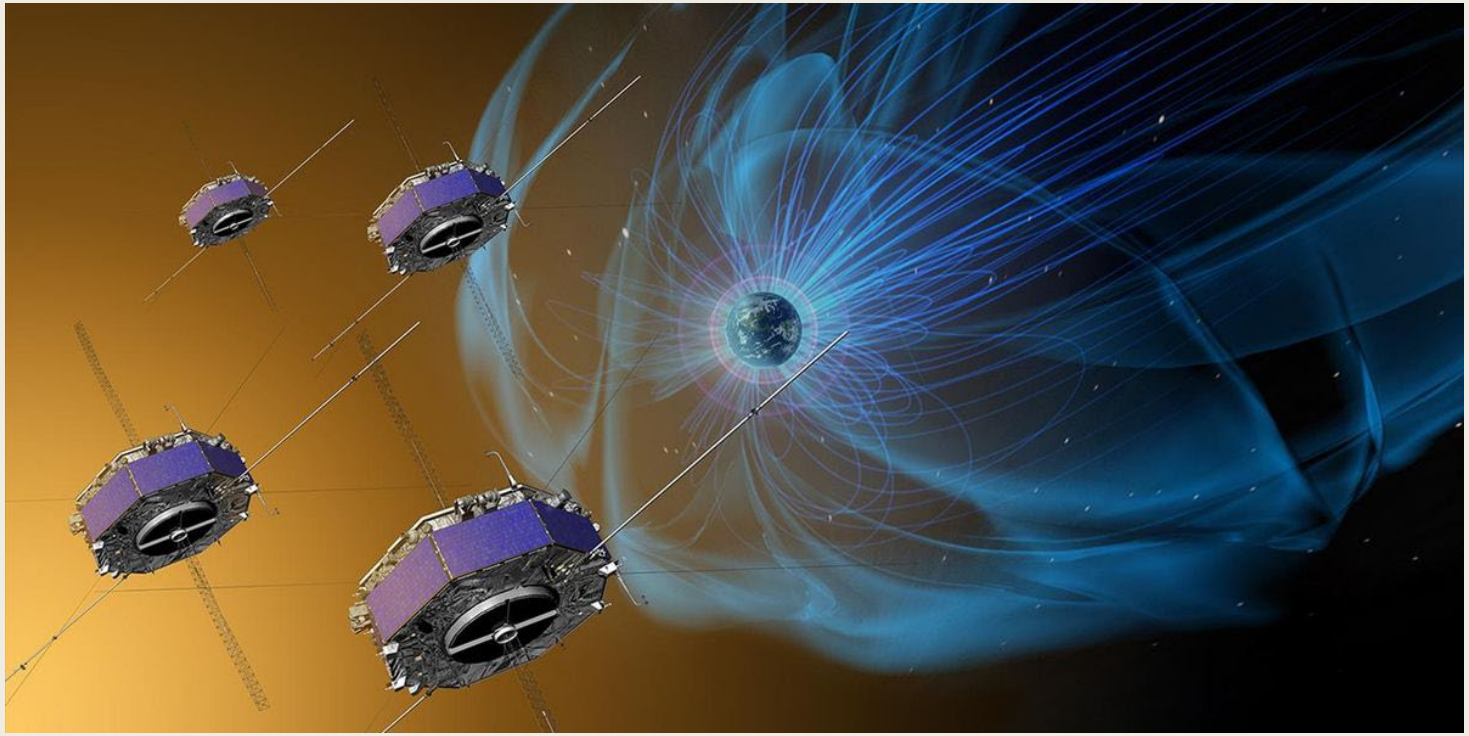
Thank you



(MMS - Courtesy of NASA)