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Energy conversion in magnetopause Kelvin-Helmholtz waves

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Energy conversion in collisionless plasmas is central to the plasma heating and particle energization problems in space and astrophysical plasmas. Though it is known that the electromagnetic energy is converted to the flow and random kinetic energy (via J.E), a detailed understanding of how the electromagnetic energy is converted into particle energy and finally dissipated to heat is still lacking. The Kelvin-Helmholtz (KH) instability is a flow shear instability that allows plasma mixing and energy transfer. It has been inferred in remote observations such as at Orion Nebula[1] and solar atmospheres[2], as well as observed in situ at planetary magnetospheric boundaries[3, 4], and more recently in the solar wind[5].

Motivated by the rich physics of KH waves, we consider energy conversion in turbulent plasmas induced by the KH instability at the Earth's magnetopause. With observations from the NASA's Magnetospheric Multiscale mission, we consider the energy conversion from (a) the electromagnetic fields into the flow[6] and (b) from the flow into thermal energy for each plasma species through the pressure work (via P.∇.v)[7].

We find that the KH vortex regions, where the magnetospheric and magnetosheath plasmas mix, are the key sites of energy conversion activities (see Figure 1 in shaded blue). Considering the cumulative energy conversion through various channels with time, we find that the accumulated energy conversion rate through the electromagnetic channel constantly increases. However, the cumulative energy conversion rate through the pressure work channel only increases when the KH waves reach the nonlinear stage of development. Moreover, while the energy conversion between flow and heat via P.∇.v is very dynamic for electrons, we find that the main contribution, which finally dissipates the flow energy into heat, comes from ions. By separating the contributions of J.E and P.∇.v into multiple terms, we will discuss kinetic processes that are likely responsible for the energy conversion. We will also discuss the partitioning of energy conversion through the different channels for each species. This work paves the way towards an understanding of energy transfer across scales in turbulent plasmas as mediated by magnetopause KH waves. This work is partially supported by grant RTA6280002 from Thailand Science Research and Innovation.

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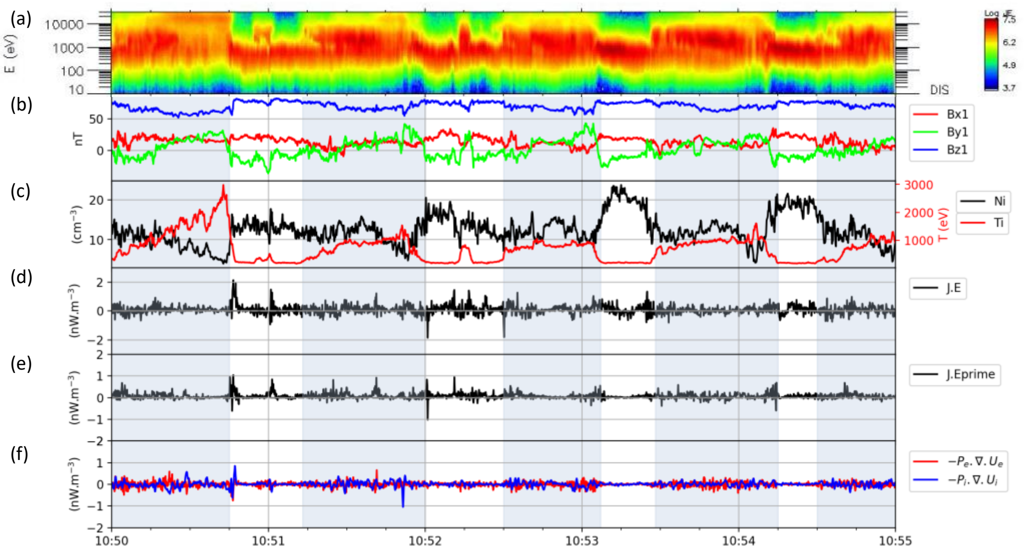

Figure 1. In situ observations of magnetopause KH waves on 8 Sep 2015 by MMS shown in (a) ion energy spectrogram, (b) magnetic fields, (c) ion number density and ion temperature. Energy conversion is shown for (d) J.E, (e) J.E' – electromagnetic energy dissipation in electron frame, and (f) pressure work P.∇.v for each plasma species. We highlight KH vortex regions, where energy conversion activities are stronger than outside regions, in blue.