Probing Preferential Heating in Turbulent Plasmas with MMS

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Abstract

Astrophysical plasmas are often collisionless, allowing them to deviate from local thermodynamic equilibrium and enabling different particle species-such as protons and electrons-to maintain distinct temperatures. Turbulence plays a critical role in mediating energy transfer from large-scale motions to small kinetic scales, where it is ultimately dissipated as heat. However, a fundamental open question remains: how is this turbulent energy partitioned between protons and electrons? Does turbulence preferentially heat one species, or is the energy distributed more evenly? This question is central to several unsolved problems in astrophysics, including the heating of the solar corona and the radiative output of accretion disks around black holes. Despite significant theoretical and numerical advances over the past three decades aimed at predicting the proton-to-electron heating ratio, comprehensive in-situ measurements remain limited. In this study, we use high-resolution data from NASA's Magnetospheric Multiscale (MMS) mission to investigate turbulent heating in the Earth's magnetosheath. By analyzing the pressure-strain interaction, we identify the spatial scales at which heating becomes efficient and examine how energy is partitioned between particle species as a function of key plasma parameters. Our findings deepen our understanding of the interplay between turbulence and plasma heating, with broader implications for interpreting observations of remote astrophysical systems.

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