Multiscale Energy Conversions in Collisionless Plasma Turbulence: Dynamo, Reconnection, and Kinetic Dissipation

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Collisionless plasma turbulence exhibits a multiscale chain of energy-conversion processes: correlation-scale flows stretch and shear magnetic fields, magnetic structures reconnect at sub-ion scales, and kinetic interactions convert bulk-flow energy into particle heating at ion and electron scales. Clarifying how these processes coexist and how they sequence in time is essential for understanding turbulent energy transfer in weakly collisional plasmas. Using high-resolution tetrahedral MMS observations in the magnetosheath, we compute a suite of diagnostics that quantify the dynamical role of velocity-gradient structures, including field-aligned magnetic stretching, compressive motions, pressure–strain interactions, field–particle energy exchange, and pressure-anisotropy instability measures. Together, these diagnostics enable an assessment of the occurrence rates of magnetic-field amplification, reconnection, and dissipation processes—key ingredients for understanding kinetic-scale dynamics in collisionless space plasmas.