Abstract Submitted
for the DPP17 Meeting of
The American Physical Society

Kinetic simulations of turbulence in relativistic plasmas[1]

VLADIMIR ZHDANKIN, JILA, DMITRI UZDENSKY, GREGORY WERNER, University of Colorado at Boulder, MITCHELL BEGELMAN, JILA, University of Colorado at Boulder — We investigate driven turbulence in collisionless, magnetized, relativistic pair plasma by applying particle-in-cell simulations with up to 1024^3 cells and 200 billion particles. The results agree with predictions from magnetohydrodynamic turbulence phenomenology at inertial-range scales, including a power-law magnetic energy spectrum with index near -5/3, scale-dependent anisotropy of fluctuations described by critical balance, log-normal distributions for particle density and internal energy (related by a 4/3 adiabatic index), and the presence of intermittency. We also show that the magnetic energy spectrum steepens (to index near -4) at sub-Larmor scales, possibly indicating a kinetic cascade. We demonstrate efficient nonthermal particle acceleration that leads to a power-law particle energy distribution, which hardens with increasing magnetization (becoming shallower than -2 for sufficiently high magnetization) and softens with increasing system size. We discuss the mechanisms of particle acceleration and propose an empirical formula for the distribution index. Our results imply that turbulence can be a viable source of energetic particles in high-energy astrophysical systems, such as pulsar wind nebulae, if scalings asymptotically become insensitive to the system size.

[1]This work was supported by NSF grant AST-1411879.

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Date submitted: 19 Jul 2017 Electronic form version 1.4