

APR08-2008-000114

Abstract for an Invited Paper
for the APR08 Meeting of
the American Physical Society

Shock Waves in the Large Scale Structure of the Universe

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Cosmological shock waves result from the supersonic flow motions induced by hierarchical formation of nonlinear structures in the universe. Like most astrophysical shocks, they are collisionless shocks which form in the tenuous intergalactic plasma via collective electromagnetic interactions between particles and electromagnetic fields. The gravitational energy released during the structure formation is transferred by these shocks to the intergalactic gas in several different forms: in addition to the gas entropy, cosmic rays are produced via diffusive shock acceleration, magnetic fields are generated via the Biermann battery mechanism and Weibel instability, and vorticity is generated at curved shocks. Here I review the properties, roles, and consequences of the shock waves in the context of the large scale structure of the universe.