APR12-2012-000647

Abstract for an Invited Paper
for the APR12 Meeting of
the American Physical Society

Particle Acceleration at Astrophysical Shocks: Are Self-Excited Magnetic Fluctuations Important?

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The physics of particle acceleration by astrophysical shocks is discussed with particular emphasis on the importance of so-called self-excited magnetic fluctuations. The origin of cosmic rays and other high-energy charged particles in space is an important unsolved problem in astrophysics. Acceleration in the converging plasma flows across a collisionless shock is the best mechanism to explain the majority of the observations. While direct comparisons between the simplest version of the acceleration theory – so-called diffusive shock acceleration – and in situ observations has revealed some discrepancies, these are reasonably accounted for by extending the simple theory to more realistic spatial and temporal geometries. A particularly important issue in shock acceleration theory is the maximum energy attainable. This is governed by the spatial diffusion of particles near the shock. When the diffusion scale is short, the particles remain near the shock and are accelerated to high energies rapidly. If the diffusion scale is long, the particles spend most of their time away from the shock and the acceleration is slow. The diffusion scale is governed by magnetic turbulence in the vicinity of the shock. It has long been thought that the energetic particles themselves excite magnetic fluctuations near the shock, which reduces their diffusion scale. However, such waves are not commonly observed in heliospheric shocks. It can be shown that pre-existing magnetic fluctuations, which are known to exist in astrophysical plasmas, are usually sufficient to account for the observed high energies for a variety of phenomena ranging from solar-energetic particles, to anomalous cosmic rays, to cosmic rays accelerated by a supernova blast wave.