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Shock Drift Acceleration in presence of turbulence: A simple model

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Analytic treatments of particle acceleration by collisionless shocks have commonly been based on the assumption that the shock surface is quasi-planar with length scales larger than the particle gyroradius. Within this framework, the derived particle distributions are not in full agreement with the observations. Recent theoretical studies as well as numerical simulations indicate that ion scales shock fluctuations could account for several features observed in shock-associated energetic particle velocity distributions. We have developed a simple model based on the shock drift acceleration mechanism in which both the shock normal direction and the shock mirror ratio $N = B_2/B_1$ are subject to random fluctuations. While, the maximum particle energy gain is dependent upon N, the pitch angle distribution is dependent to both N and shock geometry. The fluctuations could be induced by shock turbulence inherent to the shock nonstationarity occuring for high Mach number and for a wide range of shock geometries. For low energy particles, we derive the probability distributions functions $f(v_{||})$ and $f(v_{\perp})$ of ions escaping upstream; we show that the distributions significantly deviate from the conventional Maxwellian signature. At higher energy, the derived energy spectrum extends to higher energy in comparison to the one obtained when the fluctuations are suppressed. The derived results are compared to ion distributions and spectra observed upstream of the Earth bow shock. They also in turn allow us to draw possible analogy with neutral fluid turbulence involving higher moments of the particle distribution.