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# Diffusive shock acceleration: nonclassical model of cosmic ray transport

Galactic cosmic rays up to about 100 PeV are believed to be accelerated by shock waves at supernova remnants by a Fermi process called diffusive shock acceleration (DSA). In this process, a test particle undergo a number of encounters with both inhomogeneities in the interstellar space and with shock and gain an energy.
All collisionless shock calculations should approximate particle transport, and most models assume that fast particles obey standard diffusion in homogeneous medium where the mean-square displacement is proportional to time. It is known that for highly relativistic particles, this DSA gives rise to a power-law energy distribution with spectral index $\gamma = (r + 2)/(r - 1)$, where r is the compression ratio of the shock. The standard cosmic rays spectral index for a maximal compression ratio of four equals to $\gamma = 2$.
However, during last few decades many evidences of the existence of multiscale structures in the Galaxy have been found. Filaments, ribbons, clouds and voids are entities widely spread in the interstellar medium. A rich variety of structures can be related to the fundamental property of turbulence called intermittency. The fluctuation (or small-scale) turbulent dynamo mechanism, and random shock waves produce highly intermittent magnetic fields with random magnetic structures surrounded by weaker fluctuations.
Non-homogeneous character of matter distribution and associated magnetic field should be adequately incorporated into the cosmic ray diffusion model. A physically reasonable way for the generalization of the normal diffusion model is to abandon the assumption about statistical homogeneity of irregularities' distribution in favor of its fractal-like distribution and nonclassical diffusion.
In this work the theory of diffusive shock acceleration is extended to the case of nonclassical transport with Lévy flights and Lévy traps, when the mean square displacement grows nonlinearly with time. In this approach the Green function is not a Gaussian but it exhibits power-law tails. By using the propagator appropriate for nonclassical diffusion, it is found that energy spectral index of particles accelerated at shock fronts is $\gamma = [\alpha\ (r + 5) - 6\ \beta]/[\alpha(r - 1)]$, where $\alpha$ ($0 < \alpha < 2$, $r \to \infty$) and $\beta$ ($0 < \beta < 1$, $t \to \infty$) are the exponents of power-law behavior of Lévy flights and Lévy traps, respectively.
We note that this result coincides with standard slope at $\alpha$=2, $\beta$=1 (normal diffusion), and also includes those obtained earlier for the subdiffusion ( $\alpha$=2, $\beta$<1; Kirk J.G et al., AA. 1996) and superdiffusion regimes ( $\alpha$<2, $\beta$=1; Perri S. et al., ApJ. 2012).

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