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Superdiffusive shock acceleration

S. Perri and G. Zimbardo
Dipartimento di Fisica, Universita' della Calabria, Rende, Italia

Recently it has been found that the regimes of propagation of energetic particles close to interplanetary shocks in the solar wind are characterized by superdiffusion, i.e. by a mean square displacement growing superlinearly with time. Therefore, we extend the theory of diffusive shock acceleration (DSA) to the case of superdiffusion. Superdiffusion can be described by a statistical process called Levy random walk, in which case the propagator is not a Gaussian but rather it has power law tails. Using the scaling properties of the propagator appropriate to Levy random walk, it is found that the energy spectral indices are harder than those obtained by DSA. Energy spectral indices as low as one can be obtained for relativistic particles, and this allows to explain the observations of electron flat spectra in the Crab Nebula, otherwise very puzzling. Also, at the solar wind termination shock the spacecraft Voyager 2 observed a spectral index of 1.25 for ions up to 3.5 MeV, lower than that corresponding to the observed compression ratio. In this case, too, superdiffusive shock acceleration (SSA) allows to obtain a better agreement with the observations. A new scaling for the acceleration time is also found, which corresponds to shorter times with respect to the case of normal diffusion, so that higher energies can be obtained within the system age.