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Nonlocal relativistic diffusion (NoRD) model of galactic cosmic ray propagation

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Most of the modern calculations of galactic cosmic-ray (GCR) propagation are based on the local diffusion model acceptable for the Brownian motion (BM) of a heavy particle through the system of uniformly distributed uncorrelated (i.e. non-interacting) molecules. However, about 60 years ago it has been found that the BM model is unable to adequately describe the diffusion in turbulent media [1-3]. Without doubt, interstellar medium belongs to this class. For this reason, the nonlocal transport theory based on fractional calculus is developed in [4]. The series of calculations performed to 2010 confirmed the effectiveness of the approach, improved parameters and led eventually to involving the relativistic speed limit [5]. The obtained model was described in [5,6] and called NoRD in [7].

In this work, the key parameters of the NoRD model are obtained by specifying the Kolmogorov spectra of turbulence near the inertial interval edges. This specification leads to tempered power law distributions of free path lengths. The fractional differential operators are modified into their tempered generalizations. We coordinate energy dependent diffusion coefficient and truncation factor. For energies small enough for interested temporal and spatial scales, diffusion is normal. Extrapolating this dependence on large energies, we observe superdiffusive motion and tendency to ballistic motion. NoRD propagators are calculated and analyzed. Under basic assumptions about the GCR origin, the relativistic principle of maximum speed of propagation leads to the steepening of the equilibrium spectrum at energies close to the observed 'knee'. In frames of the NoRD-model, we estimate the role of the local sources and the mass composition at PeV-energies.

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