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On the nature of cosmic ray transport nonlocality

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The commonly accepted CR transport theory is based on the diffusion equation, which in turn follows from the Boltzmann kinetic equation. The latter was derived for multiple collisions of particles with local formations (atoms, molecules) under the assumption of their statistical independence, more precisely, of the Poisson nature of the ISM ensemble. It is this property that is responsible for the appearance of local operators in diffusion-type equations. However, the interstellar cloud structure, coupled with its turbulent nature, is an example of a strongly correlated medium whose motion cannot be described in terms of perturbation theory. To describe it, the author proposed a generalization of the Ornstein-Zernike integral equation for the ISM correlation function (in terms of cloud concentration), which is consistent with the results of numerical MHD calculations and observation data. The important mathematical tool connecting two dynamical systems (CR and ISM) is a new 4-parameter approximation of the power spectrum of turbulent fluctuations. It is consistent with the classical power forms in the inertial interval and gives a smooth transition beyond its limits.

The report unfolds the logic of the appearance on the stage of non-local operators (fractional derivatives), concept of fractals and multifractals. The latter also includes the mesofractal ISM model discussed in the report, which demonstrates fractal properties on small scales and transforms into a homogeneous medium upon transition to large scales. In other words, this model has asymptotic locality, and one can speak of a locality horizon beyond which the usual transfer theory becomes valid.

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