Geophysical Research Abstracts, Vol. 8, 03320, 2006
SRef-ID: 1607-7962/gra/EGU06-A-03320

Numerical simulation of anomalous, non Gaussian transport of charged particles in anisotropic magnetic turbulence

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Space plasma phenomena like solar energetic particle observations, diffusive shock acceleration, and particle entry into the magnetosphere, sensitively depend on the propagation of charged particles in the presence of magnetic turbulence, yet our physical understanding of such propagation is still poor. Indeed, very different transport regimes can be found depending on the relevant scales of the turbulence, on the turbulence anisotropy, and on the turbulence level. In order to clarify these issues, the transport of energetic particles in a mean magnetic field and the presence of anisotropic magnetic turbulence is studied numerically, for parameter values relevant to the solar wind. A numerical realization of magnetic turbulence is set up, in which we can vary the type of anisotropy by changing the correlation lengths $l_x,\ l_y,\ l_z$. We find that for $l_x,\ l_y \gg l_z$ transport can be non Gaussian, with superdiffusion along the average magnetic field and subdiffusion perpendicular to it. Also, the spatial distribution of particles is clearly non Gaussian. Such regimes are characterized by a Lévy statistics, with diverging second order moments. Increasing the ratio l_x/l_z, nearly Gaussian diffusion is obtained, showing that the transport regime depends on the turbulence anisotropy. We also change the ratio ρ/λ (Larmor radius over turbulence correlation length), finding that anomalous regimes are obtained when $\rho/\lambda \ll 1$, while normal diffusion is obtained for $\rho/\lambda \simeq 1$. New anomalous regimes appear when $\rho/\lambda > 1$. We show how the finding of perpendicular subdiffusion depend on the exponential separation of field lines, too. A new regime, called generalized double diffusion, is proposed for the cases when particles are able to trace back field lines. Applications to the transport of energetic particles in the solar wind are discussed.