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Longitudinal motion effects on transverse particle transport by random field

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Transport of a passive scalar in a given field is a common problem in plasma systems, the atmosphere, ocean flows, etc. It can be formulated as a problem to recover the temporal evolution of a particle ensemble in a given field based on known statistical characteristics of this field. An important peculiarity in such a system concerns the interplay of two time scales, namely the correlation time of the given field and the particle distribution function evolution time. When the correlation time of the random field is much shorter than the particle distribution function evolution time, the well-known Brownian motion approach is applicable to such a system. When the situation is reversed, new assumptions are needed to build a correct statistical approach. The most vivid effects of these time scales interplay are obtained for two-dimensional systems, yet the three-dimensional ones are also interesting from a practical point of view.

For the two-dimensional transport of the passive scalar, we formulated a unified statistical approach that takes into account finite and infinite correlation time and finite Larmor radius effects, and that is able to correctly recover the transition from a sub-diffusive behavior for long correlation time to a diffusive one for short correlation time of a random electric field. Such behavior of the asymptotic diffusion coefficient is inseparable from particle trapping effects and the integral of motion that is defined in two-dimensional systems. Although the three-dimensional systems lack such an integral of motion, the effect of slow motion along the third dimension is yet to be examined by our statistical approach.

In this work, we consider a three-dimensional test particle motion in crossed random electric and constant magnetic fields. We present a statistical approach based on a two-dimensional one that takes into account particle motion along a constant magnetic field. The calculations of transport coefficients obtained by this statistical approach are validated by direct numerical simulation. The effects of finite Larmor radius, finite correlation time and particle motion along the magnetic field on particle transport across the magnetic field are examined.

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