RESONANT-PARTICLE TRANSPORT AND RESONANCE-BROADENING EFFECTS

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Fluctuating electric and magnetic fields in space plasmas typically lead to transport of charged particles with respect to one or more of the adiabatically invariant quantities that serve as canonical coordinates in Hamiltonian-Jacobi mechanics. Application of quasilinear plasma theory to such processes typically leads to particle-diffusion coefficients proportional to the spectral density of relevant electric and/or magnetic fluctuations, evaluated at a characteristic frequency of the particle's underlying adiabatic motion. Depending on various physical and geometrical considerations, the appropriate characteristic frequency can be a gyration, bounce, or drift frequency, or it can be some integer multiple (i.e., harmonic) thereof. However, a rich variety of dynamical and geometrical effects can lead to meaningful broadening of the various resonances, thereby requiring that the requisite spectral densities be averaged over appropriate bandwidths (rather than just be evaluated at well defined resonance frequencies) in order to determine the corresponding transport coefficients. Particle diffusion itself is one such resonance-broadening effect. Inhomogeneity of the underlying magnetic field is another. These two resonance-broadening effects act separately in the case of gyro-resonance (violatring the first adiabatic invariant) but act together in the case of drift resonance (violating the third adiabatic invariant so as to cause radial diffusion of the representative particles and thus to randomize their drift frequencies). Azimuthal asymmetry of the underlying magnetic field in a planetary magnetosphere brings harmonics of the drift frequency into resonance with the spectrum of electric and/or magnetic fluctuations, but also makes the bounce frequency of a trapped particle time-dependent along its drift shell. Such effects limit the duration of resonant behavior and thus (through considerations that amount to a classical application of the uncertainty principle) lead to characteristic bandwidths of the response functions over which the various spectral densities need to be averaged in order to obtain good approximations for the corresponding particle-transport coefficients in space plasmas.