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Turbulent transport via wave-particle decorrelation in collisionless plasmas¹

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Understanding the transport mechanism of anisotropic turbulence in collisionless magnetized plasmas is both a fundamental physics issue and a necessary step for projecting confinement properties of next-generation fusion reactors such as the International Thermonuclear Experimental Reactor (ITER). To delineate the role of fluid convection vs. kinetic scattering in turbulent transport, we study the electron heat transport arises from the nonlinear wave-particle interaction for the parallel resonance of the electron temperature gradient mode and for the precessional resonance in collisionless trapped electron mode in large scale kinetic simulations using the gyrokinetic toroidal code, GTC [Lin et al, Science 281, 1835 (1998)]. We found that wave-particle decorrelation is the dominant mechanism responsible for the electron heat transport driven by the electron temperature gradient (ETG) turbulence characterized by radial streamers. The radial transport is driven by the local fluctuation intensity and the phase-space island overlapping leads to a diffusive process with a time scale close to the wave-particle decorrelation time associated with the spectral width of the fluctuations. The kinetic time scales relevant to the transport process are much shorter than the fluid turbulence auto-correlation time, eddy turnover time, and linear growth time. Therefore, the extrapolation of the transport level from present-day experiments to future larger devices could be over-pessimistic, if the simplistic mixing length argument is invoked with the streamer length as the random walk spatial step size and the fluid time scale as the time step size. The mechanism of electron heat transport in collisionless trapped electron mode (CTEM) turbulence through de-tuning of precessional resonance will also be reported.

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