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Accounting for the Heisenberg and Pauli principles in the kinetic approach to neutrino oscillations

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While oscillations of solar neutrinos are usually studied using the single-particle quantum-mechanical approach, flavor conversions of supernovae neutrinos are typically analyzed using the kinetic equation for the matrix of densities due to the necessity of including also the scattering processes. Using the Wigner formulation of quantum mechanics we show the equivalence of the quantum-mechanical and kinetic approaches in the limit of collisionless neutrino propagation (in a background medium). We also argue that solutions of the kinetic equation account for the Heisenberg uncertainty principle and the related effect of wave packet separation (for single neutrinos), as well as the Pauli exclusion principle, if the initial conditions are consistent with these fundamental quantum principles. Such initial conditions can be constructed e.g. by identifying the matrix of densities with the (reduced) single-particle Wigner function computed using initial conditions for the neutrino wave function. These constraints on the initial conditions may have an impact on the phenomenology of supernovae neutrinos.

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