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Neutrino Flavor Conversion in Supernovae: Quantum Kinetics and Astrophysical Implications

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High-energy astrophysical events, such as core-collapse supernovae and binary neutron-star mergers, are promising sources of detectable gravitational waves. In these extremely dense environments, neutrino transport plays a crucial role in shaping the dynamics and observables. However, most numerical models to date employ classical neutrino transport, neglecting quantum kinetic effects. In dense neutrino gases, neutrinos can change their flavors via nonlinear collective oscillations. Recent studies have revealed that quantum kinetics can induce dramatic flavor evolution over short spatial and temporal scales, fundamentally altering the neutrino radiation field in such astrophysical events.

We have performed numerical simulations based on the quantum kinetic equations and found that the neutrino system evolves toward an asymptotic state through turbulent-like cascades and collisional processes with background matter. Moreover, by modeling the asymptotic states, we are able to incorporate the effects of quantum kinetics into classical transport frameworks without solving the full quantum kinetic equations directly. In this talk, we will present our latest results and discuss the astrophysical implications of nonlinear neutrino flavor conversion, particularly its potential impact on the dynamics of core-collapse supernovae.

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