# Non-Markovian character, irreversibility, and entanglement entropy of real-time quantum many-body dynamics

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In 1872 the Boltzmann introduce an equation which describes the irreversible Markovian dynamics of a classical many-body system in terms of the mass probability where are the coordinates momenta of a "fluid particle." This equation has been extended to quantum many-body systems by Nordheim (1928) and Uehling and Uhlenbeck (1933), by introducing a generalized the collision integral and in the case of quantum systems, where is replaced with the Wigner transform of the one-body density matrix. Either the classical or quantum extension of the Boltzmann equations have an eerie similarity with the Kohn-Sham Time-Dependent Density Functional Theory (TDDFT) equations (extended to fermionic superfluid systems) which are formulated in terms of the one-body density matrix. The main difference between the two formulations is that the quantum Boltzmann equation is formulated in terms of one-body probabilities, while the TDDFT equations are formulated in terms of quantum single-particle amplitudes and thus capable of describing interference and quantum coherence phenomena.

The extension of TDDFT is mathematically equivalent to the time-dependent many-body Schrödinger equation at the one-body density level. The presence of collisions in TDDFT leads to conspicuous a non-Markovian time evolution along with irreversibility and also to quantum entanglement, even though the quantum dynamics is at the same time dissipative, aspect absent in the quantum extension of the Boltzmann equation due to Nordheim and Uehling and Uhlenbeck, which are still widely used in the description of quantum systems, which cannot describe quantum turbulence, when quantum vortices cross and reconnect. I will present several examples of the quantum dynamics of the decay of superfluid vortices in the Unitary Fermi Gas and related phenomena in nuclear systems.