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Is heavy quark diffusion applicable? – A new time scale introduced by decoherence

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Interaction of heavy quarks with particles in the quark-gluon plasma (QGP) results in the heavy quark energy loss. In the nonrelativistic regime, the effective theory for this process is the Langevin equation, a classic example in the nonequilibrium physics. In the heavy-ion collisions, several studies have applied the Langevin dynamics to phenomenology and tried to interpret the experimental data of nuclear modification factor (R_AA) and elliptic flow (v2) of charm quarks.

In this talk, I would like to introduce a new aspect to the Langevin dynamics, namely the dynamics of heavy quark color charge [1]. In the perturbative picture, each scattering rotates heavy quark color into a new color state and causes a macroscopic superposition state (Schrödinger's cat state) of the momentum. To derive classical descriptions of the Langevin dynamics, the quantum interference of the superposition must be destroyed by decoherence. I estimated this time scale to be \sqrt(M/\gamma), where \gamma is the momentum diffusion constant of heavy quarks. This time scale should be the lower limit of the discretization of the Langevin equation. Interestingly, this is estimated to be about 3-5fm for charm and bottom quarks, which is not small enough compared to the QGP lifetime so that the naïve application of Langevin equation to heavy-ion physics might be questioned.

Reference:
[1] Yukinao Akamatsu, arXiv:1503.08110 [nucl-th].

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