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The bubble wall velocity: from the local Boltzmann equations to the non-local Kadanoff-Baym equations

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There are two common methods to compute the bubble wall velocity for the cosmological phase transitions: the fluid method, which analyzes the macroscopic fluid system, and the local Boltzmann equations; the microscopic method, which studies the force acting on the bubble wall by the particle interactions. However, those two methods are not consistent with each other. In this study, we present a comprehensive analysis of the friction force and velocity for the bubble wall in the early universe cosmological phase transitions. We offer a systematic framework to solve that inconsistency between two common methods by rederiving the Boltzmann equation from the quantum field theory in the background field. Furthermore, to show the self-consistency of this framework, we derive this framework from the first-principle non-local Kadanoff-Baym equations. We apply this framework to compute the new friction force from the $2 \to 2$ scattering process in light to heavy and its inverse process in $\phi^2\Phi^2$ theory and find a γ-linearly related friction force that eliminates the run-aways bubble configurations in two-step phase transitions.

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