Timescale of Linear Thermalization

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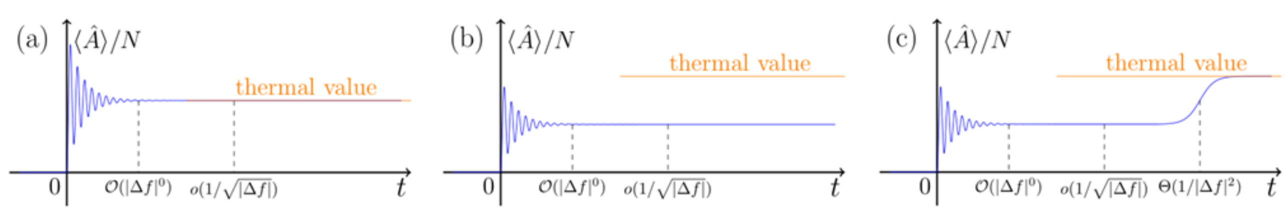
Among problems of thermalization, the timescale of thermalization is still open and is particularly nontrivial when prethermalization occurs. In this talk, we investigate the timescale of 'linear thermalization,' which is thermalization against a small change of a parameter of the system. We consider an isolated quantum many-body system prepared in an equilibrium state and its unitary time evolution induced by a small change Δf of a parameter f of the Hamiltonian. We say linear thermalization occurs for an additive observable in some timescale when its expectation value and fluctuation in that timescale are consistent with thermodynamics up to O(Δf). As explained in Shimizu's presentation of this conference, we find that the additive observable B that is conjugate to f is the key observable for linear thermalization: Under reasonable conditions, linear thermalization of B guarantees linear thermalization of all additive observables. Examining the timescale of linear thermalization in the above result, we find the following: If linear thermalization occurs in the sense of the above result, then it occurs in some time of $O(|\Delta f|^0)$ and lasts at least for a period of $o(1/\sqrt{|\Delta f|})$, as in Figure (a). On the other hand, if linear thermalization does not occur in the sense of the above result, then it does not occur in any timescale of $O(|\Delta f|^0)$ and remains absent at least until any timescale of $o(1/\sqrt{|\Delta f|})$, as in Figure (b). In particular, this result, together with the result in Shimizu's presentation, implies that linear thermalization of the single key observable B in the timescale of $O(|\Delta f|^0)$ guarantees linear thermalization of all additive observables not only in the same timescale but also in a longer timescale of $o(1/\sqrt{|\Delta f|})$. Furthermore we discuss stationarity of the system and implications for prethermalization. We show that, under the above reasonable conditions, all additive observables take macroscopically definite and stationary values, up to O(Δf), throughout a time region from $O(|\Delta f|^0)$ to $o(1/\sqrt{|\Delta f|})$. In other words, the system relaxes to a macroscopic state and stays in the same macroscopic state, up to O(Δf), throughout this time region. This result is interesting especially in a nearly integrable system where prethermalization occurs. Typically, such a system first relaxes to a nonthermal stationary state in some timescale of $O(|\Delta f|^0)$, and then relaxes to the true thermal equilibrium state at a longer timescale of $\Theta(1/|\Delta f|^2)$, as in Figure (c). For such a case, our results detect the nonthermal stationary state in the time region from $O(|\Delta f|^0)$ to $o(1/\sqrt{|\Delta f|})$ and the absence of linear thermalization in this time region.



References

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[2] Y. Chiba, A. Shimizu, arXiv:2303.03868 (2023).