Relative thermalization

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When studying thermalization of quantum systems, it is typical to ask whether a system interacting with an environment evolves towards a local thermal state. Here, we show that a more general and relevant question is "when does a system thermalize relative to a particular reference?" By relative thermalization we mean that, as well as being in a local thermal state, the system is uncorrelated with the reference. We argue that this is necessary in order to apply standard statistical mechanics to the study of the interaction between a thermalized system and a reference.

We then derive a condition for relative thermalization of quantum systems interacting with an arbitrary environment. This condition has two components: the first is state-independent, reflecting the structure of invariant subspaces, like energy shells, and the relative sizes of system and environment; the second depends on the initial correlations between reference, system and environment, measured in terms of conditional entropies. Intuitively, a small system interacting with a large environment is likely to thermalize relative to a reference, but only if, initially, the reference was not highly correlated with the system and environment. Our statement makes this intuition precise, and we show that in many natural settings this thermalization condition is approximately tight. Established results on thermalization, which usually ignore the reference, follow as special cases of our statements.