Taking the temperature of a pure quantum state

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Temperature is a deceptively simple concept that still raises deep questions at the forefront of quantum physics research. The observation of thermalization in completely isolated quantum systems, such as cold-atom quantum simulators, implies that a temperature can be assigned even to individual, pure quantum states. Here, we propose a scheme to measure the temperature of such pure states through quantum interference. Our proposal involves interferometry of an auxiliary qubit probe, which is prepared in a superposition state and subsequently decoheres due to weak coupling with a closed, thermalized many-body system. Using only a few basic assumptions about chaotic quantum systems, namely, the eigenstate thermalization hypothesis and the emergence of hydrodynamics at long times, we show that the qubit undergoes pure exponential decoherence at a rate that depends on the temperature of its surroundings. We verify our predictions by numerical experiments on a quantum spin chain that thermalizes after absorbing energy from a periodic drive. Our Letter provides a general method to measure the temperature of isolated, strongly interacting systems under minimal assumptions.