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“Exploring quantum thermalization with a magnetic quantum Newton’s cradle”

Abstract:

The question of how chaos arises in nature touches on widely disparate phenomena. For example, the fact that chaos emerges gradually in weakly nonlinear systems unpins our explanation for why the solar system remains stable. While the work of Kolmogorov and others in the 1950’s provided a firm connection between the theories of classical mechanics and classical statistical mechanics by showing how classical chaos and thermalization emerge, the analogous question in quantum physics remains a key unresolved question. That is, physicists have long wondered how quantum mechanics and quantum statistical mechanics may be connected: How, specifically, does quantum chaos – and hence, thermalization – emerge in isolated quantum systems? While isolated quantum many-body systems with integrable dynamics do not thermalize, thermalization sets in as one perturbs the system away from the integrable point. However, the nature of the crossover from integrable to thermalizing behavior is an unresolved and actively discussed question.

We will present a new experiment that explores this question by studying the dynamics of the momentum in a dipolar quantum Newton's cradle consisting of highly magnetic dysprosium atoms. This system constitutes the first dipolar strongly interacting 1D Bose gas. These interactions provide tunability of both the strength of the integrability-breaking perturbation and the nature of the near-integrable dynamics. The work sheds light on the mechanisms by which isolated quantum many-body systems thermalize and on the temporal structure of the onset of thermalization. We anticipate our novel 1D dipolar gas will yield insights into quantum thermalization and strongly interacting quantum gases with long-range interactions.