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Experimental evidence for the existence of eigenvalues of the time evolution operator governing the behavior of nuclear spins in solids
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The decay of nuclear magnetic resonance (NMR) signals in solids is an extremely difficult many-body problem with no complete solution. Utilizing frozen xenon polarized by spin-exchange optical pumping, we have observed the long-time behavior of the NMR signal decay for both free-induction decay and spin (solid) echoes. The enhanced signal has allowed us to view the behavior of the decay for up to $\sim$10 decay constants. This has given us the opportunity to test a theory about this behavior which says that at after a few time constants, the signal should decay either with a simple exponential or a simple exponential modulated by a sinusoid. The reasoning for this is that the evolution of the density matrix follows from the action of its complete time evolution operator, and that its eigenvalues determine the evolution of the spin system. Evidence for this type of behavior has been seen in classical chaotic systems, but ours is the first experimental evidence for this behavior in a quantum system. This work has the potential to help elucidate the role of chaos in quantum systems.

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