Going Beyond Fermi's Golden Rule

Researchers have calculated the likelihood that a quantum state will decay when its evolution is inhibited by a dearth of final states.

By Marric Stephens

Quantum systems are fragile, meaning a specific quantum state generally decays into other states over time. This decay process is formalized by Fermi's golden rule (FGR), which in its traditional formalization applies when there exists an infinite continuum of states for the quantum system state to decay to—for example, when an excited atom emits a photon into a vacuum. Now Tobias Micklitz at the Brazilian Center for Research in Physics and colleagues have developed and solved a model showing how a quantum system evolves when its initial state is instead coupled to a finite set of states spread across discrete energy levels [1]. Micklitz says that their model could be the foundation for models of more complex, many-body quantum systems.

FGR-obeying systems occupy one end of a scale, where the coupling strength between the systems' initial and final states is large relative to the energy gap between the various final states (zero for a continuum of states). At the other end of the scale, the coupling strength is much lower relative to this gap. A system that sits in this second regime remains in its initial state, as there are too few available final states for it to decay into.

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Micklitz and colleagues study the intermediate regime, where FGR-like behavior emerges. They analytically derive the time-dependent probability of a single excited state persisting for different coupling strengths and final-state energy spectra, finding an unexpectedly complex set of outcomes. More surprising, according to Micklitz, is that this intermediate regime can be described analytically at all. Micklitz says they plan to apply the method to an ensemble of spins coupled to a quantum dot, a much more difficult problem.

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REFERENCES

1. T. Micklitz *et al.*, "Emergence of Fermi's golden rule," Phys. Rev. Lett. 129, 140402 (2022).