Quantum dynamics in nonequillibrium environments

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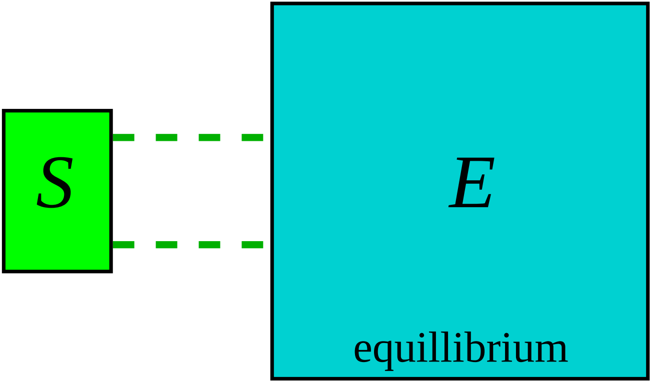
Introducing...me

- **Quantum transport**: counting statistics, coherent effects, dark-states, quantum dots
- **QIP with spins in quantum dots**: optical control, adiabatic gates (UCSD)
- **Many-body entanglement**: Characterization, phase transitions, solid-state
- **Coupled Cluster Method**: QMBT, transport (jin-jun), entanglement
- **Decoherence**: nonequilibrium environments

System-Environment-Environment’



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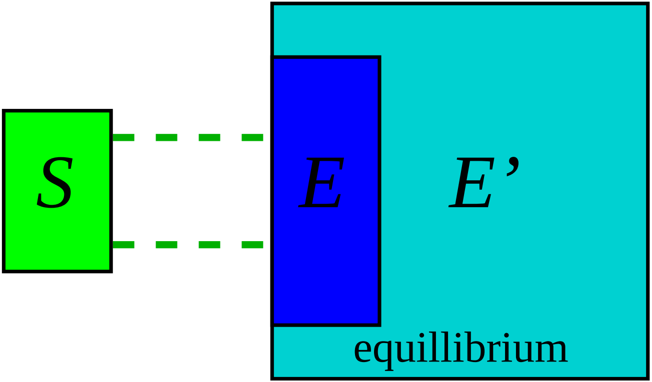
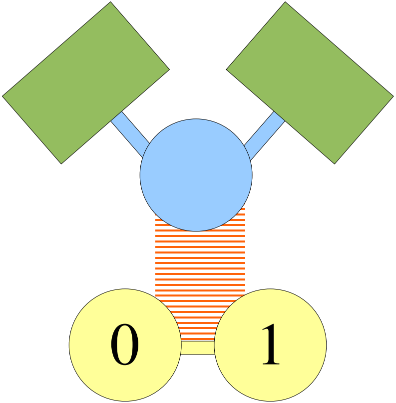


Single Impurity environment



SEE'

- S: qubit
- E: single-level
- E': electron reservoirs

-

Charge Fluctuations
Paladino PRL02,
Galperin PRL06,
Schreifl NJP07
Single electron transistor
Gurvitz & Mozyrsky, PRB08

Motivation

Interesting,..

- non-equilibrium (environment)
- non-Gaussian (correlations)
- non-Markovian (behaviour)

Systems

- Charge fluctuations
  Paladino PRL 02, Galperin PRL 06, Schreifl NJP 07
- Single electron transistor
  Gurvitz & Mozyrsky, PRB08
- Quantum point contact
  Averin & Sukhorukov, PRL05, Neder & Marquardt, NJP 07

Theoretical treatment

Coupled master equations

- Trace out E', Born-Markov approx, $\Rightarrow$ Liouvillian $\mathcal{L}_0^{\mathrm{E}}$
- Stationary state of environment: $\rho_{\mathrm{stat}}^{\mathrm{E}}$
- Generalised Master equation

$$\dot{\rho}^{\mathrm{SE}} = \left(\mathcal{L}_0^{\mathrm{S}} \oplus \mathcal{L}_0^{\mathrm{E}} + g\mathcal{M}\right) \rho^{\mathrm{SE}}$$

- Coupling Hamiltonian: $\mathcal{V}_{\mathrm{SE}} = g\sigma\epsilon$

$$\mathcal{M}\rho^{\mathrm{SE}} = -i\left[\mathcal{V}_{\mathrm{SE}}, \rho^{\mathrm{SE}}\right]$$

Effective System Liouvillian

- Trace out E (exact!) $\Rightarrow$ $\mathcal{L}_{\mathrm{eff}}^{\mathrm{S}}(z)$

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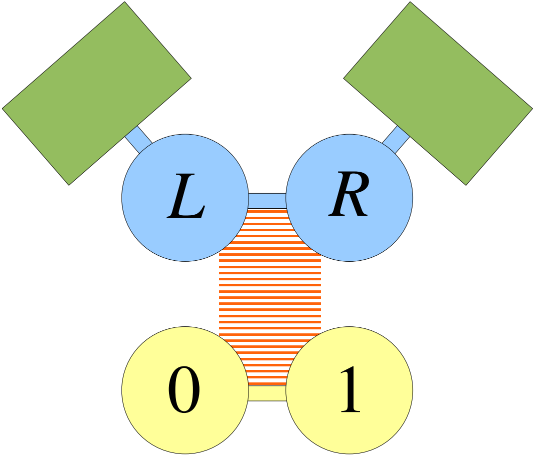
Double-Quantum-Dot-Environment



Qubit system

$$\mathcal{H}_{\mathrm{S}} = \frac{1}{2}\Delta\sigma_z^{\mathrm{S}}$$

DQD Environment

$$\mathcal{H}_{\mathrm{E}} = \frac{1}{2}\varepsilon\sigma_z^{\mathrm{E}} + T_c\sigma_x^{\mathrm{E}}$$

Level-splitting

$$\Delta_{\mathrm{DQD}} = \sqrt{\varepsilon^2 + 4T_c^2}$$

Rates: $\Gamma_L = \Gamma_R = \Gamma$

Pure dephasing: SE coupling diagonal in S

Hamiltonian

$$\mathcal{H}_S = \frac{1}{2}\Delta\sigma_z^S$$

Coupling

$$\mathcal{V}_{SE} = g\sigma_z\epsilon$$

Pure Dephasing

Qubit Coherence decays as

$$\rho_{01}^S(t) = D(t)\rho_{01}(0)$$

Visibility

$$v(t) = |D(t)|$$

Full fluctuation statistics

Long-time limit

$$D(t) \sim e^{\tilde{z}t}$$

$\tilde{z}$ = Cumulant generating function for zero-frequency Keldysh-ordered correlation functions of environment operator ϵ

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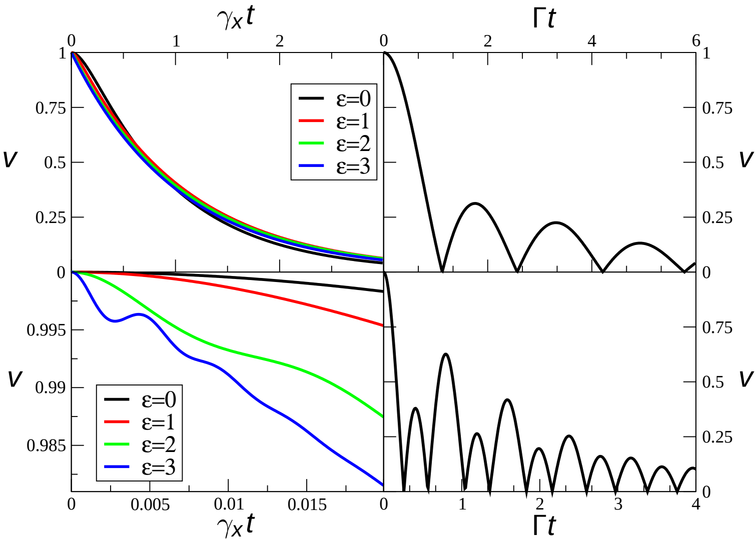

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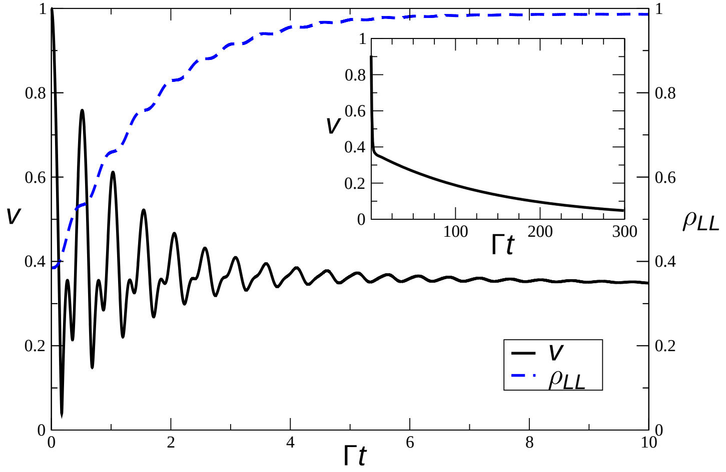
Quantum Zeno effect



Summary

- General approach to dephasing in nonequilibrium environments
- The three nons:
  - non-equilibrium
  - non-Gaussian
  - non-Markovian
- Full fluctuation statistics
- DQD in transport: Quantum environment
- Relaxation: Quantum/Classical, measurement back-action