Transport Through A Critical Magnetic Quantum Dot Away From Equilibrium

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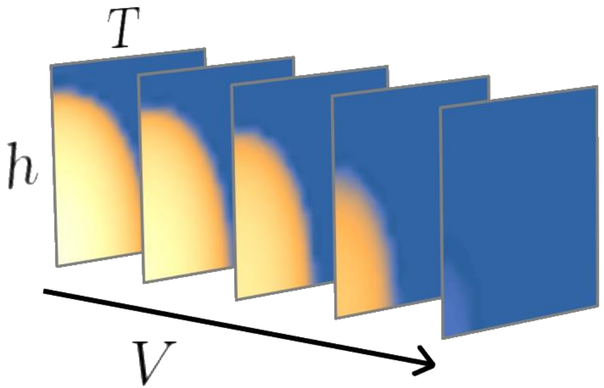
MEFT



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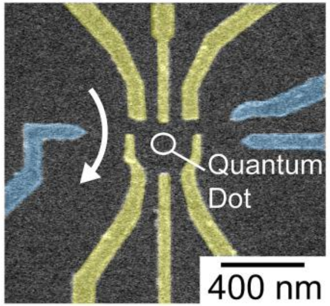
2nd Cycle Integrated Project (PIC2) in Engineering Physics

Out-of-Equilibrium Quantum Matter

What is Quantum Matter?

- Can only be described by **quantum mechanics**
- Technologically relevant



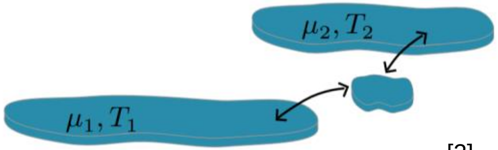
[1]

Quantum Dots: Spintronics, Quantum Computing, Sensing

What does "Out-of-Equilibrium" Mean?

In short:
Saying goodbye to the usual thermodynamic variables.

Example:



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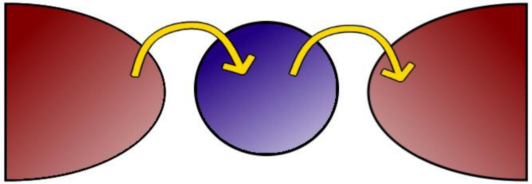
Prospect:
Create novel phases of matter

This project:

Investigate **phase transitions** of a **magnetic quantum dot** in a transport setup



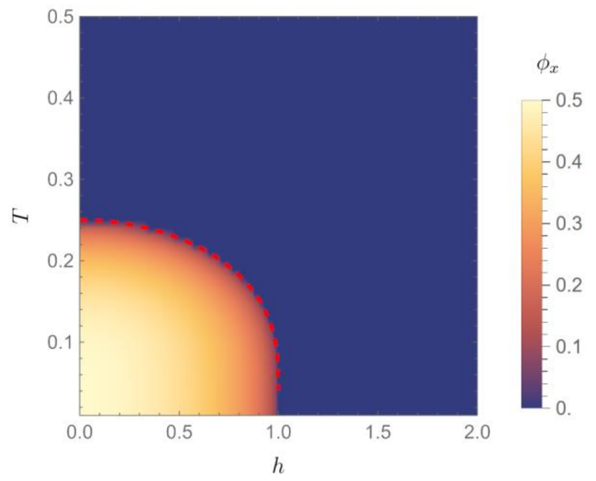
[1] Credit: Osaka University
[2] Walldorf, N. (2020). PHD Thesis, Department of Physics, TU Denmark

The Model

- **Lipkin-Meshkov-Glick (LMG) model**:

$$H_{\text{dot}} = -hS_z - \frac{\gamma_x}{N} S_x^2 \,, \quad S_\alpha = \frac{1}{2} \sum_{i,ss'} d_{i,s}^\dagger \, [\sigma_\alpha]_{ss'} \, d_{i,s'}$$

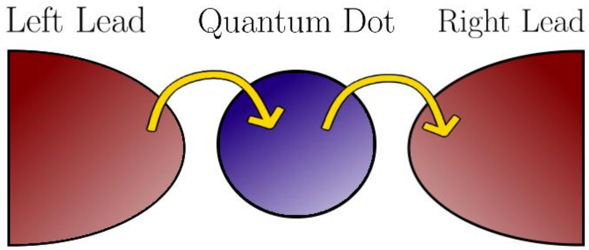
Phase transition in $\boldsymbol{\phi_x = \langle S_x \rangle / N}$ at $\boldsymbol{T = 0}$ and **finite temperature**



- **Full model (dot+leads):**

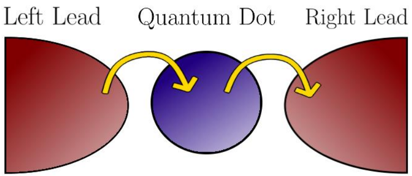
$$H_{\text{leads}} = \sum_{l,i,s} \varepsilon_i c_{l,i,s}^\dagger c_{l,i,s} \qquad H_{\text{dot-leads}} = -\sum_{l=\text{L,R}} w_l c_{l,i,s}^\dagger d_{l,i,s} + \text{h.c.}$$

$$H = H_{\text{dot}} + H_{\text{leads}} + H_{\text{dot-leads}}$$



This Project

The model:



$$H_{\text{dot}} = -hS_z - \frac{\gamma_x}{N} S_x^2$$

$$H_{\text{dot}} + H_{\text{leads}} + H_{\text{dot-leads}}$$

Methods:

Out-of-equilibrium quantum field theory:
Keldysh formalism

$$Z = \frac{1}{\text{Tr}[\hat{\rho}(-\infty)]} \text{Tr}[\hat{U}_{\mathcal{C}}[V]\hat{\rho}(-\infty)]$$

Objectives:

- Establish **Non-Equilibrium Phase Diagram** for the LMG model
- Derive **effective theory** near the transition

Big Picture:

Extend the theoretical framework of out-of-equilibrium phase transitions

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Advance understanding of quantum materials and their manipulation

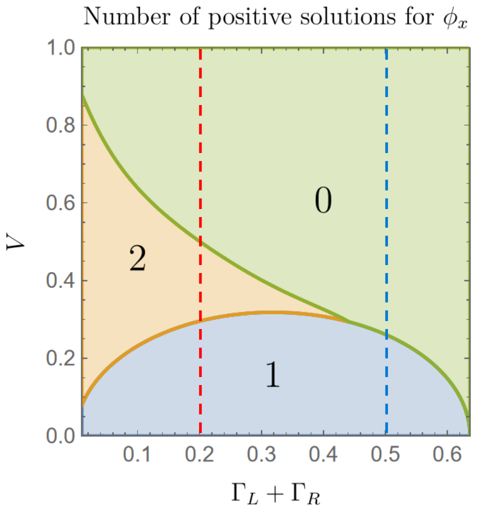
Preliminary Results

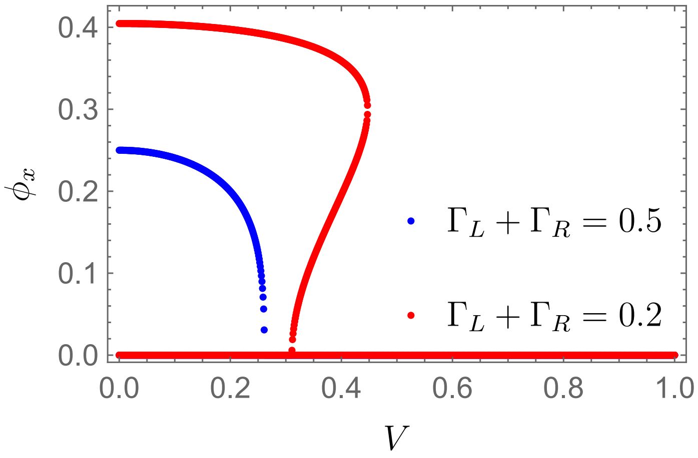
Effective Bosonic Action:

$$S[\phi^{cl}(t),\phi^{q}(t)] = N\int_{-\infty}^{\infty} dt\; 2\gamma_x\phi^q\phi^{cl} - i\mathrm{Tr}\ln\left[i\left(\mathbf{G}_0^{-1} - \frac{\gamma_x}{\sqrt{2}}(\phi^{cl}\hat{\gamma}^{cl} + \phi^q\hat{\gamma}^q)\sigma_x - \mathbf{\Sigma}\right)\right]$$

Mean-field self-consistent equation:

$$\phi_x = -\frac{i}{2}\int\frac{d\omega}{2\pi}G^K_{\uparrow\downarrow}(\omega)[\phi_x]$$





Next steps:

Classify stability of solutions to arrive at phase diagram

Thank you for your attention!