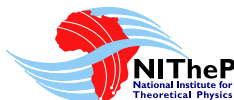


Relaxation timescales in closed long-range quantum spin models

Michael Kastner



Stellenbosch, South Africa

Rutgers, 16 December 2012

based on:

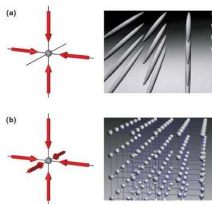
M. van den Worm, B. C. Sawyer, J. J. Bollinger, M. K., arXiv:1209.3697
R. Bachelard, M. K., submitted to PRL

Stellenbosch



Experimental motivation:

Lattices of ultracold atoms or ions



After the cooling is switched off:

- conservation of energy
- conservation of particle number

Bloch *et al.*, RMP **80** (2008) 885

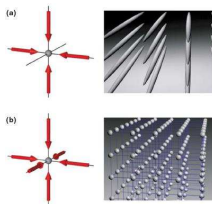
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- ⇒ Equilibration in closed quantum systems?
- ⇒ Statistical description in the microcanonical ensemble

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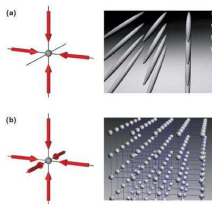
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Beryllium ions in a Penning trap

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$$\text{Hamiltonian } H = \sum_{i \neq j} J_{ij} \sigma_i^z \sigma_j^z - \sum_i \mathbf{B} \cdot \boldsymbol{\sigma}_i$$

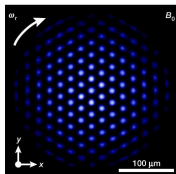
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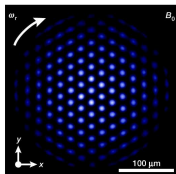
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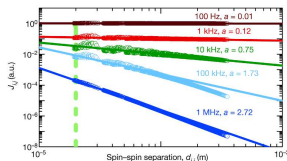


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Long-range Ising model

Spin-1/2 particles on a lattice Λ in a magnetic field h

$$H_{\Lambda} = -\frac{J}{2} \sum_{\substack{i,j \in \Lambda \\ i \neq j}} \frac{\sigma_i^z \sigma_j^z}{|i-j|^{\alpha}} - h \sum_{i \in \Lambda} \sigma_i^z$$

Everybody's favorite comment: But isn't this model *classical*?

No, it's not...

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- dynamics can create entanglement

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$$\langle \sigma_i^u \sigma_j^v \rangle(t) = \text{Tr} [e^{iH_\Lambda t} \sigma_i^u \sigma_j^v e^{-iH_\Lambda t} \varrho(0)]$$

Simplification: ϱ_0 is **diagonal in the σ_i^x -eigenbasis** [G. G. Emch, JMP 7, 1198 (1966)]

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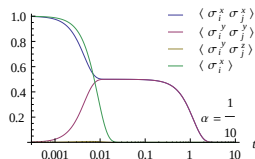
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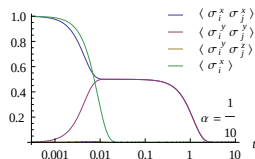
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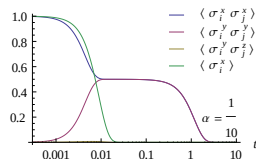
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M. van den Worm, B. C. Sawyer, J. J. Bollinger, M. K., arXiv:1209.3697

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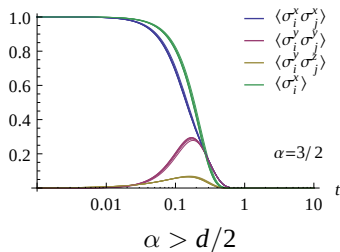
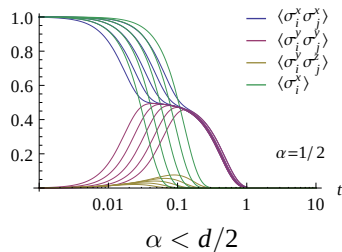
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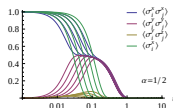
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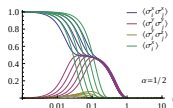
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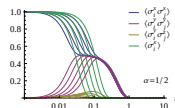
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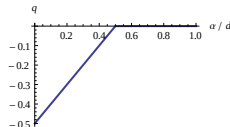


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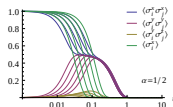
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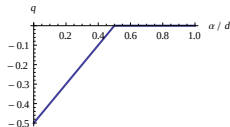
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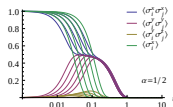
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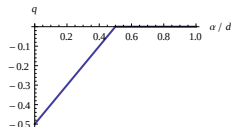
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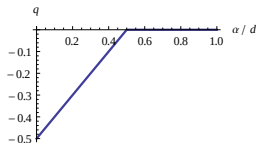
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Universal long-range threshold at α_{th} ?

quantum Ising model



classical XY model

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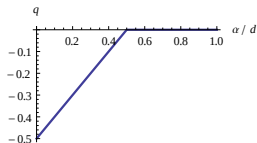
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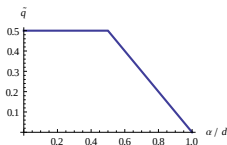
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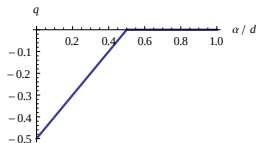
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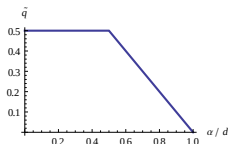
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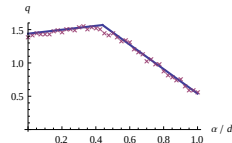


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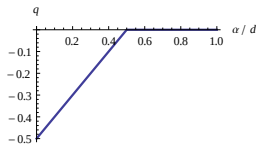
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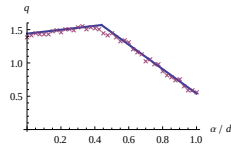
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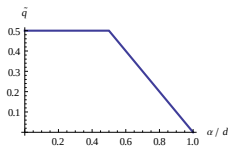


classical XY model



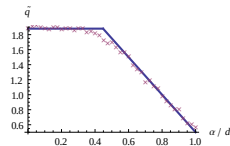
$$H = -\frac{J}{2NP} \sum_{i,j} \frac{\sigma_i^z \sigma_j^z}{|i-j|^\alpha} - h \sum_i \sigma_i^z$$

$$p = \max\{0, 1 - \alpha/d\}$$



$$H = \sum_i \frac{p_i^2}{2} - \frac{J}{2NP} \sum_{i,j} \frac{\cos(\phi_i - \phi_j)}{|i-j|^\alpha}$$

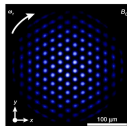
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R. Bachelard, M. K., submitted to PRL

Summary / Outlook

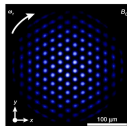
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 - theoretical: foundations of statistical mechanics
- Exact results (upper bounds) on correlation functions of long-range Ising model
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 - Prethermalization
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M. van den Worm, B. C. Sawyer, J. J. Bollinger, M. K., arXiv:1209.3697; R. Bachelard, M. K., submitted to PRL

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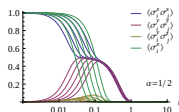
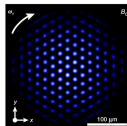
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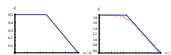
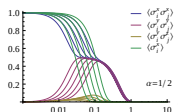
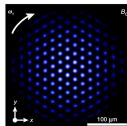
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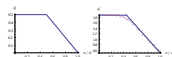
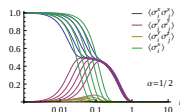
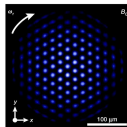
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