



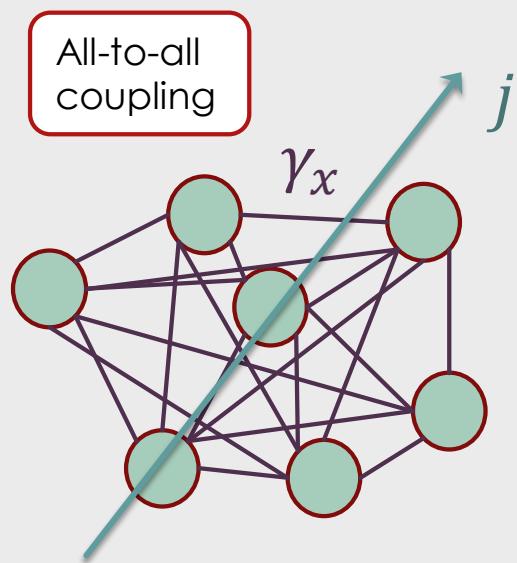
ESQPT in the Lipkin-Meshkov-Glick model and its influence on the non-adiabatic dynamics

WASSILIJ KOPYLOV, GERNOT SCHALLER
AND TOBIAS BRANDES

Lipkin-Meshkov-Glick Model (LMG) [1]

2

$$\hat{H}_{LMG} = -h\hat{J}_z - \frac{\gamma_x}{N}\hat{J}_x^2$$



$\hat{J}_{x,y,z} = \frac{1}{2} \sum_{k=1}^N \hat{\sigma}_{x,y,z}^{(k)}$
collective spin operators

γ_x – interaction strength

N – number of atoms

\hat{J}^2 – conserved

restriction $j = N/2$

[1] H.J. Lipkin et al. Nucl. Phys. 62 (1965)

LMG

(ES)QPT
and
Obsv

Exp

Adiab.
and ESQPT

Spectral
width

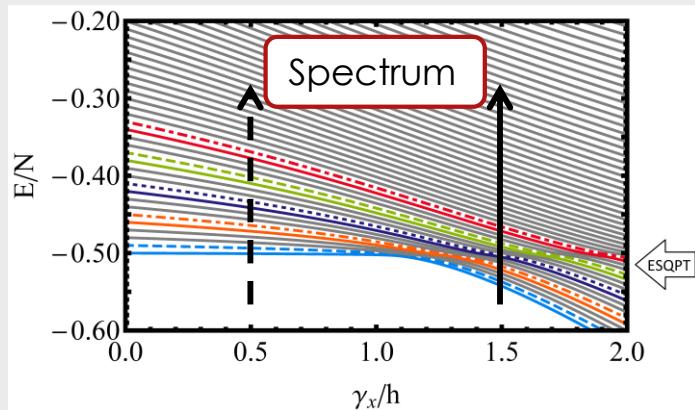
Scaling

Mean
Field

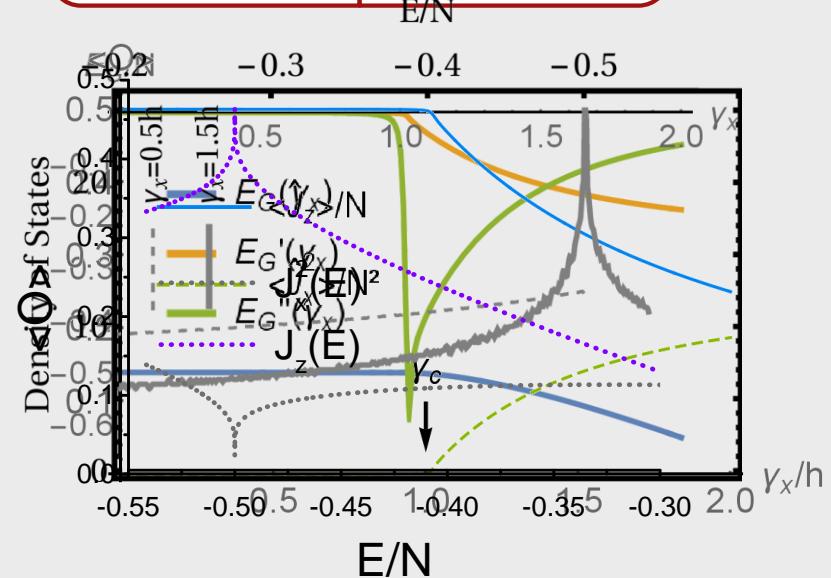
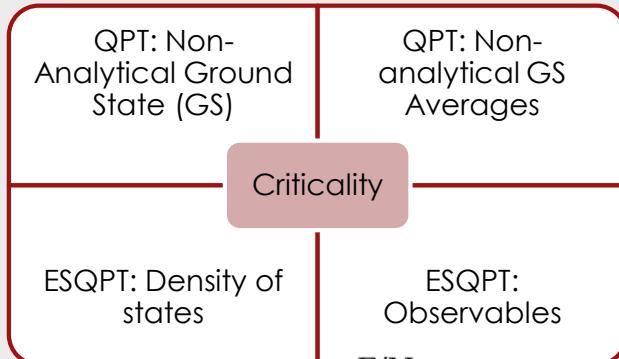
LMG: QTP, ESQPT and Observables[2]

3

$$\hat{H}_{LMG} = -h\hat{J}_z - \frac{\gamma_x}{N}\hat{J}_x^2$$



Critical Point: $\gamma_x^{cr} = h$ for $N \rightarrow \infty$



- [2] S. Dusuel et al., PRB **71** (2005);
 P. Ribeiro et al., PRE **78** (2008);
 M. Caprio et al. Ann. Phys. **323** (2008)

LMG

(ES)QPT and
Obsv

Exp

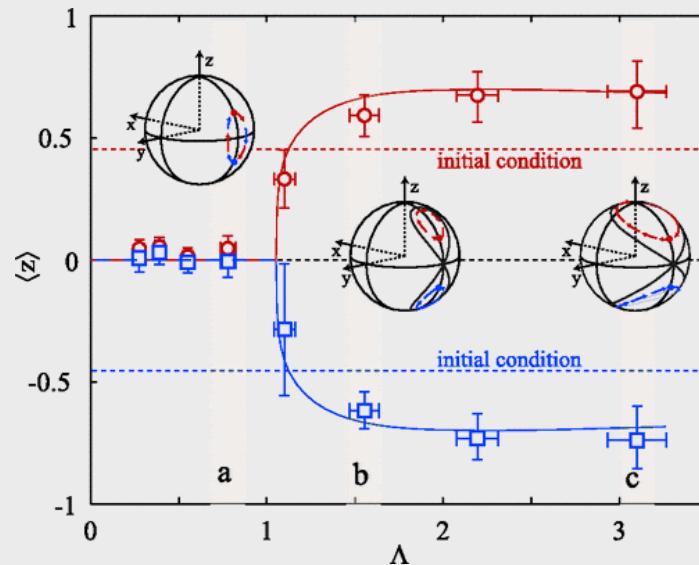
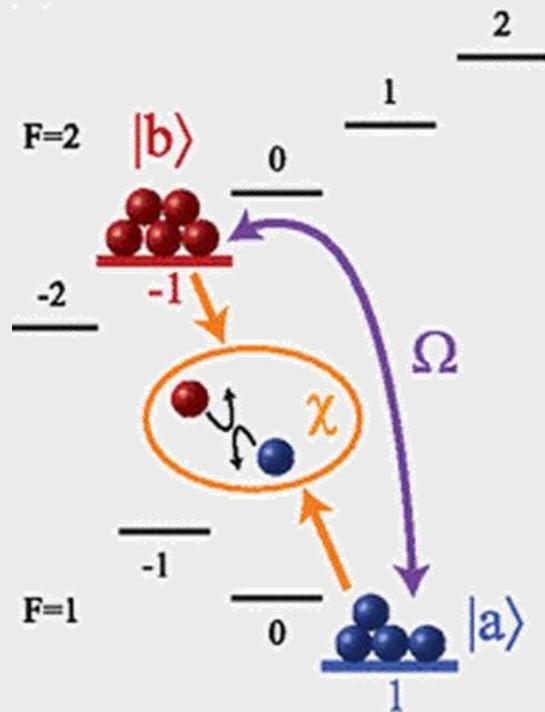
Adiab.
and ESQPT

Spectral
width

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Mean
Field

LMG: Experiments BEC in a Cavity and Hyperfine states [3]

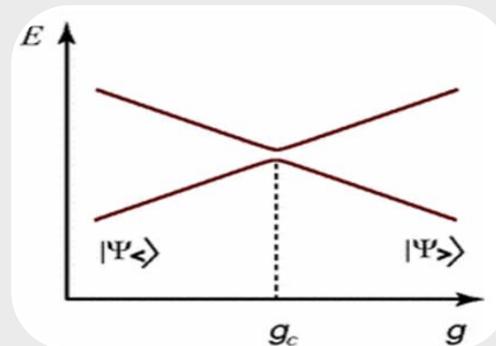


[3] T. Zibold et al., PRL 105, 204101 (2010)

Adiabatic Dynamics in Different Systems

$$H_1 \rightarrow H_2$$

Quantum Computation

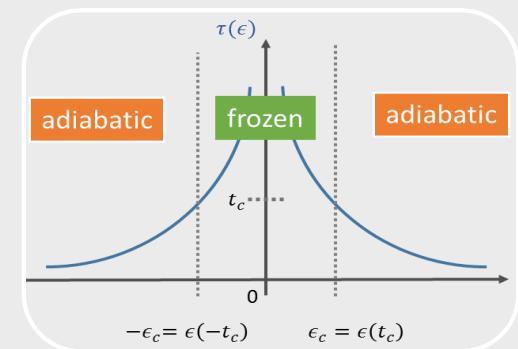


Landau-Zener Transitions

G. Schaller et al. PRA 73 (2006)

S. Mostame et al. PRA 81 (2010)

T.W.B. Kibble, Phys. Rep. 67 (1980)



Universal Scaling

LMG

(ES)QPT
and
Obsv

Exp

Adiab.
and ESQPT

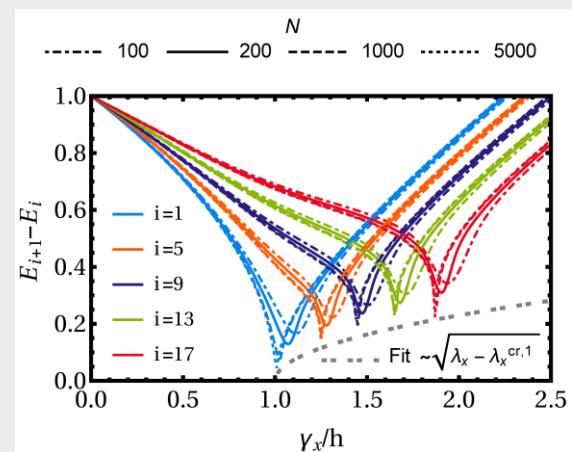
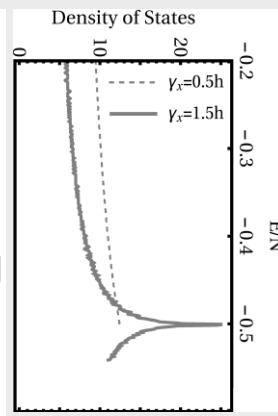
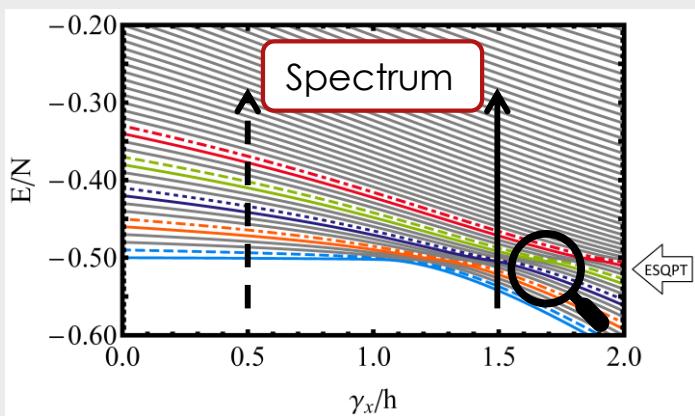
Spectral
width

Scaling

Mean Field

LMG: Level distance [4]

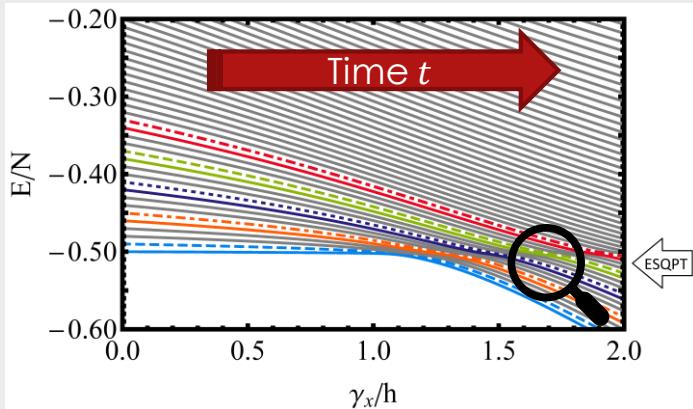
$$\hat{H}_{LMG} = -h\hat{J}_z - \frac{\gamma_x}{N}\hat{J}_x^2$$



- [4] M. Caprio et al. Ann. Phys. **323** (2008)
- R. Puebla et al. PRE **92**, 012101 (2015)
- Milan Šindelka et al. PRA **95** (2017)

LMG: time-dependent studies [5]

$$\hat{H}_{LMG} = -h\hat{J}_z - \frac{\gamma_x}{N}\hat{J}_x^2$$



Previous time-dependent studies: Ground state properties

- Adiabatic/non-adiabatic scaling
- Impact of excited states
- Connection to Landau-Zener-Effect
- Connection to Kibble-Zurek-Mechanism

- [5] T. Caneva et al. PRB 78 (2008)
 P. Solinas et al. PRA 78 (2008)
 M.J Hwang et al. PRL 115 (2015)

LMG

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and
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Exp

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Spectral
width

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Mean
Field

LMG: adiabaticity of excited states

8

$$\hat{H}_{LMG} = -h\hat{J}_z - \frac{\gamma_x}{N}\hat{J}_x^2$$

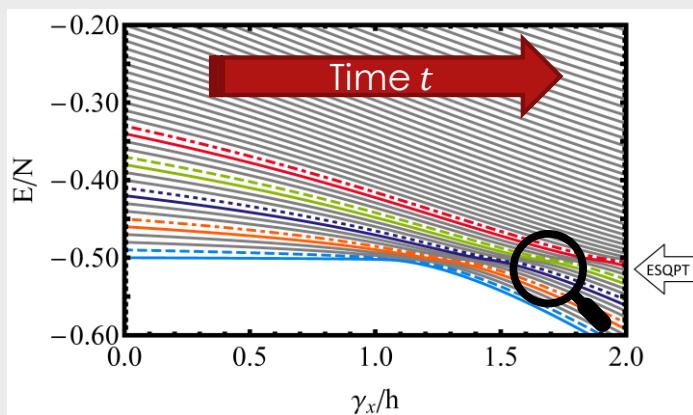
Protocol:

$$\gamma_x \rightarrow \gamma_x(t) = \frac{t}{Q}$$

$$t \in [t_i, t_f]$$

time-local eigenstates:

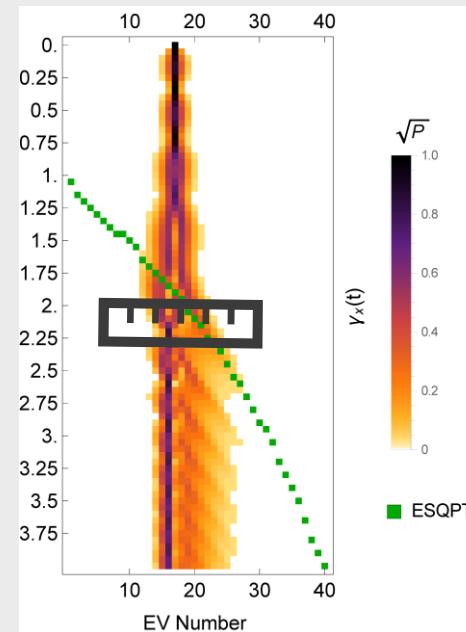
$$\hat{H}(t)|k(t)\rangle = E_k^{(t)}|k(t)\rangle$$



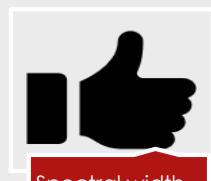
Procedure:



Time-local state occupation ($Q = 10/h^2$)



Res. Energy



Spectral width σ

LMG

(ES)QPT
and
Obsv

Exp

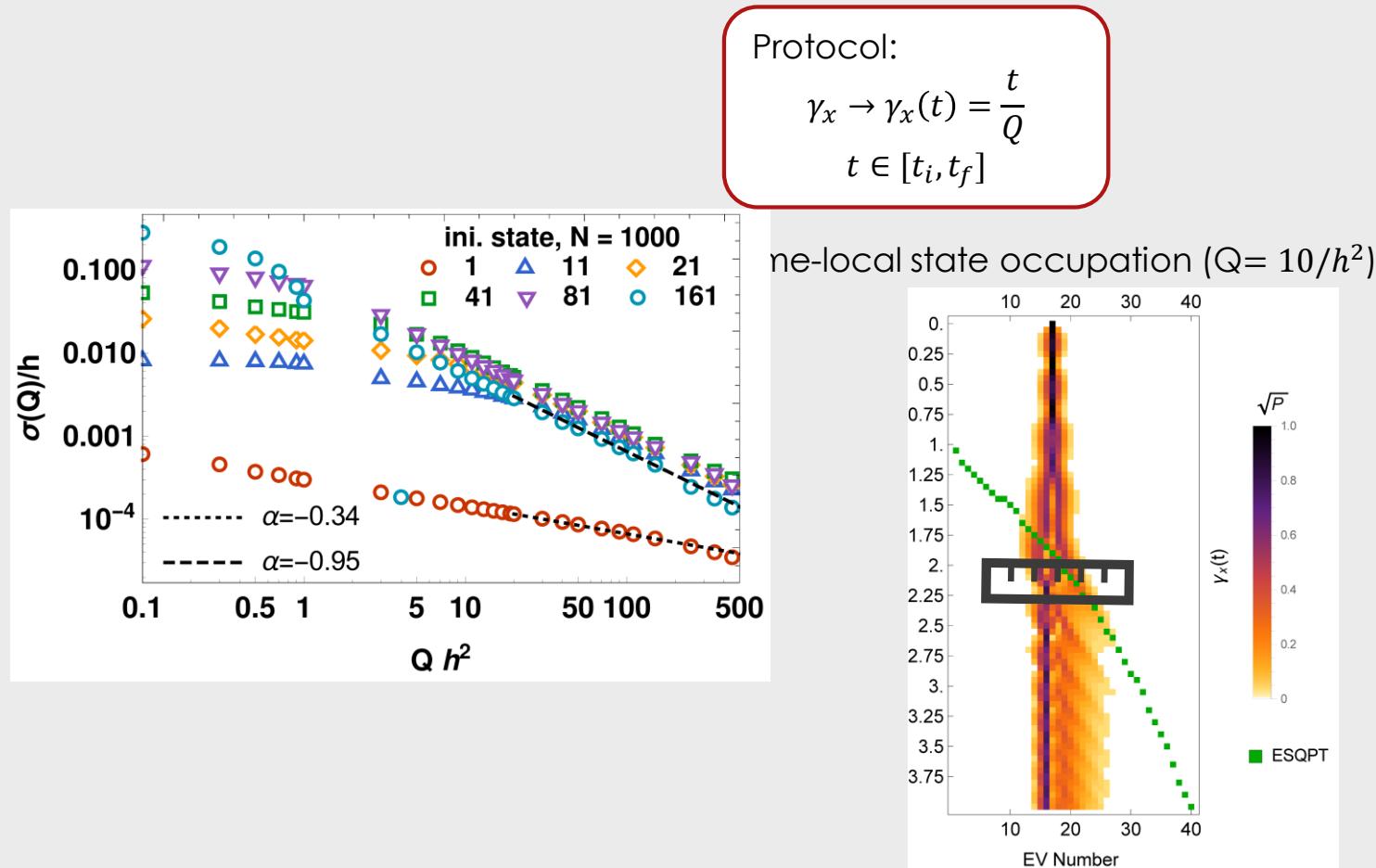
Adiab.
and ESQPT

Spectral
width

Scaling

Mean
Field

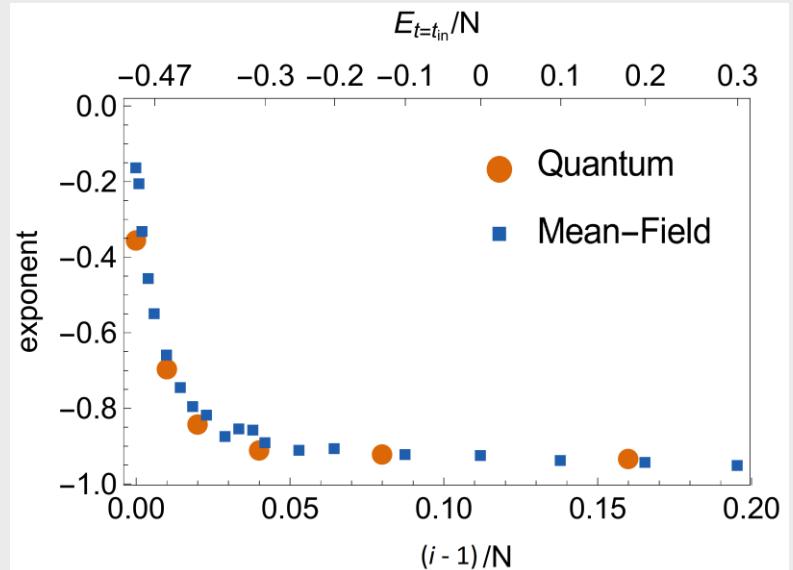
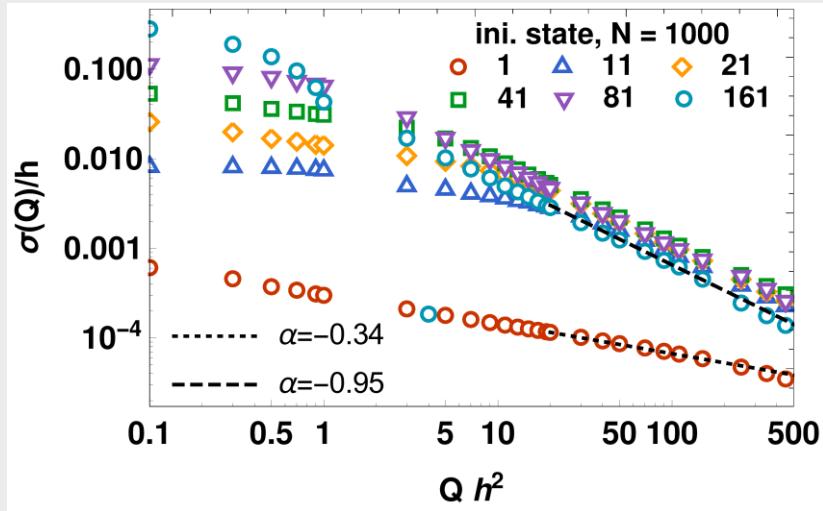
LMG: Non-Adiabatic Dynamics



Non-Adiabatic Dynamics

$$\hat{H} = -\hbar \hat{j}_z - \frac{\gamma_x}{N} \hat{j}_x^2$$

$$\gamma_x \rightarrow \gamma_x(t) = \frac{t}{T}$$

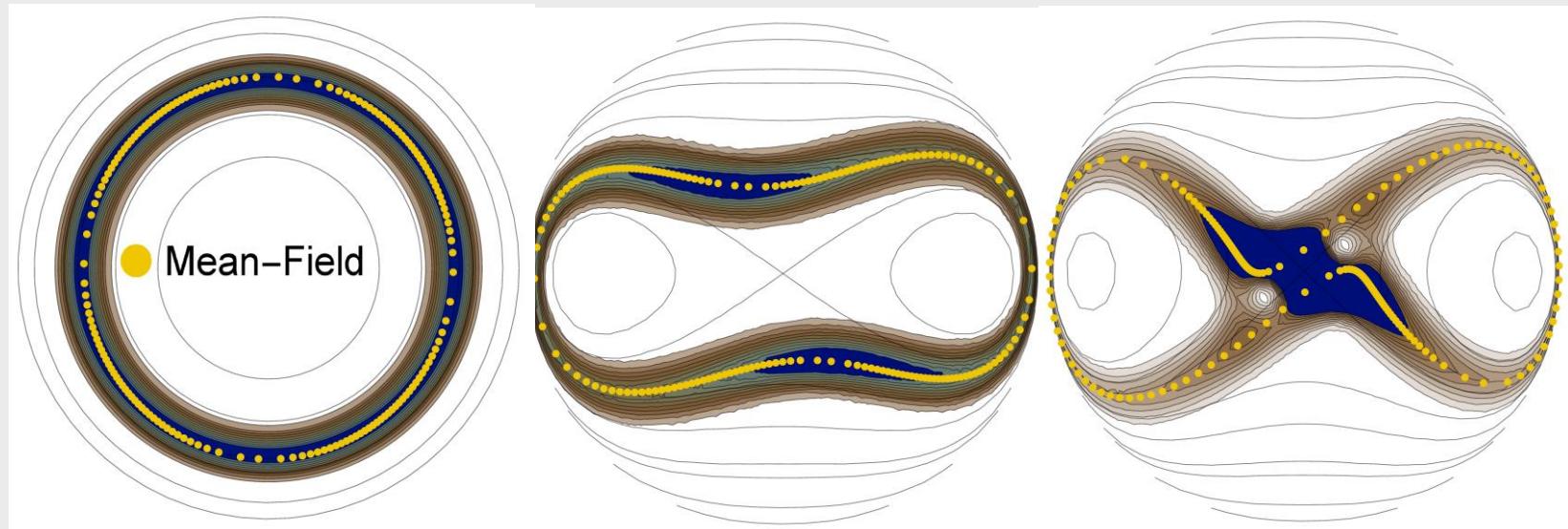
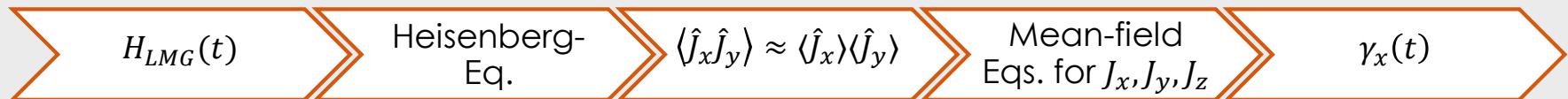


Different scaling for different initial excited states

LMG: Mean-Field Dynamics vs. Quantum

$$\hat{H} = -h\hat{j}_z - \frac{\gamma_x}{N} \hat{j}_x^2$$

$$\gamma_x \rightarrow \gamma_x(t) = \frac{t}{Q}$$



P. Ribeiro et al. PRE 78
(2008)

G. Engelhardt et al. PRA 91
(2015)

LMG

(ES)QPT
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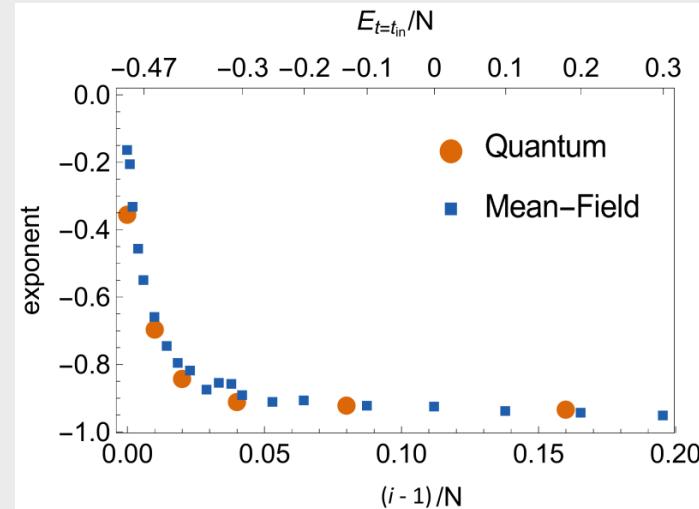
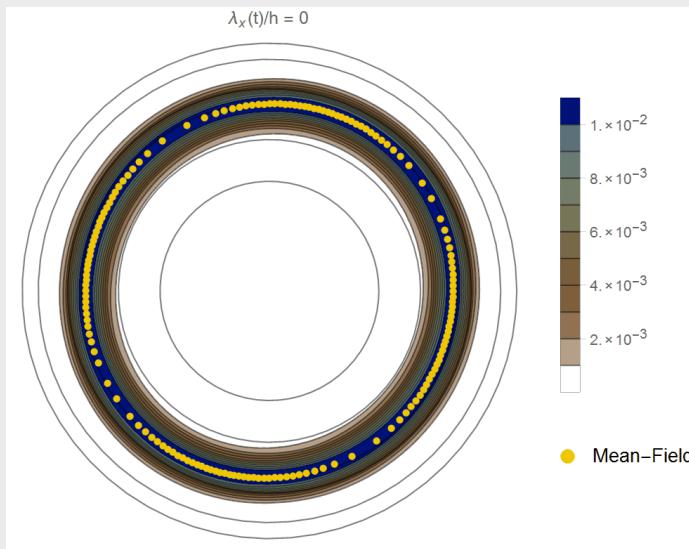
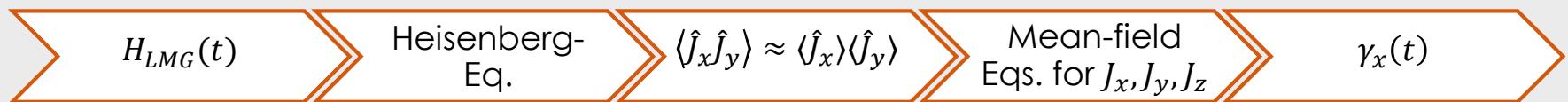
Scaling

Mean
Field

LMG: Mean-Field Dynamics vs. Quantum

$$\hat{H} = -h\hat{j}_z - \frac{\gamma_x}{N}\hat{j}_x^2$$

$$\gamma_x \rightarrow \gamma_x(t) = \frac{t}{Q}$$



Summary

13

Non-
Adiabatic
Dynamics

ESQPT

Excited
States
scaling

Mean-Field
treatment

Thank You for Your
Attention!

arXiv:1703.06083



SFB 910