Shortcuts to adiabaticity in many-body systems

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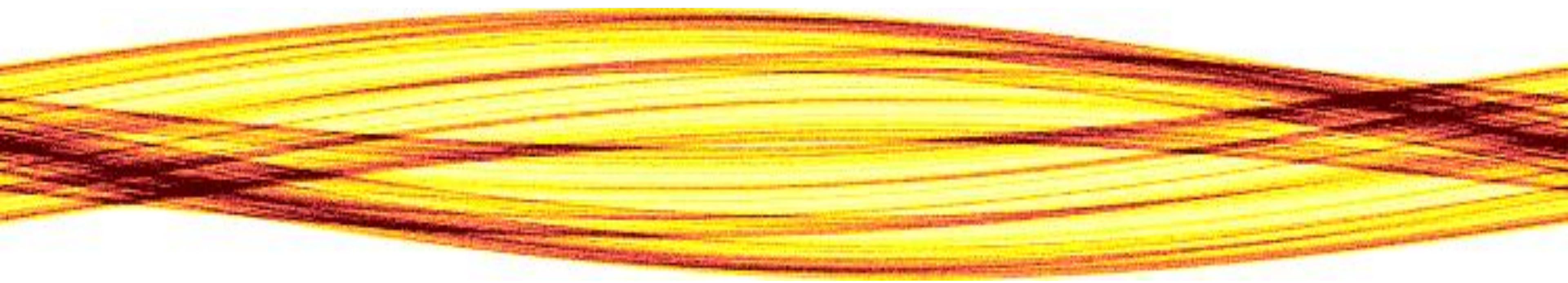

KITP Santa Barbara, October 30th 2012

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Contents

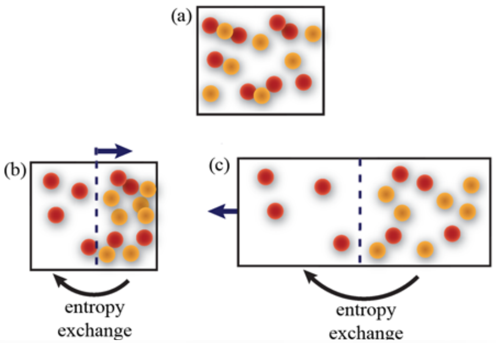
- Motivation
- Self-similar dynamics
- Inhomogeneous phase transitions & KZM
- Excitation-free quantum phase transitions

Why speeding up things?

•Quantum quenches

Probing correlations in many-body systems

E. Cornell'09 finite time-of-flight in ultracold gases



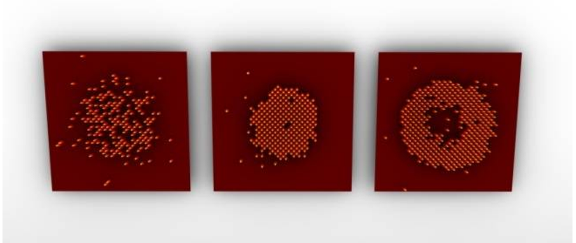
• Quantum thermodynamics

Adiabatic expansions are the bottleneck
in quantum refrigerators & engines

• Quantum simulation

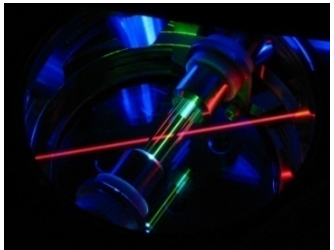
Preparation of novel-quantum phases

Crossing critical points



• Quantum Information Processing & Quantum Optics

Faster Quantum gates, STIRAP, RAP, ion-transport



• Prevent decoherence and role of perturbations

STA beyond this talk

Chen, AdC, Guery-Odelin, Modugno, Muga, Ruschhaupt, Torrontegui
adiabatic invariants

Calarco, Fazio, Li, Stefanatos
Optimal control theory

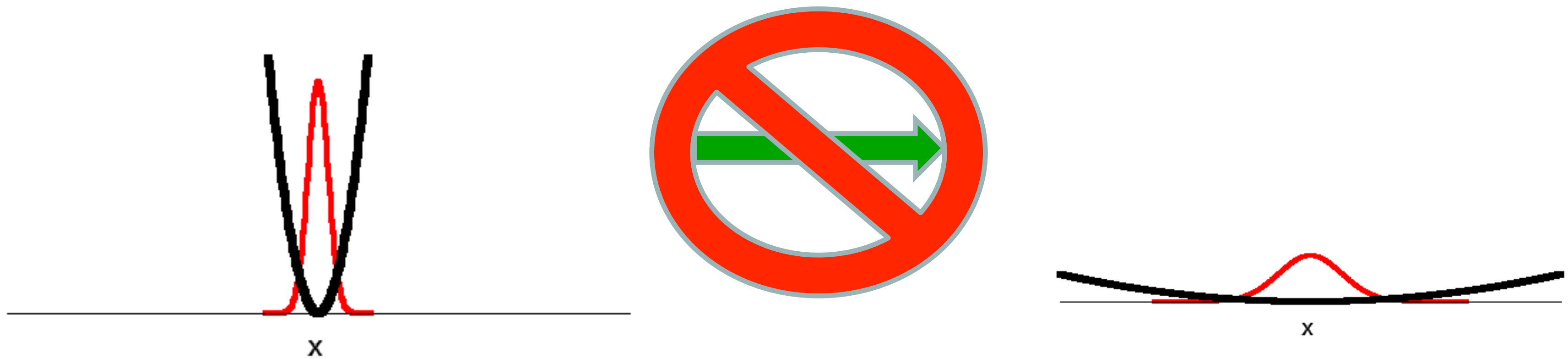
Barankov, De Chiara, Polkovnikov, Sengupta
Nonlinear quantum quenches

Masuda, Nakamura
Fast forward technique

Berry, Demirplak, Morsch, Rice
Transitionless quantum driving
& counterdiabatic fields

…

Fast expansions

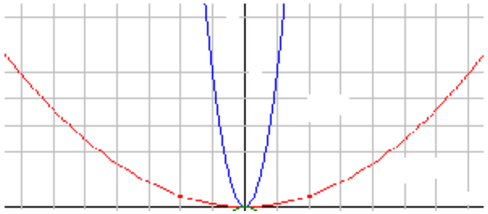


A. del Campo & M. G. Boshier, Sci. Rep. 2, 648 (2012)
A. del Campo, Phys. Rev. A **84**, 031606(R) (2011)
A. del Campo, EPL 96, 60005 (2011)
X. Chen, A. Ruschhaupt, Schmidt, A. del Campo, D. Guery-Odelin, J. G. Muga, PRL**104**, 063002 (2010)

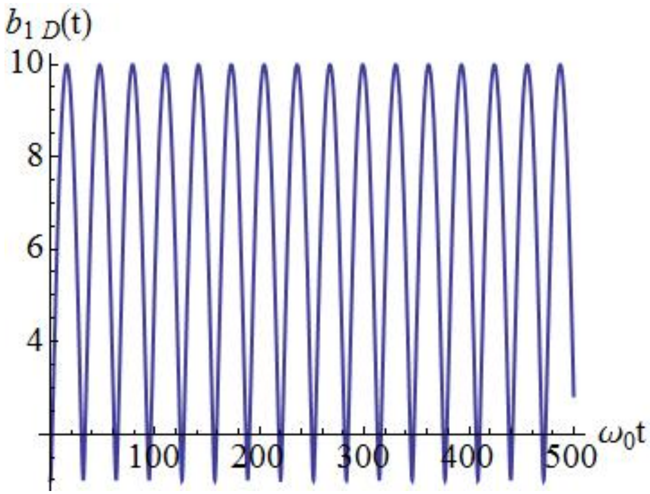
Example: Standard Quench

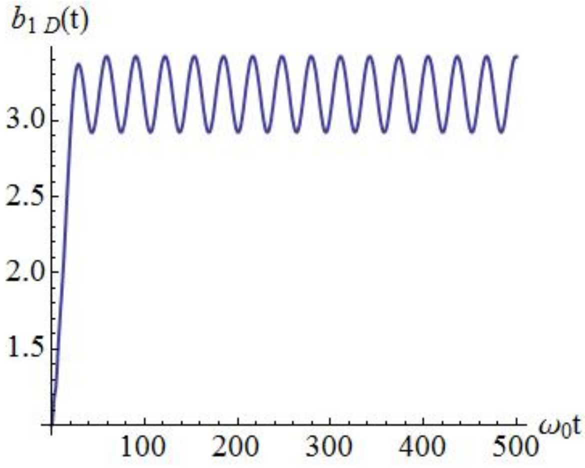
Opening the trap

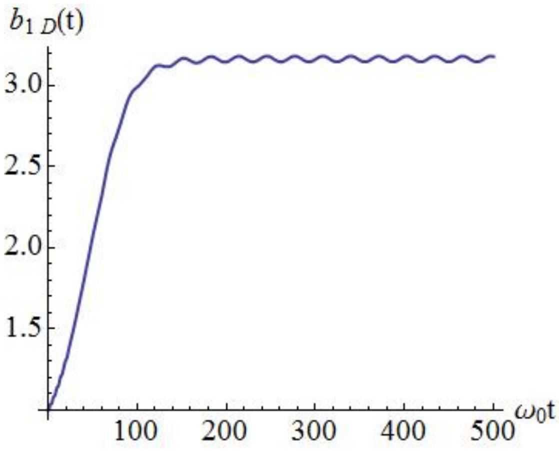
$$\omega(t) = \omega_i \left[1 + \frac{\omega_f - \omega_i}{\omega_i} \tanh \frac{t}{\tau}\right]$$



from sudden to adiabatic

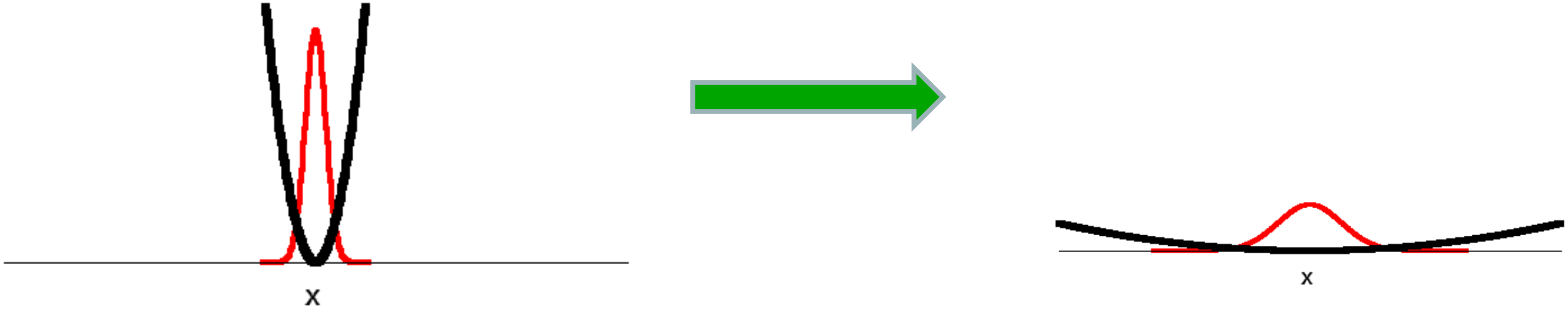






Excitation: breathing mode in the time-evolution of the width of the cloud

Fast expansion without vibrational heating



Self-similar dynamics

1. **Take a somewhat general many-body time-dependent Hamiltonian**

$$\hat{\mathcal{H}} = \sum_{i=1}^{N}\left[-\frac{\hbar^2}{2m}\Delta_i^{(D)} + \frac{1}{2}m\omega^2(t)\mathbf{x}_i^2\right] + \epsilon\sum_{i<j} \mathrm{V}(\mathbf{x}_{ij}) \qquad \mathbf{x}_i \in \mathbb{R}^D,\ \mathbf{x}_{ij} = \mathbf{x}_i - \mathbf{x}_j$$

With a potential satisfying $\mathrm{V}(\lambda\mathbf{x}) = \lambda^{\alpha}\mathrm{V}(\mathbf{x})$

2. **Impose a self-similar dynamical ansatz**

$$\Phi\left(\{\mathbf{x}_i\}, t\right) = \frac{1}{b^{D/2}} e^{i\sum_{i=1}^{N}\frac{m\mathbf{x}_i^2\dot{b}}{2b\hbar} - i\mu\tau(t)/\hbar}\Phi\left(\left\{\frac{\mathbf{x}_i}{b}\right\}, 0\right)$$

3. **Get the consistency equations, i.e.**

$$\ddot{b} + \omega^2(t)b = \omega_0^2/b^3 \qquad \epsilon(t) = b^{\alpha-2}$$

V. Gritsev, P. Barmettler, E. Demler, New J.Phys.**12**, 113005 (2010)
A. del Campo, Phys. Rev. A **84**, 031606(R) (2011)

Exact dynamics of correlations

Under self-similar dynamics

$$g_1(\mathbf{x},\mathbf{y};t) = \frac{1}{b^D} g_1\left(\frac{\mathbf{x}}{b},\frac{\mathbf{y}}{b};0\right)\exp\left(-\frac{i}{b}\frac{\dot{b}}{\omega_0}\frac{\mathbf{x}^2-\mathbf{y}^2}{2l_0^2}\right)$$

One-body reduced density matrix

$$n(\mathbf{k},t) = b^D \int d\mathbf{x}d\mathbf{y}\; g_1(\mathbf{x},\mathbf{y};0) \times \exp\left[-ib\left(\frac{\dot{b}}{\omega_0}\frac{\mathbf{x}^2-\mathbf{y}^2}{2l_0^2} - \mathbf{k}\cdot(\mathbf{x}-\mathbf{y})\right)\right]$$

Momentum distribution

Adiabatic limit:

$$g_1(\mathbf{x},\mathbf{y};t) = \frac{1}{b^D(t)} g_1\left(\frac{\mathbf{x}}{b(t)},\frac{\mathbf{y}}{b(t)};0\right),$$

$$\begin{aligned} n(\mathbf{k},t) &= b^D(t)\int d\mathbf{x}d\mathbf{y}\; g_1(\mathbf{x},\mathbf{y};0)\exp\left[i\gamma\mathbf{k}\cdot(\mathbf{x}-\mathbf{y})\right] \\ &= b^D(t)\, n(b(t)\mathbf{k},0), \end{aligned}$$

Slow, unstable against losses, decoherence, perturbations

Exact dynamics of correlations

Under self-similar dynamics

$$g_1(\mathbf{x},\mathbf{y};t) = \frac{1}{b^D} g_1\left(\frac{\mathbf{x}}{b},\frac{\mathbf{y}}{b};0\right) \exp\left(-\frac{i}{b}\frac{\dot{b}}{\omega_0}\frac{\mathbf{x}^2-\mathbf{y}^2}{2l_0^2}\right)$$

$$n(\mathbf{k},t) = b^D \int d\mathbf{x}d\mathbf{y}\; g_1(\mathbf{x},\mathbf{y};0) \times \exp\left[-ib\left(\frac{\dot{b}}{\omega_0}\frac{\mathbf{x}^2-\mathbf{y}^2}{2l_0^2} - \mathbf{k}\cdot(\mathbf{x}-\mathbf{y})\right)\right]$$

Sudden quench: $(\omega(t>0) = \omega_f = 0)$ $\quad b(t) = \sqrt{1+\omega_0^2 t^2}$

$$b(t) \sim \omega_0 t,\; \dot{b} = \omega_0$$

$$n(\mathbf{k},t) \sim |2\pi\omega_0 l_0^2/\dot{b}|^D g_1(\omega_0 \mathbf{k} l_0^2/\dot{b}, \omega_0 \mathbf{k} l_0^2/\dot{b})$$

Loss of off-diagonal elements, distortion of correlations (dynamical fermionization)

Design of a shortcut to adiabaticity

1. Force the scaling ansatz to reduce to the initial and final states considered
   Boundary conditions:

$$
\begin{aligned}
b(0) &= 1, \quad \dot{b}(0) = 0, \quad \ddot{b}(0) = 0 \\
b(\tau) &= \sqrt{\frac{\omega_f}{\omega_0}}, \quad \dot{b}(\tau) = 0, \quad \ddot{b}(\tau) = 0
\end{aligned}
$$

2. Determine an ansatz for the scaling factor (e.g. a polynomial)

$$b(t) = \sum_{j=0}^{5} a_j t^j \qquad\qquad s = t/\tau$$

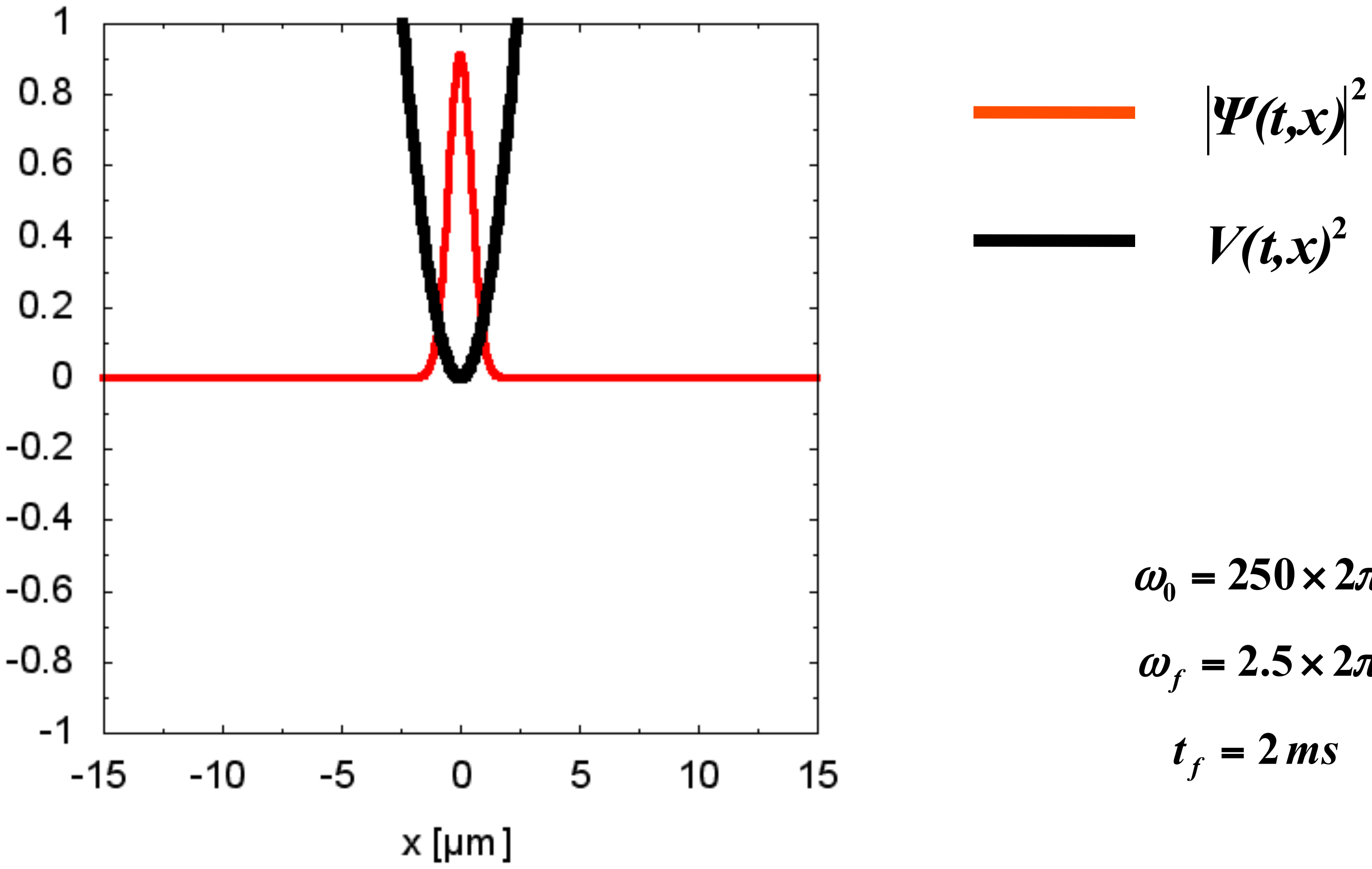
$$b(t) = 6\,(\gamma - 1)\,s^5 - 15\,(\gamma - 1)\,s^4 + 10\,(\gamma - 1)\,s^3 + 1$$

3. Find the driving time-dependent frequency and coupling strength from the
   consistency equations

$$\ddot{b} + \omega^2(t) b = \omega_0^2 / b^3 \qquad\qquad \epsilon(t) = b^{\alpha - 2}$$

Example

Time Evolution:

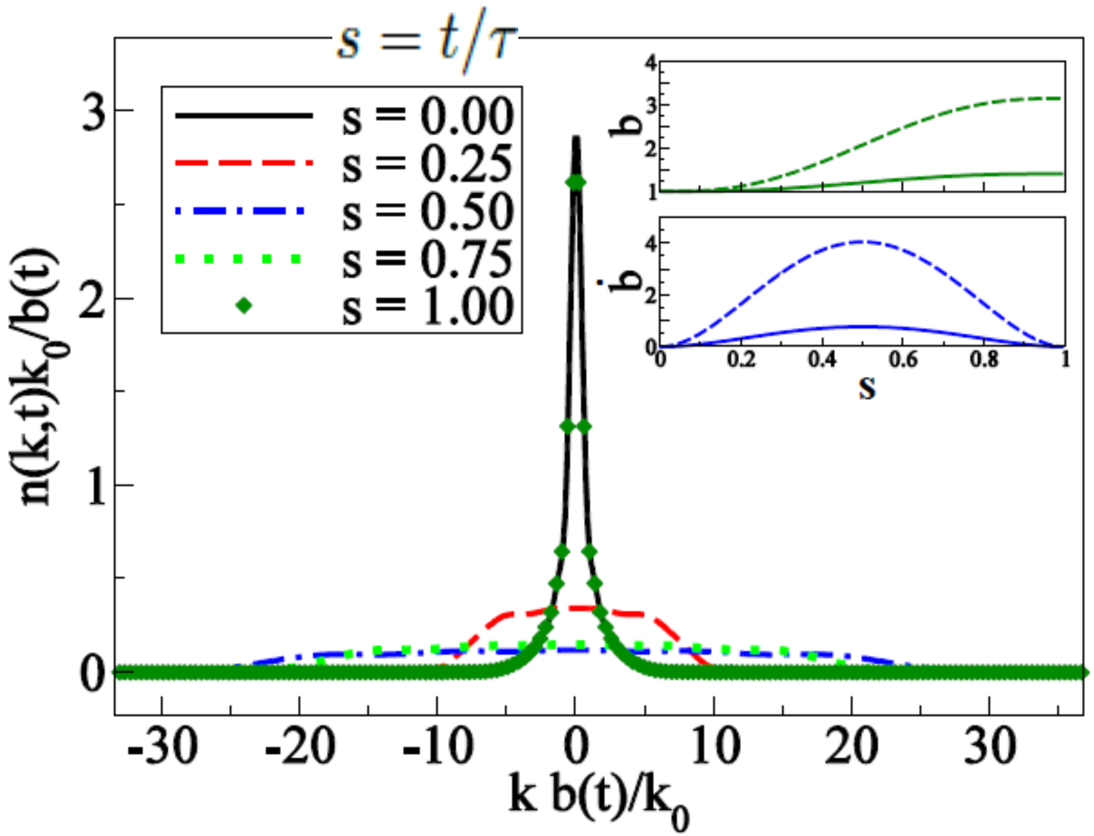


$$\omega_0 = 250 \times 2\pi \; Hz$$

$$\omega_f = 2.5 \times 2\pi \; Hz$$

$$t_f = 2\, ms$$

Shortcut in a Tonks-Girardeau gas



Preserves correlations

Robust against perturbations

A quantum dynamical microscope!

AdC, PRA **84**, 031606(R) (2011)

Experiment with a thermal cloud

Labeyrie's group: Phys. Rev. A 82, 033430 (2010)

87 Rb in Ioffe-Pritchard trap

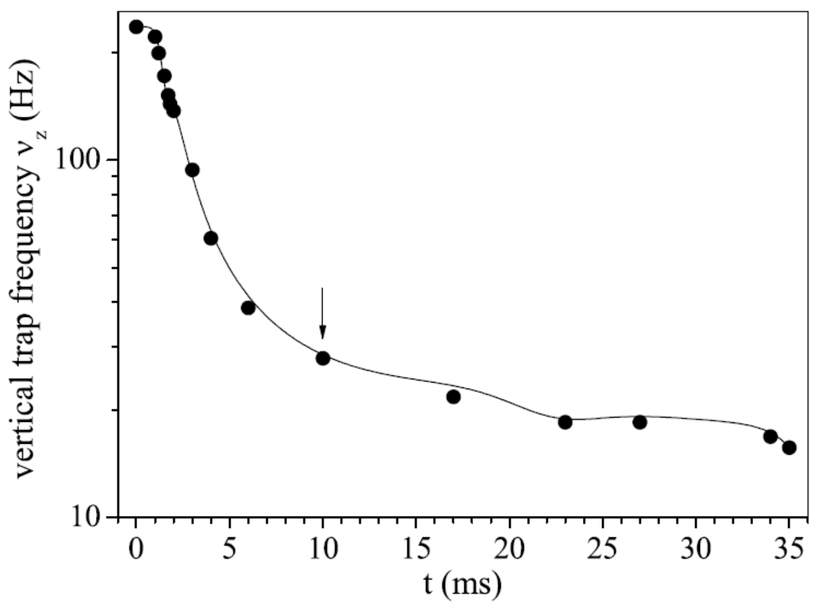


FIG. 2: Optimal trap frequency trajectory for a 35 ms vertical decompression. We plot (line) $\nu_z(t)$ for a 35 ms vertical decompression from $\nu_{0z} = 235.8$ Hz to $\nu_{fz} = 15.7$ Hz, obtained with the invariant method (see text). The symbols correspond to measured values of the vertical trap frequency during the decompression process.

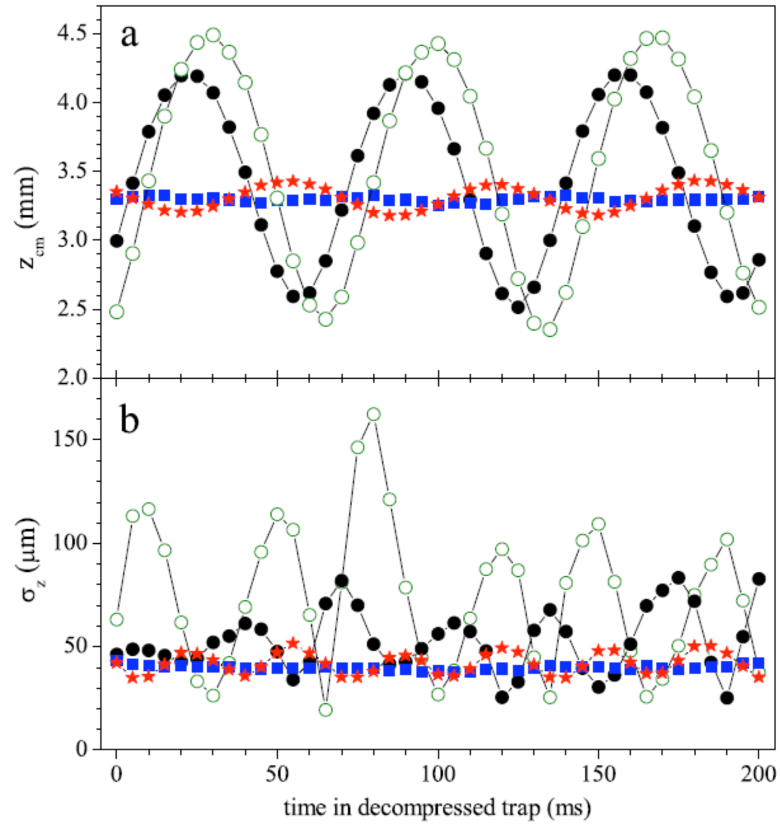


FIG. 3: (Color online) Vertical trap decompression in 35 ms. We report on (a) and (b) respectively the cloud's vertical center-of-mass position z_{cm} and size σ_z versus time after decompression, for four different sequences. Open circles (green online): abrupt decompression; solid circles (black online): linear decompression in 35 ms; stars (red online): shortcut decompression in 35 ms; squares (blue online): linear decompression in 6 s.

Experiment with an interacting BEC

Labeyrie's group: EPL 93, 23001 (2011)

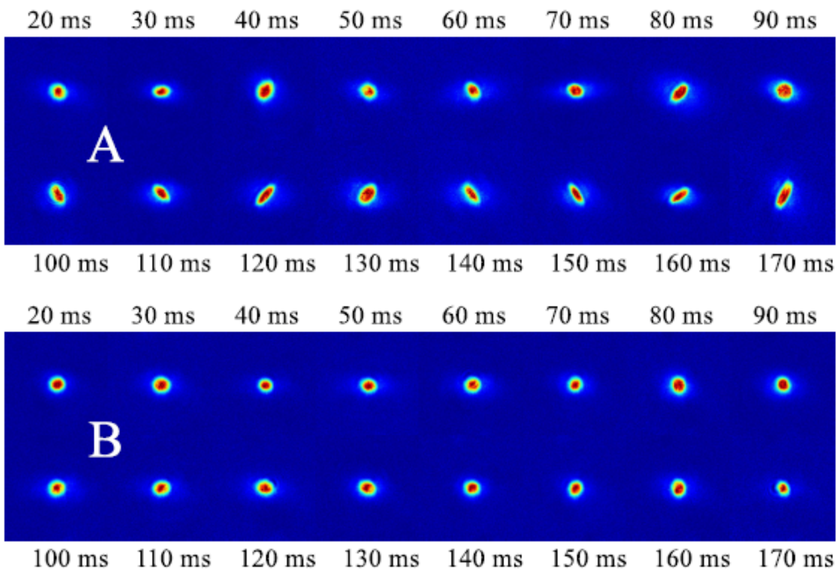


FIG. 1: Linear versus shortcut BEC decompression. We compare the time evolution of the BEC after two different decompression schemes: (**A**) a 30-ms-long linear ramp and (**B**) the shortcut trajectory (see text). The center of mass motion has been subtracted from these time of flight images for clarity.

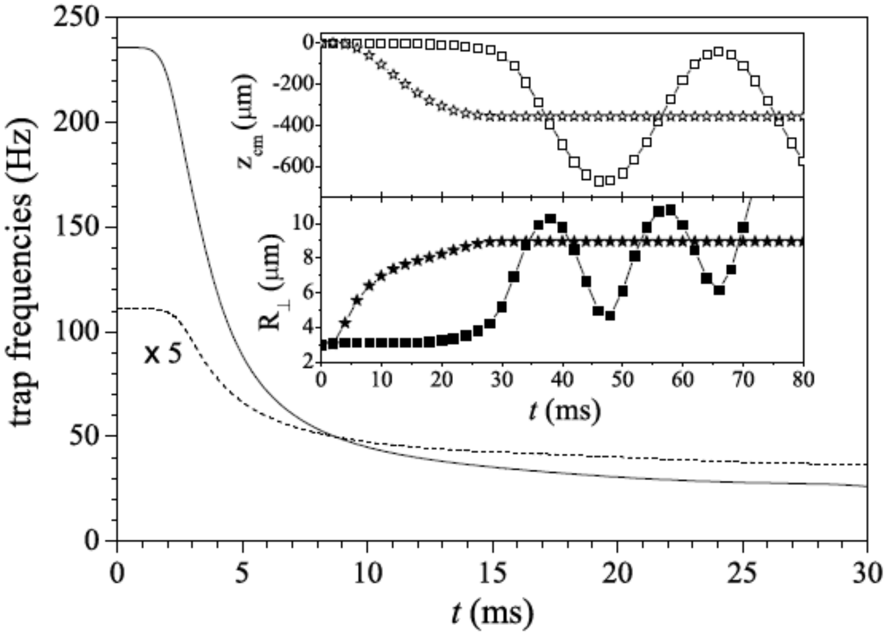


FIG. 2: Optimal BEC decompression in 30 ms. We plot the optimal trajectories $\omega_\perp(t)/2\pi$ (solid) and $\omega_\parallel(t)/2\pi$ ($\times 5$, dashed). The insert compares the subsequent evolution of the BEC's center of mass (open symbols) and radial size (solid symbols) for the optimal (stars) and linear (squares) decompressions (GPE simulation).

Self-similar dynamics: applicability

Easy and very general applicability to classical and quantum fluids

In other traps: AdC & Boshier, Sci. Rep 2, 648 (2012)

It does *not* require diagonalization of the Hamiltonian

Limited to processes associated with self-similar dynamics

Expansions

Transport

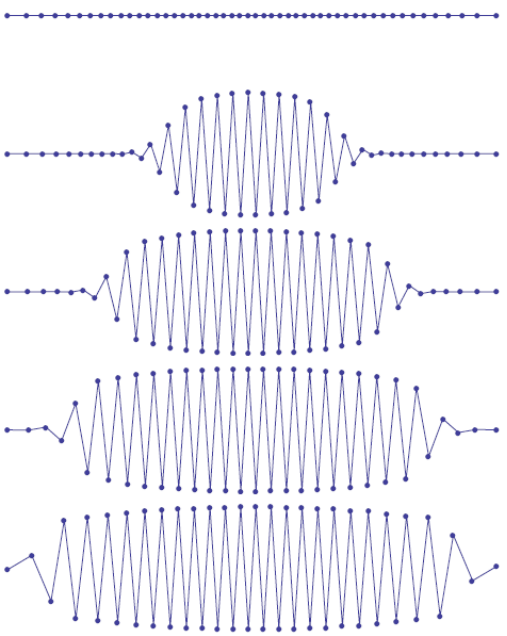
Theory @ Muga's group: Torrontegui et al. PRA '11

Exp @ Wineland's group: Bowler et al. PRL '12

Interaction tuning in BEC: AdC EPL '11

~~Splitting, Interferometry, ...~~

2nd recipe: Inhomogeneous phase transitions



Idea:

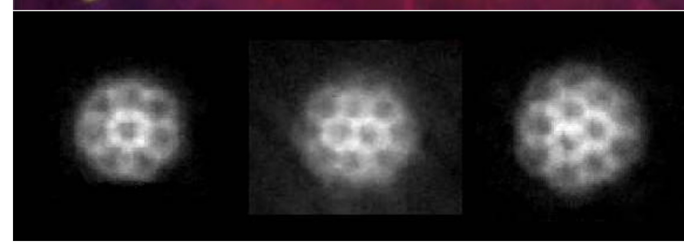
When a inhomogeneous system faces a symmetry breaking scenario, let different parts of the system talk to each other, so that the same ground state in the low symmetry phase is chosen everywhere (no vortices, kinks, solitons, etc.).

Theory: Inhomogeneous Kibble-Zurek mechanism.

Classical phase transitions:
T. W. B. Kibble, G. E. Volovik, JETP 1997
W. H. Zurek, *PRL*102,105702 (2009)
A. del Campo et al. *PRL*105, 075701 (2010)
A. del Campo et al. *NJP 13, 083022 (2011)*

Quantum phase transitions:
W. H. Zurek, U. Dorner, PTRSA 2008
J. Dziarmaga, M. M. Rams, NJP 2010
B. Damski, W. H. Zurek, NJP 2009

Cosmology in the lab



- Cosmology : symmetry breaking during expansion and cooling of the early universe
- Condensed matter:
  - Vortices in Helium
  - Liquid crystals
  - Superconductors
  - Superfluids

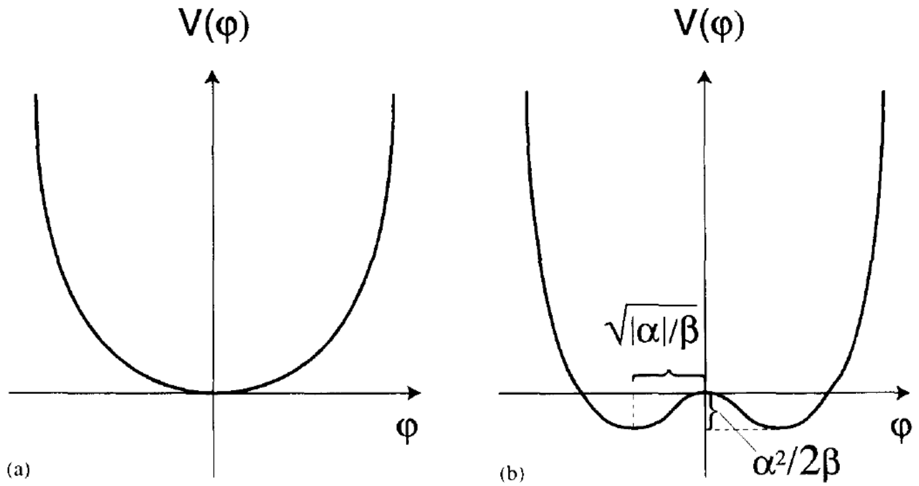
Similar free-energy landscape

near a critical point

T. W. B. Kibble, JPA 9, 1387 (1976); Phys. Rep. 67, 183 (1980)
W. H. Zurek, Nature (London) 317, 505 (1985); Acta Phys. Pol. B. 1301 (1993)

Second order phase transitions

Landau theory: Free energy landscape, changes across a 2PT from single to double well potential, parameterized by a relative temperature



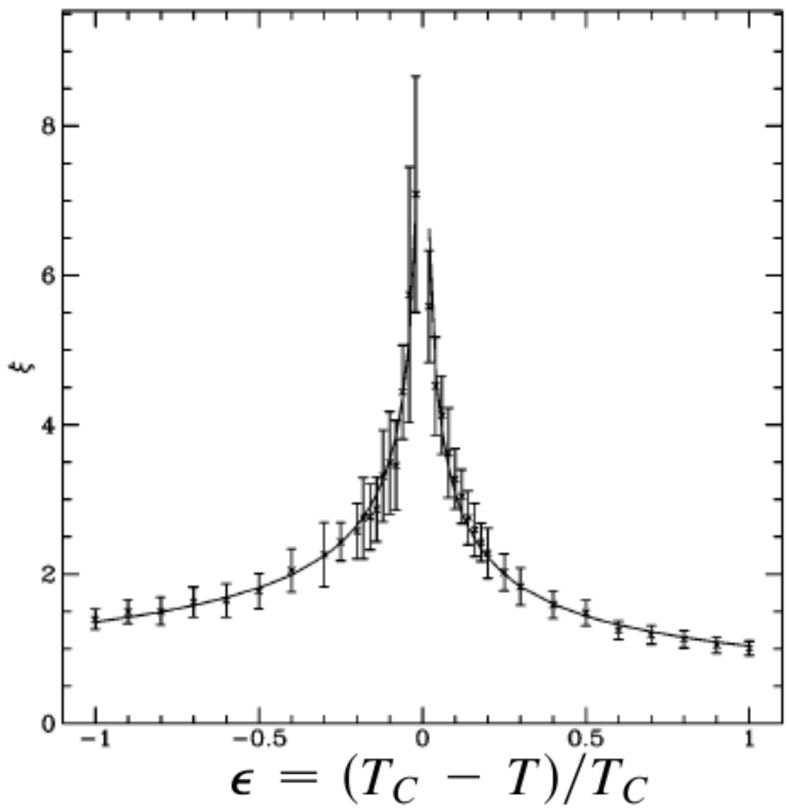
$$V(\varphi) = \alpha(T - T_c)|\varphi|^2 + \tfrac{1}{2}\beta|\varphi|^4$$

Second order phase transitions

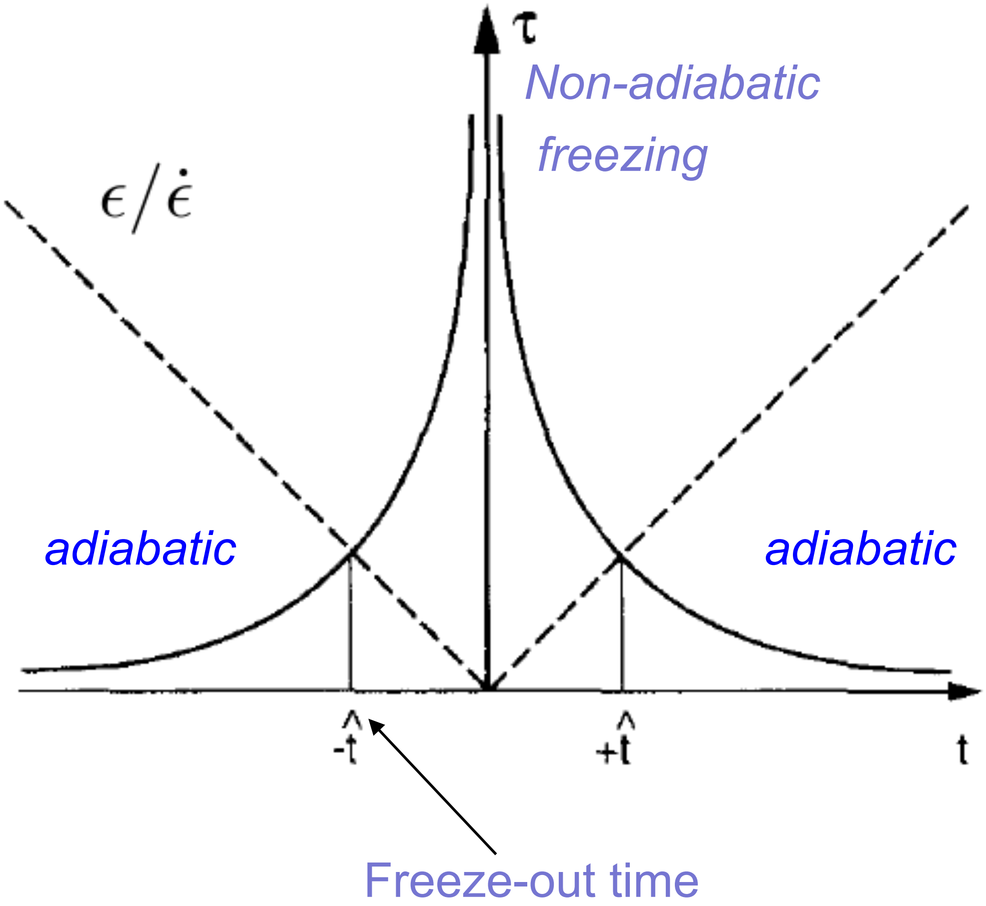
Universal behaviour of the order parameter: divergence of

Correlation/healing length $\xi = \xi_0/|\epsilon|^\nu$

Dynamical relaxation time $\tau = \tau_0/|\epsilon|^\mu$



The Kibble-Zurek mechanism

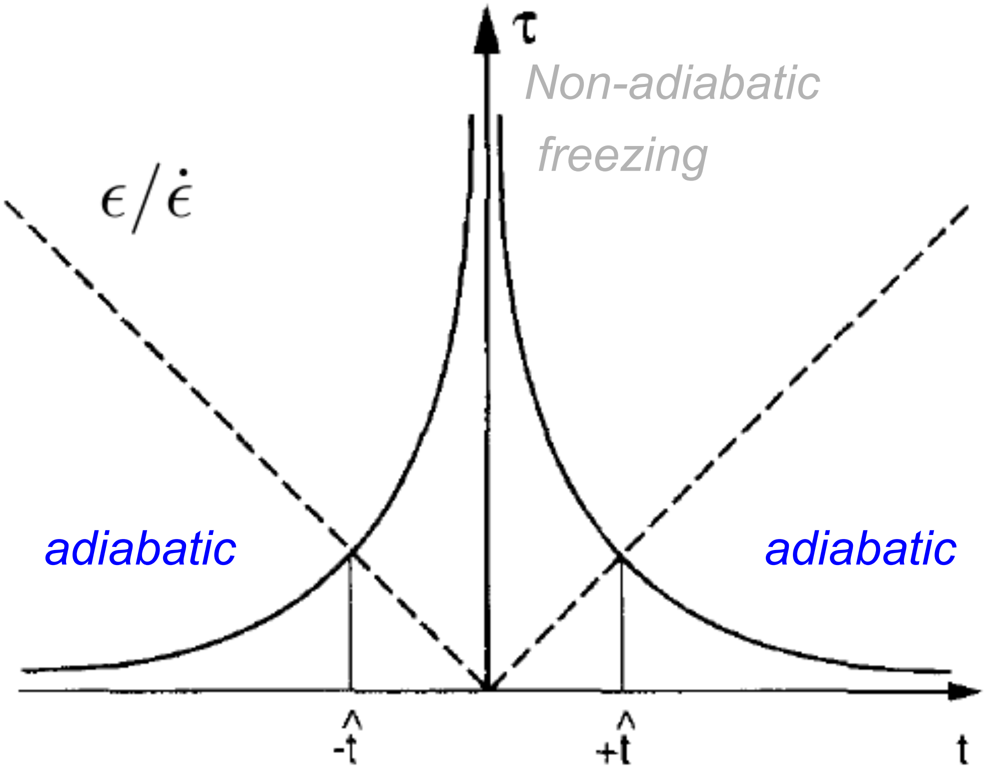


Linear quench

$$\epsilon = t/\tau_Q$$

$$\tau = \tau_0/|\epsilon|^{\mu}$$

The Kibble-Zurek mechanism



Linear quench

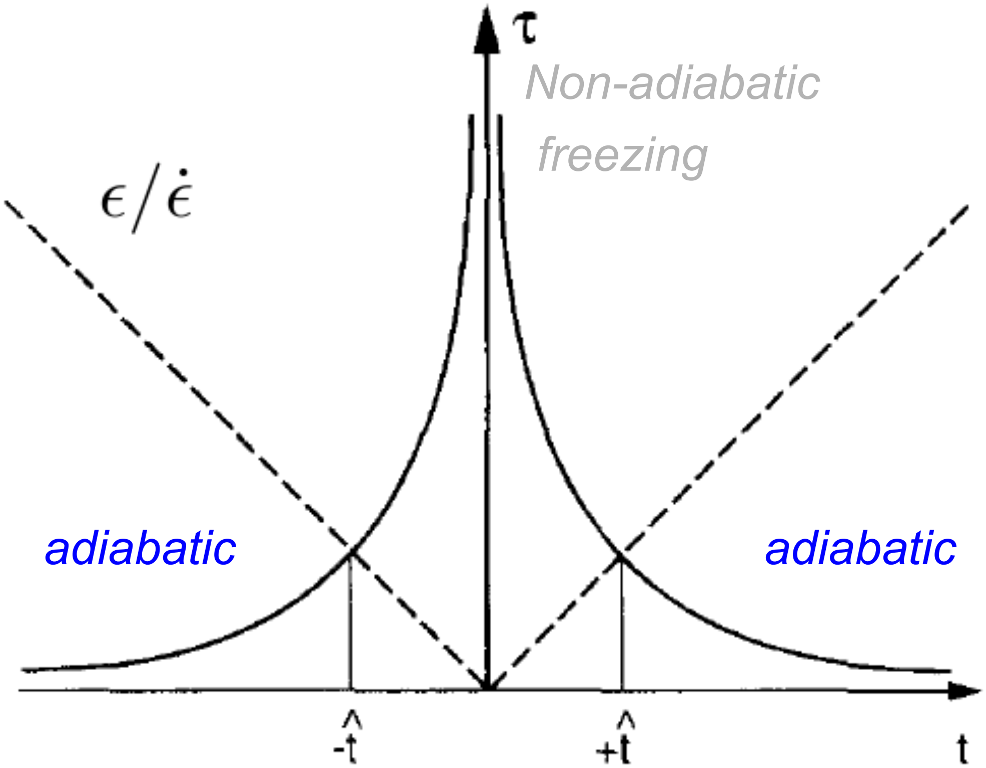
$$\epsilon = t/\tau_Q$$

$$\tau = \tau_0/|\epsilon|^{\mu}$$

The average domain size is given by the equilibrium correlation length at the freeze-out time

$$\hat{\xi} = \xi(\hat{t}) = \xi_0/|\epsilon(\hat{t})|^{\nu}$$

The Kibble-Zurek mechanism



Linear quench

$$\epsilon = t/\tau_Q$$

$$\tau = \tau_0/|\epsilon|^{\mu}$$

The average domain size is given by the equilibrium correlation length at the freeze-out time

$$\hat{\xi} = \xi_0(\tau_Q/\eta)^{1/4}$$

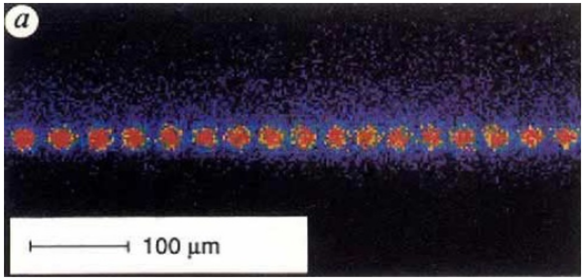
Structural phases in trapped ions

N ions on a ring trap with harmonic transverse confinement

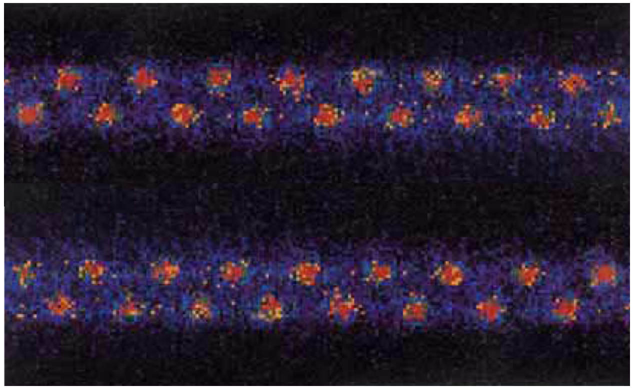
$$H = \frac{1}{2} m \sum_n \dot{\boldsymbol{r}}_n^2 + \frac{1}{2} m \sum_n (\nu_t^2 z_n^2) + \frac{Q^2}{2} \sum_{n \neq n'} \frac{1}{|\boldsymbol{r}_n - \boldsymbol{r}'_n|}$$

Critical transverse frequency

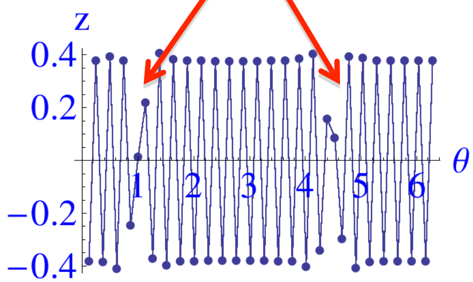
Linear chain



Degenerated zig-zag chains



Excitations (kinks)



Domain of size

$$\hat{\xi} = \xi_0 (\tau_Q / \eta)^{1/4}$$

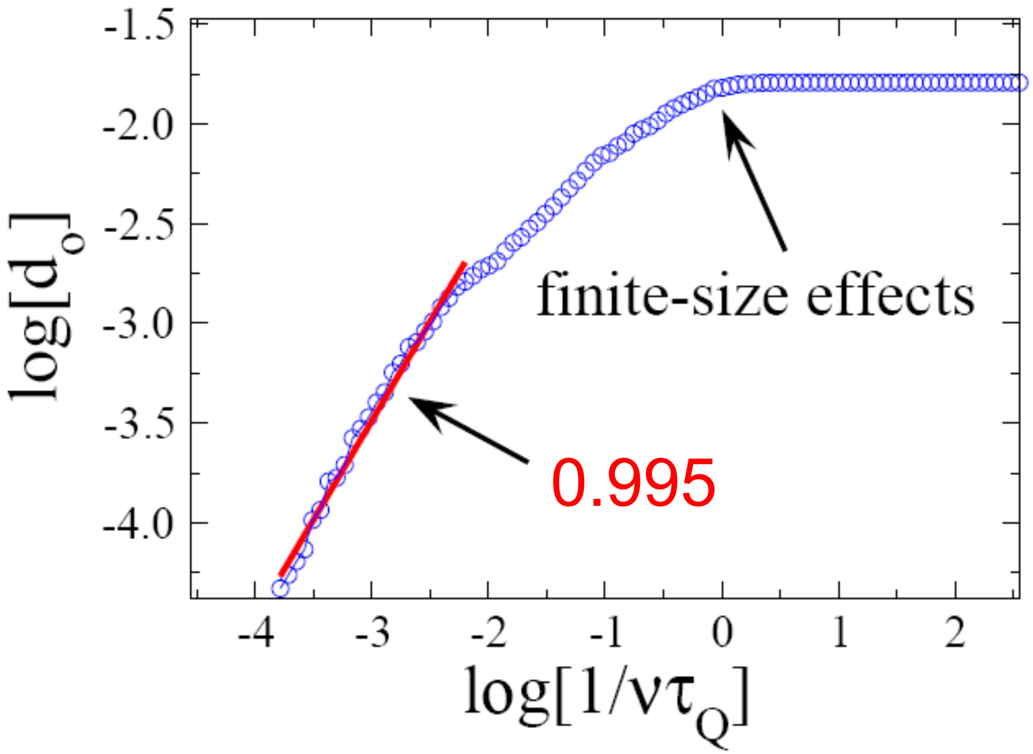
$$\nu_t^{(c)2} = 4 \frac{Q^2}{m a(0)^3}$$

Fishman PRB '08

Testing KZM in the lab

Axial and transverse harmonic potential (instead of a ring trap)

$$H = \frac{1}{2}m\sum_n \dot{\boldsymbol{r}}_n^2 + \frac{1}{2}m\sum_n(\nu_t^2 z_n^2 + \nu^2 x_n^2) + \frac{Q^2}{2}\sum_{n\neq n'}\frac{1}{|\boldsymbol{r}_n - \boldsymbol{r}'_n|}$$



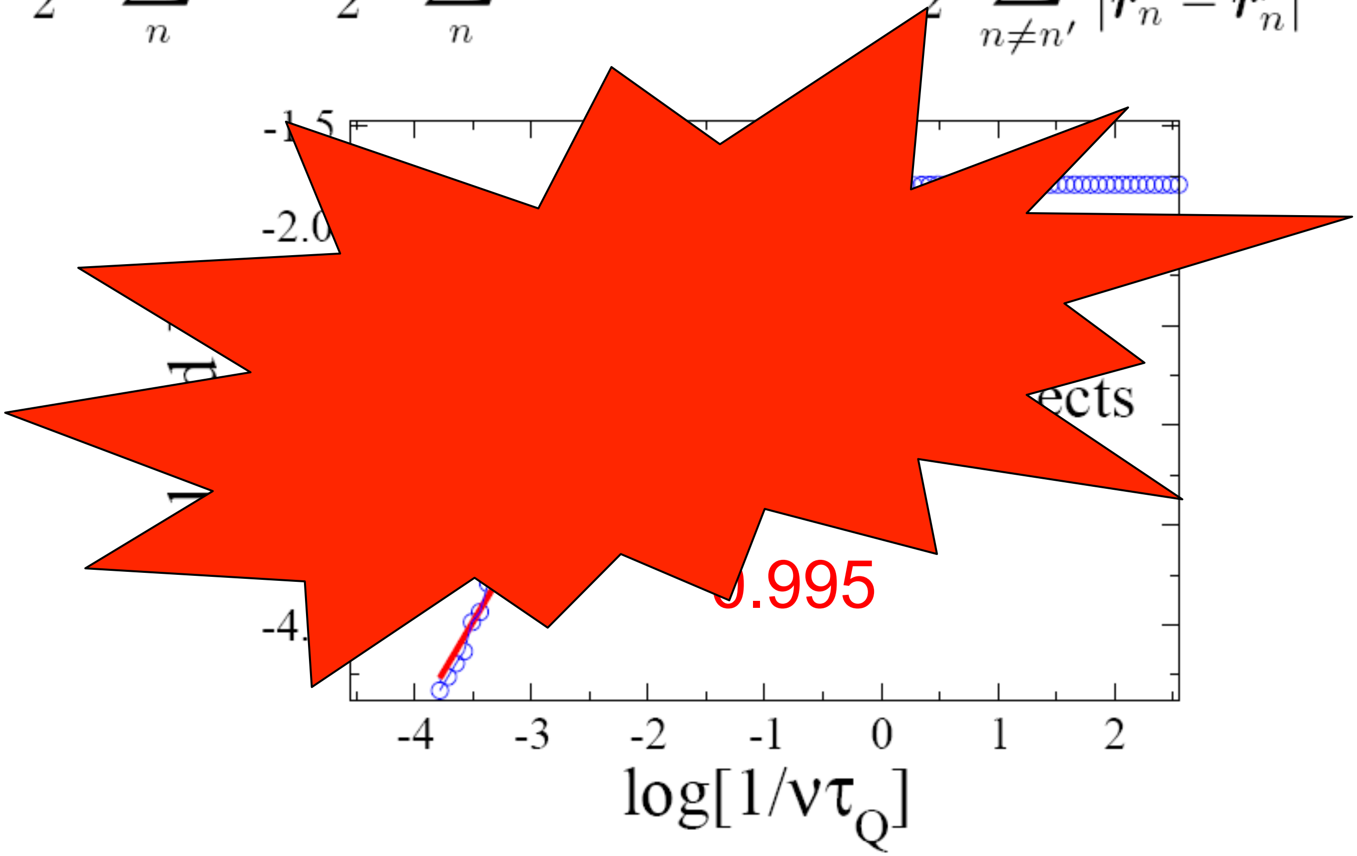
MD numerics: Langevin dynamics including laser cooling

N=50, 2000 realizations, quench of the transverse trapping frequency

Testing KZM in the lab

Axial and transverse harmonic potential (instead of a ring trap)

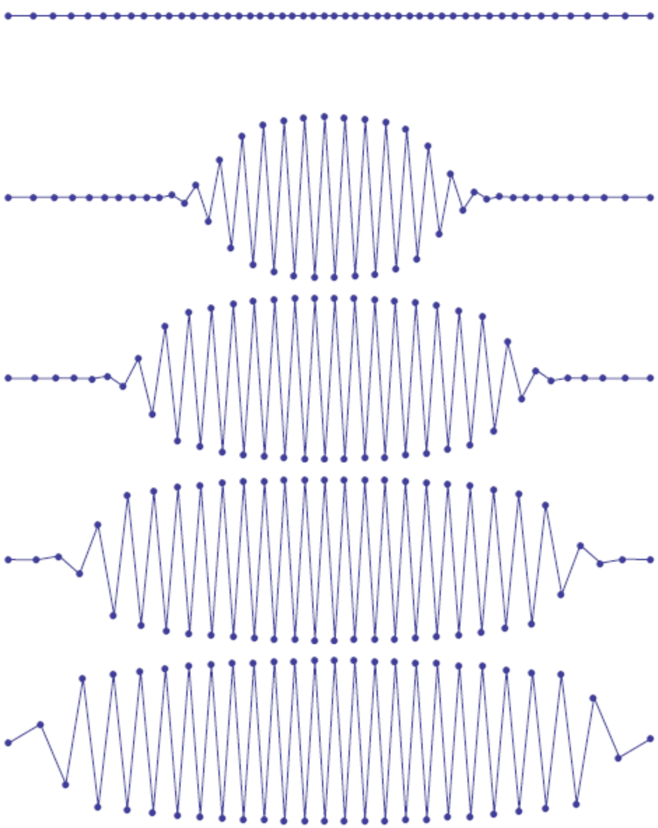
$$H = \frac{1}{2} m \sum_n \dot{\boldsymbol{r}}_n^2 + \frac{1}{2} m \sum_n (\nu_t^2 z_n^2 + \nu^2 x_n^2) + \frac{Q^2}{2} \sum_{n \neq n'} \frac{1}{|\boldsymbol{r}_n - \boldsymbol{r}'_n|}$$



Inhomogeneous KZM

Axial and transverse harmonic potential (instead of a ring trap)

$$H = \frac{1}{2}m\sum_n \dot{\boldsymbol{r}}_n^2 + \frac{1}{2}m\sum_n(\nu_t^2 z_n^2 + \nu^2 x_n^2) + \frac{Q^2}{2}\sum_{n\neq n'}\frac{1}{|\boldsymbol{r}_n - \boldsymbol{r}'_n|}$$



$$\nu_t^{(c)2} = 4\frac{Q^2}{ma(0)^3}$$

$$\nu_t^{(c)}(x)^2 = 4\frac{Q^2}{ma(x)^3}$$

Spatially dependent critical frequency (within LDA)

Inhomogeneous KZM

Inhomogeneous density, spatially dependent critical frequency

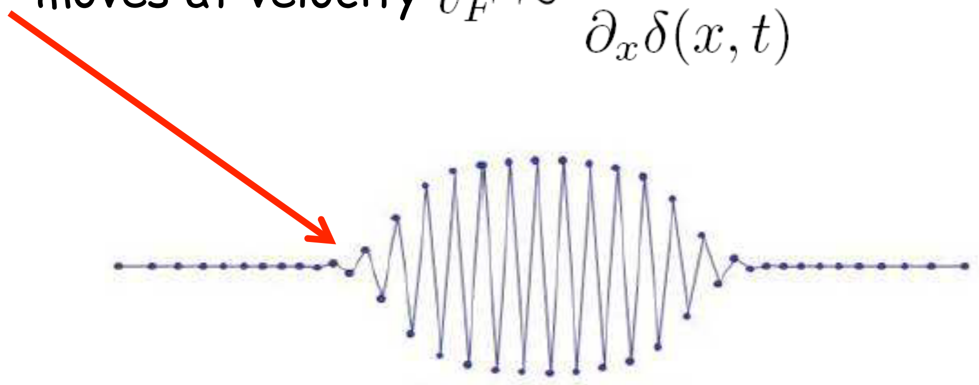
Linear quench:

$$\delta(x,t) = \nu_t(t)^2 - \nu_t^c(x)^2$$
$$= \nu_t^{(c)}(0)^2 - \nu_t^{(c)}(x)^2 - \delta_0 \frac{t}{\tau_Q}$$

Causality restricts the effective size of the chain

Front satisfying $\delta(x_F, t_F) = 0$ moves at velocity $v_F \sim \frac{\partial_t \delta(x,t)}{\partial_x \delta(x,t)}$

Sound velocity $\hat{v}_x = \hat{\xi}_x / \hat{\tau}_x$



IKZM for solitons in BEC: Zurek *PRL* 102, 105702 (2009)
AdC et al. *PRL*105, 075701 (2010)

Inhomogeneous KZM

Inhomogeneous density, spatially dependent critical frequency

Linear quench:

$$\delta(x,t) = \nu_t(t)^2 - \nu_t^c(x)^2$$
$$= \nu_t^{(c)}(0)^2 - \nu_t^{(c)}(x)^2 - \delta_0 \frac{t}{\tau_Q}$$

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Front satisfying $\delta(x_F, t_F) = 0$ moves at velocity $v_F \sim \frac{\partial_t \delta(x,t)}{\partial_x \delta(x,t)}$

Sound velocity $\hat{v}_x = \hat{\xi}_x / \hat{\tau}_x$

Adiabatic dynamics is possible even in the thermodynamic limit when

$$v_F < \hat{v}_x$$

in contrast with the (homogeneous) KZM

Inhomogeneous KZM

Inhomogeneous density, spatially dependent critical frequency

Linear quench:

$$\begin{aligned}\delta(x,t) &= \nu_t(t)^2 - \nu_t^c(x)^2 \\ &= \nu_t^{(c)}(0)^2 - \nu_t^{(c)}(x)^2 - \delta_0 \frac{t}{\tau_Q}\end{aligned}$$

Causality restricts the effective size of the chain

Front satisfying $\delta(x_F, t_F) = 0$ moves at velocity $v_F \sim \frac{\partial_t \delta(x,t)}{\partial_x \delta(x,t)}$

Sound velocity $\hat{v}_x = \hat{\xi}_x / \hat{\tau}_x$

Defects appear if $v_F > \hat{v}_x$ ⇒ effective size of the chain $2|\hat{X}_*|$

Inhomogeneous KZM

Inhomogeneous density, spatially dependent critical frequency

Linear quench:
$$\begin{aligned}\delta(x,t) &= \nu_t(t)^2 - \nu_t^c(x)^2 \\ &= \nu_t^{(c)}(0)^2 - \nu_t^{(c)}(x)^2 - \delta_0 \frac{t}{\tau_Q}\end{aligned}$$

Causality restricts the effective size of the chain

Front satisfying $\delta(x_F, t_F) = 0$ moves at velocity $v_F \sim \frac{\partial_t \delta(x,t)}{\partial_x \delta(x,t)}$

Sound velocity $\hat{v}_x = \hat{\xi}_x / \hat{\tau}_x$

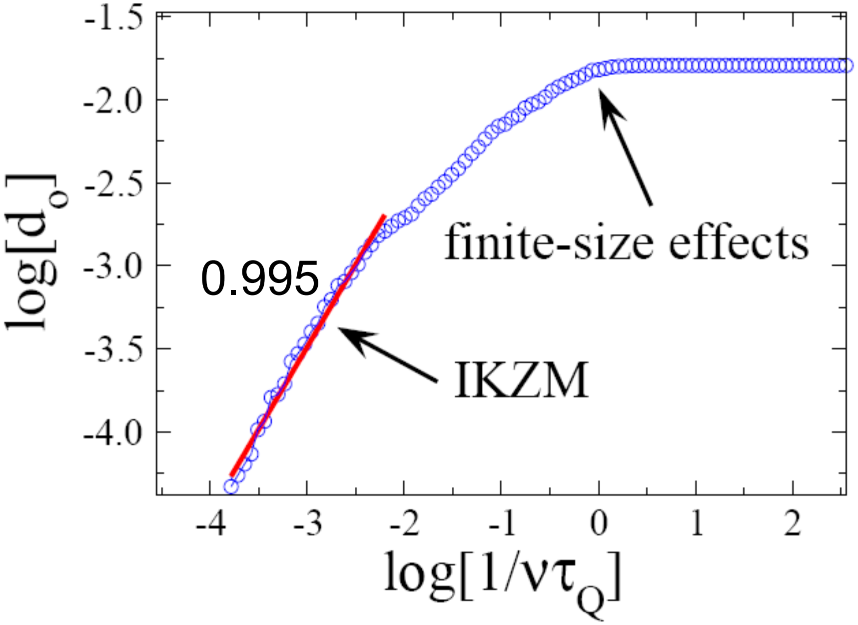
Defects appear if $v_F > \hat{v}_x$ ➡ effective size of the chain $2|\hat{X}_*|$

where *homogeneous* KZM theory applies

NEW SCALING LAW

$$d_o \sim \frac{2|\hat{X}_*|}{\hat{\xi}} = \frac{L}{3\nu_t^{(c)}(0)^2 a^2 \omega_0^2} \frac{\eta \delta_0}{\tau_Q}$$

Theory vs "experiment"!



$$d_o \sim \frac{2|\hat{X}_*|}{\hat{\xi}} = \frac{L}{3\nu_t^{(c)}(0)^2 a^2 \omega_0^2} \frac{\eta\delta_0}{\tau_Q}$$

Nice agreement!

Inhomogeneous KZM: applicability

Any second-order phase transition or classical/quantum quench in the presence of critical slowing down

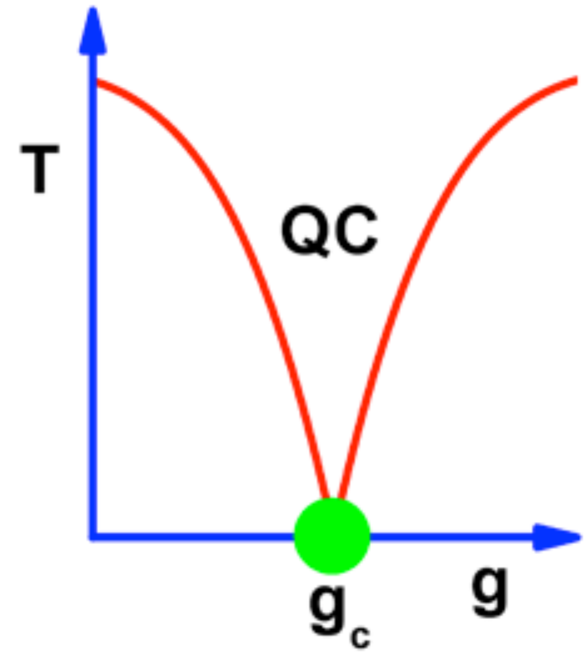
No experiments yet (ongoing)
Inhomogeneous ion chains (Mehlstäubler's group @ PTB)

It does NOT require diagonalization of the Hamiltonian

Partial applicability to adiabatic quantum computation

3rd part:

Transitionless quantum driving & QPT



Single discrete-level system: Demirplak & Rice ‘03, 2005; M. V. Berry ’09
Experiment for TLS: Bason et al. Nature Phys. ‘12

Many-body: A. del Campo, M. M. Rams, W. H. Zurek, PRL 109, 115703 (2012)

Transitionless quantum driving

Take a time-dependent Hamiltonian with instantaneous eigenstates:

$$\hat{H}_0(t)|n(t)\rangle = E_n(t)|n(t)\rangle$$

Write the adiabatic approximation including the geometric phase

$$|\psi_n(t)\rangle = \exp\left\{-\frac{\mathrm{i}}{\hbar}\int_0^t \mathrm{d}t' E_n(t') - \int_0^t \mathrm{d}t' \langle n(t')|\partial_{t'} n(t')\rangle\right\} |n(t)\rangle$$

Look for the Hamiltonian for which these are the exact evolving states

$$\mathrm{i}\hbar\partial_t|\psi_n(t)\rangle = \hat{H}(t)|\psi_n(t)\rangle$$

It follows that

$$\hat{H}(t) = \sum_n |n\rangle E_n\langle n| + \mathrm{i}\hbar\sum_n (|\partial_t n\rangle\langle n| - \langle n|\partial_t n\rangle|n\rangle\langle n|) \equiv \hat{H}_0(t) + H_1(t)$$

Single discrete-level system: Demirplak & Rice 2003, 2005; M. V. Berry 2009
Experiment for TLS: Bason et al. Nature Phys. (2012)

Quantum critical systems

Family of quasi-free fermion models

$$\mathscr{H}_0 = \sum_{\mathbf{k}} \psi_{\mathbf{k}}^{\dagger} \left[\vec{a}_{\mathbf{k}}(\lambda(t)) \cdot \vec{\sigma}_{\mathbf{k}} \right] \psi_{\mathbf{k}}$$

$$\vec{\sigma}_{\mathbf{k}} = (\sigma_{\mathbf{k}}^x, \sigma_{\mathbf{k}}^y, \sigma_{\mathbf{k}}^z)$$

$$\psi_{\mathbf{k}}^{\dagger} = (c_{\mathbf{k},1}^{\dagger}, c_{\mathbf{k},2}^{\dagger})$$

Model dependent vector $\vec{a}_{\mathbf{k}}(\lambda) = (a_{\mathbf{k}}^x(\lambda), a_{\mathbf{k}}^y(\lambda), a_{\mathbf{k}}^z(\lambda))$

Examples: Ising, XY in 1D, Kitaev model in 1D, 2D

General Auxiliary Hamiltonian in Fourier space

$$\mathscr{H}_1 = \lambda'(t) \sum_{\mathbf{k}} \frac{1}{2\varepsilon_{\mathbf{k}}^2} \psi_{\mathbf{k}}^{\dagger} \left[(\vec{a}_{\mathbf{k}}(\lambda) \times \partial_\lambda \vec{a}_{\mathbf{k}}(\lambda)) \cdot \vec{\sigma}_{\mathbf{k}} \right] \psi_{\mathbf{k}}$$

Quantum Ising Chain

Ising chain hamiltonian $$\mathcal{H}_0 = -\sum_{n=1}^{N} (\sigma_n^x \sigma_{n+1}^x + g\sigma_n^z)$$

Critical point $g = 1$

$g \gg 1$ $\quad |\rightarrow\rightarrow\rightarrow \ldots \rightarrow\rangle$

$|\uparrow\uparrow\uparrow \ldots \uparrow\rangle$

$|\downarrow\downarrow\downarrow \ldots \downarrow\rangle$

$g \ll 1$

Excitations: $|\ldots \uparrow\downarrow\downarrow\downarrow\downarrow\downarrow\uparrow\uparrow\uparrow\uparrow\uparrow\uparrow\uparrow\downarrow\downarrow\downarrow\downarrow\uparrow\uparrow\uparrow\uparrow\uparrow\uparrow\downarrow \ldots\rangle$

Jordan Wigner transformation+Fourier transform

$$\mathcal{H}_0 = 2\sum_{k>0} \psi_k^\dagger \left[\sigma_k^z (g - \cos k) + \sigma_k^x \sin k\right] \psi_k$$

$$\mathcal{H}_1 = -g'(t) \sum_{k>0} \frac{1}{2} \frac{\sin k}{g^2 + 1 - 2g\cos k} \psi_k^\dagger \sigma_k^y \psi_k$$

Auxiliary Hamiltonian in real space

Auxiliary Hamiltonian

$$\mathcal{H}_1 = -g'(t)\left[\sum_{m=1}^{N/2-1} h_m(g)\mathcal{H}_1^{[m]} + \frac{1}{2}h_{N/2}(g)\mathcal{H}_1^{[N/2]}\right]$$

$$\mathcal{H}_1^{[m]} = 2i\sum_{n=1}^{N}\left(c_n c_{n+m} + c_n^\dagger c_{n+m}^\dagger\right)$$

$$h_m = \frac{1}{8}\begin{cases} g^{m-1} & \text{for } |g|<1 \\ g^{-m-1} & \text{for } |g|>1 \end{cases}$$

A time dependent long-range interaction!

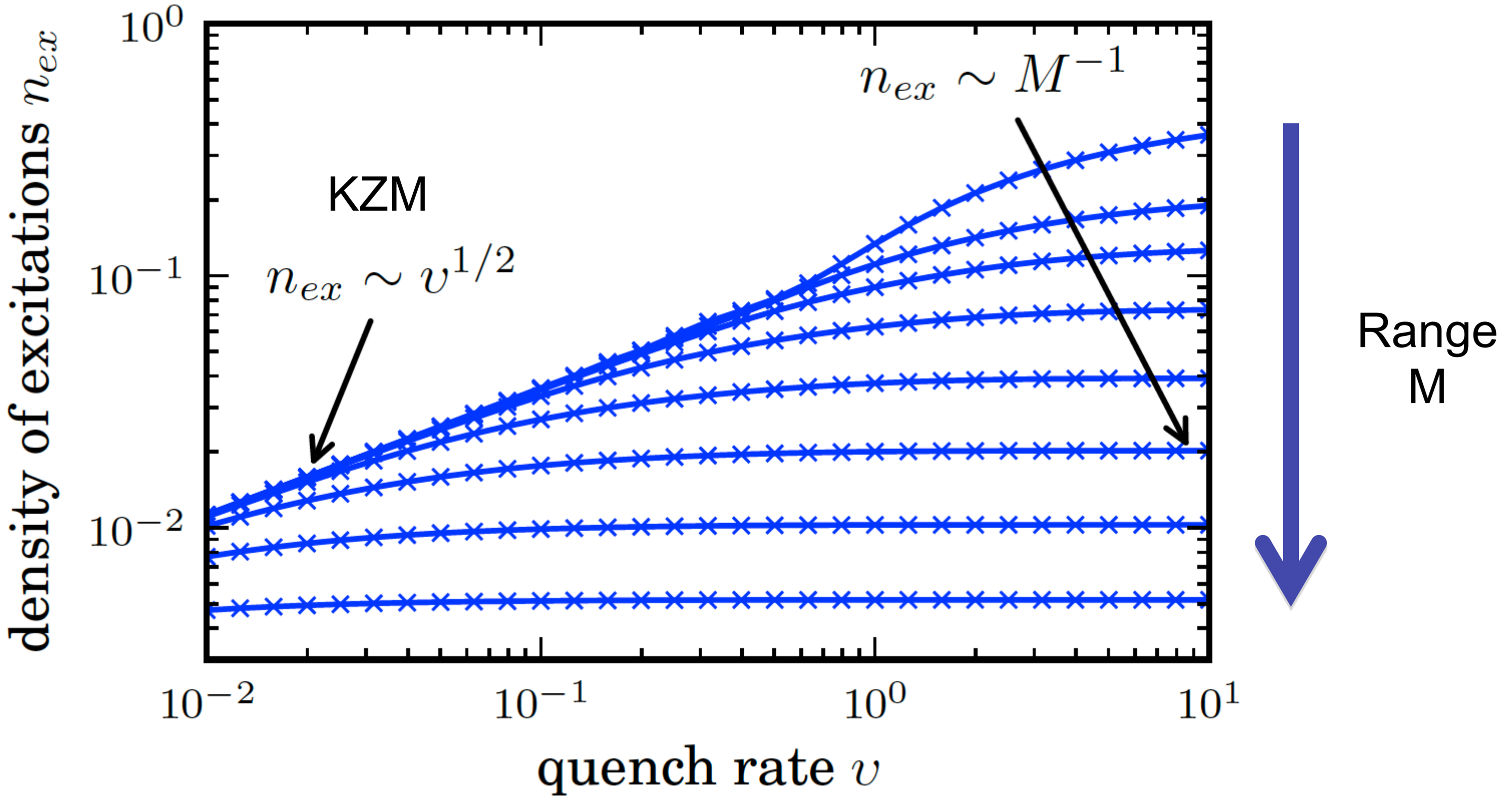
In spin representation

$$\mathcal{H}_1^{[m]} = \sum_{n=1}^{N}\left(\sigma_n^x\sigma_{n+1}^z\cdots\sigma_{n+m-1}^z\sigma_{n+m}^y + \sigma_n^y\sigma_{n+1}^z\cdots\sigma_{n+m-1}^z\sigma_{n+m}^x\right)$$

Truncated Auxiliary Hamiltonian

Transverse field: linear quench of through critical point $g(t) = g_c - \upsilon t$

Truncated Auxiliary Hamiltonian $\tilde{\mathscr{H}}_1(M) = \upsilon \sum_{m=1}^{M} s_m h_m(g) \mathscr{H}_1^{[m]}$



Summary

Recipes for "Fast-good" dynamics

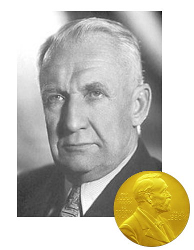
I- Self-similar scaling laws
II- Inhomogeneous KZM
III-Transitionless quantum driving & QPT

New techniques

Design of experiments

Quantum speed limits?

1945 Mandelstam and Tamm: isolated systems
2012 AdC et al. arXiv:1209.1737
all systems, also coupled to an environment



STA and thermodynamics, work statistics

Los Alamos
NATIONAL LABORATORY
EST. 1943

Collaborators

@ LANL

M. Boshier

M. M. Rams (now at Vienna)

W. H. Zurek

Quantum Lunch Seminar series @ LANL

Invariants of motion

X. Chen (Bilbao)

D. Guery-Odelin (Tolouse)

J. G. Muga (Bilbao)

A. Ruschhaupt (Hannover/Cork)

Inhomogeneous KZM

M. B. Plenio (Ulm)

A. Retzker (Jerusalem)

G. De Chiara (Belfast)

G. Morigi (Saarland)

Speed limits

I. L. Egusquiza (Bilbao)

M. B. Plenio (Ulm)

S. F. Huelga (Ulm)