Correlations after quantum quenches in the XXZ spin chain: Failure of the Generalized Gibbs Ensemble

Marton Mestyan

MTA–BME "Momentum" Statistical Field Theory Research Group,
Budapest University of Technology and Economics

MŰEGYETEM 1782

II. LDQS Summer School, İzmir
30 August 2014

B. Pozsgay, MM, M. A. Werner,
M. Kormos, G. Zarand and G. Takacs.
PRL, in press, arXiv:1405.2843 (2014)

Outline

Outline:

1. The Generalized Gibbs Ensemble (GGE)
2. Quenches of the Heisenberg XXZ spin chain
3. Real time simulation: failure of the GGE
4. The Quench Action (QA) GTBA and steady state correlators
5. Recent developments and outlook

Thermalization in isolated quantum systems

- Out-of-equilibrium, isolated quantum systems
- Steady state?

Gibbs Ensemble for nonintegrable systems

$$\hat{\rho} = \frac{1}{Z} e^{-\beta \hat{H}} \qquad \langle \hat{O} \rangle = \mathrm{Tr}\, \hat{\rho} \hat{O}$$

Integrable systems: infinitely many local conserved charges

$$[\hat{Q}_j, \hat{Q}_k] = 0$$
$$\hat{Q}_2 = \hat{H}$$

- Gibbs Ensemble: $\langle \hat{Q}_j \rangle = \mathrm{Tr}\, \hat{\rho} \hat{Q}_j$ differs from initial state value

The Generalized Gibbs Ensemble

The Generalized Gibbs Ensemble

$$\hat{\rho}_{\mathrm{GGE}} = \frac{1}{Z_{GGE}} e^{-\sum_j \beta_j \hat{Q}_j} \qquad \langle \hat{O} \rangle_{\mathrm{GGE}} = \mathrm{Tr}\, \hat{\rho}_{\mathrm{GGE}} \hat{O}$$

- Includes all local conserved charges
- β_j's are set to ensure charge conservation

The Generalized Gibbs Ensemble

The Generalized Gibbs Ensemble

$$\hat{\rho}_{\mathrm{GGE}} = \frac{1}{Z_{GGE}} e^{-\sum_j \beta_j \hat{Q}_j} \qquad \langle \hat{O} \rangle_{\mathrm{GGE}} = \mathrm{Tr}\, \hat{\rho}_{\mathrm{GGE}} \hat{O}$$

- Includes all local conserved charges
- β_j's are set to ensure charge conservation
- Does the GGE predict other local observables correctly?
  - free theories, theories equivalent to free fermions $\rightarrow$ yes
  - genuinely interacting systems?

The Heisenberg XXZ chain

The Heisenberg XXZ chain

$$\hat{H} = \sum_{j=1}^{L} \left(\sigma_j^x \sigma_{j+1}^x + \sigma_j^y \sigma_{j+1}^y + \Delta(\sigma_j^z \sigma_{j+1}^z - 1) \right)$$

- Periodic boundary conditions
- $\Delta > 1$ regime
- $\Delta \to \infty$ limit is the quantum Ising chain
- Charges: logarithmic derivatives of the transfer matrix

The Heisenberg XXZ chain

The Heisenberg XXZ chain

$$\hat{H} = \sum_{j=1}^{L} \left(\sigma_j^x \sigma_{j+1}^x + \sigma_j^y \sigma_{j+1}^y + \Delta(\sigma_j^z \sigma_{j+1}^z - 1) \right)$$

- Periodic boundary conditions
- $\Delta > 1$ regime
- $\Delta \to \infty$ limit is the quantum Ising chain
- Charges: logarithmic derivatives of the transfer matrix
- **Quench:** time evolution from the ground state of a local Hamiltonian after the Hamiltonian is altered

Initial states of studied quenches

Translationally Invariant Néel state

$$|\Psi_0^{\mathrm{N}}\rangle = \frac{1+\hat{T}}{\sqrt{2}}\,|\uparrow\downarrow\uparrow\downarrow \ldots\rangle = \frac{1}{\sqrt{2}}\left(|\uparrow\downarrow\uparrow\downarrow \ldots\rangle + |\downarrow\uparrow\downarrow\uparrow \ldots\rangle\right)$$

A ground state of the Ising Hamiltonian ($\Delta \to \infty$)

Translationally Invariant Dimer state

$$|\Psi_0^{\mathrm{D}}\rangle = \frac{1+\hat{T}}{\sqrt{2}}\,|\frac{(\uparrow\downarrow-\downarrow\uparrow)}{\sqrt{2}}\frac{(\uparrow\downarrow-\downarrow\uparrow)}{\sqrt{2}}\ldots\rangle$$

A ground state of the Majumdar—Ghosh Hamiltonian

GGE for XXZ quenches?

- The main question: does the GGE correctly describe the post-quench steady state?

[1] B. Wouters, M. Brockmann, J. De Nardis, D. Fioretto, M. Rigol, J.-S. Caux. *PRL, in press, arXiv:1405.0172 (2014)*

GGE for XXZ quenches?

- The main question: does the GGE correctly describe the post-quench steady state?
- GGE: NOT the exact steady state GTBA string densities from Quench Action[1] (explained later)

---

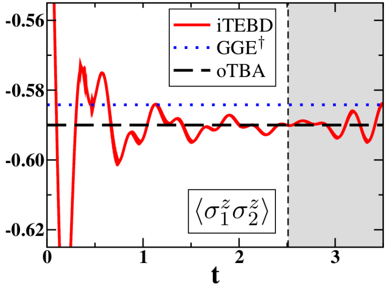
[1]B. Wouters, M. Brockmann, J. De Nardis, D. Fioretto, M. Rigol, J.-S. Caux. *PRL, in press, arXiv:1405.0172 (2014)*

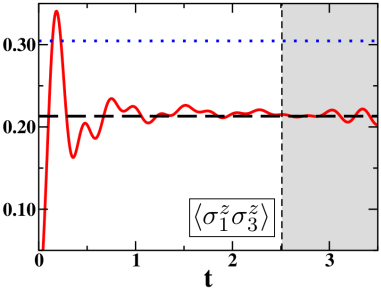
GGE for XXZ quenches?

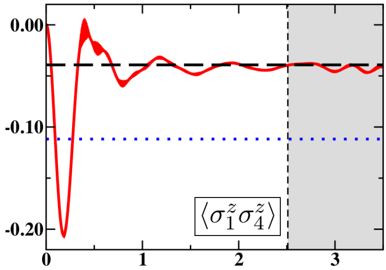
- The main question: does the GGE correctly describe the post-quench steady state?
- GGE: NOT the exact steady state GTBA string densities from Quench Action[1] (explained later)
- But maybe GGE still yields the correct local correlators?

[1] B. Wouters, M. Brockmann, J. De Nardis, D. Fioretto, M. Rigol, J.-S. Caux. *PRL, in press, arXiv:1405.0172 (2014)*

Time evolution of zz correlations, dimer initial state, $\Delta = 4$







†GGE data from: M. Fagotti, M. Collura, F. H. L. Essler, P. Calabrese. *Phys. Rev. B 89, 125101 (2014)*

Shaded area: iTEBD simulation is unreliable

Discrepancy explained by a slow drift?

The quench action GTBA in general [2]

Quench action for a TBA macrostate with string densities $\{\rho_n\}$

$$\mathcal{S}(\{\rho_n(\lambda)\}) = -\frac{2}{L}\mathrm{Re}\,\ln\langle\Psi_0|\{\rho_n(\lambda)\}\rangle - s(\{\rho_n(\lambda)\})$$

- Ψ_0 is the initial state
- λ is the Bethe ansatz rapidity
- $s(\{\rho_n(\lambda)\}$ is the entropy of the macrostate described by $\{\rho_n\}$

- Quench action: roughly the negative logarithmic overlap of all the microstates of a given $\{\rho_n(\lambda)\}$ with the initial state $|\Psi_0\rangle$

[2] J.-S. Caux, F. H. L. Essler. *Phys. Rev. Lett. 110, 257203 (2013)*

The quench action GTBA in general [2]

Quench action for a TBA macrostate with string densities $\{\rho_n\}$

$$\mathcal{S}(\{\rho_n(\lambda)\}) = -\frac{2}{L}\mathrm{Re}\,\ln\langle\Psi_0|\{\rho_n(\lambda)\}\rangle - s(\{\rho_n(\lambda)\})$$

- Ψ_0 is the initial state
- λ is the Bethe ansatz rapidity
- $s(\{\rho_n(\lambda)\}$ is the entropy of the macrostate described by $\{\rho_n\}$

- Quench action: roughly the negative logarithmic overlap of all the microstates of a given $\{\rho_n(\lambda)\}$ with the initial state $|\Psi_0\rangle$
- In the TDL, the post-quench steady state is described by the $\{\rho^*_n(\lambda)\}$ for which $\mathcal{S}(\{\rho^*_n(\lambda)\})$ is minimal

[2] J.-S. Caux, F. H. L. Essler. *Phys. Rev. Lett. 110, 257203 (2013)*

The quench action GTBA for the XXZ chain (oTBA) - 1

$$\mathcal{S}(\{\rho_n(\lambda)\}) = -\frac{2}{L}\mathrm{Re}\langle\Psi_0|\{\rho_n(\lambda)\}\rangle - s(\{\rho_n(\lambda)\})$$

[3] M. Brockmann, J. De Nardis, B. Wouters, J.-S. Caux. *J. Phys. A 47, 145003 (2014)*

[4] B. Pozsgay. *J. Stat. Mech.: Theor. Exp. P06011 (2014)*

The quench action GTBA for the XXZ chain (oTBA) - 1

$$\mathcal{S}(\{\rho_n(\lambda)\}) = -\frac{2}{L}\mathrm{Re}\langle\Psi_0|\{\rho_n(\lambda)\}\rangle - s(\{\rho_n(\lambda)\})$$

- Entropy term (half of the standard Yang–Yang entropy)
  $s(\{\rho_n(\lambda)\}) = \frac{1}{2}\sum_{n=1}^{\infty}\int d\lambda \left[\rho_n \ln\left(1+\frac{\rho_n^{\mathrm{h}}}{\rho_n}\right) + \rho_n^{\mathrm{h}}\ln\left(1+\frac{\rho_n}{\rho_n^{\mathrm{h}}}\right)\right]$

[3] M. Brockmann, J. De Nardis, B. Wouters, J.-S. Caux. *J. Phys. A 47, 145003 (2014)*

[4] B. Pozsgay. *J. Stat. Mech.: Theor. Exp. P06011 (2014)*

The quench action GTBA for the XXZ chain (oTBA) - 1

$$\mathcal{S}(\{\rho_n(\lambda)\}) = -\frac{2}{L}\mathrm{Re}\langle\Psi_0|\{\rho_n(\lambda)\}\rangle - s(\{\rho_n(\lambda)\})$$

- Entropy term (half of the standard Yang–Yang entropy)
  $s(\{\rho_n(\lambda)\}) = \frac{1}{2}\sum_{n=1}^{\infty}\int d\lambda\left[\rho_n \ln\left(1+\frac{\rho_n^{\mathrm{h}}}{\rho_n}\right)+\rho_n^{\mathrm{h}}\ln\left(1+\frac{\rho_n}{\rho_n^{\mathrm{h}}}\right)\right]$
- Overlap term in TDL[3] [4]
  $-\frac{2}{L}\mathrm{Re}\langle\Psi_0|\{\rho_n(\lambda)\}\rangle = \sum_{n=1}^{\infty}\int d\lambda\rho_n(\lambda)g_n(\lambda)$

[3] M. Brockmann, J. De Nardis, B. Wouters, J.-S. Caux. *J. Phys. A 47, 145003 (2014)*

[4] B. Pozsgay. *J. Stat. Mech.: Theor. Exp. P06011 (2014)*

The quench action GTBA for the XXZ chain (oTBA) - 1

$$\mathcal{S}(\{\rho_n(\lambda)\}) = -\frac{2}{L}\mathrm{Re}\langle\Psi_0|\{\rho_n(\lambda)\}\rangle - s(\{\rho_n(\lambda)\})$$

- Entropy term (half of the standard Yang–Yang entropy)
  $s(\{\rho_n(\lambda)\}) = \frac{1}{2}\sum_{n=1}^{\infty}\int d\lambda \left[\rho_n \ln\left(1+\frac{\rho_n^{\mathrm{h}}}{\rho_n}\right) + \rho_n^{\mathrm{h}}\ln\left(1+\frac{\rho_n}{\rho_n^{\mathrm{h}}}\right)\right]$
- Overlap term in TDL[3] [4]
  $-\frac{2}{L}\mathrm{Re}\langle\Psi_0|\{\rho_n(\lambda)\}\rangle = \sum_{n=1}^{\infty}\int d\lambda \rho_n(\lambda) g_n(\lambda)$
  - $g_1^{\mathrm{N}}(\lambda) = -\ln\frac{\tan(\lambda+i\frac{\eta}{2})\tan(\lambda-i\frac{\eta}{2})}{4\sin^2(2\lambda)}$
  - $g_1^{\mathrm{D}}(\lambda) = -\ln\frac{\sinh^4(\eta/2)\cot^2(\lambda)}{\sin(2\lambda+i\eta)\sin(2\lambda-i\eta)}$

---

[3] M. Brockmann, J. De Nardis, B. Wouters, J.-S. Caux. *J. Phys. A 47, 145003 (2014)*

[4] B. Pozsgay. *J. Stat. Mech.: Theor. Exp. P06011 (2014)*

The quench action GTBA for the XXZ chain (oTBA) - 1

$$\mathcal{S}(\{\rho_n(\lambda)\}) = -\frac{2}{L}\mathrm{Re}\langle\Psi_0|\{\rho_n(\lambda)\}\rangle - s(\{\rho_n(\lambda)\})$$

- Entropy term (half of the standard Yang–Yang entropy)
  $s(\{\rho_n(\lambda)\}) = \frac{1}{2}\sum_{n=1}^{\infty}\int d\lambda \left[\rho_n \ln\left(1+\frac{\rho_n^{\mathrm{h}}}{\rho_n}\right) + \rho_n^{\mathrm{h}}\ln\left(1+\frac{\rho_n}{\rho_n^{\mathrm{h}}}\right)\right]$
- Overlap term in TDL[3] [4]
  $-\frac{2}{L}\mathrm{Re}\langle\Psi_0|\{\rho_n(\lambda)\}\rangle = \sum_{n=1}^{\infty}\int d\lambda \rho_n(\lambda) g_n(\lambda)$
  - $g_1^{\mathrm{N}}(\lambda) = -\ln\frac{\tan(\lambda+i\frac{\eta}{2})\tan(\lambda-i\frac{\eta}{2})}{4\sin^2(2\lambda)}$
  - $g_1^{\mathrm{D}}(\lambda) = -\ln\frac{\sinh^4(\eta/2)\cot^2(\lambda)}{\sin(2\lambda+i\eta)\sin(2\lambda-i\eta)}$
  - $g_n^{\mathrm{N,D}}(\lambda) = \sum_{j=1}^{n} g_1^{\mathrm{N,D}}\left[\lambda + \frac{i\eta}{2}(n+1-2j)\right]$

---

[3] M. Brockmann, J. De Nardis, B. Wouters, J.-S. Caux. *J. Phys. A 47, 145003 (2014)*

[4] B. Pozsgay. *J. Stat. Mech.: Theor. Exp. P06011 (2014)*

The quench action GTBA for the XXZ chain (oTBA) - 2

- Minimize $\mathcal{S}(\{\rho_n(\lambda)\}) = -\frac{2}{L}\mathrm{Re}\langle\Psi_0|\{\rho_n(\lambda)\}\rangle - s(\{\rho_n(\lambda)\})$

The quench action GTBA for the XXZ chain (oTBA) - 2

- Minimize $\mathcal{S}(\{\rho_n(\lambda)\}) = -\frac{2}{L}\mathrm{Re}\langle\Psi_0|\{\rho_n(\lambda)\}\rangle - s(\{\rho_n(\lambda)\})$
- Conditions:
  - Bethe equations
    - $a_n(\lambda) = \rho_n(\lambda) + \rho_n^{\mathrm{h}}(\lambda) + \sum_{m=1}^{\infty}[T_{nm} * \rho_m](\lambda)$
    - $a_n(\lambda)$ and $T_{nm}(\lambda)$ are known functions
    - $[a * b](\lambda) = \int_{-\pi/2}^{\pi/2} d\lambda' a(\lambda')b(\lambda - \lambda')$

The quench action GTBA for the XXZ chain (oTBA) - 2

- Minimize $\mathcal{S}(\{\rho_n(\lambda)\}) = -\frac{2}{L}\mathrm{Re}\langle\Psi_0|\{\rho_n(\lambda)\}\rangle - s(\{\rho_n(\lambda)\})$
- Conditions:
  - Bethe equations
    - $a_n(\lambda) = \rho_n(\lambda) + \rho_n^{\mathrm{h}}(\lambda) + \sum_{m=1}^{\infty}[T_{nm} * \rho_m](\lambda)$
    - $a_n(\lambda)$ and $T_{nm}(\lambda)$ are known functions
    - $[a * b](\lambda) = \int_{-\pi/2}^{\pi/2} d\lambda' a(\lambda')b(\lambda - \lambda')$
  - The number of down spins: $\sum_{n=1}^{\infty} \int d\lambda\, n\rho_n(\lambda) = \frac{1}{2}$
    Introducing a term μn in the quench action

The quench action GTBA for the XXZ chain (oTBA) - 2

- Minimize $\mathcal{S}(\{\rho_n(\lambda)\}) = -\frac{2}{L}\mathrm{Re}\langle\Psi_0|\{\rho_n(\lambda)\}\rangle - s(\{\rho_n(\lambda)\})$
- Conditions:
  - Bethe equations
    - $a_n(\lambda) = \rho_n(\lambda) + \rho_n^{\mathrm{h}}(\lambda) + \sum_{m=1}^{\infty}[T_{nm} * \rho_m](\lambda)$
    - $a_n(\lambda)$ and $T_{nm}(\lambda)$ are known functions
    - $[a * b](\lambda) = \int_{-\pi/2}^{\pi/2} d\lambda' a(\lambda')b(\lambda - \lambda')$
  - The number of down spins: $\sum_{n=1}^{\infty} \int d\lambda \, n\rho_n(\lambda) = \frac{1}{2}$
    Introducing a term μn in the quench action
- Variational calculus yields the minimum condition equations

The quench action GTBA for the XXZ chain (oTBA)

The quench action GTBA (overlap TBA) equations for $\eta_n = \frac{\rho_n^h}{\rho_n}$

$$\ln\,\eta_n(\lambda) = g_n(\lambda) + \mu n + \sum_{m=1}^{\infty} [T_{nm} * \ln\,(1+\eta_m^{-1})](\lambda) \qquad (1)$$

The quench action GTBA for the XXZ chain (oTBA)

The quench action GTBA (overlap TBA) equations for $\eta_n = \frac{\rho_n^h}{\rho_n}$

$$\ln \eta_n(\lambda) = g_n(\lambda) + \mu n + \sum_{m=1}^{\infty} [T_{nm} * \ln (1 + \eta_m^{-1})](\lambda) \qquad (1)$$

- After solving (1), the Bethe–Takahashi equations are used to obtain $\rho_n^*(\lambda)$ and $\rho_n^{\mathrm{h}*}(\lambda)$ that minimize $\mathcal{S}$

The quench action GTBA for the XXZ chain (oTBA)

The quench action GTBA (overlap TBA) equations for $\eta_n = \frac{\rho_n^h}{\rho_n}$

$$\ln \eta_n(\lambda) = g_n(\lambda) + \mu n + \sum_{m=1}^{\infty} [T_{nm} * \ln\left(1 + \eta_m^{-1}\right)](\lambda) \qquad (1)$$

- After solving (1), the Bethe–Takahashi equations are used to obtain $\rho_n^*(\lambda)$ and $\rho_n^{\mathrm{h}*}(\lambda)$ that minimize $\mathcal{S}$
- Consistency checks for oTBA:
  - $\mathcal{S}(\{\rho_n^*(\lambda)\}) = -\frac{1}{L}\ln\langle\Psi_0|\Psi_0\rangle = 0$

The quench action GTBA for the XXZ chain (oTBA)

The quench action GTBA (overlap TBA) equations for $\eta_n = \frac{\rho_n^h}{\rho_n}$

$$\ln \eta_n(\lambda) = g_n(\lambda) + \mu n + \sum_{m=1}^{\infty} [T_{nm} * \ln (1 + \eta_m^{-1})](\lambda) \qquad (1)$$

- After solving (1), the Bethe–Takahashi equations are used to obtain $\rho_n^*(\lambda)$ and $\rho_n^{\mathrm{h}*}(\lambda)$ that minimize $\mathcal{S}$
- Consistency checks for oTBA:
  - $\mathcal{S}(\{\rho_n^*(\lambda)\}) = -\frac{1}{L}\ln\langle\Psi_0|\Psi_0\rangle = 0$
  - Steady state value of $\langle Q_j\rangle$'s should be equal to initial state values

Calculating steady state correlations from GTBA densities

- A numerically established conjecture: steady state correlations from the $\eta_n(\lambda)$ saddle point solutions[5]

[5] MM and B. Pozsgay. *J. Stat. Mech.: Theor. Exp., in press, arXiv:1405.0232 (2014)*

[6] C. Trippe, F. Göhmann, A. Klümper. *Eur. Phys. J. B 73, 253-264 (2010)*

Calculating steady state correlations from GTBA densities

- A numerically established conjecture: steady state correlations from the $\eta_n(\lambda)$ saddle point solutions[5]

- Proof for nearest neighbour correlators: application of the Hellmann–Feynman theorem
$\hat{H} = \sum_{j=1}^{L} \left(\sigma_j^x \sigma_{j+1}^x + \sigma_j^y \sigma_{j+1}^y + \Delta(\sigma_j^z \sigma_{j+1}^z - 1) \right)$

[5] MM and B. Pozsgay. *J. Stat. Mech.: Theor. Exp., in press, arXiv:1405.0232 (2014)*

[6] C. Trippe, F. Göhmann, A. Klümper. *Eur. Phys. J. B 73, 253-264 (2010)*

Calculating steady state correlations from GTBA densities

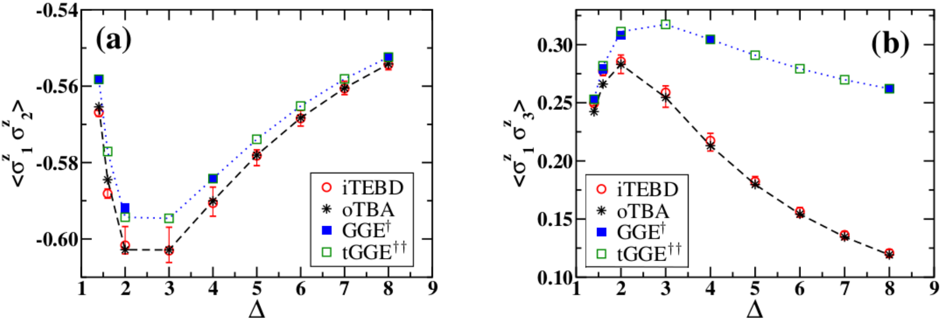
- A numerically established conjecture: steady state correlations from the $\eta_n(\lambda)$ saddle point solutions[5]
- Proof for nearest neighbour correlators: application of the Hellmann–Feynman theorem
  $\hat{H} = \sum_{j=1}^{L} \left(\sigma_j^x \sigma_{j+1}^x + \sigma_j^y \sigma_{j+1}^y + \Delta(\sigma_j^z \sigma_{j+1}^z - 1) \right)$
- Further correlators: conjectured by analogy with the QTM method formulas for correlators[6]

---

[5] MM and B. Pozsgay. *J. Stat. Mech.: Theor. Exp., in press, arXiv:1405.0232 (2014)*

[6] C. Trippe, F. Göhmann, A. Klümper. *Eur. Phys. J. B 73, 253-264 (2010)*

GGE vs. oTBA: steady state correlations plotted against anisotropy. Dimer initial state.



†GGE data from: M. Fagotti, M. Collura, F. H. L. Essler, P. Calabrese. *Phys. Rev. B 89, 125101 (2014)*

†† truncated GGE data from: B. Pozsgay. *J. Stat. Mech. P07003 (2013)*

Recent developments and outlook

- There are infinitely many ρ_n states with the same expectation values of charges
- The GGE yields the state that has the maximal conditional entropy if the Q_j charges are fixed, which is not physically relevant[7]

[7] G. Goldstein, N. Andrei. *PRA, in press, arXiv:1405.4224 (2014)*
[8] B. Pozsgay. *arXiv:1406.4613*
[9] B. Pozsgay. *arXiv:1407.8344*

Recent developments and outlook

- There are infinitely many ρ_n states with the same expectation values of charges
- The GGE yields the state that has the maximal conditional entropy if the Q_j charges are fixed, which is not physically relevant[7]
- The generalized eigenstate thermalization hypothesis (GETH) fails for systems with strings (bound states)[8]

[7] G. Goldstein, N. Andrei. *PRA, in press, arXiv:1405.4224 (2014)*

[8] B. Pozsgay. *arXiv:1406.4613*

[9] B. Pozsgay. *arXiv:1407.8344*

Recent developments and outlook

- There are infinitely many ρ_n states with the same expectation values of charges
- The GGE yields the state that has the maximal conditional entropy if the Q_j charges are fixed, which is not physically relevant[7]
- The generalized eigenstate thermalization hypothesis (GETH) fails for systems with strings (bound states)[8]
- The GGE works for the q-boson lattice model (genuinely interacting model, but no strings)[9]

---

[7] G. Goldstein, N. Andrei. *PRA, in press, arXiv:1405.4224 (2014)*
[8] B. Pozsgay. *arXiv:1406.4613*
[9] B. Pozsgay. *arXiv:1407.8344*

Recent developments and outlook

- There are infinitely many ρ_n states with the same expectation values of charges
- The GGE yields the state that has the maximal conditional entropy if the Q_j charges are fixed, which is not physically relevant[7]
- The generalized eigenstate thermalization hypothesis (GETH) fails for systems with strings (bound states)[8]
- The GGE works for the q-boson lattice model (genuinely interacting model, but no strings)[9]
- Can we find a generally valid macroscopic statistical ensemble (instead of the present GGE)?

[7] G. Goldstein, N. Andrei. *PRA, in press, arXiv:1405.4224 (2014)*

[8] B. Pozsgay. *arXiv:1406.4613*

[9] B. Pozsgay. *arXiv:1407.8344*

Summary

- Nonequlibrium dynamics of isolated integrable systems
- The GGE was expected to describe the post-quench steady states of integrable systems

Summary

- Nonequlibrium dynamics of isolated integrable systems
- The GGE was expected to describe the post-quench steady states of integrable systems
- The GGE has been refuted for the XXZ chain by real time numerical simulations of correlations

Summary

- Nonequlibrium dynamics of isolated integrable systems
- The GGE was expected to describe the post-quench steady states of integrable systems
- The GGE has been refuted for the XXZ chain by real time numerical simulations of correlations
- Quench action GTBA (oTBA) predicts steady-state correlations correctly

Summary

- Nonequlibrium dynamics of isolated integrable systems
- The GGE was expected to describe the post-quench steady states of integrable systems
- The GGE has been refuted for the XXZ chain by real time numerical simulations of correlations
- Quench action GTBA (oTBA) predicts steady-state correlations correctly

- Open question: finding a macroscopic ensemble describing the post-quench steady state of the XXZ chain

Acknowledgments

We thank F. Pollmann and P. Moca for useful conversations and their help to set up the iTEBD calculations.

We thank N. Andrei, P. Calabrese, J.-S. Caux, M. Fagotti, F. Göhmann, J. De Nardis, M. Rigol and B. Wouters for useful conservations and valuable feedback.

(B. Pozsgay, MM, M. A. Werner, M. Kormos, G. Zarand and G. Takacs. *PRL, in press, arXiv:1405.2843 (2014)*)