Closing report
for the NKFIH grant no. 125567

Balázs Pozsgai

February 12, 2020

1 The results of the work

The central part of the budget was to provide salary for a postdoctoral researcher, with whom I intended to investigate non-equilibrium dynamics in the XXZ spin chain. According to earlier plans I applied György Fehér for two years (24 months in total), and indeed we were working on this subject, and we wrote 2 papers on the subject. On top of this, I also did research independently from György, in the topics that were planned originally. There was an unexpected result that we obtained with two students Márton Borsi and Levente Pristyák; this work was also supported by the present grant. In the following I describe the results that we achieved.

With György Fehér we investigated the real time evolution of the XXZ spin chain. This was planned in the original proposal. We obtained partial results: In [1] we derived an integral series for the propagator of the interacting model. The propagator is an intermediate object that could be used to derive the time dependence of physical observables. Unfortunately we have not yet been able to use our result [1] to compute the physical observables. This is left to further work. Nevertheless the result [1] opened up interesting connections to the theory of classical many-body transport and growth models: the propagator is closely related to analogous objects in the so-called ASEP hopping model (Antisymmetric Exclusion Process). György plans to continue research in this (mathematically oriented) direction.

Independently from György, I have been working on the questions regarding integrable quenches, in collaboration with Lorenzo Piroli and Eric Vernier. Our main contribution is the classification of integrable states in spin chains, together with an understanding of their integrability properties. For local product states this work was published in arXiv:1709.04796, which was not funded by the present grant. But I am mentioning it because it already solved some of the questions posed in the original research proposal. We also continued this line of research, and investigated the non-analytic behaviour of the so-called Loschmidt echo [2]. I have also a paper on my own where I calculate exact overlaps between eigenstates and some initial states in the spin chain [3]. Furthermore, with Lorenzo Piroli and Eric Vernier we continued the same line of research and investigated both the SU3-symmetric model [4] and also integrable Matrix Product States (MPS) in a variety of models [5]. This latter research was not planned in the original proposal, because at that time it was not even known that non-trivial MPS can also be integrable, but our work clarified these integrability structures. Our approach was later used in the work arxiv:1912.09338 in the context of AdS/CFT. The papers [2], [3] and [5] are partially funded by the present grant.

In the meantime we also continued research with György. We clarified the status of the Generalized Gibbs Ensemble (GGE) in spin chains with higher rank symmetry groups. This particular research was not pre-planned either, but it was a rather natural direction. We wrote

a paper [6] which we submitted to SciPost. We obtained favorable reviews, but unfortunately there has been a significant delay due to the editorial office. At present we are still waiting for an editorial decision. The reviews and the status of the manuscript can be checked at the address https://scipost.org/submissions/1909.04470v2/. We hope that this will be accepted for publication soon.

As I mentioned above, there was an unexpected result that we obtained with two students Márton Borsi and Levente Pristyák: we derived an exact formula for the mean currents of conserved charges in integrable models. This result plays an essential role in the recent hydrodynamic theory of transport in integrable models, known as Generalized Hydrodynamics. On top if it, our result is rather interesting on its own, because it says something fundamental about integrable models: that the transport is essentially semi-classical, even with a finite number of particles. We wrote a paper [7] that we submitted to Physical Review X (2018 impact factor: 12.211). Our paper was accepted for publication, and it will appear soon (most probably it will have appeared by the time this report is read). From this grant I payed salary to Levente for 2 moths during the summer of 2019, such that he would work on finishing the paper, such that we can publish it as soon as possible.

Altogether there are 5 papers that are already published, 1 that will be published very soon, and 1 where we are waiting for the editorial office. The support from this grant is mentioned in the Acknowledgements of all these papers.

2 Conference talks

The results of our research activity were presented in these conference talks:

1. (Gy.F.) 29 June 2018, Workshop "Exactly Solvable Quantum Chains", IIP, Natal, Brazil, *The propagator of the finite XXZ spin-1/2 chain*

2. (Gy.F.) 28 August 2018, Math-Phy Seminar, University of Melbourne, Melbourne, Australia, *The propagator of the finite XXZ spin-1/2 chain*

3. (B.P.) 5. September 2018, Workshop "Correlations in Integrable Quantum Many-Body Systems", Wuppertal, Germany, *Recent exact results for non-equilibrium dynamics in integrable models*

4. (Gy.F.) 14 November 2018, Mini-workshop on Transport in One-Dimension, FMF, University Ljubljana, Slovenia, *The propagator of the finite XXZ spin-1/2 chain*

5. (Gy.F.) 17 May 2019, Workshop "Emergent Hydrodynamics in Low Dimensional Quantum Systems", Natal, Brazil, *The propagator of the finite XXZ spin-1/2 chain*

6. (B.P.) 16. May 2019, Workshop "Emergent Hydrodynamics in Low Dimensional Quantum Systems", International Institute of Physics, Natal, Brazil, *Mean values of current operators in Bethe Ansatz solvable models*

References

[1] G. Z. Fehér and B. Pozsgay, "The propagator of the finite XXZ spin-$\frac{1}{2}$ chain," *SciPost Physics* **6** (2019) no. 5, 063, arXiv:1808.06279 [cond-mat.stat-mech].

[2] L. Piroli, B. Pozsgay, and E. Vernier, "Non-analytic behavior of the Loschmidt echo in XXZ spin chains: exact results," *Nuclear Physics B* **933** (2018) 454–481, arXiv:1803.04380 [cond-mat.stat-mech].

[3] B. Pozsgay, "Overlaps with arbitrary two-site states in the XXZ spin chain," *Journal of Statistical Mechanics: Theory and Experiment* **2018** (2018) no. 5, 053103, arXiv:1801.03838 [cond-mat.stat-mech].

[4] L. Piroli, E. Vernier, P. Calabrese, and B. Pozsgay, "Integrable quenches in nested spin chains II: the Quantum Transfer Matrix approach," *Journal of Statistical Mechanics: Theory and Experiment* **6** (2019) no. 6, 063104, arXiv:1812.05330 [cond-mat.stat-mech].

[5] B. Pozsgay, L. Piroli, and E. Vernier, "Integrable Matrix Product States from boundary integrability," *SciPost Physics* **6** (2019) no. 5, 062, arXiv:1812.11094 [cond-mat.stat-mech].

[6] G. Z. Fehér and B. Pozsgay, "Generalized Gibbs Ensemble and string-charge relations in nested Bethe Ansatz," *arXiv e-prints* (2019) , arXiv:1909.04470 [cond-mat.stat-mech].

[7] M. Borsi, B. Pozsgay, and L. Pristyák, "Current operators in Bethe Ansatz and Generalized Hydrodynamics: An exact quantum/classical correspondence," *arXiv e-prints* (2019) , arXiv:1908.07320 [cond-mat.stat-mech].