Quantum simulators for fundamental physics

Sebastian Erne[*1]
1. Atominstitut, TU Wien, Stadionallee 2, 1020 Vienna, Austria

Ultracold atoms and their non-equilibrium evolution present an ideal platform to study fundamental processes of quantum field theory and the relaxation dynamics of quantum many-body systems. Here, we present recent results and future prospects for analogue quantum simulators based on effective field theory descriptions. In particular, we discuss the relaxation in an inhomogeneous extended bosonic Josephson junction and its connection to the sine-Gordon model [1], superradiant instabilities and recurrences in multiquantum vortex decay [2], common sound-rings during the relaxation of vortex clusters [3], and measurement of the analogue circular Unruh effect via local interferometric two-frequency detectors [4][5]. The continuous non-destructive measurements of cold atom systems paves the way to study this fundamental and yet still untested prediction of quantum field theory, that a linearly accelerated observer in the vacuum observes a thermal state at the Unruh-temperature.

References

[1] J.-F. Mennemann, I. E. Mazets, M. Pigneur, H. P. Stimming, N. J. Mauser, J. Schmiedmayer, S. Erne, Phys. Rev. Res. **3** 023197 (2021) [2] S. Patrick, A. Geelmuyden, S. Erne, C. Barenghi, S. Weinfurtner, *in preparation* (2021) [3] A. Geelmuyden, S. Erne, S. Patrick, C. Barenghi, S. Weinfurtner, arXiv 2105.11509 (2021) [4] C. Gooding, S. Biermann, S. Erne, J. Louko, W. G. Unruh, J. Schmiedmayer, S. Weinfurtner, Phys. Rev. Let. **125** 213603 (2020) [5] S. Biermann, S. Erne, C. Gooding, J. Louko, J. Schmiedmayer, W. G. Unruh, S. Weinfurtner, Phys. Rev. D **102** 085006 (2020)

[*]Corresponding author: erne@atomchip.org

Dynamics of rapidly crossing a phase transition

Sebastian Erne[*1]
1. Atominstitut, TU Wien, Stadionallee 2, 1020 Vienna, Austria

Universality near continuous phase transitions has led to a tremendous increase in our understanding of the fundamental aspects governing the large scale structure formation of seemingly different systems. This insensitivity to microscopic details culminated in the renormalization group (RG) program of quantum field theory, enabling a comprehensive classification of systems based on their universal properties near fixed points of the RG flow. We discuss implications of universal aspects on the real time evolution during and after rapidly driving a system through a phase transition. In particular, we present results on (i) defect nucleation and its connection to the Kibble-Zurek mechanism for rapidly cooling quenched one-dimensional Bose gases [1] and coupled quantum wires [2] and (ii) universal self-similar scaling dynamics, e.g. associated with the approach of a non-thermal fixed point, during the relaxation of isolated [3] or open [4] systems driven far from equilibrium.

References

[1] S. Erne, R. Bücker, T. Gasenzer, J. Schmiedmayer, *in preparation* (2021) [2] S. Erne, T. Schweigler, T. Gasenzer, J. Schmiedmayer, *in preparation* (2021) [3] S. Erne, R. Bücker, T. Gasenzer, J. Schmiedmayer, Nature **563** 225-229 (2018) [4] R. G. Wu, S. Erne, J. Schmiedmayer, et.al, *in preparation* (2021/22)

[*]Corresponding author: erne@atomchip.org