Universal dynamics far from equilibrium

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Understanding the behaviour of isolated quantum systems far from equilibrium and their equilibration concerns one of the most pressing open problems in quantum many-body physics. Here we report on the first experimental observations [1,2] of universal scaling dynamics far from equilibrium. In [1], following a strong cooling quench transferring a 3D ultra-cold Bose gas into a one-dimensional quasicondensate, the systems, during the course of its relaxation, exhibits universal scaling in time and space, associated with the approach of a non-thermal fixed point. The time evolution within the scaling period is described by a single universal function and scaling exponent, independent of the specifics of the initial state. The non-equilibrium evolution features the transport of an emergent conserved quantity in the scaling region, finally leading to the build-up of a quantum degenerate quasicondensate. Our results provide a quantum simulation in a regime, where to date no theoretical predictions are available and constitute a crucial step in the verification of universality far from equilibrium. If successful, this will provide a conceptually new access to time evolution based on a comprehensive classification of systems according to their universal properties far from equilibrium. This can be the basis for a new type of non-equilibrium quantum simulation relevant for a large variety of systems, including the early Universe after inflation, quark-gluon matter generated in heavy-ion collisions, and cold quantum gases.

[1] S. Erne, R. Bücker, T. Gasenzer, J. Berges, and J. Schmiedmayer, Nature 563: 225 (2018).

[2] M. Prüfer, P. Kunkel, H. Strobel, S. Lannig, D. Linnemann, C.-M. Schmied, J. Berges, T. Gasenzer, and M. K. Oberthaler, Nature 563: 217 (2018).