Study sheds light on the role of the entropy in a quantum system

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Any understanding of the irreversibility of the arrow of time should account the quantum nature of the world that surrounds us. The is the key result of the work carried out by Vincenzo Alba and Pasquale Calabrese of the International School for Advanced Studies (SISSA) of Trieste, recently published in the journal *Proceedings of the National Academy of Sciences* (*PNAS*).

According to one of the main laws of thermodynamics, the entropy of a system tends to increase in time until equilibrium is reached. This accounts for the irreversibility of the flow of time for macroscopic phenomena. Since the beginning of the last century, physicists have been dealing with the dilemma of reconciling the laws of thermodynamics with the microscopic laws of nature, which have no privileged temporal direction. The problem becomes conceptually more difficult within the context of quantum mechanics, in which a pure isolated system with zero entropy will remain thus forever, even if not in thermodynamic equilibrium.

The work by Alba and Calabrese illuminates how this perspective, despite being substantially correct, actually fails to explain the problem. In particular, the authors have shown that any single point in an extended quantum system that is far from equilibrium actually has entropy that increases in time, exactly as in thermodynamics. The origin of this entropy is in the entanglement between the part we are looking at and the rest of the system. Entanglement is a peculiar correlation that exists only in quantum mechanics in which pairs or groups of particles interact in ways such that no particle can be described independently of the others.

More information: Vincenzo Alba et al. Entanglement and thermodynamics after a quantum quench in integrable systems, *Proceedings of the National Academy of Sciences* (2017). DOI: 10.1073/pnas.1703516114

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