Foundations of statistical mechanics from symmetries of entanglement

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Quantum entanglement is among the most fundamental, yet from classical intuition also most surprising properties of the fully quantum nature of physical reality. Envariance—entanglement assisted invariance—is a recently discovered symmetry of composite quantum systems. We show that thermodynamic equilibrium states are fully characterized by their envariance. In particular, the microcanonical equilibrium of a system S with Hamiltonian H_S is a fully energetically degenerate quantum state envariant under every unitary transformation. The representation of the canonical equilibrium then follows from simply counting degenerate energy states. Our conceptually novel approach is free of mathematically ambiguous notions such as ensemble, randomness, etc., and, while it does not even rely on probability, it helps to understand its role in the quantum world. In addition, we report several experiments performed on IBM's Quantum Experience demonstrating envariance as a pedagogical illustration of these novel concepts. These very easily reproducible and freely accessible experiments on Quantum Experience provide simple tools to study the properties of envariance, and we illustrate this for several cases with "quantum universes" consisting of up to five qubits.

[1] S. Deffner and W. H. Zurek, New J. Phys. 18 (2016) 063013

[2] S. Deffner, arXiv:1609.07459