Universal scaling in far-from-equilibrium quantum systems

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Recent progress in out-of-equilibrium closed quantum systems has significantly advanced the understanding of mechanisms behind their evolution towards thermalization. Notably, the concept of non-thermal fixed points (NTFPs) - responsible for the emergence of spatio-temporal universal scaling in far-from-equilibrium systems - has played a crucial role in both theoretical and experimental investigations. In this work, we introduced a differential equation that has the universal scaling associated with NTFPs as a solution. The advantage of working with a differential equation, rather than only with its solution, is that we can extract several insightful properties not necessarily present in the solution alone. Employing two limiting cases of the equation, we determined the universal exponents related to the scaling using the distributions near just two momentum values. We established a strong agreement with previous investigations by validating this approach with three distinct physical systems, including a turbulent Bose-Einstein condensate. This consistency highlights the universal nature of scaling due to NTFPs and emphasizes the predictive capabilities of the proposed differential equation. Moreover, under specific conditions, the equation predicts a power-law related to the ratio of the two universal exponents, leading to implications concerning particle and energy transport. This suggests that the observed power-laws in far-from-equilibrium turbulent fluids could be related to the universal scaling due to NTFPs, potentially offering new insights into the study of turbulence.

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