Anatomy of the eigenstates distribution: a quest for a genuine multifractality

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Abstract

Due to a series of recent works [1, 2, 3, 4], an interest in multifractal states has risen as they are believed to be present in the MBL phase. Inspired by the success of the Rosenzweig-Porter (RP) model with normally distributed transition amplitudes, a similar ensemble but with the fat-tailed distributed amplitudes was proposed [5, 6, 7, 8, 9], with claims that it must host the desired multifractal phase. In the present work, we develop a general (graphical) approach allowing a self-consistent analytical calculation of the spectrum of eigenstate's fractal dimensions for various RP models and investigate what features of the RP Hamiltonians can be responsible for the multifractal phase emergence. We conclude that the only feature contributing to a genuine multifractality is the on-site energies distribution, meaning that no random matrix model with uniformish diagonal and uncorrelated off-diagonal disorder can host a multifractal phase and hence model a true MBL.

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