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Complexity beyond entanglement - magic of many-body systems

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Driven by groundbreaking experimental advances, quantum matter is currently entering the era of quantum error correction - where elementary computations can be demonstrated in a fault-tolerant manner. From a many-body theory viewpoint, these developments motivate the question: what are states that are challenging to realize in the presence of error correction? Entanglement alone is not informative about state complexity, and in fact, it is a free resource in such situations. In this talk, we will tackle quantum state complexity of many-body systems under the lens of non-stabilizerness - also known as magic. Magic quantifies the difficulty of realizing states in most error corrected codes, and is thus of fundamental practical importance. However, very little is known about its significance to many-body phenomena.

I will start the seminar by giving a short review on magic in spin systems, with a focus on quantities that can be used to compute it - stabilizer Renyi entropies and robustness of magic. Then, I shall present method(s) to measure magic in tensor network simulations, and illustrate a series of applications to many body systems, including its relevance in critical matter and gauge theories, and its relations to entanglement. These results indicate that a large amount of quantum resources are required to generate interesting many-body phenomena under the assumption of error correction; at the same time, a picture emerges where error correction is - unexpectedly - intimately tied to various forms of correlated quantum matter, in a universal manner.

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