Typicality and unconventional stationary states of a system of interacting spinless fermions

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Since the end of the nineteenth century, statistical physics has allowed understanding the equilibrium and weakly out-of-equilibrium properties of systems made of a large number of particles. In order to provide theoretical predictions, this framework relies on a probabilistic hypothesis defined by the microcanonical ensemble: all accessible states have the same probability of occurrence. Remarkably, this very simple postulate is now put into question by the recent progress in quantum engineering and simulation. Indeed, in experiments displaying phenomena like Many Body Localization, the interplay between disorder and interactions can prevent the emergence of the usual thermodynamical equilibrium [1]. More generally, these kind of experiments ask two fundamental questions: i) is it possible for a closed quantum system to reach a state of local equilibrium despite being at all times globally in a pure state evolving according to the Schrödinger equation? ii) if yes, what are the properties of this equilibrium state? Does it follow the usual prediction of statistical physics or is it unconventional, i.e. involving some new statistical physics yet to be discovered?

In this talk, I will present results obtained on these two questions using random matrix models and focusing on interacting spinless fermions. First, I will describe a "typicality" property, i.e. the self-averaging of the quantities of interest like occupation numbers, which has important implications for analytical and numerical calculations [2,3]. Then I will describe how the crossover towards thermalisation emerges when increasing the interaction strength between particles.

Finally, I will discuss how to calculate a new partition function [4] involving the Many Body Density of States, a quantity which has been eclipsed for a long time by Single or few Body Density of States due to the success of mean field theories and the concept of quasiparticle [5]. Interestingly, this new partition function recovers the Fermi-Dirac distribution as a particular case.

[1] Schreiber et al, 349, 6250, pp. 842-845, Science, (2015)

[2] Ithier et al, Phys. Rev. A, 96, 012108, (2017)

[3] Ithier et al, J. Phys. A: Math. Theor. 51, 48LT01 (2018)

[4] Ithier et al, Phys. Rev. E 96, 060102(R) (2017)

[5] Lefèvre et al, New J. Phys. 25, 063004 (2023)