QUANTUM DYNAMICS, CHAOS AND THERMALIZATION

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INTRODUCTION.

The overall development of statistical physics can be characterized as empirical success getting ahead of the proper microscopic derivations. Boltzmann and Gibbs have established the foundations of statistical physics without any notion of quantum theory. Planck developed the first statistical quantum theory of black-body radiation before Heisenberg and Schrödinger discovered the proper formulation of quantum mechanics. The transition from classical to quantum mechanics impeded the development of the dynamic foundations of statistical physics in two ways. On the one hand, the notion of microscopic chaos, that was thought to underlie the macroscopic statistical behavior, cannot be rigorously defined for quantum systems. On the other hand, the statistical analysis normally assumes the classicality of the macroscopic observables, i.e. it does not admit quantum superpositions of macroscopically distinct states, which are otherwise allowed by linear quantum mechanics. As a result, the statistical derivations normally represent a subtle mixture of quantum and classical steps, whose range of validity remains unclear, especially, when one starts thinking of non-equilibrium phenomena.

DISCUSSION.

Should one investigate the detailed properties of microscopic chaos in systems of many classical particles, even though one knows that the real macroscopic systems are made of quantum particles? Should one investigate statistical ensembles that admit superpositions of macroscopically distinct quantum states, even though such superpositions have not yet been observed in Nature? Our answer to both of these questions is yes. Regarding the first question, our work [1,2] indicates that there is still a lot to learn about the properties of many-particle *quantum* systems from the detailed studies of many-particle classical systems. Regarding the second question, one needs to take the linear quantum mechanics to its limit in order to discover the range of validity of quantum statistical physics [3]. The fact that the Gibbs equilibrium is overwhelmingly supported by experiments does not necessarily suggest that there exist a self-contained justification for excluding macroscopically distinct superpositions in the framework of purely linear quantum mechanics. In a typical experiment, macroscopic quantum systems are being continuously "monitored" by the environment.

CONCLUSIONS.

It remains an open possibility that the linear quantum mechanics fails somewhere as the number of particles in a system increases to the macroscopic value of the order 10^{23}, in which case, the linear Schrödinger equation alone might be insufficient to justify the Gibbs distribution, and a fundamentally non-linear process such as quantum collapse would be required. This is also not a purely academic question, because the answer can be relevant to the properties of quantum systems with not too large a number of particles.

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