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Remarks on chaos in classical and quantum mechanics

Abstract

From the linear structure of the Schrödinger equation, it is easy to show that the difference between two wave functions cannot increase. Therefore it is tempting to conclude that a consequence of the linear structure of the equation ruling the evolution law, chaos cannot exist in quantum world. On the other hand although classical mechanics is typically described by nonlinear equations, it is formally analogous to quantum mechanics in many respects. Indeed, the Liouville equation of classical mechanics affords a linear theory for the evolution of probabilities, at the cost of switching from a finite dimensional phase space to an infinitely dimensional function space, analogously to the quantum mechanics based on the Schödinger equation. For instance considering two initial conditions of the probability density in the phase space it is possible to show that their difference cannot increase, this in spite of the fact that the existence of chaotic behaviour in classical mechanics is rather common. I discuss how the presence of classical chaos has nontrivial impact of the behavior of quantum systems; in particular for: the classical limit as emergent property, and the relevance of the coarse-graining description.

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