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Complex Behaviour in Classical and Quantum Chaos

I shall explain how chaos (chaotic behavior) can emerge in deterministic systems of classical dynamics. It is due to the sensitive dependence on initial conditions, meaning that two nearby initial states of a system develop in time such that their positions (states) separate very fast (exponentially) in time. After a finite time (Lyapunov time) the accuracy of orbit characterizing the state of the system is entirely lost, the system could be in any allowed state. The system can also be ergodic, meaning that one single orbit describing the evolution of the system visits any other neighborhood of all other states of the system. In this sense, chaotic behavior in time evolution does not exist in quantum mechanics. However, if we look at the structural and statistical properties of the quantum system, we do find clear analogies and relationships with the structures of the corresponding classical systems. This is manifested in the eigenstates and energy spectra of various quantum systems (mesoscopic solid state systems, molecules, atoms, nuclei, elementary particles) and other wave systems (electromagnetic, acoustic, elastic, seismic, water surface waves, etc), which are observed in nature and in the experiments.