清华大学高等研究院

Institute for Advanced Study, Tsinghua University

学术报告

Title: **Nonlinearity, interactions and chaos in quantum systems**

Speaker: **Prof. Jean-Claude Garreau**
Laboratoire de Physique des Lasers, Atomes et Molécules – Université Lille 1, Villeneuve d'Ascq, France

Time: **3:30pm, Monday, Oct 13, 2014**

Venue: **Conference Hall 322, Science Building, Tsinghua University**

Abstract

Quantum mechanics is supposed to be the ultimate theory of the physical world, and classical mechanics a limit case of it. The classical limit of quantum mechanics is however mathematically nontrivial, and one knows that classical behaviors can be very qualitatively from quantum ones. A particularly intriguing example is that of classical chaos (that is, chaos due to sensitivity to initial conditions, intimately related to nonlinearity): The Schrödinger equation is linear, and thus forbids chaotic dynamics in quantum systems, while the classical world is full of examples of chaotic systems.

Ultracold-atom systems are an almost ideal tool to study such questions. From the theoretical point of view, cold atom dynamics can often be modelled from first principles. From the experimental point of view, one learned in the last decade to "engineer" quantum hamiltonians using ultracold atoms interacting with electromagnetic fields. Such systems allow a very precise control of their properties: One can vary the parameters of the hamiltonian, one can make "mesoscopic" systems – somewhere in the middle of the way from the quantum to the classical world -- by using Bose-Einstein condensates, and one can finely tune the interaction of the atoms by using the so-called "Feshbach resonances".

Even more interestingly, in a variety of situations of experimental interest, weakly interacting degenerate boson gases (Bose-Einstein condensates) are very well described by the Gross-Pitaevskii equation, which is much simpler than the underlying many-body problem, and displays a cubic nonlinearity. In this talk, I will introduce a "toy" model displaying "quasiclassical" chaos, that is, chaotic behavior related to sensitivity to the initial conditions in a quantum system. I will show that the observed behavior, although intrinsically quantum, can be described by the very "classical" KAM (Kolmogorov-Arnold-Moser) theorem. However, the mean-field approach that leads from the many-body problem to the Gross-Pitaevskii equation hides the microscopic origin of the nonlinearity. Using different levels of approximation of the many-body problem, I will present some hints on the physical origin of the nonlinearity.