Indian Institute of Technology, Kanpur

Course 666: QUANTUM CHAOS

1. Course Description:

A) Objectives: The ubiquitous manifestation of chaos in classical systems and industrial relevance of the miniaturization of physical systems makes it necessary to seek/analyze the signatures of chaos in the quantum limit. The standard mathematical tool for such an analysis is random matrix modelling of quantum chaotic system which can be justified in semiclassically using Gutzwiller's periodic orbit theory. The random matrix theory also has been applied successfully in many other wide-ranging areas of complex systems e.g. disordered systems and financial markets. With growing complexity of physical systems of human interests especially in quantum limits, it is therefore imperative for a student of natural sciences to acquire a good knowledge of quantum chaos as well as random matrices.

B) Contents:

S. No.	Broad Title	Topics	No. of Lectures
	Introduction	Classical Chaos and integrability, Quantum Mechanics of classically chaotic systems and connection with random matrices, Berry conjecture for chaotic states, Bohigas-Giannoni-Schmidt conjecture, eigenstate thermalisation hypothesis, correspondence principle, Kicked rotor as a prototype model	**10**
	Random matrix Theory	Definition, Dense, banded and Sparse Random matrix ensembles, distribution of eigenvalues and eigenfunctions of a random matrix, Fluctuation measures, symmetry based universality classes	**12**
	Semiclassical description	Periodic orbit theory and Gutzwiller Trace formula, Bohr Sommerfeld Quantization rule, Hannay-Almeida sum rule for periodic orbits, role of symmetry, semiclassical formulation of fluctuation measures	**8**
	Many body quantum chaos	Quantum Chaotic dynamics of interacting many body systems, connection with random matrices, partition function expansion of spectral form factor, quantum butterfly effect,	**6**

	Physical Applications	Mesoscopic systems e.g quantum dots, quantum entanglement, transport properties of strongly interacting properties, spectral statistics based analogy of quantum chaotic systems with wide-ranging complex systems, e.g. disordered systems, atoms, molecules and nuclei, financial markets, complex networks etc.	**4**
		Total number of lectures	**40**

*= Only concepts will be discussed; no formal rigorous proof will be done.

C) Pre-requisites, if any: Basics of Classical Mechanics, Basics of Quantum Mechanics

D) Short summary for including in the Courses of Study Booklet: Quantum mechanics of classically chaotic systems, fluctuations of energy levels and eigenfunctions, connection with random matrices, Berry conjecture, Bohigas-Giannoni-Schmidt conjecture, semiclassical formulation of fluctutaion measures and periodic orbit theory, quantum mechanics of classically chaotic systems with many body interactions, application to mesoscopic systems, quantum butterfly effect etc.

Recommended books and Articles:

A). Quantum Signatures of Chaos, by Fritz Haake, Springer-Verlag, Berlin-Heidelberg, 2nd ed 2001, 479 p.

B). Quantum Chaos - An Introduction, by Hans-Juergen Stoeckmann, Cambridge University Press, 1999.

C). Quantum Chaology (The Bakerian Lecture 1987), by M. V. Berry, in Dynammical Chaos, Proceedings of the Royal Society, edited by Michael V. Berry, I.C. Percival, and N.O. Weiss, A 413, 1-198.

D). Quantum Chaos Y2K, Proceedings of Nobel Symposium 116, edited by Karl-Fredrik Berggren and Sven Aberg, in Physica Scripta, Kungl. Vetenskapsakademien and World Scientific, Singapore, 2001.

E). Postmodern Quantum Mechanics, by Eric J. Heller and Steven Tomsovic, Physics Today (American Institute of Physics) July 1993, 38-46.

F). Random Matrix Theory and Applications, NPTEL Course (Phase II), by Pragya Shukla.