INNSBRUCK COURSE: "LARGE-SCALE QUANTUM PHENOMENA"

A: FORMAL METHODS

INTRODUCTION: Quick survey of important phenomena (large-scale tunneling, interference, coherence, entanglement) in various systems. Intro to the meat of the course: quantum environments and how to evaluate their effects on dissipation, relaxation, & decoherence; & applications

PATH INTEGRALS: Recall basic ideas of path integrals. Short crash course on simple ways to compute these. Oscillators with noise. Path integrals for spin, and the semiclassical limit for spin. Interesting features of spin dynamics; spins in time-varying external fields. Path integrals for density matrices

EFFECTIVE HAMILTONIANS in QUANTUM MECHANICS: All Hamiltonians are effective. Truncation/integration out of high-energy degrees of freedom. Adiabatic limit of Quantum Mechanics. Born-Oppenheimer, Berry, Landau-Dykhne results.

QUANTUM ENVIRONMENTS: Derivation of Oscillator and Spin Bath environments. Physical examples of these. Averaging over environmental variables (i) using path integrals, to find density matrix dynamics; or (ii) using stochastic methods.

B: MODELS & APPLICATIONS

INTRO to SOME INTERESTING MODELS: How one finds the dynamics of models after integrating out the environments. I will compare different methods, and make a choice from the following models:

(i) Central spin model: Qubit coupled to oscillator or spin bath.
(ii) Central oscillator model: oscillator coupled to oscillator or spin bath.
(iii) Tunneling particle coupled to spin or oscillator bath.
(iv) Tunneling spin coupled to oscillator or spin bath.
(v) 2-slit system, coupled to spin or oscillator bath
(vi) PISCES problem: 2 qubits coupled to oscillator or spin bath.
(vii) N qubits on a line coupled to spin & oscillator baths; N wells on a line.
(viii) Particle on a ring coupled to oscillator and spin baths
(ix) Particle on a hyperlattice, coupled to oscillator and spiu baths
(x) Quantum solitons coupled to their own fields, and to "spin" variables

APPLICATION to PHYSICAL SYSTEMS: Survey of some of the interesting physics, and the physical systems of key importance. I will make a choice from the following:

(i) Spin qubits (rare earth spins, magnetic molecules, spins in semiconductors, NV centres)
(ii) Superconducting qubits, and cavity and ion-trap systems
(iii) Gravity wave detectors, and electromechanical systems
(iv) Large-scale tunneling in SQUIDs and magnetic systems (domain walls, vortices)
(v) Quantum effects in biological systems: electron transfer, light-harvesting molecules, avian compasses
(vi) Possible choices and criteria for quantum information processing systems
(vii) Quantum phase transitions (eg., LiHoF system, cold ion systems)