Frank Wilczek QC2024 -- Advanced Topics in Basic Quantum Mechanics

The foundational ideas of modern quantum theory are a hundred years old, but they take some getting used to. Close study of even the most basic processes can bring in surprises. The recent development of new technologies that exquisitely resolve quantum behavior in space and time, and attempt to control and exploit it, enhances the relevance of such studies. In these lectures I will present four instructive, loosely connected case studies.

1. Probability of Presence Versus $\psi^*(x, t) \psi (x, t) $

They're not necessarily the same thing! The yoga of effective Lagrangians, as well as the Dirac equation, suggest mind-expanding generalizations. Paper: **arXiv:2405.04493**

2. Space-Time Lattice Models for Quantum Dynamics

Upon discretizing both space and time one can realize the basic principles of quantum theory in a very flexible and tractable way. Here I will use these models to illustrate the quasi-normal mode description of radiation fields and space-time aspects of wave packet spreading and tunneling.
Notes and Paper: to come Book: Consistent Quantum Theory, R. Griffiths (Cambridge, 2002), especially chapters 1-8.

3. Causal Spreading and Tunneling

The non-relativistic Schrödinger equation is enormously useful, but it does not respect causality. This leads to conceptual uncertainty in the analysis of basic space-time process, notably including wave packet spreading and tunneling. Using appropriate mathematical tools from partial differential equations, Fourier analysis, and Green functions we can do better.
Notes and paper: to come

4. Consistent Histories and Interior Quantum Description

We have two widely used, complementary descriptions of fluid mechanics: an "exterior" (Euler) description based on the velocity field, and an "interior" (Lagrange) description based on following particle trajectories. If we want to do justice to our experience of the quantum world, we need an interior description of quantum theory. Further development of the models from Lecture 2 suggests a path forward.
Notes to come. Book: Griffiths (again), especially chapters 9-16.