The foundations of QM are controversial

Here are some voices critical of the traditional, orthodox view:

> *"With very few exceptions (such as Einstein and Laue) [...] I was the only sane person left [in theoretical physics]."*
>
> *(Erwin Schrödinger in a 1959 letter)*

> *"I think I can safely say that nobody understands quantum mechanics."*
>
> *(Richard Feynman, 1965)*

> *"I think that conventional formulations of quantum theory [...] are unprofessionally vague and ambiguous."*
>
> *(John Bell, 1986)*

Topics of this course

- The Schrödinger equation, the Born rule
- Self-adjoint operators, axioms of the quantum formalism, collapse of the wave function, decoherence
- The double-slit experiment and variants thereof, interference and superposition
- Spin, the Stern-Gerlach experiment, the Pauli equation, representations of the rotation group
- The Einstein-Podolsky-Rosen argument, entanglement, non-locality, and Bell's theorem
- The paradox of Schrödinger's cat and the quantum measurement problem. Views of Bohr and Einstein.
- Heisenberg's uncertainty relation
- Interpretations of quantum mechanics (Copenhagen, Bohm's trajectories, Everett's many worlds, spontaneous collapse theories, quantum logic, perhaps others)
- POVMs and density matrices
- No-hidden-variables theorems
- Identical particles and the non-trivial topology of their configuration space, bosons and fermions

Mathematical tools needed in this course

- Complex numbers
- Vectors in n dimensions, inner product
- Matrices, their eigenvalues and eigenvectors
- Multivariable calculus (including Gauss integral theorem)
- Probability; continuous random variables, the Gaussian (normal) distribution

Philosophical questions that will come up in this course

- Is the world deterministic, or stochastic, or neither?
- Can and should logic be revised in response to empirical findings?
- Are there in principle limitations to what we can know about the world (its laws, its state)?
- Which theories are meaningful as fundamental physical theories? In particular:
- If a statement cannot be tested empirically, can it be meaningful? (Positivism versus realism)
- Does a fundamental physical theory have to provide a coherent story of what happens?
- Does that story have to contain elements representing matter in 3-dimensional space in order to be meaningful?