Schrödinger's Cat and Quantum Reality

It's not your great-great-grandfather's reality.

The Quantum World

- Quantum mechanics describes the functioning of nature on the atomic scale.
- A QUANTUM STATE of a particle is a state with certain values for various physical quantities.
- Values of physical quantities are restricted. Ex: electron spin ($\pm\hbar$).
- A particle can exist in a superposition of quantum states - in this case the values of the physical quantities may be indeterminate.

Wheeler's Game

- The difference between the classical world (where all physical quantities have definite values) and the quantum world (where the values can be indeterminate) can be illustrated with a game of twenty questions.
- Classical world: the usual game. The answer is "out there" waiting for you to guess.
- Quantum world: no word is chosen ahead of time, but answers must be consistent with SOME word. Each question is like a measurement.

Wheeler's Quote

- "No elementary phenomenon is a real phenomenon until it is an observed phenomenon."
- It makes no sense to talk about the spin of an electron until you measure it.

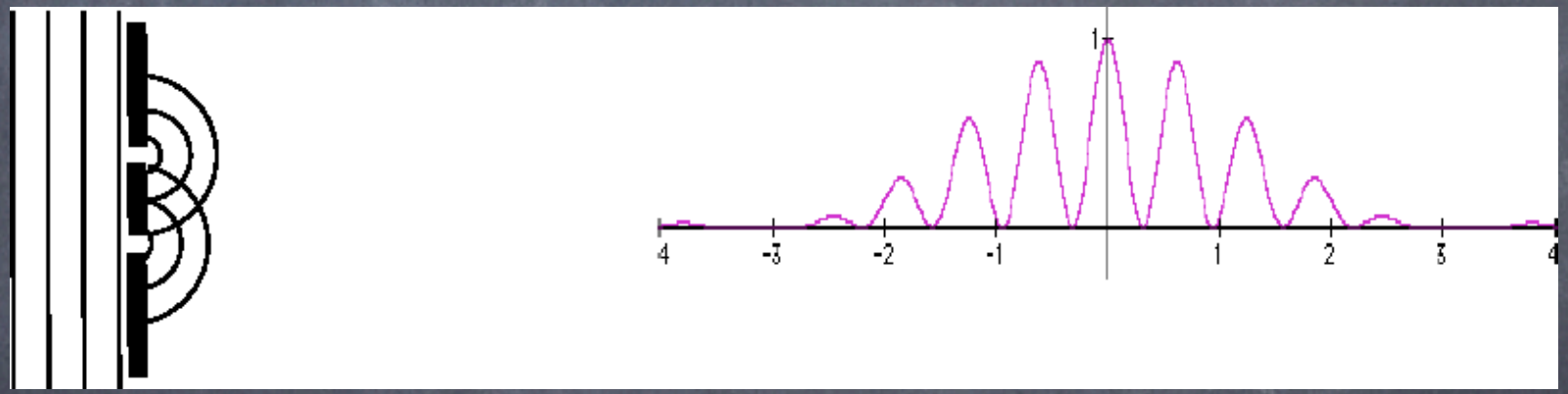
Quantum Measurement

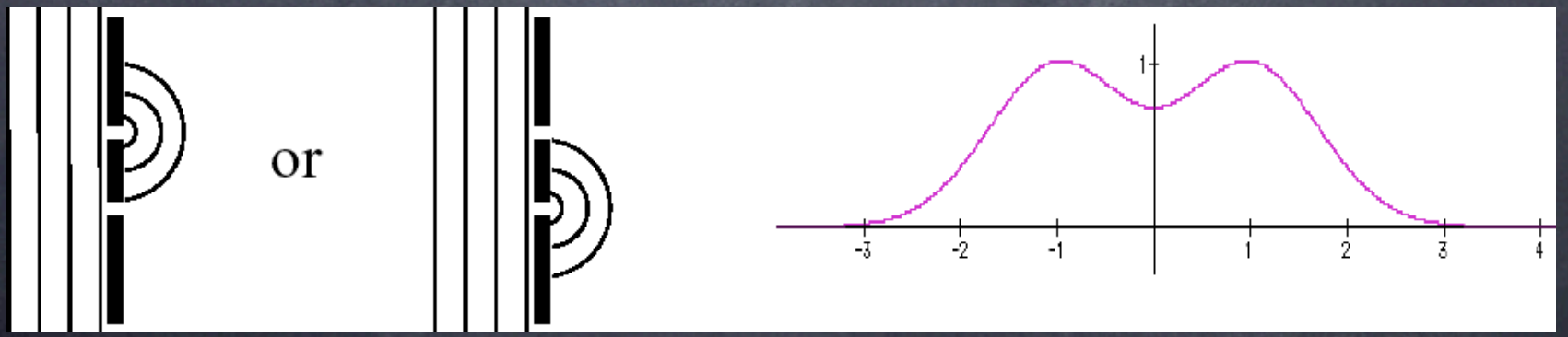
- Q: What happens when we measure the spin of an electron in a superposition of up and down?
- A: We always get one or the other of the possible values ($\pm\hbar$), with probabilities determined by the details of the superposition.
- After the measurement the electron is either up or down (no longer in a superposition). This is called the "collapse of the wavefunction".

The Two-Slit Experiment

- Electrons can behave like waves. When a beam of electrons passes through a double-slit it can produce an interference pattern (even if the electrons go through one at a time). So the wave of an individual electron must go through both slits.
- If you MEASURE to see which slit the electron went through you will find that it always goes through one or the other, but...

- … you no longer get the interference pattern!
- If you measure which slit it goes through, the electron's wavefunction collapses and only goes through one slit or the other.



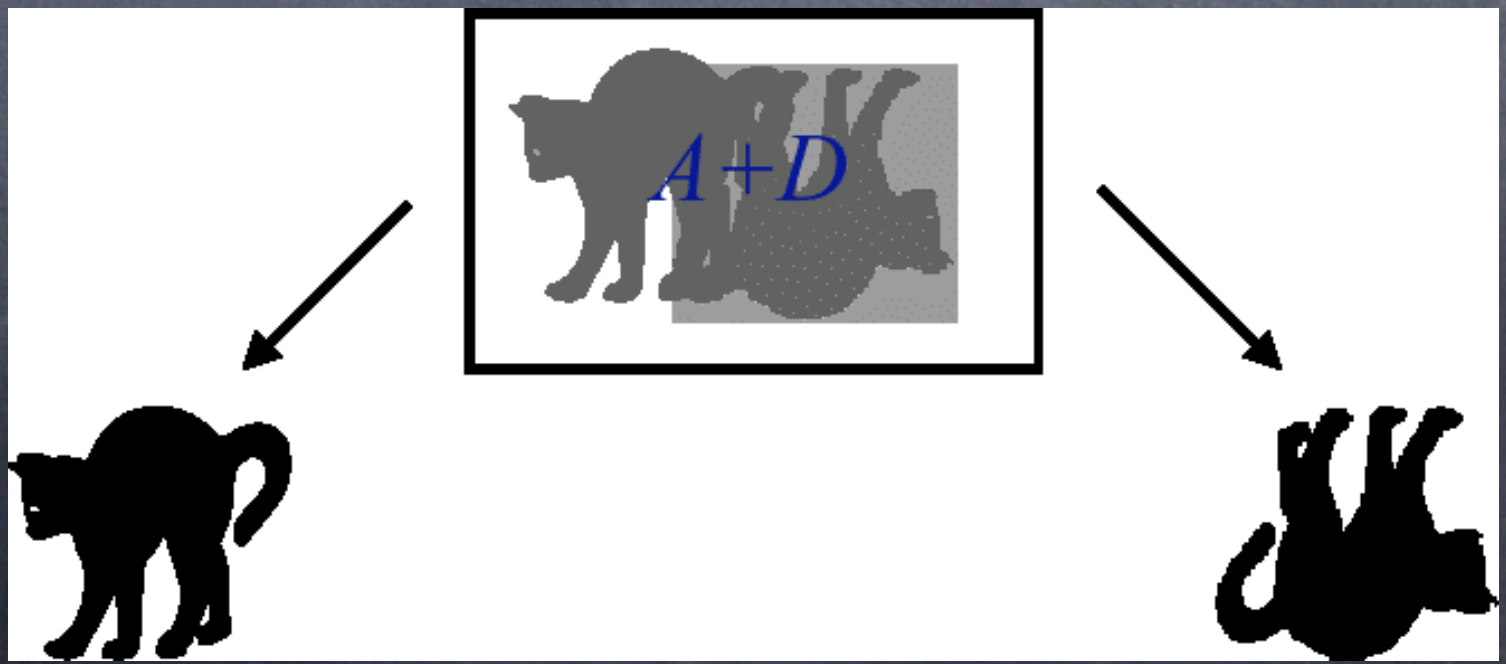


Schrödinger's Cat (modern variant)

- Suppose you put a cat in a box with a vial of poison gas. The gas is released if a Stern-Gerlach analyzer measures a spin down electron.
- Send an electron in an equal superposition of up and down states into the analyzer.
- What is the state of the cat?
- Where/when does the measurement/collapse occur?

If a tree falls...

- If the measurement doesn't occur until WE look, then the cat must be in a superposition of alive and dead!
- It is only when we look that it becomes either alive or dead.



Consciousness and Quantum Mechanics

- If observation by a conscious entity is required to collapse the wavefunction, what happens if you take a picture?
- ...and have it automatically mailed to people in ten different countries?
- Who collapses the wavefunction? Who kills (or saves) the poor cat?

What if there is no collapse?

- Then the cat IS in a superposition, but so are we when we look at it.
- Many Worlds Interpretation: all parts of this (extended) superposition continue, but different parts can't interact.
- Effectively, any measurement/observation splits the Universe in two!

Bohr's Idea

- Copenhagen Interpretation: the collapse occurs because of an "irreversible act of amplification" in the Stern-Gerlach analyzer.
- But why should the collapse occur there? Why can't the analyzer be in a superposition just like the electron?
- Bohr: we "know" when a measurement has been made, and there is no reality independent of observation.

Decoherence

- A quantum particle that interacts strongly with its environment will quickly go from a superposition into a definite state (can't say which, but the probabilities are given by the usual quantum mechanics). This is a PHYSICAL mechanism for the collapse of the wavefunction.
- Electrons are small and don't interact much with their environment.
- Stern-Gerlach analyzers and cats are big and CONSTANTLY interact with their environment.

A Physicist's Reality

- Classical view of reality: the stone castle.
- Quantum view of reality: a papier-maché construct framed with a few iron posts of true observation (Wheeler).
- Decoherence allows measurements to be made. As for what happens when we don't measure - that question has no meaning (Bohr).