Consciousness and the Collapse of the Wave Function

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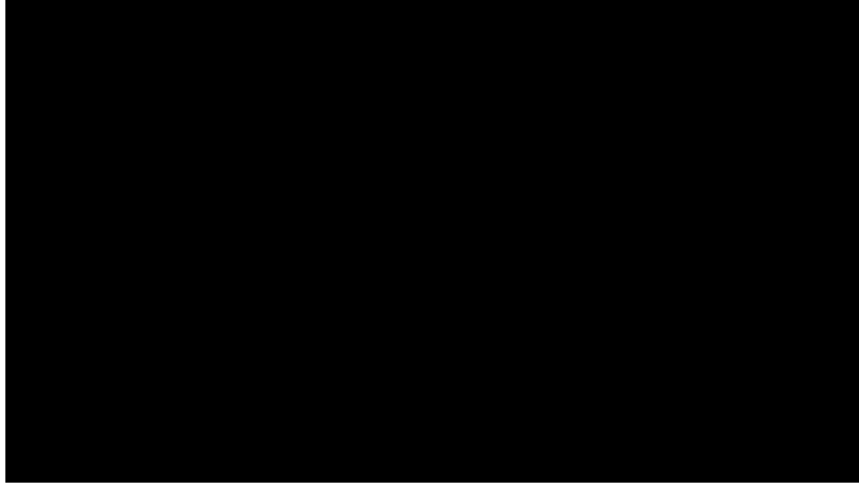
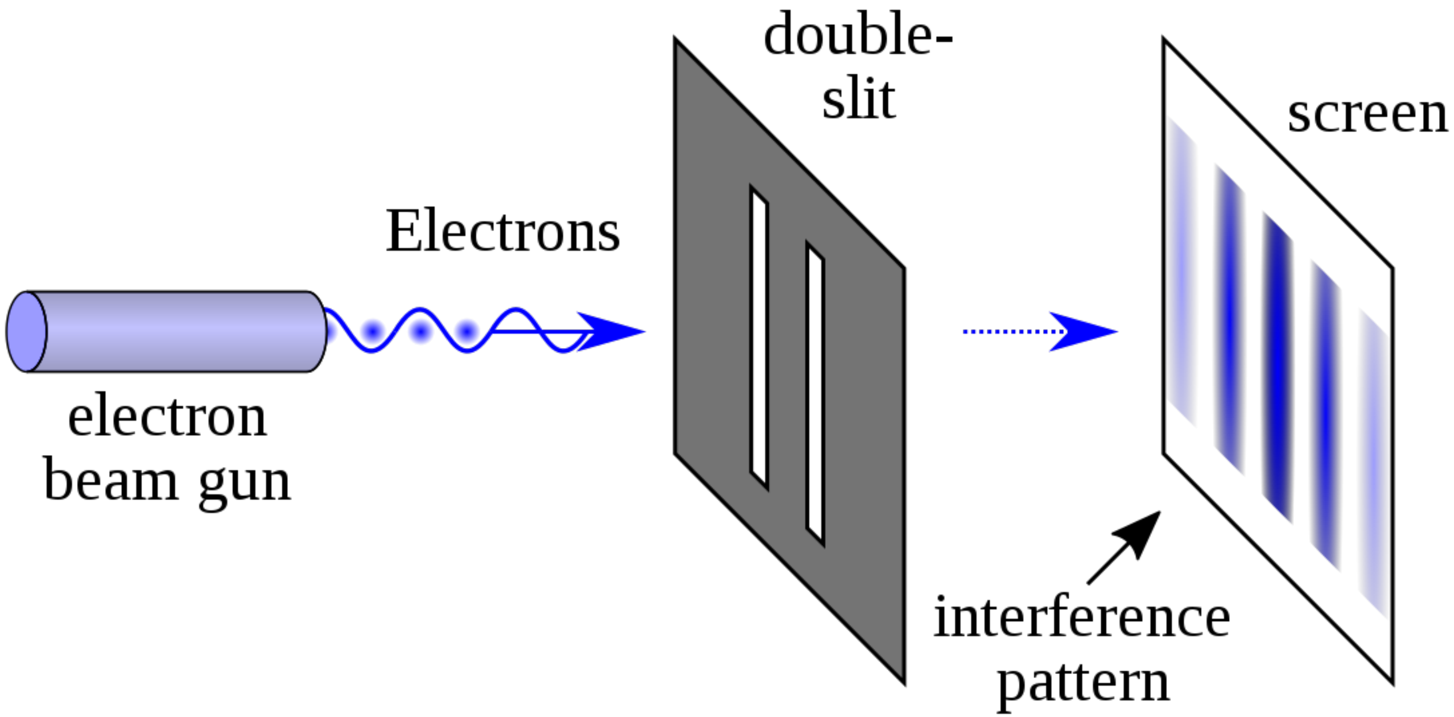
Background
The big picture



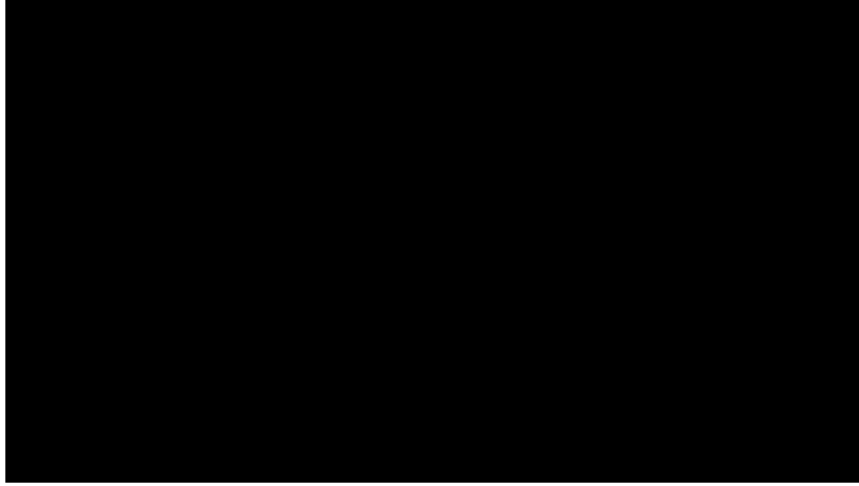
- Does consciousness collapse the quantum wave function?
- This idea was taken seriously by John von Neumann and Eugene Wigner but is now widely dismissed
- Paper combines mathematical theory of consciousness (IIT) with an account of quantum collapse dynamics
- Simple versions of the theory are falsified by the quantum Zeno effect, but more complex versions remain compatible with empirical evidence.
- In principle, versions of the theory can be tested with quantum computers. The field is worthy of further exploration

Quantum mechanics
Double slit experiment

- Electrons are fired through a double slit
- A detector behind the slits records an inference pattern
- Any given electron ends up in one specific place
- Experiment implies that the electrons exist in superposed states until a measurement is performed, upon which their states collapse



Quantum mechanics
The effects of measurement



- It is widely accepted that quantum-mechanical systems are describable by a wave function.

- The wave function may assign a superposition of multiple values for position, momentum, and other properties.

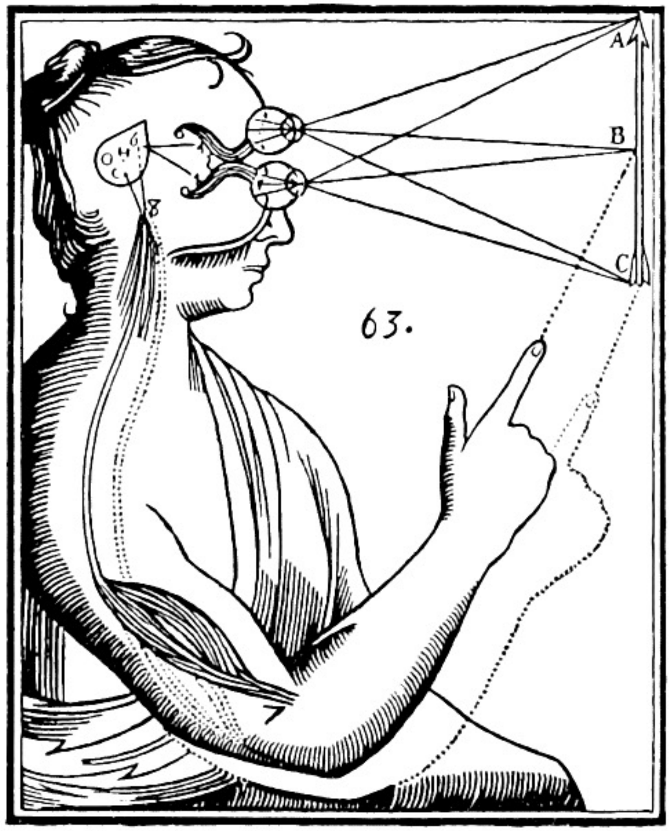
- The wave function is guided by two separate principles.
  - There is a process of evolution according to the Schrödinger equation, which is linear, deterministic, and constantly ongoing
  - There is a process of collapse into a definite state, which is nonlinear, nondeterministic, and happens only on certain occasions of measurement.

- Above is accepted for empirical predictions, but is less popular as a story about the underlying physical reality
  - Measurement problem: Collapses happen when and only when a measurement occurs.
  - the notion of “measurement” is vague and anthropocentric, and is inappropriate to play a role in a fundamental specification of reality
  - To make sense of quantum reality, one needs a much clearer specification of the underlying dynamic processes.

$$H(t)\,|\,\psi(t)\rangle = i\hbar \frac{d}{dt}\,|\,\psi(t)\rangle$$

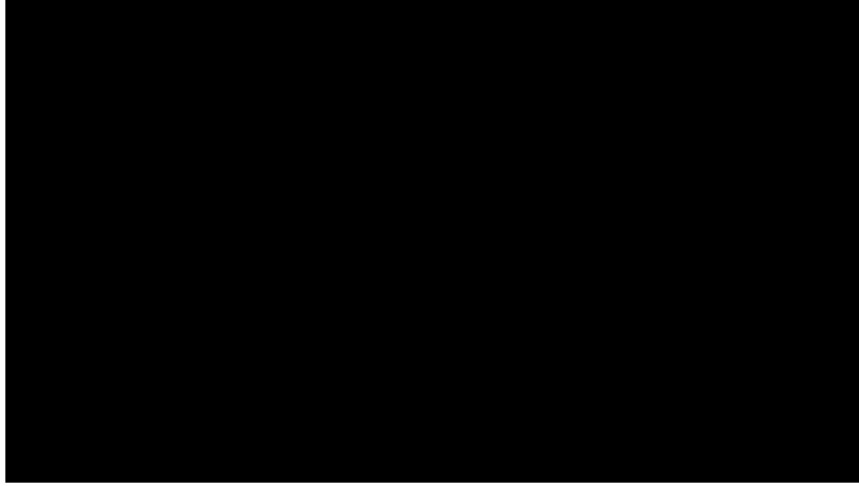
Mind-body problem
Physically manifesting the mind

- What is the relation between mind and body, or more specifically, between consciousness and physical processes?



- A system is conscious when there is something it is like to be that system
- A mental state is conscious when there is something it is like to be in that state
- Why do physical processes give rise to consciousness at all
- How does consciousness play a causal role in the physical world

Does consciousness bring about wave function collapse?



- Saying that measurement is an act of consciousness, and that consciousness brings about wave function collapse solves consciousness-causation problem and the quantum measurement problem at the same time

- Provides an interpretation of quantum mechanics that accepts the standard measurement-collapse principle.
    - It provides one of the few non-arbitrary criteria for when measurement occurs
    - It is arguable that our concept of measurement is that of measurement by a conscious observer

- Not popular among contemporary physicists since:
    - Popular view in unscientific circles and is frequently discarded on the basis of imprecision and dualism
    - The view seems to exempt consciousness from the standard quantum-mechanical laws governing physical systems

How could consciousness collapse the wave function?

Variable locus:

- Closest to standard quantum mechanics.
- Many different observable quantities can be measured and thereby serve as the locus of collapse

e.g. position, momentum, mass, and spin

- Wave function collapses upon measurement with probabilities according to the Born rule

What determines which observable is being measured?

Fixed locus:

- Consciousness itself (or perhaps its physical correlate) serves as the locus of collapse.
- Can be developed with special superposition-resistant observables, which resist superposition and cause the system to collapse

Super-resistance

Fixed locus models have been the paper's focus, largely due to their relative simplicity

super-resistance

- Works well with measurement-collapse interpretations of quantum mechanics
  - Most simple approach is to assume conciseness is absolutely super-resistant
  - Leads to fatal problem for absolute super-resistance

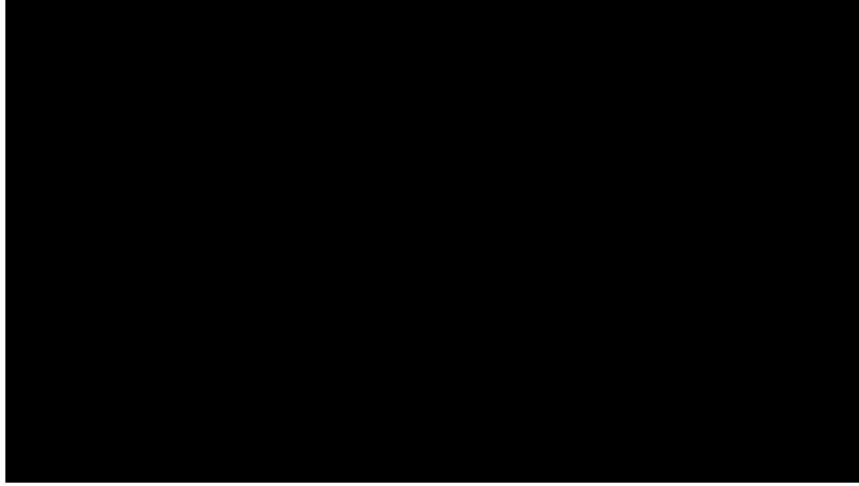
- Think of a super-resistant property as a **measurement property** (e.g. a conscious experience), not as a **measured property** (e.g. particle position)

- To sketch the idea intuitively: Suppose there is a special class of measurement devices (e.g. oscilloscopes) which have special **measurement properties** (e.g. meter readings or pointer locations) that resist superposition and tend to collapse.
  - Upon measurement, a **measured property** affects a **measurement property**.
  - Suppose that we have a quantum system (e.g. a particle) in a superposition of locations a and b
  - If not for this principle the particle interaction would yield an entangled superposition $|a\rangle\,|M(a)\rangle + |b\rangle\,|M(b)\rangle$, where $M(a)$ and $M(b)$ are the states of the measurement system.
  - Because M is super-resistant, the particle and measurement system will instead collapse into $|a\rangle\,|M(a)\rangle$ or $|b\rangle\,|M(b)\rangle$

Similar to the measured property collapsing directly, but now measurement properties bring collapse.

- Compatible with materialist and dualist views
  - Materialist view is simpler
  - Dualist view says a subject will only be in a certain state of consciousness if it is in the corresponding PCC (physical correlates of consciousness) state

Superselection



- Certain superpositions are ruled out entirely (the strong form of super-resistance)
  - The collapse postulate says that whenever a system would enter a superposition of eigenstates of an operator it instead enters a definite eigenstate
  - Dynamics are equivalent to if the resistant observables were continuously measured by an outside observer

- The model will specify a superselection observable, so physical systems must always be in eigenstates of the operator corresponding to the observable.

- Unfortunately, the quantum Zeno effect says that if an observable is measured continuously, it cannot change its state at all.
  - For a system to evolve under Schrödinger evolution between eigenstates of an operator, it must evolve through superpositions of eigenstates

- Will solve this problem by abandoning superselection for a weaker version of superresistance.
  - An approximately super-resistant observable is one that can enter superpositions but nevertheless resists superposition, at least in some circumstances
  - Making approximate super-resistance precise requires nonstandard physics.