CLAIM: Reality does not exist until it is measured OR observables do not have values until measured

Wheeler Delayed Choice Idea and Experiment(s)

Proposed gedanken experiment by John Wheeler —> explore counterintuitive aspects of particle-wave duality.

Imagine "cosmic interferometer." Suppose light from distant distant quasar were gravitationally lensed by closer galaxy —> light from single quasar coming from 2 slightly different locations. Observe in 2 different ways. 1st, detector aimed at each lensed image —> particle measurement. 2nd, combine light from 2 images in interferometer —> wave measurement. QM —> results of these 2 experiments (particle or wave) exactly as observed in their standard form. But light began journey billions of years ago, long before decided which experiment to perform. Through this "delayed choice" seems as if quasar light "knew" whether would be seen as particle or wave billions of years before experiment devised.

Experiment proposed isn't practical, modern experimental equipment —> perform similar experiment, where decision to measure particle or wave done at random after quantum system "committed." For example, in 2007 delayed-choice experiment made using laser light to create delayed-choice double slit experiment(will discuss in detail later during measurement lecture).

New(2016) experiment used an ultracold helium atom to do similar delayed-choice interference experiment. Experiments results exactly as predicted by quantum theory —> both matter and light exhibit this strange quantum effect.

Result not unexpected. Quantum theory —> clear prediction about experiment, and prediction confirmed. Things get fuzzy in interpretation. One way to interpret quantum theory —> quanta have a potential wavefunction, which then collapses into definite state when observed —> act of measurement gives reality to quantum. In delayed-choice experiment means quantum doesn't become "real" until measure it, —> could be billions of years after origin.

Some say, overly simplistic. Quantum objects are real, but have indefinite properties. Properties defined by experiments do(context). Delayed choice experiments —> quanta don't exist as particles or waves, but unique objects which can exhibit particle and wave properties in certain experiments(context).

Seems strange, but not magical or mystical. Moon wouldn't vanish from existence if everyone closed their eyes, and reality isn't dependent upon us observing it. Reality seems to be dependent on CONTEXT.

Latest Experiments

Australian experiment confirmed quantum physics's bizarre predictions about nature of reality, by proving that reality doesn't actually exist until measure it - at least, not on very small scale.

Experiment poses simple question: if have object that can either act like particle or wave, at what point does object 'decide'?

General logic —> object either wave-like or particle-like by very nature, and measurements —> nothing to do with answer. But quantum theory predicts that result depends on how object measured at end of journey —> what Australian experiment found.

> QUOTE: "It proves that measurement is everything. At the quantum level, reality does not exist if you are not looking at it,"

40 years after Wheeler proposal Australian team recreated experiment using helium atoms scattered by laser light.

QUOTE: ”Quantum physics predictions about interference seem odd enough when applied to light, which seems more like a wave, but to have done the experiment with atoms, which are complicated things that have mass and interact with electric fields and so on, adds to the weirdness,"

To successfully recreate experiment, trapped bunch of helium atoms in suspended state known as Bose-Einstein condensate, and then ejected them until there was only single atom left.

Atom dropped through pair of laser beams, which made grating pattern that acted as crossroads that would scatter path of atom, much like solid grating would scatter light.

Then randomly added second grating that recombined paths, but only after atom had already passed first grating.

When second grating added, led to constructive or destructive interference <—> expect if atom had travelled both paths, like wave. But when second grating not added, no interference observed, as if atom chose only one path.

Fact that second grating only added after atom passed through first crossroads suggests that atom hadn't yet determined its nature before being measured second time.

So if you believe that atom did take particular path or paths at first crossroad, this means that future measurement was affecting atom's path.

QUOTE: ”The atoms did not travel from A to B. It was only when they were measured at the end of the journey that their wave-like or particle-like behavior was brought into existence,”

Say experiment details again….

Dr. Truscott's team forced 100 of helium atoms into state of matter called Bose-Einstein condensate. After this, ejected atoms until only one left.

Then, used pair of laser beams to create **grating pattern** —> scatter atom passing through like a solid grating scatters light. Thus, atom either act as particle and pass through one arm or act as wave and pass through both arms.

Thanks to random number generator, **second grating** then randomly added in order to recombine paths. Done only after atom had already passed first grate.

Addition of second grating caused **interference in measurement,** showing atom had "traveled both paths", behaving like wave. At same time, when second grating was added, **there was no interference** and atom appeared to have traveled only one path.

The results and their interpretation

As second grating added only after atom had passed through first one, would be reasonable to suggest that **atom hadn't yet 'decided' whether was particle or wave before second measurement.**

Two possible interpretations of these results. Either atom 'decided' how to behave based on measurement or future measurement affected atom's past.

QUOTE: "The atoms did not travel from A to B. It was only when they were measured at the end of the journey that their wave-like or particle-like behavior was brought into existence"

Experiment —> validity of quantum theory and —> idea that reality doesn't exist without an observer.

Now come the Italians….

Physicists gone to some lengths – literally – by splitting and merging light and then bouncing from satellite before testing its odd-ball properties. Team of Italian physicists has gone super-size in effort to see if process can be scaled up from previous record distance of 144 km (about 90 miles) to 3,500 km (about 2,200 miles). Not surprised to learn experiment's results still true, and form quantum system takes seems to depend on context of observation.

Researchers split pulse of laser light using Italian Space Agency's Matera Laser Ranging Observatory (MLRO), so photon could either take shorter path, or be sent on slightly more convoluted detour.

Two paths merged before heading on several thousand km journey to orbiting satellite, from where photon bounced back to planet's surface. Back at MLRO, quantum random number generator chose whether or not device delayed incoming photon.

Letting it through —> researchers knew which path took; equivalent of measuring as defined particle with clear history. Delaying photon makes impossible to tell whether had arrived early or not, leaving history unknown. Importantly, random decision made well after photon set off on extensive journey, thousands of km in past.

Researchers found could affect whether photon perceived as wave or particle well after had passed through important parts of experiment —> as if random decision to let photon pass through made it go back in time and choose one path, while delaying it meant it still had a history of possibilities, each of which would then interfere with its detection to reveal a wave-like nature.

Doesn't completely solve mystery of what “collapse” means.

But even after horse has bolted 3,500 km out of gate, it seems that it can still wait until finish line to decide which race it ran.

It isn't that reality doesn't exist when we don't look at it. It's that certain quantities only become well defined in the context of particular measurements.

Quantum measurements happen without intelligent agents. For example, a decaying radioactive isotope in an asteroid might still emit a particle capable of starting a chain reaction, in say, interstellar gas.

This experiment is further evidence that the Quantum scale universe is imprecise until we force it to be. As always this has very deep and complicated philosophical implications, but the truth has a funny way of doing that.

That "reality does not exist until we measure it" is a stupid, meaningless statement. What is more accurate is that we don't know what we will measure until we measure it. Whatever has the potential to produce a measurement certainly exists before we measure it. It is simple to express its "before-measurement" reality mathematically.