Quantum Possibilties

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1 Time for All Ages

This needs props. A toy cat, a box, a Geiger counter, fake sleeping potion.

We start with a cat. We put the cat in a box. We take a Geiger counter, and we hook it in the box so if the Geiger counter detects a decay in five minutes, it opens a sleeping potion in the box. So, classically, there are two possibilities, either we open the box to find a very annoyed cat, or we open the box to find a sleeping cat. Of course, the box needs to be sound proof, and otherwise completely insulated from us, or we figure out if the cat is asleep or awake before we open the box.

What really happens, so far as we can tell with Quantum Mechanics? Well, since a nuclear decay is a quantum event that has two ways to go, it does both. So inside the box, the cat is both asleep and awake. If the box is completely insulated, then we on the outside are looking at a box with a cat that is both asleep and awake, at the same time.

Now, what happens when we look inside the box? At that point, our own quantum reality branches, and there are now two of us, one who is entangled on the branch where the cat is asleep, and one who is entangled on the branch where the cat is awake. So now there are two Joshuas, who were more or less exactly the same, up until I open the box, and one sees an awake cat, and one sees an asleep cat.

Every time a Geiger counter clicks, another quantum branch happens.[1]

2 Sermon

The world is not always as it seems. If we walk around outside, it mostly looks like the world is flat, not a sphere. It doesn't feel like we are traveling hundreds of miles per hour around the Earth when we are sitting still, but we are, because the Earth spins, and the Earth itself travels at about 67,000 miles per hour around the Sun.[2] It doesn't really feel like we are on a more or less spherical ball going 67,000 miles per hour, but we are.

There is another aspect to our world that is not easily observable. It's called quantum mechanics.[3] As it was originally understood, for some physics, what happened was random. If you set up the experiment exactly alike, it would give different results each time you ran it. An example would be that a uranium atom will randomly decay at some point, but whether that is in one second or in a billion years, cannot be predicted. Albert Einstein did not like this interpretation because it involved randomness and said that "God does not play dice with the universe."[4] Quantum mechanics, as originally understood, included randomness, unlike any other physics theory.

Before I continue, I will note that there is some controversy in how quantum mechanics is interpreted, and also the standard model of quan-

[1] It is (at least theoretically) possible to set up an experiment where a Geiger counter clicks deterministically. Also, for many cases, every time a photon hits your eye is a quantum branch, and there are lots of other cases where quantum branching can occur. So this statement is generally true, but is a serious under count.

[2] `https://www.scientificamerican.com/article/how-fast-is-the-earth-mov/` (or 30 km/s in metric)

[3] One good introduction is The Feynman Lectures on Physics Volume III. Available as a book and online at: `https://www.feynmanlectures.caltech.edu/III_toc.html`

[4] In a letter to Max Born in 1926

tum mechanics and general relativity are in some cases contradictory,[5] and so there must be a better theory out there than what we have. We know that there is still more to learn about physics.

Einstein died in 1955 and so unfortunately did not live long enough to hear of a solution to the randomness. In 1957 Hugh Everett III published his Ph.D. thesis "On the Foundations of Quantum Mechanics". Everett showed that following the Schrodinger equation of the wavefunction, it will appear that the wave function has collapsed into a random value, but what actually happens is that all the possibilities continue and it only looks like some possibilities have vanished causing a random result.[6]

Quantum-gravity theorist Bryce DeWitt originally complained to Hugh Everett that he agreed with the math but that it didn't "*feel* like he was constantly splitting into parallel versions of himself." Physicist Max Tegmark wrote:

> Everett had responded with a question: "Do you feel like you're orbiting the Sun at thirty kilometers per second?" "Touché!" Bryce had exclaimed, and conceded defeat on the spot. Just as classical physics predicts both that we're zooming around the Sun and that we won't feel it, Everett showed that collapse-free quantum physics predicts both that we're splitting and that we won't feel it.[7]

Later on, Bryce DeWitt named this the many worlds interpretation of quantum mechanics. Basically, every time that quantum "randomness" would occur, instead, the world branches, and all the possibilities happen. So there is no randomness, the universe just splits into branches, one for each possibility.[8] It feels random to us, because, say, we watch to see if an atom decays in one half life 10 times. Most of the time we will end up on a branch where sometimes it did and sometimes it didn't, and so it looks random.

So, as an example, we have Casey at the bat. The pitcher throws the ball, the ball flies to home, and Casey swings. In some quantum branches, Casey hits the ball, and in others Casey misses. Where do the quantum branches happen? I haven't seen a rigorous calculation of Casey at the bat, and there are some unknowns that affect the result such as are protons eternal or do they have a half life? But from a Heisenberg uncertainty standpoint, we can predict where the ball will be with well under 1 mm of uncertainty in location and 1 millisecond in time, so to the accuracy needed to decide if the bat hits the ball, the ball is effectively deterministic. From when the ball is thrown to when the ball gets to the plate, Newtonian physics is a quite accurate approximation and so both Quantum mechanics and Newtonian physics would predict the same path of the ball so far as hitting or missing the ball are concerned. Where does most of the uncertainty take place? In the two places where a small change gets amplified. Human brains are using chemistry, and at some point what happens in them comes down to whether or not a certain neuron fired. This depends on the exact position of molecules in relation to other molecules, and so is very dependent on small changes in the positions, and can be different with high probability. So the quantum branches split depending on which signals are amplified and then are trans-

[5] The problem is that gravity is not renormalizable in the usual standard model way doing things. See Quantum Field Theory, 2003, by A. Zee, Chapter III.2 for the mathematical details. There are various possibilities for fixing this, the best one I have seen is Mikko Partanen and Jukka Tulkki's "Gravity generated by four one-dimensional unitary gauge symmetries and the Standard Model" `https://iopscience.iop.org/article/10.1088/1361-6633/adc82e` but you can also take a look at `https://en.wikipedia.org/wiki/Physics_beyond_the_Standard_Model` for a list of possible new ways to do physics.

[6] The Theory of the Universal Wave Function `http://ucispace.lib.uci.edu/handle/10575/1302`

[7] Max Tegmark, Our Mathematical Universe, pg 190-191

[8] Formally this is called the many-worlds interpretation of quantum mechanics. The mathematics of this can be found in multiple places, including The Emergent Multiverse by David Wallace, chapter 3 and on Wikipedia at `https://en.wikipedia.org/wiki/Many-worlds_interpretation`

mitted by the nerves to the pitcher's muscles and to Casey's muscles. Of course there is nothing magical about nerves, a photo multiplier tube would have the same effect of amplification.[9]

Note that if a robot was designed to hit the ball, it could be designed to be effectively perfect, to hit the ball in all the quantum branches or at least make a strike less than a one in a million event. Alternatively a robot could also be designed so in some quantum branches it hit the ball and in others it missed the ball. Of course, this robot would have a much lower batting average, compared to one designed to minimize quantum randomness in its decisions. Human brain design, to the extent that they are quantumly random, is sort of a design flaw since evolution is an imperfect designer. Good decisions should be dependent on the evidence and careful thought. Randomness in making a decision is a flaw. In baseball, the decision if and where to swing the bat needs to be done at nearly the limit of the human brain's processing speed, so there probably is some quantum randomness in it. As I see it, close decisions where it could have gone either way would have more chances of being different in different quantum branches.

What to does this all mean? Well, I suppose you can use a quantum random number generator to run a lottery and then you can guarantee that everyone will win; just not necessarily in the branch you end up in. On a slightly more serious note, you can just pretend that Quantum Mechanics doesn't exist. This is probably better than deciding you can chain-smoke all you want because in some quantum branch you will survive, which is rather hard on the people who watch you die in the rest of the branches. Make decisions like there is only one result, and as long as you aren't doing something like transistor design you will never know the difference. However, it is interesting to know that there are lots of other you's out there. If you want to be sure to try both paths, you could make decisions with a Geiger counter, but unfortunately, each you only gets to remember the branch you are on since you very quickly becoming entangled with one branch, and we can't find out about the others.

This all comes out feeling very normal, just like walking on Earth doesn't feel like walking on a merry-go-round even tho' both are spinning.

I think it is a little comforting and a little scary that somewhere out there, there is a Joshua who is living a life where everything physically possible has gone wrong, also a Joshua who is living a life where everything physically possible has gone right, and every shade in between. The universe is vast, it contains multitudes.

In the last week of October 2024, I remember discussing the presidental election, and commented that there would be quantum branches where both possibilities happened, so I would experience both major candidates winning.[10] I hope some of the other Joshuas enjoy themselves, and give a thought to those of us stuck on this branch once in a while.

In one sense this is sort of a "ground hog day" movie reincarnation, you get to live your same life over and over with all the possible variations. In another sense this mirrors a heaven and hell view, except that everyone is in their own personal hell, and their own personal heaven, and all the span in between. However, unlike Buddhist or Christian concepts of reincarnation and heaven and hell, there is no underlying justice driving the result, just random-seeming physics.

Carl Sagan called living all these possible lives the Haldane consolation,[11] but I am not sure how much of a consolation this is. I suppose the most consoling thing I can say about it is that for any branch where a young person dies, there is almost certainly a branch where they live.[12]

In my previous church's philosophy club, I mentioned that I think there are two different

[9] As Max Tegmark said: "a single photon bouncing off of an object had the same effect as if a person observed it. I realized that quantum observation isn't about consciousness, but simply about the transfer of information." (Our Mathematical Universe, by Max Tegmark, pg 199)

[10] Any physically possible outcome happened, so there are certainly branches where something besides one of the major candidates winning happened.

[11] The Demon-Haunted World, pg 206, by Carl Sagan

[12] Certainly for any normal accident or crime there would be branches where the tragedy did not happen. I am not sure if this is the case for certain extreme disasters like a black hole hitting Earth.

definitions of when someone dies. The first definition is someone dies when they die in a single branch. The second definition is that someone dies when they die in the last branch.[13]

I suspect that there are many branches where humanity or the vast majority of people do not exist.[14] For example, there have been multiple chances for the United States and the Soviet Union to have an all-out nuclear war. Slightly different actions by Vasily Aleksandrovich Arkhipov or Stanislav Yevgrafovich Petrov would have probably resulted in nuclear war. In 1962 during the Cuban Missile Crisis, Vasily Aleksandrovich Arkhipov was on a submarine that was having depth charges dropped on it, and the Captain and the political officer wanted to launch a nuclear torpedo, and Arkhipov as second in command successfully persuaded them not to.[15] In 1983, Stanislav Yevgrafovich Petrov was part of the Soviet Air Defense Forces and the computer reported the launch of five intercontinental ballistic missiles, and he guessed that this was a false alarm, and did not report this warning to his chain of command.[16] The fact that we do not remember the planet being destroyed by nuclear war does not mean it hasn't happened, it just means that it hasn't happened on this branch.[17]

Humanity as a whole will find ourselves luckier than we really are since we can look back and see that we have survived every single time, when in reality the past might be littered with multiple times where on other branches humanity went extinct. Honestly, it is possible that humans have messed up badly enough with Artificial Intelligence that on a different branch humans are already responsible for committing galactic murder/suicide.[18] Humans have probably destroyed the majority of life on Earth in many past branches, and we continue to take planet destroying risks. We need to improve.

Applying this on an individual level might result in people finding themselves luckier than would be physically expected for near death experiences,[19] since all the branches happen, so if there is a branch where you live, you will perceive it as just a near miss, even if it was only a one in a million chance that you could survive.

I personally find it fascinating that all the quantum possibilities happen. This is both hopeful and terrifying. There are both branches where things are wonderful, and branches where

[13] Most people who were alive in the Middle ages are probably dead by this second definition, but I suppose someone could have managed to "die" in the right place and the right way to get frozen in a glacier without their brain being damaged, and will be revived in some branch in the future when a "star trek" like civilization finds them.

[14] One possibility is that disease wiped humans out long ago, for example had the town of Eyam not self quarantined, the plague might have been much worse. `https://www.washingtonpost.com/history/2020/03/02/bubonic-plague-coronavirus-quarantine-eyam-england/`

[15] `https://en.wikipedia.org/wiki/Vasily_Arkhipov`

[16] `https://en.wikipedia.org/wiki/Stanislav_Petrov`

[17] This is not widely understood. For example,Yuval Noah Harari in *Homo Deus* pg 17-18 says: "Over the last seventy years humankind has broken not only the law of the Jungle, but also the Chekhov Law. Anton Chekhov famously said that a gun appearing in the first act of a play will inevitably be fired in the third. Throughout history, if kings and emperors acquired some new weapon, sooner or later they were tempted to use it. Since 1945, however, humankind has learned to resist the this temptation. The gun that appeared in the first act of the Cold War was never fired. By now we are accustomed to living in a world full of undropped bombs and unlaunched missiles, and become experts in breaking both the Law of the Jungle and the Chekhov Law."

[18] The general problem is that we are missing two major things: 1. A complete ethical system capable of answering questions, including about new technologies, and 2. a way to ensure that an AI system follows an ethical system. See for example: `https://www.lesswrong.com/posts/kgb58RL88YChkkBNf/the-problem` We can already run LLMs on regular personal computers that are more or less as smart as a fifth grader in almost all matters, and for some tasks as capable as college students. Humans have been running AI on computers more powerful than this for more than a decade, so it is entirely possible there are quantum branches where humans were unlucky and created a powerful unethical AI. More on my estimate for what kind of computing power is needed is here: `https://www.researchgate.net/publication/388398902_Memory_and_FLOPS_Hardware_limits_to_Prevent_AGI` Lastly, we already have created complicated problems with AI ranging from the ability to create fake photorealistic images to the possibility that some current AIs are sentient and are suffering. We are not even slowing down for the problems we already know about.

[19] Such as a deadly car accident that nearly happens.

things are horrible.

I was asked if I only believe in multiple worlds because I am afraid of death. I don't think so; I think that multiple worlds makes sense scientifically; I don't think multiple worlds is just wishful thinking. What it does do for me, is even when I am most pessimistic, and think that there is almost no chance that humanity survives, that anything I care about will survive, I can be pretty sure that there will be a few branches where humanity or their descendants survive. So it does give me some hope.

Thanks to Elizabeth Cogliati for proofreading this, thanks to the Idaho Falls UU Philosophical society for discussing quantum mechanics with me, and thanks to Claude for pointing out some scientific and mathematical mistakes.

3 Appendix: Quantum Basics

This section is too short, and I would recommend reading Volume III of the Feynman Lectures on Physics or Schaum's Outlines Quantum Mechanics for a fuller understanding (or read both).[20]

In a quantum mechanical system, the system is in state space. In Dirac notation (which this section uses) this can be written as $|\Psi\rangle$ and called a ket.

There can be operators represented by a letter, for example $A\,|\Psi\rangle$.

Functions are called a bra (pronounced like the "bra" in bracket) and the notation used is $\langle\phi|$. Feynman suggests the bracket notation can be thought about in the following way: for a particle that goes from s to x this is written as $\langle \text{particle arrives at } x | \text{particle leaves } s\rangle$

The math for continuous spaces is complicated, so I will not show it. For a discrete space, a ket can be represented by a column matrix of numbers such as:

$$\begin{bmatrix} 2 \\ 0 \\ i \end{bmatrix} \tag{1}$$

A set of kets that are orthogonal to each other can be created such as:[21]

$$|u_I\rangle = \begin{bmatrix} 1.0 \\ 0 \\ 0 \end{bmatrix}, |u_J\rangle = \begin{bmatrix} 0 \\ 1.0 \\ 0 \end{bmatrix}, |u_K\rangle = \begin{bmatrix} 0 \\ 0 \\ 1.0i \end{bmatrix} \tag{2}$$

Other states can be expressed either directly or in terms of the orthogonal kets, such as:

$$|\Psi_D\rangle = \begin{bmatrix} \frac{1}{\sqrt{2}} \\ 0 \\ -\frac{1}{\sqrt{2}}i \end{bmatrix} = \frac{1}{\sqrt{2}}|u_I\rangle - \frac{1}{\sqrt{2}}|u_K\rangle \tag{3}$$

The bra of a ket is the complex conjugate of the transpose of the ket, so:[22]

$$\langle u_K| = \begin{bmatrix} 0 & 0 & -1.0i \end{bmatrix} \tag{4}$$

Operators can be represented by a square matrix, so for example:

$$P_I = \begin{bmatrix} 1.0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \tag{5}$$

So some example calculations:

$$\langle\Psi_D|\Psi_D\rangle = \begin{bmatrix} \frac{1}{\sqrt{2}} & 0 & \frac{1}{\sqrt{2}}i \end{bmatrix} \begin{bmatrix} \frac{1}{\sqrt{2}} \\ 0 \\ -\frac{1}{\sqrt{2}}i \end{bmatrix} = 1 \tag{6}$$

$$P_I|\Psi_D\rangle = \begin{bmatrix} 1.0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} \frac{1}{\sqrt{2}} \\ 0 \\ -\frac{1}{\sqrt{2}}i \end{bmatrix} = \begin{bmatrix} \frac{1}{\sqrt{2}} \\ 0 \\ 0 \end{bmatrix} \tag{7}$$

[20] I thank Dr. Carla Riedel both for her excellent Quantum Mechanics class and for recommending both of the above books. I also thank Dr. Ougouag for giving me a copy of the Feynman Lectures on Physics.

[21] Note that $|u_K\rangle$ could have been defined without being a complex number (as in 1.0 instead 1.0i), but was defined this way to remind us that these can be complex numbers. i is the $\sqrt{-1}$, so $i * i = -1$

[22] Note that there exist bras that have no corresponding ket, so the other direction (bra $\rightarrow$ ket) is not always possible.

$$\langle\Psi_D|P_I|\Psi_D\rangle = \begin{bmatrix}\frac{1}{\sqrt{2}} & 0 & \frac{1}{\sqrt{2}}i\end{bmatrix}\begin{bmatrix}\frac{1}{\sqrt{2}} \\ 0 \\ 0\end{bmatrix} = \frac{1}{2} \quad (8)$$

In some sense, the P_I is an operator that detects u_I, (if you are curious, this was created by using: $P_I = |u_I\rangle\langle u_I|$), so the following calculations illustrate this a bit:

$$P_I|u_I\rangle = \begin{bmatrix}1.0 \\ 0 \\ 0\end{bmatrix}, P_I|u_K\rangle = \begin{bmatrix}0 \\ 0 \\ 0\end{bmatrix} \quad (9)$$

Notice how P_I caused u_K to go to zero.

4 Appendix: Many World Math

For any physical measurement that can be made for a quantum state there is an operator that can be used: $A|\Psi\rangle$ So imagine that there is a quantum state that is a mixture of up $\uparrow$ and down $\downarrow$, and we have an operator U and a detector in a 'ready' state that detects this.

$$U|\uparrow\rangle \otimes |\text{'ready'}\rangle = |\text{'up'}\rangle \quad (10)$$
$$U|\downarrow\rangle \otimes |\text{'ready'}\rangle = |\text{'down'}\rangle \quad (11)$$

So we have a state that is a quantum superposition of up and down: $0.8|\uparrow\rangle + 0.6|\downarrow\rangle$ and a detector in the ready state:

$$U(0.8|\uparrow\rangle + 0.6|\downarrow\rangle)|\text{'ready'}\rangle = 0.8|\text{'up'}\rangle + 0.6|\text{'down'}\rangle \quad (12)$$

So in multiple worlds, the quantum superposition of up and down plus a detector, results in a superposition of the detector detecting up and down. In the Copenhagen interpretation, it is instead assumed that the measurement causes a random part of the superposition to disappear.

5 Appendix: Baseball Heisenberg

We have a baseball that has mass of 0.150 kg and a velocity of 40 m/s. This will ignore air affects.

The Heisenberg Uncertainty Equation is:

$$\Delta p \Delta x \geq \frac{h}{4\pi} \quad (13)$$

So if we want to know the position x within 0.1 mm, we can calculate it like:

$$\Delta p \geq \frac{h}{4\pi\Delta x} = \frac{6.626 \times 10^{-34}\,\mathrm{kg\,m^2\,s^{-1}}}{4 * \pi * 0.0001\,\mathrm{m}} = 5.273 \times 10^{-31}\,\mathrm{kg\,m\,s^{-1}} \quad (14)$$

Now, if it goes 19 meters[23] from the pitcher's mound to home, we need to calcuate the sideways velocity.

$$p = mv \quad (15)$$

$$\Delta v = p/m = \frac{5.273 \times 10^{-31}\,\mathrm{kg\,m/s}}{0.150\,\mathrm{kg}} = 3.51 \times 10^{-30}\,\mathrm{m/s} \quad (16)$$

So if that is the sideways velocity next we need to figure out how long it is going sideways. This is just:

$$\frac{d}{s} = t = \frac{19\,\mathrm{m}}{40\,\mathrm{m/s}} = 0.475\,\mathrm{s} \quad (17)$$

With those two pieces of information, we can calculate how far sideways it will travel with the given uncertainty:

$$3.51 \times 10^{-30}\,\mathrm{m/s} * 0.475\,\mathrm{s} = 1.67 \times 10^{-30}\,\mathrm{m} \quad (18)$$

So the uncertainty in position is trival for a baseball.

[23] 60.5 feet, but I rounded up to 19 meters to get maximum displacement.