

Quantum indeterminism and the flow of time

Often when humans think of randomness it's things that are not fundamentally random such as throwing a dice, it's just difficult to predict.

Difficulty predicting the outcome can be due to issues with measurements or simply difficulties doing exact enough calculations, currently using quantum chromodynamics to calculate the half life of uranium-235 isn't possible even though it should be possible in principle if the actual theory itself is correct.

But what about true randomness?

Current experiments in modern physics strongly suggest that reality is fundamentally unpredictable, when you measure a quantum system the outcome cannot be predicted, you only get probabilities.

Everything in physics as we know it is fundamentally time-symmetrical and deterministic with one exception, when a quantum wave-function collapses it is time-irreversible and you the outcome cannot be predicted, the Born rule only tells you the probabilities.

Within a deterministic system there will not be any true passage of time since the future already exists (determined), it's only in a non-deterministic system that there will be any true passage of time.

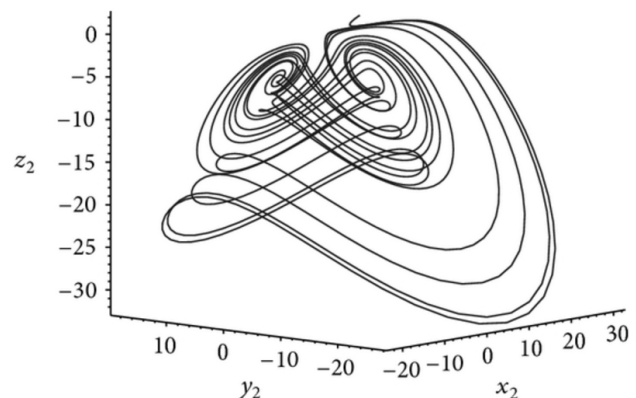
Thinking about time this way resolves the apparent craziness within quantum mechanics "spooky action at a distance" since fundamentally the measurement and the initial entanglement process happen at the same time.

This paints a picture of the passage of time fundamentally being a discrete process. It only seems to be continuous to us because of our perception similar to how we don't notice pixels on a screen if they are small enough or notice the passage of time when we are not conscious.

The question of why a measurement collapses the wave-function still remains, what actually happens fundamentally? It's not very clear, there are many ways to interpret it and we cannot currently tell these interpretations apart. We cannot even rule out "consciousness causing the collapse of the wave-function" since we don't currently know what consciousness even is, what if consciousness is everywhere? (panpsychism).

It is sometimes claimed that nobody understands quantum mechanics but is that really true? Surely someone someone will have guessed what the correct interpretation is so far.

Some people may think that the effects of quantum indeterminism are too small to make any real difference at the large scale but over time these smaller differences will grow into bigger and bigger differences via something like the butterfly effect.



Originally the butterfly effect referred to the possibility of a deterministic system being unpredictable in finite time no matter how precise we can measure that, a possible candidate for that is the Navier-Stokes equations used to predict weather among other things.

But let's go back to the dice example again, when is it fundamentally determined where the die will land, is it when it's in the air or 5 minutes before you even throw it, how predictable is the behavior of humans? What is the relationship between quantum mechanics and consciousness? Are they even related at all? Currently we simply don't know but we can always guess and maybe delude ourselves into thinking we know for sure when in reality it was an educated guess at best.

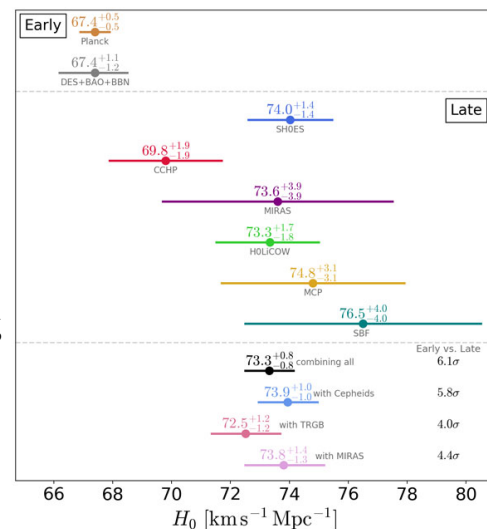
At first we were thinking that the gravitational law discovered by Newton were the correct one but then it didn't really fit with experiments, this was later resolved with General Relativity but how do we know General Relativity is correct, so far it has agreed with experiments except that on very large scales there are deviations.

0. We need to add in dark matter to get enough gravitational pull, this is however already needed for other reasons and doesn't invalidate the theory, but why hasn't we directly detected dark matter and what is it even?

1. What we were thinking as just a cosmological constant seem to be growing over time "Hubble tension" and why is that? At which point shall we trust our measurements and conclude that dark energy indeed is getting stronger?

We always have to deal with probabilities, not even mathematical proofs are fully reliable since there is a small probability that everyone is mistaken about the proof thinking it's valid when it is not.

Since humans are uncomfortable with uncertainty we try to ignore it and want to believe that we can use maths and science to better predict things and get more in control, in reality everything is either already determined or fundamentally random.



What we think of as free will can be defined non-determinism meaning the outcome cannot fundamentally be predicted, not even in theory. By that definition humans have free will iff we cannot predict which action a human will take in the future with arbitrary accuracy, not even in principle, no matter how accurate we would do a brain-scan we would always come up short and guess wrong.

This Essay was written by Carl Sebastian Andersson sebbe.and@gmail.com (public email).

References

Regarding dark energy

<https://arxiv.org/abs/1907.10625>

<https://arxiv.org/abs/2003.07355>

The real butterfly effect

<https://iopscience.iop.org/article/10.1088/0951-7715/27/9/R123/meta>