On Self-Collapsing Wavefunctions and the Fine Tuning of the Universe

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Abstract

A new variation on the Copenhagen interpretation of quantum mechanics is introduced, and its effects on the evolution of the Universe are reviewed. It is demonstrated that this modified form of quantum mechanics will produce a habitable Universe with no required tuning of the parameters, and without requiring multiple Universes or external creators.

1 Introduction

One of the oldest questions in the fields of science is the question of why we exist. And perhaps even more important, why should the Universe be such that life can exist. As scientific knowledge has increased, humanity has learned about the birth of the Universe through the Big Bang Model, and has studied the nature of matter down to the sub-subatomic scales. Yet we are no closer the answering the key question of why the Universe should be habitable at all.

This question has become increasingly interesting in the last century, with better models for cosmology, astrophysics and nuclear physics revealing that inhabitable Universes appear to be rare. Although there is some debate about how much variation of the fundamental constants of nature is permissible to generate life, the general consensus is that most of the relevant parameter space generates physical laws that generate a Universe either too cold, too hot, too carbon-poor , or too short-lived to produced life[1, 2].

Several proposals have been made over the past three decades to explain the improbable nature of a habitable Universe. The anthropic principles argue that we live in a habitable Universe because there would be no one to ask the question if it were not habitable. However this argument is dubious, since it still suggests that we should not exist at all. It has also been suggested that we may live in one of many random Universes[3] or that the Universe itself could be evolving to support life[4].

In this article, we present the possibility that quantum mechanics forces the Universe to contain a conscious observer. It is demonstrated that a subtle change in the traditional Copenhagen Interpretation of quantum mechanics, in which an observer is part of the wavefunction and is capable of collapsing their own wavefunction, necessarily leads to the fundamental constants of nature taking on values which support life, regardless of how improbable that may be in general.

2 Self Collapsing Wavefunctions

Although there are unresolved problems with the Copenhagen interpretation of quantum mechanics, it is currently the standard method used to both teach quantum mechanics and to perform routine calculations. In the Copenhagen interpretation, the system is divided into two separate pieces - the wavefunction which describes the behaviour of the system under study, and the observer whose observations and measurements cause the wavefunction to collapse to a single state (or more accurately, a subset of the Hilbert space which is consistent with the measurement.). The benefits and faults with this interpration have been well studied, and we will not repeat them here.

However there is a philosophical if not physical objection to this apparent separation of the observer from the observed system. In the now famous Schrodinger's cat thought experiment, it is usually assumed that the cat is part of the wavefunction, and the scientist is the observer. But couldn't the cat observe for herself whether she is alive or not?

If the Universe cannot be divided into observers and wavefunctions, then by necessity the observer must also be part of a larger wavefunction. Suppose now that the observer can affect their own wavefunction. Suppose that an observer can make a measurement on themselves, and can therefore collapse their own wavefunction.

In the remainder of this article, we will refer to such systems as *self-*

collapsing wavefunctions, since they represent a closed system in which the wavefunction collapses without external observations.

3 The Fine Tuned Universe

Suppose that at the moment of the Big Bang[1] the Universe is in a superposition of possible Universes, each with its own laws of physics and values of its fundamental constants. While these states are expected to be complicated and describe numerous properties of the Universe, for simplicity the possible states will be grouped into two sets - habitable Universes denoted $|H>$ and uninhabitable Universes denoted $|N>$. Then the wavefunction of the Universe is

$$\Psi = \alpha|H> + \beta|N> \tag{1}$$

where

$$\alpha^2 + \beta^2 = 1$$

As discussed in the introduction, it is expected that $\alpha << \beta$. In fact α is many orders of magnitude smaller than β but is non-zero.

The Universe continues in this superposition until one of the habitable Universe states contains an observer. This observer in some way senses their surroundings, and effectively makes a measurement of the Universe. In this simple model there is then a probability of α^2 that the Universe is observed to be habitable and immediately collapses to the habitable subspace of Hilbert space, $|H>$. Once this has occured, the Universe remains habitable for all time.

However there is a probability of β^2 that the Universe will not be habitable. In this case, there is no observer and therefore no collapse of the wavefunction. As such the Universe will continue in the original superposition.

A moment later, the primordial life form makes another measurement of its surroundings and the process repeats. Once more there is a probability

[1] There is an issue here of time. It is possible that other Universes in this superposition have different ages. There are also issues with defining time outside of the Universe. However we will ignore these issues in the present article.

of α^2 that the Universe collapses to a habitable state, and a probability of β^2 that it remains in a superposition.

It follows that the probability that the Universe is habitable after T such measurements is

$$P_H(T) = \alpha^2 + \beta^2\alpha^2 + \beta^4\alpha^2 + ... = \frac{\alpha^2(1-\beta^{2T})}{1-\beta^2} = 1 - \beta^{2T} \qquad (2)$$

Assuming that $\beta^2 < 1$, and that it is at least possible if not probable that the Universe is habitable, then Eq 2 implies that the probability of the Universe collapsing to a habitable state increases over time. In the limit of a very large number of possible observations, the probability reduces to

$$\lim_{T\to\infty} P_H(T) = 1 \qquad (3)$$

and the wavefunction is certain to collapse to a habitable Universe.

From this very simple toy model of a wavefunction for the Universe, it is clear that as long as habitable Universes are not explicitly forbidden, the Universe will always evolve to a state that supports some form of life. The Universe will fine-tune itself.

4 Boltzmann Brains

This method of fine-tuning the Universe is presented as a toy model, and as such we do not concern ourselves in this article with the potential flaws in it, there is one issue common to such models that does need to be discussed. Specifically the issue of Boltzmann brains.

The only requirement for the Universe to be fine-tuned is that it is hospitable to at least one entity capable of making an observation that collapses the wavefunction of the Universe. As such it woudl seem that the expected Universe would contain one single consciousness, with minimal physical form, whose sole purpose is to fix the Universe's fundamental constants.

This issue is too complicated to cover adequately in this article, and has been covered extensively already in the literature. However we contend that an entire race of observers is actually more probable than a single Boltzmann brain for two key reasons. The first is that evolution increases the probability of an intelligent observer over the case of a single "mind from the void". The second is that the collapse of the Universe's wavefunction is not likely to be a single event, but rather a series of reductions of the relevant Hilbert space as more sophisticated experiments are conducted. For example, a Boltzmann brain can observe its own existence, but likely would be incapable of building a particle accelerator capable of measuring subatomic particles and their properties.

We intend to cover this argument in more detail in a forthcoming article.

5 Conclusions

In this article, a variation of the traditional Copenhagen Interpretation of quantum mechanics was presented in which observers are able to collapse their own wavefunction. This results in the existence of wavefunctions which spontaneously collapse to a superposition of states in a reduced Hilbert space without requiring any external causes.

This property is especially useful in studying cosmology, in which there is no external observer. It is argued that the entire Universe could be represented by a single self-collapsing wavefunction representing all possible Universes.

However the wavefunction can only collapse to states which contain observers. Uninhabitable Universes will never self-collapse, and so regardless of how improbable it might be that a random Universe has physical laws conducive to life it will always be the final state of the Universe.

Therefore if self-collapsing wavefunctions are permitted by the laws of quantum physics, then there is no fine-tuning problem with the Universe. The Universe requires life to exist, and therefore uninhabitable Universes simply do not exist.

6 Acknowledgments

The authors wish to acknowledge the numerous individuals who have discussed these ideas in various formats. While we are not aware of another presentation of this particular simple toy model, we do acknowledge that similar ideas have been debated for almost as long as quantum mechanics has been studied. In particular, proponents of the many worlds interpretation of quantum mechanics have written about fine tuned Universes as a consequence of that model. (See for example Ref [5] and Ref [6])

References

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