The Cosmological Anthropic Principle

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January 28, 2009

Abstract

I start with a brief history of the anthropic principle. Then I state the problem of the cosmological parameters seemingly fine tuning for life to appear. I go through several proposed solutions to this. The Why now? problem is stated which has to do with the energy density of the cosmological constant. It is seemingly coincidental equal (approximately) in size to the mass energy density. A few proposed solutions to this are described. Some tentative and speculative conclusions are drawn at the end.

1 Introduction

For most of humanitys history the existence of humans has been held as natural. Humans were also believed to be at the center of the universe and very important for the creation. In western civilization Copernicus removed humans from the center of the universe by putting earth in orbit around the sun like the rest of the planets. Newton later provided laws that governed the planetary motions and with increasing knowledge the first anthropic questions arised. Why is the earths orbit exactly right for life?

Later through Darwins evolutionary theory and others geological research it was discovered that the earth was very old and had to be very old to allow life to develop. This implied a very old and stable sun for life to be possible. Einsteins theory of general relativity provided the means for old stars to develop through the fusion reaction. General relativity also revolutionized the field of cosmology. Cosmology developed models of the universe which depend on certain parameters. Sometimes they are called constants since they appear to be constant in our universe. Here they will be called parameters though, since a lot of the proposed explanations for their values treat them as parameters. Seemingly those parameters must have certain values for life to be possible. This is one question in this paper. The second is the seemingly coincidence that the mass energy density Ω_M is of the same order as the cosmological constant energy density Ω_Λ when we are living. This is the so called Why now? problem. This could of course also be regarded as yet a cosmological parameter. There are however some differing explanations for this proposed. It also differs in that it seemingly is not as fine tuned for life as the other parameters. This warrants a special treatment of it.

2 The Cosmological Parameters

Our cosmological models are dependent on certain parameters. Those parameters often needs to have a certain value for life to be possible. So the anthropic principle says that we live in a universe where those values are just right for us since we are here to observe them. From [7] and [3] we get a short list of the most important parameters for cosmology and life as we know it:

- The electromagnetic force is 39 orders of magnitude stronger than the gravitational force. This allows stars to form.
- The u-d quark mass difference. d is just enough heavier to make the proton (uud) stable and the neutron (udd) unstable. If it was even heavier on the other hand deuterium would be unstable and heavier elements than hydrogen would have problems to form.
- The carbon nucleus has an excited energy level at around 7.65 MeV. Otherwise insufficient heavy elements for life would form in stars.
- Our universe consist of three spatial dimensions and one time dimension. If there were more or less spatial dimensions, planetary systems would not form.

We now present some proposed solutions to this seemingly fine tuning of the cosmological parameters.

2.1 Wild Chance

It could of course be a wild chance encounter that the universe have those parameter values. That is we live in the only universe that by chance has the correct values on the parameters for life to evolve. A problem with this is if the parameters are random it should amount to an awfully small probability for the right values. Even if some of the parameters shows to be somewhat dependent on each other it should still amount to a very small probability.

2.2 More Complete Theory

One solution to the fine tuning of the cosmological parameters would be if we came up with a more general theory from which the parameters follows naturally. This could be compared to the problem in Newtonian mechanics where it was a mystery why an objects gravitational mass m_g is equal to its inertial mass m_i. Then General relativity was discovered which is a more general theory where it follows natural that it is the same mass. In [5] Kane, Perry and Zytkow argues that string theory, or more precisely its offspring M-theory is such a theory. From this the cosmological parameters should follow natural, even the dimensionality of space (3 spatial dimensions and 1 time dimension) should follow naturally with the rest of the dimensions demanded by string theory being curled and very small. There are two parameters called α', the inverse string tension which sets the scale for all observations and the string coupling constant which determines the strength with which strings interact. Those are still left for anthropic arguments.

2.3 Varying Cosmological Parameters

Another possibility is that the cosmological parameters are not constant but vary in the universe. If we have an infinite universe they could vary over all possible values. Then at some places in the universe they will be just right for life to appear. Of course the parameters seem to vary slowly, at least in our vicinity of the universe since stars and galaxies form in the whole visible universe. A special version of this is the so called chaotic inflation scenario as outlined in [6]. Chaotic inflation states that the potential field ϕ that drives inflation has videly varying values. This gives rise to inflation of different size in different parts of the universe and different values on the cosmological parameters. Then of course we live in a part where the constants are right for life to appear.

2.4 Multiple Universes

There could also be that there exist an infinity of different universes. Each has its own set of cosmological parameters so that all possible parameter values appear in some universe. Then of course we exist in a universe where the parameter values are just right for life. As pointed out in [1] this is not disprovable in any way in totally disconnected universes. Thus it is more of a philosophical or metaphysical solution.

2.5 The God Hypothesis

One possibility to explain the parameters are to invoke a God who created the universe. He would then have fine tuned the parameters to make them appropriate for life. This leads to a lot of other questions though. This also risks running into the problem of not being disprovable and thus not really a scientific theory.

3 The Why Now Problem

The energy density in the universe is usually assumed to consist of three parts. Ω_R which is the ratio of radiation energy to the critical energy. It is probably around 8.4×10^{-5}. We also have $\Omega_M = 0.3$ and $\Omega_\Lambda = 0.7$ which is the energy ratio of matter and the cosmological constant respectively to the critical energy. Since we probably live in a flat universe they sum to 1. Ω_R is very small compared to the others which are of comparable size at present time. Why they are of comparable size right now is the so called Why now? problem.

3.1 Measurement Errors

There could be something wrong with our measurements of the cosmological constant. Or there could be something wrong with our understanding of the universe leading to the measurements and conclusions. Either of this could lead to either $\Omega_\Lambda << \Omega_M$ or $\Omega_\Lambda >> \Omega_M$ and there would be no Why now? problem.

3.2 Wild Chance

Of course this could also be explained by a chance occurrance. Probably a cosmological constant is not necessary for life but it just happens to be there at the observed value. This suffers from the problem of being very unprobable.

3.3 The Probability Solution

By using standard models and making a flat assumption for the probability distribution of Ω_Λ [2] derive a probability distribution between the start time of cosmological constant domination t_Λ and the time scale of galaxy formation t_G. They find that the times are generally of the same order of magnitude. Then they make some assumptions about the appearance of carbon based life. For example that there should have been produced enough carbon in stars. Through this they conclude that the appearance of life time t_l is of the same magnitude as t_G. Through these two relations $t_\Lambda \sim t_G$ and $t_l \sim t_G$ they conclude that there should come as no surprise that $t_\Lambda \sim t_l$.

3.4 Supergravity

Supergravity d=4, N=8 where d is number of dimensions and N is a parameter used by the theory is also a viable candidate for the cosmological constant. In [4] Kallosh and Linde derive a solution where a cosmological constant follows naturally from the theory. Assuming 14 billion years as necessary for intelligent life to develop they derive the probability for living in a $0.5 < \Omega_\Lambda < 0.9$ universe to be 10%. With this result it is still a coincidence that Ω_M and Ω_Λ are of the same magnitude, albeit a not too unlikely one. This can be increased somewhat by tweaking the model. Of course the parameter N=8 is anthropically chosen.

4 Conclusion

As this is a rather speculative area any conclusions drawn have to be very speculative. One might even call them guesses. Anyway, I will say some words on what I find probable.

On the cosmological parameter issue I like the idea of chaotic inflation. A universe containing all parameter values in different inflated parts of the universe. This suffers somewhat from the problem of being hard to observe though. The wild chance solution I see as a final explanation if everything else fails. A more complete theory is a viable option but the string theory proposal in this paper still leaves two parameters to anthropic reasoning. But of course there could be another more complete theory which does not suffer from this drawback. Multiple universes suffers hard I think from the problem of not being provable or disprovable. Scientifically, I think, it is more or less on equal terms with the wild chance idea. Finally, the God hypothesis raises more questions than it solves. Questions like What created the God in the first place? If he has created the world for us, why can't we detect his presence somehow?

For a solution to the Why now? problem I like the idea of the probability solution. In any universe approximately like ours life usually observe a cosmological constant energy density that is approximately of the same order as the matter energy density. Here also I see the wild chance solution as a last resort. The measurement or our understanding of the universe could of course be wrong. But I think it is more probable with another explanation. The supergravity theory is a viable candidate but suffers from having a parameter left to anthropic reasoning. So, in effect, it exchanges one explained parameter for another.

References

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