The Universe Shows No Evidence for Design

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November 14, 2010

For the *Oxford Dialogues in Christian Theism.*

The Fine-Tuning Argument

In recent years many theologians and Christian apologists have convinced themselves that they have a knock-down argument for the existence of God. They claim that the parameters of physics are so finely tuned that if any one of them were just slightly different in value, life would have not been possible anywhere in the universe. Assuming, on no basis whatsoever, that those parameters are independent and could have taken on any value over a wide range, they conclude that the probability of a universe with the particular set of parameters as ours is infinitesimally small. Further assuming, on no basis whatsoever, that the probability of a divine creator is not equally infinitesimally small, they conclude that such a creator existed who fine-tuned the universe for life, particularly human life. Note that there is also no basis whatsoever to assume that this creator was the personal God worshipped by Christians. Muslims, and Jews. A deist creator works equally well.

Leading Christian apologist William Lane Craig summarized the argument this way in his 1998 debate with Philosopher/Biologist Massimo Pigliucci (and in other debates):[1]

During the last 30 years, scientists have discovered that the existence of intelligent life depends upon a complex and delicate balance of initial conditions given in the Big Bang itself. We now know that life-*prohibiting* universes are vastly more probable than any life-*permitting* universe like ours. How much more probable?

The answer is that the chances that the universe should be life-permitting are so infinitesimal as to be incomprehensible and incalculable. For example, Stephen Hawking has estimated that if the rate of the universe's expansion one second after the Big Bang had been smaller by even one part in a hundred thousand million million, the universe would have re-collapsed into a hot fireball.[2] P.C.W. Davies has calculated that the odds against the initial conditions being suitable for later star formation (without which planets could not exist) is one followed by a thousand billion billion zeroes, at least.[3]

John Barrow and Frank Tipler estimate that a change in the strength of gravity or of the weak force by only one part in 10^{100} would have prevented a life-permitting universe.[4] There are around 50 such quantities and constants present in the Big Bang which must be fine-tuned in this way if the universe is to permit life. And it's not just *each* quantity that must be exquisitely fine-tuned; their *ratios* to one another must be also finely-tuned. So improbability is multiplied by improbability by improbability until our minds are reeling in incomprehensible numbers.

Cosmologists have proposed a very simple, purely natural, solution to the fine-tuning problem. Their current models strongly suggest that ours is not the only universe but part of a *multiverse* containing an unlimited number of individual universes extending an unlimited distance in all directions and for an unlimited time in the past and future. If that's the case, we just happen to live in that universe which is suited for our kind of life. The universe is not fine-tuned to us; we are fine-tuned to our particular universe.

Now, theists and many non-believing scientists object to this solution as being "non-scientific" because we have no way of observing a universe outside our own. In fact, a multiverse is more scientific and parsimonious than hypothesizing an unobservable creating spirit and a single universe. I would argue that the multiverse is a legitimate scientific hypothesis, since it agrees with our best knowledge.

Although, I believe the multiverse explanation is adequate to refute fine-tuning, it remains an untested hypothesis. In this essay I will make a case against fine-tuning that will not rely on speculations beyond well-established physics or on the existence of multiple universes. I will show that fine-tuning is a fallacy based on our knowledge of this universe alone.

Laws and Models

Before I get to the parameters that are supposedly fine-tuned, let me say a word about my basic, underlying assumptions. First, I assume that the models of physics are human inventions, and so it follows that the quantities, parameters, and "laws" that appear in these models are likewise. These elements must agree with observations, and so they must have something to do with whatever objective reality is out there. They are not arbitrary. But we have no way of knowing if the ingredients of the models, such as space, time, mass, and elementary particles exist in close correspondence to that reality.

And so, the parameters that are supposedly fine-tuned by a deity are just those physicists use in their models and need not have any specific ontological significance. The claim of fine-tuning of the parameters of physics is equivalent to a claim that our languages have been fine-tuned so they have grammatical rules that are highly unlikely to have occurred naturally.

Second, physicists in the twentieth century discovered that there is a set of principles or "metalaws" that must be present in all physics models. In order to describe the universe objectively, physicists must formulate their models so that they describe observations in ways that are independent of the point-of-view of particular observers. This gives the model-builders no choice but to include the great conservation principles of energy, linear momentum, angular momentum, and electric charge and all of classical physics including Maxwell's equations of electromagnetism and Einstein's theory of special relativity. Much of quantum mechanics, including the Heisenberg uncertainty principle, also must be included.[5]

Thus, when I argue below that some parameter is in a range consistent with known physics, the apologist cannot come back with "Where did the physics come from?" The physics came from physicists formulating models that must include the metalaws. And, as we will see, the values of the parameters in the models that successfully describe all observations in our universe are within the ranges expected from these metalaws.

The Parameters

While many authors have written on fine-tuning and given examples, I will rely on the most complete list assembled by microbiologist Rich Deem on his *God and Science* website.[6] Deem also lists, without details, estimates of the precision at which each parameter had to be tuned to produce our kind of life. These are the numbers that make Craig's mind reel.

Deem's main reference is physicist and Christian apologist Hugh Ross and his popular book *The Creator and the Cosmos* first published in 1993.[7] Ross is the founder of *Reasons to Believe*, which describes itself as an "international and interdenominational science-faith think tank *providing powerful new reasons from science to believe in Jesus Christ*."[8] A list of twenty-six claimed "design evidences" can be found in the book.[9] Ross has further developed his arguments in a chapter called "Big Bang Model Refined by Fire" in the anthology *Mere Creation: Science, Faith & Intelligent Design*.[10]

Two of the parameters that appear in most lists of fine-tuned quantities are

- The speed of light in a vacuum c
- Planck's constant h

As basic as these parameters are to physics, their values are arbitrary. The fundamental unit of time in physics is the *second*. The units for all other variables are defined relative to the second. The value of c is then just chosen to define what units will be used to measure distance. To measure distance in *meters* you choose $c = 3\text{x}10^8$. To measure distance in light-years you choose $c = 1$.

Note that the speed of light in a medium can be different from c.

The value of Planck's constant h is chosen to define what units you will be using to measure energy. To measure energy in *joules* you use $h = 6.626\text{x}10^{-34}$. To measure energy in electron-volts you use $h = 4.136\text{x}10^{-15}$. Physicists like to work in what they call "natural units," where $\hbar = h/2\pi = c = 1$.

Conclusion: No fine tuning; units are chosen for convenience and have fundamental significance.

I will move next to the five parameters that Deem lists as being so finely tuned that no form of life could exist in a universe in which any of the values differed by an infinitesimal amount from their existing values in our universe. These are given in Table 1, along with the maximum allowed deviation according to Deem.

Table 1. Fine-Tuning of Five Physical Parameters.

Parameter	**Max. Deviation**
Ratio of Electrons to Protons	$1/10^{37}$
Ratio of Electromagnetic Force to Gravity	$1/10^{40}$
Expansion Rate of Universe	$1/10^{55}$
Mass density of Universe	$1/10^{59}$
Cosmological Constant	$1/10^{120}$

Ratio of electrons to protons

Ross asserts that if this ratio were larger, there would be insufficient chemical binding. If smaller, electromagnetism would dominate gravity preventing galaxy, star, and planet formation.

The fact that the ratio is one can be easily explained. The number of electrons in the universe should exactly equal the number of protons from charge conservation, on the reasonable assumptions that the total electric charge of the universe is zero—as it should be if the universe came from "nothing" and charge is conserved.

Conclusion: no fine-tuning; the parameter is fixed by established physics and cosmology.

Ratio of electromagnetic force to gravity

Ross says that if this ratio were larger, there would be no stars less than 1.4 solar masses and hence short and uneven stellar burning. If it were smaller, there would be no stars more than 0.8 solar masses and hence no heavy element production.

The ratio of the forces is calculated for a proton and electron and depends on their charges and masses. If the masses were much larger, the forces would be closer in value. Despite the statement often heard in most physics classrooms that gravity is much weaker than electromagnetism, there is no way one can state absolutely the relative strengths of gravity and any other force.

The reason gravity is so weak in atoms is the small masses of elementary particles. This can be understood to be a consequence of the standard model of elementary particles in which the bare particles all have zero masses and pick up small corrections by their interactions with other particles.

Conclusion: no fine-tuning; the parameter is fixed by established physics and cosmology.

Expansion rate of the universe

Ross claims that if it were larger there would be no galaxy formation; if smaller the universe would collapse prior to star formation.

This is also the parameter that apologists William Lane Craig[11] and Dinesh D'Souza[12] referred to when they lifted out of context a quotation from Stephen Hawking's bestseller *A Brief History of Time*, which also bears repeating:

> If the rate of expansion one second after the Big Bang had been smaller by even one part in a hundred thousand million million, the universe would have collapsed before it ever reached its present size.[13]

Craig and D'Souza both ignored the explanation Hawking gave seven pages later for why no fine-tuning was needed:

> The rate of expansion of the universe would automatically become very close to the critical rate determined by the energy density of the universe. This could then explain why the rate of expansion is still so close to the critical rate, without having to assume that the initial rate of expansion of the universe was very carefully chosen.[14]

Conclusion: no fine-tuning; the parameter is fixed by established physics and cosmology.

The expansion rate and mean mass/energy density of the universe go hand-in-hand, so let me bring in the next of Deem's critical parameters.

Mass density of the universe

While Deem lists this as the "mass of the universe," I am sure he meant mass density. This is what Ross lists. Ross tells us that if it were larger, there would be too much deuterium from the big bang and stars would burn too rapidly. If it were smaller, there would be insufficient helium from the big bang and too few heavy elements would form.

According to inflationary cosmology, during a tiny fraction of a second after the universe appeared, it expanded exponentially by many orders of magnitude so that it became spatially flat like the surface of a huge balloon. This implied that the mass/energy density of the universe is now very close to its critical value in which the total kinetic energy of all its bodies is exactly balanced by their negative gravitational potential energy. In fact, this was a prediction of inflation that was not an established fact when the model was first proposed. If it had not turned out they way it did, inflation would have been falsified. The success of this prediction is one of several reasons cosmologists consider inflationary cosmology to be now a well-established part of the standard model of cosmology.

The critical density depends on the Hubble parameter, whose inverse is the rate of expansion. The "one part in a hundred thousand million million" that Hawking and the apologists refer to is the precise relation between the density and the Hubble parameter that follows to at least that precision from the inflationary model.

Conclusion: no fine-tuning; the parameter is fixed by established physics and cosmology.

The cosmological constant

Deem gives $1/10^{120}$ as the maximum deviation for the cosmological constant, which is a parameter in Einstein's general theory of relativity. Apparently he obtained this number from the result of the calculation of the total zero-point energy density of boson (integer spin) fields in the universe. Elementary particles are identified as the "quanta" of these fields. The zero-point energy is the energy left over when all the quanta of a field are removed. This calculation comes out 120 orders of magnitude higher than the observed upper limit on the vacuum energy density of the universe.[15] A principle called *supersymmetry* that is predicted to exist at high energy but is not yet verified, pending results from the Large Hadron Collider, reduces the energy density to "only" 10^{50} times the observed value, still a long way from agreement.

The energy density associated with the cosmological constant is the favorite candidate for the dark energy that is presumed to be responsible for the acceleration of the universe's expansion. The dark energy constitutes almost three quarters of the total mass/energy of the universe. Since the universe has an average density equal to the critical density, the dark energy density is almost as big, though still many orders of magnitude below its calculated value. I think it is fair to conclude that the calculation is simply wrong—as far wrong as any other calculation in the history of physics. It should not be taken literally.

Now, physicists still have not reached a consensus on the cosmological question. Some prominent figures such as Steven Weinberg, Stephen Hawking, and Leonard Susskind think the answer lies in multiple universes.

However, one idea that is currently getting much attention is the *holographic universe*. This is a speculation based on established physics, and so is not simply off the wall.

In calculating the zero-point energy density we sum over all the states in a volume equal to the instantaneous volume of the visible universe.The holographic principle says that maximum information that can be stored in a region of space is proportional to he surface area of that region. Thus,to get the zero point energy density we should have summed over just the states on the surface rather than the full volume. When we do that we obtain an energy density equal to the critical density, just the value it appears to have.

Conclusion: The standard calculation of this parameter is grossly wrong and should be ignored. Viable possibilities exist for explaining its value and until these are all ruled out, no fine-tuning can be claimed.

This takes care of the five parameters that are claimed to be fine-tuned to such precision that even a tiny deviation would make life of any kind impossible. Next let us move to those parameters for which proponents of fine-tuning can only claim that life would be very unlikely if the values of the parameters were different.

The Hoyle prediction

We begin our discussion of the less critical parameters by relating how, in 1951, astronomer Fred Hoyle argued that the carbon nucleus had to have an excited state at 7.7 MeV above its ground state in order for enough carbon to be produced in stars to make life in the universe possible. This story is of great historical interest because it is the only case where anthropic reasoning has led to a successful prediction.

However, recent calculations have demonstrated that the same carbon would have been produced if the excited state were anyplace between 7.716 MeV and 7.596 MeV. Furthermore, sufficient carbon for life would have occurred for an excited state anywhere from just above the ground state to 7.933 MeV. A state somewhere in such a large range is expected from standard nuclear theory. Furthermore, carbon may not be the only element upon which life could be based.

Conclusion: no fine-tuning; the parameter is within the range allowed by established physics and cosmology.

Relative Masses of the elementary particles

The masses of elementary particles affect many features of the universe and a number of fine-tuning claims refer to their values. Let me begin with the mass difference between the neutron and proton. If the difference in masses between the neutron and proton were less than the sum of the masses of the electron and neutrino (the neutrino mass in our universe is negligible for this purpose, but may not be in some other universe), there would be no neutron decay. In the early universe electrons and protons would combine to form neutrons and few, if any, protons would remain. If the mass difference were greater than the binding energies of nuclei, neutrons inside nuclei would decay leaving no nuclei behind.

There is a range of 10 Mev or so for the mass difference to still be in the allowed region for the full Periodic Table to be formed. The actual mass difference is 1.29 Mev so there is plenty of room for it to be larger. Since the neutron and proton masses are equal to a first approximation, and the difference results from a small electromagnetic correction, it is unlikely to be as high as 10 MeV.

Next let us bring in the mass of the electron, which also affects the neutron decay story. A lower electron mass gives more room in parameter space for neutron decay, while a higher mass leaves less.

Conclusion: no fine-tuning; the parameter is within the range allowed by established physics and cosmology.

The ratio of the electron and proton masses helps determine the region of parameter space for which chemistry is unchanged from our universe, which we can show is quite substantial. No fine-tuning is evident here either.

Relative strengths of the forces and other physics parameters

The dimensionless relative force strengths are the next set of physical parameters whose fine-tuning is claimed for reasons I find wanting. The gravitational strength parameter α_G is based on arbitrary choice of units of mass, so it is arbitrary. Thus α_G cannot be fine-tuned. There is nothing to tune.

Next let me consider the strength of the weak interaction α_W. Ross claims it is fine-tuned to give the right amount of helium and heavy element production in the big bang and in stars. The key is the ratio of neutrons to protons in the early universe when, as the universe cools, their production reactions drop out of equilibrium. A range of parameters is allowed.

The electromagnetic strength represented by the dimensionless parameter α, historically known as the fine-structure constant and having the famous value 1/137 at low energies. Ross tells us that there would be insufficient chemical bonding if it were different. But, the many-electron Schrödinger equation, which governs most of chemistry, scales with α and the mass of the electron. Again a wide range allows for the chemistry of life.

There are many places where the value of α relative to other parameters comes in. We saw that the weakness of gravity relative to electromagnetism in matter was due to the natural low masses of elementary particles. This can also be achieved with a higher value of α, but it's not likely to be orders of magnitude higher.

The relative values of α and the strong force parameter α_S also are important in several cases. When the two are allowed to vary, no fine-tuning is necessary to allow for both nuclear stability and the existence of free protons.

There are two other facts that most proponents of fine-tuning ignore: (1) the force parameters α, α_S, and α_W are not constant but vary with energy; (2) they are not independent. The force parameters are expected to be equal at some unification energy. Furthermore, the three are connected in the current standard model and are likely to remain connected in any model that succeeds it.

Conclusion: no fine-tuning; the parameters are in the range expected from established physics.

Other parameters such as the decay rate of protons and the baryon excess in the early universe have quite a bit of room to vary before they result in excess radiation.

Cosmic parameters

We have already disposed of the cosmic parameters that seem so crucial in making any livable universe possible. The mass density of the universe, the expansion rate, and the ratio of the number of protons and electrons are not only not fine-tuned, they are fixed by conventional physics and cosmology.

The deuterium abundance needed for life is small and a wide range of two orders of magnitude is allowed.

Martin Rees and others have claimed that the lumpiness of matter, represented by a quantity Q, in the universe had to be fine-tuned within an order of magnitude to allow for galaxy formation. An order of magnitude is hardly the kind of fine-tuning the theists are claiming. What's more, varying the nucleon mass along with Q allows, again, for more parameter space for life.

More detailed calculations using the standard concordance model of cosmology indicate that five parameters contribute to the density fluctuations that provide for galaxy formation. So it is a gross simplification to just talk about varying the single parameter Q. And, when an alternative, the cold big bang model, is used, an even wider range of parameters becomes possible.

Simulating universes

The gross properties of the universe are determined by just three parameters: the electromagnetic strength α and the masses of the proton and electron, m_p and m_e.

From these we can estimate quantities such as the maximum lifetime of stars, the minimum and maximum masses of planets, the minimum length of a planetary day, and the maximum length of a year for a habitable planet. Generating 10,000 universes in which the parameters are varied randomly on a logarithmic scale over a range of 10 orders of magnitude, I find that 61 percent of the universes have stellar lifetimes over 10 billion years, sufficient for some kind of life to evolve.

Christian theologian Robin Collins, my opponent in this debate, objected to my preliminary, twenty-year old conclusion that long stellar lifetimes are not fine-tuned.[16] He argues that not all these universes are livable, that I have not accounted for life-inhibiting features. He refers to Barrow and Tipler, who estimated that $\alpha \leq 11.8\alpha_S$ for carbon to be stable.[17]

Since, in this study I was varying all the parameters by ten orders of magnitude, I would not expect such a tight criterion to be satisfied very often. Nevertheless, I have checked and found the Barrow-Tipler limit to be satisfied 59 percent of the time. As we will see below, I have also studied what happens when the parameters are varied by just two orders of magnitude. Then 91 percent of the time we have $\alpha \leq 11.8\alpha_S$.

Applying rather tight limits to all three parameters, 13 percent of all universes are capable of supporting some kind of life not too different from ours. Varying by two orders of magnitude, which is more realistic since the parameters are not independent but related, I find that 92 percent of the universes have stellar lifetimes over 10 billion years and 37 percent are capable of supporting some kind of life not too different from ours. Life very different from ours remains possible in a large fraction of the remaining universes, judging from the large stellar lifetimes for most.

A Final Conclusion

The proponents of fine-tuning make serious errors in physics, cosmology, probability theory, and data analysis. While not every proponent makes every error, there is a remarkable similarity to the arguments you find in the theist literature. Let me list the errors of fine-tuning proponents that I have uncovered in my research:

1. They make fine-tuning claims based on the parameters of our universe and our form of life, ignoring the possibility of other life forms.
2. They claim fine-tuning for physics constants such a *c* and *h* whose values are arbitrary.
3. They assert fine-tuning for quantities such as the ratio of electrons to protons, the expansion rate of the universe, and the mass density of the universe whose values are precisely determined by physical theory.
4. They assert that the relative strengths of the electromagnetic and gravitational forces are fine-tuned, when in fact this quantity cannot be universally defined.
5. They assert that an excited state of the carbon nucleus had to be fine-tuned for stars to produce the carbon needed of life, when calculations show a wide range of values for the energy level of that state will produce enough carbon.

6. They claim fine-tuning for the masses of elementary particles when the ranges of these masses are set by well-established physics and sufficiently constrained to give some form of life.
7. They assume the strengths of the various forces are constants that can independently change from universe to universe. In fact, they vary with energy and their relative values and energy dependences are close to being pinned down by theory, in ranges that make some kind of life possible.
8. They make a serious analytical mistake in always taking all the parameters in the universe to be fixed and varying only one at a time. This fails to account to the fact that a change in one parameter can be compensated by a change on another, opening up more parameter space for a viable universe.
9. They misunderstand and misuse probability theory.
10. They claim many parameters of Earth and the solar system are fine-tuned for life, failing to consider that with a hundred billion to a trillion planets in the visible universe, and the countless number beyond our horizon, a planet with the properties need for life is likely to occur many times.

I also assert that the fine-tuners are wrong to reject the multiverse solution as "unscientific." I will not call that an error, since the issue is arguable, whereas the ten examples above are not. But I do not think it is unscientific to speculate about invisible, unconfirmed phenomena that are predicted by existing models that, so far, agree with all the data. The neutrino was predicted to exist in 1930 based on the well-established principle of energy conservation and was not detected until 1956, and even then indirectly. If the physics community used the fine-tuners' criterion, my late colleague Fred Reines and his collaborator Clyde Cowen would not have been able to get the money and support to engage in their search.

As my discussion illustrates, the explanations for apparent fine-tuning are technical and require adequate training to understand. With so many errors and misjudgments, and with such a gross lack of understanding of the basic science we have seen exhibited by the supporters of supernatural fine-tuning, we can safely say that their motivation is more wishful thinking than scientific inference. A proper analysis finds there is no evidence that the universe is fine-tuned for us.

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Notes

[1] William Lane Craig, "The Craig-Pigliucci Debate: Does God Exist?," http://www.leaderu.com/offices/billcraig/docs/craig-pigliucci2.html (accessed February 13, 2010).

[2] Stephen W. Hawking, *A Brief History of Time: From the Big Bang to Black Holes*, (New York: Bantam, 1988), pp. 121-22.

[3] P. C. W. Davies, *Other Worlds*, (London: Dent, 1980), p. 6.

[4] John D. Barrow, and Frank J. Tipler, *The Anthropic Cosmological Principle*, (Oxford; New York: Oxford University Press, 1986).

[5] Victor J. Stenger, *The Comprehensible Cosmos: Where Do the Laws of Physics Come From?* (Amherst, NY: Prometheus Books, 2006).

[6] Rich Deem "Evidence for the Fine Tuning of the Universe," God and Science, http://www.godandscience.org/apologetics/designun.html (accessed November 27, 2008).

[7] Hugh Ross, *The Creator and the Cosmos: How the Greatest Scientific Discoveries of the Century Reveal God*. (Colorado Springs: NavPress, 1995)

[8] Reasons to Believe, http://www.reasons.org/ (accessed December 20, 2008).

[9] Evidence for Design, http://www.reasons.org/resources/apologetics/index.shtml#design_in_the_universe (accessed December 20, 2008).

[10] Hugh Ross, "Big Bang Model Refined By Fire," in *Mere Creation: Science, Faith & Intelligent Design*, ed. William A. Dembski (Downers Grove, Ill: Intervarsity Press, 1988), pp. 363-83.

[11] William Lane Craig, "The Craig-Pigliucci Debate: Does God Exist?," http://www.leaderu.com/offices/billcraig/docs/craig-pigliucci1.html (accessed February 13, 2010).

[12] D'Souza, *Life After Death*, p. 84.

[13] Hawking, *A Brief History of Time*, pp. 121-22.

[14] Ibid p. 128.

[15] Stenger, *The Comprehensible Cosmos*, pp. 308-09.

[16] Robin Collins, "The Teleological Argument: An Exploration of the Fine-Tuning of the Universe," in *The Blackwell Companion to Natural Theology*, ed. William Lane Craig, and James Porter Moreland (Chichester, U.K. ; Malden, MA: Wiley-Blackwell, 2009).

[17] Barrow and Tipler, *The Anthropic Cosmological Principle*, p. 326.