

# Vilenkin's Cosmic Vision A Review Essay of emMany Worlds in One The Search for Other Universesem, by Alex Vilenkin

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## SUMMARY

Vilenkin's recent book is a wonderful popular introduction to contemporary cosmology. It contains provocative discussions of both the beginning of the universe and of the fine-tuning of the universe for intelligent life. Vilenkin is a prominent exponent of the multiverse hypothesis, which features in the book's title. His defense of this hypothesis depends in a crucial and interesting way on conflating time and space. His claim that his theory of the quantum creation of the universe explains the origin of the universe from nothing trades on a misunderstanding of "nothing."

## VILENKIN'S COSMIC VISION A REVIEW ESSAY OF EMMANY WORLDS IN ONE THE SEARCH FOR OTHER UNIVERSESEM, BY ALEX VILENKIN

The task of scientific popularization is a difficult one. Too many authors think that it is to be accomplished by frequent resort to explanatorily vacuous and obfuscating metaphors which leave the reader puzzling over what exactly a particular theory asserts. One of the great merits of Alexander Vilenkin's book is that he shuns this route in favor of straightforward, simple explanations of key terms and ideas. Couple that with a writing style that is marvelously lucid, and you have one of the best popularizations of current physical cosmology available from one of its foremost practitioners.

Vilenkin vigorously champions the idea that we live in a multiverse, that is to say, the causally connected universe is but one domain in a much vaster cosmos which comprises an infinite number of such domains. Moreover, each causally connected domain is subdivided into an infinite number of subdomains, each constituting an observable universe bounded by an event horizon. As if that were not enough, Vilenkin also endorses Everett's Many Worlds Interpretation of quantum physics, so that even the infinite multiverse is but one of an indefinitely large class of distinct multiverses. The result is a breath-taking vision of physical reality.

At the heart of Vilenkin's vision of the world is the theory of future-eternal, or everlasting, inflation (Vilenkin misleadingly calls it eternal inflation, even though he holds that the inflationary multiverse has only a finite past). According to generic inflationary theory, our universe exists in a true vacuum state with an energy density that is nearly zero, but earlier it existed in a false vacuum state with a very high energy density. The energy density of the false vacuum overwhelms even the intense gravitational attraction generated by the extremely high matter density of the early

universe, causing a super-rapid, or inflationary, expansion, during which the universe grew from atomic proportions to a size larger than the observable universe in a thirtieth of a microsecond. Vilenkin does a nice job of explaining the empirical evidence that supports the fact of such an early inflationary era.

But Vilenkin needs more than generic inflationary theory. In order to ensure eternal inflation, Vilenkin hypothesizes that the scalar fields determining the energy density and evolution of the false vacuum state are characterized by a certain slope which issues in a false vacuum expanding so rapidly that, as it decays into pockets of true vacuum, the "island universes" thereby generated in this sea of false vacuum, though themselves expanding at enormous rates, cannot keep up with the expansion of the false vacuum and so find themselves increasingly separated with time. New pockets of true vacuum will continue to form in the gaps between the island universes and become themselves isolated worlds. Despite the fact that the multiverse is finite and geometrically closed, Vilenkin claims that the false vacuum will go on expanding forever. He does not explain how this is consistent, apart from special pleading, with the Second Law of Thermodynamics.

At this point Vilenkin executes a nifty piece of legerdemain. As the island universes expand, their central regions eventually grow dark and barren, while stars are forming at their ever-expanding perimeters. We should think of the decay of false vacuum to true vacuum going on at the islands' expanding boundaries as multiple Big Bangs. From the global perspective of the inflating multiverse, these Big Bangs occur successively, as the island boundaries grow with time. In the global time of the multiverse, each island is at any time finite in extent though growing. Now comes the sleight of hand. When we consider the internal, cosmic time of each island universe, each can be traced back to an initial Big Bang event. We can now string together these various Big Bang events as occurring simultaneously. Big Bangs which will occur in the global future are now to be regarded as present. As a result, the infinite, temporal series of successive Big Bangs is converted into an infinite, spatial array of simultaneous Big Bangs. Hence, from the internal point of view each island universe is infinite in extent.

This blurring of appearance and reality leads Vilenkin to some bizarre conclusions. Since each island universe is taken to be infinite by its inhabitants, it can be subdivided into an infinite number of observable regions (or O-regions) each the size of our observable universe. Quantum mechanics implies that there is only a finite number of histories from the Big Bang to any moment in any O-region. Hence, given an infinite number of O-regions, it follows that every single history is repeated an infinite number of times. Thus, our own world in minutest detail is duplicated an infinite number of times throughout the O-regions in our island. Indeed, "all possible variations" on our world's history will appear an infinite number of times in the ensemble of O-regions.

Notice that this conclusion presupposes that the physical world can be completely described by the equations of quantum mechanics. As such, it is subverted by the presence in the world of agents endowed with freedom of the will whose actions are emphatically not random. There is no reason whatsoever to think that in some O-region Adolf Hitler (or his counterpart) will deliver his Nürnberg address standing on his head, much less that he (or they) would decide to do something so silly an infinite number of times. But never mind; the more fundamental error on Vilenkin's part is his deft transformation of an infinite, temporal succession of future O-regions into an infinite, spatial array of simultaneous O-regions. We see the switch when he says, "any history that has a nonzero probability will happen—or rather has happened—in an infinite number of O-regions!" (p. 112). Viewed globally, these O-regions are in the future and will be infinite in number only in the sense that the island will continue to exist forever. Even more fundamentally, Vilenkin's conclusion seems to presuppose spacetime realism or, as it is sometimes called, four-dimensionalism, for if tense and temporal becoming are objective features of reality, then the future is potentially infinite only, and future O-regions do not in any sense exist. If there is a global tide of becoming, then there is no actually infinite collection of O-regions after all.

This reviewer cannot help but wonder about the psychology of persons who seem to find a certain glee in the prospect of infinite duplicates of our world. (I'm told that Vilenkin initially found this idea depressing; but if so, he seems to have gotten over it.) Why do some people seem to find this idea so attractive? I think we have a clue in Vilenkin's "A Farewell to Uniqueness," where he writes,

In the worldview that has emerged from eternal inflation, our Earth and our civilization are anything but unique. Instead, countless identical civilizations are scattered in the infinite expanse of the cosmos. With humankind reduced to absolute cosmic insignificance, our descent from the center of the universe is now complete (p. 117).

Never mind the odd assumption that the significance of humankind is to be assessed in terms of its rarity in the cosmos; it is the note of celebration that accompanies this alleged demotion that strikes me.

Much of Vilenkin's interest in postulating many worlds in one is to find purchase for the Anthropic Principle in order to explain away the fine-tuning of the universe. Quantum fluctuations in the scalar fields determine what sort of vacuum will decay out of the false vacuum, each associated with a different set of values for the constants of nature. By postulating an infinite array of island universes, randomly varying in their constants, Vilenkin can appeal to the Anthropic Principle to explain away the observed fine-tuning: our observations are constrained by a selection effect imposed by our own existence. Postulating many worlds enables one to avoid the inference to design, which might be taken to place *homo sapiens* (the most complex structure in the world) at

the center of the universe. The delight in duplicate worlds springs from the consequent dethronement of mankind as the crown of creation.

But if an infinite ensemble of simultaneous island universes does not actually exist, Vilenkin's attempt to explain away the fine-tuning of the universe for intelligent life collapses. For if, in fact, an infinite array of island universes does not yet exist, if most of them lie in the potentially infinite future and are therefore unreal, then there actually exist only as many universes as can have formed in the false vacuum since the multiverse's inception at its boundary in the finite past. Given the incomprehensible improbability of the constants' all falling randomly into the life-permitting range, it may well be highly improbable that a life-permitting island universe should have decayed this soon out of the false vacuum. In that case the sting of fine-tuning has not been relieved.

Vilenkin's whole multiverse scenario depends, it will be recalled, on the hypothesis of eternal inflation, which in turn is based upon the existence of certain primordial scalar fields which govern inflation. Although Vilenkin observes that "Inflation is eternal in practically all models suggested so far" (p. 214), he also admits, "Another important question is whether or not such scalar fields really exist in nature. Unfortunately, we don't know. There is no direct evidence for their existence" (p. 61). One would have thought that this lack of evidence would have tempered the confidence with which Vilenkin promotes the multiverse hypothesis.

Wholly apart from its speculative nature, however, the multiverse hypothesis faces a potentially lethal problem, which Vilenkin does not even mention. Simply stated, if our universe is but one member of an infinite collection of randomly varying universes, then it is overwhelmingly more probable that we should be observing a much different universe than that which we in fact observe. This same problem proved devastating for Ludwig Boltzmann's appeal to a multiverse hypothesis in classical physics in order to explain why, if it has existed forever, the universe is not now in a state of thermodynamic equilibrium or heat death. Boltzmann made the bold speculation that the universe as a whole does, in fact, exist in a state of heat death, but that here and there random fluctuations produce pockets of disequilibrium, which Boltzmann referred to as "worlds." Ours is one of these, and we should not be surprised to observe our world in such a highly improbable disequilibrium state, since observers cannot exist anywhere else. Boltzmann's daring hypothesis has been universally rejected by contemporary physics on the grounds that were our universe but one such world in a multiverse, it is vastly more probable that we should be observing a much smaller region of disequilibrium—even one in which our solar system alone was produced in the twinkling of an eye by a random fluctuation—than what we do observe, since that is incomparably more probable than the whole universe's being progressively formed by a decline in entropy from an equilibrium state.

Now a similar problem afflicts the contemporary appeal to the multiverse to explain away fine-tuning. Roger Penrose has calculated that the odds of our universe's low entropy condition obtaining by chance alone are on the order of  $1:10^{10^{123}}$ , an inconceivable number. If our universe were but one member of a multiverse of randomly ordered worlds, then it is vastly more probable that we should be observing a much smaller orderly universe. The odds of our solar system's being formed instantly by random collisions of particles is, according to Penrose, about  $1:10^{10^{60}}$ , a vast number, but inconceivably smaller than  $10^{10^{123}}$ . Or again, if our universe is but one member of a multiverse, then we ought to be observing highly extraordinary events, like horses' popping into and out of existence by random collisions, or perpetual motion machines, since these are vastly more probable than all the constants and quantities of nature's falling by chance into the virtually infinitesimal life-permitting range. Observable universes like those are much more plenteous in the ensemble of universes than worlds like ours and, therefore, ought to be observed by us if the universe were but one member of a multiverse of worlds. Since we do not have such observations, that fact strongly disconfirms the multiverse hypothesis. On naturalism, at least, it is therefore highly probable that there is no multiverse.

But Vilenkin is not through yet. While acknowledging that most physicists take an agnostic attitude toward the physical interpretation of quantum mechanics, Vilenkin feels compelled to embrace Everett's Many Worlds Interpretation. On the Copenhagen interpretation it is measurement by an observer which reduces quantum indeterminacy to a precise state. "The 'orthodox' Copenhagen interpretation, which requires an external observer to perform measurements on the system, cannot even be formulated in this case [*i.e.*, quantum cosmology]: there are no observers external to the universe" (p. 115). Such an assertion seems, however, to presuppose atheism. Moreover, it ignores the fact that Copenhagen and Many Worlds do not exhaust our choices: there are plenty of alternatives.

Tellingly, Vilenkin later asserts that his own favored theory of quantum creation presupposes as a necessary condition the Many Worlds Interpretation:

If the Copenhagen interpretation is adopted, then the creation was a one-shot event, with a single universe popping out of nothing. This, however, leads to a problem. The most likely thing to pop out of nothing is a tiny Planck-sized universe, which would not tunnel, but would instantly collapse and disappear. Tunneling to a larger size has a small probability and therefore requires a large number of trials. It appears to be consistent only with the Everett interpretation (p. 187).

Vilenkin had better hope that such is not the case, for most philosophers and physicists would regard it as the *reductio ad absurdum* of his creation account.

This brings us to the other great cosmological question that occupies Vilenkin in the book: whether the universe—or, rather, multiverse—had an absolute beginning. After recounting the prediction of an absolute beginning by the standard Big Bang model and cataloguing various attempts to avert it, Vilenkin explains his formulation with Arvind Borde and Alan Guth in 2003 of a theorem which establishes that any universe which has on average over its past history been in a state of expansion cannot be infinite in the past but must have a spacetime boundary. This is a theorem of great power which applies both to inflationary models and to current, higher dimensional, brane cosmological models based on string theory, as well to as typical expansion models. Vilenkin pulls no punches: "It is said that an argument is what convinces reasonable men and a proof is what it takes to convince even an unreasonable man. With the proof now in place, cosmologists can no longer hide behind the possibility of a past-eternal universe. There is no escape, they have to face the problem of a cosmic beginning" (p. 176).

While recognizing that theologians have often welcomed evidence of the universe's beginning as evidence for God's existence, Vilenkin dismisses such a view as "far too simplistic" (p. 177). How so? Vilenkin cites the Jain poet Jinasena, who asked, "If God created the world, were was He before creation?" and "How could God have made the world without any raw material?" (p. 170). Since Vilenkin rejects the Jain view that the world is uncreated and eternal, he knows that similar "paradoxes" face him as well (p. 177). If theism is simplistic, therefore, it will not be because it confronts peculiar problems, but because it stops short of addressing those problems. Vilenkin seems to assume that the theist is stupefied in the face of such questions. But that is hardly the case. Jinasena's first question concerns the efficient cause of the universe and his second the material cause. The first question is not difficult to answer: "Nowhere," since space and time come into being at creation, so that there is no "before" and "where" prior to the beginning. The second question is more baffling; but if Vilenkin's theory of quantum tunneling provides an account of how the universe can arise without a material cause, then the theist may freely avail himself of it also. The advantage of theism over naturalistic accounts is that theism provides an efficient cause of the universe, whereas naturalism cannot.

The naturalist is therefore constrained to say that the universe came into being without either an efficient or a material cause. Vilenkin's theory of quantum creation is precisely an attempt to make such a view plausible. His exposition of his model is so clear and simple that it is easy for the metaphysician to see where Vilenkin has misconstrued its ontological import. He invites us to envision a small, closed, spherical universe filled with a false vacuum and containing some ordinary matter. If the radius of such a universe is small, classical physics predicts that it will collapse to a point; but quantum physics permits it to "tunnel" into a state of inflation. (Recall that such an event is nonetheless so improbable that the Many Worlds Interpretation must be invoked

to save the account.) If we allow the radius to shrink all the way to zero, there still remains some positive probability of the universe's tunneling to inflation. Now Vilenkin equates the initial state of the universe explanatorily prior to tunneling with nothingness: "what I had was a mathematical description of a universe tunneling from zero size—from nothing!—to a finite radius and beginning to inflate" (p. 180). This equivalence is patently mistaken. As Vilenkin's diagram on the same page illustrates, the quantum tunneling is at every point a function from something to something. For quantum tunneling to be truly from nothing, the function would have to have a single term, the posterior term. Another way of seeing the point is to reflect on the fact that "to have no radius" (as is the case with nothingness) is not "to have a radius whose measure is zero."

Vilenkin himself seems to realize that he has not really described the tunneling of the universe from literally nothing, for he allows, "And yet, the state of 'nothing' cannot be identified with *absolute nothingness*. The tunneling is described by the laws of quantum mechanics, and thus 'nothing' should be subjected to these laws" (p. 181). It follows that the universe described by those laws is not nothing. Unfortunately, Vilenkin draws the mistaken inference that "The laws of physics must have existed, even though there was no universe" (p. 181). Even if one takes a Platonistic view of the laws of nature, they are at most either mathematical objects or propositions, abstract entities that have no effect on anything. (Intriguingly, Vilenkin entertains a conceptualist view according to which the laws exist in a mind which predates the universe [p. 205], the closest Vilenkin comes to theism). If these laws are truly descriptive, then obviously it cannot be true that "there was no universe." Of course, the laws could have existed and been false, in which case they are non-descriptive; but then Vilenkin's theory will be false.

That Vilenkin has not truly grasped how radical being's coming from non-being is is evident from his incredulity at the claim of the Hartle-Hawking model that an infinite universe should arise from nothing. He exclaims, "The most probable thing to pop out of nothing is then an infinite, empty, flat space. I find this very hard to believe!" (p. 191). Vilenkin finds it easier to believe that an itsy-bitsy universe should pop into being out of nothing. He thereby evinces a lack of understanding of the metaphysical chasm that separates being from non-being. As A. N. Prior pointed out, if something can come out of nothing, then it becomes inexplicable why anything and everything—including an infinite universe—do not come into being out of nothing.

Vilenkin, then, cannot answer the paradoxes of creation as well as can the theist. In fact, the conjunction of theism with Vilenkin's model would be a congenial account of creation. We could have a complete, scientific description of the universe back to its beginning, at which God created the initial state of the universe. But naturalism on its own cannot do the job. If efficient causality apart from material causation seems difficult, then the origin of the universe without either efficient or material causation is even more so.

One might try to rescue a naturalistic quantum tunneling account by providing a mathematical description of it in terms of Euclidean, or what Hawking calls imaginary, time. In that case the universe does not come into being at all but exists timelessly as a non-singular, four-dimensional manifold having a shape analogous to that of a shuttlecock. Hawking, at least, famously took this to eliminate the need for a Creator. But it is interesting that Vilenkin will have no truck with such a realist construal of the Euclidean four-space. It is introduced "only for computational convenience" (p. 182). The Hartle-Hawking no-boundary proposal "lost much of its intuitive appeal" after switching to Euclidean time; in fact, "it instructs us to sum over histories that are certainly impossible, because we do not live in Euclidean time" (pp. 190-1). This is sensible metaphysics; but it precludes recourse to imaginary time as a way of avoiding the so-called paradoxes of creation.

Vilenkin has interesting things to say on other topics—physical eschatology, for example—, but his treatment of the central themes of fine-tuning and cosmic origins, discussed in this review, will be especially interesting to philosophers of religion interested in cosmological and teleological arguments for a Creator and Designer of the universe.