The End of the World

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SUMMARY

What does science tell us about the way the universe will end and how does this relate to Christian views?

THE END OF THE WORLD

For millennia men have wondered whether the world as we know it will come to an end and if so, how the world will end. In ancient Judaism speculation about the world's end took the form of apocalypticism, the view that God will bring about the end of human history, exercising judgement upon the life of every person, and inaugurating His everlasting Kingdom. This apocalyptic viewpoint was taken up into early Christianity through its founder Jesus of Nazareth. The early Christians looked forward to the return of Christ at some unknown time in the future when he would inaugurate a new heaven and a new earth fit for eternal habitation. Here is how that event is described in the Apocalypse of John, the last book in the New Testament:

Then I saw a great white throne and him who was seated on it. From his presence earth and sky fled away, and no place was found for them. And I saw the dead, great and small, standing before the throne, and books were opened. Then another book was opened, which is the book of life. And the dead were judged by what was written in the books, according to what they had done. And the sea gave up the dead who were in it, Death and Hades gave up the dead who were in them, and they were judged, each one of them, according to what they had done. Then Death and Hades were thrown into the lake of fire. This is the second death, the lake of fire. And if anyone's name was not found written in the book of life, he was thrown into the lake of fire.

Then I saw a new heaven and a new earth, for the first heaven and the first earth had passed away, and the sea was no more. And I saw the holy city, new Jerusalem, coming down out of heaven from God, prepared as a bride adorned for her husband. And I heard a loud voice from the throne saying, "Behold, the dwelling place of God is with man. He will dwell with them, and they will be his people, and God himself will be with them as their God. He will wipe away every tear from their eyes, and death shall be no more, neither shall there be mourning nor crying nor pain anymore, for the former things have passed away."—Rev. 20.11-21.3 ESV

Because of its commitment to apocalypticism, one of the major categories of Christian theology came to be Eschatology. From the Greek word eschaton, which means last or final, eschatology is the doctrine of the last things, including the return of Christ, the last judgement, and heaven and hell. For millennia eschatology remained the exclusive province of theology.

During the last half century all that has changed. Eschatology has now also become a branch of physics, and, yes, the very term eschatology is the preferred nomenclature for this field of study. Physical eschatology is a sub-discipline of cosmology, which is the study of the large-scale structure and evolution of the universe. Cosmology subdivides into two parts: Cosmogony is the sub-discipline which studies the origin and past history of the universe. Eschatology, by contrast, is the sub-discipline which explores the future and final fate of the universe. Just as physical cosmogony looks back in time to retrodict the history of the cosmos based on traces of the past and the laws of nature, so physical eschatology looks forward in time to predict the future of the cosmos based on present conditions and laws of nature. The challenge for those interested in the interface between theology and science is how to arrive at an integrated perspective on the world's future adequate to the concerns of both theology and science.

The key to physical eschatology is the Second Law of Thermodynamics. About the middle of the nineteenth century, several physicists sought to formulate a scientific law that would bring under a general rule all the various irreversible processes encountered in the world. The result of their efforts is now known as the Second Law of Thermodynamics. As first formulated by Clausius, it stated that heat only flows of itself from a point of high temperature toward a point of low temperature; the reverse is never possible without compensation. But heat is only an instance of an even more general tendency toward levelling in nature; the same is true, for example, of gases and electricity. Without this general tendency toward levelling, life would be completely impossible. For example, because of such levelling, the air in the room never suddenly separates into oxygen at one end and nitrogen at the other. It is also why when we step into a bath we may be confident that the water will be pleasantly warm instead of frozen at one end and boiling at the other. It is easy to see why life would not be possible in a world where the Second Law of Thermodynamics did not hold.

The German physicist Ludwig Boltzmann deepened our understanding of the Second Law by showing that this tendency toward levelling is founded on the tendency of any system to pass from a less probable to a more probable state. According to Boltzmann, the probability of a state is a function of its order: more ordered states are less probable, and less ordered states are more probable. The most probable state is therefore a totally disordered state, that is, a state which is completely undifferentiated. Thus, the Second Law could be formulated: all systems have the tendency to pass from a more ordered to a less ordered state.

A third important step in the development of the Second Law was the realization that disorder is connected with entropy, or the measure of unusable energy: the greater the disorder the greater the entropy. This yields a third formulation of the law: all systems have the tendency to pass from a state of lower entropy into a state of higher entropy. In order to exlude the possibility of the system's leaking energy to its surroundings or acquiring energy from them, an additional stipulation is required: the system must be closed. This leads to a fourth formulation of the Second Law: spontaneously proceeding processes in closed systems are always attended by an increase in entropy. Thus, processes taking place in a closed system tend toward a state of equilibrium. The law in this form is virtually certain. To illustrate: the probability of all molecules in one litre of gas occupying only 99.99% of the volume instead of 100% is about 1:1010(20). For all practical purposes, therefore, the Second Law of Thermodynamics may be regarded as certain.

Now the cosmologist's interest in the law concerns what it predicts when it is applied to the universe as a whole. For the universe is, on a naturalistic view at least, a gigantic closed system, since it is everything there is and there is nothing outside it. Already in the nineteenth century, scientists realized that the application of the Second Law to the universe as a whole implied a grim eschatological conclusion: given sufficient time, the universe will eventually come to a state of equilibrium and suffer "heat death." Once the universe reaches heat death, no further change is possible. P. J. Zwart describes such a state:

. . . according to the second law the whole universe must eventually reach a state of maximum entropy. It will then be in thermodynamical equilibrium; everywhere the situation will be exactly the same, with the same composition, the same temperature, the same pressure etc., etc. There will be no objects any more, but the universe will consist of one vast gas of uniform composition. Because it is in complete equilibrium, absolutely nothing will happen any more. The only way in which a process can begin in a system in equilibrium is through an action from the outside, but an action from the outside is of course impossible if the system in question is the whole universe. So in this future state of maximal entropy, the universe would be in absolute rest and complete darkness, and nothing could disturb the dead silence. Even if there would by chance occur a small deviation from the state of absolute equalization it would of itself rapidly vanish again. Because almost all energy would have been degraded, i.e. converted into kinetic energy of the existing particles (heat), this supposedly future state of the universe, which will also be its last state, is called the heat death of the universe. [1]

Thus, the implication of the Second Law is that the universe faces inevitable extinction.

The advent of relativity theory and its application to cosmology altered the shape of the eschatological scenario predicted on the basis of the Second Law of Thermodynamics but did not fundamentally affect the outcome. Assuming that there is no positive cosmological constant fueling the expansion of the universe, that expansion will decelerate over time. Two radically different eschatological scenarios then present themselves. If the density of the universe exceeds a certain critical value, then the internal pull of the universe's own gravity will eventually overcome the force of the expansion and the universe will collapse in upon itself in a fiery Big Crunch. Beatrice Tinsley described such a scenario:

If the average density of matter in the universe is great enough, the mutual gravitational attraction between bodies will eventually slow the expansion to a halt. The universe will then contract and collapse into a hot fireball. There is no known physical mechanism that could reverse a catastrophic big crunch. Apparently, if the universe becomes dense enough, it is in for a hot death. [2]

If the universe is fated to re-contraction, then as it contracts the stars gain energy, causing them to burn more rapidly so that they finally explode or evaporate. As everything in the universe grows closer together, the black holes begin to gobble up everything around them, and eventually begin themselves to coalesce. In time, "All the black holes finally coalesce into one large black hole that is coextensive with the universe," from which the universe will never re-emerge. [3] There is no known physics that would permit the universe to bounce back to a new expansion prior to a final singularity or to pass through the singularity into a subsequent state.

On the other hand, if the density of the universe is equal to or less than the critical value, then gravity will not overcome the force of the expansion and the universe will expand forever at a progressively slower rate. Tinsley described the fate of this universe:

If the universe has a low density, its death will be cold. It will expand forever at a slower and slower rate. Galaxies will turn all of their gas into stars, and the stars will burn out. Our own sun will become a cold, dead remnant, floating among the corpses of other stars in an increasingly isolated Milky Way. [4]

At 1030 years the universe will consist of 90% dead stars, 9% supermassive black holes formed by the collapse of galaxies, and 1% atomic matter, mainly hydrogen. Elementary particle physics suggests that thereafter protons will decay into electrons and positrons, so that space will be filled with a rarefied gas so thin that the distance between an electron and a positron will be about the size of the present galaxy. At 10100 years, some scientists believe that the black holes themselves will dissipate by a strange effect predicted by quantum mechanics. The mass and energy associated with a black hole so warp space that they are said to create a "tunnel" or "worm-hole" through which the mass and energy are ejected in another region of space. As the mass of a black hole decreases, its energy loss accelerates, so that it is eventually dissipated into radiation and elementary particles. Eventually all black holes will completely evaporate and all the matter in the ever-expanding universe will be reduced to a thin gas of elementary particles and radiation. Because the volume of space constantly increases, the universe will never actually arrive at equilibrium, since there is always more room for entropy production. Nonetheless, the universe will become increasingly cold, dark, dilute, and dead.

Very recent discoveries provide strong evidence that there is effectively a positive cosmological constant which causes the cosmic expansion to accelerate rather than decelerate. Paradoxically, since the volume of space increases exponentially, allowing greater room for further entropy production, the universe actually grows farther and farther from an equilibrium state as time proceeds. But the acceleration only hastens the cosmos's disintegration into increasingly isolated material particles no longer causally connected with similarly marooned remnants of the expanding universe. Therefore, the grim future predicted on the basis of the Second Law remains fundamentally unaltered.

Reflection on this exchatological conclusion led some philosophers to question the meaning of life itself. In a famous paassge, the British philosopher Bertrand Russell lamented,

That man is the product of causes which had no prevision of the end they were achieving; that his origin, his growth, his hopes and fears, his loves and his beliefs, are but the outcome of accidental collocations of atoms; that no fire, no heroism, no intensity of thought and feeling, can preserve an individual life beyond the grave; that all the labours of the ages, all the devotion, all the inspiration, all the noonday brightness of human genius, are destined to extinction in the vast death of the solar system, and that the whole temple of Man's achievement must inevitably be buried beneath the debris of a universe in ruins— all these things, if not quite beyond dispute, are yet so nearly certain, that no philosophy which rejects them can hope to stand. Only within the scaffolding of these truths, only on the firm foundation of unyielding despair, can the soul's habitation henceforth be safely built. [5]

(Annie, where are you when we need you?) A bleak picture, indeed; but as Freeman Dyson has reminded us, the predictions of physical eschatology are subject to the proviso that intelligent agents do not interfere with the envisioned natural processes. [6] If intelligent beings are able significantly to manipulate natural processes, then the actual future of the cosmos could look quite different than the trajectory predicted on the basis of laws and present conditions. Dyson's own attempt to craft a scenario whereby immanent agents might stave off extinction, is, doubtless, desperate and implausible. [7] But why should we restrict our attention to immanent agents? Theists believe in the existence of an intelligent being who is the Creator of the space-time universe and transcends the laws that govern the physical creation. On the Christian view God will bring about the end of human history and the present cosmos at such time as He deems fit (Mk. 14.32; Mt. 24.43; 1 Thess. 5.2; Heb. 1.10-12; 2 Pet. 3.10; Rev. 3.3). He will not allow events predicted on the basis of present trends in even the relatively near future, such as the extinction of the human race, to occur, much less events in the unfathomably distant future such as stellar extinction or proton decay. Before these events can take place, God will act to terminate human history and usher in a new heavens and a new Earth (1 Cor. 15.51-52; 1 Thess. 4.15-17; Rev. 21.1).

Theological eschatology therefore takes the findings of physical eschatology to be at best projections of the future course of events rather than actual descriptions. They tell us with approximate accuracy what would take place were no intelligent agents to intervene. Thus, the findings of physical eschatology are in no way incompatible with Christian eschatology, since those findings involve implicit ceteris paribus conditions with respect to the actions of intelligent agents, including God.

Of course, physical eschatologists might ask whether there is any reason to take seriously the hypothesis of a transcendent, intelligent agent with requisite power over the course of nature to affect the projected trajectories of physical eschatology. Intriguingly, physical eschatology itself furnishes grounds for taking seriously such a hypothesis. As we have seen, already in the nineteenth century scientists realized that the application of the Second Law of Thermodynamics to the universe as a whole implied that the universe will eventually come to a state of equilibrium and suffer heat death. But this apparently firm projection raised an even deeper question: if, given sufficient time, the universe will suffer heat death, then why, if it has existed forever, is it not now in a state of heat death? If in a finite amount of time the universe will inevitably come to equilibrium, from which no significant further change is physically possible, then it should already be at equilibrium by now, if it has existed for infinite time. Like a ticking clock, it should by now have run down. Since it has not yet run down, this implies, in the words of Richard Schlegel, "In some way the universe must have been wound up." [8]

Ludwig Boltzmann offered a daring proposal in order to explain why we do not find the universe in a state of heat death or thermodynamic equilibrium. [9] Boltzmann hypothesized that the universe as a whole does, in fact, exist in an equilibrium state, but that over time fluctuations in the energy level occur here and there throughout the universe, so that by chance alone there will be isolated regions where disequilibrium exists. Boltzmann referred to these isolated regions as "worlds." We should not be surprised to see our world in a highly improbable disequilibrium state, he maintained, since in the ensemble of all worlds there must exist by chance alone certain worlds in disequilibrium, and ours just happens to be one of these. [10]

The problem with Boltzmann's daring Many Worlds Hypothesis is that if our world were merely a fluctuation in a sea of diffuse energy, then it is overwhelmingly more probable that we should be observing a much tinier region of disequilibrium than we do. In order for us to exist, a smaller fluctuation would have sufficed and been much more probable than one so large as the observable universe. Moreover, even a colossal fluctuation that produced our world instantaneously by an enormous accident is inestimably more probable than a progressive decline in entropy over billions of years to fashion the world we see. In fact, Boltzmann's hypothesis, if adopted, would force us to regard the past as illusory, everything having the mere appearance of age, and the stars and planets as illusory, mere "pictures" as it were, since that sort of world is vastly more probable given a state of overall equilibrium than a world with genuine, temporally and spatially distant events. Therefore, Boltzmann's Many Worlds Hypothesis has been universally rejected by the scientific community, and the present disequilibrium is usually taken to be just a result of the initial low entropy condition mysteriously obtaining at the beginning of the universe.

As we have seen, the application of relativity theory to cosmology has altered the shape of the eschatological scenario predicted on the basis of the Second Law, but it has not materially affected the fundamental dilemma. Thus, the same pointed question raised by classical physics persists: why, if the universe has existed forever, is it not now in a cold, dark, dilute, and lifeless state? In contrast to their nineteenth century forbears, contemporary physicists have come to question the implicit assumption that the universe is eternal in the past. P. C. W. Davies reports, Today, few cosmologists doubt that the universe, at least as we know it, did have an origin at a finite moment in the past. The alternative - that the universe has always existed in one form or another—runs into a rather basic paradox. The sun and stars cannot keep burning forever: sooner or later they will run out of fuel and die.

The same is true of all irreversible physical processes; the stock of energy available in the universe to drive them is finite, and cannot last for eternity. This is an example of the so-called second law of thermodynamics, which, applied to the entire cosmos, predicts that it is stuck on a one-way slide of degeneration and decay towards a final state of maximum entropy, or disorder. As this final state has not yet been reached, it follows that the universe cannot have existed for an infinite time. [11]

Davies concludes, "The universe can't have existed forever. We know there must have been an absolute beginning a finite time ago." [12]

In the 1960s and '70s some cosmologists tried to escape this conclusion by adopting an oscillating model of the universe which never began to exist nor ever reaches a final state of equilibrium. [13] If the internal gravitational pull of the mass of the universe were able to overcome the force of its expansion, then the expansion could be reversed into a cosmic contraction, a Big Crunch. If the universe were not homogeneous and isotropic, then the collapsing universe might not coalesce at a point, but the material contents of the universe might pass by one another, so that the universe would appear to bounce back from the contraction into a new expansion phase. If this process could be repeated indefinitely, then the universe might be eternal both in the past and the future (Fig. 1).

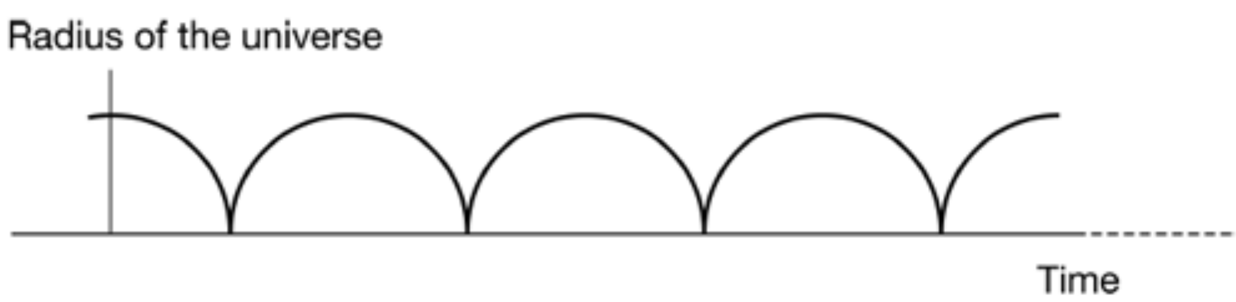

Fig. 1: Oscillating Model. Each expansion phase is preceded and succeeded by a contraction phase, so that the universe in concertina-like fashion exists beginninglessly and endlessly.

Not only was such a theory extraordinarily speculative, but the prospects of such a model were severely dimmed in 1970 by Roger Penrose and Stephen Hawking's formulation of the Singularity Theorems which bear their names. [14] The theorems disclosed that under very generalized conditions an initial cosmological singularity (or beginning point) is inevitable, even for inhomogeneous and non-isotropic universes. Reflecting on the impact of this discovery, Hawking notes that the Hawking-Penrose Singularity Theorems "led to the abandonment of attempts (mainly by the Russians) to argue that there was a previous contracting phase and a non-singular bounce into expansion. Instead almost everyone now believes that the universe, and time itself, had a beginning at the big bang." [15]

But wholly apart from these difficulties, the thermodynamic properties of this model turned out to imply the very problem that its proponents sought to avoid. For entropy is conserved from cycle to cycle in such a model, which has the effect of generating larger and longer oscillations with each successive cycle (Fig. 2).

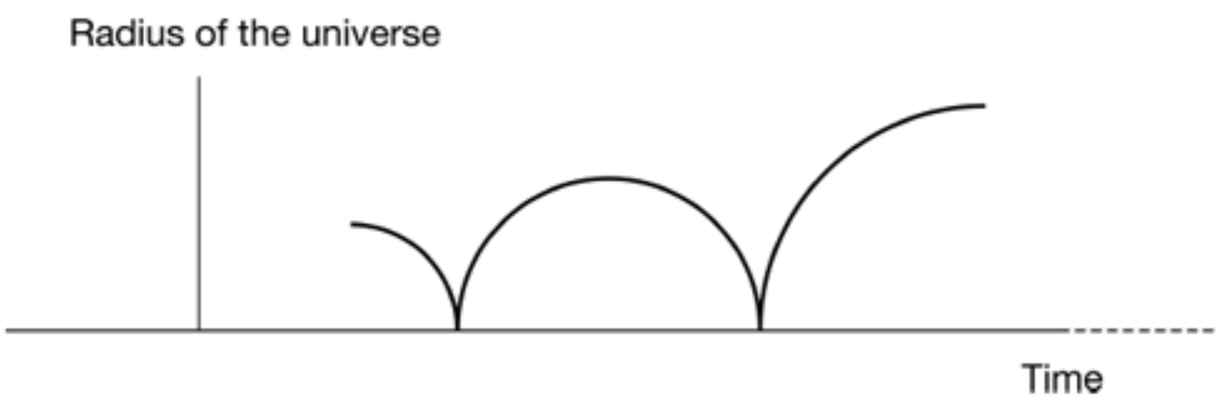

Fig. 2: Oscillating Model with Entropy Increase. Due to the conservation of entropy each successive oscillation has a larger radius and longer expansion time.

As one scientific team explains, "The effect of entropy production will be to enlarge the cosmic scale, from cycle to cycle. . . . Thus, looking back in time, each cycle generated less entropy, had a smaller cycle time, and had a smaller cycle expansion factor then [sic] the cycle that followed it." [16] Thus, as one traces the oscillations back in time, they become progressively smaller until one reaches a first and smallest oscillation. Zeldovich and Novikov therefore conclude, "The multicycle model has an infinite future, but only a finite past." [17] In fact, astronomer Joseph Silk estimates on the basis of current entropy levels that the universe cannot have gone through more than 100 previous oscillations. [18]

Even if this difficulty were avoided, a universe oscillating from eternity past would require an infinitely precise tuning of initial conditions in order to persist through an infinite number of successive bounces. A universe rebounding from a single, infinitely long contraction is, if entropy increases during the contracting phase, thermodynamically untenable and incompatible with the initial low entropy condition of our expanding phase. Postulating an entropy decrease during the contracting phase in order to escape this problem would require us to postulate inexplicably special low entropy conditions at the time of the bounce in the life of an infinitely evolving universe. In either the case such a universe involves a radical fine-tuning of a very special sort, since the initial conditions are set at minus infinity. [19]

If one is to avoid the inference that the universe has not existed forever, then one must find some scientifically plausible way to overturn the predictions of physical eschatology so as to permit the universe to return eventually to a youthful condition such as we observe. But no realistic and plausible scenario is forthcoming.

For example, the Russian cosmologist Andrei Linde once proposed that a model of the universe which is eternally inflating toward the future might also be extended infinitely into the past, with the result that the beginning of the universe was averted. Inflationary models represent an attempt to explain the astonishing large-scale homogeneity and isotropy of the universe. Theorists have proposed that between 10^{-35} and 10^{-33} sec after the Big Bang singularity, the universe underwent a phase of super-rapid, or inflationary, expansion which served to push the inhomogeneities out beyond our event horizon. [20] In most inflationary models, as one extrapolates backward in time, prior to the Inflationary Era, the universe continues to shrink down to an initial cosmological singularity. Inflationary theory, though criticized by some cosmologists as unduly "metaphysical," is widely accepted among cosmologists. In Linde's Chaotic Inflationary Model inflation never ends: each inflating domain of the universe when it reaches a certain volume gives rise via inflation to another domain, and so on, ad infinitum (Fig. 3). [21]

Fig. 3: Chaotic Inflationary Model. The wider universe produces via inflation separate domains which continue to recede from one another as the wider space expands.

Linde's model thus has an infinite future. But Linde is troubled at the prospect of an absolute beginning. He writes, "The most difficult aspect of this problem is not the existence of the singularity itself, but the question of what was before the singularity . . . This problem lies somewhere at the boundary between physics and metaphysics." [22] Linde therefore proposed that chaotic inflation is not only endless, but beginningless. Every domain in the universe is the product of inflation in another domain, so that the singularity is averted and with it as well the question of what came before (or, more accurately, what caused it). Perhaps one could account for the appearance of youth in the observable universe by postulating an infinite regress of prior inflationary domains.

In 1994, however, Arvind Borde and Alexander Vilenkin showed that a universe eternally inflating toward the future cannot be geodesically complete in the past, that is to say, there must have existed at some point in the indefinite past an initial singularity. They write,

A model in which the inflationary phase has no end . . . naturally leads to this question: Can this model also be extended to the infinite past, avoiding in this way the problem of the initial singularity?
. . . this is in fact not possible in future-eternal inflationary spacetimes as long as they obey some reasonable physical conditions: such models must necessarily possess initial singularities.

. . . the fact that inflationary spacetimes are past incomplete forces one to address the question of what, if anything, came before. [23]

In response, Linde concurred with the conclusion of Borde and Vilenkin: there must have been a Big Bang singularity at some point in the past. [24]

In 2001 Borde and Vilenkin in co-operation with Alan Guth were able to strengthen their theorem by crafting a new theorem independent of the assumption of the so-called "weak energy condition," which partisans of past-eternal inflation might have denied in an effort to save their theory. [25] The new theorem, in Vilenkin's words, "appears to close that door completely." [26] Thus, future-eternal inflationary space-times cannot be past-eternal: they must involve initial boundaries and so an absolute beginning of the universe. Vilenkin is adamant:

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. [27]

Alternatively, some theorists have speculated that the universe might in the future undergo quantum tunneling into a radically new state. For example, if the universe were currently in a false vacuum state, then it would eventually tunnel into a lower-energy vacuum state (Fig. 4).

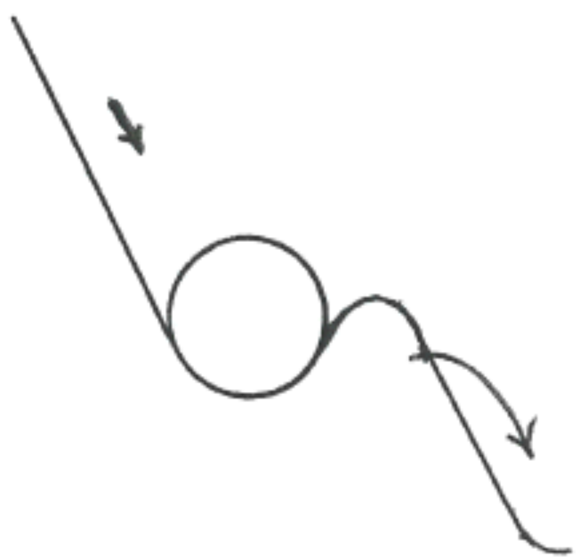

Fig. 4. If the universe is currently caught in a false vacuum state, eventually it will tunnel to the lower energy state of the true vacuum, resulting in a metamorphosis of nature.

In going through such a phase transition all the physical constants' values would change and a totally new universe would emerge. Perhaps one could hypothesize that such a transition took place at some point in the finite past after an infinite lapse of time, thereby giving to the universe its appearance of youth.

But even if such a transition were to take place, the probability that the values of all the constants would fall into the unimaginably narrow life-permitting range is vanishingly small (a staple of discussions of cosmic fine-tuning [28]). Hence, it is highly improbable that our present life-permitting constellation of physical constants is the chance result of such a phase transition from a higher-level vacuum state about 13 billion years ago. Worse, if there is any non-zero probability that such a meta-stable state would tunnel to a true vacuum state, then given infinite past time it should have already occurred infinitely long ago, not just some 13.5 billion years ago. But then it again becomes inexplicable why the universe is not already dead.

Speculations about our universe begetting future "baby universes" have also been floated in eschatological discussions. It has been conjectured that black holes may be portals of wormholes through which bubbles of false vacuum energy can tunnel to spawn new expanding baby universes, whose umbilical cords to our universe may eventually snap as the wormholes close up, leaving the baby universe an independently existing spacetime (Fig. 5).

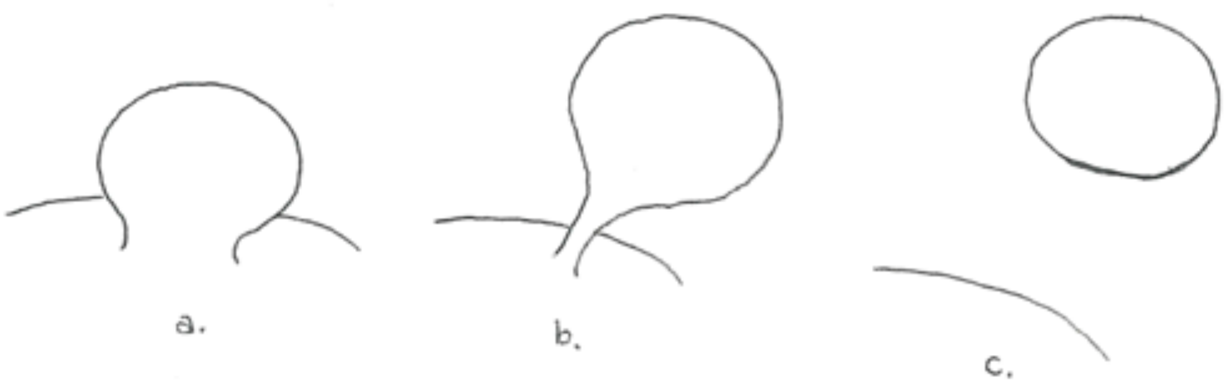

Fig. 5. A baby universe spawned from its mother universe eventually becomes a disconnected and causally isolated space-time.

Perhaps we might imagine that our observable universe is just one of the newly birthed offspring of an infinitely old, pre-existing universe.

The conjecture of our universe's spawning future offspring by such a mechanism was the subject of a bet between Stephen Hawking and James Preskill, which Hawking in 2004 finally admitted, in an event much publicized in the press, that he had lost. [29] The conjecture would require that information locked up in a black hole could be utterly lost forever by escaping to another universe. One of the last holdouts, Hawking finally came to agree that quantum theory requires that information is preserved in black hole formation and evaporation. The implications? "There is no baby universe branching off, as I once thought. The information remains firmly in our universe. I'm sorry to disappoint science fiction fans, but if information is preserved, there is no possibility of using black holes to travel to other universes." [30] Even if Hawking were wrong about this, the question remains, could such an eschatological scenario be in any case successfully extrapolated into the past, such that our universe is one of the baby universes spawned by the mother universe or by an infinite series of ancestors? It seems not, for while such baby universes appear as black holes to observers in the mother universe, an observer in the baby universe itself will see the Big Bang as a white hole spewing out energy. But this is in sharp contrast to our observation of the Big Bang as a low-entropy event with a highly constrained geometrical structure. And again, what rescues the infinite sequence of cosmic descendants from the consequences of the Second Law of Thermodynamics is unclear.

Since such speculative conjectures fail to elude the problem, we seem left with the conclusion that the universe is not past eternal. The Big Bang represents the absolute beginning of the universe, just as it does in the Standard Big Bang model; and the low entropy condition was simply an initial condition.

Indeed, thermodynamics may provide good reasons for affirming the reality of the singular origin of space-time postulated by the Standard Model. Roger Penrose states, "I have gradually come around to the view that it is actually misguided to ask that the space-time singularities of classical relativity should disappear when standard techniques of quantum (field) theory are applied to them." [31] For if the initial cosmological singularity is removed, then "we should have lost what seems to me to be the best chance we have of explaining the mystery of the second law of thermodynamics." [32] What Penrose has in mind is the remarkable fact that as one goes back in time the entropy of the universe steadily decreases. Just how unusual this is can be demonstrated by means of the Bekenstein-Hawking formula for the entropy of a stationary black hole. The total observed entropy of the universe is 1088. Since there are around 1080 baryons in the universe, the observed entropy per baryon must be regarded as extremely small. By contrast in a collapsing universe the entropy would be 10123 near the end. Comparison of these two numbers reveals how absurdly small 1088 is compared to what it might have been. Thus, the structure of the Big Bang must have been severely constrained in order that thermodynamics as we know it should have arisen. So how is this special initial condition to be explained? According to Penrose, we need the initial cosmological singularity in order to provide the constraints on the initial geometry which have the effect of producing a state of very low entropy. By contrast on a singularity-free, time symmetrical theory, we should have white holes spewing out material, in contradiction to the Second Law of Thermodynamics as well as observation. [33] Penrose supplies the following figure to illustrate the difference:

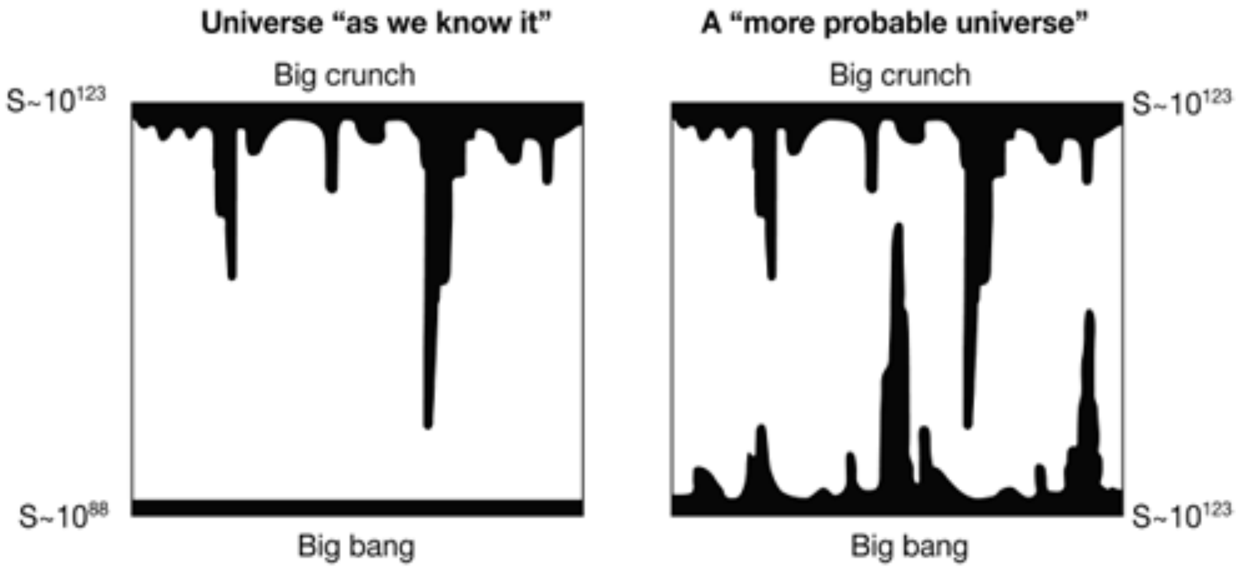

Fig. 6. Contrast between the universe as we know it (assumed for convenience to be closed) with a more probable universe. In both cases the Big Crunch is a high entropy (~10123), complicated, unconstrained singularity. For the left-hand picture the Big Bang is a low entropy (<1088), highly constrained, initial singularity, while for the right-hand picture it is an unconstrained, much more probable Big Bang. The "stalactites" represent singularities of black holes, while the "stalagmites" represent singularities of white holes.

If we remove the initial cosmological singularity, "we should be back where we were in our attempts to understand the origin of the second law." [34]

Could the special initial geometry have arisen sheerly by chance in the absence of a cosmic singularity? Penrose's answer is decisive: he calculates that, aiming at a phase space whose regions represent the likelihood of various possible configurations of the universe, "the accuracy of the Creator's aim" would have to have been one part in 1010(123)in order for our universe to exist. [35]He comments, "I cannot even recall seeing anything else in physics whose accuracy is known to approach, even remotely, a figure like one part in 1010(123)." [36] Thus, the initial cosmological singularity may be a virtual thermodynamic necessity.

What all this implies, in Davies' words, is that even though we may not like it, we must say on the basis of the thermodynamic properties of the universe that the universe's low entropy condition was somehow simply "put in" at the creation as an initial condition. [37] Prior to the creation, says Davies, the universe simply did not exist.

This conclusion has profound metaphysical implications. For the beginning of the universe is the point at which the universe literally came into being. The universe does not transition from nothingness into something; rather it comes into being absolutely. But if anything seems metaphysically impossible, it is that something can come into being absolutely without a cause. Being only comes from being. There must therefore be causally prior (if not temporally prior) to the Big Bang an ultra-mundane cause of the universe.

Such a cause must transcend physical space and time and therefore be immaterial not physical. Since the only immaterial entities of which we know are either minds or abstract objects (like numbers), and since the latter do not stand in causal relations, it is plausible that the cause of the universe is an unembodied mind or person who created the universe. Thus, physical eschatology itself provides grounds for believing in the existence of just that sort of agent who is capable of altering the projections of physical eschatology.

The naturalist might insist that we have no good reason for thinking that the personal Creator would intervene in the natural world so as to avert the consequences toward which the universe tends. But Christian eschatology is inextricably bound up with the person of Jesus of Nazareth: his physical resurrection is the harbinger not only of our own eschatological resurrection but also of a sort of cosmic resurrection as well (Rom. 8.19-23). The Christian eschatological hope is therefore based on the historical reality of Jesus' resurrection.

It is perhaps not appreciated outside the field of New Testament studies how impressive the historical credentials for this remarkable event are. [38] Today the majority of New Testament historians who have written on the topic agree that (1) Jesus of Nazareth was executed by crucifixion under Roman authority; (2) Jesus' corpse was then laid in a tomb by Joseph of Arimathea, a member of the Jewish Sanhedrin; (3) On the Sunday morning after the crucifixion Jesus' tomb was found empty by a group of his women followers; (4) Thereafter, different individuals and groups under a variety of circumstances experienced appearances of Jesus alive;

and (5) The earliest disciples came suddenly and sincerely to believe that God had raised Jesus from the dead, despite their strong predisposition to the contrary. While these points are by no means uncontested, they nonetheless do represent the majority view.

The remaining question is how these facts are best explained. We have seen reason to think that a transcendent, personal Creator of the universe exists. In that light, it can be plausibly argued that, when assessed by such standard criteria as explanatory power, explanatory scope, plausibility, and so forth, the Resurrection Hypothesis (viz., "The God of Israel raised Jesus from the dead") emerges as the best explanation. [39] If that is the case, then the prospect of an eschatological return of Christ to inaugurate fully the Kingdom of God, with a new heavens and a new Earth, cannot be dismissed as mere mythology.

One last point deserves to be made in this connection. Doubtless, one of the chief difficulties presented by Christian eschatology is that it just seems incredible that next year, say, or next Tuesday the universe is going to be obliterated by the return of Christ and Judgement Day. New Testament Christians themselves already faced such expressions of incredulity. In the second epistle of Peter we read that scoffers were saying, "Where is the promise of his coming? For ever since our ancestors died, all things continue as they were from the beginning of creation!" (II Peter 3.4). What these scoffers did not and, of course, could not realize is that physical eschatology itself contains its own apocalyptic scenario of impending worldwide destruction. I mentioned earlier that if the universe is currently suspended in a meta-stable false vacuum state, then at some point in the future it will inevitably tunnel into a lower energy state, bringing with it a complete metamorphosis of nature. Because this tunneling is an indeterminate quantum phase transition, it is unpredictable and could happen, in the words of Adams and Laughlin, "at virtually any time, as soon as tomorrow." [40] In such a transition regions of true vacuum will begin to form at places throughout the universe, rather like ice forming on the surface of a pond, except that in this case the regions of true vacuum will propel themselves across the universe at fantastic speed, approximating the speed of light. Adams and Laughlin describe such a cosmic apocalypse in the following words:

Silently, and without warning of any kind, it came. Every cosmic structure it swept over was left disembodied and disfigured in its wake. The destruction was frightening in both its awful swiftness and its devastating completeness.

The shock wave began at a particular but rather undistinguished point of space-time and then traveled outward at blinding speed, rapidly approaching the speed of light. The expanding bubble then enveloped an ever larger portion of the universe. Because of its phenomenal velocity, the shock wave impinged upon regions of space with no advance warning. No light signals, radio waves, or causal communication of any kind could outrun the advancing front and forewarn of the impending doom. Preparation was as impossible as it was futile.

Inside the bubble, the laws of physics and hence the very character of the universe were completely changed. The values of the physical constants, the strengths of the fundamental forces, and the masses of the elementary particles were all different. New physical laws ruled in this Alice-in-Wonderland setting. The old universe, with its old version of the laws of physics, simply ceased to exist.

One could view this death and destruction of the old universe as a cause for concern. Alternately, this natural course of events could be looked upon as a reason for celebration. Inside the bubble, with its new physical laws and the accompanying new possibilities for complexity and structure, the universe has achieved a new beginning. [41]

As I read this passage written by these two physical scientists concerning the looming apocalypse of physical eschatology, I could not help but be reminded of the admonition written by the author of II Peter concerning the scoffers of his day:

Do not ignore this one fact, beloved, that with the Lord one day is like a thousand years, and a thousand years are like one day. The Lord is not slow about his promise, as some think of slowness, but is patient with you, not wanting any to perish, but all to come to repentance. But the day of the Lord will come like a thief, and then the heavens will pass away with a loud noise, and the elements will be dissolved with fire, and the earth and everything that is done on it will be disclosed.

Since all these things are to be dissolved in this way, what sort of persons ought you to be in leading lives of holiness and godliness, waiting for and hastening the coming of the day of God, because of which the heavens will be set ablaze and dissolved, and the elements will melt with fire? But, in accordance with his promise, we wait for new heavens and a new earth, where righteousness is at home (2 Peter 8-13).

The parallels between the theological and physical eschatological apocalypses are striking and unmistakable: a complete and worldwide metamorphosis of nature, sudden, without warning, like a thief in the night, unavoidable, issuing in a new heavens and a new earth, a renovated universe.

Unlike Adams and Laughlin, however, the author of II Peter does suggest that we do something in preparation for the cosmic transformation that will sweep away the old order: since those who belong to the Lord shall be part of the world to come, this future prospect should affect how we presently live.

Now please do not misunderstand me: I am in no wise suggesting that what we read in II Peter is a poetic description of an impending quantum phase transition of the universe. Rather I am making the more modest point that if physical eschatology involves apocalyptic doomsday predictions that could be realized tomorrow, then we should not balk at similar forecasts of impending eschatological destruction made by theology simply on the grounds of its unexpectedness and mind-boggling otherness.

The plausibility of Christian eschatology vis à vis the projections of physical eschatology is thus inherently bound up with one's ontology. If, as physical eschatology itself intimates, there exists a personal, transcendent agent who created the universe with all its natural laws and boundary conditions, and if that agent has raised from the dead Jesus of Nazareth, who promised his eschatological return, then it is eminently rational to entertain "the blessed hope" of Christian eschatology, while accepting the findings of physical eschatology as more or less accurate projections based on present conditions.

Footnotes:

[1] P. J. Zwart, *About Time* (Amsterdam: North-Holland, 1976),p. 136.

[2] Beatrice Tinsley, "From Big Bang to Eternity?" *Natural History Magazine,* October 1975, p. 103.

[3] Duane Dicus, *et al.*, *"*The Future of the Universe," *Scientific American* (March 1983), p. 99.

[4] Tinsley, "Big Bang," p. 105.

[5] Bertrand Russell, "A Free Man's Worship."

[6] Freeman J. Dyson, "Time without End: Physics and Biology in an Open Universe," *Reviews of Modern Physics* 51 (1979): 447.

[7] See Lawrence M. Krauss and Glenn D. Starkman, "Life, the Universe, and Nothing: Life and Death in an Ever-Expanding Universe," *Astrophysical Journal* 531 (2000): 220-30.

[8] Richard Schlegel, "Time and Thermodynamics," in *The Voices of Time*, ed. J. T. Fraser (London: Penguin, 1968), p. 511.

[9] Ludwig Boltzmann, *Lectures on Gas Theory*, trans. Stephen G. Brush (Berkeley: University of California Press, 1964), ?90 (pp. 446-48).

[10] For a fascinating contemporary reprise of Boltzmann's hypothesis and a discussion of its central weakness, see Lin Dyson, Matthew Kleban, and Leonard Susskind, "Disturbing Implications of a Cosmological Constant," http://archiv.org/abs/hep-th/0208013v3 (14 November 2002). Their point of departure is Henri Poincare's argument that in a closed box of randomly moving particles every configuration of particles, no matter how improbable, will eventually recur, given enough time; given infinite time, every configuration will recur infinitely many times. Eschewing a global perspective in favor of a restriction to our causally connected patch of the universe, they argue for the inevitability of cosmological Poincare recurrences, allowing the process of cosmogony to begin anew. "The question then is whether the universe can be a naturally occurring fluctuation, or must it be due to an external agent which starts the system out in a specific low entropy state?" (Ibid, p. 4). They recognize that the central weakness of the fluctuation hypothesis is that there are "far more probable ways of creating livable ('anthropically acceptable') environments" than those that begin in a low entropy condition. See further note 37 below.

[11] Paul Davies, "The Big Bang - And Before," The Thomas Aquinas College Lecture Series, Thomas Aquinas College, Santa Paula, Calif., March 2002.

[12] Paul Davies, "The Big Questions: In the Beginning," ABC Science Online, interview with Phillip Adams, http://aca.mq.edu.au/pdavieshtml.

[13] See, *e.g.,* E. M. Lifschitz and I. M Khalatnikov, "Investigations in Relativist Cosmology," *Advances in Physics* 12 (1963): 207.

[14] R. Penrose, "Gravitational Collapse and Space-Time Singularities," *Physical Review Letters* 14 (1965): 57-59; S. W. Hawking and R. Penrose, in *The Large-Scale Structure of Space-Time,* ed. S. W. Hawking and G. F. R. Ellis (Cambridge: Cambridge University Press, 1973), p. 266.

[15] Stephen Hawking and Roger Penrose, *The Nature of Space and Time,* The Isaac Newton Institute Series of Lectures (Princeton, N. J.: Princeton University Press, 1996), p. 20.

[16] Duane Dicus, *et al.*, "Effects of Proton Decay on the Cosmological Future," *Astrophysical Journal* 252 (1982): 1, 8.

[17] I. D. Novikov and Ya. B. Zeldovich, "Physical Processes near Cosmological Singularities,"

Annual Review of Astronomy and Astrophysics 11 (1973): 401-2.

[18] Joseph Silk, *The Big Bang,* 2d ed. (San Francisco: W. H. Freeman, 1989), pp. 311-12.

[19] George Ellis remarks,

"The problems are related: first, initial conditions have to be set in an extremely special way at the start of the collapse phase in order that it is a Robertson-Walker universe collapsing; and these conditions have to be set in an acausal way (in the infinite past). It is possible, but a great deal of inexplicable fine tuning is taking place: how does the matter in widely separated causally disconnected places at the start of the universe know how to correlate its motions (and densities) so that they will come together correctly in a spatially homogeneous way in the future?? Secondly, if one gets that right, the collapse phase is unstable, with perturbations increasing rapidly, so only a very fine-tuned collapse phase remains close to Robertson-Walker even if it started off so, and will be able to turn around as a whole (in general many black holes will form locally and collapse to a singularity)" (G. F. R. Ellis to James Sinclair, 25 January, 2006).

Ellis then pointedly asks, "Who focused the collapse so well that it turns around nicely?"

[20] Guth, "Inflationary Universe: A Possible Solution to the Horizon and Flatness Problems," *Physical Review D* 23 (1981): 247-56.

[21] See, *e.g.,* A. D. Linde, "The Inflationary Universe," *Reports on Progress in Physics* 47 (1984): 925-86; idem, "Chaotic Inflation," *Physics Letters* 1298 (1983): 177-81. For a critical review of inflationary scenarios, including Linde's, see John Earman and Jesus Mosterin, "A Critical Look at Inflationary Cosmology," *Philosophy of Science* 66 (1999): 1-49.

[22] Linde, "Inflationary Universe," p. 976.

[23] Borde and A. Vilenkin, "Eternal Inflation and the Initial Singularity," *Physical Review Letters* 72 (1994): 3305, 3307.

[24] Andrei Linde, Dmitri Linde, and Arthur Mezhlumian, "From the Big Bang Theory to the Theory of a Stationary Universe," *Physical Review D* 49 (1994): 1783-1826.

[25] Arvind Borde, Alan Guth, and Alexander Vilenkin, "Inflation Is Not Past-Eternal," http://arXiv:gr-qc/0110012v1 (1 Oct 2001): 4. The article was updated in January 2003.

[26] Alexander Vilenkin, "Quantum Cosmology and Eternal Inflation," http://arXiv:gr-qc/0204061v1

(18 April 2002):10.

[27] Alex Vilenkin, Many Words in One: The Search for Other Universes (New York: Hill and Wang, 2006), p. 176.

[28] See my "Design and the Anthropic Fine-Tuning of the Universe," in God and Design: The Teleological Argument and Modern Science, ed. Neil Manson (London: Routledge, 2003), pp. 178-99.

[29] For a first-hand account see James Preskill's website www.theory.caltech.edu/~preskill/jp-24jul04.html.

[30] S. W. Hawking, "Information Loss in Black Holes," http://arXiv:hep-th/0507171v2 (15 September 2005): 4.

[31] Roger Penrose, "Some Remarks on Gravity and Quantum Mechanics," in Quantum Structure of Space and Time, ed. M. J. Duff and C. J. Isham (Cambridge: Cambridge University Press, 1982), p. 4.

[32] Ibid., p. 5.

[33] Hawking and Penrose, Nature of Space and Time, p. 130.

[34] Penrose, "Remarks on Gravity," p. 5.

[35] Roger Penrose, "Time-Asymmetry and Quantum Gravity," in Quantum Gravity 2, ed. C. J. Isham, R. Penrose, and D. W. Sciama (Oxford: Clarendon Press, 1981), p. 249; cf. Hawking and Penrose, Nature of Space and Time, pp. 34-5.

[36] Penrose, "Time-Asymmetry," p. 249.

[37] P. C. W. Davies, The Physics of Time Asymmetry (London: Surrey University Press, 1974), p. 104. Dyson, Kleban, and Susskind (see note 10 above) respond to such a suggestion as follows: "Another possibility is that an unknown agent intervened in the evolution and for reasons of its own restarted the universe in the state of low entropy characterizing inflation. However, even this does not rid the theory of the pesky recurrences. Only the first occurrence would evolve in a way that would be consistent with usual expectations" (Dyson, Kleban, and Susskind, "Disturbing Implications of a Cosmological Constant," pp. 20-1). But so saying, they have misconstrued the hypothesis. The hypothesis was not of an external agent which "restarted" the universe but of "an external agent which starts the system out in a specific low entropy state" (Ibid., p. 4). On such a

hypothesis "Some unknown agent initially started the inflation high up on its potential, and the rest is history" (Ibid., p. 2). On this hypothesis the recurrence problems do even not arise. By contrast, Dyson, Kleban, and Susskind are finally driven to suggest that "Perhaps the only reasonable conclusion is that we do not live in a world with a true cosmological constant" (Ibid., p. 21), a desperate hypothesis which flies in the face of the evidence.

[38] See William Lane Craig, Assessing the New Testament Evidence for the Historicity of the Resurrection of Jesus (Lewiston, N.Y.: Edwin Mellen, 1989); N. T. Wright, the Resurrection of the Son of God (London: SPCK, 2003).

[39] For an illustrative application of these criteria to rival hypotheses see William Lane Craig and Gerd Ldemann, Jesus' Resurrection: Fact or Figment?, ed. Paul Copan and Ronald Tacelli (Downer's Grove, Ill.: Inter-Varsity Press, 2000).

[40] Fred C. Adams and Gregory Laughlin, "A Dying Universe: the Long-Term Fate and Evolution of Astrophysical Objects," Reviews of Modern Physics 69:2 (1997): 364.

[41] Fred Adams and Greg Laughlin, The Five Ages of the Universe (New York: Free Press, 1999), p. 154.