Articles

The Multiverse Conjecture: Whitehead's Cosmic Epochs and Contemporary Cosmology

Leemon McHenry

Leemon McHenry teaches philosophy at California State University, Northridge. E-mail: <leemon.mchenry@csun.edu>.

Abstract: Recent developments in cosmology and particle physics have led to speculation that our universe is merely one of a multitude of universes. While this notion, the multiverse hypothesis, is highly contested as legitimate science, it has nonetheless struck many physicists as a necessary consequence of the effort to construct a final, unified theory. In Process and Reality (1929), his magnum opus, Alfred North Whitehead advanced a cosmology as part of his general metaphysics of process. Part of this project involved a theory of cosmic epochs which bears a remarkable affinity to current cosmological speculation. This paper demonstrates how the basic framework of a multiverse theory is already present in Whitehead's cosmology and defends the necessity of speculation in the quest for an explanatory description.

Introduction

In his masterpiece, *Process and Reality* (1929), subtitled *An Essay in Cosmology*, Whitehead advanced a cosmology as part of his general metaphysics of process. Metaphysics seeks the most general principles of reality. As he says it is "the science which seeks to discover the general ideas which are indispensably relevant to the analysis of everything that happens" (*RM* 84). Cosmology is "the effort to frame a scheme of the general character of the present stage of the universe" (*FR* 76). Metaphysics therefore seeks principles that are necessary for any possible world or cosmic epoch while cosmology discovers by observation what happens to be the case about our actual world or this cosmic epoch.[1] In this connection, the quest for what physicists refer to as a "final theory" combining the standard model of particle physics with general relativity would, in Whitehead's view, apply only to our cosmic epoch—a mere phase of the universe that began with the big bang.[2] While Whitehead knew nothing of the great advances in big bang theory, expansion, inflation, and the unification of physics in post-Hubble cosmology when he wrote *Process and Reality* in the 1920s,[3] his theory of cosmic epochs anticipates in an uncanny manner what has become the most challenging development in contemporary cosmological theory, namely, the multiverse hypothesis. If indeed this hypothesis is borne out in further developments in physics and cosmology, it promises to be as fundamentally transformative as the Copernican revolution was in the seventeenth century.

My aim in this essay is to demonstrate how the basic framework of a multiverse theory is already present in Whitehead's cosmology and defend the necessity of speculation as the basis for the continuum between science and metaphysics. I will explicate the basic principles of Whitehead's theory of society and the extensive continuum, and then explore affinities and contrasts with contemporary theorizing about the multiverse. Finally, I examine criticisms of multiverse speculation and defend the hypothesis against these objections.

Whitehead's theory of cosmic epochs

As part of Whitehead's metaphysics, he formulated a merelogical theory that he called "the theory of society." This theory of whole-part relations accounts for the order of nature in the extensive continuum. He used the general term "nexus" to define a special togetherness of the basic entities of his system. Some nexūs (plural of nexus) are purely temporal or spatial, e.g., consciousness, interstellar space. A "society" is a macroscopic object. It is a nexus that has what Whitehead calls "social order." That is, there is a common element of form among the entities of that society, and the imposition of reproduction among those members of that society so that one generation of entities after another reproduce the same pattern. The extended universe is a system of societies embedded in societies embedded in societies, etc. So, the society of electrons is embedded in the society of atoms, which is embedded in society of molecules and so on.

This very broad notion of society involves the idea of a character that endures over time given the manner in which the present members inherit and modify the defining characteristic. The new metaphysical meaning extends the usual meaning so that a philosophy of process accounts for *things*. A society, for Whitehead, is the massive average objectification of the dominant characteristics or, as he puts it, the eternal objects in the actual occasions forming the society. A structured society is one that includes sub-ordinate societies and sub-ordinate nexūs with a definite pattern of structural inter-relations; e.g., a molecule, a cell, a planet, a solar system or a galaxy. Most societies with which we come into contact are "democracies" in the sense that their subordinate societies function together without a central unified mentality. Cell colonies, plants, eco-systems and galaxies are democracies in this sense. Each society is an organism that is harbored within the environment of another larger society, which serves as an organism for another and so on. The special sciences—physics, chemistry, biology, geology, astronomy—study some layer of society or organisms and their environment—subatomic particles, atoms, molecules, cells . . . plants, animals . . . planets and galaxies. Cosmology, the study of the large-scale structure and evolution of the universe, investigates the most general features of organism at the very limits of observation. Whitehead calls his view "the philosophy of organism" to distinguish his position from the mechanism of Galileo, Descartes, and Newton.

While societies are the things in nature that endure (more or less corresponding to Aristotle's substances), they are not the things that are truly real in Whitehead's ontology. They are rather aggregates of micro-events, the actual occasions. Accordingly, sub-atomic particles such as electrons and protons, quarks and leptons or superstrings would not qualify as the basic entities; rather they are societies of actual occasions. Change is a character of an event—a nexus of occasions—or a society. Actual occasions, by contrast, become and perish but do not change, again since change according to Whitehead is understood as what occurs in a nexus. It is imperative here to note that actual occasions become by "prehending" other occasions in their immediate causal past. The contemporary occasions forming a society are in unison of becoming and as such are casually independent of one another (*PR* 123).

Whitehead defines the extensive continuum of the physical universe as: "one relational complex in which all potential objectifications find their niche . . . it is a complex of entities united by the various allied relationships of whole and part, and of overlapping. . . . This extensive continuum expresses the solidarity of all possible standpoints throughout the whole process of the world" (*PR* 66) from bottom to top, i.e., from the most basic entities, actual occasions, which atomize the continuum, to the most general conceivable sort of social order. At the far end, the three largest societies Whitehead postulates within the extensive continuum are: (1) the society of cosmic epochs, (2) the geometrical society, and (3) the society of pure extension. Social order beyond the physical order of any cosmic epoch involves the more general geometrical, mathematical and mereological characteristics, of which any cosmic epoch must conform. As he makes the point:

> In these general properties of extensive connection, we discern the defining characteristic of a vast nexus extending far beyond our immediate cosmic epoch. It contains in itself other epochs, with more particular characteristics incompatible with each other. Then from the standpoint of our present epoch, the fundamental society in so far as it transcends our own epoch seems a vast confusion mitigated by the few, faint elements of order contained in its own defining characteristic of 'extensive connection.' We cannot discriminate its other epochs of vigorous order, and we merely conceive it as harbouring the faint flush of the dawn of order in our own epoch. This ultimate, vast society constitutes the whole environment within which our epoch is set, so far as systematic characteristics are discernible by us in our present stage of development. (*PR* 97)

For Whitehead, cosmology is the study of the order in our cosmic epoch including the discovery of its general laws. A cosmic epoch is the largest society of events that are governed by a certain set of laws of nature. He says: "the phrase 'cosmic epoch' is used to mean that widest society of actual entities whose immediate relevance to ourselves is traceable" (*PR* 91). A cosmic epoch is more specifically a vast structured society which includes the vast nexus of interstellar space and the constituent structured galactic societies existing within a larger geometrical society permitting the possibility of diverse dimensionalities of space. Whitehead identifies *our* cosmic epoch as the four-dimensional "electromagnetic society," of which he credits James Clerk-Maxwell with the discovery of its general character. He says further: "This epoch is characterized by electronic and protonic actual entities, and by yet more ultimate actual entities which can be dimly discerned in the quanta of energy" (*PR* 91).

Within this context of post-Hubble cosmology, what Whitehead calls "our cosmic epoch" is the electromagnetic society that began at a space-time singularity known as the big bang roughly 14 billion years ago and has been expanding and cooling ever since. By the best measurements of astronomers at present, we are able to make observations of the most distant objects now in our cosmic epoch at about 4×10^{26} m away (Tegmark 99). This sphere of the radius is our *horizon volume* demarcating observable objects from which light has travelled during the 14 billion years since the big bang and those even more distant objects unobservable now in principle.

From this discussion, it is clear that our universe should be conceived as the entire set of cosmic epochs or *cosmoi*, one giving birth to another as the order in a predecessor degenerates and gives rise to a new order in a successor. Cosmic epochs, like all societies, arise from disorder (*PR* 91). Our cosmic epoch emerged from the disintegration of its predecessor epoch, and another epoch will emerge from the disintegration of our epoch, perhaps at what cosmologists call "the omega point" at the conclusion of "the big crunch" or at the rebound initiating a new cycle of expansion. A new cosmic epoch emerges, like the phoenix from the ashes, from the collapse of its predecessor. While Whitehead has not given much attention to the idea of contemporaries, his view of social order beyond cosmic epochs implies that within the geometrical society and the society of pure extension, there will be a plurality of cosmic epochs, each with a different sort of order and physical laws, existing in causal independence from one another. Our electromagnetic cosmic epoch, finite and bounded within the wider geometrical society "constitutes a fragment" (*PR* 92); others will be characterized by some other general type of order. In other words, Whitehead's *cosmoi* are spread out in both time and space.[4]

Given Whitehead's view on the plurality of cosmic epochs, laws of nature evolve with the attainment of the ideal for the society in question. In contrast to philosophers such as Descartes and Kneale, who viewed scientific laws as necessary and universal, i.e., omnitemporally and omnispatially unrestricted in scope,[5] Whitehead views scientific laws as contingent, evolving concurrently with the creative advance of nature and restricted in scope to the cosmic epochs in which they apply. He says: "a system of 'laws' determining reproduction in some portion of the universe gradually rises into dominance; it has its stage of endurance, and passes out of existence with the decay of the society from which it emanates" (*PR* 91). More explicitly, in *Adventures of Ideas*, he says:

> since the laws of nature depend on the individual character of the things constituting nature, as the things change, then correspondingly the laws will change. Thus the modern evolutionary view of the physical universe should conceive of the laws of nature as evolving

> concurrently with the things constituting the environment. Thus the conception of the Universe as evolving subject to fixed, eternal laws regulating all behaviour should be abandoned. (143)

The laws of nature are not logically necessary since we can imagine a place where they do not hold without contradiction; nor are they universally and physically necessary since they change with the becoming and passing of the societies in question. Physical laws are grounded in the periodicity of nature found in a particular cosmic epoch. Other laws, such as those of geometry and mathematics, hold not only for our cosmic epoch but all others contained in the geometrical society. Mathematical truths are therefore true in all cosmic epochs. In the most general society of pure extension, extremely general merelogical laws apply, such as the relation of whole and part and extensive connection; these will likewise hold in any possible cosmic epoch, but even here Whitehead is hesitant to claim this is a necessary conclusion (*PR* 35-36). As he emphasizes, what we know beyond our cosmic epoch is merely "a vast confusion mitigated by the few, faint elements of order" (97).

The multiverse hypothesis: the world is not enough

Whitehead's view of cosmic epochs appears to have support in contemporary cosmology even though his work has not been recognized among the more recent proponents of this view.[6] Contemporary cosmologists, such as Martin Rees, Lee Smolin, Stephen Hawking, Max Tegmark, and Steven Weinberg, have speculated that our universe created at the big bang is merely one episode, one universe in a multiverse.[7] As Rees puts it in *Before the Beginning*:

> What is conventionally called "the universe" could be just one member of an ensemble. Countless others may exist in which the laws are different. The universe in which we've emerged belongs to the unusual subset that permits complexity and consciousness to develop. . .
>
> Each universe starts with its own big bang, acquires a distinctive imprint (and its individual physical laws) as it cools, and traces out its own cosmic cycle. The big bang that triggered our entire universe is, in this grander perspective, an infinitesimal part of an elaborate structure that extends far beyond the range of any telescopes. (3)

The acceptance of such an idea has astounding revolutionary implications, for as Rees argues, the new idea is "potentially, as drastic an enlargement of our cosmic perspective as the shift from pre-Copernican ideas to the realization that the Earth is orbiting a typical star on the edge of the Milky Way, itself just one galaxy among countless others" (*Before* 3). If indeed he is right, the multiverse revolution is just as profound in our paradigm shift as the Copernican revolution was in the seventeenth century. For those who embrace the idea, the multiverse hypothesis is seen as plausible step in the progressive enlargement of our understanding, beginning with the geocentric view to the heliocentric view, the galactocentric view to the cosmocentric view, and now to the multiverse.

While cosmologists use different terminology for the "multiverse," such as "megaverse," "holocosm," or "parallel worlds," there is general agreement about the need for this new theory from three different but related perspectives. (1) It is necessary to understand the origin of our universe. This is largely due to the attempt to understand emergence from models of expansion and re-collapse. (2) It is also seen as a necessary development of the attempt to find the ultimate unified theory, the Theory of Everything (TOE). One candidate, M-Theory, requires extra dimensions beyond the four familiar ones of space and time, of which our universe is merely a "brane" in a higher-dimensional "bulk." Unification is then sought in these higher-dimensional theories. And finally, (3) it gives legitimacy to the anthropic principle because if there is a multiplicity of universes, it is a simple matter of natural selection that a fraction of these will produce the fine tunings necessary for the emergence of life and consciousness such as we find in our universe.

The two most important developments, the "golden moments," in modern cosmology were Hubble's discovery of the red shift of distant galaxies and Penzias and Wilson's accidental discovery of cosmic microwave radiation showering the Earth with equal strength from all directions (Peebles). The first led Hubble to formulate his law of kinematics: galaxies are receding from us with a speed proportional to their distance. The second, the so-called "afterglow of creation," is interpreted as left over radiation from the early, hot universe. Both of these developments provided observational support for the big bang theory and led to the development of the oscillating model, according to which our universe has been expanding and cooling and will at some point begin to contract to a "big crunch" where astronomers will begin to observe worrying blue shifts from distant galaxies and the temperature of cosmic microwave radiation will start to rise (Weinberg, *First* 151-52). One simple motivation for proposing the multiverse hypothesis is the attempt to understand how this emergence, expansion, and re-collapse occur within a larger theoretical context. The multiverse offers such a context where, contrary to *creatio ex nihilo*, something had to emerge from something. The big bang was the result of the collapse of a predecessor universe.

There are several versions of multiverse theory, including Everett's many-worlds interpretation of quantum mechanics, bubble theory, ensemble theory, string landscapes, etc. Proponents vary in that some cosmologists view different universes as spread out in *time*, i.e., expansion and re-collapse of a single universe in cycles; some view them as spread out in *space;* and others that view the universes as spread out in both *time and space*. The simplest model of a multiverse, oscillationism, is one spread out in a single-line succession. This could be conceived as one universe continually undergoing different cycles or epochs of expansion and re-collapse, or a new universe at each fresh big bang (Tolman; Weinberg, *First* 153-54). In the bubble scenario, our universe underwent rapid inflation in the early phases of expansion (Guth). But our universe is merely one bubble among numerous other bubbles spread out in space. In a combination of these two, eternal inflation, each universe is continually self-reproducing. According to one of these versions, cosmologists speculate that new "embryo" universes form within existing ones when implosion around a black hole triggers the expansion of a new spatial domain. From this disjoint space, if those universes are like our own, stars, galaxies, and black holes would form, and those black holes would in turn spawn another generation of universes and so on (Rees, *Cosmic* 158; Hawking 121; Smolin 100). We have no information about these universes since we only know our own, but they bear the imprint of their parents, or leave behind an "umbilical cord" for a baby universe. As Whitehead put it, our cosmic epoch is the society immediately traceable to ourselves, beyond which we have only faint hints of order.

The quest for a unified theory, a grand synthesis of the fragmentary theories of physics, has been a central aim of physics since Einstein sought a unified field theory of electromagnetism and general relativity. Grand Unified Theories (GUTs) in particle physics have attempted to unify the electromagnetic, weak, and strong nuclear interactions, but the Holy Grail has been the unification of these fundamental forces with gravity in a Theory of Everything (TOE). Such a theory holds the same promise of unification achieved by Newton in classical physics. Perhaps the most impressive development is offered by the string theory scenario which, if successful, promises the realization of Einstein's dream of a unified field theory and beyond by tackling the more difficult unification of quantum mechanics and general relativity (Weinberg, *Dreams* 212).

String theory proposes that all matter and all forces of nature are understood as a manifestation of particular patterns of string vibration within multi-dimensional branes. M-theory, the master theory of all formulations of string theory, or *super*string theory, proposes eleven dimensions (ten of space and one of time). Our understanding of the electromagnetic space-time continuum (of four dimensions) is merely an evolutionary accident of our sensory organs, namely, the fact that we see reality within the limitations of a narrow band of electromagnetic radiation within which our visual perception is sensitive. In the braneworld scenario postulated by string theory, "we could be floating within a grand, expansive, higher-dimensional space but the electromagnetic force—eternally trapped within our dimensions—would be unable to reveal this" (Greene, *Fabric* 393-94). Explaining the force of gravity, however, requires the extra dimensions of M-theory. While at present a work in progress, the expectation is the development of a theory that explains the big bang by a realm in which the cyclic expansion-contraction-rebound occurs. This very roughly approximates Whitehead's notion of the geometrical society that harbors the existence of the cosmic epochs, one that contains all possible geometrical configurations, allowing multiple dimensions required by M-theory. According to one version of the theory, our universe is a three-brane set within a string landscape of many other three-branes, all of which are connected and drive the cosmological evolution within the branes by colliding and thereby causing a rebound (Greene, *Elegant* 407). The expansion-contraction-rebound cycle is therefore a result of a much larger cycle of attraction and collision of branes beyond our universe or cosmic epoch.

The fine-tunings of the physical constants (in place and time, in nuclear forces, gravity and chemical elements) necessary for the emergence of life and consciousness have also contributed to the cautious acceptance of the multiverse concept. The anthropic argument states: The physical constants have certain specific values, when they could in principle have any values at all. Hence, unless there is a god, there must be an infinite number of other "places" where the constants take on all possible combinations of values. We find ourselves in one that has become self-aware, because conditions here are such that consciousness can arise. But if any number of the fundamental constants or initial conditions were slightly different, no complexity would have emerged that permits life and evolution to take place. As Gribbin and Rees make this point about our own place in the scheme of things: "we do not inhabit a typical place in the Universe. Most of the Universe is empty space, filled with a weak background sea of electromagnetic radiation, with a temperature of only 3 degrees above absolute zero of temperature, which lies at -273 degrees C. . . . Clearly, our home represents a special place in the Universe (although not necessarily a *unique* place)" (6).

One delicate balance of place, the CHZ (continuously habitable zone) demonstrates the uniqueness of Earth. If Earth's orbit had been only five percent closer to the Sun, the primordial water vapor outgassed from volcanoes in the early history of the planet would not have condensed to form the oceans, but rather would have remained in a gaseous state similar to Venus. On the other hand, if the orbit of Earth been even one percent greater, then the lowered radiation from the youthful Sun, coupled with the reduced greenhouse effect, would have left Earth covered with massive glaciers in the manner of the deep freeze of Mars (Casti 351). Beyond the conditions suitable for life on planets, Rees in *Just Six Numbers* has refined the list of finely-tuned cosmological constants to identify which universes provide for the possibility of a *biophilic* universe; any one of these cosmic numbers 'un-tuned' results in a stillborn or sterile universe (2-3):

1. $N = 10^{36}$ The measure of the strength of the electrical forces that hold atoms together divided by the force of gravity between them: if N were less, the universe would be too young and too small for life.

2. $\varepsilon = 0.007$ Nuclear binding energy as a fraction of rest mass energy: ε defines how firmly atomic nuclei bind together; if more or less, the complex chemistry for matter and life could not exist.

3. $\Omega = 0.3$ The amount of matter in the universe in units of critical density: if Ω were greater, the universe would have already collapsed; if less, no galaxies would have formed.

4. $\lambda = 0.7$ The cosmological constant in units of critical density: λ controls the expansion and fate of the universe; if it were

larger, cosmic evolution would have made it impossible for stars and galaxies to form.

5. Q = 10^{-5} The amplitude of density fluctuations for cosmic structures: if Q were smaller, the universe would be featureless since matter would be blown away from a galaxy instead of being recycled into stars forming planetary systems; if Q were larger, the universe would be dominated by black holes and far too violent for life to exist.
6. D = 3 The number of spatial dimensions in our world; if D were 2 or 4, life could not exist. In a three-dimensional world, forces like gravity and electricity obey an inverse square law, which provides for stable orbits of planets around a star and electrons around a positively-charged nucleus.

While the strong anthropic principle argues that such a universe could only be the product of God or a god, the weak version draws the more modest inference that all one need postulate is the plurality of universes with a variety of properties, of which at least one is hospitable to our existence, i.e., the multiverse (Smolin 203).

Affinities and contrasts explained

The notions of the big bang and a dynamic, expanding universe are consistent with Whitehead's notion of what occurs within a cosmic epoch. Of the diversity of multiverse theories, the oscillationist model—a series of big bang to big crunch, expansion to contraction epochs—seems the closest fit to Whitehead's model of how cosmic epochs process, become, and perish, except that it appears he also thinks that cosmic epochs are spread out in space as well, each one born from chaos or the disintegration of a predecessor epoch and existing in causal independence of the others.[8] As noted above, there is also a rough correspondence between the larger framework of M-theory and Whitehead's notion of a geometrical society that harbors the existence of cosmic epochs. All of the detailed findings of twentieth-century cosmology are, of course, absent in Whitehead's theory, but disagreements in the variations of multiverse theory aside, the basic insights can be adapted to the general framework that he constructed. The major affinities include the following:

- What we call our universe or cosmic epoch is simply one finite element in an infinite ensemble.

- The new universe emerges from the disintegration or re-collapse of the old.
- The laws of nature change from epoch to epoch or universe to universe.
- Cosmic epochs or universes other than our own are unobservable, but are seen as a necessary conjecture in theory.
- The multiverse hypothesis resulted in part from a quest for an ultimate unified theory in both Whitehead and contemporary cosmology.

Whitehead continued to use the term "universe" to refer to the totality of what is, namely the whole scheme of the extensive continuum, whereas contemporary multiverse theorists refer to what he calls a "cosmic epoch" as one universe among a multitude of universes. What was previously believed to be the totality has been surpassed by a new theory; both Whitehead and contemporary cosmologists have contributed to this enlargement of thought about the structure of reality.

As for the contrasts between Whitehead and contemporary multiverse views, there is one major difference in which the laws of nature are understood to change. Whitehead thinks that the fundamental laws of nature change from epoch to epoch. In most contemporary views, by contrast, there must be one basic, unified theory of physical laws that applies to all universes in the multiverse, but gives rise to different local laws due to different outcomes of symmetry breaking. Rees, for example, thinks the exact layout of planets and asteroids in our solar system or even the structure of galaxies in our universe are accidents of history and are therefore arbitrary, so "*the underlying laws governing the entire multiverse may allow variety among the universes*" (*Cosmic* 173). The local by-laws are variations of the more stable laws in the grander perspective. The search for a TOE presumes a fundamental stability in the ultimate laws even if there is local variation.

This difference can be explained by a difference in ultimate metaphysics. Whitehead's metaphysics is one in which process is the fundamental principle of reality; physical laws change with the advance of novelty. Contemporary cosmologists and physicists seldom, if ever, express their views in metaphysical terms. Nonetheless, in so far as there is some basic ontology underlying multiverse views, theorists appear to embrace a classical field theory as a rough model for the TOE, but the field appears to be interpreted along the lines of substance as a matrix of becoming for the individual universes. By "substance" here I have in mind the traditional notion of extension—that which remains the same throughout change. The dispositional properties determine the varying intensities of the field but the field itself provides for a stability in which cosmologists seek the fundamental laws. M-theory, for example, conjectures a receptacle, a higher-dimensional super-space, in which the different universes emerge. And even in the case of the oscillating model of a single-line succession of universes, there is still the notion of persistent laws throughout the collapse of predecessor universes. Some physicists think that the different forces—gravitation, electromagnetism, weak and strong nuclear interactions—are united at extremely high temperatures (10^{32} ° K) and become differentiated through spontaneous symmetry breaking as the temperature drops (see Weinberg, *First* 145-46; Rees, *Before* 152-53). The outcomes of the symmetry breaking might be different on different occasions, but statistical predictions from the basic unified theory would describe the different local by-laws in each rebound (see Hawking 63). The TOE seeks the ultimate laws in the ensemble or infinite sequence that are unchanging. In this way there is a lawful change of the local by-laws in each universe.

It is clear on this point that Whitehead's view will be unacceptable to most modern cosmologists since it will appear to violate the basic premise behind the search for the TOE. If, however, we keep in mind that he has a hierarchy of order whereby the societies of cosmic epochs are harbored within the geometrical society and beyond that, the society of pure extension, the stability of more general laws are to be found in these larger societies. Whitehead's point is that the nature of the laws must be based on the nature of the things to which they refer; if the things change, then so do the laws. But as we ascend the extensive continuum, the change in the wider societies is so miniscule that the laws at this level appear to be permanent. The problem, however, is that these laws are mathematical, geometrical, and merelogical rather than physical laws of nature. Rees, who argues for a complementarity between chance and necessity in the laws governing the production of the individual universes, nonetheless concedes that there is no consensus among physicists on the issue: "there could be a unique physics; there could, alternatively, be googles of alternative laws" ("Cosmology" 65). In this respect, Whitehead's view is not ruled out.

Critical evaluation: speculation run amuck?

Cosmology has arrived at a critical juncture. The multiverse hypothesis seriously entertained by the mainstream of physics challenges our traditional conception of science, one that has emphasized the necessity of observational or experimental corroboration. Detractors therefore argue that the mulitverse hypothesis is: (1) wildly speculative, unobservable and untestable, and (2) a violation of Occam's Razor in that it multiplies entities (or universes) beyond necessity and results in an aesthetically ugly theory. If universes or cosmic epochs are disconnected from our own and therefore unobservable in principle, then there is no empirical means of corroboration. As some physicists have charged it is not science at all, but rather metaphysics (Davies 491), always a disreputable endeavor for any serious scientist. Proponents counter that there is a price to forswearing cosmological speculation. Our hubris and lack of imagination in the past have been an obstacle to scientific progress. In this connection the dismissal of the multiverse hypothesis on the basis of our failure to make the necessary observations *from our vantage point* has far too many similarities to previous episodes in the history of physics where we have underestimated the vastness of the physical world (Tegmark 100).

By Whitehead's very definitions of "metaphysics" and "cosmology," it is clear that the highly speculative multiverse hypothesis falls within the province of metaphysics, but since he never embraced a sharp dichotomy between metaphysics and science, the scientific status of the theory of *cosmoi* was not a matter of concern. He rejected the traditional concept of metaphysics as a purely *a priori* endeavor and instead advanced the notion that it is the general end of theory that originates in natural science (*PR* 3-17). Science begins in the general description of observed fact, but Whitehead notes that the impulse toward speculation is grounded in the unrest with which scientists are confronted. Hubble, for example, thought our knowledge fades rapidly with increasing distance; when we have exhausted our empirical resources, the limits of our telescopes, etc., we then pass into the "dreamy realm of speculation" (202). Dreamy or not, the speculation is necessary. Lack of satisfaction with simple description or even the *general* description of observed fact is the justification of speculative extension. This urge toward an *explanatory* description is the basis for the continuum between science and metaphysics (*AI* 164). In *The Function of Reason*, Whitehead describes the necessity of metaphysics as arising from the fatigue of methodology and the need for the refreshing novelty in answering fundamental questions (22-23). Positivism is just one example of methodology, of strict adherence to observation, which the history of science itself demonstrates is untenable.

The evidence for other cosmic epochs is indirect; it is at best an inference from what is observed in our cosmic epoch. Thus the hierarchy of societies beyond our cosmic epoch must be considered metaphysical in the sense that it is an extension of theory beyond the observable, yet it is clear that our epoch must be set in a larger society that serves as its environment and it must have originated from the disintegration of its predecessor epoch. Whitehead thus argues that the inference is justified by the search for a more complete theory. He described his theory as a "conjecture," (*PR* 96) but it appears to be a conjecture that is necessary to achieve the goal of complete unification. Beginning with Maxwell's electromagnetic theory to grand unified theories and ultimately the TOE, unification has been a central goal in modern physics. From his earliest foray into the philosophy of physics, Whitehead was preoccupied with his own version of a TOE, one that attempted to unify the natural sciences in a metaphysics of process. This, I take it, is what he means by the urge toward *explanatory* description taken to its ultimate conclusion.

The sharp boundary between metaphysics and science on the basis of observability is faced with an undeniable difficulty provided that we accept the basic idea of an expanding universe. What is observable is limited by two horizons: *the technical horizon* determined by the sophistication of our telescopes at present and *the speed-of-light horizon* determined by the present rate of acceleration (Rees,"Cosmology" 61). With the development of more powerful telescopes in the future, more galaxies will be revealed, thus extending the technical horizon. Beyond that horizon, if expansion continues to accelerate, light from the most distant galaxies will never reach us and therefore remain unobservable in principle; but if the expansion decelerates at some point, resulting in recollapse, those galaxies will be visible in a very remote future. Our cosmic epoch or universe extends beyond our present 10-20 billion-light-year horizon; this is not metaphysics, but rather an inference from observed fact. The inference to predecessor and contemporary universes is admittedly greater, but the objection that they are ruled out by the observability criterion loses all force when we realize that the boundary between observable and unobservable is blurred by the dynamics of expansion.

Even Karl Popper, whose criterion of falsifiability would rule out the multiverse as science, recognized that metaphysics is an inevitable precursor to science, as a sort of embryo in the development of scientific hypotheses (*Postcript* 199-211). The question remains, however, as to whether the multiverse hypothesis is testable and therefore falsifiable. Is there any conceivable test in which the hypothesis could be refuted? The physicists, as expected, disagree, but as theory guides experiment and experiment further refines theory, there are hints of what future experiments can be conducted. Just as Einstein's theory of general relativity took more than fifty years before any reliable tests could be conducted that gave results with better than ten percent accuracy, twenty-first century physicists have outlined generally the sorts of testing that could in principle falsify particular multiverse hypotheses (Rees, *Cosmic* 171-72; "Cosmology" 66-74).[9] The multiverse hypothesis is not part of accepted, fundamental physical theory at present, but it is not irredeemably untestable; as a speculative idea currently considered as a solution to many problems, it could join the ranks of accepted theory if it becomes testable.

Regarding the second major objection to multiverse theory, the history of physics has demonstrated that simplicity in theories is the result of successful unification, as for example is the case in Newton's law of gravitation or Maxwell's equations of electromagnetism. Multiverse theories seek the same result in unification, but pay a high price in ontology, analogous to set theory in mathematics. Whitehead's famous quip on the subject is instructive: "The guiding motto in the life of every natural philosopher should be, Seek simplicity and distrust it." He argued that every age prides itself for having discovered "the ultimate concepts in which all that happens can be formulated," but the problem is that we fall into the trap of "thinking that the facts are simple because simplicity is the goal of our quest" (*CN* 163). Occam's Razor remains a guiding principle for the development of eloquent and beautiful theories, but not to the point of restraining speculation when the sheer complexity and magnitude of things suggests otherwise. Whitehead was always clear that reality is complex beyond our apprehension and our ability to express our apprehension; oversimplification is the ever-present danger in philosophy and science.

Conclusion

Whitehead's theory of cosmic epochs might very well appear quaint to the physicist steeped in contemporary string theory or inflationary cosmology. There is no doubt that his theory offers little in terms of detailed science or a fruitful direction for testing multiverse theory. The point, however, is not what Whitehead contributes today, but rather how well he pioneered a general framework of multiverse theory roughly seventy years before such theories began to enter the mainstream of physics. Whitehead's genius lies in his power of generalization, particularly in his formulation of a metaphysics from the early advances in twentieth-century physics. He saw early in the game that the breakdown of the Newtonian paradigm required a new unifying concept to bring together the fragmentary theories of physics, from the large-scale structures determined by gravity to the small-scale energetic vibrations. Part of this project involved his theory of cosmic epochs and a process metaphysics that explained their emergence and decay. Many physicists such as David Bohm, Henry Stapp, Abner Shimony, Shimon Malin, and Timothy Eastman have become champions of Whitehead's philosophy for the general frameworks, the ontological foundations, and unifying concepts he provided rather than the particular details. Whitehead also weighs in on the contemporary debate concerning the scientific status of the multiverse conjecture. Physics without speculation is sterile. Some metaphysical daring is required to break the cake of custom and conjure fresh perspectives—ones that will need to be formulated specifically and result in the possibility of testing to be taken seriously.

Plato famously said in his masterpiece of cosmology, *Timaeus*, that any account of the cosmos is at best a likely story. That is, as mere mortals "we ought to accept the tale which is most probable and inquire no further," for the universe is a process of becoming and so are our accounts of it (29d). Indeed the idea of a final theory in physics is a receding horizon perhaps for the very reason Plato gave. It is in this connection that Whitehead praised the *Timaeus*: "what it lacks in superficial detail, it makes up for by its philosophical depth" (*PR* 93). Multiverse theory, whether that postulated by Whitehead or contemporary cosmologists, might very well be a likely story, but in our quest for enlarging our understanding by theoretical unification, it appears to be a rational development even if disparagingly metaphysical.[10]

Notes

1. Whitehead's theory of cosmic epochs is not to be confused with the *a priori* investigations into the nature of alethic modalities in the fashion of Gottfried Leibniz, Saul Kripke, and Alvin Plantinga. Nor is he advancing an argument for modal realism in the manner of David Lewis, that all possible worlds are real. Whitehead's cosmic epochs are more in accordance with what cosmologists refer to as parallel worlds or a multiverse comprised of a plurality of universes. The cosmologists, in contrast to the philosophers, are engaged in *a posteriori* investigations into the nature of the physical universe and scientific theorizing arising from these investigations. Possibilities in Whitehead's metaphysics are treated in his theory of eternal objects.

2. See Weinberg's *Dreams of a Final Theory,* chapters IX and X, and Greene's *The Elegant Universe,* chapters 14 and 15. Beyond the unification of the standard model and general relativity, if a final theory is understood in the context of superstring theory or M-theory (encompassing the multiverse hypothesis), there is then even more basis for the comparison with Whitehead's theory of cosmic epochs, for the ultimate theory would extend beyond the unification of forces in our limited cosmic epoch. See especially Greene's *The Elegant Universe,* 368-69.

3. When Whitehead wrote *Process and Reality* in 1928, the only known particles were electrons and protons, the only known forces gravity and electromagnetism.

4. There is a difficulty here of understanding in what sense the different cosmic epochs stand in relation to one another without some single measurement of time and space—or in a superspace—for all *cosmoi*. The view seems to assume a sort of Newtonian absolute time and space, but such conceptions can only make sense relative to some individual epoch. This problem is also recognized by multiverse theorists. See, for example, Rees' *Our Cosmic Habit,* 170.

5. In this scenario, once God created the physical world the structure (including the laws of nature) was set. Laws of nature are necessary in the sense that they were created by God, who is perfect, good, and therefore not deceiving; once set they do not change with the passage of time. The laws are universal in the sense that there is only one extended substance and the laws apply throughout this one universe. See Descartes, Part 2, XXI-XXIII, XXXVI-XXXVII, LXIV; Part 3, I; and Kneale. Also see Popper's *The Logic of Scientific Discovery,* 430-31.

6. The one exception in the physics literature is *The Anthropic Cosmological Principle* by Barrow and Tipler (192-93.) I owe this reference to Roland Faber.

7. The term "multiverse" was first used by William James in 1895. (See James 43.) In cosmology, however, the idea has been advanced at least as far back as Nicholas of Cusa in the 15th century and was espoused by Giordano Bruno in his *On the Infinite Universe and Worlds* (1584). Bruno's proposal was just one of the heresies that brought him before the Inquisition and had him burned at the stake at the Campo dei Fiori in Rome in 1600.

8. When most commentators on Whitehead's metaphysics discuss this topic they seem to assume there is only one cosmic epoch at a time, i.e., that the *cosmoi* form a single-line sequence. One exception is Rem Edwards, who, in his 2000 article in *Process Studies*, notes that Whitehead affirms contemporary cosmic epochs spread out in an infinite Superspace (87).

9. One such promising observational test for the eternal inflation hypothesis has been conducted using cosmic microwave background data. Bubble collisions with other universes produce inhomogeneities in our inner-bubble, thereby resulting in observable signatures that are detected in the cosmic microwave background. See Feeney, et al.

10. This paper was presented at the Claremont Graduate University, California State University-Los Angeles, California State University-Northridge, and the University of Edinburgh. I wish to thank John Cobb for the invitation to present this paper in Claremont and Nicholas Maxwell, George Allan, Martin Rees, John Lango, Takashi Yagisawa, and John Llewelyn for helpful suggestions and much-needed critical evaluation.

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