Mathematics, Cosmology, and the Contingent Universe

THE REV. BRUCE A. HEDMAN, Ph.D.

Associate Professor
Department of Mathematics
University of Connecticut
West Hartford, CT 06117

To say that the universe is "contingent" means that it need not be the way it is. A contingent universe does not contain within itself a sufficient explanation of itself. Although the doctrine of contingence is an article of faith which transcends scientific demonstration, modern cosmology has made new discoveries and is asking new questions which point to the contingent character of the universe. Does the universe have a "beginning?" Is the extent of the universe finite? Does mathematical undecidability preclude any system from containing within itself a sufficient explanation of itself? Classical physics thought of the universe as closed, necessitarian, and incontingent. Thus, certain questions basic to Christian thought were dismissed out-of-hand as invalid. An incontingent universe precludes any revelation from outside itself. Modern scientific models of the universe offer a more hospitable arena for the discussion of Christian theology.

Purpose

I propose to indicate: 1) ways in which modern cosmology points to the contingence of the universe; and, 2) guidance of the doctrine of contingence can lend to cosmological thinking.

Definitions

To say that the universe is "contingent" means that it need not be the way it is. Its particular space-time structure is not a necessary consequence of its existence. Alternately, an "incontingent" universe would possess a necessary structure; such a world would be uniquely determined by just the requirement of self-consistency. A contingent universe does not contain within itself a sufficient explanation of itself. For an incontingent

This paper was supported by the University of Connecticut while the author was on sabbatical leave, fall term, 1988. It was read at the Consultation on Theology/Science, Center for Theological Inquiry, Princeton, New Jersey, October 23, 1988.

universe one conceivably could find a single, consistent theory from which one could deduce uniquely the structure of the world, including the numerical values of all constants of nature. A contingent universe will here be termed "open;" an incontingent universe will be termed "closed."

The contingence of the universe has played a crucial role in the development of modern, experimental science. The majority of scholars in the ancient world did not appreciate the contingent character of the world, and so attempted to reason about the world *a priori*. Modern experimental science owes a debt to the Medieval doctrine of contingence, as scholars recognized that to answer questions about nature required asking nature itself. Although Newton himself denied that "the world exists by necessity and by the same necessity follows the laws proposed," Newtonians interpreted his laws as determining the entire structure of the "closed" universe.[1] This reductionism was recognized as inadequate only in the wake of field theory, which appealed to non-particle structures, "fields," as first suggested by Michael Faraday and later formalized by James Clerk Maxwell. Today, contingence is an issue between the two options considered by theoretical cosmologists with regard to the way the universe began. Is there only one type of universe that is logically possible, which would uniquely determine all the presently unexplained values of the fundamental constants of nature? Or are there arbitrary elements in the composition of both the structure of the universe and its fundamental constants?[2]

Limitations

If the universe is contingent, and so does not contain within itself a sufficient explanation of itself, it would seem odd were we able to prove this fact from within the universe itself. The doctrine of contingence is an article of faith, which, I believe, transcends scientific demonstration, and is implied by God's sovereignty in the *creatio ex nihilo*. Aquinas held that the very idea that the world did not always exist could be known only by revelation and not reason.[3]

Likewise, incontingence begs proof. Those who favor a "closed" system tend to believe in the "eternity of the universe," which has been called the "first article of the secular faith."[4] Incontingence has often been a tacit presupposition of many scientists, but is not inherent to the scientific method.

Our convictions about the contingent nature of the universe grow out of God's dynamic and free activity rooted in the revelation of Jesus Christ. Christians believe that the Incarnation was a unique event which cannot be understood just in terms of this world, as the Arians had tried to do. The Incarnate Christ transcended this world, and, far from being explained by it, became the explanation from which the world itself drew its meaning. The Logos entered into this world, taking upon himself human nature, and became the Word of God incarnate, speaking to us from within, but above, the created order.

> It is because all contingent realities . . . have their final truth in God's Word rather than in themselves, that in their employment by the Word himself they may serve the communication to us of a knowledge of God that is quite beyond us. But because these created realities which God uses as the medium of his communication have their final truth in his Word rather than in themselves, they are in themselves far different from what they are in our knowledge and formalization of them.[5]

I do not believe that the contingence of the universe can be decided by the scientific method. In particular, we should avoid any attempt to "prove" *creatio ex nihilo* by an appeal to "Big Bang"-type theories. At present, cosmology has no adequate explanation of the origin of the Big Bang. Some cosmologists theorize that the Big Bang resulted from quantum relativistic effects in the virtual vacuum.[6] Although this model has some experimental support, it remains controversial among cosmologists. Yet, an appeal to a "God of the gaps" as the source of the Big Bang (i.e., "The Big Banger"?)

Bruce Hedman is an associate professor of mathematics at the University of Connecticut, where he has been on faculty since 1982. He is, also, the pastor of the Abington Congregational Church, which boasts the oldest meetinghouse (1751) in the state. He obtained a Ph.D. in mathematics from Princeton University in 1979 and a Masters of Divinity from Princeton Theological Seminary in 1980. Ordained by the Presbytery of Philadelphia in 1980, he has served six churches in New Jersey, Pennsylvania, North Carolina, and Connecticut. He has written a dozen research articles in graph theory, and currently is working on a book, Infinity in Mathematics and Theology.

only invites criticism and retraction if a quantum theory of gravity is successfully formulated.

Cosmological Pointers to Contingence

Although the contingence of the universe is not decidable scientifically, nevertheless modern cosmology has made new discoveries and is asking new questions which point to the contingent character of the universe. These changes in the foundations of cosmology have far-reaching implications for a unitary understanding of the created universe.

Those who favor a "closed" system tend to believe in the "eternity of the universe," which has been called "the first article of the secular faith."

Through most of the nineteenth century, mechanists thought of the universe as closed, self-contained, and self-explanatory. Such an eternal and divine nature bars the possibility of revelation.[7] Questions about origin and purpose, which contingence raises, were not even considered legitimate by the mechanists. Today, however, such questions are discussed in scientific papers and are regarded as amenable to scientific inquiry. Questions about first and final causes, which were excluded by a single-minded emphasis on efficient causes, have returned in discussions about the Big Bang and the Anthropic Principle.[8]

The first cosmological indicator of contingence I want to discuss is time. Mechanists thought of the universe, and hence of time, as without a beginning. This eternity of space and time is a corollary of incontingence, as otherwise one is forced to seek an origin of the universe outside of the universe itself. However, today modern cosmology has found evidence indicating a finite age of the universe of about 10 to 20 billion years. This age was arrived at by studying the transformation of the galaxies as we now observe them. The scientific account "does not go beyond that, to the singularity when there was nothing and then suddenly the inconceivably energetic seed for the universe abruptly came into being. Here science seems up against a blank wall."[9]

The strongest evidence for the finite age of the universe is its observed expansion, one of the "great intellectual revolutions" of this century.[10] Mechanists thought of the universe as static. Einstein's *General Theory of Relativity*, published in 1916, predicted an expanding or contracting universe. But such a conclusion was so unthinkable that Einstein introduced the "cosmological constant," a hypothetical anti-gravity force, so that a static universe would result.[11] But in 1922, the Russian physicist Alexander Friedmann mathematically formulated general relativity without the cosmological constant, and advocated the expansion of the universe. This idea received observational support in 1929 when Edwin Hubble analyzed the red shift in the light earth receives from the stars, and concluded that all galaxies are moving away from earth at a speed directly proportional to their distance from earth. By extrapolating backwards from this expansion, one arrives at a singular point of infinite density some 10 to 20 billion years ago, the point of origin of the observable universe from which all matter and energy were thrown out in the "Big Bang." Alternative theories have been suggested to explain the observed recession of the galaxies. However, these have failed to account for two further observations, as can the Big Bang theory: the isotropic background radiation of 2.7° K (for which discovery Arno Penzias and Robert Wilson of Bell Laboratories were awarded the Nobel Prize in 1978), and the apparent percentage of hydrogen and helium in the universe.

Not only do modern cosmologists consider space-time as having a beginning, but they recognize a property of time which is difficult to explain within the universe itself. Physicists speak of "arrows of time," a term, like "vector," which implies unidirectionality. In at least two ways the universe induces a direction upon time which so far appears irreversible. First, by its very origin and subsequent expansion the universe has an "absolute clock" which distinguishes between prior and subsequent events.[12] Secondly, the Second Law of Thermodynamics implies that all closed systems proceed to states of increasing entropy, or disorder. Attempts to explain the irreversibility of time have not been successful.[13] Time irreversibility is an important characteristic for those who see the universe as an arena

We should avoid any attempt to "prove" creatio ex nihilo *by an appeal to "Big Bang"-type theories. . . . An appeal to a "God of the gaps" as the source of the Big Bang (i.e., "The Big Banger"?) only invites criticism and retraction.*

for some higher purpose, or teleology, toward which history moves.

A second cosmological indicator of contingence I want to discuss is the finite extent of the universe. The mechanists of the last century thought of the universe as being of infinite extent in all directions. The infinity of space is a corollary of incontingence, as otherwise, one is forced to consider a "boundary" to the universe and ask about what lies "beyond" that boundary. General relativity predicts the universe has finite mass and is finite in extent. Light is no longer thought of as traveling indefinitely in a straight line, but follows a closed geodesic path whose curvature is determined by the shape of space-time. If the cosmological estimates of the Big Bang are correct, and if light speed is the universal maximum velocity, then the observable universe has a radius of 10 to 20 billion light years.

A third and final indicator of contingence I want to discuss is the implication of Gödel's theorem for cosmology. Toward the end of the nineteenth century, the "formalist" school of mathematical interpretation sought to reduce all of mathematics to a single, logical system. In 1900 David Hilbert posed twenty-three unsolved questions which were to guide the progress of mathematics into the present day. His second question asked for a demonstration of the consistency of the axioms of arithmetic. A decade later Bertrand Russell and Alfred North Whitehead published *Principia Mathematica*, a minutely detailed program which showed that all known results of pure mathematics could be derived from a small number of axioms. But this left Hilbert's second question unanswered. In 1931 Kurt Gödel published the surprising result that a finite, internal proof of the consistency of the axioms of arithmetic was impossible. He showed that, in any system large enough to contain at least the arithmetic axioms, there are statements in the language of that system whose truth value is undecidable by that system. If then an undecidable statement is merely appended to that system as an axiom, that now-larger system will again contain other undecidable propositions. That is, undecidability cannot be simply "legislated" away.

The far-reaching implications of Gödelian theorems are still being realized. For mathematics, Gödel's result meant the end of a purely formalistic interpretation of mathematics as a logical system. Mathematical truth is larger than any axiomatic system. Stanley Jaki appears as the first to have developed Gödelian implications for cosmology.[14] There will always be truths about the universe which are beyond any formal cosmological theory. Seemingly, this supports the contingent character of the universe, as no single theory could determine completely the structure of the world. "Doomed also, as a result [of Gödel's theorem], is the ideal of science—to devise a set of axioms from which all phenomena of the natural world can be deduced."[15]

There will always be truths about the universe which are beyond any formal cosmological theory.

John Barrow has questioned the relevance of Gödel's theorem to science.[16] The type of undecidable proposition guaranteed by Gödel is self-referencing. Alfred Tarski suggested limiting admissible statements to only those which do not mix language with meta-language. Given this restriction, Barrow then asks how we know that there will be significant undecidable cosmological statements.[17] He asks rhetorically for just one example of an undecidable proposition which had stumped mathematicians and had led to a significant scientific breakthrough. In answer I cite the parallel postulate, the undecidability of which led to the creation of new geometries which eventually became the language of relativity theory. Another significant undecidable proposition is the Continuum Hypothesis.[18]

Guidance Contingence Lends Cosmology

The great problem confronting particle physics is the unification of the four known forces in the universe—electromagnetism, gravity, weak, and strong interaction—the so-called "unified field theory." Such would have profound implications for cosmology, as it would explain the particle interaction during the cosmic "cooking" of the cosmic "yolk" in the Big Bang at which temperatures and density gravitational attraction between subatomic particles becomes significant. Such a unifying theory between electromagnetic and weak forces has been experimentally confirmed ("electroweak theory") in recent years at the European Center for Nuclear Research (CERN). A promising unification between electroweak and strong forces has been proposed (the "Grand Unification Theory" or GUT). Accelerators do not have the energy to simulate the temperatures of the cosmic cooking needed to unify the GUT forces with gravity, which at normal temperatures are 10^{39} times weaker than electromagnetic force. A unified field theory does not appear to be readily forthcoming, but nevertheless may be achieved someday.

We must, however, make a distinction between a unified field theory and a "Theory of Everything," which claims to explain the structure of the universe uniquely and completely. A Theory of Everything is not possible in a contingent universe. A belief in such a Theory of Everything appears "unashamedly in scientific papers, but it is essentially a religious or metaphysical view, in the sense that it rests only upon an unstated axiom of faith."[19]

In 1965 Steve Hawking realized that if he reversed the direction of time in Roger Penrose's theory about black holes he could describe the Big Bang singularity. He published a joint paper with Penrose in 1970 which developed the mathematical techniques to prove that there must have been a Big Bang singularity provided only that general relativity is correct and the universe contains only as much matter as we observe.[20]

It is ironic that the cosmologist who worked so hard to convince others of the Big Bang singularity has now changed his mind. For the last ten years, Hawking has speculated about a quantum theory of gravity which would permit the absorption of a black hole. Furthermore, he surmises that a time-reversal argument similar to his 1970 paper will account for the appearance of the Big Bang from quantum gravitational effects in the virtual vacuum. He seeks, then, to avoid any singularity or beginning to the universe. In his own words:

> The quantum theory of gravity has opened up a new possibility, in which there would be no boundary to space-time and so there would be no need to specify the behavior at the boundary. There would be no singularities at which the laws of science break down and no edge of space-time at which one would have to appeal to God or some new law to set the boundary conditions for space-time. The universe would be completely self-contained and not affected by anything outside itself. It would neither be created or destroyed. It would just BE.[21]

Although today it has little experimental support, such an integration of the quantum and relativity theories would be a revolutionary intellectual triumph. But Hawking claims too much for it as he elevates such integration to a Theory of Everything. In his attempt to get behind the Big Bang singularity, he thinks he can remove all singularities. I believe that the doctrine of contingence in a Gödelian form would lead us to expect the scientific enterprise to generate an unending hierarchy of widening theories, earlier theories being limiting cases of their successors. Singularities, or points where a theory breaks down, play a vital role in the pursuit of broader theories. Thus, scientists should seek to get behind singularities, as they expand their understanding of nature, but should not expect ultimately to remove all singularities by achieving some comprehensive Theory of Everything. We are exploring a universe "open" to an ever-widening understanding of its infinite pattern and simplicity, not "closed" within any one self-contained model of its structure.

Conclusion

Modern scientific models of the universe offer a more hospitable arena for the discussion of Christian theology than did their predecessors in the last century. When the universe was thought of as closed, necessitarian, and incontingent certain questions basic to Christian thought were dismissed out-of-hand as invalid. An incontingent universe precludes any revelation from outside itself. Today, scientific thinking about the contingent universe allows a rapprochement with Christian thinking, that together they may work toward an interdisciplinary understanding of the created universe.

NOTES

[1]Quoted in Barrow, John D., *The World Within the World*, (London: Oxford University Press, 1988), p. 323.

[2]Barrow, *op. cit.*, p.360.

[3]Aquinas, Thomas, *Summa Theologica* III, 46, 2. "The reason for this is that the newness of the world cannot be demonstrated from the world itself. For the principle of demonstration is the essence of a thing."

[4]Jaki, Stanley L., *Cosmos and Creator*, (Edinburgh: Scottish Academic Press, 1980), p. 108.

[5]Torrance, T.F., *Christian Theology and Scientific Culture*, (New York: Oxford University Press, 1981), pp. 128–129.

[6]Hawking, Stephen W., *A Brief History of Time*, (New York: Bantam, 1988), p. 136.

[7]Jaki, *op. cit.*, p. 68.

[8]For an excellent survey, cf. Neidhardt, W. Jim, "The Anthropic Principle: A Religious Response," *Journal of the American Scientific Affiliation*, Dec. 1984, pp. 201–207. This paper portrays the contingence of the universe as intimated by the enormous degree of its specificity, the fascinating details of which I do not have space here to discuss.

[9]Gingerich, Owen, "Let There Be Light: Modern Cosmology and Biblical Creation," in Frye, R. (ed.), *Is God a Creationist?* (New York: Charles Scribners, 1983), p. 128.

[10]Hawking, *op. cit.*, p. 39.

[11]This term, however, does have contemporary use in regards to an "anti-gravity" phase among the GUT forces in the inflationary model of the universe.

[12]This term is used in Barrow, *op. cit.*, p. 234.

[13]Barrow, *op. cit.*, p. 367. Boltzmann has offered a subtle argument in favor of time-reversibility. But this is a technical question, over which there is little consensus. The interested reader is referred to the following: Davies, P.C.W., *The Physics of Time Asymmetry*, (Berkeley: University of California Press, 1974); Brush, Stephen G., *Statistical Physics and the Atomic Theory*, (Princeton: Princeton University Press, 1983); DiFrancia, G. Toraldo, *The Investigation of the Physical World*, (Cambridge: Cambridge University Press, 1976); Prigogine, Ilya and Stengers, Isabelle, *Order Out of Chaos*, (Toronto: Bantam Books, 1984).

[14]Jaki, Stanley L., *The Relevance of Physics*, (Chicago: University of Chicago Press, 1966), pp. 127–130.

[15]Boyer, Carl B., *A History of Mathematics*, (New York: John Wiley, 1968), p. 656.

[16]Barrow, *op. cit.*, p. 258.

[17]At the Consultation on Theology/Science at the Center of Theological Inquiry, Princeton, Dr. Christoph Wassermann, of the University of Geneva, pointed out the inherent significance of self-referencing statements. Whereas a scientific theory may be able to avoid self-referencing statements within itself, as soon as the theory claims to be true it has made a self-referencing statement. At the same Consultation, Dr. David Wilcox, of Eastern College, St. Davids, Pennsylvania, actually used self-referent statements in his proposed model of the code sequence for amino acids on the DNA. The definition takes the form of a large riboprotein which can recognize both the code words and the amino acid which it represents.

[18]Cohen, P.J., "The Independence of the Continuum Hypothesis," *Proceedings of the National Academy of Science*, 50(1963), 1143–1148; 51(1964), 105–110.

[19]Barrow, *op. cit.*, p. 338.

[20]Hawking, *op. cit.*, p. 50.

[21]*Ibid.*, p. 136.