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Religion and Cosmology

Cosmology, the systematic attempt to understand the universe taken as a whole, has in the past been closely intertwined with religious belief. Only within the last half-century or so has a specialized science of cosmology developed that makes no explicit mention of God and in which human concerns appear to dwindle to insignificance in the scale of cosmic time and space. Before that, it often seemed that any serious investigation of the ordered universe led to a Mover or a Designer who could be assimilated to the being whom men and women worshipped as God.

Introduction

In this brief essay, the outlines of this story will be traced, and the focus will be primarily on the religions of the West in which God came to be understood as the creator of the universe, and in which the dealings of God with men and women were set down in a sacred book. (The corresponding story in the East takes a very different shape.) Long before these religions appeared, of course, people looked at the skies in awe and saw in the regularities of the movements of the celestial bodies a testimony of the Gods, the powerful beings on whom human affairs depended. Why that early association of sun, moon, and planets with the gods? The dependence of human life on the sun's bounty was evident enough, as was the importance of the seasons, which were most clearly marked by the phenomena of the skies. The immensity of the heavens, the invariability of the celestial motions, marked off the bright lights of sky from all the familiar things of earth. And among the celestial lights a few seemed to have a special role because their motions were more complex than the single daily circle that all the others followed.

For the Babylonians, the ancient people who developed the most detailed knowledge of the celestial movements (and who were fortunate in their choice of semipermanent clay tablets for their records), cosmology and religion were very close (see MESOPOTAMIAN COSMOLOGY). In omen lists going back almost two millennia B.C., significant celestial appearances like eclipses and first and last appearances of planets over the horizon were correlated with such significant events as war, plague, or drought in a designated part of the kingdom. Gradually, records came to be kept of these appearances; by the fourth century B.C., a sophisticated mathematics enabled the significant sky events to be accurately anticipated. What in the first place motivated this complex set of observational, archival, and mathematical practices was the belief that the intricate movements of the celestial bodies were significant for the affairs of man, that the skies served, as it were, as the message board of the gods. The cosmic order thus had a direct religious significance; cosmology testified to religious belief, and religious belief prompted the construction of a detailed cosmology. Those who were charged with this construction, the astronomer-astrologers (the Magi of the gospel story of the three wise men "from the

East" who followed a star to Bethlehem), were also priests of the state religion, affiliated with the temple and serving as interpreters of the gods.

The tie between cosmology and religion was not always as specific and as direct as it was in ancient Babylonia. But as we range over what we know of the beliefs and practices of the ancient world, we commonly find an association of specific planets with specific gods, as well as a conviction that the configuration of the night sky had a special religious significance. Furthermore, the seasonal order of equinox and solstice was universally celebrated and, indeed, seems to have provided a framework for religious ritual in general. The discovery of an underlying order of the seasons or of celestial appearance was itself a religious act. One function of religion was to reassure men and women of the reality of this order, on which human life so obviously depended.

At an even deeper level, there were myths of origins: how the world first came about, how seas and land separated off and mountains were formed, and who the first humans were and what their role in the story was. All this was seen as the mighty work of the gods, beings cast in a human image and yet recognized as being more than human. Order and disorder alike were of their making; they were worshipped and feared and placated. Always there was the attempt to understand their purposes, for only thus might the whole, and the relations of humans to that whole, be understood.

One of these religious traditions has a special interest for us. The Hebrews celebrated Yahweh as their special protector. To him they were bound in solemn covenant. It was Yahweh who had brought them out of Egypt and displaced other peoples to ready for them a new land, the land he had promised them. As they reflected on the powers of Yahweh, the conviction deepened that he was not just one god among others; he was the potent creator of all that is—of earth, sun, moon, and stars—and the power who had first separated land and water and fashioned all the kinds of living things. In some of the most evocative poetry ever written—in *Isaiah*, *Job*, and *Psalms*—a being gradually took shape who "tells the number of the stars and calls each by name" (*Ps.* 147), who "stretches the heavens like a tent [and] fixed the earth on its foundations," who "made the moon to tell the seasons and [told] the sun when to set" (*Ps.* 104). This is a being omnipotent and omniscient, on whom the entire universe depends and yet who cares deeply for human welfare. It is he who established the cosmic order, who perpetually holds back the forces of chaos, and who has communicated to his people a knowledge of how important a part of the whole is their own fragile history.

The universe is presented here as the work of a single being, who relates to men and women as a person would; knowledge of that universe comes either directly from Him by way of revelation or on the basis of human reflection on what His cosmic role may be. What is striking, in the context of our theme, is that there is no attempt to build a "scientific" cosmology like the Babylonian one, relying on systematic observation and mathematical analysis. The planets are not associated with particular gods; the heavens are not the continuing source of omens and portents that they were for the Babylonians. The gods do not have to be placated for the sun to begin its trip southward again after the winter solstice. Cosmology and religious belief are intertwined now in a rather different way. There is no strong religious incentive to pay attention to the details of the goings-on in the sky. The heavens display the glory of the Lord, but they carry no special messages beyond that. The cosmos is of God's making, and we can rely on the regularities he has built into it; but reflecting on God's power and his message is a better means to a true cosmology than a study of planetary movements would be.

Greek Cosmology

Beginning in the Greek-speaking world of the eastern Mediterranean around the sixth century B.C., a very different approach to a cosmology began to take shape. The first philosophers of ancient Greece were preoccupied, indeed, with cosmology, with questions about the origin and constitution of the universe (see EARLY GREEK COSMOLOGY).

But they tended to disconnect themselves from the myths of making that characterized earlier religious traditions. They sought to answer these questions in terms of homely insights into natural process and analogies shrewdly chosen from the repertoire of human making. The unspoken presupposition was that human beings, relying on their own unaided resources, *could* in principle provide plausible answers to such questions. Notions of reason, evidence, cause, and proof were gradually developed; one could seek a reasoned understanding of any given subject matter.

The first recorded Greek philosophers suggested plausible cosmogonies. Perhaps the world had come from an initial simple watery state, in which earth is deposited (as it is in lake bottoms), and water vapor (air) is given off. Or perhaps there is more than one primary element. Perhaps the kinds of living things originated from random configurations of organs and limbs, only a few of which could survive and propagate their kind. And so on. The details are familiar. What is important to our theme is that religious beliefs, whether about the Orphic deities or the Olympic gods, were not invoked. The role of Mind (i.e., Spirit or Soul) was sometimes emphasized but it was not associated with any specific religious belief or practice. Of course, such an emphasis left open a role for a causality beyond the human. But the impersonal and abstract character of Mind as mover and maker contrasted starkly with the earthy stories of the gods of Olympia. Democritus and his followers, indeed, took the process a long stage further and formally excluded the action of the gods from their conception of the universe as a whirl of atoms. And they decried the beliefs and practices of the popular religion as unworthy superstition.

The fate of Socrates bears eloquent testimony to the tensions that were beginning to destroy the ancient unity of cosmology and religion. Socrates, the tireless questioner of unsuspected presuppositions, was accused of impiety and of corrupting the youth of Athens. One (false) charge was that he had taught that the sun was no more than a "stone," an earthlike body, an offence for which Anaxagoras had earlier been exiled. What was at issue, in part, was philosophy itself and its proclivity for undermining traditions, religious and political. The growing resentment against the naturalism and rationalism of the "physicists" was finally visited on Socrates, who was, ironically, a critic of the very materialism of which his enemies so strongly disapproved. But it was not just a matter of doctrine, it was a matter of method. And Socrates was the exponent of a style of question and answer that would enable cosmologies to be constructed in a new manner, a manner that traditional religions would have either to recognize or to oppose.

After Socrates, the two greatest Greek philosophers, Plato and Aristotle, each produced a distinctive cosmology of the new sort; these cosmologies affirmed the existence of a God, but a God quite unlike those of the pantheon sanctified by the popular culture of the day. In one of his last works, the *Timaeus*, Plato constructed a "likely story," as he calls it, of a Demiurge (Craftsman) who is responsible for the manifest evidences of intelligence we find everywhere in the physical world (see PLATO'S COSMOLOGY). Plato had earlier shown the importance of form or idea in explaining how knowledge itself is possible, and had argued that the world of sense participates only imperfectly in the intelligible world of form. But imperfect though this participation may be, it is everywhere to be found; it is constitutive of the sense world, particularly of its mathematically describable aspects. Plato suggests a speculative geometrical atomism as an account of the underlying constitution of sensible things, but is skeptical of observational astronomy as a means to genuine understanding. The Demiurge is not a creator in the full sense but imposes form on a preexistent matter-space. The recalcitrance of that matter-space is responsible for the defects that are as evident in the sense world as are its intelligible aspects. Although the world is a cosmos, an ordered whole, the ordering is not complete, nor can there be a strict science of it. A study of that order (i.e., a cosmology) should terminate in a plausible affirmation of the existence of a shaping Intelligence. (Plato elsewhere speaks of a "world soul" as animating the whole; this would lead to a very different sort of cosmology.)

Aristotle adopted a different starting point for his cosmology (see ARISTOTLE'S COSMOLOGY). The final book of his massive work, the *Physics*, argues for the necessity of an unmoved Mover if the motions of the physical universe are to continue. The fundamental premise of his physics is that whatever is in motion must be kept in motion by something other than itself. A rigorous application of this principle shows that all motions, celestial and terrestrial, must terminate in a Mover (or Movers) able to cause motion in others although it is (or they are) itself (or themselves) unmoved. This motion is imparted to the spheres carrying the planets and is transmitted downward to earth. Eudoxus, a contemporary of Aristotle, had proposed an ingenious system of circular motions to account for the complex movement of each planet (including the sun and the moon). Aristotle converted this into an extraordinarily complicated system of fifty-five interlocking spheres. In this system the axis of rotation of each sphere was carried by the sphere next outside it, to which its poles were assumed to be attached. Each planet had a set of four spheres (three for the sun and the moon) and a set of "counteracting" spheres to cancel all the motions needed to explain the motion of that planet (save that of the sphere of the fixed stars), so that these "proper" motions were not transmitted to the next planet downward. The motion of each sphere was essentially the mechanical resultant of all the motions above it, plus an intrinsic motion proper to the particular sphere itself, for which the intelligence associated with that sphere was responsible. Here was cosmology, with a vengeance! Aristotle attempted, not altogether consistently, to reduce all physical motions to a single order on the basis of systematic astronomical observations, on the one hand, and mechanical-teleological principle, on the other. The primary natural science, physics, was completed by the postulate of a First Mover itself unmoved. The primary virtue of the construction was its explanatory force: the solid spheres *explained* the motions of the planets in an intuitively satisfactory way, although the system was far too cumbersome to be of practical use for purposes of prediction.

The First Mover could also be regarded as God, but it was nothing like the gods of traditional religion. It was pure act, a thinking being reflecting on itself, totally self-enclosed, in no way concerned for, or even aware of, the changing fortunes of mortals. Hardly accessible to prayer or relevant to ritual, it was an abstract explanatory principle incapable of animating faith or devotion. Aristotle could use the term *theology* to describe his "science of God," but his cosmology would have had little interest, one suspects, for the religious believers of his day.

Christianity

The advent of Christianity was to have two very different implications for cosmology. On the one hand, the *Genesis* account of origins suggested a tidy scenario of a making that was spread over six days, when all the kinds of things were brought abruptly to be by God. Cosmology would then be largely derivative from the Bible. On the other hand, the philosophical elaboration of the biblical notion of creation on the part of philosopher-theologians like Augustine and Aquinas gave an entirely new perspective on how cosmology and religion might be related at a deeper level.

Augustine developed, more fully than anyone before him, the consequences of taking God to be *fully* the Creator, responsible not just for the movement of, or the forms imposed on, matter but also for the fact that there *is* any matter in the first place. The Creator not only brings the universe to be from no preexistent makings, but also holds it in being at each moment of its existence. As Augustine sees it, the lord of heavens and earth evoked by the writers of Scripture brings time itself to be in the moment of creation. There is no time, he points out, at which the universe did not exist. The act of creation is a timeless act, an act outside time, since God is outside time. God's providence is thus woven into that single divine act from which the universe—past, present, and future—sprang.

Nature is whole and entire in its own right; the "seeds" of all natural kinds are implanted at the beginning—Augustine argues that the six days of the *Genesis* account have to be understood as metaphor—and the corresponding kinds appear when conditions are right. God's purposes in the natural order are brought about not by intervening (i.e., by overriding natural causality) but by ensuring that the desired result comes about naturally. It is not easy to make a consistent story of all this, particularly when one has to go on to imagine how such a timeless God could enter time and become an active participant in the story of human salvation. There has to be room for miracle and grace, and above all for the incarnation of God in the person of Christ. Augustine had to struggle to bring these diverse threads together, and was not always successful in doing so. One context in which he *did* succeed was in making room (in principle, at least) for an autonomous cosmology based on "sense-observation and necessary demonstration," as Galileo would later put it. Such a cosmology, if pursued in the proper spirit, would recognize in the wonders of the natural world the signs of God's creative action.

The rediscovery of Aristotle's "natural works" in the Latin West in the early thirteenth century led to further developments, as it had already done in the Islamic world (see MEDIEVAL COSMOLOGY). The naturalism of these works worried theologians: they seemed to present a self-contained world in no need of the divine, except for the sustaining of motion. And their conception of science as rooted in necessary principles challenged the religious view of the Creator as radically free in his choice of worldkind. Aquinas set out to show that one could be both an Aristotelian and a Christian, that the cosmology of Aristotle could coexist with the theology of creation. He argued, even more strongly than Augustine had, for the existence of real causal relations between created things, and hence for the genuineness of a natural science based on such causal relations. Although God is the primary cause of the existence and action of each creature, He has endowed these creatures with natures and enabled them to act on one another in ways we can discover and understand.

Aristotle's proof of a First Mover is now subordinated to a larger scheme in which the Creator is responsible not just for the motions of the material world but, more fundamentally, for its continued existence. The supplying of motion is simply one index of the entire dependence of the cosmos on its Creator. There is a tension here, nevertheless, between two ways of inferring to God's existence. One situates God, as the supplier of motion required by mechanical principle, within the cosmology itself. The other views God as a precondition to *any* cosmology, required by a metaphysical argument from the contingency of any material cosmos. If one accepts the first, as Aquinas did on the strength of Aristotle's physics, cosmology bears directly on religious belief, provided one can construe the god in whom the argument from motion terminates as the God who is central to theistic belief and practice. But as we shall see, this direct link between cosmology and religion was not to endure.

Copernican Challenge

Aquinas's blending of Aristotelian science and Christian theology did not persuade everyone. Shortly after his death, an assembly of French bishops issued a condemnation of many of the features of Aristotelian thought that they found objectionable (1277). Yet quite soon, opposition diminished and Aristotelian cosmology began to be comfortably linked with Christian belief. A new philosophical critique of Aristotelian thought was mounted by the nominalist followers of Ockham, but most Christian thinkers seemed to find Aquinas's synthesis satisfactory. People's imaginations were shaped by Aristotle's concentric model of the universe, with the earth at the center and the planets carried around it on nested spheres. There were some—like Nicole d'Oresme and Nicholas of Cusa, both prominent churchmen—who suggested the possible advantages of a sun-centered cosmology, but little attention was paid to what were no more than suggestions until Copernicus transformed suggestion into actual mathematical calculation and showed that a heliocentric model could explain several features of the planetary motions that were merely *ad hoc* postulates in the rival geocentric astronomy (see COPERNICUS'S COSMOLOGY).

In his play *The Life of Galileo*, Bertolt Brecht has an elderly cardinal fulminate against the Copernicans who would demote human beings from their rightful place at the center of the universe God had created around them. Brecht was echoing a standard modern reading of why the Copernican theory was so strongly opposed by the Church. But this is anachronism; there is nothing in the record to support it. The real issue was the interpretation of Scripture—and who should be the interpreter. Luther's challenge to Rome bore on this very issue. Should the authority to interpret rest in the individual believer, or should it rest in the Church, represented by the bishops? What role should Church tradition play? Both sides in the spreading dispute cited Scripture in support of their theological views. Not surprisingly, the stress on *literal* interpretation grew. Where an earlier generation of theologians had been comfortable with allegory and metaphor, now the suggestion that a particular passage or phrase of Scripture ought to be taken nonliterally was likely to be greeted with suspicion, by reformers and supporters of Rome alike. Copernicus's book simply came at the wrong time.

No wonder, then, that Copernicus's Lutheran friend, Osiander, charged with the publication of *De revolutionibus* as its author lay dying, added a brief foreword in which the heliocentric astronomy of the book is passed off as a useful calculational device of no relevance to the *real* motions of sun or earth. This instrumentalist interpretation of mathematical astronomy was, indeed, more or less standard; it had its roots in the physically uninterpretable epicycles and equants of the Ptolemaic tradition. But it ran quite counter to Copernicus's manifest intention to claim that the earth really *was* in motion. Osiander was clearly hoping to defuse the opposition he expected from literalist readers of the Old Testament who would recall passages in which the earth is said to be at rest or the sun in motion. And for a time he seemed to have succeeded.

Kepler was the first, half a century later, to draw attention to the fact that the foreword could not have been written by Copernicus himself, as the reader would naturally have supposed it to have been, and that the foreword, in effect, falsified the author's intentions. Kepler, himself a devout Lutheran, saw no difficulty in reconciling the new cosmology with the Scriptures. In his view, the disputed biblical phrases testified only to popular usage at the time the works were written. There was absolutely no warrant for treating them as literal claims about which cosmic bodies were at rest and which were in motion.

But the battle was not really joined until Galileo made his famous discoveries with the telescope in 1609 and the years following (see GALILEO AND THE INQUISITION). These discoveries undermined Aristotle's cosmology of concentric spheres centered on the earth. Under siege, the defenders of Aristotle responded by calling on the authority of Scripture for support. Galileo, outraged, penned the *Letter to the Grand Duchess Christina* (1615), an eloquent defense of Copernicanism against theological attack. In the *Letter* Galileo asks what is to be done when there is an apparent contradiction between a finding in the science of nature and the literal interpretation of a passage of Scripture, and draws skillfully on theological tradition (notably, Augustine and Aquinas) in his reply. He defends two rather different strategies, without perhaps realizing how different they were in their implications for his own defense of the Copernican cosmology. The first (traceable to Augustine) is that if a claim that is supported by "the senses and necessary demonstration" appears to contradict a scriptural passage, then an alternative reading of Scripture must be found, since real contradiction is inadmissible. If, however, the claim falls short of demonstration, the literal reading of Scripture should be maintained. (The implication of this maxim is that he will have to find a *demonstrative* proof of the Copernican system.)

The second principle Galileo enunciates, one that was not without precedent among theologians but was unlikely to gain favor in tense Counter-Reformation Rome, is that the Scriptures are simply not relevant to matters of natural science, that they were not written with deep truths about nature in mind, that they were accommodated to the capacities of the listeners, and that their function was to teach people "how to go to heaven and not how the heavens go." If *this* were to be accepted, Galileo would not have to produce a demonstration of the Copernican position in order to be heard. A degree of likelihood would suffice, since the scriptural objection is ruled out from the beginning.

The arguments of the *Letter* fell on deaf ears in Rome. A few months later (1616), a committee of consultors of the Holy Office (popularly known as the Inquisition) declared that the claim that the sun was at rest in the center of the universe was heretical and the claim that the earth was in motion was close to heretical. (The stronger emphasis on the first of the two claims was due to the fact that the biblical references to the sun's motion are more numerous than those to the earth's immobility.) The Holy Office banned the works of Copernicus "until corrections would be made" (i.e., until assertions about the "real" motions of earth or the "real" position of the sun should be removed), which was done a few years later. It was made clear that there was no objection to retaining Copernicus's work as a major resource in mathematical astronomy, in the purely instrumentalist sense given that discipline by philosophers and theologians of the day.

The decree of 1616 set the stage for the final scene, perhaps the most celebrated moment in the long history of interaction between cosmology and religion in the West. The accession of his friend Urban VIII to the papal throne gave Galileo the encouragement to write the extended work in defense of Copernican cosmology that he had long been contemplating. The *Dialogue Concerning the Two Chief World Systems* appeared in 1632 and almost immediately caused a storm of controversy. Urban VIII was especially enraged, in part, perhaps, because an argument he had himself proposed against the realist Copernican claim had been put in the mouth of the hapless Simplicio, who was the representative of Aristotle in the *Dialogue*, and was on the losing side of every argument. Galileo was put on trial before the Inquisition (1633), forced to retract his defense of Copernicus's work as a cosmology, and sentenced to lifetime house arrest.

In retrospect, it seems clear that a clash of so dramatic a sort was in no way inevitable. Had the sensitivities over the interpretation of Scripture been less keen (the issue, after all, was primarily one about how the literal reading of the Scripture should be circumscribed), had the committee of consultors in 1616 taken the arguments of Galileo's *Letter* into account, had Galileo not antagonized so many potential supporters, and had he found a more convincing demonstration of the merits of the Copernican case (particularly over what was by then its *real* rival, the Tychonic cosmology), the outcome might have been different. But as it was (in Catholic Europe, at least), the new cosmology was called into doubt, and a pattern of long-lasting distrust was established.

Newtonian Cosmology

When news of Galileo's condemnation reached Descartes, he abandoned work on an ambitious cosmological treatise, *Le Monde*, in which he proposed to provide a mechanical basis for the heliocentric Copernican model (see DESCARTES'S MECHANICAL COSMOLOGY). But in his *Discourse on Method* shortly after (1637), he sketched what would turn out to be a more revolutionary idea, even, than Copernicus's reordering of sun and earth. What, Descartes asked, if a chaos of particles in motion were to have been created by God, simply obeying the laws of the mechanics Descartes believed he had discovered? Might this chaos not in a perfectly natural way eventually form sun, planets, earth, and even on the earth the complex sorts of bodies that we know? He was convinced that a cosmology could be devised in which the origins of even the most complex kinds of organisms might ultimately be explained by means of mechanical laws only, with no particular specification of the initial universe-state (no "fine-tuning," as it would be described today) needed. This may be called the "Cartesian principle" in cosmology.

Here was the first hint of a potentially self-contained science-based cosmology, one that, if successful, would need no special divine intervention to explain the origins of even the most highly organized natural kind. It had as yet little evidence in its support, but it had a plausible ring, for large material systems like the planets, at least. But what of living things? Robert Boyle, John Ray, and other students of nature argued that the adaptation of means to ends everywhere in the living world, particularly in the instinctual behaviors peculiar to each natural kind, could not be explained by the mere operation of mechanical law. A Designer was needed, a being who could shape the original structures and behaviors of each kind for the benefit of that kind. Cosmology testified directly, therefore, to the existence of a Designer, though no longer to a First Mover in Aristotle's sense. The law of inertia, first formulated by Descartes and foundational to Newton's mechanics, obviated the need for a continuing Mover, as a matter of mechanical principle, at least.

Newton was sensitive to the charge that the new science implicitly promoted atheism, and so he was at some pains to point out that God would still be needed to maintain the stability of the planetary system, for example (see NEWTONIAN COSMOLOGY). His own mechanics could not, he thought, explain that stability. Newton's own belief in an omnipotent creator in nowise depended on such considerations as these. But in an age when religious belief was under challenge, it was tempting to base an apologetics as directly on the new science as possible. And so a new sort of science-based natural theology, appealing to adaptation as evidence of design in the living world as well as to various apparent gaps in the new mechanical cosmology, became popular among Christian believers, especially in Britain. Cosmology could still, it would seem, cohere with, even sustain, religious belief.

But the Newtonian gaps were, to all appearances, gradually filled. Laplace, for example, argued that the laws of mechanics *could* of themselves explain the stability of the solar system (see LAPLACE). And what had been only a promise in Cartesian cosmology gradually took on concrete shape as Newtonian mechanics was applied by Kant and others to the problems of cosmogony. The formation of planetary systems, even perhaps of the Milky Way galaxy itself, could be understood in mechanical terms as a gradual coalescence of particles acted on by gravitational forces (see KANT). The geological complexities of the earth's surface testified to aeons of gradual development under the action of erosion, deposition on lake and sea bottoms, volcanic eruption, and the rise and fall of land surfaces—all potentially intelligible in physical terms.

As telescopic improvements continued and astronomical knowledge became ever more detailed, this developmental approach to cosmogony led, more or less naturally, to a belief in the vast number of habitable planets (see PLURALITY OF WORLDS). It was a short step to supposing them actually inhabited, and the argument most often relied on in making this step was based on a religious premise: the Creator would not have provided so many abodes for life in vain. What had seemed little more than literary fancy in 1686, when Fontenelle published his *Conversations on the Plurality of Worlds*, gradually became an almost universal belief, despite the lack of direct evidence in its support. Kant, in his *Universal Natural History* (1755), was one of the most assured: the plenitude of God's creative power is such that it would be "sheer madness" to deny that most of the solar planets must be inhabited by thinking beings. Furthermore, since planets are generated in the process of stellar formation, and there are uncountable other systems of stars besides our own Milky Way, we should expect life to be found throughout the boundless universe. There is no suggestion that this might pose a difficulty for the Christian, perhaps in part because it was a specifically religious premise that, in those pre-Darwinian days, enabled Kant to infer that the innumerable planets would, in fact, be inhabited.

But not everyone saw it that way. Thomas Paine, in *The Age of Reason* (1793), made use of the general belief in a plurality of worlds to argue *against* Christianity: "From whence, then, could arise the solitary and strange conceit that the Almighty, who had millions of worlds equally dependent on his protection, should quit the care of all the rest and come to die in our world because, they say, one man and one woman had eaten an apple!" If, on the other hand, a Redeemer were to be sent to each of those worlds, "the person who is irreverently called the Son of God, and sometimes God himself, would have nothing else to do than to travel from world to world." For a deist, like Paine, cosmology had become a powerful argument against the particularity of any religion claiming a privileged place for God's dealings with earth. (Paine's critique has recently been revived by Roland Puccetti, who uses the optimistic Sagan-Drake estimates of the likelihood of extraterrestrial intelligence.)

The most celebrated response to this objection came from Thomas Chalmers, a Scottish divine, who, in a set of sermons later published as *Astronomical Discourses* (1817), acknowledged the insignificance of earth in purely physical terms but argued eloquently that the generosity of a Creator who cares for even the least organism on earth would not draw back from sending a Redeemer to the humblest of his provinces, even to a species as undeserving as the human one is. According to Chalmers, we know nothing of how the plan of redemption extends to the peoples of other planets; for all we know, they may not need redemption or, if they do, they may receive it through some form of participation in the redemptive action of Christ on earth. Chalmers labors to transform the new cosmology from a challenge to an earth-centered religion into a celebration of God's magnificence and grandeur.

Later, a very different sort of response came from William Whewell, the celebrated master of Trinity College, Cambridge, and the ablest philosopher-historian of science of his generation. He disagreed with Chalmers and the many others who had made the plurality of worlds almost a Christian doctrine. Whewell saw the force of the type of objection that Paine had leveled, but instead of drawing the inference that Paine had, he preferred as a Christian to argue that the premise of the plurality of worlds was unsound. The scientific eminence of the author made the unfashionable thesis of *The Plurality of Worlds* (1853) all the more unexpected to his contemporaries. How, he asks, can a Christian possibly assent to the view that the earth, the scene of Christ's redemptive work, is merely one among millions of planets inhabited by rational beings? And he goes on to challenge at every step the astronomical arguments that purported to establish the plurality of worlds: the existence of galaxies other than our own, the great multiplicity of sunlike stars in our own galaxy, the likelihood of planetary formation around an average star, and so on. His most effective objection was to the almost universal supposition that the planets of the solar system were habitable. (One author, Thomas Dick, inferred the total population of the solar system to be almost 20,000 *billion*, based on an estimate of surface areas and the assumption that the average population density would be roughly that of England!) Whewell considers the planets one by one, and argues that from what is known of each, only earth could be the abode of complex life. His book was a *tour de force*, and although it did not win the assent of many, it served indirectly to underscore that the vastly expanded universe of the new cosmology might raise more of a problem for specifically Christian belief than Christians had up to that point acknowledged.

Evolutionary Cosmology

The publication of Darwin's *Origin of Species* in 1858 drastically altered the parameters of the debate about the implications of cosmology for religion. Darwin's use of the evidence of adaptation to support the theory of natural selection undermined the Design argument on which (in Britain, at least) Christian apologetics had become so dangerously dependent. It seemed that now, at last, one could envision an entirely self-contained cosmology, one in which neither Mover nor Designer had any role. For many, including Darwin himself, the increasing autonomy of cosmology meant a loss of the primary motive for belief in God. From having been a strong support for a religious worldview, natural history had now become for many a strong disincentive.

Some of those who accepted an evolutionary origin of natural kinds remained unpersuaded, however, that this could be explained simply in terms of natural selection working on chance variation. Alfred Wallace, co-formulator with Darwin of the original hypothesis of natural selection, was one of the skeptics. Development of such complex organs as the human brain could not, he argued, be explained by a blind process of chance variation and differential reproduction; a more directive agency was required. And so, to account for the orthogenetic aspects of evolutionary change, he postulated an Intelligence acting to supplement the effects of natural selection. In Wallace's view, although Design in the older sense of an instantaneous creation of natural kinds was no longer needed, God's action in the world could still be discerned in evolutionary process itself.

By the turn of the century, a new and more comprehensive cosmology had begun to make its way. It was based on Darwinian theory rather than on physics. Although the term *cosmology* was not usually attached to it, it was in fact a cosmology, an attempt to give a speculative account of world order in general. The evolutionary philosophy propounded by scientists like Herbert Spencer was explicitly cosmological in intent. Spencer extended the notion of evolution from the biological back in the physical and forward in the social realms. Everything was to be understood in terms of origins, and the path from these origins to the structures of the present day was governed entirely by scientific law. Newtonian mechanics had been able to explain the origin of some large-scale gravitationally bound structures, but not much more than that. The evolutionary mechanisms proposed by Darwin had far more potential for cosmology; in Spencer's view, nothing more would be needed.

Among the evolutionary philosophers, two distinct strains can be noted. On one side were those like Spencer and Ernst Haeckel, for whom a deductive Darwinist model of explanation could be used to support a broader materialism that excluded theism of any sort. They were especially critical of the major institutional religions of the West, which were, in their estimation, no better than superstitions serving mainly political ends. Their own mission was to propagate the new evolutionary cosmology, particularly by influencing the education of the young, and in this way to lessen the influence of organized religion on its adherents. They were willing to recognize that religion had in the past provided support for desirable ethical values; this dimension of religion they hoped to maintain.

But there were others, on the contrary, who, like Wallace earlier, took evolution to testify rather to the direct action of God in the world and who built an entire cosmology around this intuition. Best known of these was Henri Bergson, whose book, *Creative Evolution* (1907), drew heavily on the French vitalist tradition in biology. He argued that many features of the evolutionary record could not possibly be explained by Darwinian mechanics only. The steady increase in organic complexity, the apparent coordination of changes occurring together in the organism, and the advent of the human required an agency capable of shaping outcomes in a way that mechanical energies alone could never bring about. An *élan vital*, or living impulse, was required, and evolution itself was the main testimony to the continued operation of this transformative force in all living things. Bergson originally doubted that evolution manifested an overall directional character, but in his later writings, as he more and more explicitly identified *élan vital* with God's guiding action, he sometimes spoke of the appearance of the human on the scene as the goal of evolution.

The Bergsonian inspiration is clearly recognizable in the speculative cosmology of Pierre Teilhard de Chardin, a Jesuit paleontologist, notably in his posthumous work *The Phenomenon of Man* (1955). Teilhard, like Bergson, saw a special nonmechanical agency (which he called "radial" or "psychic" energy) at work in the history of evolution, particularly in the growing "complexification" of the organic realm and in the major transitions such as those between nonliving and living, nonsentient and sentient, nonreflective and reflective. For such transitions as these to occur, the higher properties must already have been present in a latent state from the beginning. Once the level of the human is reached, evolution shifts into the realm of the social, the "noosphere." As this latter develops toward a higher degree both of complexity and of unity, the universe progresses toward Omega Point, the end of history, where the complex becomes fully one and the distinction between material and spiritual is finally overcome. Evolution for Teilhard is "no longer an hypothesis but a light which illuminates all hypotheses." Someone who views the universe from the Christian perspective (he claims) will see in radial energy the transformative power of Christ and will find all sorts of resonances in evolution for the doctrines of God's becoming man and of man's eternal destiny with God. Teilhard's vision was greeted with enthusiasm by those who sought for a closer unity between science and the spiritual, but it evoked rebuke from traditional theologians and angry hostility from defenders of the neo-Darwinian synthesis.

Alfred North Whitehead's system of thought was broader in basis and less specifically theological in inspiration. Beginning from mathematics and relativity theory, he developed a general metaphysics, in which the world appears as a system of extended and interlocking events and objects appear as recurrent patterns in this complex. In *Process and Reality: An Essay on Cosmology* (1929), he distinguishes between metaphysics, which deals with the formal character of all *possible* facts, and cosmology, which is generalized from the empirical sciences of a particular period and thus reflects the contingent character of one particular type of world order. The fundamental metaphor of this cosmology is that of *organism*: all actual entities have a "subjective aim" toward which they strive. Even the molecule exhibits a form of sentience, though not of consciousness; the latter is for Whitehead an incidental, not a basic, property. Like Teilhard, he denies the emergence of strictly new levels of existence; all basic properties have been there from the beginning, in some sense. Evolution is one consequence of the striving on the part of all actual entities toward novelty and self-creation. The original ordering of the world from which this process takes its rise is identified as the "primordial nature of God." In the process of cosmic becoming, God also provides the other actual entities with the impetus to self-creation, and in that way acquires a "consequent nature" in which each entity is "objectified" or reflected. God is thus both the beginning and end of natural process, and evolution is ultimately God's own gradual self-realization.

Cosmology and religion in one sense could hardly come closer. Yet Whitehead's God is so abstract, so remote (it would seem) from the categories of traditional religion, that it is hard at first sight to see how to bring them together. But one school of theology, process theology, has labored to do just that. The traditional theology of creation stressed God's transcendence, his independence of the universe, even the possibility that the world might never have been. Evolutionary cosmotheologies of the "process" type tend to place God in time and to describe God as "groping" through cosmic process toward an uncertain self-fulfillment. They lean to immanence; in traditional terms, they would be pantheistic rather than theistic. The best-known writer, perhaps, in this tradition is Charles Hartshorne, whose *A Natural Theology for our Time* (1967) defends a relationship between God and Universe—panentheism—that is neither pantheism nor theism of the traditional sort.

Recent cosmologies of biological, and specifically evolutionary, inspiration have obviously been far from neutral where religious belief is concerned. Jacob Bronowski's popular television series, *The Ascent of Man*, began from a broadly evolutionary account of human origins and went on to assert that as science has advanced, ignorance and superstition in the form of institutional religion have retreated. Writers like Jacques Monod (*Chance and Necessity* [1971]) and Eric Dawkins (*The Blind Watchmaker* [1986]) have argued that the basic explanatory concepts of the neo-Darwinian "modern synthesis" exclude design in any form, showing not just that it is not necessary but, more fundamentally, that it is not possible because of the crucial role that chance plays in evolutionary process. Not only is a natural theology blocked, then, but also postulating a God is otiose, since there is nothing for such a being to do and there is good reason, furthermore, to suppose that such a being could not exercise the sort of providence traditionally assigned to the Creator.

Theologians, on the other hand, have criticized these naturalist objections as misplaced. Many theologians would agree that a natural theology of the traditional sort (i.e., one based on a specific feature of the world [like design] that science is supposedly unable to explain) no longer carries weight, but they would point out that cosmological arguments of this kind have only been in vogue since natural science attained authority in the seventeenth century, and that the argument most favored by theologians relies on a deeper existential contingency of the natural world as a whole, of the world that science simply presupposes as its object. Other theologians have insisted that religious belief is not motivated by an appeal to God's role as an explainer in the first place. And the objection regarding chance would be countered by the Augustinian response that a Creator who brings the universe to be in a single act is not dependent on the present for his knowledge of, or dominion over, the future.

Physical Cosmology

Evolutionary theory served to prompt cosmological speculation rather more than did Newtonian physics. True, Newton postulated an absolute and unbounded framework of space and time as a necessary framework for his new way of conceptualizing the relation between force and acceleration. And his "Third Rule of Reasoning" allowed him to assume that the properties of the limited sample of the world where his mechanics had been shown to apply could be universalized to the world as a whole and at all levels of size. But there was no way to know how far outward in space matter in the form of planets and stars extended, nor at what point in time these bodies had taken shape. Kant, indeed, argued that the attempt to characterize the universe as a whole inevitably led to antinomy. His own search for an adequate foundation for Newtonian science led him to seek this in mind rather than in an autonomous material world over against the knower. In later debates between materialists and their critics, the authority of Kant would often be invoked in support of some form of idealism. And idealism came to seem to many the most secure defense of religion against materialist attack, particularly in Germany, where Kant's influence was strongest.

In England in the period between the two world wars, this debate took on a distinctive form. The two leading astrophysicists of the day, James Jeans and Arthur Eddington, were best known to the public as the authors of immensely successful popular works on cosmology. Each defended his own brand of idealism, each linked it with the new scientific discoveries, and each also saw it as a natural bridge between science and religion. In *The Mysterious Universe* (1930), Jeans proposed a view strongly reminiscent of Plato's *Timaeus*. As physics has progressed, it encompasses the world more and more in the symbols of pure mathematics. The universe is clearly built on a complex mathematical pattern that pervades all levels from the galaxy to the atom. The only way to explain this is to see it as the work of pure mind, specifically, of a Divine Mathematician. Science can thus testify directly to the existence of a Creator; it can furnish a natural theology sufficient to sustain religious belief.

In *The Nature of the Physical World* (1928), Eddington took a different approach (see EDDINGTON). He argued, along Kantian lines, for the mind-dependence of the sense world in general, stressing the various forms this dependence takes, in quantum theory in particular. He saw the influence of mind everywhere, not as an original creator but as actively and continuously moving within nature. "I simply do not believe that the present order of things started off with a bang" (Eddington 1928, 84). "Philosophically, the notion of an abrupt beginning of the present order of Nature is repugnant to me" (*New Pathways in Science* 1933, 59). Abrupt beginnings suggested to him an unacceptable sort of deism, conveying that there had been "a single winding-up at some remote epoch" and that the work of the Creator was then done, whereas Eddington wanted to emphasize the continuing presence of a Universal Mind, a mind that was in some way constitutive of nature itself and whose role was effectively revealed in post-Newtonian science.

He opposed Jeans's project of a natural theology, since the Mind whose traces science everywhere discerns was too unspecific to serve as object of religious belief. Besides, according to Eddington, it is *our* mind whose traces we are finding, *our* mind that imposes mathematics on the universe. All that he has himself tried to do (Eddington says) is to remove difficulties against religious belief that were rooted in the determinism and materialism of the Newtonian worldview, and to give "grounds for an idealistic philosophy which is hospitable towards a spiritual religion" (Eddington 1933, 306). The most that science unaided could testify to would be a "colorless pantheism"; his own religion, by contrast, is a mystical one, based on a personal experience accepted in advance as fundamental.

The support offered to religion by Jeans and Eddington did not go unchallenged. In a sharply critical work, *Philosophy and the Physicists* (1937), Susan Stebbing likened them to "revivalist preachers" and accused them of "cheap emotionalism" and "serious mental confusion." She was much more critical of Jeans than of Eddington; in her view, Jeans's argument for a Creator was a tissue of fallacies from beginning to end; he had shown himself to be inexcusably unaware of the distinctions that philosophers had insisted on in arguments of the sort. She devoted more space to Eddington, but in the end concluded that his attempt to base a quasi-Kantian idealism on science also failed. Hence, his indirect mode of linking science and religion would not work. Stebbing's criticisms may have stung; in their later books, neither Jeans nor Eddington returned to the confident religious declarations of their earlier works.

There was by then a new and much more powerful cosmological synthesis in the making, and the term *cosmology* was coming to be appropriated almost exclusively by physicists as a convenient label for the part of physics that deals with the nature and mode of formation of the largest material structures. Einstein's general theory of relativity employed a non-Euclidean formalism that would permit one, under certain constraints, to represent the cosmos once again *as* a cosmos, as a single finite (though unbounded) whole. Further, the large galactic redshifts discovered by Hubble could best be understood, Lemaître argued, as indicators of a cosmic expansion beginning from a "primeval atom" (see HUBBLE'S COSMOLOGY; LEMAÎTRE; BIG BANG COSMOLOGY). Eddington gave the new cosmology wide currency in an immensely popular little book, *The Expanding Universe* (1932). The affinities between the "big bang" model, as it was later dubbed, and the Judaeo-Christian notion of creation did not go unnoticed. Neither Lemaître nor Eddington, however, would countenance any sort of inference from one to the other: for Lemaître (among other reasons), there was no way to show that the expansion had not been preceded by a contraction, and Eddington, as we have seen, found the notion of an abrupt beginning unsatisfactory on philosophical grounds and preferred to suppose that the expansion had begun from an instability in an enormously dense concentration of energy that had remained in an "embryo" state for an indefinitely long time.

There were problems with the big bang model; in particular, the calculated expansion appeared to be too rapid, since it gave an age for the universe (1 billion to 2 billion years) that was too short to accommodate the findings of geology and paleontology. Bondi and Gold proposed an alternative in 1948, a steady state model that avoided the suspect singularity, but at the cost of introducing a host of lesser singularities. In the steady state model, hydrogen atoms are supposed to appear *ex nihilo* at an imperceptibly low rate in order to maintain the steady state, as galaxies move away from one another (see STEADY STATE THEORY). This model was adopted and extended by Fred Hoyle, who objected to the clear affinity he perceived between the big bang model and the traditional Christian view of creation. In a number of popular works, from *The Nature of the Universe* (1950) to *Ten Faces of the Universe* (1977), Hoyle combined an exposition of popular science with scathing attacks, after the manner of Haeckel, on organized religion. Reacting against the strong religious cast of the leading British cosmologists of the older generation, he pounced on anyone unwary enough to suggest (as Pope Pius XII did in an address to the Pontifical Academy of Sciences in 1951) that big bang cosmology gave aid and comfort to the Christian believer.

The identification of the ubiquitous microwave radiation, discovered by Penzias and Wilson in 1965, as having the "signature" of the 3 degree K radiation predicted by the big bang model, had two almost immediate effects. First, it gave this model what proved to be a decisive advantage over the steady state alternative, erasing the slight lead the latter had by then built up. Second, and even more significantly, it persuaded many of the skeptics that cosmology had at last become respectable. Critics, like the positivist philosopher of science Herbert Dingle, had dismissed relativistic cosmological models as irresponsible speculation based on idealized assumptions misleadingly described as "cosmological principles." So many assumptions, indeed, were involved even in the interpretation of the galactic redshift as expansion that it seemed as though almost any finding could be "explained" by an *ad hoc* adjustment of one kind or another. But now a precise unadjusted observational consequence of one of the models had been unexpectedly verified, traditionally the mark of a "mature" science.

Fine-Tuning the Universe

One last story remains to be told. The big bang model, unlike the steady-state alternative, involved an initial moment when energy densities were extremely high and, hence, when quantum effects would be the controlling factor. Thus one could hope that the application of quantum theory to these extreme conditions could both help to elucidate the sequence of states as the universe cooled and serve to test the current versions of quantum theory in a way that laboratory conditions on earth never could. These hopes have been amply borne out. But one major surprise was in store.

In the early 1970s, reconstruction of the likely sequence of events as, first, the various elementary particles and, then, hydrogen and helium atoms made their appearance made it seem that the sort of universe we have (long-lived, populated by galaxies of stars, and containing appreciable quantities of the heavier elements) required an extraordinarily delicate balance of initial conditions and of the laws relating the four fundamental forces. Had these been even slightly different, the universe might have been very short-lived, either collapsing on itself or expanding too rapidly for matter to form into stars and planets. Or it might have consisted of hydrogen alone or helium alone. In short, it seemed that the Cartesian principle had been refuted. Descartes, we recall, maintained that the application of a simple set of mechanical laws (themselves justified on *a priori* grounds) to an initial "chaos" would be sufficient to explain how the major structures of the universe originated. In the Cartesian system, no limitations had to be set on the initial cosmic conditions, whereas in quantum cosmology, an extreme sort of "fine-tuning" seemed to be required both of the initial energy density and of the contingent-seeming relative magnitudes of the fundamental forces. (*Fine-tuning* has something of the ambiguity of the term *creation*; if it be understood as an action, then the existence of a "Fine-Tuner" seems to follow. Perhaps a more neutral term would be better.) Among the *possible* universes (possible in terms of quantum cosmology), only a vanishingly small proportion would be of the sort we inhabit: long-lived, galactic, etc. Does the fact that the universe *is* of this sort require explanation? B.J. Carr, Martin Rees, and several other British cosmologists suggested that it did, and proposed an "anthropic principle" by way of explanation (see ANTHROPIC PRINCIPLE). The so-called principle took a number of different forms, but in a general way it asserted that the presence of human beings somehow explains why the universe has the unlikely form it has. A universe of a fairly specific sort is *necessary*, they argued, in order for complex life-forms to appear.

But what follows from this? For there to be creatures of a broadly human sort, let us suppose that the universe must be of the specific kind described. But did there have to be creatures of this sort in the first place? This is where a religious answer suggested itself, to some at least. According to the biblical account of creation, God chose a world in which human beings would play an important role, and would thus have been committed to whatever else was necessary in order for this sort of universe to come about. If fine-tuning was needed, this would present no problem to the Creator. In this perspective, the significance of the human in God's plan could be said to explain why the universe is of the sort it is, if indeed this *needs* special explanation. This is a genuine explanation, *provided* that the premises are correct. From the Christian perspective, then, the appeal to a Creator in order to explain the supposed fine-tuning is attractive. The further step to a natural theology is, however, highly dubious. For this step to be permissible, the claim of fine-tuning would have to be validated *and* alternative explanations, or approaches to the issue of explanation, would have to be undermined. This would be hard, if not impossible, to do.

We are, after all, dealing with a highly speculative theory about a situation entirely remote from any of which we have direct experience. An important modification of the original big bang model was proposed by Alan Guth in 1981, involving a brief period of extraordinary inflation in the first fraction of a second of cosmic expansion (see INFLATIONARY UNIVERSE). This would help to solve the so-called horizon and flatness problems of the standard model, and would eliminate part of the need for "fine-tuning." An initial cosmic energy density permitting a long-lived universe, for example, would cease to be so improbable. But inflation itself causes some new problems; the pros and cons of this imaginative modification are still under debate. The moral is, however, clear: what appears as fine-tuned today may find an explanation tomorrow in a new or modified model of that remote instant when the processes of expansion and cooling began. The force of the metaphor of fine-tuning depends on establishing a special sort of contingency or unlikelihood that requires explanation. As long as the theory is as speculative as it still is, what now appears contingent can easily turn out after all to be necessary. And some will argue that even if it remains contingent, any kind of scientific explanation must ultimately end with a state of affairs that is just *given*.

The theistic explanation is, of course, not a scientific one and depends for its force on a *prior* belief in a Creator who would be likely to assign privileged status to human nature in the work of creation. A *scientific* alternative is offered by a variant of the "many-worlds hypothesis" postulated by Everett and Wheeler in quantum theory (see MULTIPLE UNIVERSES). According to this variant, if there are immeasurably many *real* worlds constantly causally diverging from one another, we would, of course, find human beings only in those of the worlds in which the conditions for the development of advanced organic life were satisfied. And so, the "because we are here" of Brandon Carter's original anthropic principle would become quasi-explanatory, in the sense that the apparent fine-tuning would vanish. The many-worlds approach is, however, faced with many difficulties in its own right and enjoys little support among scientists.

What made this episode in quantum cosmology so intriguing to religious believers was that, for the first time since the heyday of physico-theology, scientific theory seemed to point to a state of affairs that would itself require an explanation of a different order. And unlike all other such leads in the past, this was one that would not require an alteration of natural process on the part of the Creator, no intervention of a miraculous sort, only a creative setting of the original stage. Physicists like Freeman Dyson (*Disturbing the Universe*, 1979) and writers of popular works on cosmology like Paul Davies (*God and the New Physics*, 1983) have found this sort of resonance between cosmology and theistic belief appealing, even if it in no sense constitutes a natural theology—in no sense, that is, capable of yielding a persuasive argument for the existence of a Creator.

The popularity of Stephen Hawking's *A Brief History of Time* (1988) no doubt derived in part from his cryptic remarks therein about the negative implications of recent cosmology for belief in a Creator. Critics were quick to point out that he had improperly assumed that the Christian view of creation required one to suppose that time had an abrupt beginning and that, therefore, his own novel conjecture (which dispenses with an abrupt temporal origin) would eliminate the need for a Creator. Aquinas, as we saw, faced with the Aristotelian thesis of a world without a temporal beginning, reminded his readers that even such a world would still need a reason why it should be rather than not be. Although Christians have always believed, on theological grounds, that the world did begin at a finite time in the past, this is not (Aquinas insisted) part of the content of the notion of creation itself, which merely signifies dependence on *being*, not necessarily an abrupt origin in time.

Cosmologists are agreed that the question "Why should the universe have existed in the first place?" is not a scientific one, but they are divided on the further question of its legitimacy *as* a question. Some would insist on the traditional positivist tenet that only questions that are, in principle, capable of scientific answer are permissible in the first place. Carl Sagan gave this restrictive thesis memorable life in his widely watched TV series *Cosmos*: "The cosmos—as known by science—is all there is, all there was, and all there will be." The thesis is itself a philosophical one, of course, and has been put to work in the cosmological context rather more by philosophers of science (among whom Michael Scriven and Adolf Grünbaum have been particularly emphatic) than by cosmologists themselves (see CREATION IN COSMOLOGY). Indeed, the relatively few cosmologists who have been willing to venture into the published record on this undeniably nonscientific topic (among them Robert Jastrow, Allan Sandage, and Christopher Isham) have been on the whole more sympathetic to the legitimacy of the existence question than have their philosopher colleagues.

Conclusion

Cosmology and religion are not as intertwined as they once were. The naturalization of cosmology that began with Descartes, accelerated with Newton and Darwin, and continues with Hawking and Dawkins has led religious believers to recognize that the motives for belief animating the three great religions of the Book (Christianity, Judaism, and Islam) were not in the first instance cosmological. Implicit in the notion of creation has always been the idea of a universe coming whole and entire from God's hands, without gaps or supplements that would give a handhold to those who seek "scientific" ways to assure themselves of God's existence. Does this make God an idle wheel? No, because God's role in the history of salvation has been direct and dramatic, even if not of the gap-filling sort that philosophers and scientists have debated. No, because one may still ask the basic question, "If the universe that science presupposes as its object is (as it seems to be) contingent, why should it ever have existed in the first place?" It is not enough to answer in terms of vacuum fluctuations or the like. One would still want to know why there should have been a vacuum, a space-time alive with possibility.

Recent cosmology may not offer religious believers an easy argument in support of their faith, but it surely does present a universe that is a fit subject of wonder. The vaster heavens of the quantum cosmologist proclaim to believers the glory of a Creator far further beyond their comprehension than even the mystics could have dreamed. If the new cosmology offers a special challenge to the believer, it is not so much that the work of creation is more hidden than it was as that earth seems so limited an arena for a Creator who holds a billion galaxies in being.

See also ANTHROPIC PRINCIPLE; ARISTOTLE'S COSMOLOGY; BIG BANG COSMOLOGY; COPERNICAN REVOLUTION; CREATION IN COSMOLOGY; GALILEO AND THE INQUISITION; KANT'S COSMOLOGY; MEDIEVAL COSMOLOGY; MULTIPLE UNIVERSES; PLATO'S COSMOLOGY; PLURALITY OF WORLDS; STEADY STATE THEORY

[E.M.]

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Robertson-Walker Metric

The American Howard P. Robertson and the Englishman A.G. Walker independently deduced in 1935 the most general form of the metric for a space-time satisfying the cosmological principle, the postulate that the universe is spatially homogeneous in its large-scale appearance. Although their mathematical model was later incorporated into big bang cosmology, neither Robertson nor Walker did much initially to link their model to physical reality.

See also BIG BANG COSMOLOGY; RELATIVISTIC COSMOLOGY

Robinson, Thomas Romney (1793–1882)

Born in Dublin, Ireland, Robinson was a child prodigy. At age 12 he entered Trinity College, Dublin. In 1814 he was elected a fellow of Trinity College, and for several years he lectured as deputy professor of natural philosophy.

In his early career, Robinson had no particular interest in astronomy, but in 1823 he was appointed astronomer at Armagh Observatory, a position he held for fifty-eight years. Nearly all of his work at Armagh focused on traditional positional astronomy,