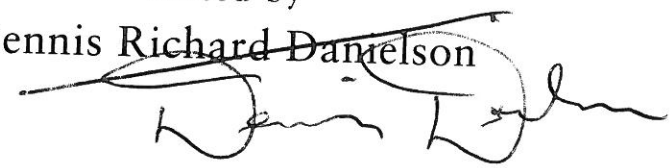
the Book of the Cosmos

Imagining the Universe from Heraclitus to Hawking

A Helix Anthology

edited by

Dennis Richard Danielson



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The Peculiar Nature of the Universe

Claudius Ptolemy

Claudius Ptolemy (c. 100–c. 175) was the author of the single most influential astronomy textbook ever written. Known as Almagest*—which means "the greatest"—this book was originally (and forgettably) entitled* Mathematical Systematic Treatise. *It is truly an advanced technical and mathematical work encompassing enormous numbers of diagrams, charts, and equations. It appeared first in Greek, probably shortly after the year 150, in the world's greatest center of learning at that time, Alexandria. In the entire Mediterranean area and in Europe east and west,* Almagest *became the standard authority on astronomy for well over a thousand years.*

The adjective Ptolemaic *is still used as synonymously with "geocentric," and it is still subject to the misunderstandings that sometimes cluster around that word. Clichés notwithstanding, it does not imply, for example,* anthropocentric. *Moreover, some who have not read Ptolemy—or Aristotle, upon whose physics Ptolemy's system is based—may assume that Ptolemaic cosmology arises from mere authority or abstract philosophical thought devoid of observation. However, as we can see from Ptolemy's attempt to reconstruct the process by which civilization arrived at a geocentric concept, he takes physical evidence very seriously—particularly mutually corroborating evidence obtained from different locations.*

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It is plausible to suppose that the ancients got their first notions on these topics from the following kind of observations. They saw that the sun, moon, and other stars moved from east to west along circular paths which were always parallel to each other, that they started by rising up from below the earth itself as it were, gradually achieving their ascent, and then kept circling in the same way and getting lower, until, seeming to fall to earth, they vanished completely. Then, after remaining invisible for some time, they rose and set once more. And they saw that the intervals between these motions, and also the locations of the rising and setting, were on the whole determined and regular.

The main phenomenon that led them to the idea of a sphere was the revolution of the ever-visible stars. They observed that this revolution was circular as well as continuous about a single common center. Naturally they considered that point to be the pole of the heavenly sphere. For they saw that the closer were stars to that point, the smaller were their circles. And the farther were stars from it, the greater were their circles—right out to the limit where stars became invisible. But here too they saw that some heavenly bodies near the ever-visible stars remained visible for only a short time, while some farther away remained invisible for a long time, again depending on how far away they were from the pole. So they arrived at the idea of the heavenly sphere merely from this kind of inference. But from then on, in subsequent investigations, they found that everything else fit with this notion, and that absolutely all appearances contradicted any alternative notion that was proposed.

For suppose that the stars' motion takes place in a straight line towards infinity, as some have thought. How then could one explain their appearing to set out from the same starting-point every day? How could the stars return if their motion were towards infinity? Or, if they did return, would not the straight-line hypothesis be obviously wrong? For according to it, the stars would gradually have to diminish in size until they disappeared, whereas in fact they appear greater at the very moment of their disappearance, at which point they are obstructed and cut off, as it were, by the earth's surface.

It is also absurd to imagine the stars ignited as they rise out of the earth and extinguished again as they fall to earth. Just suppose that the strict order in their size and number, their intervals, positions, and periods could be restored by such a random and chance process, and that one whole region of earth has igniting properties, and another has extinguishing properties—or rather that the same region ignites stars for one set of observers and extin-

guishes them for another set, and that the same stars are already ignited or extinguished for some observers while they are not yet for others! Even on this ridiculous supposition, what could we say about the ever-visible stars, which neither rise nor set? The stars that are ignited and extinguished ought to rise and set for observers everywhere, while those that are not ignited and extinguished should always be visible to observers everywhere. How would we explain the fact that this is not so? We can hardly say that stars that are ignited and extinguished for some observers never undergo this process for other observers. Yet it is utterly obvious that the very same stars that rise and set in certain regions of the earth neither rise nor set in other regions.

Finally, to assume any motion at all other than spherical motion would entail that the distances of stars measured from the earth upwards must vary, regardless of where or how we assume the earth itself is situated. Hence the apparent sizes of the stars and the distances between them would necessarily vary for the same observers during the course of each revolution, for their distances from the objects of observation would be now greater, now lesser. Yet we see that no such variation occurs. And the apparent increase in their sizes at the horizon is caused not by a decrease in their distances but by the exhalations of moisture surrounding the earth. These intervene between the place from which we observe and the heavenly bodies. In the same way, objects placed in water appear bigger than they really are, and the lower they sink, the bigger they appear.

When he turns to the shape of the earth, Ptolemy likewise relies on physical evidence: He reasons from phenomena, from things which are "sensible," that is to say, apprehended by the senses. Then he supports his conclusion by engaging in thought experiments, imagining for example how the phenomena would be different if the earth, instead of being spherical, were concave, flat, or cylindrical.

THE EARTH TOO, TAKEN AS A WHOLE, IS SENSIBLY SPHERICAL

That the earth, too, taken as a whole, is sensibly spherical can best be grasped from the following considerations. To repeat, we see that the sun, moon, and other stars do not rise and set simultaneously for everyone on earth, but do so earlier for those towards the east and later for those towards the west. And eclipses, especially lunar eclipses, take place simultaneously for all observers yet are not recorded by all observers as occurring at the same *hour* (that is, at an equal distance from noon). Rather, the hour recorded by observers in the east is always later than that recorded by those in the west. And we find that the differences in the recorded hour are proportional to the

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distances between the places of observation. Hence, one can reasonably conclude that the earth's surface is spherical, because its evenly curving surface (for so it is when considered as a whole) cuts off the heavenly bodies for each set of observers in a manner that is gradual and regular.

This would not happen if the earth's shape were other than spherical, as one can see from the following arguments. If the shape were concave, the stars would be seen rising first by those more towards the west; if it were a plane, they would rise and set simultaneously for everyone on earth; if it were triangular or square or any other polygonal shape, similarly they would rise and set simultaneously for all those living on the same planar surface. Yet clearly nothing like this takes place. Nor could the earth be cylindrical, with the curved surface in the east-west direction, and the flat sides towards the poles of the universe, as some might suppose more plausible. For to those living on the curved surface none of the stars would be ever-visible. Either all stars would rise and set for all observers, or the same stars, for an equal celestial distance from each of the poles, would always be invisible for all observers. In fact, however, the further we travel toward the north, the more of the southern stars disappear and the more of the northern stars become visible. Clearly, then, here too the curvature of the earth cuts off the heavenly bodies in a regular fashion in a north-south direction and demonstrates the sphericity of the earth in all directions.

Moreover, if we sail towards mountains or elevated places from whatever direction, north, south, east or west, we observe them to increase gradually in size as if rising up from the sea itself in which they had previously been submerged. This is due to the curvature of the surface of the water.

*Ptolemy goes on to argue, for reasons largely based on observation, that the earth is in the center of the world (note: not "*is *the center" but "is* in *the center"). Having done so, he then states "that the earth has the ratio of a point to the heavens." This claim can be confusing if we take it in a mathematical sense, for in Euclidean geometry a point has no dimension whatsoever. Thus, if the earth does have some dimension, then Ptolemy can appear to imply that the heavens are infinitely large, which he does not. His claim does make sense, however, when we consider the qualification which he adds: "to the senses." That is to say,* to all appearances *the earth is a point in relation to the heavens. Again, then, his appeal is to visible evidence. Normally when we view a distant object from two different vantage points we see the object from different angles and in altered relations to its surroundings (the phenomenon known as parallax). But when we view the stars from widely different points on earth, we perceive none of these usual variations, no parallax—in other words, as if our different perspective points were in fact one and the same point.*

THE EARTH HAS THE RATIO OF A POINT TO THE HEAVENS

The earth has, to the senses, the ratio of a point to the distance of the sphere of the so-called fixed stars. This is strongly indicated by the fact that the sizes and distances of the stars at any given time appear equal and the same from any and every place on earth. Observations of the same celestial objects from different latitudes are found to have not the least discrepancy from each other. Moreover, gnomons set up in any part of the earth whatever, and likewise the centers of armillary spheres, operate like the real center of the earth. . . .

Another clear demonstration of the above proposition is that a plane drawn through the observer's line of sight at any point on earth—we call this plane one's "horizon"—always bisects the whole heavenly sphere. This would not happen if the earth were of perceptible size in relation to the distance of the heavenly bodies. In that case only the plane drawn through the center of the earth could exactly bisect the sphere, and a plane through any point on the surface of the earth would always make the section of the heavens below the plane greater than the section above it.

Even when Ptolemy argues for a proposition we know to be mistaken, namely that the earth is immobile, he begins with a pretty impressive account of how falling objects behave on earth and of how up *and* down *are merely relative terms. He then moves to arguments—again a kind of thought experiment—that are difficult for us to follow simply because they have been so decisively disposed of. They reappear, nevertheless, in various kinds of literature on into the seventeenth century; and they indicate how nearly impossible it was for even a brilliant critical mind such as Ptolemy's to take seriously, much less accept, the concept of the earth's mobility.*

NEITHER DOES THE EARTH HAVE ANY MOTION FROM PLACE TO PLACE

One can show by arguments like the one above that the earth can have no motion in the directions mentioned, nor indeed can it ever move at all from its position at the center. For if it did move, the same phenomena would result as those that would follow from its having any position other than the central one. To me it seems pointless, therefore, to ask why objects move towards the center of the earth, once it has been so clearly established from actual phenomena that the earth occupies the middle place in the universe, and

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that all heavy objects are carried towards that place. The following fact alone amply supports this claim. Absolutely everywhere on the face of the earth—which has been shown to be spherical and in the middle of the universe—the direction and path of the motion (I mean proper, natural motion) of all heavy bodies is everywhere consistently at right angles to the plane that is tangent to the point of impact on the earth's surface. Clearly, therefore, if these falling objects were not stopped by the earth's surface, they would certainly reach the center of the earth itself, since any line drawn through the center of a sphere is always perpendicular to the tangent plane at the line's point of intersection with the sphere's surface.

As he proceeds, Ptolemy in effect acknowledges the way in which cosmology is still recognized to be unique among sciences: Its object, the universe, is one of a kind. One of the consequences of this recognition is that what we assume concerning something within the "local sphere" of our own experience often cannot validly be assumed of the whole.

Those who think it paradoxical that the earth, having such great weight, is not supported by anything and yet does not move, seem to me to be making the mistake of judging on the basis of their own experience instead of taking into account the peculiar nature of the universe. They would not, I think, consider this fact strange if they realized that the magnitude of the earth, when compared with the whole surrounding mass of the universe, has the ratio of a point to it. Given this way of thinking, it will seem quite consistent that (relatively speaking) the smallest of things should be overpowered and pressed in equally from all directions to a position of equilibrium by the greatest of things (which possess a uniform nature). For there is no up and down in the universe with respect to itself, any more than "up" and "down" make sense within a sphere. Rather, in the universe, the proper and natural motion of compound bodies is as follows: light and rarefied bodies drift outwards towards the circumference, but seem to move in the direction which is "up" for each observer, since the overhead direction for all of us, which we also call "up," points towards the surrounding surface. Heavy and dense bodies, on the contrary, are carried towards the middle and the center, but seem to fall downwards, again because the line of movement towards our feet, which we call "down," also points towards the center of the earth. These heavy bodies, as one would expect, settle about the center because of their mutual pressure and resistance, which is equal and uniform from all directions. For the same reason it is plausible that the earth, since its total mass is so great compared with the bodies which fall towards it, can remain motionless under the impact of these very

small weights (for they strike it from all sides), and receive, as it were, the objects that fall upon it. . . .

Certain people, however, propose what they consider to be a more convincing model. They do not disagree with what I have said above, since they have no argument to bring against it. But they think no evidence prevents them from supposing, for example, that the heavens remain motionless and that the earth revolves from west to east about the same axis, making approximately one revolution each day. Or they suppose that both heaven and earth move by some amount, each about the same axis and in such a way as to preserve the overtaking of one by the other. However, they do not realize that, although there is perhaps nothing in the celestial phenomena to count against that simpler hypothesis, nevertheless what would occur here on earth and in the air would render such a notion quite ridiculous.

For the sake of argument, let us suppose that, contrary to nature, the most rare and light matter should either be motionless or else move in exactly the same way as matter with the opposite nature. . . . Suppose, too, that the densest and heaviest objects have a proper motion of the quick and uniform kind which they suppose (although, again, as everyone knows, earthly objects are sometimes not readily moved even by an external force). Even granted this supposition, they would have to admit that the revolving motion of the earth must be the most violent of all the motions they postulate, given that the earth makes one revolution in such a short time. Accordingly, all objects not actually standing on the earth would appear to have the same motion, opposite to that of the earth: neither clouds nor other flying or thrown objects would ever be seen moving towards the east, since the earth's motion towards the east would always outrun and overtake them, so that all other objects would seem to move backwards towards the west. Even if they claim that the air is carried around in the same direction and with the same speed as the earth, still the compound objects in the air would always seem to be left behind by the motion of both earth and air together. Or, if those objects too were carried around, fused as it were to the air, then they would never appear to have any motion either forwards or backwards. They would always appear still, neither wandering about nor changing position, whether they were things in flight or objects thrown. Yet we quite plainly see that they do undergo all these kinds of motion in such a way that they are not even slowed down or speeded up at all by any motion of the earth.

SOURCE: Adapted from Claudius Ptolemy, *Almagest*, trans. G. J. Toomer, New York: Springer-Verlag, 1984.

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The Weaknesses of the Hypotheses

Proclus

Proclus (412–485), best known as a commentator on Plato, also wrote about the Ptolemaic system. His astronomical work gives us a glimpse, from the very twilight of Greek antiquity, of strains within this system that more than a thousand years later caused it to disintegrate. The following excerpt, written in epistolary style, also touches on an issue that mathematicians still discuss: Does theory give us access to a Platonic higher world whose truths may then be applied to physical reality, or must we work outwards and upwards from the physical?

My dear friend: The great Plato thinks that the real philosopher ought to study the sort of astronomy that deals with entities more abstract than the visible heaven, without reference to either sense perception or ever-changing matter. In that world of abstract entities he will come to know slowness itself and speed itself in their true numerical relationships. Now, I think, you wish to bring us down from that contemplation of abstract truth to consideration of the orbits on the visible heaven, to the observations of professional astronomers and to the hypotheses which they have devised from these observations, hypotheses which people like Aristarchus, Hipparchus, Ptolemy and others like them are always writing about. I suppose you want to become acquainted with their theories because you wish to examine carefully all the theories, as far as that is possible, with which the ancients, in their speculations about the universe, have abundantly supplied us.

Last year, when I was staying with you in central Lydia, I promised you that when I had time, I would work with you on these matters in my accustomed way. Now that I have arrived in Athens and heaven has freed me from those many unending troubles, I keep my promise to you and will . . . explain to you the real truth which those who are so eager to contemplate the heavenly bodies have come to believe by means of long and, indeed, endless chains of reasoning. In doing so I must, of course, pretend to myself to forget, for the moment at any rate, Plato's exhortations and the theoretical explanations which he taught us to maintain. Even so, I shall not be able to refrain from applying, as is my habit, a critical mind to their doctrines, though I shall do so sparingly, since I am convinced that the exposition of their doctrines will suggest to you quite clearly what the weaknesses of their hypotheses are, hypotheses of which they are so proud when developing their theories.

Despite the fact that Proclus applies "a critical mind" to the Ptolemaic doctrines, he apparently upholds the system as a whole because it embodies "the simplest hypotheses and the most fitting."

Before I end, I wish to add this: in their endeavor to demonstrate that the movements of the heavenly bodies are uniform, the astronomers have unwittingly shown the nature of these movements to be lacking in uniformity and to be the subject of outside influences. What shall we say of the eccentrics and the epicycles of which they speak so much? Are they only conceptual notions or do they have a substantial existence in the spheres with which they are connected? If they exist only as concepts, then the astronomers have passed, without noticing it, from bodies really existing in nature to mathematical notions and, again without noticing it, have derived the causes of natural movements from something that does not exist in nature. I will add further that there is absurdity also in the way in which they attribute particular kinds of movement to heavenly bodies. That we conceive of these movements, that is not proof that the stars which we conceive of moving in these circles really move anomalously.

On the other hand, if the astronomers say that the circles have a real, substantial existence, then they destroy the coherence of the spheres themselves on which the circles are situated. They attribute a separate movement to the circles and another to the spheres, and again, the movement they attribute to the circles is not the same for all of them; indeed, sometimes these movements take place in opposite directions. They vary the distances between them in a confused way; sometimes the circles come together in one plane, at

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I want to make this further observation: the astronomers exhibit a very casual attitude in their exposition of these hypothetical devices. Why is it that, on any given hypothesis, the eccentric or, for that matter, the epicycle moves (or is stationary) in such and such a way while the star moves either in direct or retrograde motion? And what are the explanations (I mean the real explanations) of those planes and their separations? This they never explain in a way that would satisfy our yearning for complete understanding. They really go backwards: they do not derive their conclusions deductively from their hypotheses, as one does in the other sciences; instead, they attempt to formulate the hypotheses starting from the conclusions, which they ought to derive from the hypotheses. It is clear that they do not even solve such problems as could well be solved.

One must, however, admit that these are the simplest hypotheses and the most fitting for divine bodies, and that they have been constructed with a view to discovering the characteristic movements of the planets (which, in real truth, move in exactly the same way as they *seem* to move) and to formulating the quantitative measures applicable to them.

SOURCE: Proclus, *Hypotyposis astronomicarum positionum*, trans. A. Wasserstein, in *Physical Thought from the Presocratics to the Quantum Physicists*, ed. Shmuel Sambursky, London: Hutchinson, 1974.

13

Their Peculiar Behavior Confounds Mortals' Minds

Martianus Capella and Boethius

Martianus Capella (fl. 410–439) and Boethius (480?–524) are both notable for (among other things) their contributions to the development of "the Seven Liberal Arts." This classification of learning into Grammar, Rhetoric, and Logic (the Trivium) plus Arithmetic, Geometry, Music, and Astronomy (the Quadrivium) was the *taxonomy of the realms of higher education throughout the Middle Ages. Martianus and Boethius likewise both exemplify the prominent medieval tendency to use personification and allegory not only in "literary" but also in philosophical writing.*

*Although Martianus may have "garbled, distorted, and misunderstood" his sources, as Edward Grant claims (*A Source Book in Medieval Astronomy *[Harvard UP, 1974], p. 822), his account of astronomy is intriguing for the ambiguity it injects into what we sometimes blandly assume to be the simplicity of medieval astronomy. First, despite the popular stereotype that the Middle Ages considered the earth to be the center of the universe, and hence as occupying the place of privilege, Martianus repeatedly refers to earth as "clinging to" or "standing at" the middle* and bottom *position. (It is contrary to such a view that Galileo and Kepler later consciously sought to* exalt *the position of earth in the scheme of the universe.) Moreover, Martianus adumbrates a version of the system of Heraclides of Pontus, according to which Mercury and Venus revolve not around the earth but around the sun.*

Astronomy, personified, appears before an assembly of the gods to impart her wisdom.

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Before their eyes a vision appeared, a hollow ball of heavenly light, filled with transparent fire, gently rotating, and enclosing a maiden within. Several planetary deities, especially those which determine men's destinies, were bathed in its glare, the mystery of their behavior and orbits revealed. . . . As she came into their midst many of the gods smiled at her; the others admired her radiant beauty. She began her discourse as follows:

". . . Inasmuch as I have at one time or other in my peregrinations come to be known by the Greeks, whatever has been written by Eratosthenes, Ptolemy, Hipparchus, and other Greeks ought to suffice here and relieve me of the burden of discoursing at greater length. However, . . . I shall not keep silent in the presence of you celestial ones, who will be surveying the courses of your own heavenly bodies.

"The universe is formed in the shape of a globe composed entirely of four elements. The heavens, swirling in a ceaseless and rotary motion, set the earth apart in a stationary position in the middle and at the bottom. . . .

"If each belt of the encompassing substances is found to be homogeneous, no circle can waver from its ethereal orbit. When we use the word 'circles' we do not intend to convey a notion of corporeal demarcations of a fluid substance; we are merely illustrating the risings and settings of planetary bodies as they appear to us. I myself do not consider an axis and poles, which mortals have fastened in a bronze armillary sphere to assist them in comprehending the heavens, as an authoritative guide to the workings of the universe. For there is nothing more substantial than the earth itself, which is able to sustain the heavens. Another reason is that the poles that protrude from the hollow cavity of the perforated outer sphere, and the apertures, the pivots, and the sockets have to be imagined—something that you may be assured could not happen in a rarefied and supramundane atmosphere.

"Accordingly, whenever I shall use the terms axis, poles, or celestial circles, for the purpose of gaining comprehension, my terminology is to be understood in a theoretical sense." . . .

"Now I shall take up the orbits of the planets. Not because of their errant motions—for their courses are defined in the same way as the sun's, and they do not admit of any error—rather, because their peculiar behavior confounds mortals' minds, I shall call them not 'errant bodies' (*planetae*) but 'confusing bodies' (*planontes*). . . .

"For in varying amounts of time the planets strive to make up the distance that they are carried backward by a single diurnal rotation: the moon in a month, the sun in a year, Saturn in thirty years, and the others in periods of time proportional to the amount of space that they traverse.

"Although all these bodies are seen to move toward the eastern horizon, they do not move counter to the universe in a straight and direct line; rather they plod along with sideways motions across the fixed stars of the zodiac. It is well that they do, for the universe could not endure a contrary motion of its parts. . . .

"There is one motion that is common to all seven planets—an easterly one. Another point to be noted is that they all differ in the times and circumstances of their periods. For five of the planets undergo stations and retrogradations, but the sun and the moon are propelled in a steady course. Moreover, these two luminous bodies eclipse each other in turn; but the other five are never eclipsed. Three of these, together with the sun and the moon, have their orbits about the earth, but Venus and Mercury do not go about the earth.

"This general observation must be made, that the earth is eccentric to the orbits of all the planets (that is, it is not located at the center of their circles); and a second observation must be made about all seven, that although the celestial sphere rotates with the same uniform motion, the planets make daily changes in their positions and orbits. . . .

"Now Venus and Mercury, although they have daily risings and settings, do not travel about the earth at all; rather they encircle the sun in wider revolutions. The center of their orbits is set in the sun. . . .

"Now Venus, which is sometimes called Phosphoros, was manifestly thoroughly investigated by Pythagoras of Samos and his pupils. It has been shown to complete its orbit in a period of about a year. . . . When it makes its risings in the early morning, ahead of the sun, it is called Lucifer; when it blazes forth after the setting of the sun, it is called Vesper or Vesperugo. Venus is the only one of the five planets, like the moon, to cast a shadow, and it is the only planet to be clearly discernible and not yielding for a long period of time to the splendor of the rising sun."

If Martianus exemplifies medieval awe and delight in the face of an astronomical order that is beautiful even while defying consistent description, then Boethius expresses the complementary human longing that the disorder of this lower world might be more thoroughly penetrated by the harmony of the cosmos at large. While awaiting torture and execution on trumped-up charges of treason, Boethius wrote his famous Consolation of Philosophy, *in which the goddess Philosophy identifies the principle that creates union and harmony in the universe at large, as well as among human beings. In Philosophy's poem, echoed eight hundred years later by Dante at the very end of his* Divine Comedy, *Boethius praises that unifying cosmic principle, whose name is* Love.

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SOURCES: *Martianus Capell*
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The world, always changing,
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Unites the warring atoms.
The trail-blazing sun
Leads forth the rosy dawn;
The evening star makes way
For night, the moon's dominion.
The eager ocean currents
Do not transgress their bounds;
Safe fenced remains the earth
Against invading waters.
It is Love who joins all these,
Reigning over land and sea;
The universe itself is ruled by Love.

If Love let slip the reins,
Whatever now keeps peace
Would fall to constant warring:
Beauty, trust, harmony
Dissolving into discord.
Love consecrates the bond
Uniting diverse peoples;
In marriage too Love spins
The cords of holy union;
And Love again decrees,
Let faithful friendship be.
O human race, how happy—
If equally your minds were ruled
By Love, who rules the universe.

SOURCES: *Martianus Capella and the Seven Liberal Arts*, vol. 2, *The Marriage of Philology and Mercury*, trans. William Harris Stahl and Richard Johnson with E. L Burge, New York: Columbia UP, 1977; Boethius translated from the *Consolatio Philosophiae*, Book 2, poem 8.

14

We Consider Time a Thing Created

Moses Maimonides

Moses Maimonides, or "son of Maimon" (1135–1204), is widely acknowledged to be the most influential Jewish thinker of the Middle Ages, and his most famous work is The Guide of the Perplexed, *a wide-ranging work on science, philosophy, and scriptural interpretation that was originally written in Arabic.* The Guide *is a highly engaging and sometimes surprising work. While it embodies many commonplaces that have come to define our notions of medieval thought, common assumptions are just as often treated critically. For example, although Aristotelianism is everywhere evident in* The Guide, *Moses' use of Aristotle is judicious and nuanced. Above all his thought is Jewish, rejecting any temptation to place God within the limits of human reason or of simple analogy. Having drawn parallels between "the Universe" and "Man," Moses warns: "Bear in mind, however, that in all that we have noticed about the similarity between the universe and the human being, nothing would warrant us to assert that man is a microcosm." Furthermore:*

The faculty of thinking is a force inherent in the body, and is not separated from it, but God is not a force inherent in the body of the universe, but is separate from all its parts. How God rules the universe and provides for it is a complete mystery; man is unable to solve it. For, on the one hand, it can be proved that God is separate from the universe, and in no contact whatsoever with it; but, on the other hand, His rule and providence can be proved to exist in all parts of the universe, even the smallest. Praised be He whose perfection is above our comprehension.

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Typically, in volume II of The Guide, *proceeding to a consideration of things cosmological—which of course he does within a broadly Ptolemaic framework—Maimonides raises criticisms against the completeness or consistency of the Ptolemaic system. As one might expect in a medieval discussion, Moses' view is deeply hierarchical, and it is saturated with the notion of "influences" and the agency of higher created beings. However, as one might not expect, given the now-prevalent confusion between geocentrism and anthropocentrism, his views are opposed to placing human interests or "transient earthly beings" upon a pinnacle.*

When a simple mathematician reads and studies . . . astronomical discussions, he believes that the form and the number of the spheres are facts established by proof. But this is not the case; for the science of astronomy does not aim at demonstrating them, although it includes subjects that can be proved; e.g., it has been proved that the path of the sun is inclined against the equator; this cannot be doubted. But it has not yet been decided whether the sphere of the sun is eccentric or contains a revolving epicycle, and the astronomer does not take notice of this uncertainty, for his object is simply to find a hypothesis that would lead to a uniform and circular motion of the stars without acceleration, retardation, or change, and which is in its effects accordant with observation. He will, besides, endeavor to find such a hypothesis which would require the least complicated motion and the least number of spheres. He will therefore prefer a hypothesis which would explain all the phenomena of the stars by means of three spheres to a hypothesis which would require four spheres. From this reason we adopt, in reference to the circuit of the sun, the theory of eccentricity, and reject the epicyclic revolution assumed by Ptolemy.

Maimonides also addresses the issue of whether (as Aristotle believed) the universe is eternal:

Those who follow the Law of Moses, our Teacher, hold that the whole universe, i.e., everything except God, has been brought by Him into existence out of non-existence. In the beginning God alone existed, and nothing else; neither angels, nor spheres, nor the things that are contained within the spheres existed. He then produced from nothing all existing things such as they are by His will and desire. Even time itself is among the things created; for time depends on motion, i.e., on an accident in things which move, and the things upon whose motion time depends are themselves created beings, which have passed from non-existence into existence. We say that God *existed* before the creation of the universe, although the verb *existed* appears to

imply the notion of time; we also believe that He existed an infinite space of time before the universe was created; but in these cases we do not mean time in its true sense. We only use the term to signify something analogous or similar to time. For time is undoubtedly an accident [in the Aristotelian sense] and, according to our opinion, one of the created accidents, like blackness and whiteness. It is not a quality, but an accident connected with a motion. . . .

We consider time a thing created. It comes into existence in the same manner as other accidents and the substances which form the substratum for the accidents. For this reason, namely, because time belongs to the things created, it cannot be said that God produced the universe *in the beginning*. Consider this well, for he who does not understand it is unable to refute forcible objections raised against the theory of *creatio ex nihilo* [creation out of nothing]. If you admit the existence of time before the creation, you will be compelled to accept the theory of the eternity of the universe. For time is an accident and requires a substratum. You will therefore have to assume that something [beside God] existed before this universe was created, an assumption which it is our duty to oppose.

Maimonides goes on to highlight anomalies in the Aristotelian/Ptolemaic system—even though this is the system he largely accepts. The purpose of the critique is to establish the Aristotelian/Ptolemaic system as a tool, not as an absolute explanation idolatrously relied upon.

You know of Astronomy as much as you have studied with me, and learnt from the book *Almagest*; we had not sufficient time to go beyond this. The theory that [the spheres] move regularly, and that the courses of the stars are in harmony with observation, depends, as you are aware, on two hypotheses: we must assume either epicycles, or eccentric spheres, or a combination of both. Now I will show that each of these hypotheses is irregular, and totally contrary to the results of Natural Science. Let us first consider an epicycle, such as has been assumed in the spheres of the moon and the five planets, rotating on a sphere, but not round the center of the sphere that carries it. This arrangement would necessarily produce a revolving motion; the epicycle would then revolve, and entirely change its place. But that anything in the spheres should change its place is exactly what Aristotle considers impossible. . . . (1) It is absurd to assume that the revolution of a cycle has not the center of the universe for its center; for it is a fundamental principle in the order of the universe that there are only three kinds of motion—from the center, towards the center, and round the center. But an epicycle does not move away from the center, nor towards it, nor round it. (2) Again, according to

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what Aristotle explains in Natural Science, there must be something fixed, round which the motion takes place. This is the reason why the earth remains stationary. . . .

Consider, therefore, how many difficulties arise if we accept the theory which Aristotle expounds in *Physics*. For, according to that theory, there are no epicycles, and no eccentric spheres, but all spheres rotate round the center of the earth! How then can the different courses of the stars be explained? How is it possible to assume a uniform perfect rotation with the phenomena which we perceive, except by admitting one of the two hypotheses or both of them? The difficulty is still more apparent when we find—admitting what Ptolemy said as regards the epicycle of the moon, and its inclination towards a point different both from the center of the universe and from its own center—that the calculations according to these hypotheses are perfectly correct, within one minute; and that their correctness is confirmed by the most accurate calculation of the time, duration, and extent of the eclipses, which is always based on these hypotheses. Furthermore, how can we reconcile, without assuming the existence of epicycles, the apparent retrogression of a star with its other motions? How can rotation or motion take place round a point which is not fixed? These are real difficulties.

Maimonides contrasts the monotheistic doctrine of creation to the worship of the heavens by members of the Sabean religion. Abraham himself is seen as the bearer of the high view of creation in the very midst of those who worship the stars.

It is well known that the Patriarch Abraham was brought up in the religion and the opinion of the Sabeans that there is no divine being except the stars. . . . They consider the stars as deities, and the sun as the chief deity. . . . They say distinctly that the sun governs the world, both that which is above and that which is below. These are exactly their expressions. . . .

All the Sabeans thus believed in the eternity of the universe, the heavens being in their opinion God. . . . [But] when [Abraham] the "pillar of the World" appeared, he became convinced that there is a spiritual Divine Being, which is not a body, nor a force residing in a body, but is the author of the spheres and the stars; and he saw the absurdity of the tales in which he had been brought up. He therefore began to attack the belief of the Sabeans, to expose the falsehood of their opinions, and to proclaim publicly in opposition to them, "the name of the Lord, the God of the universe" (Gen. 21:33), which proclamation included at the same time the existence of God, and the creation of the universe by God.

Maimonides also engages—again with rather surprising results—the perennial cosmological issue of teleology: what, if any, is the purpose of the universe?

Intelligent persons are much perplexed when they inquire into the purpose of the Creation. I will now show how absurd this question is, according to each one of the different theories. An agent that acts with intention must have a certain ulterior object in that which he performs. This is evident, and no philosophical proof is required. It is likewise evident that that which is produced with intention has passed over from non-existence to existence. It is further evident, and generally agreed upon, that the being which has never been and will never be without existence is not in need of an agent. . . . The question, "What is the purpose thereof?" cannot be asked about anything which is not the product of an agent. Therefore, we cannot ask what is the purpose of the existence of God. He has not been created. According to these propositions it is clear that the purpose is sought for everything produced intentionally by an intelligent cause; that is to say, a final cause must exist for everything that owes its existence to an intelligent being. But for that which is without a beginning, a final cause need not be sought. . . . After this explanation you will understand that there is no occasion to seek the final cause of the whole universe, neither according to our theory of the creation, nor according to the theory of Aristotle, who assumes the eternity of the universe. . . .

The existence of an ultimate purpose in every species, which is considered as absolutely necessary by everyone who investigates into the nature of things, is very difficult to discover. Still more difficult is it to find the purpose of the whole universe. . . . It is clear that man is the most perfect being formed by matter; he is the last and most perfect of earthly beings, and in this respect it can truly be said that all earthly things exist for man, i.e., that the changes which things undergo serve to produce the most perfect being that can be produced. Aristotle . . . need therefore not ask to what purpose does man exist, for the immediate purpose of each individual being is, according to his opinion, the perfection of its specific form. . . . It seems therefore clear that, according to Aristotle . . . there is no occasion for the question what is the object of the existence of the universe. But of those who accept our theory that the whole universe has been created from nothing, some hold that the inquiry after the purpose of the creation is necessary, and assume that the universe was only created for the sake of man's existence, that he might serve God. Everything that is done, they believe, is done for man's sake; even the spheres move only for his benefit, in order that his wants might be supplied. . . .

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On examining this opinion as intelligent persons ought to examine all different opinions, we shall discover the errors it includes. Those who hold this view, namely, that the existence of man is the object of the whole creation, may be asked whether God could have created man without those previous creations, or whether man could only have existence after the creation of all other things. If they answer in the affirmative, that man could have been created even if, e.g., the heavens did not exist, they will be asked what is the object of all these things, since they do not exist for their own sake but for the sake of something that could exist without them? Even if the universe existed for man's sake and man existed for the purpose of serving God, as has been mentioned, the question remains, What is the end of serving God? He does not become more perfect if all His creatures serve Him and comprehend Him as far as possible; nor would he lose anything if nothing existed beside Him. It might perhaps be replied that the service of God is not intended for God's perfection; it is intended for our perfection—it is good for us, it makes us perfect. But then the question might be repeated, What is the object of our being perfect? We must in continuing the inquiry as to the purpose of the creation at last arrive at the answer, It was the Will of God, or His Wisdom decreed it. And this is the correct answer. . . .

You must not be misled by what is stated of the stars [that God put them in the firmament of the heavens] to give light upon the earth, and to rule by day and by night. You might perhaps think that here the purpose of their creation is described. This is not the case. We are only informed of the nature of the stars, which God desired to create with such properties that they should be able to give light and to rule. In a similar manner we must understand the passage, "And have dominion over the fish of the sea" (Gen. 1:28). Here it is not meant . . . that man was created for this purpose, but only that this was the nature which God gave man. But as to the statement in Scripture that God gave the plants to man and other living beings, it agrees with the opinion of Aristotle and other philosophers. It is also reasonable to assume that the plants exist only for the benefit of the animals, since the latter cannot live without food. It is different with the stars. They do not exist only for our sake, that we should enjoy their good influence. For the expressions "to give light" and "to rule" merely describe . . . the benefit which the creatures on earth derive from them.

I have already explained to you the character of that influence that continually causes the good to descend from one being to another. To those who receive the good flowing down upon them, it may appear as if the being existed for them alone that sends forth its goodness and kindness unto them. Thus some citizen may imagine that it was for the purpose of protecting his house by night from thieves that the king was chosen. To some extent this is cor-

rect; for when his house is protected, and he has derived this benefit through the king whom the country has chosen, it appears as if it were the object of the king to protect the house of that man. In this manner we must explain every verse, the literal meaning of which would imply that something superior was created for the sake of something inferior, namely, that it is part of the nature of the superior thing [to influence the inferior in a certain manner]. We remain firm in our belief that the whole universe was created in accordance with the will of God, and we do not inquire for any other cause or object. . . .

You must not be mistaken and think that the spheres and the angels were created for our sake.

SOURCE: Moses Maimonides, *The Guide of the Perplexed,* trans. M. Friedländer, 3 vols., London, 1881–1885.

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From This Point Hang the Heavens

Dante Alighieri

Probably no twentieth-century interpreter of the Middle Ages produced a more sympathetic account of the period's cosmology than did C. S. Lewis (1898–1963). In his primer on that topic for students of literature, The Discarded Image, *Lewis expounds Chalcidius, a fourth-century commentator on Plato's* Timaeus, *as a prototype of the medieval worldview.*

For Chalcidius, the geocentric universe is not in the least anthropocentric. If we ask why, nevertheless, the earth is central, he has a very unexpected answer. It is so placed in order that the celestial dance may have a center to revolve about—in fact, as an aesthetic convenience for the celestial beings. It is perhaps because his universe is already so well and radiantly inhabited that Chalcidius, though he mentions the Pythagorean doctrine (which peopled the moon and other planets with mortals), is not interested in it. . . .

Centuries later . . . Alanus ab Insulis [d. 1203] compares the sum of things to a city. In the central castle, in the Empyrean, the Emperor sits enthroned. In the lower heavens live the angelic knighthood. We, on earth, are "outside the city wall." How, we ask, can the Empyrean be the center when it is not only on, but outside, the circumference of the whole universe? Because, as Dante was to say more clearly than anyone else, the spatial order is the opposite of the spiritual, and the material cosmos mirrors, hence reverses, the reality, so that what is truly the rim seems to us the hub.

The exquisite touch which denies our species even the tragic dignity of being outcasts by making us merely suburban, was added by Alanus. In other

respects he reproduces Chalcidius' outlook. We watch "the spectacle of the celestial dance" from its outskirts. Our highest privilege is to imitate it in such measure as we can. The Medieval Model is, if we may use the word, anthropoperipheral.

As Lewis indicates, one of the most imaginative works written within the world view of the middle ages is Dante Alighieri's The Divine Comedy *(c.1310–1314). The first volume of* The Comedy, The Inferno, *provides a moral analogy to medieval cosmology's assumption that the center of the universe, which is occupied by the center of the earth, is a kind of cosmic sump where that which is grossest and heaviest accumulates if nothing grosser and heavier stands in its way. This center Dante (sounding quite Aristotelian) refers to as "the middle, / Where everything of weight unites together." In Dante's moral universe, the "circles" of hell are thus worse according to their proximity to the center. Moreover, it is cold, not heat, that characterizes the symbolic terrain encountered there. Dante, in his narration of the end of his journey towards the center, recalls:*

> Then I beheld a thousand faces, made
> Purple with cold; whence o'er me comes a shudder,
> And evermore will come, at frozen ponds.
> (*Inferno* 32.70–72)

And in the very center of hell, which coincides with the center of the earth, one finds the perpetrator of the worst evil, Satan himself—yet (again) not in flames but in ice, which depicts the utter lack of vitality and dynamism that is the nature of evil.

After leaving hell, Dante is led up from the center of the earth, up Mount Purgatory, and up through the heavens to the ninth sphere, the Primum Mobile. However, once here, he finds himself in some profounder sense no longer looking out onto the Empyrean but looking in. *As Robert Osserman puts it in his discussion of the "poetry of the universe," in Dante "we are to think of the Empyrean as somehow both surrounding the visible universe and adjacent to it" (see also Osserman on Dante and the "curved space" of Riemann, chapter 57).*

> A point beheld I, that was raying out
> Light so acute, the sight which it enkindles
> Must close perforce before such great acuteness.

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SOURCES: C. S. Lewis, *T*
Dante, *The Divine Come*
New York [c. 1895].

And whatsoever star seems smallest here
Would seem to be a moon, if placed beside it.
As one star with another star is placed.

Perhaps at such a distance as appears
A halo cincturing the light that paints it,
When densest is the vapor that sustains it,

Thus distant round the point a circle of fire
So swiftly whirled, that it would have surpassed
Whatever motion soonest girds the world;

And this was by another circumcinct,
That by a third, the third then by a fourth,
By a fifth the fourth, and then by a sixth the fifth;

The seventh followed thereupon in width
So ample now, that Juno's messenger
Entire would be too narrow to contain it.

Even so the eighth and ninth; and every one
More slowly moved, according as it was
In number distant farther from the first.

And that one had its flame most crystalline
From which less distant was the stainless spark,
I think because more with its truth imbued.

My Lady, who in my anxiety
Beheld me much perplexed, said: "From that point
Dependent is the heaven and nature all."

(*Paradiso* 28.16–42)

SOURCES: C. S. Lewis, *The Discarded Image*, Cambridge: Cambridge UP, 1964; Dante, *The Divine Comedy of Dante Alighieri*, trans. Henry Wadsworth Longfellow, New York [c. 1895].

16

If a Man Were in the Sky and Could See the Earth Clearly

Nicole Oresme

Nicole Oresme (c. 1325–1382) was a French bishop and Aristotelian scholar who nevertheless presented one of the most cogent pre-Copernican statements of the hypothesis that the earth, not the universe, rotates once every twenty-four hours. He also speculated about the possibility of other worlds. However, Oresme's brilliant logical mind earned him a place in the history of economics as well as astronomy, and the principle he seems to have applied in both fields is in fact a kind of relativity. In economics, he emphasized the need for a stable coinage so that goods could be valued relative to a fixed currency. Perhaps from this concept it was not a big step to the recognition that, in the physical universe, fixity could be attributed as easily to the heavens as to the earth. In a word, Oresme was attracted by this explanation's economy.

In a thought experiment, Oresme imagines a man trying to judge movement and direction from on board a moving ship—and in the process provides us with a thematic link backward to Ptolemy and forward to Einstein.

It seems to me that we might well affirm, subject to correction, . . . that it is the earth that makes a daily rotation, and not the heavens. And I would like to assert the impossibility of establishing the contrary claim first by means of any observation or, secondly, by means of any rational process. And thirdly I will give my own reasons why the earth's movement might indeed be supported.

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As for observation, we see with our own eyes that the sun, the moon, and a number of stars do rise and set, day after day, while some stars revolve about the north pole. And this could not happen unless the heavens turned. . . . So it is the heavens that make a daily rotation.

A further observation is this: if it is the earth that turns, then it makes a complete revolution in one natural day. And accordingly trees, houses, and we ourselves are moving very quickly eastwards—so that it would seem the air and the wind should always blow very strongly from the east and make a rushing sound just as it does against a shaft shot from a crossbow, only much louder. But this is not at all what we do see.

The third observation is one cited by Ptolemy: if someone were on board a ship moving very rapidly eastwards and he shot an arrow straight up in the air, then it would not fall onto the ship but far off to the west. Likewise, if the earth were rotating very rapidly from west to east, then supposing someone threw a stone straight up into the air, it would not fall there where it started off but far off to the west. But that is not what we actually see.

What I shall say about these arguments can also, I think, be directed against all the rest that will be put forward on the same topic.

Accordingly, I assume first that the whole physical system—the whole mass of all physical bodies in the universe—is divided into two parts. One is the heavens with the sphere of fire and the upper region of the air, all of which, according to Aristotle's first book of *Meteorology*, makes a daily rotation. And the other part, everything else—namely, the middle and lower regions of the air, the water, the earth, and the composite bodies—all of this, according to Aristotle, is immobile, unaffected by any daily rotation.

Furthermore, I assume that movement from one place to another can be apprehended by the senses only insofar as we apprehend that one body changes its situation relative to another body. Thus, if a man is in a ship A moving smoothly, be it fast or slow, and sees nothing but another ship B moving in exactly the same manner as A in which he is located, then it will appear to this man that neither of the ships is moving. If A is at rest and B is moving, then it appears to him as if B is moving. And if A is moving and B is at rest, it still appears to him as if A is at rest and B is moving. Thus, if A remained at rest for an hour while B was moving, and if, conversely, during the very next hour A were moving and B at rest, then this man would be unable to apprehend the change, the variation. Rather, it would seem to him the whole time that B was moving. This is what experience tells us. The reason is that these two bodies A and B stand in the same relative position the one to the other whether A moves and B is at rest, or B moves and A is at rest. As is affirmed in Witelo's *Perspective* [ca. 1270], book 4, we

apprehend movement only insofar as we apprehend the change of a body's position relative to that of another.

I assert accordingly that if, of the two parts of the universe mentioned earlier, the upper part today made a daily rotation—as it does—and the lower part did not, but tomorrow the situation were reversed so that the part down here made a daily rotation while the other, the heavens, did not, we would be able to apprehend nothing of this change. Rather, everything would still seem just the same tomorrow and today as far as this matter is concerned. It would continue to appear to us that our part stayed put while the other part kept on moving, just as to a man in a moving boat it appears that the trees outside are moving. Likewise, if a man were in the sky and moving along with it in its presumed daily rotation, and if he could see the earth clearly and make out mountains, valleys, rivers, cities, and castles distinctly, then it would seem to him that *the earth* made a daily rotation, just as it seems to us here on earth that the heavens do. Similarly, if the earth made a daily rotation and the heavens did not, then it would seem to us that the earth was at rest and that the heavens moved. This can easily be imagined by anybody with good sense.

Thus we have a clear rejoinder to the first argument. For we would assert that the sun and the stars seem accordingly to rise and to set, and the heavens to revolve, on account of the movement of the earth and of the elements which we inhabit.

And it would seem that the second argument is answered, according to this interpretation, by the claim that the earth moves not merely by itself but together, as already mentioned, with the air and the water, albeit the water and the air down here can also be given additional motion by the winds and other causes. The case is similar to that of a ship, in which the enclosed air seems to those who are in it not to be moving.

The third argument—concerning the arrow or stone launched straight up, etc.—looks like the hardest to answer. But we could say that the arrow shot upwards is carried swiftly eastwards together with the air through which it is passing and with the whole mass of earth's lower regions, as described earlier, which makes a daily rotation. And this is why the arrow falls back to the same place on earth from which it departed.

To see how this is possible, compare it with the case of a man on board a ship moving swiftly eastwards without his being aware of the movement. Now if he brings his hand straight down along the line of the ship's mast, it will seem to him that his hand has not moved other than straight down. And likewise, according to the view we are considering, it seems to us that the arrow moves straight up or straight down.

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Similarly, on a ship moving in the manner described, there can be movements lengthways, sideways, up, down, and any other way, and they appear to take place exactly as if the ship were at rest. This is why, if a man on board this ship were to walk westwards less quickly than the ship was heading eastwards, it would seem to him that he was moving farther west when actually he was moving farther east. And likewise in the case we have been considering, all movements down here would appear just as if the earth were stationary.

To sharpen the answer to the third objection, let me add to this artificial example a more natural one, whose validity is endorsed by Aristotle. Suppose that, in the upper region of the air there is a bundle of pure fire called A which is very light, so that it rises as high as it can, up to a place called B near the concave surface of the heavens. Now the case here will be the same as that of the arrow mentioned earlier. In this case the movement of A will consist of a movement that is rectilinear *and*, in part, circular, for the region of the air and the sphere of fire that A passed through both move, according to Aristotle, in a circular manner. And if they did not move thus, A would rise straight up along the vertical line AB. But because, in keeping with the earth's daily rotation, B has in the meantime moved to place C, obviously A in its ascent describes the line AC, and the movement of A consists in a movement at once rectilinear and circular. And likewise the flight of the arrow. . . .

Therefore I conclude we could make no observation that would establish that the heavens make a daily rotation and that the earth does not.

SOURCE: Translated (with kind advice from Richard Holdaway) from Nicole Oresme, *Le Livre du ciel et du monde* (1377); in *Mediaeval Studies*, vol. 4, Toronto: Pontifical Institute of Mediaeval Studies, 1942.

17

A Single Universe in Which Each Star Influences Every Other

Nicholas Cusanus

Nicholas Cusanus (1401–1464) was born in Kues (or Cusa) on the Moselle River a year after the death of Geoffrey Chaucer. He led an active life as international ecclesiastical diplomat and was made Cardinal in 1448. The contemplative side of his career culminates in the treatise On Learned Ignorance *(1440), whose title hints at the paradoxical and at times mystical nature of its contents.*

What is perhaps most startling about this work is the manner in which Nicholas arrives at apparently prescient conclusions about the universe using a methodology that is entirely abstract and speculative. Contrary to still-popular beliefs concerning the empirical nature of what was to become Copernican cosmology, the reevaluation of the Ptolemaic system in fact was grounded on a critical refusal to accept the evidence of the senses. It was really Aristotle who was empirical. For philosophers like Nicholas, on the other hand, a truly critical critique of physical reality is possible precisely because there is a higher Reality that the physical may imitate but does not comprise. Not unlike Kepler almost two centuries later, Nicholas employs a form of Platonic or Neoplatonist deduction to undermine Aristotelian/Ptolemaic tenets concerning the shape and structure of the world. In his discussion of movement there is even a hint, as there is in Oresme, of what in the twentieth century would come to be known as relativity.

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Clearly, it is actually this earth that moves, though to us it does not appear to do so; for we apprehend motion only relative to something motionless. Anyone on board ship but not knowing that the water is flowing, nor able to see the riverbanks—how would he, from midstream, apprehend that the ship was moving? This is why to anyone at all, whether he be on earth, or on the sun or another planet, it always seems as if he is in the center, immobile as it were, while everything else is in motion. Certainly one always establishes one set of fixed points relative to oneself, whether one inhabits the sun or the earth, the moon or any of the other planets. Thus it is as if the world system had its center everywhere and its circumference nowhere, for God is its circumference and center, and he is everywhere and nowhere.

Just as for Plato no physical table or man or just act perfectly participates in the Forms (respectively) of the Table, or Man, or Justice; so for Nicholas no physical object has a shape that perfectly conforms to the mathematical ideal toward which our language of shapes (circles, spheres, cubes, etc.) gestures. Nicholas's discussion also adumbrates a geometry that is more Riemannian than Euclidean (that is, based on surfaces of spheres rather than flat planes).

Even this earth is not spherical, as people have said it is, though it tends towards the spherical. The shape of the universe is limited in its parts, just as its motion is. But when an infinite line is considered as limited so that, as limited, it can be neither more perfect nor more capacious, then it is circular, for it is in a circle that beginning meets end. Thus the more perfect motion is also circular, and from this it follows that the more perfect solid shape is spherical. . . .

The earth, then, has a noble, spherical shape and a circular motion, but it could be more perfect. For as regards the perfection, motion, and shape of the world there is no maximum or minimum. So clearly it is wrong to call this earth most vile or base. For although it seems more central than other things in the universe, it is therefore also farthest from the center, as explained earlier.

One of the consequences of this paradoxical deconstruction of location is the qualitative "neutralizing" of place. In contrast to Aristotle or Dante, for Nicholas Cusanus there is no "dead center," no location that marks a body's grossness or baseness. The importance of this contrast with the standard medieval understanding of the place and nature of the earth is profound. Among other implications, it entails a revision of the medieval doctrine of "influences," whereby the power and quality of stars and planets are communicated downward to the earth. For if downward *becomes a relative term,*

then influence may travel a two-way street, and the earth itself may be reconceived as a star shedding its own influence.

Therefore the earth is a magnificent star possessing light, heat, and influence different and distinct from all other stars, just as each of these is unique as regards light, nature, and influence. Each star communicates light and influence to the next, though this is not its purpose. For all stars move and shine in order to be most fully what they are, from which their sharing of influence arises as a consequence. Likewise, light gives light because that is its nature and not so that I may see, yet the sharing of light arises as a consequence when I use it for purposes of seeing. And in this way holy God has created all things: as each thing desires to preserve its own being as a gift from God, it does so within a fabric of sharing with other things.

Furthermore, just as physical location is no marker of excellence or baseness, so physical size for Nicholas becomes a neutral matter. It is rather "intellectual nature" that constitutes excellence. Therefore, even though Nicholas's speculations lead him briefly to contemplate the existence of extraterrestrial life, he returns to that intellectual nature here on earth—and to a suggestion that is actually more anthropocentric than any that raw Aristotelian geocentrism could ever have generated.

The fact that the earth is smaller than the sun and receives influence from it is no reason for calling it more contemptible, for the whole region of the earth, reaching all the way to the outer sphere of fire, is huge. It is true, as we see from its shadow in eclipses, that the earth is smaller than the sun; yet it is not known by how much the region of the sun is greater or smaller than that of the earth. In any case they cannot be precisely equal, for no star can be equal to another. Nor is earth the smallest star, for, as we know from eclipses, it is greater than the moon and even, some would say, than Mercury and perhaps also the other planets. From its size, therefore, no argument can be constructed for the earth's inferiority. . . .

Nor can *place* support such a claim: namely, that this place in the universe is the home of humans, animals, and plants which are of a less noble rank than those dwelling in the sun and other planets. God is the center and circumference of all the starry realms, and from him proceed natures of manifold excellence that inhabit those realms. It is not fitting that such celestial and stellar locations be empty while this perhaps little earth is inhabited. And yet, in accordance with the intellectual nature inhabiting earth and its environs, it seems impossible to postulate one that is more perfect or more noble, even if other planets be inhabited by beings of a different kind. Human be-

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ings, indeed, desire not to take on a different nature but merely to achieve the perfection of their own nature. . . .

Since we know nothing of that whole realm, we likewise know nothing at all of its inhabitants. A similar pattern is observable even here on earth: animals of one species join together as it were to make their own domain, and they share this domain and its features among themselves, neither caring much nor indeed knowing much about outsiders. Animals of one species have no concept of outsiders other than that communicated in the form of vocal expression, and this in a rather minimal way that produces nothing better than mere opinion, even after long experience. How very much less, then, can we know of the inhabitants of other worlds.

If the earth is a star, however, shedding influence upon and receiving influences from other stars, then the medieval notion of earth and the "sublunary sphere" as a unique realm of mutability "quarantined" from the rest of the universe cannot stand. Although empirical proof of change in the heavens came only later, with the observation of comets and novas in the last half of the sixteenth century and with Galileo's subsequent account of sunspots, Nicholas in his own time radically undermined the division of the cosmos into two "zones" of mutability and immutability. To put it positively, he retheorized the unity *of the physical universe.*

Not even the corruptibility of things which we here experience is compelling evidence of earth's baseness. For given a single universe in which each star influences every other, we have no grounds for declaring anything to be utterly corruptible. It is better instead to conceive of corruption as one or another mode of being: where influences so to speak were once knit together, they now unravel, so that a thing's mode of being either this or that passes away. Thus death has no place, as Virgil says. Rather, death appears to be merely the dissolving of a composite thing into its components. And who can know whether such dissolution occurs only among things of this earth?

For Nicholas Cusanus, the whole physical universe radically falls short of perfection, if only because it is a created thing. Yet its glory and unity are not therefore diminished, for these reflect the glory of the Maker, whose creative skills Nicholas conceives of as combining those of an arithmetician, a geometrician, and a musician.

It is the unanimous judgment among the wise that the vastness, beauty, and order of the visible creation cause us to be astounded at God's artistry and excellence. Now having touched on some of the products of his marvelous

skill, let us add a further brief word of wonder regarding the creation of the universe as far as the setting and composition of its components are concerned.

In creating the universe God employed arithmetic, geometry, music, and astronomy, arts that we too use when we investigate the structure of things, including their substance and motion. By means of arithmetic God joined things together. By means of geometry he shaped things according to the rank of each so as to produce solidity, stability, and mobility. By means of music he gave things proportion in such a way that there should be no more earth in earth than there is water in water, air in air, or fire in fire; accordingly, no element may be wholly resolved into another. And from this it follows that the world system cannot pass away. . . .

Thus God composed the elements in a wonderful and orderly manner, creating all things in number, weight, and measure—number in keeping with arithmetic, weight with music, measure with geometry. Heaviness is sustained and constrained by lightness. For example, fire suspends the heavy earth as it were in its midst, and lightness is supported by heaviness, as fire is by earth. Moreover, in ordaining these things, Eternal Wisdom employed an inexpressible symmetry. He foreknew by what degree each element should precede another, and he measured them in such a way that water should be as much lighter than earth, as air is than water, and as fire is than air; and at the same time that weight should be proportionate to size, and that a container should occupy a larger space than that which it contains. He linked things together in such interdependence that they are necessary to each other's existence. And thus the earth, as Plato says, is like an animal whose bones are stones, whose arteries are rivers, whose hairs are trees; and animals feed among those hairs just as mites do among the hairs of the animals. . . .

Who will not stand in awe of the Craftsman who employed this same skill in the spheres and stars and realms of stars? For thus he has made all things to blend in unceasing diversity and harmony. In one single universe he weighed out the multitudinous stars in their places, ordaining their motions and their distribution in such a way that, unless each region were precisely as it is, neither could it exist nor persist in its place and arrangement, nor could the universe itself continue to be. He gave to each star its unique brightness, influence, shape, and color, as well as heat which is transmitted along with brightness. And he so proportionately and harmoniously composes the proportions of parts, that in all things the motion of the part is relative to the whole—heavy things moving downward towards the center and light things rising upwards from the center, or else about the center, as we observe with the orbital movement of stars.

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These matters are indeed full of wonder, variety, and contrast. Yet in them, learned ignorance teaches us what we have already heard: that we have not the capacity to fathom the reason for all of God's works; but we may stand in awe before them. For great is the Lord, and his greatness is without bounds. As he is absolute greatness, the author and comprehender of all his works, so too is he their end. In him all things *be*, and without him is nothing. He is the beginning, the middle, the end of all things, the center and circumference of all that is. Accordingly, it is he who is to be sought in all things, for apart from him all things are nothing. To possess God alone is to possess all things, for he is all. And to know him is to know all things, for he is the truth of all. It is his will that the system of this universe should cause us to stand in wonder; yet the more we wonder at it, the more he hides it from us, since it is *he* whom he would have us seek with all diligence and with all our heart.

SOURCE: Translated from *Nicolai Cusani De docta ignorantia libri tres*, Bari: Laterza, 1913.