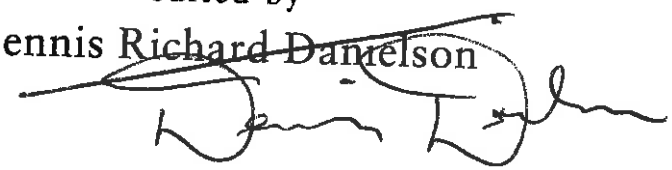
the Book of the Cosmos

Imagining the Universe from Heraclitus to Hawking

A Helix Anthology

edited by

Dennis Richard Danielson



PERSEUS
PUBLISHING

18

Almost Contrary to Common Sense

Nicholas Copernicus

There is great pathos in the story of Nicholas Copernicus (1473–1543) being brought a freshly published copy of De Revolutionibus Orbium Caelestium *on his deathbed. We can only speculate what his thoughts then might have been about his book's future reception and impact. Yet perhaps his dedicatory letter to Pope Paul III gives us a clue. In this letter, Copernicus is most obviously defensive; he worries his opinions will be merely "shouted down." Less obviously, however, we sense that, while surely believing in the scientific veracity of his theory, Copernicus as a person is still reeling with amazement at what he hears himself propounding. Repeatedly he uses the term* absurd *to characterize his own teachings, and that is how they initially must have tasted even to the teacher himself, who nevertheless presents his views with undoubted if reluctant courage.*

To His Holiness Pope Paul III

Holy Father, I can guess already that some people, as soon as they find out about this book I have written on the revolutions of the universal spheres, in which I ascribe a kind of motion to the earthly globe, will clamor to have me and my opinions shouted down. Nor am I so pleased with my own work that I disregard others' judgments concerning it. I know that a philosopher's thoughts are beyond the reach of common opinion, because his aim is to search out the truth in all things—so far as human reason, by

God's permission, can
are to be avoided.

My thoughts, then,
many centuries support
the heavens—their cent
I on the contrary declar
Should I publish my arg
better to follow the ex
handed down the secret
orally, not in writing—a
so, it seems to me, not
their teachings, but out
covered by great men fr
fort to literary accompl
the advice and example
of philosophy, are, as a
like drones among bees
would face on account
gave up completely the

And yet, although for
drew me along. Foremos
Capua, famous in all fi
Tiedemann Giese, Bisho
all good literature. For r
times sharply, to publish
buried and hidden, not
than a few other eminen
urged me to set aside m
work for the common go
more absurd my doctrine
greater would be their a
lished and the clouds o
These persuasions and th
friends, as they had long

However, Your Holine
these findings—after hav
through, even to the poir
concerning the earth's m
your desire to hear why i
ions of astronomers and
ine any motion of the ear

God's permission, can do that. But I do think that completely false opinions are to be avoided.

My thoughts, then, were these: Those who know that the judgment of many centuries supports the view that the earth stands firm in the midst of the heavens—their center, as it were—will think it an absurd bit of theater if I on the contrary declare that the earth moves. So for a long time I wavered. Should I publish my argument showing that the earth moves? Or would I be better to follow the example of the Pythagoreans, and some others, who handed down the secrets of their philosophy only to relatives and friends—orally, not in writing—as the letter of Lysis to Hipparchus indicates. They did so, it seems to me, not (as some think) out of mere unwillingness to share their teachings, but out of a desire to protect beauties and profundities discovered by great men from the contempt of those who refuse to give any effort to literary accomplishment unless it turns a profit—or who, even if by the advice and example of others they do apply themselves freely to the study of philosophy, are, as a result of their native stupidity, among philosophers like drones among bees. Accordingly, when I contemplated the contempt I would face on account of the novelty and absurdity of my opinion, I almost gave up completely the work I had started.

And yet, although for a long time I hesitated and even resisted, my friends drew me along. Foremost among them was Nicholas Schönberg, Cardinal of Capua, famous in all fields of learning. Next to him was my dear friend Tiedemann Giese, Bishop of Kulm, a great student of the sacred writings and all good literature. For repeatedly he encouraged me, commanded me, sometimes sharply, to publish this book and let it see the light of day after lying buried and hidden, not for nine years but going on four times nine. More than a few other eminent and learned men advised me to do the same. They urged me to set aside my anxieties, abandon my reluctance, and share my work for the common good of astronomical learning. According to them, the more absurd my doctrine of the earth's motion appeared to most people, the greater would be their amazement and gratitude once my book was published and the clouds of absurdity had been dispersed by radiant proofs. These persuasions and this hope, therefore, finally convinced me to allow my friends, as they had long requested, to prepare an edition of this work.

However, Your Holiness, perhaps your amazement that I would publish these findings—after having so exerted myself in the work of thinking them through, even to the point of deciding to commit to writing my conclusions concerning the earth's motion—perhaps your amazement is not so great as your desire to hear why it would occur to me, contrary to the received opinions of astronomers and almost contrary to common sense, to dare to imagine any motion of the earth.

Accordingly, Your Holiness, I would have you know that what moved me to conceive a different model for explaining the motions of the universal spheres was merely my realization that the astronomers are not consistent among themselves regarding this subject. In the first place, they are so uncertain concerning the motions of the sun and the moon that they can neither observe nor predict even the constant length of a tropical year. Secondly, in calculating the motions of these as well as the other five planets, they do not use the same principles and assumptions, nor the same explanations for their apparent revolutions and motions. For while some use only concentric circles, others employ eccentrics and epicycles, from which however the desired results do not quite follow. Those relying on concentrics, though they may use these for modelling diverse motions, nevertheless have not been successful in using them to obtain firm results in perfect accordance with the phenomena. Yet those who have invented eccentric circles, while they seem for the most part to have solved apparent motion in a manner that is arithmetically consistent, at the same time also seem to have introduced several ideas that contradict the first principles of uniform motion. Nor have they been able to discover or deduce by means of their eccentrics the main point, which is to describe the form of the universe and the sure symmetry of its parts. Instead they have been like someone attempting a portrait by assembling hands, feet, head, and other parts from different sources. These several bits may be well painted, but they do not fit together to make up a single body. Bearing no genuine relationship to each other, such components, joined together, would compose a monster, not a man.

Thus in their process of demonstration—"method," as they call it—those employing eccentrics have either omitted something essential or else admitted something extraneous and irrelevant. This would not have happened if they had observed sound principles. For unless the hypothesis they adopted were fallacious, all the predictions following from them would be verifiable beyond dispute. (Even if what I am saying here is obscure, it will become clearer in its proper place.)

Thus I pondered for a long time this lack of resolution within the astronomical tradition as far as the derivation of the motions of the universal spheres is concerned. It began to irritate me that the philosophers, who otherwise scrutinized so precisely the minutiae of this world, could not agree on a more reliable theory concerning the motions of the system of the universe, which the best and most orderly Artist of all framed for our sake. So I set myself the task of rereading all the philosophers whose books I could lay my hands on, to find out whether anyone had ever held another opinion concerning the motion of the universal spheres than those asserted by the teachers of astronomy in the schools. Indeed, I found, first in Cicero, that Nicetus

supposed the earth to
others held the same op
Following their exan
bility that the earth mo
that others before me h
cles they chose in order
sumed that I likewise w
of the earth, whether a r
enly spheres were possil
Accordingly, I posited
earth. And by deep and
tion of the other planet
earth, and if this calcul
not only do the phenom
nitudes of all the orbs
that not one of its parts
and the whole universe i
In the arrangement of
order. In the first book I
motions I ascribe to the
overall structure of the u
tions of the rest of the
earth in order to show tc
to the earth's motion, ca
I have no doubt that a
in keeping with the chie
examine—not superfici
which I set forth in this
may see I am a person wl
to dedicate these my late
anyone else. For even he
you are held to be the hi
your love for all literatur
cernment you may easil
proverb says) there is no
Perhaps some idle talke
pletely ignorant of it, an
their purposes, will dare
waste time on them; I h
known, Lactantius, othe
speaks quite immaturely

know that what moved me
.e motions of the universal
onomers are not consistent
rst place, they are so uncer-
ıon that they can neither ob-
tropical year. Secondly, in
ıer five planets, they do not
same explanations for their
: use only concentric circles,
ich however the desired re-
ntrics, though they may use
have not been successful in
dance with the phenomena.
hile they seem for the most
that is arithmetically consis-
:d several ideas that contra-
ɔr have they been able to
: main point, which is to de-
:try of its parts. Instead they
ssembling hands, feet, head,
:al bits may be well painted,
dy. Bearing no genuine rela-
together, would compose a

ıod," as they call it—those
ıg essential or else admitted
not have happened if they
ɔothesis they adopted were
:m would be verifiable be-
is obscure, it will become

esolution within the astro-
: motions of the universal
the philosophers, who oth-
: world, could not agree on
the system of the universe,
med for our sake. So I set
/hose books I could lay my
held another opinion con-
hose asserted by the teach-
irst in Cicero, that Nicetus

supposed the earth to move. And later I discovered in Plutarch that some others held the same opinion. . . .

Following their example, therefore, I too began to contemplate the possibility that the earth moves. To be sure, it seemed an absurd idea. Yet I knew that others before me had been accorded the liberty to imagine whatever circles they chose in order to explain the astronomical phenomena. Thus I presumed that I likewise would surely be permitted to test, given some motion of the earth, whether a more solid explanation of the revolutions of the heavenly spheres were possible than had so far been provided.

Accordingly, I posited the motion which later in this volume I assign to the earth. And by deep and extensive investigation I finally found that if the motion of the other planets is viewed in relation to the circular motion of the earth, and if this calculation is made for the revolution of each planet, then not only do the phenomena follow consistently, but also the orders and magnitudes of all the orbs and spheres and heaven itself are so interconnected that not one of its parts could be removed without throwing the other parts and the whole universe into confusion.

In the arrangement of this work, therefore, I have observed the following order. In the first book I set out all the positions of the spheres along with the motions I ascribe to the earth, so that this book comprises as it were the overall structure of the universe. And in the remaining books I relate the motions of the rest of the planets and all the spheres to the movement of the earth in order to show to what extent their appearances, if we do relate them to the earth's motion, can be saved.

I have no doubt that astute and learned astronomers will agree with me if, in keeping with the chief requirement of this discipline, they will study and examine—not superficially but in depth—the evidence for these matters which I set forth in this work. However, so that learned and unlearned alike may see I am a person who flees the judgment of no one at all, I have chosen to dedicate these my late-night studies to you, Your Holiness, rather than to anyone else. For even here in this remote corner of the earth which I inhabit, you are held to be the highest authority by virtue of your exalted office and your love for all literature, even astronomy. Thus by your authority and discernment you may easily repress the malice of slanderers, even if (as the proverb says) there is no remedy against the teeth of a backbiter.

Perhaps some idle talkers, thinking they can judge astronomy though completely ignorant of it, and distorting some passage of Scripture twisted to their purposes, will dare to criticize and censure my teaching. I shall not waste time on them; I have only contempt for their audacity. As is well known, Lactantius, otherwise a distinguished writer but no astronomer, speaks quite immaturely about the shape of the earth when he mocks those

who assert that the earth is spherical. No scholar need be surprised, therefore, if such persons ridicule me likewise. Astronomy is written for astronomers—and they, if I am not mistaken, will see the value that these efforts of mine have for the ecclesiastical community over which Your Holiness now holds dominion. For not long ago, under Leo X, the Lateran Council raised the issue of emending the church calendar. No decision was then arrived at merely because the Council concluded that the lengths of the year and the month and the motions of the sun and the moon were not yet measured accurately enough. Since then, at the urging of that most eminent man Dr. Paulus, Bishop of Sempronia, who was in charge of the proceedings, I have concentrated on studying these matters with greater accuracy. What I have accomplished in this regard, however, I hand over to be judged by Your Holiness in particular and by all other learned astronomers. And lest Your Holiness should think I promise more regarding the usefulness of this volume than I can fulfill, I now proceed to the work itself.

Chapter 1. The universe is spherical

The first thing for us to realize is that the universe is spherical. This is so either because, of all forms, the sphere is the most perfect, requiring no joins, and being an integrated whole; or because it is the most capacious of all forms, and so best fitted to enclose and preserve all things—or also because the most perfected parts of the universe such as the sun, the moon, and the stars display this shape; or because all things strive to be bounded thus, as we observe in drops of water and other liquids when they seek to be bounded within themselves. There can be no doubt, then, about the rightness of ascribing this shape to the heavenly bodies.

Chapter 2. The earth too is spherical

The earth also has the shape of a globe, because all of its parts tend towards its center. We do not immediately perceive it as a perfect sphere because the mountains are so high and the valleys so deep, and yet these hardly affect the overall sphericity of the earth. This is clear from the fact that if one travels northward, the pole of the diurnal rotation gradually rises, while the opposite pole sinks accordingly, and more stars in the northern sky seem never to set, while some in the south seem never to rise. Thus Italy does not see Canopus, which is visible from Egypt; and Italy does see the last star of the River, which up here in our frozen territory is unknown. Conversely, as one travels southward, such stars rise higher, while those which appear high to us sink lower. Also, the angle of elevation of the poles is everywhere constantly pro-

portionate to the dista
happens with no other
is delimited by poles ar
of sun or moon are no
by inhabitants of the w
by the former and earli

Seafarers know that
not visible from the shi
light is placed at the to
appears gradually to si
light as it were sets and
nature as a fluid, alwa
farther inland than the
that whatever land eme

In chapter 3, "How t
Copernicus almost bel
His rejection of other a
cylindrical—makes his
Fourteen centuries earl
earth is a globe, and fa
faring, and in particula
lier, lent freshness to
Europeans' ideas about
cus postulates (pretty a
lieve that America is lo

Chapter 4 then move
his stunning (and stunn
ingly have to attribute t
here on a body that is n
arbitrary geometrical ic
mind, only a circle brin
labors of Kepler to disp

Chapter 4. Th
is unifo
or ma

Let us now recall that
movement which a sphe

ır need be surprised, there-
ronomy is written for as-
ill see the value that these
nity over which Your Holi-
r Leo X, the Lateran Coun-
ıdar. No decision was then
that the lengths of the year
ıe moon were not yet mea-
; of that most eminent man
harge of the proceedings, I
h greater accuracy. What I
l over to be judged by Your
stronomers. And lest Your
ıe usefulness of this volume

SPHERICAL

e is spherical. This is so ei-
perfect, requiring no joins,
the most capacious of all
all things—or also because
he sun, the moon, and the
: to be bounded thus, as we
ı they seek to be bounded
about the rightness of as-

S SPHERICAL

ll of its parts tend towards
perfect sphere because the
l yet these hardly affect the
the fact that if one travels
ıally rises, while the oppo-
ıorthern sky seem never to
us Italy does not see Cano-
e the last star of the River,
Conversely, as one travels
ich appear high to us sink
verywhere constantly pro-

portionate to the distance one thus travels across the earth, something that happens with no other shape than a sphere. Hence we see that the earth too is delimited by poles and thus shaped like a globe. Moreover, evening eclipses of sun or moon are not seen by inhabitants of the east, nor morning eclipses by inhabitants of the west; but those that occur in between are observed later by the former and earlier by the latter.

Seafarers know that the waters too conform to this shape, for land that is not visible from the ship is observed from the top of the mast. And if a bright light is placed at the top of the mast, then to those remaining on the shore it appears gradually to sink as the ship moves farther off from land. Finally, the light as it were sets and disappears. Also, like earth, water, in keeping with its nature as a fluid, always obviously seeks a lower level and so does not push farther inland than the curvature of the shore permits. Hence, one accepts that whatever land emerges from the ocean is higher than it is.

In chapter 3, "How the earth and the water together make up a globe," Copernicus almost belabors the point that the earth as a whole is spherical. His rejection of other alternatives—that the earth is flat, or bowl-shaped, or cylindrical—makes his own suggestion seem more novel than it in fact is. Fourteen centuries earlier Ptolemy had also declared authoritatively that the earth is a globe, and for similar reasons. Nevertheless, the extension of seafaring, and in particular the discoveries of Columbus only half a century earlier, lent freshness to the conception of earth as a sphere and extended Europeans' ideas about how opposite sides of it might be inhabited. Copernicus postulates (pretty accurately) that "geometrical reasons cause us to believe that America is located diametrically opposite to India of the Ganges."

Chapter 4 then moves from earth to the heavens. In it Copernicus makes his stunning (and stunningly simple) proposal that the irregularities we seemingly have to attribute to the heavenly bodies are a function of our viewpoint here on a body that is not at the center of things. But we also notice a certain arbitrary geometrical idealism that underlies Copernicus's argument: To his mind, only a circle brings a body back to where it started. It took the long labors of Kepler to dispel this wrong assumption.

Chapter 4. The Motion of the Heavenly Bodies Is Uniform, Perpetual, and Circular, or Made Up of Circular Motions

Let us now recall that the motion of heavenly bodies is circular. For that movement which a sphere possesses is movement in a circle, by which action

it expresses its own form as the simplest shape, in which no beginning or end is to be discerned, nor can these be distinguished from each other, while the sphere keeps on moving within its own bounds. Yet a multitude of motions applies to the various spheres. The most obvious of all is the daily rotation, which the Greeks call *nuchthemeron*, which measures the passage of a day and a night. By this motion, it is assumed the whole universe—except for the earth—glides round from east to west. This is recognized as the common measure of all motion, since we reckon even time itself mainly by counting days.

Next we see other, as it were contrary revolutions, moving from west to east, namely those of the sun, the moon, and the five planets. Thus the sun metes out our year and the moon our month, these being the other most common measures of time. In this way too each of the five planets completes its circuit. Yet there are differences among their various motions. First, these do not turn about the same axis as the primary motion but take a slantwise course through the zodiac. Secondly, they are not observed moving uniformly in their orbits. For we see that the sun and moon in their courses sometimes move slowly and sometimes more quickly. As for the other five planets, as we observe, sometimes they even come to a stop and retrace their steps. And while the sun always keeps strictly to its own pathway, these others wander in various ways, sometimes towards the south, sometimes towards the north—which is why they are called planets [from Greek *planetes*, "wanderer"]. Moreover, sometimes they are nearer the earth and said to be "in perigee"; at other times they are farther off and said to be "in apogee."

We must admit, nonetheless, that their motions are circular, or made up of several circles, because these nonuniformities conform to a consistent law and to the fact that the planets return to where they began, which could not be the case unless the motions were circular, for only a circle can replicate what has already taken place. For example, by a motion made up of circles the sun causes for us a repetition of unequal days and nights and of the four seasons. In this cycle we discern several motions, since no simple heavenly body can move irregularly in a single sphere. For such irregularity would have to result either from an inconstancy in the force of movement, whether arising internally or externally, or from some irregularity in the revolving body. But either alternative is abhorrent to reason. We must not ascribe any such indignity to things framed and governed optimally.

We must conclude, then, that their uniform motions appear to us as irregular either because they take place around different axes, or else because the earth is not at the center of their circles of revolution. For us on earth as we observe the movements of these planets, this is what happens: because of their nonuniform distances they appear larger when they are near us than

when they are farther
across equal portions o
will appear unequal be

Above all, then, I thi
earth to the heavens. (
highest order we may r
takenly attributing thin

CHAPTER 5. IS THE EARTH?

*Chapter 5 begins by re
though "the authorities
the universe," Copernic
cerning earth's location.*

Every apparent change
server or of the thing ob
position of both. (When
each other, no motion is
circuit of the heavens; it
fore if any motion is pre
all that is beyond the ear
moving about it. The pri
parently the whole unive
ever, if you grant that th
earth itself turns from we
will find this is actually t
and stars are concerned.
ens, which serve as the lo
apparent why motion sh
contents, to the location
opinion of Heraclides an
cero, of Nicetus of Syracu
universe. For their judgm
the way and rise when it

*Having introduced the no
now broaches the issue of
olution not in the center t*

: which no beginning or end
l from each other, while the
Yet a multitude of motions
: of all is the daily rotation,
asures the passage of a day
ole universe—except for the
recognized as the common
ıe itself mainly by counting

ions, moving from west to
: five planets. Thus the sun
:hese being the other most
ıf the five planets completes
arious motions. First, these
notion but take a slantwise
observed moving uniformly
in their courses sometimes
the other five planets, as we
ıd retrace their steps. And
thway, these others wander
ı, sometimes towards the
om Greek *planetes*, "wan-
.e earth and said to be "in
ıid to be "in apogee."
are circular, or made up of
nform to a consistent law
ıey began, which could not
only a circle can replicate
motion made up of circles
and nights and of the four
, since no simple heavenly
or such irregularity would
orce of movement, whether
regularity in the revolving
ı. We must not ascribe any
mally.
ions appear to us as irregu-
ıt axes, or else because the
:ion. For us on earth as we
what happens: because of
hen they are near us than

when they are farther away (optics proves this principle). And similarly, across equal portions of their circumferences their motions over a given time will appear unequal because viewed from different distances.

Above all, then, I think we must examine carefully the relationship of the earth to the heavens. Otherwise, in our desire to investigate things of the highest order we may remain ignorant of what is nearest to us, likewise mistakenly attributing things that are earthly to things that are heavenly.

Chapter 5. Is circular motion appropriate to the earth? And what is earth's location?

Chapter 5 begins by reformulating the questions contained in its title. Although "the authorities generally agree that the earth rests in the middle of the universe," Copernicus calls for closer consideration of the matter concerning earth's location.

Every apparent change of place is caused by the movement either of the observer or of the thing observed, or indeed by some unequal alteration in the position of both. (When observer and observed move uniformly relative to each other, no motion is perceived.) Yet it is from earth that we behold the circuit of the heavens; it is here that its spectacle is represented to us. Therefore if any motion is predicated of the earth, the same motion will appear in all that is beyond the earth, but in a contrary direction, as if everything were moving about it. The prime example of this is the daily rotation, whereby apparently the whole universe except for the earth itself is driven round. However, if you grant that the heavens have no part in this rotation, but that the earth itself turns from west to east, then considering the matter seriously you will find this is actually the case as far as the rising and setting of sun, moon, and stars are concerned. And since everything is contained within the heavens, which serve as the location and setting of all things, it is not immediately apparent why motion should be attributed to the container rather than the contents, to the location rather than the thing located. Indeed, this was the opinion of Heraclides and Ecphantus the Pythagoreans and, according to Cicero, of Nicetus of Syracuse, who held that earth rotates in the middle of the universe. For their judgment was that the stars set when the earth comes in the way and rise when it ceases to be in the way.

Having introduced the notion of merely the rotation of the earth, Copernicus now broaches the issue of the other main motion of the earth, namely its revolution not in *the center but* about *the center.*

Given this rotation, a further, equally important question follows concerning the earth's location. Admittedly, virtually everyone has been taught, and believes, that the earth is the center of the universe. However, anyone who denies that the earth occupies the center or midpoint may still assert that its distance from the center is negligible by comparison with that of the sphere of the fixed stars, yet noticeable and noteworthy relative to the spheres of the sun and other planets. He may consider that this is why their motions appear nonuniform, and that they are regular relative to some center other than that of the earth. In this way, perhaps, he can offer a not-so-inept explanation for the appearance of irregular motion. For the fact that we observe the planets sometimes nearer the earth and sometimes farther away is logical proof that the center of the earth is not the center of their orbits. . . .

Chapter 6. The immensity of the heavens compared to the size of the earth

As evidenced by his respectful mention of Heraclides and the Pythagoreans, Copernicus is careful not to appear to be promoting mere novelties. Moreover, some of his arguments, though they lead in a non-Ptolemaic direction, begin with Ptolemaic materials. Chapter 6 is a good example, beginning with a virtual recapitulation of Ptolemy's argument regarding the immense—literally immeasurable*—disparity between the size of the universe and that of the earth. Like Ptolemy, Copernicus makes this case by pointing out that a horizontal plane tangent to the earth's surface* appears *to bisect the universe. Mathematically, a bisecting plane necessarily contains the center point. Even in a geocentric universe, however, to claim that the horizontal plane itself does so implies a contradiction, for a plane tangent to the earth's surface is at that point distant from the center by the length of the earth's radius. Ptolemy's point, and Copernicus's, is that earthly distance is as nothing compared to the size of the universe. Although neither believed that the universe is actually infinite, both considered that the immense extent of the heavens rendered earth, so far as our ability to measure is concerned, a mere point by comparison. In Copernicus's words: "So far as our senses can tell, the earth is related to the heavens as a point is to a body and as something finite is to something infinite."*

From this agreement with Ptolemy, Copernicus moves to the next critical step of his argument, which comprises two discernible parts. First (and this relates to the question of earth's rotation on its axis), given that the earth is a point within an immensity, why should we expect the immensity to turn while the point stands still? "How astonishing, if within the space of twenty-four hours the vast universe should rotate rather than its least point!" And second (this being the argument that de-centers the earth), if

the surface *of the earth verse, as Ptolemy declar ing the location of eart (or orbit) "near the cen ment relative to the imm*

Copernicus ends the c cal analogy between th more than half a century

Things enclosed within turning in a larger circl in thirty years, while th circuit of one month. I space of a day and a ni once more.

And yet the question because of what was sai describable size of the h of that immensity rema there are minuscule indi perceptible, when they a up any visible body. Yet there are enough of thei the position of the earth its distance from the cen the distance of the spher

Chapters 7 and 8 form a

Chapter 7. That the ... the univ

and

Chapter 8. ... and

In short, chapter 7 summ to which earth, the heav low-point, and accordin

the surface *of the earth merely* appears *to be in the very center of the universe, as Ptolemy declares, then the same explanation can be applied regarding the location of earth if it is not perfectly central but moves in a sphere (or orbit) "near the center." For, the earth being near the center, its movement relative to the immensity of the universe will be very small indeed.*

Copernicus ends the chapter by bolstering his argument with a parenthetical analogy between the macroscopic and the microscopic (this, of course, more than half a century before the invention of telescopes and microscopes).

Things enclosed within a smaller orbit revolve more quickly than those turning in a larger circle. Thus Saturn, the highest of the planets, revolves in thirty years, while the moon, undoubtedly the nearest the earth, has a circuit of one month. Finally, one will presume, earth rotates within the space of a day and a night. Hence the question of the daily rotation arises once more.

And yet the question of earth's location remains uncertain, all the more so because of what was said above. For nothing has been proven except the indescribable size of the heavens compared to that of the earth. But the degree of that immensity remains unclear. (Consider that at the opposite extreme there are minuscule indivisible bodies called "atoms." Because they are imperceptible, when they are taken two or several at a time they do not make up any visible body. Yet they can be sufficiently multiplied to the point where there are enough of them to form a visible mass. The same thing applies to the position of the earth. Even though it is not in the center of the universe, its distance from the center is nevertheless inconsiderable when compared to the distance of the sphere of the fixed stars.)

Chapters 7 and 8 form a pair, as their titles indicate:

Chapter 7. Why the Ancients Believed That the Earth Rests in the Middle of the Universe as If It Were Its Center

and

Chapter 8. Explanation of These Reasons and of Their Insufficiency

In short, chapter 7 summarizes the Aristotelian/Ptolemaic physics according to which earth, the heaviest of the elements, must seek the universal center or low-point, and according to which a daily rotation of the earth would cause

the earth to lose its coherence and "fly apart," an idea Copernicus dismisses as "quite ridiculous."

He continues his refutation in chapter 8 by demonstrating in effect that Ptolemy and his like employ circular reasoning. The notion of a stationary, central earth is so firm a component of what Aristotelian physics conceives of as natural that it rejects any movement of the earth precisely on the grounds that it is unnatural. However, Copernicus simply undercuts this line of argument by declaring that if the earth does indeed move, then it does so in accordance with nature, not contrary to it.

In the course of this discussion, Copernicus momentarily looks beyond a medieval, enclosed universe, though he quickly averts his gaze.

Ptolemy therefore has no reason to fear that earth and all things terrestrial will fly apart on account of a rotation brought about by means of nature's own operation, which is very different from anything artificial or devised by human ingenuity.

Yet why is he not just as worried about the universe as a whole, whose swiftness of motion must be that much greater in proportion as the heavens are greater than the earth? Or are the heavens so immense precisely because the ineffable force of their motion impels them away from the center? Would they otherwise collapse if they did stand still? If this reasoning were sound, then surely the magnitude of the heavens must expand to infinity. For the higher they are impelled by the force of their motion, the faster their motion will be on account of the continuously expanding circumference which has to make its revolution every twenty-four hours. In turn, as the motion increased, so would the immensity of the heavens—speed thus increasing size, and size increasing speed, *ad infinitum*. Yet according to that axiom of physics, nothing that is infinite can be traversed nor moved by any means, and so the heavens are necessarily at rest.

But beyond the heavens, it is said, there is no body, no place, no vacuity, absolutely nothing, and so there is nowhere for the heavens to go. It is truly miraculous, then, if something can be contained within nothing. However, if the heavens are infinite, and finite only in their hollow interior, then perhaps there will be greater reason to believe that outside the heavens there is nothing, for in this case every single thing, no matter how much space it takes up, will be inside them. But the heavens will remain motionless. For the strongest piece of evidence produced in support of the earth's finitude is its motion. Whether the universe is finite or infinite, however—let us leave that question for the natural philosophers to dispute while we hold firmly to the belief that the earth is delimited by its poles and enclosed by a spherical surface.

Why, then, do we s
with the nature of its
verse, whose bounds a
tation, why not grant
the reality? It is like
from the harbor, and
when a ship glides alc
everything outside o
everything else on bo
ment of the earth mak

CHAP
TO M
WHERE

Since therefore nothir
consider whether it m
regarded as one of the

For earth is not th
strated by the appar
variable distances fro
cles concentric to the
worth asking whethe
of earthly gravity. In
which by divine pro
whereby they draw th
globe. The same desir
and the other luminc
shape in which we be
bits.

Therefore, if the ea
ple—then this must s
them, it would seem,
the sun, we exchange
and settings of the co
ing and evening will a
as both the backward
their own motions bu
motions. Finally, it w
universe.

Why, then, do we still hesitate to accept the earth's movement in keeping with the nature of its form instead of attributing motion to the whole universe, whose bounds are unknown and unknowable. As regards the daily rotation, why not grant that in the heavens is the appearance but in the earth is the reality? It is like the case spoken of by Vergil's Aeneas: "We sail forth from the harbor, and lands and cities draw backwards" [*Aeneid*, III.72]. For when a ship glides along smoothly, its passengers see its motion reflected by everything outside of the ship and, by contrast, suppose themselves and everything else on board to be motionless. No wonder, then, that the movement of the earth makes us think the whole universe is turning round.

Chapter 9. Can the earth be said to move in more ways than one? Where is the center of the universe?

Since therefore nothing precludes the earth's movement, I propose we now consider whether it may be thought to move in more than one way: can it be regarded as one of the planets?

For earth is not the center of all the revolutions. This claim is demonstrated by the apparently nonuniform motion of the planets and by their variable distances from the earth, which cannot be conceived as implying circles concentric to the earth. Therefore, there being numerous centers, it is worth asking whether the center of the universe, or some other, is the center of earthly gravity. In my view gravity is nothing but a certain natural desire which by divine providence the Creator of all has infused into the parts, whereby they draw themselves into a unity and an integrity in the form of a globe. The same desire may be credibly predicated also of the sun, the moon, and the other luminous planets; by its efficacy they persist in the rounded shape in which we behold them, although they pursue their own various orbits.

Therefore, if the earth too moves in other ways—about a center, for example—then this must similarly be reflected in many external things. Among them, it would seem, is the annual revolution. For if, granting immobility to the sun, we exchange earthly movement for solar movement, then the risings and settings of the constellations and the fixed stars which accompany morning and evening will appear just as they do. Furthermore, the stations as well as both the backward and forward motions of the planets will be seen not as their own motions but as earthly motion transmuted into apparent planetary motions. Finally, it will be accepted that the sun occupies the center of the universe.

We learn all these things by discerning the order whereby the planets follow one another and by the harmony of the entire universe—if only we examine these matters (as they say) with both eyes open.

Chapter 10. The Order of the Heavenly Spheres

In the last half of chapter 10, Copernicus summarizes the model of the solar system which we most readily associate with his name. He begins with the moon, so long thought to circle the earth along with the other planets, but now together with the earth seen as forming a system which itself orbits the sun.

We should not be ashamed to admit that this whole domain encircled by the moon, with the center of the earth, traverses this great orbit amidst the other planets in an annual revolution around the sun, and that near the sun is the center of the universe; and moreover that, since the sun stands still, whatever motion the sun appears to have is instead actually attributable to the motion of the earth. Furthermore, although the distance between the earth and the sun is quite noticeable relative to the size of the other planetary orbits, it is imperceptible as compared with the sphere of the fixed stars—so great indeed is the size of the universe. I think it is a lot easier to accept this than to drive our minds to distraction multiplying spheres almost *ad infinitum*, as has been the compulsion of those who would detain earth in the center of the universe. Instead, it is better to follow the wisdom of nature, which just as it strongly avoids producing anything superfluous or useless, so it often prefers to endow a single thing with multiple effects.

This whole matter is difficult, almost paradoxical, and certainly contrary to many people's way of thinking. In what follows, however, God helping me, I shall make these things clearer than sunlight, at least to those not ignorant of the art of astronomy. And so, with the first principle firmly established (for nobody can propose one more fitting than that the magnitude of a planet's orbit is proportionate to its period of revolution), the order of the spheres is as follows, beginning with the highest:

First and highest of all is the sphere of the fixed stars, containing itself and all things, and therefore immovable, the very location of the universe, that to which the motion and position of all the other heavenly bodies is referred. . . . This is followed by the first of the planets, Saturn, which completes his circuit in thirty years. Then comes Jupiter, moving in a revolution with a twelve-year period. Next, the circuit of Mars is two years. Fourth

comes the annual revol
ried along, with the mc
cles round in nine mor
course in the space of e

And behold, in the m
tiful temple, would set
minate all things at
lantern—and others th
megistus calls him the
all things. Truly indeed
his family of planets as
of the moon's services;
moon shares closest kin
nated by the sun, by wh

Thus we discover in
the universe and a firm
size of the spheres such
model permits anyone
and regressions of Jupit
than those of Mars, and
reversals appear more
rarely in Mars and in
pear for the same reason

However, that none c
that these are immensely
nual revolution, or the a
ible thing has a certain li
demonstrated in optics.
distance remains betwee
This is principally what
be an enormous differe
not. So great, certainly,
greatest and the best.

SOURCE: Translated from
lestium, Nuremberg, 1543
gabe, vol. 2, Munich: Olde

comes the annual revolution in which, as mentioned earlier, the earth is carried along, with the moon as it were in an epicycle. Venus, in fifth place, circles round in nine months. And then in sixth place Mercury completes his course in the space of eighty days.

And behold, in the midst of all resides the sun. For who, in this most beautiful temple, would set this lamp in another or a better place, whence to illuminate all things at once? For aptly indeed do some call him the lantern—and others the mind or the ruler—of the universe. Hermes Trismegistus calls him the visible god, and Sophocles' Electra "the beholder" of all things. Truly indeed does the sun, as if seated upon a royal throne, govern his family of planets as they circle about him. Nor is the earth thus deprived of the moon's services; rather, as Aristotle asserts in his book on animals, the moon shares closest kinship with the earth. Meanwhile, the earth is impregnated by the sun, by whom is begotten her annual offspring.

Thus we discover in this orderly arrangement the marvelous symmetry of the universe and a firm harmonious connection between the motion and the size of the spheres such as can be discerned by no other means. For this model permits anyone who is diligent to comprehend why the progressions and regressions of Jupiter appear greater than those of Saturn and smaller than those of Mars, and again greater for Venus than for Mercury. And the reversals appear more frequently in Saturn than in Jupiter, and even more rarely in Mars and in Venus than in Mercury. . . . All these phenomena appear for the same reason: that the earth moves.

However, that none of these phenomena appears in the fixed stars proves that these are immensely distant, for which reason even the motion of the annual revolution, or the appearance thereof, vanishes from sight. For each visible thing has a certain limit of distance beyond which it becomes invisible, as demonstrated in optics. The sparkling of the stars shows what an enormous distance remains between their sphere and that of the highest planet, Saturn. This is principally what distinguishes them from the planets, for there had to be an enormous difference between that which moves and that which does not. So great, certainly, is the divine handiwork of Him who is himself the greatest and the best.

SOURCE: Translated from Nicholas Copernicus, *De Revolutionibus Orbium Caelestium*, Nuremberg, 1543, in consultation with *Nikolaus Kopernikus Gesamtausgabe*, vol. 2, Munich: Oldenbourg, 1949.

19

The Poetic Structure of the World

Fernand Hallyn and Thomas Kuhn

Historians—including historians of science—sometimes perform their best work not in telling us what we don't know but in causing us to reexamine what we think we do know. In fact, part of the task of this anthology is to let cosmologists such as Copernicus emerge from the fog of history's clichés and be heard afresh. When we do hear Copernicus, a number of those clichés begin to dissipate, among them the century-old construction of what Andrew Dixon White (1832–1918) called the "warfare of science with theology." While it is true that Copernicus had some theological qualms about his own teachings, it is also the case that his deepest motivations go far beyond any narrow sense of the "scientific" to include the religious, the literary, and the aesthetic.

The two historians excerpted here both make this point in relation to the famous passage in Book I, chapter 10, of De Revolutionibus *where Copernicus virtually sings a hymn praising the sun at the center of the universe and the harmony of the system as a whole:*

And behold, in the midst of all resides the sun. For who, in this most beautiful temple, would set this lamp in another or a better place, whence to illuminate all things at once? For aptly indeed do some call him the lantern—and others the mind or the ruler—of the universe. Hermes Trismegistus calls him the visible god, and Sophocles' Electra "the beholder" of all things. Truly indeed does the sun, as if seated upon a royal throne, govern his family of planets as they circle about him. . . .

Thus we discover in th
the universe and a firm h
size of the spheres such as

Fernand Hallyn (b. 1945
lows in his aptly titled Th

This is an often cited pas
identifies for us "the de
Yates calls particular atte
notes that "it is, in short,
the Copernican revolutio
important argument affi
of modern science.

Without a doubt, Edw
late the allusion to Herm
in the midst of reference
Pliny—not all of whom
It is true moreover . . .
struct the development
Copernicanism was not
theme.

Should we go farther
is "suspect of being pure
dynamic role in the m
metaphors likening the
unsatisfactory. Through
external support for his
the sun appear less of a

An expression like "s
pect. It would be more
ducing by choice of ter
relevance of the inform
tees for the passage. On
participate in a dyna
nonetheless true that i
"symmetry" according
is organized. A point o
duces into homogeneou

The decision to treat
from a modern prejudi

cture of
d

nomas Kuhn

netimes perform their best
in causing us to reexamine
k of this anthology is to let
fog of history's clichés and
umber of those clichés be-
struction of what Andrew
of science with theology."
ical qualms about his own
vations go far beyond any
gious, the literary, and the

is point in relation to the
utionibus where Coperni-
enter of the universe and

who, in this most beauti-
r place, whence to illumi-
all him the lantern—and
es Trismegistus calls him
r" of all things. Truly in-
overn his family of plan-

Thus we discover in this orderly arrangement the marvelous symmetry of the universe and a firm harmonious connection between the motion and the size of the spheres such as can be discerned by no other means.

Fernand Hallyn (b. 1945), a European literary historian, comments as follows in his aptly titled The Poetic Structure of the World:

This is an often cited passage. [Alexandre] Koyré goes so far as to say that it identifies for us "the deepest motivation of Copernican thought." Frances Yates calls particular attention to the reference to Hermes Trismegistus and notes that "it is, in short, in the atmosphere of the religion of the world that the Copernican revolution is introduced." For Yates, the passage becomes an important argument affirming the role of the hermetic tradition in the birth of modern science.

Without a doubt, Edward Rosen is right to judge that one should not isolate the allusion to Hermes Trismegistus from its context. It appears, after all, in the midst of references to other figures—to Plato, Cicero, Sophocles, and Pliny—not all of whom can be classified as writing in the hermetic tradition. It is true moreover . . . that the geocentric cosmos did not in any way obstruct the development of a significant solar symbolism. The passage to Copernicanism was not absolutely necessary for the development of that theme.

Should we go farther and agree with Jean Bernhardt that the entire passage is "suspect of being purely literary"? Given that the Copernican sun plays no dynamic role in the motion of the planets, Bernhardt concludes that the metaphors likening the sun to a "ruler" or "governor" are exaggerated and unsatisfactory. Throughout the passage, Copernicus seeks solely "to provide external support for his arguments and to make the position that he assigns the sun appear less of an innovation than it really is."

An expression like "suspect of being purely literary" is of course itself suspect. It would be more neutral to speak of a stylistic marking, without introducing by choice of terms the idea of an inverse proportionality between the relevance of the information conveyed and the visibility that a style guarantees for the passage. On the other hand, although the sun does not effectively participate in a dynamic relation with the motion of the planets, it is nonetheless true that it "governs," that it is the "ruler," the center of the "symmetry" according to which the relationship between distance and time is organized. A point of reference for the cosmicality of the cosmos, it introduces into homogeneous space . . . a *perspectiva superior*.

The decision to treat the passage as an "exterior" element obviously arises from a modern prejudice concerning the separations among "science," "liter-

ature," "philosophy," and so on. Elsewhere, Copernicus wrote that astronomy leads to the "contemplation of the highest good." His meditation on the meaning of the sun's centrality invites precisely such an act of contemplation, and that explains the passage's lyricism and proliferation of devices such as the rhetorical question, enumeration, asyndeton, metaphor, and comparison. Rather than consider such passages as "literary," why not recognize in their coherence and insistence a specific constituent element in the comprehensiveness and unity of the Copernican enterprise?

Thomas Kuhn (1922–1996), perhaps the most famous late-twentieth-century historian of Copernicanism, likewise emphasized the importance (if not the sufficiency) of the aesthetic—of "evidence drawn from harmony"—both in the motivation and in the reception of Copernicus's model.

Throughout [the] crucially important tenth chapter, Copernicus's emphasis is upon the "admirable symmetry" and the "clear bond of harmony in the motion and magnitude of the Spheres" that a sun-centered geometry imparts to the appearances of the heavens. If the sun is the center, then an inferior planet cannot possibly appear far from the sun; if the sun is the center, then a superior planet must be in opposition to the sun when it is closest to the earth; and so on and on. It is through arguments like these that Copernicus seeks to persuade his contemporaries of the validity of his new approach. Each argument cites an aspect of the appearances that can be explained by either the Ptolemaic or the Copernican system, and each then proceeds to point out how much more harmonious, coherent, and natural the Copernican explanation is. There are a great many such arguments. The sum of the evidence drawn from harmony is nothing if not impressive.

But it may well be nothing. "Harmony" seems a strange basis on which to argue for the earth's motions, particularly since the harmony is so obscured by the complex multitude of circles that make up the full Copernican system. Copernicus' arguments are not pragmatic. They appeal, if at all, not to the utilitarian sense of the practicing astronomer but to his aesthetic sense and to that alone. They had no appeal to laymen, who, even when they understood the arguments, were unwilling to substitute minor celestial harmonies for major terrestrial discord. They did not necessarily appeal to astronomers, for the harmonies to which Copernicus' arguments pointed did not enable the astronomer to perform his job better. New harmonies did not increase accuracy or simplicity. Therefore, they could and did appeal primarily to that limited and perhaps irrational subgroup of mathematical astronomers whose

Neoplatonic ear for ma
page after page of comp
tions scarcely better than
were a few such astronoi

SOURCES: Fernand Hallyn, T
trans. Donald M. Leslie, Ne
nican Revolution: Planetar
Cambridge, Mass.: Harvarc

pernicus wrote that astron-
ood." His meditation on the
ich an act of contemplation,
liferation of devices such as
metaphor, and comparison.
" why not recognize in their
ement in the comprehensive-

mous late-twentieth-century
d the importance (if not the
n from harmony"—both in
is's model.

pter, Copernicus's emphasis
ear bond of harmony in the
sun-centered geometry im-
un is the center, then an in-
the sun; if the sun is the
sition to the sun when it is
rough arguments like these
praries of the validity of his
of the appearances that can
pernican system, and each
nonious, coherent, and nat-
e a great many such argu-
harmony is nothing if not

a strange basis on which to
the harmony is so obscured
the full Copernican system.
appeal, if at all, not to the
to his aesthetic sense and to
even when they understood
inor celestial harmonies for
y appeal to astronomers, for
pointed did not enable the
onies did not increase accu-
appeal primarily to that lim-
matical astronomers whose

Neoplatonic ear for mathematical harmonies could not be obstructed by page after page of complex mathematics leading finally to numerical predictions scarcely better than those they had known before. Fortunately . . . there were a few such astronomers.

SOURCES: Fernand Hallyn, *The Poetic Structure of the World: Copernicus and Kepler*, trans. Donald M. Leslie, New York: Zone Books, 1990; Thomas S. Kuhn, *The Copernican Revolution: Planetary Astronomy in the Development of Western Thought*, Cambridge, Mass.: Harvard UP, 1957.

20

This Art Unfolds the Wisdom of God

John Calvin and Johannes Kepler

Especially since the late nineteenth century, the progress of Copernicanism has often been portrayed as the struggle of science against religion. Of course, the most famous case superficially supporting this view is that of Galileo and his persecution by the Inquisition.

A balanced telling of the story, however, should not neglect two important facts. First, and most simply, cosmologists such as Copernicus and Kepler were deeply religious Christians (compare also Campanella, chapter 27). And second, both the Renaissance and the Reformation promoted a scholarly and critical approach to the reading of texts, especially the Bible, that had its counterpart in how scientists were coming to read the book of nature. In this sense the work of Copernicus may be seen as akin to "systematic theology": as a re-reading of the text of the heavens, taking the literal surface (the appearances) very seriously indeed, but trying anew to understand their coherence at a level beyond the merely apparent.

This search for overall coherence is exemplified by the method that the reformer John Calvin (1509–1564) used to interpret the Bible. Sometimes called the "analogy of faith" (a term Calvin borrows from Romans 12:6), this method interprets any particular doubtful passage of Scripture in conformity with what is already firmly established by Scripture as a whole. However, if God is author of both Scripture and Nature, then of course the same principle may be applied to both "books" at once. Therefore, when a clear, well founded reading of Nature appears to conflict with a literalistic reading of the Bible, the solution is to pursue a scriptural interpretation which, like

true science, penetrate
what is already known

Calvin, though acce
decade after the appear
as a precursor, hermen
(1571–1630). Both Cal
relates to the creation b
both endorse the view c
is in some sense clothe
words, "God . . . clothe
which he would presen
thus magnificently arra
the earth." Moreover,
Calvin draws a sharp
senses and the theoretic
tice and value he defen

1:15. "Let them be for
fore, that it is not here
heaven, and how great,
to us from them. For
knowledge of the gifts
fore, in order to apprel
above the heavens; let
enkindles for us in the
had respect to us rathe
the fact that the moor
unless it borrowed fro

1:16. "The greater li
cant, as a philosophe
words. First, he assign
stars; but astronomers
teach that the fixed st
makes two great lumi
that the star of Saturn
least of all, is greater tl
a popular style things
dued with common se
with great labor what
Nevertheless, this stuc
demned, because som

true science, penetrates the merely superficial and seeks consistency with what is already known to be true.

Calvin, though accepting a geocentric cosmology (and writing only a decade after the appearance in 1543 of De Revolutionibus*), may thus be seen as a precursor, hermeneutically, of a Copernican such as Johannes Kepler (1571–1630). Both Calvin and Kepler explain the style of the Bible where it relates to the creation by referring to what ordinary people actually see, and both endorse the view of creation as a divine text/textile/fabric in which God is in some sense clothed for, and so revealed to, his creatures. In Calvin's words, "God . . . clothes himself, so to speak, with the image of the world in which he would present himself to our contemplation"; we may "behold him thus magnificently arrayed in the incomparable vesture of the heavens and the earth." Moreover, elsewhere in his commentary on Genesis (1554), Calvin draws a sharp distinction between the practical experience of the senses and the theoretical knowledge gained through astronomy, whose practice and value he defends.*

1:15. "Let them be for lights." It is well again to repeat what I have said before, that it is not here philosophically discussed how great the sun is in the heaven, and how great, or how little, is the moon; but how much light comes to us from them. For Moses here addresses himself to our senses, that the knowledge of the gifts of God which we enjoy may not glide away. Therefore, in order to apprehend the meaning of Moses, it is to no purpose to soar above the heavens; let us only open our eyes to behold this light which God enkindles for us in the earth. . . . For as was appropriate for a theologian, he had respect to us rather than to the stars. Nor, in truth, was he ignorant of the fact that the moon had not sufficient brightness to enlighten the earth, unless it borrowed from the sun . . . .

1:16. "The greater light." I have said that Moses does not here subtly descant, as a philosopher, on the secrets of nature, as may be seen in these words. First, he assigns a place in the expanse of heaven to the planets and stars; but astronomers make a distinction of spheres and, at the same time, teach that the fixed stars have their proper place in the firmament. Moses makes two great luminaries; but astronomers prove by conclusive reasons that the star of Saturn, which on account of its great distance appears the least of all, is greater than the moon. Here lies the difference: Moses wrote in a popular style things which, without instruction, all ordinary persons endued with common sense are able to understand; but astronomers investigate with great labor whatever the sagacity of the human mind can comprehend. Nevertheless, this study is not to be reprobated, nor this science to be condemned, because some frantic persons are wont boldly to reject whatever is

unknown to them. For astronomy is not only pleasant but also very useful to be known; it cannot be denied that this art unfolds the admirable wisdom of God. Wherefore, as ingenious men are to be honored who have expended useful labor on this subject, so they who have leisure and capacity ought not to neglect this kind of exercise. Nor did Moses truly wish to withdraw us from this pursuit in omitting such things as are peculiar to the art; but, because he was ordained a teacher as well of the unlearned and rude as of the learned, he could not otherwise fulfill his office than by descending to this grosser method of instruction. Had he spoken of things generally unknown, the uneducated might have pleaded in excuse that such subjects were beyond their capacity.

Lastly, since the Spirit of God here opens a common school for all, it is not surprising that he should chiefly choose those subjects which would be intelligible to all. If the astronomer inquires respecting the actual dimensions of the stars, he will find the moon to be less than Saturn; but this is something abstruse, for to the sight it appears differently. Moses therefore rather adapts his discourse to common usage. For since the Lord stretches forth, as it were, his hand to us in causing us to enjoy the brightness of the sun and moon, how great would be our ingratitude were we to close our eyes against our own experience. There is therefore no reason why janglers should deride the unskillfulness of Moses in making the moon the second luminary; for he does not call us up into heaven; he only proposes things which lie open before our eyes. Let the astronomers possess their more exalted knowledge; but, in the meantime, they who perceive by the moon the splendor of night are convicted by its use of perverse ingratitude unless they acknowledge the beneficence of God.

Kepler for his part, in the introduction to his Astronomia Nova *(1609), employs similar distinctions between scientific and popular style in order to solve apparent conflicts between heliocentrism and the Bible.*

It must be confessed that there are very many devoted to holiness who dissent from the judgment of Copernicus, fearing to give the lie to the Holy Ghost speaking in the Scriptures, if they should say that the earth moves and the sun stands still. But let such consider that, since we judge of very many and those the most principal things by the sense of seeing, it is impossible that we should alienate our speech from this sense of our eyes. Therefore many things daily occur of which we speak according to the sense of sight, when we certainly know that the things themselves are otherwise, as for example in that verse of Vergil, "We sail forth from the harbor, and lands and cities draw backwards." . . .

Thus we conceive c
their ascension and d
same time others say t
affirm that the planets
be fixed, although they
line either downwards
nations use the word
stand still. . . . And so i

But now the Sacrec
which they were not i
that they might be u
granted by all, whereb
What wonder is it, the
sion at such time wher
all men, whether learn
is a poetical allusion (J
course of the Gospel,
world, undertaken for
forth from his "tabern
his chamber, and rejoi
knew that the sun wen
and yet it seems to the
because it appeared to
were so to his seeming
the perception of the ey
Psalmist in shadowing
peregrination of the So

Kepler considers a nun
chapter 38) and suggest
tion is to "meddle with
reading such texts we s
scope and intent of Scri

But Psalm 104 is thoug
in that it concerns natu
the foundations of the
But here also the Psalm
he wholly acquiesces in
sings a hymn to God th
order, as it appeared to

asant but also very useful to
ds the admirable wisdom of
onored who have expended
sure and capacity ought not
truly wish to withdraw us
peculiar to the art; but, be-
nlearned and rude as of the
than by descending to this
things generally unknown,
t such subjects were beyond

mon school for all, it is not
jects which would be intel-
ig the actual dimensions of
aturn; but this is something
oses therefore rather adapts
d stretches forth, as it were,
ness of the sun and moon,
close our eyes against our
janglers should deride the
cond luminary; for he does
s which lie open before our
lted knowledge; but, in the
splendor of night are con-
ey acknowledge the benefi-

ronomia Nova *(1609), em-*
popular style in order to
d the Bible.

voted to holiness who dis-
o give the lie to the Holy
y that the earth moves and
ice we judge of very many
of seeing, it is impossible
ise of our eyes. Therefore
ding to the sense of sight,
s are otherwise, as for ex-
the harbor, and lands and

Thus we conceive of the rising and setting of the stars, that is to say, of their ascension and descension; we affirm that the sun rises, when at the same time others say that it goes down. . . . So in like manner, the Ptolemaics affirm that the planets stand still, when for some days together they seem to be fixed, although they believe them at that very time to be moved in a direct line either downwards to or upwards from the earth. Thus the writers of all nations use the word "solstice," and yet they deny that the sun does really stand still. . . . And so in other cases of the like nature.

But now the Sacred Scriptures, speaking to men of vulgar matters (in which they were not intended to instruct men) after the manner of men, so that they might be understood by men, do use such expressions as are granted by all, whereby to intimate other things more mysterious and divine. What wonder is it, then, if the Scripture speaks according to man's apprehension at such time when the truth of things dissents from the conception that all men, whether learned or unlearned, have of them. Who knows not that it is a poetical allusion (Psalm 19) where, under the similitude of the sun, the course of the Gospel, as also the peregrination of our Lord Christ in this world, undertaken for our sakes, is described. Thus the sun is said to come forth from his "tabernacle" of the horizon "as a bridegroom coming out of his chamber, and rejoices as a strong man to run a race." . . . The Psalmist knew that the sun went not forth from the horizon as out of its tabernacle, and yet it seems to the eye so to do. Nor did he believe that the sun moved because it appeared to his sight so to do. And yet he says both, because both were so to his seeming. Neither is it to be adjudged false in either sense, for the perception of the eyes has its verity, fit for the more secret purpose of the Psalmist in shadowing forth the current passage of the Gospel, as also the peregrination of the Son of God. . . .

Kepler considers a number of passages from the Psalms and from Job (e.g., chapter 38) and suggests that to give poetic figures a purely literal interpretation is to "meddle with the Holy Spirit" and to bring him into contempt. In reading such texts we should "turn our eyes from natural philosophy, to the scope and intent of Scripture." He continues:

But Psalm 104 is thought by some to contain a discourse altogether physical, in that it concerns natural philosophy. Now God is there said to have "laid the foundations of the earth, that it should not be removed for ever" (v. 5). But here also the Psalmist is far from the speculation of physical causes. For he wholly acquiesces in the greatness of God, who did all these things, and sings a hymn to God the Maker of them, in which he runs over the world in order, as it appeared to his eyes. And if you well consider this psalm, it is a

paraphrase upon the six days work of the creation. For in it the three first days were spent in the separation of regions: the first, of light from exterior darkness; the second, of the waters from the waters, by the interposition of the firmament; the third, of the sea from land, when also the earth was clothed with herbage and plants. And the three last days were spent in filling the regions thus distinguished: the fourth, of heaven; the fifth, of the seas and air; the sixth, of the earth. Likewise here in this psalm there are so many distinct parts proportionable to the analogy of the six days works. For in verse 2 he clothes and covers the Creator with light (the first of creatures, and work of the first day) as with a garment. The second part begins at verse 3 and treats of the waters above the heavens, the extent of heaven and of meteors (which the Psalmist seems to intend by the waters above) as namely of clouds, winds, whirl-winds, lightnings. The third part begins at verse 6 and celebrates the earth as the foundation of all those things which he here considers. For he refers all things to the earth, and to those animals which inhabit it, since in the judgment of sight the two principal parts of the world are heaven and earth. He therefore here observes that the earth after so many ages has not faltered, tired, or decayed, whereas no man has yet discovered upon what it is founded. He aims not to teach men what they do not know, but puts them in mind of what they neglect, namely, the greatness and power of God in creating so huge a mass so firm and steadfast.

If an astronomer should teach that the earth is placed among the planets, he overthrows not what the Psalmist here says, nor does he contradict common experience. For it is true notwithstanding that the earth, the structure of God its Architect, does not decay (as our buildings are wont to do) by age, or consume by worms, nor sway and lean to this or that side; that the seats and nests of living creatures are not molested; that the mountains and shores stand immoveable against the violence of the winds and waves, as they were at the beginning. But the Psalmist adds a most elegant hypothesis of the separation of the waters from the continent or mainland, and adorns it with the production of fountains, and the benefits that springs and rocks exhibit to birds and beasts. Nor does he omit the apparelling the earth's surface, mentioned by Moses among the works of the third day, but more sublimely describes it in his case in expressions infused from divine inspiration; and flourishes out the commemoration of the many commodities which redound from that exornation for the nourishment and comfort of man, and covert of beasts.

The fourth part begins at verse 20 celebrating the fourth day's work, namely the sun and moon, but chiefly the commodiousness of those things which in their seasons befall to all living creatures and to man, this being the subject matter of his discourse. So that it plainly appears he acted not the

part of an astronomer. For
tion the five planets, than
more excellent, nothing th
Creator among the learne
day's work. And it stores
The sixth part is more obs
creatures that were created
of God in general, who da
ever he said of the world is
ing but what is granted o
known, and not to dive ir
plate the benefits that red
days.

And I also beseech my re
on mankind, the considerat
he returns from the temp
would with me praise and
which I discover to him by
the disquisition of causes, a
not only extol the bounty o
kinds, and establishing the
strange, so admirable, he w

But he who is so stupid a
so weak and scrupulous as
nicus, him I advise that, le
opinions of philosophers at
and that, desisting from fur
home and manure his own
sees, being elevated toward
his whole heart in thanks ar
that he shall therein perforn
whom God has bestowed th
eye of his understanding, ye
willing to extol his God abo

SOURCES: Adapted from *A Com*
called Genesis, trans. Thomas T
cilings of Scripture Texts, in Th
lations, London, 1661.

on. For in it the three first
first, of light from exterior
ers, by the interposition of
, when also the earth was
st days were spent in filling
en; the fifth, of the seas and
salm there are so many dis-
ix days works. For in verse
the first of creatures, and
cond part begins at verse 3
ent of heaven and of mete-
vaters above) as namely of
part begins at verse 6 and
things which he here con-
o those animals which in-
rincipal parts of the world
hat the earth after so many
no man has yet discovered
n what they do not know,
y, the greatness and power
dfast.
placed among the planets,
or does he contradict com-
t the earth, the structure of
are wont to do) by age, or
hat side; that the seats and
he mountains and shores
ls and waves, as they were
ant hypothesis of the sepa-
nd, and adorns it with the
rings and rocks exhibit to
g the earth's surface, men-
y, but more sublimely de-
n divine inspiration; and
mmodities which redound
fort of man, and covert of

g the fourth day's work,
diousness of those things
and to man, this being the
appears he acted not the

part of an astronomer. For if he had, he would not then have omitted to mention the five planets, than whose motion nothing is more admirable, nothing more excellent, nothing that can more evidently set forth the wisdom of the Creator among the learned. The fifth part begins, verse 25, with the fifth day's work. And it stores the seas with fishes, and covers them with ships. The sixth part is more obscurely hinted at, verse 28, and alludes to the land-creatures that were created the sixth day. And lastly, he declares the goodness of God in general, who daily creates and preserves all things. So that whatever he said of the world is in relation to living creatures. He speaks of nothing but what is granted on all hands, for it was his intent to extol things known, and not to dive into hidden matters, but to invite men to contemplate the benefits that redound unto them from the works of each of these days.

And I also beseech my reader, not forgetting the divine goodness conferred on mankind, the consideration of which the Psalmist chiefly urges, that when he returns from the temple, and enters into the school of astronomy, he would with me praise and admire the wisdom and greatness of the Creator, which I discover to him by a more narrow explication of the world's form, the disquisition of causes, and detection of the errors of sight. And so he will not only extol the bounty of God in the preservation of living creatures of all kinds, and establishing the earth; but even in its motion also, which is so strange, so admirable, he will acknowledge the wisdom of the Creator.

But he who is so stupid as not to comprehend the science of astronomy, or so weak and scrupulous as to think it an offence of piety to adhere to Copernicus, him I advise that, leaving the study of astronomy, and censuring the opinions of philosophers at pleasure, he betake himself to his own concerns, and that, desisting from further pursuit of these intricate studies, he keep at home and manure his own ground; and with those eyes wherewith alone he sees, being elevated towards this to-be-admired heaven, let him pour forth his whole heart in thanks and praises to God the Creator, and assure himself that he shall therein perform as much worship to God, as the astronomer, on whom God has bestowed this gift, that though he sees more clearly with the eye of his understanding, yet whatever he has attained to, he is both able and willing to extol his God above it.

SOURCES: Adapted from *A Commentary of John Calvin, upon the first book of Moses called Genesis*, trans. Thomas Tymme, London, 1578; *Johannes Keplerus, His Reconcilings of Scripture Texts*, in Thomas Salusbury, *Mathematical Collections and Translations*, London, 1661.

21

A Star Never Seen Before Our Time

Tycho Brahe

Tycho Brahe (1546–1601) often appears as a sort of extended footnote in the history of astronomy, most famously because of his "Tychonic" system, according to which the planets revolve around the sun, which in turn still revolves around a stationary earth. Yet his keen pretelescopic observations of the heavens in fact laid the foundation for subsequent cosmological theory, in particular that of his successor, Johannes Kepler. Moreover, precisely because they were observational rather than principally theoretical, some of Tycho's claims must have had an even more radical imaginative and evidential impact than those of Copernicus. Copernicus's main contribution was to rethink the structure of what we now call the solar system, but he did so within a fundamentally medieval (if expanded) sphere of immutable fixed stars. Tycho, on the other hand, presented ocular evidence of mutability even in those celestial realms. As Annie Jump Cannon puts it, Tycho's "discovery was a death knell to the natural philosophy of Aristotle. A change had taken place in that 'solid crystal sphere of the fixed stars,' which had been assumed, during nearly two thousand years, to be subject neither to growth nor to decay." Or we may put it this way: Contrary to previous beliefs, even the highest heavens themselves are in the grip of Time.

Having already for more than a decade been an avid and knowledgeable sky-watcher, one night in 1572 Tycho noticed, disbelievingly, a new star in the constellation Cassiopeia. In his awed response one can almost hear the cracking of the foundations of medieval cosmology.

A Star Never Seen Before

Last year [1572], in th
month, in the evening,
templating the stars in a
passing the other stars
head. And since I had a
ens perfectly . . . it was
any star in that place in
conspicuously bright as
ashamed to doubt the tr

But when I observed
them, could see that the
miracle indeed, either
range of nature since th
be classed with those at
its course in answer to t
face at the time of the
clearly prove it to be t
world no change, in th
place; but that the heav
out increase or diminu
number or in size or in
the same, like unto the
Furthermore, the obse
thousands of years ago
same number, position,
observation on the part
to preserve even in our
noted by any one of the
tial world, except only
lieve Pliny [A.D. 23–79]
Natural History) notice
born in his own age. . .

*Although more technic
selection shows how cr
cated. If it were sublu
markable. If it were loc
the doctrine of stellar in
star were truly among th
tions would be shaken.*

Seen
Time

e

of extended footnote in the
his "Tychonic" system, ac-
sun, which in turn still re-
etelescopic observations of
quent cosmological theory,
ler. Moreover, precisely be-
ılly theoretical, some of Ty-
imaginative and evidential
ain contribution was to re-
ystem, but he did so within
immutable fixed stars. Ty-
of mutability even in those
Tycho's "discovery was a
A change had taken place
:h had been assumed, dur-
r to growth nor to decay."
; beliefs, even the highest

avid and knowledgeable
believingly, a new star in
one can almost hear the

Last year [1572], in the month of November, on the eleventh day of that month, in the evening, after sunset, when according to my habit I was contemplating the stars in a clear sky, I noticed that a new and unusual star, surpassing the other stars in brilliancy, was shining almost directly above my head. And since I had almost from boyhood known all the stars of the heavens perfectly . . . it was quite evident to me that there had never before been any star in that place in the sky, even the smallest, to say nothing of a star so conspicuously bright as this. I was so astonished at this sight that I was not ashamed to doubt the trustworthiness of my own eyes.

But when I observed that others, too, on having the place pointed out to them, could see that there was really a star there, I had no further doubts. A miracle indeed, either the greatest of all that have occurred in the whole range of nature since the beginning of the world, or one certainly that is to be classed with those attested by the Holy Oracles, the staying of the sun in its course in answer to the prayers of Joshua, and the darkening of the sun's face at the time of the crucifixion. For all philosophers agree, and facts clearly prove it to be the case, that in the ethereal region of the celestial world no change, in the way either of generation or of corruption, takes place; but that the heavens and the celestial bodies in the heavens are without increase or diminution, and that they undergo no alteration, either in number or in size or in light or in any other respect; that they always remain the same, like unto themselves in all respects, no years wearing them away. Furthermore, the observations of all the founders of science, made some thousands of years ago, testify that all the stars have always retained the same number, position, order, motion, and size as they are found, by careful observation on the part of those who take delight in heavenly phenomena, to preserve even in our own day. Nor do we read that it was ever before noted by any one of the founders that a new star had appeared in the celestial world, except only by Hipparchus [fl. 2nd-century B.C.], if we are to believe Pliny [A.D. 23–79]. For Hipparchus, according to Pliny (Book II of his *Natural History*) noticed a star different from all others previously seen, one born in his own age. . . .

Although more technical than is the norm for this anthology, the following selection shows how crucial it was to establish where the new star was located. If it were sublunary, then the phenomenon would be merely unremarkable. If it were located among the planets, then at least no revision of the doctrine of stellar immutability would be required. However, if the new star were truly among the "fixed" stars, then two thousand-year-old assumptions would be shaken.

The nonmathematician requires only patience to appreciate the simplicity and force of Tycho's argument.

It is a difficult matter, and one that requires a subtle mind, to try to determine the distances of the stars from us, because they are so incredibly far removed from the earth; nor can it be done in any way more conveniently and with greater certainty than by the measure of the [diurnal] parallax, if a star have one. For if a star that is near the horizon is seen in a different place than when it is at its highest point and near the vertex, it is necessarily found in some orbit with respect to which the earth has a sensible size. How far distant the said orbit is, the size of the parallax compared with the semidiameter of the earth will make clear. If, however, a [circumpolar] star, that is as near to the horizon [at lower culmination] as to the vertex [at upper culmination], is seen at the same point of the Primum Mobile, there is no doubt that it is situated either in the eighth sphere or not far below it, in an orbit with respect to which the whole earth is as a point.

In order, therefore, that I might find out in this way whether this star was in the region of the element or among the celestial orbits, and what its distance was from the earth itself, I tried to determine whether it had a parallax, and if so how great a one. And this I did in the following way: I observed the distance between this star and Schedir of Cassiopeia (for the latter and the new star were both nearly in the meridian), when the star was at its nearest point to the vertex, being only 6 degrees removed from the zenith itself (and for that reason, though it were near the earth, would produce no parallax in that place, the visual position of the star and the real position then uniting in one point, since the line from the center of the earth and that from the surface nearly coincide). I made the same observation when the star was farthest from the zenith and at its nearest point to the horizon, and in each case I found that the distance from the above-mentioned fixed star was exactly the same, without the variation of a minute: namely, 7 degrees and 55 minutes. Then I went through the same process, making numerous observations with other stars. Whence I conclude that this new star has no diversity of aspect, even when it is near the horizon. For otherwise in its least altitude it would have been farther away from the above-mentioned star in the breast of Cassiopeia than when in its greatest altitude. Therefore, we shall find it necessary to place this star not in the region of the element, below the moon, but far above, in an orbit with respect to which the earth has no sensible size.

For if it were in the highest region of the air, below the hollow region of the lunar sphere, it would, when nearest the horizon, have produced on the circle a sensible variation of altitude from that which it held when near the vertex.

A simple way of express
language of earthly rota
view an object X vertic
of the angular distance
overhead, and then six h
both now on the horizo
the angular distance bet
lack of parallax justifies
measurable distance fro

In the same, way Tyc
that the new star is a pl
tive. His conservative int
luctant he remains to ad

Therefore, this new star
moon, nor among the o
eighth sphere, among the
Hence it follows that it
kind of fiery meteor bec
heavens themselves, but
air, as all philosophers te
comets are produced not
has observed a comet ab
be the case is not yet cl
shows itself in our age, I
we assume that it can ha
can hardly admit), still i
first, by reason of its ve
stars and different from t
cause, in such a length of
nally by any motion of i
although these sometim
when the observation is
not to keep the same posi

I conclude, therefore, t
teor, whether these be ge
that it is a star shining in
been seen before our time

SOURCE: Tycho Brahe, *De N*
tronomy, ed. Harlow Shaple

ıce to appreciate the simplicity

ı subtle mind, to try to deter-
e they are so incredibly far re-
ıy way more conveniently and
he [diurnal] parallax, if a star
s seen in a different place than
rtex, it is necessarily found in
s a sensible size. How far dis-
mpared with the semidiameter
cumpolar] star, that is as near
vertex [at upper culmination],
le, there is no doubt that it is
below it, in an orbit with re-

his way whether this star was
stial orbits, and what its dis-
ine whether it had a parallax,
following way: I observed the
iopeia (for the latter and the
ıen the star was at its nearest
ed from the zenith itself (and
vould produce no parallax in
ɔ real position then uniting in
earth and that from the sur-
ɔn when the star was farthest
horizon, and in each case I
.ed fixed star was exactly the
y, 7 degrees and 55 minutes.
numerous observations with
ır has no diversity of aspect,
in its least altitude it would
ıed star in the breast of Cas-
ɛfore, we shall find it neces-
ement, below the moon, but
ɛarth has no sensible size.
below the hollow region of
ɪizon, have produced on the
which it held when near the

A simple way of expressing the same argument (though using the Copernican language of earthly rotation) is this: Suppose that, standing on the equator, I view an object X vertically overhead somewhere in the heavens, taking note of the angular distance between X and a "fixed" star also roughly vertically overhead, and then six hours later I view the same object X and the same star both now on the horizon (since I have moved 90° about the earth's axis). If the angular distance between X and the fixed star remains the same, then this lack of parallax justifies the inference that X and the fixed star are at an immeasurable distance from earth.

In the same way Tycho marshals evidence against the second possibility, that the new star is a planet, and so is left with but one astounding alternative. His conservative interpretation of comets in this context reveals how reluctant he remains to admit evidence of change beyond the sublunary sphere.

Therefore, this new star is neither in the region of the element, below the moon, nor among the orbits of the seven wandering stars, but it is in the eighth sphere, among the other fixed stars, which was what we had to prove. Hence it follows that it is not some peculiar kind of comet or some other kind of fiery meteor become visible. For none of these are generated in the heavens themselves, but they are below the moon, in the upper region of the air, as all philosophers testify, unless one would believe with Albategnius that comets are produced not in the air but in the heavens. For he believes that he has observed a comet above the moon, in the sphere of Venus. That this can be the case is not yet clear to me. But, please God, sometime, if a comet shows itself in our age, I will investigate the truth of the matter. Even should we assume that it can happen (which I, in company with other philosophers, can hardly admit), still it does not follow that this star is a kind of comet; first, by reason of its very form, which is the same as the form of the real stars and different from the form of all the comets hitherto seen, and then because, in such a length of time, it advances neither latitudinally nor longitudinally by any motion of its own, as comets have been observed to do. For, although these sometimes seem to remain in one place several days, still, when the observation is made carefully by exact instruments, they are seen not to keep the same position for so very long or so very exactly.

I conclude, therefore, that this star is not some kind of comet or fiery meteor, whether these be generated beneath the moon or above the moon, but that it is a star shining in the firmament itself—one that has never previously been seen before our time, in any age since the beginning of the world.

SOURCE: Tycho Brahe, *De Nova Stella*, trans. John H. Walden, in *A Source Book in Astronomy*, ed. Harlow Shapley and Helen E. Howarth, New York: McGraw-Hill, 1929.

22

This Little Dark Star Wherein We Live

Thomas Digges

Thomas Digges (c. 1546–1595) is notable not only for being the first translator of Copernicus into English but also for drawing from Copernicus's theory bold inferences concerning the size, and perhaps the infinity, of the universe. Digges's A Perfit Description of the Caelestiall Orbes *was published in 1576 as an appendix to an edition of a largely meteorological work by his father, Leonard Digges, entitled* A Prognostication *(1553, with subsequent revisions). The senior Digges prefaces his book with a defense of astronomy against two standard charges: that it is useless, and that it is impious:*

To avoid tediousness I refer all of that sort which have tasted any learning (the rest not regarded) to the first part of famous Guido Bonatus' *On the Common Utility of Astronomy*. . . . Also for brevity I appoint all nice [i.e., fastidious] divines, or (as Melanchthon termeth them) "theological Epicureans," to his high commendations touching astronomy, . . . where he showeth how far wide they allege the Scriptures against the astronomer, which [agree] wholly with the astronomer.

The controversial themes of astronomy's usefulness and piety become part of the undercurrent too of Thomas's discussion in A Perfit Description. *The younger Digges should not be seen merely as a translator of Copernicus. His paraphrase is mainly of chapters 10, 7, and 8 (in that order) of the first book of the* Revolutions, *with some inclusions from other chapters; however, he both digresses freely from and embellishes Copernicus's text. In his almost*

nervous high praise of philosopher Aristotle" new world picture, an we enjoy a unique tast which Digges sets forth

Having of late (gentle negligence have crept ir things I found a descri celestial and elementary universities (led thereto sented. But in this our a time to time more and dities in their theories, confess any mobility in tice, and rare invention ing that the earth resteth center of this our mort enclosed in the moon's c carried yearly round al reigneth and giveth laws rious beams of light thr self to be one of the plar every twenty-four hours great globe of fixed stars main fixed.

Digges distances himself mere hypothesis, construc

So many ways is the sen course of wit having ope with demonstrations ma livered, I thought it con this, to the end such nobl sort of men) might not b phy. And to the end it mi some have fondly excuse only as mathematical p averred, I have also fron Aristotle and others prod

nervous high praise of the newcomer Copernicus, in his deft use of "our own philosopher Aristotle" against the Aristotelians he knows will oppose the new world picture, and in his charming flattery of "noble English minds," we enjoy a unique taste of the new and inevitably controversial cosmology, which Digges sets forth for the first time in the English language.

Having of late (gentle reader) corrected and reformed sundry faults that by negligence have crept into my father's *General Prognostication*, among other things I found a description or model of the world and situation of spheres celestial and elementary according to the doctrine of Ptolemy, whereunto all universities (led thereto chiefly by the authority of Aristotle) since have consented. But in this our age one rare wit (seeing the continual errors that from time to time more and more have been discovered, besides the infinite absurdities in their theories, which they have been forced to admit that would not confess any mobility in the ball of the earth) hath by long study, painful practice, and rare invention delivered a new theory or model of the world, showing that the earth resteth not in the center of the whole world, but only in the center of this our mortal world or globe of elements which, environed and enclosed in the moon's orb, and together with the whole globe of mortality, is carried yearly round about the sun, which like a king in the midst of all reigneth and giveth laws of motion to the rest, spherically dispersing his glorious beams of light through all this sacred celestial temple. And the earth itself to be one of the planets, having his peculiar and straying courses turning every twenty-four hours round upon his own center, whereby the sun and great globe of fixed stars seem to sway about and turn, albeit indeed they remain fixed.

Digges distances himself from those who would defend Copernicus's model as a mere hypothesis, constructed only to "save the appearances."

So many ways is the sense of mortal men abused, but reason and deep discourse of wit having opened these things to Copernicus, and the same being with demonstrations mathematical most apparently by him to the world delivered, I thought it convenient together with the old theory also to publish this, to the end such noble English minds (as delight to reach above the baser sort of men) might not be altogether defrauded of so noble a part of philosophy. And to the end it might manifestly appear that Copernicus meant not as some have fondly excused him to deliver the grounds of the earth's mobility only as mathematical principles, fained and not as philosophical truly averred, I have also from him delivered both the philosophical reasons by Aristotle and others produced to maintain the earth's stability, and also their

solutions and insufficiency, wherein I cannot a little commend the modesty of that grave philosopher Aristotle, who seeing (no doubt) the insufficiency of his own reasons in seeking to confute the earth's motion, useth these words: "We have explained these matters so far as our capacity permits." Howbeit, his disciples have not with like sobriety maintained the same.

Thus much for my own part in this case I will only say: There is no doubt but of a true ground, truer effects may be produced than of principles that are false; and of true principles, falsehood or absurdity cannot be inferred. If therefore the earth be situate immovable in the center of the world, why find we not theories upon that ground to produce effects as true and certain as these of Copernicus? Why cast we not away those "equant circles" and motions irregular, seeing our own Philosopher Aristotle, himself the light of our universities, hath taught us: "A simple body has a simple motion." But if contrary it be found impossible (the earth's stability being granted) but that we must necessarily fall into these absurdities, and cannot by any means avoid them, why shall we so much dote in the appearance of our senses, which many ways may be abused, and not suffer ourselves to be directed by the rule of reason, which the great God hath given us as a lamp to lighten the darkness of our understanding and the perfect guide to lead us to the golden branch of verity amid the forest of errors?

Behold a noble question to be of the philosophers and mathematicians of our universities argued not with childish invectives but with grave reasons philosophical and irreprovable demonstrations mathematical. . . .

The globe of elements enclosed in the orb of the moon I call the globe of mortality, because it is the peculiar empire of death. . . . In the midst of this globe of mortality hangeth this dark star or ball of the earth and water balanced and sustained in the midst of the thin air only with that propriety which the wonderful workman hath given at the creation to the center of this globe with his magnetical force vehemently to draw and hale unto itself all such other elementary things as retain the like nature. This ball every twenty-four hours by natural, uniform, and wonderful sly and smooth motion rolleth round, making with his period our natural day, whereby it seems to us that the huge infinite immovable globe should sway and turn about.

The moon's orb that environeth and containeth this dark star and the other mortal, changeable, corruptible elements and elementary things is also turned round every twenty-nine days, thirty-one minutes, fifty seconds . . . and this period may most aptly be called the month.

Digges's title, repeated in its entirety following the preface and before his paraphrase of chapter 10 of the first book of the Revolutions, *employs a strategy often used by those presenting new ideas. Just as Protestant reform-*

ers insisted that the R
early church, so here
elty but as a reviver of

A Perfect D
According to
Pythagoreans, I
Geometri

Although in this most
have been sundry opini
celestial, yet in certain
have agreed and consen
the most high, the farth
of wandering stars. An
philosophers thought it
ter should swiftliest mo
est overpassed, and the
moon being swiftest in
agreed that the orb of S
is also the biggest; Jupit
cury there hath been gr
from the sun as the rest
sun, as Plato in his *Tima*
of them that followed hi

If we situate the orbs c
to the same center, so as
also the earth, happily w
residue of Copernicus' *R*
these planets nigh the sur
are much greater in sight
ter of them is rather to th
of Venus and Mercury als

But if all these to the
must there needs betwe
Mars a huge space be left
with the lunar orb, of du
may not be far removed,

tle commend the modesty of
doubt) the insufficiency of
motion, useth these words:
apacity permits." Howbeit,
ed the same.
only say: There is no doubt
d than of principles that are
dity cannot be inferred. If
nter of the world, why find
fects as true and certain as
e "equant circles" and mo-
tle, himself the light of our
simple motion." But if con-
being granted) but that we
annot by any means avoid
ance of our senses, which
s to be directed by the rule
amp to lighten the darkness
us to the golden branch of

ers and mathematicians of
es but with grave reasons
thematical. . . .
e moon I call the globe of
h. . . . In the midst of this
f the earth and water bal-
only with that propriety
eation to the center of this
w and hale unto itself all
re. This ball every twenty-
and smooth motion rol-
y, whereby it seems to us
and turn about.
h this dark star and the
elementary things is also
ninutes, fifty seconds . . .

e preface and before his
Revolutions, *employs a*
ust as Protestant reform-

ers insisted that the Reformation was a return *to the Scriptures and to the early church, so here Digges depicts Copernicus not as a champion of novelty but as a reviver of "ancient doctrine."*

A Perfect Description of the Celestial Orbs According to the Most Ancient Doctrine of the Pythagoreans, Lately Revived by Copernicus and by Geometrical Demonstrations Approved.

Although in this most excellent and difficult part of philosophy in all times have been sundry opinions touching the situation and moving of the bodies celestial, yet in certain principles all philosophers of any account of all ages have agreed and consented: First, that the orb of the fixed stars is of all other the most high, the farthest distant, and comprehendeth all the other spheres of wandering stars. And of these straying bodies called "planets" the old philosophers thought it a good ground in reason that the nighest to the center should swiftliest move, because the circle was least and thereby the soonest overpassed, and the farther distant the more slowly. Therefore as the moon being swiftest in course is found also by measure nighest, so have all agreed that the orb of Saturn, being in moving the slowest of all the planets, is also the biggest; Jupiter the next; and then Mars. But of Venus and Mercury there hath been great controversy, because they stray not every way from the sun as the rest do. And therefore some have placed them above the sun, as Plato in his *Timaeus*; others beneath, as Ptolemy and the greater part of them that followed him. . . .

If we situate the orbs of Saturn, Jupiter, and Mars referring them as it were to the same center, so as their capacity be such as they contain and circulate also the earth, happily we shall nor err, as by evident demonstrations in the residue of Copernicus' *Revolutions* is demonstrated. For it is apparent that these planets nigh the sun are always least, and farthest distant and opposite are much greater in sight and nigher to us; whereby it cannot be but the center of them is rather to the sun than to the earth to be referred, as in the orbs of Venus and Mercury also.

But if all these to the sun as a center in this manner be referred, then must there needs between the convex orb of Venus and the concave of Mars a huge space be left wherein the earth and elementary frame, enclosed with the lunar orb, of duty must be situate. For from the earth the moon may not be far removed, being without controversy of all other nighest in

place and nature to it, especially considering between the same orbs of Venus and Mars there is room sufficient. Therefore need we not to be ashamed to confess this whole globe of elements enclosed with the moon's sphere, together with the earth as the center of the same, to be by this great orb, together with the other planets, about the sun turned, making by his revolution our year. And whatsoever seem to us to proceed by the moving of the sun, the same to proceed indeed by the revolution of the earth, the sun still remaining fixed and immovable in the midst. And the distance of the earth from the sun to be such as, being compared with the other planets, maketh evident alterations and diversity of aspects, but if it be referred to the orb of stars fixed, then hath it no proportion sensible, but as a point or a center to a circumference, which I hold far more reasonable to be granted, than to fall unto such an infinity of multitude of absurd imaginations, as they were fain to admit that will needs wilfully maintain the earth's stability in the center of the world. But rather herein to direct ourselves by that wisdom we see in all God's natural works, where we may behold one thing rather endued with many virtues and effects, than any superfluous or unnecessary part admitted.

And all these things although they seem hard, strange, and incredible, yet to any reasonable man that hath his understanding ripened with mathematical demonstration, Copernicus in his *Revolutions*, according to his promise, hath made them more evident and clear than the sunbeams. These grounds therefore admitted, which no man reasonably can impugn, that the greater orb requireth the longer time to run his period, the orderly and most beautiful frame of the heavens doth ensue.

*Continuing to hew closely to Copernicus's own discussion (*Revolutions *1.10), Digges makes clear the mathematical symmetry of the heliocentric system, in particular its elegance in ridding astronomy of the embarrassment of many irregularities in the heavens, irregularities which may now be concluded are merely apparent, and "follow upon the earth's motion."*

However, as one set of problems is solved, another problem comes into view, namely that of annual parallax: If the earth revolves around the sun in an enormous annual orbit, why don't the stars, like the planets, appear to vary their movement as the earth moves?

And that none of these alterations do happen in the fixed stars, it plainly argueth their huge distance and immeasurable altitude, in respect whereof this great orb wherein the earth is carried is but a point, and utterly without sensible proportion being compared to that heaven. For as it is in perspective

demonstrated, every qu
unto it may be discerne
tance therefore of that
whole "great orbit" van

*In concluding thus, Dig
his teacher, however, in
nitude, hinting even at i*

Herein can we never suf
ble huge frame of God's
the earth, wherein we m
spect of the moon's orb
wherein earth is carried,
velously is that orb of an
we live. But that great o
spect of the immensity
what little portion of G
never sufficiently be abl
that fixed orb garnished
altitude without end.

*At this point Digges depa
namely, there are countle
an inference only confirm
telescope, though it was t
ing Digges in part echoes:*

Of these lights celestial it
the inferior parts of the s
and lesser quantity, even
ceive, the greatest part r
unto us. And this may w
great God, whose unsear
visible, conjecture: to wh
surmounting all other bo

*In this way, although D
when referring to the fi
meaning. Hence, in the f*

ing between the same orbs of
Therefore need we not to be
ients enclosed with the moon's
of the same, to be by this great
the sun turned, making by his
o us to proceed by the moving
he revolution of the earth, the
the midst. And the distance of
compared with the other plan-
of aspects, but if it be referred
portion sensible, but as a point
ld far more reasonable to be
multitude of absurd imagina-
needs wilfully maintain the
ut rather herein to direct our-
ural works, where we may be-
virtues and effects, than any

rd, strange, and incredible, yet
ading ripened with mathemati-
ons, according to his promise,
the sunbeams. These grounds
can impugn, that the greater
l, the orderly and most beauti-

own discussion (Revolutions
mmetry of the heliocentric sys-
nomy of the embarrassment of
ities which may now be con-
the earth's motion."
another problem comes into
rth revolves around the sun in
rs, like the planets, appear to

n the fixed stars, it plainly ar-
titude, in respect whereof this
oint, and utterly without sen-
en. For as it is in perspective

demonstrated, every quantity hath a certain proportionable distance whereunto it may be discerned and beyond the same it may not be seen, this distance therefore of that immovable heaven is so exceeding great, that the whole "great orbit" vanisheth away, if it be conferred to that heaven.

In concluding thus, Digges agrees exactly with Copernicus. He goes beyond his teacher, however, in expatiating upon the meaning of astronomical magnitude, hinting even at infinitude.

Herein can we never sufficiently admire this wonderful and incomprehensible huge frame of God's work proponed to our senses, seeing first this ball of the earth, wherein we move, to the common sort seemeth great, and yet in respect of the moon's orb is very small, but compared with the great orbit wherein earth is carried, it scarcely retaineth any sensible proportion, so marvelously is that orb of annual motion greater than this little dark star wherein we live. But that great orbit being as is before declared but as a point in respect of the immensity of that immovable heaven, we may easily consider what little portion of God's frame our elementary corruptible world is, but never sufficiently be able to admire the immensity of the rest, especially of that fixed orb garnished with lights innumerable and reaching up in spherical altitude without end.

At this point Digges departs from the Copernican text and draws an inference, namely, there are countless more stars than can be viewed with the naked eye, an inference only confirmed more than three decades later by Galileo with his telescope, though it was theorized earlier by Nicholas Cusanus, whose reasoning Digges in part echoes:

Of these lights celestial it is to be thought that we only behold such as are in the inferior parts of the same orb; and as they are higher, so seem they of less and lesser quantity, even till our sight being not able farther to reach or conceive, the greatest part rest, by reason of their wonderful distance, invisible unto us. And this may well be thought of us to be the glorious court of that great God, whose unsearchable works invisible we may partly, by these his visible, conjecture: to whose infinite power and majesty such an infinite place surmounting all other both in quantity and quality only is convenient.

In this way, although Digges continues to use the traditional term "orb" when referring to the fixed stars, his inference dissolves that term's usual meaning. Hence, in the famous diagram that heads A Perfit Description of

the Caelestiall Orbes *(see the figure on the opposite page), the text that accompanies the starry "orb" reads:*

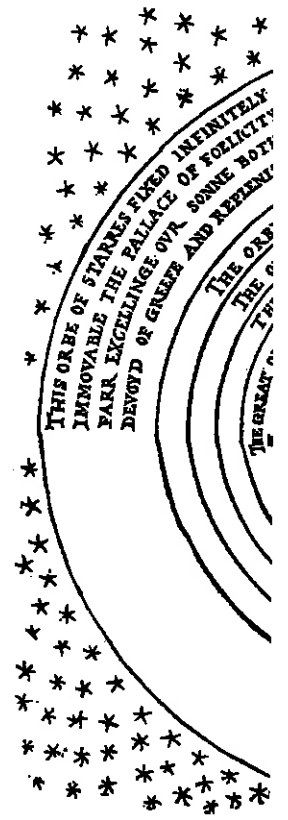
This orb of stars fixed infinitely up extendeth it self in altitude spherically and therefore immovable, the palace of felicity garnished with perpetual shining glorious lights innumerable far excelling our sun both in quantity and quality, the very court of celestial angels devoid of grief and replenished with perfect endless joy, the [habitation] for the elect.

A more sober tone is found in the sentences with which Digges closes his paraphrase of and extrapolations from Copernicus's Revolutions *1.10:*

But because the world hath so long a time been carried with an opinion of the earth's stability, as the contrary cannot but be now very impersuasible, I have thought good out of Copernicus also to give a taste of the reasons philosophical alleged for the earth's stability, and their solutions, that such as are not able with geometrical eyes to behold the secret perfections of Copernicus' theory, may yet by these familiar natural reasons be induced to search farther, and not rashly to condemn for fantastical so ancient doctrine revived, and by Copernicus so demonstratively approved.

Although Digges's version of Revolutions *1.7 and 1.8 is more nearly a straight translation than is his paraphrase of 1.10, near the end of 1.8 he imports a burst of reasoning from 1.9 concerning gravity in which Copernicus adumbrates some implications of the new recognition that the universe contains various orbs and that "these orbs have several centers." For Aristotle, gravity attached to* place, *namely, to the center of the universe—a place, moreover, which the earth occupied simply because it is heavy. But if there are several centers, gravity can no longer be accounted for in terms of a single center.* Body *thus dethrones place as the primary gravitational determinant. Copernicus, and with him Digges, dimly anticipating Newton, recur to what Digges has already identified as "that propriety which the wonderful workman hath given at the creation to the center of this globe with his magnetical force vehemently to draw and hale unto itself all such other elementary things as retain the like nature."*

Seeing therefore that these orbs have several centers, it may be doubted whether the center of this earthly gravity be also the center of the world. For gravity is nothing else but a certain proclivity or natural coveting of parts to be coupled with the whole, which by divine providence of the creator of all is given and impressed into the parts, that they should restore themselves into



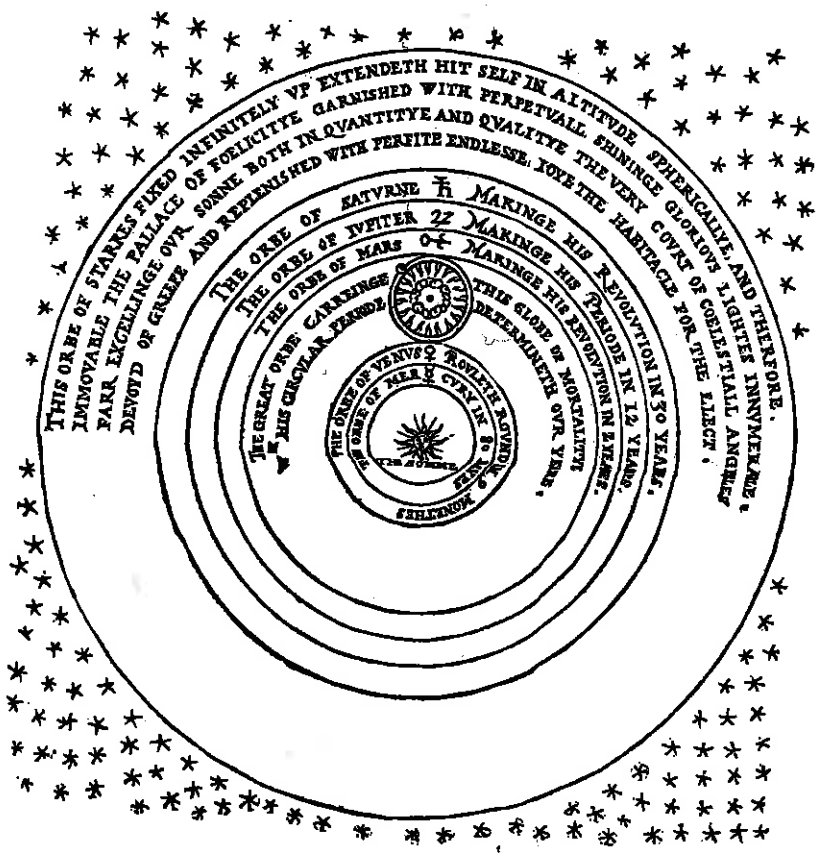
A perf

their unity and integrity cc
ety or affection it is likely
not to knit and combine t
round shape, which bodie
ways conveyed.

SOURCE: Thomas Digges, *A P*
Leonard Digges, *A Prognostic*

A perfit defcription of the Cæleſtiall Orbes,

according to the moſt auncient doctrine of the Pythagoreans. &c.



their unity and integrity concurring in spherical form, which kind of propriety or affection it is likely also that the moon and other glorious bodies want not to knit and combine their parts together, and to maintain them in their round shape, which bodies notwithstanding are by sundry motions sundry ways conveyed.

SOURCE: Thomas Digges, *A Perfit Description of the Caelestiall Orbes*; appended to Leonard Digges, *A Prognostication Everlasting*, London, 1576.

23

Innumerable Suns, and an Infinite Number of Earths

Giordano Bruno

Giordano Bruno, born in 1548 in Nola, Italy (and thus sometimes called by his contemporaries "Nolanus"), pursued an itinerant philosophical career in Switzerland, France, England, and Germany, finding trouble and provoking polemics wherever he went, principally as a result of his outspoken views on various topics, especially cosmology. In 1591 he became a candidate for the chair of mathematics at the University of Padua, but the position was given a year later to Galileo. From then on Bruno faced increasing persecution, and prosecution, for his views; and after a seven-year trial, the Roman Inquisition finally burned him alive in 1600. This event is one that impressed itself indelibly, no doubt, on Galileo's consciousness.

At one level Bruno can be seen as a convinced Copernican, but his conception of the universe goes far beyond finite heliocentrism and, with its emphasis on infinity, forms a bridge between the atomism of Lucretius and the absolute space of Newton. What seems most to have rankled the authorities of his day is Bruno's anti-Aristotelianism, which is conspicuous from the start of his 1584 dialogue On the Infinite Universe and Worlds.

The speakers here are Philotheo (Bruno's main spokesperson), Fracastoro, and Elpino. Philotheo attempts to deconstruct the very notions of finite place and space upon which Aristotle's physics is based.

Philotheo. If the world is finite, and if there is nothing beyond the world, then I ask you: *Where* is the world? *Where* is the universe? Aristotle's reply is: The world is in itself. The convex surface of the primordial heaven is uni-

versal space, and as the
else; for location is mere
who has no containing
you mean by "the loca
which is beyond the wo
the world will surely not
Fracastoro. Therefore th
ing.
Philotheo. The world wi
seems to me that you a
nothing. But if you say th
ing, so that God becom
have a hard job explaini
and dimensionless can b
say that this location as
body, then you are not a
what exists beyond the
claring that where there
such thing as location or
such are mere words and

Having thus unsettled
Philotheo is able to hy
Elpino objects that the i
ists, but is incorporeal."

We agree concerning the
larly accepting the exist
that infinite which is im
mordial First Cause not
boundless image, instead
a shame for us to contin
us seems so great and
point, even as a nothing.
Elpino. Since the greatne
real size (nor does this w
the greatness of his image
Philotheo. True enough;
ment. I am not insisting
nite space—for the sake
sake of corporeal nature

s, and an
of Earths

no

nd thus sometimes called by
erant philosophical career in
ıding trouble and provoking
ılt of his outspoken views on
: became a candidate for the
but the position was given a
l increasing persecution, and
ar trial, the Roman Inquisi-
:t is one that impressed itself

Copernican, but his concep-
entrism and, with its empha-
mism of Lucretius and the
have rankled the authorities
ch is conspicuous from the
se and Worlds.
ı spokesperson), Fracastoro,
e very notions of finite place
d.

nothing beyond the world,
ıe universe? Aristotle's reply
he primordial heaven is uni-

versal space, and as the primordial container it is not contained by anything else; for location is merely the containing body's surfaces and limit, so that he who has no containing body has no location. But, dear Aristotle, what do you mean by "the location is in itself"? What will you tell us about that which is beyond the world? If you say there is nothing, then the heavens and the world will surely not be anywhere at all.

Fracastoro. Therefore the world will be nowhere. Everything will be in nothing.

Philotheo. The world will then be something impossible to find. It certainly seems to me that you are trying somehow to avoid the terms *vacuum* and *nothing*. But if you say that beyond the world there is a divine intellectual being, so that God becomes the location of all things, then you are going to have a hard job explaining how something at once incorporeal, intelligible, and dimensionless can be the location of something dimensional. And if you say that this location as it were contains a form, as the spirit contains the body, then you are not answering the question about the "beyond," or about what exists beyond the universe. And if you wish to excuse yourself by declaring that where there is nothing, and where not anything is, there is no such thing as location or beyond or outside, I shall not be at all satisfied. For such are mere words and excuses.

Having thus unsettled the Aristotelian conception of space and place, Philotheo is able to hypothesize "countless *other spaces like this one." Elpino objects that the infinite—in particular, infinite Good—"certainly exists, but is incorporeal." Philotheo responds:*

We agree concerning the incorporeal infinite. But what prevents our similarly accepting the existence of the good *corporeal* infinite? Why should that infinite which is implicit in the absolutely simple and indivisible primordial First Cause not wish to make itself explicit in his own infinite and boundless image, instead of within such narrow bounds? Surely it would be a shame for us to continue to believe that the body of this world, which to us seems so great and vast, may from God's perspective appear a mere point, even as a nothing.

Elpino. Since the greatness of God does not by any means consist in corporeal size (nor does this world add anything to him), we ought not to think of the greatness of his image as consisting in its greater or lesser size.

Philotheo. True enough; but you are not addressing the heart of my argument. I am not insisting on infinite space—and nature does not possess infinite space—for the sake of sheer magnitude or physical size, but for the sake of corporeal natures and species themselves. For infinite excellence is

incomparably better expressed in things innumerable than in things merely numerable and finite. Indeed, it is fitting that an inaccessible divine countenance should have an infinite likeness with infinite parts—such as those countless worlds I have postulated. Moreover, since innumerable degrees of perfection must unfold God's incorporeal excellence by corporeal means, it follows that there must be innumerable individuals such as those great creatures are (our earth being one of them—the divine mother who gave birth to us, nourishes us, and will finally receive us again into herself). To encompass these innumerable creatures requires an infinite space. Yet it is good that this should be so. It means that there can be innumerable worlds like ours, which achieved and continues to achieve existence. And existence is good.

Various influences are traceable in Bruno's cosmology. There is a good dose of Platonism, and Bruno's repeated reference to the physical universe as a mirror naturally recalls Timaeus's description of the cosmos as a moving image of eternity. Philotheo also cites Nicholas Cusanus, whose assertion of the oneness of the unbounded universe seems to undergird Bruno's position, which is successfully imparted to the receptive Elpino, whose conventional views slowly succumb to Philotheo's combination of reason and imagination. It is worth emphasizing that the theory Bruno unfolds in his dialogue precedes Galileo's telescopic "expansion" of the universe.

Philotheo. All things then are one: the heavens, the immensity of space, our mother earth, the encompassing universe, the ethereal region through which all things move and continue on their way. Herein our senses may perceive innumerable heavenly bodies, stars, spheres, suns, and earths; and reason may deduce an infinitude of them. The universe, immense and infinite, is the sum total of all that space and all the bodies it contains.
Elpino. So there are no orbs with surfaces concave or convex, no deferent circles. Instead, all is one field, a single common envelope.
Philotheo. That is right.
Elpino. Thus the opinion concerning diverse heavens has come about as a result of diverse astral motions, along with what appears to be a star-filled heaven circling about the earth. These lights can by no means be seen to move relative to each other; rather, they always maintain the same distance and mutual relation, and the same fixed arrangement. And they seem to revolve about the earth, just as a wheel on which are attached countless mirrors turns about its own axis. So it is considered obvious from ocular evidence that the luminous bodies have no motion of their own, nor can they

move about like birds in
the circles to which they
higher intelligence.
Philotheo. Yes, that is the
is attributed to this earth
circle but impelled throu
herent principle, spirit,
about its own center—the
of the true principles of n
advance along the road of
bestial imaginations, hidd
tudes of things—ever sinc
the dark night of rash sop
Elpino. There is no doubt
of axes, of deferent circles
monstrous notions—is fou
the earth is in the midpoint
cles about this fixed statior
Philotheo. This appearanc
on the other stars sharing
Elpino. For now, then, le
for what appears to be the
versity of earth's motion a
stars. If so, then we would
moves by her own force
Mars, and the others—w
about the same source of l
Philotheo. That is right.
Elpino. The respective mo
apart from those attributa
the actual motions of thos
fixity, along with the unive
various and plentiful than
serve the motion of each o
same pattern or measure,
the stars' huge distance fro
solar fire or rotate about
heat of the sun, we simply
creasing distances from us.
Philotheo. That is right.

merable than in things merely
an inaccessible divine counte-
infinite parts—such as those
; since innumerable degrees of
ellence by corporeal means, it
lividuals such as those great
–the divine mother who gave
eive us again into herself). To
res an infinite space. Yet it is
re can be innumerable worlds
hieve existence. And existence

mology. There is a good dose
to the physical universe as a
of the cosmos as a moving im-
sanus, whose assertion of the
undergird Bruno's position,
Elpino, whose conventional
on of reason and imagination.
unfolds in his dialogue pre-
iverse.

, the immensity of space, our
thereal region through which
rein our senses may perceive
uns, and earths; and reason
, immense and infinite, is the
ontains.
cave or convex, no deferent
envelope.

vens has come about as a re-
t appears to be a star-filled
an by no means be seen to
maintain the same distance
ement. And they seem to re-
are attached countless mir-
lered obvious from ocular
n of their own, nor can they

move about like birds in flight. Instead, they move only with the turning of the circles to which they are affixed, and governed by the divine impulse of a higher intelligence.

Philotheo. Yes, that is the commonly accepted opinion. But once that motion is attributed to this earthly star that we inhabit, affixed to no such deferent circle but impelled through the open fields of space by means of its own inherent principle, spirit, and nature, revolving about the sun and rotating about its own center—then this illusion will be dispelled. Our understanding of the true principles of nature will be set free, and with great strides we shall advance along the road of truth, which has been obscured by such sordid and bestial imaginations, hidden until now by the injuries of time and the vicissitudes of things—ever since the daylight of ancient wisdom was overtaken by the dark night of rash sophistry. . . .

Elpino. There is no doubt that this entire fantasy of star- and fire-bearing orbs, of axes, of deferent circles, of cranking epicycles—along with plenty of other monstrous notions—is founded merely on the illusory notion that, as it appears, the earth is in the midpoint and center of the universe, while everything else circles about this fixed stationary earth.

Philotheo. This appearance is the same for those who dwell on the moon and on the other stars sharing the same space, be they earths or suns.

Elpino. For now, then, let us suppose the earth's own motion is the reason for what appears to be the daily rotation of the universe, and thus that the diversity of earth's motion accounts for the apparent motions of the countless stars. If so, then we would still affirm that the moon (which is another earth) moves by her own force through the air about the sun. Likewise, Venus, Mars, and the others—which are still other earths—pursue their journeys about the same source of life.

Philotheo. That is right.

Elpino. The respective motions of these bodies are those they appear to have *apart from* those attributable to the presumed rotation of the universe. And the actual motions of those known as the fixed stars (though their apparent fixity, along with the universal rotation, is only relative to the earth) are more various and plentiful than are those bodies themselves. For if we could observe the motion of each one, we would see that no two stars ever exhibit the same pattern or measure, and what keeps us from realizing the variations is the stars' huge distance from us. However much these stars revolve about the solar fire or rotate about their own centers in order to partake of the vital heat of the sun, we simply cannot apprehend their various decreasing or increasing distances from us.

Philotheo. That is right.

Elpino. And so there are innumerable suns, and likewise an infinite number of earths circling about those suns, just like the seven near to us which we see circling about the sun.
Philotheo. That is right.

SOURCE: Translated (with kind advice from Arielle Saiber) from *De l'infinito universo et Mondi*, 1584; in *Le opere italiane di Giordano Bruno*, Göttingen, 1888.

Neith
Observed
C

In 1898 Agnes Clerke wrot

No one could at first have
by which Hans Lippershey,
upon an arrangement of le
pened in 1608; and Galileo
wards at Venice, prepared o
it, early in 1610, the satellit
streams of the Milky Way, a
sun, and the strange appenc
the telescopic revelation of

It does not diminish Galile
our sense of his humanity—
cially from the box seat occ
Medici II, to whom he dedi
Starry Messenger), *and afte*
"the Medicean Stars." Galil
blurb summarizing, excitedl
list of discoveries he is abou

In the present small treatise
observers of Nature to loo
think, first, from their intrir