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KELLY, O.S.B., Sister Mary Suzanne, 1929-
CELESTIAL MOTORS: 1543-1632.

The University of Oklahoma, Ph.D., 1964
History, general

University Microfilms, Inc., Ann Arbor, Michigan

THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

CELESTIAL MOTORS: 1543-1632

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

DOCTOR OF PHILOSOPHY

BY

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Norman, Oklahoma

1964

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and

THOMAS M. SMITH

ACKNOWLEDGEMENTS

To Duane H. D. Roller, McCasland Professor of the History of Science, and Thomas M. Smith, Associate Professor of the History of Science, for their suggestions and criticisms regarding this dissertation and for their continued assistance and encouragement throughout my years of graduate study.

To Alfred B. Sears, Professor of History, David B. Kitts, Associate Professor of Geology and the History of Science, and Leroy E. Page, Assistant Professor of the History of Science, for reading and criticizing this dissertation.

To Mrs. George Goodman, Librarian of the History of Science Collections, for her aid in obtaining sources needed for this study.

To my mother, Mrs. J. M. Kelly, for typing the final copy.

To the National Science Foundation for fellowships which have made this work possible.

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CELESTIAL MOTORS: 1543-1632

INTRODUCTION

The century following the publication of Nicolas Copernicus's De revolutionibus orbium coelestium in 1543 was a period of intense interest in many aspects of astronomy. Old theories were revived; new ones were proposed. The standard astronomical instruments were improved and used with greater care to obtain more accurate observational data. The fixed stars were recounted and recharted; the apparent paths of the wandering stars were remapped. The same questions were asked, but different answers were given. Arguments from authority, reason, observation and Scripture were used to support and to refute both familiar and strange hypotheses; and while neither proofs nor disproofs established or falsified any one position, the ferment of argument and counter-argument served to spread one set of new ideas and to provide the background for the newer set yet to come.

Many facets of this area of intellectual history have been examined in detail: the development of astronomical systems,[1] the change

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[1] J. L. E. Dreyer, History of the Planetary Systems from Thales to Kepler (Cambridge: at the University Press, 1906); Alexandre Koyré, La revolution astronomique: Copernic, Kepler, Borelli (Paris: Hermann, 1961).

from the image of a finite to that of an infinite universe,[2] the question of the probability of the existence of many worlds,[3] the successive concepts of space,[4] the conflict between the new learning and the old religion,[5] the effects of this different world outlook on magic and experimental science,[6] the impact of the new astronomy on the other sciences.[7] Such studies have examined the search for satisfying answers to questions that were parts, consequences or accompaniments of the transition in philosophic thought that moved man from the unique physical position he formerly occupied at the center of creation.

This work is concerned with yet another such question: What moves the celestial bodies? The problem of who or what moved the stars, planets, Sun and Moon was an old one. During the period from 1543 to 1632 many answers--some new, others not so new--were proposed to it. Like a number of queries handed down through the ages, this one acquired a new significance when discussed by both the Copernicans and

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[2] Alexandre Koyré, From the Closed World to the Infinite Universe (Baltimore, Maryland: The Johns Hopkins Press, 1957).

[3] Grant McColley, "The Seventeenth-Century Doctrine of a Plurality of Worlds," Annals of Science, I (1936), pp. 385-430.

[4] Max Jammer, Concepts of Space: The History of Theories of Space in Physics (Cambridge, Massachusetts: Harvard University Press, 1954).

[5] Paul H. Kocher, Science and Religion in Elizabethan England (San Marino, California: The Huntington Library, 1953).

[6] Lynn Thorndike, A History of Magic and Experimental Science. Volumes V and VI: The Sixteenth Century. Volumes VII and VIII: The Seventeenth Century (New York: Columbia University Press, 1941-1958).

[7] Thomas S. Kuhn, The Copernican Revolution: Planetary Astronomy in the Development of Western Thought (Cambridge, Massachusetts: Harvard University Press, 1957).

the non-Copernicans in the latter part of the sixteenth century and the early part of the seventeenth. Although these discussions produced no long-lived answers, they did tend to show how unsatisfactory were many of the proposed possible sources of motive power; thus, they clarified the problem that confronted the next generation.

CHAPTER I

THE HEAVENLY SPHERES

Although cosmological speculation is one of man's most ancient intellectual activities and every culture has constructed its own myths to explain the surrounding world, from the fourth century before Christ Greek cosmology dominated western speculations in this area for the next two thousand years.[1] Two Hellenic cosmologies were of particular influence: The Platonic and the Aristotelian. The older of these systems, the Platonic, postulated a finite, spherical, Earth-centered universe in which fixed and wandering stars governed by anima circled around a stationary Earth. For Plato (427-347 B.C.) the world soul dominated this cosmos and by its intelligence gave an east-to-west diurnal motion to the fixed stars and all else beneath them.[2] The other celestial bodies each had a separate soul which although it caused that body to move in a west-

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[1]For the early cosmologies see: Milton K. Munitz (ed.), Theories of the Universe from Babylonian Myth to Modern Science (Glencoe, Illinois: The Free Press, 1957), pp.5-40; William Fairfield Warren, The Earliest Cosmologies. The Universe as Pictured in Thought by the Ancient Hebrews, Babylonians, Egyptians, Greeks, Iranians, and Indo-Aryans. A Guidebook for Beginners in the Study of Ancient Literatures and Religions (New York: Eaton & Mains, 1909); Kathleen Freeman, The Pre-Socratic Philosophers. A Companion to Diels, Fragmente der Vorsokratiker (3d ed.; Oxford: Basil Blackwell, 1953).

[2]Francis MacDonald Cornford, Plato's Cosmology. The Timaeus of Plato Translated with a Running Commentary (London: Routledge & Kegan Paul Limited, 1948), pp. 74-93; Timaeus 36 C-D.

to-east direction was not entirely independ of either the world soul or of all other planetary souls.[3] The world soul extended throughout the entire universe,[4] but the planetary souls had three possible modes of existence:

> (1) The soul may reside within the whole spherical body, and move it as our souls move our bodies. (2) Or the soul may provide itself with a body of its own, consisting of fire or air, which envelopes the star's body on the outside and moves it mechanically. (3) Or the soul may have no body at all and guide the star by 'some surpassingly wonderful powers . . . which it possesses.'[5]

Man had no way of knowing in which of these three ways the soul moved the planet dependent upon it. The whole had been created but would never be destroyed; it was a unique, geocentric plenum that was an imperfect, physical form of a perfect ideal upon which it was modeled.[6]

Plato had asked his students "to find what are the uniform and ordered movements by the assumption of which the phenomena in relation to the movements of the planets can be saved."[7] One answer to this problem was proposed by Eudoxus (fl. 367 B.C.), a pupil of Plato, who described the motion of a given planet by devising a set of concentric, Earth-centered spheres for that planet. The outermost sphere of each set duplicated the motion of the sphere of fixed stars, that is it rotated from east-to-west in twenty-four hours. The next inner sphere turned so as to account for the planet's motion along the zodiac; the

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[3]Cornford, Plato's Cosmology, pp. 105-114; Plato Timaeus 38 C-39D.

[4]Cornford, Plato's Cosmology, p. 58; Plato Timaeus 34 A-B.

[5]Cornford, Plato's Cosmology, p. 108.

[6]Plato Timaeus xi, xiv, xv, xxx.

[7]Simplicius De caelo, p. 488, 18-24 Heib. as quoted in Thomas L. Heath, Greek Astronomy (London: J. M. Dent & Sons Ltd., 1932), p. 67.

third sphere had a period equal to the time interval between successive conjunctions of that planet and the Sun; the period of the fourth sphere which carried the planet on its equator, was the same as that of the two innermost spheres explained the planet's motion in latitude from the ecliptic and its inequality of motion in longitude.[8]

This theory of celestial spheres, which Eudoxus apparently considered only a mathematical device, when joined to Plato's two maxims, (1) that the apparent, irregular movements of the heavenly bodies must be the result of multiple, regular, circular motions, and (2) that the phenomena must be saved, formed the foundation for astronomical systems until the beginning of the seventeenth century.

The second of the major Greek cosmologies, the Aristotelian system, incorporated many of the Platonic ideas into its broader theoretical structure. The cosmos was still finite, spherical and filled as was the Platonic one; however, Aristotle (348-322 B.C.) modified the planetary _anima_ of the Platonic system and added physical causes to non-corporeal beings in accounting for celestial movements.

Motion in the heavens was but a special form of the first type of _motus_, local motion. This movement from one place to another Aristotle divided into two kinds: natural and violent. Natural motion was further categorized as the rectilinear motion that was natural to terrestrial bodies and the uniform, circular motion around a stationary

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[8] J. L. E. Dreyer, _History of the Planetary Systems from Thales to Kepler_ (Cambridge: at the University Press, 1906), pp. 87-107; Pierre Duhem, _Le système du monde. Histoire des doctrines cosmologiques de Platon a Copernic_, I (Paris: Hermann et fils, 1913), pp. 111-123.

center, the Earth, that was proper to the celestial globes.[9] Thus, in the Aristotelian cosmology the movement of the celestial bodies was governed by the same theoretical considerations as motus in general.

All motions involved three things:

> the moved, the movent, and the instrument of motion. Now the moved must be in motion, but it need not move anything else: the instrument of motion must both move something else and be itself in motion: . . . and the movent--that is to say, that which causes motion in such a manner that it is not merely the instrument of motion--must be unmoved.[10]

In the heavens the things moved were the fixed stars, the wanderers, the Sun and the Moon; the instruments of motion were the spheres moving these bodies, and the movent was the Prime or Unmoved Mover. This First Mover was eternal, unmovable, without magnitude or parts, indivisible, impassive, unalterable; it existed of necessity and was located beyond the sphere of the fixed stars.[11]

In order to explain how the spheres acted as instruments of motion and how the incorporeal First Mover moved these corporeal bodies, Aristotle concluded that this "final cause, then, produces motion as being loved, but all other things move by being moved."[12] However, unless the aethereal sphere were joined to an intellective appetite capable of loving, the celestial sphere would be unable to respond to the First Mover and the Final Cause could not produce motion. Therefore "we may infer that the first

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[9]Aristotle De anima i. 3. 406[a] 12-14; De caelo i. 2. 268[b] 11-269[b] 17; iii-iv.

[10]Aristotle Physica viii. 5. 256[b] 14-20.

[11]Aristotle Metaphysica Λ 7. 1072[a] 23-1073[a] 12.

[12]Ibid., 1072[b] 3-4.

movable [i.e. the first instrument of motion or the outermost heavenly sphere] is a body animated by an intellectual soul."[13]

The intellectual soul of the sphere of fixed stars thus responded to the Prime Mover and produced the diurnal motion of the fixed stars. This "primary eternal and single movement" imparted to the outermost sphere of the universe by the incorporeal Prime Mover through the intellective appetite was transmitted by the material sphere to all other celestial spheres.[14] Having accounted for the primary celestial movement, Aristotle explained the rest of the system in much the same manner. All of the celestial bodies below the fixed stars exhibited a motion other than the simple primary one. Since all celestial movements were eternal and since

> eternal movement must be produced by something eternal and a single movement by a single thing, and since we see that besides the simple spatial movement of the universe, which we say the first and unmovable substance produces, there are other spatial movements--those of the planets--which are eternal (for a body which moves in a circle is eternal and unresting; we have proved these points in the physical treatises), each of these movements also must be caused by a substance both unmovable in itself and eternal.[15]

These substances, unmovable in themselves and eternal, were the spheres Aristotle adopted from Eudoxus each animated by its own soul.[16] These devices were now arranged in a single array of some fifty-five geocentric spheres, one nested within another; each attached to the next

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[13]Thomas Aquinas, Treatise on Separate Substances, trans. Francis J. Lescoe, (West Hartford, Connecticut: Saint Joseph College, 1959), p. 25.

[14]Aristotle Metaphysica Λ 8, 1073^a 24-1073^b 2.

[15]Ibid., 1073^a 25-34.

[16]Aquinas, Treatise on Separate Substances, p. 25.

larger sphere. Every sphere had an axis inclined to the axis of the next larger sphere, and each had a proper rate of natural motion about its axis. All of the spheres were composed of a special non-terrestrial element, aether.

Previously these spheres had not been thought of as physical realities nor had they been joined into a single system. Aristotle's making the system a highly physical one gave a pleasing cosmological arrangement but introduced structural difficulties. While the joining of each sphere to the sphere above it allowed the motion of the sphere of the fixed stars to be transmitted to all inner spheres, it also communicated the specific motion of each sphere to all those within it. Thus, each received not only the motion of the fixed stars but also the motion proper to every planet above it. To counteract this accumulation of motions Aristotle placed a set of unrolling spheres between the set of spheres governing one planet and that of the next. These unrollers had the same angles of inclination and rates of motion as those above them but the directions of rotation were reversed.[17]

The entire system consisted of a nest of rotating, homocentric spheres centered about a non-moving Earth. The Prime Mover of the universe affected a complete rotation of the outermost sphere, that of the fixed stars, every twenty-four hours. Immediately within the starry sphere and joined to it at two axial points was the first of Saturn's four spheres; this sphere moved with the motion of the sphere of fixed stars and also had, under the guidance of its _anima_, its own proper motion. With-

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[17] Aristotle _Metaphysica_ Λ 8, 1073[b] 38-1074[a] 14.

in this sphere and joined to it was the second sphere of Saturn; this sphere moved with the motion of the sphere of fixed stars, the motion of Saturn's first sphere and its own natural motion. The system continued on inward through the spheres required to explain the apparent motions of the planets and the "unrollers" which canceled the motions from one planet's set of spheres so that the first sphere of the next planet received only the motion of the sphere of the fixed stars.

Aristotle provided an integrated and highly mechanistic theoretical structure to account for the celestial motions; he did not give the mathematical details for it. The angles of inclination and the speeds of the spheres were not specified; computations in the system would not work with the fifty-five spheres counted in the *Metaphysica*.[18] Such things, apparently, were of little interest to him. The calculations of the values of the parameters were left to someone who was interested: Aristotle was not.

Five centuries later Claude Ptolemy (fl. 150 A.D.), a man who was interested in such matters, applied quantitative and mathematical techniques to the problem of planetary motions and published the results of these studies in his *Almagest*.[19] This great synthesis was an astronomical system not a cosmological one. In his efforts to describe

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[18] *Ibid.*, 1074ª 2-13.

[19] Claudius Ptolemaeus, *Magnae compositionis Cl. Ptolemaei Alexandrini libri à Georgio Trapezuntio e Greco Conversi in Clavdii Ptolemaei pelusiensis Alexandrini omnia quae extant opera, praeter geographiam, quam non dissimili forma nuperrimè aedidimus: summa cura & diligentia castigata ab Erasmo Osualdo Schrekhenfuchsio, & ab eodem isagoica in almagestum praefatione, & fidelissimis in priores libros annotationibus illustrata, quemadmodum sequens pagina catalogo indicat* (Basileae: [In officina Henrichi Petri, 1551]), pp. 1-327.

the motions of the fixed and wandering stars, Ptolemy attempted to reduce the apparent celestial motions to a series of uniform, circular ones by using not only homocentric and eccentric spheres but also epicycles, spheres whose centers lay on the surface of other celestial spheres rather than being homocentric with them. Each circle of the Ptolemaic system had its own natural movement,[20] and although each of the speeds was uniform and circular, the Aristotelian requirement that all celestial motions be centered around a stationary Earth was ignored. A second type of uniform circular motion, a non Earth-centered movement, had been incorporated into astronomical theory.

Ptolemy also included a new concept of sphere in his system. In the homocentric arrangement each sphere had depth but no parts. Associated with each planet were several spheres whose combined motions accounted for the apparent motion of the moving body. In the Ptolemaic system the sphere of each planet included the parts of that planet's system. Thus, for example, the sphere of Venus was composed of an eccentric deferent (the circular path around the Earth along which the center of the epicycle moved) and an epicycle.[21] Each planet, however, had only one sphere, comprising the whole of its system, which was considered geocentric. In later writings the expression "the sphere of Venus" could mean either the set of Aristotelian homocentric spheres connected with Venus's motion, the specific homocentric sphere upon which the planetary body was carried, or the geocentric Ptolemaic sphere of Venus.

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[20] Ibid., Book III, Chapter 3, p. 62.

[21] Ibid., Book X, Chapters 1-3, pp. 234-236.

Usually the writer of a general cosmology did not distinguish between the Aristotelian and Ptolemaic spheres for the planets. He simply stated that eight, nine or sometimes ten spheres composed the heavens. Those astronomers concerned only with describing the heavenly motions most frequently preferred the Ptolemaic system while those interested in the physical reality of the heavens either rejected the system of the Almagest or tried to incorporate the mathematically useful Ptolemaic hypotheses into the Aristotelian cosmology.

The first attempt to explain the heavens physically in terms of the theory of the Almagest was made by Ptolemy himself in the Hypotheses planetarum,[22] a work written sometime after he had developed the theory of the Almagest. The universe, as described in the Hypotheses, consisted of nine homocentric spheres. The outermost of these was a sphere without stars, the motor sphere; nested within this sphere were the sphere of the fixed stars and the seven spheres for the remaining celestial bodies. Each planetary sphere was divided into two shells with an eccentric-deferent shell between them. A small planet-carrying sphere, the epicyclic sphere, moved through the deferent region and rotated around its axis as its center progressed along the deferent path. All parts of the sphere were interconnected and the poles of one sphere were fixed in the lower surface of the sphere above it. The non-moving Earth rested at the center of the system.[23]

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[22] George Sarton, Introduction to the History of Science, I (Baltimore, Maryland: The Williams and Wilkins Co., 1950), p. 277 gives the Greek title and a brief description of this work.

[23] E. J. Dijksterhuis, The Mechanization of the World Picture, trans. C. Dikshoorn (Oxford: at the Clarendon Press, 1961), pp. 66-67; Duhem, Le système du monde, II, pp. 87-93.

The motor forces in this system resided in several bodies: the motor sphere, the starry sphere, the planets. The motor sphere imparted the east-to-west diurnal motion to the sphere of fixed stars at the same time that this starry sphere had its own very slow west-to-east motion. The combination of these two movements produced the diurnal motion of the heavens as well as the precession of the equinoxes which Hipparchus (fl. 129 B.C.) had postulated.[24] Although the spheres were joined in one system, Ptolemy did not allow the motion of one sphere to affect those within it except for the transfer from the motor sphere to the starry one. Each sphere in the rest of the system was independent of all the others.[25]

The movements within each sphere were proper to it, but all followed a general plan. Each celestial body possessed a vital force which controlled all the motions of its sphere:

> "c'est donc l'astre lui-même qui donne le mouvement, d'abord à l'épicycle, puis à l'orbe excentrique, enfin à l'orbe qui a pour centre le centre du Monde; d'ailleurs, le mouvement qu'il communique est différent aux divers lieux où il est reçu; de même, en nous, la force de la pensée n'est pas égale à la force de l'impulsion même (que cette pensée détermine); la force de cette impulsion n'est pas égale à celle qui agit dans les muscles, ni celle ci à la puissance qui meut les pieds; ces forces différent les unes des autres sous un certain rapport, sous le rapport de la tendance par laquelle elles se manifestent au dehors."[26]

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[24] Duhem, Le système du monde, II, p. 90.

[25] Ibid., pp. 93-94.

[26] Ibid., pp. 97-98: "it is thus, the star itself which gives movement first to the epicycle, then to the eccentric orb, finally to the orb which has for its center the center of the world; moreover, the movement which it communicates is different in the diverse places where it is received; in the same way, as in us, the force of thought is not equal to the force of the impulse (which that thought determined); the force of that impulse is not equal to that which it makes in the muscles, nor that last to the power which moves the feet. These forces are different one from another in a certain respect, in respect to the tendency by which they manifest themselves on the outside." Duhem cited as the source for this quotation: Claudii Ptolemaei, Opera quae exstant omnia. Volumen II: Opera astronomica minora. Edidit J. L. Heiberg. Lipsiae, MDCCCCVII, pp. 119-120.

From man's observational station at the center of this system, the various manifestations of the vital force of a celestial body were the same motions as those which had been discussed in the Almagest. The astral force made the outer and inner surfaces of the planetary sphere move with the diurnal motion and the slow motion of the starry sphere respectively. The motion of the epicyclic sphere along the deferent path was the same as the speed of the center of the epicycle on the deferent, and the rotational motion of the epicyclic sphere corresponded to the motion of the planet on the epicycle.[27]

In the centuries that followed, the physical system of the Hypotheses was not so widely accepted as the mathematical theory of the Almagest. Ibn Al Haitam, Alhazen (964-1039), presented a modified version of this system in his Resume of Astronomy in which he limited the diurnal rotation to the non-planetary spheres, but even this simplification did not increase the popularity of the theory.[28] The basic reason for the reception of the mathematical system and the rejection of the physical one was probably the non-Earth centered, uniform, circular motion. While it was permissible to use this, or any similarly imagined movement, in composing a system that merely accounted mathematically for celestial phenomena, for anyone wishing to describe the universe as it actually existed the Earth centeredness of all motions was an absolute requirement. Such a prerequisite condition in theory meant a return in practice to the homocentric sphere system.

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[27]Duhem, Le système du monde, II, pp. 90-91, 98.

[28]Alhazen, Resume of Astronomy from the Latin translation by Abraham de Balems, Codex Vaticana Latina 4566, "Sermo de orbe," pp. 9-10, "Sermo de maximo orbe," pp. 10-15; Duhem, Le système du monde, II, pp. 119-129.

As a result of this situation two distinct traditions prevailed in astronomical writings. In the mathematical, theoretical works no attempt was made to account for the motor forces in the system. Epicycles and eccentric deferents were only mental images and the thought process which created them was sufficient explanation for their motions. The sphere of the fixed stars, with or without a motor sphere above or below it, turned about the Earth once a day and carried all other spheres with it. Whatever other elements were included in the system had their own motions assigned to them. So long as these motions were uniform and circular and so long as only one motion was natural to each, no cause of the motion needed to be given. Everyone knew the heavenly bodies moved and if one charted these motions it was not necessary to explain them.

In contrast, those concerned with the physical reality of the universe were not interested in the details of the day by day movements in the system but did want to know the causes of these motions. Aristotle's postulate that heavenly bodies moved "naturally" with a uniform, circular motion was inadequate by itself to account for the variation in celestial movements. All of the heavenly spheres, although composed of the same fifth element, aether, did not have the same speed.[29] Such an inconsistency could not be explained, as unequal natural terrestrial motions could, by a difference in heaviness or by an eagerness of the body to reach its natural place because the quintessence could "possess no lightness or heaviness at all,"[30] and it was already in its natural place. The

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[29]Caesar Cremonis, Disputatio de coelo in tres partes divisa. De natura coeli. De motu coeli. De motoribus coeli abstractis. Adiecta est apologia dictorum Aristotelis de via lactea. De facie in orbe lunae. (Apud Thomam Baliornum: Venetiis, 1613), p. 203.

[30]Aristotle De caelo i. 3. 270^{a} 6-7.

intellective appetite Aristotle had implied was joined to the material sphere had long been overshadowed by the motion natural to the heavens. Some additional cause for celestial motions was needed.

The cause most frequently assigned for the next thousand years was some form of a non-corporeal being. That such creatures existed had been inferred from the pattern of creation. Since the lowest form of created being was the purely material, non-spiritual matter, symmetry demanded that the highest form of creatures be non-material, purely spiritual beings. The attributes, functions and uses which philosophers assigned to these creatures varied, but both Christian and Arabic writers in this period made use of them to account for the motions of the planets.

In the Judeo-Christian tradition these creatures were called angels. Whether a European Christian writer in the period following the fall of the western Roman Empire built his cosmology upon what Hellenistic knowledge was available to him or upon an extreme literal interpretation of Scripture, he could easily introduce angels as operative agents in the universe.[31] The function of moving the planets which Plato had assigned to anima was quickly transferred to the heavenly messengers known from both the Old and the New Testament writings, and such Scriptural passages as "Benedicite Domino, omnes angeli ejus, potentes virtute, facientes verbum illius, ad audiendam vocem sermonum ejus. Benedicite Domino, omnes virtutes

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[31]The early Christian writings on cosmology are discussed in: Lynn Thorndike, A History of Magic and Experimental Science during the First Thirteen Centuries of Our Era (New York: Columbia University Press, 1947), I, pp. 480-503; A. C. Crombie, Augustine to Galileo. The History of Science A.D. 400-1650 (London: Falcon Educational Books, 1952), pp. 1-6; Duhem, Le système du monde, II, pp. 393-501; Dreyer, History of the Planetary Systems, pp. 207-228.

ejus, ministri ejus qui facites voluntatem ejus"[32] were interpreted as authority for the view that the fixed and wandering stars were moved by angelic power.[33]

As Christian philosophical thought conceived a series of angelic choirs which included all spiritual beings other than the human soul, the eastern Islamic culture developed its own highly organized theory of non-material beings. The highest, those which emanated directly from the Creator, were the Intelligences. From these, in turn, came the souls, sometimes accompanied by a second degree intelligence. A third common but not ever-present spiritual being was the first substance which may or may not have originated from the souls. This general pattern was wide-spread in Arabic metaphysical literature but the subdivisions within it were not uniform from one school to another.[34]

Of the many schools of Islamic philosophic thought only two will be considered here: The encyclopaedists whose published works included all branches of knowledge but whose treatment of their subject was a general popularized one, and the _falasifa_ school, the foremost philosophers,

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[32]Psalm cii: 21-22: "Bless the Lord, all you angels of his; angels of sovereign strength, that carry out his commandment, attentive to the word he utters; bless the Lord, all you hosts of his, the servants that perform his will. . . ." English translation from: _The Old Testament. Newly translated from the Vulgate Latin by Msgr. Ronald Knox at the Request of His Eminence The Cardinal Archbishop of Westminster_ (2 vols.; New York: Sheed & Ward, Inc., 1950), II, p. 873.

[33]Cosmas Indicopleustes, _Cosmae Aegyptii monachi Christiana topographia, sive Christianorum opinio de mundo_ in Migne, _Patrologiae Graecae_, LXXXVIII, cols. 403-414.

[34]Avicenna, _Avicennae Metaphysices compendium_, translated from Arabic into Latin by Nematallah Carame (Roma: Pont. Institutum Orientalium Studiorum, 1926), pp. 169-172; Henry Corbin, _Avicenna and the Visionary Recital_, translated from the French by Willard R. Trask (New York: Pantheon Books, Inc., 1960), pp. 46-77.

whose writings were generally less diverse but whose method emphasized a study of the Greek sources whenever possible and a return to the teachings of Aristotle at all times.[35] It was the latter group, as represented by Avicenna (d. 1039), Averroës (1126-1198) and Moise Maimonides (1135-1204), that exercised the greater influence on western European scholars.

The Encyclopaedia of the Brothers of Purity, a tenth century Arabic Brotherhood devoted to the study of religion and philosophy, assigned two powers to the universal soul that was the first soul originating from Intelligence. By the first power, that of knowing, the world soul united with first substance to form all material objects. Thus, the celestial spheres were formed. By the second, the power of doing, this soul endowed each piece of matter with the perfection it should have. The perfection of the heavenly bodies included a circular motion natural to each; in this manner the second power turned the spheres: "C'est à cette force qu'on donnera désormais le nom d'âme particulière du corps céleste."[36] The Brothers of Purity apparently did not go beyond the naming of these individual acts of operative power in the world soul. The cosmology of the Encyclopaedia as described by Pierre Duhem and others had neither the fine structure nor the lasting influence of the falasifa school.

To Avicenna the origin of his planetary souls and their operation was somewhat different. For him as for the Brothers the first intelligence

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[35]Carra de Vaux, Avicenne (Paris: Félix Alcan, 1900), pp. 79-126; De Lacy O'Leary, Arabic Thought and Its Place in History (rev. ed.; London: Routledge & Kegan Paul Ltd., 1954), pp. 135-180.

[36]Duhem, Le système du monde, II, pp. 168-170: "It is to that force that one will henceforth give the name of the particular soul of a celestial body."

proceeded directly from the Creator. From it, however, three things emanated: a second intelligence, the soul (form) of the first celestial sphere, and the body (matter) of that sphere. The second intelligence was the source of the third intelligence, the soul and body of the third sphere and so on inward through the nine celestial spheres. The intelligence of the ninth sphere produced the tenth intelligence which governed the world and the soul and body of the Earth.[37] Each of the first nine souls impressed a force, mayl, upon the body of the sphere it governed. Since "'le mayl est une qualité par laquelle le corps repousse ce qui l'empêche de se mouvoir dans une direction quelconque,'"[38] since there was no resistance offered to celestial movements, and since Avicenna's mayl did not diminish unless the moving object in which it resided met some obstacle to its motion, the movements of the spheres would remain constant eternally.[39]

Although their terminology differed, both the Brothers and Avicenna considered the effective turning power of the sphere, either the soul or the mayl, to reside within the sphere while the source of that resident power came from a higher spiritual being. Some intermediate step between the highest of the created beings and the material heavens was considered

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[37]Corbin, Avicenna, pp. 59-62; A. M. Goichon, Le récit de Hayy ibn Yaqzān. Commenté par des textes d'Avicenne. Avant-propos, traductions, explications et notes (Paris: Desclee de Brouwer, 1959), pp. 131-140.

[38]S. Pines, "Les précursenrs Musulmans de la theorie de l'impetus," Archeion, XXI (1938), p. 301: "The Mayl is a quality by which the body repels that which hinders it from moving itself in any direction whatever." Pines cited as the source for this quotation: "risâlat al-hudûd, tis' rasâ'l Istanbul 1298h, p. 65."

[39]Pines, Archeion, pp. 300-303; A. C. Crombie, "Avicenna's Influence on the Medieval Scientific Traditions," in Avicenna: Scientist & Philosopher. A Millenary Symposium, ed. G. M. Wickens (London: Luzac & Company, Ltd., 1952), pp. 100-101.

necessary since the constancy of the heavenly motions eliminated the continued direct action of an intelligence but also demanded an intelligence as the ultimate source.

Averroës and Maimonides followed Avicenna in the falasifa tradition. Both, however, disagreed with him about the causes of celestial motions; and each denied that it was possible for man to know them. In The Incoherence of the Incoherence Averroës, after a discussion on the symmetry and perfection of the living being of the heavens, simply stated that circular motion was natural to the heavens because it was the noblest of the motions and should be assigned to the most noble creature. He explained the planetary motions as necessary for generation and corruption in the sublunary world and closed the discussion with:

> and it is not of the nature of the human intellect that it should apprehend more in such discussions and in this place than what we have mentioned.[40]

Maimonides accounted for man's lack of knowledge of the heavens as due to the limitations on human faculties. He saw such knowledge as the prerogative of God just as familiarity with sublunar phenomena was proper to man:

> "C'est-à-dire que Dieu seul connait parfaitement la véritable nature du Ciel, sa substance, sa forme, ses mouvements et leurs causes; mais pour ce qui est au-dessous du Ciel, il a donné à l'homme la faculté de le connaître, car c'est là son monde, et la demeure où il a été placé et dont il forme lui-même une partie. Et c'est la vérité, car il nous est impossible d'avoir les éléments nécessaires pour raissonner sur le Ciel, qui est loin de nous et trop élevé par sa place et son rang."[41]

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[40]Averroës, Averroes' Tahafut al-Tahafut (The Incoherence of the Incoherence), translated from the Arabic with Introduction and Notes by Simon van den Bergh (London: Luzac & Co., 1954), I, pp. 289-299.

[41]Duhem, Le système du monde, II, p. 145: "That is to say that God

The Arabic astronomical motor systems and the denial of the possibility of any knowledge of such systems were theoretical discussions. They were important in the later history of astronomy in western Europe more for their emphasis on the materiality of the heavens than for their concepts of celestial motors.

Among those Islamic writers who considered the spheres hard bodies, some wondered about the movements of such objects and invented devices to permit a smooth passage of one sphere over the other. Thabit ibn Qurra (836-901) introduced a subtle resistless fluid between the spheres for such a purpose[42] while Al Biruni (937-1048) placed "little balls" between the spheres. These balls absorbed the motion of the sphere above them and left the sphere below free for its own motion.[43] Others ignored the possibility of inter-spherical friction; almost all stressed the firmness of the spheres. When the Arabs passed the Greek knowledge accompanied by their own additions on to the West, the homocentric spheres included in it were composed of a solid, crystalline substance, not the fluid, limp material of the De caelo.

The mass of information which became available to Latin scholars during the eleventh and twelfth centuries included parts of all of the

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alone knows perfectly the true nature of the heavens, its substance, its form, its movements and their causes; but for those things beneath the heavens, he has given to man the faculty of knowing for that is his world and he lives there, where he has been placed and of which he himself forms a part. And it is true that it is impossible for us to have the necessary elements to reason about the heavens which is far from us and high by its place and its rank." Duhem quoted: Maimonide, Le guide des egares, deuxieme partie, ch. xxiv; trad. Munk, t. II, pp. 194-195.

[42]Duehm, Le système du monde, II, p. 119.

[43]Ibid., pp. 43-44.

traditions discussed above. After a period of conflict between what had been available and the new learning, adjustments, compromises and new interpretations were made which resulted in Aristotelianism becoming dominant in Christian philosophy while the system of Ptolemy's Almagest, often as expressed in the simplified form presented by John of Holywood (fl. c. 1240) in his Sphaera, emerged as the astronomer's handbook in the age of Scholasticism.[44]

Scholasticism "if the term has any definable meaning, simply stands for the theology and philosophy and the subsidiary disciplines of the schools of western Europe in the great period of medieval culture."[45] The subsidiary disciplines included everything, since one of the aims of the scholastics was to join what was considered true from the Greek, Jewish, and Arabic learning with Christian revelation in a united, systematic whole. The closest approach to this goal was achieved in the works of Saint Thomas Aquinas (1225-1274) whose Summa theologica, Summa contra genetiles and commentaries on the works of Aristotle fused the Christian theology with the acquired rational, theoretical, and methodological knowledge of previous cultures.[46]

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[44] John of Holywood, Sphaera mvndi ([Venetiis: 1490]). The Sphaera, written about 1233, was the earliest presentation of the Ptolemaic system in Latin and became one of the most popular textbooks on astronomy. An English translation, a list of the manuscripts and printed editions of this work, a biography of the author and a discussion of the influence of this presentation of Ptolemaic astronomy are found in: Lynn Thorndike, The Sphere of Sacrobosco and Its Commentators (Chicago, Illinois: The University of Chicago Press, 1949).

[45] The Library of Christian Classics. Vol. X: A Scholastic Miscellany: Anselm to Ockham, ed. and trans. Eugene R. Fairweather (London: SCM Press Ltd., 1956), p. 18.

[46] F. C. Copleston, Aquinas (Baltimore, Maryland: Penguin Books Inc., 1957), pp. 9-14.

Saint Thomas was not an astronomer. His interest in the construction and motions of the heavens was but a small segment of his interest in the structure of the universe. Thus, his celestial system was a general one. For him the heavens were composed of ten homocentric spheres beyond which was the realm of the blessed. The spheres could have been either the Aristotelian or the Ptolemaic ones for in regard to the theory of epicycles and eccentrics Saint Thomas wrote:

> licet enim talibus suppositionibus factis appareant solvere, non tamen oportet dicere has suppositiones esse veras: quia forte secundum aliquem alium modum nondum ab hominibus comprehensum, apparentia circa stellas salvatur. . . .[47]

Of more concern to Saint Thomas was the power that moved the celestial bodies. He disagreed with the theory of spiritual beings taught by the Islamic philosophers, and he objected to the way in which some Christian writers had identified the souls of the spheres with the angels. The celestial motors could not be the Intelligences described by Avicenna since each of these had the power to create another Intelligence, a soul and a material body; Christian theology reserved the creative power to God alone.[48] The angels, while commissioned by God to supervise the celestial motions, were not the forms joined to the spheres.

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[47] Thomas Aquinas, S. Thomae Aqvinatis in qvatvor libros Aristotelis de coelo, et mvndo commentaria: qvae, cvm morte praeventvs perficere non potverit, absolvit Petrus de Alvernia: cvm dvplici textvs tralatione, antiqua videlicet, & Iovannis Argyropili nova, diligenter recognitis, quae omnia nuper sunt maxima diligentia castigata (Venetiis: Apud Hieronymum Scotum, 1562), col. 228: "for such suppositions are allowed to save the appearances, it is not, however, necessary to say that these suppositions are true; because, perhaps, according to some other way not yet understood by men, the appearances concerning the stars may be saved. . . ." Cf. Maurice de Wulf, History of Mediaeval Philosophy, trans. Ernest C. Messenger (2 vols; London: Longmans, Green & Co. Ltd., 1926), II, p. 19.

[48] Aquinas, Treatise on Separate Substances, Chapter X "The Opinion of Avicenna on the Coming of Things from the First Principle and Its Refutation," pp. 65-70.

In the Thomistic universe the heavenly region was composed of its own special matter and form. The matter was a fifth element unlike the four terrestrial ones; the form of any part of this matter was an astral soul. Such a soul while not more noble than an animal soul was absolutely a higher form than the sensitive soul because it perfected all of the celestial matter assigned to it and because the motion it produced was the perfect circular one. These souls were "apprehending substances" and were united to the spheres extrinsically, rather than intrinsically, as a motor to a mobile. One could speak of the heavenly bodies as living creatures, only if by living one meant composed of motor and mobile. The Prime Mover was God Himself who immediately produced the diurnal motion of the ninth sphere but left other celestial motions to the matter and form of the individual spheres under angelic care.[49]

While Saint Thomas made this distinction between astral and angelic souls, his less philosophically trained contemporaries often did not. The ten-sphere celestial region of Dante Alighieri (1265-1321) was similar to that of Saint Thomas in structure and operation. "The movers thereof" were "substances apart from material, that is, Intelligences, which the common people term Angels," each of whom was responsible only for the motion proper to its sphere.[50] Dante did not know if the diurnal motion of the great crystalline sphere were transmitted to all the lower spheres and

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[49]Thomas Aquinas, The Summa Theologica, translated by the Fathers of the English Dominican Province, revised by Daniel J. Sullivan in Great Books of the Western World, ed. Robert Maynard Hutchins (London: Encyclopaedia Britannica, Inc., 1952), XIX, pp. 365-367; Duhem, Le système du monde, V, pp. 536-559.

[50]Dante Alighieri, Il Convito: The Banquet of Dante Alighieri, trans. Elizabeth Price Sayer (London: George Routledge and Sons, 1887), pp. 55-57.

left the question unresolved and unresolvable: "God knows, for to me it seem presumptuous to judge."[51]

Although the introduction and acceptance of the Aristotelian corpus had overshadowed all else and the views of Saint Thomas and Dante were the commonly accepted ones, peripatetic philosophy was not universally acclaimed. The scholars at Oxford and Chartres disagreed with the Dominicans at Paris and concentrated their efforts on the study of the additional Platonic writings which had recently been acquired. Thus, the Platonism already baptized by Saint Augustine in the fourth century was confirmed by the Franciscans in the thirteenth. The Summa philosophiae written about 1270, first attributed to Robert Grosseteste (d. 1253) but now considered Pseudo-Grosseteste,[52] "is an outstanding statement of humanistic scientific augustinianism as it flourished at Oxford in the thirteenth century and Chartres in the twelfth."[53]

The author of the Summa philosophiae employed intelligences to move the celestial bodies but used them in a somewhat different way than the writers previously discussed. The basis of his theory was the concept of natura which was "a power (vis) of acting and suffering which is present in things."[54] There was a universal natura which included the first or uncreated power in the universe and the immediate or primary expression of

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[51] Ibid., pp. 64-65.

[52] Charles King McKeon, A Study of the Summa Philosophiae of the Pseudo-Grosseteste (New York: Columbia University Press, 1948), pp. 3-13.

[53] Richard McKeon, Selections from Medieval Philosophers Volume I: Augustine to Albert the Great (New York: Charles Scribner's Sons, 1929), p. 288.

[54] McKeon, The Summa philosophiae, p. 174.

the first power, the intelligence governing creation. The latter of these controlled the heavenly empyrean, the non-moving sphere which produced the diurnal motion in the non-starry sphere immediately below it. Coexistent with the universal natura were particular natures, some of which were the intelligences that moved the inner spheres. A third type of agent, the corporeal power which resulted from the action of light upon the substance of the sphere, combined with these two to move the heavens. The last force was the weakest of the three and was more implied than expressed in the Summa philosophiae.[55]

The system operated by the universal intelligence's imparting the diurnal motion to all celestial bodies while each particular nature controlled the peculiar motion of its body. The action of light was incorporated in some mysterious manner but was always dependent upon the spiritual beings governing the spheres. Other than the use of the, by then, customary nine spheres below the empyrean the author gave few details about the individual movements of any components of the system. The treatment is comparable to that of Saint Thomas and as an astronomical system has been properly characterized by Duhem as disordered and confused.[56]

The intelligences were not the only medieval celestial motors. From Alpetragius (fl. 1190) in the twelfth century to Girolamo Fracastoro (1448-1553) and Giovanni Battisti Amici (1514-1538) in the sixteenth futile attempts were made to save the theory of homocentric spheres.[57]

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[55] Ibid., pp. 175-177.

[56] Duhem, Le système du monde, III, pp. 463-471.

[57] Dreyer, History of the Planetary Systems, pp. 264-267, 302-304;

The motor forces in these systems were a Prime Mover and the spheres themselves. The Prime Mover turned the ninth sphere daily; the ninth sphere then became the motive power for the lower spheres in such a way that the spheres closer to the Earth were turned more slowly than the higher ones, and each sphere had its own natural motion.

Levi ben Gerson (1288-1344) proposed a system of spheres non-homocentric in which the first intelligence resided in or near the center of the Earth. This central force was the source of all movement although each of the spheres had its own spirit which imparted its individual motion. A resistless fluid separated the units and allowed the motion from one sphere to pass to the next. The system, although it appears to have been well known throughout Europe, was never popular.[58] One explanation for the failure of the theory to be accepted is the predominance of mystical rather than mathematical elements. Such a system could not be used to make accurate predictions.

Another departure from traditional thought was the impetus theory of Jean Buridan (fl. 1350). The theory, primarily an attempt to explain projectile motion, impressed in any moving body a force which was dependent on the speed and weight of the body and which decreased only as the moving object met resistance. Since the celestial bodies met no resistance, Buridan could

> explain the everlasting movement of the heavens by the imposition of impetus by God at the time of the world's creation: " . . . it does

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Girolamo Fracastoro, Hieronymi Fracastorii homocentrica. Eivsdem de cavsis criticorvm diervm per ea qvae in nobis svnt ([Venetiis]: 1538).

[58]Duhem, Le système du monde, IV, pp. 39-41; Sarton, Introduction, III, pp. 599-600.

> not appear necessary to posit intelligences of this kind, because it could be answered that God, when He created the world, moved each of the celestial orbs as He pleased, and in moving them impressed in them impetuses which moved them without his having to move them any more. . . . And these impetuses which he impressed in the celestial bodies were not decreased or corrupted afterwards because there was no inclination of the celestial bodies for other movements. Nor was there resistance which would be corruptive or repressive of that impetus."[59]

Buridan was neither a cosmologist nor an astronomer. In evaluating this application of impetus to the heavens, Marshall Clagett stated:

> One point should be made clear, and that is that the suggestion of the use of impetus to account for the continuing movement of the heavens more economically than by the use of intelligences, although it was made by Buridan in more than one place, is still a rather incidental suggestion. It is probably an exaggeration to say that Buridan by this doctrine was seeking to apply a single mechanics to terrestrial and celestial phenomena. It is evident throughout his writings that he accepts the basic Aristotelian dichotomy . . . and in fact he asserts in these very passages that there is no resistance in the heavens, while of course there is resistance in the terrestrial area. This immediately separates the two areas.[60]

If Buridan preserved the Aristotelian two-region universe, others did not. Nicolas of Cusa (1401-1464) in his Of Learned Ignorance not only disregarded the common philosophical concepts of his time on knowledge, but he also rejected the current views on cosmology. For Nicolas the universe was an unbounded, centerless cosmos composed of many worlds, some of these probably inhabited as was the Earth. Motion he considered natural to any and every body, including the Earth, and he sought to save the phenomena by a combination of the motion of the Earth and the motion of heavenly bodies.[61]

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[59]Marshall Clagett, The Science of Mechanics in the Middle Ages (Madison, Wisconsin: The University of Wisconsin Press, 1959), pp. 524-525. Clagett quoted: John Buridan, Quaestiones super libris quattuor de caelo et mundo, ed. E. A. Moody (Cambridge, Massachusetts: 1942).

[60]Clagett, The Science of Mechanics, p. 525.

[61]Nicolas Cusanus, Of Learned Ignorance, trans. Germain Heron (New

Although two centuries later writers expressing such ideas were looked upon with suspicion, Nicolas of Cusa seems to have been unknown or ignored until the late sixteenth century.

These, briefly, were the traditions to the beginning of the fifteen hundreds. Systems which provided good computational devices, epicycles and eccentrics, could not be considered as physical realities because they were incompatible with the prevailing philosophical thought. Systems which sought to describe the physical reality, homocentric spheres with or without angels, impetuses or intelligences, presented difficulties when applied to the details of planetary movements. Few thinkers tried to deal with both problems simultanuously. One either described the heavens and explained how various parts were moved, or one charted the movements of the celestial bodies using abstract mathematical devices. Or one possibly did a little of both.

The part-of-this, some-of-that approach was the one used by Nicolas Copernicus (1473-1543). Ptolemy in his Almagest had expressed his belief in a geocentric universe and then described its celestial region geometrically. Copernicus in De revolutionibus orbium coelestium presented his arguments for the acceptance of a heliocentric system and then manipulated its parts by the same mathematical devices Ptolemy had used.[62] Spheres and epicycles remained as heavenly movers carrying the wandering stars around a stationary center; the sphere of fixed stars limited the

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Haven, Connecticut: Yale University Press, 1954), "The Second Book" pp. 65-122.

[62]Nicolas Copernicus, Nicolai Copernici Torinensis de revolvtionibvs orbium coelestium, libri vi. (Norimbergae: Apud Ioh. Petreium, 1543).

cosmos; uniform circular motion saved the celestial phenomena. From its outward appearances the new system contained only minor changes: The Earth moved while the Sun was at rest in the center of the world and the fixed stars were unmoved at its boundary.[63]

The appearances were deceptive. Aside from the glaring removal of man from the focal point of the universe, the system contained unstated but important conceptual changes in the theory of cosmic structure. Without comment the ninth sphere and the Prime Mover beyond it had been abolished. The raison d'être for the eighth sphere was no longer either a necessary or a sufficient reason for its existence. The sublunar world had slipped into the unchanging supralunar region as the Earth with its orb of mortality circled the Sun. The terrestrial globe moved with the uniform circular motion proper to the celestial bodies.

Copernicus claimed that his system gave a more satisfying explanation for the apparent movements of the wandering stars.[64] He did not add and he may not have noticed that it simultaneously nullified the acceptable answers to other cosmological questions. If the Earth had a motion like that of the known planets, why were not these planets Earth-like? Where was up? What was heavy? How did one account for natural rectilinear motion in a Sun-centered system? Who was man if he lived at

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[63] Derek J. de S. Price, "Contra-Copernicus: A Critical re-estimation of the Mathematical Planetary Theory of Ptolemy, Copernicus, and Kepler," in Critical Problems in the History of Science: Proceedings of the Institute for the History of Science at the University of Wisconsin, September 1-11, 1957, ed. Marshall Clagett (Madison, Wisconsin: The University of Wisconsin Press, 1959), pp. 197-218. Price concluded that Copernicus's work "as a mathematical astronomer was uninspired. From this point of view his book is conservative and a mere re-shuffled version of the Almagest." Ibid., p. 216.

[64] Copernicus, De revolutionibus, p. 7. recto.

any point other than at the center of creation? Within less than half a century, the opponents to and the acceptors of the new system found it impossible to avoid the unspoken problems of the De revolutionibus. The motor force of the system was only one of many such difficulties. Yet, among the first things to be questioned was the existence, real or imagined, hard or soft, of the celestial spheres.

CHAPTER II

DESTRUCTION OF THE SPHERES

The heliocentric system as presented by Copernicus in the _De revolutionibus_ did not directly challenge the prevailing concepts of celestial motors. Angels, intelligences, souls or natural motions assigned to the bodies in Earth-centered systems could have been transferred, without difficulty, to the new Sun-centered system. Spheres and epicycles, real or mathematical, were as necessary to Copernicus as they had been to Ptolemy. It was not the new system by itself but other factors incorporated into or co-existent with it that mitigated against retaining the celestial orbs and their component parts. The destruction of these devices and their replacement was a complex phenomenon to which adherents to every system made contributions.

There was nothing new in the sixteenth century thinkers' denying the existence of the spheres. Some writers of every age had questioned their existence while others had disputed their substance. What were new were the sets of arguments accumulated in the late fifteen hundreds that gained widespread acceptance as proof that the heavens contained no spheres and the status of the originators and supporters of these arguments. Earlier the reasons for or against the spheres had been highly theoretical; now they were supported more strongly by interpretations of observational data. In previous ages those who rejected the spheres generally were men of minor importance; by the late sixteenth century those who discarded the spheres were among the leading astronomers of Europe.

Before any kind of motive force similar to a terrestrial motor could be introduced into the heavens, it was necessary that there be a new conception of the celestial region in which such a motor could operate. So long as the idea of a supralunar region as a place totally unlike the sublunar world prevailed, no Earthly mode or cause of motion could be imagined in the heavens. The transition from the old, unchanging and unchangeable aethereal region to the new concept of a vast space sprinkled with Earth-like globes was a by-product of the astronomical and philosophical thought of the century. No one set out specifically to break the dichotomy between the heavens and the Earth that so dominated the Aristotelian cosmology, yet by the end of the sixteenth century the total distinction between the two was no longer acceptable to any but the most conservative philosophers.

The changes which occurred in every phase of life in western Europe in the fifteenth and sixteenth centuries included the study and acceptance of philosophies other than Aristotle's on a wider scale than had been known in the west since the introduction of the Greek learning in the twelfth century. Thus while the Italians turned to Plato, the scholars at Louvain investigated atomistic theories. Each philosophical system contained a celestial region unlike the one in the _De caelo_: The Platonists' heaven was fiery; the atomists' partially void. The ideas were not new but they were a departure from what had become accepted doctrine. Furthermore, some of the teachers and supporters of these teachings were zealots (for example Peter Ramus, Bernardino Telesio) who took radical positions and attracted the attention and following such extremists generally do.[1] These men and their associates destroyed the Aristotelian heavens by fiat. Their sayings were sanctioned by others who claimed to supply supporting evidence from the study of the physical world.

One of the major factors which aided the breakdown of the celestial-terrestrial dichotomy was a New Star that appeared in the constellation Cassiopea. The star first appeared in the fall of 1572 and remained visible with magnitudes of varying brightness until the winter of 1574. Astrologers foretold great and disastrous events that would happen throughout Europe. Astronomers observed and measured and measured and observed; they calculated and recalculated but the best among them could not find the parallax that would have been detectable if the star had been a sublunar occurrence. The accounts of the measurements were similar to those in previous astronomical treatises.[2] The reasons given for the absence of parallax indicated a new way of thinking about the heavens.

The interpretations of the data varied. Many, either claiming to have measured considerable parallax or ignoring its absence, regarded the

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[1] Maurice de Wulf, History of Mediaeval Philosophy, trans. Ernest C. Messenger (2 vols; London: Longmans, Greene and Co. Ltd., 1926), II, pp. 265-274.

[2] Many of the works written about the New Star are summarized in Tycho Brahe, Astronomiae instauratae progymnasmotum pars tertia in Tycho Brahe, Tychonis Brahe Dani opera omnis, ed. I. L. E. Dreyer (15 vols; Hauniae: In Libraria Gyldendaliana, 1913-1929), III, pp. 5-299; a shorter survey of the literature on the New Star is in Raphael Aversa, Philosophia metaphysicam physicamqve complectens qvaestionibvs contexta. In duos tomos distributa. (Romae: Apud Iacobum Mascardum, 1627), pp. 84-91.

star as sublunar.[3] Tycho Brahe (1546-1601), the Danish astronomer who became known as the most accurate observer in Europe, studied the position and appearance of the New Star and concluded that

> lucentem in ipso firmamento esse stellam, nulla aetate a mundj exordio ante nostra tempora prius conspectam. Atque haec de stellae eius situ, tum quo ad zodiacum, tum quo ad mundj diametrum, & coelj orbes, sufficienter dicta demonstrataque existimo. . . .[4]

William the Landgrave of Hesse (1532-1592),[5] Paul Fabricius (1529-1588), the imperial physician and mathematician at Vienna,[6] the two Bohemians Cyprianus Leovitius (1524-1574)[7] and Thaddaeus Hagecius (1525-1600),[8] Michael Maestlin (1550-1631), German professor of mathematics,[9] Hieronymus Munosius (d. 1584) in Spain,[10] and Erasmus Reinhold Junior (fl. 1580), son of the author of the Prutenicae tabulae,[11] agreed with Brahe

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[3]See Brahe, Opera, III, pp. 50-52, 120-127, 135-143, 263-279, 279-288, 289-294, 294-296, 296-299 for Tycho's summaries of and comments on the works of Paul Hainzelius, Caspar Peucer, Wolfgang Schulerus, Andreas Nolthius, Georgius Buschius, Theodorus Graminaeus, Adam Ursinus and Andreas Rosa, respectively, all of whom considered the New Star to be below the Moon.

[4]Tycho Brahe, Tychonis Brahe, Dani de nova et nvllivs aevi memoria privs visa stella, iam pridem anno a nato Christo 1572. mense Novembrj primum conspecta, contemplatio mathematica (Hafniae: Impressit Lavrentivs Benedictj, 1573) in Brahe, Opera, I, p. 28: "the shining star is in the firmament itself, seen previously by no age from the beginning of the world before our time. And I judge this to be sufficiently said and demonstrated concerning the location of this star from its place with respect to the zodiac, the diameter of the world and the celestial orbs."

[5]Brahe, Opera, III, pp. 114-120, 127-129, passim.

[6]Ibid., pp. 43-44.

[7]Ibid., pp. 218-219.

[8]Ibid., pp. 19-43.

[9]Ibid., pp. 58-67.

[10]Ibid., pp. 80-87.

[11]Ibid., pp. 212-216.

that the New Star was in the celestial region and was a star which had not existed in the sky previously.

Others, Bartholomaeus Reisacherus (fl. 1575), professor of mathematics at Vienna,[12] Annibal Raimondo Veronese (fl. 1570), the Italian,[13] Cornelius Frangipanus (1533-1630),[14] and Francesco Maurolyco of Messina (1494-1575)[15] placed the star in the heavens but considered it some already existing star that had suddenly gained in brilliance. Cornelius Gemma (1535-1577), professor of medicine and astronomy at the University of Lowen,[16] Thomas Digges (d. 1595)[17] and John Dee (1527-1607)[18] in England, and Elias Camerarius (fl. 1572), professor of mathematics in the Academy at Frankfort-on-the Oder,[19] joined those who thought this was an already formed fixed star. They tried to explain its variations in appearance by assigning to the star a rectilinear motion away from the Earth. The physician to King Philip II of Spain, Francis Vallesius (fl. 1560), suggested that the star itself had not changed but that its new appearance was due to some alteration in the part of the heavens through

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[12] Ibid., pp. 45-48.

[13] Ibid., pp. 233-251.

[14] Ibid., pp. 254-259.

[15] Francesco Maurolyco, "Maurolyco's 'Lost' Essay on the New Star of 1572," transcribed, translated and edited by C. Doris Hellman, Isis, LI (1960), pp. 322-336.

[16] Brahe, Opera, III, pp. 67-80.

[17] Ibid., pp. 167-193.

[18] Ibid., pp. 203-205.

[19] Ibid., pp. 205-212.

which its light traveled to the Earth.[20] Philip Apianus (1531-1589) at Tübingen thought "Stellam hanc nihil aliud esse, quam Cometae quandam speciam, ut ut sine coma & barba seu cauda,"[21] while Johannes Praetorius (1537-1619), professor of mathematics at the University of Wittenberg, wanted it placed in the category of meteors.[22] Both, however, considered the object to be beyond the Moon.

Although the details of the interpretations varied, the writers, with the exception of those who considered the New Star to be sublunar, had made a tacit acceptance of change in the immutable heavens. Those who accepted the New Star as just that--a new star--thereby allowed generation and corruption into the celestial region. Those who considered it some fainter star grown brighter thereby permitted alteration in the unalterable part of the universe. Those who assigned the cause of increased brightness to a change in the spheres only altered a different part of the heavens. Those who postulated a receeding star introduced rectilinear motion into the region of circular motion. Many of these had considered the star a miraculous omen, but they had, nevertheless, used ideas heretofore reserved to the terrestrial region to save a celestial phenomenon.

The New Star of 1572 might have been written off as a miracle and the implication inherent in placing it in the heavens might have remained unnoticed for many years had not a series of unusual objects, the comets

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[20] Ibid., pp. 87-93.

[21] Ibid., p. 159: "this star is nothing else than a certain species of comet as those without fringe, beard or tail."

[22] Ibid., pp. 153-157.

of 1577, 1580, 1585, appeared in the heavens. One miracle in nature under the proper extraordinary circumstances might be widely accepted; a number of such incidents, all similar to one another, ceased to be unusual.

In trying to refute the arguments of those who judged the New Star to be a comet and therefore a sublunar event, Tycho Brahe had wished that a suitable comet would appear so that he could observe it and determine if it were above or below the Moon.[23] When such a comet appeared in November, 1577 and remained visible until January of the following year, Brahe and other astronomers had ample opportunity to observe and measure. New and better instruments were used and again accurate measurements failed to show sufficient parallax for a sublunar object. Many of the observers concluded that the object being studied, this time a comet, was beyond the Moon.[24]

Writers in earlier ages and, more recently, Jerome Cardan (1501-1576)[25] and Jean Pena (1528-1558),[26] had expressed the opinion that comets were not the sublunar phenomenon Aristotle had claimed. These men had not had the support from observational data Brahe and his contemporaries did, and one cannot but wonder if it would have made any difference to their audiences if they had. The men in the last half of the sixteenth century who knew that the heavens did not change and that comets were below

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[23] Brahe, De nova in Brahe, Opera, I, p. 28.

[24] Lynn Thorndike, A History of Magic and Experimental Science. Vol. VI: The Sixteenth Century (New York: Columbia University Press, 1941), pp. 67-98.

[25] Jerome Cardan, Hieronymi Cardani Mediolanensis, medici, de svbtilitate, libri xxi. Nunc demum ab ipso autore recogniti, atque perfecti (Lvgdvni: Apud Gulielmum Rouillium, 1559), p. 155; Hieronymi Cardani Mediolanensis medici de rervm varietate libri xvii. Adiectus est capitum, rerun & sententiarum notatu dignissimarum index (Basileae: [Per Henrichvm Petri], 1557), pp. 1-12.

[26] Tycho Brahe, Tychonis Brahe Dani de mvndi aetherei recentioribvs

the Moon could explain the phenomena to their own satisfaction as easily as those who considered the possibility of change.

Brahe was not content simply to demonstrate that the comet was beyond the Moon. He went further and used the data that had been collected to support his assertions about the motion of the comet:

> Patet igitur & sufficienter comprobatum est, idipsum quod ab initio asseruimus; Primum, Cometam suo motu descripsisse Circulum exquisite maximum, Sphaeram bifariam in duo aequali diuidentem. . . .
>
> Alterum Quod affirmauimus, Motum Cometae sub hoc ipso Circulo maximo, non fuisse inordinarium, vtpote interdum velociorem, deinde rursus remissum, aut subito varie sese alterantem, etiam liquido patet. . . .
>
> Tertium etiam vna satis induciter, Cometae motum diurnum proprium in suo ductu nusquam fuisse cursu diurno Lunae vel lentissimo tardiorem. . . .
>
> Vltimum vero quod diximus, Cometae Principium & Finem, in suo tramite, fuisse ab vno Circulo Tropico vsque in alterum, etiam ex praemissis facile colligi poterit; . . .
>
> Insuper sub hoc Circulo, motum ordinarium nec instabilem reseruasse, sed successiue pedetentimque sese remittentem, prout in erraticis Sideribus fieri consueuit. . . .[27]

The orb easily drawn for the Comet was an orb just beyond the sphere of Venus.

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phaenomenis. Liber secvndvs qvi est de illvstri stella cavdata ab elapso fere triente Nouembris anni 1577, vsque in finem Ianuarij sequentij conspecta (Vranibvrgi: 1588) in Brahe, Opera, IV, pp. 136-137.

[27] Ibid., pp. 92-94: "It is clear, therefore, and it has been confirmed sufficiently, that which we have asserted from the beginning: First that the comet by its motion described a great circle accurately dividing the sphere twice into two equal parts. . . . Secondly we have affirmed that the motion of the comet under this great circle itself has not been irregular namely sometimes faster, then again slower or suddenly altering itself in various ways. . . . Third furthermore, at the same time it is clear enough that the diurnal motion proper to the comet in its path has not been slower than the diurnal course of the Moon or the slowest celestial body. . . . Finally we truly say the beginning and end of the comet in its transit has been from one tropical circle to another, furthermore, it can be drawn up easily from the things above. . . . Moreover, under this circle the ordinary motion is not revealed as unstable but as successively advancing and retarding itself just as it has been the custom to consider the wandering stars. . . ."

All of this was contrary to the tenets of peripatetic cosmology. In the *De mundo* Aristotle had placed comets not in the "Ethereal and Divine Element, which we have shown to be governed by fixed laws and to be, moreover, free from disturbance, change, and external influence," but in the region "subject throughout to external influence and disturbance and . . . corruptible and perishable."[28] To put a comet, previously considered a fiery exhalation of the Earth, into the celestial region one had either to permit an Earthly object to exist beyond the limits of the terrestrial region, extend the terrestrial region as Pena had done by eliminating Fire and Aether and placing Air in the celestial part of the universe, or consider comets heavenly bodies. Any one of the solutions was a contradiction to traditional thought. If Earthly bodies were not confined to the sublunar region, then there could be change, an innate property of all terrestrial objects, in the heavens. If the Air occupied all the space between the planets, there were no spheres. If the comets were heavenly bodies, then there was a new celestial body with a unique movement to be incorporated into the system of uniform circular motion.

Brahe and Maestlin tried to salvage some of the old order by giving the comet a circular orbit. Others placed the comet in the heavens and ignored the questions raised by doing so.[29] Those who wished to save the Aristotelian universe in its entirety denied that the comet was beyond the Moon. The last group was numerically large; it was the least influential.[30]

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[28] Aristotle *De mundo* 3. 392^{a} 31-35.

[29] C. Doris Hellman, *The Comet of 1577: Its Place in the History of Astronomy* (New York: Columbia University Press, 1944), pp. 121-122, 153-155.

[30] *Ibid*., pp. 307-317.

A change had been accepted in the heavens.[31]

While the observational astronomers were attacking the immutability of the heavens by their interpretations of data, a direct attack was being made on the existence of the spheres. Thomas Digges had tried to measure an annual parallax of the New Star in 1572 hoping thereby to gain observational evidence which he could use to support the Copernican hypothesis. He failed to measure the desired parallax but continued to support the heliocentric theory and in 1576 published an English version of part of the De revolutionibus.[32] Digges did more than just translate the work of Copernicus; he made additions whenever he considered it expedient to do so.

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[31] By the early seventeenth century the celestial nature of comets was admitted even by some defenders of the Aristotelian cosmology. See: [Horatio Grassi], On the Three Comets of the Year MDCXVIII. An Astronomical Disputation Presented Publicly in the Collegio Romano of the Society of Jesus by One of the Fathers of That Same Society, trans. C. D. O'Malley in The Controversy on the Comets of 1618: Galileo Galilei, Horatio Grassi, Mario Guiducci, Johann Kepler (Philadelphia, Pennsylvania: University of Pennsylvania Press, 1960), p. 14; Lothario Sarsi [Horatio Grassi], The Astronomical and Philosophical Balance on Which the Opinions of Galileo Galilei Regarding Comets Are Weighed, as Well as Those Presented in the Florentine Academy by Mario Guiducio and Recently Published, trans. C. D. O'Malley, Ibid., pp. 72-73, 80; Libertus Fromundus, Liberti Fromondi S. Th. L. Collegij Falconis in Academia Louaniensi philosophiae professoris primarij meteorologicorvm. Libri sex (Antverpiae: Ex officina Plantiniana, 1627), pp. 88-89.

[32] Thomas Digges, "A Perfit Description of the Caelestiall Orbes according to the Most Aunciente Doctrine of the Pythagoreans, Latelye Reuiued by Copernicvs and by Geometricall Demonstrations Approued," in Leonard Digges, A Prognostication Euerlastinge of Righte Good Effecte, Fruitfully Augmented by the Auctour, Contajning Plaine, Briefe, Plesaaunt, Chosen Rules to Iudge the Weather by the Sunne, Moone, Starres, Comets, Rainebow, Thunder, Cloudes, with Other Extraordinary Tokens, not Omitting the Aspects of Planets, vvith a Briefe Iudgement for Euer, of Plenty, Lacke, Sickeness, Dearth, VVarres, &c. Opening also Many Naturall Causes VVorthy To Be Knovven. To These and Other Now at the Last, Are Ioyned Diversu Generall, Pleasaunt Tables vvith Manye Compendious Rules, Easye To Be Had in Memory, Manifolde VVayes Profitable to Al Men of Vnderstanding (London: Thomas Marsh, 1576).

One such alteration was the change Digges made in the structure of the eighth sphere. Whether one accepts Grant McColley's thesis that Copernicus implied an infinite world when he placed the stars at varying depths in the eighth orb[33] or acknowledges Francis Johnson's claim that Digges introduced the concept of an infinite world,[34] or agrees with Alexandre Koyré and A. O. Lovejoy that neither Copernicus nor Digges but Giordano Bruno is to be regarded "as the principal representative of the doctrine of the decentralized, infinite, and infinitely populous universe"[35] there can be no doubt that Digges destroyed the eighth sphere. Whereas the region of the fixed stars in the diagram of the universe in the De revolutionibus was structurally no different from the corresponding Ptolemaic sphere, the eighth sphere in Digges's system was different, so different that it no longer locked like a sphere in the diagram. Furthermore, Digges associated the immobility of this region with its lack of definite boundary:

> This orbe of starres fixed infinitely up extendeth hit self in altitvde sphericallye, and therefore immovable. . . .[36]

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[33]Grant McColley, "Nicolas Copernicus and an Infinite Universe," Popular Astronomy, XLIV (1936), pp. 525-533; "The Eighth Sphere of De Revolutionibus," Annals of Science, II (1937), pp. 354-356; "The Universe of De Revolutionibus," Isis, XXX (1939), pp. 452-472.

[34]Francis R. Johnson, Astronomical Thought in Renaissance England: A Study of the English Scientific Writings from 1500 to 1645 (Baltimore, Maryland: The Johns Hopkins Press, 1937), pp. 161-210.

[35]The quotation is from: Arthur O. Lovejoy, The Great Chain of Being: A Study of the History of an Idea. (The William James Lectures Delivered at Harvard University, 1933) (Cambridge, Massachusetts: Harvard University Press, 1950), p. 116; it is quoted in: Alexandre Koyré, From The Closed World to the Infinite Universe (Baltimore, Maryland: The Johns Hopkins Press, 1957), p. 39.

[36]Digges, A Prognostication, f. 43 recto.

A few years later Giordano Bruno (1548?-1600) reversed the argument. Digges scattered the stars and then added that they were "therefore immouable." For Bruno, since the stars were not circling the Earth, they were not in the eighth sphere but scattered:

> Conosciuto che sará, che l'apparenza del moto mondano é caggionata dal uero moto diurno della terra (il quale similmeute si troua in astri simili) non sará raggione che ne constringa á stimar l'equidistanza de le stella che il uolgo intende in una ottaua sphera come inchiodate et fisse: et non sara persuasione che ne impedisca di maniera che non conosciamo che de la distanza di quelle innumerabili, sieno differenze innumerabili di lunghezza di semidiametro.[37]

Believers in a moving Earth had provided both the necessary and sufficient reasons, if one wanted to accept them as such, for the elimination of a sphere for the fixed stars. A geocentric theorist, Tycho Brahe, led the attack on the inner spheres.

In 1588 Brahe proposed a new astronomical system in which Saturn, Jupiter, Mars, Venus and Mercury revolved around the Sun while Sun and Moon orbited the stationary Earth.[38] The theory combined the advantages of the Copernican explanation for the retrograde motions of the planets with the avoidance of the theological and spatial questions in-

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[37]Giordano Bruno, Giordano Brvno Nolano. De l'infinito vniuerso et mondi (Stampato in Venetia [i.e. London: J. Charlewood], 1584), p. 106: "As soon as we have recognized that the apparent world-motion is caused by the real diurnal motion of our earth (which happeneth similarly to other similar stars), no argument will constrain us to accept the vulgar opinion that the stars are equidistant from us, that they are as though nailed and fixed in an eighth sphere; and no persuasion will hinder us from knowing that the differences are innumerable in the distances from us of these innumerable stars." English translation from Dorothea Waley Singer, Giordano Bruno, His Life and Thought. With Annotated Translation of His Work on the Infinite Universe and Worlds (New York: Henry Schuman, 1950), p. 328. In a footnote Singer notes that the literal translation of the last line of this quotation is: "in the length of the radii of the distances from us."

[38]Brahe, De mvndi aetherei, Opera, IV, pp. 155-170.

volved in assigning motions to the Earth. As a compromise between the heliocentric and geocentric hypotheses, Tycho's system was acceptable in many ways, but as a representation of the universe as it was in very truth the theory presented some difficulties. There were two centers of motion in the system, Sun and Earth, and in some cases the path of one heavenly body crossed that of another.

The dual centers of motion was the lesser problem of the two. While this was contrary to the Aristotelian definition of celestial motion, multiple and even moving circular centers were common and acceptable by Ptolemaic standards. Tycho could and did ignore this difficulty.

The problem of intersecting spheres could not be so easily passed over. From the time that the spheres had been considered firm bodies, the advocates of an entirely homocentric theory had used the impossibility of the intersection of paths as one argument against the existence of epicycles.[39] In the Tychonic hypothesis the paths of Mercury, Venus and Mars crossed the Sun's path.[40] While one could use a system similar to the one Ptolemy presented in his Hypotheses to allow for the movement of an epicyclic sphere within the planetary region, there was no precedent for allowing one planetary deferent sphere to penetrate another. Thus, if the orbs were solid, Tycho's new theory could not be the true system of the world.

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[39] See for example: Girolamo Fracastoro, Hieronymi Fracastor homocentrica eivsdem de cavsis criticorvm diervm per ea qvae in nobis svnt ([Venetiis]: 1538), 63 verso-65 verso; Jerome Cardan, Hieronymi Cardani Mediolanensis medici de rervm varietate libri xvii. Adiectus est capitum, rerum & sententiarum notatu dignissimarum index (Basileae: [Per Henrichvm Petri], 1557), pp. 51-52.

[40] Brahe, Opera, IV, pp. 158.

Brahe was aware of this difficulty. When writing to Caspar Peucer in September, 1588, Tycho described the steps by which he had arrived at his system. For many years, he wrote, both the theory of Ptolemy and that of Copernicus had seemed to him to be insufficient as representations of the physical world. From his study of observational data, he had concluded that at times Mars was closer to, at times farther from, the Earth than was the Sun. This could not be explained by the Ptolemaic system. The Copernican system saved the phenomena but assigned a triple motion to the Earth, a postulate objectionable to Brahe.[41] Both the Copernican and the Ptolemaic theory employed epicycles, and while, to be sure, Tycho had two centers of motion in his system, both were occupied by real objects; he would not accept as anything other than a mathematical device a circular motion that did not have a physical body for its center. Thus, dissatisfied with the existing theories, he formed his own, a system in which "revolutions coelestes ordinarentur, tunc omnia, quae in Ptolemaica et Coperniana assumptione absona et irrita supervacaneaque incidunt, tolli et praecaveri."[42] The system was satisfying "sed nihilominus adhuc scrupulum iniecit, quod orbis Martius respectu Solaris tantus non invenire-

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[41]Tycho Brahe, Letter to Caspar Peucer dated September, 1588, VII, pp. 127-141; compare with: Letter to Henricus Brucaeus dated 1585 in Opera, VII, pp. 78-82; Letter to Thaddaeus Hagecius dated Calends of July old stle, 1586, Ibid., pp. 105-109; Letter to William Landgrave of Hesse dated January 20, 1587, Ibid., pp. 85-104; Letter to William Landgrave of Hesse dated August 16, 1588, Ibid., pp. 121-132; Letter to Christophor Rothmann dated August 17, 1588, Ibid., pp. 134-148.

[42]Brahe, Opera, VII, p. 130: "the heavenly revolutions are ordered so that all which occur in the Ptolemaic and Copernican assumption as discordant and invalid and unnecessary are taken away and guarded against beforehand."

tur, ut eum totaliter includere posset, verum duobus in locis necessario ipsum penetraret."[43]

In the letter Brahe indicated that at the time he conceived his system he was puzzled over the difficulty of the intersecting orbs, because he was

> adhuc diu recepta et ab omnibus fere approbata opinione imbutus, coelum esse quibusdam realibus orbibus, sidera circumferentibus, refertum, ideoque hanc orbium incongruam penetrationem non admittendam duxi, indeque evenit, ut haec propria inventio mihi ipsi aliquandiu suspecta fuerit.[44]

He next stated that the difficulty was solved by his observations of comets:

> Tandem vero cum ex quorundam Cometarum accurata circa motum et parallaxes eorum eximinatione certo exploratum haberem, eos in ipso coelo longe supra Lunam cursus sui norman absolvisse et nihilominus nullis corporeis et realibus orbibus, quibus Planetae vehi creduntur, fuisse obnoxios, sed peculiarem quandam ab his motus rationem invenisse, ut latius et exquisitius in opere nostro de his asciticijs coeli phaenomenis demonstratur, praesumptionem illam de orbium coelestium dura et impervia materia prorsus abieci.[45]

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[43]Ibid., p. 130: "but, nevertheless, still a doubt remained because the orb of Mars is not found so great with respect to that of the Sun so it can include it totally, truly in two places, it, of necessity, penetrates the solar orbit."

[44]Ibid.: "at that time still imbued with the usual and established opinion accepted by all that the heavens is filled with certain real orbs carrying the stars, and therefore I considered not admitting this inconsistent penetration of the orbs, and for that reason it happened, that this special invention was suspect to me for some time."

[45]Ibid.: "Truly at last after I had established with certainty from the accurate examination of the motions and parallaxes of certain comets that they were free in the heavens itself far above the lunar pattern of its path and nevertheless were subject to no bodies and real orbs by which the planets are believed to be carried but that a certain particular reason of motion was found from these as is shown more fully and more admirably in our work covering these admitted phenomena of the heavens, I rejected absolutely that presumption of the hard and impervious material of the celestial orbs."

Thus, in the Letter to Peucer, Brahe gave the sequence: (1) The formulation of the Tychonic system; (2) reservations about the system because of the intersection of planetary and solar paths; (3) observations of comets and conclusion that the phenomena are supralumar; and (4) discarding of solid orbs because of the motion of comets in the celestial region. Brahe's other writings do not support this order.

In 1588 Tycho printed the first two volumes of his Astronomicae instauratae progymasmata. The first volume concerned the New Star of 1572; the second was the De mundi aetherei recentioribus phaenomena.[46] The latter not only contained the discussion of the Comet of 1577, it also presented the first published version of the Tychonic System. The major portion of the De mundi aetherei is a record of the night-by-night observations made while the comet was visible and the results of various calculations made with these data.[47] The new world system appears in about the middle of the work between Brahe's own observational account of the comet and his remarks on the reports of others.[48] The three sections are quite distinct and could well have been written at various times.

In his discussion of the comet of 1577 Brahe's frequent conclusion was that the comet was "in ipso aethere";[49] furthermore, its orbit was

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[46] J. L. E. Dreyer, Tycho Brahe. A Picture of Scientific Life and Work in the Sixteenth Century (Edinburgh: Adam and Charles Black, 1890), pp. 162-164.

[47] Brahe, De mvndi aetherei, Opera, IV, pp. 11-154.

[48] Ibid., pp. 155-170

[49] Ibid., pp. 83, 84, 86, 94, 104, 107, 110, 114, 116, 119, 123, 124, 133, 134, passim.

"non longe ab Orbibus, quos ♀ & ☿ circa Solem describunt."[50] Neither statement, by itself, had any bearing on the reality of the spheres. Since all heavenly bodies existed "in ipso aethere," since the orbit was compared to the planetary orbits,[51] and since the system in which the comet had its place near Venus was not specified, the comet could have moved through the aether without disturbing the spheres just as the planets moved. When, however, the comet was placed beyond the orb of Venus in the Tychonic system, it did pass through one other sphere, that of the Sun.[52] This no longer mattered: The spheres had been abolished when the system was formed.

In presenting his system in the *De mundi aetherei* Brahe did not ask if the spheres were real or demonstrate that they were not. He simply denied that such bodies were in the heavens and postponed the demonstration of this until the end of the work:

> vbi per Cometarum motus prius ostensum & liquido comprobatum fuerit, ipsam Coeli machinam non esse durum & imperuium corpus varijs orbibus realibus consertum, vt hactenus a plerisque creditum est, sed liquidissimum & simplicissimum, circuitibusque Planetarum liberis, & absque vllarum realium Spaherarum opera aut circumvectione, iuxta diuinitus inditam Scientiam administratis, vbique patere, nihilque prorsus obstaculi suggerere.[53]

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[50] *Ibid.*, p. 86: "not far from the orbs which Venus and Mercury make around the Sun."

[51] *Ibid.*, p. 94.

[52] *Ibid.*, p. 160.

[53] *Ibid.*, p. 159: "where first through the motions of comets it will be shown and clearly proven that the machine of heaven is not a hard and impervious body connected by various real orbs as thus far has been believed by many, but it is most liquid and most simple and with free circuits of the planets administered accordingly to a divinely given knowledge, and without the works of revolutions of any real spheres, to lie open everywhere and absolutely to carry nothing of an obstacle." Compare *Opera*, IV, p. 224.

The proof was deferred but its conclusion was used immediately:

> Vnde etiam constabit, nullam absurditatem in hac Orbium Coelestium ordinatione ex eo sequi, quod Mars Acronichus Terris proprior fiat, quam ipse Sol. Neque enim Orbium aliqua realis & incongrua penetratio (cum illi reuera Coelo non insint, sed docendi & intelligendi rem gratia saltem proponantur) hoc modo admittitur, neque ipsa vllorum Planetarum corpora sibvnquam occurrere possunt, aut motuum Harmoniam, quam singuli eorum obseruant, vlla ratione interturbare, vtut Mercurii, Veneris & Martis imaginarii Orbes Solari per misceantur, eundemque transeant; prout haec latius eo in loco, circa totius (vt dixi) Operis Colophonem, praesertim vero in volumine nostro Astronomico, vbi ex professo de his agemus, apertius declarabitur.[54]

Brahe never finished the work which was to have included the details of his system and the expanded demonstration that the heavens contained no spheres.[55] He did, however, in other writings consider the subject and give different reasons for his denial. At times he included it in discussions of the measurements of solar and stellar refraction. The actual bending of the light rays Brahe attributed to the vapours in the atmosphere surrounding the Earth rather than to any variation in density between the air and the celestial aether. Having eliminated any difference

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[54] Ibid.: "From whence even it will remain that I follow no absurdity in this ordering of the celestial orbs because Mars when an evening star is nearer to the Earth than the Sun itself. And indeed neither any real and incongrous penetration of the orbs is admitted in this way (since, indeed, they are not in the heavens, but they are proposed, at all events, for the sake of teaching and understanding the thing) nor can those bodies of any planets meet one another at any time or disturb, by any reason, the harmony of motions, which they each observe, as the imaginary orbs of Mercury, Venus and Mars are mingled with the Sun's and cross the same; accordingly this will be declared more extensively and more openly in its place near the Colophon of this work (as I have said) especially in fact in our astronomical volume, where we will expound professedly about these things."

[55] Brahe had planned the Astronomicae instauratae progymasmata to be a three volume work. The third volume was to have been about the later comets. Tycho printed the first two volumes at Uraniborg in 1588, but he never completed the project. Johann Kepler edited and republished the two 1588 volumes with new title pages in 1602, 1603. Dreyer, Tycho Brahe, pp. 162-164, 368-470.

in the denseness between the supra and sublunar regions, Tycho could deny the existence of any solid spheres in the heavens.[56] The argument quite probably would have been totally non-conclusive to a man committed to solid spheres who could have countered the reasoning by denying any refractive property to the crystalline orbs.[57] It did, however, provide a second "proof" from observational data for the assertion that the heavens contained no solid spheres.

Another reason was the enevitable, for that period, argument from Scripture. There were no texts that stated outright that there were no spheres so Brahe had to be content with assembling quotations which either did not contradict his theory or disproved something contrary to it.[58] Such arguments required only a little ingenuity in interpreting the Scriptures and an equally ingenious opponent could twist them to the other side.

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[56]Tycho Brahe, Letter to Christopher Rothmann dated January 20, 1587 in Brahe, _Opera_, VI, pp. 85-104; Letter to Christopher Rothmann dated August 17, 1588, _Ibid._, pp. 134-148; Letter to Johann Kepler dated April 1, 1598, _Ibid._, VIII, p. 45; _Astronomiae instauratae progymnasmatum pars tertia_, _Opera_, III, p. 91.

[57]In 1616 even Galileo refuted the refractive argument: "In questo medesimo errore sono incorsi alcuni, mentre si sono persuasi di poter mostrare la sostanza celeste non differir dalla prossima elementare, nè potersi dare quella moltiplicità d'orbi; auuenga che quando ciò fusse, gran diuersità caderebbe negli apparenti luoghi delle stelle, mediante le refrazzioni fatte in tanti diafani differenti; il qual discorso è vano, perche la grandezza di essi orbi, quando ben tutti fussero diafani trà loro diuersissimi, non permetterebbe alcuna refrazzione algi occhi nostri, come riposti nell' istesso centro di essi orbi." Galileo Galilei, _Il saggiatore nel quale con bilancia esquisita e giusta si ponderano le cose contenute nella libra astronomicae filosofica di lotario sarsi sigensano scritto in forma di lettera All' Illmo et Revermo Monsre D. Virgginio Cesarini Acco. Linceo Mo di Camera di N. S._ (Roma: Appresso Giacomo Mascardi: 1623), p.111.

[58]Tycho Brahe, Letter to Christopher Rothmann dated November 24, 1589, _Opera_, VI, pp. 185-199; Letter to Caspar Peucer 1590, _Ibid._, VII, pp. 228-239.

The comments on refraction and Scripture were only supplementary reasons. Brahe's foremost reason given in support of his denial of the spheres was that he had proved this from his observations of the comets.[59] Actually he had nowhere clearly demonstrated the non-existence of the heavenly orbs but had repeatedly said he would do so in a later work.[60]

In the writings of Brahe included in the Dreyer Opera, the earliest denial of the spheres occurred in 1587.[61] Tycho used both the argument from the placement and motion of comets and the evidence from refractive phenomena at this time.[62] His first use of Scriptural support was in 1589.[63]

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[59] Tycho Brahe, Letter to Christopher Rothmann dated January 20, 1587, Opera, VI, pp. 85-104; Letter to Henry Brucaeus dated November 4, 1588, Ibid., VII, p. 163; "Apologetica responsio ad Craigum Scotum de cometis (1589)," Ibid., IV, pp. 427-428, 474-475; Letter to Thaddaeus Hagecius dated August 3, 1590, Ibid., VII, pp. 262-275; Letter to Johann Antonius Magine dated Calends of December, 1590, Ibid., pp. 289-299; Letter to Caspar Peucer dated 1590, Ibid., p. 229; Astronomicae instauratae progymnasmatum pars tertia, Ibid., III, p. 111.

[60] Tycho Brahe, Letter to Christopher Rothmann dated August 17, 1588, Opera, VI, p. 148; "Apologetica responsio ad Caaigum Scotum de cometis (1589)," Ibid., IV, p. 427; Astronomicae instauratae progymnasmatum pars tertia, Ibid., III, pp. 111, 151; see fn. 53 supra.

[61] All of the following letters discuss astronomical topics but do not contain a denial of the spheres: Letter to Iohannem Pratensem dated February 14, 1576, Opera, VII, pp. 25-29; Letter to Thaddaeus Hagecius dated November 4, 1580, Ibid., pp. 58-60; Letter to Bartholomaeus Scultetus dated October 12, 1581, Ibid., pp. 61-63; Letter to Thaddaeus Hagecius dated October 12, 1581, Ibid., pp. 64-69; Letter to Thaddaeus Hagecius dated september 23, 1582, Ibid., pp. 72-75; Letter to Carolus Danzaeus dated August 21, 1583, Ibid., pp. 75-76; Letter to Henricus Brucaeus 1584, Ibid., pp. 78-82; Letter to Thaddaeus Hagecius dated August 25, 1585, Ibid., pp. 93-97; Letter to William Landgrave of Hesse dated Calends of March, 1586, Ibid., VI, pp. 33-40; Letter to William Landgrave of Hesse dated January 18, 1587, Ibid., pp. 63-75.

[62] Tycho Brahe, Letter to Christopher Rothmann dated January 20, 1587, Opera, VI, pp. 85-104

[63] Tycho Brahe, Letter to Christopher Rothmann dated November 24, 1589, Opera, VI, pp. 185-199.

Yet, the Tychonic system was formulated in 1583,[64] several years after his observations of comets but sometime before he questioned in writing the existence of the spheres.

Therefore, the chronological arrangement must have been: (1) The observations of comets and the acceptance of these as supralunar bodies;[65] (2) the formulation of the Tychonic system; (3) the realization of the conflict between the new theory and the solid crystalline spheres; and (4) the discarding of the spheres and the use of observational data to support the discard.

Thus, it seems that Brahe thought of using the data from his astronomical observations to support a denial of the solid heavenly spheres only after he wanted to propose a physical system that was incompatible with the existence of those spheres. This association of astronomical phenomena with his theoretical considerations made Brahe's denial of the spheres different from the similar statements of other natural philosophers before and after him.

The existence of the planetary spheres had been rejected by other recent writers before the publication of the De mundi aetherei. Bernardino Telesio (1509-1588) in his De rerum natura of 1570 discarded the solid spheres because the agent calor was the predominant power in his celestial region. One of the distinguishing properties of bodies governed by calor was their lack of hardness. Therefore, there could be no solid bodies in

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[64] According to J. L. E. Dreyer, the editor of Brahe's Opera the De mundi aetherei was written in 1587. When presenting his system in this work Brahe stated that it was one he had thought of four years previously. Dreyer, Tycho Brahe, pp. 163-167; Brahe, Opera, IV, pp. 155-156.

[65] Tycho Brahe, "Obseruatio cometae quem primum conspexi Huenae anno 1577," Brahe, Opera, XIII, pp. 303-304.

the heavens: The stars were fires and the rest of the heavenly region was filled with a most subtle fluid.[66]

Giordano Bruno published three of his major cosmological works in 1584.[67] In all of these the vast regions of his infinite universe were filled with a finely attenuated substance in order to allow freedom of movement to the bodies within these regions. The following year Honoratus de Robertis (fl. 1580) printed a small treatise defending the fiery nature of the sky.[68]

Many writers after Brahe also found it necessary or convenient to eliminate the solid spheres from the celestial region. In 1588 Nicolas Rymers (d. 1600) proposed a geocentric system similar to the Tychonic one but which included a diurnal motion for the Earth and a rest state for the fixed stars. Planetary and solar paths crossed in this scheme as they had in Tycho's.[69] Rymers, however, avoided the difficulty not by denying the existence of the solid spheres but by postulating that there were only three elements--Earth, Water and Air-- and that of these three Air, the

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[66]Bernardino Telesio, Bernardini Telesii Consentini de rerum natura iuxta propria principia, liber primus et secundum, denuo editi (Neapoli: Apud Josephum Cacchium, n.d.), pp. 8-9.

[67]Giordano Bruno, La cena de le ceneri. Descritta in cinqve dialoghi per quattro interlocutori, con tre considerationi, circa doi suggettj (Stampato in Venetia [i.e. London: J. Charlewood], 1584); De la causa, principio et uno (Stampato in Venetia [i.e. London: J. Charlewood], 1584); De l'infinito vniuerso et mondi (Stampato in Venetia [i.e. London: J. Charlewood], 1584).

[68]Thorndike, History of Magic and Experimental Science, VI, p. 371.

[69]Nicolas Rymers, Nicolai Raymari Vrsi dithmarsi. Fvndamentvm astronomicvm: id est. Nova doctrina sinvvm et triangvlorvm. Eaqve absolvitissima et perfectissima, eivsqve vsvs in astronomica calculatione & obseruatione (Argentorati: Excudebat Bernardus Iobin, 1588), ff. 37 recto-40 verso.

"essentia tenuissima & subtilissima,"[70] extended far beyond the Earth into the regions among the heavenly bodies.[71] Thus, in this work Rymers ignored the spheres. Later in 1597 he assumed that the stars "per aerem sese movent, non sicut radij volvuntur in rotâ, (id est, non infixa fictitijs illis orbibus, ut vulgus astronomorum credit, opinatur, ac perhibet). . . ."[72]

Francesco Patrizi (1529-1597) had one basic reason for not including solid spheres within his system: His commitment to Platonism. No Platonist would allow such crass objects in the heavens and Patrizi was an ardent admirer of Plato. As Telesio and Bruno had filled their interplanetary regions with a subtle fluid, so did Patrizi. He differed from the two earlier writers in the choice of a name; the Patrizian celestial space filler was *lumen*.[73]

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[70] *Ibid.*, f. 37 *recto*.

[71] *Ibid.*, f. 38 *verso*.

[72] Nicolas Rymers, *Nicolai Raimari Vrsi Dithmarse So. Soe. Rom. Caesx. Mtis. Mathematici. De astronomicis hypothesibvs, sev systemate mvndano, tractatvs astronomicus & cosmographicus: scitu cum jucundus, tum utilissimus. Item: Astronomicarvm hypothesivm a se inventarum, oblatarum, & editarum, contra quosdam eas sibite merario seu potius nefario ausu arrogantes, vendicatio et defensio, eque sacris demonstratio: earundemque vsus. In quo vsv tota genuina astronomia, ipsumque fundamentum astronomicum latitat; spectatur, exhibetur, ac manifestatur. Cum quibusdam novis subtilissimisque compendijs et artificijs, in planê novâ doctrinâ sinuum & triangulorum iterum, jamque alterâ vice, exhibitâ: Nec non aliquibus exercitijs mathematicis jucundissimis, ad solvendum omnibus, ac praesertim suis zoilis & sugillatoribus, ob palmam magisteriumque mathematicum, mathematicique exercitij gratiâ, propositis. Ac denique problemata totius processus astronomicae observationis, seu rationis observandi* (Pragae Bohemorvm: Apud Avtorem, 1597), E. *recto*: "move themselves through the air, not as spokes are turned in a wheel (that is, not fixed in those imagined orbes as the vulgar of the astronomers believe, suppose and ascribe). . . ." Cf. Giiij *verso*-H *recto*.

[73] Francesco Patrizi, *Francisci Patricii nova de vniversis philosophia in qva Aristotelica methodo, non per motum, sed per lucem, & lumina, ad primam causam ascenditur. Deinde propria Patricii methodo; tota in*

In his work on magnetism, De magnete, William Gilbert (1544-1603) included a brief section on cosmology.[74] The world system which Gilbert presented was not a complete one but did contain an explicit denial of the sphere of fixed stars:

> Praetereà quis ille vnquam artifex stellas quas nos fixas appellamus, in vna eademque sphaera deprehendit, aut sphaeras vllas reales, & quasi adamantinas esse ratione confirmauit: nullus hoc ipsum demonstrauit vnquam; nec dubium est quin quemadmodùm planetae dissimilibus interuallis à terra distant; ita ingentia illa & frequentissima lumina, altitudinibus à terra varijs, & remotissimis disiunguntur; non sphaericae alicui compagini, aut firmamento (vt fingunt) & concamerato corpori inhaerent: ita nonnullorum interualla, opinione quadam potiùs quàm reuera, propter inscrutabilem distantiam concepta sunt, alia multò magis illa superant, & sunt longè remotissima, quae cùm in caelo varijs distantijs collocata sint, aut in tenuissimo aethere, aut quinta illa subtilissima substantia, aut vacuo; quomodo permanebunt in tanta vasti orbis, corporis incertissimi, vertigine.[75]

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contemplationem venit Diuinitas: Postremo methodo Platonica, rerum vniuersitas, a conditore Deo deducitur (Ferrariae: Apud Benedictum Mammarellum, 1591), "Pancosmios," ff. 73 verso-75 recto.

[74]William Gilbert, Gvilielmi Gilberti Colcestrensis, medici Londinensis, de magnete, magneticisqve corporibvs, et de magno magnete tellure; physiologia noua, plurimis & argumentis, & experimentis demonstrata (Londini: Excvdebat Petrvs Short, 1600), pp. 211-240.

[75]Ibid., p. 215: Besides, who is the Master who has ever made out that the stars which we call fixed are in one and the same sphere, or has established by reasoning that there are any real and, as it were, adamantine sphaeres? No one has ever proved this as a fact; nor is there a doubt but that just as the planets are at unequal distances from the earth, so are those vast and multitudinous lights separated from the Earth by varying and very remote altitudes; they are not set in any sphaerick frame or firmament (as is feigned), nor in any vaulted body: accordingly the intervals of some are from their unfathomable distance matter of opinion rather than of verification; others do much exceed them and are very far remote, and these being located in the heaven at varying distances, either in the thinnest aether or in that most subtile quintessence, or in the void; how are they to remain in their position during such a mighty swirl of the vast orbe of such uncertain substance." English translation from: William Gilbert, William Gilbert of Colchester, Physician of London. On the Magnet, Magnetick Bodies Also, and on the Great Magnet the Earth; a New Physiology, Demonstrated by Many Arguments & Experiments (London: Chiswick Press, 1900 [i.e. 1901]), p. 215.

The non-existence of the planetary spheres was implied in the *De magnete*, but only in his later work, *De mundo nostro sublunari*,[76] was Gilbert more emphatic about discarding all spheres and placing a void in the heavens. Empty space or a region filled with only a most tenuous aether was necessary in Gilbert's scheme since he wished to have his globes and their surrounding effluvia free to rotate about an inner axis.[77] Solid crystalline spheres could have been considered an impediment to this motion. Therefore, Gilbert needed to postulate either that solid spheres offered no resistance to movement or that there were no solid spheres. He choose the latter:

> Astra igitur moventia in vacuo, seu aethere incorporeo, feruntur, & inter se formis effusis combinantur, mutuisque & propriis viribus concitantur, efferuntur, advocantur, & varia φαινόμενα, differentesque nobis apparitiones ostendunt. Mathematicorum illae viae conceptus sunt, quas admittere oportet ad computationes & astrorum calculum; longe vero à Philosophorum institutis alienae esse debent corporeae sphaerae, globos ferentes. Nec amplius credendum, quod sint globi densiores partes sphaerarum, vt vulgus Sophorum putat, & sit concavum Lunae, distinctio mundi corruptibilis ab incorrputibili.[78]

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[76] William Gilbert, *Gvilielmi Gilberti Colcestrensis, medici regii, de mundo nostro sublunari philosophia nova. Opus posthumum, ab authoris fratre collectum pridem & dispositum, nvnc ex duobus MSS. codicibus editum. Ex museio viri perillustris Gvilielmi Boswelli equitis aurati &c. & oratoris apud Foederatos Belgas Angli* (Amstelodami: Apud Ludovicum Elzevirium, 1651).

[77] *Ibid.*, pp. 48-54.

[78] *Ibid.*, pp. 154-155: "Therefore the moving stars are carried in the void, or in the incorporeal aether, and are contained within themselves by their effused forms, and are excited by mutual and proper virtues, are carried, are called together, and by various appearances, they show different appearances to us. Those ways are concepts of the mathematicians, which it is necessary to admit to computations and the calculations of the stars; truly far from the precepts of the philosophers must be any corporeal spheres carrying globes. Nor is it more credible that the globes are the more dense parts of the spheres, as the vulgar of the Sophists think, and that the inner surface of the lunar sphere separates the corruptible world from the incorruptible."

In the celestial region of Nicolas Hill's (1570?-1610) universe there were no planetary or stellar spheres. Heavenly bodies either traveled unhindered through a region filled with a most tenuous aether or remained in their respective places freely suspended in this same substance.[79]

All of these men had rejected the solid planetary spheres because such spheres could not exist within their cosmological systems. None had supported his denial with anything less speculative than his general theory. Brahe's elimination of the spheres originated, as had Telesio's, Bruno's, Patrizi's and Gilbert's, in his theoretical framework, but the discussion quickly passed from the abstract to the concrete when Tycho related the sphereless heaven to the comet-containing celestial region.

Johann Kepler (1571-1630) in his Mysterium cosmographicum of 1596 stated his belief that there were no spheres in the heavens and then added: "In qua sententia video Nobilem et excellentissimum Mathematicum TYCHONEM BRAHE, Danum, versari."[80] At this time Kepler gave no reason for excluding the spheres, but later he credited Brahe with having disproved their existence:

> Solidos orbes tribus rationibus refellit TYCHO BRAHEVS: vna est à motu Cometarum, altera à lumine irrefracto: tertia à proportione

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[79] Nicolas Hill, Philosophia Epicvrea, Democritiana Theophrastica proposita simpliciter, non edocta (Coloniae Allobrogvm: Prostant in Officina Fabriana, 1619), pp. 22, 43, 47, 69, 150-151.

[80] Johann Kepler, Prodromus dissertationvm cosmographicarvm, continens mysterivm cosmographicvm, de admirabili proportione orbivm coelestivm, deqve cavsis coelorum numeri, magnitudinis, motuumque periodicorum genuinis & proprijs, demonstratvm, per qvinqve regularia corpora geometrica (Tvbingae: Excudebat Georgius Gruppenbachius, 1596) in Johann Kepler, Johannes Kepler Gesammelte Werke, ed. Max Caspar (München: C. H. Beck'sche Verlagsbuchhandlung, 1937-1959), I, p. 76: "In which sentiment I see that the noble and most excellent Mathematician Tycho Brahe, Dane, is concerned."

orbium. Nam si solidi essent orbes, Cometae non cernerentur ex vno orbe in alium trajicere, impedirentur enim à soliditate; at trajiciunt ex vno inalium, vt demonstravit BRAHEVS.

A lumine porrò sic: cum sint orbes eccentrici, et terra ejusque superficies, in qua oculi, non sita sit in ipso centro cujusque orbis; ergo si solidi essent orbes, densiores nimirum quàm illa limpidissima aura aetherea, tunc radij stellarum refracti ad Aerem nostrum pervenirent, vt docet Optica: itaque planeta irregulariter appareret, et quasi in locis longè alijs, quàm quae ab Astronomo praedidi possent.

Tertia ratio est ipsius BRAHEI accommodata principijs: testantur illa, vt et Copernicana, Martem fieri quandoque propriorem terris, quàm est Sol: hanc verò permutationem non potuit BRAHEVS credere possibilem, si solidi sint orbes, cùm Martis orbis deberet intersecare orbem solis.[81]

Kepler was not the only writer to cite Brahe as the one who had de-

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[81]Johann Kepler, Epitomes astronomiae Copernicanae, usitata formâ quaestionum & responsionum conscriptae, liber quartus, doctrina theoricae primus: quo physica coelestis, hoc est, omnium in coelo magnitudinum, motuum, proportionumque, causae vel naturales vel archetypicae explicantur, et sic principia doctrinae theoricae demonstrantur. Qvi, qvod vice svpplementi librorum Aristotelis de caelo esset, certo consilio seorsim est editus (Lentiis ad Danubium: Excudebat Johannes Plancus, 1620) in Kepler, Gesammelte Werke, VII, pp. 260-261: "Tycho Brahe disproved the solidity of the spheres by three reasons: the first from the movement of comets; the second from the fact that light is not refracted; the third from the ratio of the spheres. For if spheres were solid, the comets would not be seen to cross from one sphere into another, for they would be prevented by the solidity; but they cross from one sphere into another, as Brahe shows. From light thus: since the spheres are eccentric, and since the Earth and its surface--where the eye is--are not situated at the center of each sphere; therefore if the spheres were solid, that is to say far more dense than that very limpid ether, then the rays of the stars would be refracted before they reached our air, as optics teaches; and so the planet would appear irregularly and in places far different from those which could be predicted by the astronomer. The third reason comes from the principles of Brahe himself; for they bear witness, as do the Copernican, that Mars is sometimes nearer the Earth than the sun is. But Brahe could not believe this interchange to be possible if the spheres were solid, since the sphere of Mars would have to intersect the sphere of the sun." English translation from: Johann Kepler, Epitome of Copernican Astronomy in Great Books of the Western World Vol. XVI: Ptolemy, Copernicus, Kepler, ed. Robert Maynard Hutchins (Chicago, Illinois: Encyclopaedia Britannica, Inc., 1952), pp. 856-857. Kepler's references to Brahe as the man who had demonstrated that there were no solid spheres were numerous throughout his works. See, for example, Johann Kepler, Astronomia nova ΑΙΤΙΟΛΟΓΗΤΟΣ, sev physica coelestis, tradita commentariis de motibvs stellae martis, ex observationibvs G. V. Tychonis Brahe (Pragae : n.p., 1609), pp. ***3 recto, 168. The quotation from the Epitomes is used here because it is the most complete statement by Kepler about Brahe and the spheres.

stroyed the spheres. Federico Cesi (1585-1630),[82] founder of the Accademia dei Lincei, and Giovanni Battista Baliana (1582-1660),[83] a Genoese patrician who later published works on the natural motions of solids, both credited Brahe with the destruction of the spheres. In his Apologia pro Galileo Thomas Campanella (1568-1639) listed several near-contemporary and contemporary writers who had proposed new concepts of the heavens which had not included a solid celestial region. The others, Nicolas of Cusa, Copernicus, Bruno, Patrizi, Gilbert, were cited for their opinions;[84] Brahe for his observations which confirmed these opinions.[85] Helisäus Röslin (d. 1616) in the same year, 1597, in which he published De opere dei creatoris, seu de mundo hypotheses, an hypothesis similar to Brahe's, used Tyche as the comparison for Kepler's denial of the spheres.[86]

Others did not mention Brahe but gave the argument that since the comets were above the Moon, there could be no spheres. Thomas Lydiat (1575-1646) titled the fourth chapter of his Praelectio astronomica "Astra non vehi solidis orbibus sed liquido aethere pendere."[87] Along with

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[82]Federico Cesi, Letter to Galileo Galilei dated June 20, 1612 in Galileo Galilei, Le opere di Galileo Galilei (Edizione Nazionale; Firenze: G. Barbera, 1890-1909), XI, pp. 332-333.

[83]Giovanni Battista Baliana, Letter to Galileo Galilei dated January 31, 1614 in Galilei, Le opere, XII, p. 21.

[84]Thomas Campanella, F. Thomae Campanellae Calabri, ordinis praedictorvm, apologia pro Galileo, mathematico Florentino. Vbi disqviritvr, vtrvm ratio philosophandi, qvam Galilevs celebrat, faueat sacris scripturis, an aduersetur (Francofvrti: Impensis Godefridi Tampachii, 1622), pp. 9-10.

[85]Ibid., pp. 18, 49, 54.

[86]Helisäus Röslin, Letter to Herwart von Hohenburg dated October, 1597, in Kepler, Gesammelte Werke, XIII, pp. 146-147.

[87]Thomas Lydiat, Praelectio astronomica. De natvra coeli &

the observations on comets, Lydiat included quotations from ancient writers, a denial of a special fifth element (for him the aether was just extremely tenuous air and the stars were fires), and "sententia complurium nostrae & superioris aetatis doctorum virorum" among his reasons for excluding the spheres from the heavens.[88]

Occasionally a writer questioned or denied the existence of the spheres in an aside remark that was related to but not important for the advancement of his major topic. Thus, although Edward Wright (1558?-1615) was writing a preface to Gilbert's De magnete concerning "magneticis hisce libris," when he mentioned "totum coelum, omnesque sphaerae," he added, "(siquae sint)."[89] Mark Ridley (1560-1624) writing almost twenty years later on the same subject, magnetism, defended Gilbert's theories including that of the diurnal motion of the Earth, tossing in the parenthetical remark "(for Spheres are but fained)."[90]

In his attempt to reconceil scriptural texts and the theory of a moving Earth, Paolo Antonia Foscarini (1580-1616) found it necessary to eliminate the spheres from the heavens. Foscarini stressed that the sacred texts had been written for the common people according to their under-

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conditionibus elementorum: tum autem de causis praecipuorum motuum coeli & stellarum. (Londini: Ioannes Bill, 1605), p. A6 recto: "That the stars are not carried by solid orbs but hang in the liquid aether."

[88]Ibid., p. 29: "the thought of many of the learned men of our superior age.

[89]Edward Wright, "Ad gravissimvm doctissimvmque virum De Gulielmum Gilbertum, medicinae apud Londinenses doctorem eximium, magneticaeque philosophiae parentum; de magneticis hisce libris, Edwardii VVrighti parainedis echnomiasine ," in Gilbert, De magnete, xiij verso-xv verso.

[90]Mark Ridley, Magneticall Animadversions upon Certaine Magneticall Advertisements from W. Barlow (London: N. Okes, 1617), p. 8.

standing and that therefore the true meaning was not always the literal interpretation of a given passage. In order to apply scriptural statements about the Earth to the whole universe, he denied that the celestial region was "constituted of a Matter different from that of the Elements, being free from all Mutation in it's Substance, Quantity, and Quality: Nor so admirable and excellent as Aristotle would make us to believe; not yet a solid Body, and impermeable; and much lesse (as the generality of men verily believe) of an impenetrable and most obdurate Density."[91]

Although Galileo Galilei (1564-1642) described the heavens as "solidissimum et densissimum ac proinde maxime potens ad resistendum contariis" in 1584,[92] by 1612 he had adopted a somewhat different position:

> . . . e per consequenza son sicurissimo che ci sono moti circolari che descrivono cerchi eccentrici e epicicli: ma che per descriverli tali la natura si serva realmente di quella faragine di sfere ed orbi figurati da gli astronomi, ciò reputo io così poco necessario a credersi, quanto accomodato all' agevolezza de' computi astronomici; e sono d'un parer medio tra quegli astronomi li quali ammettono non solo i movimenti eccentri delle stelle ma gli orbi e le sfere ancora eccentriche, le quali le conduchino, e quei filosofi che parimente negano e gli orbi e i movimenti ancora intorno ad altro centro che quello della terra.[93]

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[91]Paolo Antonio Foscarini, An Epistle of the Reverend Father Paolo Antonio Foscarini, a Carmelite, Concerning the Pythagorian and Copernican Opinion of the Mobility of the Earth, and Stability of the Sun, and of the New System or Constitution of the World. In Which, the Authorities of Sacred Scripture, and Assertions of Divines, Commonly Alledged against This Opinion Are Reconciled. Written to the Most Reverend Father Sebastiano Fantoni, General of the Order of Carmelites, Englished from the Original by Thomas Salusburie (London: William Leybourne, 1661 in Thomas Salusburie, Mathematical Collections and Translations in Two Parts. From the Original Copies, of Galileus, and Other Famous Modern Authors (London: George Sawbridge, 1667), p. 494. The letter was dated January 6, 1615.

[92]Galileo Galilei, "Iuvenilia," in Galilei, Le Opere, I, p. 66.

[93]Galileo Galilei, Istoria e Dimostrazioni intorno alle macchie

Twenty years later in the Discorre sopra i due massimi sistemi del mondo Tolemaico, e Copernicano Galileo wrote of the free movement of the planets without considering it necessary to discuss the existence or non-existence of the solid orbs.[94]

These men typified those who were no longer content with the generally accepted learning. With regard to the movement of the heavenly bodies, they had become dissatisfied with both the Ptolemaic and the Aristotelian explanations of celestial motions. Some had accepted the Copernican hypothesis; some had proposed systems of their own. When considering the structure of the heavens, some had abandoned the fifth element; some had scattered the fixed stars. In their considerations of the supralunar region a few had left it distinct from the sublunar world; none had allowed it to remain entirely different from the terrestrial world. All had

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solari in Galilei, Le opere, V, pp. 102-103: "Hence I am quite sure that there exist circular motions which describe eccentric and epicyclic circles. But that Nature, in order to provide these, really makes use of that farrago of spheres and orbs composed by the astronomers is, I think, not so much something we are expected to believe as it is a convenience in astronomical computations. My opinion lies midway between that of astronomers who assume eccentric movements on the part of stars as well as eccentric orbs and spheres to conduct them, and that of philosophers who deny equally the existence of such orbs and all movements not concentric with the Earth." English from Galileo Galilei, Letters on Sunspots in Discoveries and Opinions of Galileo, trans. Stillman Drake (Garden City, New York: Doubleday & Company, Inc., 1957), p. 97.

[94]Galileo Galilei, Dialogo di Galileo Galilei Linceo matematico sopraordinario dello stvdio di Pisa. E filosofo, e matematico primario del serenissimo Gr. Dvca di Toscana. Doue ne i congressi di quattro giornate si discorre sopra i due massimi sistemi del mondo Tolemaico, e Copernicano; proponendo indeterminatamente le ragioni filosofiche, e naturali tanto per l'vna, quanto per l'altra parte (Fiorenza: Per Gio. Batista Landini, 1632). See Maurice Clavelin, "Galilee et la cosmologie traditionnelle: La premiere journée du Dialogue," Revue d'Histoire des Sciences et de leurs applications, XV (1962), pp. 1-26 for a discussion of Galileo's agreements with and disagreement with the Aristotelian cosmology.

altered some part of the Aristotelian cosmology.

Not everyone agreed. Lynn Thorndike has evaluated the works of one group as follows:

> For more than half a century after the publication of De revolutionibus Aristotelian works on the heavenly bodies continued to appear as if nothing had happened. These expositions were normally purely theoretical and argumentative. They were not only unruffled by any extended reference to the Copernican theory, but for that matter to the Ptolemaic. They cited a wealth of past philosophical opinion from Plato down through Alexander of Aphrodisias, Philoponus, Themistius, Plotinus, Proclus, Eustratius, through Avicenna, Avicebron, Averroës, and other Arabic commentators, even through Latin schoolmen such as Aquinas, Aegidius, Occam, Capreolus and Cajetan, to recent writers like Ficino, Achillini and Zimara. But they seldom utilized anyone who possessed a first-hand knowledge of astronomy, and should therefore be regarded as largely ignoring astronomy and observation of any sort, rather than as opposing or neglecting the work of Copernicus in particular.[95]

Such an approach left no place for either a rejection or an affirmation of the celestial spheres.

The Ptolemaic tradition also continued. John of Holywood's (early thirteenth century) Sphaera,[96] George Purbach's (1423-1461) Theoricae novae planetarum,[97] the two standards, were each republished repeatedly in the

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[95] Thorndike, History of Magic and Experimental Science, VI, pp. 47-48.

[96] The Tractatus de sphera by John of Holywood was one of the earliest elementary astronomical textbooks written in western Europe to include the Ptolemaic system. For a discussion of the work, its author and the many manuscripts and printed editions of the Sphera see: Lynn Thorndike, The Sphere of Sacrobosco and Its Commentators (Chicago, Illinois: The University of Chicago Press, 1949), pp. 1-75.

[97] The Theoricae novae planetarum was first printed in 1488. For a list of subsequent publications see: J. C. Poggendorff, Biographisch-Literarisches Handwörterbuch zur Geschichte der exacten Wissenschaften Enthaltend Nachweisungen über Lebensverhältnisse und Leistungen von Mathematikern, Astronomen, Physikern, Chemikern, Mineralogen, Geologen usw. aller Völker und Zeiten (Leipzig: Johann Ambrosius Barth, 1863; Lithoprinted by Edwards Brothers, Inc., Ann Arbor, Michigan, 1945), II, col. 422.

last half of the sixteenth century, while new astronomical treatises using spheres, equants and epicycles followed one after another from the English and European presses.[98] In some of these the authors stated that the spheres were solid; in most they used the celestial orbs without regard for their physical reality. One could have conceived of them as either mathematical or physical devices.

In the popular literature the traditional doctrine also remained. The Zodiac vitae,[99] Le compost et kalendrier des bergiers[100] and the Image du monde[101] had been translated into various vernacular languages and were, thus, available to the peoples of many countries. Although the content of these and other writings, such as the Sphera of George Buchanan (1506-1582)[102] and La Sepmaine of Guillaume de Salluste Sieur Du Bartas (d. 1590),[103] ranged from astrological folklore to good descriptive

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[98] Thorndike, A History of Magic and Experimental Science, VI, pp. 3-66 surveys the works on astronomy published during the last half of the sixteenth century.

[99] Rosemond Tuve, "Introduction" in The Zodiake of Life by Marcellus Palingenius, trans. Barnabe Googe (New York: Scholars' Facsimiles & Reprints, 1947), pp. vi-xxvi.

[100] G. C. Heseltine, "Foreword," in The Kalendar & Compost of Shepherds from the Original Edition Published by Guy Marchant in Paris in the Year 1493, and Translated into English c. 1518: Newly Edited for the Year 1931 (London: Peter Davies, 1930), pp. v-ix.

[101] Oliver H. Prior (ed.), "Introduction," in Caxton's Mirror of the World (London: Kegan Paul, Trench, Trübner & Co., Ltd., 1913), pp. v-xi.

[102] George Buchanan, Georgii Buchanani Scoti Franciscanus et fratres. Elegiarum liber i. Silvarum liber l. Hendecasyllabon liber l. Epigrammaton libri iii. De sphaera fragmentum. s. l. (n.p.: n.p., 1584). This citation of the title page of the first edition and "A Partial Census of Copies and Editions" are given in: James R. Naiden, The Sphera of George Buchanan (1506-1582). A Literary Opponent of Copernicus and Tycho Brahe (n.p.: n.p., [1952]), pp. 157-165.

[103] Guillaume De Salluste Sieur Du Bartas, La Sepmaine, ou Création

astronomy, most of them postulated a geocentric, geostatic universe in which solid spheres carried the planets through the heavens. This type of learning was often the only source for the common people and generally retained its hold on its reading audience longer than the more accademically written literature contemporary with it.

These writers, the Aristotelians, the Ptolemaists, the popularizers, all generally accepted the universe as the universe had been thought of for the last thousand years. Even among these, however, some authors began to depart from the traditional cosmology and to allow a few minor changes in the sphere-filled heavens. Henry Decimator (c. 1580) formed the heavenly spheres of "aqua in aerem";[104] William Scribonius (fl. 1580) thought the ten celestial spheres to be "made of water, thinne like a skinne";[105] Joseph Acosta (1539-1600) did not specify the material of which the heavens were composed but affirmed "that this space & region by which they faine that stares do continually march and rowle, is elementarie

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du Monde, de Guillaume de Salluste, Seigneur du Bartas (Paris: Chez Michel Gadoulleau, 1578). This citation and the editions of Du Bartas are listed in: Guillaume De Salluste Sieur Du Bartas, The Works of Guillaume De Salluste Sieur Du Bartas. A Critical Edition with Introduction, Commentary, and Variants, ed. Urban Tigner Holmes, Jr. et al. (3 vols; Chapel Hill, North Carolina: The University of North Carolina Press, 1935-1938), I, pp. 67-110.

[104]Heinrich Decimator, Libellvs de stellis fixis et erraticis non tantum astronomis, verum etiam ijs, qui in scribendis se versibus, exercent vtilis. In fine brevis additvs est tractatus de stellis crinitis siue cometis, & stellis cadentibus (Magdeburgi: 1587), p. A2 recto.

[105]Gulielmus Adolphus Scribonius, Natvrall Philosophy: Or a Description of the World, and of the Severall Creatures Therein Contained: Vis. of Angels, of Mankinde, of the Heavens, the Starres, the Planets, the Foure Elements, with Their Order, Nature and Government: As Also of Minerals, Mettals, Plants, and Precious Stones: With Their Colours, Formes and Vertues, trans. Daniel Widdowes (2d ed.; London: Tho. Cotes, 1631), p. 6. Compare: Gulielmus Adolphus Scribonus, Rerum physicarum

and corrputible."[106] Loys le Roy (c. 1590) left the spheres in the heavens but also permitted change in that hitherto incorruptible region.[107]

No one of these or similar minor changes in the Aristotelian corpus was of itself sufficient to change the prevailing concepts. Yet, cumulatively they gained such acceptance that writers of the early seventeenth century considered the belief in a sphereless heaven more widespread than the adherence to a sphere-filled one. Godefridus Chassinus (fl. 1610) after much study became dissatisfied with the traditional cosmologies and presented a world system based upon his own reflections rather than on the ideas of previous philosophers. When discussing the fluid nature of the celestial region, Chassinus remarked that formerly men had thought the heavens were solid but now they knew them to be of a subtle substance.[108]

In 1619 Mario Guiducci (1585-1646), friend of Galileo and consul of the Florentine Academy, wrote that

E prima, io lascio stare che 'l porre quelle distinzioni di sfere

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iuxta leges logicas methodica explicatio Gulielmi Adolphuo Scribonius Marpvrgensis. Nunc denuo recognita, & in plurimis locis emendata (Francofvrti: Apud Andream Wechelum, 1579), pp. 29-30.

[106] Ioseph Acosta, The Natvrall and Morall Historie of the East and West Indies Intreating of the Remarkeable Things of Heaven, of the Elements, Mettalls, Plants and Beasts Which Are Proper to That Country: Together with the Manners, Ceremonies, Lawes, Governements, and Warres of the Indians, trans. [Edward Grimstone] (London: Edward Blount and William Aspley, 1604), p. 7.

[107] Loys le Roy, Of the Interchangeable Covrse, or Variety of Things in the Whole World; and the Concvrrence of Armes and Learning, Through the First and Famousest Nations: From the Beginning of Civility, and Memory of Man, to This Present. Moreover, Whether It Be True or No, That There Can Be Nothing Sayd, Which Hath Not Bin Said Heretofore: And That We Ought by Our Owne Inuentions To Augment the Doctrine of the Auncients; Not Contenting Ourselues with Translations, Expositions, Corrections, and Abridgments of Their Writings, trans. R. A. (London: Charles Yetsweirt, 1594), f. 1. recto.

[108] Thorndike, The History of Magic and Experimental Science, VI, p. 384.

> e orbi celesti, ne' quali fermamente le stelle fussero affisse e che solo al movimento di quegli andassero in volta, è ormai tanto notoriamente pieno d'inverisimili e di repugnanze, che 'nsino a buona parte de più ostinati contradittori s'inducono a deporgli, e a credere i pianeti esser mobili per loro stessi. . . .[109]

A few years later Francis Bacon (1561-1626) dismissed the subject with:

> Explosa enim fere jam pridem sunt, illa, Raptus Primi Mobilis, et Soliditas Coeli, (stellis in orbibus suis tanquam clavis in laqueribus infixis).[110]

The reasons why the doctrines had been exploded are a mixture of theoretical and observational considerations. The speculative elements were somewhat different, but not radically so, from those arguments which had been presented by earlier writers. Whenever the spheres had interfered with a theory, theorists had seldom hesitated to sacrifice the spheres. In previous ages, however, such theorists had been men whose influence on later generations turned out to be less significant than

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[109] Mario Guiducci, Discorso delle cometė di Mario Gvidvcci Fatto da lvi nell' accademia Fiorentina nel svo Medesimo consolato (In Firenze: 1619) in Galileo, Opera, VI, p. 86: "First, let it be said that the assumption of distinct celestial spheres and orbs in which stars are firmly fixed and by whose motion alone they are set to turning has at length become so notoriously full of improbabilities and contradictions that even many of our most stubborn antagonists have been led to get rid of them by believing the planets to move by themselves." English translation from: Mario Guiducci, Discourse on the Comets in The Controversy on the Comets of 1618, pp. 48-49.

[110] Francis Bacon, The Works of Francis Bacon, Baron of Verulam, Viscount St. Albans, and Lord High Chancellor of England, ed. James Spedding, et al. (15 vols; New York: Hurd and Houghton, 1864), II, p. 270: "For those Dogmaes and Paradoxes are almost vanisht, & long agoe exploded, namely, the Rapture of the First Mover: and the Solidity of Heaven (starres being there fixt as nailes in the arched Roofe of a Parlour)." English translation from: Francis Bacon, Of the Advancement and Proficience of Learning or the Partitions of Sciences ix Bookes. Written in Latin by the Most Eminent Illustrious & Famous Lord Francis Bacon, Baron of Verulam, Vicunt St. Alban, Counsilour of Estate and Lord Chancellor of England, Interpreted by Gilbert Wats (Oxford: Rob. Young, & Ed: Forrest, 1640), pp. 145-146.

that of many of their contemporaries. Lucretius (d. c. 55 B.C.),[111] Sosigne (c. 190),[112] Proclus (410-483),[113] Giles of Rome (1247-1316)[114] and Nicolas of Cusa (1401-1464)[115] had, each in turn, suggested that the planets wandered freely through space. Their ideas were overshadowed by the writings of Aristotle, Ptolemy, Simplicus (fl. 580), Al Fargani (fl. 833) and Al Farabi (fl. 950), Saint Thomas Aquinas and John of Holywood, writings in which the more orthodox doctrines of astronomy were taught. The situation was reversed around 1600. The men--Brahe, Gilbert, Kepler, Galileo--who denied the spheres were among the prominent natural philosophers in Europe in their own time and were the most influential in later ages.

After 1588, the date of the publication of Brahe's De mundi aetheri the rejection of the solid heavens was linked to observational data. Robert Burton (1577-1640) in The Anatomy of Melancholy provided his readers

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[111] Lucretius De rerum natura i, ii, v.

[112] Sosigne, the tutor of Alexander of Aphrodisias, wrote a work against the homocentric sphere theory. Parts of this have been preserved in Simplicius' commentary on Aristotle's De caelo. See: Pierre Duhem, Le système du monde. Histoire des doctrines cosmologiques de Platon a Copernic I (Paris: A. Hermann et fils, 1913), pp. 400-404.

[113] Proclus surnamed the Successor was head of the Academy until 485 and one of the foremost Neoplatonists of the fifth century. Among his writings is the Hypotheposis astronomicarum positionum in which he suggests that the movements of the stars which are observed are the true movements of those bodies. See Duhem, Le système, II, pp. 103-107.

[114] Giles of Rome, a student of Saint Thomas Aquinas, tried to incorporate atomism into the Aristotelian cosmology. See: George Sarton, Introduction to the History of Science (Baltimore, Maryland: The Williams and Wilkins Co., 1947), III, pp. 546-547.

[115] See p. 28 supra.

with a review of recent theories:

> Is it much controverted betwixt Tycho Brahe, and Christopher Rothmann the Landgrave of Hassias Mathematician, in their Astronomicall Epistles, whether it be the same Diaphanum, cleereness, matter of the Aire and Heavens, or two distinct Essences? Christopher Rothmann, Iohn Pena, Iordanus Brunnus, with many other late Mathematicians contend that it is the same, and one matter throughout, sauing that the higher, still the purer it is, and more subtile. Tycho will have two distinct matters of Heaven and Aire; but to say truth, with some small qualifications, they haue one and the selfesame opinion, about the Essence and matter of Heavens, that it is not hard and impenetrable, as Peripateticks hold, transparent of a quintaessentia, but that it is penetrable and soft as Aire itself is, and that the Planets move in it, as Birds in the Aire, Fishes in the Sea. This they proue by motion of Comets and otherwise, which are not generated as Aristotle teacheth, in the aeriall Regions of an hot and dry exhalation, and so consumed, but as Anaxagoras & Democritus held of old, of a celestiall matter & as Tycho, Helisanus, Roeslin, Thaddaeus Haggesius, Pena, Rothmann, Fracastorius, demonstrate by Paralaxes, refractions, motions of the Planets which interfeire & cut one anothers orbs, now higher, and then lower, as Mars amongst the rest, which sometimes, as Kepler confirmes by his owne, and Tycho's accurate observations, comes nearer the Earth than the sun, and is again sometimes aloft in Juppiters orbe. & by other sufficient reasons, farre aboue the Moone: exploding in the meanetime that Element of Fire, those monstrous Orbes of Eccentricks, and Eccentre Epicycles. Which howsoever Ptolemy, Athasen, Vitello, Maginus, Clavius, and many of their associates stiffely maintaine, to be reall orbes, excentricke, concentricke, circles aequant &c. are absurd and ridiculous. For who is so mad to thinke, that there should be so many circles, like subordinate wheeles in a clock, all impenetrable and hard, as they faine, adde and substract at their pleasures.[116]

The spheres had been destroyed. Not by Copernicus. Not by the appearance of the New Star of 1572 or of the Comet of 1577. Not by the Platonists or atomists who had long denied them. But by the repeated statements of many men who conceived of a celestial region in which solid sphere were inconceivable and who joined their disavowal to recently ob-

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[116] Robert Burton, The Anatomy of Melancholy: What It Is. With All the Kindes, Cavses, Symptomes, Prognosticks, and Severall Cvres of It. In Three Maine Partitions, with Their Seuerall Sections, Members, and Svbsections. Philosophically, Medicinally, Historically Opened and Cut Up (2d ed.; Oxford: Henry Cripps, 1624), pp. 214-215.

served astronomical phenomena. Each man had destroyed the spheres in order to solve some problem within his own specialized theoretical framework. Few of them seemed to realize that the solution to one problem had created several others.

CHAPTER III

VITALISTIC MOTORS

By eliminating the spheres from the celestial region natural philosophers had countered one argument against placing comets above the Moon, avoided the necessity of an *ad hoc* hypothesis of non-refractiveness for the solid aethereal bodies, and permitted themselves and others to devise planetary systems in which the path of one globe intersected that of another. While a sphereless heaven solved these difficulties, new problems arose when the supralunar region no longer contained the solid orbs. Writers could and did use Air, Aether, Fire or some equally subtle substance to occupy the space left vacant in the celestial world; but, while these fluids could and did replace the spheres spatially, they were not suitable as the efficient causes of planetary motions. For those who wished to consider such causes of celestial movements some adjustments were needed.

Not all wanted to discuss this question. Throughout the centuries many astronomers had avoided the debate over the reality of the spheres and epicycles. These writers had written of a motion natural to the heavens and then proceeded to describe the movements of the bodies governed by these motions rather than attempting to explain what produced them. Nicolas Copernicus in his *De revolutionibus* followed this tradition, and Thomas Digges in his English presentation of the heliocentric theory did likewise.[2] Both men used the terms "sphere" and "orb" in relation to the planets, but neither indicated whether or not he considered these as solid bodies.[3]

Tycho Brahe assumed a regular circular motion for the heavenly bodies but did not concern himself with any details of the agents producing these motions or any mechanism for transmitting motion. It was sufficient for him that

> ipsa Sidera obtinere naturalem quandam & connatam, aut potius Diuinitus ab initio inditam, & perpetuo conseruatam motus regularis Scientiam, qua cursus suos, nullis Orbibus impulsi, vel fulciti, perfectissime constantissimeque absoluunt.[4]

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[1]Nicolas Copernicus, Nicolai Copernici Torinensis de revolvtionibvs orbium coelestium, libri vi. (Norimbergae: Apud Ioh. Petreium, 1543).

[2]Thomas Digges, "A Perfit Description of the Celestiall Orbes according to the Most Aunciente Doctrine of the Pythagoreans, Latelye Reuiued by Copernicvs and by Geometricall Demonstrations Approued," in Leonard Digges, A Prognostication Euerlastinge of Righte Good Effecte, Fruitfully Augmented by the Auctour, Contajning Plaine, Briefe, Pleasaunt, Chosen Rules to Iudge the Weather by the Sunne, Moone, Starres, Comets, Rainebow, Thunder, Cloudes, with Other Extraordinary Tokens, Not Omitting the Aspects of Planets, vvith a Briefe Iudgement for Euer, of Plenty, Lacke, Sickeness, Dearth, VVarres, &c. Opening also Many Naturall Causes VVorthy To Be Knovven. To These and Other Now at the Last, Are Ioyned Divers Generall, Pleasaunt Tables, vvith Mayne Compendious Rules, Easye To Be Had in Memory, Manifolde Vvayes Profitable to Al Men of Vnderstanding (London: Thomas Marsh, 1576).

[3]Coperncius, De revolutionibus, pp. 7 verso-10 recto; Digges, A Prognostication Euerlastinge, pp. A1, recto, A4 recto, passim.

[4]Tycho Brahe, Tychonis Brahe Dani de mvndi aetherei recentioribvs phaenomenis. Liber secvndvs qvi est de illvstri stella cavdata ab elapso fere triente Nouembris anni 1577, vsque in finem Ianuarij sequentis conspecta (Vranibvrgi: [1588]) in Tycho Brahe, Tychonis Brahe Dani opera omnia, ed. I. L. E. Dreyer (15 vols.; Hauniae: In Libraria Gyldendaliana, 1913-1929), IV, pp. 223-224: " . . . those stars possess a certain natural and innate, or rather infused from the beginning by Divine Providence, knowledge of regular motion, constantly maintained, by which they complete most perfectly and most constantly their courses, driven or supported by no orbs."

Galileo Galilei sidestepped the problem of naming the efficient causes of celestial movement by dismissing it along with the principles involved in other well-known motions:

> Salv. Io non hò detto, che la terra non habbia principio, nè esterno, nè interno al moto circolare, ma dico, che non so qual de dua ella si habbia; & il mio non lo sapere, non haforza di leuarglielo; ma se questo autore sa da che principio sieno mossi in giro altri corpi mondani, che sicuramente si muouono; dico che quello, che fa muouer la terra, è vna cosa simile a quella, per la quale si muoue Marte, Gioue, e che e' crede, che si muoua anco la sfera Stellata; e se egl' mi assicurerà chi sia il mouente di vno di questi mobili, io mi obbligo a sapergli dire chi fà muouer la terra. Ma più; io voglio far l'istesso, s'ei mi sà insegnare chi muoua le parti della terra in giù.[5]

After Simplicius had answered that the weight (la gravita) of a body caused it to fall downward and that this cause was well known, Salviati continued:

> Salv. Voi errate Sig. Simpl. voi doueui dire, che ciaschedun sa ch' ella si chiama grauità; ma io non vi domando del nome, ma dell' essenza della cosa: della quale essenza voi non sapete punto più di quello, che voi sappiate dell' essenza del mouente le Stelle in giro; eccettuatone il nome, che a questa è stato posto, e fatto familiare, e domestico per la frequente esperienza, che mille volte i giorno ne veggiamo; ma non è che realmente noi intendiamo più,

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[5]Galileo Galilei, Dialogo di Galileo Galilei Linceo matematico sopraordinario dello stvdio di Pisa. E filosofo, e matematico primario del serenissimo Gr. Dvca di Toscana. Doue ne i congressi di quattro giornata si discorre sopra i due massimi sistemi del mondo Tolemaico, e Copernicano; proponendo indeterminatamente le ragioni filosofiche, e naturali tanto per l'vna, quanto per l'altra parte (In Fiorenza: Per Gio. Batista Landini, 1632), pp. 229: "Salv. I did not say that the earth has neither an external nor an internal principle of moving circularly; I say that I do not know which of the two it has. My not knowing this does not have the power to remove it.

"But if this author knows by which principle other world bodies are moved in rotation, as they certainly are moved, then I say that that which makes the earth move is a thing similar to whatever moves Mars and Jupiter, and which he believes also moved the stellar sphere. If he will advise me as to the motive power of one of these movable bodies, I promised I shall be able to tell him what makes the earth move. Moreover, I shall do the same if he can teach me what it is that moves earthly things downward." English translation from: Galileo Galilei, Dialogue Concerning the Two Chief World Systems--Ptolemaic & Copernican, trans. Stillman Drake (Berkeley, California: University of California Press, 1953), p. 234.

> che principio, ò che virtù sia quella, che muoue la pietra in giù, di quel che noi sappiamo chi la muoua in sù, separata dal proicienti, ò chi muoua la Luna in giro, eccettochè (come hò detto) il nome, che più singulare, e proprio gli habbiamo assegnato di gravità, doueche a quello con termine più generico assegnamo virtù impressa, a quello diamo intelligenza, o assistente, ò informante; & a infiniti altri moti, diamo loro per cagione la natura.[6]

These men were less concerned with the motive forces than with the movements themselves, and they had used a time-honored device, the assuming of a motion natural to the heavens, to avoid discussing what was to them a non-important topic; this subject they left to those who considered it important. Among the men so interested two approaches to the problem appeared. The writers discussing the entire cosmos often used vitalistic principles as efficient causes for planetary motions; those dealing with only the planetary system more frequently looked for some previously known, non-vitalistic motor that could be incorporated into the heavenly system.

The natural philosophers who had denied the spheres and who wished to use some non-corporeal beings as planetary movers, had available models

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[6]Galileo, Dialogo, p. 230: "Salv. You are wrong, Simplicio; what you ought to say is that everyone knows that it is called 'gravity.' What I am asking you for is not the name of the thing, but its essence of which essence you know not a bit more than you know about the essence of whatever moves the stars around. I except the name which has been attached to it and which has been made a familiar household word by the continual experience that we have of it daily. But we do not really understand what principle or what force it is that moves stones downward, any more than we understand what moves them upward after they leave the thrower's hand, or what moves the moon around. We have merely, as I said, assigned to the first the more specific and definite name 'gravity,' whereas to the second we assign the more general term 'impressed force' (virtue impressa), and to the last named we give 'spirits' (intelligenza), either 'assisting' (assistente) or 'abiding' (informante); and as the cause of infinite other motions we give 'Nature.'" English translation from Galilei, Dialogue, pp. 234-235. In the Two New Sciences (1638) when discussing the motion of falling bodies. Galileo again avoided a discussion of the cause of this motion. See: Galileo Galilei, Discorsi e dimostrazioni matematiche, intorno à due nuoue scienze attenenti alla mecanica & i movimenti locali (In Leida: Appresso gli Elsevirii, 1638), p. 163.

from contemporary as well as from earlier writers. The homocentric theory as revived by Girolamo Fracastoro (1483-1553) saved the heavenly phenomena by the use of geocentric spheres having natural motions.[7] Fracastoro considered the possibility that some intelligence guided each sphere and insisted that if such intelligences ruled the system, there could be one and only one intelligence for every sphere in the system:

> Siue igitur orbis a se ipso moueatur, siue a mente aliqua & vocata intelligentia, uno tantum modo moueri necesse est. quoniam unum et naturae unius est principium, quod movet. a duabus enim intelligentijs unum orbem moueri nemo est, qui dixerit. una igitur si est quae mouet intelligentia, nec duos quidem praebere motus potest, nec unum diuersimode se habentem, si simplex est & unum. Per uoluntatem autem & ex libito mouere (tametsi pius nemo simpliciter negare debet) at in orbibus tamen induci non potest, quorum motus, naturales omnino sunt. omne enim corpus naturalem sibi aliquem motum poscit. Igitur si intelligentia eo semper motu mouet, qui orbi pro natura debetur, uno quidem semper mouebit motu. si uero non eodem semper motu mouet, sed quandoque & contrario, inconueniens certe erit pungantiam uimque intercedere inter mouentem intelligentiam, & motum orbem diuinum corpus & immortale.[8]

Because he considered each sphere a simple natural body capable of a simple natural motion, Fracastoro demanded that any intelligence in the celestial

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[7]Girolamo Fracastoro, Hieronymi Fracastorii homocentrica evisdem de cavsis criticorvm diervm per eaqvae in nobis svnt ([Venetiis]: 1538), pp. 3-4.

[8]Ibid., p. 5 recto-verso: "Therefore whether the orb is moved by itself or by some mind and named intelligence, it is necessary, moreover, that it be moved in one way, because it is one principle and of one nature that moves. For there has been no one who has said that one orb is moved by two intelligences. One, therefore, if that which moves it is an intelligence, neither can it [the intelligence] certainly lead two motions, nor one [orb] having a diverse motion, if it is simple and one. However, it is not possible that it move through its will and from its pleasure (which any pious person must simply deny) but it is, moreover, led in orbs, whose motions are entirely natural. For every body possesses some motion natural to itself. Therefore, if the intelligence moves always by the same motion which must be natural to the orb, indeed it will move by one motion; if truly it does not always move by the same motion, but now and then and to the contrary, it will certainly be unsuitable to a divine and immortal body, and a fighting spirit will come between the moving intelligence and the moved orb."

system be completely independent of any other and not governed by a common intelligence.[9]

Jerome Cardan (1501-1576), mathematician, physician, natural philosopher, and one of the most prolific and popular writers of the period, not only used the postulate that Angels moved the solid orbs but assigned choirs and individual angelic spirits to certain spheres. Cardan, like many of his contemporaries, mixed astronomy and astrology so that the celestial bodies served as intermediaries between the Angels and the sublunar world.

In Cardan's system the Angels under Gabriel controlled the Moon, which affected the elements and bodies of living things. The Virtues led by Raphael governed Mercury, the planet assigned to the intellect and senses. Venus, the mother of enjoyment and delight, guarded the procreation of the species under the direction of the Dominations and their leader Anael. Since the Sun was the principal source of all life, it was placed in the care of Michael, the Prince of the Archangels. Mars, guided by Samael and the Powers, protected the bold while Jupiter, directed by Sachiel and the Principalities, established peace and tranquility. Thrones, whose leader was Cassiel, accompanied Saturn and the Seraphim and Cherubim respectively turned the eighth and ninth orbs.[10]

Cardan did not distinguish between angelic beings and the non-corporeal but knowing spirits that other writers named Intelligences. For him the two terms were interchangeable: "De Angelis, seu intelligentiis."[11]

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[9] _Ibid._, pp. 5 _verso_-6 _recto_.

[10] Jerome Cardan, _Hieronymi Cardani Mediolanensis, medici, de svbtilitate, libri xxi. Nunc demum ab ipso autore recogniti, atque perfecti_ (Lvgdvni: Apud Gulielmum Rouillium, 1559), pp. 696-697.

[11] _Ibid._, p. 693.

Francisco Vicomercato (d. 1570), physician and royal professor to the French crown, followed the Aristotelian teaching that the principles of any natural motion were internal ones,[12] but he showed little concern for the name of this principle in the celestial region: "Motus vero in orbem ab anima est, seu forma coeli, sua etiam ab intelligentia. . . ."[13]

One of the Italian group who continued the Averroesian tradition was more precise. Caesar Cremonis (1550-1631) would not allow intelligences to run the heavenly spheres in his system because

> In intelligentia tria considero, substantiam, intellectionem, intelligibilitatem. . . . Non potest coniungi coelo ratione substantiae, quia est prorsus de se subsistens, nullam ad aliud includens relationem; non potest etiam coniugi ratione intellectionis, quia intellectio, quae coniungatur alteri debet esse intellectio practica. Per hanc enim intellectus recedit extra se, sicut per speculatiuam secedit in se; intellectio vero intelligentiae est speculatiua, quare non potest esse coniunctio ratione intellectionis. Relinquitur intelligibilitas, quod erit id quod recipiemus.[14]

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[12] Francisco Vicomercato, Francisci Vicomercati Mediolanensis de principiis rervm natvralivm. Libri tres. Nunc primvm in lvcem editi. Cum privilegio (Venetiis: Apud Franciscum Bolzetam Bibliopolam Patauinum, 1596), pp. 15 recto, 120 recto.

[13] Ibid., p. 118 recto: "Truly motion in the orb is from the soul, or form of the sky, even from its intelligence." Cf. Francisci Vicomercati philosophi regii in eam partem duodecimi libri metaphysicorum Aristotelis, in qua de Deo, divinisque omnibus mentibus differitur, commentarij, vna cum eivsdem partis è Graeco in Latinum conversione (Venetiis: Exofficina Dominici Gverrei, et Io. Baptistae Fratrvm, 1580), p. 1-4.

[14] Cesare Cremonini, Caesaris Cremonini disputatio de coelo in tres partes diuisa. De natura coeli. De motu coeli. De motoribus coeli abstractis. Adiecta est apologia dictorum Aristotelis de via lactea. De facie in orbe lunae (Venetiis: Apud Thomam Balionum, 1613), p. 110: "In the intelligence I consider three things, substance, knowing, understanding. . . . It [the Intelligence] cannot be joined to the heavens by reason of substance because it certainly subsists de se enclosing another in no respect; it cannot even be joined by reason of knowing because knowing which is joined to another must be an active knowing. For through this the intellect recedes outside itself as it withdraws in itself through speculation; knowing of the intelligence is truly speculative where it cannot be joined by reason of knowing. There remains understanding which will be that which we will accept."

The understanding thus accepted was joined to a celestial anima which then became the incorporeal agent of heavenly motions. The heavenly souls could be and were joined to the material heavens, although Cremonis, like Averroes before him, was unable to explain the exact mode of their operation:

> semper autem relinquitur considerandus modus, quo ille motor abstractus componatur mobili corporeo, quae ibi non potuit exponi, nec faciebat ad intentum illius disputationis.[15]

One of Cremonis's contemporaries, John Combachius of Wetteram (1585-1651), professor of philosophy at the University of Marburg, tried to separate the motion natural to the heavens from the cause of this motion by discussing the movement in two different aspects. If one considered the object being moved, then the movement of that body was natural "quoad motus is perficitur passo non repugnante, hoc est quoad violentus non est."[16] In this case the subject "per naturam est habile & idoneum ad eum motum recipiendum."[17] However, if one studied the agents of heavenly motions, then one passed from the realm of natural motion to that of voluntary ones. Such a movement "proxime ab agente intellectuali proficiscitur."[18] The

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[15] Ibid., p. 113: "always, however, the consideration of the way in which that abstract motor is joined to the moving body remains, which could not be explained there nor was it made the extent of this disputation."

[16] John Combachius, Joh. Combachii Wetterani physicorum libri iv. Juxta sensum Aristotelis & Peripateticorum magno studio & labore e diversis authoribus collecti, & in Academia Marpuggensi antehac publice propositi. Editio altera priori auctior & emendatior (Francofurti ad Moenum: Impensis Johan-Caroli Unckelii Bibliopolae ac civis, 1629), p. 354: "as long as the motion is completed by permitting it not by resisting it, that is as long as it is not violent."

[17] Ibid.: "is by nature suited and proper to receive that motion.

[18] Ibid., p. 355: "orginates directly from an intellectual agent."

celestial intelligence was an assisting one and was controlled by the anima mundi or vis vniversi.[19] The diversity of motion produced by the one principle was explained by assuming that while the action of the anima mundi was uniform the mode of receiving it varied from one body to another and "operatur pro natura specialium corporum."[20] Combachius was an Aristotelian and with the exceptions of his denial of the celestial-terrestrial dichotomy[21] and the admission that comets were supralunar[22] his work differed little from similar commentaries written a century or more earlier.

While any one of these, angels, intelligences or anima could have been transferred from the spheres to the globes themselves, the angels and intelligences were seldom, if ever, used in this way. Joseph Acosta considered the possibility of an "Angell or intellectuall Spirite" guiding the Comet of 1577,[23] but he was less specific about the planetary movers: "The diverse aspects which we see appeare in planets & starres may proceede from the diversity of motion which he that guides them doth voluntarily give them."[24]

If Acosta were referring to an "Angel or intellectual Spirite," this is the only occasion of assigning such a being to a celestial body not attached to a sphere (Acosta considered the comets to be sublunar) that this writer has been able to find. Perhaps the reason for this is that many

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[19] Ibid., pp. 152, 310-315, 353.

[20] Ibid., p. 314: "it operated for the nature of the specialized bodies.

[21] Ibid., p. 342

[22] Ibid., pp. 365-375.

[23] Ioseph Acosta, The Natvrall and Morall Historie of the East and West Indies Intreating of the Remarkeable Things of Heaven, of the Elements, Mettalls, Plants and Beasts Which Are Proper to That Country: Together with the Manners, Ceremonies, Lawes, Governements, and Warres of the Indians, trans. [Edward Grimstone] (London: Edward Blount and William Aspley, 1604), p. 137.

Ibid., p. 7.

philosophers may have agreed with the Spanish theologican Pedro Sanchez di Licaraco (d. 1614). Sanchez asked:

> Vtrum Angelus moueat coelum? & respondendum est quod non: quia si moueret, tam tiui suorum correlatiuorum essent inferius & biles superius, & etiam per suam forman iam non moueret elementa, nec elementata, sed per suam materiam quod est impossible.[25]

Although he eliminated the Angels as celestial movers, Sanchez and others like him wanted to allow some form of a soul to control the motions of the heavens:

> Quaeritur utrum coelum habeat animam motiuam: & respondendum est quod sic; nam aliter sensitiua, & vegetatiua non haberent animas motivas: nec elementa haberent motus.[26]

As the late sixteenth century writers had changed the concepts of

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[25] Pedro Hieronymo Sanchez di Licaraco, Generalis et admirabilis methodvs ad omnes scientias facilivs, et scitivs addiscendas: in qua eximij & piissimi doctoris Raimundi Lullji ars breuis, explicatur: & multis exemplis, variisque quaestionibus, circa facultates, quae in scholis docentur, ad praxim (quod nunquam factam legitur) apertissime reducitur (Turiasonae: Per Carolum â Lauayen, 1619), pp. 394-395: "Whether an Angel moves the heaven? and the answer is that he does not. Because if he did move it, then the "tiui" of his correlatives would be the inferior and the "biles" the superior, and furthermore, then he would move the elements or the bodies composed of elements not through his form but through his matter which is impossible." The exact meaning of "tiuus" and "biles" in this passage is difficult to ascertain. The words are not listed in the standard Latin dictionaries. Sanchez probably picked them up from his medieval source Raymond Lully. Rev. Marcian Strange, O.S.B. of Saint Meinrad Archabbey, Saint Meinrad, Indiana suggested this possibility: "BILES is the nom. pl. of VILIS (b switching with v) meaning low or inferior, and TIUI is the nom. pl. of DIVUS or DIUUS (v is same as u, and the dental t could, I think, replace another dental d) meaning divine or superior. Translation: Does an angel move the sky? The answer is no: because, if an angel moved the sky, then the superior (tiui) angels--in case they were the ones moving the sky--would be below their own peers (namely those superior angels who would not be lowered by contact with something as low as the sky), or the inferior (biles) angels--in case they were the ones moving the sky--would be above their peers (namely those inferior angels who would not be raised in dignity by contact with something as high as the sky)." For another denial of the possibility of the angels moving the heavens see: Nicholas Hill, Philosophia Epicvrea, Democritiana, Theophrastica proposita simpliciter, non edocta (Coloniae Allobrogum: Prostant in Officina Fabriana, 1619), pp. 47-48.

[26] Ibid., p. 395: "It is asked whether the heaven has a motive soul. And the answer is that it does, for otherwise the sensitive and vegetative

the heavenly region, so did two of them propose their own ideas of the souls dwelling within the universe. Both men were Italians; both were anti-Aristotelian. One was an atomist, the other a Platonist. Neither was an observational astronomer. Each wrote on a wide variety of subjects and each had his works containing his cosmological ideas placed on the Index. The two men were Giordano Bruno and Francisco Patrizzi.

The man who exalted and extolled the celestial anima to the greatest extent in the sixteenth century was the younger of the two, Giordano Bruno. An Italian Dominican trained in the Aristotelian-Thomistic tradition, Bruno was among those who found the accepted cosmology unacceptable and sought to replace it. His philosophical and theological speculations were such that he was soon disagreeing with Church, state, philosophers and theologians. The protectors of dogma condemned him as a heretic; the defenders of the geocentric universe considered him a fool; few, if any, of his contemporaries understood his world vision.[27]

The universe, as Bruno conceived it, was infinite in time and space. Numberless worlds, peopled by innumerable multitudes, moved eternally in an unbounded region. Within this vast cosmos, the heliocentric system that Copernicus had described contained man's globe, the Earth, a planet not unlike many in the universe with creatures only accidentally different from those elsewhere.[28] The atomic theory of Leucippus and Democritus as

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beings would not have motor souls; nor would the elements have motions."

[27]Dorothea Waley Singer, Giordano Bruno, His Life and Thought. With Annotated Translation of His Work On the Infinite Universe and Worlds (New York: Henry Schuman, 1950), pp. 3-25, 49-50, 133-180.

[28]Alexandre Koyré, From the Closed World to the Infinite Universe

presented by Lucretius in his De rerum natura provided Bruno with a forerunner of his mimina or monads from which all things were formed, while the theory of Nicolas of Cusa gave him a recent predecessor for the infinite extension of the limits of the universe.[29] Everything from monads to celestial bodies responded to surrounding conditions according to its nature. This response, while brought about by factors external to the object, came from within and was governed by the soul of that body.[30] Thus, all motion in Bruno's world was directed by anima.

Bruno expressed his idea of universal animism as early as 1582 in his De umbris idearum.[31] The concept of a living cosmos composed of animated parts was only incidental in this work;[32] it was one of the many speculations mixed among the aids for improving one's memory.

> There are, in De Umbris, foreshadowings of his philosophic syncretism; but he has not yet welded the conclusions of others into a vital whole or made them live anew in his own completer thought; the work is tentative and contains only the germ of the Bruno that was presently to appear. . . .[33]

Two years later while in London Bruno delineated his cosmology in

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(Baltimore, Maryland: The Johns Hopkins Press, 1957), pp. 39-55; Singer, Giordano Bruno, p. 323.

29Singer, Giordano Bruno, pp. 50-51, 71-74.

30Ibid., pp. 74-79.

31Giordano Bruno, Iordanvs Brvnvs Nolanvs de vmbris idearvm. Implicantibus artem, quaerendi, inveniendi, iudicandi, ordinandi, & applicandi: ad interam scripturam, & non vulgares per memoriam operationes explicates (Parisiis: Apud Aegidium Gorbinum, 1582), in Giordano Bruno, Jordani Bruno Nolani opera latine conscripta publicis subptibus edita, edited F. Fiorentino (3 vols. in 8 parts; Neapoli: Dom Morano, 1879-1891), II, Pars 1, pp. 1-177.

32Ibid., pp. 30, 42-44, 47, 91-92.

33William Boulting, Giordano Bruno, His Life, Thought, and Martydrom (London: Kegan Paul, Trench, Trübner & Co. Ltd., 1914), p. 70.

three works writtin in Italian: La cena de la ceneri,[34] De la cause, principio et uno,[35] and De l'infinito universo et mondi.[36] All three were published the same year; all dealt with the same subject and they "are perhaps the most important among all Bruno's writings."[37]

In Brunerian thought there were two causes for all motion, one finite, one infinite:

> Dico dumque che nelle cose é da contemplare (se cossi uolete) doi principii attiui di moto; l'uno finito, secondo la raggione del finito soggetto, et questo muoue in tempo: l'altro infinito, secondo la raggione dell' anima del mondo, ouero della diuinitá, che é come anima de l'anima la quale é tutta in tutto, et fá esserl'anima, tutta in tutto; et questo muoue in istante.[38]

The infinite principle was the world soul, "il principio formale constitutivo de l'universo e di ciò, che in quello si contiene."[39] The primary faculty of this world soul was the universal intellect which was "l'efficiente

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[34]Giordano Bruno, La cena de le ceneri. Descritta in cinque dialoghi per quattro interlocutori con tre considerazioni circa doi suggetti (London: J. Charlewood, 1584) in Giordano Bruno, Opere di Giordano Bruno Nolano, ora per la prima volta raccolte e pubblicate (2 vols; Lipsia: Weidmann, 1830), I, pp. 113-200.

[35]Giordano Bruno, De la cause, principio et uno (London: J. Charlewood , 1584) in Bruno, Opere, I, pp. 201-292.

[36]Giordano Bruno, Giordano Brvno Nolano. De l'infinito vniuerso et mondi (Stampato in Venetia: [i.e. London: J. Charlewood], 1584).

[37]Singer, Giordano Bruno, p. 93. Cf. Boulting, Giordano Bruno, pp. 117-147.

[38]Bruno, De l'infinito universo et mondi, pp. 24-25: "I declare that there are to be observed (if you will) within things two active principles of motion: the one finite according to the nature of the finite subject, and this moveth within time; the other infinite, according to the nature of the soul of the world or indeed of Divinity which is as the soul of the soul which is all in all, and it createth the soul, all in all, and this doth move instantaneously." English translation from Singer, Giordano Bruno, p. 267.

[39]Bruno, De la cause, principio et uno, Bruno, Opera, I, p. 242: "the formal constitutive principle of the universe, and of that which is contained in it." English translation from: Sidney Greenberg, The Infinite in Giordano Bruno. With a Translation of His Dialogue Concerning the Cause, Principle and One (New York: King's Crown Press, 1950), p. 119.

fisico universale."[40] Thus, the soul was simultaneously the formal principle and the efficient cause of the universe. By the soul itself the world was formed, illuminated, filled and vitalized:

> L'anima dunque del mondo è il principio formale constitutivo de l'universo e di ciò, che in quello si contiene; dico che, se la vita si trova in tutte le cose, l'anima viene ad esser forma di tutte le cose; quella per tutto è presidente a la materia, e signoreggia ne li composti, effettua la composizione e consistenzia de la parti. È però la persistenza non meno par, che si convegna a cotal forma, che a la materia. Questa intento essere una di tutte le cosa; la qual però, secondo la diversità de le disposizioni de lat materia, e secondo la facultà de' principj materiali attivi e passivi, viene a produr diverse figurazioni, et effettuar diverse facultadi, a le volte mostrando effetto di vita sensa senso, tal volta effetto di vita e senso senza intelecto, tal volta par, ch' abbia tutte le faccultadi suppresse e reprimute o da l'imbecillità, o da altra ragione de la materia.[41]

The world intellect as an efficient cause of an infinite principle impressed an infinite force on bodies and caused them to move with instantaneous motion. Such a motion could not be distinguished from stillness; instantaneous motion and stillness, for Bruno, were one.[42] So the action of the world soul as motor force was unperceived.

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[40] Bruno, De la cause, principio et uno, Bruno, Opera, I, p. 235: "The universel physical efficient cause.

[41] Ibid., p. 242: "The World soul then, is the formal constitutive principle of the universe, and of that which is contained in it. I declare that if life is found in all things, this soul emerges as the form of all things that which presides over matter, through everything; and which is master of composites, effects the composition and consistency of the parts. And, therefore, persistence belongs no less to such form than to matter. This I understand to be one in all things, which, whoever, according to the diversity of the dispositions of matter, and according to the power of the material principles, active and passive, comes to produce diverse configurations, and to effect different powers, sometimes showing the effect of life without sense, sometimes the effect of life and sense without intellect, and sometimes it appears that all the powers are suppressed and repressed either by weakness or by other conditions of matter." English translation from Greenberg, The Infinite in Giordano Bruno, p. 119.

[42] Bruno, La cena de le ceneri, pp. 101-126; De l'infinito universo et mondi, pp. 22-27.

In order to explain the relation between the world soul in its dual role as formal principle and efficient cause and the body of the universe as the informed and affected matter, Bruno used an analogy:

> Dico, che questo non è inconveniente, considerando, che l'anima è nel corpo, come nocchiero ne la nave, il qual nocchiero, in quanto vien mosso insigme con la nave, è parte di quella; considerato, in quanto che la governa e move, non s'intende parte, ma come distinto efficiente. Così l'anima de l'universo, in quanto che anima et informa, viene ad esser parte intrinsecae formale di quello; ma come che drizza e governa, non à parte, non ha ragione di principio, ma di causa.[43]

Since, however, the movements which resulted from the action of the primary efficient cause were imperceptible to man, while other movements not affected by the world soul were observable, other efficient causes were needed. These were the finite principles, the individual astral souls.

Although Bruno distinguished between the world souls and the souls belonging to specific bodies, he denied a numerical ranking such as the Islamic scale of Intelligences for these souls:

> Quanto à quello che socondariamente diceuate, Vi dico che ueramente é un primo e prencipe motore; ma non talmente primo et prencipe, che per certa scala per il secondo, terzo et altri, da quello si possa discendere numerando al mezzano et ultimo, atteso che tali motori non sono, ne possono essere. . . .[44]

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[43]Bruno, De la cause, principio et uno, Bruno, Opera, I, p. 238: "I say that this is not unsuitable considering that the soul is within the body as the pilot is within the ship: which pilot, in so far as he shares the motion of the ship, is part of that; considered in so far as he governs and moves it, he is understood not as a part but as a distinct efficient cause. Just so the soul of the universe, in so far as it animates and informs, is an intrinsic and formal part of that universe ; but in so far as it directs and governs, it is not a part: it has not the role of a principle, but of a cause." English translation from Greenberg, The Infinite in Giordano Bruno, p. 114.

[44]Bruno, De l'infinito universo et mondi, p. 155: "As for you second argument, I declare to you that there is in truth one prime and principal motive power, but not prime and principal in the sense that there is a second, a third and other motive powers descending down a certain scale to the midmost and last, since such motive powers neither do nor can exist." English translation from Singer, Giordano Bruno, p. 364.

Such motive powers could not exist because the number of worlds was infinite. Each of the infinite worlds had its own soul which was it own motive power:

> perche doue é numero infinito, iui non é grado, ne ordine numerale, benche sia grado et ordine secondo la raggione et dignitá ó de diuerse spacie et geni, ó de diuerse gradi in medesimo geno et medesima specie.[45]

Bruno had little to say about these individual souls. The astral anima unquestionably possessed a "maggior, et piu eccellente raggione"[46] than ordinary terrestrial animals; they were "non solo sensitive, . . . ma anco intellettiue; non solo intellettiua, come la nostra, ma forse anco piu."[47] Each controlled the motions of its globe and each motion was different from all others. This was true even among the so-called fixed stars:

> Moti proprii di ciascuno son quei che si ueggono oltre questo moto detto mondano, et proprii de le chiamte fisse (de quali l'uno et l'altro si denno referire alla terra) et cotai moti sono di piu che di tante differenze, che quanti son corpi; di sorte che mai si uedranno doi astri conuenire in uno et medesimo ordine et misura di moto, se si uedrá moto in quelli tutti; quali non mostrano uariatione alchuna per la gran distanza che hanno da noi.[48]

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[45]Bruno, De l'infinito universe et mondi, p. 155: "For where there is infinite number, there can be neither rank nor numerical order, although there is rank and order according to the nature and worth either of diverse species and kinds, or of diverse grades of the same kind and species." English translation from Singer, Giordano Bruno, p. 364.

[46]Bruno, De l'infinito universo et mondi, p. 88: "greater and more excellent mind." English translation from Singer, Giordano Bruno, p. 315.

[47]Bruno, La cena de le ceneri, p. 70: "not only sensitive . . . but even intelligent; not only intelligent, as we are, but perhaps even more."

[48]Bruno, De l'infinito universe et mondi, p. 70: "The proper motions of each of these of their apparent motions which are not due to our so-called world motion; and the proper motions of the bodies known as fixed stars (though both their apparent fixity and the world motion should be referred to our earth) are more diverse and more numerous than the celestial bodies themselves. For if we could observe the motion of each one of them, we should find that no two stars ever hold the same course at the same speed; it is but their great distance from us which preventh us from detecting the variations." English translation from Singer, Giordano Bruno, pp. 303-304.

The details of these variations were not discussed in Bruno's writings. The general statements he made about the Earthly soul also applied to the remaining astral souls. All of these impelled their astral bodies in a manner similar to that of the Earthly soul.

Whatever the souls did was of some benefit to the bodies which they controlled. Thus, as the Earth's soul turned the Earth so that various parts of the globe would receive the necessary light and heat from the Sun, so did other indwelling souls provide for their bodies. By this means the rotational and orbital movements were regulated according to the body's distance from the Sun:

> Voleuate dumque ché que corpi benche fussero tanto discosti dal sole, possono peró participar tanto calor che baste: perche uoltandosi piu uelocemente circa il proprio centro, et piu tardi circa il sole; possono non solamente participar altre tanto calore, ma anchor di uantaggio se bisognasse; atteso che per il moto piu ueloce circa il proprio centro, la medesima parte del conuesso de la terra che non fu tanto scaldata, piu presto torni á ristorarsi; per il moto piu tardo circa il mezzo focoso, et star piu saldo all' impression di quello: uegna a riceuere piu uigorosi gli fiammiferi raggi.[49]

Bruno made no attempt to join his theory to quantitatine data; he gave no speeds, angles of inclination or distances for the planetary bodies. His method was entirely a qualitative descriptive one for his was a universe without specialized regions or formalized laws of motion.

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[49]Bruno, De l'infinito universo e mondi, p. 74: "You maintain then that though so distant from the sun, these bodies can derive therefrom all the heat that they need. Because, spinning at a greater rate around their own centre and revolving more slowly around the sun, they can derive not only as much heat but more still if it were needed; since by the more rapid spin around her own centre, such part of the convexity of the earth as hath not been sufficiently heated is the more quickly turned to a position to receive heat; while from the slower progress around the fiery central body, she stayeth to receive more firmly the impression therefrom, and thus she will receive fiercer flamming rays." English translation from Singer, Giordano Bruno, p. 305.

Bruno later restated his cosmological theories in other writings,[50] but he introduced no great changes into his system. In these later writings he included more astronomical details, re-emphasized the actuality and necessity of an infinite universe and sought to make a closer association and a finer distinction between the world-soul and all other vital principles; yet he never assumed that the celestial motors were or could be anything but souls.[51]

The universe was infinite; it was also living and composed of living parts. A living being required an animated form and, therefore, the universe and every part of it had a soul. Bruno may have been uncertain in his own mind about some aspects of the infinite universe; he was certain that all movement therein, celestial and terrestrial, was controlled by souls.'

The second major proponent of the astral souls was Francesco Patrizi, a thinker who rejected the peripatetic philosophical system and sought to replace it with Platonism. While Patrizi did not go to the

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[50]Giordano Bruno, Libri physicorvm Aristotelis explanati (Wittenberg: 1587) in Bruno, Opera, III, pp. 259-393; Iordani Brvni Nolani camoeracensis acrotismvs, seu rationes articvlorvm physicorum aduersus peripateticos Parisijs propositorum, etc. (Vitebergae: Apud Zachariam Cratonem, 1588); De rervm principiis, elementis et cavsis ([Helmstedt: 1590]) in Bruno, Opera, III, pp. 507-567; Jordani Bruni Nolani de triplici minimo et mensvra ad trivm specvlatiuarum scientiarum & multatum actiuarum artium principia, libri v (Francofvrti: Apud Ioannem Wechelum & Petrum Fischerum consortes, 1591); Iordani Brvni Nolani de monade nvmero et figura liber consequens quinque de minimo magno & mensura. Item de innvmerabilibvs, immenso, & infigurabili; seu de vniuerso & mundis libri octo (Francofvrti: Apud Ioan. VVechelum & Petrvm Fischerum consortes, 1591).

[51]I. Frith, Life of Giordano Bruno, the Nolan, rev. Moriz Carriere (London: Trübner & Co., 1887), pp. 235-237; Émile Namer, Giordano Bruno cause, principe et unité. Traduction accompagnée de notes et d'analyses et précédée d'un étude sur la philosophie de Bruno (Paris: Librairie Félix Alcan, 1930), pp. 14-19; Singer, Giordano Bruno, pp. 149-157; Boulting, Giordano Bruno, pp. 227-224.

extreme Peter Ramus (1515-1572) had--"Quaecumque ab Aristotele dicta essent, commenticia esse"[52]--there was little in the Stagirite's writings with which Patrizi could agree.[53]

The four previously accepted terrestrial elements with or without the celestial one were not the basic substances of the world: according to Patrizi, God had made the universe from spacium, lumen, calor, and fluor. The first three were incorporeal elements; the last was a material substance. Either lumen filled all spacium itself or it was accompanied by and joined with calor; the two then acted upon fluor, Patrizi's prime matter, to produce material bodies.[54] That part of the universe so formed retained the geocentricity and the sphericity of the Plantonic world, but the whole lacked the latter's finiteness: Infinite space surrounded Patrizi's corporeal world.[55]

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[52]George Sarton, Six Wings: Men of Science in the Renaissance Bloomington, Indiana: Indiana University Press, 1957), pp. 39-42. "All the things that Aristotle said are wrong" was the thesis Ramus defended at his public examination in 1536.

[53]Berjamin Brickman, An Introduction to Francesco Patrizi's Nova de universis philosophia (New York: n.p., 1941), pp. 14, 20. According to Brickman "It is when the latter [Aristotle] broke with his teacher, says Patrizi, and launched out on his own that he began to fall into error." Ibid., p. 20.

[54]Francesco Patrizi, Francisci Patricii nova de vniversis philosophia in qva Aristotelica methodo non per motum, sed per lucem, & lumina, ad primam causam ascenditur. Deinde propria Patricii methodo; tota in contemplationem venit Divinitas: Postremo methodo Platonica, rerum vniuersitas, a conditore Deo deducitur (Ferrariae: Apud Benedictum Mammarellum, 1591), "Pancosmia," pp. 61 recto-79 verso. The Nova philosophia consists of four main divisions: "Panargia," "Panarchia," "Pampsychia," and "Pancosmia." Since the pagination is not continuous throughout the entire work, the name of the division has been included in the reference.

[55]Ibid., pp. 61 recto-65 verso. An English translation of this section of the Nova Philosophia is available. See: Francesco Patrizi, "On Physical Space," trans. Benjamin Brickman, Journal of the History of Ideas, IV (1943), pp. 224-245.

Co-existent with the material world were the immaterial beings. Patrizi introduced his own ladder of creation which extended from the incorporeal creatures to the corporeal ones and allowed for extension within each division. The scale included nine grades:

> Gradus hi nouem, sunt primus rerum atque entium ordo, in profundum, a summo ad imum ductus. Est alius ordo in latitudinem actus, in singulo quoque gradu. In primo nimirum productorum gradu, est vnitas primaria, & ab ea, & in ea vnitates omnes, eam ordine consequentes, nouem & ipsae, vt haec ratio dictat, in latitudinem gradibus distinctae. ita vt primariae vnitati, proxima Essentiarum sit vnitas, sequatur vnitas Vitarum. tertio sit loco, Mentium vnitas. quarto Animarum. quinto Naturarum vnitas, sexto vnitas Qualitatum; septimo Formarum. postrema sit omnium vnitas Corporum. Ita fit, vt quot sunt in vniuersitate post principium rerum gradus in profundum, totidem sint etiam gradus, earum latitudinis.[56]

God the uncreated, incorporeal being, was the final cause of all created beings while the higher forms were the efficient causes of the lower ones. Thus, in Patrizi's system *unitas* produced the primary *Essentia* which in turn produced all other essences and the primary *vitam*. The primary *vita* generated all other lives and the primary *mens*; the primary *mens* all other minds and the primary *anima*, and so on.[57] Each grade formed a link between the level above and that below it, and each served some special function in the overall pattern.

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[56]Patrizi, *Nova philosophia*, "Panarchia," p. 24 *recto*: "These nine levels are the *first of things and* the order of beings *leading* in extent from the highest to the lowest. Another order is in the latitude of act, also in every level. In the first level of preferable things, certainly, is the primary unity, and from it, and in it all unities, in order following it, nine with itself, as this reason dictates, in latitude by grades of distinction. Thus as from the primary unity is the next unity of Essences, the unity of lives follows. In the third place is the unity of minds. In the fourth that of souls. In the fifth the unity of natures, in the sixth the unity of qualities; in the seventh that of forms. Lastly is the unity of all bodies. Thus it is that as there are degrees of things in depth after the principles in the universe, so there is the same even in their degrees of latitude."

[57]*Ibid.*, pp. 22 *verso*-27 *verso*.

The anima, however, were more than just the connecting link between mens and natura. They were also the beings which in a special manner served as the bridge between the non-material and the material worlds. Unitas, essentia, vita and mens were incorporeal beings;[58] natura, qualitas, forma and corpus were corporeal;[59] anima was the incorporeal-corporeal.[60]

Patrizi recognized two types of souls: the (feminine) anima or human soul, and the (masculine) animus, all other souls. The human soul as a special case, a being directly created by God, was to be the subject of another work,[61] a work which Patrizi apparently never wrote.[62] Although in the Nova philosophia he dealt only with the animus, Patrizi sometimes used the term anima to refer to the incorporeal-corporeal beings collectively; at other times he considered only the animus as the class of beings which occupied the middle position between the incorporeals and corporeals:

> Supra animum quatuor esse demonsttauimus abunde, Intellectum, vitam, essentiam, vnitatem. Sub eo totidem sunt. Natura, Qualitas, Forma, corpus.[63]

From this central position the anima acted as intermediary between the higher and lower orders and governed, directly or indirectly, the motions of all

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[58]Ibid., "Panarchia," pp. 25 recto-28 verso, 31 recto-33 recto.

[59]Ibid., pp. 47 recto-48 recto. In Patrizi's system natura, qualitas and form were not simple corporeals but corporeal-incorporeals. Corpus was the only completely corporeal being.

[60]Ibid., "Pampsychia," pp. 51 recto-52 recto.

[61]Ibid., p. 49 recto: "Quas ad humanae nostrae philosophia initia differimus."

[62]Brickman, An Introduction, p. 40.

[63]Patrizi, Nova philosophia, "Pampsychia," p. 49 verso: "Above the animus we have clearly demonstrated that there are four, Intellect, Life, Essence, Unity. Below it there are just as many. Nature, Quality, Form, Body."

bodies:

> Principium ergo motus corporei omnis, anima est procul dubio. Ab alio ergo corpora mouentur omnia. Anima vero non ab alio, sed mouetur a se ipsa.[64]

The primary reason which Patrizi gave for putting anima in charge of motion was that of necessity. Since beings were either in motion or not in motion, and since of the beings in motion some moved by themselves while some were moved by another, all beings belonged to one of three classes: "alimobilium, se mouentium, & immobilium.[65] An "alimobile" had to be moved either by an "alimobile" or by a "se movente." Of the "se movens" which moved another body

> necesse ergo est, hoc mouens sui natura extra corpus esse; & per se esse, & ex se stare. Et in se ipso substare: Et se mouere primo; alia mouere secundo. Hunc motum motorem, nos cum Platone, & Platonicis, incassum Peripato reclamante, Animas vocamus.[66]

As a "motor of motion" several properties were necessary for an anima. In order to continue the chain of being unbroken from the incorporeal to the corporeal world, it had to be

> non corporea, non incorporea. sed vtrumque & incorporea, & corporea, ita vt media quaedam sit inter vtramque. Incorporeo suo, ab incorporea pendens. Corporeo uero ad corpus vergens.[67]

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[64] Ibid., "Panarchia," p. 1 verso: "Therefore the principle of all corporeal motion is without doubt the anima. All bodies, therefore, are moved by another. The anima truly not by another but a se itself is moved."

[65] Ibid., p. 1 recto.

[66] Ibid., p. 1 verso: "It is necessary, therefore, that this moving be by its nature outside the body, and to exist per se, and to stand ex se. And to subsist in se. And to move itself first; to move another secondly. We, with Plato and the Platonists, crying out incessantly to the Peripatetic, call this motor of motions animas."

[67] Ibid., "Pamsychia," p. 51 verso: "not corporeal, not incorporeal but both incorporeal and corporeal. Thus it is a certain mean between the two. As an incorporeal coming from the incorporeal. As a corporeal tending toward the material."

The *anima* was not, however, to be a simple mean between the two. The properties of the two extreme groups were to be "mista, & non mista, temperata, & non temperata, composita, & non composita."[68] Patrizi did not explain just how this was to occur or the manner in which the unlike properties were to exist side-by-side in the same body; but he stressed that:

> necesse ergo est, quia incorporea sit, incorporeorum proprietates teneat. Non simplicissimas illas, quales in uere incorporeis sunt, sed gradu inferiore.[69]

The incorporeal characteristics retained by the *anima* were: non-materiality, indivisibility, unalterability, incapacity of passion, unchangeableness, immortality;[70] at the same time, since they were in some respects corporeal, the *anima* moved in time and could be joined to wholly corporeal bodies.[71]

Along with its incorporeal-corporeal nature two attributes of the *animus*[72] seemed of particular importance to Patrizi.[73] The first was the plurality of the *animus* and the unity of this plurality in a greater *animus*. This characteristic permitted Patrizi to have different souls joined to the

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[68] *Ibid.*, p. 51 *verso*.

[69] *Ibid.*, p. 51 *verso*: "It is necessary, therefore, because it is incorporeal that it retain the properties of the incorporeal. Not most simply, as they are in the true incorporeal, but in an inferior degree."

[70] *Ibid.*

[71] *Ibid.*, p. 52 *recto*.

[72] All of the characteristics of the incorporeal-corporeal beings mentioned thus far were common to both *anima* and *animus*. Those following are peculiar to the *animus*.

[73] Of the five books in the "Pampsychia" one is on the unity and diversity of the *anima*, "Qvotvplex sit animus," and another is "De animis irrationalibus," which denies the existence of irrational souls.

various bodies in the material world and at the same time to have them dominated by the mundi animus:

> respondebimus cum Hermete, cum ratione, vnius mundi, vnum esse animum. Partes quoque eius principes proprios sibi habere animos affimare non dubitabimus. . . .[74]

The other property to which Patrizi gave his special consideration was the rationality of the animus.

> Nobis uero distinctio haec animi rationalis, & irrationalis minime probatur. Nullum enim animum sui natura irrationalem esse existimamus. Neque enim rerum ordo a nobis constitutus, eam admittere uidetur posse. Quia nimirum omnem animum ab intellectu esse est iam demonstratum. A mento ergo productrice, quo modo res amens prorsus, sine medio presertim prouenire potest?[75]

However, since the animus was produced by the mens or intellectus, it necessarily received the characteristics of the incorporeals but possessed them only in an inferior manner. Thus, the animus could not be intelligentis in the complete sense of the term, only in some partial meaning. It was rationales but not racionationes. To Patrizi this meant that the animus could have knowledge of a thing but they could not reflect upon this knowledge.[76]

Although he devoted the third of the four main divisions of the Nova

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[74]Patrizi, Nova philosophia, "Pampsychia," p. 56 recto: "We answer with Hermes, with reason, that of one world there is one soul. Also we will not hesitate to affirm that its principal parts have souls proper to themselves.

[75]Ibid., p. 57 recto: "Truly this distinction of the rational and irrational souls seems less probable to us. For we think that no soul is by its nature irrational. And in the order of things constituted by us even, it is seen that it can not be admitted. Because certainly it has already been demonstrated that every soul is from the intellect. Therefore produced by the mind, how can it appear a straight-forward senseless thing without a medium especially?"

[76]Ibid., p. 57 verso.

philosophia to the animus in general, Patrizi, like Bruno, wrote little about the individual kinds of souls. He mentioned that there were two main divisions of the animus, the "supramundanos" and the "intramundanos,"[77] but this seems to have been included more in order to maintain Patrizi's theory of contrary pairs than to further his discussion on the nature of the animus.[78] The "supramundanos" were those animus not joined to a body while the "intramundanos" were the animus dwelling within the corporeal world. The celestial animus belonged to the latter class.[79]

Patrizi nowhere in his new philosophy gave special consideration to the celestial animus. In the first chapter of the "Panarchia," the book dealing with first principles, he ruled out the intelligences as the heavenly motors:

> Quia coeli corpora sunt trine dimensa, intellectus vero incorporei sunt omnino. Contrarij ergo sunt. Contraria autem inter se iungi nequeunt, nisi prius contemperentur. At quae contemperatio in incorporeis, cum corporum sit propria. Ergo primus ille primi coeli motor, anima fuerit, & non intellectus: Et multo minus, est summus Deus.[80]

Later, he eliminated the Angels because they were "mentes seu intellectus," and

> mentes sui natura, nulli addicuntur corpori. Neque ergo coelis, ne-

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[77]Ibid., pp. 50 verso, 53 recto.

[78]For a complete scale, Patrizi thought it necessary that for every type of being there be a contrary type. One of the few exceptions to this was the denial of the existence of irrational souls.

[79]Patrizi, Nova philosophia, "Pampsychia," p. 53 verso

[80]Ibid., "Panarchia," p. 1 verso: "Because the bodies of the heaven have three dimensions, the intellectus are truly entirely incorporeal. Therefore they are contraries. Contraries, however, can not be joined among themselves, unless first they are moderated. But what moderation is proper in incorporeals with corporeals. Therefore, that first motor of the first heaven will be a soul and not an intellect; and much less is it the highest God."

que astris sunt addicti.[81]

When, in the chapters on the motion and structure of the heavens, he did mention the animus which controlled the heavens, he did so only to support his theory. One of the difficulties which arose in a geostatic, geocentric-system without spheres was the uniformity of movement and the relative fixity among the fixed stars. If, as in Patrizi's system, each star had its own animus which was to govern its own motion, why did all of these stars appear to have a similar motion? Patrizi was not willing to sacrifice freedom of movement for each of his globes; yet, he could not deny that they appeared to move as a unit.

He saved both the appearances and his theory by applying two properties of the animus to the celestial souls. First was the partial sharing in the intellectual nature of the mens:

> Haec vero nunera, non sine ratione, non sine intelligentia possunt obiri. Demonstratum autem iam est, ordinem omnem, ortum a mente habere. Si ortum, cur non & medium & finem? Ordo igitur inter sydera, & situs, & distantia, ab animo, ab intellectu, syderum, & non ab vlla eorum in coelo fixione venit. Quia animalia sunt, & quidem diuina. Animo scilicet, & ratione, & mente praedita. Et quia sunt, vitae, & actionis, vt reliqua animalia, participia.[82]

This guaranteed some independence for each globe while the second

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[81] Ibid., "Pampsychia," p. 55 recto: "minds by their nature are attached to no body. And therefore they are attached neither to the heavens nor to the stars."

[82] Ibid., "Pancosmia," p. 91 recto: "Truly they can perform these offices not without reason, not without intelligence. For it has already been shown that all order has its beginning from the mind. If the beginning why not the middle and the end? The order, therefore, among the stars and their places and distances comes from the animus, from the intelligence, of the stars and not from any fixation of them in the sky. Because they are living and indeed divine. Whereby as had been mentioned before with a soul, with reason and with a mind. And because they participate in life and action as other living beings."

property, the unity of animus in the mundi animus, saved the appearances:

> Et liber per coelum sideribus cursus dabitur, & appetentiae omnes saluabuntur. Si intelligantur astra, vt reuera sunt, spiritu propria vehi, animo moueri, intellectu ordine regi: . . . Non enim, corpora, vt appellat antiquitas, diuina, sine animo esse est possibile. Et neque solo mundi animo, esse animata. Sed & hoc, & suo quaeque stella proprio. Et ita propria & communi viuere vita, & proprio, & communi intelligere intellectu. Et proprio, & communi vehi spiritu. Cuius, quia iam sepius mentionem facimus, suo loco, tractationem instituemus. Concludendum igitur, sidera, quia sint animalia, & quidem diuina, & diuinum animum, & diuinem vitam, & diunum intellectum habere esse necesse. Qui intellectus cum sit mundi intellectui coniunctus & in eo sit. Et sit item in primo intellectu, necesse est, vt a superiorum nutu, omnis eorum pendeat voluntas, neque ab eo discedat vnquam, omniaque ordine exsequantur, quae illum vel voluisse ab initio, vel in dies velle intelligant.[83]

Although Patrizi's animus were definitionally different from Bruno's (the former were inferior to the human anima, the latter superior), both performed the same function: They moved the wandering and fixed stars. Both writers left many questions concerning the astral souls unasked and unanswered. Each had substituted a completely vitalistic principle for the solid spheres.

As a cosmological explanation the anima had long been satisfactory; as efficient causes in an astronomical system, they had to a large extent

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[83] Ibid., p. 91 verso: "And freely through the heaven will a path be given to the stars and all appearances will be saved. If the stars are intelligent, as they are regarded, they are led by a proper spirit, moved by an animus, governed by an intelligent order: . . . For it is not possible for divine bodies, as the ancients called them, to be without a soul. And not only is it animated by the soul of the world, but by this and each star by its proper soul. And thus it lives by a proper and common life and knows by a proper and common intellect, and is drawn by a proper and common spirit. Of which we have already made mention frequently; in its place we have arranged the treatment. It is concluded therefore, that it is necessary that the stars which are living and certainly divine have a divine animus and a divine life and a divine intellect. Which intellect is joined to the intellect of the world and is in it. And it is the same in the first intellect; it is necessary as from the pleasure of the superiors it holds together all their wills and it does not separate anyone from it and all follow out in order because they know that it either has been willed from the beginning or it was taken up in time."

been ignored. In each respect the removal of the spheres exposed weaknesses of the uses of these creatures. The reasons were varied. William Gilbert lessened the role of the anima in his De mundo without giving any explanation for so doing.[84]

Kepler objected to a direct effect of the souls upon the planetary bodies for "corpus aliquod ab anima sua transportari non posse de loco in locum, si destituta fuerit orbis instrumento, qui per totum circuitum absolvendum sit exporrectus, si item absit corpus immobile, cui orbis innitatur."[85] Thomas Lydiat expressed his opinion that "absurdum & puerile sit existimare ea corpora esse animata."[86]

However, even if the anima could move the globes, both the regularity and the irregularities of the paths of the freely moving globes were

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[84]Compare: William Gilbert, Gvilielmi Gilberti Colcestrensis, medici regii, de mundo nostro sublunari philosophia nova. Opus posthumum, ab authoris fratre collectum pridem & dispositum, nvnc ex duobus MSS. codicibus editum. Ex museio viri perillustris Gvilielmi Boswelli equitis aurati &c. & oratoris apud Foederatos Belgas Angli (Amstelodami: Apud Ludovicum Elzevirium, 1651), pp. 135-143, 159-161; Gvilielmi Gilberti Colcestrensis, medici Londinensis, de magnete, magneticisqve corporibvs, et de magno magnete tellure; physiologia noua, plurimis & argumentis, & experimentis demonstrata (Londini: Petrvs Short, 1600), pp. 220-225.

[85]Johann Kepler, Epitomes astronomiae Copernicanae, uistata formâ quaestionum & responsionum conscriptae, liber quartus, doctrinae theoricae primus: quo physica coelestis, hoc est omnium in coelo magnitudinum, motuum, proportionumque, causae vel naturales vel archetypicae explicantur, et sic principia doctrinae theoricae demonstrantur. Qvi, qvod vice svpplementi librorum Aristotelis de caelo esset, certo consilio seorsim est editus (Lentiis ad Danubium: Excudebat Johannes Plancus, 1620), in Kepler, Gesammelte Werke, VII, p. 294: "A body cannot be transported by its soul from place to place, if the sphere lacks the organ which reaches out through the whole circuit to be traversed, and if there is no immobile body upon which the sphere may rest." English translation from Kepler, Epitome, Great Books, XVI, p. 892.

[86]Thomas Lydiat, Praelectio astronomica. De natvra coeli & conditionibus elementorum: tum autem de causis praecipuorum motuum coeli & stellarum (Londini: Ioannes Bill, 1605), p. 65: "it is absurd and childish to think that those bodies are animated."

unfavorable to the acceptance of living beings as celestial motors. Earlier some writers had objected to joining an intelligence to a regular circular motion because the continued repetition of the same pattern did not seem to demand an intelligent being to control it directly.[87] For Kepler the deviations from the perfect form were unworthy of such a being. An intelligent creature would guide its charge with utmost intelligence: "ordinaret vtique eam in perfectum circulum, cujus est mentalis pulchritudo et perfectio."[88] Yet, the planetary paths were elliptical and the laws governing the movements of a body traversing such a path were "potius naturam staterae seu necessitatem materialem quàm conceptum et distinationem mentis."[89]

Furthermore, in such a system where would the soul reside, If in the center, in what body did it rest, for the central figure, the Sun, resided in one focus of the ellipse? If in the planet, how could the mind know where the center was? Both questions were unanswerable in the Keplerian world. Therefore,

> haud obscurum esse poterit: neque mentem aliquam introducendam esse, quae dictamine rationis et veluti nutu globos circumagat, neque animam, huic quidem circumlationi, praeficiendam, quae sic, vt fit in convolutione circa axem, virium aequabili contentione faciat impressionem in globos. . . .[90]

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[87]See p. 19 _supra_.

[88]Kepler, _Gesmmalete Werke_, VII, p. 295: "it would lay out the orbit in a perfect circle, which has beauty and perfection to the mind." English translation from Kepler, _Epitome_, _Great Books_, XVI, p. 892.

[89]Kepler, _Gesammelte Werke_, VII, p. 295: "of the nature of the balance or of material necessity rather than of the conception and determination of the mind." English translation from Kepler, _Epitome_, _Great Books_, XVI, pp. 892-893.

[90]Kepler, _Gesammelte Werke_, VII, p. 297: "it will of necessity be clear that no mind is to be introduced which should turn the planets by the dictation of reason and so to speak by a nod, and that no soul is to be put in charge of this revolution, in order that it should impress something into

If there were neither spheres nor astral souls to move the heavenly bodies, what did move them? Francis Bacon complained that "at vix quisquam est, qui inquisivit causas physicas tum de substantia coelestium,"[91] yet he himself, made no such inquiry. A few of his contemporaries did.

The accumulation of increasingly accurate observational data and the controversy as to whether the universe was heliocentric or geocentric had focused men's attention on the heavens. The Renaissance, Reformation and other humanistic movements had changed the intellectual atmosphere of western Europe. Already some men were convinced not only that God had made the world by "number, weight and measure,"[92] but that these Divine designs could be known and understood by man. So long as physical phenomena were considered the results of spiritual agents, man could marvel at the universe but he could hope only for a limited knowledge of it.

Indwelling souls not only supplied an explanation for all the reg-

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the globes by the balanced contest of the forces, as takes place in the revolution about the axis. . . ." English translation from Kepler, Epitome, Great Books, XVI, p. 895.

[91]Francis Bacon, The Works of Francis Bacon, Baron of Verulam, Viscount St. Albans, and Lord High Chancellor of England, ed. James Spedding, et al., (15 vols; New York: Hurd and Houghton, 1864), II, p. 270: "there is scarce any one who has made inquiries into the physical causes, as well of the substance of the heavens." Ibid., VIII, p. 488.

[92]Wisdom 11:21. Cf. Tycho Brahe, Tychonis Brahe Dani epistolarvm astronomicarvm libri. Quorum primvs hic illvstrissus et lavdatissus principis Gvlielmi Hassiae Landtgravii ac ipsius mathematici literas, vnaque responsa ad singulas complectitur (Vranibvrgi: 1596), in Brahe, Opera, VI, p. 89; Gabriel Plattes, A Discovery of Infinite Treasvre, Hidden Since the Worlds Beginning. Whereunto All Men, of What Degree Soever, Are Friendly Invited To Be Sharers with the Discovered (London: G. Hutton, 1639); p. 1; John Dee, "Mathematicall Praeface," in The Elements of Geometrie of the Most Auncient Philosopher Evclide of Megara. Faithfully (Now First) Translated into the Englishe Toung, by H. Billingsley (London: Iohn Daye, [1570]), p. Aiiij verso.

ular and irregular heavenly movements, they also allowed for any unexpected, unpredicted event. Such causes that saved all the phenomena were unsatisfying to many, especially to those thinkers who were trying to find a model of the universe that accounted for the celestial motions, described the structure of the physical world, and enabled the compilers of astronomical tables to predict accurately the future positions of the heavenly bodies.

The men who employed vitalistic motors were seldom, if ever, interested in all three aspects. Bruno and Patrizi each delineated the cosmos as he believed it actually existed; both provided efficient causes for motion within their systems; neither presented a computational device that could be used to calculate forthcoming astronomical events. Those who continued with the homocentric spheres had natural motions and *anima*-motors united in an integrated physical structure, but they found difficulty in saving the celestial movements in terms of this structure. Ptolemy's followers suffered or ignored the physical and motor difficulties inherent in a system of epicycles and eccentrics. Brahe was interested in the actual structure of the universe, but he showed little concern for the causes of the phenomena. Copernicans like Digges and Galileo focused most of their attention on the physical reality of the heliocentric theory, a theory they were confident would account for the heavenly movements; yet they seemed to care little for the power or powers that moved the globes.

To a few the celestial *anima* were essential; to others they were convenient; to many they were a disturbing factor. Among this last group some tried to devise substitute agents, motors with a material basis.

The suggestions were varied, their uses diverse. Their one common element was that each took a terrestrial motive power and placed it unaltered in the celestial world.

CHAPTER IV

MAGNETIC CELESTIAL MOTORS

One of the concepts the post-Copernicans tried to utilize in explaining celestial motions was magnetism. Writers from Antiquity to the Middle Ages had noted the ability of the lodestone to draw iron, but until sometime in the interval between the eleventh and thirteenth centuries, this phenomenon was only one of many curiosities of nature. After the eleventh century, the knowledge of the north-south orientation of a freely suspended magnetic body and the technique of producing artificial magnets combined to produce the mariner's compass. The curiosity had become a useful instrument.[1]

By the middle of the thirteenth century a number of theories had been developed to explain what was known about magnetic attraction. Since natural philosophers created the concept of magnetic poles as an analogy to the poles of the sphere of fixed stars and then considered the orientation of the compass relative to the celestial pole, magnetism became associated with the supralunar region.[2] Thus, when a renewed interest in

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[1] Duane H. D. Roller, The De magnete of William Gilbert (Amsterdam: Menno Hertzberger, 1959), pp. 11-49 reviews the history of magnetism and electricity before Gilbert.

[2] Peter Peregrinus, Epistle of Peter Peregrinus of Maricourt to Sygerus of Foncaucourt, Soldier, concerning the Magnet, trans. Silvanus P.

the compass and its properties accompanied the increased navigational activity of the fifteenth and sixteenth centuries, the men investigating magnetic properties were necessarily concerned with the structure and motion of the heavens. Moreover, the Prutannic Tables, the best astronomical tables available in the late sixteenth century, were based on the heliocentric theory. Thus, frequently the same men were acquainted with the Copernican hypothesis and with magnetic theories. In less than a century the two distinct studies were joined in a common theory.

When in 1576 Thomas Digges added an English version of the Copernican system, "A Perfect Description of the Celestial Globes," to a revised edition of his father's A Prognostication Euerlasting,[3] he included two innovations in the system. One, the scattering of the fixed stars, has been discussed previously.[4] The other was a casual statement which placed a "magneticall force" in the center of the Earth:

> In the midst of this Globe of Mortalitie hangeth this darck starre or ball of earth and water balanced and sustained in the midst of the

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Thompson ([London: Chiswick Press, 1902]), Chapters iv, v; H. D. Harradon, "Some Early Contributions to the History of Geomagnetism I," Terrestrial Magnetism and Atmospheric Electricity, XLVIII (1943), pp. 5, 9, 11.

[3]Thomas Digges, "A Perfit Description of the Caelestiall Orbes according to the Most Aunciente Doctrine of the Pythagoreans, Latelye Reuiued by Copernicus and by Geometricall Demonstrations Approued," in Leonard Digges, A Prognostication Euerlastinge of Righte Good Effecte, Fruitfully Augmented by the Auctour, contajning Plaine, Briefe, Pleasaunt, Chosen Rules to Iudge the Weather by the Sunne, Moone, Starres, Comets, Rainebow, Thunder, Cloudes, with Other Extraordinary Tokens, not Omitting the Aspects of Planets, vvith a Briefe Iudgement for Euer, of Plenty, Lacke, Sickeness, Dearth, VVarres, &c. Opening also Many Naturall Causes VVorthy To Be Knovven. To These and Other Now at the Last, Are Ioyned Divers Generall, Pleasaunt Tables vvith Manye Compendious Rules, Easye to Be Had in Memory, Manifolde VVayes Profitable to Al Men of Vnderstanding (London: Thomas Marsh, 1576).

[4]See pp. 41-42 above.

> thinne ayer onely with that propriety which the wonderfull workman hath giuen at the Creation to the Center of this Globe with his magnetical force vehemently to draw and hale unto it self all such other Elementall things as retaine the like nature.[5]

There is little to indicate in this one cryptic reference in the "Perfect Description" how Digges used his "magnetical force," whatever it was. The diurnal motion, according to him, was due to a "naturall, uniforme and wonderfull slie & smoth motion"[6] which "alwaye contynueth unyforme and equall by reason of this cause whiche is indeficient and alway continuinge."[7] This cause is not further defined nor is there any reason to assume that Digges associated the magnetical force with the Earth's motion.

Although he used the verb "to draw" in regard to the magnetical force which he placed in the center of the Earth, Digges did not consider magnetism as the cause of falling bodies. This he attributed to "Gravitie" which

> is nothinge els but a certaine proclivitye or naturall covetinge of partes to be coupled with the whole, whiche by diuine providence of the Creator of al is giuen & impressed into the parts, that they should restore themselves into their unity and integritie concurringe in sphericall fourme, which kinde of propriety or affection it is likelye also that the Moone and other glorious bodyes wante not to knit & combine their partes together, and to mainteyne them in their round shape, which bodies notwithstandinge are by sundrye motions, sundrye wayes conveighed.[8]

Digges neither compared nor contrasted the "natural covetinge" with the magnetical force. He repeated the assumptions from the De Revolutionibus that surface, aerial and falling objects shared the natural rotational

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[5] Thomas Digges, A Prognostication, p. M2 recto.

[6] Ibid.

[7] Ibid., p. D2 verso.

[8] Ibid., p. [D3] recto.

motion of the Earth. Such a natural property kept separated objects in position in relation to the Earth and allowed falling bodies to drop perpendicularly to the Earth's surface.[9] Digges did not use his magnetic property for this purpose as some later writers did.

The use of magnetism in the "Perfit Description" is neither a major consideration nor does it reflect an important physical force in Digges's system. It is, however, an example of an early attempt to place some recognized source of force within the Earth. Nicolas Rymers also assumed a magnetic property to be in the Earth, but he did no more than place it there.[10]

A quarter of a century after Digges, William Gilbert published his study of magnetism, De magnete.[11] After reviewing earlier ideas and adding his own theories of magnetic bodies together with descriptions of experiments which displayed certain properties of these bodies,[12] Gilbert introduced the "magnetic virtue" as an explanation for the diurnal motion of the Earth.

Whereas Digges considered the magnetic property to be implanted in

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[9] Ibid., pp. D1 recto-[D3] recto.

[10] Nicolas Rymers, Nicolai Raymari Vrsi dithmarsi. Fvndamentvm astronomicvm: id est. Nova doctrina sinvvm et triangvlorvm. Eaqve absolvtissima et perfectissima, eivsqve vsvs in astronomica calculatione & obseruatione (Argentorati: Bernardus Iobin, 1588), p. 40 recto.

[11] William Gilbert, Gvilielmi Gilberti Colcestrensis, medici Londinensis, de magnete, magneticisqve corporibvs, et de magno magnete tellure; physiologia noua, plurimis & argumentis, & experimentis demonstrata (Londini: Excvdebat Petrvs Short, 1600).

[12] Ibid., pp, 1-210. This is in the first five books of the De magnete, the part which deals with general magnetic theory. The sixth book, pp. 211-240, is primarily concerned with cosmological speculations. See Roller, The De magnete of William Gilbert, pp. 128-153 for a discussion of Gilbert's contributions to magnetic theory.

the center of the globe, for Gilbert the whole Earth was a great lodestone, magnus magnes:

> Atque istud quidem experimentum solum, magneticam naturam telluris inclytam, per omnes eius internas partes igenitam, & fusam, admirabili indicatione tanquam digito ostendit. Magneticus igitur vigor in tellure existit quemadmodùm in terrella quae pars est telluris, naturâ homogenica, Arte vero sphęrica, vt telluris globosae figurae corresponderet, & praecipuis experimentis cum telluris globe consentiret.[13]

The properties which he had postulated for lodestones, Gilbert now gave to the Earth. This globe, like a natural magnet, had innate poles and a fixed axis.[14] As a magnet was surrounded by a sphere of influence, orbis virtutis, so the great magnet, the Earth, had its orb of virtue extending from it and affecting all earthly bodies within it.[15]

Having established these properties in the Earth, Gilbert used them to explain and to defend the diurnal rotation of the Earth. He first attacked the theory of the spheres and stated that any motion proper to a heavenly body would be either a rotational or an orbital motion of its own. He denied the hypothesis of the Prime Mover, and finally, after stressing the great simplicity of a system which included a diurnal rotation of the Earth, declared

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[13] Gilbert, De magnete, p. 212: "And that single experiment, by a wonderful indication, as with a finger, proclaims the grand magnetick nature of the earth to be innate and diffused through all her inward parts. A magnetick vigour exists then in the earth just as in the terrella, which is a part of the earth, homogenic in nature with it, but rounded by Art, so as to correspond with the earth's globous shape and in order that in the chief experiments it might accord with the globe of the earth." English translation from William Gilbert, William Gilbert of Colchester, Physician of London. On the Magnet, Magnetick Bodies Also, and on the Great Magnet the Earth; a New Physiology, Demonstrated by Many Arguments and Experiments (London: at the Chiswick Press, 1900 [i.e. 1901]), p. 212

[14] Gilbert, De magnete, pp. 211-214.

[15] Ibid., see diagrams pp. 76, 77, 96, 191, 229.

> Ex his igitur rationibus, non probabilis modo, sed manifesta videtur terrae diurna circumuolutio, cum natura semper agit per pauciora magis, quam plura; atque rationi magis consentaneum vnum exiguum corpus telluris diurnam volutationem efficere potius, quam mundum totum circumferri.[16]

The final cause of this motion was the wisdom of the Creator in providing a suitable dwelling place for man; the primary efficient cause was the magnetic nature of the Earth:

> Quam miseram, & horrendam vtrinque faciem, ipsa tellus cum pati noluerit; magnetica astrea mente, in orbem voluitur, quo perpetua commutatione luminis, perpetua esset rerum vicissitudo, calores & frigora, ortus & interitus, dies & nox, mane & vespera, meridies & multa nox. Ita petit tellus solem & repetit, auersatur & insequitur, admirabili sua magnetica virtute.[17]

Gilbert's basis for associating the magnetic nature of the Earth with its diurnal rotation was Peter Peregrinus's assumption that a spherical lodestone balanced on polar pivots with its axis parallel to the celestial axis would turn once a day. Because the Earth was such a balanced spherical magnet, it turned on its axis once daily.[18]

To the earthly magnetic property Gilbert added two non-terrestrial causes for the Earth's motion: The Sun and the stars. He did not, however,

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[16] Ibid., pp. 219-220: "So for these reasons, not only probable but manifest, does the diurnal rotation of the earth seem, since nature always acts through a few rather than through many; and it is more agreeable to reason that the Earth's one small body should make a diurnal rotation, than that the whole universe should be whirled around." English translation from Gilbert, On the Magnet, pp. 219-220.

[17] Gilbert, De magnete, p. 224: "Since the Earth herself would not choose to endure this so miserable and horrid appearance on both her faces, she, by her magnetick astral genius, revolves in an orbit, that by a perpetual change of light, there may be a perpetual alternation of things, heat and cold, risings and settings, day and night, morn and eve, noon and midnight. Thus the Earth seeks and re-seeks the Sun, turns away from him and pursues him, by her own wondrous magnetick virtue." English translation from Gilbert, On the Magnet, p. 224.

[18] Gilbert, De magnete, pp. 220-224.

state how these agents acted upon the Earth. The Sun by its own orb of virtue and by its light moved the planets in their orbits and incited the daily turning of the Earth.[19] That the same cause, the Sun, effected a circular orbital motion in the planets and a rotational motion in the Earth did not, apparently, disturb Gilbert. He made no attempt to clarify the action of the Sun on the other globes and was even more vague about the influence of the stars upon the Earth:

> . . . tum quia tellus tota vti mouetur à se, ita etiam ab alijs astris promouetur. . . .[20]

While Gilbert presumed that the Sun and stars affected the Earth, he did not in the De magnete suggest that this action was reciprocal.[21] The only globe acted upon by the Earth was the Moon, and it was only in Gilbert's later work, De mundo nostro sublunari, that this relationship was specified as a magnetic one.[22]

Gilbert also used the magnetic nature of the Earth to answer the

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[19]Ibid., pp. 223-225.

[20]Ibid., p. 223: "as well as because the whole Earth, as she is moved of herself, so also is she propelled by other stars. . . ." English translation from Gilbert, On the Magnet, p. 223.

[21]In another work which he left in manuscript, Gilbert gave his cosmological ideas in greater detail. Since this book was not published until 1651, the ideas which it contains have not been included in this study. See: William Gilbert, Gvilielmi Gilberti Colcestrensis, medici regii, de mundo nostro sublunari philosophia nova. Opus posthumum, ab authoris fratre collectum pridem & dispositum, nvnc ex duobus MSS. codicibus editum. Ex museio viri perillustris Gvilielmi Boswelli equitis aurati &c. & oratoris apud Foederatos Belgas Angli (Amstolodami: Apud Ludovicum Elzevirium, 1651). For a summary of the De mundo and a comparison of the cosmological ideas expressed in it with those advanced in the De magnete see: Sister Mary Suzanne Kelly, "The De mundo of William Gilbert," (unpublished Master's thesis, Department of History, University of Oklahome, 1961), pp. 20-85.

[22]Compare: Gilbert, De magnete, pp. 86, 232; De mundo, pp. 186-187.

objection that falling bodies would not fall perpendicularly to the ground if the Earth were moving. To do this he made a precise distinction between the motion of a body toward the Earth and the motion of a body with the Earth. The former movement was a result of the body's weight and was a straight-line motion; the latter was due to a sharing in the Earth's magnetic nature and the body's being within the Earth's orb of virtue. Thus, this second motion was a circular one about the Earth's axis.[23] The solution differs from the Copernican one although in both cases earthly objects have the same motion as the Earth. In the system of the De revolutionibus each object moved independently with a diurnal movement.[24] In Gilbert's system the orb of virtue moved as a unit and all objects within it were carried along.

The magnetic virtue as described by Gilbert retained some animism. While the virtue was an innate power and the primary vigor of the Earth, it was also the principal attribute of the soul dwelling within the Earth. As Aristotle had implied that a non-corporeal substance controlled the motion of each sphere but had repeatedly referred to these motions as natural ones, so Gilbert pushed the vitalistic principle into the background and associated the Earth's motion with its magnetic property.[25] He did not explain why or how the magnetic property of the Earth caused it to move; he simply stated that it did.

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[23] Gilbert, De magnete, pp. 225-230.

[24] Nicolas Copernicus, Nicolai Copernici Torinensis de revolvtionibvs orbium coelestium, libri vi. (Norimbergae: Apud Ioh. Petreium, 1543), pp. 5 verso-7 recto.

[25] Gilbert, De magnete, pp. 208-210.

The theory is not an elegant one. Even in its expanded form in the De mundo many of the details are lacking. In the De magnete Gilbert never specified whether his cosmos were geocentric or heliocentric; he denied that the planets moved around the Earth but never discussed the movement or lack of motion of the Sun. The magnetic virtue accounted for only one motion in the system--the daily rotation of the Earth; other movements were passed over with little comment. The Moon moved around the Earth because it was "quasi vinculis alligata";[26] but no identification of the type of chain was given. Inelegant and incomplete as it was, Gilbert's theory proved useful to many of his successors. The most important of these was Johann Kepler who built his "totam Astronomiam Copernici Hypothesibus de Mundo, Tychonis vero Brahei Observationibus, denique Gvlielmi Gilberti Angli Magneticae Philosophiae."[27]

The "whole astronomy" to which Kepler referred is that presented in the Epitome astronomiae Copernicanae (1618-1621),[28] the fourth and last of

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[26]Ibid., p. 232.

[27]Johann Kepler, Johannes Kepler Gesammelte Werke, ed. Max Caspar (München: C. H. Beck'sche Verlagsbuchhandlung, 1937-1959), VII, p. 254: "whole astronomy upon Copernicus hypotheses concerning the world, upon the observations of Tycho Brahe, and lastly upon the Englishman William Gilbert's philosophy of magnetism." English translation from Johannes Kepler, Epitome of Copernican Astronomy in Great Books of the Western World Vol. XVI: Ptolemy, Copernicus, Kepler, ed. Robert Maynard Hutchins (Chicago, Illinois: Encyclopaedia Britannica, Inc., 1952), p. 850.

[28]The Epitome astronomiae Copernicanae was published in three parts: Johann Kepler, Epitome astronomiae Copernicanae. Usitatâ formâ quaestionum & responsionum conscripta, inque VII. libros digesta, quorum tres hi priores sunt de doctrina sphaericâ (Lentijs ad Danubium: Excudebat Johannes Plancus, 1618); Epitomes astronomiae Copernicanae, usitata formâ quaestionum & responsionum conscriptae, liber quartus, doctrinae theoricae primus: quo physica coelestis, hoc est, omnium in coelo magnitudinum, motuum, proportionumque, causae vel naturales vel archetypicae explicantur, et sic principia doctrinae theoricae demonstrantur. Qvi, qvod vice svpplementi librorum Aristotelis de caelo esset, certo consilio seorsim est editus (Lentiis ad Danubium: Excudebat Johannes Plancus, 1620); Epitomes astronomiae Coper-

his works on the celestial system. From the first, Mysterium cosmographicum (1596),[29] through the Astronomia nova (1609)[30] and the Harmonices mundi (1619)[31] to the last, the main features of his theory remained the same. Kepler believed in an harmonious, heliocentric universe in which the distances of the planets from the Sun were proportional to the radii of the spheres inscribing and circumscribing the five regular solids.[32] The details, however, especially those details concerned with the forces which moved the heavenly bodies, were more explicitly defined in successive presentation of the system.

When Kepler compared the calculations of Planetary positions based on the theory in the Mysterium cosmographicum with the available observational data, he found discrepancies between the two. These differences he attributed to two causes: The lack of accurate astronomical tables and the theoretical displacement of the Sun from the center of the universe in the

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nicanae vsitatâ formâ quaestionum & responsionum conscriptae, libri V. VI. VII. quibus propriè doctrina theorica (post principia libro IV. praemissa) comprehenditur (Francofvrti: Sumptibus Godefridi Tampachij, 1621). All are in Kepler, Gesammelte Werke, VII.

29 Johann Kepler, Prodromus dissertationvm cosmographicarvm, continens mysterivm cosmographicvm, de admirabili proportione orbivm coelestivm, de qve cavsis coelorum numeri, magnitudinis, motuumque periodicorum genuinis & proprijs, demonstratvm, per qvinqve regularia corpora geometrica (Tvbingae: Excudebat Georgius Gruppenbachius, 1596) in Kepler, Gesammelte Werke, I, pp. 1-80.

30 Johann Kepler, Astronomia nova ΑΙΤΙΟΛΟΓΗΤΟΣ, sev physica coelestis, tradita commentariis de motibvs stellae martis, ex observationibus G. V. Tychonis Brahe ([Pragae]: n.p., 1609).

31 Johann Kepler, Ioannis Keppleri harmonices mvndi (Lincii Austriae: Excudebat Ioannes Plancvs, 1619).

32 This idea was first presented in the Mysterium cosmographicum, Kepler, Gesammelte Werke, I, pp. 23-50. Compare: Kepler, Harmonices mundi, pp. 48-66, 180-192, and Kepler, Epitome astronomiae Copernicanae in Kepler, Gesammelte Werke, VII, pp. 264-289.

Copernican system. Kepler did little more than comment on the first of these. He corrected the second by transposing the center of the Earth's orbit, and with it the centers of all planetary orbits, from a point near the Sun to the Sun itself.[33] Few reasons were given to justify or support this move. Copernicus would have used the Sun as the center of all planetary orbits if he had not wished to adhere to Ptolemy's system as closely as possible;[34] the observational data would agree more closely with Kepler's theoretical calculations if such a change were to be made.[35] Yet, Kepler's primary reason for placing the Sun in the center of the universe was neither of these but his absolute knowledge that the Sun was in that position. For Kepler the harmony of creation demanded a truly Sun-centered system.

As he had postulated the Sun to be in the center of the planetary orbits, so Kepler hypothesized the Sun to be the agent responsible for the planetary movements.[36] This causal relationship between the Sun and the wanderers presented a conceptual difficulty which the transfer of the orbital centers had not. Planetary motions had been centered on stationary Earth or an equant in the geocentric systems. In a heliocentric system,

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[33]Kepler, Mysterium cosmographicum in Kepler, Gesammelte Werke, I, pp. 50-54.

[34]Ibid., p. 50: "Ante omnia autem retexendi numeri Copernici, atque peculiariter accommodandi sunt ad praesens institutum. Nam etsi ille sine dubio centrum totius vniuersi in corpore solari constituit: tamen vt calculum iuuet compendio, et ne nimium à Ptolemaeo recedendo, diligentem eius lectorem turbet. . . ."

[35]Ibid., p. 51: "Quos numeros si retinerem in praesenti negocio; illud incommodum sequeretur, quòd aut error committeretur in inscriptione, dum terrae orbis pro corpore censeretur, qui superficies saltem esset: vt videre est in praeced. Tabella IIII. aut orbi terreno nullam, vt caeteris relinquerem crassitiem."

[36]Ibid., p. 70

either the stationary Sun or a designated point near the Sun would be an equally acceptable center. The Sun had replaced the Earth as the central point of the universe, but the center in one system was no different as a center for calculational purposes than its parallel in the alternate scheme. This was not true, however, when the center of motion became, in Kepler's theory, a cause of the motion. The new theory could no longer be considered simply a change in coordinate systems for computational purposes.

Throughout antiquity and the Middle Ages many ideas concerning celestial motions had gone virtually unchallenged. A Prime Mover was the principal efficient cause of all heavenly motions. This Prime Mover was beyond the sphere of the fixed stars and was unlike anything else in the universe. Below this Mover, the heavenly spheres, each with its own natural motion, carried the fixed and wandering stars around the Earth. Not all writers accepted the transmission of motion from one sphere to another, but all who assumed such a transfer agreed that the motion could be transmitted only from the outer spheres toward the center. The spherical motion of lower spheres could not be transferred to outer spheres or affect them in any way. The heliocentric system of the De revolutionibus with its non-moving sphere of fixed stars had eliminated a Prime Mover beyond these stars and any transfer of motion from one celestial body to another; each sphere had simply retained its own natural motion.

In his first system, Kepler kept the spheres of the Copernican system but returned to a one-mover concept. This mover he placed in an unmoved

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[37] There is at least one exception to this. Levi ben Gerson (1288-1344) placed the source of motion in the Earth or near it; this source transmitted its motion outward from the Earth to the spheres.

[38] Copernicus, De revolutionibus, pp. 133 verso-196 recto.

center. He then changed the orientation of the cause-effect relation from a centrally directed to a centrally dispersed force. Moreover his mover was a known celestial body, the Sun, not the traditional, vague, indefinite Prime Mover of antiquity.

When he wrote the Mysterium cosmographium, Kepler had no force other than the traditional anima to implant in the Sun and little demand from the physics of his system to place it there. In order to account for eccentricities, he assigned a depth to each of the orbital spheres, but he had not discarded the concept of uniform circular motion for the celestial bodies.[39] Such movements were natural for heavenly objects and an indwelling anima in each planet would have been a sufficient traditional explanation for planetary motions. Yet, for Kepler it was not. He not only made the Sun the center of the planetary orbits, he used the Sun to keep these wandering stars wandering.

Kepler's discussion of the Sun as the new Prime Mover of the solar system is, in the Mysterium cosmographium, little more than repeated statements that the Sun does move the planets. He presented an either-or situation:

> Quòd si tamen praecisiùs etiam ad veritatem accedere, et proportionum aequalitatem vllam sperare velimus: duorum alterum statuendum est: aut Motrices animas, quò sunt à Sole remotiores, hoc esse imbecilliores: aut, vnam esse motricem animam in orbium omnium centro, scilicet in Sole: quae, vt quodlibet corpus est vicinius, ita vehementiùs incitet: in remotioribus propter elongationem et attenuationem virtutis quodammodò languescat.[40]

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[39] Kepler, Mysterium cosmographium in Kepler, Gesammelte Werke, I, pp. 48-49, 75-77.

[40] Ibid., p. 70: "Because if, however, more concisely we wish even to approach to the truth and to hope for any equality of proportion, it is set forth in one of these two: either the soul motors, which are farther from the Sun, are weaker, or there is one soul motor in the center

Although there was no reason why the _anima_ in some planets could not have been weaker than those in others and there were many objections to assuming a central _anima_ for the entire system, Kepler considered only one solution possible. After presenting the two considerations, he immediately accepted the second alternative and extolled the role of the Sun:

> Sicut igitur fons Lucis in Sole est, et principium circuli in loco Solis, scilicet in centro: ita nunc vita, motus et anima mundi in eundem Solem recidit: vt ita fixarum sit quies, Planetarum actus secundi motuum; Solis actus ipse primus: qui incomparabiliter nobilior est actibus secundisin rebus omnibus: non secus atque Sol ipse et speciei pulchritudine, et virtutis, efficacia, et lucis splendore caeteris omnibus longe praestat. Hic iam longe rectius in Solem competunt illa nobilia epitheta, Cor mundi, Rex, Imperator stellarum, Deus visibilis, et reliqua.[41]

In Chapter XXII of the _Mysterium cosmographicum_, Kepler used his theory of the decrease of the Sun's vigor as the distance from the Sun increased to explain the variation of speed in the orbit of a given planet. The planet moved more slowly at aphelion because it was then least influenced by the Sun. At this time, however, he gave no further explanation of the nature of this force or any new reason for its location at the center of the universe.[42]

Thirteen years later when he published the _Astronomia nova_, Kep-

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of all the orbits, whereby in the Sun; which, as whatever body is nearer, this it incites more vehemently; in farther ones because of their distance and the attenuation of the power it languishes in some measure."

[41]_Ibid._, p. 70: "Therefore as the font of light is in the Sun, and the origin of the orbit is in the place of the Sun, thereby in the center, so now the life, motion and soul of the world resides in the same Sun; thus as rest is of the fixed stars, the action of the second motion of the planets, the action of the Sun is itself first. Which is incomparably nobler than the secondary acts in all things; no differently than the Sun itself by its special beauty, its efficacy of virtue and splendor of light precedes by far all the others. Those noble epithets--heart of the world, king, ruler of the stars, visible God, and the rest--come together more rightly in the Sun."

[42]_Ibid._, pp. 75-77.

ler could specify the nature of the force in the Sun and give some reasons for its being there. His need for such a force had become pressing, for his new hypotheses that the planets moved in elliptical orbits with varying speeds eliminated natural uniform, circular motion from the system; the other "natural" motion, rectilinear, was of little use in astronomical theory. But in Gilbert's magnetism he found a force that seemed suitable.[43]

In the section devoted to the physics of astronomy, chapters thirty-three to forty-two, Kepler started by asserting "Virtutem quae Planetas movet, residere in corpore SOLIS."[44] Because the speeds of the planets were proportional to their distances from the Sun, because the Sun was in the center of the universe, and because the Sun was the source of heat and light, it was also, for Kepler, the center and source of the planetary motions.[45] The arguments given were much the same as those presented earlier, but they were presented in greater detail and the "motrix anima" of the Mysterium had been changed to a "virtutem motricem" in the Astronomia nova.[46]

Having established this virtutem motricem in the Sun as the cause

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[43]Kepler, Astronomia nova, pp. 172-177; Gerald Holton, "Johannes Kepler's Universe: Its Physics and Metaphysics," American Journal of Physics, XXIV (1956), pp. 340-351.

[44]Ibid., p. 167: "The virtue which moves the planets resides in the body of the sun."

[45]Ibid., pp. 167-172. In the Epitome astronomiae Copernicanae, (Kepler, Gesammelte Werke, VII, pp. 311-312) Kepler reversed this argument and placed the center of the planetary orbits in the Sun because the Sun was the source of the planetary movements.

[46]Kepler, Mysterium cosmographium in Kepler, Gesammelte Werke, I, p. 70; Astronomia nova, p. 168. In the second edition of the Mysterium cosmographium published in 1623, Kepler added notes which incorporated some of his later theories into his first work. After Chapter XX, he modified the anima: "Si pro voce anima vocem vim substituas, habes ipsissimum

of planetary motions, Kepler proceeded to describe this power and to explain how it operated. The description he based on a comparison of the new power of the Sun with a well known solar attribute, light. The motive virtue was like light in many respects. Both extended from the Sun in all directions; both traveled instantly from source to object; both were immaterial substances implanted in the Sun by the providence of the Creator. The two also differed in many respects. Light displayed an inverse square law in its rate of decrease; virtue an inverse first power law. An opaque body could stop light but it did not impede the virtue. Light affected only the surface of an object; motive virtue penetrated the entire substance.[47]

Although the virtue thus described could have been either the animistic power described in the Mysterium cosmographium or the light-like property described without a vital principle, the life-like agent in the earlier work was no longer acceptable to Kepler. In the Astronomia nova he posed the question "quale igitur corpus esse Solis putam, a quo haec species motrix descendit?"[48] His answer, given after a discussion of the similarities and differences between the body of the Sun and a magnetic body, was:

> Itaque plausibile est, cum terra Lvnam cieat per speciem, sitque corpus magneticum; & Sol Planetas cieat similiter per emissam

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principium, ex quo physica coelestis in Comment. Martis est constituta, et lib. IV. Epitomes Astr. exculta." Johann Kepler, Joannis Kepleri astronomi opera omnia, ed. Ch. Frisch, I (Frankofurti a.m.: Heyder & Zimmer, 1858), p. 176.

[47]Kepler, Astronomia nova, pp. 170-172, 177-178; Epitome astronomiae Copernicanae in Kepler, Gesammelte Werke, VII, pp. 303-306.

[48]Kepler, Astronomia nova, p. 176: "of what nature, therefore, do I think the body of the Sun to be, from which this motor species descends?"

> speciem: Solem itaque similiter corpus esse magneticum.[49]

This magnetic property of the Sun was retained in his subsequent astronomical systems.[50]

In order to explain how this virtue moved the planets, Kepler assigned a rotational motion to the Sun:

> Specie ergo mota in gyrum, ut eo motu motum Planetis inferat, corpus Solis, seu fontem, una moveri necesse est; non quidem de spacio in spacium mvndi: dixi enim me id corpus Solis cum Copernico in centro mundi relinquere: sed super suo centro, seu axe, immobilibus; partibus ejus de loco in locum (in eodem tamen spacio, toto corpore manente) transeuntibus.[51]

When he first postulated this solar movement in the _Astronomia nova_, Kepler, by assuming that the ratio of the Moon's distance from the Earth to the Lunar period was equal to the same ratio between Mercury and the Sun, calculated a three-day solar rotational period.[52] After Galileo published

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[49] _Ibid._, p. 177: "Therefore it is plausible, as the Earth moves the Moon by its specific nature, and is a magnetic body, and the Sun moves the planets in like manner by its specific emission: and thus similarly the Sun is a magnetic body."

[50] Kepler, _Epitome astronomiae Copernicanae_ in Kepler, _Gesammelte Werke_. VII, pp. 314-315, _passim_. Kepler did not deal specifically with the physics of his system in the _Harmonices mundi_; there are, however, repeated references to his discussion of this subject in the _Astronomia nova_ and the _Epitome astronomiae Copernicanae_, as well as several references to the innate virtue in the Sun. Henceforth, no attempt will be made in this study to trace the development of the details of Kepler's magnetic theory. Since the _Epitome astronomiae Copernicanae_ is organized on a question-answer plan and is the last of his systems to be published, most of the remaining discussion of Kepler's theory has been based on this work.

[51] Kepler, _Astronomia nova_, p. 173: "Therefore, since the motion of the planets is inferred from its motion, the motion by nature in a circle, the body of the Sun, or font, must be moved; not as from one space to another in the world: I say that I leave the body of the Sun with Copernicus in the center of the world; but upon its center, or axis its parts move from place to place (in the same space, however, the whole body remaining)." Compare Kepler, _Epitome astronomiae Copernicanae_ in Kepler, _Gesammelte Werke_, VII, pp. 299-300.

[52] Kepler, _Astronomia nova_, p. 175.

his observational data on Sun spots, Kepler adopted a longer twenty-six day solar period.[53] The length of time necessary for one revolution of the Sun about its axis was, however, of lesser importance to Kepler than the turning itself. This motion he attributed to an anima[54] residing in the Sun which turned that globe about its axis; as the body of the Sun turned, the orb of virtue which extended from the Sun due to its magnetic character also turned and thereby moved the planets:

> Nimirum corpore Solis converso, virtus etiam ista convertitur, quemadmodum magnete converso, vis partis vnius tractoria in plagas mundi alias atque alias transfertur. Cumque Sol illâ virtute sui corporis arripuerit planetam, seu trahens illum, seu repellens, seu dubius inter vtrumque; secum etiam circumducit illum, et cum illo fortè etiam omnem auram aethereum circumfusam. Trahendo quippe et repellendo retinet, retinendo circumducit.[55]

Qualitatively this system was entirely satisfying. The Sun in the center of the system emitted a virtue which extended to all of the planets; as the Sun turned about its axis, the virtue turned and carried the planets with it.

Quantitatively, however, the system was not pleasing. If the Sun's rotation moved all of the planets and if the virtue diminished by an inverse first power law, the planetary periods should have been directly proportional to the planetary distances from the Sun. They were not. Rather than re-

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[53]Kepler, Epitome astronomiae Copernicanae in Kepler, Gesammelte Werke, VII, p. 290.

[54]Ibid., pp. 92-93.

[55]Ibid., p. 301: "Indubitably by the turning of the solar body the virtue too is turned, just as by the turning of a loadstone the attractive force of one part is transferred to different regions of the world. And since by means of that virtue of its body the sun has laid hold of the planet, either attracting it or repelling it, or hesitating between the two, it makes the planet also revolve with it and together with the planet perhaps all the surrounding ether. Indeed, it retains them by attraction and repulsion; and by retention it makes them revolve." English translation from Kepler, Epitome, Great Books, XVI, p. 899.

strict the power of the Sun, Kepler placed the cause of the inequality in other factors. The first of these was "quod Planetae corpus natura inclinatum sit ad quietem in omni loco, in quo solitarium ponitur."[56]

On this planetary inclination to rest, introduced as an undetermined factor in the Astronomia nova, Kepler placed definite specifications in the Epitome astronomia Copernicanae. He postulated that the ratio between the rest factor in any planet to that in the next farthest planet was proportional to the one-half power of the ratio of their distances from the Sun.[57] Kepler gave no reason for this rate of increase, but from the use which he made of it, it would seem that the increment was so determined as to give theoretical support to the relationship Kepler had postulated between the planetary distances from the Sun and their periods. Since Kepler considered that his rest principle had to reside in a material body, the planets, like the Earth, were corporeal globes.[58] The volumes occupied by the planets increased in the same ratio as did their distances from the Sun; the rest property, however, was in no way dependent upon the volume of the planet.

Along with this inherent tendency to stay at rest, Kepler endowed each planet with a magnetic virtue.[59] This power was not identical to the virtue in the Sun: That from the Sun was stronger and extended to the planets while the virtue from the planet could not affect the Sun; the magnetic

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[56]Kepler, Astronomia nova, p. 186: "That the body of the Planet is inclined by nature to rest in any place in which it is placed by itself."

[57]Kepler, Epitome astronomiae Copernicanae in Kepler, Gesammelte Werke, VII, pp. 306-307.

[58]Ibid, pp. 283-285.

[59]Ibid., pp. 319-321; Kepler, Astronomia nova, pp. 269-272.

nature of the other planets was similar to that of the Earth as Gilbert had described it. Each planet, therefore, had two unlike poles which had a fixed orientation with respect to the fixed stars and also, in Kepler's system, with respect to the body of the Sun. The two magnetic regions in the Sun were not concentrated in poles but in the center and on the surface of that globe. Thus, the pole of a planet which was unlike the surface of the Sun was attracted to that body while the pole which was like the surface was repelled. However, since the spatial orientation of the planetary poles was constant as the globe moved around the Sun, the planet was at some points in its orbit drawn toward the Sun and at others pushed from it. This varying attractive and repulsive force exerted by the Sun on the planet brought it closer and then farther from the Sun and aided the increase and decrease of the orbital speed.[60]

The magnetic virtue also accounted for the planet's straying from the ecliptic, governed the planet's rotational motion if it had one, and controlled any secondary planets or satellites. The virtue which extended from a rotating planet also gyrated, and as the Sun's virtue carried the planets so a planet's virtue carried its satellites around their center.[61] The satellites had no need for such a virtue or motion as there were no globes dependent upon them.[62]

With the placement of the magnetic virtue in the planets, Kepler had extended his concept of force from the center, the Sun, to other subordinate members of the system; yet, he had not allowed for any mutual action

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[60] Kepler, Epitome astronomiae Copernicanae in Kepler, Gesammelte Werke, VII, pp. 299-301, 328-330, 335-342.

[61] Ibid., pp. 315, 318-319, 343-346.

[62] Ibid., p. 319.

between a body and the globes governed by it. The Sun controlled the motion of the planets, and the planets with the Sun controlled the secondary planets, but no lesser body could influence the movement of a greater one.[63] The system contained sufficient motors to account theoretically for any lack of harmony in the motions within the system, but the mathematical details concerning the mode of operating and combining among the motors varied from one part of the system to another.

Thus, in explaining the ratios of the periodic times, Kepler assigned four causes for the planetary periods: The length of the orbit, the inertia of the planet, the amount of virtue received from the Sun and the amount of space occupied by the planet. Kepler assumed that the amount of virtue received from the Sun decreased at the same rate that the quantity of space occupied by the planet increased so these two factors canceled each other. The relationship between planetary distances and periodic times was justified, therefore, by the addition of the orbital factor which was directly proportional to the distance from the Sun and the inertial factor which increased by the one-half power of the interval between successive planets.[64] Of these four causes, only one--the proportion between the orbital length and the distance from the Sun--had a non-Keplerian basis. All the others including the additive nature of the force factors were assumptions made by Kepler.[65]

To show why the Earth made $365\frac{1}{4}$ revolutions in the course of one

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[63] Ibid., p. 336: This is stated by Kepler only for the virtue of a planet in regard to the Sun; however, he never mentions the effect of a lesser body upon a greater one when calculating the motions of a globe.

[64] Ibid., pp. 306-307.

[65] Ibid., pp. 307-308.

circuit around the Sun rather than the 360 which was the proximate archetype, Kepler used no proportion. He simply stated "residuas et veluti supernumerarias revolutiones quinque cum quadrante, accedere illis 360, propter adjumentum ex Sole."[66] This added aid from the Sun was also responsible for the Moon's making twelve and one-third rather than twelve revolutions per year around the Earth.[67] In each case the difference between what harmony demanded and what observational data offered was explained by a theoretical consideration; in none of them did Kepler give the finer details, if indeed such existed, of his theory.

While he insisted upon physical forces controlling planetary movements, the forces were of less interest to Kepler than the harmonies produced by them. He formulated no mathematical expression governing magnetic phenomena; he gave no simple statement for celestial forces comparable to his laws describing planetary motions; he did not presume a reciprocal action among the heavenly bodies but kept a hierarchical global system. The underlying mathematical structure that Kepler attributed to the formation of the universe extended to the physical forces operative in that universe only in a lesser degree. He seems to have had no "a priori" knowledge of a geometric pattern, similar to the unique five regular solids, to use as a model for the motive forces in his system. Perhaps he never asked himself what was the mathematical archetype for the causes of celestial motions. Without the question, an answer was impossible.

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[66]Ibid., p. 316: "the $5\frac{1}{4}$ remaining and as it were supernumerary revolutions are added to those 360 on account of some assistance from the Sun." English translation from Kepler, Epitome, Great Books, XVI, p. 916.

[67]Kepler, Epitome astronomiae Copernicanae in Kepler, Gesammelte Werke, VII, pp. 352-353.

Kepler was not the only writer who incorporated magnetism into his system. Only a year after the publication of Gilbert's De magnete, Nicholas Hill (1570-1610) included twelve arguments defending Gilbert's magnetic property of the Earth in his Philosophia Epicurea.[68] Hill, a fellow of Saint John's College, Oxford, secretary to the Earl of Oxford and a dependent of Henry Percy, Earl of Northumberland, presented not a unified philosophy based on atomistic principles but a collection of over five hundred short comments covering a wide range of topics.[69] In some instances he grouped the statements on one topic together under a common heading,[70] at other times he changed from one subject to another without warning.[71] The whole presents neither a complete cosmological system nor a detailed astronomical plan, and it is impossible to form either from it.

Hill formed his cosmos of "prima corpuscula" which were "vere solida, impenetrabilia, inalterabilia, multiformia,"[72] and in constant random motion.[73] From this point on Hill's atomism bore little resemblance to that of the classical atomists. He included the Scholastic teaching that God was the primary efficient cause of all effects:

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[68] Nicholas Hill, Philosophia Epicvrea, Democritiana, Theophrastica proposita simpliciter, non edocta (Coloniae Allobrogvm: Prostant in Officina Fabriana, 1619). This is the second edition of Hill's book; the first edition was published in 1601.

[69] See Grant McColley, "Nicholas Hill and the Philosophia epicurea," Annals of Science, IV (1939-1940), pp. 390-405 for a discussion of the content and influence of Hill's book.

[70] Hill, Philosophia Epicvrea, pp. 29, 41, 53, 61, 62, 68, 155.

[71] Ibid., pp. 10-13, 18-20, 44, 66-67, 80, 102.

[72] Ibid., p. 30.

[73] Ibid., p. 101.

> Prima vis, causa rerum efficiens, actiua, vniuersalis, simplex, absoluta essentia, materiale virtutum fundamentum Deus est. . . .[74]

He introduced a non-atomistic simplicity principle:

> Deus, natura, sapiens nihil frustra faciunt, frustra fit per plura quod fieri potest per pauciora, per motum quod fieri potest per quietem, per motum velocem quod fieri potest per tardum, per spatij improportionabiliter maioris emensionem quod paucis, & formicae repentis passibus vno, aut altero praestatur. Cum ergo motus terrae suppositus eam habeat ad solarem proportionem quam 1. ad 45:16 terra potius sole mouetur.[75]

He connected the magnetic property of the Earth with the motion of that body. The first two reasons listed in "Terrae motvm sufficienter probant" were:

> 1. Magneticus confluxus grauissimorum.
> 2. Polorum magneticorum constantia & axeos.[76]

He postulated an interaction among the primary globes:

> Orbes non se exhauriunt, aut exinaniunt, sed mutuis viribus se refocillant, & confoederati alterna idiomatum communicatione seinuicem corroborant, & redintegrant fractas vires alter alterius.[77]

He extended the magnetic property and its influence throughout the universe:

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[74] Ibid., p. 28: "The primary virtue, the efficient cause of things, active, universal, simple, the absolute essence, the material fundamental vigor is God. . . ."

[75] Ibid., pp. 16-17: "God, nature, wisdom do nothing in vain; it is in vain through more to do that which can be done through fewer; through motion to do that which can be done by rest; through a swift motion to do that which can be done by a slow one; to complete a course through a greater space improportionally than a smaller one; and to have one body overtaken by the hasty pace of another. Therefore, since the supposed motion of the earth has to the sun the proportion of 1:45.16, the earth is moved rather than the sun."

[76] Ibid., p. 155: "1. The magnetic conflux of heavy things. 2. The constancy and axes of the magnetic poles."

[77] Ibid., p. 67: "The orbes do not exhaust or empty themselves, but by a mutual vigor renew themselves and united by an interchange and communication of idioms strengthen one another and renew the broken vigor of one another."

> Ratio decumbentium primariorum globorum in hanc potius quam illam partem est mutuus eorum ad se inuicem respectus, iuxta leges magneticas. . . .[78]

And he accepted at least part, if not all, of the Copernican hypothesis:

> Omnis apparentia Coelestis diurna, menstrua, annua, secularis, & periodica conuenientius, facilius, aptius per motum terrae suppositum, quam solis saluatur, & soluitur.[79]

These ideas scattered through Hill's work were not developed individually, connected into a logical whole, or even discussed relative to one another at any length. The reader is left with the impression that Hill collected ideas and then listed them in an unorganized fashion. He occasionally altered the ideas he collected from others. Thus, the magnetic property in Hill's Philosophia Epicurea was slightly different from that in the Gilbert's De magnete.

The emphasis on the extensions of magnetism throughout the infinite world[80] and on the interactions among the primary globes[81] expanded a terrestrial force into what could have been a universal unifying principle; the use of the phrase "magnetic laws"[82] was a step away from the vitalism in the earlier work for Hill's magnetism was less animistic than Gilbert's. His system contained souls, but they were informing principles not opera-

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[78] Ibid., p. 160: "The reason for the inclination of the primary globes more in one part [of their orbits] than in another is their reciprocal effect among themselves according to magnetic laws. . . ."

[79] Ibid., pp. 10-11: "Every appearance of the heavens, daily, monthly, yearly, of a generation, and of the periodic conjunctions, is more easily, more aptly, saved and solved through the supposed motion of the Earth than of the Sun."

[80] Ibid., pp. 12-13, 55, 73, 192-193.

[81] Ibid., pp. 79-80, 160.

[82] Ibid., p. 160.

tive agents.[83] Actions were produced by viribus or virtutibus.[84] The distinction was an important one, for by using it Hill seems to have tried to govern his cosmos by contact forces.[85] The magnet with its orb of virtue[86] provided such a force, but Hill was unwilling or unable to explain, logically or mathematically, how it operated.

The attempts in the Philosophia epicurea to spread the magnetic property throughout the universe were vague assumptions presented in a disordered fashion. When the Dutch mathematician Simon Stevin (1548-1620) included the results of Gilbert's study in his work, De Hemelloop (1605),[87] he was somewhat more precise. Stevin was an avowed Copernican. Although he often worked from the assumption of a fixed Earth, there can be no doubt that he considered such a practice permissible only from a mathematical viewpoint. Whenever he described the world as he believed it actually was, he used the heliocentric theory.

> De bepalinghen beschreven sijnde soo sal dit eerste bouck acht onderscheytsels hebben, vande vinding deur ervarings dachtafels des loops van Son, Maen, Saturnus, Iupiter, Mars, Venus, Mercurius, ender vaste sterren, alles met stelling eens vasten Eertcloots als uveerelts middelpunt, uvant hoeuvelse eyghentlick in een rondt draeyt ghelijck d' ander Duvaelders, nochtans leertmen de beghinselen deser const licht

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[83] Ibid., pp. 185-186.

[84] Ibid., pp. 8, 11-12, 16, 37, 39, 73, 179, 180.

[85] Ibid., pp. 10, 149-150.

[86] Hill often called Gilbert's magnetic orb of virtue an effluvium although Gilbert used the term "effluvium" solely in explaining electric phenomena.

[87] Simon Stevin, De Hemelloop in The Principal Works of Simon Stevin. Vol. III: Astronomy, ed. A. Pannekoek. Navigation, ed. Ernst Crone (Amsterdam: C. V. Swets & Zeitlinger, 1961). This edition has the Dutch text and the English translation on facing pages. For a discussion of Stevin's life, works and influence see: George Sarton, "Simon Stevin of Bruges (1548-1620)," Isis, XXI (1934), pp. 241-303.

> elicker verstaen deur het schijnbaer, dan deur het eyghen, soo daer af breeder gheseyt sal uvorden in des 3 boucx 7 voorstel. Angaende voorder spieghelinghen uvaer toe de eyghen stelling des loopenden Eertcloots bequameris, daer af salick int boveschreven derde bouck handelen.[88]

This open adherence to the new system was the summary of the opening section of "the first textbook destined to give a simple and easy exposition of the heliocentric theory."[89]

If Stevin had been among the first to announce his acceptance of the physical reality of the world described in the De revolutionibus, he was also among the last to believe in the actuality of the heavenly spheres. The celestial orbs were, to him, concentric corporeal bodies carrying the planets.[90] The combination of the two ideas presented difficulties. The assumption that circular motion was natural to the heavens could be joined to solid spheres to explain the planetary motions and also to the diurnal rotation of the Earth to save the primary motion in the heavens,[91] but neither of these could be used to account for the third motion of the Earth as described by Copernicus:

> Nochtans moest dit roersel soo toeghelaten sijn, om al d'ander natuerlicke overeen comminghen die uyt stelling des roerenden Eertcloots volghen een sekergront te gheven: Doch is daer na int licht ghecommen

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[88] Ibid., pp. 28-29: "After the definitions have been described, this first book is to comprise eight sections, of the finding by means of empirical ephemerides of the motion of Sun, Moon, Saturn, Jupiter, Mars, Venus, Mercury, and of the fixed stars, all this on the assumption of a fixed Earth as centre of the universe; for though in reality it revolves in a circle, like the other Planets, nevertheless it is easier to understand the elements of this science from the apparent than from the true motion, as will be set forth more in detail in the 7th proposition of the 3rd book. As to further theories, for which the true assumption of the moving Earth is better suited, I will deal with those in the third book referred to above." Compare pp. 110-111, 116-117.

[89] A. Pannekoek, "Introduction to the Work," Ibid, p. 6.

[90] Stevin, Principal Works, III, pp. 130-135.

[91] Ibid., pp. 118-127.

> het bouck vander grooten * Eertclootschen seylsteen, beschreven deur Guilielmus Gilbertus, waer in de natuerlicke oirsaeck deses roersels, mijns bedunckens ghetroffen en gheopenbaert is. . . .[92]

Some adaptation of Gilbert's magnetic theory was needed to have it "hit off" and "reveal" anything about the third motion of the Earth, for Gilbert had never applied his theory to this motion. He had explained the diurnal motion of the Earth by Peregrinus's assumption that a correctly aligned, freely suspended magnet would rotate around its axis once in twenty-four hours, but Stevin ignored this application of the magnetic virtue and used only the tendency of a magnet to adjust its position with respect to any other magnetic body. The Earth, a magnetic sphere, constantly maintained its axis in the same direction because it stayed in a fixed position relative to the magnetic poles in the universe around it. Thus, Stevin eliminated the necessity of assuming a third motion for the Earth. He offered a proof by example:

> Maer om dit roersel en strecking vanden as gheduerlick na een selven oirt, te verclaren mette bequaemste gelijckenis die my nu te vooren comt, ick segh aldus: Ghenomen dat ymant opt middelpunt des ront papiers van een seecompas stack een stroyken, streckende evewijdich metten as des Eertcloots, dat seecompas staende in een schip, varende neem ick in een ronde gracht van een Slot of Schans, t'is kennelick dattet selve schip een keer ghedaen habbende van plaets tot plaets na d'een sijde, soo sal daerentusschen t'compas in sijn plaets oock eens ghekeert sijn na d'ander sijde, dats teghen den keer vant schip, en sulcken ghedeelte eens keers t'selve schip ghedaen heeft na d'een sijde, soodanich ghedeelte sal oock het seecompas ghedaen hebben na de ander sijde, blijvende het boveschreven stroyken gheduerlick evewijdich metten as des Eertcloots: En alsoo salmen derghelijcke oock verstaen vanden loop des Eertcloots in haer wech, welcke te wijle sy daer een keer doet, soodraeytse een keer in haer plaets teghen den voorgaenden keer, en blijvende den as altijt na een selven oirt streckende.[93]

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[92] Ibid., pp. 128-129: "Nevertheless this motion had to be admitted in order to give a sure basis for all the other natural correspondences that follow from the theory of a moving Earth. But thereafter there was published the book about the great terrestrial magnet, described by Guilelmus Gilbertus, in which the natural cause of this motion in my opinion is hit off and revealed."

[93] Ibid., pp. 126-128: "But to explain this motion and constant tend-

Because this motion, as described by Copernicus, took place in a East-to-West direction while all other natural heavenly motions had a West-to-East direction and because Stevin attributed the fixity of the Earth's axis to a magnetic body's retaining a fixed orientation, he preferred to call the third motion of the Earth "haer seylsteenighe stilstandit."[94]

Having solved one difficulty in this manner, Stevin applied the same principle to other planets and their orbs and eliminated the second contradiction that arose in a solid sphere, heliocentric system. This was the lack of any transfer of motion from one sphere to another.

> Noch moet ick seggen dat ick over een tijt van desen handel onbesloten gedachten hadde, houdende ter eender sijde voor ghemeene reghel, dat alle begrepen die wech henen moet daer hem sijn berijpende draecht, waer uyt volghen soude dat elck Dwaelders een roersel moest hebben gehmengt uyt al de roersels der Dwaelders die boven hem sijn: Ter ander sijde sach ick metter daet t'verkeerde ghebeuren: Dit dede my dencken oft soude meughen sijn dat de Dwaelders niet en waren in Hemelen ghehecht, maer deur de locht vloghen ghelijck de voghelen om een torre, sonder het roersel van d'een, ant roersel van d'ander eenige beweeghnis te veroirsaken, waer tegen ander redenen my weerom anders deden vermoeden. . . .[95]

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ency of the axis in the same direction by means of the most convenient comparison that now occurs to me, I say as follows; if a man were to put in the centre of the round paper of a mariner's compass a straw parallel to the axis of the Earth, this compass standing in a ship sailing, I assume, in a circular moat of a Castle or Entrenchment, it is evident that when this ship has made one turning from place to place towards one side, in the mean time the compass in its place will also have made one turning towards the other side, i.e. against the turning of the ship; and such part of a turning as the ship shall have made towards one side, the same part the compass will also have made towards the other side, the aforesaid straw constantly remaining parallel to the axis of the Earth. And it must be similarly understood also with regard to the motion of the Earth in its orbit: while it performs one revolution, it rotates once in its place against the former revolution, the axis always tending in the same direction."

[94] Ibid., pp. 130-131: The literal translation is "its loadstony standstill," but the translator has preferred "its magnetic rest" in this edition. Ibid., p. 14.

[95] Ibid., pp. 132-133: "I also have to say that for some time I was undecided in my mind about this matter, holding it on the one hand a gen-

Among the reasons which made Stevin think differently was the fixed orientation of a magnetic body. First he extended the property of "magnetic rest" to the Earth's orbit, then to the orbits of the other planets, and, finally, to "inde heele hemelsche clooten daerse in ghedreghen worden, sulcx dat haer assen (gelijck vooren int tweede voorstel vanden Eertcloots as gheseyt is) geduerlick na een selven oirt strecken."[96] This constancy of direction prevented the motion of one sphere from turning the sphere below it, and, thus, provided an explanation for the seeming paradox of interconnected but independent spheres.

Throughout the development and application of his theory of "magnetic rest" Stevin had assumed (if not explicitly at least implicitly in his constant use of the analogy of the magnetic compass[97]) that whatever kept the Earth, orbits and spheres in their respective positions was outside these bodies. In the fourth proposition of the third book, he stated that since these bodies were so oriented and since the motion of one planet was not transferred to that below it, "plaets der crachten die den Eertcloot, vveghen, en Hemelen der Dvvaeders in haer seylsteenighe

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eral rule that all bodies contained by other bodies must take the course in which their containing bodies carry them, from which it would follow that every Planet must have a motion consisting of a combination of all the motions of the Planets that are above it. On the other hand, in practice I saw the reverse happening. This caused me to think whether it could be possible that the Planets were not attached to Heavens, but were flying through the air like birds about a tower, without the motion of the one causing any change in the motion of the other; but other reasons again made me think differently."

[96] Ibid., pp. 130-131: "the entire heavenly spheres in which they are carried, such that their axes (as has been said above in the second proposition of the Earth) constantly tend in the same direction."

[97] Ibid., pp. 126-127, 128-129, 130, 131, 134-135.

stilstandt houden" must be in the heaven of the fixed stars.[98] The one exception was the "attractive force" for the Moon which would have to revolve in another box or lower Heaven. This Stevin located between Mars and Jupiter.[99] Stevin never explained either what this "attractive force" was or if the heaven of the fixed stars contained only a common force for all the heavenly bodies other than the Moon or a special one for each. Such details, apparently, did not concern him. The natural motions of the spheres coupled with the "magnetic rest" provided efficient causes for the celestial movements; observational and mathematical data told what movements these causes effected. Stevin treated the two aspects of celestial phenomena independently.[100] There was nothing in his theory to join them into a unified whole.

The attempts of Kepler and Stevin to use magnetism with the Copernican system were not the only adaptations of this force to an astronomical hypothesis. David Origanus (1586-1628) and Nathanael Carpenter (1589-1628) each described an Earth centered system similar to the Tychonic one. Both men disagreed with Tycho about the diurnal motion, a motion which they attributed to a rotating Earth rather than to a motion of the fixed stars, and

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[98] Ibid., pp. 132-135: "the place of the forces which keep the Earth, the orbits and the Heavens of the Planets in their magnetic rest. . . ."

[99] Ibid., pp. 134-135.

[100] At the beginning of the first chapter of the third book of the De Hemelloop, the section which contains theoretical speculations, Stevin limited his subject: "Since the object is here to describe the Planets' motions on the theory of a moving Earth, it seems appropriate to set forth as much about the nature and figure of the world--being the basis on which the foregoing is built--as we know or surmise and is conducive to the knowledge of the motion in view" (Ibid., pp. 118-119). This section separates the explanations of methods based on the theory of a fixed Earth from those using a moving Earth postulate. When working with both systems, Stevin treats the celestial motions without regard to their causes.

both suggested that the terrestrial magnetic virtue account for this motion.[101]

As some astronomers found magnetism helpful in saving the celestial phenomena, so a few writers on magnetism included astronomical aspects in their works on magnetism. Mark Ridley (1560-1624) in his A Short Treatise of Magneticall Bodies and Motions[102] repeated many of Gilbert's theories and experiments and extrapolated the cosmology of the De magnete. All the planets and any bodies which accompanied them such as "the two starres which support Saturn, the foure attenders vpon Iupiter," the Sun and the Moon were all magnetic globes.[103] These bodies had poles, axes and possibly rotational motons, but Ridley was not certain about the details of these. Later times would know more and he was satisfied to leave much of the study of the heavens to them.[104] He did, however, account for one celestial occurrence other than the apparent motion of the fixed stars--the diurnal movement of the Earth--by an application of magnetic principles. This was the lack of any apparent rotational motion in the Moon.

Ridley assumed that the Moon was a magnetic body with four poles:

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[101]David Origanus, Novae motuum coelestium ephemerides Brandenbvrgicae, annorvm LX, incipientes ab anno 1595, & desinentes in annum 1655, calculo duplici luminarium, Tychonico & Copernicaeo, reliquorum planetarum posteriore elaboratae, & varijs diversarum nationum calendarijs accommodatae, cum introductione hac pleniore, in qua chronologica, astronomica & astrologica ex fundamentis ipsis tractantur (Francofurti cis Viadrum: Apud Davidem Reichardum bibliopolam Stetinensem, 1609), pp. b-c 3. Nathanael Carpenter, Geography Delineated Forth in Two Bookes. Containing the Sphaericall and Topicall Parts Thereof (Oxford: Henry Cripps, 1625), pp. 75-76.

[102]Mark Ridley, A Short Treatise of Magneticall Bodies and Motions (London: Printed by Nicholas Okes, 1613).

[103]Ibid., p. 4.

[104]Ibid., p. 14.

the usual north and south poles and an additional east and west pair. The lunar north and south poles maintained the body's balance as "it was the vertue polar and Magneticall that holdeth all globes in their position whatsoeuer."[105] Two other celestial bodies, Jupiter and the Sun, turned about their axes as the Earth did; the Moon did not for it was "kept firme and vnmoueable from circular motion about her axis, by other two poles that be vpon the edges and aequator of her body, because her spots be always alike on her East and West side, that hold her firmely & stiffely that she can by no means turne about upon her first two poles."[106]

It was evident that the Earth had no such poles not only because of its diurnal motion[107] but also because "if we were so happy to find any in the East or West of the earth, then the matter of longitude would be perfectly attained vnto, which hath so greatly busied all the ingenious wits of the world."[108] The remarks on the Moon and other planets were only passing comments which Ridley did not develop. Having digressed to and dismissed the Moon, he continued with his major topic, the magnetic Earth.

The side comments on the extension and application of the magnetic virtue beyond the Earth, while only a minor consideration in Ridley's early writing, were an important part of his later works. When, in 1616, another English writer, William Barlowe (d. 1625), published a book on the subject without including the application to the cosmos, Ridley became engaged in a controversy with him. Like Ridley, Barlowe had drawn heavily from Gilbert

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[105]*Ibid.*, p. 15.

[106]*Ibid.*

[107]*Ibid.*, p. 16.

[108]*Ibid.*

when writing his Magneticall Advertisements;[109] unlike Ridley, he disagreed with the cosmological speculations in the sixth book of the De magnete.[110]

In 1617 Ridley published Magnetical animadversions in which he attacked Barlowe and reaffirmed his belief in the diurnal motion of the Earth and the magnetic nature of the terrestrial and all other globes.[111] Barlowe replied by publishing a second edition of the Magneticall Advertisements to which he added A Briefe Discovery of the Idle Animadversions of Marke Ridley Doctor in Phisicke vpon a Treatise Entituled, Magneticall Aduertisements;[112] this latter work was intended as a refutation of Ridley's arguments.

Barlowe based his disagreement with Ridley upon the difference in their definitions of a magnetic body. Ridley accepted as such a body anything "which seated in the aether or aire, doth remaine and place it selfe

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[109] William Barlowe, Magneticall Aduertisements: or Divers pertinent Obseruations, and Approued Experiments Concerning the Nature and Properties of the Load-stone: Very Pleasant for Knowledge, and Most Needfull for practise, of Trauelling, or Framing of Instruments Fit for Trauellers Both by Sea and Land (London: Timothy Barlow, 1616).

[110] William Barlowe, Magneticall Aduertisements: or Divers Pertinent Obseruations, and Approued Experiments, Concerning the Natures and Properties of the Load-stone. Very Pleasant for Knowledge, and Most Needfull for Practise, of Trauelling, or Framing of Instruments Fit for Trauellers Both by Sea and Land. Whereunto is Annexed a Briefe Discouerie of the Idle Animaduersions of Mark Ridley Dr. in Physicke, upon a Treatise Entituled Magneticall Aduertisements (2d ed.; London: Timothy Barlow, 1618), p. B1 verso.

[111] Mark Ridley, Magneticall Animadversions upon Certaine Magneticall Advertisements from W. Barlow (London: N. Okes, 1617).

[112] William Barlowe, A Briefe Discouerie of the Idle Animaduersions of Mark Ridley Dr. in Physicke, upon a Treatise Entituled Magneticall Aduertisements (London: Timothy Barlow, 1618), bound with Barlowe, Magneticall Aduertisements, 1618.

in one place, or kinde of situation naturall, not alterable."[113] Barlowe rejected this and starting from his definition "that the Magneticall Motion is a natural inclination of two Magnets or Magneticall bodies, that may freely moue, respecting the one the other within the Orbe of their forces with their convenient ends, that is to say, the North end of the one alwaies respecting the South of the other,"[114] he concluded no motion could be ascribed to a single magnetic body.

> Nor forasmuch as all Magneticall motions are alwaies respectiue of the one Magnet or Magneticall bodie towards another, it followeth by necessarie consequent, that no Magnet or Magneticall body, can either moue, or be moued of it selfe, but is vtterly voide of all intrinsecall or selfe-Motion, the true and onely cause of his Motion being euermore without it self.[115]

The terrestrial globe was a magnetic body but there was no other magnetic body within its orb of virtue. Without this second body any motion of the first was impossible. There, "mine Animaduersors selfe-motions of the Globe of the earth circularly, by Magneticall vigour, in the which he doth so gallantly triumph, is but an idle figment, and a meere Chimara."[116]

Throughout the series of assertions, accusations, replies and rebutals between the two men, each remained steadfast in his original position. Neither could offer a supporting reason or demonstration for his own theory that seemed valid to the other. Each readily saw the error in his opponent's argument and refused to believe that there was any similar flaw in his own.

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[113] _Ibid._, p. 7.

[114] _Ibid._, p. 6.

[115] _Ibid._

[116] _Ibid._, p. 7.

Barlowe and Ridley typify the positions of the men who wished to deny or accept the extension of Gilbert's magnetic virtue to a cosmic force. Those who rejected the use of magnetism in explaining astronomical phenomena were offered no compelling arguments in its favor. Those who wanted to incorporate it in their system were limited only by their own ingenuity. Digges considered the magnetic center of the Earth to be a balancing factor; Gilbert had a totally magnetic Earth effect a twenty-four hour motion. Kepler made magnetic virtue both the central and local motive force in a heliocentric system with freely moving planets, while Stevin applied the same virtue as a constraining agent in a Sun-centered cosmos filled with corporeal spheres. Nicholas Hill combined atomism and magnetism. David Tost and Nathanael Carpenter altered the Tychonic system in order to include a rotating magnetic Earth. Mark Ridley explained the non-rotation of the Moon with a four-pole argument, and William Barlowe denied the Earth's diurnal movement because only one body was present.

All of these men had used the same qualitative force; each had employed it as he desired. None had been able either to account for the phenomena solely in terms of the magnetic virtue or to limit the force so that wherever it was placed the same effects were always observable. The one attempt at a rigid mathematical expression of its mode of operation, Kepler's inverse first power hypothesis, needed several supporting assumptions to approximate the observational data. As a theoretical device magnetism had an almost unlimited range of application; as a practical efficient motor whose effects could be measured and predicted in the celestial region, it was a failure. Gilbert had provided the natural philosophers with an innate force that seemed to be applicable throughout the universe, but neither he nor his followers placed sufficient restrictions upon it to make the magnetic virtue useful.

CHAPTER V

MECHANISTIC MOTORS

Magnetism as a celestial motor was but a step from the animistic theories. Most of the men who employed the magnetic virtue to move the heavenly bodies had specified that a living form dwelt in and controlled at least one physical body in the universe; this one body by its magnetic virtue then moved the others. For Gilbert an *anima* was in the Earth and probably in every other globe;[1] Kepler's vital principle resided in the Sun;[2] the vagueness of Hill's atomism included multiple souls;[3] Ridley and others who accepted Gilbert's magnetic theory had not eliminated the vitalism from it.[4] These men had assumed that an attribute of the *anima* was

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[1]William Gilbert, *Gvilielmi Gilberti Colcestrensis, medici Londinensis, de magnete, magneticisqve corporibvs, et de magno magnete tellure; physiologia noua, plurimis & argumentis, & experimentis demonstrata* (Londini: Excudebat Petrvs Short, 1600), pp. 208-210.

[2]Johann Kepler, *Astronomia nova ΑΙΤΙΟΛΟΓΗΤΟΣ, sev physica coelestis, tradita commentariis de motibvs stellae martis, ex observationibvs G. V. Tychonis Brahe* ([Pragae]: n.p., 1609), pp. 173, 185-186.

[3]Nicholas Hill, *Philosophia Epicvrea, Democritiana, Theophrastica proposita simpliciter, non edocta* (Coloniae Allobrogum: Prostant in Officina Fabriana, 1619), pp. 13-14.

[4]Mark Ridley, *A Short Treatise of Magneticall Bodies and Motions* (London: N. Okes, 1613), p. 13; Nathanael Carpenter, *Geography Delineated Forth in Two Bookes. Containing the Sphaericall and Topicall Parts Thereof* (Oxford: Henry Cripps, 1625), pp. 76-79; David Origanus, *Novae motuum coelestium ephemerides Brandenbvrgicae, annorvm LX, incipientes ab anno 1595, & desinentes in annum 1655, calculo duplici luminarium, Tychonico*

the magnetic virtue and had proceeded to explain celestial movements in terms of that attribute rather than with regard to the source of it, but for each of them an anima as the indwelling primary principle of the universe remained.

A few of their contemporaries tried to depart completely from the living form and save the celestial phenomena by the use of some mechanical system. Such attempts at this time were generally confused and incomplete; the men proposing them were caught between the crumbling structure of classical cosmology and the cloudy vision of the edifice they were constructing to replace it.

One of the earliest of these efforts during the period under consideration was the calor-frigus hypothesis of Bernardino Telesio. Born in Italy and educated in the scholastic tradition as well as in the new learning of the Renaissance, Telesio began his attack on medieval Aristotelianism while lecturing at Naples. In 1565 he presented his new theory, a theory which its author intended should replace the traditional concept of the structure of the world, in his De rerum natura.[5] In his later works, Telesio expanded, modified slightly and often re-iterated the hypothesis of the De rerum natura.[6]

& Copernicaeo, reliquorum planetarum posteriore elaboratae, & varijs diversarum nationum calendarijs accommodatae, cum introductione hac pleniore, in qua chronologica, astronomica & astrologica ex fundamentis ipsis tractantur (Francofurti cis Viadrum: Apud Davidem Reichardum Bibliopolam Stetinensem, 1609), pp. 121-122.

[5]Bernardino Telesio. Bernardini Telesii Consentini de rerum natura iuxta propria principia liber primus et secundum, denuo editi (Neapoli: Apud Iosephum Cacchium, 1570). The first edition appeared in 1565.

[6]Bernardino Telesio, Bernardini Telesii Consentini de his, quae in aëre fiunt; & de terraemotibus, liber vnicum (Neapoli: Apud Iosephum

The cosmos was formed, according to Telesio, not from Earth, Water, Air and Fire but from one type of substance, corporea moles, acted upon by two operative agents: "agentes naturae duae, calor frigusque, et corpora moles una."[7] The agents were incorporeal

> et utrumque, ut subsistat, corporea opus habere mole; et ex ea omnino entia omnia constare. Itaque rerum omnia principia tria esse: agentes naturas duas incoporeas, et, quae illas suscipit, corpoream unam; et omnis ipsam actionis omnisque expertem esse operationis, et invisibilem sui natura nigramque esse.[8]

By their diverse modes of acting the operative agents produced different effects and unlike regions. Calor produced the heavens, while the work of frigus brought forth the Earth:

> Quoniam igitur caelum terraque, longe nimirum maxima mundi corpora et quae prima a Deo constituta esse sacrae divinae testantur litterae, a calore illud, hoc a frigore constitutum est; et manifeste reliqua entia e terra a solis calore immutata fiunt omnia: patet calorem frigusque agentia rerum omnium principia esse. Nam si, una terra excepta, reliquorum entium nullum prorsus a frigore, sed, ut dictum est atque dicetur, a calore constituta sunt omnia; quoniam ut, qualia effecta sunt, fierent frigoris etiam opera opus fuit, quod caloris actionem veluti interciperet moderareturque, et alterum primorum corporum frigoris, ut dictum est, est opus, ipsum itidem alterum agens principium ponendum videtur.[9]

Cacchium, 1570); Bernardini Telesii Consentini de rervm natvra ivxta propria principia. Libri ix. (Neapoli: Apud Horatium Saluianum, 1587); Bernardini Telesii Consentini, barii de natvralibvs rebvs libelli ab Antonio Persio editi (Venetiis: Apud Felicem Valgrisium, 1590).

[7]Bernardino Telesio, Bernardini Telesii de rerum natura, a cura di Vincenzo Stampanto (3 vols.; Modena: A. F. Formittini, 1910-1913), I, p. 18.

[8]Ibid., p. 17: "and each, if it is to remain, needs corporea mole; and from it all beings continue to stand. Therefore all the principles of things are three: two incorporeal natural agents, and, that which supports them, one corporeal substance; and every action and every operation that does not have part in it [the corporeal] is by its nature invisible and dark."

[9]Ibid., pp. 16-17: "Therefore the heavens and the earth, most certainly the greatest bodies of the world and those first made by God as Sacred Scripture testifies, have been made the one by heat, the other by cold; and it is manifest that the remaining beings of the earth are all interchanged by the heat of the sun: it is evident that heat and cold are

Each agent not only produced one special region of the cosmos, it also determined the character of that region. Telesio asserted that "calorem sui natura mobilem, frigus contra immobile esse; et propterea molem illi quam subit, tenuem levemque, huic contra densam gravemque, faciendi facultatem tributam esse; et albedinem omnem caloris speciem et veluti faciem esse."[10]

Since calor, the agent producing motion and light bodies, acted upon the corporea moles to form the tenuous heavens, while the immobile frigus shaped the heavy Earth, the heavens were the moveable part of the universe, the Earth the non-moving segment. The non-uniform speeds in the heavenly region Telesio explained by varying the amounts of calor acting upon the diverse quantities of corporeal moles in different celestial bodies,[11] and by the variation in the density of the heavenly region itself. Some parts were "minore tenuitate, itaque copiosiore" and therefore offered a greater resistance to the bodies moving through them.[12]

The change in density within the heavenly region was less important than the amount of calor the globe received. The greater the quantity of the agent, the faster the motion of the recepient body. Although the quan-

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the principal agents of all things. For thus, the earth excepted, certainly none of the other entities are constructed by cold, but as it has been said and will be said, all things are formed by heat; however, in order that the condition be completed, they need even the works of cold because it, as it were, intercepts and moderates the action of heat; and it is necessary, as it has been said, that the other of the first bodies, cold, is itself seen in the same way as one of the named principal agents."

[10]Ibid., p. 12: "heat is by its nature mobile, cold on the contrary immobile; and for that reason when the former approaches the substance it forms a tenuous and light body; when the latter a dense and heavy thing; thus the thing made is according to the power; and every species of heat is white and as it were visible.

[11]Ibid., pp. 151-154.

[12]Ibid., p. 36; compare, pp. 23, 40-41.

titative relation between the intensity of calor and the speed of the globe was never expressed, much of Telesio's writing implies a direct one-to-one ratio.[13]

Telesio considered calor and frigus to be the immediate creations and under the direct control of the Creator, who made and ruled them. Few doubted that God had created the Earth and watched over the Earth without using intermediaries; Telesio stressed that the same care had been shown in the creation of the heavens:

> Non sane caloris, per se, et temere, nullaque agentis ratione, sed a Deo, a longe nimirum potentissimo longeque sapientissimo opifice, et a quo ipse factus est calor, directi, et Dei arbitrio imperioque agentis, caelum opus esse, et sacrae nos divinae litterae et humana etiam docet ratio: quae scilicet nec calori nec enti alii prorus ulli, sed uni Deo opus attribui sint, quod arte tanta tantaque sapientia et potentia constructum sit tanta.[14]

The hot-cold dichotomy of this system, if accepted, accounted for the observable phenomena. The Earth, cold and heavy, rested in the center of the heavens while the hot, light celestial bodies moved around it.[15] The Sun supplied heat for the Earth and all motus upon the Earth; the unequal quantities of calor assigned by an all-wise God to the Moon and other supralunar globes explained the varied motions beyond the Earth.

Telesio's system was structurally much like Aristotle's. Each assumed a dichotomy for the universe and then had explained all motions in

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[13]Ibid., pp. 151-154, 255-259.

[14]Ibid., pp. 36-37: "It is absolutely necessary that the heavens be made from heat not per se, or by accident, or by any reason of origin, but by God, certainly the most powerful and most wise builder, by whom heat itself has been made directly; by God, judge and ruler of the agent heat, as Sacred Sciriture and even human reason teaches us. Undoubtedly neither to heat nor to any other being directly, but to one God must it be attributed because it has been constructed with such great art, wisdom and power."

[15]Ibid., pp. 14-17.

terms of the special properties of each region. One could neither predict nor calculate astronomical events in either system without assigning arbitrary values to various component parts; one could explain phenomena only in the most general terms. Thus, while both Aristotle and Telesio provided logically coherent theories, neither was satisfying to such men as Brahe and Kepler who were intent upon the exact description of the celestial region and the precise predictions of events therein.

The idea of heat as an active agent in the cosmos was an old one. From ancient times Fire and heat had often been joined with the heavenly motions and during the late sixteenth and early seventeenth century the combination continued to be used. We have seen that Francesco Patrizi postulated *calor* as one of his four elements and had it accompany *lumen* to act on *fluor* to form all corporeal objects.[16] Thomas Campanella incorporated much of Telesio's theory into his own.[17] Yet, heat theories were never especially popular; Telesio's was no exception.

There were only a few other writers in the late fifteen hundreds who attempted a mechanical explanation without spheres for all or part of their astronomical systems. Nicolas Rymers stated that some force kept the fixed stars in their respective positions but he added that he did not know what that force was: "Tota autem fixarum stellarum nescio

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[16] See p. 89 *supra*

[17] Thomas Campanella, *Campanellae ordin. praedic. astrologicorum libri vi. in quibus astrologia, omni superstitione Arabum & Iudaeorum eliminata physiologicè tractatur, secundum S. Scripturas, & doctrinam S. Thomae, & Alberti, & summorum theologorum; ita vt absque suspicione mala in ecclesia Dei multa cum vtilitate legi possint* (Lugdvni: Sumptibus Iacobi, Andreae, & Matthaei Prost, 1629), pp. 2, 96-97.

quo vinculo cohaerens atque coagmentata connexio. . . ."[18] Forces, as such, were only incidental items in Rymers work. This one seems to have been included because he had no spheres and needed some device to keep the fixed stars moving as a unit. The movements of the rest of the heavenly bodies were described without consideration of their causes.[19]

Giovanni Battista Benedetti used both the location of the celestial bodies and some outside influence as the effective movers in his system:

> Motus corporum coelestium sit ratione situs, & varietatis virtutis stellae in diuersis locis, haec autem varietas absque diuerso situ eiusdem stellae, nec diuersus hic situs absque motu fieri posset, ita vt motus stellarum sit ratione diuersitatis situum ipsarum, ergo motus, & diuersitas situum, fit, ob diuersam influentiam.[20]

Benedetti, like Rymers, did not go into detail. Both hinted at but did not explicate a mechanical model for the heavens. It was only after the turn of the century that motor systems without either spheres or _anima_ were presented in any detail. Benedetti's and Rymers's celestial motors were actually no more than passing comments in an astronomical treatise.

The English mathematician Nathaniel Torporley (1564-1632) submitted his theory of celestial motors to his readers as an addendum to his book

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[18] Nicolas Rymers, _Nicolai Raymari Vrsi Dithmarsi fvndamentvm astronomicvm. Id est nova doctrina sinvvm et triangvlorvm. Eaqve absolvtissima et perfectissima, eivsqve vsvs in astronomica calculatione & obseruatione_ (Argentorati: Excudebat Bernardus Iobin, 1588), p. 38 _verso_: "However, all of the fixed stars hang together by what bond I know not. . . ."

[19] _Ibid._, pp. 37 _recto_-38 _verso_.

[20] Giovanni Battista Benedetti, _Io. Baptistae Benedicti Patritij Veneti philosophi. Diversarvm specvlationvm mathematicarum, et physicarum liber_ (Tavrini: Apud Haeredem Nicolai Beuilaque, 1585), p. 413: "The motion of the celestial bodies is by reason of their location and the diversity of stellar virtue in diverse places; this diversity, however, can not be without a different location of the same star, nor this different location without motion; thus, as the motion of the stars is by reason of their diverse location, therefore, motion, and diversity of location, is from a different influence."

Diclides coelometricae (1602),[21] a work explaining various ways to make accurate astronomical observations and presenting tables of results from such observations. Torporley gave his system only in the most general manner, and although he promised to provide a more complete treatment later, he apparently never did so.[22] Torporley's arrangement was in many respects the traditional one. The Earth rested in the center of the universe with Moon, Sun and planets orbiting around it in the accepted order. He presented no theory of the structure of the heavens, made no comment on the nature of the Sun, Moon or planets; he neither included nor excluded comets from the supralunar world, and he ignored the fixed stars completely. No one of these was a major consideration for him.

Torporley did not deny the existence of the heavenly spheres although there were none in his system. While retaining the homocentricity of the universe usually associated with these spheres, he added a new element: "Sunt autem Hypotheses nostrae rectilineares, & fere homocentrae."[23] The innovation was, traditionally, incompatible with any theory of motion in the celestial region; Torporley maintained the combination by assigning "cuique Planetarum rectam lineam, quam per musicam simili-

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[21]Nathaniel Torporley, Diclides coelometricae seu valvae astronomicae vniversales. Omnia artis totius munera psephophoretica in satis modicis finibus duarum tabularum methodo noua, generali, & facilima continentes. Praeeunte directionis accurata consumata doctrina, astrologia hactenus plurimum desiderata (Londini: Excudebat Felix Kingston, 1602), pp. v2 recto-verso.

[22]Nathaniel Torporley, " The Dictionary of National Biography. Founded in 1882 by George Smith, ed. Leslie Stephen and Sidney Lee (22 vols.; London: Oxford University Press, 1937-1938), XIX, pp. 988 does not list any later writings published by Torporley.

[23]Torporley, Diclides coelometricae, p. v2 recto: "Our hypotheses, however, are rectilinear and approximately homecentric."

tudinem dicimus Chordam vel Neruum, aut cum Mechanicis Vectim."[24] While he said nothing about the Sun and Moon when he first assigned the "rectam lineam" to the planetary bodies, these globes also had such a line segment associated with them. The length of the segment varied for each of the celestial bodies, presumably increasing as the distance from the Earth increased, but Torporley assigned no specific value to any one of them.

This straight line was the base upon which Torporley built the remainder of his system:

> In huius altero termino collocamus ipsum Planetam, uti molem in vectis termino mouendam; in alio verò eius extremo ipsam vim motricem, quam alter musicè dicamus Magadem.[25]

From this description to the end of his discussion Torporley see-sawed between a physical lever and his original straight line. At times he seemed to have considered this a physical reality; on other occasions it was nothing more than a conceptual device. Real or imagined having placed the Magas on the "rectam lineam" opposite the planetary body and having declared this to be the motive virtue of the system, he proceeded to explain how it moved:

> Et mouetur Magas per lineam medij motus Planetae in circulo quodam maiori, sed in opposita parte eiusdem lineae medij motus; & ideo huius circuli diameter nullateus maior est quam Planetae vectis; ita enim Planeta nihilominus ad locum verum spectabit, ambiente terram dicto circulo.[26]

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[24] Ibid.: "a straight line to each of the planets, which through a musical analogy we call a chord or string, or with the mechanics a lever."

[25] Ibid.: "We place on one end of this the planet itself as the weight moving on the end of the lever; on the other extreme, truly, the motor virtue itself which we call by another musical term 'Magas'."

[26] Ibid.: "And the Magas is moved through a path of mean motion, the planets in a somewhat greater circle, but in the opposite part of the same line of mean motion, and for this reason the diameter of this circle

Thus, any planet and its corresponding Magas would always be on opposite sides of the Earth. Torporley did not specify whether or not the Earth was at the exact center of his system; the orbit described by the Magas was not the same as that traced by the planetary body, but the two did have a common central point that was not the Earth between them. The Earth could well have been in the physical center of the system, and the geometric center of the circles described by the Magas and the planet could have been some point other than the Earth.

The Magas-planet arrangement accounted only for the planetary orbit around the Earth. To explain the planet's motion with regard to the ecliptic, Torporley introduced "aliud quoddam punctum vagum, quod Plectrum aut Hypomoclium dicimus."[27] He located this fulcrum between the planet and its motor virtue and made it the center of a "cuiusdam alterius circuli, minoris primo." [28] By what means or in exactly what way this affected the planetary motion, Torporley did not state. He explained only: "Et mouetur illa semidiameter ratione Anomaliae."[29]

The one detail concerning his system which Torporley did give was the placement of the magas and the plectrum for each of the celestial bodies:

Habent praeterea tres superiores ♄♃♂ commune Plectrum, ipsius forte

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is by no means greater than the lever of the planet; for thus the planet notwithstanding will be situated at its true place moving around the Earth in the said circle."

[27] Ibid.: "another certain wandering point which we call the Plectrum or fulcrum.

[28] Ibid.: "certain other circle, smaller than the first."

[29] Ibid.: "And that semidiameter is moved by reason of the Anomaly."

> ☉ centrum, sed Magades diuersas. Tres vero sequentes ☉ ♀ ☿ habent communem Magadem, sed Plectra diuersa: Sed ☽ utrunque proprium obtinet. Et propter latitudinem, tres superiores habent Magades in circulis obliquis suis; sed Plectrum (quia ☉) in ecliptica: ♀ autem & ☿ habent Magadem in eccliptica (aut si quando per libramentum extra eccliptica, in superficie tamen eidem parallela) sed Plectrum in obliquis. ☉ vero habet utrunque in eccliptica. Et ☽ utrunque in obliquo.[30]

Thus, for Torporley the various planetary relations to the ecliptic were maintained. With either the *Magas* or the fulcrum on the ecliptic, the planetary body could not wander too far from this path. The Sun and Moon were for him extreme cases. In the solar system the Plectrum moved toward the *Magas* until it was identical with it; this gave the plectrum its greatest proportional length from the planetary body. In the lunar situation the *Magas* advanced until it joined the Plectrum; the proportional length between *Magas* and planet was a minimum. In all other cases, the two points were separate.

After settling the positions of the *Magas* and Plectrum for each of the heavenly bodies, Torporley ended his discussion of the celestial motor system. "Atque istis concessis, omnia motus phaenomena, ut corollaria non inuitio, ... sequetur."[31] How they followed was left to the reader.

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[30]*Ibid.*: v2 *verso* "Besides the three superior planets have a common plectrum, the center of which is by chance the Sun, but their Magas are diverse. Truly, the next three have a common Magas but diverse Plectra: But the Moon keeps both proper. And on account of the latitude the three superior planets have Magas in their oblique circles; but the Plectrum (which is the Sun) on the ecliptic: Venus and Mercury, however, have the Magas on the ecliptic (or if at any time through weight outside the ecliptic in the upper surface parallel to the same, however), but the Plectrum in the oblique circle. The Sun, truly, has both on the ecliptic. And the Moon has both on the oblique."

[31]*Ibid.*: "And these things being admitted, all phenomena of motion follow by deduction not from induction."

Torporley's system was not mentioned by his contemporaries. The vagueness and incompleteness of it, at a time when more detailed systems were available, were handicaps to its being accepted. A greater hindrance was the lack of definiteness about the nature of the "lina recta" which connected the planet and its Magas. If this were a physical lever, one could easily explain how the motive force moved the planet, but one had difficulty passing over the intersections of the various planetary levers among themselves as well as their collisions with the Earth. If the "lina recta" were no more than a mental concept, the difficulty of intersecting corporeals was avoided, but the question of the nature of the Magas--a question that could be ignored more easily if one worked in a system of physical levers--and how it acted upon the planet to produce motion was immediately in the foreground. For, once the "linea recta" became no more than an imagined link between Magas and planet, the motors in the system had to move their mobiles without having contact with them. The only forces of this kind available at the time were virtues linked with some vital principle.

The presence in the celestial region of physical bodies other than the planets was non-acceptable to the majority of the natural philosophers at this time. So was action at a distance. Torporley's system as presented in the Diclides coelometrica could not avoid using one or the other. A longer, more detailed treatise on the subject might have "saved the phenomena" and saved Torporley's system. Such a work was never published, and the system as stated never became popular. It is interesting only as one man's answer to "What moves the celestial bodies?"

Another Englishman presented his answer to the same question a few years later. Thomas Lydiat, mathematician and courtier, combined some postulates from classical astronomical systems, ideas current among his contemporaries, and original adaptations of these ideas in his Praelectio astronomica.[32] Although he retained the concept of a geostatic, Earth-centered spherical universe, Lydiat considered the Aristotelian distinction between the celestial and terrestrial regions to have been disproven by the astronomers who had shown that the comets were "in ipsa coelesti regione supra lunae a terra distantiam & altitudinem."[33] The elimination of this dichotomy permitted him to consider the supralunar region in the same terms as the sublunar one and to use familiar Earthly movements and causes in the heavens.

Lydiat adopted the traditional scholastic approach that "cognitio rei dependet a cognitione causae," but singled out the cause of motion, "praecipue de causis eorum motuum," as the prime necessity.[34] Furthermore, Lydiat accused previous astronomers of neglecting this study and thereby contributing to the error and lack of development in astronomical studies.[35]

Before introducing his own theory, Lydiat refuted the arguments of three groups: those who allowed intelligences to move the heavens; those

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[32]Thomas Lydiat, Praelectio astronomica. De natura coeli & conditionibus elementorum: tum autem de causis praecipuorum motuum coeli & stellarum (Londini: Ioannes Bill, 1605).

[33]Ibid., p. 24: "in the celestial region itself far beyond the distance and height of the Moon from the Earth."

[34]Ibid., p. 51: "Knowledge of a thing depends on the knowledge of its cause, . . . particularly of the causes of their motions.

[35]Ibid.

who attributed celestial motions to the proper form of the heavens; and those who introduced some divine virtue or power into the celestial region. He rejected the intelligences because

> non potest demonstrari in Aristotelis Philosophiâ, vtrum sint vllae intelligentiae vel in rerum natura vel extea eam, an non.[36]

To those who attributed the celestial motions to the proper form of the heavens, Lydiat replied that this explanation could not be accepted unless one admitted that the heavens were animated. Since however,

> Verumenim vero neque coelum neque stellas esse animatas, praeterquam quod ij qui affirmant esse non probant, cum non demonstrant ipsas moueri sua sponte potiùs quam naturali quadam necessitati; illud argumento esse potest quod appareant esse corpora regularia & vniformia, non organica, ideoque minimè accommoda animae habitacula, vti recte docet Aristoteles.[37]

Lastly Lydiat answered those who postulated that some divine virtue or power moved the heavens. While there could be no doubt that God had made the world and that He sustained all creation

> nimirum huic primae & supremae & communi & Theologicae rerum omnium causae, subordinantur aliae secundariae & propinquae & propriae & naturalium quidem rerum Physiologicae. . . .[38]

As a replacement for the no longer acceptable heavenly spheres, dis-

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[36]*Ibid.*, p. 52: "it can not be demonstrated in the philosophy of Aristotle whether or not there are any intelligences either in the nature of things or outside that nature.

[37]*Ibid.*, pp. 54-55: "indeed neither the heavens nor the stars are animated, especially since those who affirm it have not proved it by experience, since they have not demonstrated that the heavens are moved voluntarily rather than naturally or by necessity; that last could be the argument because they appear to be regular and uniform bodies, not organisms, and therefore they are less likely to be the dwelling place of a soul, as rightly teaches Aristotle."

[38]*Ibid.*, p. 55: "but certainly to this first and supreme and universal and theological cause of all things, other secondary and near and proper and certain physiological causes of natural things are subordinated."

placed intelligences, proper forms and divine intervention, Lydiat proposed that "elementum aquae multo maximam partem ex sacrarum literarum & nostra sententia nuper exposita firmamento coeli circumfusum."[39] The use of this agent depended upon the natural fluidity of water and the existence of the supercelestial waters. The former was a well-known observable natural phenomenon.[40] The latter was stated in Holy Scripture.[41]

In explaining how this agent caused celestial motions, Lydiat divided the heavenly movements into three groups: the diurnal motion, the west-to-east planetary motion, and the retrograde movements of the planets. The first of these, the east-to-west motion of the fixed stars, was the immediate result of the existence and position of the waters above the heavens.[42]

While elsewhere in his work, Lydiat denied that the spheres were hard and solid,[43] in order to provide a firm surface upon which the supercelestial waters could rest and a base for the fixed stars which could be moved as a unit by these waters, he needed some type of physical sphere for the fixed stars. This sphere was added to his system without any de-

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[39] Ibid., p. 56: "element of water a great part of which according to Sacred Scripture and our sentiment flows about the upper firmament of the heavens."

[40] Ibid., pp. 33, 56-57.

[41] Ibid., p. 56

[42] Ibid., pp. 57-58

[43] Ibid., pp. 23-25.

scription, and just beyond it Lydiat placed the waters above the heavens.[44]

In this position the waters had no shores to contain them and thus they moved continually.[45] Lydist assumed that his readers would accept this motion without question. He noted that there was not "vullum corpus circumfusum ipsi supercoelesti aquae, neque aliud quicquam impediuerit quo minus eius motus circa aequatorem siue intra tropicos fuerit celerrimus,"[46] but he gave no reason why the waters above the north celestial pole did not flow south or any explanation for a given area on the surface of the stellar sphere simultaneously acting as a higher position for the water leaving it and a lower level for those approaching. His probable answer to the first objection would have been the Providence of the Creator in the ordering of the universe;[47] his implied answer to the second was the statement in his general discussion of the motion of water that "eodem pars praecedens trahat sequentem . . . sequens autem tradat praecedentem."[48] As the waters moved they moved the sphere beneath them which in turn carried along all within it "tenuissimae aethrae circumuolutio." Thus Lydiat accounted for the primary celestial motion.

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[44] Ibid., pp. 57-58.

[45] Ibid., p. 57.

[46] Ibid., p. 58: "any body surrounding those supercelestial waters, nor anything which impeded it in the least so that its motion around the equator within the tropics will be the fastest."

[47] Ibid.; Lydiat used the care of God in creation whenever he needed a reason and had nothing else available. See pp. 58, 65.

[48] Lydiat, Praelectio astronomica, p. 56.

[49] Ibid., p. 57.

The second motion, the direct motion of the planets, Lydiat explained by a combination of the impetus all the planets received from the primary motion and the position of each planet at the time it received this impetus.[50] While there was no impediment to the motion of the supercelestial waters,[51] there was apparently some resistance in the aether that prevented all of the globes beneath the spheres of the fixed stars from moving with a speed equal to that which the stellar sphere had received as a result of its contact with the moving waters.[52] This resistance increased the closer a body was to the Earth, and, thus, position accounted for the varying duration of the heavenly periods. The Moon, closest to the Earth, met the most resistance and so fell behind more than any of the others in one twenty-four hour period; Saturn, the farthest from the Earth, lagged the least.[53]

Having explained the varying speeds of the planetary bodies, Lydiat accounted for the changing rate of motion along a planetary path by making the speed at any given point inversely proportional to the distance at that point from the celestial equator.[54] The movement of the supercelestial waters supported this assumption because while all the heavenly waters completed their circuits around the Earth in twenty-four hours, the waters above the equator had to move much faster than those above the poles. The

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[50] Ibid., p. 61

[51] Ibid., pp. 57-58.

[52] Ibid., p. 62.

[53] Ibid., pp. 59-61.

[54] Ibid., pp. 61-63.

bodies below the waters, since they were carried by the movement of them, had similar unequal speeds depending on their position: "ideoque ibi maior obliquitas vbi maior impetus, vt circa aequatorem quàm circa tropicos."[55]

While the position north or south of the equator and the distance from the center of the Earth accounted for a planet's speed at any point in its orbit, Lydiat had difficulty explaining the accepted fact that the apparent planetary paths were not circular and that the distance of a planet from the Earth varied in the course of its revolution about the Earth. This latter phenomenon for the Sun could be explained by Lydiat's often used, unanswerable argument, the Providence of the Creator:

> Omnino sapientissimo Dei opt. Max. consilio factum esse videatur, vt Sol longiùs a terra fertur circa tropicos; vt ea ratione temperentur ardores sub ipsis propter longiorem eius moram ibi alioqui futuri intolerabiles.[56]

Divine Providence need not be so concerned about other bodies in the universe so Lydiat had no explanation for their non-circular movements: "equidem modo nihil habeo quod dicam, nisi forte & hoc sit visus hallucinatio."[57] The reader could supply his own reason if he wished or, like Lydiat, consider it something seen but not real and accept it without understanding why God had made it this way.

To discuss the third movement of the heavens, the retrograde motion

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[55] Ibid., p. 61: "And therefore where there is the greater obliquity, there the greater impetus, as around the equator compared to that around the tropics."

[56] Ibid., p. 65: "All is seen to have been made by the most wise plan of the most high God, as the Sun is taken farther from the Earth around the tropics; in order that by this arrangement its rays are tempered under the tropics; otherwise because of the sun's long delay there everything would be intolerable."

[57] Ibid., "For my part I have nothing that I may say unless perhaps that is an hallucination."

of the planetary bodies, Lydiat had to introduce a second causal force in his system. The supercelestial waters, even for Lydiat, had their limitations. While formerly natural philosophers had explained this motion by epicycles or a series of spheres, such devices were not permissible in a system which had no spheres. The aether by itself was not capable of producing such a motion so Lydiat assumed that the Sun was in someway responsible for the variation in direction evident in the planetary movements.[58] The action of the Sun was related to the amount of light each globe received from the Sun; thus, as the distances between the Sun and the planets increased the effect of the Sun on the planets decreased.[59]

For the three superior planets the distances between each globe and the Sun was so great that the only effect of the Sun on the wandering body was a slowing down, stopping, changing of direction or speeding up of the planet's motion. The inferior planets, however, were so close to the Sun that they were drawn to it and traced their paths around it as it circled the Earth.[60]

Of all the movements of Lydiat's system this third type of heavenly motion was the least clearly explained. The discussion given in the _Praelectio astronomica_ was based upon a comparison of Lydiat's theory with the explanation provided by the use of epicycles.[61] The planets were not treated separately but only in their two main divisions and an occasional compar-

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[58] _Ibid._, pp. 66-67.

[59] _Ibid._, pp. 68-69.

[60] _Ibid._, pp. 68-73.

[61] _Ibid._, pp. 66-73.

ison of one with another.[62] The retrograde motion was not seen in the fixed stars because the distance between these globes and the Sun was so great:

> ob eandem rationem stellis inerraticis nullam, quia eae propter nimiam a sole distantiam quasi extra telorum eius iactum videntur constitutae: nisi forte sole versante circa tropicos, vbi ipsum aliquantò sublimiorem & coelo viciniorem.[63]

The Moon also showed no backward or stopping motion

> vel quia infima cum sit, minimè omnium vim primi motus adiuuantis solarium radiorum vires sentit; vel quia grauius eius corpus quam caeterorum, praesertim in crassiori aere, radijs solaribus minus est obnoxium.[64]

While describing the effect of the Sun upon the other heavenly bodies, Lydiat seemed to have forgotten his supercelestial waters. He had previously attributed the movement of all the planets around the Earth to these waters; yet, when in the explanation of the retrograde motion he orbited Mercury and Venus around the Sun, he did so without changing the previous arrangement.

Lydiat's theory attracted little notice at the time of its publica-

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[62] See for example: "Huiusmodi igitur motus differentiam, tum altitudinis, tum cursus respectu, tribus superioribus planetis impertiri videtur sol; maximam quidem vti par erat (quodidem in latitudinibus quoque obseruatur) proximo, id est, Marti; maximam vero remotissimo, Saturno scilicet." <u>Ibid</u>., p. 70; "Quod autem Venus longius a sole feratur quam Mercurius." <u>Ibid</u>., p. 72.

[63] <u>Ibid</u>., p. 70: "for the same reason none of the fixed stars, which on account, certainly, of their distance from the Sun are seen, as it were, placed beyond the spreading of its sunbeams; unless by chance by the sun's remaining around the tropics, where it is somewhat higher and nearer to the sky."

[64] <u>Ibid</u>., p. 73: "either because it is the lowest, feeling the least of all the vigor of the sun's rays to help the first motion, or because it is a heavier body than the others, and is in the heavier air where the solar rays are less steadfast."

tion. It assumed too much on a speculative basis and offered too little on the practical level. The Praelectio astronomice included no precise rate of motion for the supercelestial waters or anything more than an implied one-to-one ratio for the decrease of motion as the distance from its source increased. Comets, which were considered supralunar phenomena,[65] were not included in the discussion of motions of heavenly bodies; the irregularities in the lunar path were not discussed. Lydiat was himself aware of the inconsistencies and incompleteness of his theory:

> Haec itaque de astronomia, abunde quidem ad nostrum institutum, nobis dicta sunto, ad rem vero ipsam parum plenè aut perfecte: sed quae, si totos quadraginta vel quinquaginta annos (vt caeteri fere Astronomi) huic vni studio impendissemus, fortasse poterant esse perfectiora. Interim vero de his qualibuscunque Deo optimo maximo ac. sapientissimo vniuersi architecto gratias habemus.[66]

Lydiat did not continue the study of astronomy, and while many others did during the next forty years, no one seems to have spent any time on his theory of supercelestial waters. Geocentric theories together with heavy reliance on scriptural support and divine intervention soon ceased to be among the popular components included in discussions of astronomical systems.

Several years after the publication of Lydiat's Praelectio astronomica, a third English natural philosopher wrote about the heavens. Francis Bacon like his two predecessors did not present either a new astronomical

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[65] Ibid., p. 25.

[66] Ibid., p. 75: "And therefore, these things of astronomy, adding indeed to our purpose, have been said by us although the thing itself is far from complete or perfect; but, if for forty or fifty years (as others have studied astronomy) to this one study we apply ourselves, perhaps these things can be perfected. In the meanwhile, truly, concerning these things of whatever kind, to God the greatest and most wise architect of the universe we give thanks."

system or a complete one.[67] His theory included the fiery heavens of the Platonists,[68] the static Earth-centeredness of Antiquity and the Middle Ages,[69] and certain similarities between the celestial and terrestrial regions that were common to many writers at this time.[70]

Bacon cast out the spheres,[71] scorned the <u>anima</u>,[72] and ignored any system including angels or intelligences, but he offered no satisfactory substitute for these. He complained that too few men studied the physical causes of the heavenly motions; yet, he himself did nothing more than divide the movements of the Sun, Moon, planets and fixed stars into two categories: The cosmical motions that were governed "ex consensu non coelestium tantum, sed universitatis,"[73] and the mutual ones "in quibus alia corpora coelestia ex aliis pendent."[74] In neither case did he specify the forces governing these motions.

Although Bacon expressed his opinion that men needed to study the

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[67]In 1612 Bacon wrote but did not publish two short works dealing with cosmology, the "Descriptio globi intellectualis" and "Thema coeli." See: Robert Leslie Ellis, "Preface to the <u>Descriptio globi intellectualis</u>," Francis Bacon, <u>The Works of Francis Bacon, Baron of Verulam, Viscount St. Albans, and Lord High Chancellor of England</u> (New York: Hurd and Houghton, 1864), VII, pp. 269-270.

[68]Bacon, <u>Works</u>, VII, pp. 345-347; X, pp. 464-467.

[69]<u>Ibid.</u>, VII, pp. 300-301; X, pp. 420-421.

[70]<u>Ibid.</u>, VII, pp. 316-328; X, pp. 434-445.

[71]<u>Ibid.</u>, VII, pp. 325-326; X, pp. 442-443.

[72]<u>Ibid.</u>, VII, pp. 349-351; X, pp. 469-471.

[73]<u>Ibid.</u>, VII, p. 350: "by consent, not only of the heavens, but likewise of the universe." <u>Ibid.</u>, X, p. 469.

[74]<u>Ibid.</u>, VII, p. 350: "in which one celestial body depends on another." <u>Ibid.</u>, X, p. 469.

physical causes of the heavenly motions, he rejected two such theories that had been presented. Telesio's heat hypothesis was dismissed by Bacon as an old theory newly presented,[75] while Gilbert's magnetic theory as applied to the supralunar world was repeatedly denied by him.[76] Bacon wanted a known force included in astronomical theory, but he was unable to name the force himself and unwilling to accept those virtues suggested by others.

Generally speaking mechanistic motors were not particularly popular during the last of the sixteenth and the early part of the seventeenth centuries. Those writers primarily concerned with describing the structure and operation of the heavens as one region of the universe generally favored some vitalistic principle as the best operative agent in the supralunar world. Telesio with his theory of heat versus cold was an exception rather than a representative of this group. Those who wanted to explain the celestial movements in more detail usually either assumed a natural motion for the heavens or adopted the magnetic virtue as presented in Gilbert's _De magnete_. Devices similar to the levers of Torporley or the fluid motion of Lydiat were seldom employed. A few wrote of a force of unspecified origin.

Why the majority of those who placed a known terrestrial force in the heavens preferred magnetism is uncertain. The only motors eliminated by name were the spheres and some forms of _anima_; others were not mentioned. It seems that with the exception of magnetism, causes of motion known

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[75] _Ibid._, V, p. 310; X, p. 365.

[76] _Ibid._, I, pp. 260, 268; II, pp. 140, 287; III, pp. 205-206, 300; VI, p. 132; VII, pp. 75, 118-119; VIII, pp. 84, 93, 504; IX, pp. 370-469.

to be effective on Earth were not even considered as possible candidates for the celestial movers. The reasons could have been many. Most terrestrial forces were contact forces and with the elimination of the spheres, the heavens were without a suitable connection between mover and moved. If the air on Earth could not transmit a force, the aether was presumably far less able to do so. A second difficulty was the placement of such a force. In the traditional Earth-centered systems, terrestrial motors were inconceivable. Spheres or anima remained. For the supporters of the Copernican theory there were multiple physical centers of motion in the system. One force acting from either the center of the entire system, the Sun, or the external boundry, the fixed stars, had to produce different effects depending on the placement of the various globes. If more forces were introduced, one in each center of motion, they created the problem of two or more agents simultaneously acting on one body to produce two or more motions. A third inconsistency arose when the agents of straight-line motion were assigned as the producers of the curved motion in the heavens; and another appeared if the changing and changeable, finite terrestrial forces were to govern the movements of the unchanging, seemingly eternal celestial bodies.

The use of magnetism avoided all of these. Gilbert's invisible "orb of virtue" around every magnet provided a connection between moving and moved objects. If every center of motion were a magnet, then one body could move the bodies within its orb and at the same time be moved because it lay within the radius of the active power of another body. The Earth had a natural rotational motion because it was a magnet. It took little ingenuity to reverse the statement and say that because the celestial bodies were global magnets, they had a natural circular motion. Finally, the magnetic virtue was a non-decreasing power. Magnets remained magnets without any noticeable decline in their attractive power.

No other known force offered so many of the basic requirements for a celestial motor. Heat had an upward motion; liquids a downward one. Wind and water forces varied with seasons. Levers and pulleys moved things up and down, while wheels went around; these and all other machines needed contact with the thing moved. Electric virtue had only just been named; it was not yet recognized as a possible power. Pushers and pullers, common to the times, pushed and pulled only in straight lines and had to be joined to the objects they moved. Each force had a well-recognized limitation that made it unsuitable as a mover of the celestial globes.

Among these forces, magnetism was a new, a different type of virtue. Its power was occult enough to make it suitable for the celestial region; it was common enough to be considered a known force. It was a virtue found in nature with what appeared to be a power almost beyond the natural. And while the knowledge of the loadstone's attracting objects was old enough to be familiar to all educated men, the study of it was new enough that no one had yet imposed restrictions upon its actions. The magnetic virtue seemed at the time the best available replacement for spheres and *anima*.

CONCLUSION

"What moves the heavenly bodies?" The natural philosophers during the century following the publication of the De revolutionibus did not formulate a satisfactory answer. Copernicus, following a well-established custom, bypassed the problem of effective causes when he presented his heliocentric system in two ways. He separated the physical from the mathematical description of the universe. So long as this separation was maintained, the above question was seldom raised.

During the latter half of the sixteenth century, some natural philosophers tried to join the two descriptions of the world. When the observational astronomers used the interpretations of their data to support their denial of the celestial spheres, others, who wished to eliminate these solid bodies from the heavenly region because such objects were foreign to their theoretical system, picked up the phenomenological argument. By the beginning of the seventeenth century the spheres were gone from many celestial regions.

To discard the spheres was one thing; to replace them another. While many agreed that a supralunar world with firm, interconnected shells was not possible, there was disagreement on the nature of the agents moving the stars and planets. The anima advanced by the Platonists had no great supporters after Patrizi and Bruno. The concept of a universe in which the regular motions of the heavens were controlled by vitalistic principles became increasingly less popular in the seventeenth century.

The first widely accepted force used in the celestial region was the magnetic virtue as described by William Gilbert in his De magnete. Kepler, in Germany, Simon Stevin in the Netherlands, and numerous English writers tried to incorporate magnetism into every possible astronomical system. The attempts met with varying degrees of success; none was ultimately acceptable to any large group.

Magnetism, while the most popular, was not the only terrestrial force placed in the heavens. Torporley's system of levers and Lydiat's fluid theory were naive in many respects. They were, nevertheless, indications of the change that was taking place in astronomy. For almost two thousand years "to save the phenomena" had meant to describe the apparent movements using only certain accepted motions. This could be and was done without regard for the causes of these motions. By 1632 astronomers and natural philosophers had a different task. They not only had to chart the movements of the heavenly bodies, they had to explain what forces were acting upon these bodies to produce such motions.

The transition in outlook was difficult; the theoretical changes were major in some instances, minor in others. The thinkers of the sixteenth and early seventeenth century did not solve the problem: "What moves the planets?" They did change the meaning of the question. No longer was it permissible to describe the heavens mathematically on one page and physically on another. The two descriptions had to correspond. Furthermore, the trials and errors of the men who tried to join the previously disjointed studies had set certain prerequisites for the force that was to govern the heavens. It could not be totally vitalistic, but must be at least an attribute of a physical body. It had to be several forces acting together or one force common to many bodies. It had to extend wherever celestial bodies were in motion. And it had to be constant. It had to be something yet unknown, because the known forces did not qualify.

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