COSMOLOGY without HEADACHES

(Lecture Series)

(compiling, transcribing, researching, editing always in progress)

LECTURE XI: **What is Space?; The Copernican Revolution; Bruno Burned for Breaking Open the Universe; Dancing to Music of the Spheres**

Collect assigned 'Anselm papers' and discuss the 'ontological proof' [Review especially **Aquinas** *(p.486-490); and* **Duns Scotus** *(p.564-572) in* ***PHILOS. IN THE MIDDLE AGES*** *by Hyman & Walsh (poss. handouts)] before commencing with the changing concept of space and time in blind anticipation of the cosmic sea-change about to occur with Copernicus.*

Hellenic Space:

Looking back to early Greek concepts of space, we find the Pythagoreans first to abstract the notion of space as the measurable demarcation between the surfaces of objects, though for most of them the idea was not actually a vacuum. At least one of them seems to have had an understanding of nothingness, as **Archytas** is the first, in a book about this subject, to have recorded the question as to whether it would be possible to stretch out one's hand at the end of the world – i.e., 'What is beyond everything?' But he spoke of space more in terms of 'place,' noting that each thing occupies some place and cannot exist unless its place also, in some manner, exists. It seemed to him that places must have a prior existence to the bodies occupying them. Not only that, his concept of space seems to have included some limiting force as a boundary to each item, which prevented things from expanding indefinitely. Max Jammer explains: for Archytas, it was "owing to this constraining power of space that the universe as a whole occupies a finite space" [Max Jammer, CONCEPTS OF SPACE: The History of Theories of Space in Physics (ch.1, p.10); Dover, NY, 1993] I.e., the Universe, too, has its 'place.' The question then is: Where is *it*s place?— and relative to what? What then is *outside* of the place of the Universe? Though the question may have been uncommon among ancients, we moderns cannot help wondering: What lies beyond?—even beyond everything.

With Democritus and/or Leucippus (the original atomists) came the idea of space as a receptacle of material things, though there is no true vacuum as such. Since the atoms are infinite in number, they must exist in an infinite void. This idea was never the 'accepted' view among the ancients. Although Democritus seems not to have attributed weight to the atoms (they apparently got their inertia from collisions), he may have essentially initiated a prototype of the Newtonian concept of absolute space as empty extension without any influence on matter or motion. His disciples, however, in seeking to explain the cause of motion, gave the atoms weight and introduced the 'up and down' direction: an anisotropic space in which the atoms (and/or the things or elements formed by them) incessantly fall or rise according to their nature. The final picture of this was drawn by Lucretius, and even here, with his 'nothing but atoms and the void,' he attempts to prove infinite space by saying that if space were finite, over the past eternity all matter would have sunk to the bottom into a mass so that existence would already be over (this is not so far fetched, since moderns are divided over whether the Universe might yet expand into virtual nonexistence or 'fall' back into singularity). While these ancient, theoretically-minded atomists could not quite imagine a continuous homogeneous and isotropic space, they did manage to introduce the first known conception of infinite 'non-corporeal reality.'

But Gorgias argued that space cannot be infinite. If it were, where would we be? If the existent were infinite, everything would be nowhere. Plato, in the confusing vagaries of the *Timaeus* seems to be saying that the 'ideal' forms are somehow of space, which are filled with matter—in such a way that physics becomes geometry. Dr.Jammer suggests this notion, which had great influence on the thought of the Middle Ages, was significant in retarding strict mathematical research regarding the concept of space—until Aristotle's *Physics* was revealed to the West, mainly via Islam through the Moors in southern Spain.

In his *Categories*, Aristotle explains space as belonging to the category of quantity, and therefore it is continuous in its nature. The parts of solids occupy a certain space, and thus have a common boundary with space. In fact, space is only the sum total of all places occupied by bodies. Aristotle does not believe in empty space, such a notion being incompatible with his physics. His notion of space is rather one of positions of things: a theory rather of 'place' than 'space.' But it is confusing, since things have their present place, yet they tend to move toward their natural or, perhaps, predetermined place (two different sorts of place?): fire and air rising outward while water and earth settle toward the center of the Universe, which coincides with the center of Earth. Why they would so move is mysterious, since such motion is not based upon anything like an Archimedean principle of buoyancy—and there is as yet no theory of gravity.

Aristotle's pupil, **Theophrastus** [370-285 B.C.], who eventually took over as leader of the Peripatetic school, broke with the Master and conceived of the Universe as being *in* space and even possibly moving *through* space, such that space became purely abstract: merely a relationship of material things; an ordering of all locations by relative positions; a system of interconnected relations.

The Stoa, on the other hand, developed a kind of dual conception of space: space *within* the world, and another kind of space, nothingness: the void *outside* the world system. Since the void is nothingness, there can 'be' no such thing inside the world. But, within the world, through a kind of tension (something like an æther connection perhaps?), the distant parts of the Universe influence eachother—a coherence of matter suggesting something like gravity, or a rudimentary field theory simmering on a mental back burner—but we are speculating, as no such ancient theory actually emerged.

Judaic Space:

There is also a concept of space found in, or to be developed out of the Old Testament. It might be asked: Shall we really expect to find science in the Bible? Isn't the Bible a purely religious book? Indeed, and the philosophers who cracked open the door for science in the Middle Ages were seriously religious men in a seriously religious era. Even a scientist's work and thought is refracted through the lens of his time; his views and his truths shaped in accordance with his birth date and his training. So "natural philosophy," said Colin Maclaurin in his study of Newton's great achievements,

> is subservient to purposes of a higher kind, and is chiefly to be valued as it lays a sure foundation for natural religion and moral philosophy; by leading us in a satisfactory manner, to the knowledge of the Author and Governor of the Universe. To study nature is to search into His workmanship: every new discovery opens to us a new part of his scheme.

So space becomes an attribute of God. In fact, to Newton (according to Dr.Jammer) "absolute space is the sensorium of God; to [Thomas] More [a Newton mentor], it is divine extension." Such ideas "can be traced back to Palestinian Judaism during the Alexandrian period."

[*found in* Jammer: CONCEPTS OF SPACE, ch.2, p.28]

In Palestinian Judaism of the first century B.C., the term '*makom*' ['place'] is actually used as a name for God, stemming from the Divine Omnipresence. "Say the Rabbis,"

> Moses made Him fill all the space of the Universe, as it is said "The Lord he is God in the heaven above, and upon the earth beneath; there is none else," which means that even empty space is filled with God.
>
> [S.Schechter: SOME ASPECTS OF RABBINIC THEOLOGY, p.25; N.Y., 1910]

There is an even more ancient tradition associating space with light and God as the source of universal light, e.g., Ikhnaton's *Re* and Zarathustra's *Ahura Mazda.* And, in India, *Brahman* is often referred to as Primordial Light. The New Testament God is also identified with light: *Ego sum lux mundi*. Although *Genesis* does not name 'space' outright as a product of creation, "Let there be light" were God's first words—thus, a primordial light filled the Universe before the existence of the sun and stars (so this had to be a different sort of 'light'). Such light might be space itself. At least the 'creation' of space (or perhaps its *a priori* 'existence') is implied by the propagation of this light—this primal light, in the eyes of some philosopher/theologians, being a metaphor for the Spirit of the Universe: God propagating himself. Thus 'empty' space would not exist. The *appearance* of emptiness between perceivable objects is always filled with unperceived spirit. And so, for some, this identification of space with God allowed proof of space by the same ontological proof of God—both having the property of 'necessary existence.'

Such arguments seeking to establish science-like theories of space in holy books are, truthfully, somewhat weak. Dr.Jammer himself, who advocates them, admits:

> It has been established that the theory of atoms in Islam and the corresponding conception of space were originally of a purely profane character and became adapted to an extreme theistic dogma only during later stages of their development…[and]…the Kalamic theory of space did not originate on the background of religious speculations.

For both Muslims and Christians in the Middle Ages, the 'profane' theories were adjusted and adapted to support what were considered revelatory truths in scripture. Thus, in the spirit of St.Augustine, pagan theories of space were read back into the meaning of the Word of God, reason being thus shaped by revelation. This is how philosophy became the handmaid of theology. But a handmaid has subtle influence on her mistress. As we have seen many Roman pagans take to the Christianity of their slaves, we will see, in the intellectual realm, as with the about-to-be-discovered physical laws of motion, this theist action has its secular reaction, and revelation is about to become entangled in reason.

It would be several centuries before Erigena's outlook could be expressed without condemnation. But this long and nearly complete dominance of blindness (hence, 'Dark Ages') demonstrates that radicals and revolutionaries are necessary for spotting a charlatan behind the curtain and exposing intellectual as well as political despotism.

Another rebel had cropped up even earlier. In c.575 A.D., **John the Grammarian**, known as **Philoponus**, challenged Aristotle's concept of space as the adjacent boundary of the containing body.

Aristotle had seen that this was a relative position. E.g., a stone held motionless in a river could not be understood as contained by the moving water, since, though motionless, it would be changing its position continually. Its position, therefore, had to be related to the inner surface of the next immobile containing body—in this case, the river bed (which already is problematical since the stone is not actually 'contained' by the river bed, but only rests upon it; or, if held in our hands, is wholly separated from it—or would our hand, then, be the next 'containing body'?). Philoponus then inquires about the position of the whole sub-lunar world. For Aristotle, it would be relative to the concave (inner) surface of the lunar sphere. But Philoponus points out that this sphere rotates and is thus also in motion. To move farther out to larger containing spheres is no avail, since they all, even the all-encompassing sphere of fixed stars, are in motion—which brings up the added problem: To what is the motion of the outermost sphere (i.e., the Universe itself) related? Aristotle tried to sidestep this question by saying "It is clear that there is neither place nor void nor time beyond the heaven" [*De caelo*, 279 a.12], upon which Philoponus has cast serious doubt.

Philoponus must replace Aristotle's idea of space. He chooses, as do some of the atomists, to identify space with void. Space thus becomes abstract: incorporeal; pure dimensionality, so it can no longer interact physically with matter to cause motion. With Aristotle, seeing space as containment or boundaries, the movement of the outermost sphere (divinely started) is transferred to all things below, such motions sorting out the final places toward which each of the finite number of elements tends. For Philoponus, space has no effect on matter. Movement is caused by each body tending toward its natural place by assignment—pre-programmed, as it were, by the Demiurgus. This is not at all satisfactory, speaking purely mechanically. But from a Christian theistic view there is no problem with God being the constant mover—his spirit being everywhere. Philoponus does agree with Aristotle, however, about the finite nature of the Universe. It is totally confined within the last sphere, its center corresponding to the center of the Earth—thus defining 'down.' A body falls 'inward' or 'downward' not because of any strain imposed by the movements of the spheres or the changing boundaries of place, but because it possesses the tendency toward the place pre-assigned to it by God.

This idea closely resembles the explanation of gravity given by **Copernicus**:

> *Equidem existimo gravitatem non aliud esse, quam appententiam quondam naturalem partibus inditam a divina providentia opificis universorum, ut in unitatem integritatemque suam sese conferant in forman globi coëuntes.*
>
> [*De revolutionibus orbium coelestium*, liber I cap.IX]
>
> (I myself think that gravity or heaviness is nothing except a certain appetency implanted in the parts by Divine Providence of the universal Artisan, in order that they should unite with one another in their oneness and wholeness and come together in the form of a globe.)
>
> [Trans., Charles Glenn Wallis *in* GREAT BOOKS OF THE WESTERN WORLD, vol.16]

indicating, however revolutionary his heliocentric system, Copernicus was not modern.

During the Western Dark Ages, Aristotle was subjected to more scrutiny in the Arab world, where he was better known. **Hasdai Crescas** (or *Adonai* c.1400) offered some severe criticism from the perspective of Jewish orthodox theology. He pointed out many inconsistencies and contradictions in the Philosopher's concepts, particularly having to do with space as 'place,' suggesting that space becomes materially extended only where it is occupied by matter. In his particular opposition to Aristotle's claims of the impossibility of an infinite universe, Crescas (says Dr.Jammer) became "the first [known] proponent of infinite homogeneous space"—that is, outside of the 'heavenly' sphere. Unfortunately, as a Catalonian Jew in the midst of major political upheavals in 15th century Spain, he was unable to carry his ideas any closer to the modernist view.

In Italy, however, in the same age, **Nicolaus of Cusa** offered something new. If space were infinite, there could be no center of the Universe. Thus he not only removed Earth from the center (*'Terra non est centrum mundi,'* anticipating Copernicus) but argued there could be no center at all. Not only that, infinite extension of space (thus no center) would make the ideas of absolute motion or absolute rest impossible, implying an unrealized proto-relativity theory. '**Cusanus**' even offers his *docta ignorantia*, whereby one could be placed anywhere in the heavens, and it would still seem to that observer that he was in the center of the Universe—anticipating what is called in modern astronomy the 'cosmological principal.' This, then, is actually much more radical than the later shift from an Earth-centric to the sun-centered Universe of Copernicus. In fact, from a modern perspective, he overleaps Kepler and Galileo, going even beyond Newton in foresight to provide a strong argument for claiming Cusanus to be the real turning point from ancient to modern astronomy—though his means of attaining to this concept (principally a mystic-speculative approach) is not the method of modern science. Still, as Alexandre Koyré points out, "there is a good deal of relativity in Nicholas of Cusa's world-view":

> ...[W]e cannot discover motion unless it be by comparison with something fixed, that is [by referring to] the poles or the centers and assuming them in our measurements of the motions [as at rest]; it follows therefrom that we are always using conjectures, and err in the results [of measurement]. And [if] we are surprised when we do not find the stars in the places where they should be according to the ancients, [it is] because we believe [incorrectly] that they were right in their conceptions concerning the centers and poles as well as in their measurements.
>
> [Alexandre Koyré: FROM THE CLOSED WORLD TO THE INFINITE UNIVERSE; John Hopkins Univ. Press, Baltimore & London, 1979; p.14. *Quoted from* de docta ingnorantia by Cardinal Nicholas of Cusa; (Koyré, trans.)]

"Indeed, pursues 'Cusanas', curiously reversing a famous Aristotelian argument in favor of the limitation of the world":

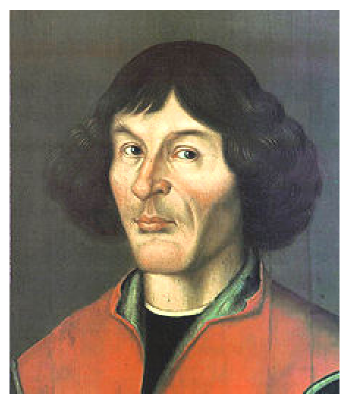
> The world has no circumference, because if it had a center and a circumference, and thus had a beginning and an end in itself, the world would be limited in respect to something else, and outside the world there would be something other, and space, things that are wholly lacking in truth. Since, therefore, it is impossible to enclose the world between a corporeal centrum and a circumference, it is [impossible for] our reason to have a full understanding of the world, as it implies the comprehension of God who is the center and the circumference of it.
>
> [Ibid., p.11]

While to Giordano Bruno this suggested an infinite Universe, that is not quite what Nicholas had in mind. He only saw the earth and the celestial spheres as imperfect, precluding thereby an exact center. He believes only God is infinite, still:

> . . . though the world is not infinite, yet it cannot be conceived as finite, since it has no limits between which it is confined.
>
> [Ibid., p.11]

Cusanas left us no drawing, believing an actual diagram of the Universe is impossible since wherever one stands it looks as if he is in the center, thus it has no absolute shape. Actually, however, he leaves open the idea that space (not the world) might be infinite. This may have been what suggested to Bruno that there must be other worlds in infinite space; worlds unconnected with ours; "island universes". At least as important as his suggestion of infinite space is his rejection of the hierarchical nature of the world. Without a center of space, the earth is just another celestial orb. He is not afraid to suggest that God may well have placed creatures who are advanced beyond us on some or all of these other worlds, including the Sun. And he expects, since only God is perfect and infinite, that corruption of matter and morals is also universal.

Still, without astronomical support, a mathematical description, or even an artistic rendering of this revolutionary view, his concept was impractical as well as theologically unacceptable. Besides, the reputation of Aristotle, having lasted so many centuries, was much too firmly entrenched to allow him to be so quickly overturned. But such ideas were in the air, swirling, as it were, around the unsatisfactory vacuum left by the incongruence of 'revealed' explanations and the accepted classical traditions—by the troublesome, still open questions concerning the 'how' of the Universe. There is debate, in fact, over whether Copernicus (despite the suggestive double entendre of his book's title) was really a revolutionary.



Nicolaus Coperncus [1473-1543]

Many scholars see his cosmic system as merely a reformation or upgrading of Ptolemy's geocentric scheme, since we are still dealing with nesting and confining spheres and ancient 'mechanics', and even the retention of many of those complicated epicycles. There is also argument over whether either of these systems was considered as 'real' by its architect (or would they have seen themselves as discoverers, rather than inventors?) The answer seems to be 'sometimes.' There are references aplenty in both men's books to support either argument.

The best case for establishing that he believed (mostly) in the truth of his system is to be made out of Copernicus's own statements to that affect in *DE REVOLUTIANIBUS* [1543]. In order to disguise that notion, in fact (and without the knowledge of Copernicus, who may actually have died before seeing his treatise in print—or, on his deathbed, may have seen a copy of it only too late), the man who saw to its publication had added a forward of his own. Had Copernicus seen that, he might not have been happy with the 'letter to the public' that had been attached as a preface. It was written by **Andreas Osiander**, who asks the reader, in essence, not to take the book as truth, explaining that it is only a kind of mathematical model offering some valuable resolutions to several unresolved problems of Ptolemy's system.

This misrepresentation of Copernicus's intent is plainly offered by Osiander to ward off charges of heresy, and it may actually have been instrumental in postponing serious attacks from the God-fearing proponents of Scripture. But Copernicus did not need saving. Before his book could be distributed he had passed beyond inquisition.

Although the Copernican hypothesis became known to many scholars before its complete expression was published, and though his great work was much respected for its mathematics, few contemporaries concurred with this account of the Universe. Perhaps due to his death, almost simultaneous with publication of his *De revolutionibus* (which meant censure would only call undue attention to a work that might better be repressed by simply ignoring it); perhaps in part due to Osiander's uncalled for prefatory letter encouraging readers not to take it too seriously; and in part due to its complexity, tending to reduce expectations of popularity (even his title page, although at first encouraging his 'diligent reader' to 'buy, read, and enjoy,' warns emphatically (as did Plato), "*Let no one untrained in geometry enter here*.")—and although it was certainly not accepted by the Church—heliocentrism, *per se*, had not been officially condemned as heretical…yet.

There were those who did believe in the truth of *Revolutianibus*: Christoph Rothmann, Michael Maestlin, and Kepler (then Maestlin's pupil), among others in Germany; Thos. Digges *[A Perfit Description of the Caelestial Orbes]* and Wm. Gilbert in England; and Galileo in Italy. But it took a freethinking, foresightful, unpenitent cleric

Giordano Bruno [1548-1600]

to stir the pot sufficiently to have the Copernican system banned by the Church and to get himself roasted alive in the bargain.

Although it is tempting to see Bruno as a martyr to science, it should be pointed out that he was burned for heresy, generally, and only incidentally for his heliocentric views and belief in the plurality of worlds. Still, even if he was burned only for blasphemy, he must be considered a martyr to freedom of thought, a concept crucial to the development of science and modernism.

No doubt, he was a heretic. Taking the Arian heresy even further, though Dominican and ordained, it seems he did not even believe Christ was God—or even part of God, but only "an unusually skilful magician" [*Catholic Encyclopedia*; 1908]. Also, a copy of banned writings of the irreligious Erasmus, annotated by Bruno, was discovered in the convent privy at Naples. As expected (Christ being mortal), he also denied the virgin birth, miracles generally, and thought the devil himself could be saved.

His notions were more philosophical than scientific (though he was contemporary with Galileo, 'the father of modern science'). But in 1940 some records of the proceedings against Bruno were discovered, including a listing of his offenses:

Earliest known portrait of Bruno

- Holding opinions contrary to the Catholic and speaking against it and its ministers.
- Holding erroneous opinions about the Trinity, about Christ's divinity and Incarnation.
- Holding erroneous opinions about Christ.
- Holding erroneous opinions about Transubstantiation and Mass.
- Claiming the existence of a plurality of worlds and their eternity.
- Believing in metempsychosis and in the transmigration of the human soul into brutes.
- Dealing in magics and divination.
- Denying the Virginity of Mary.

["*Il Sommario del Processo di Giordano Bruno, con appendice di Documenti sull'eresia e l'inquisizione a Modena nel secolo XVI*", edited by Angelo Mercati, *in* STUDI E TESTI, vol. 101. *Listing of offenses by* Luigi Firpo, *Il processo di Giordano Bruno*, 1993.]

Though he may not have believed in miracles, it seems to all intents miraculous that he was able to keep out of Cardinal Bellarmine's hands for as long as he did (until one discovers that the Cardinal himself once had a work on the *index,* briefly). As an early indicator of the opening of the Western mind, Bruno managed (often was forced) to travel widely (sometimes without ecclesiastical garb), at first spreading his unorthodoxies all over Italy, then to France, to England, back to Paris, and to Germany. Alternately being accepted and banned; embraced then attacked by his new friends, he was often allowed to lecture and teach, but could not secure a stable position. He journeyed to Prague, and then to Helmstedt, lecturing there until he was excommunicated by the Lutherans and had to flee again. He even joined the Calvinists for a while in Geneva, and made of himself altogether a great nuisance to a Catholic church already in considerable torment over Protestantism. He seemed at least as concerned with freeing thought from the restricted finiteness of Aristotle as he was in leaping over religious dogma. In the dialogue format, commonly used in his era, we find him saying through a character:

> Henceforth I spread confident wings to space;
> I fear no barrier of crystal or of glass;
> I cleave the heavens and soar to the infinite.
> And while I rise from my own globe to others
> And penetrate ever further through the eternal field,
> That which others saw from afar, I leave far behind me.

[*ON THE INFINITE UNIVERSE AND WORLDS* (Dorothea Waley Singer, trans.) *In Singer's* GIORDONO BRUNO; Schuman, NY, 1950; p.251]

In the fifth dialogue of that work, Bruno's character Philotheo gives voice to this new concept of space:

> There is a single general space, a single vast immensity which we may freely call void; in it are innumerable globes like this one on which we live and grow. This space we declare to be infinite, since neither reason, convenience, possibility, sense-perception nor nature assign to it a limit…It diffuseth throughout all, penetrateth all and it envelopeth, toucheth and is closely attached to all, leaving nowhere any vacant space; unless, like many others, thou preferest to give the name of void to this which is the site and position of all motion, the space in which all have their course.

[Singer; GIORDONO BRUNO; p.249]

Copy and hand out Ch.2: The New Astronomy and the New Metaphysics, pp.28-57 of FROM THE CLOSED WORLD TO THE INFINITE UNIVERSE; Alexandre Koyré (especially noting the treatment of Bruno) for supplemental reading.

Bruno was invited to Venice to teach a wealthy patrician his famous tricks of memory. With that and the possibility of a teaching position at Padua, and with the apparent waning of the Inquisition, he felt it safe to return to Italy—but he was wrong. His Venetian host, who apparently found no benefit in Bruno's memory instruction, denounced him to the Inquisition. He was arrested and sent to Rome and tried for his heresies by the very inquisitors who were later to try Galileo. Unlike Galileo, he (courageously or recklessly) refused to recant, and was ultimately purified by fire.

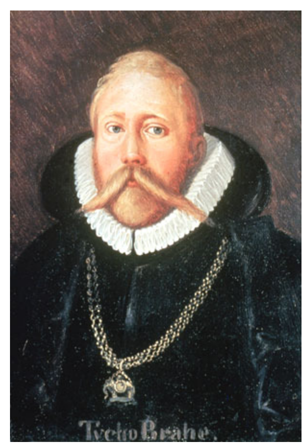
Despite these efforts of the Church to contain it, the Universe continued its expansion in the hands of Telesio and Patritius in Italy, and also Thomasso Campanella (who opined that God must have 'created' space as a 'capacity' for containing his newly made material). And in England there was the famous physician and first expert on magnetism, **William Gilbert** [1544-1603]. Criticizing the need of some astronomers to ascribe motion to the eighth sphere to explain the Earth's precession, "and atop of this to construct a ninth heaven, nay a tenth and an eleventh," Gilbert says:

> We must pardon slips in mathematicians, for one may be permitted in the case of movements difficult to account for to offer any hypotheses whatever in order to establish a law and to bring in a rule that will make the facts agree. But the philosopher never can admit such enormous and monstrous celestial constructions.
> [Gilbert: ON THE LOADSTONE; ch.9, *end of* 1st par.; p.119b, GREAT BOOKS, vol.28]

All of these men helped inspire Galileo.

Pierre Gassendi [1592-1655]
(instrumental in the revival of the atomists)

In the following century, attempting to defend the concept of the void, Gassendi joined it with infinite space. He argued that space is not only infinite but (as a receptacle of matter) is necessarily eternal, preceding God's creation of the atoms.



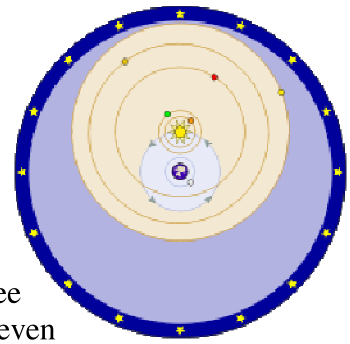
The New Astronomers

At the time of Bruno's immolation the most famous of true astronomers was:

Tycho Brahe [1546-1601].

Even without the assistance of astronomies most identifiable tool, the yet-to-be-invented telescope, Tycho Brahe managed to make himself the first modern astronomer by the quality and quantity of his observations and in his suggesting of testable theory in attempting to explain, mathematically and logically, the data he accumulated. He was granted an island of his own by the King of Denmark, on which he constructed a dwelling and observatory, which he called Uraniborg.

He did not believe the sun was the center of creation, but he thought Copernicus had bested Ptolemy mathematically and had resolved some problems of the geocentric system, so he proposed another alternative whereby Earth was unmoved at the center, but the planets all are satellites of the Sun (which revolved about Earth). Although he likely arrived at this configuration himself , it is essentially the system proposed in antiquity by a contemporary of Plato: Heraclides (or possibly Ecphantus), thus preceding Tycho by nearly 2,000 years. Tycho, however, benefited from many more observations and much greater accuracy. He made the best attempt up to that time to find the distance to the fixed stars by parallax. But his refined instruments (his own designs of armillary spheres, widely used since ancient times until rendered obsolete by the astronomical telescope) were incapable of measuring to the degree of accuracy required for ascertaining stellar parallax. But in that even the early telescopes would fail.



He faced a dilemma: either Earth is centered and motionless ('fixed' stars moving about the planetary system per Ptolemy and Aristotle) or, if Copernicus were correct about the Earth being in motion about the Sun, the stars would have to be too far away to measure (or even notice) parallax. He considered that the immense distance to the stars required by the latter solution to be impossible, so he made the common sense (but nonetheless wrong) choice: keeping the Earth motionless in his system and centered in a finite universe, as opposed to the limitless vision of Bruno. In Brahe's own words:

> …the body of the Earth, large, sluggish and inapt for motion is not to be disturbed by movement…anymore than the Aetherial Lights [*stars*] are to be shifted, so that such ideas are opposed to physical principles and also Holy Writ….Consequently I shall not speak now of the vast space between the orb of Saturn and the Eighth Sphere [*the starry vault*] left utterly empty of stars by this reasoning….

[*in* Michael J. Crowe, THEORIES OF THE WORLD: *From Antiquity to the Copernican Revolution* (2nd edition), ch.7, 'The Tychonic System'; Dover, NY, 2001]

As we recall, Heraclides/Ecphantus may have been closer to the correct concept, with Earth (perhaps) rotating on its axis, giving the heavens only the illusion of being in motion and thus inviting the infinite concept or, at least, a much expanded, open universe, though he (they) do not seem to have made that leap in perspective.

Tycho Brahe eventually moved his equipment to Prague, to become Imperial Mathematician. Soon he received a copy of *Mysterium Cosmographicum.*

Johannes Kepler (1571-1630)

In that book Kepler advances an idea that had required a vast effort over years of frustrating errors: a numerical relationship between the planetary spheres, somewhat in the manner of Pythagoras. Why were there six planets—could it be because six is the first perfect number, divisible by an even number into two odds (3+3), and by an odd number into three evens (2+2+2)?

Surely there was some significance to this, something useful to the Creator. He also tried geometrical figures, considering that the triangle might be a key to the answer. Finally it dawned upon him that to make a real universe, God needed more than infinitesimal points and widthless lines. Plane geometry was insufficient; a world needed solids. He thought about the sphere as the perfect and simplest solid: a solid, in fact, with but one side. But there was a kind of perfection in straight lines too, and from them were constructed a total (as proved by Euclid) of only five regular solids: those formed by equal polygons having equal angles—which could be inscribed within spheres, and smaller spheres could be inscribed within them. He imagined inscribing "the solids in the spheres and the spheres in the solids until no solid remains to be placed within or beyond the moving spheres."

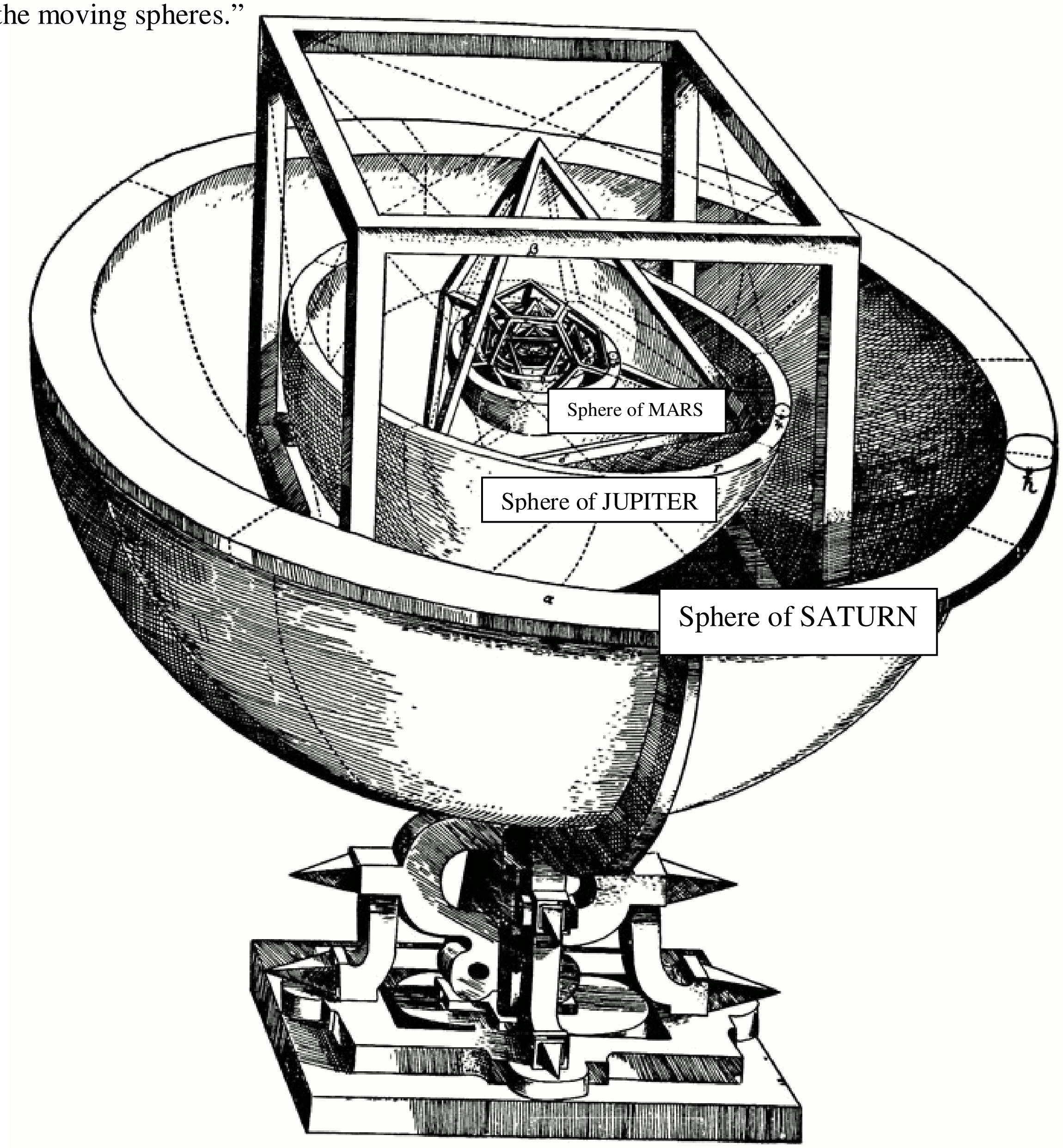


Fig.1 -- Kepler's Platonic solid model of the Solar system from *Mysterium Cosmographicum* (1596).

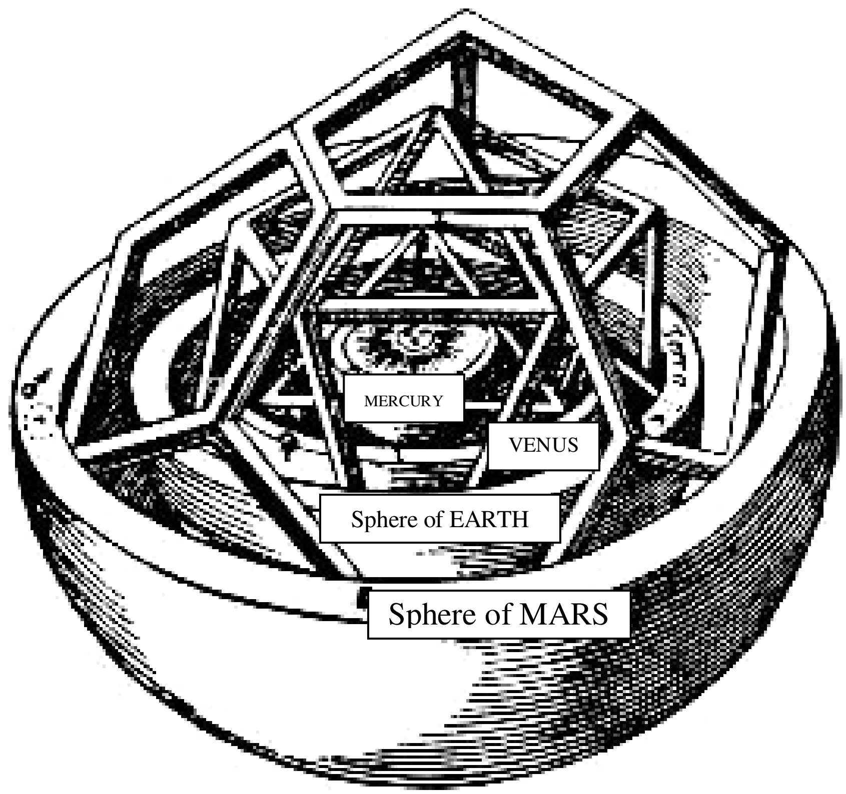


Fig.2 -- Kepler's Platonic solid model of the Solar system (the inner portions here enlarged for clarity) from *Mysterium Cosmographicum* (1596). Diagrams from Wikimedia Commons.

...Therefore, if the five solids with their corresponding spheres be inserted one within the other, the number of spheres will be equal to six.

....

Now, therefore, if some era of the world's existence conceived the idea of arranging the Universe in such a way as to place six moving spheres round the Sun, then that era has imparted the true Astronomy to us. It happens that Copernicus has precisely six spheres of this kind, and taken two by two they are in the required proportion for being placed between the five solids in question.

....

The Earth [the sphere of the Earth—*i.e., in modern terms, its orbit*] is the measure for all the other spheres. Circumscribe a Dodecahedron about it, then the surrounding sphere will be that of Mars; circumscribe a Tetrahedron about the sphere of Mars, then the surrounding sphere will be that of Jupiter; circumscribe a Cube about the sphere of Jupiter, then the surrounding sphere will be that of Saturn. Now place an Icosahedron within the sphere of the Earth, then the sphere which is inscribed is that of Venus; place an Octahedron within the sphere of Venus, and the sphere which is inscribed is that of Mercury.

Therefore you have the reason for the number of the planets. [*see diagram*]

[Kepler: *Mysterium Cosmographicum*; Tübingen, 1595-1596; *quoted in* Alexander Koyré: THE ASTRONOMICAL REVOLUTION: *Copernicus-Kepler-Borelli*; Dover, NY, 1992, p.145-6; *a republication of* Methuen & Co. Ltd, London, and Cornell Univ., Ithaca, NY, 1973; *from original* LA REVOLUTION ASTRONOMIQUE; Hermann SA, 293 rue Lecourbe, Paris, 1961]

Ingenious as this is, it did not exactly match any of the contemporary estimates of the actual orbits. But of course none of those estimates were accurate since they were all based on faulty conceptions of the whole system. Still, they were ‘in the ball park’, so to speak, and the Kepler concept was adjustable by simply varying the thickness of the spheres. Even when adjusted for the eccentricity of the spheres (due to Copernicus having utilized a *mean* sun, since the actual Sun was not precisely in the center of his system), the closest and furthest distances of each of the each planets from the actual Sun could be understood as reaching from the inner surface to the outer surface of their respective spheres.

Kepler had heard that Tycho Brae had the most accurate figures due to the thoroughness and extraordinary care taken in his observations. So he contacted Brae to see what he might think about this universe as nested polyhedrons idea. Though he did not agree with Kepler’s scheme, since it did not fit with his own, differently conceived geocentric system, Tycho was much impressed with the work done by Kepler and the power of the mind behind it.

Kepler became Tycho Brae’s assistant, hoping to get access to his observations. But Brahe was somewhat distrustful of Kepler. Perhaps because of the latter’s very perspicacity, he restricted Kepler’s access to his records. Despite Kepler’s begging to see the whole, he assigned only the problem of resolving the orbit of Mars to Kepler, expecting that its difficulty would absorb his energy while Brahe completed work on his own cosmic system.

Ironically, it was the struggle over this very problem that ultimately forced Kepler to the conclusion that the planets, contrary to two thousand years of unexamined assumption, did not revolve in perfectly circular paths; that their orbits (as the ancient Heraclides had intuited but had, himself, rejected out of already very old and mistaken tradition) were slightly flattened into ellipses. With this realization, plus his personal preference for the Copernican system over that of either Ptolemy or Brahe (solidified in part by his admiration of Galileo, Kepler formulated his *three laws of planetary motion*:

(1) Each planet orbits around the Sun in an ellipse of which the Sun is at one focus;

(2) The line between a planet and the Sun sweeps out equal areas in equal times: hence the planet moves faster when closer to the Sun than when farther away;

and,

(3) The square of the time taken by a planet to orbit the Sun is proportional to the cube of its mean distance from the Sun.

Thus, in the world of astronomy, he eclipsed his reluctant mentor. Kepler had to wait for his fame, however, until Tycho died, allowing him, finally, to examine those precious observations that turned out to be crucial to his major contribution to astronomy.

More of a visionary than was Tycho, Kepler may also be the first science-fiction author (‘astro-fiction’ might be more accurate) with his fantasy about a trip to the moon [*Somnium* (The Dream)], so that he could picture for his readers (based on his extraordinary astronomical data and mathematical calculations) how that world would be experienced and how Earth would look to the ‘Volvans’ (the Lunians).

Ultimately, however, “the purely geometrical concept of the structure of the Universe…showed itself to be inadequate,” says Koyré:

It was too static. It would probably have suited a Universe at rest, but not one in motion; and especially not a Universe in which the planets do not move in concentric circles with constant velocities at fixed distances from the Sun, but describe eccentric orbits, periodically approaching, or moving away from, the Sun, and changing their velocity at every moment…. It was because time was ignored, that the *Mysterium Cosmographicum* failed to reveal the true structure of the Cosmos. Purely geometrical relationships were needed; for God, whilst being a geometer, was not solely and architect—a fact which the ancient Pythagoreans had certainly apprehended. He was also, even primarily, a musician.

[Koyré: THE ASTRONOMICAL REVOLUTION; Dover, NY, p.327]

Collectively, Kepler's Laws superseded the ancient Ptolemaic concept of a spherical universe with its epicyclic motion. They also suggested a foundation for Isaac Newton's much later theory of universal gravitation. In the tradition of Pythagoras (6^{th} century B.C.), Kepler, for not viewing science and spirituality as mutually exclusive, was not alone in his era. As an astrologer he was at least as controversial as he was as an astronomer. Kepler thought he saw a deeper significance in his laws: the reconciliation of the emerging vision of a Sun-centered planetary system with the ancient Pythagorean concept of *armonia*, or universal harmony.

So, putting on his dancing shoes, Kepler found the varying distances of the planets from the Sun and their velocities to be of musical significance. "The movements of the heavens" he wrote, "are nothing except a certain everlasting polyphony." This was announced along with his Third Law, in *Harmonice Mundi* (1618). Here, in this regard, I would like to read a notation found in Koyré's book:

According to Kepler, music is based on geometry, and not on arithmetic; but is not to be identified with it, for geometry embraced all relationships between magnitudes (expressible and non-expressible, and infinite in number), whereas music is based on a small number, namely, seven very simple, fundamental ratios between the lengths of strings, or the divisions of a monochord. Seeing that these numerical ratios do not form the basis of harmony—according to Kepler, nothing is based on pure numbers which represent only the expressible ('effable'), and therefore rational and cognizable, part of geometrical magnitudes and ratios, in contrast with 'ineffable', and therefore irrational and incognizable ratios and magnitudes—Kepler sought the justification for harmony in geometrical structures, particularly, in the division of the circle (which represents the monochord) by inscribed polygons. Certain of these polygons are 'constructible' (by means of ruler and compass), others are not. On the one hand, this constructibility [*sic*] is identified by Kepler with rationality—we 'know' only that which is constructible, he said in 1605; as for that which is not constructible , it is impossible, not only for us, but even for God, to know (*scire*) it. Consequently, we cannot 'know' the side of the heptagon [to inscribe an equilateral 7-sided figure inside a circle, divide 360 degrees by 7 to find the angle of the apex of each triangle meeting in the center. The angle is 51.42857…, which cannot be resolved, thus cannot be divided into equal shares of 360 degrees, so such a figure can only be approximately constructed]. On the other hand, the constructibility (*sic*) of the figures corresponds to the 'consonance' of sounds. By restricting himself to 'directly constructible' polygons, *i.e.*, those which do not imply the

> previous construction of another figure, Kepler was finally able to co-ordinate the notes and harmonic ratios with the sides of the constructible polygons. Then, he declared that only these ratios are to be taken into account for the construction of the Universe, and that God *could not* make use of any others.
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> [Koyré: THE ASTRONOMICAL REVOLUTION; note 4 to Part III, ch.II, p.451]

HANDOUT: *Kepler & the Music of the Spheres*; *article by* David Plant *found at* http://www.skyscript.co.uk/kepler.html -- (Supplemental Reading)
Also copy musical notation of each planet's 'tune' *from* HARMONICE MUNDI; p.337 *of* Koyré: THE ASTRONOMICAL REVOLUTION

Influenced by his mentor, Kepler accepted the rotating and revolving Earth, but could not accept Bruno's idea concerning an infinite expanse. He always considered the universe to have a shape, particularly a sphere (of whatever enormous size implied by Galileo's telescope) with the Sun (nearly) at its center. Though he admitted that the stars might be of different sizes, so that very bright ones might be small and closer, and very dim ones might actually be quite large and further away, he thought this very unlikely as it violated the general expectation that the universe was by nature, as by God's plan, homogeneous. Furthermore, though he understood that they glowed from their own light, he would not admit that any of the fixed stars could be as great or as luminous as our Sun; nor would he admit (even after Galileo's discovery of satellites about Jupiter [the 'Medicean Planets,' which he readily accepted as moons] that, similar to our Sun, the stars might have planets of their own—i.e., like everyone, except apparently Bruno and maybe Thomas Digges, he did not see the Sun as just another star (or the fixed stars as a multitude of suns), but considered it unique in all the Universe.

Visible stars form at least a quasi-sphere about a great void between them (at least the nearer ones) and our solar system. The Universe, then, has a shape. But infinity can have neither center nor shape. Since Galileo's huge expansion of the visible Universe, the question arose in many minds: Can there not be even more stars, millions more, that are invisible to us? Kepler took a scientific stance, saying that astronomy cannot speculate on the unseen, but still made arguments against the possibility of an infinite Universe—or even infinite space. The best of those, it seems, are *(1)* that a real (that is visible) star cannot be infinitely far from us. Whatever we can see is certainly at a finite (even if immeasurable) distance. And *(2)* what we cannot see, though we know nothing else of it, we know that, if it really exists—i.e., whatever exists beyond Earth—it is at some finite distance. No matter how far away we place an imaginary star, it will not be infinitely far.

"Now," says Alexandre Koyré, "even if we deny that there is an infinite number of stars in space, there still remains, for the infinitist, a last possibility: that of asserting a finite world immersed in an infinite space."

"Kepler does not accept this, either," Koyré explains, "and his reasons for rejecting it reveal the ultimate metaphysical background of his thinking." Says Kepler:

> If you are speaking of void space, that is, of what is nothing, what neither is, nor is created, and cannot oppose a resistance to anything being there, you are dealing with quite another question. It is clear that [this void space], which is obviously nothing, cannot have an actual existence. If, however, space exists because for the bodies located in it [it will not be infinite as] it is already demonstrated that no body that can be located is actually infinite, and that bodies of finite magnitude

> cannot be infinite in number. It is therefore by no means necessary that space be infinite on account of the bodies located in it. And it is also impossible that between two bodies there be an actually infinite line. For it is incompatible to be infinite and to have limits in the two individual bodies or points that constitute the ends of the line.
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> [*quoted from* Kepler's *Epitome astronomiae Copericanae*
> *in* Alexandre Koyré; FROM THE CLOSED WORLD TO THE INFINITE UNIVERSE; ch.3;
> Johns Hopkins Univ.; Baltimore/London; 1957]

But can we not imagine this process (finding always the next further star) to go on and on?

Certainly Kepler would admit that. But that is only an imaginary infinity. Infinity, it seems, cannot be realized, therefore cannot 'exist.' So this "great and truly revolutionary thinker," says Koyré, "was, nevertheless, bound by tradition. In his conception of being, [and] of motion, though not of science, Kepler, in the last analysis, remains an Aristotelian." One would have to argue with Koyré on that, since, with his planetary laws and the content of his arguments concerning infinity, Kepler had to have dispensed with the material reality of the concentric spheres, with the possible exception of the outermost sphere, though it grew immensely thick with the idea that the stars seemed brighter or dimmer due to their lesser or greater distance from the earth. It is unclear whether he considered the outer sphere as substantial; something impenetrable.

The question we moderns might like to ask does not seem to have occurred to these pre-moderns: Of course infinity cannot be completed—by definition. But in the sense that a process has existence (as an ongoing event), cannot the *process* of the Universe be infinite? We will have to wait a while to deal with that.