First translation of Kepler's 'New Astronomy'

Kepler said, "The occasions by which people come to understand celestial things seem to me not much less marvellous than the nature of the celestial things themselves." A review from Sylvia Brewda.

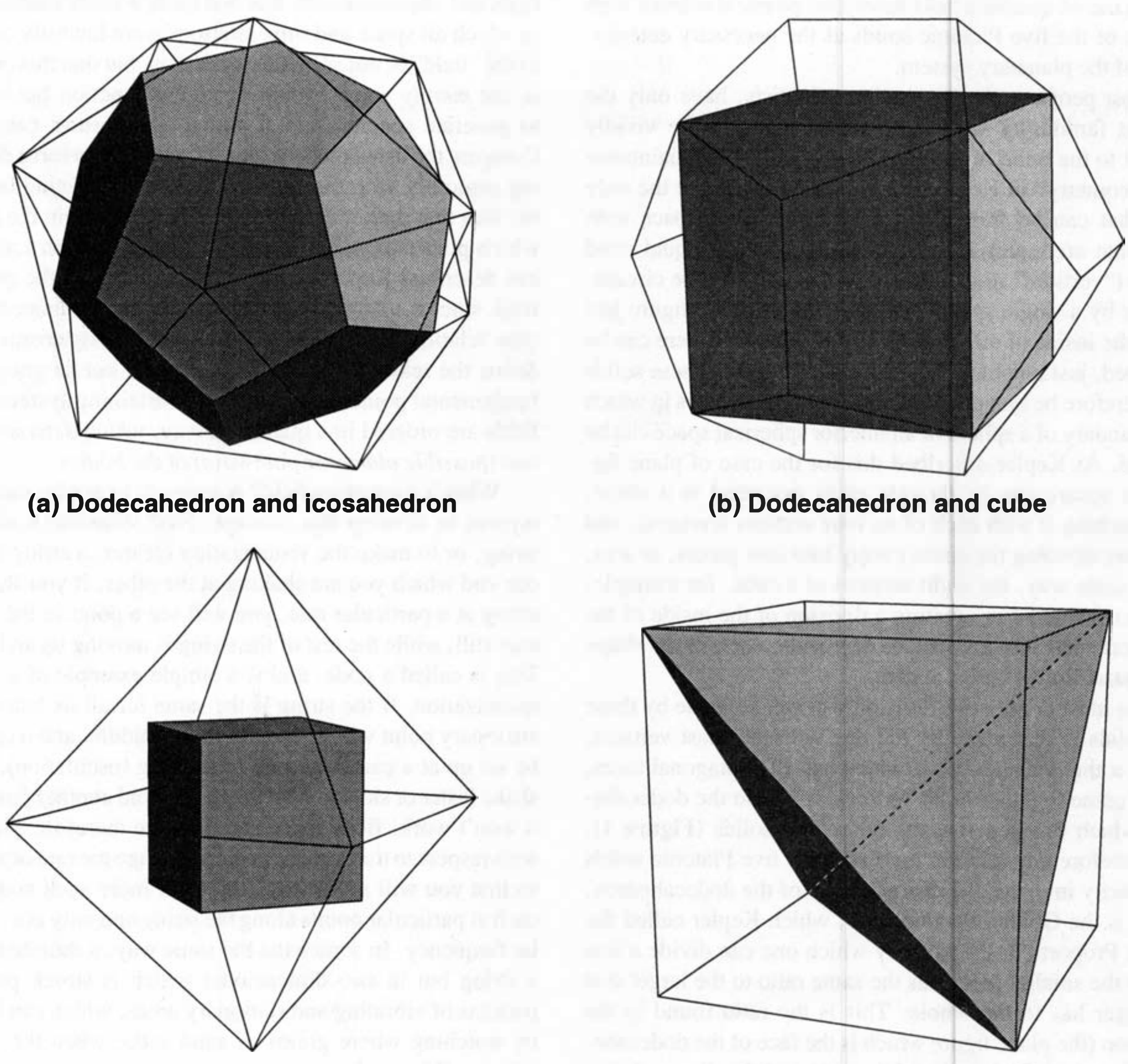
Johannes Kepler: New Astronomy
translated by William Donohoe
Cambridge University Press, Cambridge, U.K., 1992
665 pages, hardbound, $140

The *New Astronomy,* or, as it was originally titled, *Commentary on the Motions of the Star Mars,* is the work, published in 1609, in which the great German astronomer Johannes Kepler (1571-1630) announced his discovery that the orbits of the planets are ellipses, rather than various compoundings of circular motion, and that the rate at which a given planet travels is inversely proportional to its distance from the Sun (a law which later became, because of the approximation used by Kepler for calculation, the law of equal areas).

The appearance of the first English translation of this groundbreaking work by the father of modern astronomy, and one of the greatest scientists known, is cause for rejoicing, even though the book is not easy reading for those not familiar with the terms and operations of observational astronomy. As Kepler himself says, unlike the tales of the discoveries of Columbus, Magellan, and the Portuguese mariners, "the difficulties and thorns of my discoveries infest the very reading" about these mathematical discoveries.

This is only the second complete English translation of any of Kepler's book-length writings, none of which is available in other languages except German and the original Latin. To those not fluent in either language, other works of the most celebrated astronomical physicist have only been available as selections or in brief pieces which Kepler himself considered secondary within his life's work. The translator and the publisher are therefore to be thanked for making this complete version of a major work available, in an edition marked by scrupulous attention to the technical apparatus (calculations, star positions, diagrams) of the original. However, the reader must be wary of the attempts, embedded in this edition, to explain Kepler's achievements as the result of his abandonment of his previous commitment to the outlook of Christian Platonism in favor of an Aristotelian adherence to data, and the reduction of the *reasons* for things to the mere physical causes by which they occur. In fact, the publication of this monumental work may have been in part prompted by the idea that here, Kepler could be portrayed as he is described in the Foreword by Prof. Owen Gingerich of Harvard, as having "passed through the refiner's fire," with the "youthful speculations of his *Mysterium Cosmographicum* . . . behind him." These comments are of particular importance since the entire translation is characterized in the acknowledgements as "still very much his project." It is true that, because of the task he had set himself, Kepler does not specify as much as elsewhere the hypothetical foundations of his analysis. However, the misunderstanding indicated by describing this work as "a foundation for the development of classical [i.e., Newtonian] physics" is refuted by Kepler's own words throughout. For example, Kepler places an attack on the proto-Newtonian Ramus, and his demand for "an astronomy

FIGURE 1
Relations between the five Platonic solids



The dodecahedron can generate the icosahedron (20 triangular faces) by placing the center of a triangle over each vertex (a). The cube can be generated from the dodecahedron by connecting non-neighboring pairs of vertices (b), while the octahedron and tetrahedron can be constructed from the cube, the octahedron by placing the center of its eight triangular faces over each of the vertices of the cube (c), and the tetrahedron (four triangular faces) by connecting each non-neighboring vertex of the cube. Although the icosahedron can regenerate the dodecahedron, and the octahedron and tetrahedron can be used to generate the cube and each other, there is no way *to use the cube, octahedron, or tetrahedron to generate the dodecahedron/icosahedron pair. Although Kepler never references this characteristic of the dodecahedron, it is consistent with his original conception of the planetary system, which begins with the dodecahedron, and also with the Pythagoreans' attribution of the highest quality to the dodecahedron, which they described as defining the essence of the heavenly bodies, or as Plato and Timaeus say, as "the construction which God used to paint the zodiac of the universe."*

constructed without hypotheses," directly after the title page, an attack which the translator mistakenly references as an endorsement in his Introduction. Throughout the book, footnotes detail the errors which Kepler made in computation, and often reflect the translator's amazed incomprehension that Kepler could arrive at accurate conclusions despite them.

The 'secret' of method

The secret of the work which is recorded in this book is Kepler's method, which led him to become the first scientific elaborator of the concept of the quantum field, which is the basis for all significant advances in physics since. To understand his method, let us start where he started, in the book he wrote at the age of 25 with the seemingly immodest title, *The Secret of the Universe* (usually referred to by its Latin name, *Mysterium Cosmographicum*). Here, Kepler lays out the first known use of quantum field theory for physical science with his use of the five Platonic solids as the necessary determinants of the planetary system.

Most people today, including scientists, have only the vaguest familiarity with these solids, which were vividly present to the mind of "anyone having a slight acquaintance with geometry" in Kepler's time. These solids are the only ones that can be formed in three-dimensional space with faces that are equal, regular plane figures and equal solid angles ("vertices" or corners), and that can both be circumscribed by a single sphere (all the vertices of the figure just touch the inside of the sphere), and in which a sphere can be inscribed, just touching the center of each face. These solids can therefore be thought of as representing the ways in which the boundary of a sphere or an interior spherical space can be divided. As Kepler described this for the case of plane figures, a square can be thought of as inscribed in a circle, just touching it with each of its four vertices (corners), and therefore dividing the circle evenly into four pieces, or arcs. In the same way, the eight vertices of a cube, for example, can be considered as creating a division of the inside of the spherical shell into six surface segments, each in the shape of a square drawn onto a sphere.

The most dense such division that can be made by these five solids is that made by the one with the most vertices, which is the dodecahedron, which has 12 pentagonal faces, which come together in 20 vertices. It is also the dodecahedron which can generate the other four solids (**Figure 1**), and therefore any relation involving the five Platonic solids necessarily involves the characteristic of the dodecahedron, which is the Golden Section ratio, which Kepler called the Divine Proportion, the ratio by which one can divide a line so that the smaller piece has the same ratio to the larger that the larger has to the whole. This is the ratio found in the pentagon (the plane figure which is the face of the dodecahedron) between the lengths of the side and the diagonal (between any non-neighboring pairs of vertices). Relationships involving this same ratio $[(1+\sqrt{5})/2) : 1]$ are found in the dodecahedron, for example between the radius of the circumscribing sphere and the length of an edge, which is the product of the Golden Section and $\sqrt{3} : 2$.

In the introduction to *Mysterium Cosmographicum*, Kepler records his discovery as the thought originally came to him: "The Earth is the circle which is the measure of all. Construct a dodecahedron around it. The circle surrounding that will be Mars. Round Mars construct a tetrahedron. The circle surrounding that will be Jupiter. Round Jupiter construct a cube. The circle surrounding that will be Saturn [the outermost planet known at the time]. Now construct an icosahedron inside the Earth. The circle inscribed within that will be Venus. Inside Venus inscribe an octahedron. The circle inscribed within that will be Mercury."

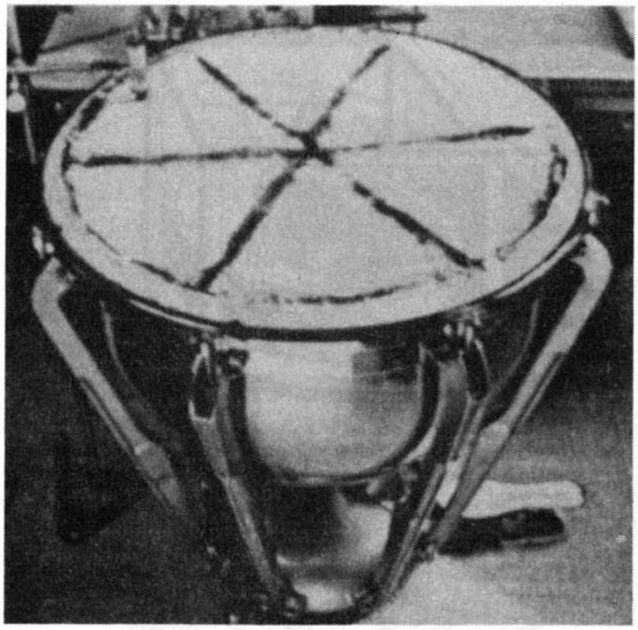
The idea of quantum field

The concept which Kepler expresses here, and the basis of his first work and all his succeeding marvelous elaborations and improvements, was that there was not merely a way in which all space and time relations were lawfully ordered, as the "field" of our planetary system is, but that this ordering is *not merely* some evenly changing function but such as to generate specific loci at which singularities can occur. Compare the usual modern idea of gravity, as a force decreasing smoothly with the distance from the attracting body, to the idea that there were particular distances from the Sun, at which planets *could occur*. This is why Lyndon LaRouche has described Kepler as the first elaborator of the quantum field, since Kepler understood not only the existence of field-type relationships (such as gravity and magnetism) which define the relationships between bodies, but he grasped the fundamental point that in real, self-sustaining systems, such fields are ordered in a quantized way, *which determines the loci (possible places or pathways) of the bodies*.

What is a quantum field? A series of examples can help a layman to develop this concept. First, consider a vibrating string, or to make the visualization clearer, a string fixed at one end which you are shaking at the other. If you shake the string at a particular rate, you will see a point in the middle stay still, while the rest of the string is moving up and down. This is called a node, and is a simple example of a type of quantization. If the string is the same for all its length, that stationary point will be exactly in the middle, and it can only be set up at a particular rate of shaking (oscillation). If you shake faster or slower, or if you try to hold another point still, it won't work. Both space and time are therefore quantized with respect to that string. You can change the rate of shaking so that you will set up two, three, or more such nodes, but each at particular points along the string and only at a particular frequency. In somewhat the same way, a drumhead (like a string but in two dimensions) which is struck produces patterns of vibrating and stationary areas, which can be seen by watching where grains of sand settle when the surface vibrates (**Figure 2**).

These examples are clearly special cases, because of the artificial boundaries, and the fact that the energy is being supplied from outside. How could Kepler say that the space around the Sun is ordered in a similar way? How could this help him to determine the laws of planetary motion which are still valid today, laws which also govern the motions of the outer planets and of systems of moons, of which he knew nothing? To answer these questions demands that the reader confront some of the most basic dogmas of professional science today. However, recent occurrences in science itself ought to convince us that this body of theory is in need of such critical examination. Witness the hysterical denial with which the proven repeatability of the cold fusion phenomenon has been met; the deafening silence which greeted the appearance of a number of "spokes" or areas of different reflectivity in one of the major rings of Saturn, as well as the spectacular

FIGURE 2
A simple example of quantization



The grains of sand show the stationary areas by the pattern they form on a drumhead that is being vibrated.

appearance of a "braided" structure in a fine outer ring (which prompted one scientist to exclaim, "Obviously, the rings are doing the right thing: It's just that we don't understand the rules"); and the proof that according to Newtonian mechanics, there is *no* lawful way to predict the outcome of a collision between three or more bodies if there is the slightest uncertainty about the relative masses and velocities of the bodies.

Consider the case of the spectrum of light emitted by hydrogen gas. This is one of the best-known physical facts in science today, and is used as a measuring rod for many areas of physics, such as astronomy. The reason is that, when hydrogen is heated, it emits light only at certain very clearly defined and consistent frequencies (colors). However, if the space around the nucleus were homogeneous, the electrons should be able to revolve at any distance from the nucleus, to expand or contract the radii of their orbits in a continuous way, and therefore to emit light of all frequencies (since light is emitted when an electron changes from one orbit to another of lower energy, nearer to the nucleus, and the frequency of the light is determined by the amount of energy involved). Therefore, there must be an ordering of the atom as a system which defines only certain transitions in the electrons' orbits as possible: those transitions which correspond to the particular frequencies of the emitted light.

In the same way that Kepler considered quantized orderings of the space in the solar system, scientists should ask: What ordering must exist in the micro-space of the atom? In one formulation by the French physicist Louis de Broglie, the electron orbits could be defined as those in which the wave-forms associated with the electrons could exist as standing waves (like the waves on the string). De Broglie knew that electrons behave like waves rather than particles under certain experimental conditions. For example, in passing through a slit or by a straight-edge, electrons form exactly the same diffraction patterns as water waves or visible light, but on a scale five orders of magnitude smaller than light. He calculated wave-length which pertains to the hydrogen electrons and used it to determine the lengths or circumferences of the particular orbits which they could occupy and create standing waves, and thus the energies which could be emitted in the transitions between them. These turn out to be exactly what are observed in the hydrogen spectrum.

What has this to do with the orbits of the planets? one might ask. Are we saying, or did Kepler say, that the planets were actually waves? No, but this example indicates the kinds of experimental evidence, known but ignored by the vast majority of scientists today, which demands the application of Kepler's method.

In the tradition of Plato and Cusa

In the *New Astronomy,* Kepler presents the results of his method, rather than its basis. However, the method which Kepler used to achieve these results remained consistent throughout his work, as proven by his later masterpiece, *Harmonice Mundi* (*Harmony of the World*). As Kepler specified in *Mysterium Cosmographicum,* and as he reaffirmed in his footnotes to that book, written 25 years later, after his triumphant proclamation of the three laws which bear his name, his method is that of Plato and the great Renaissance philosopher and scientist, Cardinal Nicolaus of Cusa. There he referred to Plato's formulation, which he took as the axiomatic basis of science, that "by a most perfect Creator it was absolutely necessary that a most beautiful work should be produced. 'For it neither is nor was right' (as Cicero . . . quotes from Plato's *Timaeus*) 'that he who is the best should make anything except the most beautiful.' " From Cusa, he noted in particular the absolute distinction and hierarchy existing between curved and straight lines: "For in this one respect Nicolaus of Cusa and others seem to me divine: that they attached so much importance to the relationship between a straight and a curved line, and dared to liken a curve to God, a straight line to his creatures." Here, Kepler referred, among other points, to Cusa's proof that no polygon can actually equal a circle, but that the circle was of a different order, and could *generate* those figures made with straight lines, but not the other way around (**Figure 3**).

It was from this methodological base that Kepler was able to conceive of the planetary system as one ordered whole, because nothing would be created were it not so ordered, and that he could be certain that the ordering had to come from the Sun, rather than the relatively tiny Earth. Thus, he was able to assert, before the empirical evidence provided by sun-

FIGURE 3

Quadrature of the circle

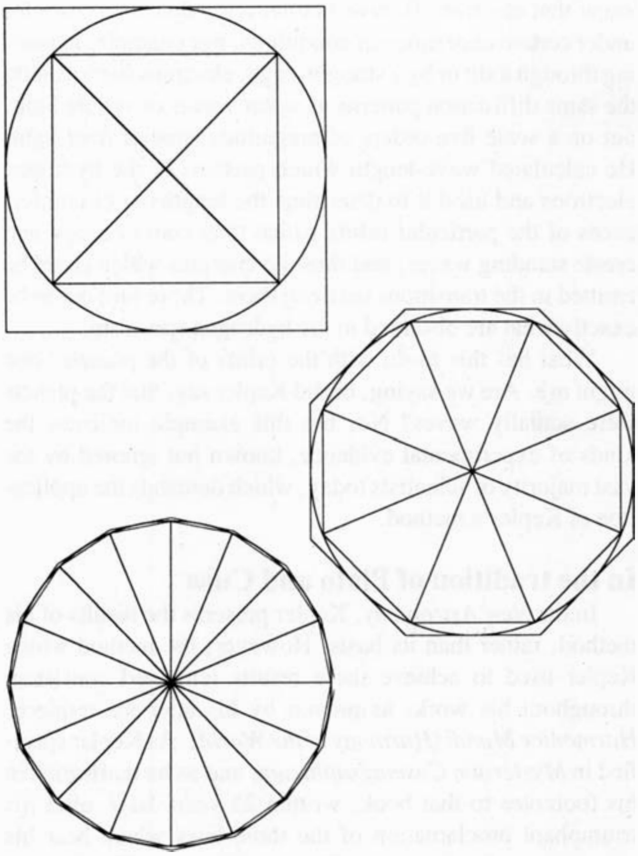
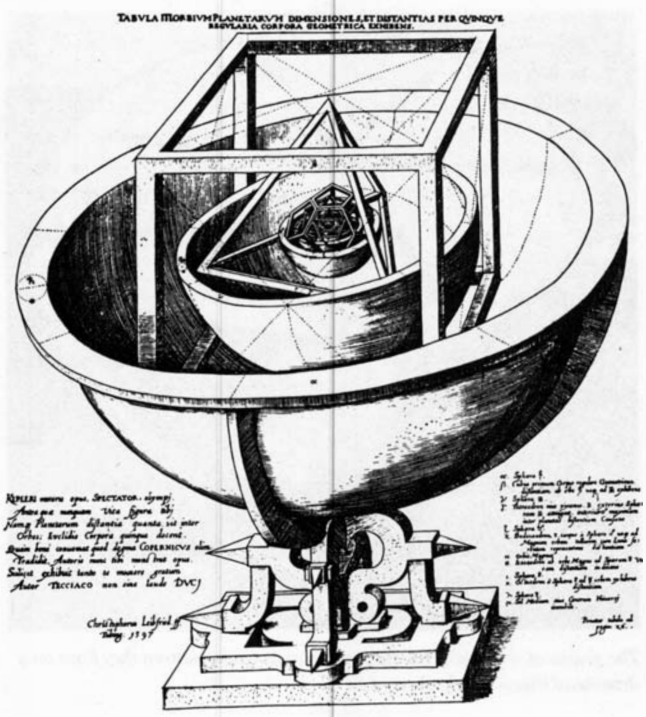


FIGURE 4

Kepler's model of the solar system



spots was discovered, that the Sun itself, as the center and defining singularity of this system, must rotate on its axis.

In *Mysterium Cosmographicum,* Kepler also attempts to explain the eccentricities of the planets, the fact that the planets did not appear to make perfect circles around the Sun. At the time, it was assumed that all motion of the planets was compounded from circular motion, and therefore the Copernican hypothesis was that the planets traced out circles (or actually sections of spheres, since each travels in a plane slightly tilted with respect to the orbits of the others) around different points, all close to the Sun but none exactly coinciding with it. Kepler could not accept such an idea, and instead depicted each planet as travelling in a course bounded by two circles of slightly different radii, but each centered on the Sun. This then represented the spherical shell, inside which a Platonic solid was constructed; within which, in turn, a sphere could be inscribed, representing the outer boundary of the shell within which the next planet moved (**Figure 4**). While Kepler did not specify the relation of this arrangement to Cusa's analysis of the relation between a circle and the squares inscribed and circumscribed with it, the relation is clear. As Cusa knew, the squares can be replaced with octagons, sixteen-sided figures and so on, without either the outer or inner figure ever coinciding with the perimeter of the circle. Thus, there is always a non-zero width between the linear figure and the curved one. LaRouche has pointed out that this width, even though it can be made smaller than any given value, must always contain the singularity which defines both the inner and outer polygons, and thus the transition between "inside-ness" and "outside-ness." In the same way, Kepler's formulation here gives the planets a place which is almost zero on the astronomical scale, but within which the matter of the planet exists, and which determines the transition between the inner Platonic solid, which is being bounded by this shell, and the next one out. One can consider the difference between the inscribed and circumscribed figures as follows: From the inside, the spherical shell is the locus of the points at which the faces and edges of the solid terminate, thus of singularities with respect to this figure; from the outside, the exterior surface of the shell touches the centers of the faces of the exterior solid, points which are *not* singular, determining the direction of these planes, but not their extent. Thus, the matter in this singular location defines the space surrounding it, and in a way which is different, although related, in the interior and exterior areas.

It should be noted that these shells are the loci for the processes which Dr. Dan Wells described in his 1988 paper on a model for the formation of the solar system (see *21st Century Science & Technology,* July-August 1988, "How the Solar System Was Formed"). In this model, certain rings are defined by the characteristics of a rotating plasma with a non-zero magnetic field, the matter of the field arranges itself in these ring areas in shapes like those of concentric smoke rings, and at a certain moment each ring snaps, and the matter in it condenses into a blob at the point on its circumference opposite where the break occurred (a phenomenon which Dr. Wells describes having observed in actual giant smoke rings). Wells describes the locations of the rings as determined by their existence as force-free structures (structures which tend to maintain their existence because they are configured so that the energy available to create instabilities is reduced to a minimum), but these rings exist only with certain specific radii. While Dr. Wells did not consider the spherical geometry of the Platonic solids, the Bessel functions which indicate these specific radii were developed in part as algebraic representations for the study of observed planetary motions, and have subsequently been used to represent, among other things, the harmonic vibrations on a circular membrane (drumhead).

The characteristic of the universe which Kepler was reflecting in assigning the number of the planets (as visible with the naked eye) and the relative sizes of their orbits to the Platonic solids, which are defined as those which can circumscribe and be circumscribed in spheres, was that which he elaborates in a short work called *The Six-Cornered Snowflake*. Here, he expresses in many different and playful ways the idea that space is essentially spherically ordered, or as LaRouche put it, infinitely dense with spherical bubbles.

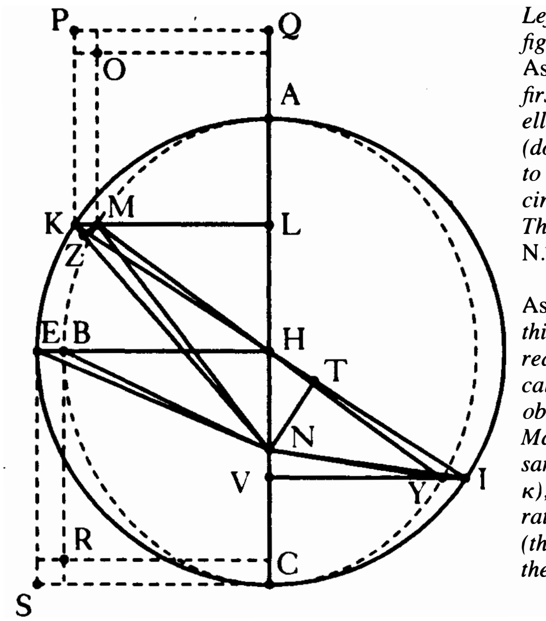
One further, crucial aspect of Kepler's determination of the ordering of the planetary system by the Platonic solids should be brought out. Since the work of Leonardo da Vinci and his teacher Pacioli, it had been known that in everyday life, those shapes which exhibited the types of symmetry related to the dodecahedron, and thus to the pentagon and the Golden Section were those characteristic of living things, while inorganic matter was commonly characterized by either tetrahedral or cubic symmetries. Kepler points to this distinction in *The Six-Cornered Snowflake,* where he contrasts the symmetry of the snowflake with that of common five-petalled flowers. He also points out there that the characteristics of spheres considered from the outside, i.e., of balls forced together, will be a four- or six-sided symmetry. Thus, when Kepler had defined the solar system as ordered by the Platonic solids, which include and, hence, are defined by the dodecahedral, Golden Section relation, he placed it in the same domain as that of living things, rather than of the inorganic domain here on Earth. Thus, it and other astronomical entities such as galaxies must be considered as having the same fundamental characteristics as living organisms, that is as negentropic, or self-ordering. Kepler would surely have been delighted with the compelling evidence which we can now assemble to show that the domain of the very small, that is, atomic structure, is also ordered in the same way. The late Dr. Robert Moon, a pioneer researcher on the Manhattan Project, developed a model for the arrangement of protons in the atomic nuclei based on the Platonic solids, which accounts for some of the most puzzling periodic variations in such characteristics of the elements as abundance, atomic density, and melting point (see Laurence Hecht, "*Mysterium Microcosmicum:* The Geometric Basis for the Periodicity of the Elements," *21st Century Science & Technology,* May-June 1988).

Elliptical orbits and musical harmonies

So far, we have been discussing the quantization of the solar system as if the planets moved in circles. While this is appropriate to the underlying rotational characteristic of the system, as Kepler re-emphasizes in his late work *The Epitome of Copernican Astronomy,* it is not accurate. One of the great achievements of *New Astronomy* was to eliminate the twin irrationalities of circles centered on different, undifferentiated points in space and the variable speeds of motion along these circles, which were described in terms of yet other undifferentiated points, from which the observed motions would appear to be uniform in speed. In *New Astronomy,* Kepler explored the actual data, which he had available thanks to the extraordinary work of Tycho Brahe, and applied to it his own rigorous understanding that all the linear observations of astronomy were projections of the actual circle-like motions which were occurring. He used this to develop new and startling methods, for example, using the revolutions of Mars to determine the Earth's orbit with extraordinary precision. In this work, he came to know that the orbits could not be true circles, but instead ellipses, and that the variation in speeds of each planet was exactly determined by its varying distance from the Sun along its elliptical path, so that it sweeps out equal areas in equal times.

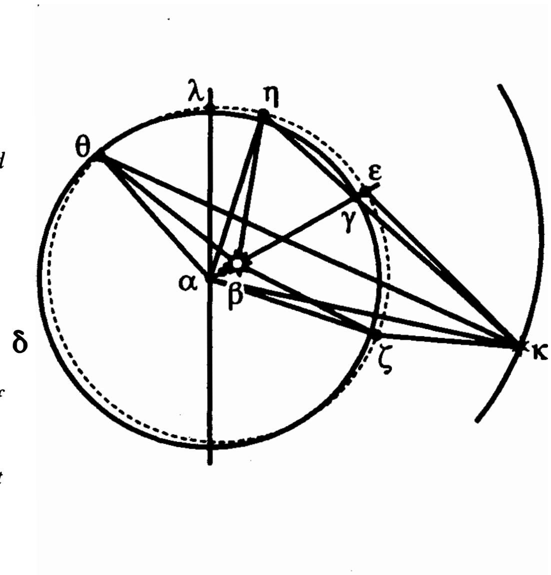
After the completion of this book and the announcement of these two conclusions, Kepler was faced with a problem: He had sucessfully understood the varying spaces between the orbits by the specific divisions of the interiors of spherical surfaces, which define the Platonic solids. He knew that the Creator does not make mistakes, and that, hence, the orbits were not just badly made circles, but precise ellipses; therefore, he was faced with the question of how this was *better,* what beauty was added to the system by this greater complexity.

Here, Kepler found the application of his long-held idea that musical harmonies are key to understanding the solar system. Although he had not been successful in earlier attempts to find such a relationship, he had devoted considerable attention to laying out a rigorous geometrical basis for the musical scale, based on the ratios which exist between the lengths of strings which sound in musical intervals. These ratios he analyzed as those of the arcs cut on a circle by inscribed polygons, if the inscribed polygon could be *constructed* from circle and straight-edge, if the relationship of its side to the diameter of the circle could also be constructed,* and if the remainder of the circle had a relation to the first part cut and to the whole, which could be described by one of the previous criteria. Using these rules, he had come



Left: This groundbreaking figure from the New Astronomy *shows Kepler's first representation of the elliptical orbit of a planet (dotted curve), as compared to the circle which circumscribes the ellipse. The Sun is located at point* N.

Right: In the New Astronomy, *Kepler used this diagram to help the reader understand his calculation, from a series of observations taken when Mars was always at the same point in its orbit (point κ), of the actual path and rate of movement of Earth (the dotted curve) around the Sun (point β).*



to grips with the geometric lawfulness of the harmonic relationships which give such great pleasure to the perceiving mind (**Figure 5**). He stresses that the harmonies so constructed do not include all the intervals of the scale, but rather are the consonant (pleasant-sounding) intervals, such as the fifth and the major and minor thirds, and that the smaller intervals are derived from these larger and more beautiful ones.

Now, Kepler applied his developed understanding of musical harmonies to the varied relations which exist in the elliptical orbits, both within a single ellipse, and between them, taken pairwise and as a system. Here, just as he knew the Sun is the defining singularity of the planetary system in terms of the circular spacing of the orbits, he also placed it as the center from which the harmonies would be perceived, since he understood harmonies as relations which exist in the perceiving soul. He discovered an extraordinary system of harmonic relations in the relationships of perceived motions of the planets at their closest and farthest points from the Sun (perihelion and aphelion, respectively). The difference between the motion of any particular planet at these two extreme points of the ellipse defines the deviation of the ellipse from a circle. Kepler measured the motion as angular motion as seen from the Sun, and therefore doubly affected by distance, both because the planet moves more slowly when it is farther from the Sun, and because the same distance covers a smaller angle when seen from farther away. He found that for each of the planets he knew, there was a ratio of a musical interval between these two angular distances. He also found that there were musical ratios between each pair of planets, when he compared the aphelial movement of one to the perihelial movement of its neighbor and vice versa.

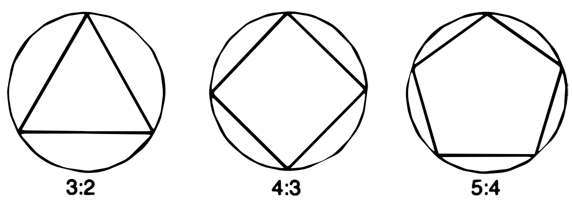
Beyond this, Kepler found that the entire system exhibited the harmonic relations of the major and minor scales as he had developed these. Lyndon LaRouche has described Kepler's genius in this respect as lying in Kepler's application of music to physics. That is, Kepler applied a system (musical harmonies) which we human beings know *from experience* is internally self-ordered, to be able to understand the lawfulness of the physical systems which we only know *must* be created as internally self-ordered. Music is such a system of experienced lawfulness because it is based on the living physiology of the human voice, first in the speaking (recitation) of poetry, where particularly the vowels define certain harmonic relations, and then by the setting of this poetry as music, using our living bone and tissue as the sounding instrument. The human singing voice in turn embodies certain discontinuities or singularities, of which the best-known are the vocal registers (see *A Manual on the Rudiments of Tuning and Registration,* Vol. I, Washington, D.C.: Schiller Institute, 1992). When pitch is returned to the scientific value of C=256 Hertz (equivalent to A=430), the 12 tones within the well-tempered system are actually defined by the upper and lower boundaries of the register shifts of the different voice types, assuming only that each interval of action (across a register shift) has to have its own boundaries, instead of the upper bound of one being the lower bound of the other (**Figure 6**). There are also indications that at this tuning each note in the 12-tone system represents a specific least-action point, where the voice is significantly more comfortable than at the pitches in between.

In fact, music is not actually constructed of notes, but of intervals, as can be heard in any great performance of Classical music. In this way also, music is uniquely suited for analysis of the quantum field, since the discrete objects (notes), while necessarily and uniquely determined, are generated by the process under way, expressed most simply as the generation of particular intervals, and on a higher level

FIGURE 5
Kepler's derivation of musical intervals

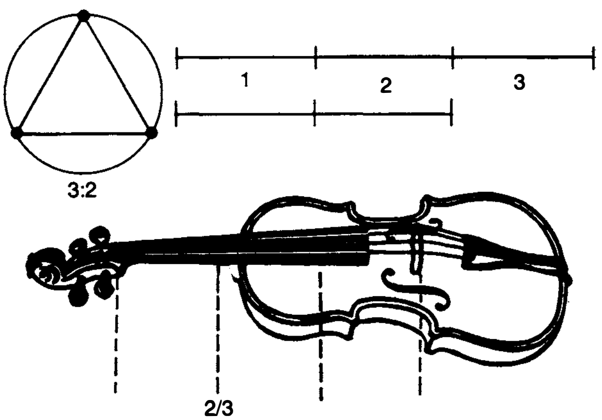
Kepler showed that the geometry of the regular polygons produced the musical relationships of the diatonic scale. The divisions of the circle defined by inscribing an equilateral triangle, a square, and a pentagon, for example, provide the frequency ratios of three consonant intervals (a). For example, the equilateral triangle yields the fifth (3:2); the square yields the fourth (4:3); and the pentagon yields the major third (5:4).

(a) Inscribing the constructable polygons



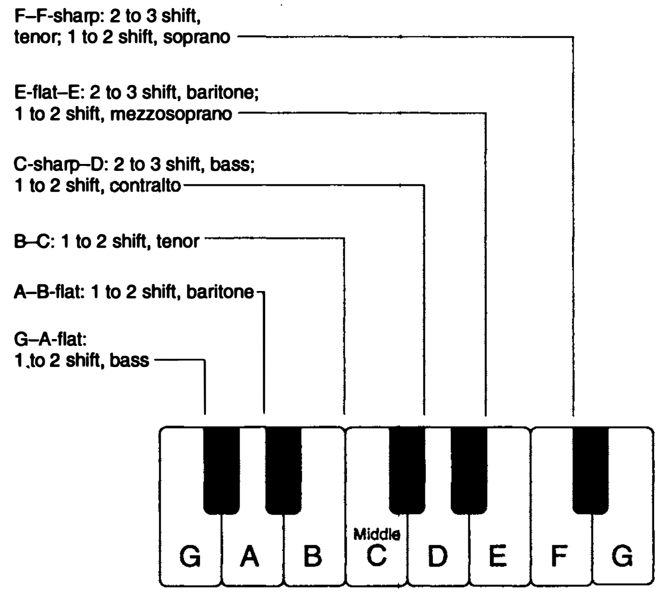
If the circumference of the circumscribing circle is taken as a musical string (b), then the triangle would divide that string into three equal parts. Plucking the string at the two-thirds point produces the musical interval of the fifth (hence the ratio 3:2).

(b) Plucking a musical string



by the process of composition. Kepler, although not a composer, understood the unique way in which musical composition represents the continuing physical process of the solar system. After a detailed analysis of the particular harmonic relationships represented by the extreme points on the planetary orbit, he finally settled on a representation of the system by the art of musical counterpoint, which had only been developed a few hundred years before he was writing. In this concept, each planet is continually moving in and out of consonant relations with the others, while the overall harmony of the system shifts back and forth between major and minor modes depending on the relation of the Earth and Venus (both of which move in almost circular orbits, so that the interval between them varies only between a major and a minor sixth).

FIGURE 6
The vocal register shifts and the 12-tone well–tempered scale



Kepler wrote in *Harmonice Mundi:* "Accordingly, the movements of the heavens are nothing except a certain everlasting polyphony (intelligible, not audible) with dissonant tunings, like certain syncopations or cadences (wherewith men imitate these natural dissonances), which tend towards fixed and prescribed clauses—the single clauses having six terms (like voices)—and which marks out and distinguishes the immensity of time with those notes. Hence, it is no longer a surprise that man, the ape of his Creator, should finally have discovered the art of singing polyphonically, which was unknown to the ancients, namely in order that he might play the everlastingness of all created time in some short part of an hour by means of an artistic concord of many voices and that he might to some extent taste the satisfaction of God the Workman with His own works, in that very sweet sense of delight elicited from this music which imitates God." Thus, as LaRouche has pointed out, the language of music is the answer to the (later) demand of physicist Bernhard Riemann for a metric for the continuous domain of space and time, which, he says, "we must seek . . . outside it."

Copies of Kepler's New Astronomy *can be ordered through Ben Franklin Booksellers. Call for prices and shipping costs: (703) 777-3661 or (800) 453-4108.*

**There is one more criterion, which is that the ratio of the part cut by a star figure to the whole will be harmonic if the number of segments included is the number of sides of a constructable, knowable figure. For example, if you divide a circle with 12 vertices but then connect every fifth one, you will produce a star figure, and Kepler says that the section of the circle cut off by one line of this figure, in other words 5/12 of the total, will have a harmonic relationship to the whole, because 5 is the number of vertices of the pentagon, which is a constructable, knowable figure.*