Kepler's Mysterium Cosmographicum: A Bridge Between Art and Astronomy?

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Abstract

Johannes Kepler published his geometrical model of the solar system in his book "Mysterium Cosmographicum" in 1596. It is suggested here that the inspiration for Kepler's model was deeply rooted in the art and craft of his time.

What Was the Origin of Kepler's Celestial Model?

Johannes Kepler published his first book, the Mysterium Cosmographicum in 1596 at age 26 while he was employed as a mathematics schoolteacher in the German provincial city of Graz. In a sense, the entire rest of his astronomical career was an elaboration of the questions he sought to address in this work: Why were there six (then known) solar system planets? Why are they spaced around the Sun as they are? Why do they move as they do? He answered these questions by apparently creating out of thin air an elaborate model for the layout of the solar system based on spheres inscribed and circumscribed around five nested Platonic solids. In many ways, this book represented a turning point for the way astronomy would be done in the future, for it sought to provide *reasons* behind what had heretofore been mainly a descriptive science. As the Kepler scholar Owen Gingerich has remarked [1] in his account of Kepler's life and work, "Seldom in history has so wrong a book been so seminal in directing the future course of science."

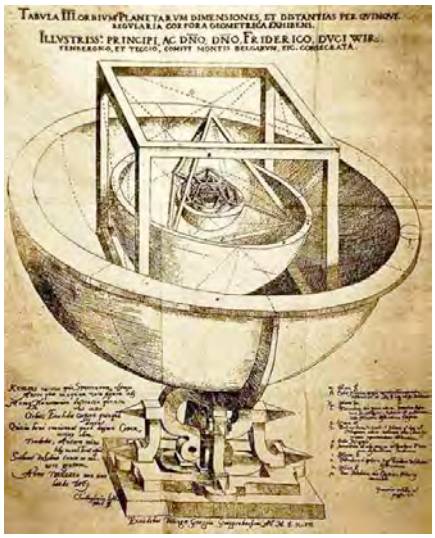


Figure 1 a, b, c: *On the left is the frontispiece for the Mysterium Cosmographicum. On the right is figure 3 from the book showing Kepler's model of the solar system. A portrait of Johannes Kepler is at Center.*

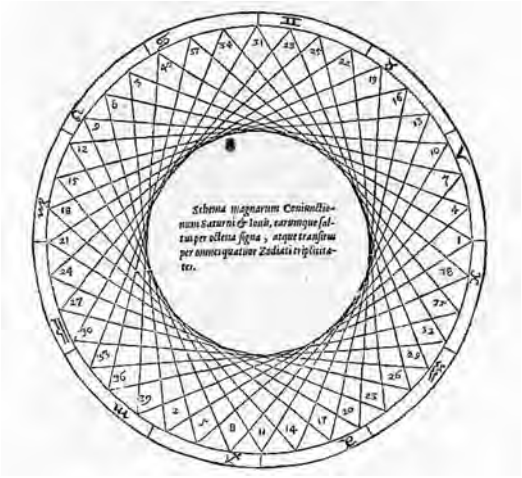
Question: What actually was the origin of Kepler's Celestial Model? That is, what led him to propose a three dimensional model based on nested Platonic solids to explain the mainly two-dimensional planetary orbital motions? More specifically, what was the inspiration for the model? Was it astronomical observations (by Tycho or Copernicus)? Or was it physical reasoning (by Kepler as the first physicist)? Or perhaps mathematical analogies (geometry, symmetry)? Or did it spring from another intellectual domain?

Origin of the Model As Reported by Kepler

"Thus it happened 19 July 1595, as I was showing in my class how the great conjunctions (of Saturn and Jupiter) occur successively eight zodiacal signs later, and how they gradually pass from one trine {an angle of 120 degrees - KB} to the another, that I inscribed within a circle many triangles, or quasi triangles, such that the end of one was the beginning of the next. In this manner a smaller circle was outlined by the points where the lines of the triangles crossed each other… And then again it struck me: why have plane figures among three-dimensional orbits? Behold, reader, the invention and whole substance of this little book! In memory of the event, I am writing for you the sentence in the words of that moment of conception: The earth's orbit is the measure of all things; circumscribed around it is a dodecahedron, and the circle containing this will be Mars; circumscribed around Mars a tetrahedron, and the circle containing this will be Jupiter;… {and so on - KB}. You now have the reason for the number of planets."

Response of Kepler Scholars

In the succeeding 400 years of Kepler scholarship, most Kepler scholars, including Owen Gingerich [1] and Max Caspar [2] - author of the definitive Kepler biography - seem to have taken Kepler at his word. J.V. Field in Kepler's Geometrical Cosmology [3] wrote: "We surely must accept Kepler's account…Whether Kepler had somewhere read something which somehow suggested the theory to him without his being aware of the source is a speculation the present writer is content to leave to others. It seems rather perverse to doubt Kepler's straightforward account of how he came to his theory." Is Kepler's account really how he went from



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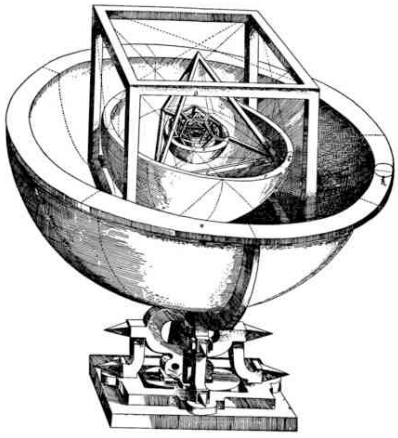

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Figure 2 a, b: *On the left is the diagram from the Mysterium Cosmographicum showing the two dimensional overlapping triangles discussed by Kepler. On the right is his three dimensional model.*

An Alternative Hypothesis

It is suggested here that Kepler's model using five nested Platonic solids was a direct outgrowth of 16th century studies of perspective and of the art and craft of that time. Specifically, it seems possible – even likely - that Kepler was inspired (either consciously or unconsciously) by then well-known paintings, engravings, books and - perhaps most directly - magnificent and memorable three-dimensional sculptures of nested regular polyhedra made on "ornamental turning" engines. These elaborate wood and ivory sculptures could be found in "Wunderkammers", the forerunners of today's art and science museums. Frederick I, Duke of Württemberg and Rudolf II - Kepler's first and second patrons - had such collections.

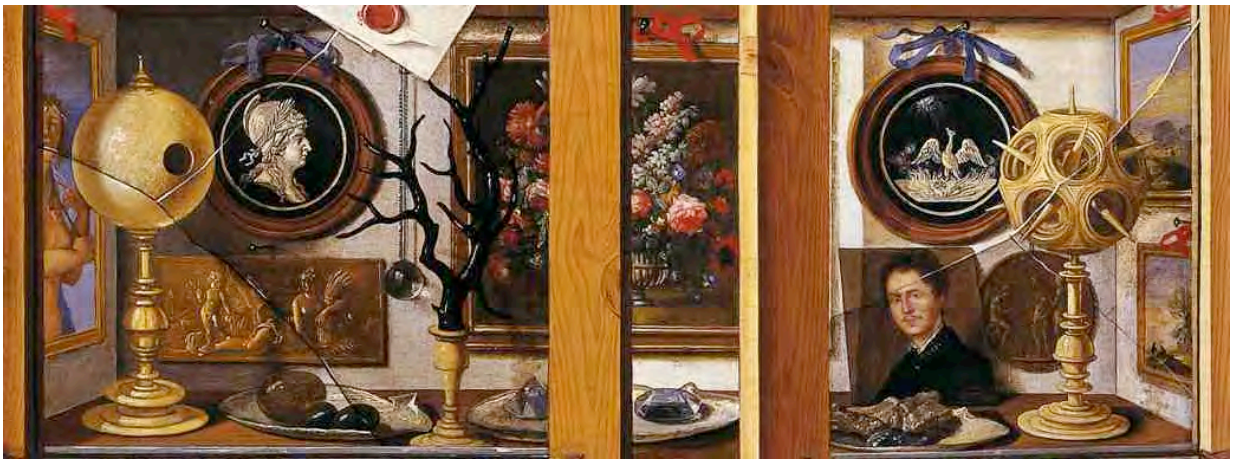

Figure 3: *Detail from the painting "Cabinet of Curiosities" by Domenico Remps, in the Opificio delle Pietre Dure, Florence. Though painted in the 1690's, it illustrates the style of renaissance Kunstkammers.*

Art, Perspective, Geometry and Platonic Solids Throughout the 15th Century

What follows is a very brief review of some of the artistic and mathematical currents that flourished beginning in the early 15th century in Italy. (For a detailed discussion, see Kemp's masterful study [4].) These developments partially sprang from attempts to develop a rigorous theory of perspective, but also from the re-introduction in Europe of the Greek knowledge of geometry and polyhedra. These techniques and ideas evolved primarily in Florence, Italy beginning with the famous perspective experiment by Filippo Brunelleschi in 1425. They were further developed by Leon Battista Alberti, Luca Pacioli, Piero della Francesca and Leonardo Da Vinci. How did their original ideas of perspective and three-dimensional geometry get from Italy to Germany in the early 16th century? Partly as a result of Durer's two visits to Italy to learn about perspective, and through his subsequent text Four Books on Measurement (published in Nuremberg in 1525). The book presented a discussion of how to render pictures with correct perspective. It contained several images of perspective renderings using mechanical and optical devices (see Figure 4). The fourth book explored regular polyhedra, including the Platonic solids. It has been reported that Kepler owned a copy of this book. In any case, at some point he had definitely seen a copy since he wrote about errors contained within it.

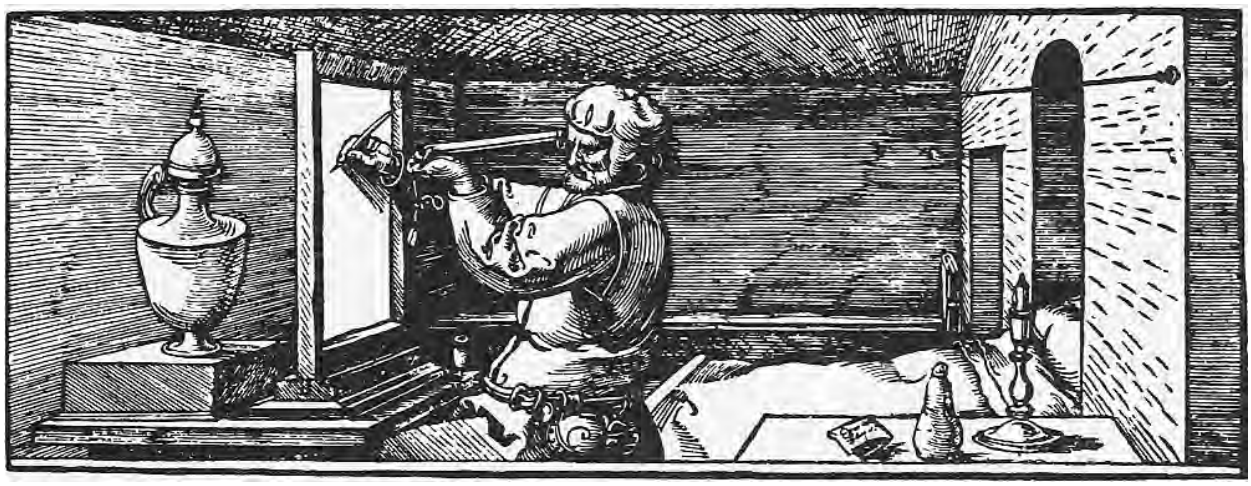

Figure 4: *Woodcut by Albrecht Durer from his book on perspective Underweysung der Messung published in Nuremberg in 1525. The size of the image in the book is almost exactly as presented here.*

Ideas of Perspective and Polyhedra Spread Throughout All of Europe, Including Germany

How far did these ideas penetrate German intellectual culture in the following years? The answer is quite deeply. These ideas - developed in the realm of painting - were used by artisans working in wood, gold, silver, as well as in ivory and other media. They were then presented in books – partly as working manuals for artisans. Several examples of pages from these are shown below.

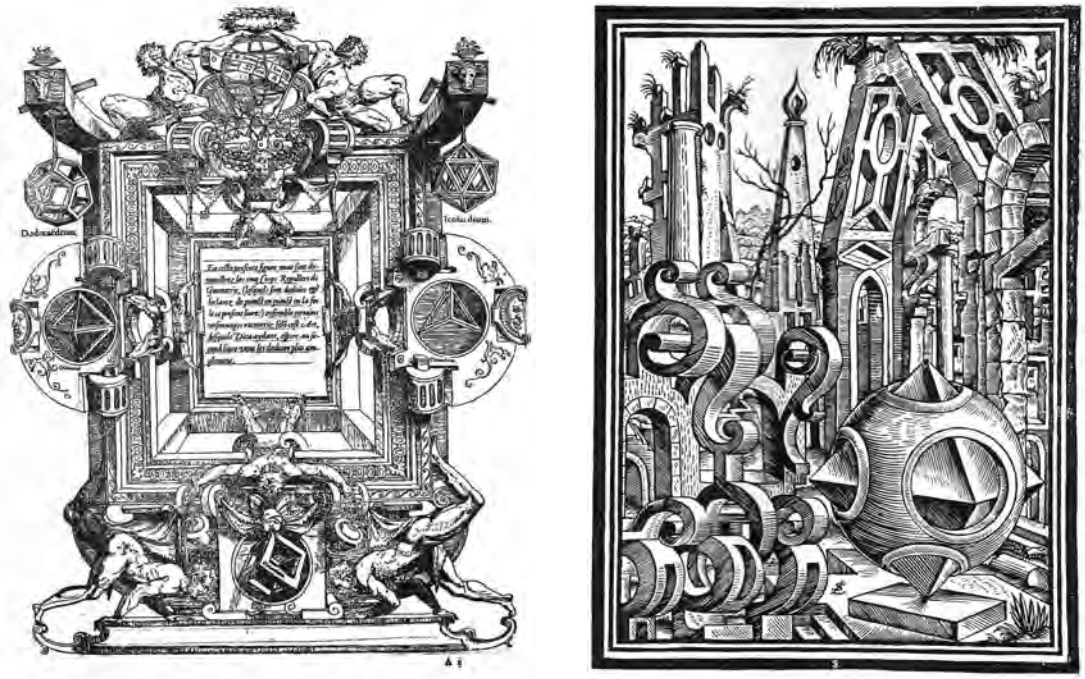

Figure 5 a, b: *On the left is the cover of the book Livre de Perspective by Jehan Cousin (1560). On the right is a page from the book Geometria et Perspectiva by Lorenz Stoer (1567).*

The cover of the Cousin book (Figure 5a) illustrates ideas of perspective and displays the five Platonic solids. Lorenz Stoer (Figure 5b) explicitly incorporated nested solids. Many such books were published during the 16th century and were included in the libraries of the nobility throughout Germany. Notice the similarity in the style of the artwork in several of these images with that displayed in Figure 3 of the Mysterium Cosmographicum. Though this may only show that the engraver was familiar with these images, it seems plausible that Kepler was as well.

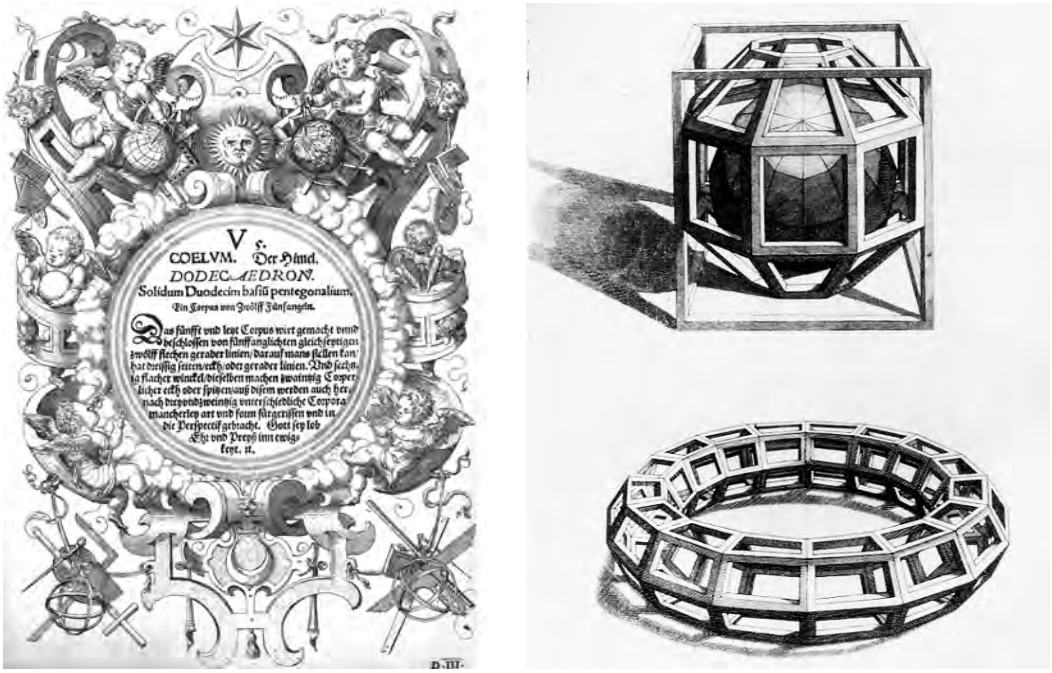

Figure 6 a, b: *On the left is a page from the book Perspectiva Corporum Regularum by Wenzel Jamnitzer (1568). On the right is a page from the book La Practica di Prospettiva by Lorenzo Sirigatti (1596).*

Figure 7 a, b, c: *Images of two European wood wall panel intarsia and of a wood inlaid writing desk.*

Kepler's Model and Ornamental Turnings

Various kinds of lathes have been used to make artistic and utilitarian objects out of wood, ivory and other materials for at least 2300 years. The first depiction of a lathe in an image is from the Egyptians. Beginning around 1500 AD in Europe, "ornamental turning engines" were devised to produce astonishingly elaborate objects. An example of such a turning engine from this period is shown below [5] along with ornamental turnings made in Germany between 1560 and 1590 AD.

Figure 8 a, b, c: *On the left is an engraving of an ornamental turning engine from about 1600 AD. In the middle and at right are examples of ivory ornamental turnings produced between about 1560 and 1590 of the kind that are in the Grünes Gewölbe (Green Vault) museum in Dresden, Germany.*

The origin of nested ivory ornamental turning in Europe is not settled: Did the idea start in China and migrate to Europe? Or did it originate independently in each society?

Figure 9 a, b, c: *On the left is an ivory turning made in Dresden by Egidius Lobenigk in 1591. In the middle is a modern Chinese "Puzzle Ball". At right is a modern wood turning made by Claude Lethiecq.*

The first record [6] of a Chinese "puzzle ball" or "mystery ball" or "dragon ball" – as the modern versions are called – dates to the year 1388 AD. In section XXXVII of the book Ko Ku Yao Lun, the author Ts'ao Chao wrote "I have seen a hollow-centered ivory ball, which has two concentric balls inside it, which can both revolve. It is called "witch ball". I was told that it was made for the Palaces of the Sung dynasty." The ivory ornamental turnings that were made in Europe were also made by and for the nobility and exchanged between themselves as gifts. However, the first record of such an object in Germany dates from around 1560. Did the Duke of Württemberg - Kepler's patron in his youth and correspondent in 1596 - show him such objects? Kepler's second employer, Rudolf II - Emperor of the Holy Roman Empire - was an enthusiastic turner. Kepler visited his Wunderkammer in 1601 and wrote about it. Did the Duke's collection of such objects encourage Kepler to hold on to his model, even after he found his three laws? Kepler never lost enthusiasm for the model, leading to the re-publication of the Mysterium in 1521.

Further Remarks About Kepler's Model and Ornamental Turnings

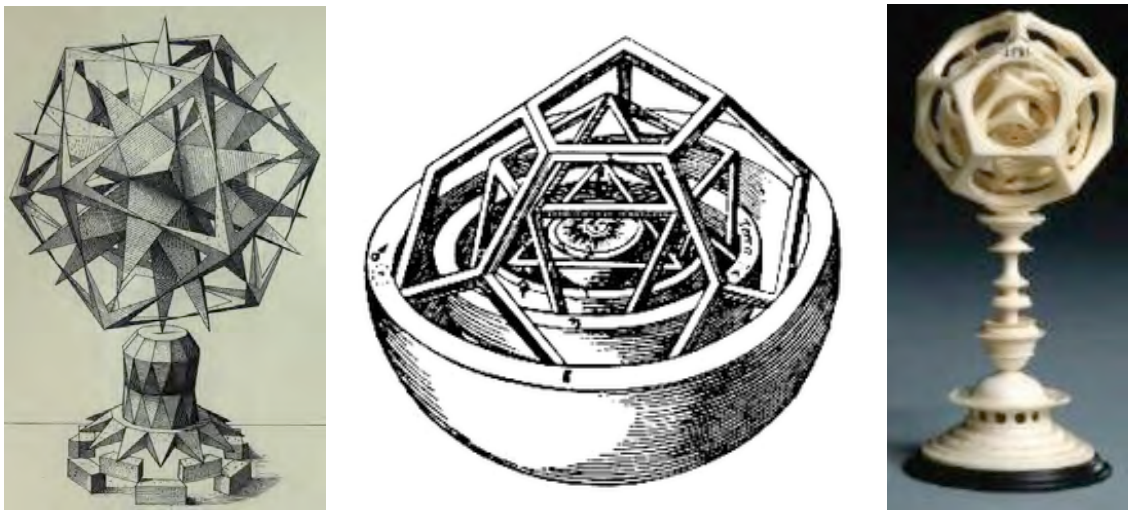

Figure 10, a b, c: *On the left is a figure from Jamitzer's Perspectiva; in the middle, the inner part of Kepler's model; on the right, an ivory ornamental turning from Dresden made ca. 1590.*

Images created by Jamnitzer, Stoer and others were used by cabinetmakers, intarsia artisans and designers of three-dimensional ornamental turnings (cf. Figures 10 a, b, c). The Duke of Württemberg - Kepler's first patron - had such objects and design books in his home. Kepler - and likely his professor from the 1590's, Michael Maestlin - could have been aware of these creations - either having seen them directly or having heard or read of them. Before the Mysterium was published, Kepler even asked the Duke to have his model made as a punch bowl!

Conclusion

Two-dimensional engravings and three-dimensional models of inscribed regular polyhedra were well known in Germany in the late 16th century. Kepler had the opportunity to have seen, read or learned of them from books and models. The style of the Mysterium Plate III engraving is in the style of many of these polyhedral engravings. It seems highly likely that Kepler's model of the solar system had direct antecedents in the arts, crafts, engravings and sculptures of his day.

Afterword

Kepler's nested polyhedral model of the cosmos presented in the Mysterium Cosmographicum in 1596 may well have been inspired by 16th century ornamental turnings, either directly or indirectly. If this is the case, then the 16th century ornamental turning engine could also reasonably be called the "*Lathe of Heaven*".

Acknowledgements

There are perhaps a few dozen ornamental wood turners who are currently making magnificent polyhedral sculptures – many based on the Platonic solids and other geometrical forms. I would like to thank three of them for sharing their insights and wonderful creations with me: Randy Rhine, Bob Rollings and Claude Lethiecq.

Randy Rhine

Claude Lethiecq

Bob Rollings

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References

[1] O. Gingerich, "Johannes Kepler", *Dictionary of Scientific Biography*, (New York, Scribner, 1979).
[2] M. Caspar, *Kepler,* (New York, Dover Publications, 1993).
[3] J. V. Field, *Kepler's Geometrical Cosmology*, (Chicago, The University of Chicago Press, 1988).
[4] M. Kemp, *The Science of Art*, (New Haven, Yale University Press, 1990).
[5] K. Maurice, *Sovereigns as Turners*, (Zurich, Verlag Ineichen, 1985).
[6] P. David (translator), *Chinese Connoisseurship: The Ko Ku Yao Lun*, (New York, Praeger, 1971).

Postscript

Kepler's nested polyhedral model of the cosmos tried to account for the relative spacing of the planetary orbits in our Solar System. This was an early attempt at a Titius-Bode "Law" of planetary distances. It would be fitting if Kepler (the NASA planet hunting satellite named for the great astronomer) leads to the discovery of more extra-solar planetary systems that show simple mathematical regularities in the spacing of planets around their central stars, perhaps some day leading to a definitive "Fourth" (or "Zeroth") Kepler Law. It would provide a wonderful example of a bridge between renaissance art, mathematics and modern science.