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Order and Harmony: Kepler's Guiding Forces

As the subject librarian for physics and astronomy at Brigham Young University, the author has had the privilege of handling some of Johannes Kepler's original books preserved in the university's archives. One of the most impressive materials in the archive is a large page from *Mysterium Cosmographicum* that unfolds to reveal a print of the Platonic solids, as shown in Figures 1 and 2.

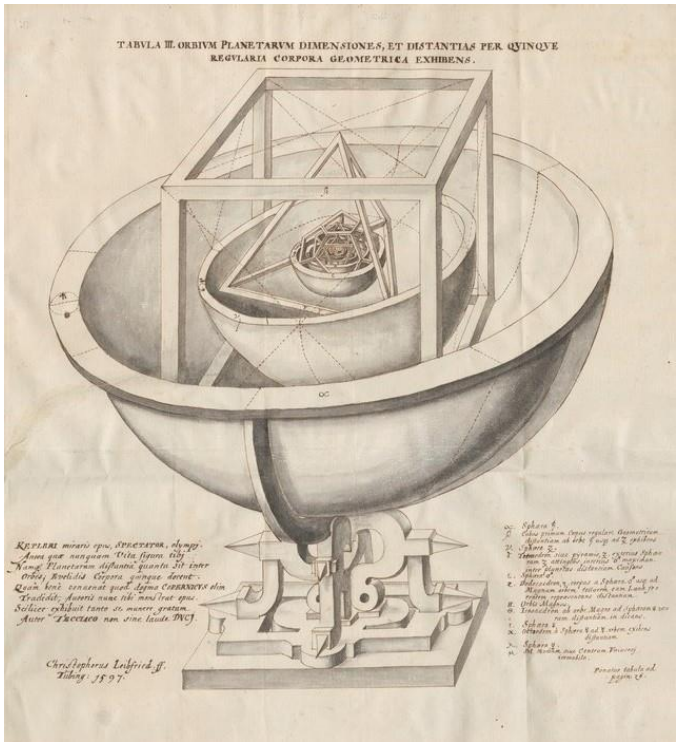

Figure 1. Image from Mysterium Cosmographicum, by Johannes Kepler. Courtesy, Perry Special Collections, Harold B. Lee Library, Brigham Young University, Provo, Utah.

Figure 2. Graduate student holding Mysterium Cosmographicum, to provide size reference.

Kepler used the Platonic solids in his attempt to explain the orbits of the six then-known planets. While unsuccessful, the effort shows how the concepts of order and harmony shaped how Kepler saw the universe and influenced how he developed explanations for his observations.

Order describes a convenient or purposefully organized arrangement. Harmony describes the consistency, congruity, or pleasing nature of that arrangement.

As Kepler observed the order and harmony of the planets' orbits, he connected that pattern with another orderly and harmonious pattern found in arranging the Platonic solids in just the right way. This correlation filled Kepler with delight, as he explained:

> It will never be possible to describe with words the enjoyment which I have drawn from my discovery. Now I no longer bemoaned the lost time; I no longer became weary at work; I shunned no calculation no matter how difficult. (Caspar, 1959, p. 63)

For Kepler, order and harmony were not just patterns to be seen and appreciated. They were the guiding forces that gave life and direction to his efforts to discover through observation and then craft an explanation. A compelling symmetry provided guidance: If what was observed had order and harmony built into it, then the explanation for what was observed would be made, naturally, from the building blocks of order and harmony.

Kepler described the invitation he felt from order to understand why it was there:

> Whenever I consider in my thoughts the beautiful order, how one thing issues out of and is derived from another, then it is as though I had read a divine text, written into the world itself . . . saying: Man, stretch thy reason hither, so that thou mayest comprehend these things. (Caspar, 1959, p. 152)

Osterhage (2020) added, "the one theme that drove [Kepler's] endeavors from his youth to his very end was the quest for order—or rather, the quest to discover the one singular order underlying all things" (p. 4). The process of figuring out this order thrilled Kepler. In his words, "the ways by which men arrive at knowledge of the celestial things are hardly less wonderful than the nature of these things themselves" ("Johannes Kepler: His life, his laws and times," 2017).

Kepler was not alone in using order and harmony. They are embedded in Copernicus's heliocentric theory. In Copernicus's own words, "in this ordering we find that the world has a wonderful commensurability and that there is a sure bond of harmony for the movement and magnitude of the orbital circles such as cannot be found in any other way" (Copernicus, 1543/1995, p. 26). Kepler based much of his work on Copernicus's theory, which ultimately led to his three laws of planetary motion.

According to Sambursky (1971), “in all his works and in his letters to friends, Kepler repeatedly expresses his belief in a universal harmony that subsists in the structure and occurrences of the physical world” (p. 95). Kepler believed that this universal harmony was a connection within each of us. In his words, “the souls of human beings were formed in such a way that man expects harmonies as well as observes and grasps them” (Kepler, 1858, p. 228).

This fundamental axiom guided his work: Nothing was created by God without a plan. In his efforts to discover that plan, Kepler differed notably from other scientists of his era. He brought everything he had to bear on the problem—not only his mathematical abilities but also his imagination and beliefs. Indeed, one of Kepler’s outstanding attributes was “his ability for lateral thinking . . . the ability to approach a given problem in multiple fashions, i.e., by using methods of analysis and synthesis of a number of different scientific disciplines, and by synthesizing these fragmented results into a coherent overall model” (Osterhage, 2020, p. 109). These abilities found productive expression through Kepler’s utilization of order and harmony.

It is important to note that order does not mean lack of change. In Kepler’s era, a supernova introduced what was thought to be a new star to the constellation of Cassiopeia. A comet also emerged and moved across the European sky. These events created difficulties for those who clung to Aristotle’s explanations that required the heavens to be perfect and unchanging. Being locked into one set of explanations prevented them from making progress as new observations were made.

In contrast, Kepler was willing to experiment with various explanations for what he observed. The difficulty was that those explanations were “so far outside the bounds of previous thought that there was no evidence in existence for him to work with. He had to use analogies” (Epstein, 2019, p. 100). To explain why planets that are farther away from the sun move slower

than those that are closer, he considered parallels with other natural orders. Smells and heat dissipate with distance. Light diminishes with distance as well. Could planetary motion be linked to the sun's light or heat? Magnetism also provided interesting possibilities; maybe the planets were like magnets. To explain why the planets all move in the same direction, Kepler drew from the effect a whirlpool's swirling waters have on floating objects (Epstein, 2019). Wherever a similar pattern or order existed, Kepler was willing to consider it.

That is not to say Kepler's efforts went smoothly. He struggled to explain the orbit of Mars, with its strange retrograde motion, for five years before he finally aligned the data from Tycho Brahe's diligent observations with an explanatory theory. No wonder Kepler referred to this work as his "war" against Mars ("Kepler's Discovery," 2021). In the end, it was extremely disappointing to him to have to abandon the perfect order and harmony of circular orbits and replace them with ellipses. "Having cleared the stable of astronomy of circles and spirals, he was left, he said, with 'only a single cartful of dung,' a stretched-out circle something like an oval" ("Cosmos - Carl Sagan," 2016).

Interestingly, that disappointment eventually gave way to a recognition of a different kind of harmony embedded in the discovery.

> The Earth was a planet, as Copernicus had said, and it was entirely obvious to Kepler that the Earth, wracked by wars, pestilence, famine and unhappiness, fell short of perfection. Kepler was one of the first people since antiquity to propose that the planets were material objects made of imperfect stuff like the Earth. And if planets were "imperfect," why not their orbits as well? ("Cosmos - Carl Sagan," 2016)

The order and harmony found in religious faith—or at least the potential for it—permeated Kepler's life and influenced his scientific approach. In his words, "there is nothing

which I desired more to investigate thoroughly and to know than this: can I also find God within myself, God, whom I readily grasp when contemplating the universe?" (Caspar, 1959, p. 221).

This faith-based approach inoculated Kepler, to a degree, from the plagues of egocentric battles and offenses that have afflicted so many great minds through the ages. In response to an allegation that Galileo had used Kepler's ideas as though his own, Kepler responded, "that makes no difference to one who has set truth and the honor of God as the highest goal, not his own fame" (Caspar, 1959, p. 372). This humility is further manifested in Kepler's statement, "I much prefer the sharpest criticism of a single intelligent man to the thoughtless approval of the masses" ("Johannes Kepler: His life, his laws and times," 2017).

In his personal life, order and harmony were often denied Kepler. The state of the world into which he was born has been described as "a time fraught with disaster, a time in which one would gladly flee to the stars in order to find home and security there" (Caspar, 1959, p. 27). His home life as a child was very turbulent. According to Love (2015), Kepler's "lifelong search for harmony in the Universe was arguably, at least in part, a reaction against the total lack of harmony in his childhood years" (p. 36). His first wife died young, and eight of his 12 children died before adulthood (Love, 2015). Because of disagreements he had with teachings from the Lutheran church, Kepler was not permitted to take communion—a serious affront to him. He also endured years of distress while his mother was tried as a witch, with the possible outcome of her being burned at the stake. (Thanks to Kepler's efforts she was finally released, but she died half a year later.) Further, some of his publications were placed on the index of prohibited books.

As a remedy to his life's many difficulties, Kepler did indeed flee to the stars for security, and he enjoyed solving riddles—injecting harmony and order on his own terms. Additionally, he often wrote poetry, including this epitaph that he penned for himself (Koestler, 1959, p. 427):

I measured the skies, now the shadows I measure.

Skybound was the mind, earthbound the body rests.

Through his determination, natural brilliance, and reliance on order and harmony, Kepler made momentous discoveries. His three laws of planetary motion, still fully in use today, describe and predict exactly how planets move, not only in our solar system but anywhere in the universe. His work laid the foundation that Isaac Newton built on to develop the law of universal gravitation. Kepler improved the understanding of optics, including how vision occurs, and made advancements in geometry and mathematics. Order and harmony are at the root of science, and both are on generous display in the works and methods of Johannes Kepler.

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