1

The Dreamer

> The promulgation of Kepler's Laws is a landmark in history. They were the first "natural laws" in the modern sense: precise, verifiable statements about universal relations governing particular phenomena, expressed in mathematical terms.
>
> Arthur Koestler, *The Watershed* (1960)

In 1627 Johannes Kepler, mathematician, astronomer, astrologer and mystic, published his last major work, the *Rudolphine Tables.* Dedicated to his patron, Emperor Rudolph II of Bohemia, it was the most comprehensive compilation of astronomical data to date; it included rules and tables for finding the position of the sun, moon, and planets, a catalog of over one thousand stars begun by his late mentor Tycho Brahe, improved tables of logarithms, and the geographical coordinates of major cities of the world. In the making for over thirty years, the work had been eagerly awaited by navigators, astronomers, and horoscope casters. Publication was delayed time and again—first, by the Thirty Year War, then by lack of funds, and finally by lawsuits from creditors and from Brahe's sons, who accused Kepler of stealing their late father's observations. The work was finally published in September 1627, three years before Kepler's death (fig. 1.1).[1]

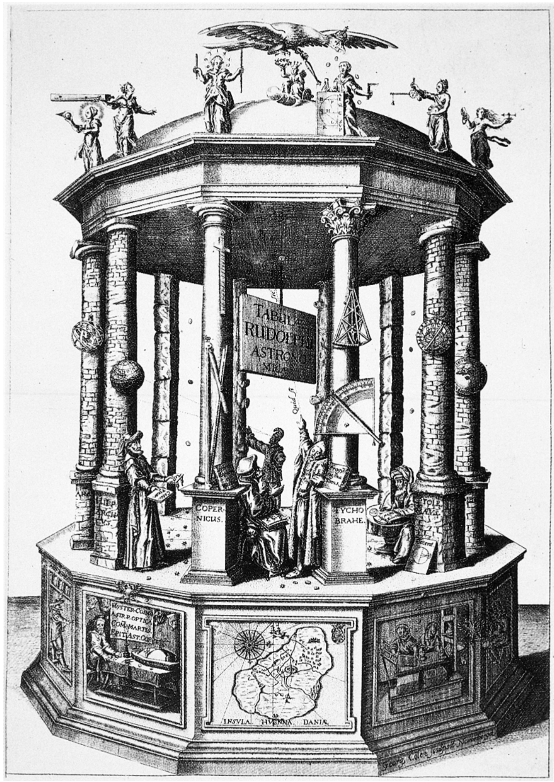

FIGURE 1.1 Frontispiece of the *Rudolphine Tables.*

Kepler, universally regarded as the founder of modern astronomy, was perhaps the most controversial scientist in history. He was born on December 27, 1571 (by the old Julian calendar then in use) to a family of vagabond misfits in the small town of Weil in the district of Swabia in southwestern Germany. Young Kepler suffered from poor health—real and imagined—and had a very low image of

himself. In his diary, which he wrote in the form of a family horoscope, we find this early entry:

> That man has in every way a dog-like nature. His appearance is that of a little lap dog. . . . He liked gnawing bones and dry crusts of bread, and was so greedy that whatever his eyes chanced on he grabbed. His habits were similar. He continually sought the good will of others, was dependent on others for everything, ministered to their wishes . . . and was anxious to get back into their favor. He is bored with conversation, but greets visitors just like a little dog; yet when the least thing is snatched away from him, he flares up and growls. He tenaciously persecutes wrongdoers—that is, he barks at them. He is malicious and bites people with his sarcasm. He hates many people exceedingly and they avoid him, but his masters are fond of him. His recklessness knows no limits . . . yet he takes good care of his life. In this man there are two opposite tendencies: always to regret any wasted time, and always to waste it willingly. . . . Since his caution with money kept him away from play, he often played with himself. His miserliness did not aim at acquiring riches, but at removing his fear of poverty—although, perhaps avarice results from an excess of this fear.[2]

"That man" is Kepler himself, speaking in third person.

Nothing in Kepler's family history showed any hint of a future greatness. His grandfather served as the mayor of Weil, but was, by Kepler's own account, "arrogant, proudly dressed, short-tempered and obstinate . . . his face betrays his licentious past." Kepler's father, Heinrich, one of twelve

siblings, was a mercenary who wandered throughout Germany, fighting on the side of whichever religious cause came his way, and narrowly escaping the hangman's rope. Kepler's mother, Katherine, was raised by an aunt who was later burned at the stake for witchcraft, and she herself would barely escape a similar fate late in life.

Johannes's opinion of his parents was as harsh as that of himself. His father was "vicious, inflexible, and doomed to a bad end. Saturn in VII [i.e., in Libra, the seventh constellation of the zodiac] made him study gunnery; many enemies, a quarrelsome marriage . . . a vain love of honors, and vain hopes about them; a wanderer . . . 1577 he ran the risk of hanging. . . . Treated my mother extremely ill, went finally into exile and died." His mother was "small, thin, swarthy, gossiping, quarrelsome, and of bad disposition." These are indeed harsh words with which to judge one's parents, and they were matched only by his low opinion of himself. This early flair for self-criticism and brutal honesty would stay with him to the end, and he would use it equally in his personal life and scientific work.

At the age of thirteen he was sent to a theological seminary, where the official language was Latin and strict discipline was the order. Irritable and quarrelsome like his forebears, he made few friends and many enemies; by his own account, he disliked his teachers, and they reciprocated in kind. At seventeen he entered the University of Tübingen, graduating three years later in theology. There he met the one teacher who left a positive impact on him—Michael Mästlin, a professor of astronomy. Through Mästlin he became acquainted with Copernicus's heliocentric (sun-centered) system, and immediately became a fervent believer. But, typically, his beliefs were based on theological rather

than sound astronomical reasons: a sun-centered universe made sense to him because God would naturally place the sun, giver of light and heat, at the center of creation. This mixture of true science with religious and mystical reasoning was to be Kepler's hallmark for his entire life.

When he was twenty-three, his life suddenly changed for the better: he was offered a position at the university of Gratz in Austria as a teacher of mathematics and astronomy. He accepted, but only reluctantly, citing "the unexpected and lowly nature of the position, and my scant knowledge of this branch of philosophy." At this stage of his life he was still set on a career in theology; but only a year later, while giving his weekly lecture to a nearly empty class, an idea struck him that would remain his credo for the rest of his life.

It happened on July 9, 1595. He was drawing a geometric figure on the board when suddenly a revelation came to him: *God designed the cosmos along simple, geometric proportions.* "The delight that I took in my discovery," he wrote later, "I shall never be able to describe in words." His "discovery"—already expressed two thousand years earlier by the Pythagoreans—was that number and shape are the essence of the universe. But Kepler went further: he proposed that the orbits of the planets around the sun were determined by the geometry of *the five regular solids.* In the two-dimensional plane, one can construct regular polygons with any number of sides—an equilateral triangle, a square, a regular pentagon, etc. (in a regular polygon, all sides are of equal length, and all angles have the same measure); but in space there exist just five regular solids: the tetrahedron, which has four equal faces, each an equilateral triangle; the cube (six faces, each a square); the octahedron (eight equi-

lateral triangles); the dodecahedron (twelve regular pentagons); and the icosahedron (twenty equilateral triangles). These five solids (fig. 1.2) were already known to the Greeks and have come to symbolize the perfect symmetry of God's design; now Kepler made them the cornerstone of his cosmos. "Why are there exactly six planets," he asked, "and not twenty or a hundred?" His answer: because six planetary orbits leave five gaps between them, and naturally these five gaps had to be filled with the five regular solids! It was too good a fit to be a mere coincidence; it had to be God's design. One almost feels grateful that Kepler did not

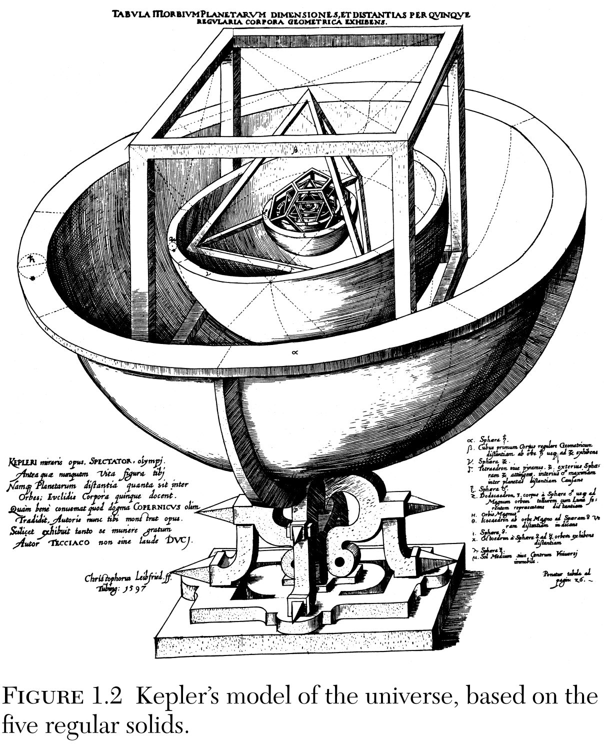

FIGURE 1.2 Kepler's model of the universe, based on the five regular solids.

know of the three remaining planets of the solar system, for they would have at once destroyed this perfect celestial harmony.

Having made his great "discovery," he now set out to perfect it with a tenacity unparalleled in the annals of science. When the observational data didn't quite fit his vision, he often changed the data—and willingly admitted so later. And when even that didn't quite help, he turned to the laws of musical harmony, assigning to each planet a tune to be sung according to its distance from the sun. Mercury, the closest planet to the sun, was given the highest notes, Saturn the lowest. This "harmony of the spheres" became an idée fixe with Kepler, guiding (perhaps "misguiding" would be a better word) him for the next thirty years. Eventually, aided by the meticulous observations made by the Danish nobleman Tycho Brahe at his elaborate observatory on the island of Hven, he finally discovered the true laws of planetary motion that bear his name. Kepler's three laws are:

1. The planets move around the sun in ellipses, the sun being at one focus of each ellipse.
2. The straight line connecting each planet to the sun sweeps equal areas in equal times.
3. The square of the period of each planet is proportional to the cube (the third power) of its mean distances from the sun.[3]

With these laws, modern astronomy was born.

Kepler was not the first one to ask, *how* do the planets move in their orbits, but he was the first to give the correct answer. By replacing the hallowed circular orbits of the Greeks with elliptical orbits, he discovered the true geometry of the planetary clockwork. Half a century later, Isaac

Newton would use Kepler's laws to answer the *why*—to discover the physical cause that drives this clockwork, the universal force of gravitation.

Notes and Sources

1. For a more detailed description of the *Tables,* see Owen Gingerich, *The Great Copernicus Chase and Other Adventures in Astronomical History* (Cambridge, Mass.: Sky Publishing Corporation, and Cambridge, U.K.: Cambridge University Press, 1992), chapter 15.

2. Kepler's quotations in this chapter are taken from Arthur Koestler's classic, *The Watershed: A Biography of Johannes Kepler* (New York: Anchor Books, 1960).

3. Expressed mathematically, $(T_1/T_2)^2 = (d_1/d_2)^3$, where T_1 and T_2 denote the periods of any two planets, and d_1 and d_2 their mean distances from the sun.