Einstein on Kepler

Albert Einstein wrote this article on the 300th anniversary of Kepler's death, for the Frankfurter Zeitung*, Nov. 9, 1930. It was translated by* EIR.

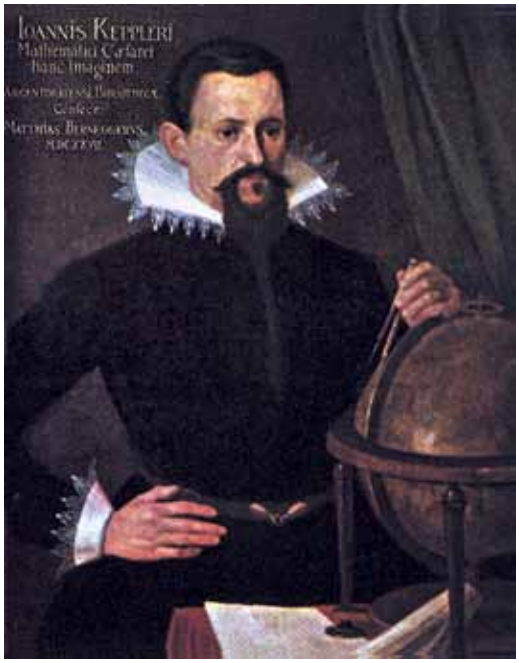
Precisely in such a troubled and turbulent time as ours, when it is hard to summon up joy about mankind and the progress of human affairs, it is especially comforting to think of such a great and serene person as Kepler.

He lived at a time when the very conception of universal lawfulness of nature was not at all established. How great must have been his faith in such lawfulness, to have the strength to endure decades of patient, difficult work—supported by no one and understood by few—in the empirical investigation of planetary movement and its lawful mathematical expression! If we want to commemorate him appropriately, we have to look as closely as possible at his problem and the stages of its solution.

Copernicus had opened the eyes of the best thinkers to the idea that the apparent motions of the planets could most clearly be understood as orbits around the Sun, which itself is conceived as stationary. If a planet simply moved in a circle with the Sun at the center, it would have been conceptually simple to discover how such motions would look from the Earth. But much more complex phenomena were involved, so the task was far more difficult. So to begin with, these motions had to be investigated empirically, using Tycho Brahe's observations of the planets. Only then could one think, for the first time, of discovering the universal laws that govern these motions.

To imagine how difficult it was even to determine the actual orbital motions, consider the following: One never sees where a planet is actually located, but only in what direction it is visible at any given time from the Earth, which, however, is itself moving in an unknown way around the Sun. The difficulties seem all but insurmountable.

Kepler had to find a way to bring order out of this chaos. First of all, he realized that he would have to try to determine the movement of the Earth itself. This would have been simply impossible, had only the Sun, the Earth, and the fixed stars existed, but no other planets. It would be impossible to establish anything empirically, except how the line from Sun to Earth changes during the course of the year (the apparent motion of the Sun against the fixed stars). It could be ascertained that these directions of the Sun-Earth line all lay in a constant plane with respect to the fixed stars, at least to the degree of observational accuracy that existed then, without telescopes. It could also be determined how the Sun-Earth line rotates around the Sun. It could thus be observed that the angular velocity of this motion changes in a regular way, during a year. But this would not help much, it would still not be known how much the distance between the Sun and Earth changes in a year. Only when the changes in this distance in a year were known, could the true shape of the Earth's orbit be discovered, as well as how this pathway is traversed.



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The Lantern of Mars

Kepler found a marvelous way out of this dilemma. First of all, observations of the Sun showed that its apparent path across the background of the fixed stars sped up at certain times of year, but that the angular velocity of this motion was the same at the same point in the astronomical year—i.e., that the rotational speed of the Earth-Sun line was the same at

each time of year, when seen against the same location among the fixed stars. It could therefore be surmised that the Earth's orbit was a *closed* curve, with the Earth returning every year to the same place, in the same way. That was by no means self-evident, *a priori*. For the advocate of the Copernican system, it was almost certain that this must also apply to the paths of the other planets.

That certainly made things easier. But how could the true shape of the Earth's orbit be determined? Think of a brightly shining lantern **M**, somewhere in the plane of the Earth's orbit; its position remains constant, so that it defines a fixed point of triangulation from which to construct the path of the Earth's orbit, a point which the Earth's inhabitants can take a sighting of, at any time of year. This lantern **M** is further from the Sun than the Earth is. Such a lantern helped to define the Earth's orbit, as follows:

First of all, every year there is a time at which the Earth E is aligned with both the Sun **S** and the lantern **M**. At that time, take a sighting from the Earth **E** toward the lantern **M**, right along the line **SM** (Sun-lantern). Imagine that the latter [the lantern—ed.] is affixed to the vault of the heavens. Now imagine the Earth being in a different place, at a different time. One would be able to see both the Sun **S** and the lantern **M**, from the Earth, forming the triangle **SEM**, with the angle at E being known. But also, from direct observation of the Sun, one can determine the direction of **SE** against the fixed stars, while previously the direction of line **SM** had been calculated against the fixed stars. But in the triangle **SEM**, we also know the angle at S. Thus we can construct on a piece of paper an arbitrary baseline **SM**, and with both the angles at **E** and at **S** known, we can also construct triangle **SEM**. This construction could be carried out frequently during the year, each time plotting on the paper the Earth's position **E**, with the relevant time/date for its position with respect to the constant baseline **SM**. The Earth's orbit could be empirically calculated in this way—except, of course, for its absolute size.

But, you will ask, where did Kepler get the lantern **M**? His own genius and Nature's beneficence (in this case) gave it to him. The planet Mars provided an example, and the length of the Martian year was known—i.e., one revolution of Mars around the Sun. The Sun, Earth, and Mars might one day line up exactly in a straight line. This location of Mars recurs after one, two, etc. Martian years, since Mars also moves in a closed orbit. At these known moments, **SM** therefore provides the same baseline, while the Earth is always somewhere else in its orbit. Observations of the Sun and Mars at these exact moments thus provide a way to determine the true orbit of the Earth, in which, at each point, Mars plays the role of the imaginary lantern described above! That is how Kepler was able to find the true shape of the Earth's orbit, and how it is traversed by the Earth, such that we subsequent generations of people—Europeans, Germans, or even Swabians[1]—could marvel and praise him.

From the Imagined, to the Observed

Now comes the second, and no less difficult, part of Kepler's life's work. The orbits were empirically established, but their laws still had to be figured out from the empirical evidence. First, to pose a conjecture about the mathematical form of the orbital curve; and then, to check it with a phenomenal amount of numerical data. If it doesn't work, then come up with another hypothesis and work through checking that one. After a prodigious search, he got it: The orbit is an ellipse; the Sun is located at one focus. He also discovered the law governing the rate of change of the speed of revolution: that the Sun-planet line sweeps through equal areas in equal times. Finally, he also discovered, that the square of the orbital period is equal to the cube of the ellipse's major axis.

Our admiration for this wonderful man is joined with another feeling of admiration and veneration, not for any person, but for the mysterious harmony of Nature into which we were born. In ancient times, men already thought about lines of the simplest conceivable regularity. Among these, the foremost, next to the straight line and the circle, was the ellipse (and also the hyperbola). We see these latter forms realized, at least in close approximation, in the orbits of the heavenly bodies.

It seems that human reason first has to independently construct the forms, before we can detect them in things. Kepler's marvelous life's work shows us especially beautifully, that cognition cannot blossom from sheer empirics, but from the comparison of what is imagined, with what is observed.

1. Both Kepler and Einstein were Swabians—ed.