

## Kepler notes from Owen Gingrich

“The Eye of Heaven – Ptolemy, Copernicus, Kepler”, Owen Gingrich, American Institute of Physics, 1993

There were three key figures from the Lutheran University of Wittenberg in dissemination of Copernicus's work. Erasmus Reinhold (Prutenic Tables), Georg Joachim Rheticus (Convinced Copernicus to publish.), and Michael Maestlin's textbook (“Epitome astronomiae”). However, these professors offered Copernican astronomy as a convenient alternative model to making astronomical predictions. They did not present helio centrism as an alternative description of reality.

Kepler and Galileo were the two men most influential in convincing people that the heliocentric system was physically plausible. Kepler's book, “Mysterium Cosmographicum”, (1596) was the first significant treatise endorsing the Copernican system.

### [Diagram of Kepler's rendition of the planetary system from Crowe's book](#)

Notice in our textbook the geometric detail Kepler uses to explain this complicated figure. It is constructed based on the five regular solids known from antiquity. Kepler is described in some writings as a “mystic”, but his deep conviction that the beauty and coherence of the physical world was a logical plan from a logical God. We also know from the ancient Greek mathematicians that geometry had a divine origin. This we see in Greeks' belief that the world is rationally knowable and the central role played by mathematics.

The visual complexity of the figure was a hallmark of Kepler's thinking. It reinforced his belief that the sun plays a crucial role as a physical cause for planetary motion. So the sun had to be in the center of the planetary system.

Kepler discarded the non causal mathematical models and replaced them by a powerful physical causal hypothesis. The sun was essential as a part of the understanding of planetary motion, not just for a description of that motion. There is in this demand, the birth of modern physics. Kepler demands the need for a special “force”, a force that can act at a distance between bodies that exists when the bodies are not in physical contact.

Kepler assumed a force existed between the moon and the waters of the ocean which caused the tides. From antiquity people recognized that certain configurations of the moon-sun-earth produced high or low tides. Galileo knew this correlation, of course, but he refused to believe there was a causal physical

connection. We will see that Galileo believed the tides were due to kinematics. Kepler's interpretation of tidal motion as due to forces acting across space seemed too “mystical” to Galileo.

Kepler recognized the critical role of the sun as located at a focus of the elliptical orbit. Since the speed of planetary motion was slower as the planet became farther from the sun he assumed a force that fell off as  $1/r$ . He speculated a kind of magnetic effect. This is incorrect quantitatively, but conceptually it is correct. The scientists of the time knew about magnetic effects. William Gilbert's work on magnetism demonstrated that “action at a distance” was an observable effect and not mystical.

Kepler was the first scientist to demand a physical explanation for celestial phenomena. His 1609 book, “Astronomia nova” was really a new astronomy. The elliptical orbit of Mars due to the collaboration of these two obsessive men, Brahe and Kepler, put the astronomers on a new path to understanding celestial phenomena. The old ways of understanding the cosmos for the prior two thousand years needed to be discarded.

| Astronomer   | Kinematics   | Dynamics  |
|--------------|--|---|
| Ptolemy      | Geocentrism, epicycles, deferents, eccentric circles             | Perfect bodies <b>must</b> move in perfectly regular circles.   |
| Copernicus   | Heliocentrism, epicyclets, eccentric circles                     | Same as Ptolemy   |
| Kepler/Brahe | Elliptical orbits with the sun at a single focus for all planets | Sun exerts a force on the planets as a cause for their orbits. <b>Action at a distance is required!</b> |

Two thousand years of circles and combinations of circle were the challenge that Kepler faced! He nearly went mad! See his introduction to the 1609 book.

Interesting side notes.

Kepler discovered that Osiander had inserted the unauthorized letter into Copernicus's book arguing for a “Save the Phenomena” philosophical position. He noted this in “Astronomia nova”.

Kepler discovered the yearly counting from the birth of Jesus was off by 4 years. This year is 2020 C.E. In the Christian calendar this year is 2024 A.D.

Kepler was buried in a Churchyard cemetery in Regensburg. The graveyard was destroyed by warring armies during the 30 years religious war in Europe. The remains of such an important scientist are scattered around Regensburg.

Kepler's three laws of planetary motion were explained some 80 years after his death by Newton's laws of motion and the law of universal gravity. We will use Kepler's 3<sup>rd</sup> law enlightened by Newtonian mechanics when we calculate the mass of the Galaxy and the mass of the black hole at the center of our galaxy.