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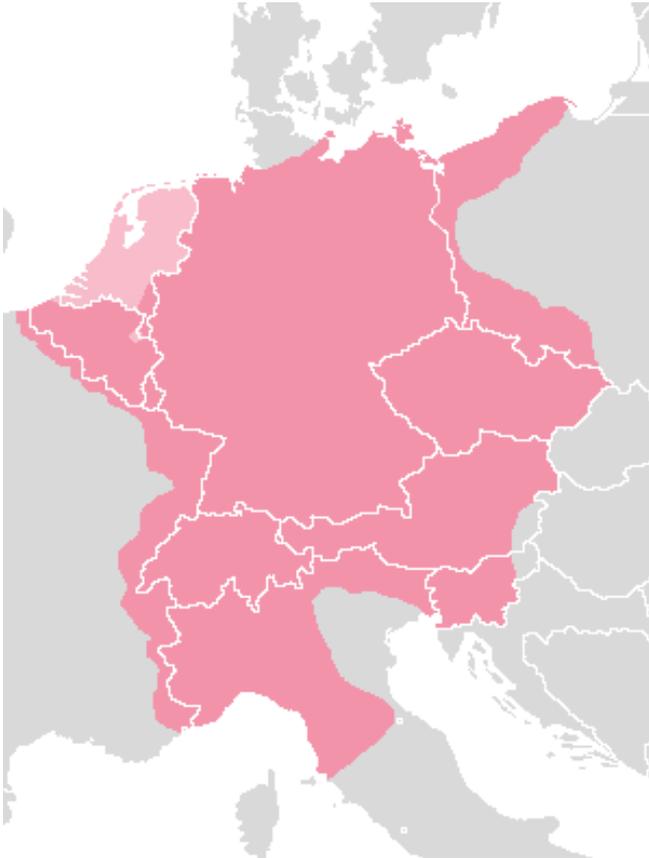
II. The Scientific Revolution

Johannes Kepler (1571-1630)

The War on Mars

Cameron & Stinner

A little background history



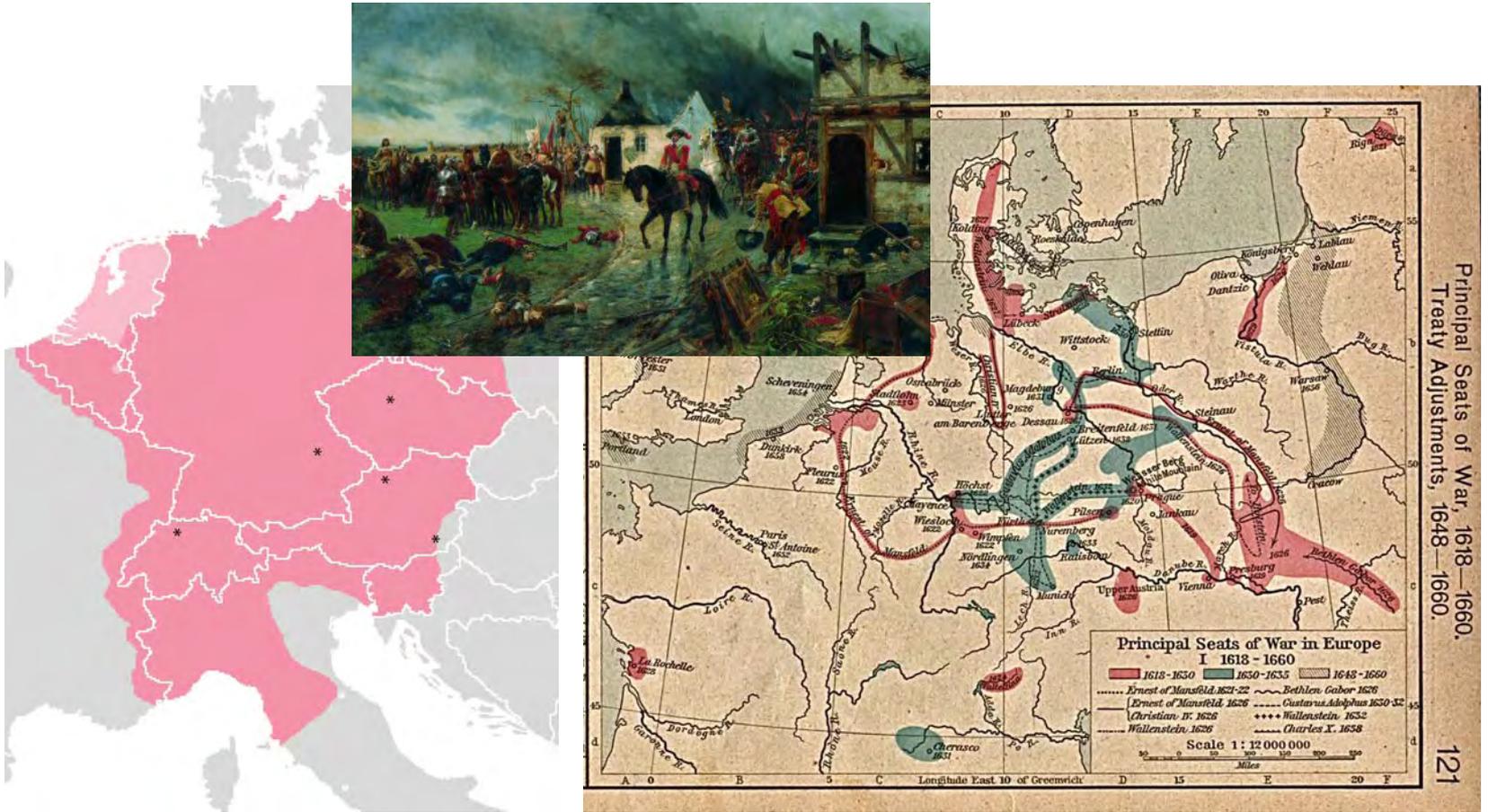
Where: Holy Roman Empire

When: The thirty years war

Why: Catholics vs Protestants



A little background history



The short biography

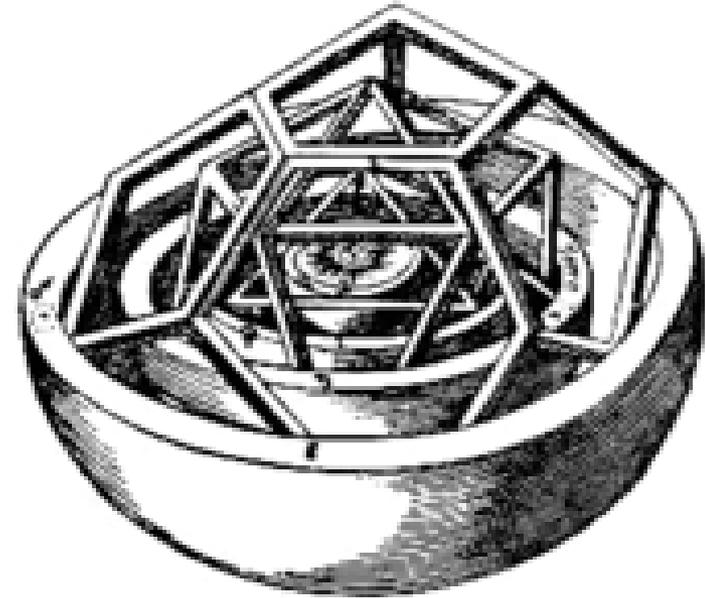
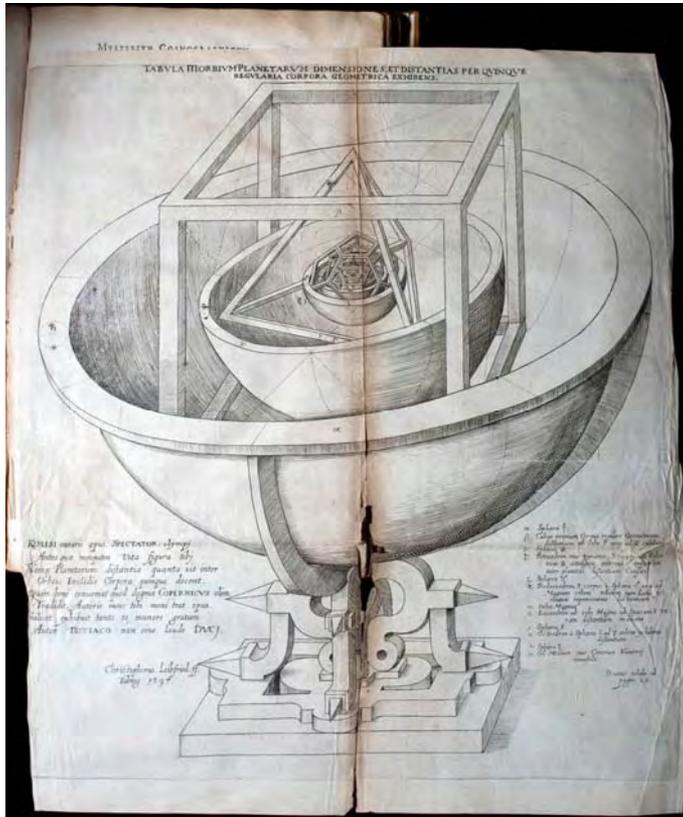


Johannes Kepler was born in **Weil der Stadt**, Germany, in 1571. He was a sickly child and his parents were poor. A scholarship allowed him to enter the University of Tübingen.

There he was introduced to the ideas of **Copernicus by Maestlin**. He first studied to become a priest in Poland but moved to **Graz**, Austria to teach school in 1596.

As mathematics teacher in **Graz**, Austria, he wrote the first outspoken defense of the Copernican system, the ***Mysterium Cosmographicum***.

Mysterium Cosmographicum (1596)



Kepler's **Platonic** solids model of the **Solar system**. He sent a copy to Tycho Brahe who needed a theoretician...

The short biography

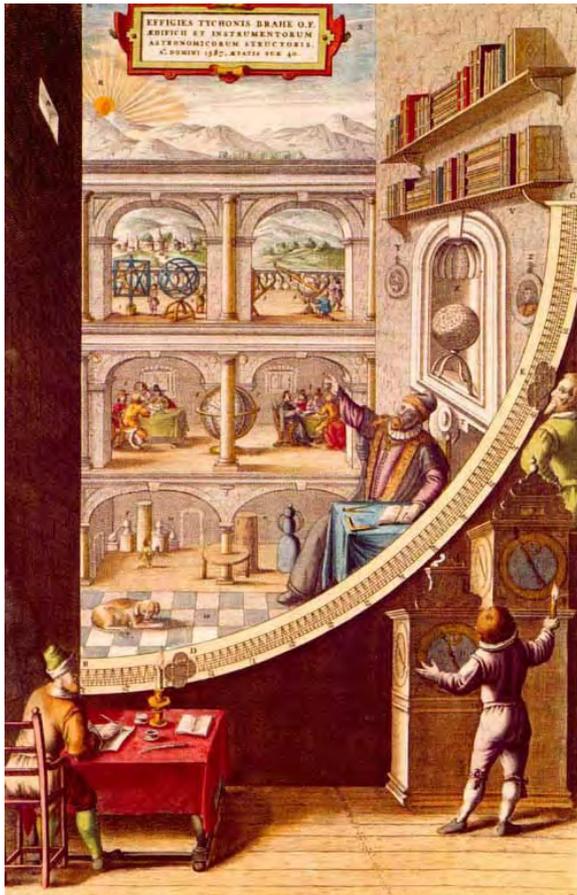


Kepler was forced to leave his teaching post at **Graz** and he moved to **Prague** to work with the renowned Danish astronomer, **Tycho Brahe**.

He inherited Tycho's post as Imperial Mathematician when Tycho died in 1601.



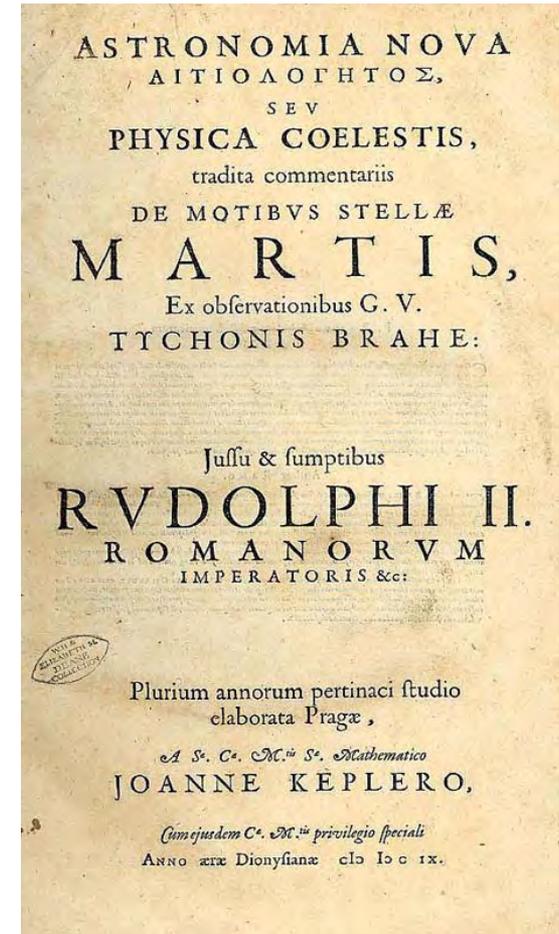
The short biography



The great Wall Quadrant. Copper etching from Blaeu's Atlas Major, 1663. Made following a depiction in Tycho Brahe's *Astronomiae Instauratae Mechanica*.

Using the precise data (~1') that Tycho had collected, Kepler discovered that the orbit of Mars was an ellipse.

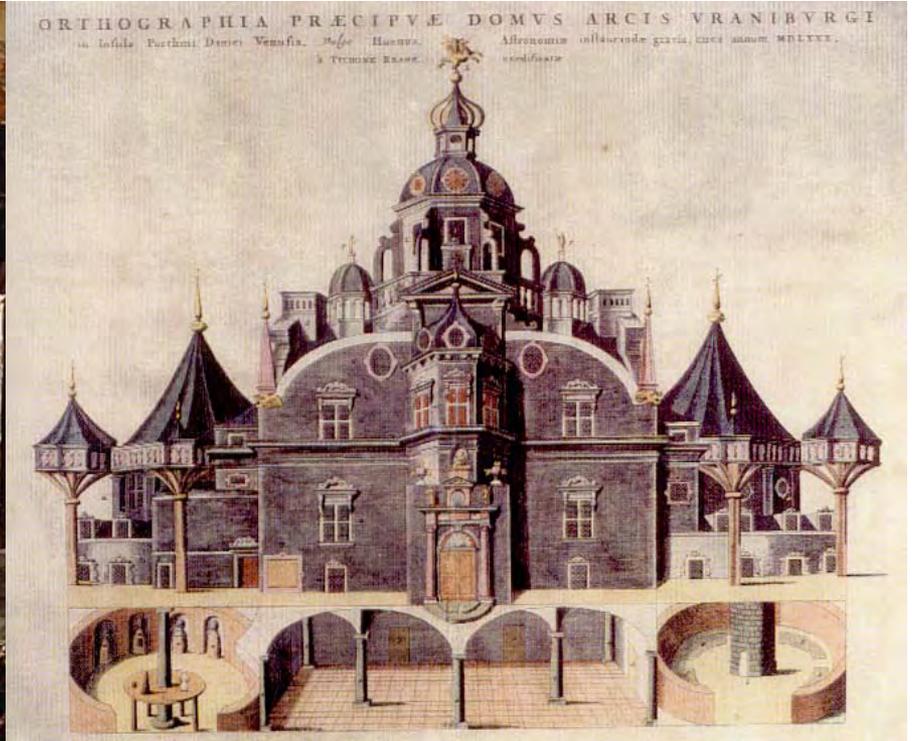
In 1609 he published *Astronomia Nova*, presenting his discoveries, which are now called Kepler's first two laws of planetary motion.



Tycho Brahe

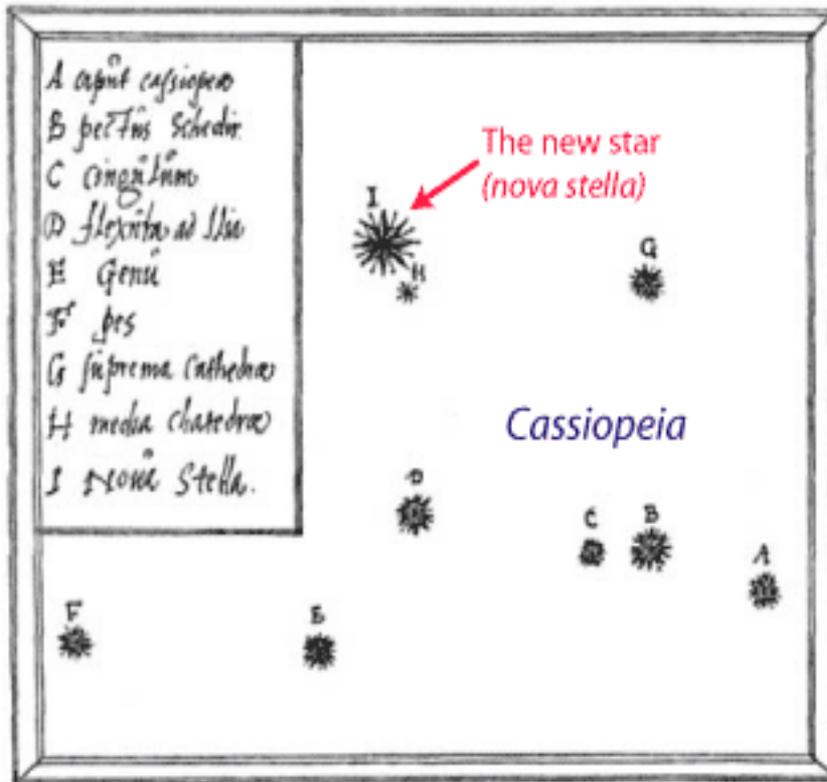


The Aristocrat

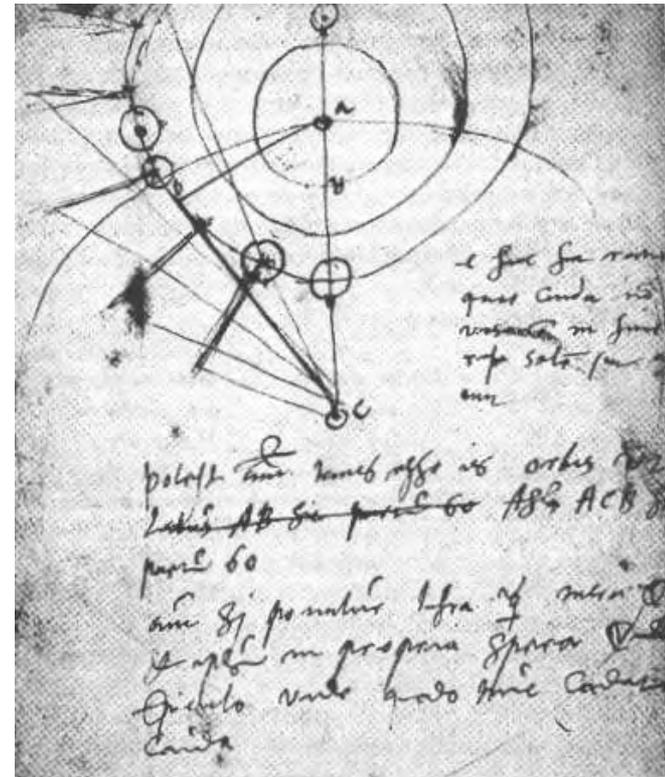


The Observer

Tycho Brahe - the Observer



Tycho Brahe's observation of a new star in Cassiopeia, published in *De stella nova*, 1573.



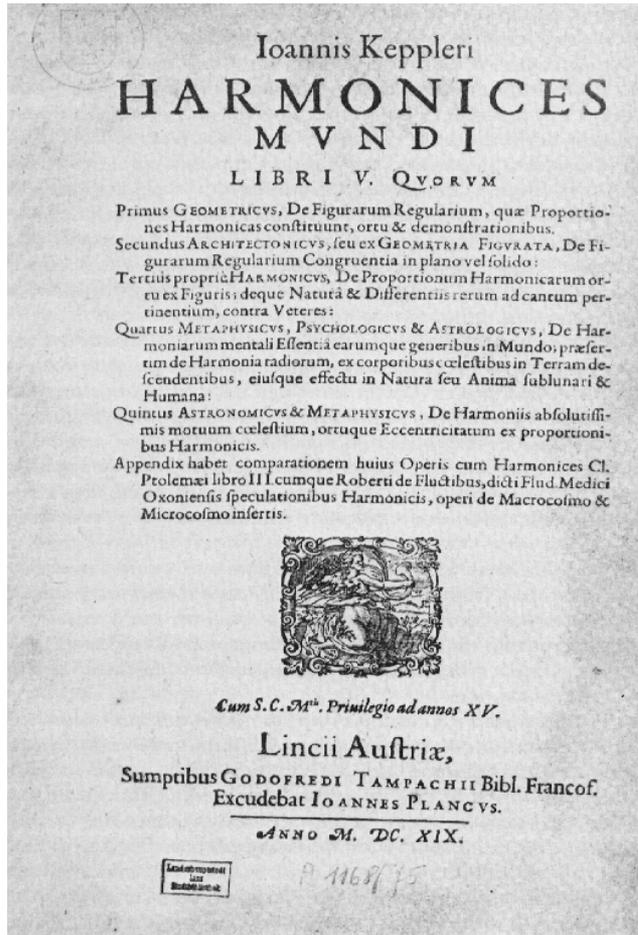
The Great Comet of 1577
-from Brahe's notebooks

The short biography



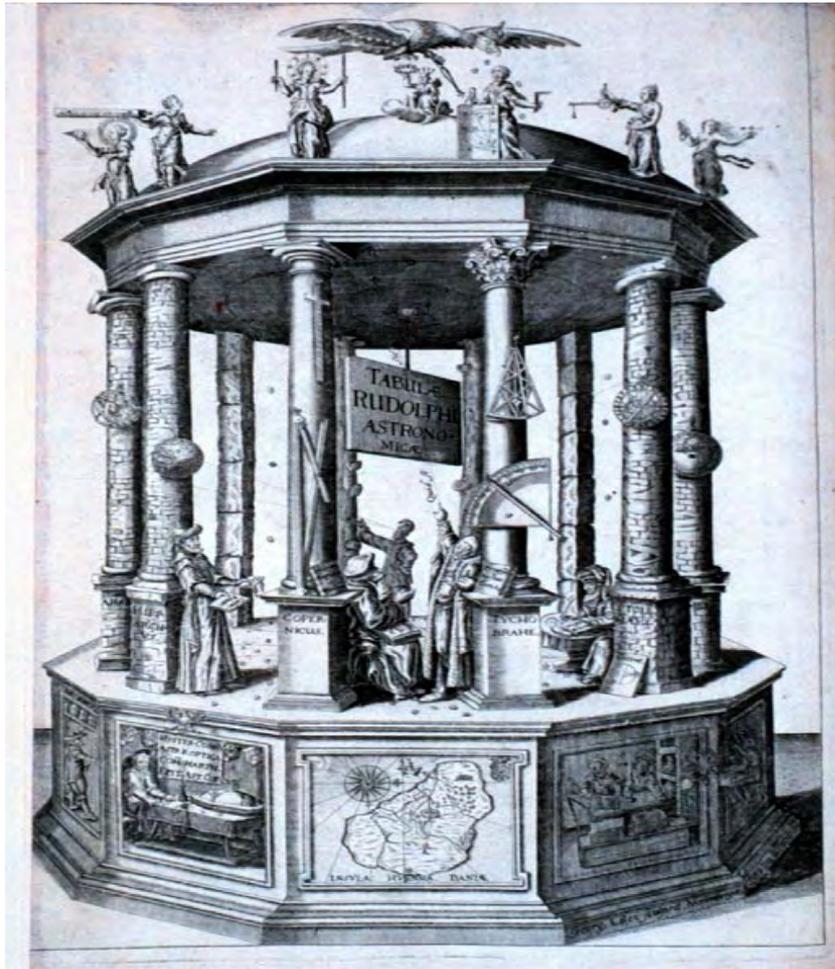
- In 1612 Lutherans were forced out of [Prague](#), so Kepler moved on to [Linz](#), Austria.
- His wife and two sons had recently died (of disease probably spread by the soldiers in the war).
- Later, two infant daughters by his second wife also died.
- Kepler had to return to [Württemberg](#), where he successfully defended his mother against charges of witchcraft.

Harmonices Mundi (1619)



In the *Harmonices Mundi* he describes his "third law."

Tabulae Rudolphinae (1627)



- The iconic frontispiece to the *Rudolphine Tables* celebrates the great astronomers of the past:
- [Hipparchus](#), [Ptolemy](#), [Copernicus](#),
- and most prominently,
- [Tycho Brahe](#)

The Rudolphine Tables (1627)

Kepler calculated the most exact astronomical tables hitherto known, whose continued accuracy did much to establish *heliocentric* astronomy.

The image shows a page from the Rudolphine Tables, specifically the 'Tabula Aequationum M.A.R.T.I.S.' (Table of Equations of Mars). The page is numbered '64' in the top left corner. The title is centered at the top. The table is organized into several columns, with headers in Latin. The columns include 'Anomalis Eccentrici', 'Intervallum', 'Anomalis Copernici', 'Intervallum Copernici', 'Anomalis Eccentrici', 'Intervallum', 'Anomalis Copernici', and 'Intervallum Copernici'. The data is presented in a grid format, with rows corresponding to different values of the anomaly. The numbers are arranged in a regular pattern, with some rows having a small number in the left margin (e.g., 110, 111, 112, etc.). The table is a classic example of a logarithmic table used for astronomical calculations.

The short biography

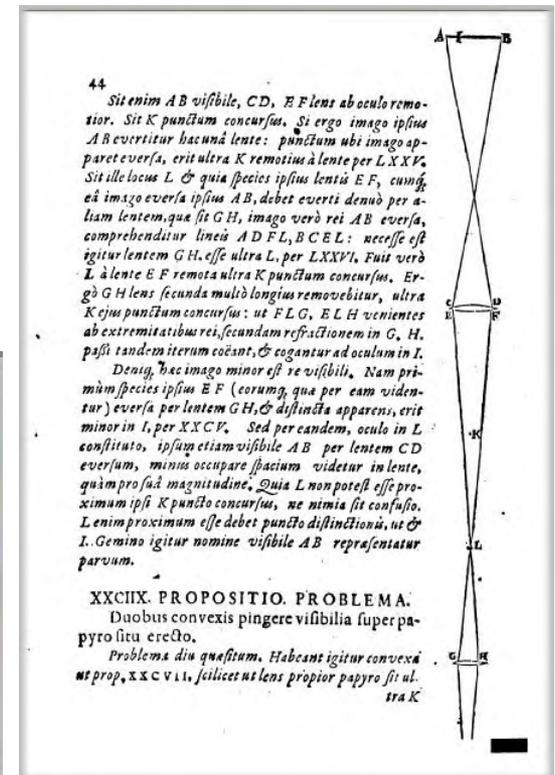
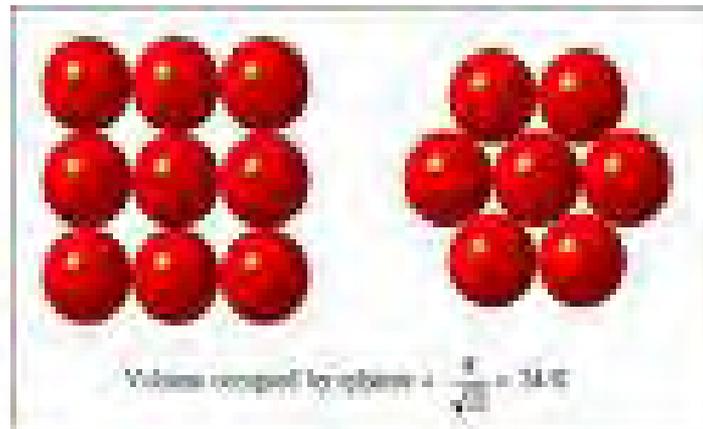
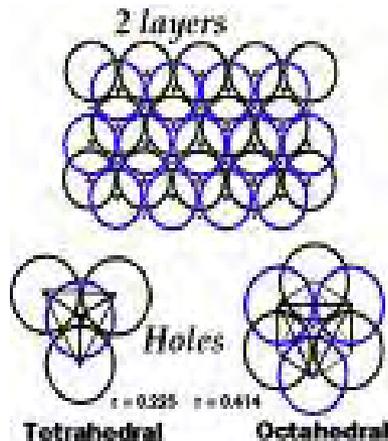


- Kepler died in **Regensburg** in 1630, after a short illness. He was staying in the city on his way to collect some money owing to him in connection with the *Rudolphine Tables*.
- He was buried in the local church, but this was destroyed in the course of the **Thirty Years' War** and nothing remains of the tomb.

accomplishments

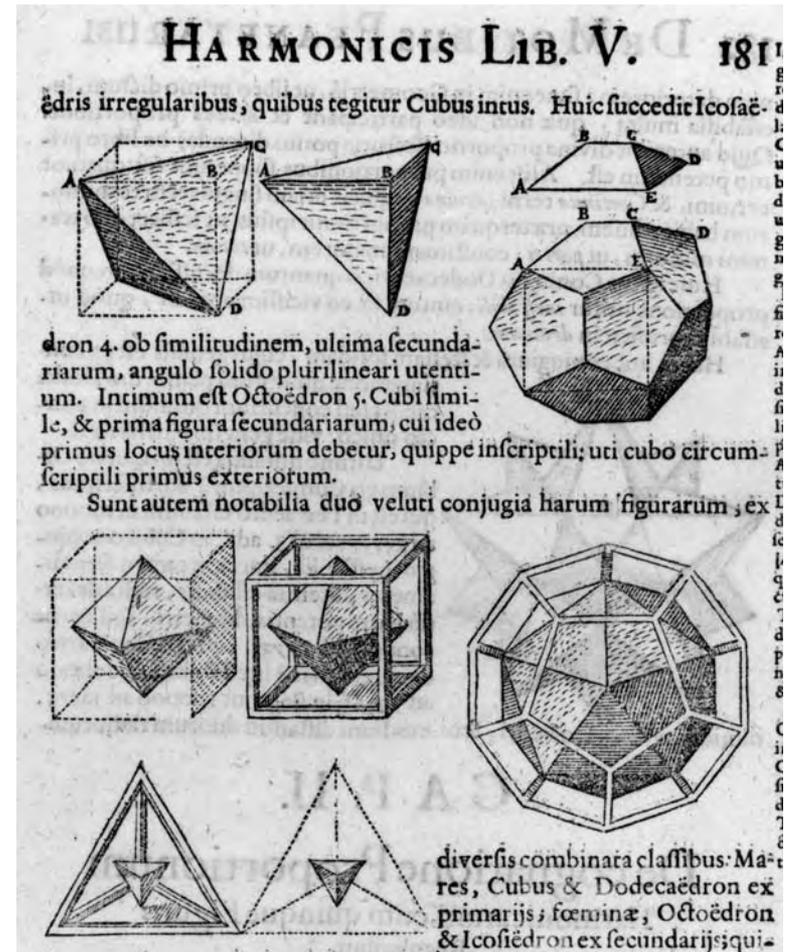
Johannes Kepler is chiefly remembered for discovering the **three laws of planetary motion** that bear his name and published in 1609 and 1619.

- He worked out the problem of packing of spheres.
- He also did important work in **optics** and improved on Galileo's *refracting* telescope.

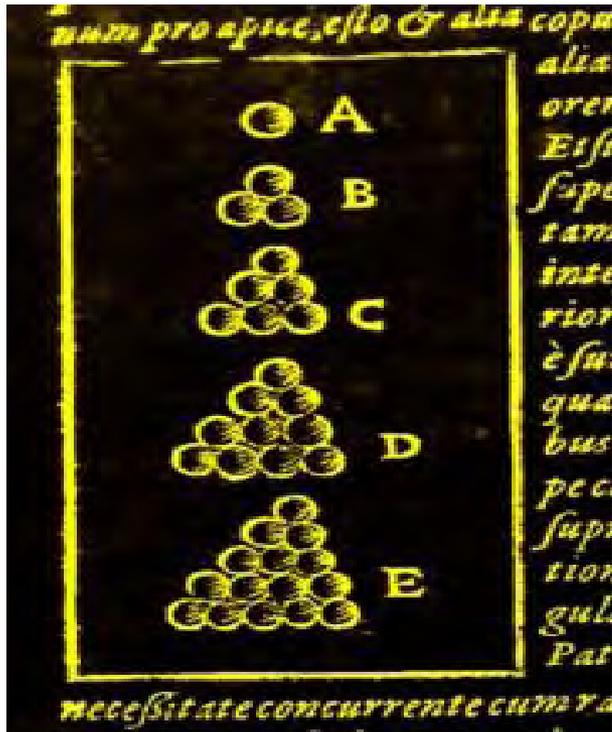


accomplishments...

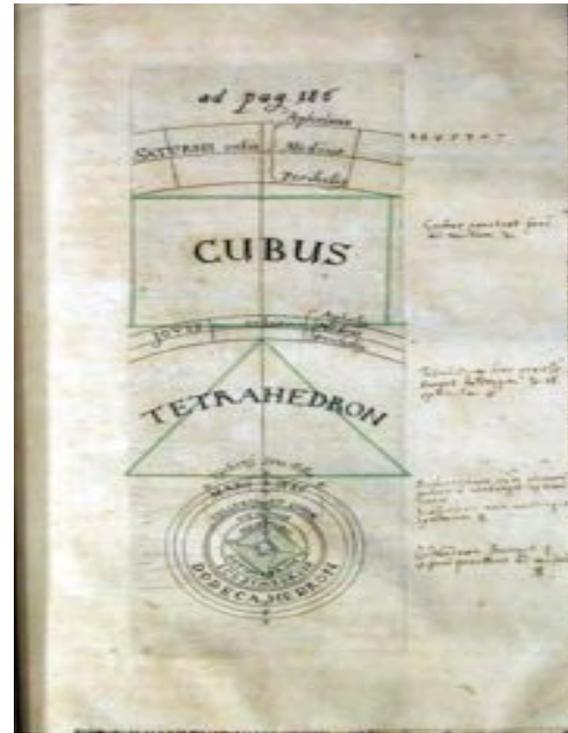
- Discovered two new regular **polyhedra** (1619).
- Gave the first mathematical treatment of **close packing of equal spheres** (leading to an explanation of the shape of the **cells of a honeycomb** (1611)



accomplishments...



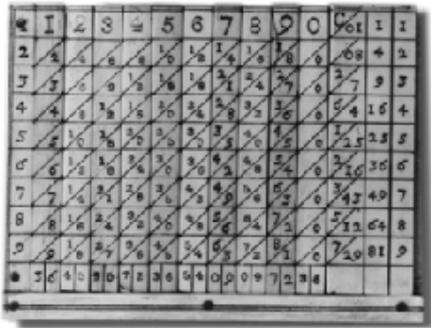
One of the diagrams from *Strena Seu de Nive Sexangula*, illustrating the [Kepler conjecture](#).



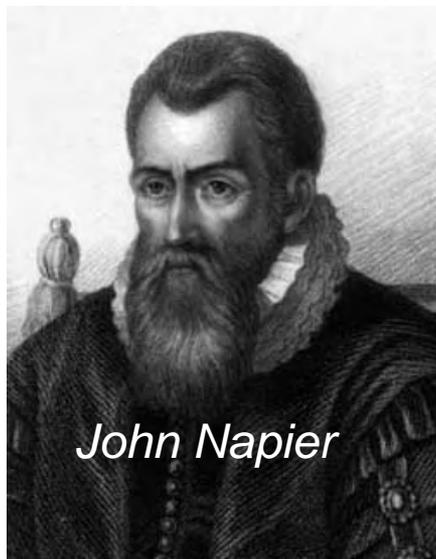
Geometrical harmonies in the regular polygons from *Harmonices Mundi* (1619)

accomplishments...

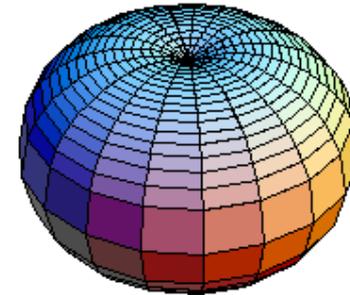
- Gave the first proof of how **logarithms** worked (1624).
- Devised a method of finding the **volumes of solids of revolution** that can be seen as contributing to the development of **calculus** (1615, 1616).



Napier's Bones



John Napier



Surface of Revolution

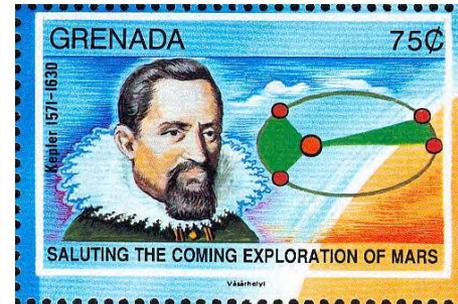
remembered



A statue of Kepler and Tycho Brahe in Prague

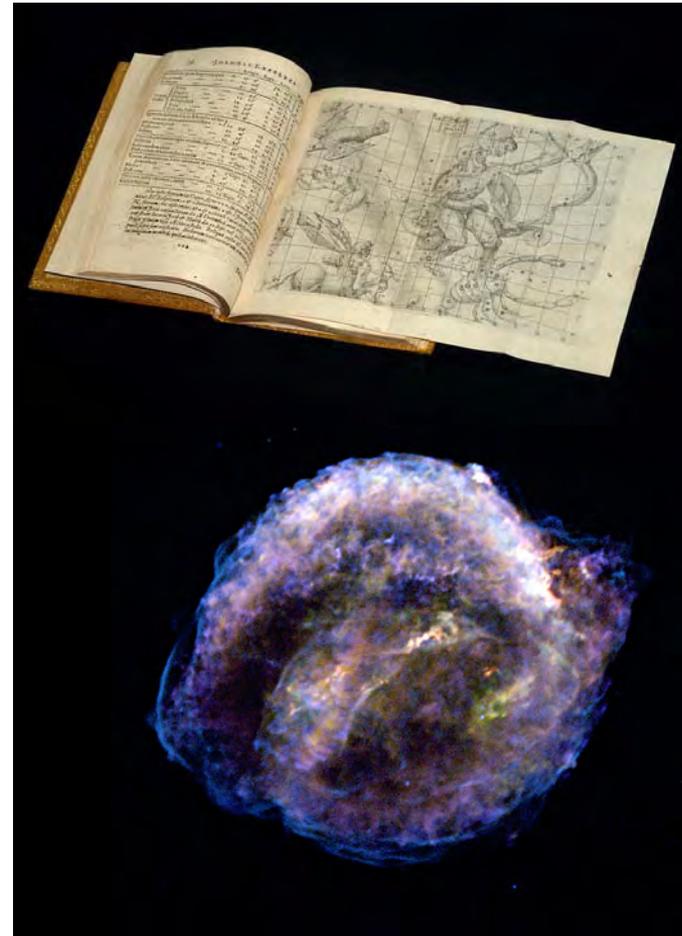
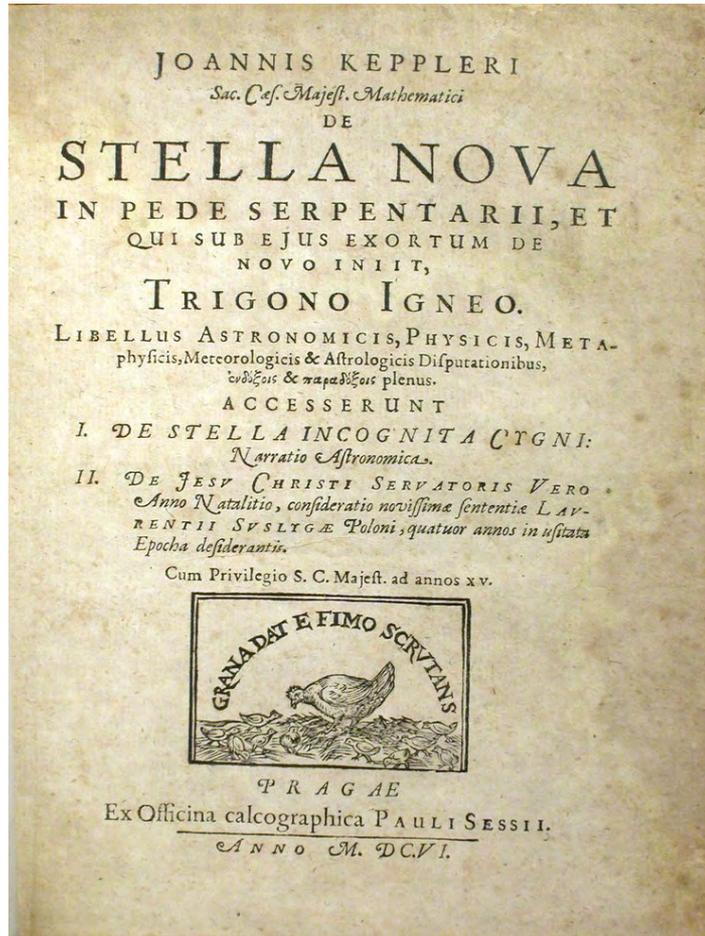


The lunar crater Kepler



Commemorative stamps

remembered...



Summary



The [Great Comet of 1577](#), which Kepler witnessed as a child, attracted the attention of astronomers across Europe.

- All of Kepler's writings contain numerous references to God, and he saw his work as a fulfillment of his Christian duty to understand the works of God.
- Kepler was convinced that God had made the Universe according to a mathematical plan (a belief found in the works of [Plato](#) and associated with [Pythagoras](#)).

Summary

- Like Galileo, he believed that mathematics provided a secure method of arriving at truths about the world.
- He used **Euclid's** geometry, and after studying **Copernicus** and using the data of **Tycho**, he was convinced that the motion of the planets were around the sun in elliptical orbits

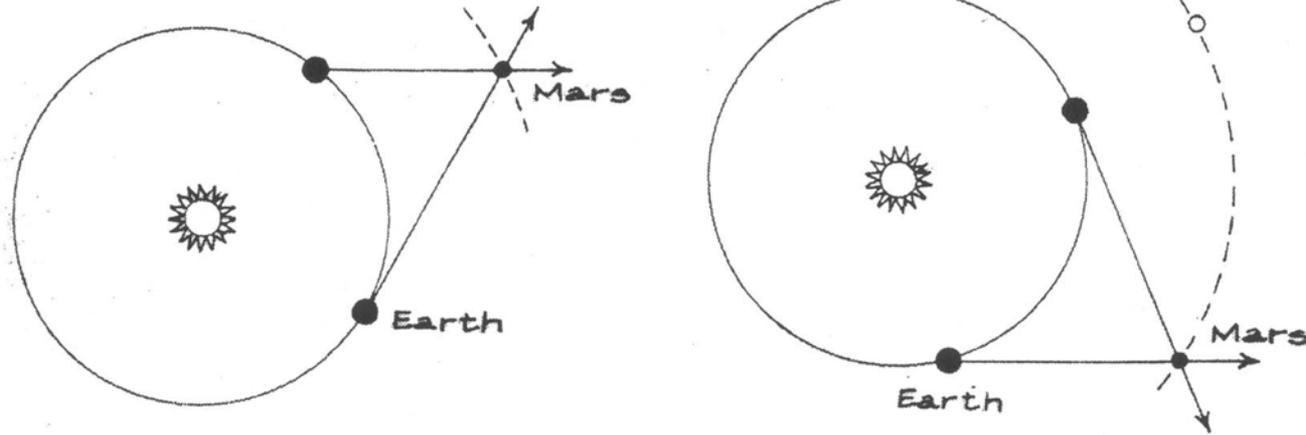
The War on Mars

Kepler spent 18 years on his 'War on Mars'.

By the study of the orbit of Mars, we must either arrive at the secrets of astronomy or forever remain in ignorance of them.

Johannes Kepler

Triangulating Mars



Kepler realized that if two observations of Mars were made **one sidereal period apart** then Mars would be back in the same location in space **but the earth would be in a different place in its orbit** thus allowing a triangulation of Mars! Many points of the Martian orbit could then be determined from the precise data he had available from Brahe's observations. He attempted to fit a variety of curves to the observations before arriving at the **ellipse** but **he had no satisfactory physical explanation for the motion of the planet.**

Recalling Appollonius!
&
Anticipating Newton

Kepler's First Law

The planets revolve
about the sun in an
elliptical orbit with the
sun at one focus.

QuickTime™ and a
decompressor
are needed to see this picture.

-visualization from Massimo Vicentini

Kepler's 2nd Law

QuickTime™ and a
None decompressor
are needed to see this picture.

Kepler's 3rd Law

$$P^2 \propto R^3$$

Harmonic Law:

the square of the period of the planet's revolution about the sun is proportional to the cube of the semi-major axis of its orbit.

QuickTime™ and a decompressor are needed to see this picture.

-model from dennis duke

Kepler's Three Laws of Planetary Motion

Important to realize that Kepler's three laws:

1. **The Elliptical Orbit Law.**
2. **The Area Law.**
3. **The Harmonic Law.**

Are empirical laws summarizing the observed planetary data and have to await Newton to provide their physical basis:

- i. Concept of force and acceleration*
- ii. A central inverse square law (gravity)*
- iii. Conservation of angular momentum*

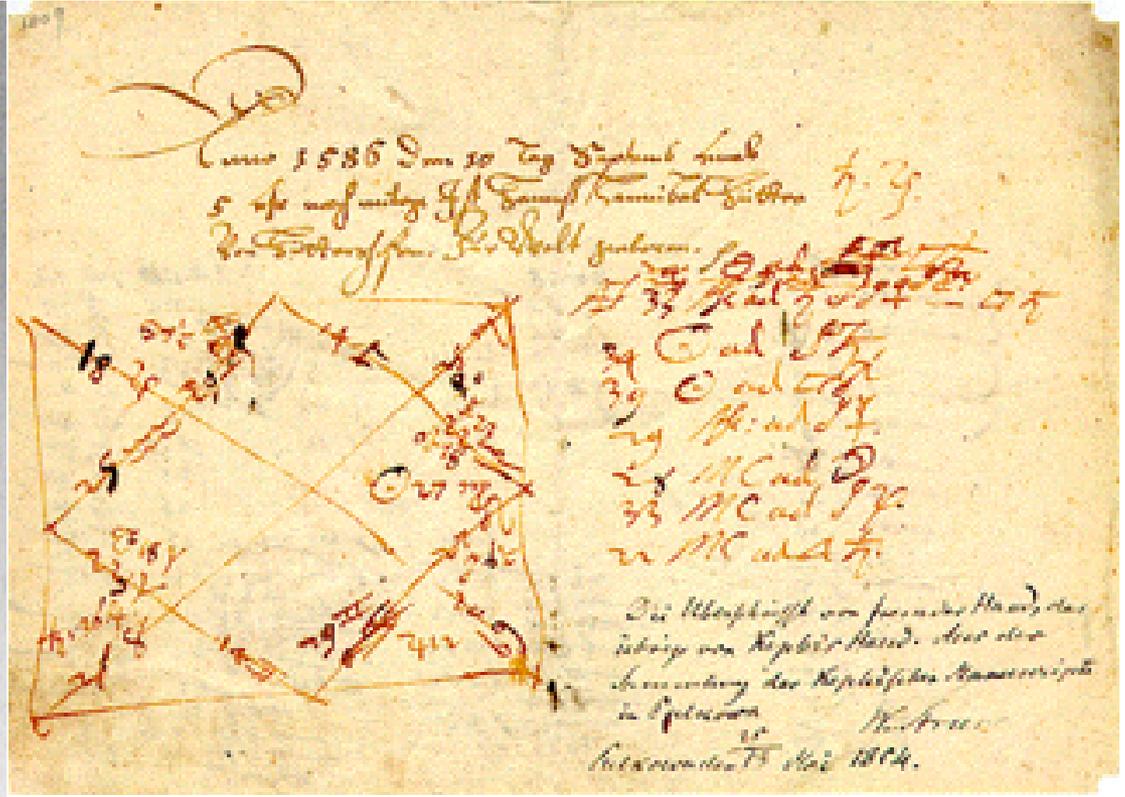
Somnium (1634)

“It is one of the curious ironies of history that the *Somnium* of Johann Kepler should have been almost completely neglected by historians both of science and of literature. Yet it was, in its final form, the last work of a great scientist; it is in itself no negligible item in the history of lunar theory; its notes include Kepler's last pronouncements on matters of great importance in both physics and astronomy. As a work of literature, it is important as the first modern scientific moon-voyage, and a chief source of many of the later "cosmic voyages" of the seventeenth and eighteenth centuries.”

-Marjorie Nicolson

Kepler, the Somnium, and John Donne(1940)

Kepler remembered



The astronomer Carl Sagan described him as
"The first **astrophysicist** and the last **scientific astrologer**."

The Questions

- 1) What classical ideas were repudiated by Kepler's Laws?
- 2) What was Newton's contribution to the understanding of Kepler's Laws?
- 3) What possible forms can orbits about the sun take?

The Bibliography

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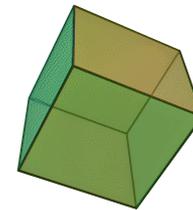
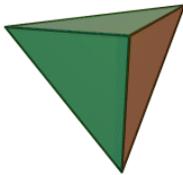
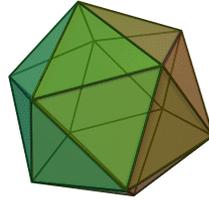
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The End

The Platonic Solids

