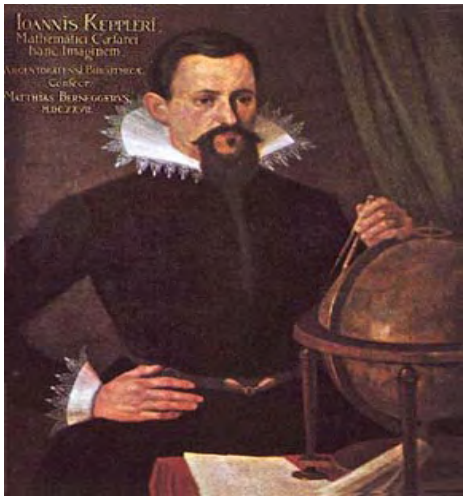
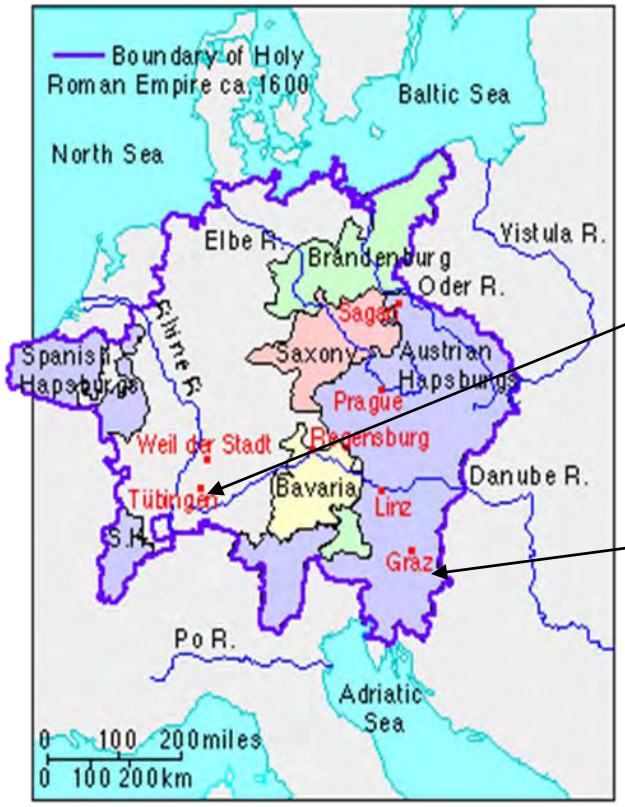


Johannes Kepler

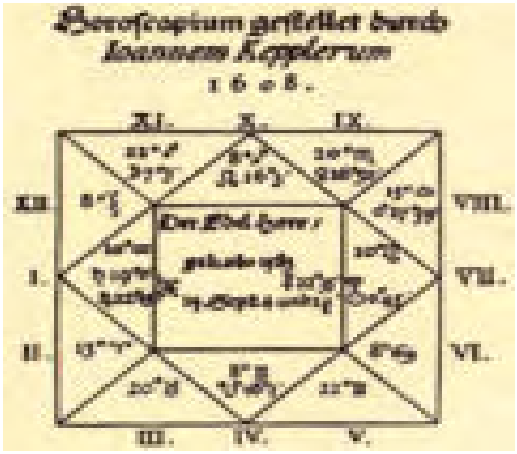
(1571-1630)

Kepler's "War on Mars"

Kepler: A short biography

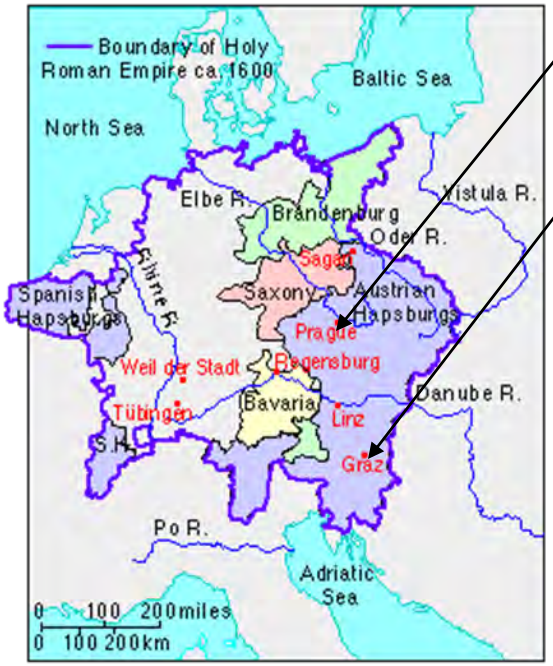


- Johannes Kepler was born in Thübingen, Germany, in1571. He was a sickly child and his parents were poor. A scholarship allowed him to enter the University of Tübingen.
- There he was introduced to the ideas of Copernicus. He first studied to become a priest in Poland but moved to Graz, Austria to teach school in 1596.
- As mathematics teacher in Graz, Austria, he wrote the first outspoken defense of the Copernican system, the *Mysterium Cosmographicum*.



A horoscope calculated by Kepler in 1608.

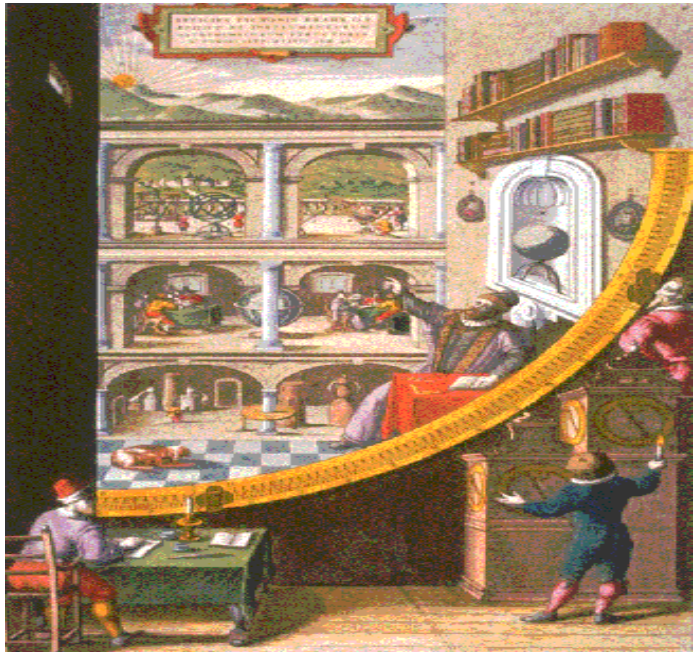
- Kepler was forced to leave his teaching post at Graz and he moved to Prague to work with the renowned Danish astronomer, Tycho Brahe.
- He inherited Tycho's post as Imperial Mathematician when Tycho died in 1601.
- Using the precise data that Tycho had collected, Kepler discovered that the orbit of Mars was an ellipse.
- .



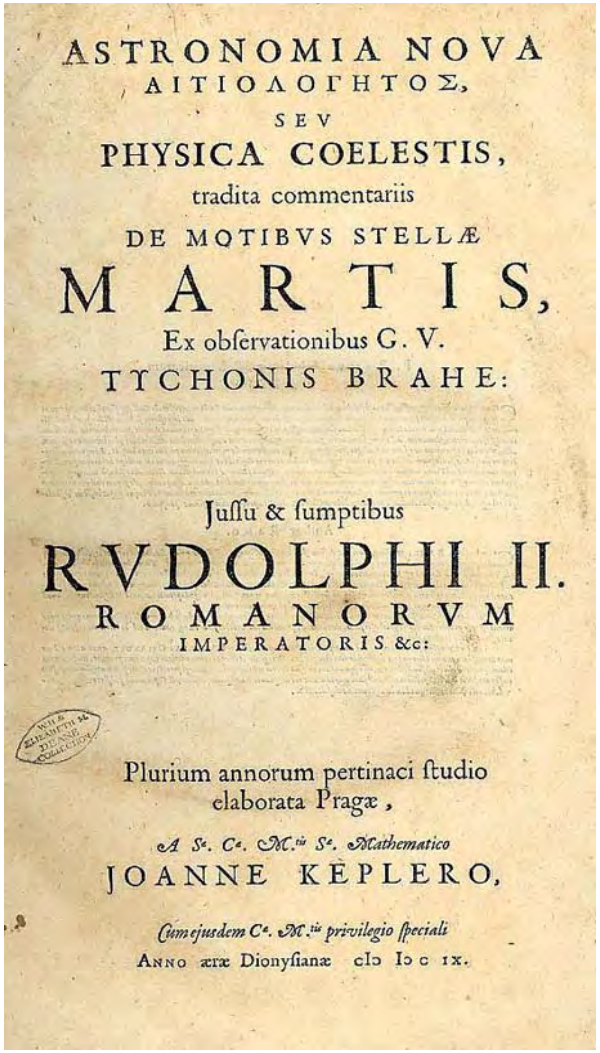
Kepler: **A short biography**

- Using the precise data 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



ASTRONOMIA NOVA
ΑΙΤΙΟΛΟΓΗΤΟΣ,
SEV
PHYSICA COELESTIS,
tradita commentariis
DE MOTIBVS STELLÆ
MARTIS,
Ex obſervationibus G. V.
TYCHONIS BRAHE:

Juſſu & ſumptibus
RVDOLPHI II.
ROMANORVM
IMPERATORIS &c:

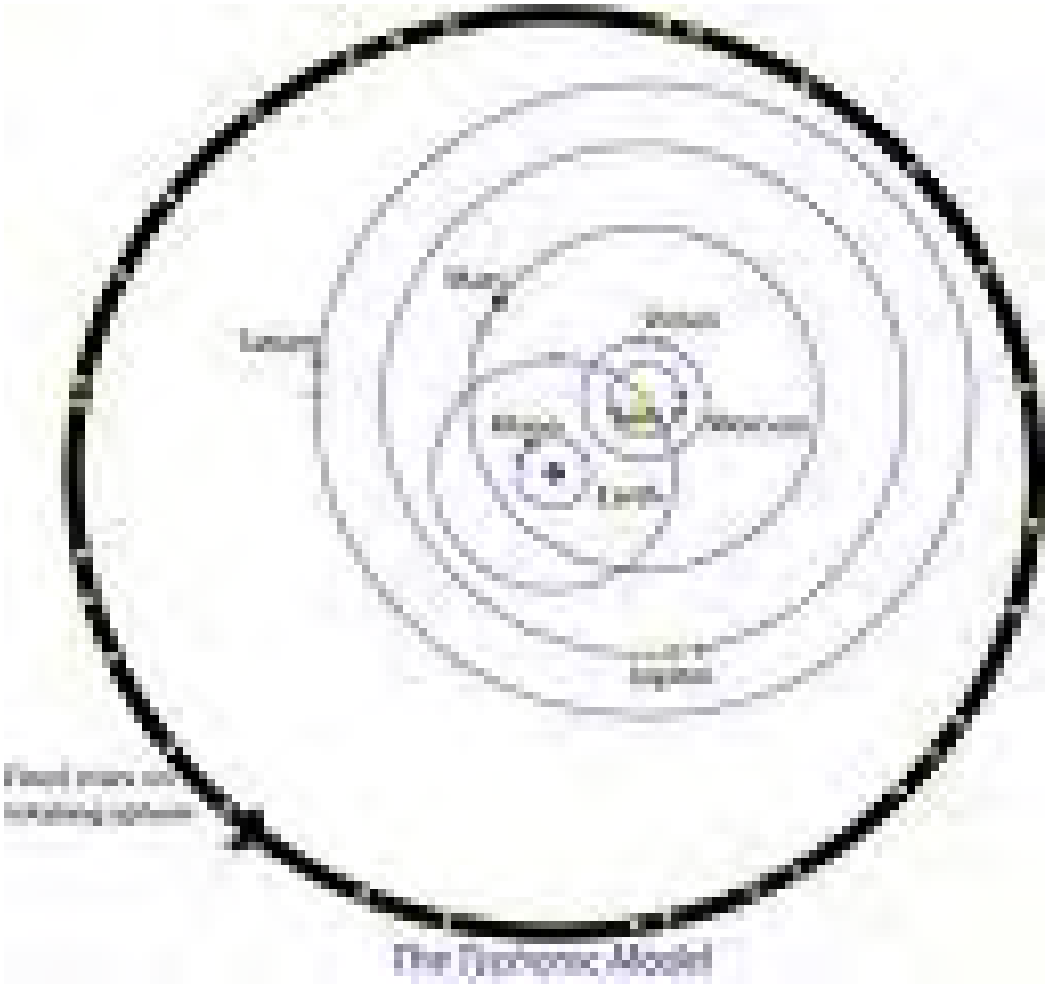
Plurium annorum pertinaci ſtudio
elaborata Pragæ,

A Sᵉ. Cᵃ. Mᵗⁱᵉ Sᵉ. Mathematico
JOANNE KEPLERO,

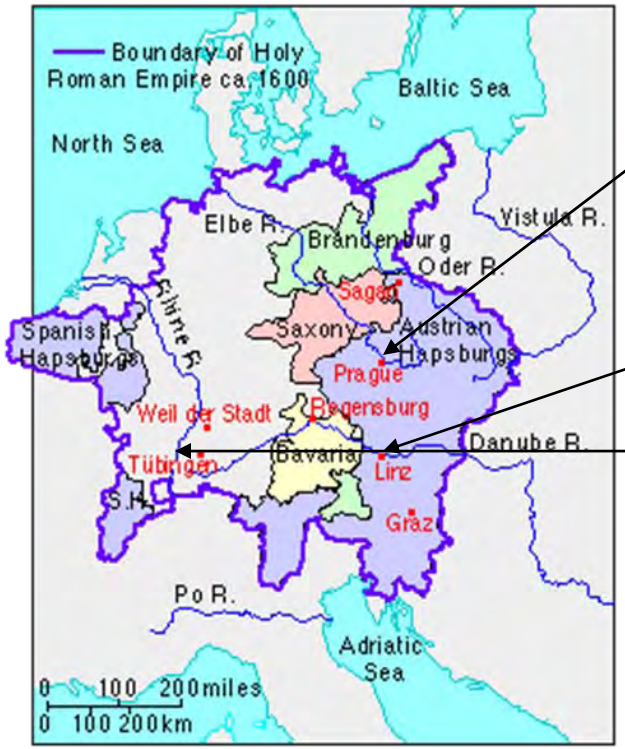
Cum ejusdem Cᵃ. Mᵗⁱᵉ privilegio ſpeciali
Anno æræ Dionyſianæ clɔ Iɔ c ix.

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

Tycho…

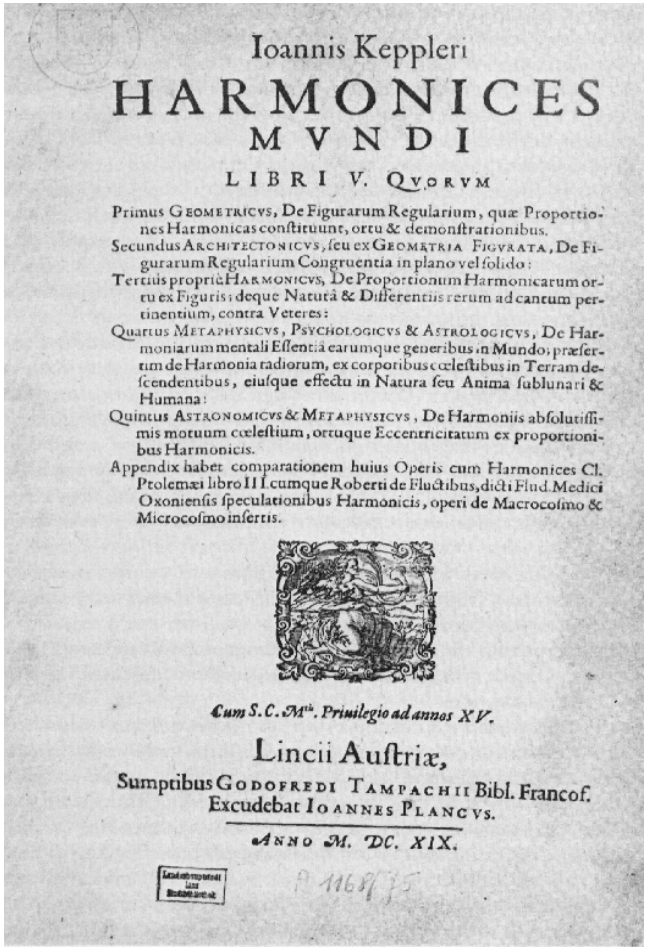


Kepler: A short biography



- In 1612 Lutherans were forced out of Prague, so Kepler moved on to Linz, Austria.
- His wife and two sons had recently died.
- Later, two infant daughters by his second wife also died.
- Kepler had to return to Württemburg, where he successfully defended his mother against charges of witchcraft.
- In 1619 he published *Harmonices Mundi*, in which he describes his "third law."

Kepler…

- 

Ioannis Keppleri

HARMONICES MVNDI

LIBRI V. QVORVM

Primus GEOMETRICVS, De Figurarum Regularium, quæ Proportiones Harmonicas constituunt, ortu & demonstrationibus.
Secundus ARCHITECTONICVS, seu ex GEOMETRIA FIGVRATA, De Figurarum Regularium Congruentia in plano vel solido:
Tertius propriè HARMONICVS, De Proportionum Harmonicarum ortu ex Figuris; deque Natutâ & Differentiis rerum ad cantum pertinentium, contra Veteres:
Quartus METAPHYSICVS, PSYCHOLOGICVS & ASTROLOGICVS, De Harmoniarum mentali Essentiâ earumque generibus in Mundo; præsertim de Harmonia radiorum, ex corporibus cœlestibus in Terram descendentibus, eiusque effectu in Natura seu Anima sublunari & Humana:
Quintus ASTRONOMICVS & METAPHYSICVS, De Harmoniis absolutissimis motuum cœlestium, ortuque Eccentricitatum ex proportionibus Harmonicis.
Appendix habet comparationem huius Operis cum Harmonices Cl. Ptolemæi libro III. cumque Roberti de Fluctibus, dicti Flud. Medici Oxonienſis ſpeculationibus Harmonicis, operi de Macrocosmo & Microcosmo inſertis.

Cum S. C. M^tis. Priuilegio ad annos XV.

Lincii Auſtriæ,
Sumptibus GODOFREDI TAMPACHII Bibl. Francof.
Excudebat IOANNES PLANCVS.

ANNO M. DC. XIX.

In 1619 he published *Harmonices Mundi*, in which he describes his "third law."

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).
- .

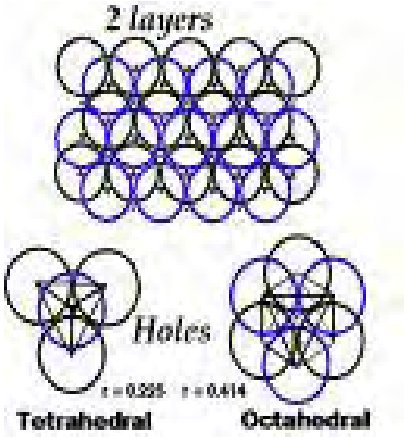
Kepler…

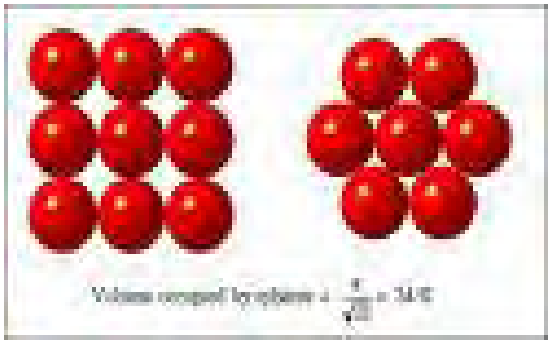
- Like Galileo, he believed that mathematics provided a secure method of arriving at truths about the world.

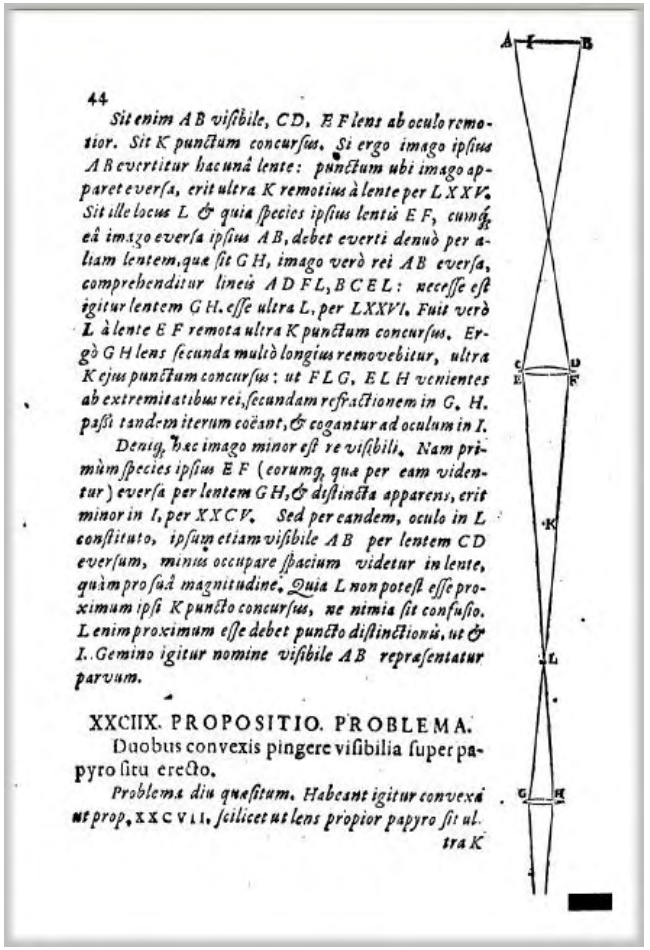
- He used Euclid's geometry, and after studying Copernicus and using the data of Tycho, he was convinced that the motion of the planets were around the sun in elliptical orbits

Kepler's accomplishments

- **Johannes Kepler** is now chiefly remembered for discovering the three laws of planetary motion that bear his name published in 1609 and 1619.
- He worked out the problem of packing
- He also did important work in optics,







44

Sit enim AB visibile, CD, EF lens ab oculo remotior. Sit K punctum concursus. Si ergo imago ipsius AB evertitur hacunâ lente: punctum ubi imago apparet eversa, erit ultra K remotius à lente per LXXV. Sit ille locus L & quia species ipsius lentis EF, cumq; eâ imago eversa ipsius AB, debet everti denuò per aliam lentem, quæ sit GH, imago verò rei AB eversa, comprehenditur lineis ADFL, BCEL: necesse est igitur lentem GH. esse ultra L, per LXXVI. Fuit verò L à lente EF remota ultra K punctum concursus. Ergò GH lens secunda multò longius removebitur, ultra K ejus punctum concursus: ut FLG, ELH venientes ab extremitatibus rei, secundam refractionem in G, H. passi tandem iterum coëant, & cogantur ad oculum in I.

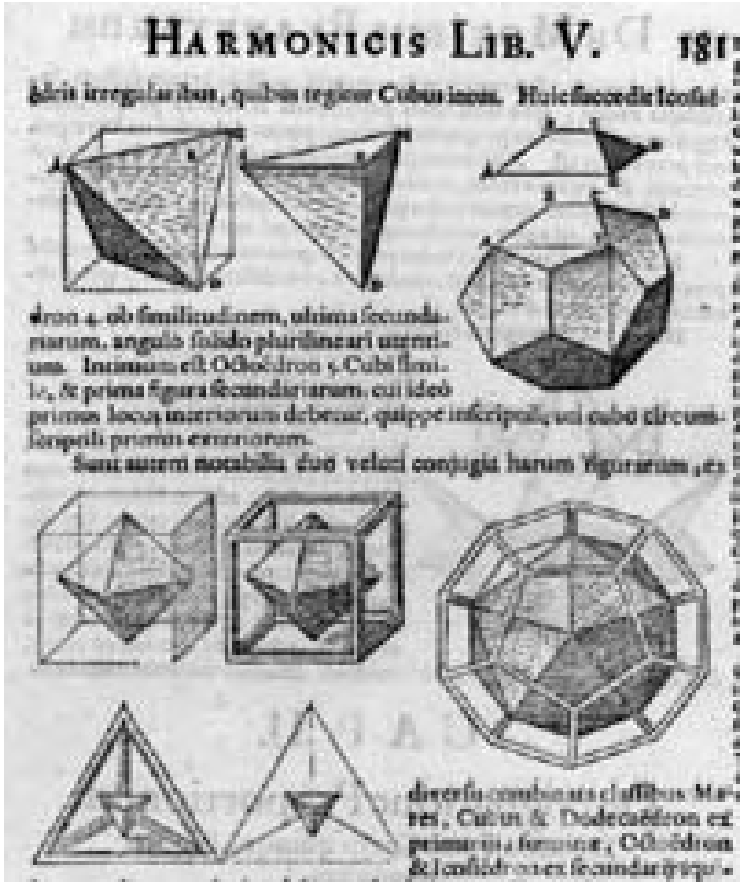
Denig, hæc imago minor est re visibili. Nam primùm species ipsius EF (eorumq; quæ per eam videntur) eversa per lentem GH, & distincta apparens, erit minor in I, per XXCV. Sed per eandem, oculo in L constituto, ipsum etiam visibile AB per lentem CD eversum, minus occupare spacium videtur in lente, quàm pro suâ magnitudine. Quia L non potest esse proximum ipsi K puncto concursus, ne nimia sit confusio. L enim proximum esse debet puncto distinctionis, ut & I. Gemino igitur nomine visibile AB repræsentatur parvum.

XXCIIX. PROPOSITIO. PROBLEMA.

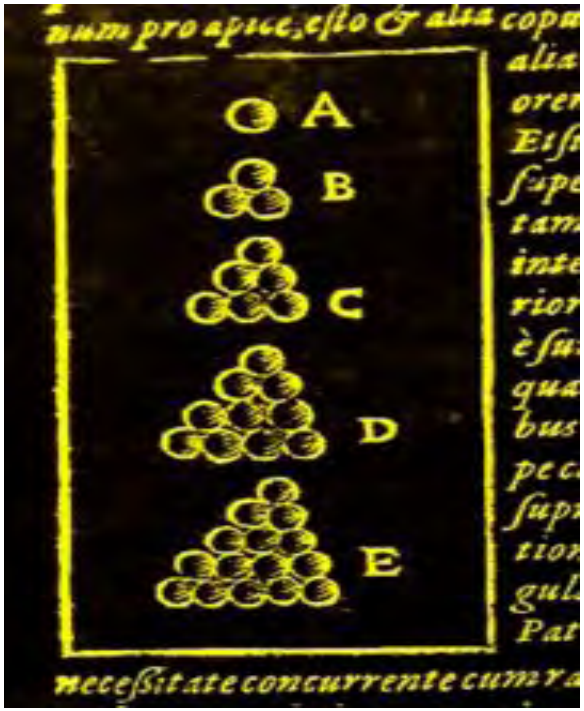
Duobus convexis pingere visibilia super papyro situ erecto.

Problema diu quæsitum. Habeant igitur convexa ut prop, XXCVII, scilicet ut lens propior papyro sit ultra K

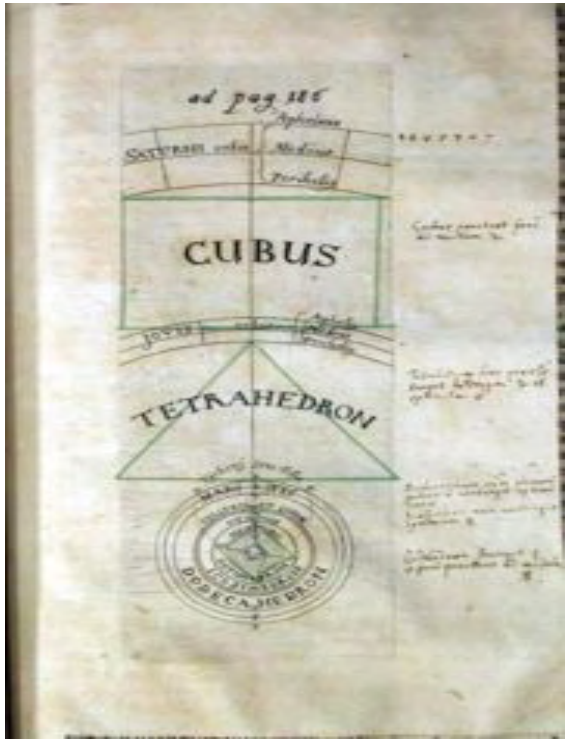
- Discovered two new regular polyhedra (1619),
- Gave the first mathematical treatment of close packing of equal spheres (leading to an explanation of the shape of the cells of a honeycomb, (1611),
-



Kepler's accomplishments…



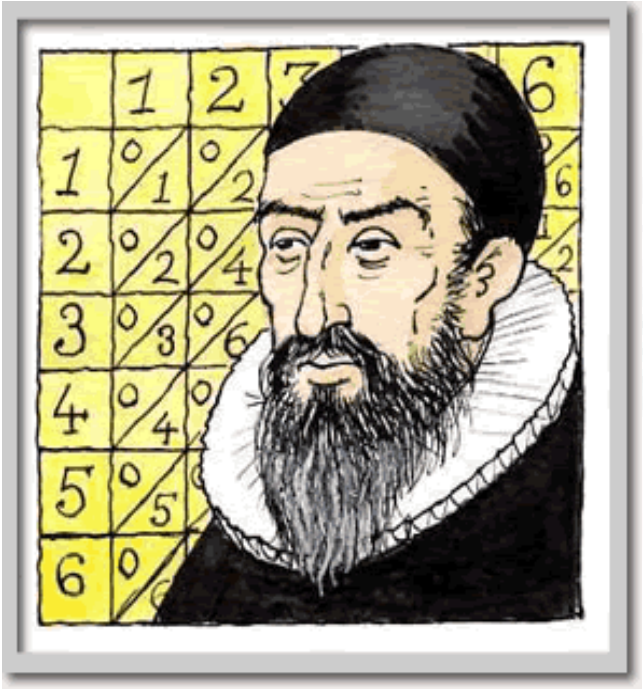
•One of the diagrams from *Strena Seu de Nive Sexangula*, illustrating the Kepler conjecture

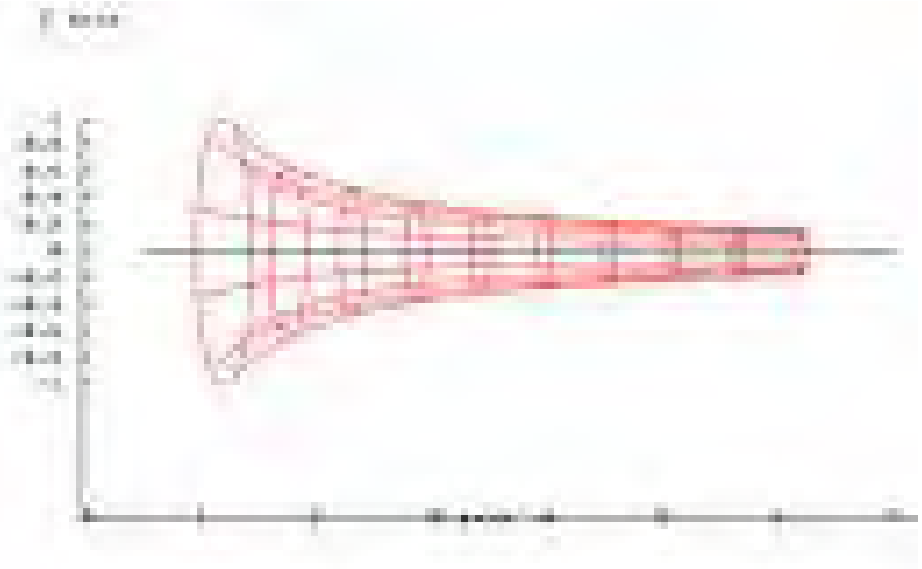


Geometrical harmonies in the regular polygons from *Harmonices Mundi* (1619)

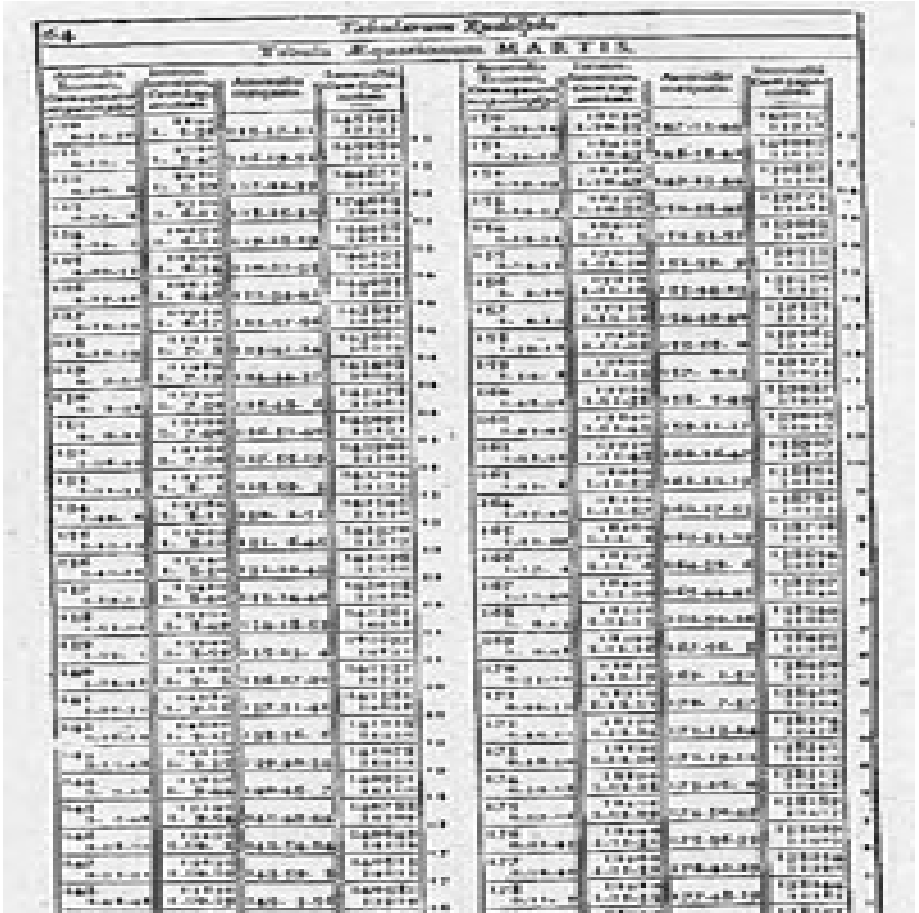
Kepler's accomplishments…

- 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).

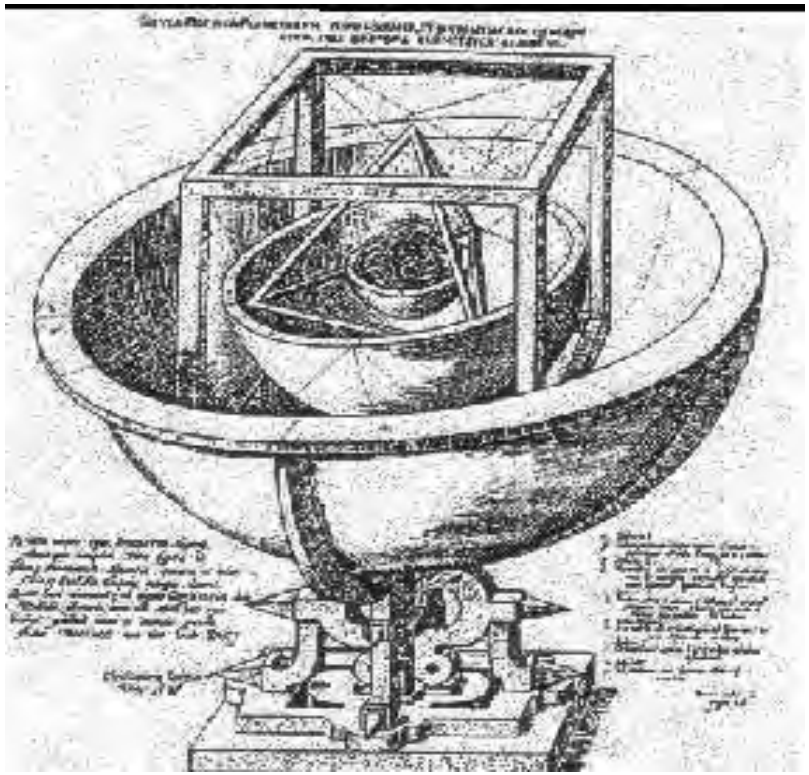


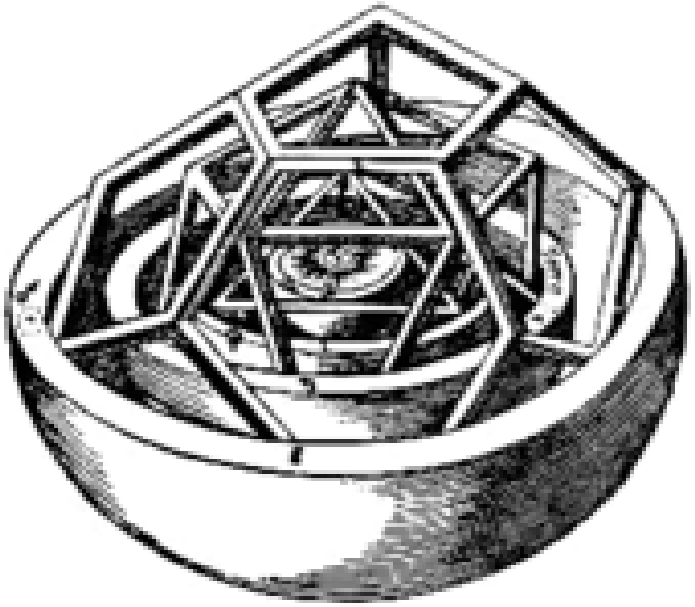


- He calculated the most exact astronomical tables hitherto known, whose continued accuracy did much to establish heliocentric astronomy (*Rudolphine Tables*, Ulm, 1627).



Kepler’s accomplishments…



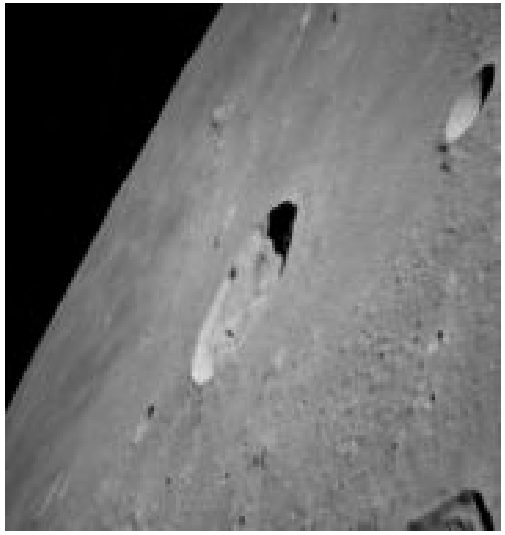


- Kepler's Platonic solids model of the Solar system from *Mysterium Cosmographicum* (1596).

.

Kepler remembered

A statute of Kepler and Tycho Brahe in Prague



The Kepler Crater on the moon

Kepler remembered…

- The iconic frontispiece to the *Rudolphine Tables* celebrates the great astronomers of the past:
- Hipparchus, Ptolemy, Copernicus,

and most prominently,

- Tycho Brahe

Kepler remembered…

- 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.

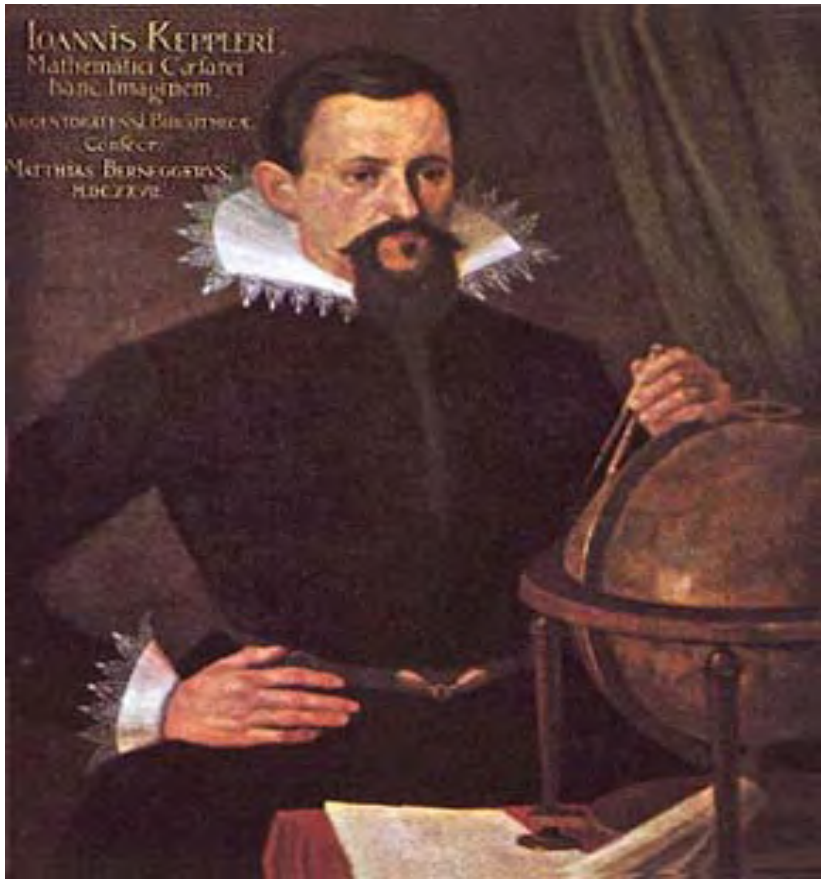
Kepler remembered…

- The astronomer Carl Sagan described him as

> “The first astrophysicist and the last scientific astrologer."

Kepler: His astronomy

Kepler
(about 1610)



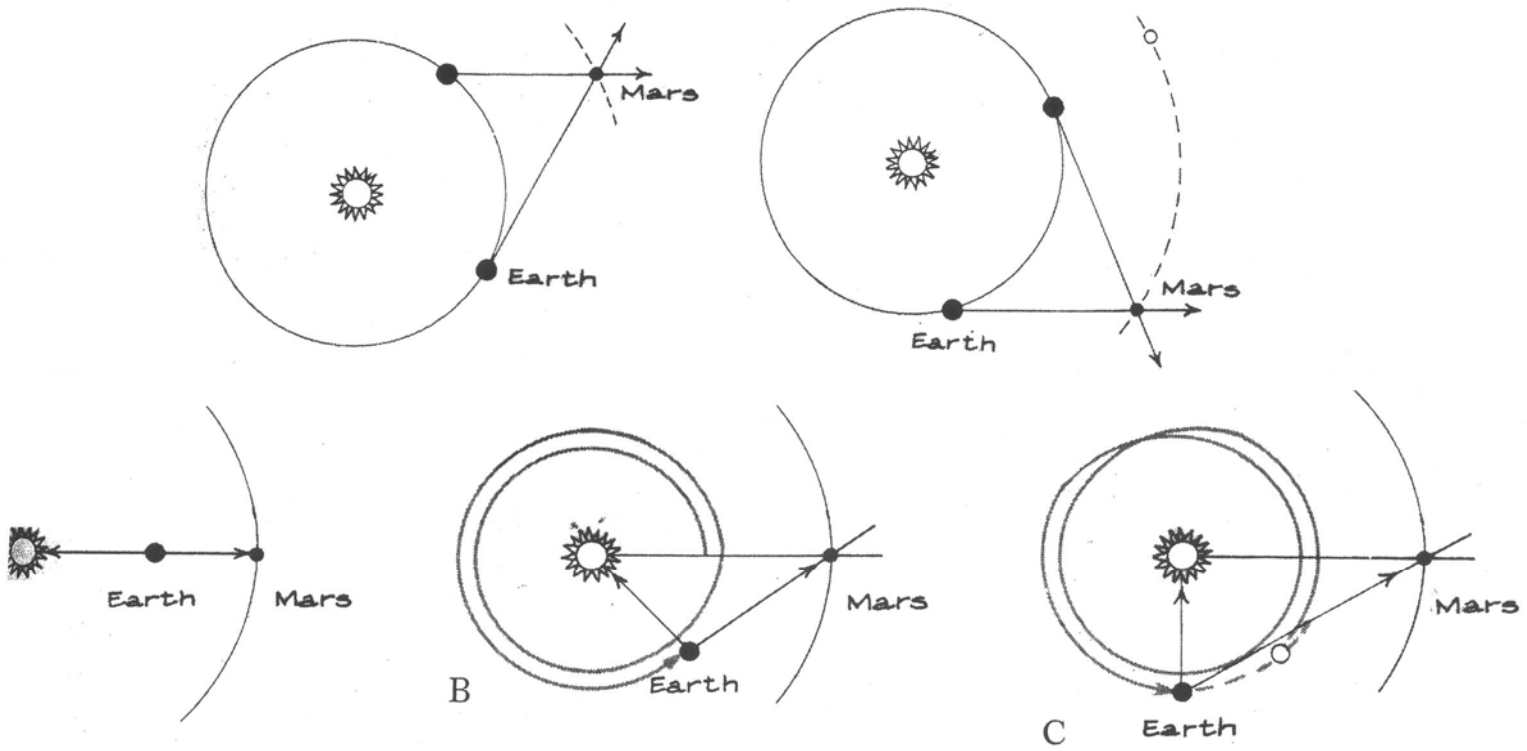
Kepler…

- Kepler's 18 years of 'My War on Mars'.

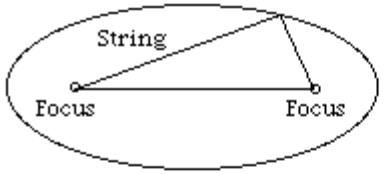
By the study of the orbit of Mars,
we must either arrive at the secrets of astronomy or forever remain in ignorance of them.

Johannes Kepler

Kepler…

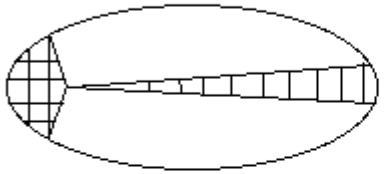


- The three laws of Kepler



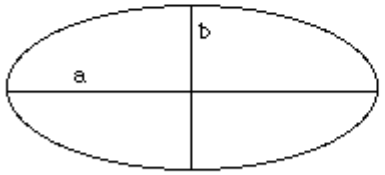
Law #1

Orbits are elliptic



Law #2

Areas swept in eaqual time are equal



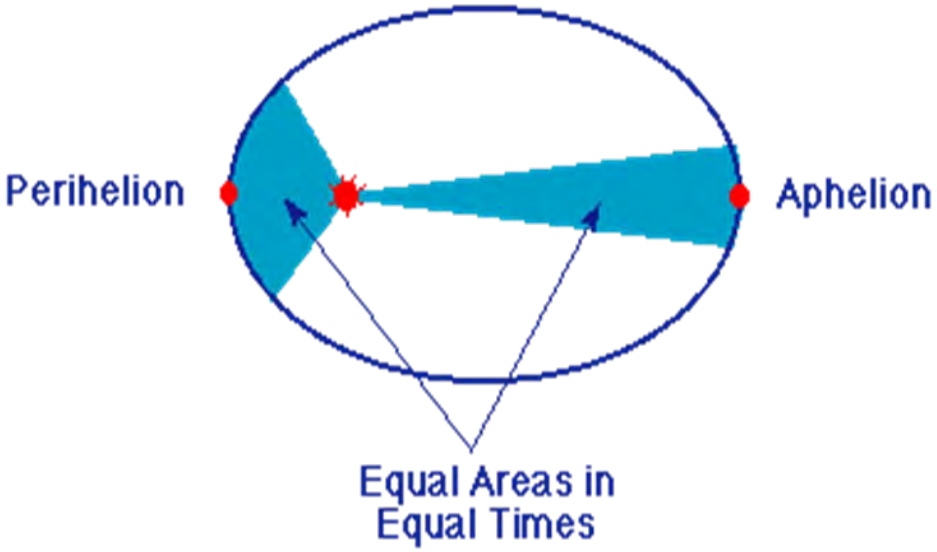
Law #3

Average distance of a planet from the sun is equal to semi-major axis of the ellipse. Square of the Time Period (time to complete one revolution around the orbit) is proportional to the cube of this distance.

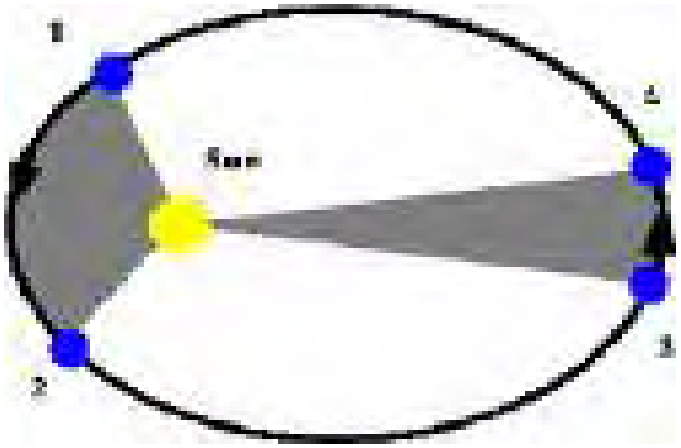
1. **Planets move in elliptical orbits.**

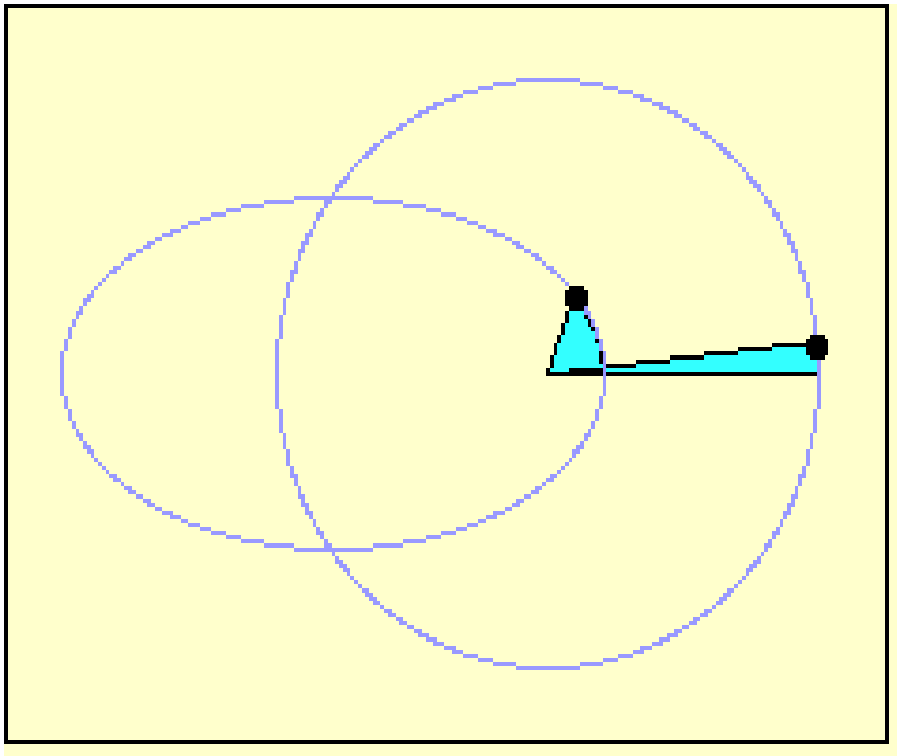
2. **Area Rule**

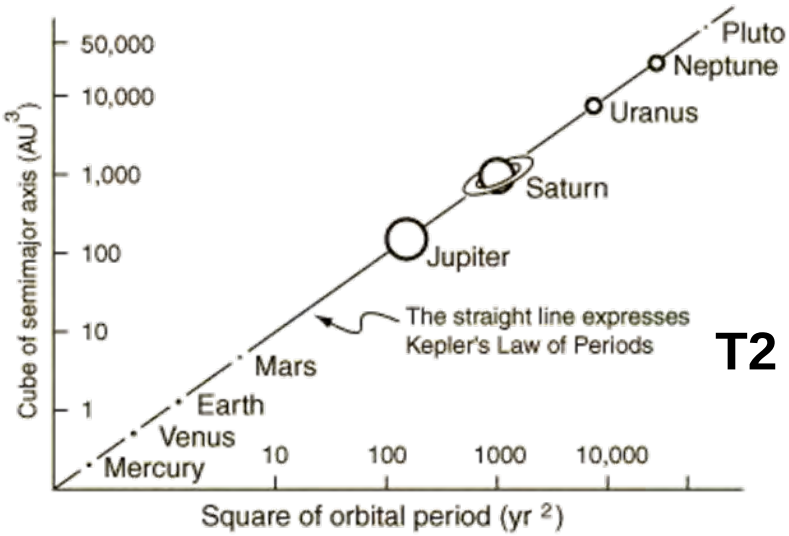
3. **T2 / R3 = Const.**



Johannes Kepler is now chiefly remembered for discovering the three laws of planetary motion

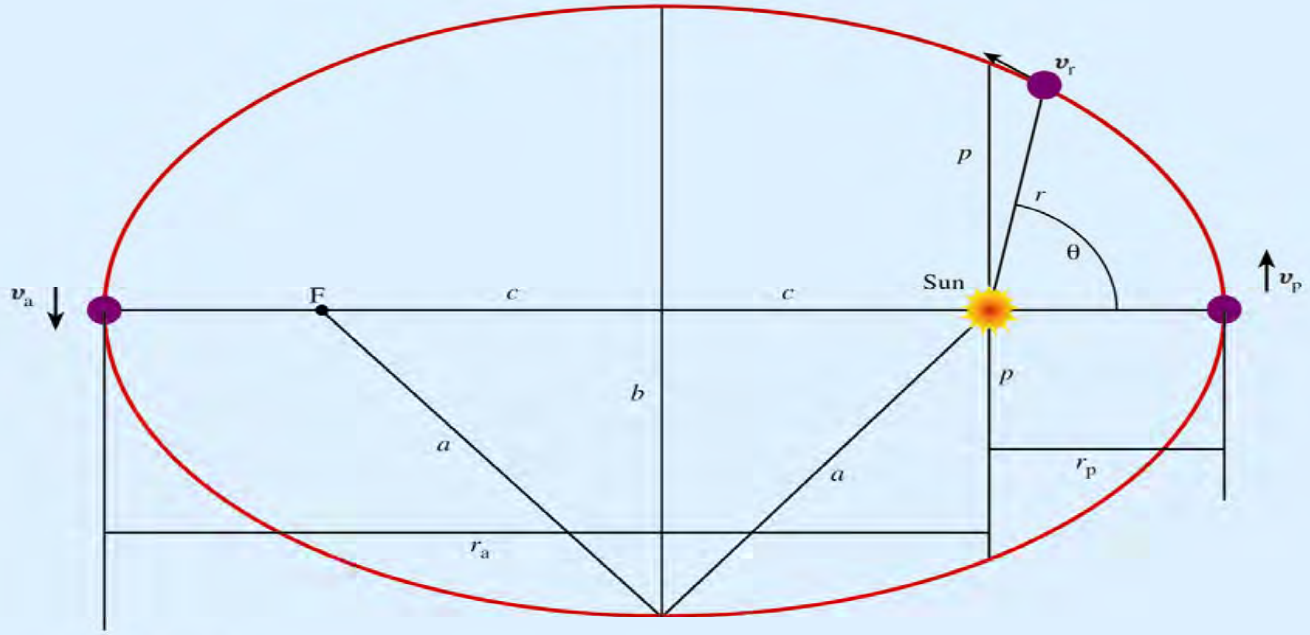






T2 / R3 = Constant

Kepler…



F = Focal point

$a = (r_p + r_a)/2$	a = semimajor axis
$e = c/a = (a - r_p)/a$	r_p = perihelion distance (closest to Sun)
$b^2 + c^2 = a^2$	r_a = aphelion distance (farthest from Sun)
$r = p/(1 - e\cos\theta)$	e = eccentricity of the orbit
$p = a(1 - e^2)$	θ = angle, defined
$v_r = 29.8\ (2/r - 1/a)^{1/2}$	v_r = the velocity of a body revolving around the Sun at a given distance r
	p = half the latus rectum

Figure 2. The ellipse and its application to orbits.

Kepler…

Newton checks his inverse square law with Kepler's third law.

- Kepler's second law is an expression of the principle of the conservation of angular momentum.

- The *vis viva* equation is based on the Principle of conservation of energy

The mathematics

- The *vis viva* equation of orbital motion.
- **$v = \{GM\,(2 / r - 1/a)\}^{1/2}$**

- This can be written as:

  $v = 29.8\,(2 / r - 1/a)^{1/2}$ (km/s)