the Scientific Revolution:

the Cosmos Mechanized

Ptolemaeus to Copernicus

One school in history of astronomy:

minor imperfections in the original Ptolemaic system were discovered through observations accumulated over time.

It was mistakenly believed that more levels of epicycles (circles within circles) were added to the models to match more accurately the observed planetary motions.

The multiplication of epicycles is believed to have led to a nearly unworkable system by the 16th century.

Copernicus created his heliocentric system in order to simplify the Ptolemaic astronomy of his day, thus succeeding in drastically reducing the number of circles.

With better observations additional epicycles and eccentrics were used to represent the newly observed phenomena till in the later Middle Ages the universe became a 'Sphere/With Centric and Eccentric scribbled o'er,/Cycle and Epicycle, Orb in Orb'

Alfonsine Tables

- Tables of solar, lunar and planetary positions wrt. fixed stars
- Called after Alfons X of Castile the Wise (el Sabio) (1221-1284)
- composed in 1252, in Toledo
- assembled by translators of Toledo
- based on observations an studies of Islamic scholars

- most popular astronomical tables for 300 years (incl. Copernicus)

Tabula equationis dierum cum nodibus suis

Tabula ... additionis dierum longioribus et ...

Ptolemaeus to Copernicus

- As a measure of complexity:

  - the number of circles is given as 80 for Ptolemy,
  - versus a mere 34 for Copernicus

- *By this time each planet had been provided with from 40 to 60 epicycles to represent after a fashion its complex movement among the stars. Amazed at the difficulty of the project, Alfonso is credited with the remark that had he been present at the Creation he might have given excellent advice.*

- **1543**
  Nicolaus Copernicus
  - publishes heliocentric universe in De Revolutionibus Orbium Coelestium
  - implicit introduction Copernican principle: Earth/Sun is not special

- **1609-1632**
  Galileo Galilei
  - by means of (telescopic) observations, proves the validity of the heliocentric Universe.

- **1609/1619**
  Johannes Kepler
  - the 3 Kepler laws, describing the elliptical orbits of the planets around the Sun

- **1687**
  Isaac Newton
  - discovers Gravitational Force as agent behind cosmic motions
  - publishes his Principia (Philosophiae Naturalis Principia Mathematica), which establishes
     the natural laws of motion and gravity (the latter only to be replaced by Einstein's theory of GR)

- **1755**
  Immanuel Kant
  - asserts that nebulae are really galaxies separate from and outside from the Milky Way,
   - calling these Island Universes

- **1785**
  William Herschel
  - proposes theory that our Sun is at or near the center of ou Galaxy (Milky Way)

Nikolaus Copernicus
(1473-1543)

Nicolaus Copernicus

1473 – born in Torun (Poland)

1491-1495 - study Univ. Krakow
1496-1501 - 3 years Univ. Bologna - canon law
1503- - Warmia
1514 - Frombork

Languages: Latin , German

1514 - Commentariolus
Nicolai Copernici de hypothesibus motuum coelestium a se constitutis commentariolus

+ theoretical treatise on heliocentric mechanism
+ 40 pages, 7 basic assumptions

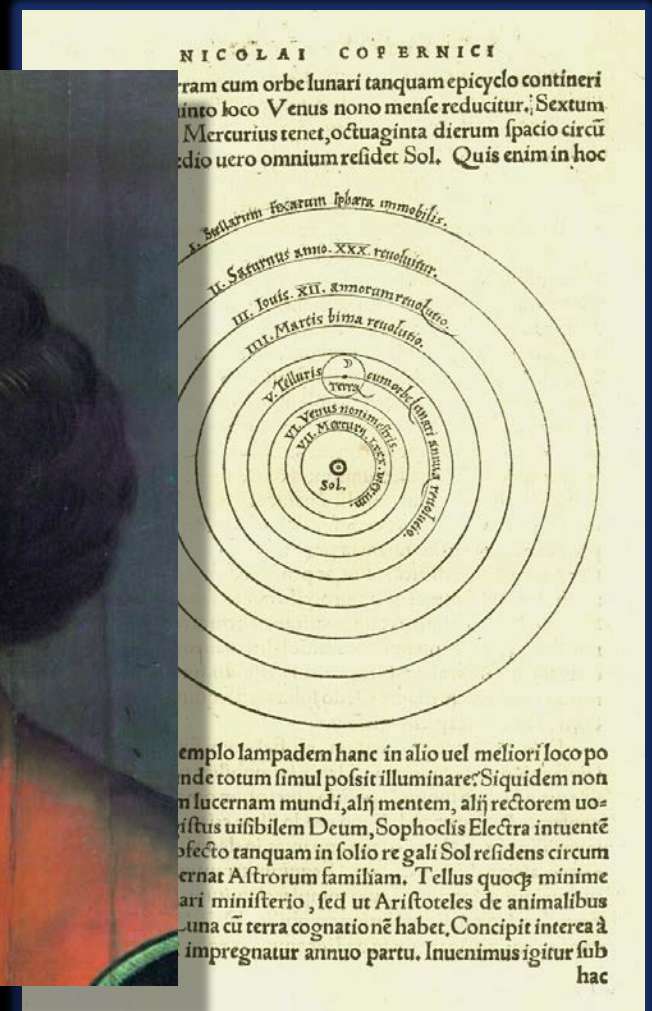

Tower (living) Copernicus, Frombork
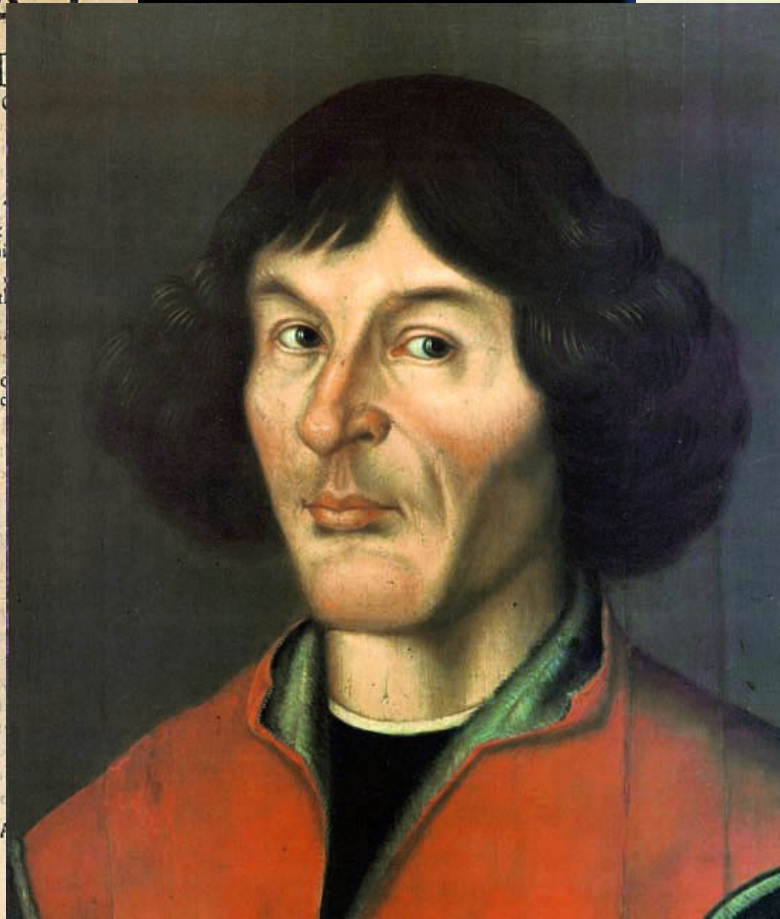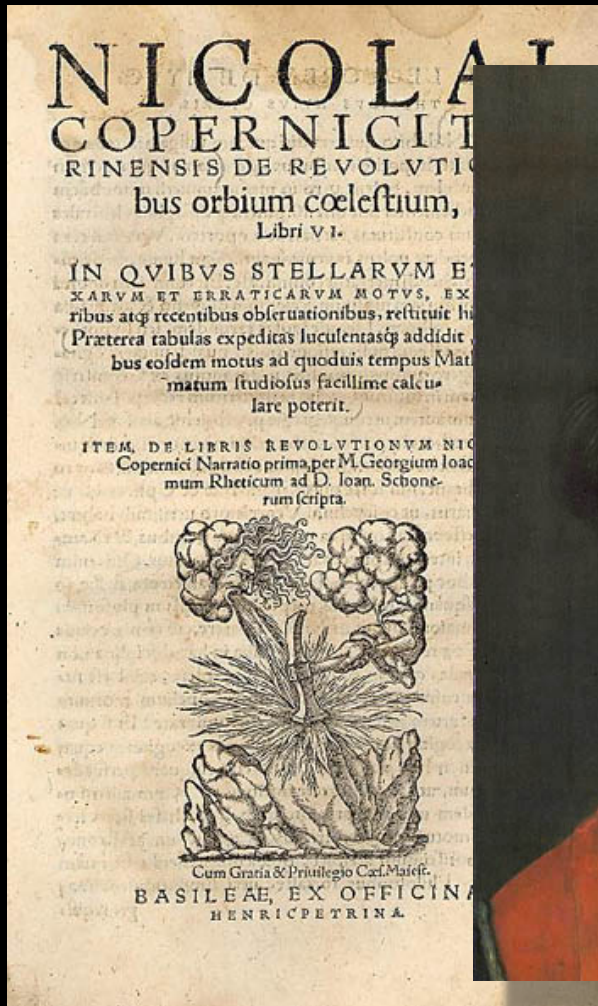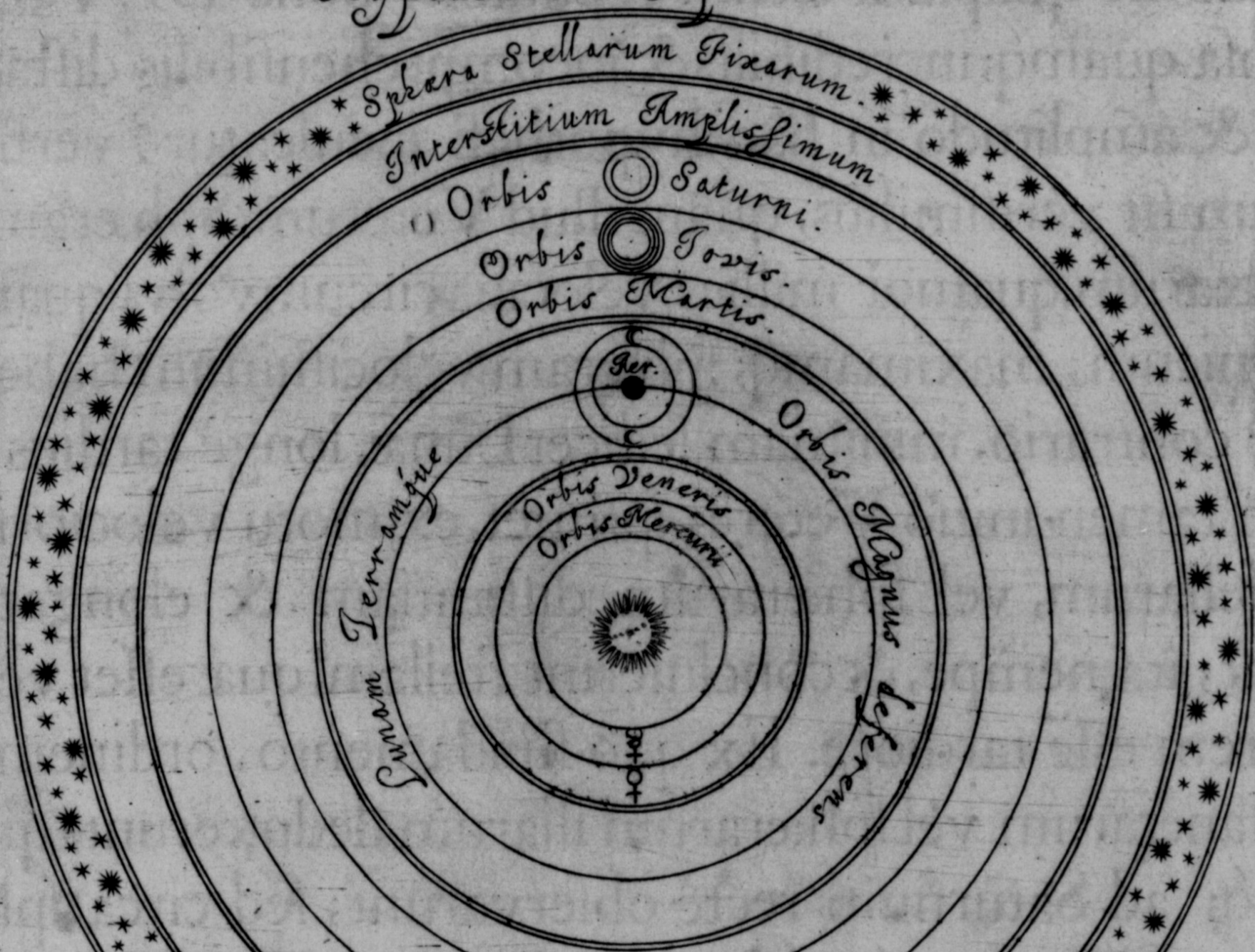

Frombork Cathedral

Commentariolus

1. There is no one center of all the celestial circles or spheres.

2. The center of the earth is not the center of the universe, but only of gravity and of the lunar sphere.

3. All the spheres revolve about the sun as their midpoint, and therefore the sun is the center of the universe.

4. The ratio of the earth's distance from the sun to the height of the firmament (outermost celestial sphere containing the stars) is so much smaller than the ratio of the earth's radius to its distance from the sun that the distance from the earth to the sun is imperceptible in comparison with the height of the firmament.

5. Whatever motion appears in the firmament arises not from any motion of the firmament, but from the earth's motion. The earth together with its circumjacent elements performs a complete rotation on its fixed poles in a daily motion, while the firmament and highest heaven abide unchanged.

6. What appear to us as motions of the sun arise not from its motion but from the motion of the earth and our sphere, with which we revolve about the sun like any other planet. The earth has, then, more than one motion.

7. The apparent retrograde and direct motion of the planets arises not from their motion but from the earth's. The motion of the earth alone, therefore, suffices to explain so many apparent inequalities in the heavens.

De Revolutionibus

NICOLAI
COPERNICI T...
RINENSIS DE REVOLUTIO...
bus orbium cœlestium,
Libri VI.

IN QVIBVS STELLARVM ET
XARVM ET ERRATICARVM MOTVS, EX
ribus atq; recentibus obseruationibus, restituit hi...
(Præterea tabulas expeditas luculentasq; addidit,...
bus eosdem motus ad quoduis tempus Math...
matum studiosus facillime calcu-
lare poterit.

ITEM, DE LIBRIS REVOLVTIONVM NI...
Copernici Narratio prima, per M. Georgium Ioac...
mum Rheticum ad D. Ioan. Schone-
rum scripta.

Cum Gratia & Priuilegio Cæf.Maiest.
BASILEAE, EX OFFICINA
HENRICPETRINA.

NICOLAI COPERNICI
...ram cum orbe lunari tanquam epicyclo contineri
...into loco Venus nono mense reducitur. Sextum
Mercurius tenet, octuaginta dierum spacio circu
...dio uero omnium residet Sol. Quis enim in hoc

...emplo lampadem hanc in alio uel meliori loco po
...nde totum simul possit illuminare? Siquidem non
...n lucernam mundi, alij mentem, alij rectorem uo
...iftus uisibilem Deum, Sophoclis Electra intuentē
...ofecto tanquam in solio re gali Sol residens circum
...ernat Astrorum familiam. Tellus quoq; minime
...ari ministerio, sed ut Aristoteles de animalibus
...una cū terra cognationē habet. Concipit interea à
...impregnatur annuo partu. Inuenimus igitur sub
hac

Orbium Coelestium

Hypothecis Copernicana.

Sphæra Stellarum Fixarum.

Interstitium Amplissimum

Orbis ☉ Saturni.

Orbis Iovis.

Orbis Martis.

Ter.

Orbis Magnus deferens

Orbis Veneris
Orbis Mercurii

Lunam Terramq́ue

Nicolaus Copernicus

1543 – publication
De Revolutionibus Orbium Coelestium
(On the Revolution of the Celestial Spheres)

1514- **Commentariolus (Little Commentary)**
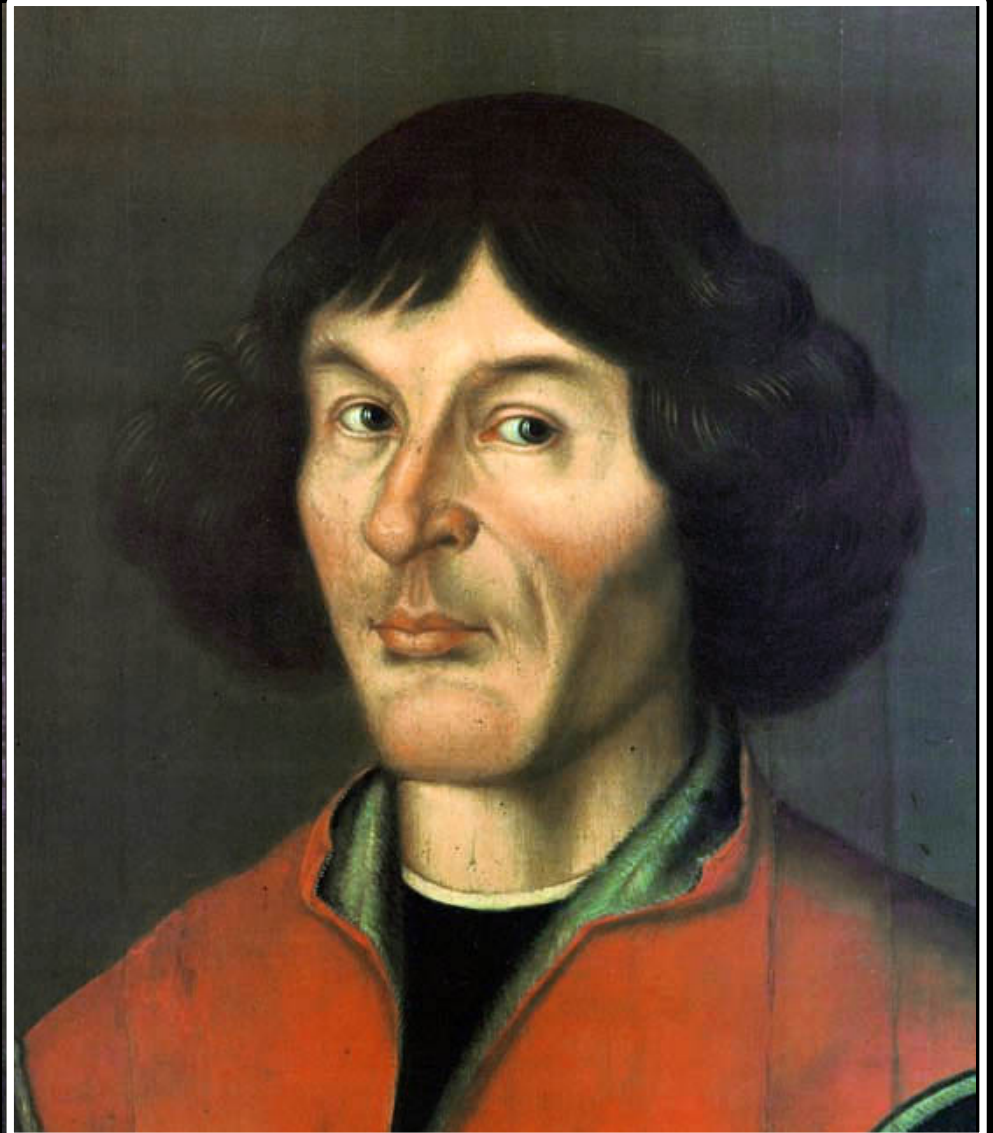1532 – finished work on Revolutionibus

1543 - publication pushed and processed
    by George Joachim Rheticus
    (mathematician Wittenberg)

  - printed by
   Johannes Petreius, Nuremburg

May 24, 1543 - death Copernicus
        - legend: presentation last
         pages printed Revolutionibus

Note:
Copernicus cited Aristarchus of Samos in an early
(unpublished) manuscript of De Revolutionibus (which
still survives), though he removed the reference from
his final published manuscript.

INSULA HVÆNA sive VENUSIA

ARCIS VRANIBVRGI, A TYCHONE BRAHE, DÑO DE KNVDSTRVP, IN INSVLA HELLESPONTI DANICI HVENNA CONSTRVCTÆ, QVO AD TOTAM CAPACITATEM, DESIGNATIO.

**Observatory Uranienborg
on island Hven (nowadays between Sweden-Denmark)**

Tycho Brahe
(1546-1601)

Tycho Brahe   (1546-1601)
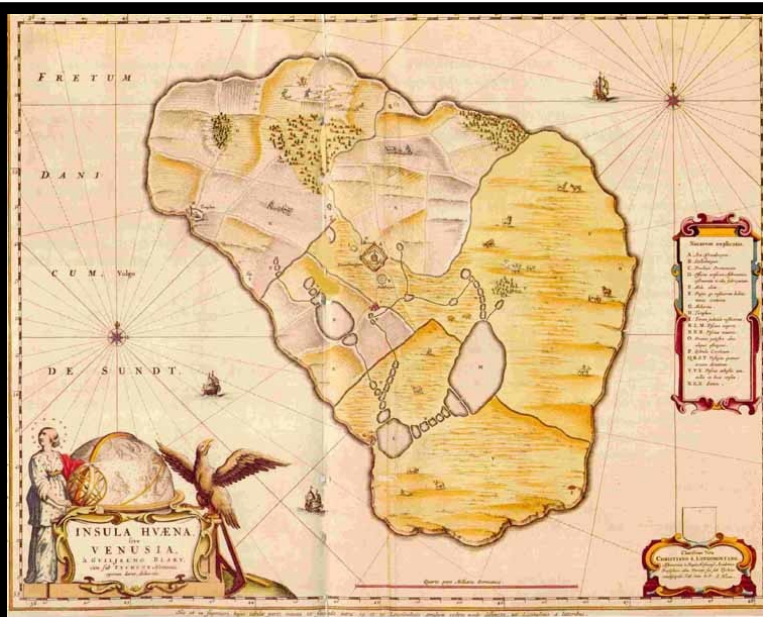
- Danish nobleman
- astronomer, astrologer, alchemist
- Observatory Uraniborg on island Hven
- Hven was his fiefdom
- entire island Hven devoted to exploitation for observatory

- Brahe famous for high
  + acccuracy
  + quantity
  astronomical and planetary observations
- before telescope

- Key to Scientific Revolution

Quadrant

Achieved
Accuracy
~1'-2'
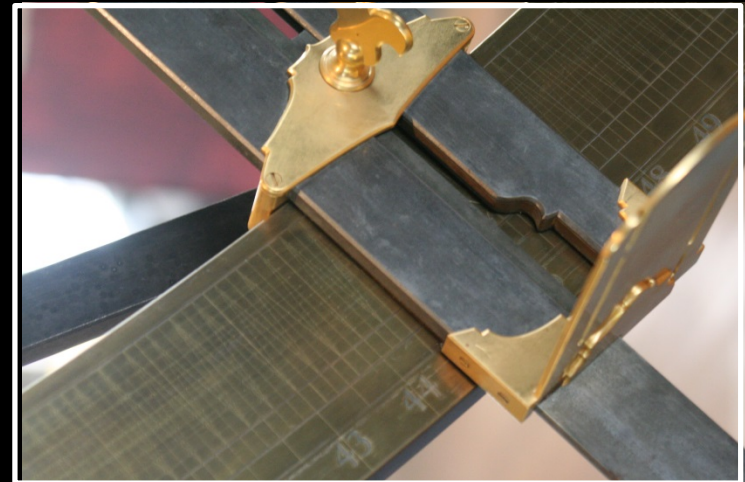
Uraniborg

Uraniborg

- Island Hven given to Tycho by Danish king Frederik II

- 1576:
  building of Uraniborg

- 1581:
  building of annex, Stjerneborg

- cellar Uraniborg:
  alchemy experiments

- 1576-1597
  ~ 100 students & assistants

- research community in Research Center & Institution of Education

QVADRANS MVRALIS
SIVE TICHONICVS.

EXPLI-
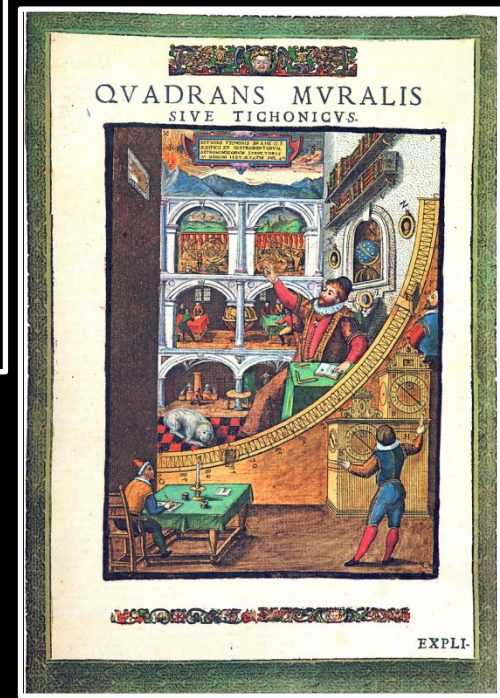
De Nova Stella (1572)

End of the Aristoteleian cosmological view that
- the world beyond the Moon is eternally unchanging

- 11 Nov. 1572
  Tycho observed
  a new star
- Constellation Cassiopeia

- At hindisight it has
  been 1 of the 5 visible
  supernovae that have
  exploded in the Galaxy
  over the past 1000 years
- distance: 7500 lightyears

- Tycho published this
  in De Nova Stella

A caput Caßiopeæ
B pectus Schedir.
C Cingulum
D flexura ad Ilia
E Genu
F Pes
G suprema Cathedræ
H media Chatedræ
I Noua Stella.
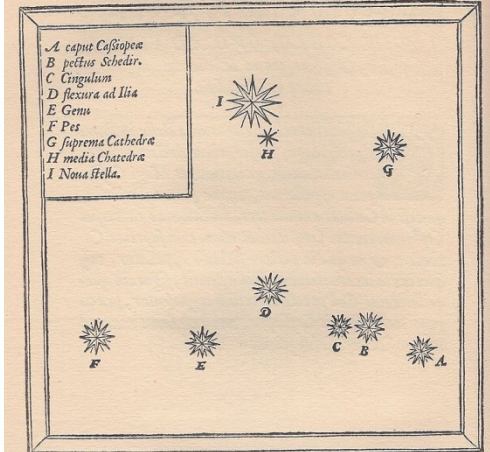
Distantiam verò huius Stellæ à fixis aliquibus
in hac Caßiopeiæ constellatione, exquisito instrumento,
& omnium minutorum capacj, aliquoties observaui. In-
ueni autem eam distare ab ea, quæ est in pectore, Schedir
appellata B, 7. partibus & 55. minutis : à superiori
verò

Supernova remnant

SN1572
Tycho's SNR (1572)

Exploding star
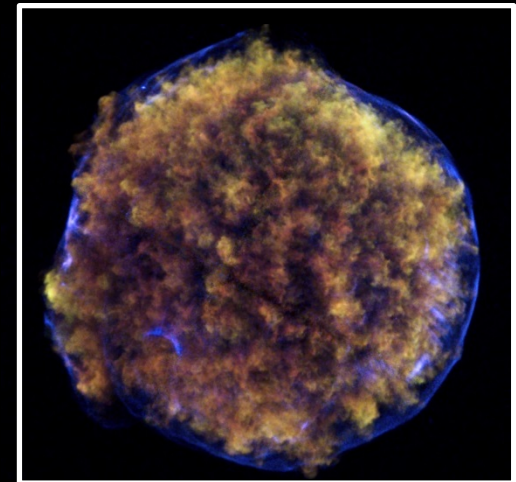
Geo-Heliocentric Model

**Tycho's Geo-Heliocentric Model:**

- Sun circles the Earth
- Planets circle the Sun
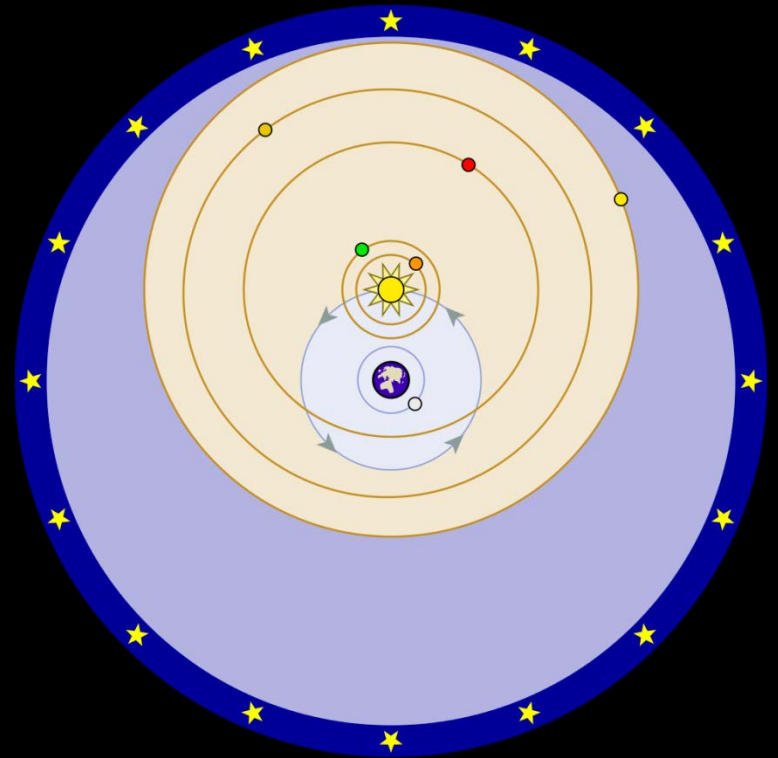
Geo-Heliocentric Model

Tycho did not accept the heliocentric view of Copernicus:

- Observational data in 16th century were not
  good enough to prove it.
- No stellar parallax could be measured:
  would imply stars to be so distant they would be larger than Sun
- Completely eliminited the ancient (Aristotelean)
  idea of heavenly spheres
- "Earth is a lazy body":
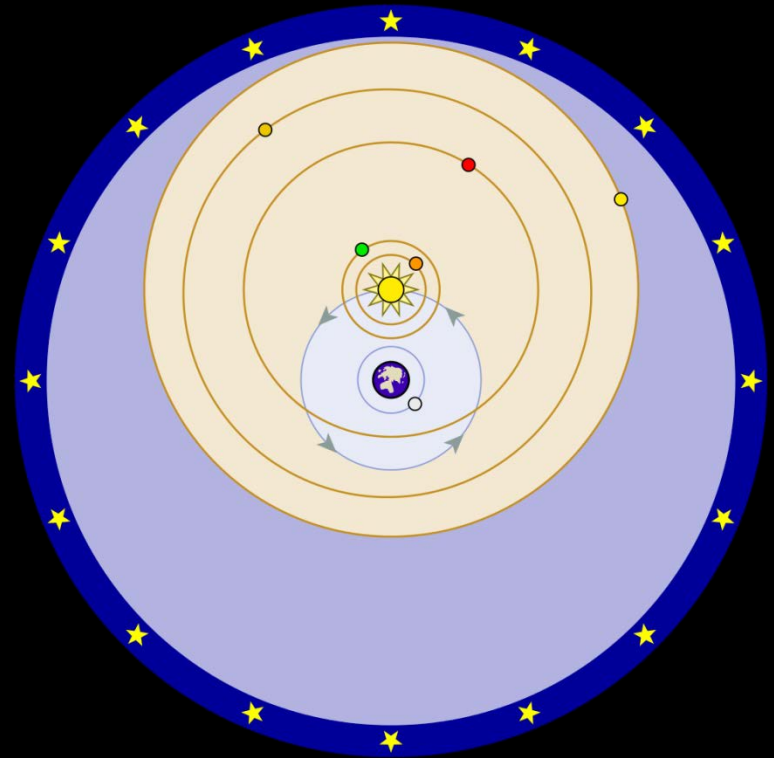
"such a fast motion could not belong to the earth, a body very heavy and dense and opaque, but rather belongs to the sky itself whose form and subtle and constant matter are better suited to a perpetual motion, however fast"

Brahe & Kepler

Arguably, the most significant step in Tycho's career:

- move to the German imperial court in Prague
  (following tensions with new Danish king Christian IV)

- meeting up with (young) Johannes Kepler

The analytical genius of Kepler gained access to the state of the art accurate observations of Tycho Brahe, opening up the path towards unravelling the laws of motion in the solar system.

Johannes Kepler
(1571-1630)
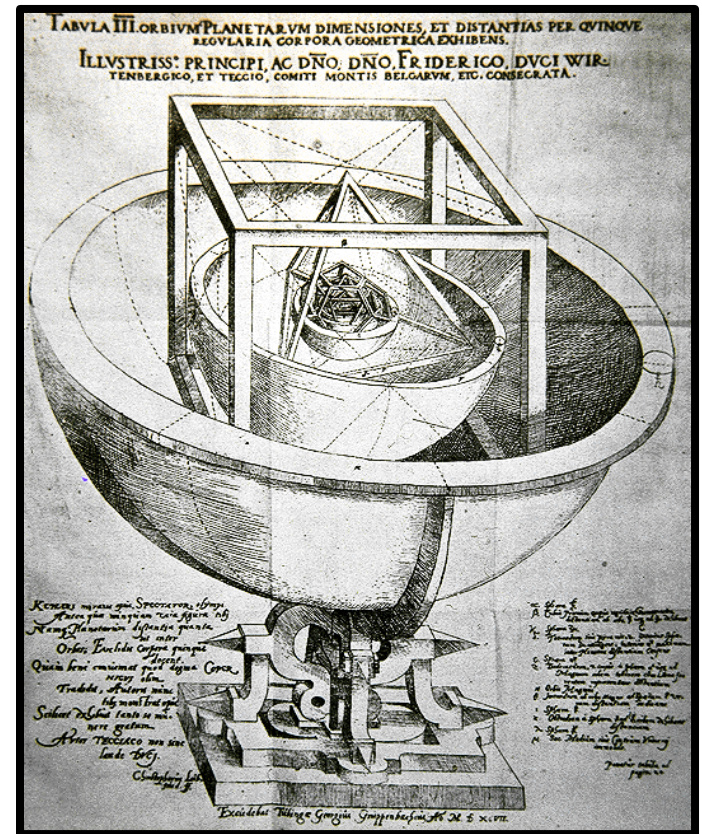
Mysterium Cosmographicum

Johannes Kepler
(1571-1630)

Johannes Kepler may be considered as THE key genius of the European Scientific Revolution

In his 3 books he established an entirely new, revolutionary, look on the workings of the Universe, **the cosmology of Kepler,**

- **Mysterium Cosmographicum**   **1596**

- **Astronomica Nova**   **1609**

- **Harmonices Mundi**   **1619**

His main goal was to reveal the **divine laws and plan** dictating the motion of the planets according to Copernicus heliocentric system,

- establishing that the orbits of the planets are **elliptical** and formulating the **3 laws of Kepler for planetary motion**

- strongly leaning on mathematics as the language of nature, much in line with **Pythagoras** and **Plato.**

Kepler Laws
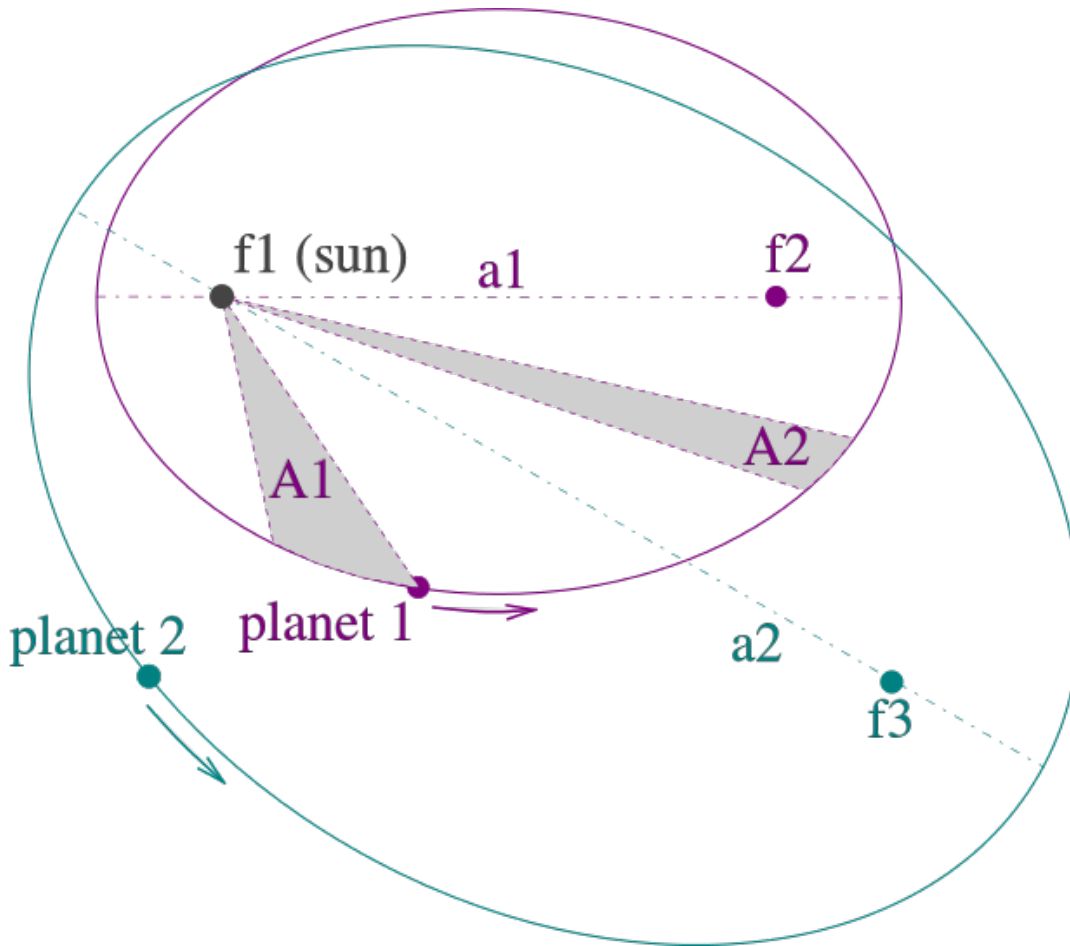
Kepler laws of planetary motion

1. The orbit of a planet is an
   ellipse with the Sun at one focus.

2. A line segment joining a planet
   and the Sun sweeps out
   equal areas
      during
   equal intervals of ime.

   (planets do not move with
    uniform speed along their orbit).

3. Relation Orbital Time – Size orbit:

   The square of the orbital period
   of a planet is proportional to
   the cube of the orbit's semi-major axis

   $T^2/a^3 = const.$

Johannes Kepler
(1571-1630)

Fields:
astronomy, astrology, mathematics, natural philosophy

Kepler described his
new astronomy as "celestial physics":

his entire astronomical career devote to elaboration of the following questions:

- **why are there six planets (then known) ?**
- **why are they spaced around the Sun as they are.**
- **why do they move as they do ?**

Johannes Kepler
(1571-1630)

Fields:
astronomy, astrology, mathematics, natural philosophy

Kepler described his new astronomy as "celestial physics",

as "an excursion into Aristotle's Metaphysics", and as "a supplement to Aristotle's On the Heavens",[

transforming the ancient tradition of physical cosmology by treating astronomy as part of a universal mathematical physics.

Mysterium Cosmographicum

Prodromus dissertationum cosmographicarum, continens mysterium cosmographicum, de admirabili proportione orbium coelestium, de que causis coelorum numeri, magnitudinis, motuumque periodicorum genuinis & proprijs, demonstratum, per quinque regularia corpora geometrica

Forerunner of the Cosmological Essays, Which Contains the Secret of the Universe; on the Marvelous Proportion of the Celestial Spheres, and on the True and Particular Causes of the Number, Magnitude, and Periodic Motions of the Heavens; Established by Means of the Five Regular Geometric Solids
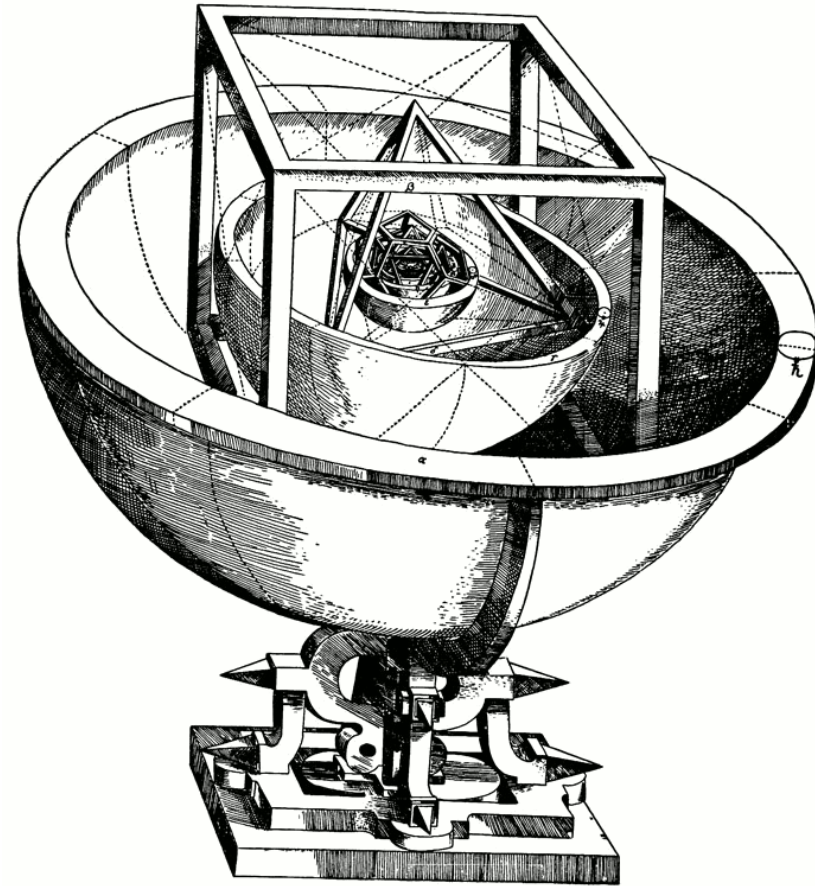
Mysterium Cosmographicum

- First published defense of Copernican system
- published 1596   (at age 26 !)
  2nd ed. 1621   (half as long)

- Book explains Kepler's cosmological theory:
       God's Geometrical Plan for the Universe
- based on the Copernican system:
  first published defense of Copernican system

- Five Pythagorean regular polyhedra dictate
  the structure of the universe and
  reflect God's plan through geometry.

- Kepler found that each of the five Platonic solids
  could be uniquely inscribed and circumscribed by
  spherical orbs;
- nesting these solids, each encased in a sphere, within
  one another would produce six layers, corresponding
  to the six known planets

- Mercury, Venus, Earth, Mars, Jupiter, and Saturn.

- By ordering the solids correctly

- octahedron, icosahedron, dodecahedron,
  tetrahedron, cube
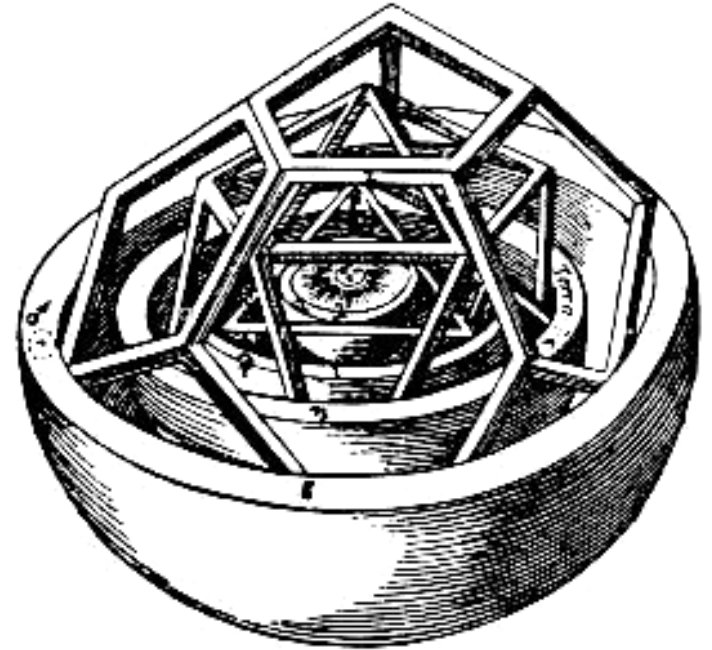
Kepler found that circumscribing spheres could
be placed at intervals corresponding

(within the accuracy limits of available
  astronomical observations)

 to the relative sizes of each planet's path,
assuming the planets circle the Sun

Mysterium Cosmographicum

Kepler thought he had revealed

God's geometrical plan for the universe.

Much of Kepler's enthusiasm for the Copernican system stemmed from his theological convictions about the connection between the physical and the spiritual.

The universe itself was an image of God,

- His first manuscript of Mysterium contained an extensive chapter reconciling heliocentrism with biblical passages that seemed to support geocentrism.[

- Kepler never relinquished the Platonist polyhedral-spherist cosmology of Mysterium Cosmographicum.
- His subsequent main astronomical works were in some sense only further developments of it,
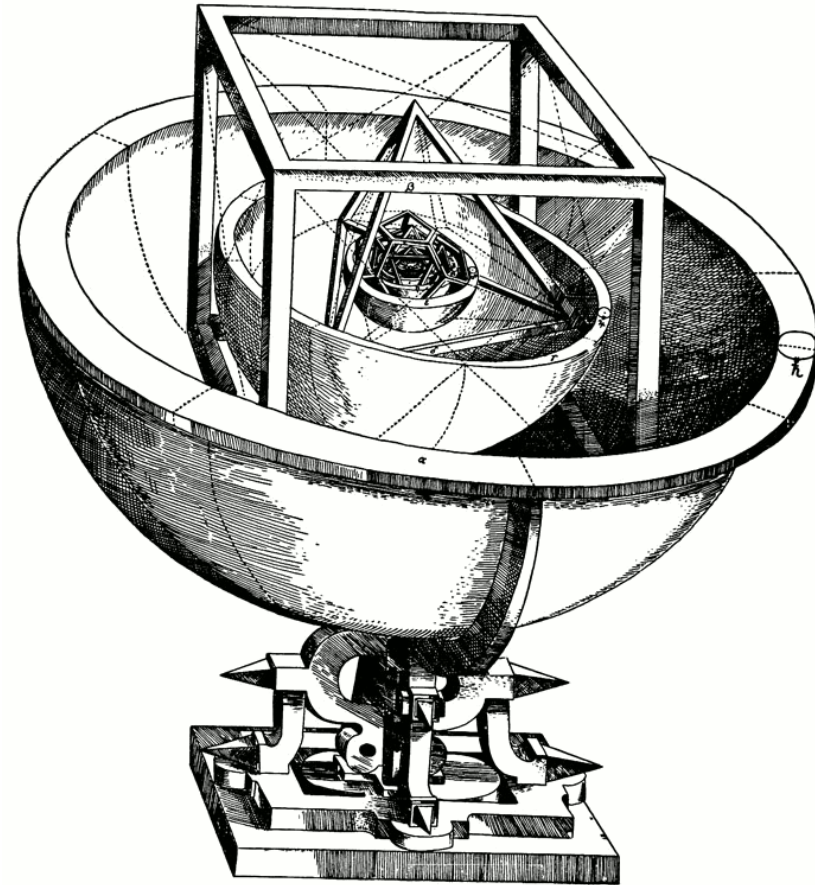
Mysterium Cosmographicum

Modern astronomy owes much to

Mysterium Cosmographicum

- Despite flaws in its main thesis, "since it represents the first step in cleansing the Copernican system of the remnants of the Ptolemaic theory still clinging to it." (Dryer)

- Especially when dealing with the geometry of the universe, Kepler consistently utilizes Platonic and Neo-Platonic frameworks of thought.

- The entirety of the polyhedral idea is based on the same "formal cause" postulated by Plato for the structure of the universe.

- In an argument from design, Kepler postulates the existence and necessity of God the Creator as this "efficient cause
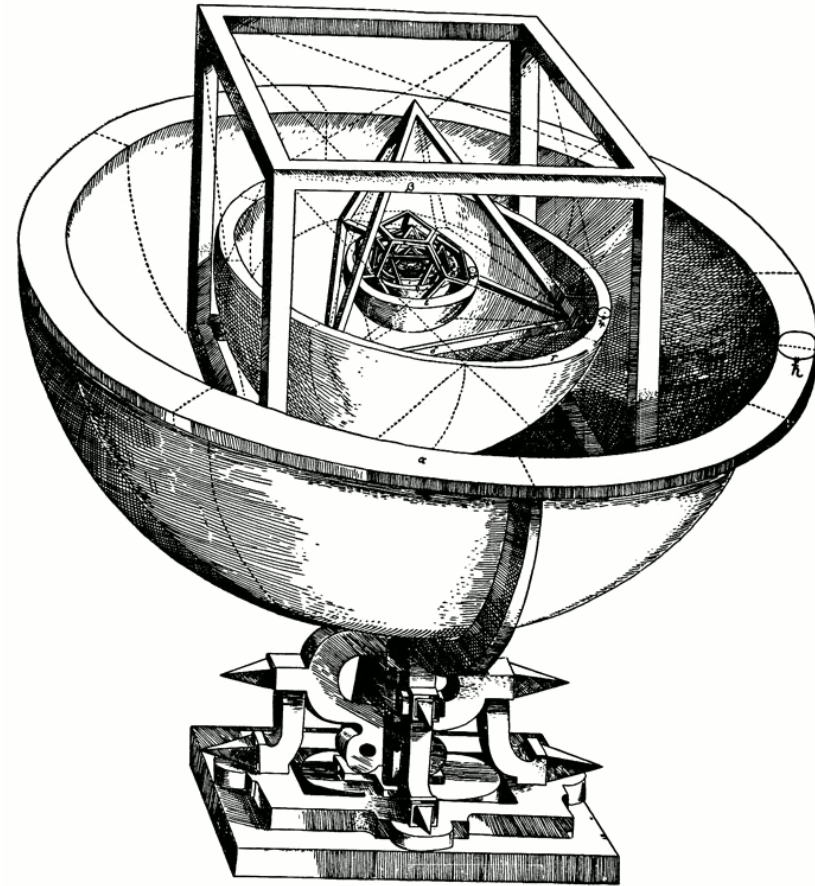
Astronomia Nova

Full title:

Astronomia Nova ΑΙΤΙΟΛΟΓΗΤΟΣ seu physica coelestis, tradita commentariis de motibus stellae Martis ex observationibus
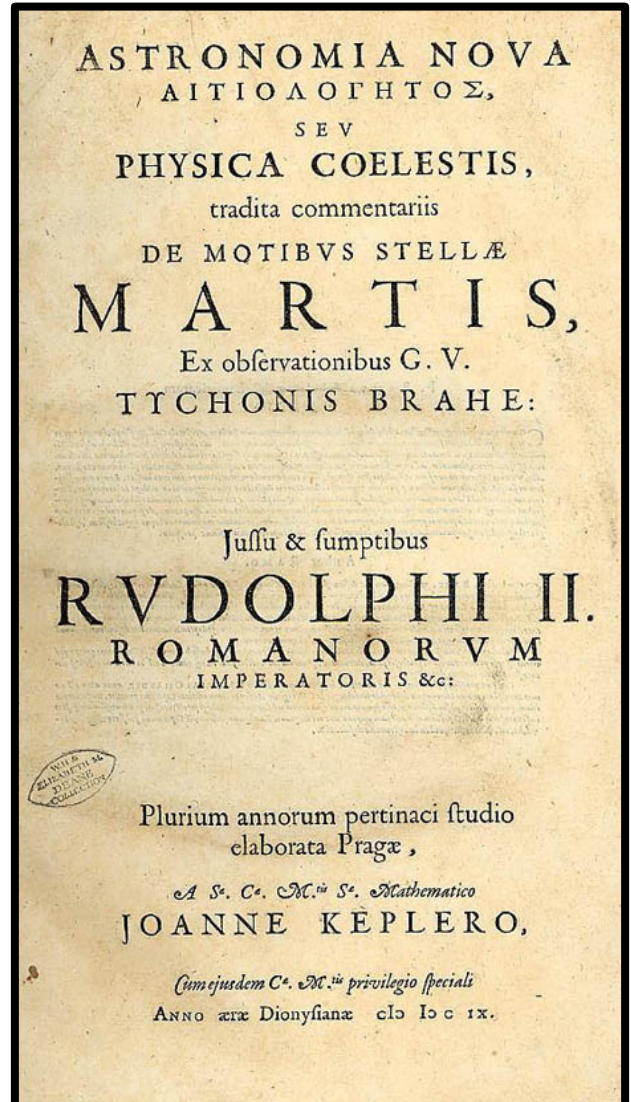*G.V. Tychonis Brahe*

Published 1609

One of the most important works of the Scientific Revolution

**Reports Kepler's 10 year long investigation of motion of planet Mars.**

In addition to providing strong arguments heliocentrism, it describes the motion of planets, incl. elliptical shape of orbits

- first 2 laws of Kepler

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 Sᵃ. Cᵉ. Mᵗⁱ Sᵉ. Mathematico
JOANNE KEPLERO,

Cum ejusdem Cᵉ. Mᵗⁱ privilegio ſpeciali
ANNO æræ Dionyſianæ ɔIɔ Iɔc IX.

Astronomia Nova

Published 1609

One of the most important works of the Scientific Revolution

In addition to providing strong arguments heliocentrism, it describes the motion of planets, incl. elliptical shape of orbits:

- **first 2 laws of Kepler:**

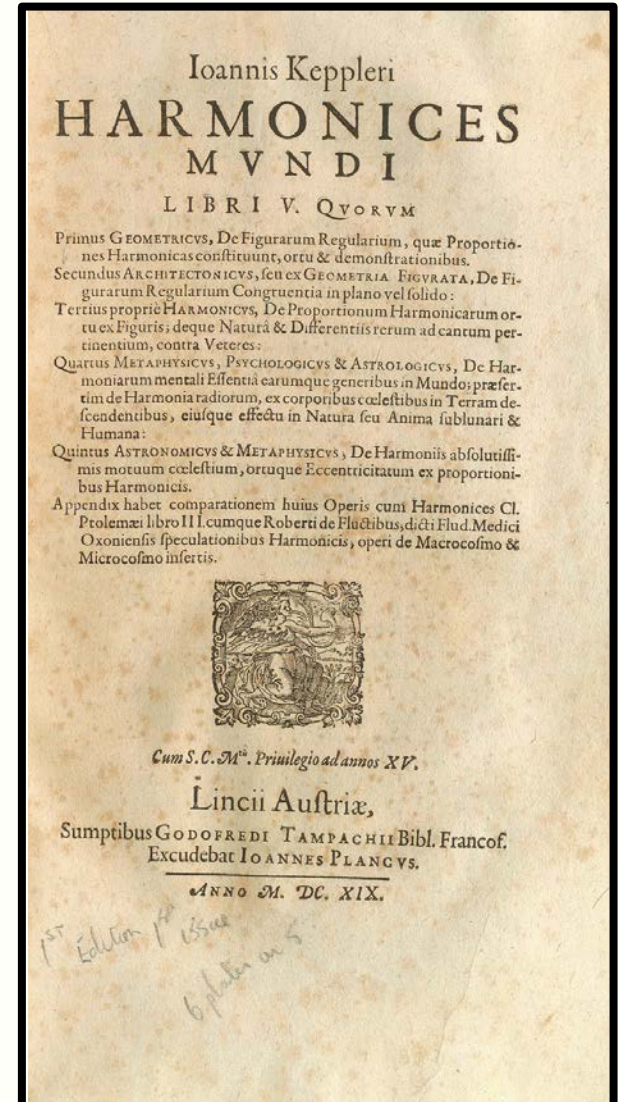 1. *The orbit of a planet is an ellipse with the Sun at one focus.*

  2. *A line segment joining a planet and the Sun sweeps out equal areas during equal intervals of time.*

     (planets do not move with uniform speed along their orbit).
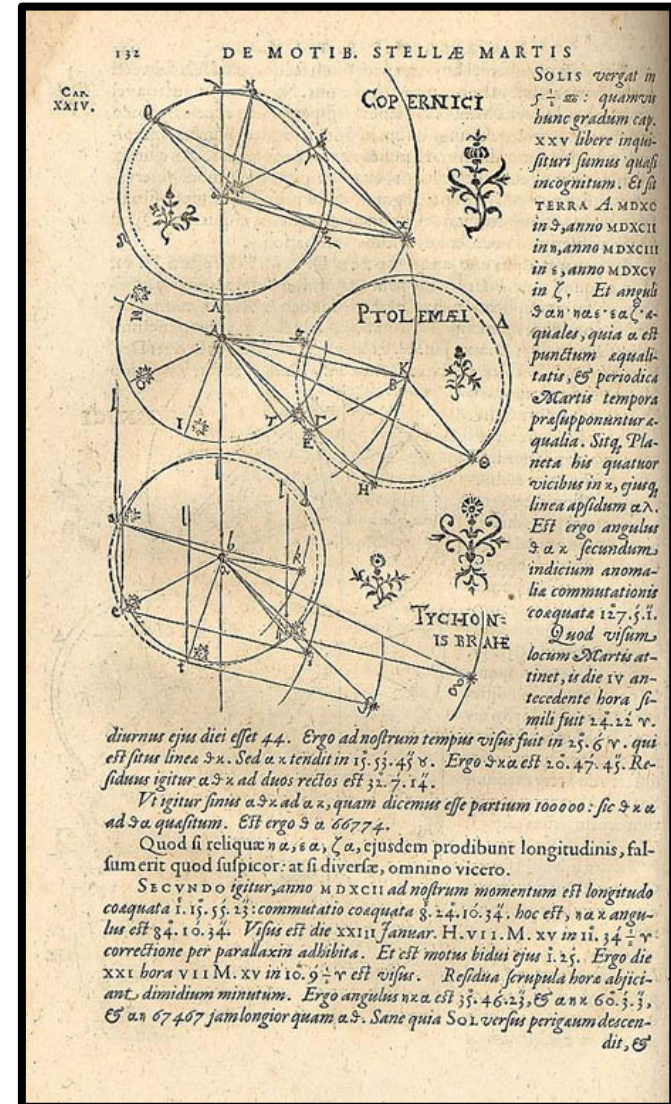
Harmonices Mundi

- **Harmony of the World**

- **Published 1619**

- **In a sense return to Pythagoras' "Music of the Spheres". However, not based on numerology, but on Geometry !**

- **Kepler discovered physical harmonies in planetary motion:**

  - **difference maximum – minimum angular speeds of a planet approximates harmonic proportion**

  - **eg. the maximum angular speed of Earth as measured from the Sun varies by a semitone (ratio: 16:15)**

Ioannis Keppleri

HARMONICES MVNDI

LIBRI V. QVORVM

Primus GEOMETRICVS, De Figurarum Regularium, quæ Proportiones Harmonicas confiituunt, ortu & demonſtrationibus.
Secundus ARCHITECTONICVS, feu ex GEOMETRIA FIGVRATA, De Figurarum Regularium Congruentia in plano vel ſolido:
Tertius propriè HARMONICVS, De Proportionum Harmonicarum ortu ex Figuris; deque Naturâ & 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 Naturâ 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. Mᵗˢ. Priuilegio ad annos XV.

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

ANNO M. DC. XIX.

Harmonices Mundi

- **Harmony of the World**

- **Published 1619**

- **Musical harmonies for arrangement and motion of heavenly bodies**

- **Celestial choir:**
  - Mercury   soprano
  - Venus   alto
  - Earth   alto
  - Mars   tenor
  - Jupiter   tenor
  - Saturn   bass

- Mercury - large elliptical orbit
  - greatest number of notes
- Venus - orbit nearly a circle
  - only a single note

Ioannis Keppleri
HARMONICES
MVNDI
LIBRI V. QVORVM

Primus GEOMETRICVS, De Figurarum Regularium, quæ Proportiònes 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 Natura & Differentiis rerum ad cantum pertinentium, contra Veteres:
Quartus METAPHYSICVS, PSYCHOLOGICVS & ASTROLOGICVS, De Harmoniarum mentali Essentia 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.
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Cum S. C. Mᵗⁱˢ. Priuilegio ad annos XV.

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

ANNO M. DC. XIX.

Harmonices Mundi

Ioannis Keppleri

HARMONICES MVNDI

LIBRI V. QVORVM

Primus GEOMETRICVS, De Figurarum Regularium, quæ Proportiónes Harmonicas constituunt, ortu & demonstrationibus.

Secundus ARCHITECTONICVS, seu ex GEOMETRIA FIGVRATA, De Figurarum Regularium Congruentia in plano vel solido:

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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. Mᵗⁱ. Priuilegio ad annos XV.

Lincii Austriæ,

Sumptibus GODOFREDI TAMPACHII Bibl. Francof.
Excudebat IOANNES PLANCVS.

ANNO M. DC. XIX.

Christiaan Huygens

(1629-1695)

Huygens & Saturn
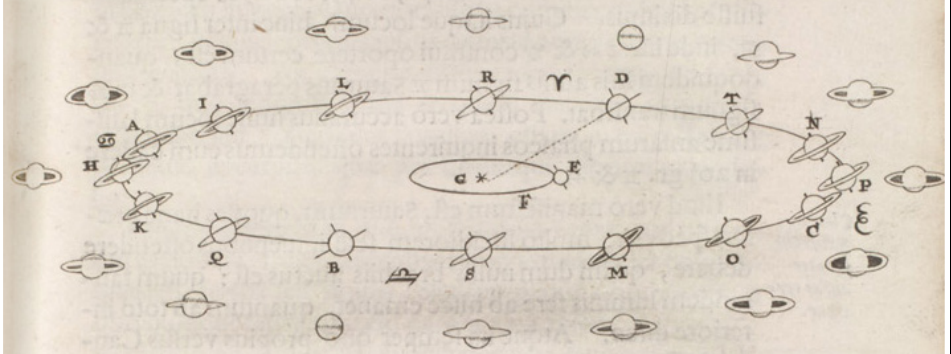
Cujus phaseos vera proinde forma, secundum ea quæ supra circa annulum definivimus, ejusmodi erit qualis hîc delineata cernitur, majori ellipsis diametro ad minorem se habente fere ut 5 ad 2.
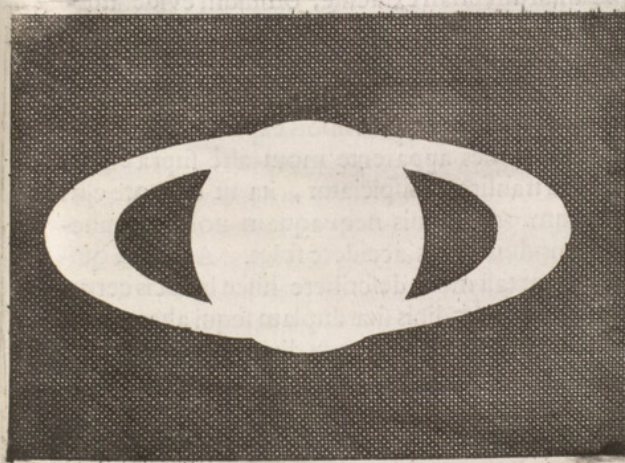
Atque

Cosmotheoros
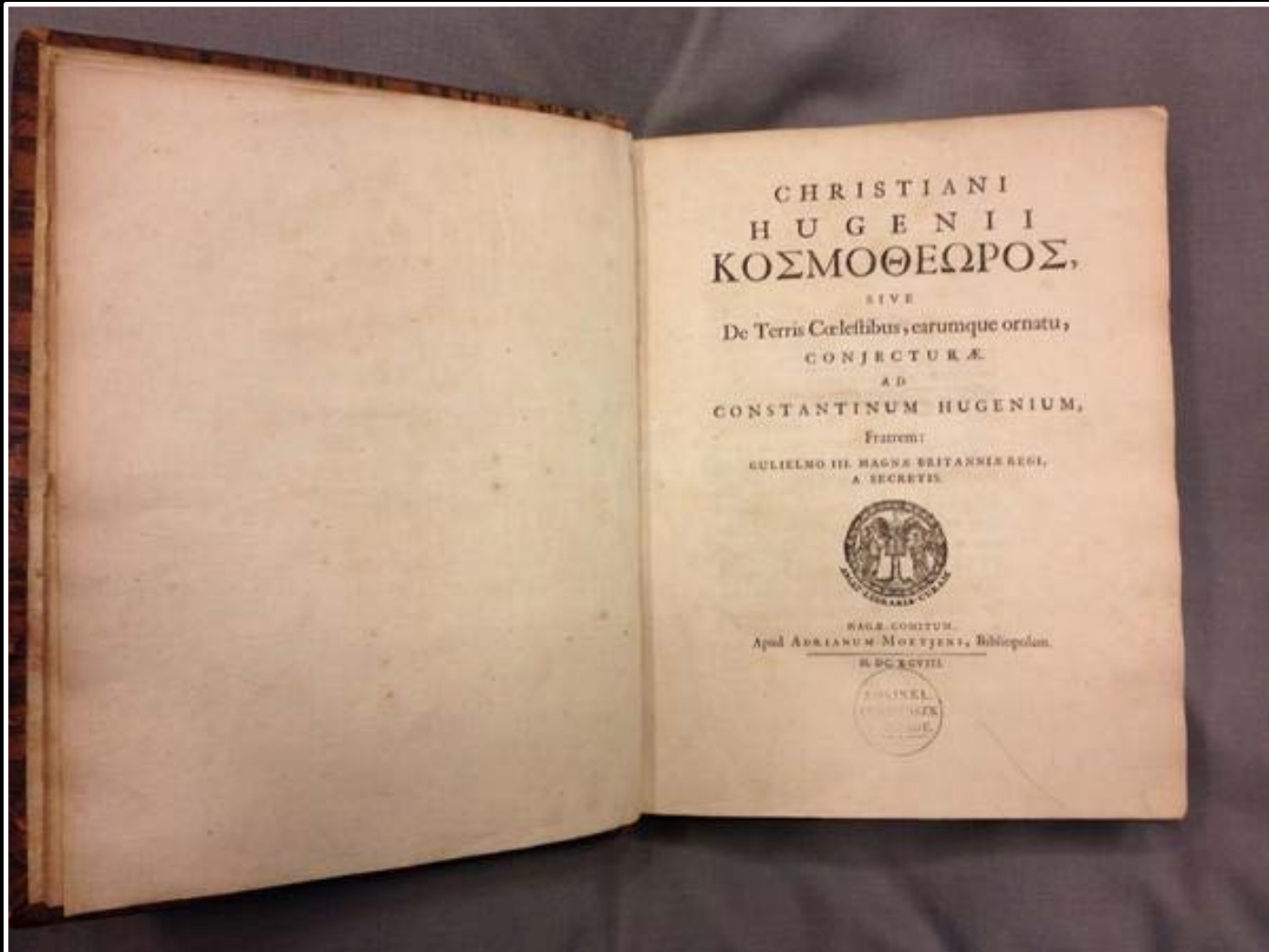
1695-1698:
- Speculation on the existence of extraterrestrial life
- Identification (liquid) water as main condition for the emergence of life
- Method for estimating distances

Galileo Galilei

(1564-1642)

(Pisa-Arcetri)

Galileo Galilei

(1564-1642)

father of observational astronomy
father of modern physics
father of scientific method

Galileo Galilei

(1564-1642)

astronomer, physicist,
engineer,
philosopher, mathematician

Telescope (1609)

Following vague descriptions of the patent for a telescope by Lippershey in the Netherlands (1608),

basically 2 lenses in line cause a magnification,

Galilei developed his own telescope in 1609:
- 3 x magnification
- 30 x magnification (later).
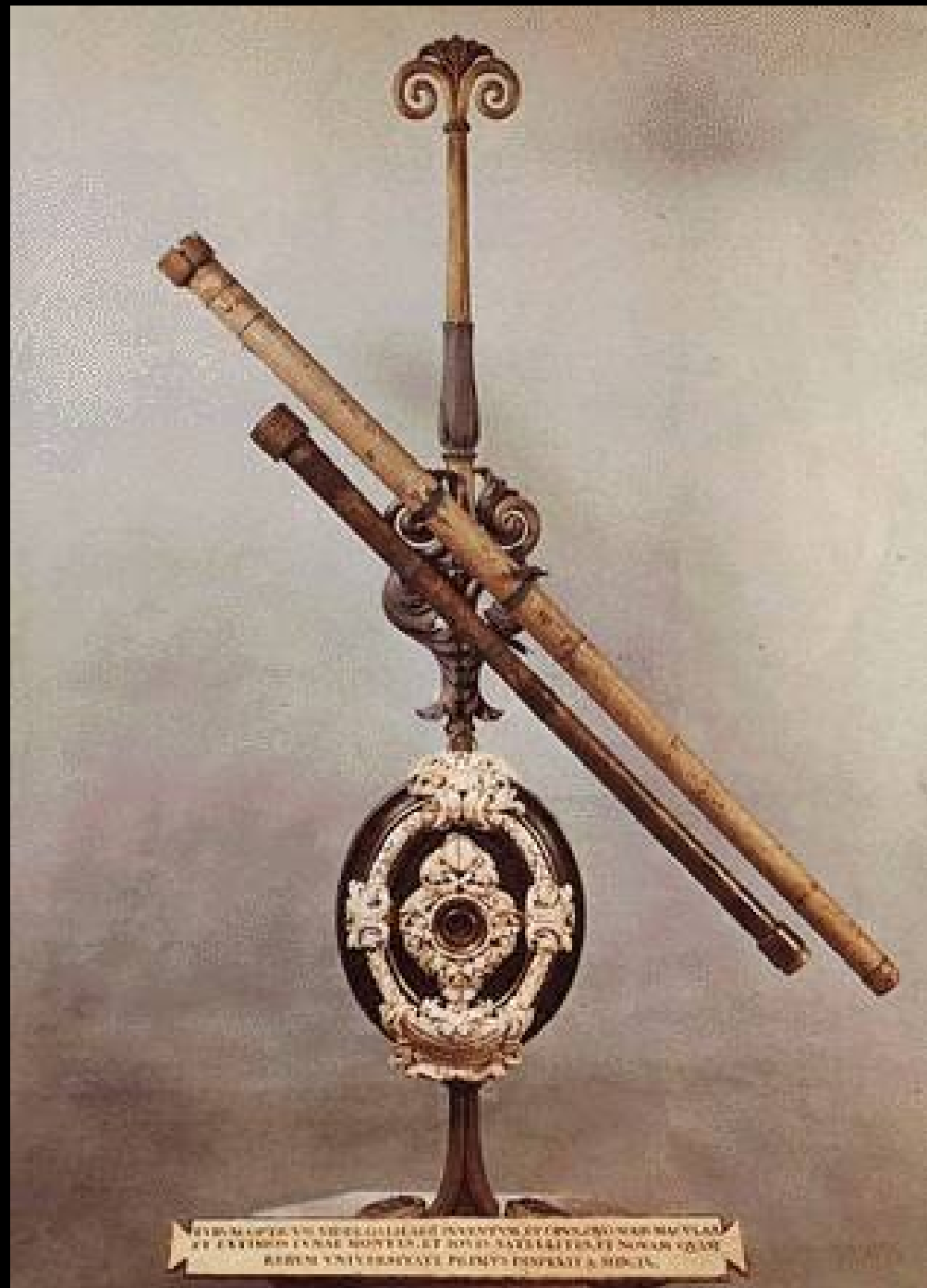
Siderius Nuncius

1610

Starry Messenger

Publication of initial telescope astronomical observations.

SIDEREVS
NVNCIVS
MAGNA, LONGEQVE ADMIRABILIA
Spectacula pandens, suspiciendaque proponens
vnicuique, præsertim verò
PHILOSOPHIS, atq. ASTRONOMIS, quæ à
GALILEO GALILEO
PATRITIO FLORENTINO
Patauini Gymnasij Publico Mathematico
PERSPICILLI
Nuper à se reperti beneficio sunt observata in LVNÆ FACIE, FIXIS IN-
NVMERIS, LACTEO CIRCVLO, STELLIS NEBVLOSIS,
Apprime verò in
QVATVOR PLANETIS
Circa IOVIS Stellam disparibus interuallis, atque periodis, celeri-
tate mirabili circumuolutis; quos, nemini in hanc vsque
diem cognitos, nouissimè Author depræ-
hendit primus; atque
MEDICEA SIDERA
NVNCVPANDOS DECREVIT.

VENETIIS, Apud Thomam Baglionum. M DC X.
Superiorum Permissu, & Privilegio.

M VIIII

Contents:

- ➤ 70 drawings of

- • Moon: real world of valleys & mountains

- • Orion
- • Pleiades: > 10 x number of stars
- • Taurus than visible by eye

- • Milky Way: congeries of innumerable stars grouped in clusters

- • Galilean Moons (Medicean stars):

  - illustrations of relative positions between Jan. 1610 – Mar. 1610
  - remain on same line: orbiting Jupiter
  - in conflict with Aristotelean cosmology (which states everything orbits Earth)

- • Phases of Venus:
  - soid evidence for Venus and Earth orbiting the Sun

- • Planet Saturn:
  - did not realize he saw rings, and thought Saturn was 3 objects

- • Neptune
  - Galilei did see Neptune, but did not realize it was a planet
  - would take another 236 years before it was discovered as planet by Le Verrier

- • Sunspots

the Moon

Galilei's telescopic study of the Moon
revealed it was a real world of its own,

with valleys, mountains, etc.

• Directly conflicting serene & perfect
Aristotle's & Ptolemaic cosmology
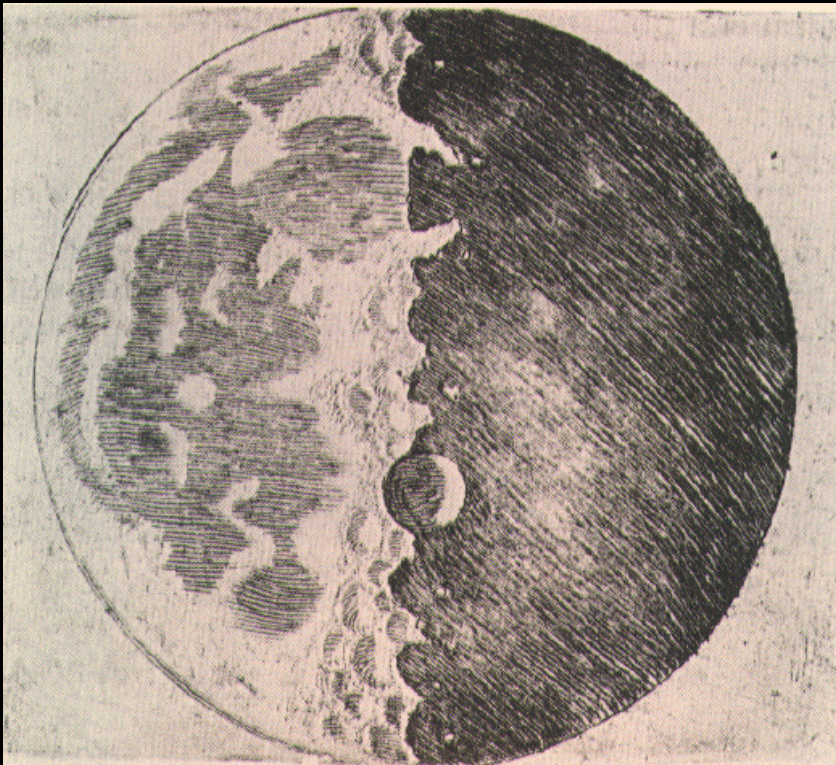
Moon:
surface valleys & hills

Galilean Moons of Jupiter:

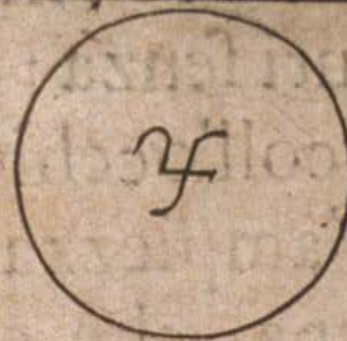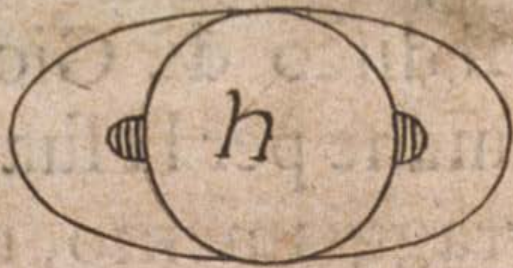**Ganymedes, Io, Callisto, Europa**

Galilean Moons

Ganymedes, Io, Callisto & Europa:

discovery of their orbital motion, demonstrated that Earth was not the only center in the Universe
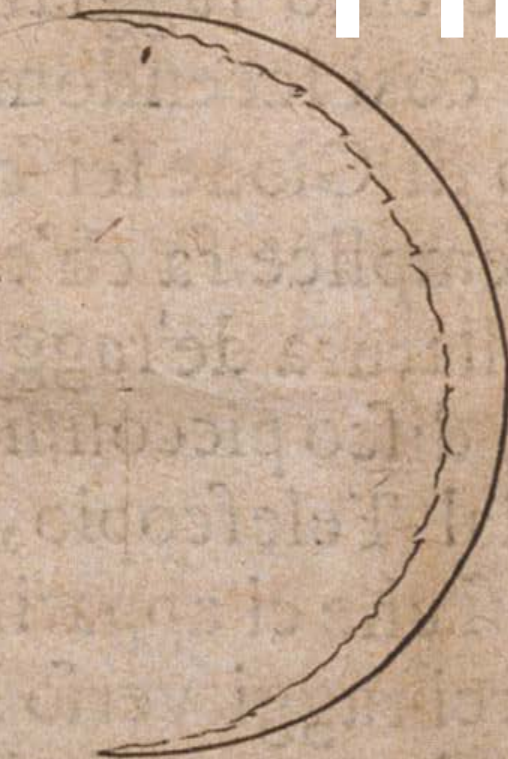
directly conflicting Ptolemaeic and Aristotle's cosmology
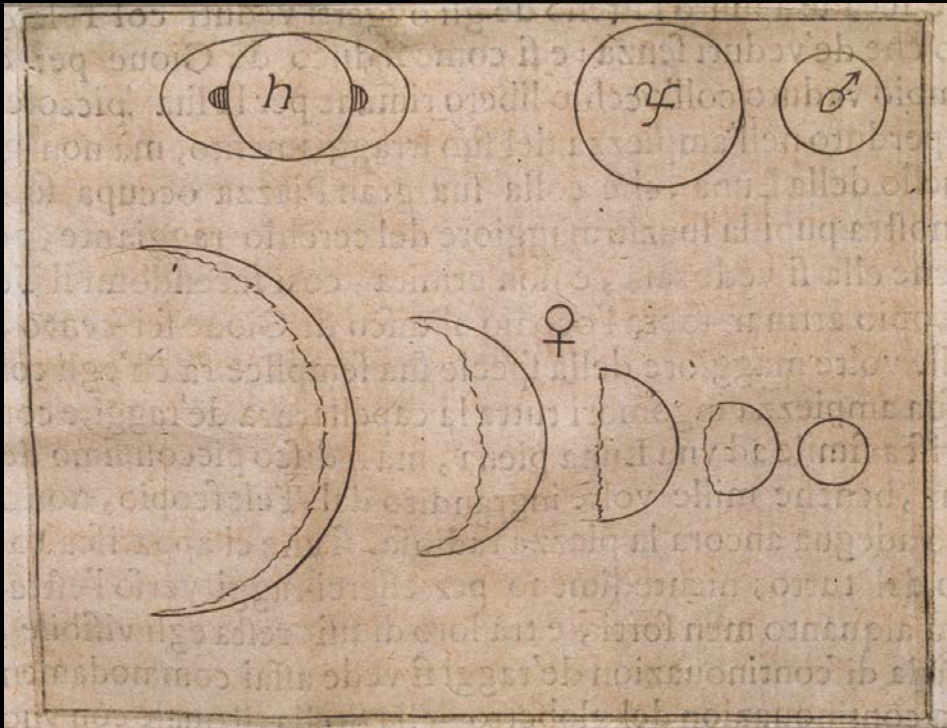
Phases of Venus

Phases of Venus
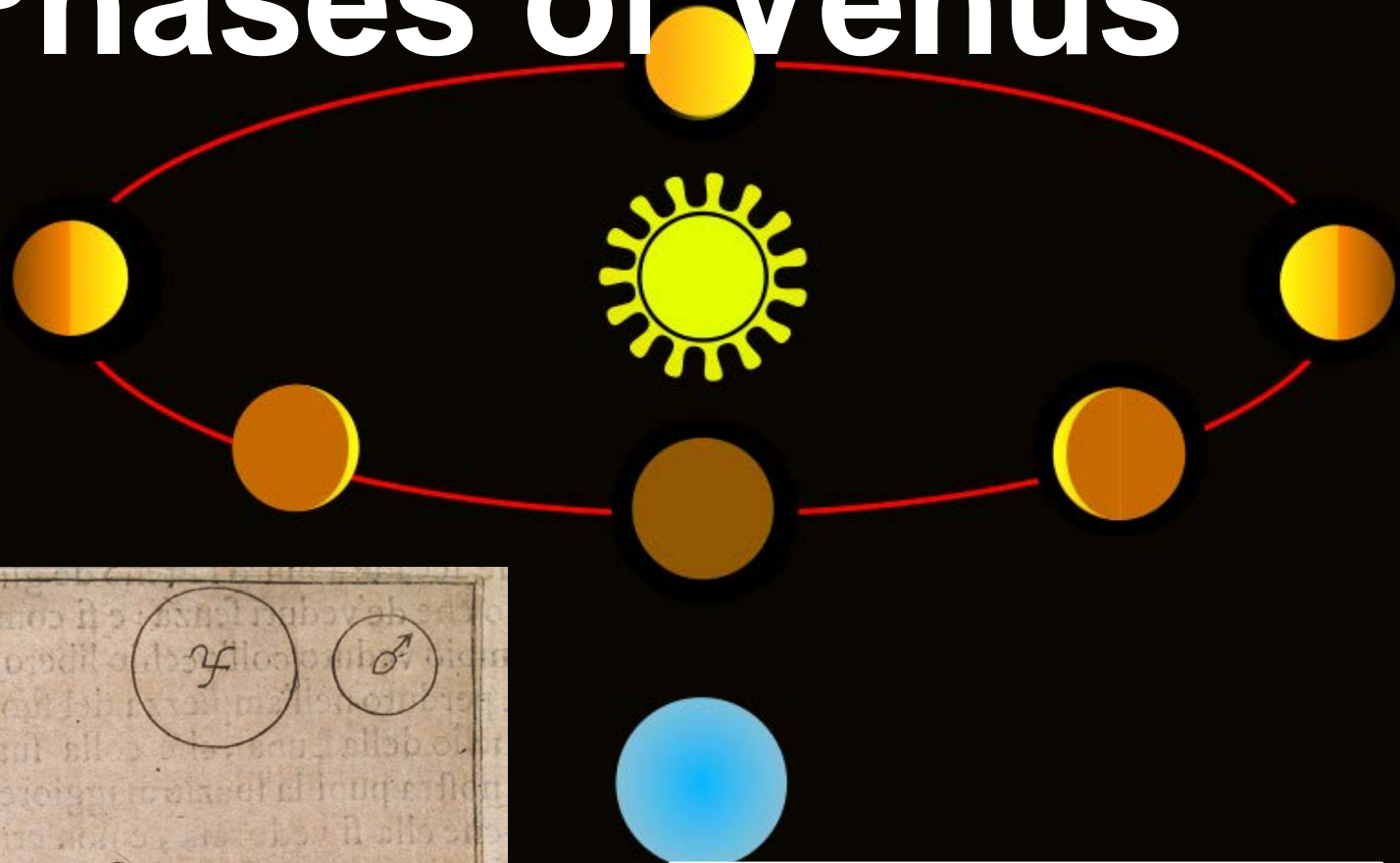
EARTH

Evidence for heliocentric Universe:

- Phases of Venus correlated with size of Venus' disk
- Full Venus: small disk
- New Venus: large disk

# Dialogue concerning the two chief world systems

(1632)

Latin: Systema Cosmicum

book comparing the
Copernican system with traditional Ptolemaic system

- Stated intention was to be objective.
- However, could not hide Galilei's conviction that
  Copernican system represented the physical reality
- book considered attack on Aristotelian geocentrism
- also insulted the pope

1633:
- Galilei accused of heresy
- Dialogo on Index of Forbidden Books (until 1835)
- Galilei narrowly escapes torture
- house arrest for the rest of his life.
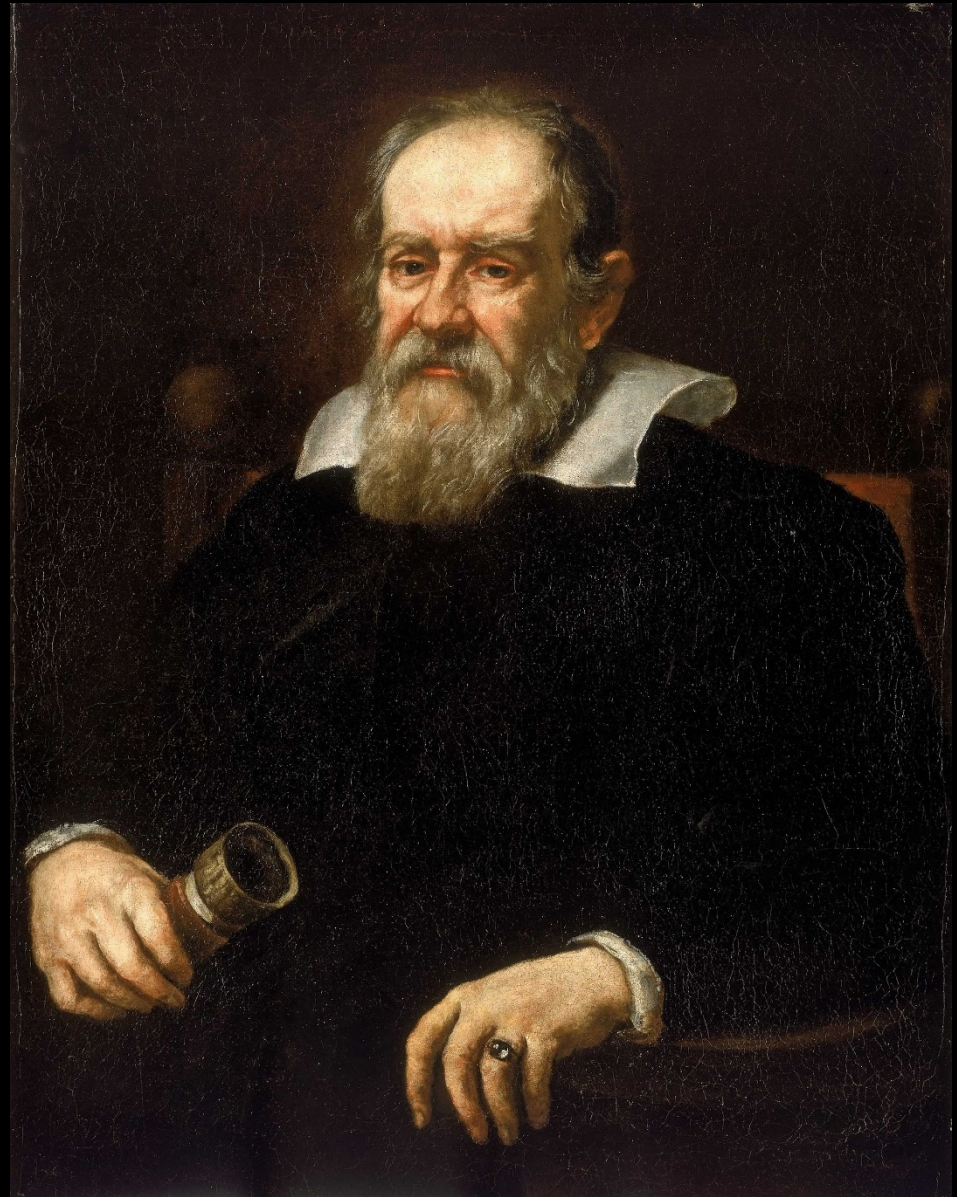
DIALOGO
DI
GALILEO GALILEI LINCEO
MATEMATICO SOPRAORDINARIO
DELLO STVDIO DI PISA.

E Filosofo, è Matematico primario del

SERENISSIMO

GR.DVCA DI TOSCANA.

Doue ne i congressi di quattro giornate si discorre
sopra i due

MASSIMI SISTEMI DEL MONDO
TOLEMAICO, E COPERNICANO;

Proponendo indeterminatamente le ragioni Filosofiche, e Naturali
tanto per l'vna, quanto per l'altra parte.

CON PRI   VILEGI.

IN FIORENZA, Per Gio: Batista Landini MDCXXXII.

CON LICENZA DE' SVPERIORI.

Galilei facing the Roman inquisition

Galileo Galilei

Scientific significance stretches to
at least 2 other main aspects:

- Physics

- Scientific Method

Physics

- velocity & speed, gravity,
- free fall
- principle of relativity
- inertia

- Pendulums &
 Hydrostatic balances
- Thermoscope

tower of Pisa:
heavy objects fall equally fast as
light objects

Galileo Galilei

Scientific significance stretches to
at least 2 other main aspects:

- Physics

- Scientific Method

Scientific Method

- Innovative combination Experiment – Mathematics

- Laws of Nature are mathematical
- in book "The Assayer":
- "Philosophy is written in this grand book, the universe ... It is
  written in the language of mathematics, and its characters are
  triangles, circles, and other geometric figures;..."

- Appreciation proper relationship
  mathematics, theoretical physics & experimental physics

Isaac Newton
(1643-1727)

"If I have seen further it is by standing on the shoulders of giants "
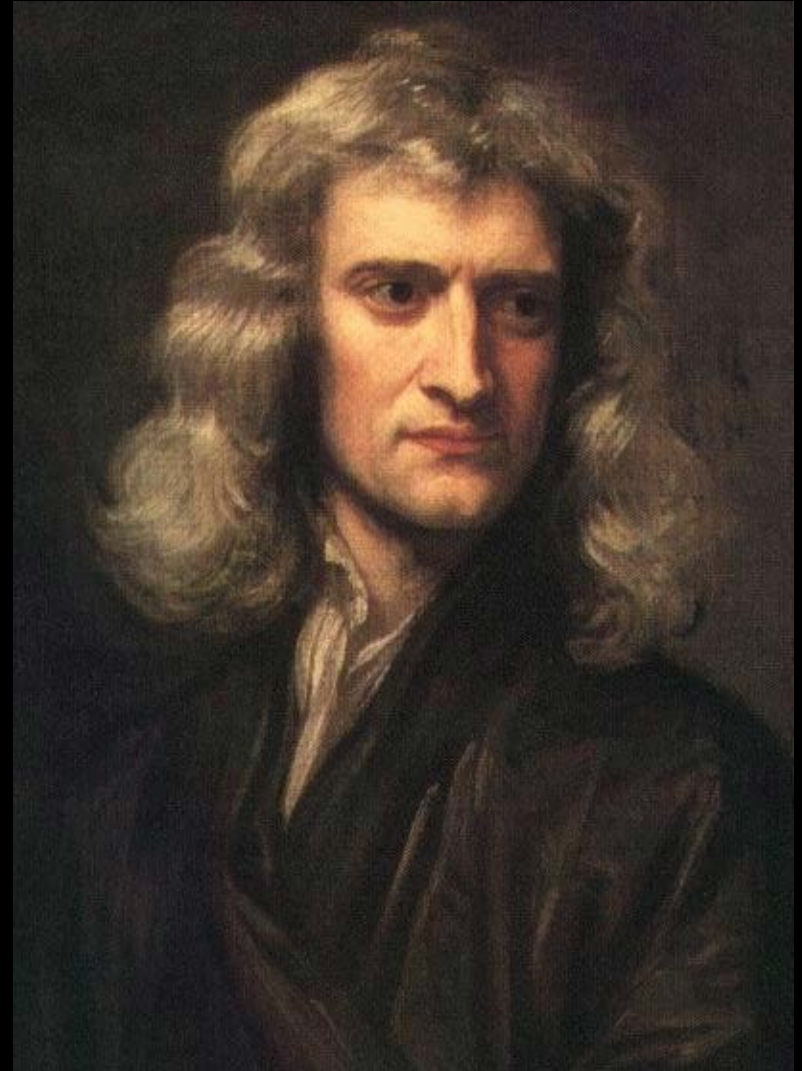
Isaac Newton

Birthhouse
Woolshorpe

PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA.

Autore JS. NEWTON, Trin. Coll. Cantab. Soc. Matheseos
Professore Lucasiano, & Societatis Regalis Sodali.

IMPRIMATUR
S. PEPYS, Reg. Soc. PRÆSES.
Julii 5. 1686.

LONDINI,

Jussu Societatis Regiæ ac Typis Josephi Streater. Prostat apud
plures Bibliopolas. Anno MDCLXXXVII.

Isaac Newton

(1642-1726)

Newton's Laws of Motion

Newton's 1st Law:

zero force - body keeps constant velocity

$$\vec{F} = 0 \quad \Rightarrow \quad \vec{v} = cst.$$

Newton's 2nd Law:

force = acceleration x mass = change of velocity x mass

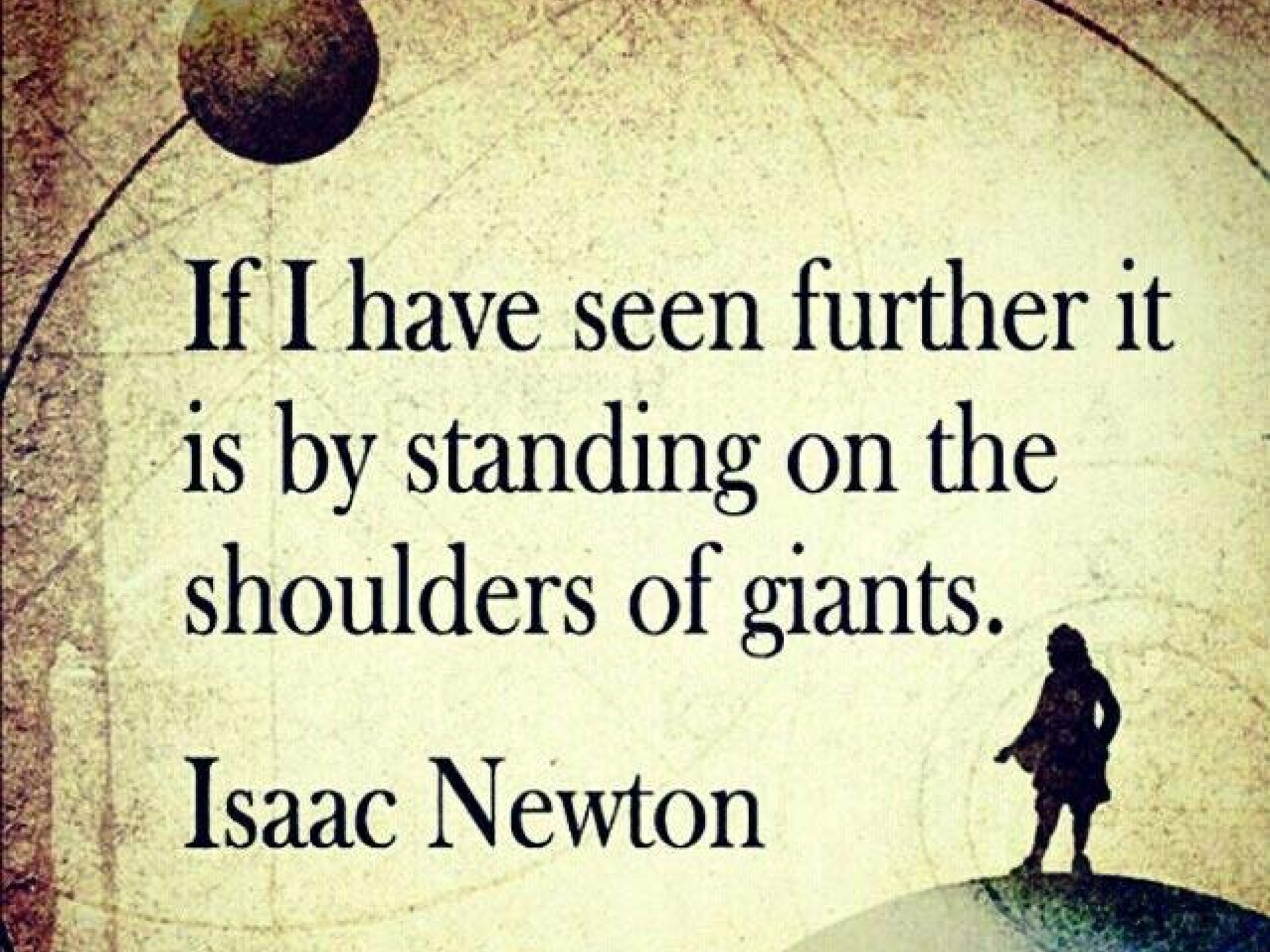$$\vec{F} = m\vec{a} = m\frac{d\vec{v}}{dt}$$

Newton's 3rd Law:

action   = reaction

$$\vec{F}_a = -\vec{F}_b$$

Newton's Gravity

$$\vec{F}_g = -G\frac{mM}{r^2}\vec{e}_r$$

If I have seen further it is by standing on the shoulders of giants.

Isaac Newton