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Borromini and the cultural context of Kepler's *Harmonices Mundi*



Overview: Geometry of the universe as inspiration for ecclesiastical architecture?

- Ecclesiastical art and architecture traditionally reflected the view of the universe (such as the 'dome of heaven' in architecture).
- Is it coincidence that geometrical oval or elliptical domes in Baroque architecture come in at the time of Kepler – and the *Harmonices Mundi*?
- Kepler changes the understanding of the mechanics of the universe
- Scientific impact of Kepler's discoveries - *but also* in art and culture



Francesco Borromini, S Carlo alle Quattro Fontane
Rome (dome)

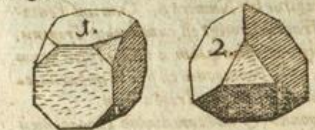
Harmonices Mundi, Bk II, p. 64
Facsimile, Carnegie-Mellon University

64 DE FIGURARUM HARMON:

que imparilaterarum rejicitur, per XXIII. cum duobus Octogonicis, planum locum implet: cum majoribus etiam superat 4 rectos; nec astringit ad solidum angulum formandum. Ita transactum est cum Tetragono, cum duae sole debent esse planorum species.

Duo Pentagonici cum uno Hexagonico aut quocumq. alio unico rejectum quid inchoant, per XXIII. quod supra etiam de Trigonico & Tetragonico cum binis Pentagonicis usurpavimus. Insuper cum uno Decagonico planitiem sternunt, nec cum illo aut majoribus astringunt in soliditatem.

Unus ergo Pentagonicus cum duobus Hexagonicis minus facit 2 rectos; & X. Truncum Icosidodecaedron.



dyhedron, quod appello Truncum Icosidodecaedron. Formam habes signa- tam numero 4. Nec plura expe- ctanda a Pentagono. Nam unus Pentagonus cum duobus Heptagoni- cis jam superat 4 rectos.

Hexagonicus cum duobus alijs implet planitiem, cum majoribus superat 4 rectos. Itaq. hic finis est mixtorum ex duabus speciebus.

Quod si triam specierum Plana concurrere possunt ad unum angulum solidum: Primum anguli duo plani, unus Tetragoni, alter Pentagoni superant 2 rectos; majores bin, multo magis: tres vero Trigonorum trium, aquant 2 rectos: nequeunt igr tres Trigonici admitti, ne summa omnium superet 4 rectos. Duo vero Trigonici cum uno Tetragonico & uno Pentagonico vel pro eo Hexagonico, aut quocumque majori, rejiciuntur, per pr. XXIII. quia Trigonus imparilatera figura cingi debet Tetragono & Pentagono, vel pro eo Hexagono & c.

Unus igitur Trigonicus cum duobus Tetragonis & uno Pentagonico, minus efficiunt 4 rectos, & congruunt 20 Trigoni cum 30 Tetragonis & 12 Pentagonis, in unum Hexacontadodecaedron, quod appello Rhombicosidodecaedron, seu solum Rhombum Icosidodecaedricum. Pingitur num. 11. sol. antecedentis.

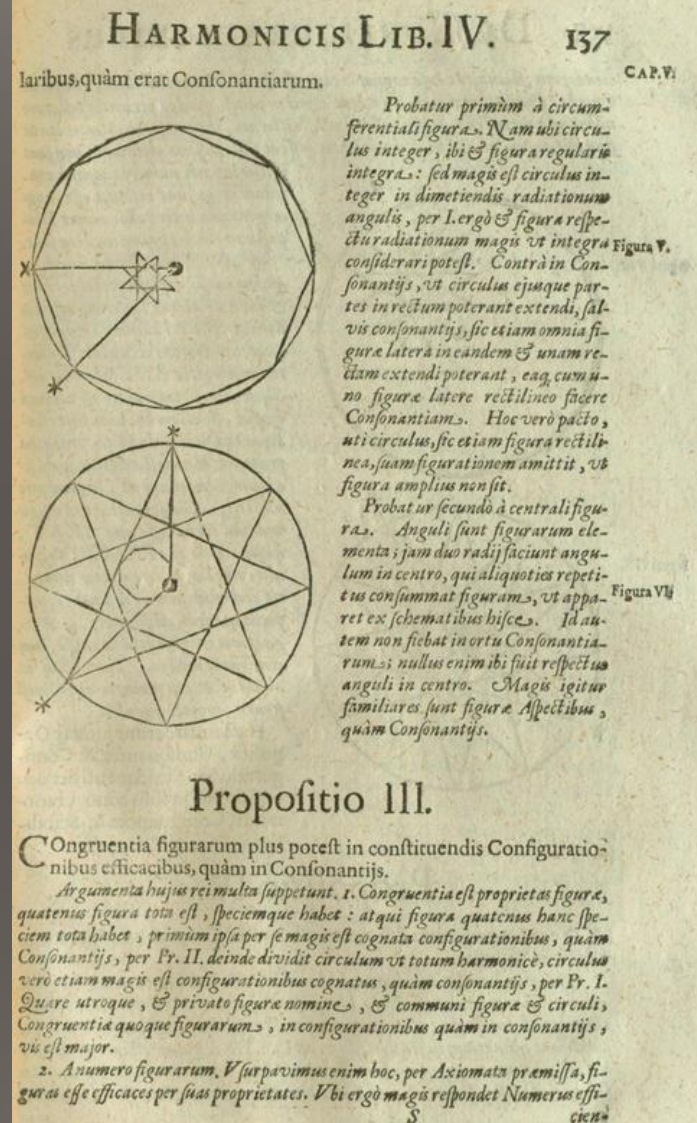
Unus Trigonicus, duo Tetragonici, cum uno Hexagonico, aquant rectos quatuor; cum uno majori, superant; nec ad solidum astringunt. Mutamus igitur duos Tetragonicos.

Unus Trigonicus, unus Tetragonicus, & duo Pentagonici superant 4 rectos, multo magis si bini majores plani anguli admiscerentur. Desinunt igitur misceri anguli plani quaterni ad formandum unum solidum; desinit ergo & Trigonus ingredi mixturam triplicem. Nam unus Trigonicus, unus Tetrago- nus &



Francesco Borromini, S Ivo alla Sapienza
Rome (dome)

Harmonices Mundi, Bk IV, p. 137



The cosmological view of the universe and art/architecture

- Vitruvius
- Scriptures – cosmology and iconography (Genesis, Isaiah, Psalms)
- Early Christian - dome of heaven
- Byzantine - domed architecture
- Renaissance revival – religious symbolism of centrally planned churches
- Baroque (17th century) non-circular domes as related to Kepler's views*

**INSAP II, Malta 1999*

Marcus Vitruvius Pollio (c 80 – 15 BC)

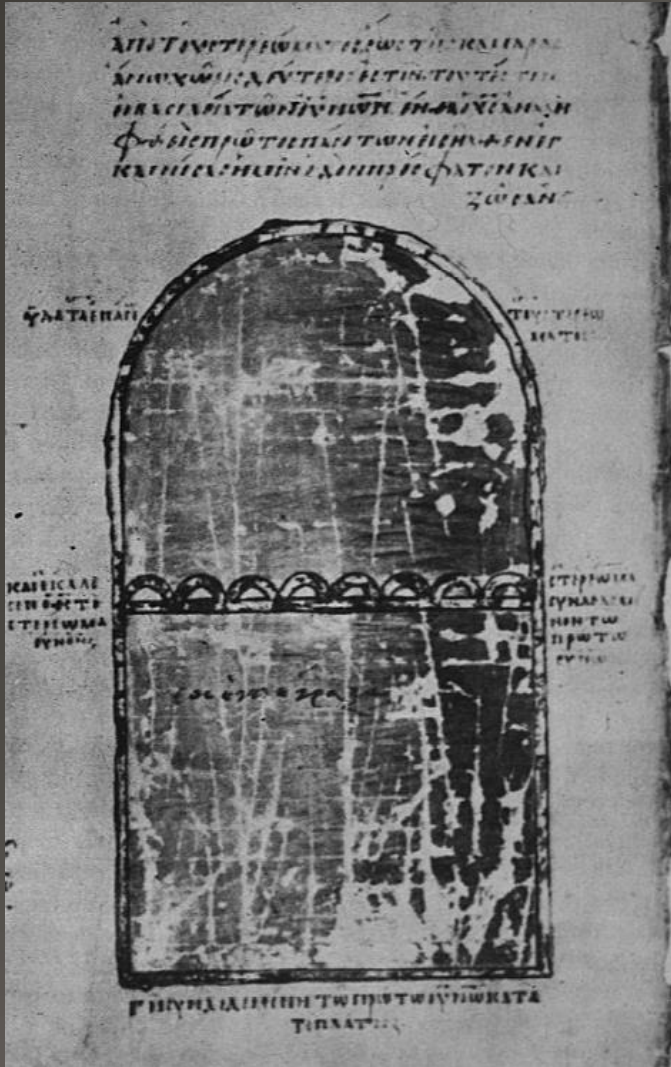
- Vitruvius, *Ten Books on Architecture* as key text for the Renaissance
- Essential for all architects to '*be acquainted with astronomy and the theory of the heavens*' (Book I).
- Sections on astronomy, zodiac, planets, sun, moon and constellations (Book IX)
- 'Universe' defined as 'the heaven that is made up of the constellations and the courses of the stars'
- cf the celestial, domed 'Pan-theon' AD 126



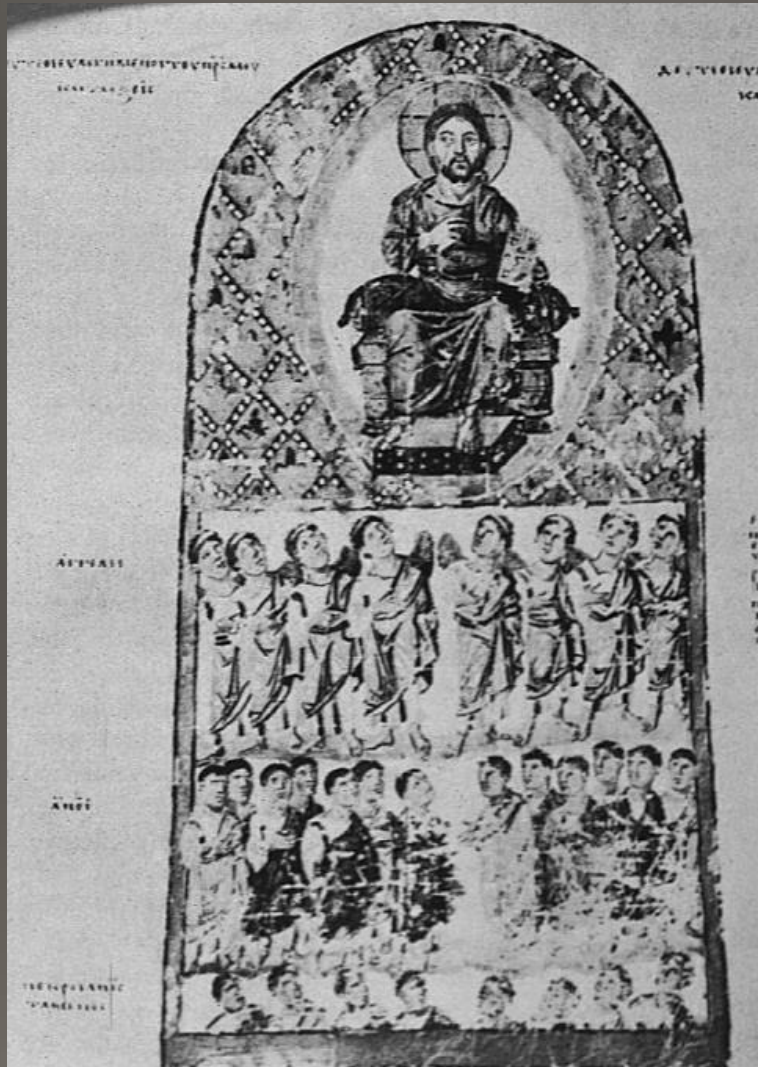
Judao-Christian view of the universe

- Establishes the view of the flat earth covered by the Dome of Heaven
- God 'sitteth upon the circle of the earth' and 'stretcheth out the heavens as a curtain and spreadeth them out as a tent to dwell in' (Genesis 1; Isaiah 40:22; cf Psalm 104; Jeremiah 10:12; Ezekiel 5:5)
- Reflected in ecclesiastical art and architecture

The view of the universe and the *Last Judgment*



Cosmas Indicopleustes, *Universe* 6th cent



Last Judgment 6th century (VatGr699)

Celestial domes



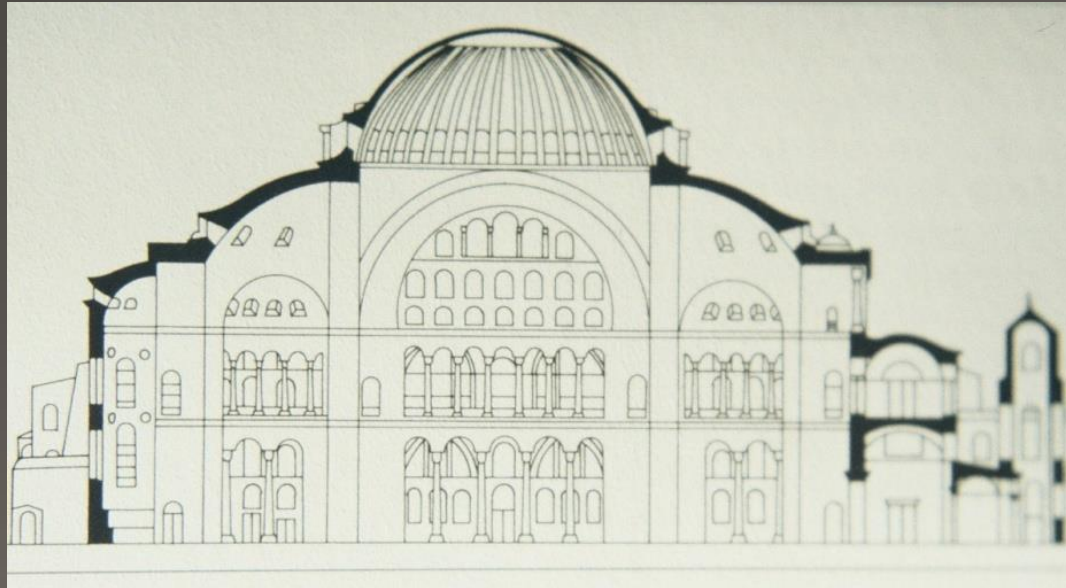
Galla Placidia, 425



Monastery
at Daphne
(Δάφνη)
11th century



S Sophia, Constantinople (built
532-37) 'hanging architecture'



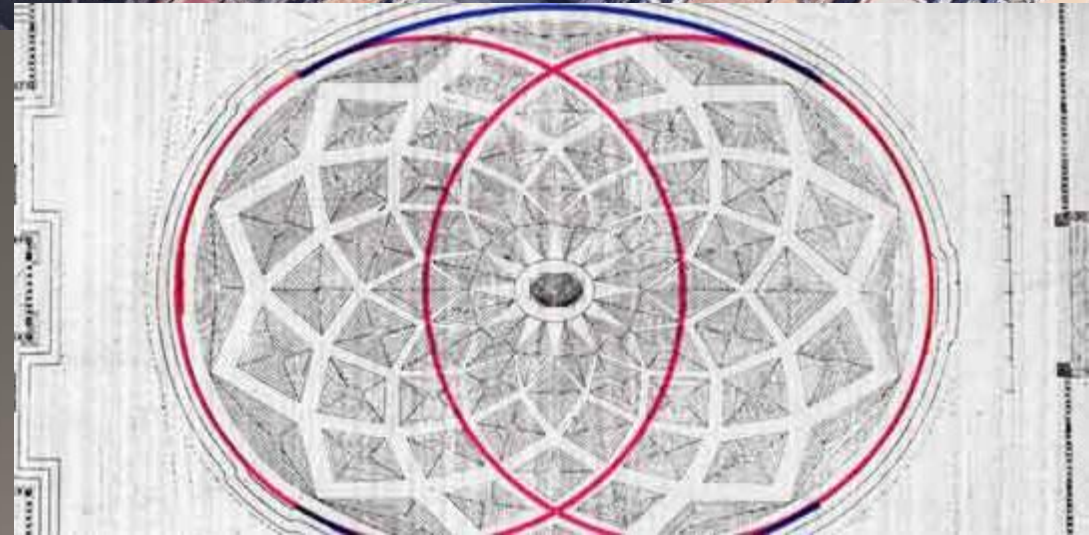
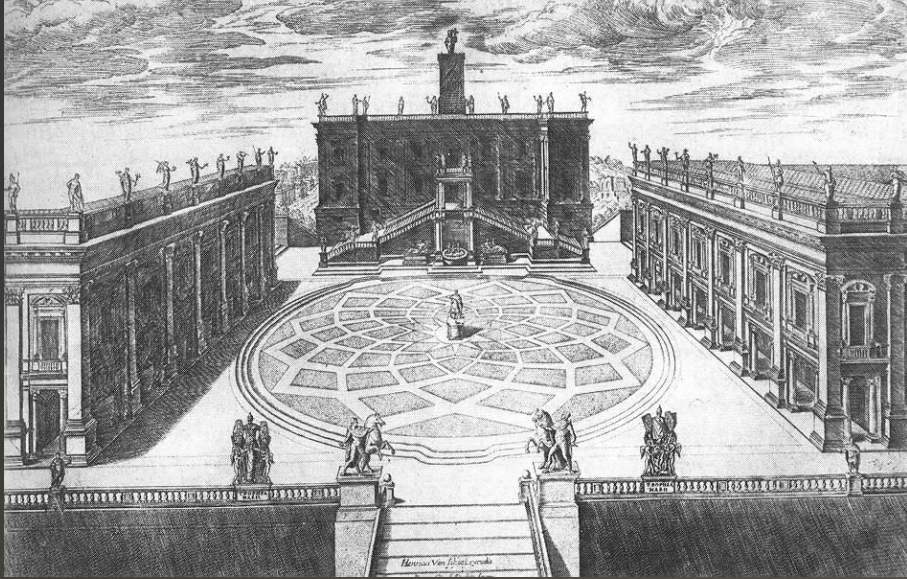
St Mark's Venice, late 11th century

Renaissance revival - perfect circular domes

- Leon Battista **Alberti**, emphasis on the dome and sky - 'the vast vault of the heavens' (*De Re Aedificatoria*, 1450); perfect circles
- Reinforced by **Neoplatonism** (Plato, *Timaeus*, 33B: cosmos 'a round in the shape of a sphere, equidistant in all directions from the centre to the extremities, which of all shapes is the most perfect')
- **Brunelleschi** (Duomo Florence and Pazzi Chapel); Leonardo drawings; Bramante (The *Tempietto*); Michelangelo (Medici Chapel, Sistine and *Last Judgment*, St Peter's 1547 dome ovoid not hemisphere?)



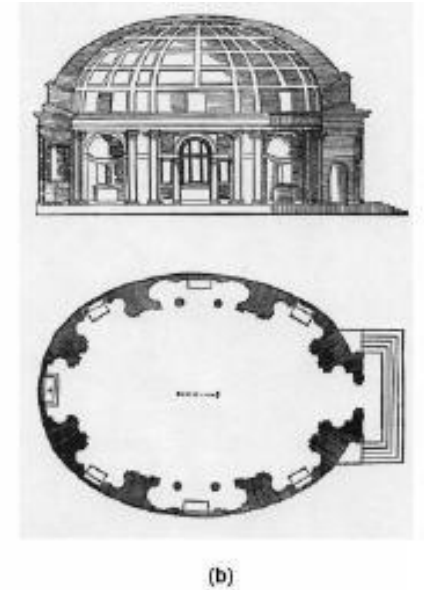
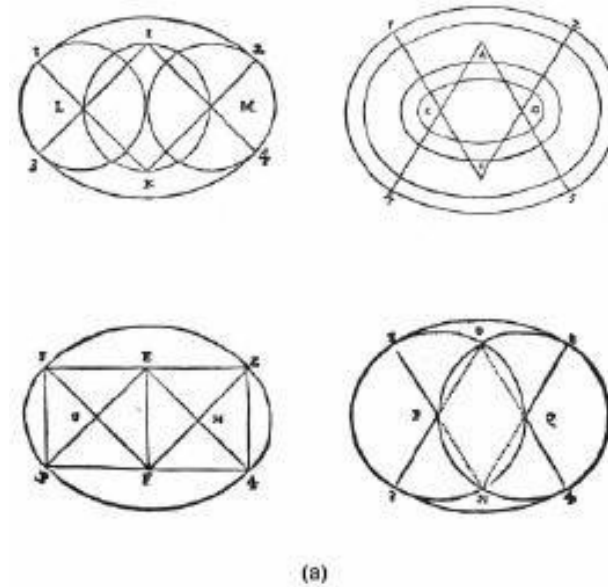
Campidoglio 1538



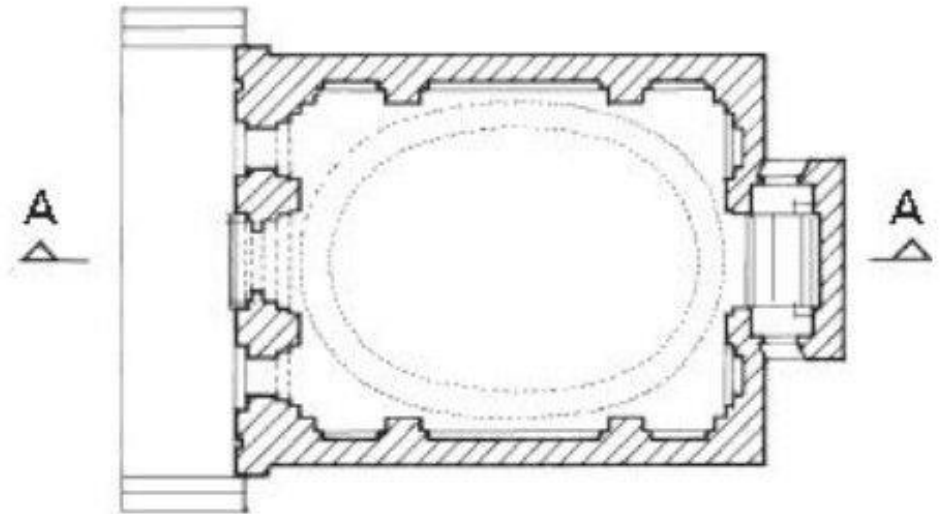
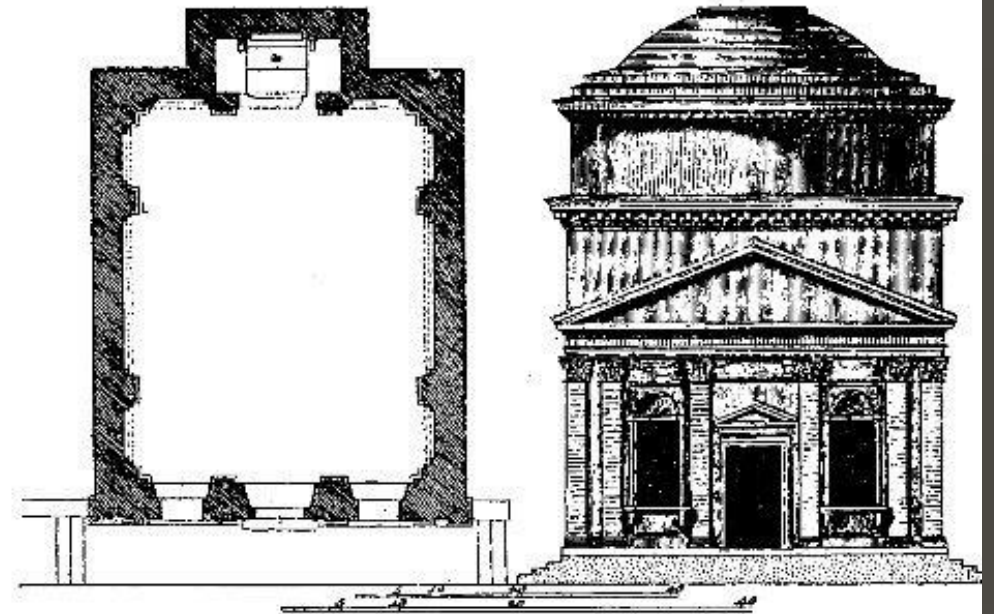
Evidence of Michelangelo interests in Art and Cosmology (Last Judgment); Music/proportion and Mathematics

Oval and elliptical (non-circular) structures/domes

- Not unknown before Renaissance (Colosseum – no corners, directional)
- Serlio 1537-1575 *Primo and Quinto Libri d'Architettura* – oval as an approximation to ellipse, a circle in perspective (1545)



Giacomo Vignola (1507-73) St Andrea in Via Flaminia 1550-1553





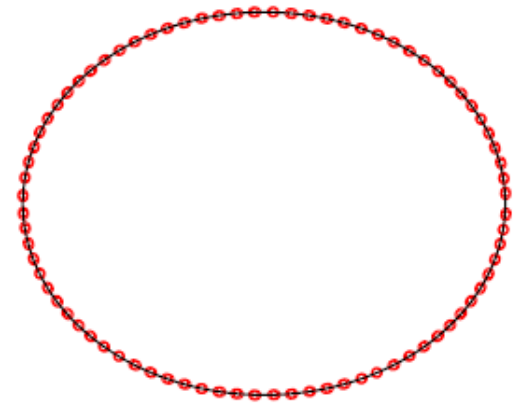
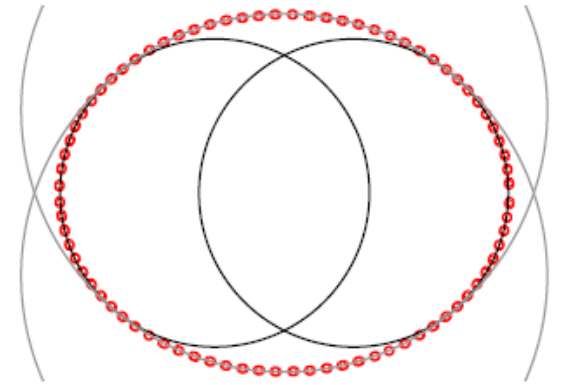
Church of San Giacomo in Augusta, in Rome, Italy, completed by Carlo Maderno 1600
[painting is 19th century]

Sant'Anna dei Palafrenieri, 1620's
(Borromini with Maderno)

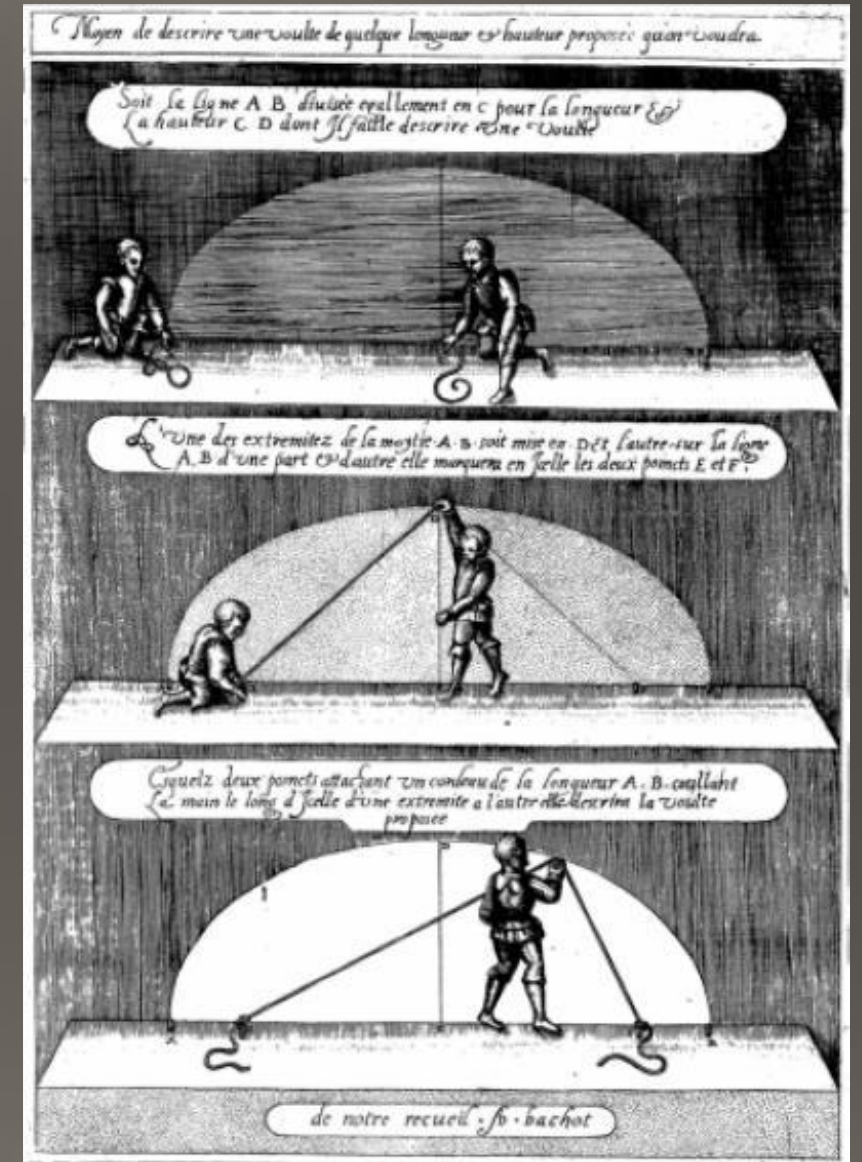
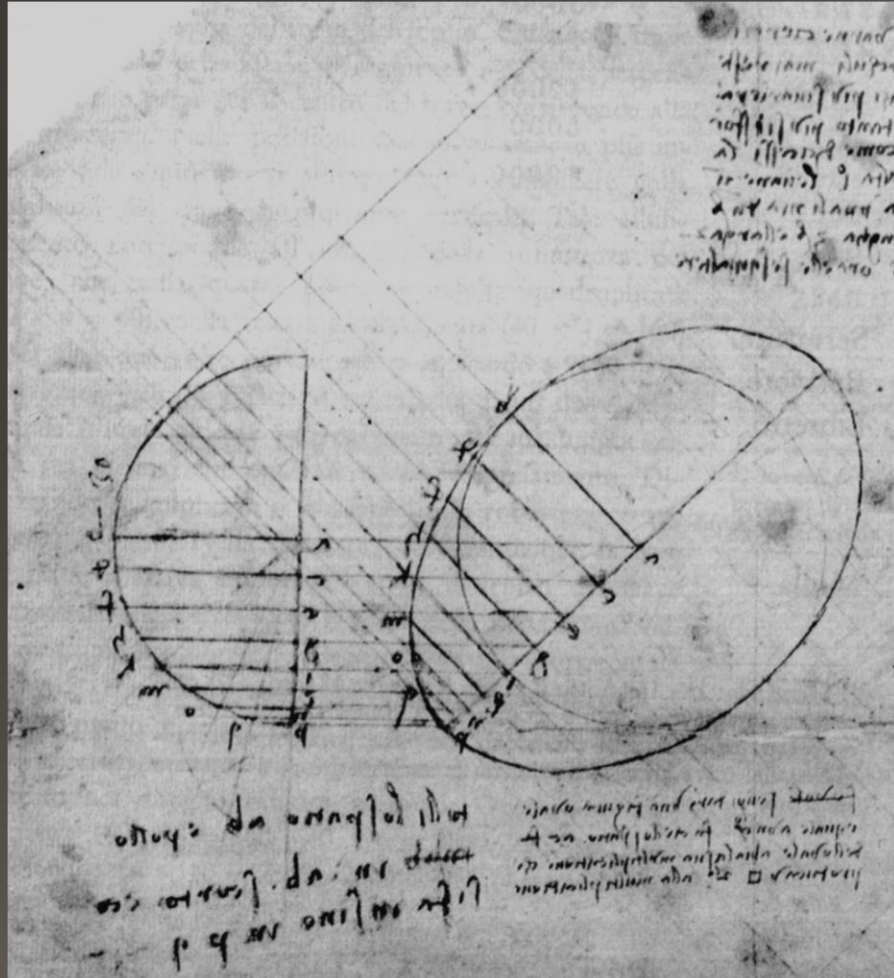


Ellipses and ovals

- Difficult to distinguish when axes similar
- Ellipse equation unknown until 17th cent
- Kepler (1602) saw orbit of Mars as oval, then as ellipse with the sun at one focus (1609)
- Use of string to trace ellipse
- Ovals in architecture as approximation of ellipse



Leonardo da Vinci, Notebooks (318r Codex Atlanticus c 1510)



Amboise Bachot, 1598

Johannes Kepler (1571 – 1630) in brief

Early years - Weil der Stadt nr Wurttemberg, Holy Roman Empire

1589 - University Tübingen, Theology

1594 - Graz, Mathematics (*Mysterium Cosmographicum*) ['sun must be the centre of the world, symbol of God, source of light and heat, force that drives planets in their orbits' – God as Geometer holds dividers]

1600 - Prague, Tycho Brahe – observational data (1596).

1601 - Imperial mathematician and advisor to Rudolph II

1609 - *Astronomia Nova* (First/Second Laws – orbits are elliptical; not uniform speed but equal areas/time)

1612 - Linz and elsewhere (after death Rudolph II)

1615 - First volume of *Epitome Astronomiae Copernicanae*, printed in 1617 (vol II 1620; vol III 1621)

1619 - *Harmonices Mundi* (Third Law - square of periodic times relate to cubes of mean distances)

1623 - Rudolphine Tables completed; Travelling Linz, Prague, Ulm

1630s - Not accepted at first (eg Galileo 1564-42; Descartes 1596-50)

1630-50 - *Epitome of Copernican Astronomy* widely read as astronomy textbook; ellipse-based astronomy

Mid/late 17th century – Hooke, Newton etc (*Principia Mathematica* 1687)

No Kepler without Tycho; no Newton without Kepler

The last scientific astrologer and the first astrophysicist (Sagan)

Ioannis Keppleri
**HARMONICES
MUNDI**

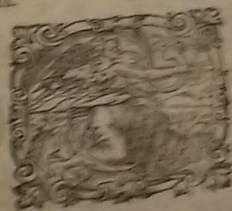
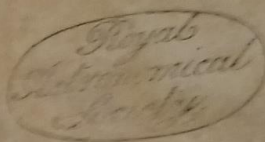
LIBRI V. QVORVM

Primus GEOMETRICVS, De Figurarum Regularium, quæ Proportio-
nes Harmonicas constituunt, ortu & demonstrationibus.
Secundus ARCHITECTONICVS, seu ex GEOMETRIA FIGVRATA, De Fi-
gurarum Regularium Congruentia in plano vel solido.
Tertius propriæ HARMONICVS, De Proportionum Harmonicarum or-
tu ex Figuris, deque Naturâ & Differentiis rerum ad cantum per-
tinentium, contra Veteres.

Quartus METAPHYSICVS, PSYCHOLOGICVS & ASTROLOGICVS, De Har-
moniarum mentali Essentiâ earumque generibus in Mundo præser-
tim de Harmonia radiorum, ex corporibus celestibus in Terram de-
scendentibus, eiusque effecta in Natura seu Anima sublimari &
Humana.

Quintus ASTRONOMICVS & METAPHYSICVS, De Harmoniis absolutissi-
mis motuum celestium, ortuque Eccentricitatum ex proportioni-
bus Harmonicis.

Appendix habet comparationem huius Operis cum Harmonicis CL
Ptolemæi libro II Icumque Roberti de Fluctibus, dicti Flud Medici
Oxonienfis speculationibus Harmonicis, operi de Macrocosmo &
Microcosmo inserta.



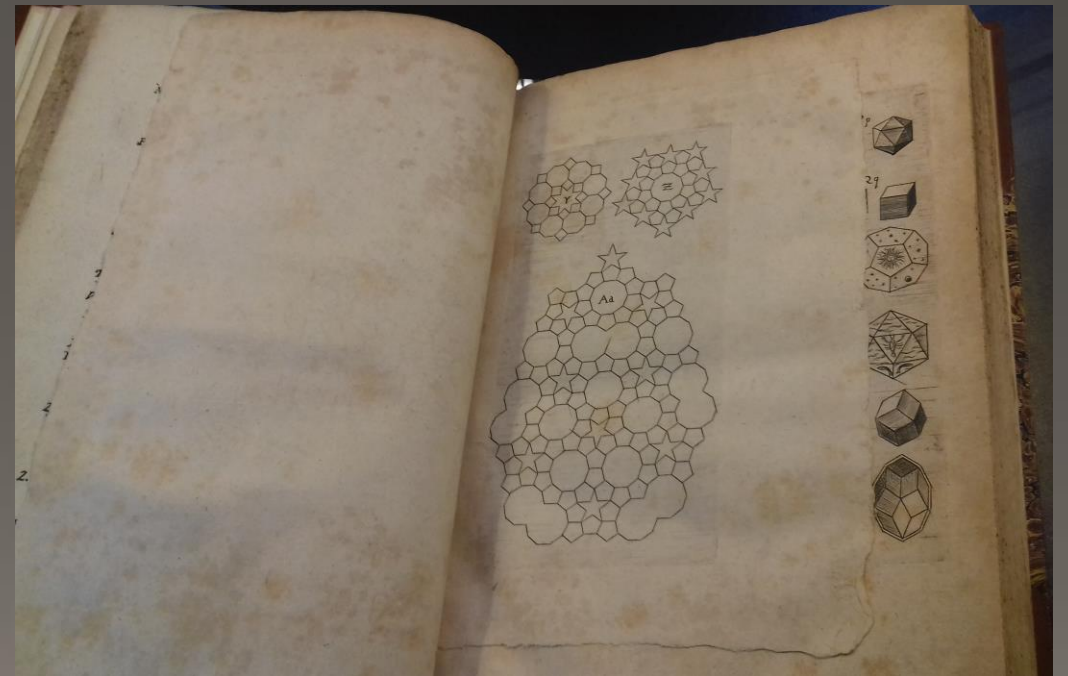
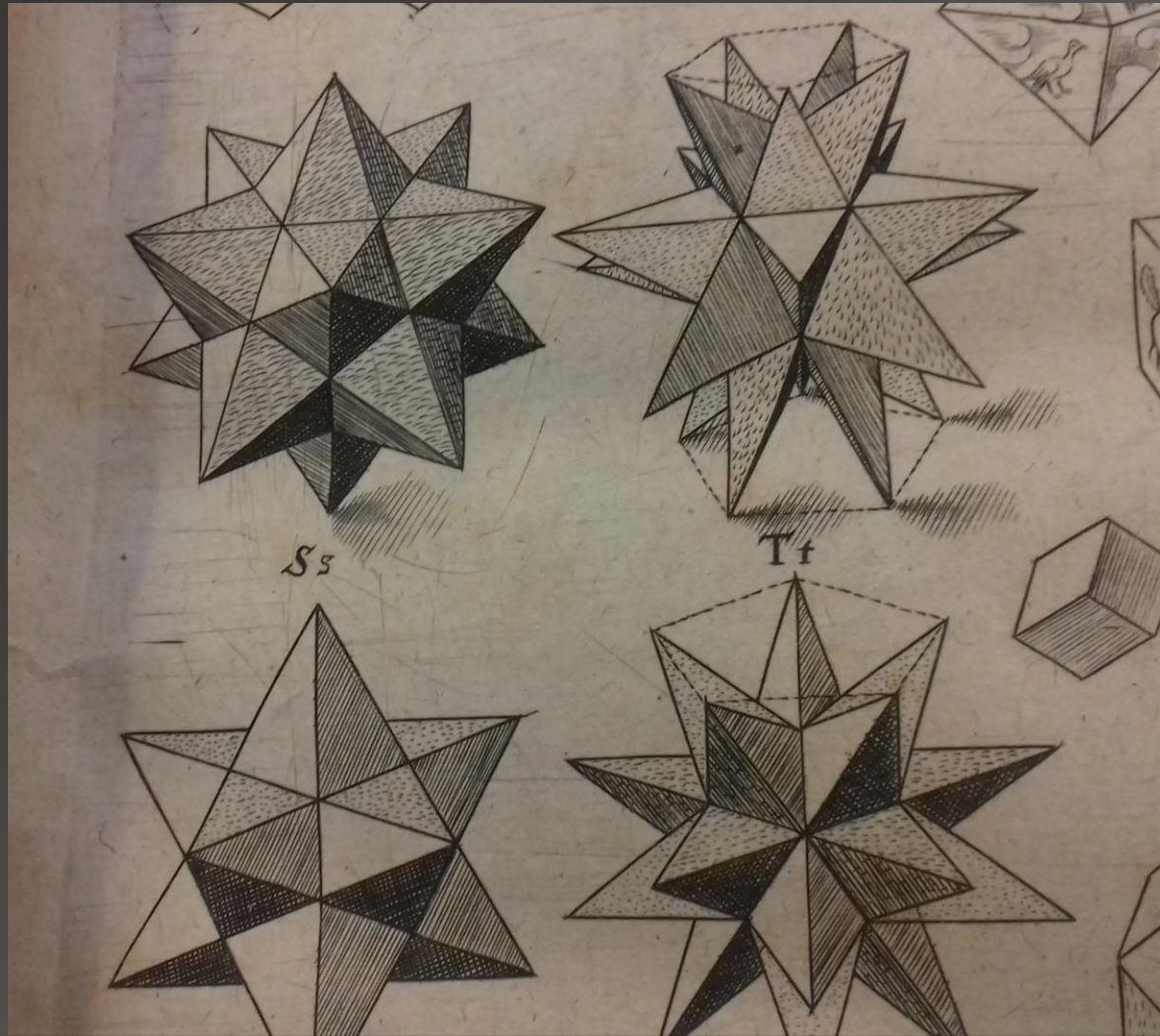
Cum S. C. M. Privilegio ad annos XV.

Lincii Austria, (Lintz)

**Sumptibus GODOFREDI TAMPACHII Bibl. Francof.
Excudebat IOANNES PLANCVS**

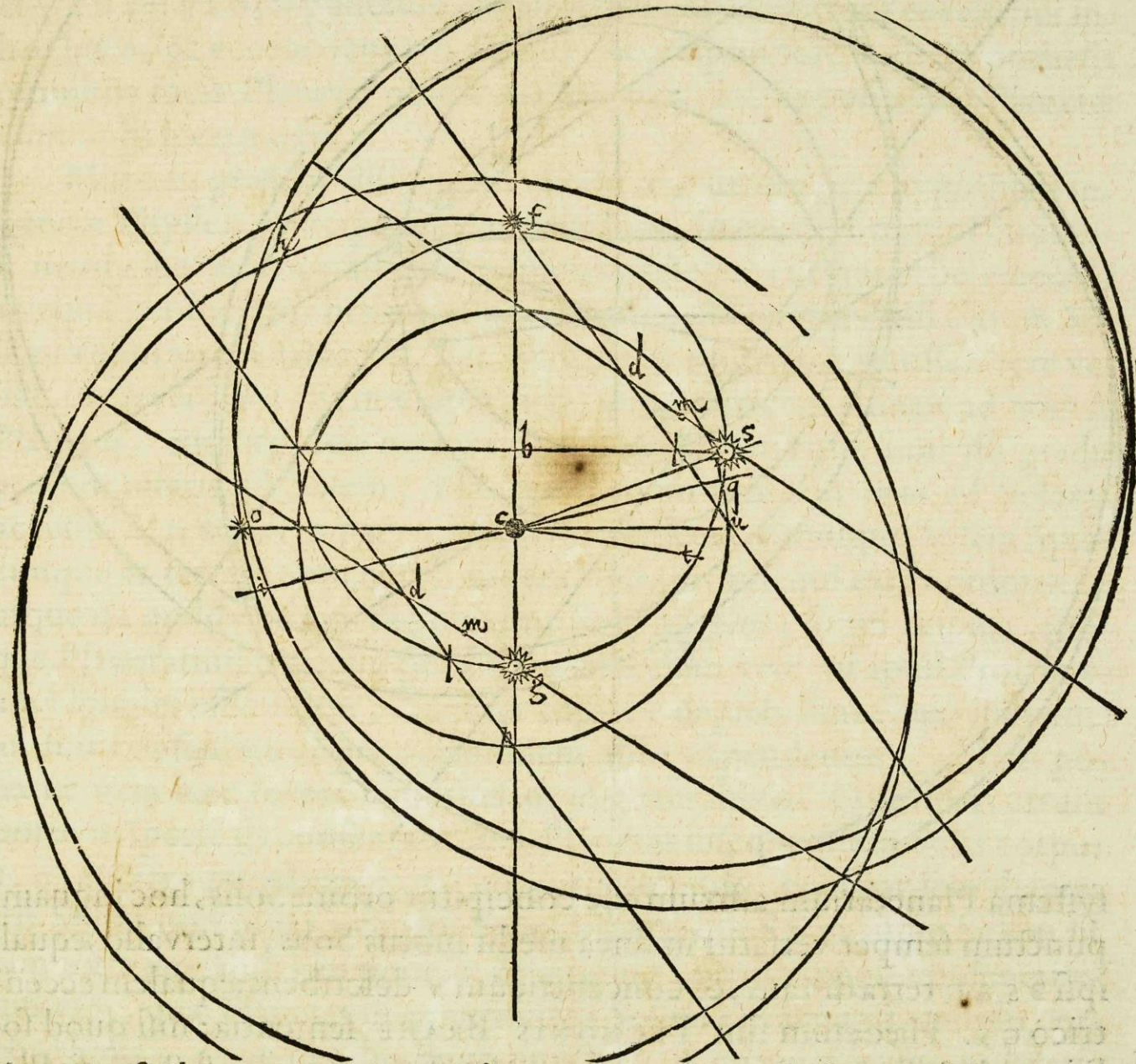
ANNO M. DC. XIX.

Following p. 52



Astronomia Nova

DENIQUE EADEM & in TYCHONICA hypothesi deducam.



Et si
Brahe
orbis
tis se
bem
quia
gener
trafo
prima
& qua
maib
netis
ventu
lui h
clude
interf
nem.
enim
ritatis
schen
fuera
tura.

Centro B scribatur eccentricus Solis G S, ut in eo B G sit linea apsidum, C lo-
cus terra immobilis, & B punctum aequalitatis, ex sententia authorum. nam in

**Significant
change/increase
in early 17th
century**

Link between architecture and cosmology (as above)

Ovals used as standard ellipse approximation

Revival of neoplatonic terms, geometrical bases (ellipse, oval, equilateral triangle)

Fundamental in *Harmonices Mundi* where orbit of every planet is ellipse with sun at one of foci

Borromini combined practical skills with scientific learning and culture

Francesco Borromini 1599-1667



- Formative years in Milan (stonemason)
- 'Artistic anarchist' – innovation and disorder.
But: underlying mathematical precision
- Scientific culture, humanism; maths; architecture
- Shared sources/influences with Kepler (eg Commandino, Muzio Oddi)
- 1519 went to Rome (patrons: Barberini family, Virgilio Spada)
- Barberini Palace and St Peter's (under Carlo Moderno 1556-1629), studied classical architecture and Michelangelo
- Bernini at St Peter's - but became rivals
- Died in Rome 1667 (suicide by sword)

1627	Palazzo Barberini (Carlo Maderno)
1620s	Sant' Anna dei Palafrenieri (from 1583), restorations hexadecagon
1623-34	Baldacchino, St Peter's, contribution to Bernini's design
1634-46	<u>S Carlo alle Quattro Fontane</u> (appt'd 1634, begun 1638)
1637-50	Oratory of S. Filippo Neri (about same time)
1643-60	<u>S Ivo della Sapienza</u> (appt'd 1632, begun 1643)
1644-55	S. Giovanni in Laterano – radical renovations, transformation
1647	Filomarino Altar, SS Apostoli Naples - startling inclusion of icosahedron motif
1653	St Agnes in Agona (P. Navona) Pope not happy (1652)so asked Borromini
1655	Three Facades of Collegio di Propaganda Fide (Urban VIII Barberini 1627) main façade Bernini 1644

Early works:

1627 Palazzo
Barberini -
helicoidal
staircase

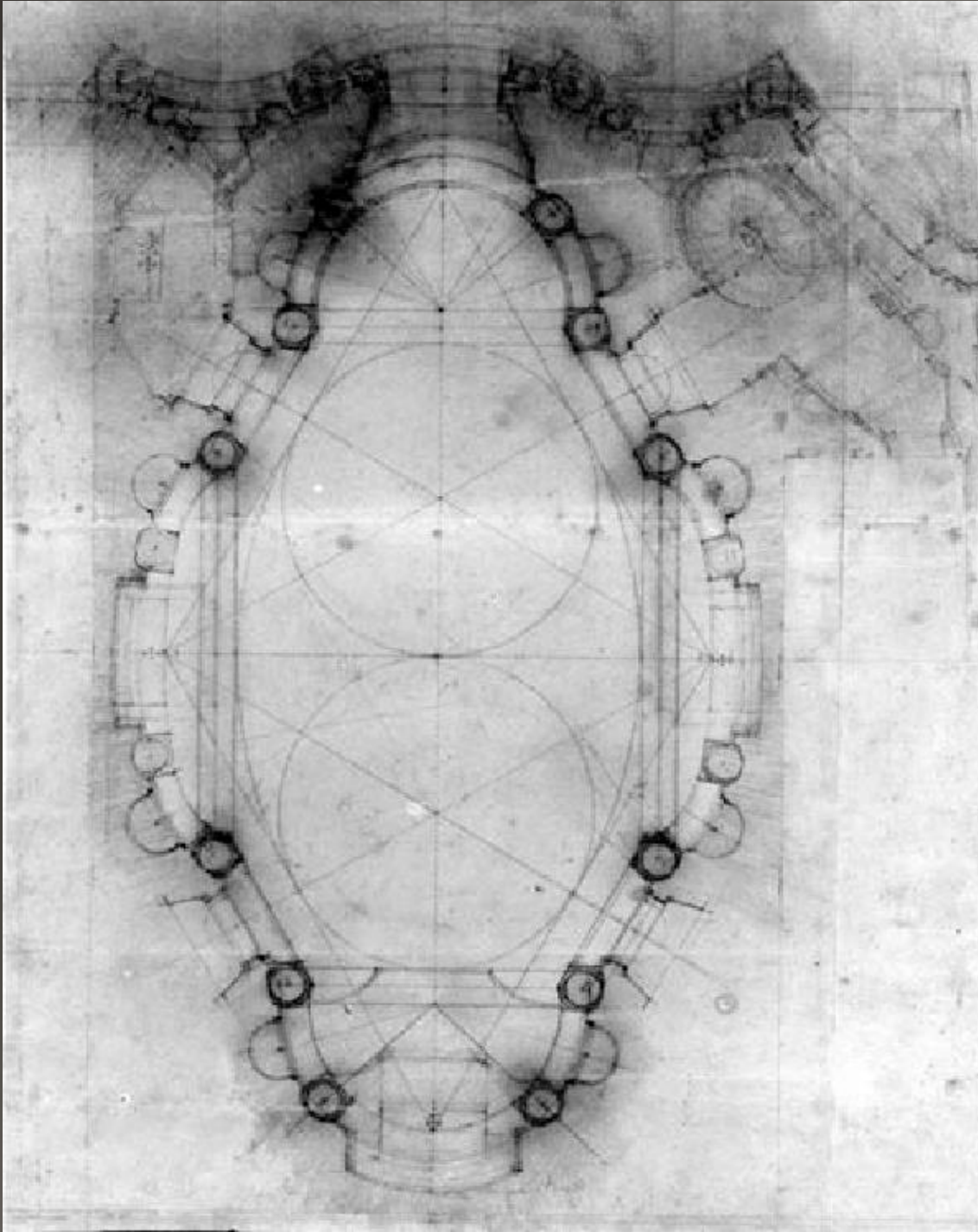


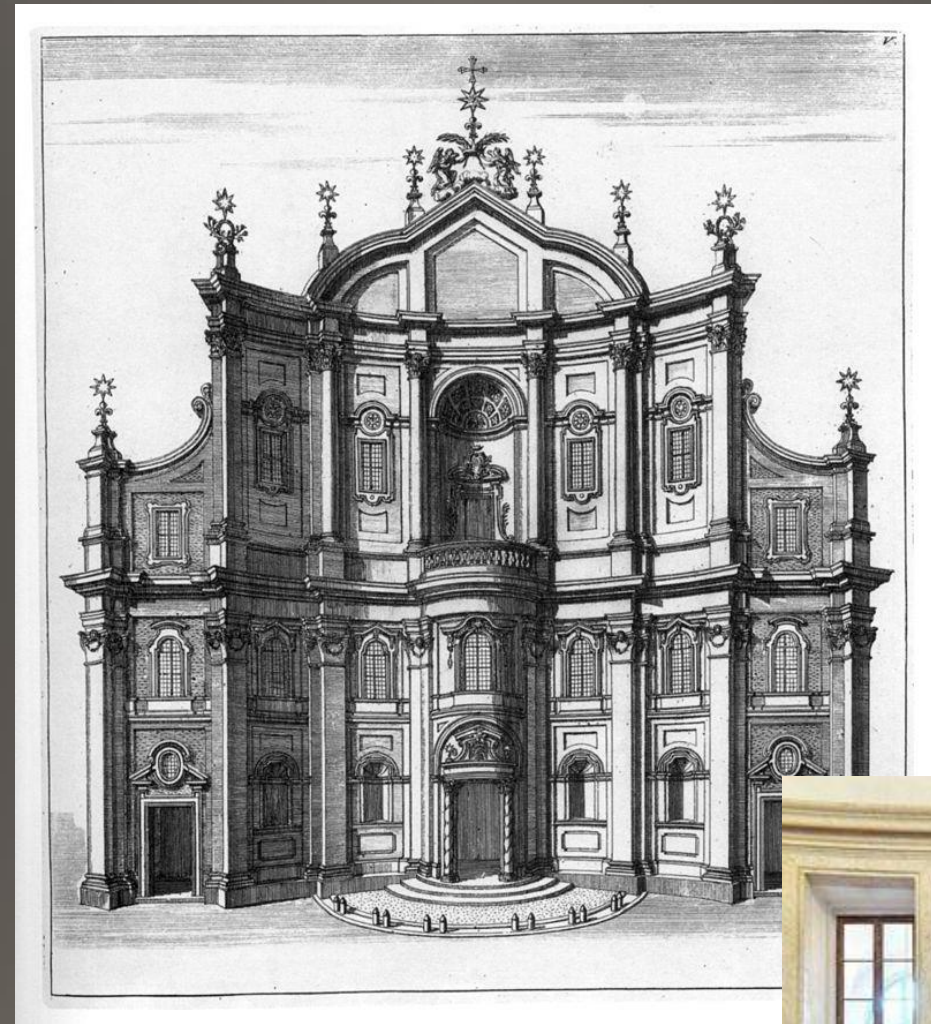
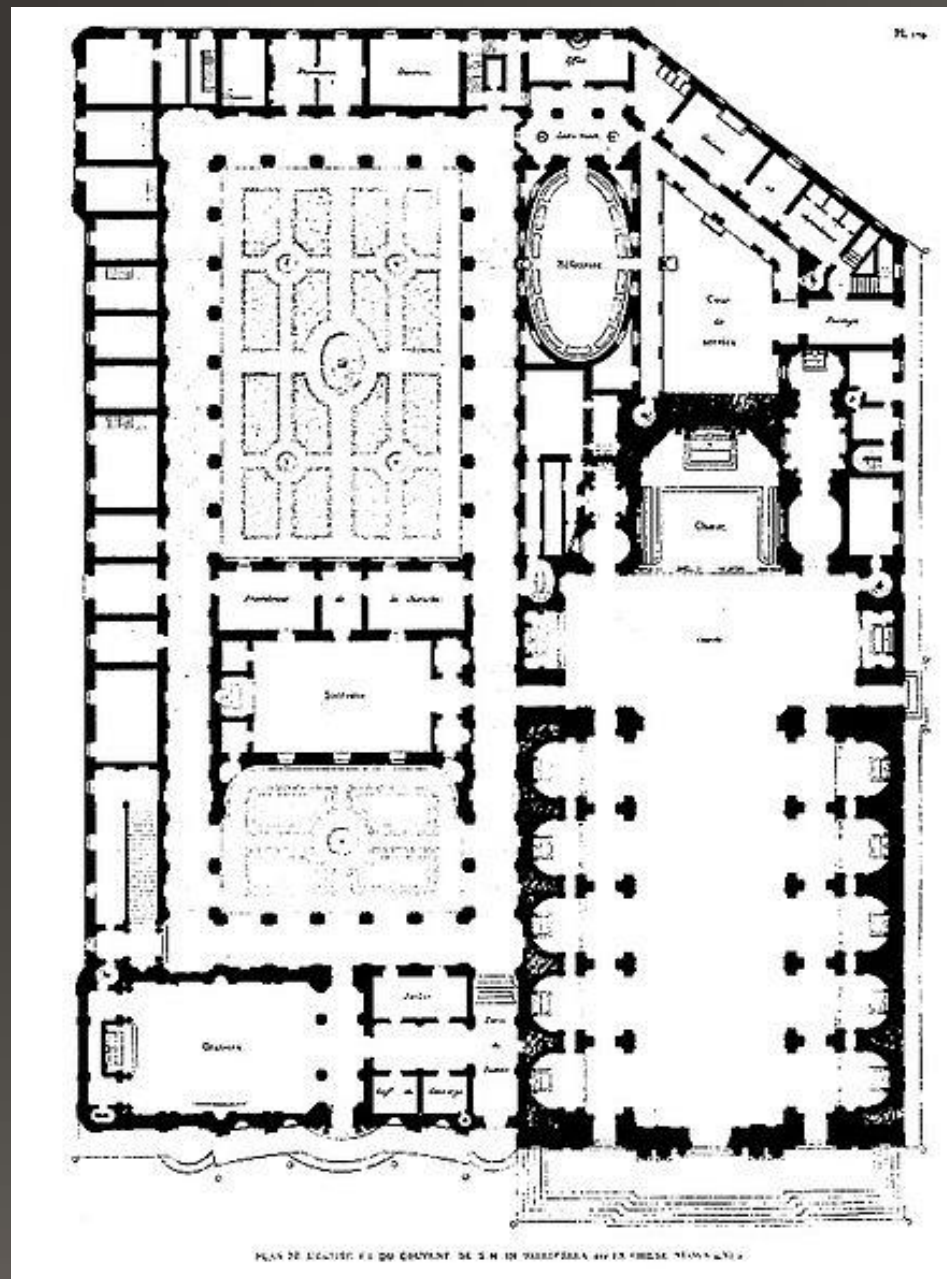
S Carlo alle Quattro Fontane

- 1634 commission,
Church 1638
- Complex - again
based on geometry
- Inscribed circles
- Represents heavens
- Holy spirit and 'rays'
in brightly lit lantern









Oratorio of S Philip Neri, 1637-50
(musical performances)



S Ivo della Sapienza

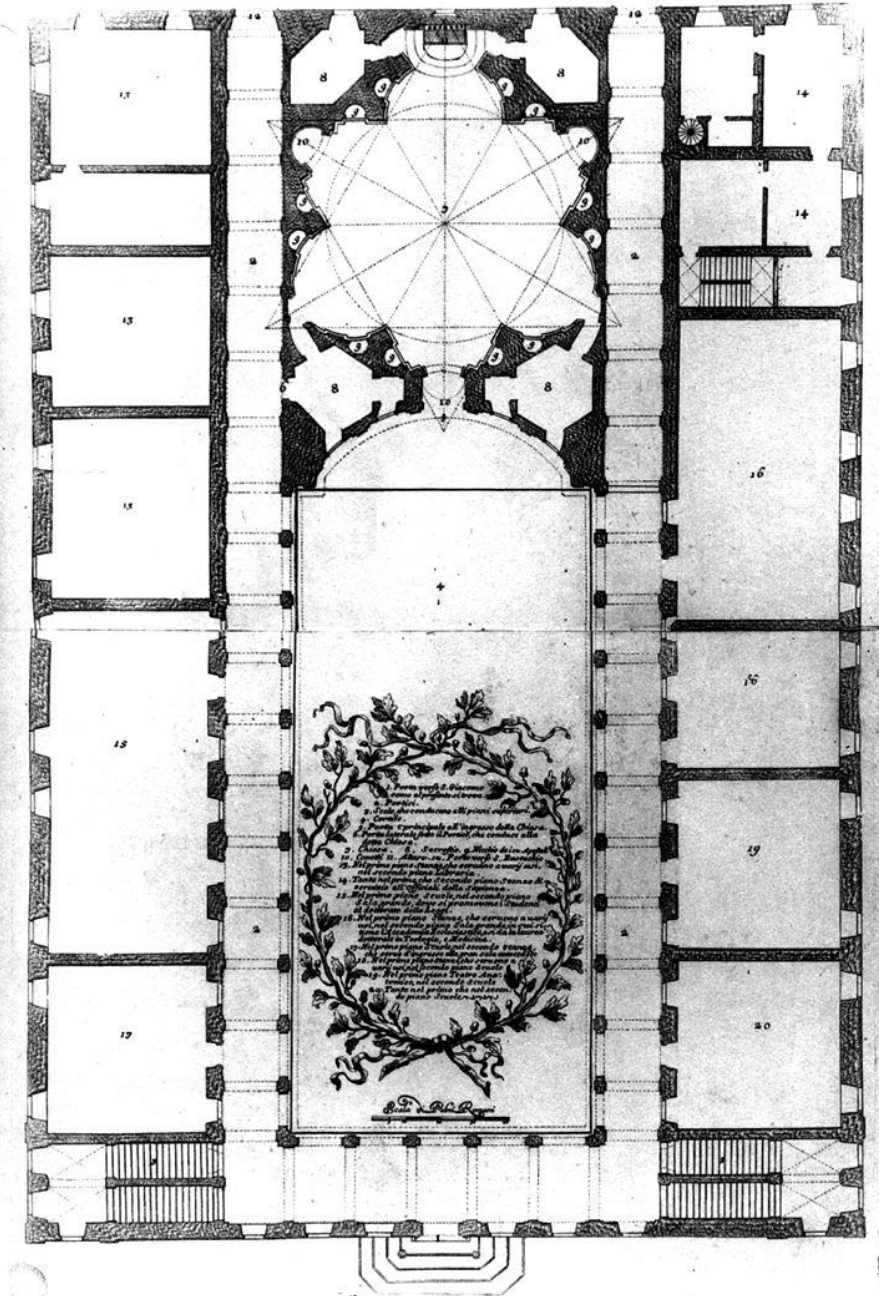
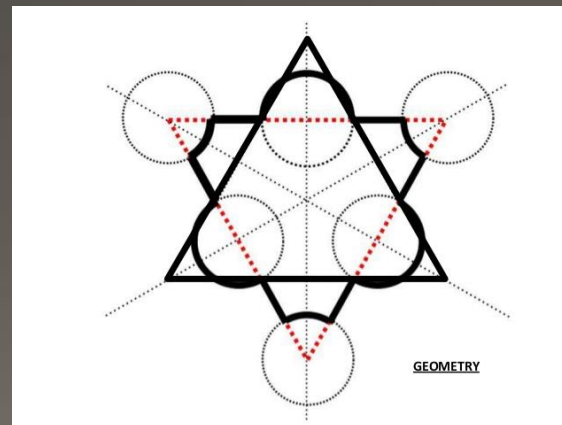
Complex, celestial and terrestrial
zones

As appropriate to the Church of
the University of Rome
(Sapienza)



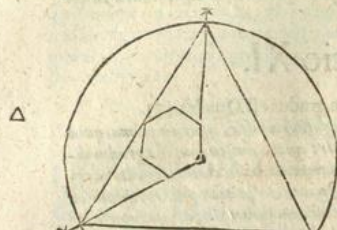
S Ivo della Sapienza

- Star/Hexagon plan, based on equilateral triangles
- 6 bays - organised through its geometry
- Ribs lead the eye up past the stars to the vault of heaven
- Unusual, significant geometry (octagonal floor design?)

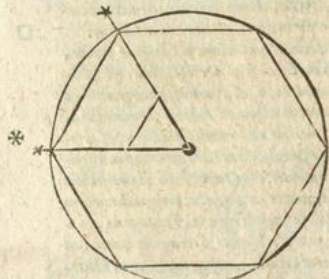


146 DE CONFIGURATIONIBUS

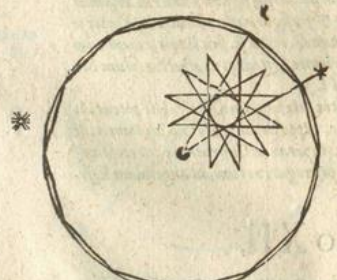
CAP. V. facit proprietatum non identitas, sed equipollentia. Primum eorum figura



differentia, ut jam modo dictum, redadatur in congruentia perfectionem.



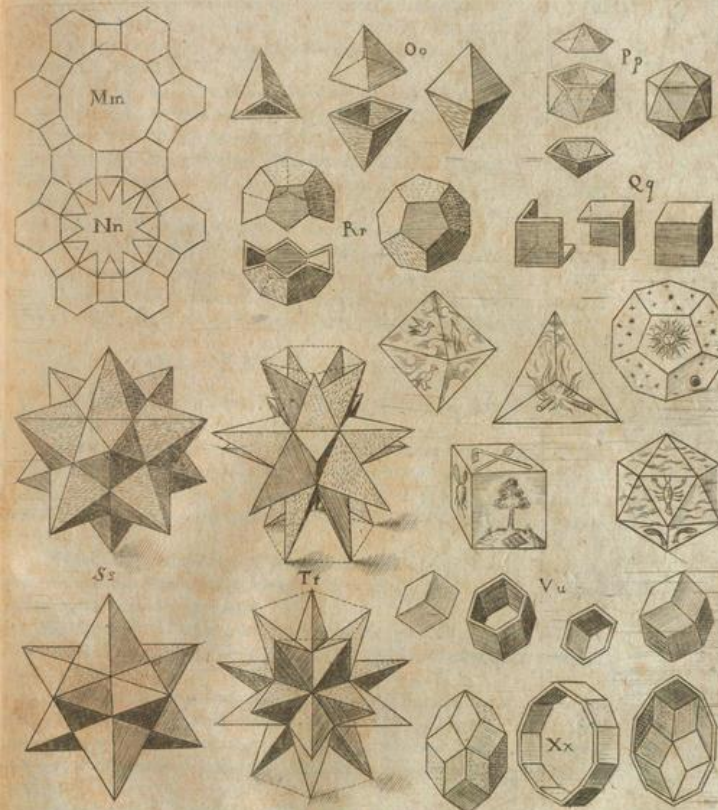
tamen proportione: ultimus hic est Dodecagonus, habens latus ineffabile. Verum scilicet nec precipuum est ad Efficaciam argumentum, nec in figura precipua, hoc est circumferentiali, consideratur: sed tantum in centrali: min' precipua. Quae si quid potest, Trinum paulo reddit efficacius Sextili, quia Trinum format angul' Hexagoni in centro; paulo min' utriusq' efficacem Semisextili, quem metitur angul' Stella Dodecagonice in centro. Est tamen ceteris sequentibus nobilior scientia Semisextili, quia lat' centralis figurae, in Ineffabilibus nobilissima est species: sc. Binominus, & in earum sub divisione duplici, semper priores tunc, adeo ut cum sociis suis, latere circumferentialia figurae, rectangulum effabile formet, quod est nota perfectionis



penè absolutae: adeoq' etiam cum Trigonis & Hexagono hanc figuram scilicet contendere, propter hanc pensionem ineffabilitatis suae, pondere jam admodum

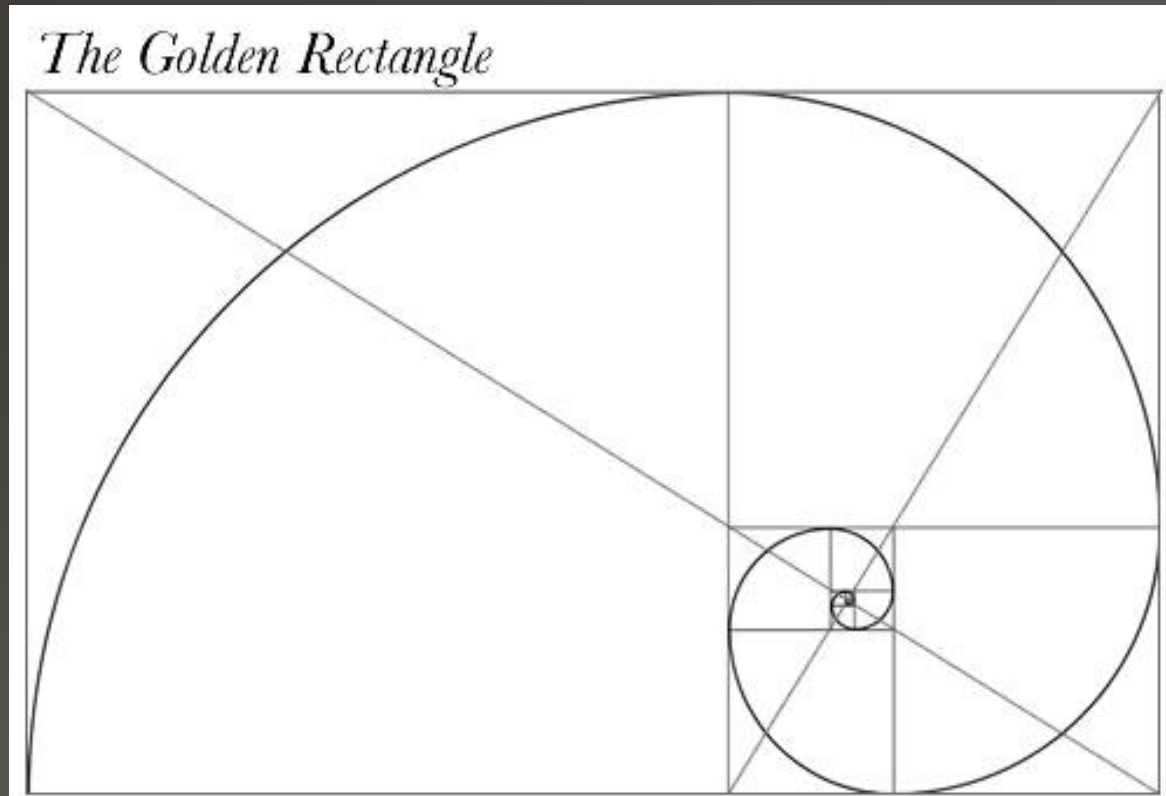
Propo-

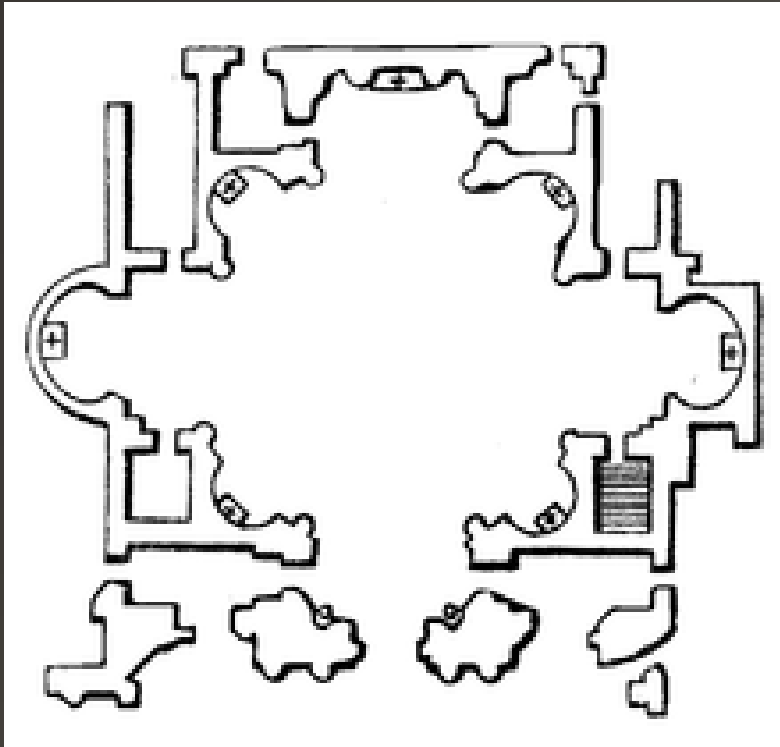
S Ivo recalls Kepler's nested solids, and *Harmonices Mundi* (esp Bk II)





S Ivo della Sapienza, exterior spirals and golden section





St Agnes in Agona (Piazza Navona), 1653

S Giovanni in Laterano, Basilica
style, with elliptical panels on
ceiling, windows 1644-55



Later works

Collegio de
Propaganda
Fide, 1644



Palazzo Spada
La Galleria Prospettiva
1652-53



Borromini and Kepler



- Knowledge of cosmological symbolism in architecture, especially domed architecture (but oval/elliptical domes rare pre-17th century)
- Borromini well educated; revival of ancient sources in Milan (Federico Commandino trans of Roman texts used by Kepler; Muzio Oddi architect and mathematician)
- Kepler's ideas in Italy, England - international fame, widely read (*Epitome of Copernican Astronomy*, Giovanni Battista Riccioli); support from Jesuits; search for harmony, proportion (and in music/intervals)
- Influence of geometric forms – architecture in the same way as Kepler saw basis of universe ('Divine Geometry' as key)
- Relation between human/divine, earth/cosmos, celestial/terrestrial. Breaking the rules of Classical Architecture.
- Earth's imperfections organised via geometrical system with divine order ruling chaos

Geometric interpretation of the cosmos

- **Galileo:** *The great book of nature is written in the language of mathematics ... triangles, circles and other geometry*
- **Kepler:** Realisation that the Cosmos is based on ellipses; sees universe as symbol of Trinity – God as sun, Christ as fixed stars and forces in between as spirit. Geometry removes mankind from centre of universe
- Borromini would have been aware of Kepler's astronomy as well as the tradition of ecclesiastical architecture as microcosm of universe
- Borromini was secretive about his geometric designs. His churches have symbols of Trinity, stars, oval/elliptical domes (not capricious)
- Gave a nod to dynamic new ideas in his architecture – leaving observers to interpret and understand

Patronage

- Both were supported by the Church/important patrons
- Kepler supported by Jesuits (although he was a Lutheran)
- Barberini family supported Borromini (worked on Palace)
- Maffeo Barberini: elected Pope Urban VIII in 1623; had a special interest in astronomy; supported Galileo (until 1633); was also a prominent patron of the arts and a reformer of the Church
- Also Spada family (cardinals, Palace)

Continued effects new approach to harmony achieved by new underlying geometry in architecture

1656-67
Bernini Piazza
St Peter's
and S Anna
dei Palafrenieri



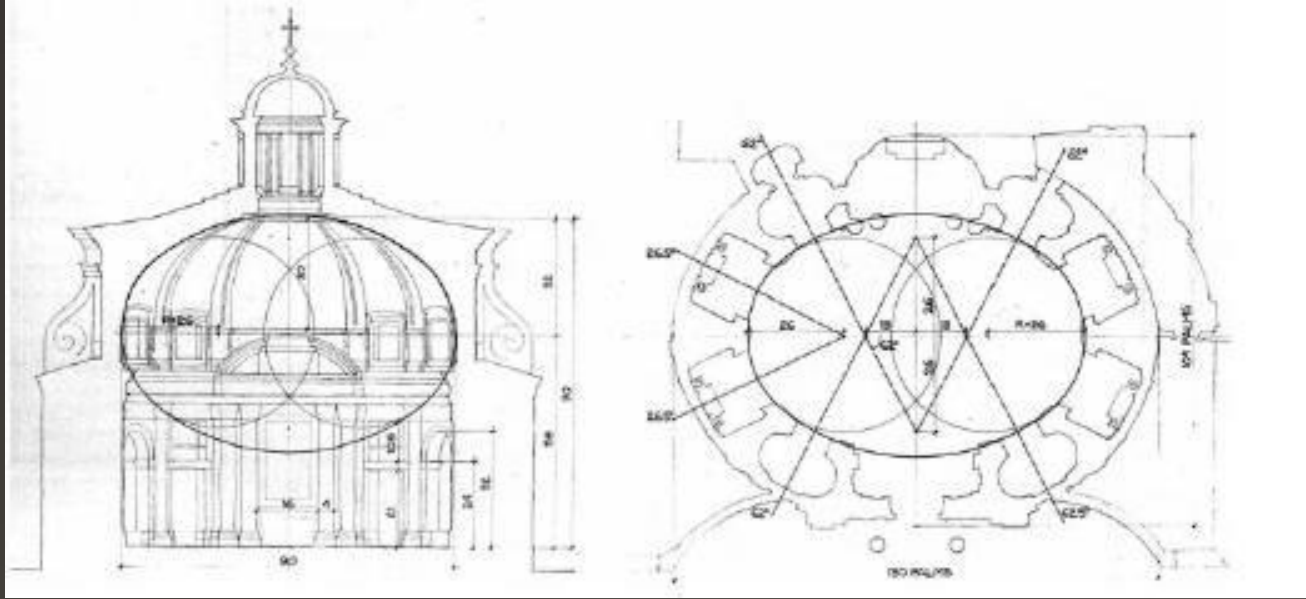
Bernini's piazza and
colonnade

Oval and trapezoidal

New dynamic approach
compared with classical
Renaissance



Bernini, Sant' Andrea al Quirinale, 1658



Bernini, Sant' Andrea
al Quirinale, 1658



England: 'appropriately' dedicated to James I



Apotheosis of James I, Banqueting House, Whitehall (1619-22, ptd c 1628-30)
Architect Inigo Jones and artist Sir Peter Paul Rubens both in Italy.
[Catalogue of Rubens' Library (Bibl Nat Fr Q2069) lists works by Tycho Brahe, Galileo and *Harmonices Mundi*]



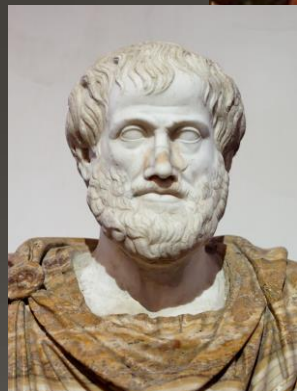
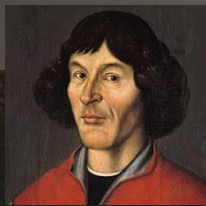
Later influences

Sir Christopher Wren (1632-1723)

- Astronomer as well as architect
- Inaugural lecture as Gresham Professor (1657) refers to Copernicus, Galileo, and the elliptical orbits of Kepler
- Some oval, elliptical designs (St Mary Abchurch, 1681)
- Colleague of Robert Hooke
- Founder of Royal Society 1660
- Change in role and status of astronomers



Niccolo Tornoli, *The Astronomers*, 1645
(148 x 248 cm, Galleria Spada – NB
links)



Kepler, 1571-1630

1571 Wiel der Stadt, Wurttemberg, HRE

1589 University Tübingen, Theology

1594 Graz, Mathematics

1596 *Mysterium Cosmographicum, 1596)*

1600 Prague, Tycho Brahe

1601 Imperial mathematician/Rudolph II

1609 *Astronomia nova* (1st, 2nd Law)

1617f *Epitome astronomiae Copernicanae*

1619 *Harmonices Mundi* (Third Law)

1623 Rudolphine Tables

1630 Died

1630-50 Widely read

Ellipse-based astronomy becomes established

Mid/late 17th century, Hooke, Newton etc

Key Dates

Borromini, 1599-1667

1599 Born Lombardy

1608/14 Milan

1620 Went to Rome (Maderno)

1627 Worked on Palazzo Barberini

1620s St Anna Palafrenieri (oval)

1634 S Carlo Quattro Fontane

1637 Oratory of S. Filippo Neri

1643 S Ivo

1644 S Giovanni in Laterano

1647 Filomarino Altar, SS Apostoli

1653 St Agnes in Agona (P. Navona)

1655 Collegio di Propaganda Fide

1667 Died in Rome

Significant events

1550 S Andrea in Via Flaminia (Vignola, oval dome)

1600 S Giacomo in Augusta (Maderno, oval dome)

1610 Galileo’s Siderius Nuncius

1618-48 Thirty Years’ War

1623 Maffeo Barberini/Urban VIII

1620s Urban VIII supports Galileo

Also huge Patron of Arts

1620s James I of England also patron (dedication of HM)

1632/3 Galileo no longer supported

1644 Death Urban VIII

1656-67 Bernini Piazza St Peter’s

1658 Bernini S Andrea al Quirinale

1660s Wren, Hooke etc

- Borromini not only looking back at ancient ideas (scriptures and classics) - also the newest ideas
- But not just copying ideas and illustrations from *Harmonices Mundi*
- Kepler as a real influence, understanding and expressing the concept of Order and Harmony in the universe (through underlying geometry, and perfection)
- A new revolutionary and dynamic approach; change in world view and mankind's place in the cosmos (new attitudes, as well as new science)
- The exuberance of the Baroque, revolutionary, new and dynamic age – yet with underlying harmony and order as ordained by God

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