Francesco Borromini and the Cultural Context of Kepler's *Harmonice Mundi*

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Abstract. The idea of circular domed architecture as imitative of the flat earth covered by the 'Dome of Heaven' was established from Byzantine times up to its revival during the Renaissance. Yet the cosmological symbolism of the circular dome was replaced in the early seventeenth century when elliptical, oval or other geometrically-inspired domes became a key feature of the Baroque. The move away from circular to oval or elliptical forms by architects such as Borromini coincides with the new cosmology and Kepler's view of elliptical orbits as the basis for the structure of the universe. Building on his *Mysterium Cosmographicum* (1596) and the view of perfect, regular nested solids as the basis for the organisation of the planets, Kepler focused on the ellipse as underlying the mechanics of the universe. His realisation that the universe was not based on perfect circular motion but on elliptical orbits (with the sun at one of the foci) was developed in *Harmonice Mundi*, linked to concepts of harmony and proportion.

In turn, the work of the architect Borromini (as at S. Carlo alle Quattro Fontane 1638-41 and S. Ivo della Sapienza 1642) involve novel and complex geometric designs that significantly align Kepler's astronomical ideas. Mathematical precision underlies Borromini's seemingly extravagant schemes, in the same way that Kepler's theories sought harmony in the universe. Documentary evidence to substantiate a claim of the influence of Kepler's theories on Borromini has yet to be found. However, it is significant that Borromini's patron in Rome was Cardinal Barberini (later Pope Urban VIII) who was well-known for his interest in astronomy. Kepler's mathematical methodology and interpretation of the geometrical structure of the universe may have appealed to Borromini and his patrons on many levels. It cannot be mere coincidence that the use of such mathematical forms in ecclesiastical architecture comes in at around the same times as Kepler's writings.

Johannes Kepler (1571–1630) was a sombre German – a Lutheran, mathematician, geometer, astronomer, astrologer and musicologist.

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Francesco Borromini (1599–1667) was a flamboyant Italian, Catholic artist, architect and courtier. These two seemingly different characters lived far apart, yet their worlds collided with dramatic effect in the evolving seventeenth-century Europe. As will be argued, the writings of the former (especially the *Harmonice Mundi* of 1619) profoundly affected the context of the European Age of the Enlightenment - not only in science but also in the arts and culture.[1] Changes were specifically demonstrated by the new dynamic architecture of the age of the Baroque, especially by Borromini, that reflect changes in world view in a similar way to scientists and astronomers of the age, such as Johannes Kepler.

Art and architecture, particularly religious, traditionally reflected the contemporary cosmological view of the universe, and the geometry of the universe has frequently been used as inspiration for spiritual architecture from Stonehenge up to the present day. The widespread use of domed architecture, for example, is a reflection of the concept of the 'dome of heaven' and the natural eye observation of the (supposedly) flat earth covered by the dome of heaven. As expressed in *Genesis, Isaiah,* and the *Psalms* which laid the foundation for much ecclesiastical iconography: as Isaiah recorded, 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'.[2] This has been widely reflected in Judaeo-Christian art and architecture, from the mosaic-encrusted golden celestial domes of Byzantine churches to the revival of perfect circular domed architecture during the Renaissance. The decoration of such domes also often alludes to astronomical symbolism of the sphere, circle and circular motion.[3] This view was reflected in ecclesiastical art and architecture: for example, the Temple of Solomon, Jerusalem was built in the same proportions as the known universe.[4] Later examples are to be found of the traditional link between domed architecture and the view of the cosmos such as the Mausoleum of Galla Placidia in

[1]. Johannes Kepler, *The Harmony of the World*, trans. E.J. Aiton, A.M. Duncan, J.V. Field (American Philosophical Society, Philadelphia, 1997).
; Johannes Kepler, *Harmonice Mundi* (1619, First edition, Royal Astronomical Society Library).

[2] Isaiah 40:22. See also Genesis 1; Psalm 104; Jeremiah 10:12; Ezekiel 5:5.

[3]. Lehmann, Karl (1945) 'The Dome of Heaven', *Art Bulletin*, 28, pp.1–27; Baldwin Smith, E. *The Dome: A Study in the History of Ideas* (Princeton: Princeton University Press, 1950), esp. pp.85–94; Valerie Shrimplin,'Boromini and the New Astronomy', *Proceedings of The Inspiration of Astronomical Phenomena* (2003) pp.413–22.

[4] I Kings 6.

Ravenna, built in 425, the 'hanging' domed architecture of Santa Sophia in Constantinople, the Monastery at Daphne in Greece, or the domes of St Mark's Venice, which also include the story of the creation of the cosmos.

The *Ten Books on Architecture* by the Roman Marcus Vitruvius Pollio (c. 80–15 BC) were a key text for Renaissance art and well-known to architects from Brunelleschi to Michelangelo and later architects.[5] In Book 1 Vitruvius emphasised that it is essential for all architects to 'be acquainted with astronomy and the theory of the heavens'.[6] He followed this in Book IX with sections on astronomy, zodiac, planets, sun, moon and constellations, defining the 'Universe' as 'the heaven that is made up of the constellations and the courses of the stars'.[7] The tradition of the deity(s) as inhabiting the heavens above the earth was also indicated in classical times, for example by the celestial, domed Pantheon ('all gods') in Rome built in AD 126.[8]

Oval and elliptical (non-circular) structures/domes were also not completely unknown before the Renaissance, for example, the Colosseum in Rome (1st century CE).But from the early seventeenth century, the elliptical (or oval) dome became a key feature of Baroque architecture, and the seventeenth century saw some remarkable developments in domed architecture that have not really been adequately explained. While the significance of the 'dome of heaven' in Byzantine and Renaissance architecture (inspired by the perception of the universe) has frequently been emphasised, less discussion seems to have taken place about post-Renaissance developments during the Baroque period.[9] The preference of architects like Borromini for elliptical rather than perfectly circular or hemispherical domes coincides with developments in astronomy and cosmology in the seventeenth century, which challenged many classical and humanist precepts, such as the perfection of the circular form. Short of the discovery of handwritten notes by the artist, it is difficult to prove that the predilection for the form of the ellipse by Borromini and others might have any direct relationship with Kepler's realisation of elliptical orbits as the basis for the structure of the universe (as first applied to the orbit of

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[5] Vitruvius, *The Ten Books on Architecture*, trans. M. H. Morgan (New York: Dover, 1960 edn).
[6] Vitruvius, *Ten Books*, pp.4–5.
[7] Vitruvius, *Ten Books*, p.257.
[8] Lehmann, 'The Dome of Heaven', especially 9ff.
[9] Demus, Otto *Byzantine Mosaic Decoration: Aspects of Monumental Art in Byzantium* (London: Routledge and Kegan Paul, 1948).

Mars and then, by 1619, to all planets).[10] However, the dramatic introduction of oval/elliptical domes at about the same time as Kepler revolutionised the perception of the universe and its mechanics, seems unlikely to be mere coincidence. The radical changes and transition to the use of oval domes in the Baroque period occur at the same time as the dissemination of ideas on Kepler's elliptical orbits.[11] Kepler's work fundamentally changed the understanding of the mechanics of the universe, having not only an immense scientific impact (in his attempts not only to describe, but to explain the cosmos) but also on culture and world view in general. Aviva Rothman shows how Kepler's cosmology took an architectural approach, and Kepler himself designed an architectural frontispiece to his *Rudolfine Tables*.[12]

The Renaissance revival of perfect circular domes was first emphasised by the architect Leon Battista Alberti who focused on the perfect circles of the dome and sky – 'the vast vault of the heavens' (*De Re Aedificatoria*, 1450).[13] Interest in the perfect circular form in the Renaissance derived from platonic thought and concepts of natural perfection. The symbolism of the circle was reinforced by the Neoplatonic revival since Plato described the cosmos as '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'.[14] Other examples include works by Brunelleschi (the Duomo Florence and the Pazzi Chapel); Leonardo (drawings of ovals); Bramante (The 'Tempietto'); Michelangelo (Medici Chapel, the dome of St Peter's, and the *Last Judgment* in the Sistine.[15]

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[10] Kepler, Johannes, *The Harmony of the World*, trans. E.J. Aiton, A.M. Duncan, J.V. Field (Philadelphia. PA: American Philosophical Society, 1997), p.208.

[11] Valerie Shrimplin, 'Domed Architecture: Image of the Universe', Presentation at the Second Conference on The Inspiration of Astronomical Phenomena: Malta (unpublished 1999); Valerie Shrimplin, 'Borromini and the New Astronomy', *Proceedings of The Inspiration of Astronomical Phenomena* (2003) pp.413–22.

[12] See Aviva Rothman, *The Pursuit of Harmony, Kepler on Cosmos, Confession, and Community* (Chicago, IL: University of Chicago Press, 2017), pp. 264–75, especially pp266, and p.269 with figure C2.

[13] Rudolf Wittkower, *Architectural Principles in the Age of Humanism* (London: Academy, 1997), pp.17 and 27f.

[14] Plato, *Timaeus*, trans. R.G. Bury (Cambridge, MA: London: Harvard University Press, 1981), 33B, pp.62–63.

[15] Valerie Shrimplin, *Sun-symbolism and Cosmology in Michelangelo's Last Judgment* (Kirksville, MO: Truman State University Press, 2000).

Some remarkable examples from the late sixteenth century can also be found that demonstrate new ways of thinking, such as Michelangelo's designs for the pavement decoration on the Piazza del Campidoglio (1538) on the top of the Capitoline Hill. The interlaced design, with sun symbol at centre, appears to indicate orbits in space. The architect Serlio (1537–1575) in his *Libri d'Architettura Book 1,* considered the oval as an approximation to ellipse, or a circle in perspective. Other sixteenth-century examples are to be found but these were often simply based on a domed square with the dome elongated along one axis.[16] It has been suggested by Blunt that the oval form of church in the sixteenth century was also influenced by liturgical requirements following the Council of Trent. In Rome in the late sixteenth century, the architect Giacomo (or Jacopo) Vignola (1507–73) chose an unusual rectangular shape with rounded corners for his design of St Andrea in Via Flaminia (1553), whilst the church of San Giacomo in Augusta, by Carlo Maderno (completed 1600) has a more distinctive oval shape. Yet actual elliptical domes do not occur until the early seventeenth century.

It is sometimes difficult to distinguish between the oval or elliptical form in architecture, since the axes are often similar.[17] In addition, the precise equation for the ellipse was not generally known until the seventeenth century.[18] By 1602, and using data obtained whilst working with Tycho Brahe, Kepler had concluded that, although he agreed with Copernicus regarding the motion of the earth (and planets) around the sun, the observations did not fit in with the traditional concept of the universe being founded on perfect eternal circles. He at first saw the orbit of Mars as oval, and then as an ellipse with the sun at one focus (1609) – a concept that he

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[16] Peter and Linda Murray, *Architecture of the Italian Renaissance* (Norwich: Jarrold, 1971), p.198; Anthony Blunt, *Borromini* (London: Allen Lane, 1979), p.68.

[17] Javier Barrallo, 'Ovals and Ellipses in Architecture,' *Proceedings of X Interdisciplinary Conference of the International Society of the Arts, Mathematics and Architecture* (Columbia College, Chicago 2011), pp.9–13; Stefano Bagliani, 'The Architecture and Mechanics of Elliptical Domes', *Proceedings of the III International Congress on Construction History,* Cottbus, Germany (2009), no pagination. http://www.bma.arch.unige.it/PDF/CONSTRUCTION_HISTORY_2009/VOL1/Bagliani-Stefano_layouted.pdf: [accessed 16 May 2019].

[18] Barrallo, 'Ovals and Ellipses', p.12.

came to see as applicable to the orbits of all the planets by the time of his Third Law of Planetary Motion as laid out in the *Harmonice Mundi*.[19]

The construction of ovals or ellipses had been addressed by Leonardo da Vinci in his *Notebooks* (*Codex Atlanticus*, c. 1510) and in architecture, where ovals were used as an approximation of an ellipse for structural reasons. The device of a string to trace an ellipse was sometimes used, as clearly illustrated by Amboise Bachot in 1598 (Fig. 1). But changes seem to have taken place when Kepler came onto the scene, and especially by the 1620s and 30s.

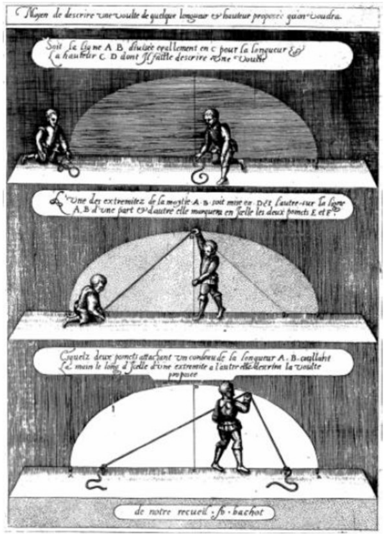

Fig. 1: Amboise Bachot, Diagram of construction of an ellipse, 1598.[20]

[19]Johannes Kepler, *The Harmony of the World*, trans. Eric Aiton, Andrew Duncan and Judith Field (Philadelphia, PA: American Philosophical Society, 1997), pp.281–385; Thomas S. Kuhn, *The Copernican Revolution: Planetary Astronomy in the Development of Western Thought* (Cambridge, MA: Harvard University Press, 1986 edn), p.212.

[20] Also see Javier Barrallo 'Ovals and Ellipses in Architecture', *Proceedings of the Tenth Interdisciplinary Conference of the International Society of the Arts, Mathematics, and Architecture*, Columbia College, Chicago, 2011, pp.9-18, figure 1, p.10.

The chronology is important so a brief synopsis of Kepler's life and work is relevant here.[21] Born in 1571 in Wiel der Stadt near Wurttemberg, Kepler studied theology at the University Tubingen in 1589, before becoming a teacher of Mathematics at Graz in 1594, where he published his *Mysterium Cosmographicum* in 1596, supporting the Copernican view. As Arthur Koestler wrote writes: These physical or metaphysical reasons' he [Kepler] explains differently in different passages [of the *Mysterium*]; but the gist of them is that the sun must be in the centre the sun must be the centre of the world, because he is the symbol of God the Father, the source of light and heat, the generator oof the force which drives planets in their orbits'.[22]

Kepler looked to the concept of perfect regular nested solids as the basis for the disposition of the planets, as derived from Plato's *Timaeus*.[23] Attempting not only to describe but also to explain the universe, from this time he saw God as 'Geometer'. Moving to Prague to be with Tycho Brahe in 1600, he made use of Brahe's observational data and eventually became Imperial mathematician and advisor to Rudolph II in 1601. Kepler had believed in Copernicus's model based on perfect circular orbits but, using Brahe's extensive and precise observations, he could not obtain a fit with the orbit of Mars, which actually has the greatest eccentricity in its orbit of all planets except Mercury. He started to question the ancient basis of astronomy founded on circular orbits and began to consider the ellipse at the basis for his view of the universe and its mechanics.[24] His *Astronomia Nova* of 1609 and *Treatise on Motion of Mars*, 1609 saw the laying out of his first and second planetary laws, showing that the orbits were elliptical and, secondly, that they did not travel at uniform speed but swept out equal areas in equal time. The *Astronomia Nova* included the first mention of the planets' elliptical paths and the idea of their movement as being free-floating as opposed to being attached to rotating celestial spheres.[25] In addition, the inclusion of the observation of a super-nova put paid to the medieval (and earlier) ideas about the fixed, immovable and unchanging stars. As such, the *Astronomia Nova* is a key work of the scientific

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[21] Kuhn, *Copernican Revolution*, pp.209–28.

[22] Arthur Koestler, *The Sleepwalkers* (Harmondsworth: Penguin, 1984), p.263

[23] Plato, *Timaeus*, trans. R.G. Bury (Cambridge, MA: London: Harvard University Press, 1981), 53D–55C, pp.127–28.

[24] Thomas Kuhn, *The Copernican Revolution* (Cambridge, MA: Harvard University Press, 1957), pp217–19; Arthur Koestler, *The Sleepwalkers*, (Harmondsworth: Penguin, 1984), pp.249–55.

[25] Johannes Kepler, *Astronomia Nova*, new revised edition, trans. William H. Donahue (Santa Fe, NM: Green Lion Press, 2015), pp.431–6.

revolution and change in world view at the time. Kepler had demonstrated that the universe did not work on perfect circular motion but the orbits of the planets were elliptical, with the sun placed at one of the foci, as explained in his first two Laws. Kepler moved to Linz after the death of Rudolph II in 1612, writing his *Epitome Astronomiae Copernicanae,* (three volumes 1617–21). The *Harmonice Mundi* followed in 1619, laying out Kepler's Third Law, that the square of the periodic times related to the cubes of the mean distances of planets from the sun.[26] He completed the massive Rudolphine Tables in 1623. At the time of his death in 1630, his ideas had not been widely accepted by such figures as Galileo (1564–42) and Descartes (1596–50). The *Epitome of Copernican Astronomy* was widely read as an astronomy textbook, and the idea of ellipse-based astronomy became increasingly well known. By the mid to late seventeenth century, in England Robert Hooke and Isaac Newton had built on Kepler's ideas, with Newton's *Principia Mathematica* appearing in 1687.

Kepler's views swiftly gained far-reaching influence not only on scientific theory but also culture and world view of the time – including the cosmological symbolism of spiritual architecture, and particularly the work of the innovator Borromini. In addition, it is significant that Borromini's patron from the time of his arrival in Rome was Cardinal Barberini (1568-44, elected Pope Urban VIII in 1623), who was well-known as a religious reformer and patron of the arts.[27] Pope Urban also corresponded with and was a supporter of Galileo. Like Kepler, Galileo also looked to a geometric interpretation of the cosmos, writing that '[the universe] is written in the language of mathematics, and its characters are triangles, circles, and other geometric figures without which it is humanly impossible to understand a single word of it; without these, one wanders about in a dark labyrinth'.[28] Kepler's mathematical methodology and interpretation of the universe were likely to have appealed to Borromini, particularly the belief in divine geometry ruling the formation and structure of the universe, and as the key to its understanding.

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[26]For a concise summary of Kepler's first two Laws (in his treatise on *Motion of Mars*, 1609) and third Law (in *Harmony of the World*, 1619) see Kuhn, *Copernican Revolution,* pp.212f.
[27] Blunt, *Borromini*.
[28] Galileo Galilei, 'The Assayer', in *Discoveries and Opinions of Galileo*, trans. Stillman Drake (New York: Anchor Books, 1957), pp.231–80 (p.238).
Galileo first presented the concept that nature should be understood in terms of mathematical tools (rather than philosophical) in his *Il Saggiatore,* (1623).
https://web.stanford.edu/~jsabol/certainty/readings/Galileo-Assayer.pdf .

Illustrations of the *Harmonice Mundi* in the 1619 first edition and the *Astronomia Nova* show significant changes in world view in the early seventeenth century. The link between architecture and world views or cosmology appeared to continue as the seventeenth century progressed. Ovals were sometimes used architecturally as an approximation for the ellipse (possibly for structural reasons) and, instead of Neoplatonic perfect circles, interest in the revival of the platonic solids and other geometric forms became prominent (ellipses, ovals, equilateral triangles and other bodies) and Borromini in particular combined practical skills with new scientific learning and culture.

Francesco Borromini (1599–1667) had led a very different sort of existence from Kepler. Born in 1599, his early years were spent in Milan as a stonemason, and from an early age he was seen as an 'artistic anarchist' expressing disorder at the same time as innovation, but with a mathematical precision underlying the apparent chaos of his designs. He was interested in the scientific ideas of the day – both cultural and humanistic aspects as well as the new learning and mathematics that were necessary for architectural schemes. Borromini's elliptical domes had a mathematical and geometrical foundation, and the concept of Borromini's elliptical domes as a possible allusion to contemporary astronomical theory is reinforced by evidence of interest in astronomical symbolism appearing in much of Borromini's work.

There was a significant revival of ancient sources where Borromini trained in Milan: the translations of Roman texts by Federico Commandino were used by Kepler, and the architect and mathematician Muzio Oddi was also based in Milan.[29] Kepler's ideas had already become widespread in Italy and as far as England. His international fame meant his works were known and the summary, *Epitome of Copernican Astronomy,* was widely read. Borromini examined geometric forms in architecture in the same way that Kepler considered them as the basis of universe. 'Divine Geometry' was key in the relation between human/divine, earth/cosmos, celestial/terrestrial. Contrary to the rules of classical architecture, earth's imperfections could be organised by means of a geometrical system with divine order ruling over chaos. Borromini would also have been well aware of the work of Federico Commandino and Muzio Oddi, both mathematicians working in Milan.[30] Moving to Rome in 1519, Borromini

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[29] Simona, 'Ovals in Borromini's Geometry', p.45–52.

[30] Federico Commandino (1509–75) translated the *Conics* of Apollonius of Pergamon (c. 247–205 BC) published in 1566 and used by Kepler in his consideration of elliptical orbits. Muzio Oddi 1569–1639 – architect in Milan

benefitted from the patronage of the Spada and Barberini families (working on the Barberini Palace and St Peter's with Carlo Maderno). Borromini also worked with Carlo Maderno on the Church of Sant'Anna dei Palafrenieri in the 1620s, demonstrating his exposure to such novel schemes as the use of a hexadecadon, reflecting the geometrical solids from Plato's *Timaeus*; as also influential on Kepler.[31] Borromini studied classical architecture and the works of Michelangelo, being responsible for major churches in Rome before his eventual suicide in 1667. Borromini's main works are listed below; the major works examined here being the churches of S Carlino and S Ivo.[32]

1627	Palazzo Barberini (Carlo Maderno)
1620s	Sant' Anna dei Palafrenieri (from 1583) restorations
1623–34	Baldacchino, St Peter's, contribution to Bernini's Design
1634-46	**S Carlo alle Quattro Fontane (appt'd 1634, Begun 1638)**
1637–50	Oratory of S. Filippo Neri (about same time)
1643–60	**S Ivo della Sapienza (appt'd 1632, begun 1643)**
1644–55	S. Giovanni in Laterano (radical renovations)
1647	Filomarino Altar, SS Apostoli Naples (icosahedron motif)
1653	St Agnes in Agona (for Urban VIII Barberini)
1655	Collegio di Propaganda Fide (Urban VIII Barberini)
1652–53	Palazzo Spada – Galleria Prospettiva

One of Borromini's earliest contributions – to the Palazzo Barberini 1627 – was a dramatic helicoidal staircase, showing ideas later taken up in S Carlo. His churches of S. Carlo alle Quattro Fontane (Rome, 1638–41) (Fig. 2) and S. Ivo della Sapienza (Rome, 1642) (Fig. 3) also involve novel and complex geometric designs. Mathematical precision underlies

showing a link between architecture and mathematic theory. Simona, Michea, 'Ovals in Borromini's Geometry,' in *Mathematics and Culture II* (New York: Springer, 2005): p.45. https://link.springer.com/chapter/10.1007/3-540-26443-4_5 [accessed May 2019].

[31] Plato, *Timaeus*, 54E–55C.

[32] John Hatch, 'The Science Behind Francesco Borromini's Divine Geometry', *Visual Arts Publications* 4 (2002): pp.127–36.

Borromini's seemingly extravagant schemes, in a similar way to seventeenth-century scientific developments.

Fig. 2: Francesco Borromini, S. Carlo alle Quattro Fontane (Rome, 1638–41), interior, dome. Wikimedia Commons

Fig. 3: Francesco Borromini, S. Ivo della Sapienza (Rome, 1642), interior, dome. Wikimedia Commons

Borromini's elliptical dome in S Carlo alle Quattre Fontane (1638–41) is not simply a rectangle with rounded corners. The construction here is based on a specific and measurable mathematical schema, resulting in a complex structure of elliptic segments that dominates the entire design of the church. The plan is based on an intricately evolved geometrical diagram, which achieves construction of the ellipse in a far more sophisticated way than late sixteenth-century examples where domes were (very rarely) simply elongated along one axis. The use by Borromini of the mathematically based or elliptical dome in S Carlo alle Quattre Fontane (1638–41) is striking in its geometric and mathematical basis. Not simply a rectangle with rounded corners, the elliptical dome rests on a stretched Greek cross. The façade of San Carlo is also based on a complex system of convex and concave forms. At about the same time, Borromini was working on the Oratory of S Philip Neri (1537–50), which also significantly uses stellar and astronomical details, such as the star motifs on the finials (in his drawing of the façade) and the astronomical fireplace (Fig. 4). An oval music room is included in the design.

Fig. 4: Drawing of star finials and/or Astronomical Fireplace, Oratory of S Philip Neri (1537–50). Wikimedia Commons.

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Borromini's famous church of St Ivo della Sapienza, Rome, slightly later in date at 1643–60, also involves complex celestial and terrestrial zones, as appropriate to the Church of the University of Rome, La Sapienza. At S Ivo, Borromini transformed the traditional central church plan by using a star hexagon plan extending into the dome. S. Ivo involves novel and complex geometric designs that are key to the understanding of the building. The six-point starred decoration completely dominates, while the octagonal floor decoration within this hexagonal building also recalls the nested solids so beloved of Kepler, especially in the use of a border or dividing line, which also evokes Kepler's approach to polygonal forms. A star/hexagon plan, is based on intersecting equilateral triangles, forming six bays and organising the structure through its geometry as ribs lead the eye up past the stars to the vault of heaven. The hexagonal ceiling is unique, and significantly, contrasts with the floor design which uses octagonal motifs, comparable to Kepler's cosmic geometry. Spiral designs, based on the golden section (like Fibonacci curves) are used in the tower on the exterior, expressing harmony and proportion.[33]

In his later works, Borromini's radical renovations at S. Giovanni in Laterano (1650/1644–55) also reflect the architect's interest in current mathematical problems, as shown by the elliptical schema on ceiling. The Filomarino Altar in SS Apostoli Naples (1635–47), was designed by Borromini for Ascanio Filomarino, a close friend of his Barberini patrons. A panel of angels making music is included as well as significant geometrical ideas, and particularly notable is the startling inclusion of the motif of the icosahedron on the top of the altar (Fig. 5) which seems to relate directly to Kepler's theory of the solids as expressed in his *Mysterium Cosmographica*, in 1596 and also in the *Harmonice Mundi* (Fig. 6). St Agnes in Agona (1653) is also significant since Urban VIII Barberini called in Borromini to rescue the project, giving it an elliptical basis. The Collegio di Propaganda Fide (1655), also for Urban VIII Barberini, has a complex ceiling vault with mathematical and geometric patterning, whilst the Palazzo Spada (1552–33) although not an ecclesiastical building, demonstrates Borromini's intense interest in geometry, perspective and scientific illusion.

[33] Wittkower, *Architectural Principles*, pp.117 and 142.

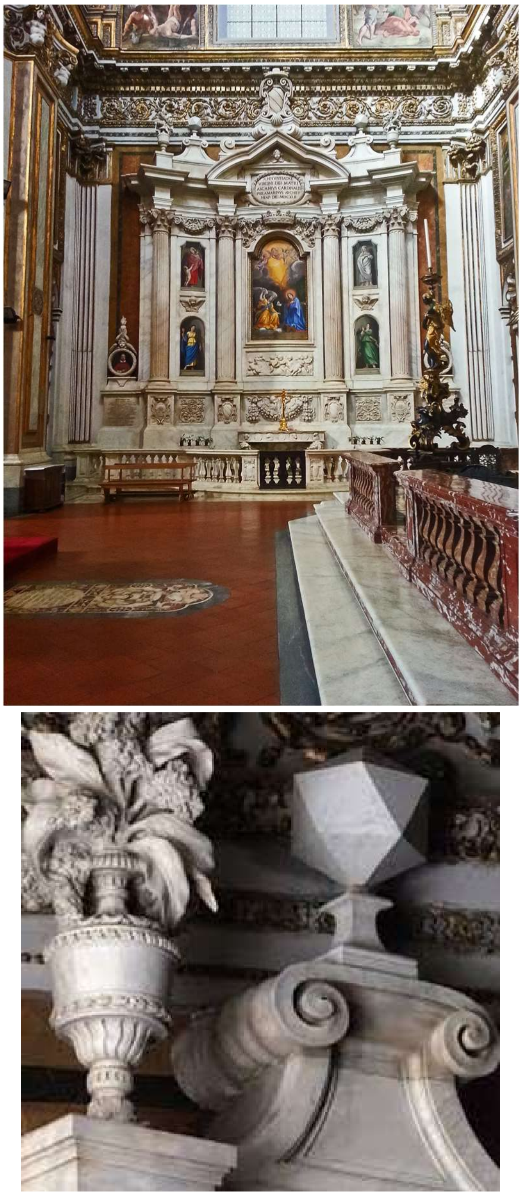

Fig. 5: Francesco Borromini, Filomarino Altar, SS Apostoli Naples (1635–47) (top). Detail showing motif of the icosahedron on the top of the altar (bottom). Wikimedia Commons.

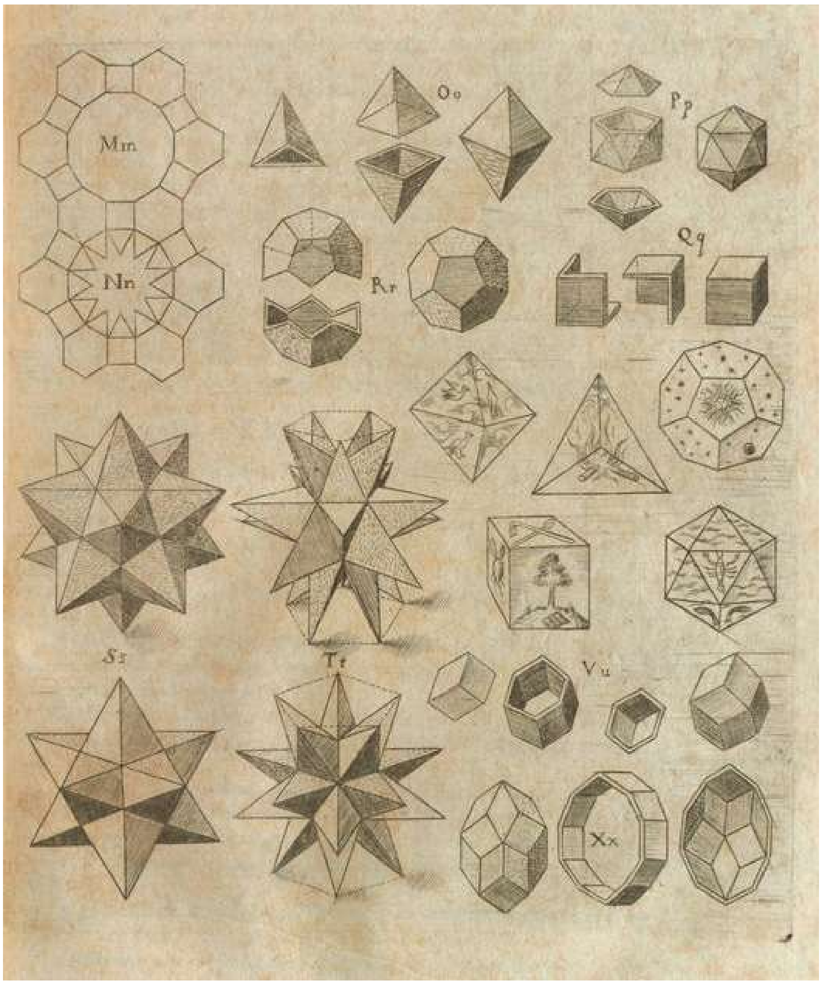

Fig. 6: Kepler, diagram of solids from *Harmonice Mundi*, 1619.[34]

As far as patronage was concerned, both Kepler and Borromini were supported by the Church and other powerful patrons. The Barberini provided patronage to both Kepler and Borromini. Borromini worked as

[34] Also see E.J. Aiton, A.M. Duncan and J.V. Field, 'Introduction' in Kepler, Johannes, *The Harmony of the World*, trans. E.J. Aiton, A.M. Duncan, J.V. Field (American Philosophical Society, Philadelphia, 1997), p. 111.

architect on the Barberini Palace, and Maffeo Barberini, elected Pope Urban VIII in 1623, had a special interest in astronomy and also supported Galileo until 1633, writing a letter to him expressing his sincere admiration.[35] He was a prominent patron of the arts and a reformer of the Church. The Spada family (including cardinals), also supported Borromini who worked on their palace, as well as being patrons of astronomy.

As far as the new astronomy was concerned, Urban VIII showed a clear interest he was offended by Galileo in 1632, by which time the fashion for elliptical domes in the Baroque had taken hold. Borromini's work did not only look back at ancient ideas (from the scriptures and classics), but also coincided with the newest ideas. Kepler's '*Harmony of the World'* can be seen to share real similarities to Borromini's architecture, based on the understanding and expression of the concept of Order and Harmony in the universe, through an underlying perfection of geometry.

In England under James I, to whom the *Harmonice Mundi* had been dedicated, Inigo Jones and Rubens took up the motif of the ellipse in the Banqueting House at Whitehall.[36] Sir Christopher Wren (1632–1723), who was an astronomer as well as architect, referred to Copernicus, Galileo, and the elliptical orbits of Kepler, in his inaugural lecture as Gresham Professor of Astronomy in 1657.[37] Wren used some oval or

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[35] For Maffeo Barberini's letter to Galileo, see Stefano Gattei, trans. and ed., *On the Life of Galileo: Viviani's Historical Account and Other Early Biographies* (Princeton, NJ: Princeton University Press, 2019), p.281, and for the poem he wrote in Galileo's honour see Christopher Graney, 'An Astro-Poem for Galileo', Vatican Observatory,
https://www.vaticanobservatory.org/sacred-space-astronomy/an-astro-poem-for-galileo/ [accessed 9 September 2021]. Blunt, *Borromini*, p.22f. and 47 (Blunt also argues the influence of Galileo on Borromini).

[36] Historic Royal Palaces, *The Banqueting House, Whitehall Palace, Rubens and the Ceiling Paintings*, https://www.hrp.org.uk/banqueting-house/whats-on/rubens-ceiling/#gs.8v63ne; Oliver Millar, 'Rubens's Whitehall Ceiling', *The Burlington Magazine* 149, no. 1247, Flemish and Dutch Art (February 2007): pp.101–104, https://www.jstor.org/stable/2007472; Giles Davison: ' Inigo Jones's Venetian Ceiling and Peter Paul Rubens's Painting in the Banqueting Hall of Whitehall Palace: The Ellipse of the Central Panel with the Apotheosis of King James I' (unpublished paper, January 2005).

[37] Sir Christopher Wren, inaugural lecture as Gresham Professor of Astronomy: 'I must reverence for giving occasion to Kepler (as he himself confesses) of introducing Magneticks into the Motions of the Heavens, and consequently of building the elliptical Astronomy.' *Life and Works of Sir Christopher Wren, from the Parentalia or Memoirs by his Son Christopher, 1549* (p.56),

elliptical designs in churches he designed after the Fire of London of 1666, such as St Mary Abchurch in 1681.

The new, revolutionary and dynamic approach as proposed by Kepler brought about a change in world view and the idea of humanity's place in the cosmos - with new attitudes, as well as new science. The seventeenth century does, in many ways, mark the beginning of the divisions between science and theology but not, it seems, as far as cosmological symbolism in Church architecture in Rome the 1630s and 40s is concerned. Borromini's use of the elliptical dome in preference to classical and humanist ideas of the perfection of the circular form, manifests at the same time as the changing cosmological view following the dissemination of Kepler's works, particularly the *Harmonice Mundi.* It seems unlikely to be a coincidence that that the predilection for elliptical domes in ecclesiastical architecture occurred following the publication of Kepler's great work. The exuberance of the Baroque was part of the revolutionary, new and dynamic age – yet with underlying harmony and order as ordained by God.

https://archive.org/stream/cu31924015672920/cu31924015672920_djvu.txt Cornell University Library [accessed 17 May 2019].