

***Between Aristotle and Archimedes:
Why Were Gears Made Visible Through Rock Crystal in the Late Renaissance?***

Abstract

This paper explores why, between approximately 1550 and 1650 – centuries before the invention of the quartz timekeeper – a combination of rock crystal and gears, the rock crystal clock, became a highly fashionable luxury item among European elites¹.

Out of all Renaissance luxury goods, rock crystal objects and geared devices have undergone the most dramatic shift in value perception since the early modern period. Toothed wheels, once meticulously crafted by skillful masters, are now regarded as the quintessential elements of mechanization and mass production. Rock crystal, once considered a natural marvel whose transparency inspired powerful symbolic associations, has lost its absolute dominion in the realm of transparent materials. The modern public can hardly distinguish between rock crystal artifacts and glass ones, as the semantic meaning of the word ‘crystal’ has shifted from indicating the semi-precious stone to the synthetic silicate glass product developed since the 15th century to imitate the mineral².

Etymologically, the term ‘crystal’ derives from the Ancient Greek word for ‘ice’. It was indeed believed that crystal originated from frozen water³. Even the Bible, in the *Book of Ecclesiastes* (43, 22), seemed to confirm such a theory: «Frigidus ventus aquilo flavit, et gelavit crystallus ab aqua» (*Douay-Rheims Bible*: «The cold north wind bloweth, and the water is congealed into crystal»). Following ancient authorities like Pliny the Elder and Propertius, it

¹ This project has received funding from the European Union’s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101025015.

² G. Mariacher, *Barovier, Angelo*, in *Dizionario Biografico degli Italiani*, vol. VI, Roma, 1964, [https://www.treccani.it/enciclopedia/angelo-barovier_\(Dizionario-Biografico\)/](https://www.treccani.it/enciclopedia/angelo-barovier_(Dizionario-Biografico)/) last accessed on January 1, 2024. Recent studies suggest a more complex origin for crystal-clear glass: M. Beretta, *Glassmaking Goes Public: The Cultural Background to Antonio Neri’s L’Arte Vetraria (1612)*, in «Technology and Culture», 2017, 58, pp. 1046-1070. In 1999, a conference on gems and crystal was organized in connection with an exhibition held in Venice. One of the exhibition’s curators, Bruno Zanettin, who is also the editor of the proceedings and catalog, recalls in the preface to the volume that he specifically asked contributors not to discuss crystal-glass in their papers, in order to avoid any confusion: *Cristalli e gemme: realtà fisica e immaginario, simbologia, tecniche e arte*, exhibition catalog and proceedings of the conference (Venezia 1999), ed. by B. Zanettin, Venezia 2003, p. 9. See also these two very useful exhibitions catalogs: *Arte trasparente: la talla del cristal en el Renacimiento milanés*, (Madrid 2015-16), editado por L. Arbeteta Mira, Madrid 2015; *Magic Rock Crystal*, (Cologne 2023), ed. by M. Beer, Munich 2023.

³ See «rock crystal» in some of the most influential lapidaries from Antiquity and the Middle Ages: Theophrastus, *On Stones*, Caley, ed. by E.A. Richards, J.F.C. *, Columbus (OH), 1956. Isidore of Seville, *Isidori Hispalensis episcopi Etymologiarum sive Originum libri XX*, Oxonii, 1911, Lib. XVI, XII. See book 37 in: Pliny the Elder, *Natural History, with an English translation*, vol. X, *Books XXXVI-XXXVII*, trans. by D.E. Eichholz, Cambridge, 1962; Alfonso X *et al.*, *Lapidario del rey d. Alfonso X*, facsimile, Madrid, 1881.

was also believed that rock crystal spheres and vases kept liquids cooler than recipients made of other materials⁴.

In the 13th century, Venetian goldsmiths began incorporating rock crystal into their trade⁵. From that moment, translucent materials, particularly rock crystal, assumed a central role in Christian Latin Europe «as newly-developed devotional and liturgical practices increased the significance of vision and visibility as a means to access and comprehend the holy»⁶. Rock crystal became *materia sacra*, a sacred material, connected with the ideas of divine light, purity and hardness, especially within the framework of Christological and Mariological symbolism⁷. Costly plates of crystal, mounted on reliquaries, were now used to adorn relics and make them more visible.

Why was crystal also used to make clock gears visible from the mid-16th century onward? Gears are essential components of mechanisms that, by engaging an unequal number of teeth, create a mechanical advantage resulting in different rotational speeds and torques. The archaeological and documentary evidence for gears dates back to ancient civilizations such as China (4th century BC) and Hellenistic Greece (3rd century BC)⁸.

The first weight-driven mechanical clocks appeared in Europe in the late 13th century. Shortly afterward, urban churches and prosperous cities began adopting turret clocks. In the 15th century, springs were integrated into clocks, allowing them to be portable while in operation. These devices, enclosed in gilded cases, were crafted for affluent patrons. By the end of the 15th century, the process of miniaturization had reached its height, giving rise to wearable clocks, later known as watches⁹.

Watches were originally placed within small cases designed to imitate various items from the elite's attire, like pomanders – spherical golden pendants containing fragrant substances used to protect against infections. These tiny watches were also integrated into

⁴ M. Pastore Stocchi, *Elementi di cristallografia poetica*, in Zanettin, *Cristalli e gemme...*, cit., pp. 633-634.

⁵ M. Agazzi, *L'opera dei cristalleri. Cristalli di rocca, diaspri, oreficerie e reliquie a Venezia (secc. XIII-XIV)* in «Hortus Artium Medievalium», 2016, 22, pp. 145-156. S. Gerevini, “*Sicut crystallus quando est obiecta soli*”: *Rock Crystal, Transparency and the Franciscan Order*, in «Mitteilungen des Kunsthistorischen Institutes in Florenz», 2014, 56, pp. 255-283, 258.

⁶ Gerevini, “*Sicut crystallus...*”, cit., p. 255.

⁷ M. Collareta, *Il Cristallo nella liturgia religiosa e civile*, in Zanettin, *Cristalli e gemme...*, cit., p. 500. See also: Arbeteta Mira, *Arte trasparente...*, cit., p. 44; see Cynthia Hahn's, Christel Meier-Staubach's, and Holger Kempkens's essays in *Magic Rock Crystal...*, cit., pp.33-49, 191201, 255-267.

⁸ D.J. de Solla Price, *On the Origin of Clockwork, Perpetual Motion Devices, and the Compass*, Washington (D.C.), 1959. On machines of the ancient Mediterranean world, see: G. Di Pasquale, *Le machine del mondo antico: dalle civiltà mesopotamiche a Roma imperiale*, Roma, 2019.

⁹ G. Brusa, *I primi orologi da persona in Italia: nuovi indizi e nuove eccellenti testimonianze*, in «La voce di Hora», 1997, 3, pp. 3-20; *Die älteste Taschenuhr der Welt? Der Henlein-Uhrenstreit*, Ausstellungskatalog (Nürnberg 2014), hrsg. von T. Eser, Nürnberg 2014; D. Matthes, *Zeit haben: tragbare Uhren vor 1550*, Dover (DE), 2018.

necklaces, jewelry, sword hilts, and magnifying glass handles. The pinnacle of this miniaturization process was the incorporation of watches into finger rings, showcasing skill and artistry that were typically reserved for royalty¹⁰.

In 16th-century portraits, timepieces frequently carry layered symbolism, intertwining *vanitas* themes with the sitter's qualities, such as wisdom, temperance, and both private and public reliability. Although early timekeepers did not match modern standards in precision, their presence in a portrait signifies wealth, given that these machines were costly items for the most part only accessible to the elite.

The most magnificent extant example of a rock crystal clock is the so-called *Wiener Kristalluhr*, or Viennese Crystal Clock (fig. 1), an astronomic machine crafted in the 1620s by the great Swiss clockmaker Jost Bürgi¹¹. Its rock crystal case and celestial sphere¹² evoked the similitude between this stone and aether, which had been introduced by Aristotle as the 'fifth element' forming the celestial spheres, whereas the traditional four elements (earth, water, air, and fire) were seen as constituting the sublunar world. In mainstream Renaissance cosmologies, aether was believed to be eternal, as well as hard and transparent like crystal. Between the *Primum Mobile* and the other lower spheres, some philosophers even envisaged the existence of another sphere called the *cristallinum* (crystalline)¹³.

From a preliminary and non-systematic investigation¹⁴, it appears that the earliest dated watch with gears visible through a rock crystal case is now held at the Walters Art Museum of Baltimore. It bears the inscription «1560». However, a thorough study by Mag Lowen Craft dates this watch to around 1600. Lowen Craft wrote: «The distinction between a heavily restored old watch, a pastiche of old and 19th or 20th century elements and a clever forgery is a difficult one to make. This distinction is more difficult with a functional object [...] that [...] suffered wear and subsequent repair and continued updating over its useful life»¹⁵.

¹⁰ V. Pérez Álvarez, *The Ring-Watch of Emperor Charles V*, in «Antiquarian Horology», 2023, 44, pp. 169-178; Matthes, *Zeit haben...*, cit., pp. 188-189; C. Zanetti, *Janello Torriani and the Spanish Empire: a Vitruvian Artisan at the Dawn of the Scientific Revolution*, Leiden, 2017, pp. 299-306.

¹¹ S. Thüringen, *Turm, Spiegel, Buch: Astronomische Tischuhren in Süddeutschland zwischen 1450 und 1650*, Berlin/Boston, 2022, pp. 274-279.

¹² A. Kugel et al., *Spheres, the Art of the Celestial Mechanics*, Paris, 2002, p. 38.

¹³ S.K. Heninger, *The Cosmographical Glass: Renaissance Diagrams of the Universe*, San Marino (CA), 1977, pp. 38-39.

¹⁴ For now I have looked into the collections of the following museums: Louvre, British Museum, Metropolitan Museum of New York, Poldi Pezzoli of Milan, Musée international d'horlogerie de La Chaux-de-Fonds, and Walters Museum of Baltimore. I have sought the expertise of Anthony Turner, Giancarlo Truffa, Dietrich Matthes, and Victor Pérez Álvarez, all of whom I thank.

¹⁵ M. Loew Craft, *Only Time Will Tell: Examination and Analysis of an Early German Watch*, in «Objects Specialty Group Postprints», 2007, 14, pp. 47-64.

The same problem arises in relation to what appears to be the oldest non-dated example of a clock with gears visible through a rock crystal case: the so-called Royal Clock Salt, a device that embodies the shapes and functions of four different objects: a timepiece, a reliquary, a jewel, and a table salt. Monumental salt cellars were popular gadgets on Renaissance princely tables. This object was crafted by the Parisian goldsmith Pierre Mangot around 1530, ten years before Cellini's famous *Saliera*. The Royal Clock Salt ended up in the English royal treasury.¹⁶

It presents a large cylinder of rock crystal, which makes the entire mechanism operating the clock and the alarm train visible. However, a recent multidisciplinary investigation has shown that in all likelihood the gears were not originally visible: only the horizontal dial was visible through the rock crystal. The Royal Clock Salt has undergone such dramatic changes that we do not even know which of two different entries in the 1547 English royal inventory refers to it¹⁷. A 1570 drawing (fig. 2) shows the first known clock salt displaying gears through crystal (Duke of Bavaria's treasury).

Later, again in France, at Lyons, similar tubular rock crystal cases were used to make the gears of two splendid clocks visible. The first one, signed by Pierre de Fobis (ca. 1506 - ca. 1575), is a mechanical celestial-terrestrial sphere. It is tentatively dated to the 1540s, being the engravings informed by Johannes Honter's star chart from 1541¹⁸. However, the sphere could be also moved to a later date, perhaps the 1550s, much as it happened to the *tempietto*-clock by Jean Naze (1539-1580), which was once traced back to the 1550s, but is now dated to the years after 1560¹⁹. A comprehensive examination is required for a more accurate dating of the object.

Nuremberg seems to be another significant place where one can find early rock crystal timepieces. Some uncertain records mention the commissioning of a costly watch enclosed within a rock crystal sphere by the city of Nuremberg in the year 1541. However, it remains unclear whether it was intended to showcase the gears of the watch or just its metal case²⁰. Another piece probably related to Nuremberg is the watch in a crystal drum signed «HG»,

¹⁶ Another impressive clock salt designed by Hans Holbein the Younger (1497/8-1543) was presented to King Henry VIII, who had 12 clock salts in his collection of 200 timepieces: T. Schroder, D. Thornton, *A Royal Renaissance Treasure and its Afterlives. The Royal Clock Salt*, exhibition catalog and conference proceedings (London 2018), London 2021, p. 85, <https://britishmuseum.iro.bl.uk/concern/books/6089308e-cb51-4969-a555-044bcf181d8d> (last accessed on May 28, 2023).

¹⁷ *Ibid.*, p. 6.

¹⁸ A. Kugel, K. Cleempoel, J.C. Sabrier, *Sphères: l'art des mécaniques célestes: catalogue*, Paris, 2002, pp. 144-151.

¹⁹ Dietrich Matthes has communicated to me that the date 1550 is a misprint for 1560. Matthes, *Zeit haben...*, cit., p. 289.

²⁰ *Ibid.*, pp. 270-272.

recently dated to the 1550s²¹. Additionally, there is a third clock possibly from Nuremberg, dated 1550-1575 and held at the British Museum (fig. 3)²².

However, the earliest dated and signed ‘transparent clock’ to be still extant was crafted in Brabant in 1567. This is Saint Luigi Gonzaga’s astronomical clock, which has been held in a nunnery near Mantua since the 16th century. Apparently, it has been preserved as a relic and it is not rigged. It was a gift from Duke Guglielmo Gonzaga to the future saint’s mother for the birth of her child in 1568. This timepiece has a gilded bronze case with a square base (18,5 x 32,5cm). At the front, it has a concentric round astronomical dial. It is signed «Johannes Valin + 1567 + a Brussel». Two arched openings on each side of the case allow the viewing of the mechanism through crystal sheets²³.

The Flemish master Jan Valin served Charles V and was in Yuste during the Emperor’s retirement there between 1557 and 1558, when he worked alongside the Lombard clockmaker Janello Torriani (or Juanelo Turriano), albeit in a subordinate position. The two likely met in Brussels between 1554 and 1557, shortly before Charles V’s abdication.

Between 1554 and 1562, Janello crafted the *Crystalline* for Charles V, a lost planetary automaton enclosed in a rock-crystal case. Planetary automata at the time represented the most ambitious attempt to express geometrically the apparent motion of the fixed stars with the Zodiac and the seven planets: Mercury, Venus, Mars, Jupiter, Saturn, the Moon, and the Sun. The last two, together with the head and tail of the dragon (i.e. the lunar nodes indicating eclipses), were the only celestial objects depicted on more simple and common astronomical clocks, of the same sort produced by other civilizations²⁴.

The *Crystalline* consisted of two squared tiers: the lower one had two rock crystal sides, whereas the upper one had five. Twelve dials provided astronomical and astrological information and the object was crowned by a crystal sphere. This was the second planetary automaton created for Charles V by Janello: between 1547 and 1551, he had crafted the *Microcosm*, also known as *Caesar’s Sky*²⁵. The emperor had Janello’s portrait featured on the

²¹ *Ibid.*, pp. 449-452.

²² Schroder, Thornton, *A Royal Renaissance Treasure...*, cit., p. 125.

²³ A. Lenner, *A Flemish Pupil for Janello? Jan Valin Horologist of Charles V*, in *Janello Torriani: A Renaissance Genius*, exhibition catalog (Cremona 2016-17; Madrid 2018), ed. by C. Zanetti, Cremona 2016, pp. 133-136, 264.

²⁴ See the three following chapters in *A General History of Horology*, ed. by A. Turner, J. Nye, J. Betts, Oxford, 2022: J. Bonnin, *Time Measurement in Antiquity*, pp. 10-23; A. Turner, *Sundials and Water Clocks in Byzantium and Islam*, pp. 94-98; D. Chang, *China to 1900*, pp. 43-44; B. Anderson, *Public Clocks in Late Antique and Early Medieval Constantinople*, in «Jahrbuch der Österreichischen Byzantinistik», 2014, 64, pp. 23-32. Di Pasquale, *Le macchine...*, cit., pp. 173-179; A. Jones, *A Portable Cosmos: Revealing the Antikythera Mechanism, Scientific Wonder of the Ancient World*, Oxford, 2017.

²⁵ Zanetti, *Janello Torriani and the Spanish Empire ...*, cit., pp. 270-297.

Microcosm's case, and the master had a Latin sentence engraved: «Thou shall understand who am I, only if thou can accomplish a work equal to mine»²⁶. Janello – who had worked in Milan, famous at the time as the city with the best rock crystal manufacturers – had a crystal celestial globe fitted on top of each of his two automata²⁷. Inside the *Microcosm*'s globe, Gerhard Mercator inserted a terrestrial paper globe. The Crystalline instead had a mechanized rotating celestial sphere enclosing a metal terrestrial globe²⁸.

As late as 1602, these two planetary automata were worth more than the rest of the Spanish royal horological collection combined: the *Microcosm* was appraised at 2,000 golden ducats, the Crystalline at 3,000. The latter surpassed Leone Leoni's bronze sculpture of Charles V enchainning the personification of Fury by 1,000 ducats²⁹.

Reporting a conversation he had with Janello about the *Microcosm*, the Spanish historiographer Ambrosio de Morales writes: «Although the brass partitions leave the movements of the planets visible and much more, a lot more is hidden: all the internal movements of the gears [1,800, according to Morales]. For this reason, he [Janello] made another square clock, a little smaller than the other and with fewer movements, and gave it crystal sides, so that all the movements of the gears could be revealed. On this clock was engraved an ingenious philosophical phrase: “UT ME FUGIENTEM AGNOSCAM [that I may recognize myself as I flee]”. He says he made the movements so visible to better understand [...] how fast you approach death»³⁰. However, beside the trope of *vanitas*, something else emerges from this passage: Janello told Morales that «he imagined in his mind to make a clock with all the movements of the heavens, so that it would be more than the one made by Archimedes»³¹. An ancient tradition attributed a mysterious planetary machine to the Syracusan³².

Archimedes' planetary sphere was said to have been made of crystal. In the first edition of his bestseller *De subtilitate* (1554), the famous Milanese scholar Girolamo Cardano, who

²⁶ *Ibid.*, p. 199.

²⁷ S. Leydi, *Un cremonese del Cinquecento "aspectu informis sed ingenio clarus": qualche precisazione per Giannello Torriani a Milano (con una nota sui suoi ritratti)*, in «Bollettino Storico Cremonese», 1997, 4, pp. 133-138, 144.

²⁸ All sources agree that the mechanism inside the Crystalline was simpler than the one of the *Microcosm*. Silvio Leydi has suggested that perhaps this was because of the use of Copernicus's recently published heliocentric cosmological model, which required a far less complicated mechanics than all geocentric models. Although fascinating, this hypothesis needs to be further substantiated. Leydi, *Un Cremonese...*, cit., p. 133.

²⁹ Zanetti, *Janello Torriani and the Spanish Empire...*, cit., p. 226.

³⁰ *Ibid.*, p. 172. Translations are here improved.

³¹ A. de Morales, *Las antigüedades de las ciudades de España que van nombradas en la Coronica, con la aueriguacion de sus sitios, y nōbres antiguos*, Alcalá de Henares, 1575, p. 92. My translation.

³² Di Pasquale, *Le macchine...*, cit., pp. 173-179.

knew Janello, praised the latter's first planetary clock. However, when discussing the differences between this modern metal marvel and Archimedes' transparent one, he added that «the ancient machine [by Archimedes] was far more noble and beautiful than ours [Janello's one], but ours is far more durable», owing to its metal construction.³³ Did Janello and his imperial patron feel challenged by Cardano's comparison? We cannot say for sure, but the fact that the construction of this second rock-crystal machine began in the same year, and that Janello wished to surpass Archimedes, seems to support such an interpretation. It also seems plausible that this automaton was, if not the prototype for all subsequent rock-crystal clocks, at least one of the first models to spark the fashion for these luxury items.

Conclusions

During the Renaissance, spring-driven clocks initially used rock crystal to make their dials visible and protect them against damage and dust. However, a significant shift occurred in the mid-16th century, when transparent cases allowed the entire clock's gears to be made visible, transforming cogs and springs into objects with a strong symbolic and aesthetic value³⁴: gears were wonders enclosed in precious rock-crystal cases (fig. 4), much like holy relics³⁵. The association of this mineral with the ethereal heavens and Christ likely explains why timepieces, sometimes even in the shape of a cross, showcased their gears through rock-crystal shells.

Among the major elements that contributed to the ennoblement of gears were:

1. Antiquarianism: inspiration from ancient machines, which represented a form of power, captivated humanists and princes. This interest is evident in the flourishing of engineering during the Renaissance, exemplified by the aestheticization of gear works by influential artists such as Francesco Di Giorgio Martini, Leonardo, and Hans Burgkmeier³⁶. This process, which explored machinery beyond physical limits, also inspired the literary genre of 'theaters of machines', which flourished in the same period as rock-crystal clocks³⁷.

³³ Zanetti, *Janello Torriani and the Spanish Empire...*, cit., p. 172.

³⁴ Thüringen, *Turm ...*, cit., p. 278.

³⁵ Collareta, *Il Cristallo...*, cit., p. 501.

³⁶ C. Zanetti, *The Diverse Agencies of Renaissance Engineers in the Shadow of War in Shadow Agents of Renaissance War. Suffering, Supporting, and Supplying Conflict in Italy and Beyond*, ed. by S. Bowd, S. Cockram, J. Gagné, Amsterdam, 2023, pp. 173-200.

³⁷ M. Popplow, *Hydraulic Engines in Renaissance Privileges for Inventions and «Theatres of Machines»*, in *Arte e scienza delle acque nel Rinascimento*, a cura di A. Fiocca, D. Lamberini, C. Maffioli, Venezia, 2003, pp. 73-84.

2. Gears represented motion and ingenuity, divine gifts reflecting God's creation: what Sacrobosco called the *Machina Mundi* (Machine of the World) in *De Sphaera*, the most popular cosmology textbook. The early 17th-century clock by Georg Schmidt of Augsburg, representing a *Resurrected Christ* standing on a rock-crystal globe containing a clockwork, provides a clear example of this symbology³⁸.
3. Skilled goldsmiths frequently crafted remarkably miniaturized watches, which fell into the category of jewelry. These watches served as substitutes for gems and pearls and were consequently encased in traditional precious ornaments like golden pendants, pomanders, and rings (Fig. 5).

³⁸ E. Bruton, *Clocks & Watches*, Feltham 1968, p. 37.



Figure 1. Jost Bürgi, Wiener Kristalluhr (Viennese Crystal Clock), 1622/27, Vienna, Kunsthistorisches Museum. (KHM-Museumsverband, inv. no. KK 1116).



Figure 2. A clock salt from the pictorial inventory of the treasury of Duke Albrecht V of Bavaria, 1570, Munich, Staatliche Graphische Sammlung, inv. no. 38876Z.



Figure 3. Nuremberg?, Cylindrical horizontal table clock with detachable alarum (alarm-mechanism on top), both with a rock-crystal case, third quarter of the 16th century, h. 15,2cm, w. 9,5cm, London, The British Museum, Museum. no. 1958,1006.2110.



Figure 4. Michael Schneeberger, Rock-crystal clock, 1606, Vienna, Kunsthistorisches Museum (KHM-Museumsverband, inv. no. KK 1148).



Figure 5. Isaac Jemin, Watch with a rock crystal case, beginning of the 17th century, Museo Poldi Pezzoli, inv. no. Inv. 0734