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Moving Shadows, Moving Sun

Early Modern Sundials Restaging Miracles

Jasmin Mersmann
Humboldt University, Berlin
jmersmann@hu-berlin.de

Abstract

Irrespective of geo- or heliocentric presuppositions, the functioning of sundials is based on the observation of moving shadows or light spots. Even though the cast shadow was often simply used to indicate the time, it could also remind the users of the ephemerality of earthly things or function as an index of planetary movements. This article examines the various ways in which early modern sundials visually interpret the moving shadow or light spot. The instruments address the shadow in inscriptions, integrate it into their design (e.g. in cruciform dials) or even manipulate its course (as in the so-called *Horologium Ahaz*). Both the crucifix and the Ahaz dials not only refer to astronomical miracles but actually restage them. Even though by means of the horologium it was not possible to explain the Old Testament miracle of the shadow moving backward, adepts were able to recreate it on a terrestrial scale.

Keywords

Horologium Ahaz – Georg Hartmann – Christoph Schissler

Galileo's character Sagredo judges a theory that would rather set the whole universe in motion than disavow the immobility of the Earth to be even more irrational than the idea of somebody standing on a lookout and asking to make the whole country rotate in order to spare him the effort of turning his head.[1]

1 Cf. Galileo Galilei, "Dialogo intorno ai due massimi sistemi del mondo tolemaico e copernicano," in *Le Opere di Galileo Galilei*, Vol. VII, edited by Antonio Favaro (Florence: G. Barbera, 1897), p. 141: "... stimerei che colui che reputasse più ragionevole il far muover tutto l'universo

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This however, is precisely the idea suggested by the vignette on the front page of Emmanuel Maignan's *Perspectiva horaria* from 1648 showing a schematic representation of the celestial sphere (Fig. 1).[2] The centre is occupied by the tip of an obelisk, around which an anthropomorphic Sun rotates, a motion indicated by a second Sun with an inverted face. The obelisk functions as a gnomon, i.e. as an orthogonal shadow-casting style, whose tip constitutes the centre of projection. According to Athanasius Kircher, every shadow-casting object can serve as a gnomon: "Gnomon esse potest omne corpus odumbrans alius."[3] Consequently, this functional space can just as well be occupied by a tree (as in the frontispiece of Mario Bettini's *Apiaria* from 1642),[4] or, as Jacques Ozanam proposes in his *Recréations Mathématiques*, a human being: "But instead of a tree, a man can avail himself of his own body as a style by placing himself in its position."[5] Since the gnomon is supposed to stand virtually in the centre of the Earth, the person's head (or, in some illustrations, his eye) would then occupy the centre of the world, crowned by the zenith and facing a Sun, which rises and sets on a daily basis.[6]

The author of the *Perspectiva horaria*, Emmanuel Maignan (1601–1676), was a theologian and member of the Minim Order.[7] His decision not to comment on the debate about Copernicanism might have been made out of conviction

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per ritener ferma la Terra, fusse più irragionevole di quello che, sendo salito in cima della vostra Cupola non per altro che per dare una vista alla città e al suo contado, domandasse che se gli facesse girare intorno tutto il paese, acciò non avesse egli ad aver la fatica di volger la testa ..."

2 Emmanuel Maignan, *Perspectiva Horaria sive de Horographia gnomonica tum theoretica, tum practica libri quatuor* (Rome: Typis, & expensis Philippi Rubei, 1648).

3 Athanasius Kircher, *Ars Magna Lucis et Umbrae* (Rome: Hermann Scheus, 1646), p. 232.

4 Mario Bettini, *Apiaria universae philosophicae mathematicae* (Bologna 1642/1645/1654 and Venice 1655). Cf. Volker Remmert, *Widmung, Welterklärung und Wissenschaftslegitimierung: Titelbilder und ihre Funktionen in der wissenschaftlichen Revolution* (Wiesbaden: Harrassowitz, 2005), pp. 201–222 and figs. 7.7, 7.1, 7.13.

5 Jacques Ozanam, *Recréations Mathématiques* (Paris: Jean Jombert, 1694), p. 256: "Mais au lieu d'un Arbre, une personne pourra se servir de sa propre hauteur pour stile, en se plaçant bien droit au pied du stile ..."

6 Ozanam's sundial would not be precise because the apparent movement of the sun around an orthogonal gnomon is irregular. The problem can be alleviated by shifting the gnomon along a month-scale over the course of the year or by inclining it at the angle of the local latitude – a technique generally used since the early 15th century. The so-called *polus* then points to the polar star and is parallel to the axis of the earth.

7 Cf. Patrick James Stigant Whitmore, *The Order of Minims in Seventeenth-Century France* (Den Haag: Nijhoff, 1967), pp. 163–186.

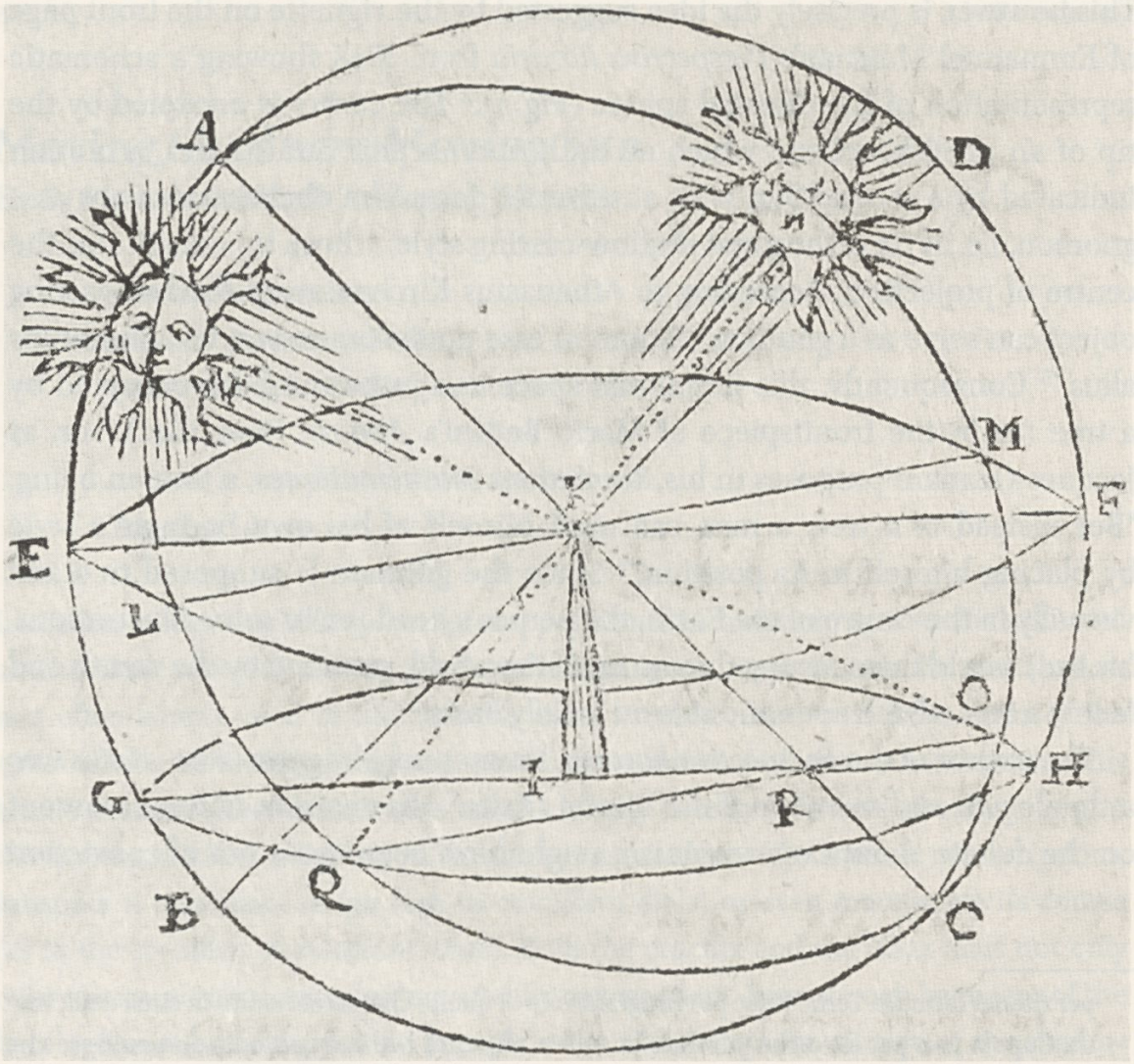

FIGURE 1 *Emmanuel Maignan, Gnomon, in* Perspectiva Horaria *(Rome: 1648), vignette, © Wolfenbüttel, Herzog August Bibliothek 17 Geom. 2°*

or out of caution – ultimately it is in the nature of gnomonics. Since in order to tell time, it is possible to bracket out the sticky question as to the motion of the Sun. All that counts is the actual motion of the shadow across the dial plate. The various interpretations of the moving shadow and its integration into the design of early modern sundials are the object of this study. In most cases, the motion of the shadow is conceived as an index of the motion of the sun; sometimes it is combined with vanitas motifs; yet some sundials even manipulate the shadow in order to use it for narrative purposes.

Rather than studying the iconography on sundials, I will examine the iconicity of the dials themselves. For images were not only a dispensable additive, but often the dial's functional parts (i.e. gnomon, dial plate and corpus) were themselves interpreted in a figurative way. Sometimes it was the irregular shape of the gnomonic grid that inspired the design of the dial (e.g., in the so-called

Portici Ham or the *Navicula de Venetiis*),[8] sometimes the functional form suggested a figurative interpretation (e.g., a compendium in the shape of a missal or a cylindrical altitude dial designed to look like a knife, a lighthouse, or a column).[9] Apart from figurative dials in the shape of stars, spoons, crucifixes, etc., apparently abstract dials can also be called representational insofar as they constitute models of the sky (according to Michel Serres, the gnomon is "more of an observatory than a clock").[10] The hemispherical *skaphe*, in particular, can be seen as an image of the celestial dome, its gnomonic grid being a projective image of the network of parallels and meridians, and the shadow moving over it functioning as an index of the Sun's movement.

Due to its status between image and text, the art historian Steffen Bogen classifies the sundial as a diagram, following Charles Sanders Peirce's definition according to which a diagram is a configuration that does not resemble a given object, but bears resemblances to it in the relation of its parts.[11] More than a simple time-measuring device, the sundial can thus also be seen as a model of mobile celestial constellations and of our position within them. While armillary spheres, astrolabes or clockwork-driven celestial globes simply *represent* those constellations on a small scale, sundials exploit their own indexical relationship with the Sun and exhibit that relationship on their surface. The moving shadow thus becomes the crucial factor. In what follows, I would like to examine if and how early modern sundials reflect this disposition in inscriptions, pictorial representations and the shape of the instruments themselves. Three dial types will be studied in more detail: cruciform sundials

8 Whereas in the case of the supposedly ham-shaped dial in the Museo Archeologico in Naples it is uncertain whether the association was intended, the *Naviculae* explicitly interpret grid and corpus in figurative terms. Cf. Nicola Severino, "The Portici Ham," *The Compendium: Journal of the North American Sundial Society*, 1997, *4*, *2*: 23–25; Catherine Eagleton, *Monks, Manuscripts and Sundials: The Navicula in Medival England* (Leiden and Boston: Brill, 2010), pp. 4–6.

9 E.g. German compendium, Florence, Museo Galileo, inv. 2481. Cf. Georg Hartmann's paper model of a quadrangular dial in the shape of a knife handle from 1560 (Nuremberg, Germanisches Nationalmuseum [GNM], HB 25489/1206); Hieronymus Lauterbach's pillar dial in the shape of a lighthouse from 1576 (Graz, Universalmuseum Joanneum, inv. 0296); Corinthian column and terrestrial globe, dated 1593 (London, British Museum [BM], 1888, 12-1.282).

10 Michel Serres, "Gnomon: The Beginnings of Geometry in Greece," in *A History of Scientific Thought: Elements of a History of Science*, edited by Michel Serres, Michel Authier et al. (Oxford and Cambridge, MA: Blackwell, 1995), p. 9.

11 Steffen Bogen, "Schattenriss und Sonnenuhr: Überlegungen zu einer kunsthistorischen Diagrammatik," *Zeitschrift für Kunstgeschichte*, 2005, *68*, *2*: 153–176, p. 160.

by the Nuremberg instrument maker Georg Hartmann (1489–1564), Maignan's catoptrical meridians in Rome from 1637 and 1643, and two specimen of the so-called "Horologium Ahaz" constructed by Hartmann and by the Augsburg instrument maker Christoph Schissler (c. 1531–1608). All three use the moving shadow or wandering spot of light not only in a symbolic but also in a performative way. It is not so much the shape, but the *motion* of the shadow that counts. Incorporated into the design of the dial, the shadow or light spot re-enact celestial phenomena on a terrestrial stage.

1 Shadows of Time, Death and Salvation

According to Marin Mersenne, a correspondent of Maignan and translator of Galileo's writings,[12] the representational arts and gnomonics are children of the same parent. The shadow "represents all sorts of bodies and seems to have given birth to painting and all arts that teach the method of representing objects. Secondly, it serves to measure the height of the Sun and other stars that cast their shadow on the horizon, and to know what time it is, such that all horologiography or gnomonics is founded on this property."[13] In alluding to the origins of painting, Mersenne makes reference to Pliny's account of Butades' daughter, who is said to have traced her lover's shadow on a wall before his departure.[14] Painting is thus understood as a technique of transcribing bodies onto flat surfaces by means of projection.[15] Likewise, the gnomonic grid can be understood as the transcription of the length and orientation of a shadow cast around the year. But early modern dial makers rather used geometrical methods, tables and auxiliary instruments to construct the hour scale. This

12 Cf. Whitmore, *The Order of Minims* (cit. note 7), pp. 140–142.

13 Marin Mersenne, *L'optique et la catoptrique, nouvellement mise en lumière après la mort de l'Autheur* [1651] in Jean François Niceron, *La Perspective curieuse* (Paris: Jean Dupuis, 1663), p. 49: "... l'ombre represente toutes sortes de corps & semble avoir donné la naissance à la peinture & à tous les arts qui enseignent la methode de representer quelque chose. Elle sert en second lieu pour mesurer la hauteur du Soleil & des autres astres qui font l'ombre sur l'horizon, & pour savoir quelle heure il est, de sorte que tout l'horlogiographie ou la gnomonique est fondée sur cette proprieté."

14 Pliny, *Naturalis historia*, XXXV.84.

15 Cf. Thomas da Costa Kaufmann, "The Perspective of Shadows: The History of the Theory of Shadow Projection," *Journal of the Warburg and Courtauld Institutes*, 1975, *38*: 258–287; George Bauer, "Experimental Shadow Casting and the Early History of Perspective," *Art Bulletin*, 1987, *69*, 2: 211–219.

scale, however, is not yet a sundial. In order to function, it requires a second projection interacting with the first: that of a shadow cast by a gnomon, the shape of which – in contrast to Pliny's account – is irrelevant.

Primarily, the cast shadow thus functions as an indicator of time. With the change in the perception of time, reflected in the grim Renaissance figure of Chronos, the interpretation of sundials also changed.[16] Invested with vanitas motifs and mottos like "quasi umbra transit vita", or "hora quasi umbra", Renaissance sundials were often interpreted as a *memento mori*.[17] The comparison of shadows with the fleeting nature of human existence can be traced back, inter alia, to Job 14:2: "... fugit velut umbra et numquam in eodem statu permanent / [man] fleeth also as a shadow, and continueth not" and Psalm 144:4: "... homo vanitati similis factus est dies eius sicut umbra praetereunt / Man is like to vanity: his days are as a shadow that passeth away."[18] Similarly, the melancholic putto depicted with a skull and hourglass on one of Hans Troschel's (1585–1628) ivory diptych dials from c. 1600 reminds its users of the finite nature of their existence: "HORA FUGIT MORS VENIT / Time flies, death approaches".[19] With the depiction of the hourglass, the engraver embeds a second, competing time-measuring device into the first – the trickling sand as an indicator of finite terrestrial time, as opposed to the long-term astronomical time indicated by the sundial itself.

There were, however, also sundials celebrating the triumph of light over death: i.e. ivory dials representing the Birth and Resurrection of Christ, and cruciform sundials the gnomons of which were constituted by the edges of

16 Cf. Erwin Panofsky, "Father Time," in *Studies in Iconology: Humanistic Themes in the Art of the Renaissance* (New York: Oxford University Press, 1939), pp. 69–93. According to Sara Schechner, "... sundials reflected the new attitude toward time"; cf. id., "The Material Culture of Astronomy in Daily Life: Sundials, Science, and Social Change," *Journal of the History of Astronomy*, 2001, *32*: 189–222, p. 207.

17 Cf. Charles Leadbetter, *Mechanick Dialling; or, the New Art of Shadows* (London, printed for E. Wicksteed, 1756), p. 110, 113 and 104; Margaret Scott Gatty, *The Book of Sun-dials*, enlarged and re-edited by H.K.F. Eden and Eleanor Lloyd (London: George Bell & Sons, 1900), pp. 459–460.

18 Cf. the motto of the two-sided vertical dial at the entry to a cemetery in Gorsleben from 1696, where the gnomon was interpreted as the Grim Reaper's scythe: "UNSERE LEBENSZEIT VERFLEUCHT, WIE EIN SCHNELLER SCHATTEN WEICHT / Our lifetime passes by like a quick shadow."

19 Oxford, Museum of the History of Science [MHS], inv. 42021, ivory and brass, 82×58×15 mm, c. 1600. Cf. Penelope Gouk, *The Ivory Sundials of Nuremberg 1500–1700* (Cambridge: Whipple Museum of the History of Science, 1988), p. 127, no. 33, pl. 1.

the beam.[20] Georg Hartmann, instrument-maker and vicar at the parish of Saint Sebaldus in Nuremberg, in 1529 developed a paper model of a cruciform dial merging two of Nuremberg's major trades, i.e. scientific instruments and printed images.[21] The upper face of the cut-out sheet shows the Crucifixion, the backside its Old Testament antetype, the Brazen Serpent.[22] For the elaborate graphic design, engraved and printed by Hartmann's own hand, he might have collaborated with the Cranach workshop.[23] In order to use the dial, the cross must be tilted in the angle of the local latitude, directed north and thus aligned with the Pole Star using a compass. The Brazen Serpent is thus eclipsed, the body of Christ exposed to sunlight. The shadow cast on the side not only indicated the time, but could also allude to the darkness that occurred after the Crucifixion (cf. Matthew 27:45) – a phenomenon vividly discussed among scholars who tried to explain it either by the interposition of a cloud or by an irregular eclipse of the sun.[24] The miraculous darkness was occasionally

20 E.g. Paul Reinmann, ivory diptych dial, 1599, Chicago, Adler Planetarium, M-246. Cf. Schechner, "Material Culture" (cit. note 16), p. 196, fig. 196. Christoph Clavius recommends cruciform dials in his *Gnomonices libri octo* (Rome, 1581), p. 636. For further references, cf. Sara Schechner, who also mentions cruciform sundials used as reliquaries, e.g. the exemplar made in Ulrich Schniep's workshop around 1560 in the Adler Planetarium, M-253 (Ibid., p. 198 and n. 24).

21 Nuremberg, GNM, HB 665–668, woodcut, 445×175 mm. Cf. Constanze Lindner Haigis, Dieter Nievergelt, "Der früheste Modellbaubogen: Ein Sonnenuhr-Kruzifix von Georg Hartmann (1489–1564) aus Nürnberg," in *Arbeitskreis Bild Druck Papier: Tagungsband Ravenna 2006*, edited by Wolfgang Brückner et al. (Münster/New York/München/Berlin: Waxmann, 2007), pp. 11–36. For an in-depth study of Hartmann's paper models, cf. Suzanne Karr Schmidt, "Georg Hartmann and the Development of Printed Instruments in Nuremberg," in *Prints and the Pursuit of Knowledge in Early Modern Europe*, catalogue edited by Susan Dackerman (New Haven and London: Yale University Press, 2011), pp. 268–279.

22 Cf. John 3, 14–15: "As Moses lifted up the serpent in the wilderness, even so must the Son of Man be lifted up, that whoever believes in Him should not perish but have eternal life."

23 Cf. Linder Haigis/Nievergelt, "Modellbaubogen" (cit. note 21), p. 14. For Hartmann's biography, cf. Hans Gunther Klemm, *Georg Hartmann aus Eggolsheim (1489–1564): Leben und Wirken eines fränkischen Mathematikers* (Forchheim: Ehrenbürg-Gymnasium, 1990).

24 Cf. Nadeije Laneyrie-Dagen, "Miracle ou phénomène scientifique? L'éclipse e la mort du Christ, de Gaddi à Rubens," in *L'art de la Renaissance entre science et magie*, edited by Philippe Morel (Rome and Paris: Académie de France à Rome/Somogy éditions d'art, 2006), pp. 129–146.

represented in contemporary paintings; the sundial re-enacts the miracle every time it is used.[25]

On the base of the cross, the paper model bears an inscription saying, "We shall praise the cross of our Lord Jesus Christ, in whom we find salvation, life and resurrection and through whom we have been saved and liberated. Georg Hartmann of Nuremberg has made this in the year of the siege."[26] To Hartmann's contemporaries, it will have been obvious that the indication "faciebat [...] anno obsidionis" referred to the Turkish siege of Vienna, successfully repelled by Emperor Ferdinand I in 1529, aided by reinforcements from Nuremberg. The inscription thus connects the redemption on Mount Golgotha with the redemption of Vienna.[27]

Precious ivory versions of the crucifix dial were made for Albrecht of Brandenburg in 1541, for Emperor Ferdinand's wife Anna in 1544 (Fig. 2) and for Luther's collaborator Philipp Melanchton.[28] In an undated letter, Melanchton (who chose the Brazen Serpent for his coat of arms), in thanking Hartmann for the delivery of his cruciform compass dial, compared the believers to iron shavings attracted to the magnet of Christ. The dial, he writes, "will remind me that this misery will finally have an end, and that our magnet will draw our souls back to the eternal home in Heaven."[29] A similar idea, translated into the interplay of gnomon and shadows, was expressed in the motto of the now lost sundial at Glasgow Cathedral: "Our Life's a flying Shadow, God's the pole / The Index pointing at Him is our Soul / Death's the Horizon, when our Sun is set / Which will through *Christ* a Resurrection get."[30]

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25 E.g. in Jörg Breu the Elder's *Erection of the Cross* from 1524, now in the Szépművészeti Múzeum in Budapest.

26 "Nos aute[m] gloriari oportet in / cruce d[o]m[ini] n[ost]ri Iesu Christi, in quo / est salus, vita et resurrectio n[ost]ra, p[er] que[m] salvati et liberati / sumus. Georgius Hartma[nn] faciebat / Noremberge An[n]o obsidionis."

27 Interestingly, Hartmann also designed some Arab dials for the latitude of Constantinople with the same inscription (Munich, Staatsbibliothek, MS Rar. 434, fols. 55 and 58).

28 London, BM, 1894,0722.1, ivory dial with compass, 96×39×17 mm, signed and dated on the base. Second specimen for the empress Anna in Nuremberg, GNM, WI 133. Melanchton's dial has been lost. Cf. Hermann Maué et al., *Quasi Centrum Europae: Europa kauft in Nürnberg 1400–1800* (Nuremberg: Verlag des Germanischen Nationalmuseums, 2002), pp. 367–371.

29 Letter of August 8 (1539?), in *Philippi Melanthonis opera quae supersunt omnia*, Vol. 4, edited by Carolus Gottlieb Bretschneider (New York: Johnson Reprint, 1837/1963), pp. 854–855.

30 The motto is documented in Leadbetter, *Mechanick Dialling* (cit. note 17), p. 115.

FIGURE 2 *Georg Hartmann, Crucifix Sundial, 1544, © Nuremberg, Germanisches Nationalmuseum, inv. WI 133*

2 Traces of Movement

"NISI CUM DEFICIT SPECTATOREM NON HABET / If [the sun] does not hide, it does not have any spectators" (Fig. 3).[31] The inscription encircling the image of an eclipsed sun on a vertical dial made in 1589 by the renowned instrument maker Erasmus Habermel (c. 1538–1606) indicates a constitutive feature of the sundial: indirect observation. Only the eagle was said to be able to look straight into the sun; men, just like the inhabitants of Plato's cave, were condemned to observe its negative image, or its index. Interpreting shadows, man can nonetheless gain insights that lead to the development of cultural techniques. The two little monkeys[32] clinging to a bar underneath the engraved Sun might thus refer to the topos of *ars simia naturae* mentioned in relation to gnomonics by the Nuremberg poet Georg Philipp Harsdörffer: "What does this outrageous art, this ape of all natural marvels, dare to do? Or rather, what does it *not* dare to do? It is so impudent as to put a stick into the ground wherever it wants and, in surrounding it with numbers, to demand an account of the Sun's daily travels."[33] The gnomon then is considered as an instrument of inquiry, even of human self-empowerment. This is slightly different from Michel Serres's description of the ancient gnomon as an observatory that does not require human intervention (although it was exactly this feature that was constitutive for the modern notion of 'objectivity'). According to the etymology of the term "gnomon", it was the instrument itself that "knew, discerned, distinguished, intercepted the light from the Sun, left lines on the sand as if it were writing on a blank page and, yes, understood" – independently of an investigator.[34]

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31 Frankfurt, Historisches Museum, inv. x 852, gilded copper, 160 mm. Cf. Reinhard Glasemann, *Erde, Sonne, Mond & Sterne: Globen, Sonnenuhren und astronomische Instrumente im Historischen Museum Frankfurt am Main* (Frankfurt/Main: Kramer, 1999), p. 107, cat. no. 57. Habermel was later appointed instrument maker at the court of Rudolf II in Prague where he met Jost Bürgi, Tycho Brahe, and Johannes Kepler.

32 Two apes also figure on the diptych sundial made by Regiomontanus for Pope Paul II in 1464/1467 (Nuremberg, GNM, WI 7). Interestingly, in the first diptych dial, made for the Emperor Frederick III by Regiomontanus' teacher Georg von Peuerbach in 1451, the figures have more human features, reminiscent of woodwoses.

33 Georg Philipp Harsdörffer, *Deliciae mathematicae et physicae: Der mathematischen und philosophischen Erquickstunden Zweyter Theil* (Nuremberg: Jeremias Dümler, 1651), p. 318: "Was unterstehet sich aber die frevele Kunst, die Aeffin aller natürlichen Wunderwercke? Ja was unterstehet sie sich nicht? Sie ist so vermessen, dass sie einen Stab in die Erde pflanzet, wohin sie will und solchen mit etlichen Zahlen umbesetzend, Gebotsweiß Reichenschafft heischet von der Sonnen Weltweiten Tagraisen ..."

34 Serres, "Gnomon" (cit. note 10), p. 80.

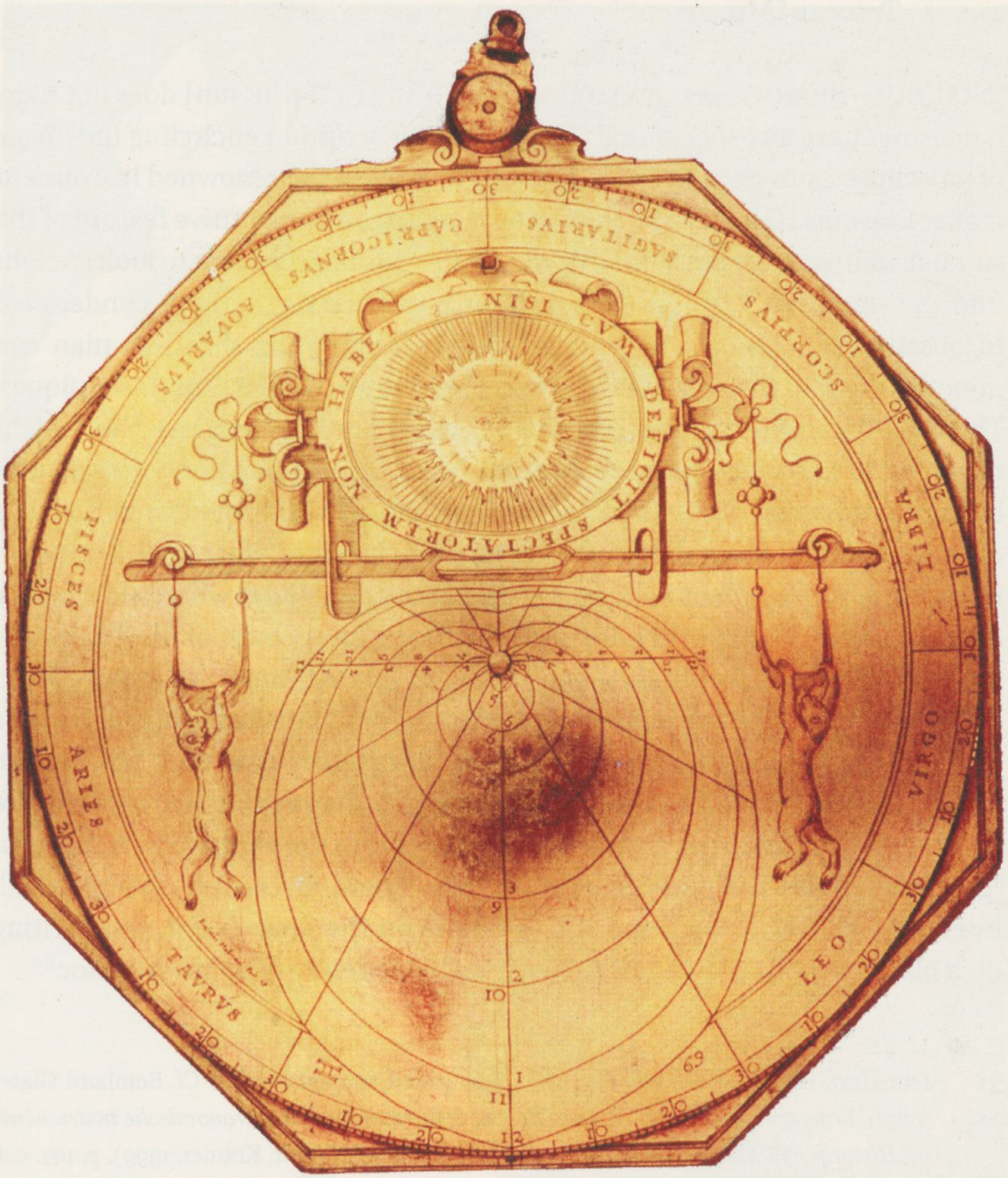

FIGURE 3 *Erasmus Habermel, Equatorial Sundial, 1589, © Frankfurt, Historisches Museum, inv. X 852*

Serres' poetic description of the cast shadow "writing on a blank page" finds historical backing in the motto of an emblem from Silvestro Pietrasanta's *De Symbolis Heroicis* that celebrates the Venetian doge Lorenzo Priuli with the emblem of a sundial. The motto "NULLA HORA SINE LINEA / Not an hour without a line" refers to the doge's diligence in a way comparable to that of the renowned painter Apelles, whose motto was "Nulla dies sine linea / Not

a day without a line".[35] When in the early 18th century, the instrument-maker Christian Karl Schindler transfers this phrase onto a vertical sundial, the association of the shadow line and the graphic line becomes even closer.[36] Finally, in Gabriel Rollenhagen's *Emblematum centuria secunda* from 1613, they become quasi-identical: In the emblematic medallion, it is a quill pen that casts a shadow like a gnomon (Fig. 4). The graphic line is presented as the trace of a manual movement, equivalent to the shadow as the ephemeral trace of the Sun's movement.[37]

3 The Moving Sun and Its Doubles

The absent agent of the sundial is often represented figuratively. Many portable sundials feature anthropomorphic images of the Sun, positioned either at the top of the diptych or at the foot of the gnomon. Combined with inscriptions like "SOLI DEO GLORIA"[38] or the Hebrew letters YHWH,[39] the eternal Sun is often equated with God or Christ. This is the case, for instance, on the cover of an ivory diptych dial attributed to Paul Reinmann (c. 1557–1609) decorated with an engraved depiction of the Adoration of the Shepherds in which the light of the newborn corresponds to the celestial light represented in the image as well as with the natural sunlight shining onto the dial.[40]

In political terms, the Sun could also be associated with sovereigns. The inscriptions on one of the polyhedral dials attributed to Stefano Buonsignori

35 Silvestro Pietrasanta, *De Symbolis Heroicis libri IX* (Antwerp: Officina Plantiniana, 1634), VI.250; text: "Nulla hora sine linea. Nullam in Principatu horam transigere sine linea, et benefactio ars est et laus multò praestantior, quàm cùm Apelles non fuit dies sine lineâ." For the origin of Apelles' phrase, cf. Oleg Nikitinski, "Zum Ursprung des Spruches Nulla dies sine linea," in *Rheinisches Museum für Philologie*, 1999, *142*, *3–4*: 430–431.

36 Oxford, MHS, 50438, brass and steel, perpetual calendar on the back, signed "Schindler, Mathe. et Mechan. fec, Pol 9. 49. 50. 51."

37 Cf. Gabriel Rollenhagen, *Selectorum Emblematum centuria secunda* (Utrecht: Passaeus/Janssonius, 1613), II.24.

38 Cf. for example Paul Reinmann's ivory diptych dial from 1578 (London, BM, 1871,1115.15) and Leonhart Miller's dial from 1637 (BM, 1855,1201.228).

39 I.e. the ivory horary quadrant of a universal altitude dial (BM, 1895,0319.2). The Yahweh-Sun also occurs on the top of the famous frontispiece of Kircher's *Ars Magna* from 1646, where the time units – eternity, zodiacal year, day and night, hours – decrease from the eternal Sun of God on the top to the sundial at the bottom (cit. note 3).

40 London, BM, 1871,1115.14, ivory, 40×30×8 mm.

FIGURE 4 *Gabriel Rollenhagen,* Selectorum Emblematum centuria secunda *(Utrecht: 1613), II.24*

(d. 1589), for example, link the moving, but eternal sun to the perpetually rejuvenated Medici dynasty, represented by Duke Ferdinando: "SOL IDEM SEMPER [NEC NON] SEMPER CURRIT ET VE[RTIT] / The Sun is always the same, [however] it always runs and rotates."[41] Correspondingly, Maignan, in dedicating his treatise to Cardinal Bernardino Spada, also compares his patron to the Sun. Bernardino in turn addresses his own benefactor, Maffeo Barberini alias Pope Urban VIII, as *lux* and *sol*.[42] This metaphor was based on the pope's Sun emblem, which not only emblazoned several Roman monuments but also

41 Florence, Museo Galileo, inv. 2459, painted softwood, 176 mm, after 1587. Cf. Anthony J. Turner, *Catalogue of Sun-dials, Nocturnals and Related Instruments* (Florence: Giunti, 2007), p. 120.

42 Maignan, *Perspectiva Horaria* (cit. note 2), n.p. Cf. Ulrike Feist, *Sonne, Mond und Venus:*

received a spectacular *mise-en-scène* in the tetracycle sundial in the Quirinal Garden, commissioned from the young Francesco Borromini and the mathematician Teodosio Rossi in 1628. This dial, recently reassembled under the supervision of Filippo Camerota, represents the paradoxical case of a shadow-caster in the shape of a Sun. It is the Sun (Urban) that intersects the light of the supreme Sun of God, the Pope (according to the inscription) being "lead by superb light" (*superbi lumini ductu*).[43] The pointers on the other sides have the form of the Barberini bees, described in another inscription as "custodians of the doors and observers of the heavens" – an activity shared with Urban VIII, who was still backing Galileo in the 1620s.[44]

Whereas in this case, it is only a brazen Sun that casts the shadow, in the monumental meridians Maignan constructed in his convent of the Trinità dei Monti in Rome in 1637 and in Bernardino Spada's palace in 1643, the Sun itself tells the time.[45] In both arrangements, the light enters through a hole in the window shutters and is reflected by a little mirror inserted in the ledge. The hour lines emanate from the zenith above the window and span the vault to the horizontal line on the opposite wall. The dial not only indicated the time in equinoctial and temporary, Italian and Babylonian hours, but also allowed for the calculation of the local time at several towns marked on the grid.[46] Apart from zodiac signs, the meridian does not have any figural decoration. Yet it nevertheless features an image: the moving effigy of the Sun, passing across the grid over the course of the day (Fig. 5). That the light projected onto the vault by means of the mirror is not only a spot of light, but also an *image* of the

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Visualisierungen astronomischen Wissens im frühneuzeitlichen Rom (Berlin: Akademie Verlag, 2013), pp. 34 and 46–47.

43 The design of the dial is explained in Rossi's *Horarium Universale Perpetuum* from 1637. Cf. Filippo Camerota, "Architettura e scienza," in *Roma barocca: Bernini, Borromini, Pietro da Cortona*, edited by Marcello Fagiolo and Paolo Portoghesi (Milano: Electa, 2006), pp. 266–277; Denis Ribouillault, "Sundials on the Quirinal: Astronomy and the Early Modern Garden," in *Gardening and Knowledge. Landscape Design and the Sciences in the Early Modern Period*, edited by Hubertus Fischer, Volker Remmert and Joachim Wolschke-Bulmahn (Basel: Birkhäuser Verlag, 2015, forthcoming).

44 Cf. Virgil, *Georgics*, vv.164–165.

45 Cf. Lionello Neppi, *Palazzo Spada* (Rome: Editalia, 1975), pp. 189–201 and Feist, *Sonne, Mond und Venus* (cit. note 42), pp. 16–73. Athanasius Kircher claims to have constructed a catoptric meridian in 1632 in Avignon (Kircher, *Ars Magna* (cit. note 3), p. 649). Interestingly, Copernicus is said to have constructed a catoptrical meridian in order to designate the date for the equinox and the irregularities of the celestial movements.

46 In the Trinità dei Monti: e.g. Constantinople, Naples, Paris, Toulouse, but also the little town of Paola, the birthplace of the founder of the Minim Order, Saint Francis of Paola.

FIGURE 5 *Emmanuel Maignan, Meridian, 1642, Rome, Santa Trinità dei Monti*

Sun in the strictest sense, only becomes evident during a partial eclipse, when the projected circle of light is equally eclipsed.[47] Maignan's second dial in the Palazzo Spada was hence celebrated by his patron as the beginning of a Golden Age of gnomonics: "The iron shadow and the iron gnomon are chased away, the time of the world is no longer made of iron, but gold."[48] Maignan is hailed as a painter who mastered the difficult projection of the sky, but failed to represent the Sun (*Aemula naturae manus hic depingere coelos tentavit, solem pingere non potuit*).[49] Yet with the help of a mirror, Maignan succeeded in abducting the Sun from the sky (*solem deducere coelo*) and in inducing it to paint its (mobile) self-portrait (*Ne tamen incoepto desit Sol ipse labori/ Seque suumque suo lumine*

47 This phenomenon had already been discussed in the pseudo-Aristotelian *Problemata Physica* and was explained by Kepler. Cf. Hans Joachim Schlichting, "Sonnentaler – Abbilder der Sonne," *Praxis der Naturwissenschaften – Physik*, 1994, *43*, *4*: 2–6.

48 Inscription, quoted in Maignan, *Perspectiva Horaria* (cit. note 2), p. 395: "Ferreus hinc Gnomon et ferrea pellitur umbra;/ AVREA pro ferro tempora mundus habet".

49 Ibid., p. 397.

pingit iter).[50] The Sun's promise to henceforth draw its course twice (*Ecce duplex mihi nunc est ineunda via*) blurs the distinction between the autopoietic image and its referent. The image *really* moves just like the Sun – although, from a cosmic point of view, it might just be standing still.[51]

4 Shadows Reversing Their Course: The Horologium Ahaz

Even though Maignan was in all likelihood familiar with Galileo's theories, the moving sunspot was not, or at least not explicitly, used as an argument for geocentrism. This, however, was the case with two biblical miracles – the Sun standing still upon Gibeon (Joshua 10:14) and the reversal of the shadows' trajectory at the behest of King Hezekiah (Isaiah 38:1–8 and 2 Kings 20:8–11). The Old Testament tells the story of Hezekiah, son of Ahaz and King of Judah, whose prayer for recovery from a mortal illness was heard. When the king asked for a sign to confirm Isaiah's prophecy that he was to live for 15 more years, God spoke through the prophet: "Behold, I will bring again the shadow of the degrees, which is gone down in the sun dial of Ahaz, ten degrees backward. So the sun returned ten degrees, by which degrees it was gone down." (Isaiah 38:8). Whereas in the 16th century this scene was primarily referred to as a healing miracle attesting to God's mercy, Volker Remmert has shown how, in the 17th century, both scenes were used as cases in point for the Ptolemaic world view.[52] Arguing that only a moving sun could be stopped or deviated from its course, Christopher Clavius chose to represent both scenes on the frontispiece of his *Operae mathematicae* in 1612.[53]

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50 Ibid.

51 Ibid.

52 Peter Glaser's 26 funeral sermons on "King Hezekiah's pestilence" for instance focus less on the astronomical miracle than on the healing and God's power to do "supernatural things" (*übernatürliche Ding*). As is appropriate for a Protestant preacher, Glaser argues that in the present, the time of miracles was over. Cf. *Sechzig kurtze Leichpredigten* (Dresden: Gimel Bergen, 1582), fols. 226^{r}–395^{v}, esp. fols. 314^{v}–317^{v}. For an account of the different approaches of Protestants and Catholics towards miracles, cf. Peter Dear, "Miracles, Experiments, and the Ordinary Course of Nature," *Isis*, 1990, *81*, *4*: 663–683.

53 Cf. Volker Remmert, "Picturing Jesuit Anti-Copernican Consensus: Astronomy and Biblical Exegesis in the Engraved Title-page of Clavius's *Opera mathematica* (1612)," in *The Jesuits: Cultures, Sciences, and the Arts, 1540–1773*, Vol. 2, edited by John W. O'Malley (Toronto: University of Toronto Press, 2006), pp. 291–313 and id., *Widmung* (cit. note 4), pp. 35–53. For the sources of Galilei's explanation of the biblical miracles in his letter to Christine

As the exact translation of the Hebrew *ma'aloth* was controversial (the Vulgate rendered the term as "lineas", "horologium" and "gradus;"[54] Luther translated "stuffen/steps" and "(Sonnen-)Zeyger Ahas/(sun) pointer Ahaz;"[55] the King James Bible, quoted above, used "degrees" and "sun dial of Ahaz"), some interpreters considered the miracle to have occurred on a staircase, whereas others spoke of a sun dial, later called "Horologium Ahaz."[56] An early representation of the miracle taking place on an adumbrated flight of stairs is found in the *Paris Psalter* from the 10th century.[57] But the Bavarian Gumbertus Bible from the 12th century already depicts Hezekiah on his sickbed looking at a wheel-shaped dial, and a lead glass window in the Cathedral of Canterbury from the 13th century depicts a semicircular vertical dial – a solution also adopted by Clavius.[58] When Johann Jakob Scheuchzer returned to the problem in his *Physica sacra* in 1733, he discussed it at length and, while he did give some credit to the staircase hypothesis and even went so far as to depict a winding flight of stairs in the full-page copperplate engraving accompanying his discussion, he argued in favour of a sundial.[59] Just as in the case of the adumbration

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of Lorraine, cf. Bernard R. Goldstein, "Galileo's Account of Astronomical Miracles in the Bible: A Confusion of Sources," *Nuncius*, 1990, *5*: 3–16.

54 Vulgate, Isaiah 38:8: "Ecce ego reverti faciam umbram linearum, per quas descenderat, in horologio Achaz in sole, retrorsum decem lineis. Et reversus est sol decem lineis per gradus, quos descenderat."

55 Cf. Martin Luther, *Biblia: Das ist: Die gantze Heilige Schrifft* (Wittemberg: Hans Lufft, 1545), 2 Kings 20: "Da rieff der Prophet Jesaja den HERRN an / Und der Schatte gieng hinder sich zurücke zehen stuffen / am zeiger Ahas / die er war niderwerts gegangen."; Iesajah 38: "Sihe / Ich wil den Schatten am Sonnenzeiger Ahas / zehen Linien zurück zihen / über welche er gelauffen ist / das die Sonne zehen Linien zu rück lauffen sol am Zeiger / über welche er gelauffen ist." The *Zürcher Bibel* translates "zehen Stafflen am zeyger Ahas" (*Die gantze Bibel* (Zurich: Froschauer, 1531), 4 Kings 20, n.p.).

56 According to Ernst Zinner, the "ars/horologium Achaz" was first mentioned by the monk Eckehard IV of St. Gallen (980–1060). Cf. id., *Deutsche und niederländische astronomische Instrumente des 11.–18. Jahrhunderts* (Munich: Beck, 1956), p. 51.

57 Paris, BNF, MS. gr. 139, fol. 446^{v}.

58 Erlangen, Universitätsbibliothek, MS 1, fol. 171^{v}. An illumination in a *Bible moralisé* from around 1250 interprets the dial as a water clock (Oxford, Bodleian Library, MS Bodly 270b, 183v). Cf. Gerhard Dohrn-van Rossum, *History of the Hour: Clocks and Modern Temporal Orders* (Chicago and London: University of Chicago Press, 1996), pp. 69–71.

59 Cf. Johann Jakob Scheuchzer, *Kupfer-Bibel, in welcher die Physica Sacra, oder Geheiligte Natur-Wissenschafft derer in Heil. Schrifft vorkommenden Natürlichen Sachen Deutlich erklärt*, Vol. 3 (Augsburg and Ulm: Wagner, 1733), pp. 268–274 and tab. CCCCXCIV. Maximillian Bobinger follows Joseph Drecker in advocating the hypothesis of a flight of stairs east-

of the sun after the Crucifixion, scholars also discussed the question of whether Hezekiah's miracle was local or global. The fact that no profane author mentions this irregular event, led, for instance, Wilhelm Friedrich Hezel to assume that the sun's backward movement was only visible from Hezekiah's palace. In his enlightened Bible encyclopaedia from 1784, moreover, he soberly presents the hypothesis of a cloud refracting the sunbeams as being the most probable explanation.[60]

As regards iconography, apart from the question whether the miracle should be represented as having occurred on a staircase or on a sundial, the more fundamental problem lay in the impossibility of rendering the temporal shift of the shadow turning backwards pictorially. One solution was the simultaneous representation of two successive states of the clock, similar to Maignan's aforementioned tactic of doubling the sun in his frontispiece (cf. Fig. 1).[61]

The collections of scientific instruments at Harvard, Toledo and Madrid include hemispherical brass dials made by Georg Hartmann, whose ingenious idea it was to simulate the miracle in real time by means of an optical trick (Fig. 6).[62] When filled with water, the sunlight is refracted such that the gnomon's shadow is shifted backwards.[63] The inscription on the Toledo dial, made for the latitude of 41°41' (corresponding to Valladolid, Saragossa, Barcelona,

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west in orientation (id., *Christoph Schissler der ältere und der jüngere* (Augsburg: Die Brigg, 1954), pp. 114–115).

60 Cf. Wilhelm Friedrich Hezel, *Biblisches Real-Lexicon*, Vol. 2 (Leipzig: Weygand'sche Buchhandlung, 1784), p. 190. A similar explanation had already been advanced by Sir Christopher Wren in 1657 (vide infra).

61 Cf. also Hans Holbein's *signum sanitatis* in his *Icones Veteri Testamenti* (Lyon 1547), n.p. [cap. xxxviij].

62 Hartmann's dial is explicitly mentioned in Scheuchzer's *Kupfer-Bibel* (cit. note 59, p. 273). The three known specimens are: (1) Cambridge, Harvard, Collection of Historical Scientific Instruments, inv. 7397, brass, for the latitude of 43°10', signed and dated 1548; cf. Stephanie Dick, cat. entry in *Art, Printmaking, and Science* (Cambridge/MA: typoscript, 2010), pp. 35–36 and Karr Schmidt, "Georg Hartmann" (cit. note 21), pp. 296–297. (2) Toledo, Museo de Santa Cruz, inv. 5045, brass, for the latitude of 41°41', signed and dated 1547 and (3) Madrid, Museo Nacional de Cienca y Tecnologia, inv. 1999/023/0001, brass, also for the latitude of 41°41', signed and dated 1547; cf. Lino Colombo, "Refractive Sundials in Italy", typescript on www.nicolaseverino.it/Articoli/Refractive_sundials.pdf.

63 Clavius dedicates a passage to the scene in his *Fabrica et usus instrumenti ad horologiorum descriptionem peropportuni* from 1586, reprinted in his *Opera mathematica*, Vol. IV, p. 6 and pp. 55–58. Cf. also Andreas Geret, *Disputatione mathematica Solem tempore Hiskias retrogradum* (Leipzig: Borckardus, 1673); Johann Andreas Schmidt, "Sciatericum Achas & in eo miraculum," in id., *Variorum philosophicorum decas* (Jena: Tobias Ohrlingius, 1691), chap. V; Anthony J. Turner, "A Biblical Miracle in a Renaissance Sundial," *Bulletin of the*

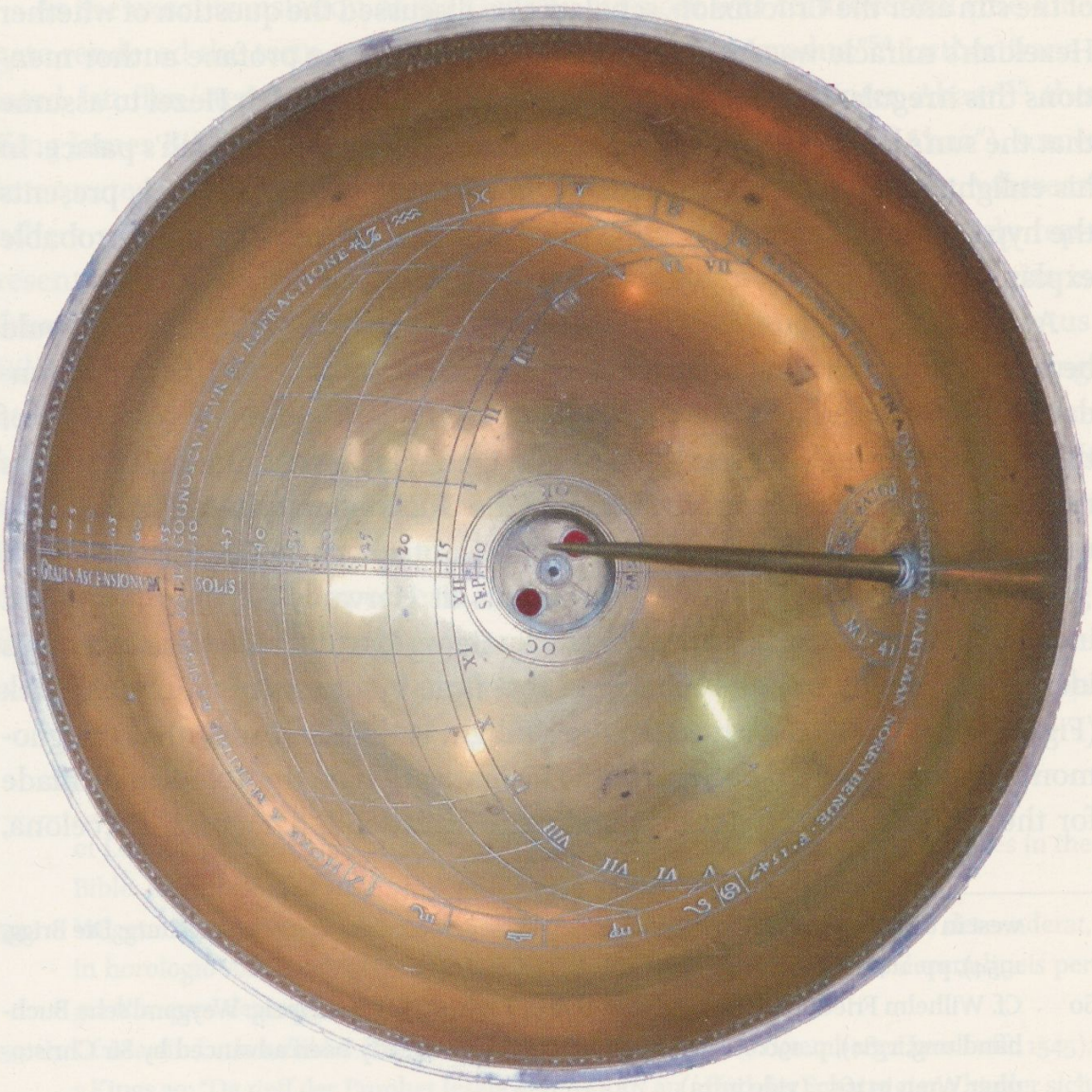

FIGURE 6 *Georg Hartmann, Horologium Ahaz, 1547, © Toledo, Museo de Santa Cruz, inv. 5045*

Rome or Naples), describes the dial as, "a water-operated instrument that miraculously imitates the dial of Ahaz on which Isaiah reversed the shadow of the Sun by ten degrees in the fourth book of Kings, chapter 20 Isaiah chapter 38; and Chronicles II chapter 32."[64] The dial's functioning is explained in the *Deliciae physico-mathematicae* published by the Nuremberg mathematician Daniel Schwenter in 1636: "Here the Horologium Ahaz comes to mind, made by the

Scientific Instrument Society, 1999, *61*: 11–14; Allan A. Mills, "The 'Dial of Ahaz' and refractive sundials in general," *Bulletin of the Scientific Instrument Society*, 1995, *44*: 21–24.

64 "HYDRAULICVM QUOD MIRABILI ARTIFICIO HOROLOGIUM ACHAS IN QVO ESAIAS VMBRAM SOLIS RETRORSVM DVXIT DECEM GRADIBVS QUARTO REGVM 20. CA: ESAIE 38. CA: PARALI 2. CA: 32/ IMITATVR", quoted from Mills, "The 'Dial of Ahaz'" (cit. note 63), p. 23.

talented Georgius Hartmann in Nuremberg many years ago, in which the sun-pointer [i.e., the shadow] regressed several degrees, just as it did during the reign of King Hezekiah in the 20th chapter of the Second Book of Kings. It was a concave dial partially filled with water, such that, when the Sun shone onto the water, the shadow that was reflected pointed back again and did so until the sun shone right onto the water, and this can be easily tested by anybody with a vessel."[65]

Since Hartmann only describes the construction of standard hemispherical dials in his manual,[66] we must rely on reconstructions to understand the configuration of lines on refractive ones. Referring to manuscripts by the physician and mathematical practitioner Ettore Ausonio (c. 1520–c. 1570), Sven Dupré has shown how refractive dials could be conceived on the basis of the writings of Ptolemy and Witelo – which significantly predate the formulation of Snell's law of refraction in 1621.[67] Dupré considers Ausonio's refractive dials "the missing link" between Hartmann's *skaphe* dial, which he might have seen in Venice, and other such instruments made in Italy in the 1570s and described in Giovanni Battista Benedetti's *De gnomonum umbrarumque solarium usu liber* of 1574.[68] Not all refractive dials were explicitly connected to the Horologium

65 Daniel Schwenter, *Deliciae physico-mathematicae* (Nuremberg: 1636), pp. 353–354: "Hie fället mir ein das Horologium Achas, welches der kunstreiche Mann Georgius Hartmann vor vielen Jahren in Nürnberg gemacht, in welchem der Sonnenzeiger um etliche Graden zuruck gienge, wie zur Zeit des Königs Hiskiae im andern Buch der Könige am 20 Capitel: Es war aber eine hole Sonnenuhr, mit Wasser zumtheil angefüllet, darinn, wann die Sonn das Wasser beschiene, der Schatten dermassen reflectiret wurde, daß er wieder zuruck zeigte, und dieses solang biß die Sonn wieder gantz von dem Wasser mit ihrem Schein gienge, und dergleichen kan einer leichtlichen in einem holen Geschirr probiren." Paul Jacob Marperger adopts this description in his *Horologiographia, oder Beschreibung der Eintheilung und Abmeßung der Zeit* (Dresden and Leipzig: self-published, 1723), pp. 94–95.

66 Cf. John Lamprey, *Hartmann's Practika. A Manual for Making Sundials and Astrolabes with the Compass and Rule* (Bellevue, CO: self-published, 2002), pp. 183–190.

67 Hartmann was in possession of a copy of Ptolemy's *Optics*, passed down to him from Regiomontanus who – according to Muzio Oddi – also constructed refractive sundials. Cf. Muzio Oddi, *De gli Horologi solari nelle superficie piane* (Venice^2: Ginammi, 1638), pp. 99–102 and Sven Dupré, "The Dioptrics of Refractive Dials in the Sixteenth Century," *Nuncius*, 2003, *18*, *1*: 39–68, pp. 43–44.

68 Cf. Ibid., p. 63. The design of the refractive dial (inv. 241) in the Museo Galileo from c. 1570, attributed to Simone Barocci, presumably stems from Guidobaldo del Monte, who is said to have made refractive dials in Urbino; cf. Turner, *Catalogue of Sun-dials* (cit. note 41), cat. no. 27, pp. 64–66 and Filippo Camerota, "Two new attributions: A Refractive Dial of Guidobaldo del Monte and the 'Roverino Compass' of Fabrizio Mordente," *Nuncius*, 2003, *18*, *1*: 26–37.

Ahaz. The Florence *skaphe*, for instance, does not bear any inscription, and when Ozanam describes the construction of a refractive dial in his *Recréations mathématiques*, he does not establish any connection to the Biblical miracle.[69] Hartmann's ingenuity, however, was to find a way to abstractly represent or even *perform* the miracle. Owen Gingerich's statement that the dial was not meant to "explain" but rather to *simulate* the miracle, is bolstered by the fact that the word "IMITATVR" on the inscription in the Toledo dial is set apart emphatically (cf. Fig. 6).[70]

Whereas Hartmann expatiates on the relation to the biblical story only by means of an inscription, Christoph Schissler, in his horizontal sundial from 1578, represented the miracle figuratively on the lower side of the dial's base preserved in the collection of the American Philosophical Society in Philadelphia (Fig. 7a).[71] An elaborate engraving – possibly modelled after Hartmann's illustrated paper model – depicts the Judaic king in his stately sickbed, pointing at a vertical sundial outside the palace.[72] Entering from the right, the prophet Isaiah is also pointing a finger at the dial. The constitutive simultaneity of the pictorial representation allows for the depiction of neither the dialogue nor the actual miracle. But following Hartmann, Schissler re-enacts the event on the dial itself. The inscription boasts that, "... this semicircular shell denotes the miracle of the 38th chapter of Isaiah. For if you fill a basin altogether with water, the shadow of the Sun is borne backward by ten degrees.

69 Ozanam, *Recréations* (cit. note 5), pp. 202–205.

70 Oral remark by Owen Gingerich, quoted in Ivar Peterson, "Turning Back Time: An Antique Sundial Simulates a Biblical Miracle," *Science News*, 1990, *137*, *6*: 91.

71 Philadelphia, American Philosophical Society, inv. 58.66, brass and alloy, 30×30 cm. Originally, the bowl was probably supported by a brass figure of Hercules, recast from the armillary sphere made in 1569 (Munich, Bayrisches Nationalmuseum, inv. L Phys 27, brass 34×19×19 cm). Cf. Bobinger, *Schissler* (cit. note 59), pp. 115 and 77. The first scholar to describe the instrument was Julius F. Sachse, who is also responsible for the first (partly erroneous) restoration; cf. id., *Horologium Achaz: Christophorus Schissler, Artifex: A Paper Read before the American Philosophical Society* (Philadelphia: MacCalla, 1895). Another early source is Alice Morse Earle, *Sundials and Roses of Yesterday: Garden Delights Which Are Here Displayed in Every Truth and Are Moreover Regarded as Emblems* (New York and London: Macmillan 1922), pp. 390–410. For the technical details, cf. Allan A. Mills, "The 'Dial of Ahaz', and Refractive Sundials in General. Part II: Horizontal Planar Dials," *Bulletin of the Scientific Instrument Society*, 1995, *45*: 25–27.

72 Hartmann's paper model forms part of the *Collectio figurarum* (Munich, Staatsbibliothek MS Rar. 434, fol. 139). It is reproduced in Hartmann, *Practika* (cit. note 66), p. 297. Bobinger interprets the frame as a "painting" representing a staircase *and* a vertical dial; cf. Hartmann, *Schissler* (cit. note 59), p. 116.

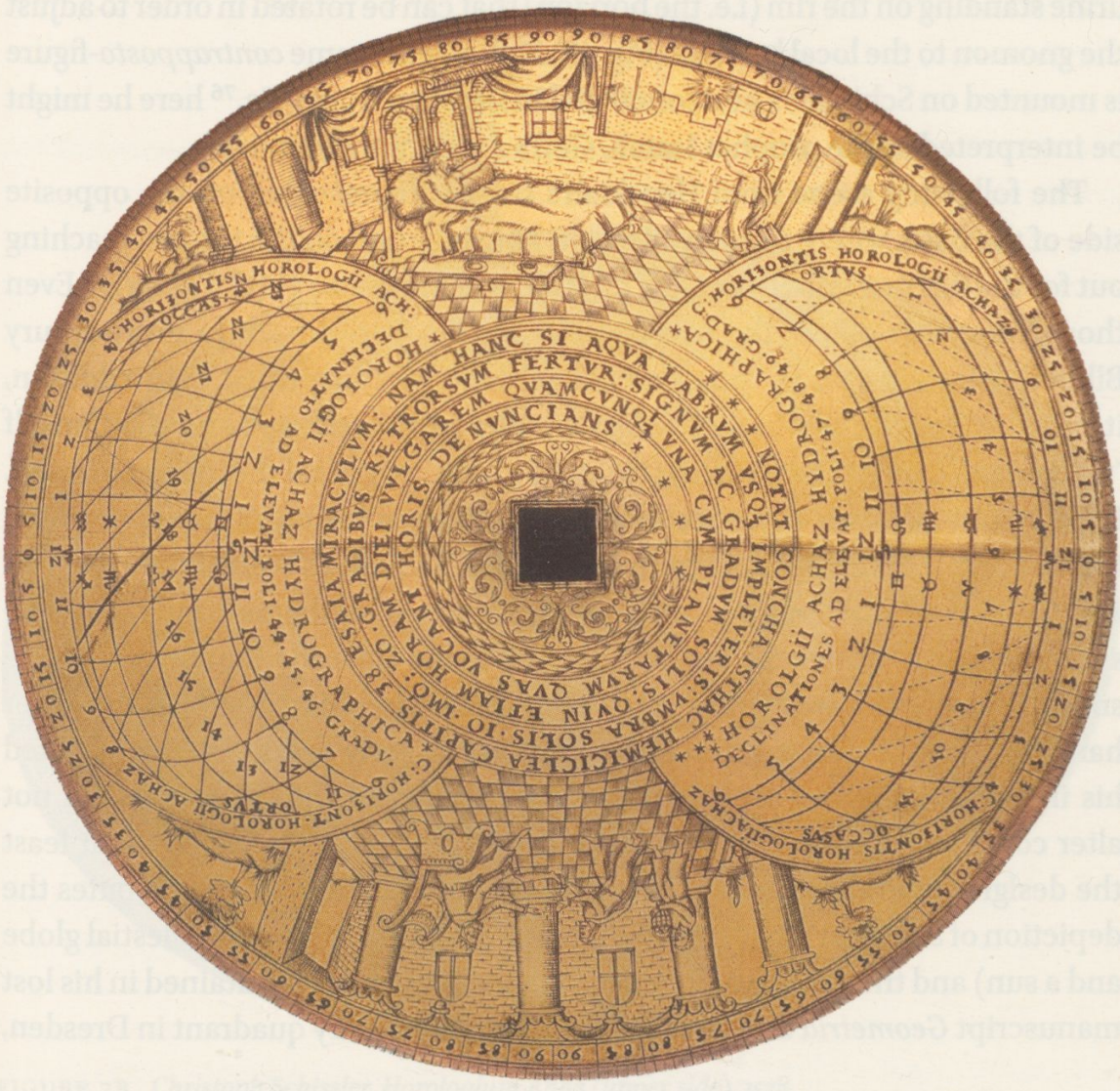

FIGURE 7A *Christoph Schissler, Horologium Ahaz (reverse side), 1578*
© Philadelphia, American Philosophical Society, inv. 58.66

Moreover, it indicates any common hour of the day, together with the so-called planetary hours."[73] Owen Gingerich and Philip Sandler, who analysed and reassembled the dial, acknowledged that the addition of water made the shadow move backward by 10° to 20°, corresponding to 40 to 60 minutes on the calibrated surface.[74] The shadow is cast by a bead on a rod held by a turbaned fig-

73 "Notat concha isthac hemiciclea capitis 38 Essaia miraculum: nam hanc si aqua labrum usque impleveris umbra solis 10 imo 20 gradibus retrorsum fertur signum ac gradum solis: Quin etiam horam diei vulgarem quamcunque una cum planetarum quas vocant horis denuncians."

74 Cf. Owen Gingerich, Philip Sadler, "Christopher Schissler's Wonderful 'Bowl of Ahaz' of 1578," *Bulletin of the American Astronomical Society*, 1989, *21*: 1218; Peterson, "Turning Back Time" (cit. note 70), p. 91.

urine standing on the rim (i.e. the horizon) that can be rotated in order to adjust the gnomon to the local latitude (Fig. 7b).[75] While the same *contrapposto*-figure is mounted on Schissler's horizontal dial in Dresden from 1562,[76] here he might be interpreted as the prophet Isaiah, God's agent in the miracle.

The following scene from Hezekiah's story is represented on the opposite side of the base, where the convalescent king is sitting on the throne, reaching out for the figs prescribed him as a divine cure (2 Kings 20:7) (cf. Fig. 7a).[77] Even though some details of the iconography can be traced back to 16th-century Bible illustrations, so far no exact model has been identified.[78] In addition, it remains uncertain whether Schissler, who in the inscription calls himself "GEOMETRICUS AC ASTRONOMICUS ARTIFEX", engraved the images himself. Despite documentary evidence that the Augsburg goldsmith's guild prevented their member Hans Bossirer from working in Schissler's workshop,[79] we can assume that he collaborated with other experts – mathematicians and artisans – some of whom are known to us by name (like the journeyman goldsmith Hans Helmbrecht and the watchmaker Feyhel Martin).[80] On the other hand, Maximilian Bobinger assumes that in his early years, Schissler crafted his instruments on his own, and since the quality of the decoration did not alter considerably over the years, he might have been responsible for at least the design of the engravings.[81] In addition, Herbert Wunderlich attributes the depiction of Schissler's extravagant coat of arms (a lion holding a celestial globe and a sun) and the artful watercolours of surveying scenes contained in his lost manuscript *Geometria* and later embossed on the horary quadrant in Dresden,

75 The cast-bronze figure is reminiscent of the oriental astronomer in the frontispiece of Peter Apian's *Folium populi* from 1533.

76 Dresden, Staatliche Kunstsammlungen, Mathematisch-Physikalischer Salon, inv. D I 37, gilded brass, wood, glass, iron, signed and dated 1562, 115 mm × 215 mm × 190 mm; the bronze figure measures 95 mm. Cf. Peter Plaßmeyer, Christoph Emmendörffer (eds.), *Weltenglanz: Der Mathematisch-Physikalische Salon Dresden zu Gast im Maximilianmuseum Augsburg* (Berlin and Munich: Deutscher Kunstverlag, 2009), pp. 86–87.

77 Between the illustrations, Schissler included two conversion tables for different hour systems.

78 Cf., for instance, Holbein's *Icones Veteri Testamenti* (cit. note 61), n.p.

79 Cf. August Weiss, *Das Handwerk der Goldschmiede zu Augsburg bis zum Jahre 1681* (Leipzig: E.A. Seemann, 1897), p. 146.

80 Schissler and Martin address a letter to August of Saxony to offer him an instrument. A documented discord in 1577, however, rules out Martin's collaboration on the horologium; cf. Bobinger, *Schissler* (cit. note 59), pp. 29–31.

81 Schissler's first known instrument is a sumptuously decorated heart-shaped dial from c. 1560 in the British Museum (1855, 12-1.219, brass, 71 × 35 × 90 mm).

FIGURE 7B *Christoph Schissler, Horologium Ahaz (upper side), 1578*
© Philadelphia, American Philosophical Society, inv. 58.66

to the master himself.[82] This attribution is reinforced by the fact that one of Schissler's autograph letters bears a similar drawing.[83]

82 Dresden, Staatliche Kunstsammlungen, 1569/1570, brass, 20×28 cm. Cf. Herbert Wunderlich, "Das Dresdener 'quadratum geometricum' aus dem Jahre 1569 von Christoph Schißler d. Ä., Augsburg," in *Veröffentlichungen des Staatlichen Mathematisch-Physikalischen Salons*, Vol. 1 (Berlin: VEB Deutscher Verlag der Wissenschaften, 1960). For the coat of arms, cf. also Samuel Gessner, "'Geometricus et astronomicus faber': Chr. Schissler aus Augsburg als Hersteller eines wenig bekannten großen Himmelsglobus (1575)", in *Weiter sehen: Beiträge zur Frühgeschichte des Fernrohrs und zur Wissenschaftsgeschichte Augsburgs*, edited by Jürgen Hamel and Michael Korey, *Acta Historica Astronomiae, Beiträge zur Astronomiegeschichte*, 2012, *45*: 123–154, pp. 149–151.

83 Dresden, Hauptstaatsarchiv, 10024, loc. 4418/1, book 1, fols. 194–195: 17.6.1570. Cf. Wunder-

What remains is the question of the intended recipient of the dial. The fact that it is calibrated for latitudes from 44 to 49° suggests that it was not made for a specific client. We can assume that it was conceived for a wealthy collector like August of Saxony, for whose Kunstkammer Schissler fabricated thirteen instruments between 1558 and 1575.[84] Even though the dial is not calibrated for the latitude of Dresden,[85] there is a letter from 1562 in which Schissler explicitly refers to a refractive dial. Among globes, spheres, astrolabes, compasses and dials, Schissler mentions "an artificial drinking vessel referring to the 4 Kings chap. 20 on the Horologium Achaz: when the shadow went back etc. and to the text of Joshua chapter 10, when the sun stood still."[86] As stated in the beginning: for dial-makers the question of whether the Sun actually moves is irrelevant.[87] There are no explicit references to helio- or geocentrism in Hartmann's or Schissler's works. Even though Samuel Gessner could show that Schissler used Copernican precession in his celestial globe from 1575, he warns against hasty conclusions concerning his cosmology.[88] Caution is advised also

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lich, "Das quadratum geometricum" (cit. note 82), p. 50. Two other horary quadrants were made for Rudolph II (1579, today kept in Oxford, MHS 8659) and for Anton Fugger, identified by Wunderlich with the instrument inv. 155 in the Museo Galileo in Florence (ibid., pp. 86–87); cf. Turner, "A Biblical Miracle" (cit. note 63), p. 56, cat. no. 18.

84 Cf. Wunderlich, "Das quadratum geometricum" (cit. note 82), p. 41. Several of these instruments are still on exhibit in the Mathematisch-Physikalischer Salon in Dresden, but unfortunately many others were lost in World War II. For Schissler's relation to August of Saxony, cf. Peter Plaßmeyer, "Christoph Schissler: The Elector's Dealer," in *European Collections of Scientific Instruments, 1550–1750*, edited by Giorgio Strano et al. (Leiden [u.a.]: Brill, 2009), pp. 15–25.

85 Dresden has the latitude of 51°. As Prague has a latitude of 50°, Rudolf II as well, whom Schissler provided with instruments from 1583, is cancelled out as a recipient.

86 Dresden, Hauptstaatsarchiv, loc. 8679/6, fols. 44–45: "... item ein sonderlich kunststück, ein trinkgeschür zu machen, auf den Text des 20. Cap. etc. im 4. buech der künigen von dem horologium Achaz: da der schatten zuruckgelauffen etc. Item auf den Text deß 10. Capitels Josua, da die Sonnen ist stil gestanden ...," quoted in Bobinger, *Schissler* (cit. note 59) pp. 35–36.

87 This is also stressed in the *Theses opticae et astronomicae* edited by Jean Baptiste Thioly and Pierre Taillandier in 1693, whose chapter on gnomonics opens with an illustration of Hezekiah's miracle occurring on a vertical sundial. Cf. *Theses opticae, et astronomicae* (Lyon: P. Valfray, 1693), pp. 41–42.

88 The globe was made in 1575, the year of Tycho Brahe's second stay in Augsburg, and responded to Tycho's request for an accurate, transportable globe; cf. Gessner, *Geometricus et astronomicus faber* (cit. note 82), pp. 137–138 and 145.

with respect to Hartmann: there is hardly enough evidence to support conjectures concerning his potential acquaintance with Copernicus' brother Andreas, or his contribution of observational data from Nuremberg.[89] Consequently, it would be too audacious to suggest that Hartmann used the dial of Ahaz as a case in point for heliocentrism. Primarily, he 'aped' the miracle for princely entertainment and thereby demonstrated man's power to manipulate nature. Maignan can take the Sun's image hostage (*Solem hic reclusum in carcere*, as Bernadino Spada says), but not the Sun itself. In reversing the shadow by means of the refractive dial, Hartmann uncouples the shadow from its origin and thus succeeds at manipulating it. For in contrast to regular sundials, in the case of Hezekiah, the recursive motion of the shadow did not necessarily imply a corresponding motion by the Sun. In his famous letter to Christine of Lorraine, Galileo stresses that Paul of Burgos was already of the opinion that Hezekiah's miracle did not take place in the Sun but only on the dial, or more precisely, that it only affected those rays that produced the narrow shadow on the scale.[90]

A more radical position was advanced by Christopher Wren (1632–1723) who, in his inaugural lecture at Gresham College in 1657, explained the miracle as an effect of a Parhelion, i.e. of "refractions made in nitrous Vapours higher than the Clouds."[91] "Even Holy Scripture itself," he writes, "sometimes requires an astronomical Interpreter" – without implying a threat "to diminish a Miracle by explaining it."[92] When explaining the shadow's regress as an effect of refraction, however, it could no longer serve as an argument for the mobility of the Sun; the moving shadow was no longer an index of the Sun's movement. And effectively, in Wren's case, this went hand in hand with a Copernican world view: in

89 Cf. Karr Schmidt, "Georg Hartmann" (cit. note 21), p. 269.

90 Cf. Galilei, *Opere*, Vol. 5, pp. 337–338. Cf. Goldstein, "Galileo's Account" (cit. note 53), pp. 6–12. For a summary of the discussion, cf. Scheuchzer, *Kupfer-Bibel* (cit. note 59), pp. 270–274. Even though he insists on the fact that miracles cannot be explained, Scheuchzer as well tends to think that only the shadow was moving (cf. Ibid., p. 272).

91 Christopher Wren, *Parentalia, or, Memoirs of the Family of the Wrens* (London: T. Osborn and R. Dodsley, 1750), p. 201. Scheuchzer mentions a "natural" repetition of the miracle in 1703 reported by a certain Romualdus, Prior in Metz, where the shadow was refracted by the condensation of air. Cf. Scheuchzer, *Kupffer-Bibel* (cit. note 59), p. 274; Ludwig Philipp Thümmig, *Phaenomenon singulare solis coelo sereno pallescentis ad rationes revocatum* (Halle and Magdeburg: Hilliger, 1722), p. 19; Gabriel Christoph Benjamin Busch, *Versuch eines Handbuchs der Erfindungen*, Vol. 6 (Eisenach: Wittekinde, 1795), p. 371.

92 Wren, *Parentalia* (cit. note 91), p. 201.

his lecture, he quite openly opts for the hypothesis of a moving Earth, the hypothesis admired by "all the mathematical Men."[93]

5 Conclusion

This article set out to examine the various interpretations of the mobile shadow in order to ascertain whether the design of sundials established any implicit or explicit relations between the motion of the shadow and the motion of the Sun. In most cases, the shadow was simply used as an indicator of time, often combined with *memento mori* motifs. When complemented with vanitas or eschatological iconography, the moving shadow made it possible to experience the passing of time rather than just representing it symbolically. Correspondingly, the moving shadow was also used to re-enact Biblical miracles. In Hartmann's cruciform sundials, the adumbration of the cross could be interpreted as repeating the miraculous darkness after the Crucifixion; in the *Horologium Ahaz*, the regress of the shadow simulated the miracle recounted in the Old Testament. The uncoupling of the miraculous phenomenon from celestial phenomena – be it by means of the dial or by explaining it as a result of atmospheric refraction – vitiated the usage of the shadow's regress as a case in point for the movement of the Sun.

Whereas in the cases of Hartmann, Schissler and Maignan, we can only conjecture their Copernican sympathies, these can be taken for granted in the case of Christopher Wren. Independently of this, there is a subtext of human self-empowerment in his study of nature viz. in the synchronisation of astronomical and terrestrial time. In an epigram accompanying a catoptric meridian Wren constructed whilst still a Tychonian and a student at Oxford in 1648, he (possibly inspired by Maignan's treatise or another intermediary source) lauds himself as having been enabled by Phoebus Apollo to create a "rival (*aemula*) of his light" travelling "over this heaven [i.e., the grid] with borrowed brightness and forming a likeness of his annual course."[94] Only in the Dial of Ahaz however, does man go so far as to manipulate the trajectory of the shadow such that it is uncoupled from the Sun's celestial orbit. Whereas the vanitas iconography on numerous sundials insists on the irreversibility of time (*Hora fugit, mors venit*), the diverting of the shadow seems to illustrate

93 Ibid., p. 204.

94 Ibid., p. 185: "Angustis satagens his laquearibus / Ad coeli methodum tempora pingere, / A Phoebo obtinuit luminis ut sui / Idæam, speculo, linqueret æmulam / Quæ coelum hoc peragret luce vicariâ, / Cursûsque effigiem fingeret annui ..."

man's capacity to intervene in natural processes. The fact that Schissler's dial was originally supported by a figure of Hercules, the duper of Atlas, stresses the cunning force of the dial's constructor (or its initiated user) who – thanks to an artifice – succeeds in governing the heavens *in imaginem*.[95]

95 In the dedication of his *Perspectiva communis* to the mathematician Johannes Tscherte, also Hartmann compares himself to Hercules mastering the heroic task of compiling a lost "Work on Shadows": "Quem defectu[m] tu nobis precorut brevi emendes, Dabo & brevi in lucem Opus nostru[m] de Umbris, quem Herculeum laborem, tua nixus autoritate, subij ...," Georg Hartmann, *Perspectiva communis* (Nuremberg: Petreius, 1542), n.p.