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A Telescopic Paradox:
The Artisans of the Accademia del Cimento, their Instruments and Their (In)Visibility

The brief life of the Accademia del Cimento (1657-1667), the first known society with a purely experimental programme,[1] is entangled with the most surprising advancements in the history of scientific instruments of that century, from the telescope to the microscope, the thermometer to the barometer, the hygrometer to the pendulum as a time-regulator, and more. The making of instruments at the Florentine court shows the interaction of princely, scholarly and artisanal actors. This paper explores this collaboration and shows how the supposed "invisibility" of artisans depended on their proximity to the academicians and princes, who mainly communicated verbally with them, directly or through middlemen. The visibility of artisans increases proportionally to their physical distance from the Court. In this essay I unveil the identity of the artisans of the Cimento and, finally, attempt to attribute five instruments (some lost and others still extant) to specific makers, shedding light also on relations between the artisan and his patron.

The instruments of the Accademia del Cimento

The Accademia del Cimento (henceforth Cimento) is traditionally believed to be the first institution with a purely experimental programme, which, over a decade, conducted approximately 600 experiments. Such activity has left a large corpus of instruments, mainly preserved at the Museo Galileo in Florence, as well as the visual and verbal record of many other instruments, now lost or never crafted.[2]

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[1] Over the period of a year and a half in 2020-2021, I had the honor to join the European-funded research group Tacitroots under the direction of Professor Giulia Giannini, at the Università Statale di Milano. My task was to research the instruments of the Accademia del Cimento through the lens of social and cultural history. I therefore approached these instruments as cultural products, investigating the agencies that shaped them: specifically, I was interested in the processes involved in their design and construction. This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No. 101025015.

[2] A selected historiography of the Accademia del Cimento in the last fifty years includes: W. E. Knowles Middleton, *The experimenters: a study of the Accademia del Cimento* (Baltimore, MA; London: Hopkins University Press, 1971); Paolo Galluzzi, 'L'Accademia del Cimento: "Gusti" del principe, filosofia e ideologia dell'esperimento', *Quaderni Storici*, 16 (1981), pp. 788–844; Maria Luisa Bonelli and Albert Van Helden, 'Divini and Campani: A Forgotten Chapter in the History of the Accademia Del Cimento', *Annali Dell'Istituto e Museo Di Storia Della Scienza Di Firenze*, 6.1 (1981), 3–176; Marco Beretta, 'At the Source of Western Science: The Organization of Experimentalism at the Accademia Del Cimento (1657-1667)', *Notes and Records of the Royal Society of London*, 54.2 (2000), pp. 131–51; Paolo Galluzzi, *Scienziati a corte. L'arte della sperimentazione nell'Accademia galileiana del Cimento (1657-1667).* (Livorno: Sillabe, 2001); Maria Grazia Tagliavini, '"Opere Di Cristallo Delicatissime e Meravigliose": Works of Art for Connoisseurs and Scientific Instruments for the Accademia Del Cimento', *Nuncius : Annali Di Storia Della Scienza Nuncius*, 22.2 (2007), pp. 309–33; Luciano Boschiero, *Experiment and Natural Philosophy in Seventeenth-Century Tuscany: The History of the Accademia del Cimento (Studies in History and Philosophy of Science, Vol 21)*, Studies in History and Philosophy of Science, 1. Aufl. (Dordrecht: Springer Netherlands, Springer, 2007), XXI; *The Accademia Del Cimento and Its European*

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These descriptions can mainly be found in the many unpublished papers of the Accademia del Cimento and in its only official collective publication, *Saggi di naturali esperienze fatte nell'Accademia del Cimento sotto la protezione del serenissimo principe Leopoldo di Toscana e descritte dal segretario di essa Accademia* (henceforth *Saggi*), published in 1667 (despite the date printed in the title page being 1666) and compiled by Count Lorenzo Magalotti, the second and also last secretary of the Academy.[3]

The quality of these instruments created for the Cimento was exquisite. They were the collective products of a group made up of broadly appreciated philosophers and talented craftsmen capable of realizing and often improving them. Listed among the scholars were the Medici princes themselves, who were first-rank intellectuals, and who financed and directed the activity of the Cimento. For instance, Grand Duke Ferdinando II was credited with having invented a number of cutting-edge instruments.

The collaborative nature of instrument-making for experimental practices is exemplified by the hermetically sealed thermometers: the Grand Duke himself was considered their inventor. The Aristotelian academician Professor Carlo Rinaldini was said to have then set the limits of cold and heat for these instruments, and to have divided their scales into grades, whereas the skilful glassblower determined the best shape and dimension to replicate successfully identical versions of such instruments (fig. 1 & 2).[4]

The Florentine experience of the Accademia del Cimento is important for better contextualizing the role of artisans in experimental practice: discussing early modern English experimental science, Stephen Shapin observes that there is a problem of the invisibility of artisans/technicians in the narratives of the time, despite the fact that they were fundamental to the experimental process.[5]

Context, ed. by Marco Beretta, Antonio Clericuzio, and Lawrence Principe (Sagamore Beach, MA: Science History Publications, 2009); Mordechai Feingold and Giulia Giannini, *The Institutionalization of Science in Early Modern Europe* (Leiden; Boston: Brill, 2019).

[3] For quotations from the *Saggi* I will make use of Richard Waller's 1684 English translation: Lorenzo Magalotti, *Essays of Natural Experiments: Made in the Academie Del Cimento, Under the Protection of the Most Serene Prince Leopold of Tuscany*, trans. by Richard Waller FRS (London: B. Alsop, 1684).

[4] Accademia del cimento and Magalotti, *Saggi di naturali esperienze fatte nell'Accademia del cimento sotto la protezione del serenissimo principe Leopoldo di Toscana e descritte dal segretario di essa accademia*, (In Firenze: Per Giuseppe Cocchini all'Insegna della stella, 1666), pp. II-IV. Gianfrancesco Rambelli, *Intorno invenzioni e scoperte italiane* (Modena: Vincenzi e Rossi, 1844), p. 167. See also below.

[5] Steven Shapin, 'Invisible Technicians: Masters, Servants, and the Making of Experimental Knowledge', in *A Social History of Truth: Civility and Science in Seventeenth-Century England* (Chicago: University of Chicago Press, 1994), pp. 355–407.

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In contrast, the context of the Medici court provides important insights into the role and personality of some of the most talented artisans involved with the design and production of the instruments used in the Cimento.[6]

A Unique Industrial Facility for the Cimento

The physical makers of the instruments of the Cimento were highly skilled artisans from the grand ducal workshops: the most important economic feature of the Accademia del Cimento is that, being a product of the Court, it could freely draw upon the facilities provided by the State, from the philosopher employed at Court and in the best Tuscan teaching institutions, to the precious instruments of the princely Guardaroba (a kind of extended Studiolo-Kunstkammer), from the materials and artisans of the Gallerie (also in the singular form *Galleria*) and other courtly related workshops, to the craftsmen provided by the Medici network.

At the Tuscan court, nearly all skills and materials were at hand for such an ambitious programme as the Accademia del Cimento. As with the scholarly members, the technicians/artisans of the Cimento were also only part-time experimenters for this Academy: their duties in the Grand Ducal workshops, especially in the Gallerie, both provided their salaries and imposed regular obligations upon them.[7]

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[6] I would like to thank my colleagues at Tacitroots and especially the libraries of the Museo Galileo and of the Biblioteca Nazionale Centrale di Firenze (henceforth "BNCF") for providing me with the digital resources needed for this investigation during the Covid-19 pandemic. Many thanks are also due to the President of HORA (the Italian society of antiquarian horology), Antonio Lenner, for assigning to me the task of the posthumous edition of Silvio Bedini's magnus opus, which first put me in touch with some of the fascinating topics discussed in this article. See Silvio A Bedini, *Giuseppe Campani, 'Inventor Romae,' an Uncommon Genius*, ed. by Cristiano Zanetti (Leiden; Boston: Brill, 2021). I also thank Dr Giorgio Strano of the Museo Galileo and Giancarlo Truffa for their help, Mordechai Feingold for offering the hospitality of this journal, and the anonymous reviewers for their useful comments. This article adds to a growing corpus of contributions that, especially in the last two decades, focus on the role of artisans in the field of the History of Science and Technology. Since the beginning of this century, the work of Edgar Zilsel (1891-1944), the pioneering sociologist of the history of science, has attracted new attention. His research attempted to demonstrate the great importance of the role played by artisans in the development of modern science. Among the most seminal studies resulting from the Zilsel revival are works by Pamela O. Long and Pamela Smith: Edgar Zilsel, *The Social Origins of Modern Science*, ed. by Diederick Raven, Wolfgang Krohn, and Robert S. Cohen, Boston Studies in the Philosophy of Science, 200 (Dordrecht; Boston: Kluwer Academic Publishers, 2000); Pamela O. Long, *Artisan/Practitioners and the Rise of the New Sciences, 1400-1600* (Corvallis, OR: Oregon State University Press, 2011); Pamela H. Smith, *The Body of the Artisan: Art and Experience in the Scientific Revolution* (Chicago: University of Chicago Press, 2004). For a recent bibliographical overview on the topic, see: Joel A. Klein, 'Practitioners' Knowledge', in *The Cambridge History of Philosophy of the Scientific* Revolution, ed. by David Marshall Miller and Dana Jalobeanu (Cambridge: Cambridge University Press, 2022) pp. 184 - 200.

[7] An historical but still useful work on the Grand ducal workshops is: Giuseppe Bencivenni gia Pelli, *Saggio istorico della Real Galleria di Firenze*, 2 vols, (Firenze: Cambiagi, 1779).

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During the era of the Cimento, the noble Bolognese Carlo Antonio Manzini (1600-1677), a famous astronomer and mathematician, emphasized the amazing artisanal skills one could find in the Grand Duke's Gallerie in the dedicatory letter to Prince Leopoldo contained in his book on a new comet, *Comete, Discorso in occasione della comparsa della Cometa…* (Bologna, 1665). Manzini wrote:

> in that Arsenal[8] one could find a great number of artisans coming from all places, and they are the most perfect in the World, excelling in any craft […] and through their work they serve your Magnificence in your studies, in your physics and mathematical speculations […] Here [in the Gallerie] one creates the oils, balsams, and the most powerful qualities of quintessence against death, and nowhere can be found in the surrounding regions any invention of a perfect creation that was not revived thanks to the Work of the *Galleria* of Florence.[9]

Precious metals, wood and stones were at the service of the Accademia. For instance, in May 1659, 36 different precious stones were tested, producing a table of nine different levels of hardness.[10] Moreover, it is clear from the many experiments described in the papers that the academicians made great use of the materials and pharmaceutical products already present in the grand ducal Fonderia, including three of the most iconic materials in experimental practice: malleable and revealing glass; emblematic mercury; and subtle *acquarzente*, i.e. spirit of wine.

The text of the *Saggi* mentions the work of several technicians: glassmakers and turners working with different materials, all professions excellently practiced at the *vetrerie* (glass workshops), the Gallerie or at the *Opificio delle Pietre Dure*, the workshop where semi-precious stones were made into precious vases and *intarsio* panels, the famous *"commesso di prietre dure"*.[11] Since the time of Gran Duke Francesco, the Tribuna, surrounded by the workshops of the Galleria and Fonderia (the vast pharmaceutical laboratory in the Gallerie

[8] At the time, an arsenal was an establishment for different manufactures, and not just a place for the production or storage of weapons. The Arsenal in Venice was the place where the Republic manufactured all the items necessary for civil and military navigation. Considered the biggest industrial establishment of the Middle Ages and early modern period, it became the industrial place for antinomy: it gave its name, in different languages, to other similar establishments all around Europe.

[9] *"… Le Gallerie che altrove servono per passeggio, nel Vostro fiorito Aeropago sono l'Arsenale, per numeroso stuolo de' più perfetti Artefici del Mondo, che in ogni genere di Manuali Discipline, da' più lontani paesi chiamati, ivi liberalmente lavorano per vezzo, e per dar perfezione a tutti quei Lavori, che possono servire alla vostra Grandezza, a' vostri Studj, alle vostre Fisiche e Matematiche Speculazioni, e a qualsivoglia vostro piacevole Trattenimento. Quivi gli Olij, i Balsami, le Quintessenze più potenti contro la morte si fabbricano, né si vede sparsa per le circonvicine Regioni cosa di nuova invenzione, o di perfetto artificio, che per Opera della Galleria di Firenze non si ravvivi."* Giovanni Targioni Tozzetti, *Notizie degli aggrandimenti delle scienze fisiche accaduti in Toscana nel corso di anni LX. del secolo XVII, raccolte dal dottor Gio. Targioni-Tozzetti …* (Firenze: G. Bouchard, 1780), I, p. 513. All translations are mine unless otherwise indicated.

[10] BNCF, Galileiano (henceforth "Gal.") 260, cc. 92r-97r.

[11] Accademia del cimento and Magalotti, *Saggi di naturali esperienze fatte nell'Accademia del cimento sotto la protezione del serenissimo principe Leopoldo di Toscana e descritte dal segretario di essa accademia*, p. CXXXXI: lathe for metals; p. CXXXXIV: lathe for wood; p. CLXXXII: lathe for metals and bronze casting; p. CLXXXIV: lathe for metals and wood; p. CCXII: lathe for wood.

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degli Uffizi), had been a unique space for the replication and investigation of experimentally collected knowledge of *naturalia* & *artificialia*.[12]

At the Medici court, there was much pride in the quality of the Florentine philosophical apparatus: Count Lorenzo Magalotti, the author-editor of the *Saggi*, recalled how an experiment had been performed at the Cimento that not even Robert Boyle, who had conducted many excellent investigations with his air pump, was able to achieve. This was because, unlike at the Cimento, he could not find an artisan sufficiently skilled to prepare the necessary apparatus:

> it has been lately practised by *Mr. Boile*, with admirable success, in those his curious and noble Experiments; among which, this was thought of also, though it was not put in Practice for want of a fit Artificer to make the Apparatus.[13]

It appears that, of all their instruments, the Medici were especially proud of their glass instruments. The presentation in the Saggi of the glass instruments of the Cimento appears to be both an act of openness, and an artifice of courtly *sprezzatura*: if on the one hand the instruments are extensively described and illustrated, it was known that nowhere else, at that time, one could find such skills in glassblowing as in the grand ducal workshops. Still today, the visitor to the Museo Galileo, on beholding the delicateness of the glass instruments produced at the time of the Cimento, feels awe at such refined craftsmanship.[14] This was generally true, except perhaps for Venice, some of which city's secrets for the production of clear optical glass were still much desired in Florence.[15]

The Glassblower

[12] Luciano Berti, *Il principe dello studiolo: Francesco I dei Medici e la fine del Rinascimento fiorentino* (Firenze: Edam, 1967) pp. 57-58.
[13] Magalotti, *Essays*, p. 51. In *Saggi*, XCVII, "…il Boile per uso delle sue bellissime, e nobilissime esperienze, tra le quali sovvennegli ancor quella, tuttoché allora non la mettesse in pratica per mancamento d'artefice atto a fabbricarne l'ordigno...".
[14] The subject of glassmaking in Florence has attracted the attention of several scholars. Among the most relevant works see: Mara Miniati, "Bocciuoli, Palle d'oncia e Termometri Gelosissimi: Vetro e Scienza Nell'Accademia Del Cimento", in Galluzzi (ed.) *Scienziati a Corte*, pp. 36-42; Anna Vittoria Laghi, "Fra Vetro d'arte e Vetro Scientifico," in Galluzzi (ed.) *Scienziati a Corte*, pp. 52–58; Marco Beretta, Paolo Galluzzi, and Carlo Triarico, *Musa Musaei: Studies on Scientific Instruments and Collections in Honour of Mara Miniati* (L.S. Olschki, 2003); Marco Beretta, "Glassmaking Goes Public: The Cultural Background to Antonio Neri's L'Arte Vetraria (1612)," *Technlogy and Culture* 58 (October 1, 2017), pp. 1046–70.
[15] BNCF, Gal. 252, see c. 4v: Letter from Vincenzo Viviani to Erasmus Bartholin (September 4, 1655), where we can see that Bartholin was interested in glass instruments from Florence and Viviani in optical glass from Venice.

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In the words of the historian of science and former director of the Museo Galileo, Paolo Galluzzi, the Accademia del Cimento, through its experimental activities, committed a "massacre of glass":[16] the great majority of the instruments described in the papers of the Academy and in the *Saggi* were indeed made of this material, and crafted in the renowned grand ducal workshops.[17]

These were superb glass-made instruments, the pride of the Accademia (fig. 1-2). It is no coincidence that the first instruments described in the *Saggi* were the thermometers and the condensation hygrometer, the latter, only partially made of glass (Fig. 3). As mentioned, a thermometer and the condensation hygrometer were believed to have been invented by none other than Leopoldo's brother, the Grand Duke Ferdinando II, the very man celebrated in the dedicatory letter both verbally and visually, with a beautifully engraved portrait. The production of glass instruments was indispensable for both the activities of the Fonderia and for the courtly experimental practices, including the Cimento's research programme. Among the courtly research projects that made the Florentine thermometers famous in Europe was Ferdinando II's vast European meteorological network, the first known endeavour on such a scale: the Grand Duke sent his thermometers to several countries, subsequently retrieving the information they supplied under the direction of his court chaplain, the Jesuit Luigi Antinori.[18] The data were collected between 1654 and 1667 (and in a few cases until 1670) in Warsaw, Innsbruck, Osnabrück, Paris, Milan, Parma, Bologna, Vallombrosa, Cutigliano, Pisa, and Florence thanks to the homogenously calibrated Florentine thermometers whose daily observation was entrusted to a network of knowledgeable scholars, mainly Jesuits.[19]

Who was the master that made all this possible? Due to the agenda of Prince Leopoldo's publicist, the academicians are never mentioned individually in the Saggi. This skilled technician is, however, cited by his nickname, as well as being vividly described and greatly praised.[20] he was the court glassblower, mentioned with his amusing moniker of *il Gonfia.* In

[16] Galluzzi, 'L'Accademia del Cimento', p. 792.
[17] During the late sixteenth and seventeenth centuries, there were at least four important Grand ducal furnaces for the production of glass: one for experimenting with materials, such as the furnace for melted rock crystal beakers, was installed at the Casino di San Marco; a second, for the production of majolica and the famous Medici porcelain, was in Pisa; a third, imitating Venetian glass, was to be found in Pratolino; and, finally, a furnace was installed in the Boboli gardens to produce glass as fine as that of Venice. See: Beretta, 'Glassmaking Goes Public'.; Miniati, "Bocciuoli, palle d'oncia…"; Tagliavini, "Opere Di Cristallo Delicatissime e Meravigliose.".
[18] The Museo Galileo website wrongly describes Luigi Antinori as "monaco Vallombrosano" (a monk of Vallombrosa). https://brunelleschi.imss.fi.it/itinerari/multimediale/ReteMeteorologicaMedicea.html [accessed 4 July 2022].
[19] Dario Camuffo and Chiara Bertolin, 'The Earliest Temperature Observations in the World: The Medici Network (1654–1670)', *Climatic Change*, 111.2 (2012), pp. 335–63.
[20] Accademia del cimento and Magalotti, p. II-IV.: *"Egli è tutto di cristallo finissimo lavorato per opra di quegli artefici, i quali fervendosi delle proprie gote per mantice, tramandano il fiato per un'organo di criftallo alla*

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1684, Richard Waller (who translated the Saggi into English for the Royal Society) translated this moniker as "Lamp-blower".[21] More recently, Middleton has preferred the translation "Glassblower".[22] Unfortunately, in English this nickname fails to convey its amusing, colorful, familiar and typically Tuscan mocking character: the term refers to the fact that by blowing into the pipe to work the malleable incandescent glass paste, the blower was inflating the glass, and perhaps also to the fact that, during the blowing process, his cheeks were puffed out. The Gonfia, who is explicitly said to have served the Grand Duke, was also recognized as a kind of celebrity: he is said to have been a "most famous craftsman", and is quoted for his technical opinions concerning the construction of the thermometers.[23]

As previously noted, at the Cimento the construction of scientific instruments appears to have been a collective process, involving the princes, the academicians and the artisans. In the *Saggi* Magalotti shows us how the artisans put the ideas of the princes and the scholars to the test, at the practical limits of the art. In this perspective, the story of the Cimento seems to provide an answer to the question posed by van Helden and Hankins in their seminal essay *Instruments in the History of Science*, in which they asked historians to focus on "how instruments have worked to determine and, perhaps, even to define the methods and content of science."[24] The skill of the glassblower, said by the *Saggi* to grow with experience, "trying and

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fiamma d'una lucerna , e quella, o intera, o in varie linguette divisa, di mano in mano dove richiede il bisogno di lor lavoro spirando, vengono a formar' opere di cristallo delicatissime, e maravigliose. Noi un tal' artefice chiamiamo il Gonfia. A lui dunque s'apparterrà di formar la palla dello strumento d'una tal capacità, e grandezza, e d'attaccarvi un cannello di tal misura di vano, che riempiendolo fin'a un certo segno del suo collo con acquarzente […] Con un simile imbuto adunque si potrà finir d'empire il Termometro […] spingendovi dentro con la forza del fiato il liquore, o risucchiandone, se fosse troppo […] di potrà fare a occhio, essendochè l'esercizio, studio, e industria dell'arte insegna da per se stessa […] Rimarrebbe da dire di molt'altre operazioni, e squisitezze di lavorare alla lucerna; ma si come in questa materia è troppo difficile spiegarsi in carta, così è affatto impossibile impararlo in iscritto; che però bisogna avere il Gonfia mediocremente istrutto, essendochè l'arte con la lunga pratica da per se stessa s'affina." For the English translation: Magalotti, *Essays*, pp. 2-4.

[21] Magalotti, *Essays*, p. 2.

[22] See translation of the Saggi in: Middleton.

[23] Accademia del cimento and Magalotti, *Saggi*, p. VII-IX: *"…la maestria del lavorare non si può insegnar per regole, volendo esser pratica, e lunghissima esperienza, provando, e riprovando, scemando, e crescendo or' il corpo della palla, ora 'l vano al cannello, ora la quantità d'acquarzente, finchè si dia nel segno. Ed un Artefice famosissimo in questo mestiero, che serviva il Sereniss. Granduca soleva dire, che gli dava ben l'animo di fabbricare due, e tre, e quanti Termometri si fosser voluti da 50 gradi, i quali circondati dallo stesso ambiente camminassero sempre del pari, ma non già di que' da 100, e molto meno di que' da 300, essendochè in maggior palla, ed in maggior lunghezza di collo più facilmente si trouano delle disuguaglianze, ed ogni minimo errore che venga fatto nel lavorargli, è abile a far' apparire in essi grandissime disorbitanze, e ad alterare la proporzione d'ugualità, ch'arebbe a essere infra di loro."* For the English translation: Magalotti, *Essays of Natural Experiments*, p. 5.

[24] Albert Van Helden and Hankins, and Thomas L. Hankins, 'Instruments in the History of Science', *Osiris*, 9.Instruments (1994), pp. 1–6 (p. 1). This is something that happens also today in important research institutions, where technicians reshape the experimental programs of the theoreticians through the limits of the technology. I would like to thank all the researchers working at Caltech and JPL for the examples they have given to me on this subject, through informal discussions, in a transdisciplinary and diachronic sense.

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trying again" – *"provando e riprovando"*,[25] incidentally, also the very motto of the Cimento, taken from the famous Florentine medieval poet Dante Alighieri – is recognized as a necessary component in the production of the most exquisite instruments. The Grand Duke had faith in his artisans' judgement, as we will soon see in the case of his turner.

The Gonfia was a court employee, and thus his wonderful products could be acquired only through the favour of the Prince. It should also be noted that what made his instruments special was not just some secret recipe or technique, but his unique artistry, as was the case for the most talented painters or sculpturers who had made the Medici famous as patrons of beauty. It was possible for certain glass instruments to be made only when the Gonfia was around, especially the thermometers, which needed to be carefully calibrated to the exact same reference scale.[26] For instance, in the period between 1657 and 1658, Prince Leopoldo told Giovanni Alfonso Borelli, one of the most original thinkers of the Cimento and a professor at Pisa University, that the construction of certain glass instruments would not have been possible in Pisa because the Gonfia had left for Florence.[27]

These skills of the Gonfia were well known outside of Florence: at the end of June 1667, the professor of Mathematics of the University of Bologna, Geminiano Montanari, who had conducted observations with a Medici thermometer at 100 degrees on the temperature of the water in a well during the solstices and on the alleged influence of the canicular stars on the temperature of the hottest days of the year, wrote to Prince Leopoldo in Florence asking for a set of new thermometers as his old one had broken. He begged that these precise thermometers be made while "this Gonfia is still alive", as he recognized the importance of this experienced Florentine artisan's skills in the production of the precise instruments necessary to his scientific activity. Their uniformity was indeed necessary for measuring temperature: "l'uniforme temperature che vi è necess[ari]a".[28] The fame of the Gonfia's works had been made visible outside of Italy, as far as Poland and France, thanks to the abovementioned meteorological network created by Grand Duke Ferdinando II.

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[25] Here, Waller's translation loses completely the original reference to Dante: "and often Trials being the onely way to effect it". Magalotti, *Essays*, p. 5.
[26] Angelo Fabroni, *Lettere inedite di uomini illustri per servire d'appendice all'opera intitolata Vitæ Italorum doctrina excellentium*, 2 vols (In Firenze: Alla stamperia di Francesco Moücke, 1773), I, pp. 112–14.
[27] Fabroni, I, pp. 112–14.
[28] BNCF, Gal. 278: letter by Geminiano Montanari to Prince Leopoldo (June, 25 1667): "Canicole. Volevo p[er]ciò proseguire più accuratam[en]te quest'anno, ma mi trovo privo affatto di termometri, sendomisi rotto quello di 100 gradi col che feci quelle osservazioni, ond'io piglio anche in ciò l'ardire di supp[lica]re l'A. Vos. Ser.ssma onorarmi di farmene provvedere d'alcuni, sin che è vivo cotesto Gonfia non potendo io tenere tanto q[uel]l impaziente che habbiamo a Bologna, che mi faccia cosa buona, stante mas[simament]e l'uniforme temperature che vi è necess[ari]a […]":

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Maria Luisa Righini Bonelli, curator of the Florentine Museum – today known as the Museo Galileo and where the precious instruments of the Cimento are kept – noted that in the manuscript containing the second draft of the *Saggi*, one could read that:

> our Gonfia […] native of Florence who was a very valuable man in this craft, so much so that, being presently passed away, we have not been able to find another similar, and we despair of ever finding one such, we even but doubt that there ever existed one as good as he was.[29]

Shortly after, on May 23, 1668, in a letter from Warsaw written by the polymath Tito Livio Burattini, the death of the Gonfia was confirmed: Burattini requested several dozen 50-degree thermometers (fig. 1-2), such as those the late Gonfia used to make: indeed, Burattini had heard that the Grand Duke had found another artisan "who also makes them very well".[30] However, on September 19 of the same year, we find evidence that this master was not as perfect as his predecessor, as Viviani lamented, although he had already inherited the epithet of "Gonfia".[31]

By the following century, the application of the nickname of Gonfia was extended by historians of the Cimento to other craftsmen employed in the furnaces of Boboli and Pisa, thus sowing confusion on the identity of the only true Gonfia of the Accademia del Cimento. According to the seventeenth-century historians Giovanni Targioni Tozzetti and Angelo Fabroni, the Gonfia was Jacopo Giuseppe Mariani (?-post 1703), nicknamed il Tordino,[32] the nephew on his mother's side to Ippolito Francini, nicknamed il Tordo (1593-1653), Galileo's famous lens-maker.[33] Like his uncle, Tordino (i.e., "small Tordo" or "small thrush") was well acquainted with dioptrics, as he was able to repair an objective lens by Giuseppe Campani.[34] In 1675, Jacopo Mariani was said to be still "a youth" that had "no experience of travel, the

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[29] Maria Luisa Righini Bonelli, *Gli strumenti superstiti dell'Accademia del Cimento* (Pisa: Domus Galilaeana 1958), p. 10.

[30] *"… La prego di mandarmi sei o quattro dozzine di quelli thermometri, ò siano strumentini, che faceva il Gonfia del Ser.mo Gran Duca, divisi in cinquanta gradi, sentendo, che doppo la morte di quello vi sia uno, che li fa assai bene."* BNCF, Gal. 158, Letter from Tito Livio Burattini to Cardinal Leopoldo , May 23, 1668, c. 179r.

[31] *"…mi trovo già in casa due assortim[en]ti di strumentini fatti portare dal Gonfia e lasciare per potergli esaminar con comodità, ma p[er]ché ho osservato che tra di loro non son d'accordo, ho ragion[evol]e sospetto che niun di loro sia giusto … sarei di parere di aspettar qualche giorno … si che tra molti che il med[esim]o Gonfia deve farne pel Sig. Card[ina]le, si possa fare scelta dei più esatti…"* BNCF, Gal. 158, *Letter from* Viviani Vincenzo to Chimentelli Valerio, September 19, 1668.

[32] Targioni Tozzetti, I, p. 381.

[33] Albert Van Helden, *Catalogue of Early Telescopes* (Firenze: Giunti, 1999), p. 34. It would be interesting to map prosopographically the artisans working around the *Galleria* over the longue durée: for instance, in the case of il Tordino and his uncle il Tordo, what was their family relation to the engineers Tommaso Francini 1571-1651 and his younger brother Alessandro Francini di Tommaso, both employed in the service of the King of France? Chiara Stefani, 'Francini, Tommaso', in *Dizionario Biografico degli Italiani* <https://www.treccani.it/enciclopedia/tommaso-francini_%28Dizionario-Biografico%29/> [accessed 3 March 2023]. Carlo Vittorio Varetti, 'L'artefice di Galileo: Ippolito Francini detto Tordo: contributo agli studi galileiani e alla storia dell'ottica', *Rendiconti della Reale Accademia nazionale dei Lincei*, 15.3–4 (1939), pp. 204–97.

[34] Silvio A Bedini, *Giuseppe Campani, 'Inventor Romae,' an Uncommon Genius*, p. 574.

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present occasion being the first time he leaves home".[35] Tordino may have later won the same nickname of Gonfia from his skilful predecessor, but he was certainly not the Gonfia of the Cimento.

One of the drafts of the *Saggi* (listed as the "fifth codex"), written in the hand of Count Magalotti, sheds a clarifying light on the identity of the Gonfia of the Cimento. This draft contains a passage that was later expurgated in the printing process, perhaps because it suggested the lost capability of the Florentine court to produce the most exquisite instruments. This passage reads: "our Gonfia, named Antonio Alamanni, born in Florence".[36] The expurgated passage was then replaced in the printed book with the following: "a famous Man in this Art, who served the most Serene Grand Duke".[37]

Very little is known of this most exquisite glassblower.[38] It would be very useful to learn more about this Antonio Alamanni of Florence and his education. This was perhaps influenced–directly or indirectly–by highly skilled Venetian glassworkers such as Niccolò Landi or Alvise Della Luna,[39] who both arrived from Murano to work in the *vetreria* of Boboli, a glass workshop founded in 1617 in the famous princely gardens, or by other artisans involved with alchemy and experiments at the Casino di San Marco. These were the master distiller Niccolò Sisti (1571–1620), who served the Medici *Gallerie* for 50 years, and the Florentine alchemist Antonio Ludovico Neri (1575/6-1614). Niccolò Sisti, who from 1592 had an atelier in Pisa where maiolica was produced,[40] was the son of the alchemist Sisto Bonsisti da Norcia.

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[35] *"[...] Si presenterà a V.S. con questa il Sig.r Jacopo Mariani che è un giovane mandato dal Ser.mo Gran Duca Nostro Sig.re alla città d'Augusta per apprendervi le finezze dell'arte del torno dove è già introdotto e perchè non ha egli alcuna esperienza nel viaggiare essendo questa la prima volta che esce di casa vuole S.A. che venga costì raccomandato a V.S. acciò ellea si contenti di provederlo d'un buon passaggio fino alla città sudetta accompagnandolo con qualche altro passeggiero che vada verso quella parte o almeno fino ad Inspruck con scriver poi colà a qualche amico di V.S. che gli trovi recapito et indirizzo per Augusta acciò non habbia a confondersi in un paese dove non conosce alcuno e non intende la lingua. [...]"* Archivio di Stato di Firenze, Mediceo del Principato f. 1583, c. 557: Letter from the court of Florence to Andrea Galleni, June 28,1675. Courtesy of Database MIA (Doc ID 25270) of The Medici Archive Project.

[36] "*il nostro Gonfia, chiamato Antonio Alamanni nativo di Firenze (che pur' era un valentissimo uomo in quest'arte, e tale che essendo egli oggi morto, non c'è per anche riuscito trovargli il compagno ne lo speriamo, ma ne meno sappiamo ch'ei l'abbia avuto in verun tempo)"*: BNCF, Gal. 266, c. 11v. As previously seen, this passage was quoted by M. L. Bonelli, *Gli strumenti superstiti dell'Accademia del Cimento*, Pisa 1958, p. 10. At cc. 6r, 23r-25v of this draft (Gal. 266), we find that, at this stage, there was a plan to include a declaration of some machines, probably created by Father Candido del Buono (1618-1676), perhaps together with his brothers Anton Maria and the abovementioned Paolo. The machine was the *arcicanna*, used since 1660 to erect long telescopes to observe Saturn. Fig. 4.

[37] Accademia del Cimento, Lorenzo Magalotti, *Saggi*, p. VII: "*un Artefice famosissimo in questo mestiero, che serviva il Sereniss. Granduca*".

[38] Antonio Alamanni signed and undated letter to Vincenzo Viviani –perhaps written around 1666, considering that Alamanni made a reference to his bad health: BNCF, Gal. 269, c. 90r.

[39] Miniati, p. 36. Tagliavini, pp. 323–24.

[40] In 1610 he had promised Galileo that he would produce optical glass for him. Miniati, p. 42, n. 4: C. V. Varetti, *L'artefice di Galileo…* 1939; Galileo Galilei, *Le opere di Galileo Galilei: Edizione nazionale sotto gli auspici di Sua Maestà il Re d'Italia*, ed. by Antonio Favaro, 21 vols (Firenze: Barbera, 1890), X, p. 441. Gerardo de Simone,

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Antonio Ludovico Neri, Don Antonio de' Medici's alchemist, was the author of the first printed book on the art of glassmaking: *L'Arte Vetraria* (1612). This book was dedicated to his patron Don Antonio de Medici, the son of Grand Duke Francesco, who had been excluded from power by his uncle Ferdinando I.[41]

Besides Antonio Alamanni, several other skilled artisans served the Medici and the Cimento, along whom a place of honour must be reserved for the Grand Duke's turner.

The Turner and Clockmaker

Lathes were machine tools that, by the sixteenth and seventeenth centuries, had reached a high degree of sophistication.[42] The Medici, from the time of Grand Dukes Cosimo I and Francesco, had attracted the best turners from abroad. Lathes and their skilful operators were instrumental to creating several parts of the scientific apparatus of the Cimento. In this regard, an interesting testimony comes from outside the traditional documents of the Cimento: among the goods of Prince Leopoldo, inventoried at the time of his death in 1675, we find a turned silver ring "used as a philosophical instrument".[43]

Alongside turning, these craftsmen were capable filers, casters, carvers and mechanicians. Targioni Tozzetti mentions the turners Teodore Sengher, German,[44] perhaps the father of Filippo Senger, (also spelled Sangers and Sanglier), ivory turner to Cosimo III,[45] and

'Niccolò Sisti e la maiolica a Pisa tra fine Cinque e primo Seicento', in *Pisa città della ceramica. Mille anni di economia e d'Arte, Dalle Importazioni Mediterranee Alle Creazioni Contemporanee*, ed. by Monica Baldassarri, (Pisa: Pacini, 2018), pp. 155-160.

[41] Beretta, 'Glassmaking Goes Public'.

[42] On German ivory turners and Florentine lathes for the *pietre dure* see: Cristina Piacenti Aschengreen, 'Una preda di guerra', in *Diafane passioni*, ed. by Eike D. Schmidt and Maria Sframeli (Livorno: Sillabe, 2013), pp. 31–33; Francesca Toso, 'L'"ingegnoso artifizio": tecniche di lavorazione', in *La fabbrica delle meraviglie*, ed. by Annamaria Giusti, (Firenze: Edifir edizioni, Opificio delle pietre dure, 2015), pp. 257–88; Francesca Toso, 'Le tecniche e le attrezzature in uso presso la Manifattura granducale', in 'Pietre colorate molto vaghe e belle'*: arte senza tempo dal Museo dell'Opificio delle pietre dure* ed. by Sandra Rossi, Peter Assmann, and Anna Patera (Mantova: Tre lune edizioni 2018), pp. 244–59.

[43] *"Un cerchio d'argento tornito liscio che doveva servire per strumenta da filosofia, pesa once nove denari 16"*: item number 239: *Inventario de' mobili e masserizie dell'eredità del Serenissimo e Reverendissimo Signore Principe Cardinale Leopoldo di Toscana, cominciato questo dì suddetto. Stateci consegnate l'appiè descritte robe da Paolo Cennini Guardaroba di detto signor Cardinale e prima*, Firenze, Archivio di Stato, Guardaroba Mediceo 826, years 1675-1676. https://www.memofonte.it/ricerche/collezionismo-mediceo/# accessed July 10, 2022. On the Milanese turners employed at court in the previous century, see: Toso, 'L'"ingegnoso artifizio"', and *Diafane passioni: avori barocchi dalle corti europee*, ed. by Schmidt, Eike and Sframeli, Maria (Livorno: Sillabe, 2013).

[44] Targioni Tozzetti, I, p. 381.

[45] Wolfram Prinz, 'Deutsche Kunstdrechsler Am Florentiner Hof. Nachrichten Über Johann Philipp Und Christoph Treffler, Drechsler Un Uhrmacher Für Ferdinando II. Und Cosimo III. de' Medici, Sowie Über Jacopo Mariani', *Mitteilungen Des Kunsthistorischen Institutes in Florenz*, 13.1/2 (1967), pp. 173–84. Several letters by Cosimo III mention this craftsman as his personal ivory turner, who worked with him: Archivio di Stato di Firenze, Mediceo del Principato, 4491, cc. 687r-716v.

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Giovan Battista Magnelli, a constructor of optical instruments and sundials. Targioni Tozzetti claimed the latter was employed "to craft instruments at the academicians' will".[46] However, as for Jacopo Mariani, it seems that the great eighteenth-century scholar had arbitrarily anticipated Magnelli's service at court: the only two extant instruments by this artisan date to the last decade of the seventeenth century.[47]

The unpublished papers of the Accademia del Cimento instead name another turner: one *monsignor* or *monsù* Filippo of Augsburg, otherwise known as Johann Philip Treffler. Even before the start of the Cimento's activities in 1657, we find this man involved in experiments. In October 1656, he assisted Vincenzo Viviani in an experiment ordered by the Grand Duke on the speed of sound.[48] Filippo's name also appears in the papers of the Cimento: for instance, on November 7, 1660, Vincenzo Viviani proposed another experiment to measure the force expressed by water when it turns into ice, whereby water was to be inserted into a metal conical tube. We read that "…Mons.re Filippo, His Most Serene Highness' turner, was ordered to make the rings and the conical shafts [or barrels?], and frames" for this experiment.[49]

Johann Philipp Treffler (1625-1698) was the Grand Duke's turner; this position included performing some tasks as a clockmaker. He had been born in Augsburg, the city that boasted a guild whose members included some of the most refined turners of the period. Treffler's father, brother and grandfather were also masters in the same profession. However, Johann Philip, or Giovanni Filippo, as he started to call himself after entering the service of the Grand Duke (thus offending the national sensibility of some later German scholars[50]), although educated as a skilled turner (and perhaps as a clockmaker, too), never become a guild master in Augsburg, something that was to haunt him for the last thirty years of his life, when he had returned to his hometown to marry and settle down.[51]

His lack of the guild title of master in turning was probably due to the fact that he had left Augsburg at a very young age, following his father, the turner Tobias Treffler, who had

[46] "per lavorare gli strumenti a piacere degli Accademici": Targioni Tozzetti, I, p. 381.
[47] The Museo Galileo of Florence houses a round sundial dated to 1692 (inventory 3189) and a terrestrial telescope signed and dated 1695 (Inv. 2550).
[48] BNCF, Gal. 268, c. 158v. letter by Viviani written after October 10, 1656.
[49] "…mons[igno]re Filippo Torniaio di S.A.S. ebbe ordine di far' gli anelli, ed i fusti conici …": BNCF, Gal. 268, c. 7v.
[50] Bedini, 'Johann Philipp Treffler: Clockmaker of Augsburg.', *Bulletin of the National Association of Watch and Clock Collectors*, 7.6 (1956), p. 29.

[51] *Ibid.*; Silvio A Bedini, 'Agent for the Archduke: Another Chapter in the Story of Johann Philipp Treffler, Clockmaker of Augsburg.', in *Patrons, Artisans and Instruments of Science, 1600 - 1750*, ed. by Bedini, Silvio A. (Aldershot: Ashgate/Variorum, 1999), pp. 137–58; Antonio Lenner, 'Johann Philipp Treffler : orologiaio in Augsburg e Firenze', *La Voce di Hora*, 41.Dicembre 2016 (2016), pp. 5–20.

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been given a position by Duke Augustus the Young of Brunswick-Wolfenbüttel (1579-1666) at the end of the Thirty Years' War (1618-1648).[52] Giovanni Filippo Treffler (henceforth Filippo, as he is mentioned in the Florentine documents and so as to distinguish him from his brother, Christoph Treffler) worked in Florence during the years of the Accademia del Cimento. Even after his departure in 1665, he maintained a strong relationship with the Medici court until his death in 1698.[53] Some of the Academy's papers depicting the experimental apparatus contain two sketches of an amusing –almost caricatural– image of a hatted mechanician filing a rod and turning a long vial upside down for the Torricellian experiment.[54] Was this young man our Filippo? Probably, considering that he is the most cited technician in the papers of the Cimento (Fig. 5 & 6).[55]

As for the Gonfia, Ferdinando II believed that his turner, thanks to his skills, could also improve his instruments, in this case a hygrometer: on November 21, 1665, Vincenzo Viviani, court mathematician and backbone of the Cimento, playing as usual the role of mediator, wrote an interesting letter to the Grand Duke's turner, Filippo, who had just resettled in Augsburg. Viviani writes: "because your lordship knows that the Most Serene Grand Duke observes and philosophizes with the unmatched precision of this noble curiosity, he [his Highness] desires in this instrument some greater perfection; therefore he ordered to me to describe it to your lordship, so that in crafting one yourself, you may think of some improvements."[56] The letter goes on to list the problems that the Grand Duke had observed in the hygrometer, with some suggestions as to how improve it for Filippo Treffler to evaluate. Filippo replied to the letter and later made a new, improved instrument.[57] The recently invented hygrometer which needed improving was most probably that recently invented in 1664 by the physician Francesco Folli, friend of Francesco Redi and one of the pioneers of blood transfusion.[58]

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[52] Günther Oestmann, 'Clocks from Nuremberg and Augsburg in the 16th and 17th Centuries', in *Time Made in Germany: 700 Years of German Horology* (presented at the Ward Francillon time symposium, Nuremberg: Deutsche Gesellschaft für Chronometrie: Jahresschrif, 2019), LVIII, 73–91 (p. 79).
[53] Silvio A Bedini, 'Johann Philipp Treffler'; Silvio A Bedini, 'Agent for the Archduke'; Lenner.
[54] BNCF, Gal. 261, cc. 20v, 23r.
[55] Tacitroots's databases, currently under construction, will be able to clarify if my claim, based on a partial investigation of the papers, is sound. Moreover, careful philological and palaeographical analysis should be done on an experimental diary written by a servant of Grand Duke Ferdinand II: the amanuensis, on one occasion, signed himself "Filippo", and made clear that he was conducting an experiment. BNCF, Gal. 260, c. 47 r. *"Si faticò p[er] equilibrare una palla di Rame con vasetto in cima a vite da me filippo p[er] vedere il peso d[e]l aria in diversi gradi di calore…"* . Published by Targioni Tozzetti.
[56] BNCF, Gal. 252, c. 105r, Letter from Viviani Vincenzo to Trefler Johann Philipp, November 21, 1665.
[57] BNCF, Gal. 254, c. 287r: Trefler Johann Philipp a Viviani Vincenzo, Dicember 4, 1665.
[58] Gabriella Belloni Speciale, 'Folli, Francesco', in "Dizionario Biografico degli Italiani' in *Dizionario Biografico degli Italiani* < https://www.treccani.it/enciclopedia/francesco-folli_%28Dizionario-Biografico%29/> [accessed 3 March 2023].

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This piece of information helps us to date the presentation of Folli's instrument to Ferdinando II: from the correspondence with Viviani, it appears that Filippo knew about the Grand Duke's obsession with humidity measurements, probably conducted with the hygrometer allegedly invented by Ferdinando II himself and illustrated in the *Saggi* (See fig. 3 on the right: VI), but he clearly did not know about Folli's invention (Fig. 7 & 8). Folli therefore must have presented the Grand Duke with this instrument during the year 1665, after Filippo's departure, and not earlier. Ferdinando II had ordered a certain number of examples of such an instrument, as we learn from Lorenzo Magalotti: at the beginning of November 1665, the secretary of the Accademia del Cimento had sent a similar instrument that he had obtained from Leopoldo (taken from among the many which Ferdinand II had in his chambers), to his brother, Cesare Magalotti, in Rome in order for it to be given as a present to Pope Alexander VII. Thus, as Lorenzo Magalotti intended, the Pontiff could use the hygrometer to improve his health thanks to a better knowledge of the humidity of the air. Lorenzo wrote that if the instrument was damaged, there were in Rome exquisite artisans such as the Campani brothers, who could adjust it.[59] We will soon encounter them too. I believe that one of the examples held in the Museo Galileo, finely made from turned and engraved brass (Fig. 9), is Filippo's improved version of Folli's hygrometer.[60]

In December 1667, Filippo Treffler was again paid for working "a small instrument of humidity", whether this is a late payment for this hygrometer or for another is not clear. He had previously also acted as a broker when asked to find a master to craft a surveying instrument and a turret clock. The instrument maker had died, but he was able to find a clockmaker for the second project. This was Georg Lederle, who then made the turret clock for the Palazzo Vecchio in Florence. The clock was completed in 1667 and sent to Florence to be assembled in the Tower of Arnolfo.[61]

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[59] BNCF, Gal. 254, c. 287r: Trefler Johann Philipp a Viviani Vincenzo, Dicember 4, 1665. BNCF: Gal. 252, cc. 103-106v, letters by Vincenzo Viviani (November 21, 1665) to Gio. Filippo Treffler. BNCF, Gal. 282, cc. 128r-130v, letter from Lorenzo Magalotti to his brother Cesare in Rome, (November 1, 1665). Silvio A Bedini, *Giuseppe Campani, 'Inventor Romae,' an Uncommon Genius*, pp. 298, 376.

[60] The Museo Galileo owns these instruments: Folli's hygrometer: Inv. 2435 (fig. 8). Another similar hygrometer (Inv. 2434), less refined, is probably the original presented by Folli to the Grand Duke. Bedini believed that another hygrometer from the Museo Galileo (Inv. 3, 2437), whose design is attributed to Vincenzo Viviani, is the one referred to in these letters: Silvio A Bedini, 'Johann Philipp Treffler', p. 15. However, the strong structural similarity of the other two (fig. 9 and 10), suggests that the second was an improvement on the first as regards material, rather than in terms of design, as emerges from the letters mentioned here. Moreover, the significant use of turned decorative parts indicates that the instrument I propose (fig. 9) is closer to Filippo's craftsmanship as a turner. Viviani's less elaborate hygrometer could also have been crafted by Filippo, but I believe that, if this was indeed the case, then it happened at a later time.

[61] Silvio A. Bedini, *The Pulse of Time : Galileo Galilei, the Determination of Longitude and the Pendulum Clock* (Firenze: Leo S. Olschki, 1991), pp. 67–68. BNCF, Gal. 255, c. 3r, letter from Filippo Treffler to Vincenzo Viviani about a surveying instrument (January 15, 1666). See also Silvio A Bedini, 'Johann Philipp Treffler', p. 15.

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This kind of brokerage shows that Filippo Treffler was considered an expert in scientific instruments and clocks: in fact, Filippo Treffler made clocks himself. Both public and private collections still hold some of his timepieces.[62] The earliest information we have on his encounter with this craft dates to 1657, when he made or adjusted an ebony clock in the chamber of the Grand Duke.[63] The first document showing a commission for a clock dates, however, to the period when he had resettled in his native Augsburg: in September 1667, Filippo was paid 25 *scudi*[64] by the Medici for the construction of a night clock, inspired by an invention of the Campani brothers.[65]

The original Campani clocks, with their cases that inspired those by Filippo, cost around three times more. This was perhaps due to two reasons: Giuseppe Campani was able to make the clock silent thanks to the crank-lever escapement, whereas Treffler's clocks were regulated by a simple pendulum that connected to a verge, which made the device tick. Moreover, Giuseppe Campani hired great artists to paint his dials, whereas Filippo used far more modest painters to decorate his nocturnal clocks.[66]

Giovanni Filippo Treffler has attracted the attention especially of historians of horology due to the fact that, during the 1650s, he was involved in Florence with the construction of some of the first pendulum-regulated clocks.[67] At the time of the Cimento, there had been a dispute between the Medici and Christiaan Huygens over the precedence of the invention of the pendulum-regulated clock. In 1657, Christiaan Huygens had obtained a privilege for the invention in Holland. The Medici believed that Huygens had stolen the idea from Galileo Galilei, who had presented the project for a pendulum-swing counter as a method to find the longitude while navigating to the General States of Holland twenty years earlier. Huygens's father was on the panel that assessed this project, but Christiaan claimed he did not know about

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[62] The nocturnal pendulum-regulated clock in the Museo Nazionale della Scienza e della Tecnologia Leonardo da Vinci of Milan, is of the same typology as the night clock paid for by the Medici in September 1667: <http://www.museoscienza.it/dipartimenti/catalogo_collezioni/scheda_oggetto.asp?idk_in=ST040-00028&arg=treffler> [accessed 4 April 2023]. This museum owns another caseless movement by Filippo. A nocturnal projector clock by Filippo Treffler is housed in the Orangerie of Kassel, which was also inspired by a 1667-1668 invention by Giuseppe Campani <https://datenbank.museum-kassel.de/226663/0/0/0/0/2/0/objekt.html> [accessed 10 July 2022]. Bedini mentioned some other clocks made or restored by Filippo Treffler: Bedini, "Johann Philipp Treffler", p. 5.

[63] Bedini, "Johann Philipp Treffler", p. 5.

[64] The *scudo* (Italian for "shield") was a 3.34-gram golden coin (plural: *scudi*). It was a common currency in the early modern period. Silvana Balbi de Caro and Luigi Londei, *Moneta Pontificia: Da Innocenzo XI a Gregorio XVI* (Roma: Edizioni Quasar, 1984), ad vocem.

[65] For a detailed history of the Campani brothers, see: Silvio A Bedini, *Giuseppe Campani, 'Inventor Romae,' an Uncommon Genius*.

[66] Silvio A Bedini, *Giuseppe Campani, 'Inventor Romae,' an Uncommon Genius*, pp. 199, 239.

[67] *Ibid.* Bedini, "Johann Philipp Treffler"; Maria Luisa Righini Bonelli, 'Di un orologio di "Gio: Filipp Trefler" di Augusta', *Physis*, 2 (1960), pp. 242–60; Prinz; Bedini, "Agent for the Archduke"; Lenner.

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it. Moreover, the Medici took this as proof of the Florentine precedence in the invention of the pendulum-regulated clock, the machine that Vincenzio Galilei, son of Galileo, had left unfinished when he abruptly died in 1649.[68] In order to collect data to oppose Huygens's claim, in 1659, Prince Leopoldo requested a history of the Florentine pendulum-regulated clock to be written.

In his history of the pendulum-regulated clock, delivered to Prince Leopoldo in August 1659, the court mathematician Vincenzo Viviani attributed to the Grand Duke's turner, Giovanni Filippo Treffler, the construction in around 1655 (after Ferdinando II's request) of a mechanical counter for pendulum vibrations.[69] Furthermore, Viviani also wrote that in the same period the engineer Francesco Generini (1593-1663) had presented the Grand Duke with an iron model of a pendulum-regulated clockwork. Viviani wrote that Generini's model was inspired by the mechanism that Galileo had imagined fourteen years earlier (1641),[70] and which his son Vincenzio Galilei had partially built. Although a very interesting character, we will have to leave the engineer, sculptor and clockmaker Francesco Generini (1593-1663) aside here,[71] because there is no evidence that he had any connection to the activities of the Cimento.[72]

In Viviani's account, Filippo's pendulum-regulated clock was inspired by Ferdinando II himself. It was the third attempt to apply a pendulum as a regulator to a clock after Vincenzio Galilei's unfinished machine and Francesco Generini's model.[73] Filippo had merged the design of these two earlier machines and Viviani notes that Filippo applied this result to several Medici clocks. A record from the Guardaroba tells us that on April 16, 1657 "Monsu Filippo Treflai [sic]" had placed an ebony clock in the chamber of the Grand Duke,[74] although it is not clear if he had worked on the case or on the movement, perhaps applying a pendulum to it. In 1658, although it is not clear exactly when, Filippo had applied a pendulum as a regulator to the clock counting hours and minutes in the Grand Duke's chamber as well as to a large turret clock "on

[68] I am preparing an article to be submitted to this very journal where I will deal with this issue in detail.
[69] See Viviani's letter to Prince Leopoldo dated August 20, 1659 in *Le opere di Galileo Galilei*, ed. by Eugenio Albèri (Firenze: Società Editrice Fiorentina, 1855), XIV, pp. 341–56.
[70] The original document contains some amendments to the way Viviani dated Generini's presentation of his clock to the Grand Duke in relation to 1641, the year Galileo, according to Viviani, had conceived the design of his pendulum-regulated clock. Viviani, writing in the summer of 1659, had first written "18 anni fa", meaning "18 years ago". He then changed this to "14 anni avanti", meaning "14 years earlier", referring here to the year Generini presented the machine: in other words, he was referring to the year 1655. BNCF, Gal. 85, c. 48v-49r.
[71] He was also the sculptor of the so-called *Fontana della Nicchia*, one of the most iconic fountains of Florence.
[72] The new databases being developed by Tacitroots will perhaps shed some new light on the issue in the future.
[73] Vincenzo Viviani, *"Lettera di Vincenzio Viviani al Principe Leopoldo de' Medici intorno all'applicazione del pendolo all'orologio"* in Albèri, XIV, pp. 341–56.
[74] Bedini, "Johann Philipp Treffler", p. 5.

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the piazza where we live", as Leopoldo wrote to Ismaël Boulliau. This clock is wrongly believed to be the one in the Palazzo della Signoria.[75]

Although Filippo was also involved with the replacement of Palazzo Vecchio's clock, Viviani and Prince Leopoldo were in fact referring to another clock.[76] The misunderstanding stems from Ismaël Boulliau's inaccurate interpretation of Prince Leopoldo's information. The French *sçavant*, who mediated between Prince Leopold and Christiaan Huygens, when writing to the Dutch mathematician had mistaken the palace where the Medici lived, i.e. instead of Palazzo Pitti, he wrote Palazzo Vecchio, Florence's old seat of power. The fact that Filippo himself, as we will see, wrote of the work he did to pierce the thick wall of the tower of the Palazzo Vecchio in order to place a new clock there confirms the wrong interpretation. Even Silvio Bedini, who had initially correctly placed the clock in Piazza Pitti, perhaps confused by Boulliau's assumption and by Filippo Treffler's later involvement in the reconstruction of the clock of Palazzo Vecchio, changed his mind as a result.[77]

An engraving from the early eighteenth century testifies to the existence of a clock in a tower on the piazza of the Pitti Palace (Fig. 11). This pendulum-regulated clock was probably dismounted under the Lorena when the southern wing or *rondò* and the Palazzina della Meridiana were erected in the second half of the following century, requiring the destruction of the previous buildings standing there with the turret clock.[78] The sketch of the mechanism of this clock, with its pendulum-regulated escapement, was sent by Leopoldo to Huygens via Boulliau, and is now in Leiden (Fig. 10). The clock shows mechanical characteristics typical only of the clocks by the Campanis and Filippo Treffler.[79] The escapement is very different from that of Galileo, being a horizontal verge engaging directly the escapement wheel. The verge transmits the movement to the pendulum through a squared horseshoe-shaped iron bar from which hangs the pendulum.

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[75] For instance, see: Bedini, *The Pulse of Time*, p. 66 and following ones.

[76] Viviani and Prince Leopoldo wrote more than once that the clock chimed "on the Piazza where they [the princes] lived", i.e. the square of Palazzo Pitti: *"et in particolare ad uno assai grande che mostra l'Ore, e suona nella piazza del nostro Palazzo doue abitiamo, e glie lo inviero."*; letter from Prince Leopoldo to Boullieu (August 21, 1659); letter from Ismaël Boulliau to Christian Huygens (February 27, 1660): Christiaan Huygens, *Oeuvres Complètes de Christiaan Huygens* (La Haye: M. Nijhoff, 1888) III, pp. 14-15, 29, 468. See Fig. 11 in this article for the reproduction of the drawing illustrating the Medici turret clock. Silvio A Bedini, 'Johann Philipp Treffler', p. 9.), Silvio A. Bedini, *The Pulse of Time: Galileo Galilei, the Determination of Longitude, and the Pendulum Clock* (Firenze: LSOlschki, 1991) Biblioteca di Nuncius. Studi e Testi, 3, pp. 55–76; Silvio A. Bedini, 'Agent for the Archduke', pp. 140–41.

[77] *"que Monsieur le Grand Duc a fait raccommoder auec la pendule dans le vieil palais de Medicis a Florence"* Letter from Ismaël Boulliau to Christian Huygens (February 27, 1660): Huygens, *Oeuvres Complètes de Christiaan Huygens*, III:29.Righini Bonelli, 'Di un orologio di "Gio…; Silvio A. Bedini, *The Pulse of Time*. Bedini, in his early work on Treffler got it probably right, but then he also adopted the wrong interpretation.

[78] Giuseppe De Logu, *L'architettura italiana del Seicento e del Settecento* (Bari: Edizioni Dedalo, 1993), p. 98.

[79] Bedini, "Johann Philipp Treffler", 10.

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Among Viviani's papers, there is another interesting sketch of such a typology of escapement applied to a horizontal wheel (Fig. 12).[80] This similarity has so far gone unnoticed, although it should be considered as a confirmation of the second type of Florentine escapement after that of Vincenzio Galilei. Prince Leopoldo wrote to Boulliau that the turret clock kept time very well with the Coster-Huygens clock sent by the King of Poland and with the abovementioned chamber clock adapted by Filippo Treffler, following an idea of Grand Duke Ferdinando II. Further research into these lost clocks is needed.

In December 1667, Filippo was paid the same sum of 25 *scudi* for another clock for the chamber of Ferdinando II.[81] This clock is traditionally identified with the one in the Museo Galileo, which has a pendulum-regulated escapement (Fig. 13 & 14).[82] Its case was unfortunately destroyed during the tragic flood of Florence in 1966. The website of the Museo Galileo dates it to 1659, identifying it with one of the first pendulum clocks built by Filippo Treffler, but this is controversial: the clockwork has been modified on more than one occasion.

The chronology of this machine is hard to determine because the dial shows hours, minutes, and seconds, as in Viviani's account, but the second dial was apparently added later. Moreover, the pendulum appears to have been modified, and the cycloidal cheeks were also added on a second occasion, as the engravings visible under the cycloidal cheeks demonstrate.[83] Furthermore, this clock is signed on its back plate by a "Gio. Filippo Treffler Augost.o". "Augost.o" stands for "*Augostano*", meaning "from Augsburg". This last element may seem to settle things once and for all, but, on the contrary, it complicates the chronology. Moreover, there were more than a clock signed in a similar way by Filippo, one of them in Florence: it was mentioned in an eighteenth-century Medici inventory. Together with the toponymic, the signature added Filippo's profession in Italian: *tornaio* (turner).[84]

Two considerations may support the hypothesis that the clock of the Museo Galileo was produced after Filippo's departure from the Florentine Court in 1665. First, artisans working within a princely court did not usually sign their pieces. The need to sign artifacts had

[80] BNCF. Gal. 269, c. 168r.
[81] Bedini, *The Pulse of Time*, p. 68.
[82] Righini Bonelli, 'Di un orologio di "Gio….
[83] I thank Andrea Palmieri, who has dismounted the mechanism, for providing me with this piece of information, which confirms what Maria Luisa Righini Bonelli had previously argued: Righini Bonelli, 'Di un orologio di "Gio…, p. 244. See also what Bonelli has to say about the problem of the backplate inscription. <https://catalogue.museogalileo.it/object/SpringdrivenClockMovementDial.html?_ga=2.25322171.786192468.1657390922-123062591.1655866417> [accessed 10 July 2022]. For some useful images of the mechanisms of the Museo Galileo's clock, see the following pdf on Keith Piggot's blog: <http://www.antique-horology.org/piggott/rh/memoranda/memotrefler.pdf> [accessed 10 July 2022]. Piggot used the images provided by Professor Andrea Palmieri.
[84] Bedini, "Johann Philipp Treffler", p. 5.

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originated especially in urban contexts where guild masters had to certify their products and pay taxes. Such a requirement did not affect court employees. At court, the artisan would produce in the name of the prince and did not sell as with a private workshop. Viviani stated that the invention was by Ferdinand II himself, and that Filippo Treffler was simply the one who turned it into a working machine. It is thus very unlikely that such a clock would have borne the artisan's signature.

Therefore, at court a signature was not just unnecessary, it was even inappropriate. From the artisan's point of view, his recognition as a court employee was already a sign of a privileged position, at least from the perspective of prestige. As we shall see, this prestige came at a cost. If they were signed, court-related products would mention the patron, rather than the artist: for instance, a very interesting pendulum-regulated clock from the 1660s-1670s, held in a private collection, is inscribed with the sentence "fatto in Gallerie de S.A.S. Fiorenza", which means: "Made in the Gallerie of His Most Serene Highness, Florence" (fig. 15 & 16). Is this perhaps one of the first clocks adjusted by Filippo with a penulum? Ferdinando II was very proud of his role in the invention of a pendulum-regulated clock: according to the clockmaker and future lens-maker Giuseppe Campani (1635-1715), who had visited Florence between 1658 and 1659, the Grand Duke himself had told him on that occasion that he had himself invented a kind of clock with a pendulum-regulated escapement.[85]

The second consideration that supports the idea that this clock was produced after Filippo's departure in 1665 is that the German artisan had entered the service of the Medici as a young turner. The Guild of clockmakers of Augsburg accused him of not having learned the craft in one of their local workshops.[86] He had therefore learned to make clocks after he left Augsburg in around 1648, most probably in Florence, where he spent almost two decades until 1665, as we shall see. This coincides with the fact that all his extant signed clocks were made after 1665: indeed, they are all inspired by timepieces produced in the period 1655-1667 by other makers, chiefly Italians. However, we cannot exclude the possibility that he had had some training in the craft before going to Florence.[87] On the contrary, supporting the identification of this clock with the one produced around 1659 can be the fact that the shape of the movement is rectangular, and that later Filippo's movements were instead circular, clearly inspired by Campani's night clocks appeared at court around that time.

[85] Giuseppe Campani, *Discorso di Giuseppe Campani intorno a' suoi muti oriuoli, alle nuove sfere Archimedee, e ad un' altra ... inventione ...* (Roma: Per F. Moneta, 1660), p. 17.
[86] Bedini, "Johann Philipp Treffler", p. 18.
[87] *Ivi*, p. 40.

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Filippo's Italian-inspired night clocks were a novelty in Germany. Considering that he did not sign any piece while at court, and that he was excluded from any guild in Augsburg, Filippo's need to put his name on these clocks was clearly a form of self-promotion directly inspired by the typology of signature by the Campani brothers. Imitating them, he was also differentiating his products from the Roman models.

At this juncture, he was probably self-fashioning himself as a refined artist and "mathematician". He had spent more than two decades in the service of one of the most sophisticated and learned courts in Europe. With such a curriculum, he probably thought that it was time to exploit that exceptional experience. Indeed, he was knowledgeable enough to be made a broker by the Medici: he was recognized as capable, not just in finding the best products in Augsburg for his Tuscan patrons, but also at turning what he had learned in Florence into courtly products targeting courtly patrons, alongside continuing to satisfy the requests from his old Florentine masters.

The fact that Filippo had converted to Catholicism, probably in Florence, may perhaps have played some role in his ostracism by the local guilds, which, however, had always been very strict regarding new admissions.[88] To escape persecutions by the clockmakers guild, he managed to secure some imperial privileges protecting his activity which, he claimed, was not in competition with the local production.[89] In this liquid conflictual situation it is possible that he signed some of his clocks with, as we have mentioned, the epithet "turner", which was certainly an unhappy and short lived solution, considering that the guild of turners was as conservative as the clockmakers guild.

During the long confrontation with the Augsburg guild of clockmakers, Filippo Treffler argued that his clocks were inventions in the "free art of mathematics", and therefore were not "items of trade" subject to the traditional production regulations of the city.[90] Filippo planned to make his clocks an exclusive product for the high nobility, such as the famous timepieces created by Giuseppe and Pier Tommaso Campani. In this perspective, he was attempting to exchange them for privileges, such as pensions and other gifts, rather than sell them with a price list, as the other 32 clockmakers of the city of Augsburg did.

Although it is possible that Filippo's signed clock in the Museo Galileo may be identified with the one ordered in 1667 by the Medici, such a clock does not seem to appear in later Medici inventories Instead, it was in the possession of Vincenzo Viviani's heirs, and was

[88] *Ivi*, pp. 17-18.
[89] *Ivi*, p. 16.
[90] *Ibid*.

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perhaps a present from the Grand Duke.[91] Nearly ten years later, on January 24, 1674, Viviani wrote to Filippo asking for a mainspring for a clock: is this a clue that Viviani had this clock by Treffler in his possession, or was he still writing on behalf of the Medici?

The bifilar pendulum and the pendulum swings counter

Considering that, once resettled in Augsburg in 1665, Filippo was commissioned by the Medici to construct metal instruments such as the abovementioned hygrometers, we can infer that he was also involved in the creation of such instruments when he was still in residence at the Florentine court.[92] Moreover, some of Filippo's letters from Augsburg demonstrate that he performed his tasks as a turner and mechanician not just for the Grand Duke, but for other members of the Tuscan court, among them Prince Leopoldo and his academicians.

Filippo's interest in experimental philosophy predates the foundation of the Cimento: as previously mentioned, in 1656 he was involved in an experiment on the speed of sound. The experiment was done with firearms and pendulums to measure from different points the time taken between the vision of the blast and its sound. In this experiment, "Filippo of Augsburg" was responsible for the pendulum.[93]

Filippo was most likely the technician responsible for the construction and operation of the most precise of pendulums: the bifilar pendulum.[94] The structure of this instrument helped to control the linearity of the swings of the pendulum. In the *Saggi*, the bifilar pendulum was declared to be more precise in experimental practice than any other clock for measuring small fragments of time.[95] The polymath Tito Livio Burattini (1627-ca. 1682), who was in contact with the Florentine court during the years of the Cimento, in his *Misura Universale* (1675) affirms, with an interesting oxymoron, that it was the Accademia del Cimento that invented this typology of "more stable pendulum".[96]

The bifilar pendulum was illustrated in the *Saggi* (fig. 17-18) together with a pendulum-regulated chronometer. Unfortunately, Lorenzo Magalotti did not provide a written description of this instrument (see fig. 17, right). The instrument has a mechanism like a drum clock placed

[91] Righini Bonelli, 'Di un orologio di "Gio…, pp. 250–55.
[92] I here follow Silvio Bedini: Bedini, "Johann Philipp Treffler"; Bedini, *The Pulse of Time*, 1991, pp. 49–51.
[93] BNCF, Gal. 268, c. 158v. letter by Viviani written after October 10, 1656.
[94] Silvio A. Bedini, *The Pulse of Time*, pp. 49–51.
[95] Magalotti and Accademia del Cimento, *Saggi*, pp. XVI-XVIII.
[96] Tito Livio Burattini, *Misura universale, overo Trattato nel qual si mostra come in tutti li luoghi del mondo si può trovare una misura e un peso universale ... di Tito Livio Burattini ...* (Nella stamperia de' padri Francescani, 1675), p. B1r.

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horizontally on the top of a column-shaped pedestal. This strange instrument contains a clockwork, considering that a winding key hangs on its shaft. The top of the drum displays a dial with a single harrow-shaped pointer. The dial is curiously divided into 15 sectors–indicated with Indo-Arabic numerals– perhaps covering a span of time equivalent to quarter of an hour.[97] In the *Saggi* Magalotti mentions the use of a pendulum-regulated clock in four experiments.[98] Are they referring to this object?

This instrument could be an evolution of the "little machine" that served as a pendulum swing-counter and which Vincenzo Viviani had attributed to Filippo in 1659. According to Viviani, some years earlier, most probably in 1655, the German artisan created a device that was activated by a string applied to the lowest part of the bob–in the Saggi plate, a similar bob is illustrated at the foot of the clockwork discussed here. Filippo was said to have been inspired by an idea expressed in the letter which Galileo had sent in 1637 to the Dutch admiral Laurens Reael (1583-1637), describing a project for a geared machine to avoid the difficulty of directly counting the swings of the pendulum used in determining longitude while navigating. Viviani himself had shown Galileo's letter to the Grand Duke, who had possibly shared this idea with his German turner.[99] In the same passage, Viviani says that Filippo, after creating such a "gentle little machine"–*galante macchinetta*– devised with his master a series of alternative counters for pendulums. The instrument illustrated in the *Saggi* could therefore be one of them: the drum might have contained a light saw-toothed wheel engaged by the apical part of the string of the pendulum, enabling the wheel to turn at each swing and thus driving the pointer. In this case the winding key may have served to rewind a coil-spring that kept the pendulum going. As the Grand Duke's turner, Filippo was able to turn the Prince's ideas into working mechanical instruments.

Social Relations among Rulers, Academicians and Artisans

In 1981, Galluzzi claimed that the Accademia del Cimento had very little to offer social historians of science. Most probably, he was aiming to criticize a certain trend in the field that was anachronistically exalting a "democratic" science from below, even in *Ancien Régime*

[97] Vincenzo Antinori and Marco Tabarrini, *Scritti editi e inediti* (G. Barbera, 1868), p. 163; Giuseppe Boffito, *Gli Strumenti della Scienza e la Scienza degli Strumenti* (Firenze: Seeber, 1929), p. 88; Silvio A Bedini, 'Johann Philipp Treffler', p. 6; Galluzzi, *Scienziati a corte. L'arte della sperimentazione nell'Accademia galileiana del Cimento (1657-1667)*, p. 98. I thank Dr Giorgio Strano and Dr Francesco Barreca for their help in revising the bibliography on this machine.
[98] See Magalotti and Accademia del Cimento, *Saggi*, pp. CLIV, CLVIII, CCXXXXII, CCXXXXIV.
[99] Albèri, XIV, pp. 341–56. Bedini, who quoted this important passage, made use of an apparently problematic and lacunose translation: Silvio A. Bedini, *The Pulse of Time*, pp. 41–43.

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settings such as the Cimento. Ironically, his article is now seen as a seminal essay in the very social and cultural history of science, which illustrates some of the most important elements that make the Cimento a uniquely informative moment of courtly scientific practices, very far from previous anachronistic idealizations. For sure, the Accademia del Cimento was a pyramidal institution, absolutely depending on the will of Leopoldo and Ferdinando II. Nevertheless, the development of experimental instruments involved several actors of very different social backgrounds and education, who contributed with their different and essential knowhow: princes, academicians, and craftsmen all partook in the development of the instruments, each contributing according to their expertise.

In addition to the skilled artisans that we have encountered, we will now meet some of the other important figures that collaborated with them in the creation of their refined instruments. Among all the academicians, the grand ducal first engineer (since 1653) and, from 1666, first court mathematician and *"idrometra"* (surveyor/measurer of the waters) Vincenzo Viviani,[100] seems to have had a special role in organizing the work of the artisans in charge of producing instruments for the Accademia del Cimento and the court in general.[101]

Viviani, the "last pupil of Galileo," was a gentleman who had shown since his teenage years a special talent in mathematics, which brought him close to the court and to old Galileo. Beside his scholarly, teaching and engineering obligations, Viviani had also the task of teaching special skills to the courtly artisans: for instance, in 1665, under Ferdinand II's command he taught the ducal turner and clockmaker Gio. Filippo Treffler how to work telescopic lenses:

> On April 30, 1665, in Florence. Considering the fact that the Most Serene Grand Duke, before leaving for Pisa […] ordered me, Vincenzio Viviani, during his vacation, to assist his turner, master Filippo Treffler, whom His Highness left in Florence for this purpose, to introduce and instruct him in the art of the glasses for "big spectacles" [*occhialoni*], which are called telescopes, teaching him these proportions and measures, which for that art one extracts from the theory and bases of dioptric.[102]

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[100] Simon Dumas Primbault, 'Viviani Franchi, Vincenzio', in *Dizionario Biografico degli Italiani* <https://www.treccani.it/enciclopedia/vincenzio-viviani-franchi_%28Dizionario-Biografico%29/> [accessed 3 March 2023].

[101] See footnote 107.

[102] BNCF, Gal. 252, c. 92r, Viviani Vincenzo to Bruto della Molara, February 4, 1664 ab Inc. (i.e. 1665) *"[…] che S.A. mi avesse ordinato di instruire Filippo […]"*; Gal. 243, c. 16r: *"Adì 30 Aprile 1665 in Firenze/ Essendo che il Ser.mo G.duca p.ma di andare a Pisa, cioè la sera del 21* [?] *Xbre prossimo passato tra l'altre cose mi comandasse che io Vincenzio Viviani nel tempo di q.sta sua Campagna assistessi a Ma.tro Filippo Treffler suo tornaio il quale S. A. lasciava a posta in Firenze con introdurlo e instruirlo nel modo di lavorare i vetri p[er] occhialoni, detti telescopi, insegnandogli quelle propor.ni e misure che p[er] tal arte si cavano dalla teorica e de fondam.ti diottrici […]"*; Gal. 243, c. 20r: *"Adì 26 Maggio 1665 in Firenze/ Essendoche il Ser.mo Granduca una sera di Dicembre prossimo passato prima d'andare a Pisa tra altre cose comandasse a mè Vincenzio Viviani scrittore della presente che nel tempo di questa sua Campagna assistessi a Mr. Filippo Treffler suo tornaio che S. A. lasciava a posta in Firenze con introdurlo e instruirlo in quelle propor.ni e misure che p[er] l'arte del lavorare i vetri da occhialoni si cavano dalla teorica e de fondam.ti diottrica […]"*. Gio. Filippo Treffler must

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The classical Alexandrine mechanical tradition, popularized by seminal works such as Vitruvius's *De architectura*, made the union of theory and practice the basis for great creative achievements.[103] This tradition is evident in the liminal activities of early modern engineers like Viviani, knowledgeable in both the craft and scholarly sectors.[104] The long service in experimental activities at the Florentine court and the theoretical and practical training that Filippo received from Viviani in dioptrics allowed the turner to self-fashion himself as a "superior craftsman" [105] in the Vitruvian tradition, creating "mathematical inventions", as we have seen: indeed, his night clocks embodied a pendulum, a complex pointer-less dial, and an optical lens, all products of practical mathematics that were absent in the local tradition.

Other superior craftsmen, such as Eustachio Divini or Giuseppe Campani, even published pamphlets and books, being conscious of their rare skills. In this way, they promoted themselves both as unique artisans and as *authors* (i.e., respected intellectuals), capable of contributing to the advancement of science (fig. 19). The claim came not only from below, but

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have been trained in this method after February 3, 1664 (*more florentino*, therefore 1665), as that day Viviani wrote to a secretary at court that he wished to help the German turner to learn the technique of lens-grinding. Letter from Vincenzo Viviani to unknown character, February 3, 1664, The British Library, *Original letters of Italian litterati and artists, 1474-1845*, Add MS 24215 : 1474-1845, c. 75v. I thank Ann McDermott of the British Library for providing me with a digital reproduction of this letter. See footnote 105 for the transcription.

[103] See for instance the chapter "*Artisans, Humanists and De Architectura of Vitruvius*" in Long.

[104] Viviani made clear the importance of this very mixed knowledge when he criticized Filippo, who, in his eyes, was ignorant in both the theory and practice of dioptric lens-grinding, which was a craft "very different from the art of working and polishing wood and metal", being the trade of a turner such as Filippo. Bedini claimed that Viviani had prized Filippo, in a letter found in the British Library and dated March 15, 1664 (cc. 61rv-62rv), Treffler. Unfortunately, the quoted letter does not discuss Treffler (Bedini, *The Pulse of Time*, 1991, 42, footnote 39). The quotation Bedini produced in relation to this letter comes instead from Vincenzo Viviani in a letter to Prince Leopoldo (August 20, 1659): Albèri, XIV, pp. 341–56. Bedini's translation contains, moreover, a blunder: Bedini translates *"ingegnosissimo e perfettissimo artefice, degno in vero di tanto Principe"* as "most ingenious and perfect of artisans, recognized as such by many princes" whereas the meaning, in my translation, is closer to "a most ingenious and perfect artisan, worthy of so great a Prince." In one of the other letters found in the folder in the British Library and quoted by Bedini, Viviani talks about Filippo Treffler. This is the abovementioned letter dated February 3, 1664, where Viviani mentions but does not praise Treffler: *"[…] sempre mi sono offerto di andar io a casa sua e d'assistergli intorno alli strum.ti necessari p[er] tal lavoro, et alla manipolazione ancora, già che da discorsi ch'egli me ne ha fatto, conosco che come inesperto ch'ei n'è, s'imbroglierebbe forse senza frutto non solo nella teorica, che nella pratica, la quale è differentissima da quella del lavorare e pulire i legni e i metalli, e senza averla mai esercitata, e senza vederne, e sentirne l'uso tenuto dagli altri, non può mai un uomo immaginarsi […] un modo migliore di quello che l'industria e l'esperienza di tanti, ne' passati secoli ha saputo inventare, sì intorno agli stromenti che alle materie appartenenti al lavoro, et al pulimento delli vetri ordinari, e molto meno intorno alli cristalli pe' cannocchiali. […] ch'io so che non si nasce con le scienze, né con le pratiche"*.

[105] A phrase coined by the sociologist of science Edgard Zilsel to emphasize this mixed Vitruvian knowledge. See: Edgar Zilsel, *The Social Origins of Modern Science*, ed. by Diederick Raven, Wolfgang Krohn, and Robert S. Cohen, Boston Studies in the Philosophy of Science, 200 (Dordrecht; Boston: Kluwer Academic Publishers, 2000); A. C. Keller, 'Zilsel, the Artisans, and the Idea of Progress in the Renaissance', *Journal of the History of Ideas*, 11.2 (1950), 235–40.

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even nobles and scholars, such as Count Manzini and Gian Domenico Cassini, recognized these craftsmen as exceptional figures and publicly prized them (fig. 20).[106]

Their visibility is greatly enhanced by their letters and publications. Nevertheless, we are still missing a large part of the picture: detailed documentary evidence of their daily social intercourse with the princes at court. This is the telescopic paradox: the closer the craftsman was physically to the prince, the more invisible he is in the documents.

Because of this, Viviani's role as a mediator becomes more evident when the artisans were far from the court. For instance, Viviani was in charge of testing new inventions and retrieving information, as in the case of three different marine chronometers produced in Rome by Giuseppe and Matteo Campani, as we shall see. As already mentioned, once returned to Augsburg, Filippo Treffler maintained professional contact with the Grand Duke through Viviani, who would put into writing what was told to him by the ruler.

Sometimes, even the Medici princes did not disdain to communicate directly with their skilled artisans: several surviving letters with a technical content and which were exchanged directly with craftsmen who worked from outside the court during the Cimento testify to this direct exchange.[107] Some of these artisans, such as Eustachio Divini and Giuseppe Campani, and virtuosi such as the priest Matteo Campani, dedicated their written works to Medici princes confirming this special relation and patronage.[108]

Moreover, the nearly invisible courtly life of Filippo Treffler becomes visible through this telescopic paradox after his departure from court in 1665. From his letters we can retrieve some important insights on the relations between courtly employed artisans and their patrons in relation to scientific activities during the Cimento.

As previously seen, once he had resettled in Augsburg, Filippo kept in touch with the Medici court for the rest of his life, sometimes working for his old masters both as a craftsman and as an agent for artistic and scientific commissions. In the 1690s, Filippo was still acting as an agent for important members of the Tuscan court, and even planned, until the last days of his life, a return to Florence. Just after he left Tuscany, Vincenzo Viviani wrote to him that the German's return was expected to take place in the same year of 1665! This return trip, however,

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[106] Silvio A Bedini, *Giuseppe Campani, 'Inventor Romae,' an Uncommon Genius*, pp. 594–95.
[107] See the names of Filippo Treffler (or Trefler), Giuseppe Campani, Matteo Campani, and Antonio Alamanni (Gonfia) in the Museo Galileo's database containing the digitized documents of the *Fondo Galileiano* in the BNCF. Caveat: there are some recording errors, for instance in relation to the Gonfia and Jacopo Mariani. Other important resources are the databases of the Medici Archive Project (letters of the *Mediceo del Principato* and documents from the *Guardaroba*): https://www.medici.org/. The ERC project Tacitroots is creating an important database of all the documents relating to the Accademia del Cimento: <https://sites.unimi.it/tacitroots/> [accessed 4 April 2023].
[108] Silvio A Bedini, *Giuseppe Campani, 'Inventor Romae,' an Uncommon Genius*, pp. 267, 316, 402, 418.

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never occurred, apparently because of Filippo's ill health and advancing age.[109] This was also due to dissatisfaction at the turner's economic treatment in Florence, as the following case interestingly shows.

Filippo Treffler, even in his voluntarily exile from Florence, had retained a monthly pension of 10 scudi, partly as a compensation for the loss of health that occurred while working in Florence, and because he was still a man of the Medici, just on temporary leave. The payment of this pension ceased abruptly sometime after his employer passed away, on Ferdinando II's death in 1670.

Filippo then attempted to keep the stream of money (and favour) flowing, in the form of requests for more patronage from the new Grand Duke, Cosimo III. This move was perhaps encouraged by jealousy: Filippo discovered that his older brother Christoph (born in 1623) had been contacted by Benedikt Winchler the Younger (or Winkler) on Cosimo III's behalf to provide the Florentine court with a new turner with the use of a lathe. Winchler, the son of an acquaintance of Cosimo III, was acting as an agent of the new Grand Duke, who sought a skilled young, unmarried, and polite turner to serve at court in Florence.[110]

Filippo made his move: reaching for pen and ink, he decided to exert some pressure on his old employers. He wrote to Apollonio Bassetti, secretary to Grand Duke Cosimo III, requesting to submit a supplication and a memorandum to the ruler.[111] In these papers, Filippo asked for further financial emoluments and commissions for new works: fearing the loss of Medici support to such a close competitor, he pleaded for more patronage "so that people can

[109] BNCF, Gal. 252, c. 106v, Letter from Viviani Vincenzo to Trefler Johann Philipp, November 21, 1665. Bedini, *Giuseppe Campani, "Inventor Romae," an Uncommon Genius*, 298; Bedini, "Agent for the Archduke," 142 and followings. See also Gal. 255, c. 3r, letter by Filippo Treffler to Vincenzo Viviani about a surveying instrument (January 15, 1666).

[110] This requirement was probably due to the difficulties Cosimo III had just experienced because of the distress suffered by Filippo Senger due to his wife's depression following the loss of a son and the miscarriage of a second. Grand Duke Cosimo III expended much energy over seven months to have "Anna Caterina Sangers" (her Italianized name in Cosimo's letter) to be sent from Hamburg to Florence. Archivio di Stato di Firenze, Mediceo del Principato, folder 4491, cc. 687r-716v. Moreover, the close presence to the person of the Grand Duke required a certain politeness and constant availability that a man with a family could have not provided. This shows how the service of the princely turner was a fashionable desideratum for rulers of the period.

[111] These documents shed light on the way young Filippo Treffler arrived at court. He was indeed employed in the house of the Gerini, an important aristocratic family connected with the Medici and with the imperial court. The mother of Ottavio Piccolomini, general of the Imperial Army at the end of the Thirty Years War, was a Gerini. Diligenti, *Genealogia: Sommario Storico Delle Famiglie Celebri Toscane*, ad vocem. Therefore, it was likely not Matthias de' Medici, as Bedini had previously suggested, who brought Filippo Treffler to Italy, but instead the Gerini network. Silvio A. Bedini, *The Pulse of Time*. Nevertheless, Matthias played an important role in the history of Medici science: besides the many mathematical instruments he brought from Germany, and that later entered the grand ducal collections, were the marvellous goblets in turned ivory from Coburg. Piacenti Aschengreen. Furthermore, Matthias had a special connection with the telescope makers of Rome: he had acquired a silent night clock and a telescope from Giuseppe Campani, who in 1664 dedicated to him his booklet on the observations he had made on Saturn. Silvio A Bedini, *Giuseppe Campani, 'Inventor Romae,' an Uncommon Genius*, pp. 190, 286, 572.

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see that I am still in His Most Serene Highness's grace".[112] In order to support such claims, Filippo Treffler detailed his devotion to the House of Medici, and especially the legitimacy of his demands:

> Whereas the late Most Serene Great Duke sent for me at the house of the most illustrious Marquis Carlo Ghirini in order to cause me move to court with all my working instruments, that, with the help of God, I wish I was able to give satisfaction for about 24 years in several sciences, not just to the late Most Serene Great Duke but also to all the other Princes and people of the Palace […][113]

Among these princes was Leopoldo with his Academy.

> […] thus, I spent my youth and largely lost my health, starting from that time when the late Grand Duke had the bad luck to fall at [the Villa of] Artimino, and helping to lift him to his bed, I began at that moment to suffer in my back and sides. This pain never left me even until the present time. The second misfortune happened during the process of stamping the *cechini* [perhaps *cerchini*, i.e., small rings],[114] when the key [presumably, a tool to fasten the mandrel of the lathe] suddenly broke and in the fall, I hurt myself badly in a part [of my body] which I do not want to name. Furthermore, in adjusting the great clock at Palazzo Vecchio, drilling the [wall of the] tower [where it is placed], because of the great effort that I endured, the pain [I had] significantly worsened, and because of these causes, the late grand duke allowed me the license to transfer myself to my fatherland where I could remain quiet, considering however one day to return to Florence, but the Medici lords refused to concede, so that I began such a long journey, for the reason I already mentioned […] therefore the late grand duke […] because of the abovementioned reason and for my long service, granted me a 10-scudi monthly salary. But because of the grand duke's passage to a better life, I could enjoy this salary for a few months only. This is a great loss for me and my 5 sons […] moreover, according to the customs of my land, I am not entitled to sell anything of my work. Because of this, I come to Your Most Serene Highness very humbly [to beg] to feel some compassion for me, and to comfort me with some monetary gift [*provigione*] so that people can see that I am still in His Most Serene Highness's grace […] In exchange I will promise to send to the *guardaroba* each year some work made at the lathe or some clock, or some other very new inventions […]. Augsburg, November 23, 1674.[115]

Filippo, besides reminding Bassetti of his 24-year service and the damage to his health that he suffered in the line of duty, went so far as to accuse the father and uncles of the new grand duke of having made false promises of rewards during his long service: from the following memorandum we can better appreciate this game played by the Medici with their servants. This

[112] Archivio di Stato di Firenze, Mediceo del Principato, folder 4491, Supplication of Filippo Treffler, Augsburg, November 23, 1674.
[113] *Ibid.*, already published in the original Italian as appendix in: Prinz, "Deutsche Kunstdrechsler…".
[114] Bedini suggests the reading "*zecchini*", i.e., a gold currency from Venice. This seems to make no sense, nor does even the reconstruction the scholar made of Treffler's accident while striking coins.
[115] Archivio di Stato di Firenze, Mediceo del Principato, folder 4491.

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is a remarkable document which provides the rare, if not unique, viewpoint of an artisan of the Cimento on his employment:

> Memorandum for the Most Serene Grand Duke [Cosimo III] written by myself, Gio. Filippo Trefler, from the year that I came to serve His Most Serene Grand Duke [Ferdinando II].
> The Most Serene Grand Duke sent a footman to the Marquess Gerini's home with the order to take me with all my tools to the Palace, so that I could set my lathe on one of the ground floor rooms. Having started to work different objects under the command of the Most Serene Grand Duke, of the Most Serene Cardinal Giovan Garlo, and of the Prince Don Lorenzo, I was ordered to eat in the *tinello* [servants' quarter] without any other income. After almost ten months, the Most Serene grand duke together with the Most Serene Cardinal came to the place where I was working, asking me if I wished to settle in these lands, and how much I asked for as a monthly salary. I answered that I let His Most Serene Highness decide. Consequently, His Most Serene grand duke told me that if I wished to stay, he would be providing me with the monthly salary of fourteen piastre in cash, plus 10 scudi in expenses, and if I were to be good, he promised to grant me an office with a 5 or 6 scudi monthly income within the next two years. And this was against my interests, because in my profession, one scudo a day is little income. Nevertheless, I carried on my duty serving [at court] with the hope to be soon elevated [in status].
> Six months later, Sir Picolo degli Albizi informed the parties and granted me fourteen scudi per month […] at that time I told His Most Serene Highness that I did not desire to carry on with my duties for seventeen scudi per month, consequently His Most Serene Highness told Si.r Benedetto Guerrini [secretary of the grand duke, who died in 1657] to add three scudi to my monthly salary, and to tell me to carry on as I had done before, that His Most Serene Highness held me dear [*mi vedeva volentieri*] and that I should not have any doubt that, at the right time, His Highness would have me comforted with other good intentions. Therefore, with this promise on the horizon, I carried on for several years not just in the science of the lathe, but also in any other things that the Most Serene Grand Duke and all the other princes were ordering me to do. Realizing that such promise had no consequence, each time that some office was vacant, I took the resolution to dare to supplicate five times to the Most Serene Grand Duke [to grant me it], but he never comforted me. Consequently, having lost all my hope, I decided to stop asking His Most Serene Highness […]. When I submitted a supplication […] asking to be granted permission to leave for my country for a period of four or five years in order to learn there more about my profession, inasmuch, when His Most Serene Highness might have desired again my services, I could offer better skills. His Most Serene Highness responded that I had to give up the idea of learning more, and at the same time the Most Serene Prince Patron [one of the Medici brothers, most probably Leopoldo] came to my workspace asking about my supplication […]. The Most Serene Prince Patron told me that the Most Serene Grand Duke had granted me three months to let me visit my fatherland, and when I returned, if the Grand Duke was not going to make me happy, he would do it himself. He told me this touching twice his chest with his hand. Therefore, I left for my land, and the Grand Duke gave me as a present a medal and chain worthy of 25 scudi.[116] This

[116] In addition to Filippo Treffler, so too did Galileo Galilei, Eustachio Divini and other scientific figures receive a gold chain with a medal as a sign of favour and protection. For the meaning of such a gift see: Mario Biagioli,

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> happened at the time when the Most Serene Prince Francesco was born [November 12, 1660]. When Sir Hippolito de Vique wrote me asking for my return, I immediately left [for Florence]. However, realizing that all promises had no consequences, after a few more years, I supplicated once more His Most Serene Highness to grant me the permission to leave for my fatherland in order to take a wife, but without ending my salary [*provisone*].[117]

As other cases have shown, early modern rulers attracted servants with vain promises of gain and social status.[118] Princes knew that the honour offered to ambitious artisans to be part of a court was a currency. In a pyramidal society a position close to the vertex was expected to provide prestige, favours and protection and it offered the mirage of future privileges and fabulous gains. Princes knew how to use this to gain cheap, skilful craftsmanship to enlarge their material refinement, a tool that consequently enhanced their prestige. In order to maintain the upper hand in this occult bargain strategy, princes had to spur competition, enjoying the spectacle of cruel brawls among poor masters who accepted underpaid positions, in the delusion of gaining something constantly promised but never delivered, except for the reflected glory deriving from such a close social intercourse with the prince. Two illuminating examples of the expected and accepted princely abuse of the servants are offered by Matteo Pellegrini, who in 1624 wrote "it is in the royal interest to keep everybody suspended between fear and hope", and by Cardinal Federico Borromeo, who in 1632 recalled: "A very important cardinal used to say, I do not know whether seriously or joking, that if one day the many courtiers of his household were to be united, it would have posed a great trouble for him."[119]

In that highly competitive and pyramidal world, the promises of princely favours made artisans treat each other with enmity, even in the same family where brothers were often educated in the same craft. This seems to have been the case for the Treffler brothers, as it was also for the three Campani brothers, who destroyed their family ties in seeking patronage and public recognition.[120]

Gio. Filippo's Treffler's claims and accusations may have disturbed the sensibility of the proud Medici. This is perhaps the reason why Cosimo III, who knew Filippo, did not ask him to produce a lathe to send to Florence. Filippo Treffler's memorandum ends as follows:

Galileo, Courtier: The Practice of Science in the Culture of Absolutism (Chicago: University of Chicago Press, 1993), pp. 40–41.

[117] Archivio di Stato di Firenze, Mediceo del Principato, folder 4491. Already published in the original Italian as an appendix in: Prinz, "Deutsche Kunstdrechsler…"

[118] Cristiano Zanetti, *Janello Torriani and the Spanish Empire: A Vitruvian Artisan at the Dawn of the Scientific Revolution* (Leiden: Brill, 2017), pp. 263–66.

[119] Biagioli, pp. 20, 38–39; Zanetti, p. 382.

[120] see appendix in Prinz, "Deutsche Kunstdrechsler…".

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> At that time [1664-65], Sir Marquess Cerbone, commanded by Your Most Serene Highness [Cosimo III, at that time was just a prince], wrote me the order to have the clock for Palazzo Vecchio made. I had it made [in Augsburg] with all possible savings, I put it into operation: I made the instrument with which I drilled [the wall of] the tower. I have been told that Francesco Toffone [a craftsman] asked for an office for [his] sons, both grown and little ones [*un offitio di figli e figlioli*], where he was able to drill the tower, however, for God's Grace, it was me who succeeded in making it as desired.

A prince was not compelled to pay or reward a subject.[121] Filippo's requests may have sounded too aggressive if not even offensive. It appears that the new grand duke punished his insolence by ignoring him. Revoking his favour and offering it to his brother must have been a terrible retaliation for Filippo, although he would later regain some favour at court.[122] In any case, Christoph Treffler, who was already married, did not move to Florence, but produced an expensive lathe "worthy of a Prince" to send to Florence. This was arranged after he won a craftsmanship contest with another German maker: they had both previously been required to produce some samples of their craft.[123]

Artisans of the Cimento and the Circulation of Technological Knowledge

Furthermore, Christoph Treffler agreed to host a young Florentine artisan in order to teach him, for the considerable fee of 1000 golden florins (or 500 thalers)–paid by the Grand Duke–the secrets of the art of turning wood, ivory, glass, and especially silver: the real secret of the Augsburg masters.[124] This young artisan was Tordino, believed sometimes to have been the Gonfia of the Cimento, as we have seen. Tordino, before joining Christoph in Augsburg, had previously learned German in Florence–perhaps from some of the Lanzi, the German bodyguards of the Grand Duke, or from some of the several German craftsmen employed at court, such as the clockmaker Mattias Coffer or turner Filippo Senger.[125] In a few months, the talented Tordino had learned all the secrets of the craft and returned to Florence to serve as Cosimo III's turner.

In the same period, Christoph Treffler, perhaps in an attempt to compete with his brother, invented a type of clock with a large painted dial similar to those of Filippo's clocks

[121] Biagioli, p. 49.
[122] Bedini, "Agent for the Archduke"
[123] Prinz, "Deutsche Kunstdrechsler…".
[124] *Ibid*.
[125] Maria Luisa Righini Bonelli mentions this clockmaker, and cites a list of instruments that belonged in his workshop in the Gallerie. Righini Bonelli, 'Di un orologio di "Gio..., p. 242. I will publish this list for the first time in a forthcoming article in La Voce di Hora.

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which were inspired by the Campani. It displayed the unusual feature of a short pendulum set in the upper part of the dial. Cosimo III bought it for 100 florins (Fig. 21). There is only one known extant clock dating to the 1670s that was inspired by this design,[126] which is today housed in the Peabody Essex Museum in Salem, Massachusetts. Its painted dial represents scenes of astronomical observation (Fig. 22). The only differences, besides the painted dial, is that the one in Christoph Treffler's drawing had a different pointer and it also displayed the month and number of the day in two small windows inserted at the top and bottom of the chapter ring.

Considering the rarity of the position of the pendulum, and the fact that Cosimo III was unhappy with the painting on the display–the extant clock displays the Medici emblem–I wonder if the two clocks are not instead the very same one: Cosimo III had requested the movement of the clock with its case to be shipped to the Tuscan court, but without the painted dial, which he said he would have made according to his taste in Florence.[127]

Christoph Treffler responded through Winchler that the clock was a unicum, given that Christoph was a turner and not a member of the guild of clockmakers. This is a further clue for a possible identification of the two clocks, which explains why the clock in the Peabody Essex Museum has no signature: as previously seen, trademarks and signatures were a requirement for the members of the guild, or could be a marketing strategy as in the several Italianate clocks made by Filippo. This was apparently Christoph Treffler's first clock. Christoph told Winchler that he had made it out of passion. Unfortunately, the painting that Cosimo III disliked was that on the dial, which he could not remove. Christoph this sold the clock to the Grand Duke, who later asked a better painter to change the painting.[128] It would be interesting to investigate with x-rays the dial of the Peabody clock to see if there are traces of a previous painting beneath the present one. The Peabody clock may also have been a new one built following Christoph Treffler's design. Some mechanical features do look different: for instance, Christoph's clock displayed the month and the day, whereas the Peabody clock does not. Moreover, the clock that appears in the 1690 Medici inventory, which is clearly the Peabody clock, had a charge

[126] Silvio A Bedini, 'A Medici Palace Clock.', *Bulletin of the National Association of Watch and Clock Collectors*, 7.1 (1955), pp. 21–26.
[127] PEM, Inv. N. 103699; Archivio di Stato di Firenze, Mediceo del Principato 4491, c. 481r, letter from Cosimo III to Benedetto Winchler the Younger, March 2, 1674-*more Florentino*, therefore 1675.
[128] Archivio di Stato di Firenze, Mediceo del Principato 4491, c. 488r, letter from Benedetto Winkler the Younger to Cosimo III, April 3, 1675.

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that lasted for three months, whereas Christoph was said to work with a charge of slightly more than four weeks.[129] This is however too late in time for the scope of this article.

Returning to the time of the Cimento, we can briefly mention three other important cases of technological transfer favoured by the Medici. At court, talented clockmakers such as Filippo Treffler and Giuseppe Campani had the chance to be updated on the most advanced state-of-the-art, pendulum-regulated clocks.[130] Giuseppe Campani visited the Florentine court in around the years 1658-59. This was just after he had invented the crank-lever pendulum escapement for silent night clocks. He headed from Rome to Florence seeking an inventor privilege, which he obtained for five years (1660-1665), although he had asked for ten: a secretary informed the Grand Duke:

> … that Giuseppe Campani by means of the enclosed memorandum [*Memoriale*] proposes to have discovered an invention of silent clocks, and requests that if your Highness concedes a Privilege that for ten years no one in the felicitous States of Your Highness can work or construct or sell such silent clocks of any type, concerning which a number of Professors of the art of clockmaking in the Galleria were consulted and who have responded that they have nothing to say against this privilege. Inasmuch as Your Highness generally concedes privileges for new inventions, it is represented that a privilege can be conceded to Campani for ten years with the usual conditions that the invention is truly a new one...[131]

Among these "Professors of the art of clockmaking in the Galleria" must have been Filippo Treffler and Mattias Coffer. Perhaps this is why the Grand Duke, a major customer of the Campani brothers, granted Giuseppe only 5 years of privilege.[132] His masters at the Gallerie could reproduce these expensive clocks at a lower price, once the inventor privilege had expired. Before that, they could probably also craft very similar clocks that, however, respected Giuseppe's privilege by avoiding the use of his pendulum-regulated crank-lever escapement.

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[129] Archivio di Stato di Firenze, Mediceo del Principato 4491, c. 488r, letter from Benedetto Winkler the Younger to Cosimo III, February 15, 1675; Guardaroba Medicea 959, f. 30r: "*Un oriuolo a dondolo, che mostra solam.te con cassa di pero tinta di nero e tabernacolo con adornam.to a frontespizio, e vasetto sopra e due colonne avvitich[iat]e di pero sim[l]e con scartocci e rabeschi di d.o pero, et altri di rame dor.to; con sua mostra dipintovi un paesino con balaustro e figurine, con sfera di stagno p[er] l'ore, entro alla quale vi è un arme di palle dove si vede l'agitazione d[e]l dondolo, con suo conrtapeso di piombo, e la caricatura serve p[er] tre mesi alto d. 1/"; lar.o d. 1. In circa posa sopra …* [sic] *Inv. di Guard.a d. 32.*"

[130] Regarding pendulum-regulated clocks, besides the prototypes by Filippo Treffler and Giuseppe Campani, at court, by the summer of 1659, drawings, engravings and working pendulum-regulated clockworks by Galileo's son Vincenzio, Francesco Generini, Christian Huygens, and Salomon Coster could be seen. Moreover, in 1667 the Polish Jesuit Adam Adamandus Kochanski showed Ferdinando II a magnetic pendulum for watches. Bedini, *The Pulse of Time*; Silvio A Bedini, *Giuseppe Campani, 'Inventor Romae,' an Uncommon Genius*, chap. 6, pp. 106-107; Sebastian Whitestone, 'Christian Huygens' Lost and Forgotten Pamphlet of His Pendulum Invention', *Annals of Science*, 69.1 (2012), pp. 91–104.

[131] Silvio A Bedini, *Giuseppe Campani, 'Inventor Romae,' an Uncommon Genius*, p. 193.

[132] *Ivi*, p. 243 (1664 to the Queen of England, Catherine of Braganza)

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The previously mentioned round movement, held in a private collection, was clearly inspired by that of Campani.[133] (fig. 15 & 16).

We have seen how, once resettled in Augsburg in 1665, Filippo had started producing very similar night clocks.[134] The strong relations that Treffler maintained with the court of Florence gave him the chance to be informed on the next great horological invention by Giuseppe Campani, dated 1667-1668: the projector silent night clock (fig. 23).[135] As with Folli's hygrometer, Treffler was probably provided with a description and sketch shortly after the Medici acquired one of these new princely desiderata. Filippo was now able, thanks to the teaching of Viviani in 1665, to produce the magnifying lens which projected the image of a dial on a distant wall. The only known projector clock by Filippo Treffler is now held in Kassel Museum.[136] Thanks to his employment at court, Filippo Treffler was perhaps the craftsman who had introduced the pendulum-regulated clock to Augsburg, where local clockmakers were rather diffident towards this innovation.[137]

It seems that Giuseppe Campani also drew upon Medici technological knowhow: the visit to the court in 1658-1659 gave him and his brother Matteo the chance to learn not just about other pendulum-regulated escapements, but perhaps also about lens-making and Galileo's old attempt to develop a device to find longitude at sea. In the next few years, Giuseppe became the most appreciated producer of dioptric instruments in Europe. The Accademia del Cimento played a major role in assessing the quality of Giuseppe's lenses and made great use of them for its celestial observations.[138] Bedini has suggested that during Giuseppe's visit he might have drawn inspiration from the lathes of the grand ducal Gallerie, which until the 1650s had produced some of the best dioptric lenses in the world.[139]

Later, Giuseppe Campani insisted that he could make his marvellous lenses thanks to a special lathe that, as a sapient clockmaker, he had been able to create and that he kept as a jealously guarded secret. His contemporaries and later historians have dismissed this claim as

[133] Bedini attributes it to Filippo Treffler, but it could also be attributed to Mattias Coffer. Bedini, *Giuseppe Campani, "Inventor Romae," an Uncommon Genius*, p. 173. See figure 69.
[134] Lenner. See images.
[135] Bedini, *Giuseppe Campani, "Inventor Romae," an Uncommon Genius*, p. 15.
[136] The website of the Museumslandschaft Hessen Kassel gives a wrong dating of 1665. Considering that Giuseppe Campani invented this type of clock between 1667 and 1668, the date of creation of the Kassel clock must be later. <https://datenbank.museum-kassel.de/226663/> [accessed 21 August 2021].
[137] Klaus Maurice, 'Jost Bürgi, or on Innovation', in *The Clockwork Universe: German Clocks and Automata, 1550-1650*, ed. by Otto Mayr (New York: Smithsonian Institution, 1980), pp. 87–102 (p. 91).
[138] The following seminal works have extensively analysed the role of the Cimento in the Campani-Divini contest for the best telescopes: Bonelli and Van Helden, "Divini and Campani"; Bedini, *Giuseppe Campani, "Inventor Romae," an Uncommon Genius,* Chapters 8-10.
[139] Bedini, *Giuseppe Campani, "Inventor Romae," an Uncommon Genius,* p. 270.

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a strategy to increase the awe that such a thing provoked among the virtuosi of the time. However, the archival work of Silvio Bedini has recently shown that Giuseppe had a special lathe to create moulds and perhaps even to work directly on some lenses.[140] Of course, the lathe was just an ingredient as much as the good glass from Venice and the skills of the artisan. By 1666 prince Leopoldo was considering Giuseppe Campani's lenses superior to any other, as we learn from a letter sent to Christiaan Huygens.[141]

A last important example we will consider here of the role played by the Medici court during the years of the Accademia del Cimento to circulate innovative instruments and their technological knowledge, is given by the brokerage of marine chronometers. Since as early as 1660, both Giuseppe and Matteo Campani, inspired by the earlier example of Galileo, made clear that they wished to enter the competition for the award offered by the Dutch States General to the discoverer of a method to find the longitude while navigating. In his 1660 book, Giuseppe (surely with the help of his learned brother Matteo), announced, without giving further details, that he had invented "another sort of automaton […] that I hope will be useful to the Art of Navigation to find longitudes with a sure rule".[142]

In the second half of the 1660s, the relationship between Giuseppe and Matteo had broken down and they each developed independent prototypes to compete for the prize. Ferdinando II, having heard from some of his agents of two attempts to develop marine chronometers in Rome, sent Viviani there in May 1663 to seek information. While another Medici agent, Niccolò Simonelli interviewed Matteo Campani, Viviani visited Pier Tommaso and Giuseppe. It emerged that all three brothers had been contemplating the matter, but only two (Giuseppe and Matteo) considered the goal achievable and were working on it.[143] Once he had discovered their identities, Ferdinando II offered them his patronage by brokering both chronometers through the Dutch States General. Viviani prepared a memorandum (for Prince Leopoldo, according to Bedini) with questions about the Dutch prize for longitude to be directed to Jan De Witt (1625-1672), one of the paramount political authorities in the Netherlands.[144]

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[140] *Ivi*, pp. 722–23.
[141] Letter sent on August 16, 1666: *"…ma circa il di lui* [Giuseppe Campani's] *Tornio ancora quà da molti è stato creduto che non sia tale ma un artifizio competentemente lecito per che altrj non camminj per la strada uera del ben fabbricare le lentj. Vero però è che i suoi Telescopi riescono, di qualsi uoglia grandezza che sieno, migliori di ogni altro che quà sia uenuto, non ostante che ne sien stati mandati dei fatti a comparazione."* Christiaan Huygens, *Oeuvres complètes*. Tome VI. Correspondance 1666-1669, p. 78. <https://www.dbnl.org/tekst/huyg003oeuv06_01/huyg003oeuv06_01_0048.php> [accessed 5 August 2022].
[142] Campani, p. XII.
[143] Bedini, *Giuseppe Campani, "Inventor Romae," an Uncommon Genius*, pp. 393-399.
[144] *Ibid*.

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This brokerage was perhaps part of the Medici agenda for the reappropriation of Galileo's merits. During the 1660s, Giuseppe and Matteo Campani sent separately their prototypes of marine chronometers from Rome to the court of Florence, where Viviani tested them in his home (fig. 24 & 25). Giuseppe's clock was promising, and by 1667 Leopoldo was using the Medici network to come into contact with the Dutch States General. He submitted the chronometer to their test, as had been previously done with Galileo's in the 1630s. In 1668, Tito Livio Burattini also sent his newly invented clock from Poland as a present to the Medici, perhaps hoping for Medici patronage in the Dutch competition.[145] Matteo Campani's chronometer was also tested in Florence, but, although ingenious, it did not pass Viviani's examination. Matteo later attempted to develop a second clever marine chronometer regulated by two pendulums, but without success. Unfortunately for Giuseppe, his machine also failed the test in the Netherlands.[146]

Conclusion

The Accademia del Cimento, as the first institution with a purely experimental agenda, compels us to understand the role played by the makers of the necessary apparatus for these experiments. Unfortunately, little can be inferred from the papers and journals of the Cimento about the quotidian interaction of the Academy with its craftsmen, or about their personalities: the proximity of the artisans to their patrons meant that the verbal medium was the most efficient means of communication. Paradoxically, for us, the visibility of these artisans increases proportionally with the distance from the court of the artisans themselves, or of the scholars interested in their instruments: the distance made of the written medium a necessity. This telescopic paradox provides us with important material on the artisans of the Cimento.

We have here focussed on two of the most important craftsmen who worked at the Florentine court, and therefore for the Cimento, which was a part of the court. From the highly prized workshops of the Medici court emerged the Florentine glassblower Antonio Alamanni and the German turner, mechanician and clockmaker Filippo Treffler. Some clocks and instruments have here been attributed to him, while another clock has been attributed to his brother, Christoph. Other artisans, such as Eustachio Divini and Giuseppe Campani, the most renowned lens-makers of the time, although they did not belong to the Florentine court, were still related to the Medici patronage network and provided the Cimento with the best telescopes

[145] BNCF, Gal. 278, c. 177v.
[146] Silvio A Bedini, *Giuseppe Campani, 'Inventor Romae,' an Uncommon Genius*, chapters 12-13.

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and microscopes on the market. Furthermore, Giuseppe Campani produced precise pendulum-regulated night clocks, which were certainly used by the Medici and perhaps also by the Cimento for nocturnal observations.

These craftsmen did not set the experimental agenda for the Cimento: they were certainly subalterns to the prince and to the learned members of the Accademia. However, this article has shown how these craftsmen, through their special artisanal skills, contributed to the experimental process in three ways: **first**, they offered a standard of workmanship that was very hard, if not impossible, to replace; **second**, their knowhow shaped the experimental programme of the Cimento, as the artisan could select the most appropriate options for the construction of the best functional instrument possible, providing the limits of practicability to the experimental projects of the scholars; **third**, the ambition of these craftsmen to win public recognition and a better socio-economic position pushed them to learn from each other at court and from the scholars around them. This ambition drove them to investigate those fields that they knew to be important for their patrons and consequently to advance craft and science. Their patrons observed this and used their privileged position to get the best out of these skilled artisans at the most convenient price (for them), as the story of Filippo Treffler well illustrates.

The story of the Accademia del Cimento shows how the development of experimental practices at court took place within a microsociety, with the princes on top, the academicians in the middle, and the artisans at the bottom. Although, this hierarchy was carved in stone, the artisans were recognized as being as necessary as the other two tiers in the implementation of the experimental programme of the Accademia Cimento, as was made especially clear in the only publication by this institution.

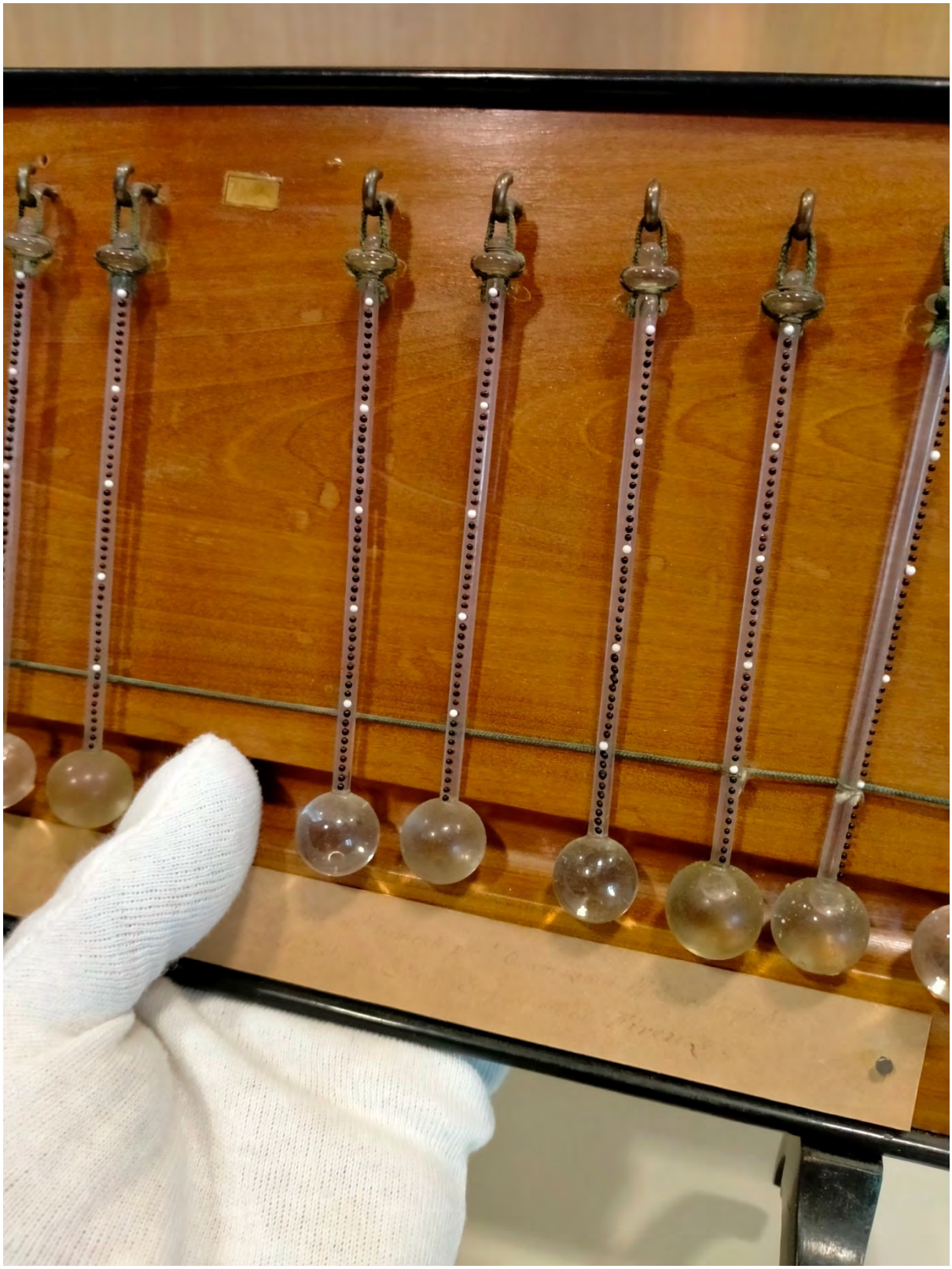

Fig. 1. Set of 50-degree thermometers invented by Ferdinando II and made by the Gonfia. Museo Galileo, inv. 31-64.

Fig. 2. A 50-degree thermometer invented by Ferdinando II and made by the Gonfia. Museo Galileo, inv. 31-64.

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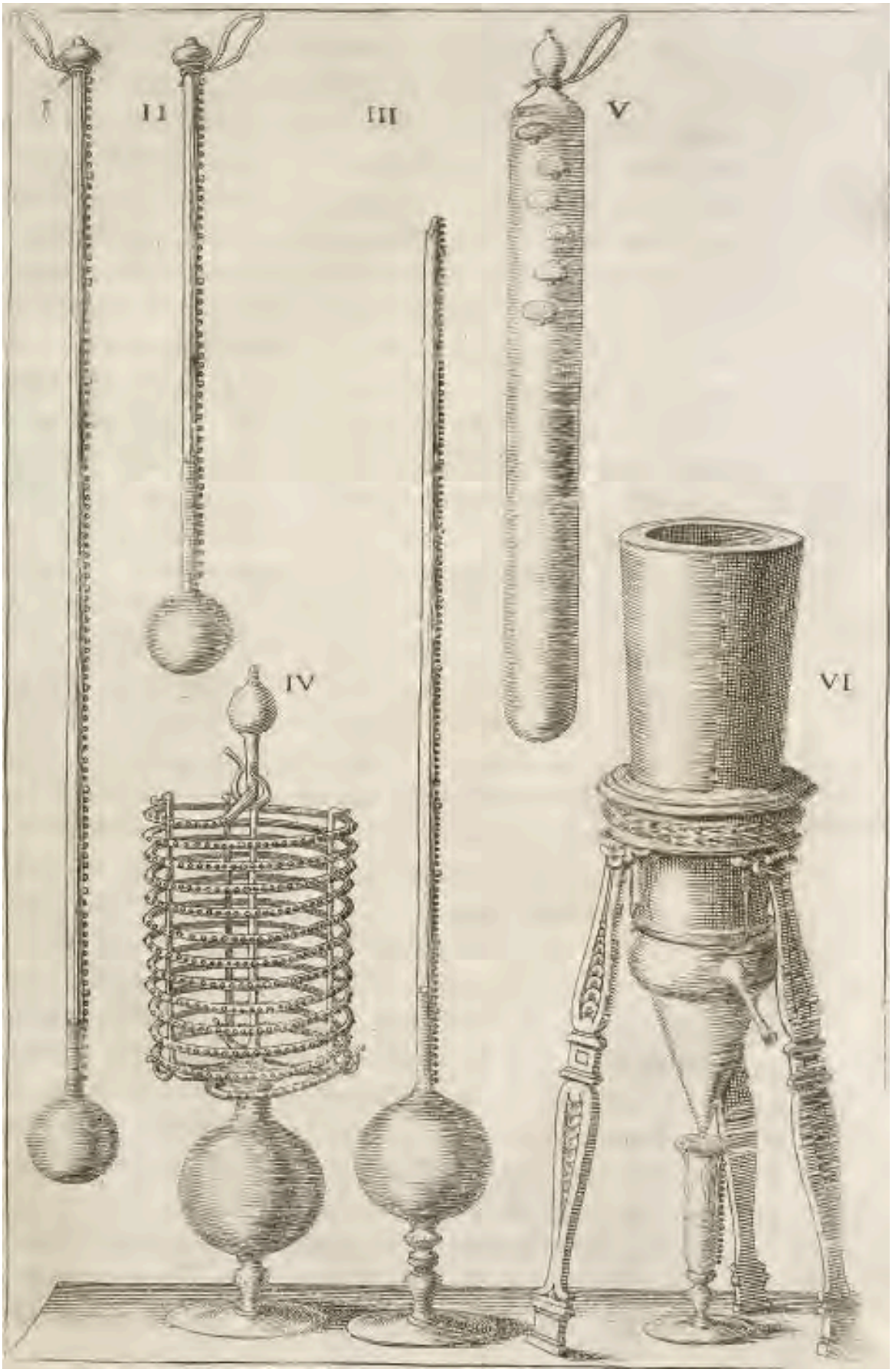

Fig. 3. First plate from the *Saggi* illustrating five types of Medici hermetic thermometers and the condensation hygrometer, whose invention is attributed to Ferdinando II.

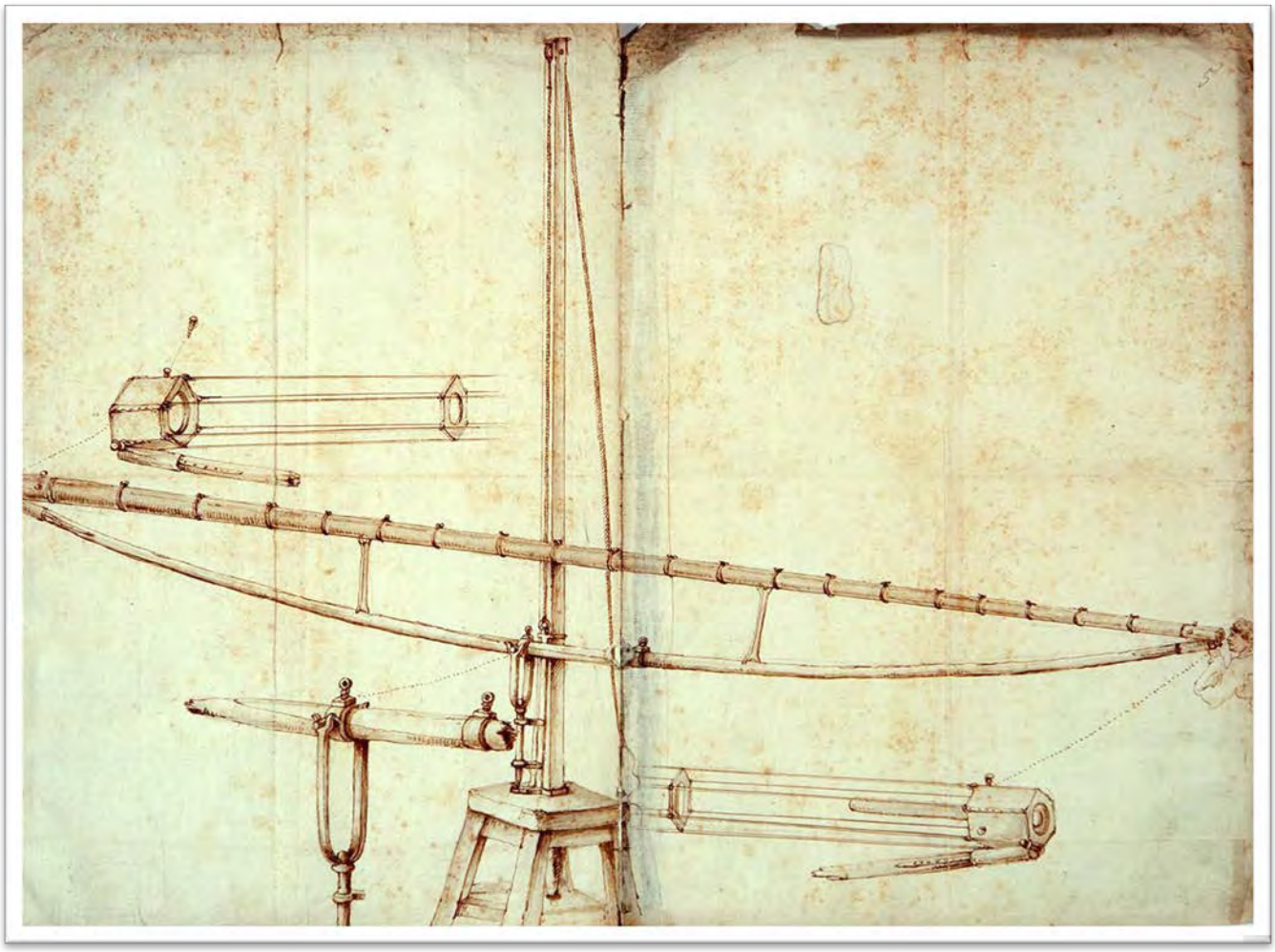

Fig. 4. Biblioteca Nazionale Centrale di Firenze, Galileiano 272, c. 5r. Candido del Buono's *Arcicanna*.

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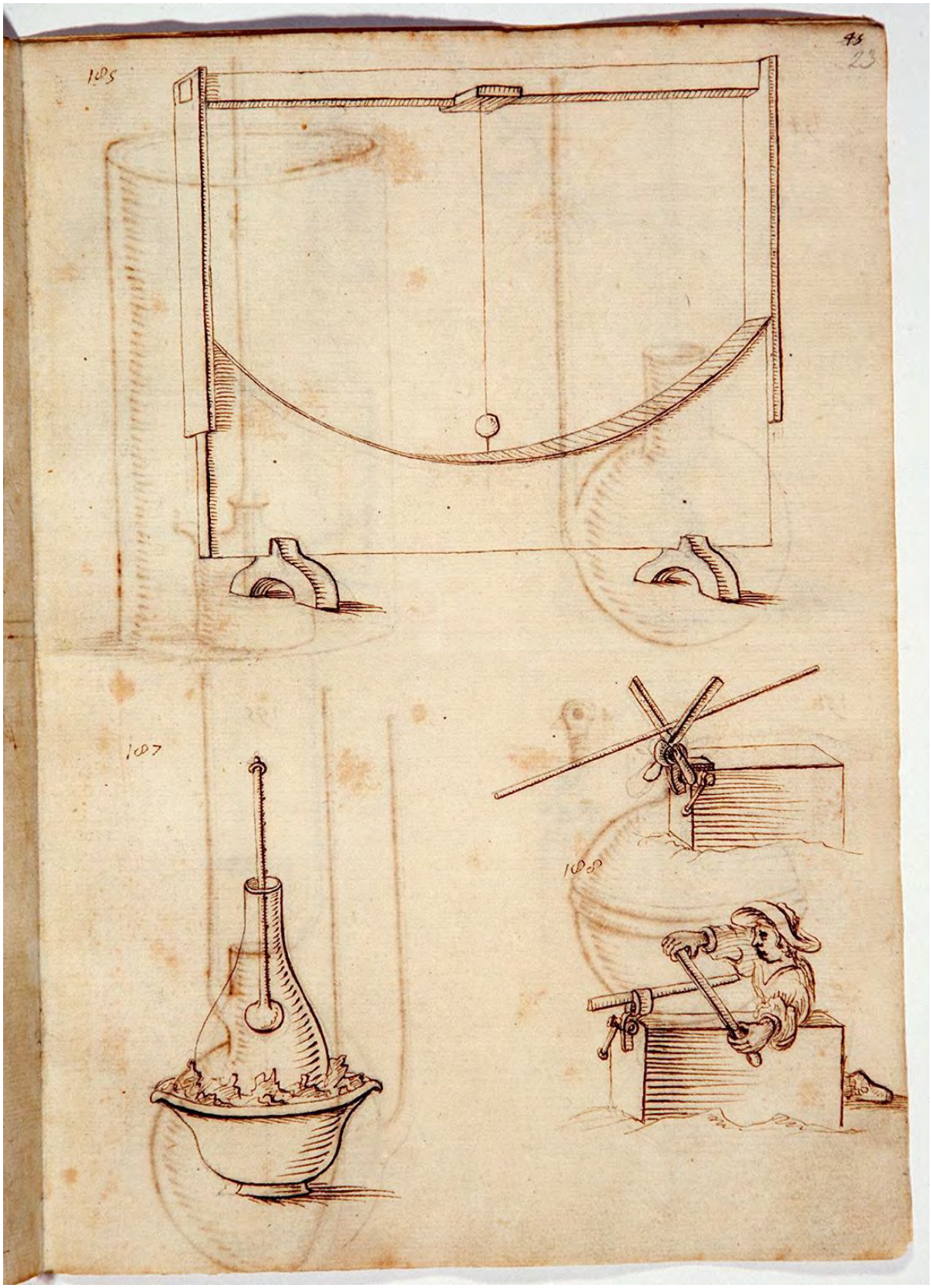

Fig. 5. Illustration of some instruments of the Cimento with a technician (perhaps Gio. Filippo Treffler), ink on paper. Biblioteca Nazionale Centrale di Firenze, Galileiano 261, c. 23r.

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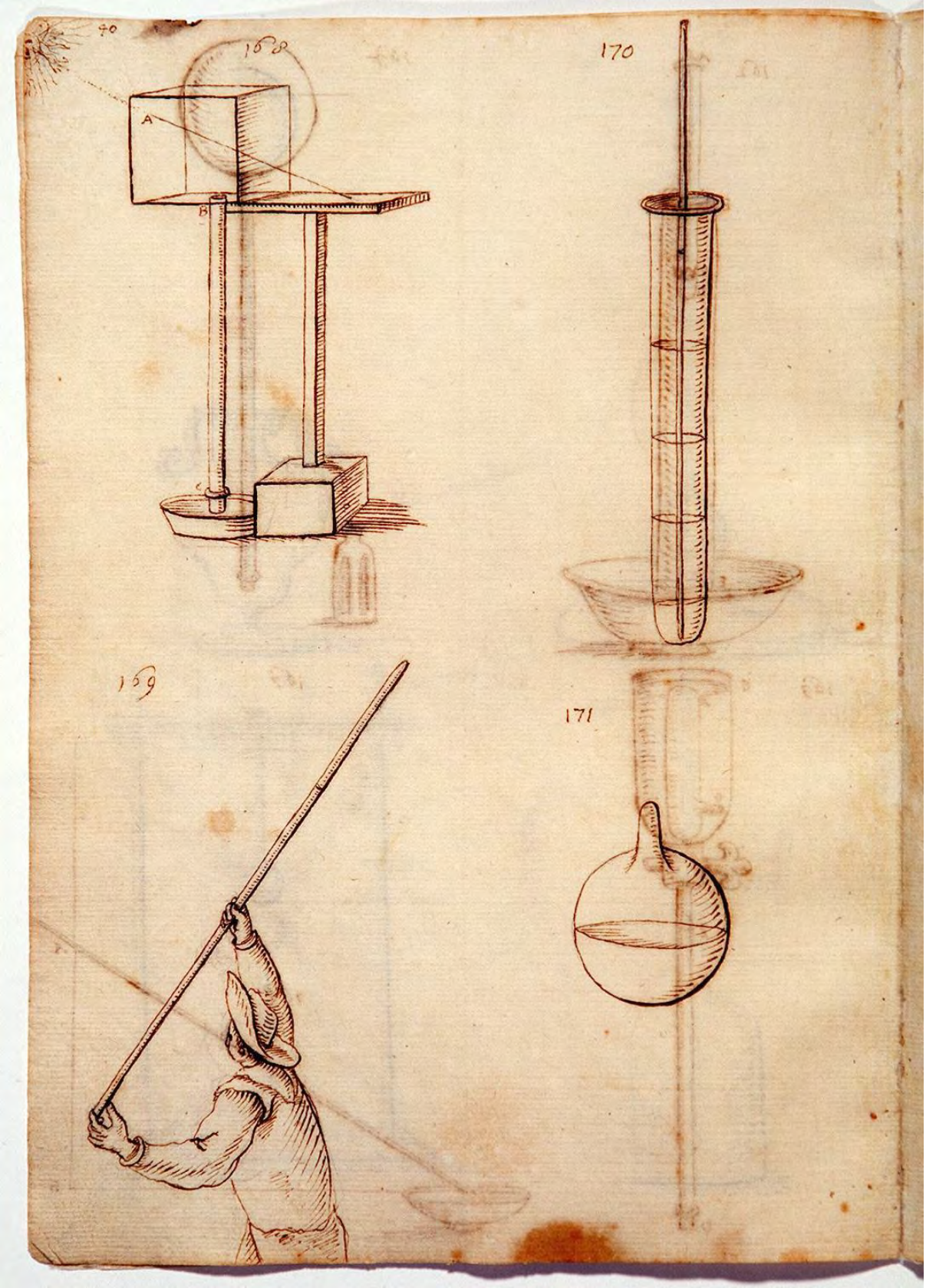

Fig. 6. Illustration of some instruments of the Cimento with a technician (perhaps Gio. Filippo Treffler) performing Torricelli's experiment, ink on paper. Biblioteca Nazionale Centrale di Firenze, Galileiano 261, c. 20v.

Fig. 7. Portrait of Francesco Folli with his inventions for blood transfusion (on the left) and the paper-ribbon hygrometer, *Stadera medica nella quale oltre la medicina infusoria ed altre novità si bilanciano le ragioni favorevoli e le contrarie alla trasfusione del sangue*, Florence: alla Condotta 1680.

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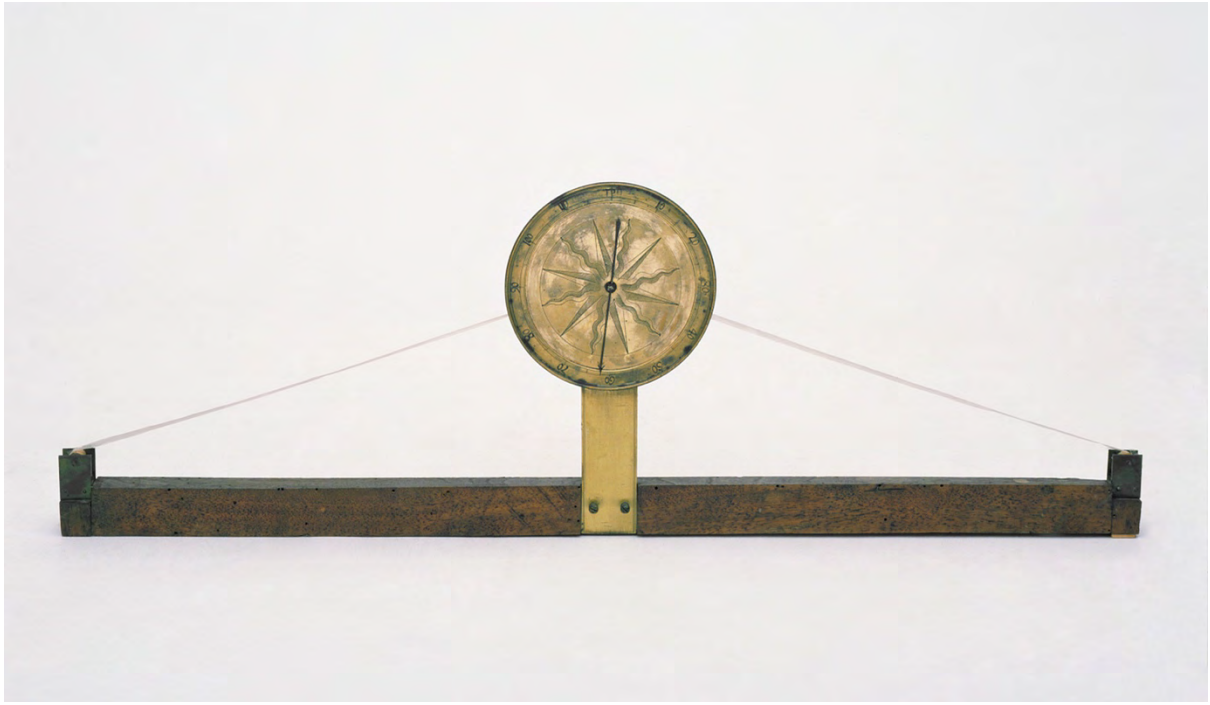

Fig. 8. Francesco Folli, paper-ribbon hygrometer, (ca. 1665). Florence, Museo Galileo, Inv. 2434.

Fig. 9. Paper-ribbon hygrometer improving on Folli's design, most probably by Gio. Filippo Treffler (1666). Florence, Museo Galileo, Inv. 2435.

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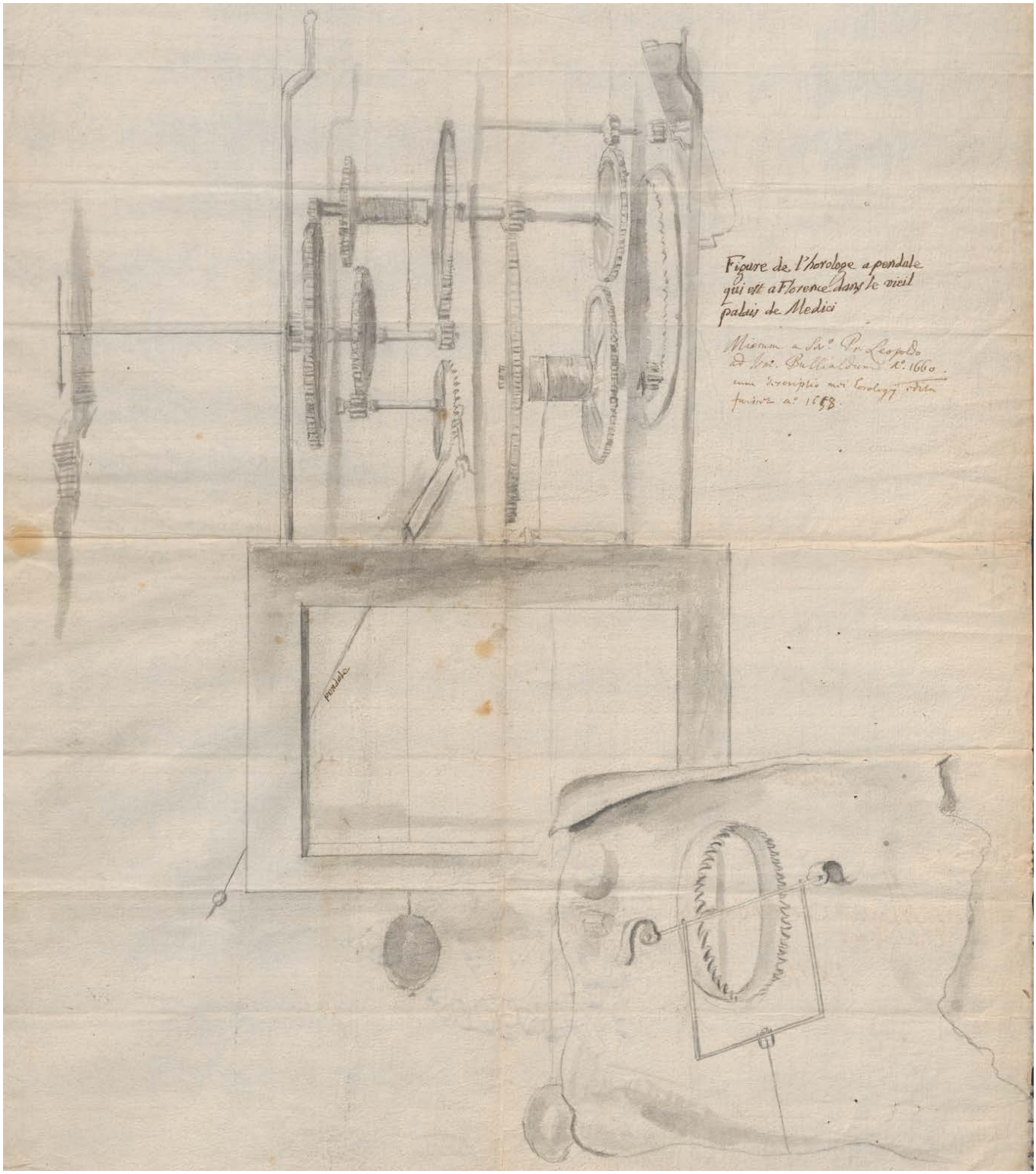

Fig. 10. Vincenzo Viviani (?), sketch of the Medici pendulum turret clock sent to Ismaël Boulliau by Prince Leopold in 1659. Courtesy of Leiden University Libraries, HUG 45.

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Fig. 11. Giuseppe Zocchi, Palazzo Pitti and its piazza. Pen and black ink and wash, over black chalk, on paper; framing lines in black ink (ca. 1750). Courtesy of The Morgan Library & Museum.

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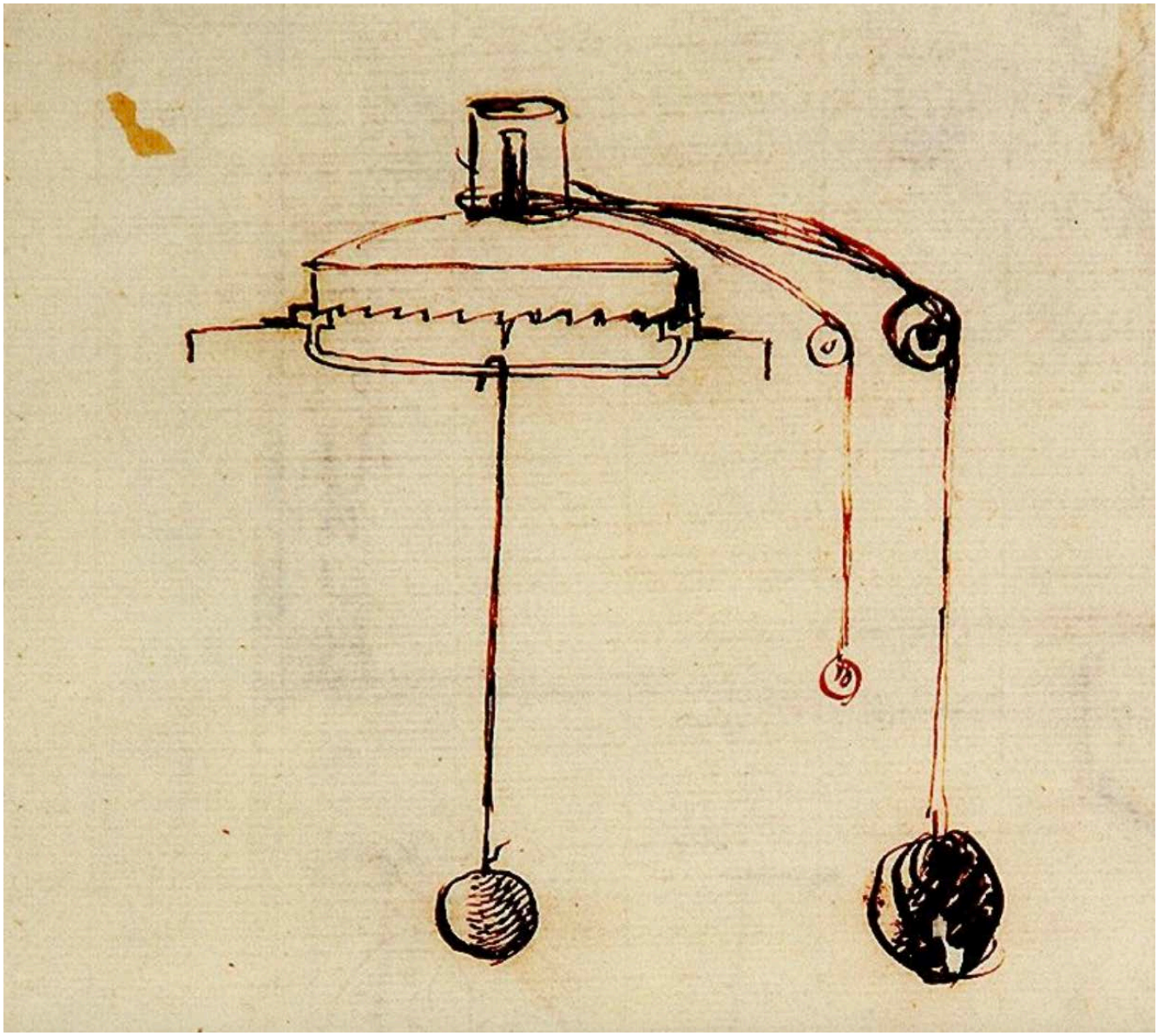

Fig. 12. Vincenzo Viviani, Biblioteca Nazionale Centrale di Firenze, Galileiano 269, c. 168r. Horizontal verge dented directly to the escapement wheel and attached to the pendulum.

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Fig. 13. Gio. Filippo Treffler pendulum-regulated spring-driven clock. The case was lost during the flood of 1966. Florence, Museo Galileo, Inv. 3557.

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Fig. 14. Gio. Filippo Treffler pendulum-regulated spring-driven clock. Signed movement: *"Gio. Filippo Treffler Augost.o"*. Florence, Museo Galileo, Inv. 3557.

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Fig. 15. Gio. Filippo Treffler (?), Mattias Coffer (?) pendulum-regulated clock from ca.1665-1670 imitating the shape of the Campani silent night clocks, although this one is not silent. Milan, private collection. It is inscribed with the sentence *"fatto in Gallerie de S.A.S. Fiorenza"* (Made in the Gallerie of His Most Serene Highness, Florence).

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Fig. 16. Case of the Medici clock *"fatto in Gallerie de S.A.S. Fiorenza"* by Gio. Filippo Treffler (?) and/or Mattias Coffer (?) in the style of the recently invented Campani night clocks. The painting on the dial, in accordance with the rhetoric of the Cimento, represents Father Time unveiling Truth in the shape of Nature. Milan, private collection.

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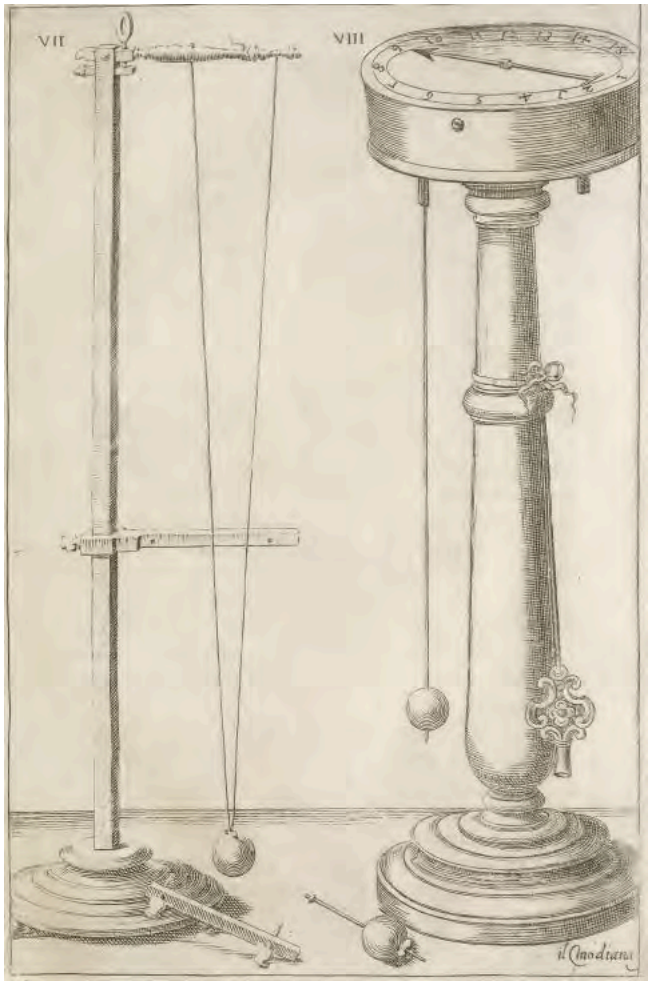

Fig. 17. Plate from the *Saggi* illustrating a bifilar pendulum and pendulum swings counter.

Fig. 18. Valerio Spada, illustrated initial from the *Saggi* showing the bifilar pendulum operated by a *spiritello* or *genietto*, who probably represents both the inquisitive genius of the House of Medici and, according to medieval physiology, the vehicle of affections and sensations.

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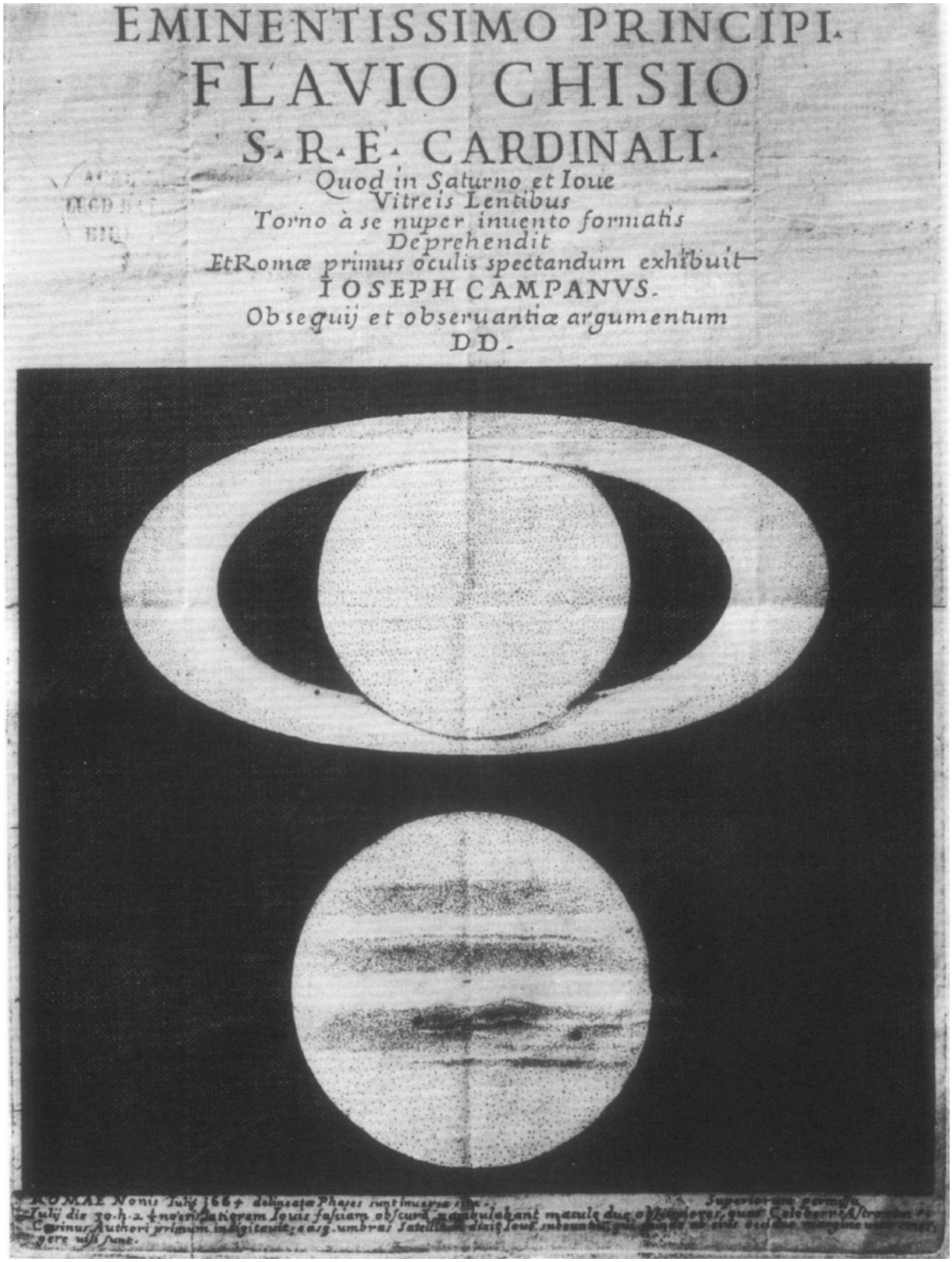

Fig. 19. Giuseppe Campani, Pamphlet in which he announces Gio. Domenico Cassini's astronomical discoveries with a telescope made by Campani himself (1664).

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Fig. 20. Engraving celebrating Eustachio Divini as the best maker of dioptric instruments of the day, Carlo Antonio Manzini, *L'occhiale all'occhio. Dioptrica pratica* 1660.

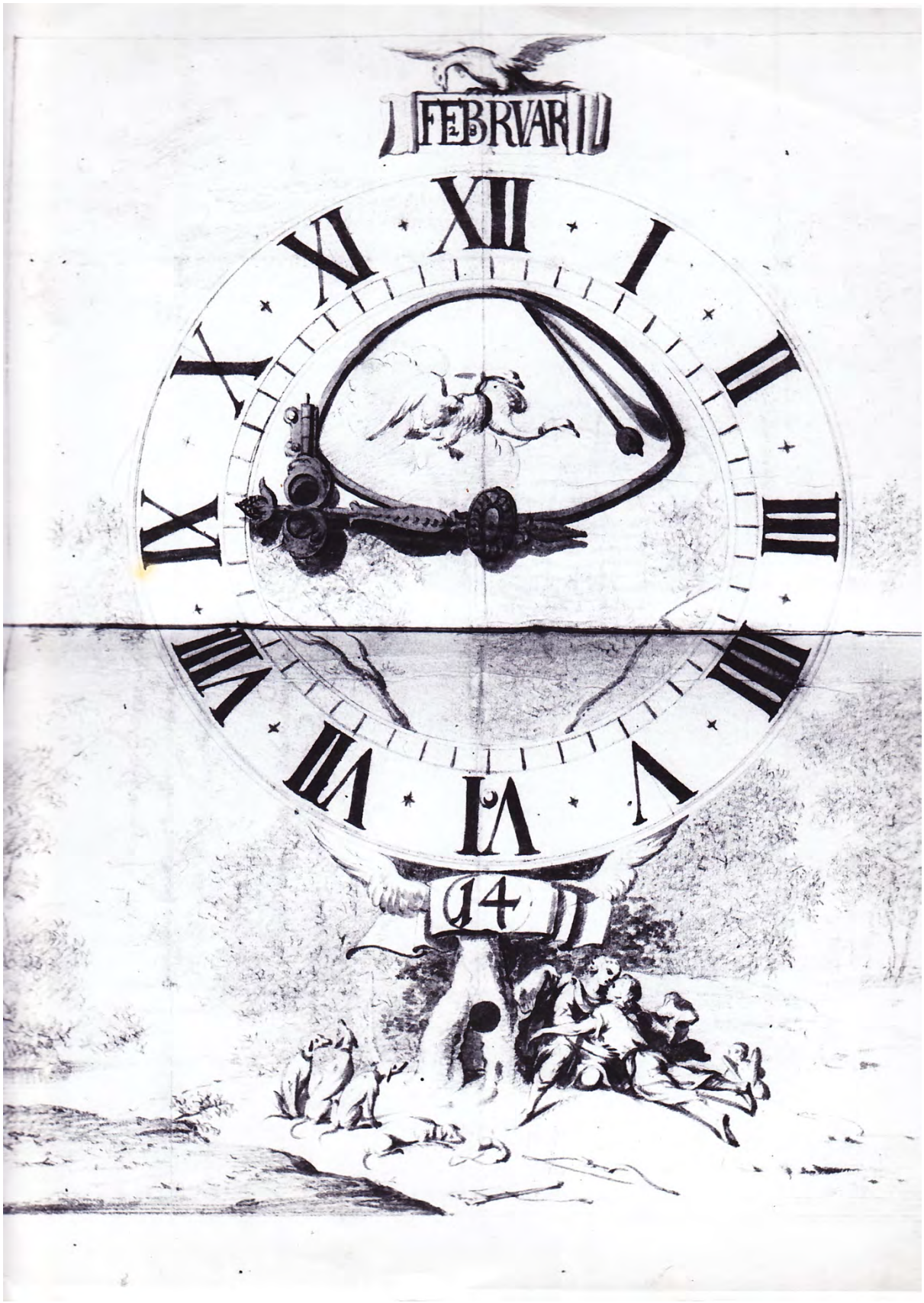

Fig. 21. Drawing in pen and wash showing Christoph Treffler's newly invented clock dial (1675). Archivio di Stato di Firenze, Mediceo del Principto, 4491, c. 483.

Fig. 22. Mantel clock by Christoph Treffler, or designed after Christoph Treffler’s invention, late 17th century

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brass, steel, pewter, oak wood, copper and bronze 37 3/4 x 22 x 9 1/2 in. (95.89 x 55.88 x 24.13 cm) H x W x D Gift of the estate of Miss Marion C. Allen and Miss Elizabeth C. Allen, 1913 103699Peabody Essex Museum.

Fig. 23 Projector night clock, Giovanni Augusto Corvino (drawing) and Johann Jakob Schübler (engraving). Bedroom of King Louis XIV. In Jeremias Wolff, Synopsis Architecturae Civilis Eclecticae (1724).

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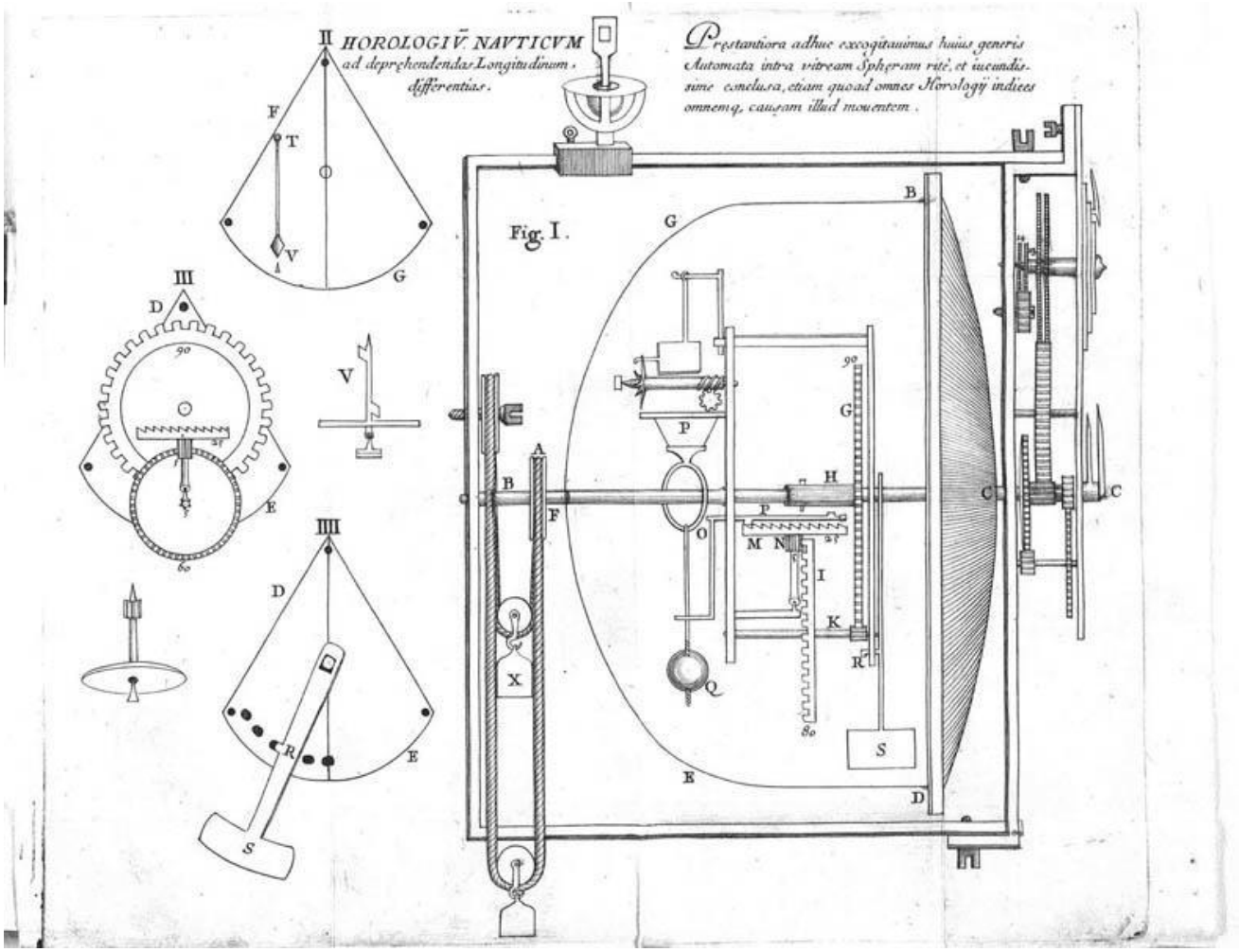

Fig. 24. Matteo Campani, plate illustrating a nautical clock within a vacuum of his own invention. From *L'Oriuolo Giusto di Antimo Tempera Utilissimo à Naviganti*. Roma, per Michele Ercole, 1668. Courtesy of the Museo Galileo, Florence, Photo by Franca Principe.

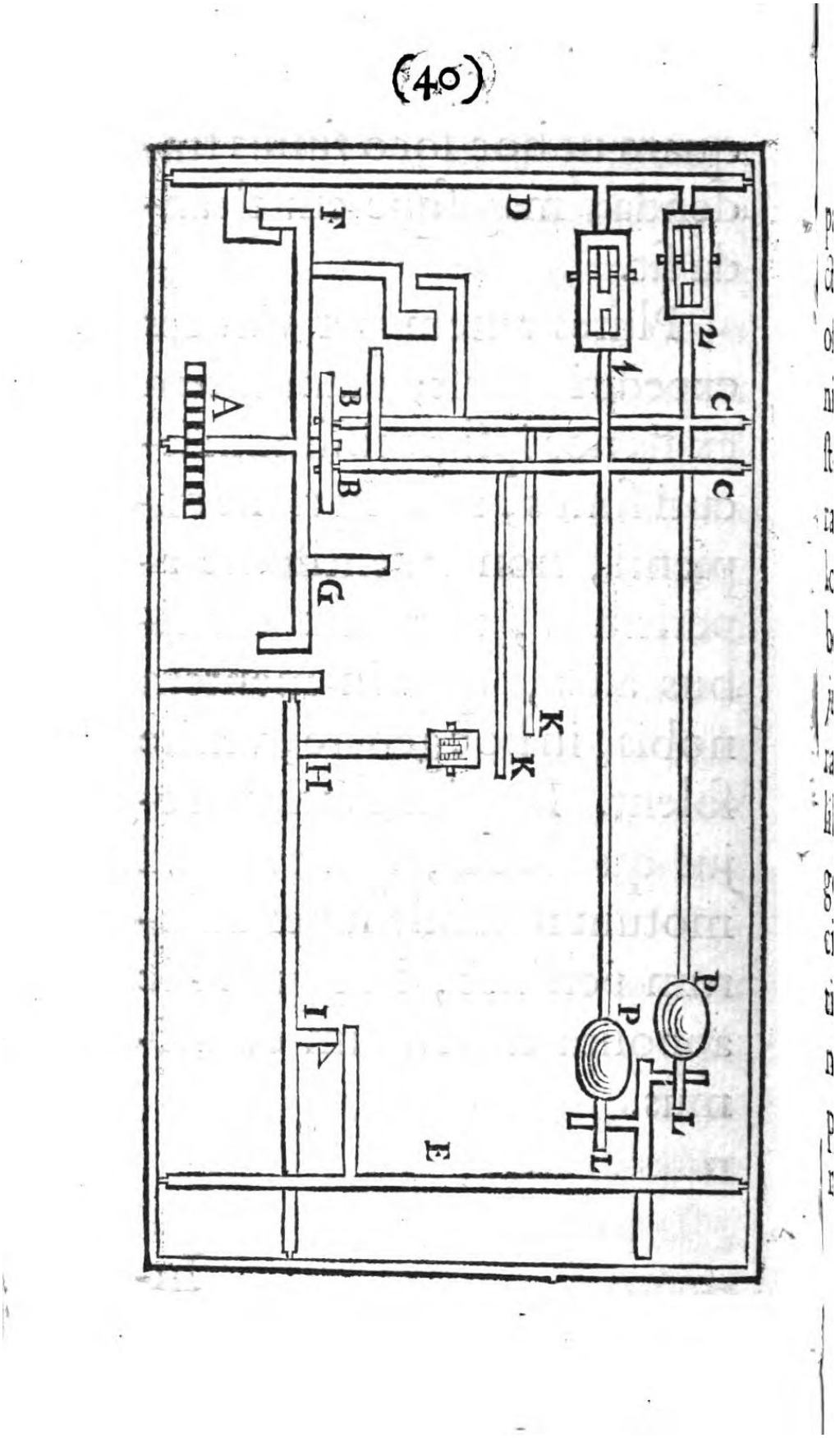

Fig. 25. Matteo Campani, plate from his *Horologium solo naturae motu, atque ingenio, dimetiens, et numerans momenta temporis, constantissime aequalia. Accedit circinus sphaericus pro lentibus telescopiorum tornandis, et poliendis, Amsterdami* (1678, p. 40).