Giulia Giannini

VEHICLES OF KNOWLEDGE: THE CIRCULATION OF THERMOMETERS BETWEEN FLORENCE, WARSAW AND PARIS (1654-1660)

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Giulia Giannini*

VEHICLES OF KNOWLEDGE: THE CIRCULATION OF THERMOMETERS BETWEEN FLORENCE, WARSAW AND PARIS (1654-1660)**

Abstract – This paper examines the paper production – letters, notes, tables, and images – that preceded, accompanied, and followed the circulation of the Florentine thermometers between 1654 and 1660 in various European locations, with a particular focus on Paris and the Polish court. By drawing upon a substantial corpus of unpublished documents, in this article I aim to demonstrate three key points. First, I show the extent to which the thermometer stimulated interest outside Tuscany. Second, I illustrate how the visual, tactile, and practical knowledge conveyed by the instruments contributed to the emergence of new research topics and forms of communication. Third, I demonstrate the need to consider the circulation of physical objects as a key factor in the construction of a shared European scientific context in the second half of the seventeenth century.

Introduction

Instruments form a central part of the legacy of the Florentine *Accademia del Cimento*. The *Saggi di naturali esperienze*,[1] published in 1667 to promote and publicise the *Accademia* and its activities, is dominated by drawings and descriptions of instruments. The volume begins with descriptions and depictions of eight instruments, together with explanations of their construction and use. Another four are illustrated in a specific section with-

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1 *Saggi*, 1667.

in the text, devoted to air compression. In addition, several instruments and apparatus are presented throughout the work in relation to the description of experiments and their possible variations.[2] The *Saggi* is a published work and must therefore present the Academy in a way that reflects the image it wishes to project to the outside world. However, many surviving documents show that the instrument was not merely a rhetorical object for this purpose. These include several manuscripts devoted to the 'fabbrica et uso' ('construction and use') of various instruments, several drawings and the Academy's diaries containing over a thousand experiments relating to the various instruments used to perform them.

The *Museo Galileo* preserves approximately 200 instruments that were designed and used in the Academy, which illustrate the considerable material investment made in their construction.[3]

Instruments also feature prominently in the correspondence of the Florentine academic circle: commissioned for construction, mentioned for use, requested as gifts, described, and drawn, they punctuate letters exchanged within and outside the circle over the years.

The *Saggi* was published at a late date, contains only a small part of the experiments carried out in Florence and was printed after the Florentine experience had essentially come to an end. Prior to its publication, these experiments were rarely shared beyond the group of scholars directly involved in their execution.[4] For this reason, the dissemination of the instruments outside of the Tuscan group, especially before the book went to press, deserves special attention.

Several Florentine instruments crossed the borders of the Grand Duchy, either through correspondence or through the passage from Florence of foreign scholars on their *grand tours*. Often donated by Leopold (1617-1675) or Ferdinand II (1610-1670) de Medici as precious and curious gifts to princes or wealthy aristocrats, the instruments that left Tuscany became objects of study and research, attracting the interest of foreign scholars.[5] These material objects acted as "silent messengers," dumb artefacts conveying knowledge without words. Instead of speaking, they prompted scholars to talk about them.[6]

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[2] On the representation of instruments in the *Saggi*, see Barreca, 2024.

[3] Righini Bonelli, 1968, p. 19. The instruments that have survived include hydrometers, pedometers, quadrants, Ferdinand II's hygrometer, and various types and specimens of thermometers.

[4] Feingold, 2009. Giannini, 2019.

[5] On the Medici's diplomatic exchange of gifts with other European courts see also Molina-Betancur, 2024.

[6] Dupré, Lüthy, 2011.

Silent by nature, scientific instruments are accompanied in the legacy of the Florentine Accademia del Cimento by a vast production of texts and images. Words and drawings describe the instrument to those who cannot touch or see it; texts and illustrations explain how to build it or have it built; letters and documents illustrate how to use it; tables, reports, and figures collect the observations made by those who were fortunate enough to be able to handle one.

The aim of this paper is to analyse the potential impact of the circulation of instruments by examining a substantial core of unpublished texts that accompany the lengthy process that culminated in the sending of some Florentine thermometers to Paris.

Through the paper production that preceded, accompanied and followed the sending of the instruments, I aim to show (1) the interest that the thermometer aroused beyond the borders of Tuscany; (2) the role of the visual, tactile, and practical knowledge conveyed by the instruments in triggering the emergence of novel research and communication topics; and (3) the need to include the circulation of material objects among the mechanisms that led to the construction of a common European scientific context in the second half of the seventeenth century.

The Spread of the Little Florentine Thermometer: A Tale In Two Acts

More than 3,000 letters relating to the work of the *Accademia del Cimento* have been identified.[7] At least one seventh of them mention one or more instruments in various ways (described, sent, drawn, requested, discussed…). The list of these instruments includes clocks, hygrometers, barometric tubes, globes, burning mirrors, and many others. However, the most frequently mentioned are the telescope and the thermometer.

For my argument, the circulation of the so-called 'little Florentine thermometer' (Fig. 1), a sealed liquid-in-glass thermometer with a scale of 50 degrees, created in Florence in 1654 or shortly before, is particularly relevant.[8]

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[7] Most of them are kept at the BNCF. As part of the TACITROOTS project, 1230 letters are currently being catalogued and annotated (by tracing mentions of instruments, books, experiments/observations, people, topics…). The complete database will be available at the end of the project.

[8] Middleton, 1966, p. 30.

Fig. 1 – A fifty-degree thermometer in the Galileo Museum in Florence. © Museo Galileo, Florence. Foto di Franca Principe.

The analysis will examine two phases in the circulation of the thermometer beyond the borders of the Grand Duchy. The first phase concerned the dissemination of the instrument immediately after its creation. This took place between 1654 and 1655, just before the Accademia del Cimento began its activities. Indeed, it was during this phase that the so-called "Medici meteorological network" was set up. Although numerous studies have reconstructed its basic characteristics,[9] the aims and consequences of this network in its precise historical context remain largely unexplored. The following section will attempt to contextualise the construction of the network, to investigate its aims, and to understand its significance within the progressive standardisation of scientific practices in early modern Europe. This will be achieved through the analysis of often neglected passages in the manuscript sources.

The second phase pertains to a later period when the thermometer, which had by then become an integral part of the experimental work of the Florentine Academy, was acquired by Ismaël Boulliau (1605-1694) in Paris through a double channel. In contrast to the previous phase, the thermometer in this period was mainly distributed as a 'gift' to aristocrats and wealthy individuals. Prestige and diplomacy were the main reasons for its spread beyond the borders of Tuscany. However, the instrument served as a vehicle for knowledge.

In this phase, between 1657 and 1664 at the latest, the Florentine thermometer was introduced in Warsaw, Paris, London, and The Hague. The most extensive and complete documentation concerns the arrival of the instrument in Paris. A relevant corpus of correspondence between Boulliau and Pierre Des Noyers (1608-1693) and between Boulliau and Prince

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[9] On the Medici meteorological network, see in particular: Boffito, 1927; Antinori, 1858; Camuffo, Bertolin, 2012.

Leopold de' Medici (1617-1675) testifies to the dispatch of the thermometer to Paris, first from Warsaw and subsequently from Florence. In addition to the detailed correspondence, which includes descriptions, expectations, and enquiries about the instrument, the record of observations made by Boulliau in Paris after receiving the thermometer is also preserved. For these reasons, in this article I will focus mainly on the correspondence between Poland, Paris, and Florence. The pivotal role played by the Polish intellectual milieu will become clear. It is noteworthy that Christiaan Huygens (1629-1695) in the Dutch Republic received the Florentine instrument from Poland, and that the Polish Court was the sole recipient of the thermometer in both phases.

First Act. From thermometers to tables via instructions: the Medici meteorological network

The figure most prominently involved in the early stage of thermometer distribution was Luigi Antinori (1599-1679). However, very little is known about him. He was a Jesuit, possibly the rector of the Collegio di S. Giovannino in Florence, where he taught, and personal theologian to the Grand Duke. Although he is commonly identified as "the theologian whom Ferdinand II turned to physical studies,"[10] he is the author of manuscripts on magnetism, the genesis and use of water, and a treatise on the Sphere.[11]

A series of letters bearing Antinori's signature attest to the sending of thermometers, referred to as 'ampoules,' to various locations between 1654 and 1655. Subsequently, tables containing the observations made with the instruments were sent to Antinori from the various 'stations.'

The Galileo collection at the National Library of Florence (BNCF) contains documents from Milan, Warsaw, Innsbruck, Bologna, Parma, Florence, Pisa, Cutigliano, and Vallombrosa.[12] About one hundred manuscripts relating to the areas outside the Grand Duchy have survived. These consist

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[10] See, among others, Antinori, 1941, p. 43.

[11] The manuscripts are currently housed in the Biblioteca Moreniana in Florence and will be the subject of a later study. Moreniana, *Bigazzi*, 14-17.

[12] Records from Milan, Warsaw, Innsbruck, Bologna, Parma, and Cutigliano are preserved in BNCF, *Gal. 307*. Records from Vallombrosa and Florence are preserved in BNCF, *Gal. 296-306*. In Pisa, Vincenzo Viviani recorded daily temperature, pressure, and humidity readings from November 1657 to May 1658 in his "Diario delle mutazioni di tempo" (Diary of Weather Changes). BNCF, *Gal. 247*, 1r-15v.

of mostly uniform tables of observation data collected almost daily. Bologna and Parma are covered for a relatively long period (from 1 December 1654 to 31 March 1656 for Bologna and from 22 December 1654 to 31 December 1660 for Parma), albeit with some gaps. Milan, Warsaw, and Innsbruck have comparatively less surviving material. The Milan records extend only from 17 February to 2 March 1655 and from 21 December 1655 to 21 February 1656. The Innsbruck records cover only the period from 6 March to 30 April 1655 and from 1 to 30 April 1656. Finally, the Warsaw records are limited to 10 to 16 May 1655.

The identities of the scholars associated with particular locations have been disclosed. Anthony Terill (1623-1676), a Jesuit professor of theology and philosophy in Parma, established contact with Antinori within the Farnese duchy.[13] The Jesuit Giovan Battista Riccioli (1598-1671) communicated from Bologna,[14] while an anonymous Jesuit sent a letter from Milan.[15] In the cases of Innsbruck and Warsaw, however, only a letter from Antinori to Paolo Del Buono (1625-1659) has survived, which mentions the dispatch of thermometers to the two transalpine cities.[16] It is therefore not possible to identify the recipients or users of the thermometers in Warsaw during the six days of May 1655, nor in Innsbruck in April-May of the same year, for which there is documentary evidence.

Record tables and instructions for filling them

At this stage, two main types of documents precede and follow the shipment of the instrument: record tables and instructions for filling them. The Galileo collection provides a wealth of direct evidence for the former. It comprises over 3800 sheets of data tables, most of which originated from Florence and Vallombrosa. However, 116 tables survive from various locations outside the Grand Duchy of Tuscany.

Indirect evidence is all that remains of the latter. On 29 December 1654, Terill wrote to Antinori, informing him that he would begin to record his observations using the "formula" he had just received:

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13 Terill to Antinori, 22 and 29 December 1654, BNCF, *Gal. 307*, 87r-v and 91r-v. Published in DIS II, pp. 165-167.

14 Riccioli to Antinori, 2 January, 6 and 20 March and 8 April 1655: ivi, 95r-v, 100r-v, 101r-v, 103r-v. Published in DIS II, pp. 169, 184-187, 194-196, 200-202.

15 Unknown to Antinori, 29 December 1654 (the letter is faded, and the signature is illegible; some have identified the Jesuit as Giulio del Re, but there is no available information about him), ivi, 93r-v. Published in DIS II, p. 168.

16 Antinori to Del Buono, 9 January 1655, ivi, 98r-v. Published in DIS II, p. 175.

Yesterday, I received a letter from Your Reverence dated the 8th of this month; I had already received the ampoules and I sent you a list of some observations, but in the future I will continue to write my observations according to the enclosed *formula* that Your Reverence sent me.[17]

Terill had already sent some initial recordings from Parma the week before: on 22 December, he sent a letter to Antinori announcing the receipt of "two ampoules to measure the variations of heat and cold."[18] The letter explained how the two thermometers had been used and included a small table with detailed instructions on how to read it.

No direct evidence remains of the instructions for compiling the tables provided by Antinori. Nevertheless, by comparing the first and subsequent tables sent by Terill, as well as those sent to Antinori by other correspondents, it is possible to assume that the compilation instructions were sent to all or many of the correspondents. It is also possible to deduce some information about their contents.

Terill presented the first data recorded in Parma to Antinori in a small table included in the text of the letter (Figs. 2-3). The measurements were taken over a four-day period using two thermometers: one facing north, the other south. Three readings were taken per day for each thermometer, resulting in a total of six readings per day. The precise time at which the measurements were taken was not reported, only general references to the time of day such as 'morning,' 'noon,' and 'evening.'

As Terill explained to Antinori, the table consisted of three columns, each showing data collected at a different time of day. Each column contained two values: the left value indicated the readings taken with the thermometer facing south, while the right value indicated the readings taken with the thermometer facing north. Finally, each row corresponded to the specific day of each observation.

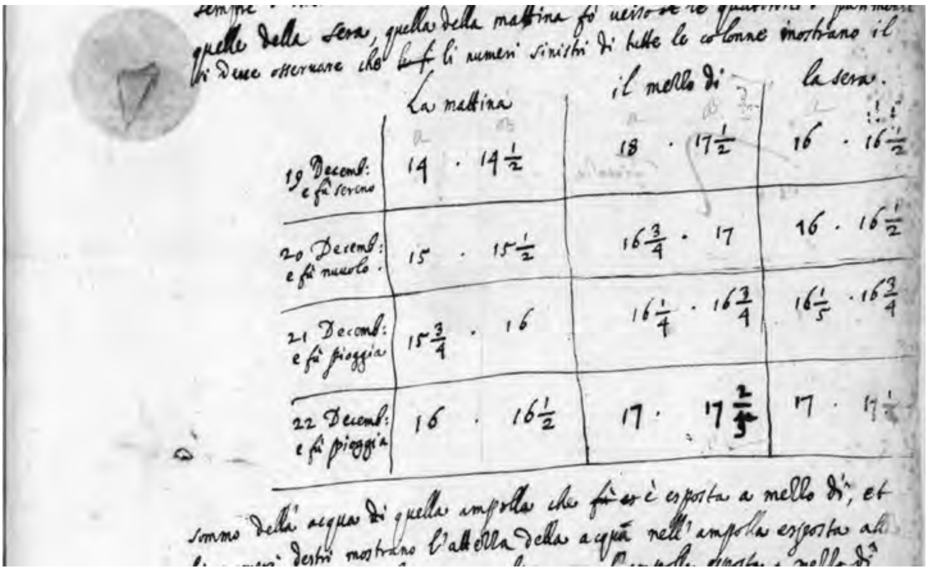
The arrangement of the data in the table was such that horizontal comparisons were possible between readings taken at different times on the same day and vertical comparisons between readings taken at the same time of day on different days. However, Terill's explanation of the arrange-

17 "Hieri ricevei una da V. R. data alli 8 del corrente, già prima avevo ricevute l'ampolline, et ho mandato una lista d'alquante osservationi, però pel' avvenire seguitarò di scrivere le mie osservazioni secondo la formula inclusa che V. R. mi ha mandato […]." Terill to Antinori, 29 December 1654. Ivi, 91r. Published in DIS II, p. 167. Italics and translation are my own.

18 "Ho ricevuta la lettera di V. R. colla scatola, nella quale erano le due ampolle per misurare la diversità del caldo et freddo," Terill to Antinori, 22 December 1654. Ivi, 87r-v. Published in DIS II, pp. 165-166. The translation is my own.

2

Figs. 2-3 – The first table of data sent by Terill to Antinori from Parma (22 December 1654. BNCF, *Gal. 307*, 87r). Su concessione del Ministero della Cultura - Biblioteca Nazionale Centrale di Firenze. È vietata ogni ulteriore riproduzione con qualsiasi mezzo.



	La mattina	il mezzo dì	la sera
19 Decemb: e fù sereno	14 · 14 1/2	18 · 17 1/2	16 · 16 1/2
20 Decemb: e fù nuvolo	15 · 15 1/2	16 3/4 · 17	16 · 16 1/2
21 Decemb: e fù pioggia	15 3/4 · 16	16 1/4 · 16 3/4	16 1/5 · 16 3/4
22 Decemb: e fù pioggia	16 · 16 1/2	17 · 17 2/5	17 · 17 [illegible]

3

ment of the data did not provide any justification for the method he had chosen.

Upon receipt of Antinori's instructions for the recording of data, Terill modified his tables. Firstly, rather than including them in the body of the letter, he presented them separately on large sheets of paper. A similar approach was adopted by individuals from other locations, who compiled and presented their data on separate sheets. The data were collected over a period of 10 to 20 days and collated on a single sheet, with the exception of Vallombrosa, which sent its data in the form of letters signed by Filiberto Casini (d. 1656) and then, from late July 1656 onwards, by Petronio Paceschi (1608-1689).

Secondly, the recordings made in Parma at different times of the day were arranged in as many rows and in a single column, rather than in different columns next to each other in the row corresponding to the day of the recording. As a result, all measurements at all times of the day on different days were placed on the same level for comparison. The potential for at-a-glance comparison between different time slots on the same day or the same time slot on different days was lost. However, the presentation of continuous data in a single column made reading easier. The layout of the data in the tables from the other locations is consistent, with the exception of Milan, where the data pertaining to the different daily measurements are always arranged in separate columns within the corresponding row for the day of observation (as observed in the original Parma dataset).

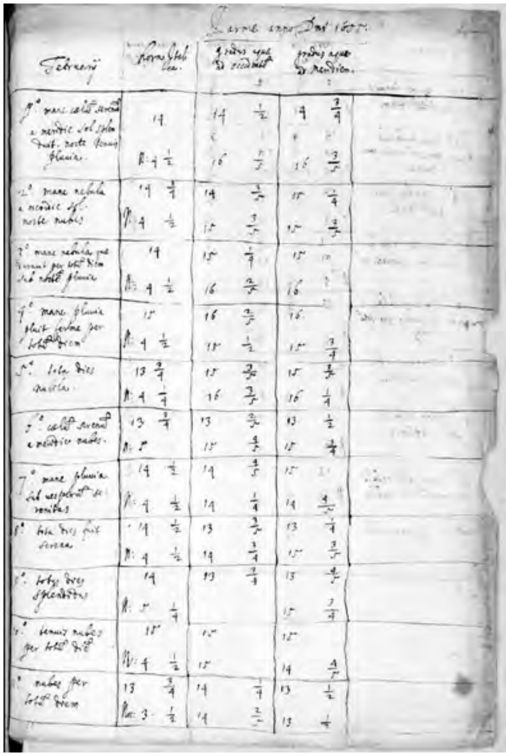
After the instructions for their compilation were received, the Parma tables underwent another noticeable change. The new version provided the exact times at which the measurements had been taken, instead of vague references to the time of day. The changes in the presentation of the data collected by Terill between the first and the subsequent transmissions correspond in time to the receipt of instructions from Antinori. The tables used elsewhere are consistent, suggesting that the changes made in Parma were based on Antinori's instructions.

Gradus Caloris et Frigoris tam versus Austrum quam Boream, observati. Anno 1655. Oeniponti.

Mense Martio.

Die	Gradus austr. Bor.
6.	mane 15---15. merid. 20---10. vesp. 16---16.
7.	16---16. 21---19. 15---14.
8.	12---11. 10---17. 16---16.
9.	16---14. 20---19. 19---19.
10.	16---16. 19---10. 17---17.
11.	15---15. 21---10. 15---17.
12.	12---14. 23---21. 10---10.
13.	10---17. 23---22. 20---20.
14.	16---17. 20---19. 10---10.
15.	14---15. 27---21. 20---20.
16.	16---17. 24---21. 20---20.
17.	17---17. 25---22. 10---10.
18.	16---16. 21---19. 10---10.

4

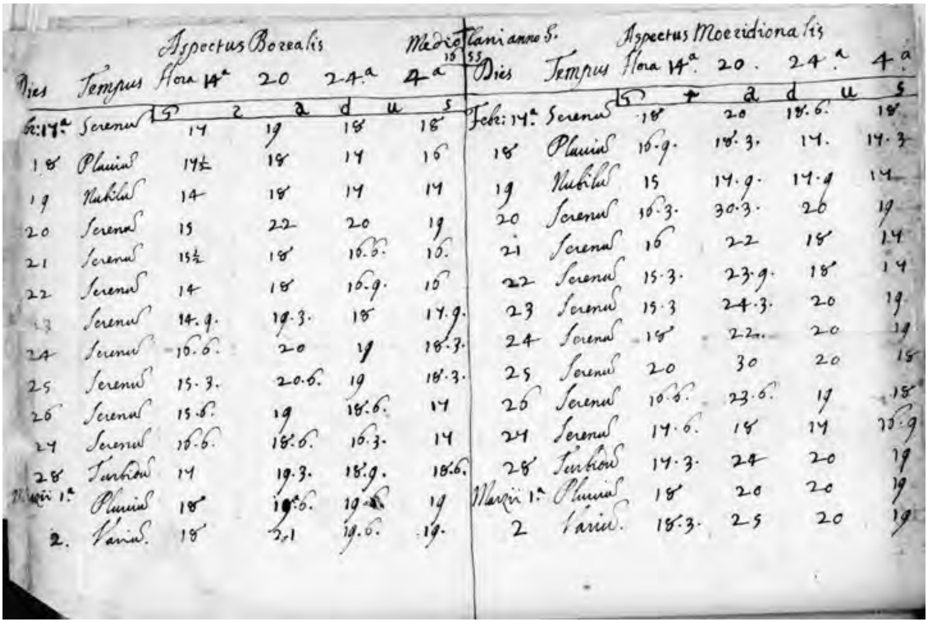


5

6

Varsaviae.	Hora	Gradus aquae a Mer	a Septent
Die 10 Maij Coelum serenum nubibus opertum	Mat media ad 6	21	11
	12 diei	31	14
	8 Vespertina	~~14~~ 29	14
Die 11a (Coeli similis constitutione)	7 matutina	23	11
	12	37	15
	9 Vespertina	26	12
Die 12	2 quadrante ad 5 matutina	21	9
	~~12 die~~ 1ma post meridiem	30	4
	9 Vespertina	25	12
Die 13 Coelum serenum	post 3m	27	15
Die 14 Coelum serenum	6 Matutina	29	13
Die 15 Serenum coelum	7ma	20	9
16 Coelum nubibus obductum	1 quadrante post quartam	17	6

7



Aspectus Borealis — Mediolani anno 1655 — Aspectus Meridionalis

Dies	Tempus	Hora 14a	20	24a	4a
		Gradus			
Feb: 17a	Serenus	17	19	18	18
18	Pluvius	17½	18	17	16
19	Nubilus	14	18	17	17
20	Serenus	15	22	20	19
21	Serenus	15½	18	16.6.	16.
22	Serenus	14	18	16.9.	16
23	Serenus	14.9.	19.3.	18	17.9.
24	Serenus	16.6.	20	19	18.3.
25	Serenus	15.3.	20.6.	19	18.3.
26	Serenus	15.6.	19	18.6.	17
27	Serenus	16.6.	18.6.	16.3.	14
28	Turbidus	17	19.3.	18.9.	18.6.
Martii 1a	Pluvius	18	19.6.	19.[illegible]	19
2.	Varius	18	21	19.6.	19.

Dies	Tempus	Hora 14a	20.	24a	4a
		Gradus			
Feb: 17a	Serenus	18	20	18.6.	18
18	Pluvius	16.9.	18.3.	17.	17.3.
19	Nubilus	15	17.9.	17.9	17
20	Serenus	16.3.	30.3.	26	19
21	Serenus	16	22	18	17
22	Serenus	15.3.	23.9.	18	14
23	Serenus	15.3	24.3.	20	19.
24	Serenus	18	22.	20	19
25	Serenus	20	30	20	18
26	Serenus	16.6.	23.6.	19	18
27	Serenus	17.6.	18	17	[illegible]
28	Turbidus	17.3.	24	20	19
Martii 1a	Pluvius	18	20	20	19
2	Varius	18.3.	25	20	19

8

Figs. 4-8 – Tables received (from the top left) from: Innsbruck (March 1655), Parma (February 1655), Bologna (January 1655), Warsaw (May 1655), and Milan (February 1655). BNCF, *Gal. 307*. Su concessione del Ministero della Cultura - Biblioteca Nazionale Centrale di Firenze. È vietata ogni ulteriore riproduzione con qualsiasi mezzo.

The thermometer does not travel in vain: a cargo of practices and issues

The considerable number of surviving tables indicates a systematic effort to collect descriptive and instrumental observational data from different geographical locations, using standardised instruments and mostly uniform survey procedures. The standardisation of both instruments and tables suggests that a comparison was made or planned,[19] but it is unclear whether this was done, how it was done, or what the objectives were.

Francesco Lana Terzi's (1631-1687) *Prodromo all'arte Maestra* (1670) offers a tantalising clue in this regard.[20] In chapter seven, which introduces the Grand Duke's thermometer, he writes:

[19] Further evidence comes from an epistle in which Antinori informs Del Buono that the climate in Milan was not yet cold enough to allow a meaningful comparison with other locations: "[…] ma fin hora mi dice il mio corrispondente che non vi è stato freddo come suole per esser misurato a paragone degli altri luoghi," Antinori to Del Buono, 4 January 1655, BNCF, *Gal. 307*, 97r-v. Published in DIS II, pp. 173-174.

[20] Also quoted by Targioni Tozzetti, 1780, I, p. 150.

An invention certainly worthy of this great prince, who […] wished to put it into practice […] also by giving it to many people in different countries, who still today observe the variations of heat and cold every day, *in order to be able to compare all the changes of the air caused by the stars in different parts of the world, and thus to deduce astronomical rules based on the inference of precisely experienced effects*.[21]

According to Lana Terzi, the meteorological network was created for the purpose of comparison, in order to study the astronomical rules underlying the changes in the air. This is a late, partial account (it is possible that Lana Terzi reinterpreted the activity in the light of his own interests), but probably well informed. Indeed, the Brescian Jesuit carried out part of his studies in Parma between 1658 and 1662, under the tutelage of Terill.[22] Furthermore, the practice of collecting data in tabular form was a long-standing feature in the field of astronomy.[23] Tables were extensively used to address a wide range of astronomical challenges and needs, including determining the time of day based on the altitude of the Sun or a fixed star, or calculating the position of a planet at a given time.

The influence of celestial bodies on meteorological phenomena was one of the topics discussed in Florence at the time of the distribution of thermometers, as evidenced by a few entries[24] in the register of "experiments made and observed by Ferdinand II, Grand Duke of Tuscany."[25] However, no comparison can be found between the data collected and celestial phenomena.

Not only are astronomical events absent from the records, but despite the use of highly sophisticated hygrometers and barometers in Florence

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[21] "Inventione degna per certo di si Gran Prencipe, il quale non contento d'haverla ritrovata con ammiratione di chi l'ha veduta, ha voluto pratticarla […] anche dando la cura a molte persone in diversi paesi, che ancor hoggi notano ogni giorno la diversità del caldo, e del freddo, per potere poscia confrontare insieme tutte le mutationi dell'aria cagionate dalle stelle in varie parti del mondo, e quindi dedurre regole d'astronomia fondate nell'induttione di effetti esattamente sperimentati." Lana Terzi, 1670, p. 63. Italics and translation are my own. Lana Terzi's statements appear to exhibit a certain degree of influence from Davisi's work (Cavalieri, 1690, p. 239).

[22] Preti, 2004.

[23] See, among others, Chabás, Goldstein, 2012. On meteorological tables, see also Daston, 2015.

[24] See, for instance: "La luna non fa differenza alcuna di freddo, e per conseguenza non è causa che l'acqua si diacci più o meno." BNCF, *Gal. 259*, 22v. Published in Targioni Tozzetti, 1780, 2, 1, p. 164. For a detailed examination of the natural-philosophical and meteorological research conducted in Florence in the early days of the Cimento, as well as the interest in the water element and cold, see Pace Gravina, 2024.

[25] This is an experimental diary detailing experiments conducted before 1657 (the year in which the Cimento began its activities), which has led some scholars to hypothesise the existence of an earlier academy. Middleton, 1971, p. 21ss.

during this period, only thermometers were sent to the various observation stations.[26]

The phenomenon under observation was the "variation of heat and cold." In order to detect a "variation," it was necessary to make several measurements, either in different places (in order to observe a possible difference between Florence and other geographical locations),[27] or over time (if the aim was to observe the variation over the course of a day or a month). From this perspective, the entry of data in a table was a natural outcome, and was not necessarily driven by more precise investigative intentions.

These aspects become particularly evident when the Florentine case is compared with the instructions given by Robert Hooke (1635-1703) to the Royal Society in 1663 "[f]or the making of a more accurate history of the change of the weather."[28] A number of the data items that Hooke suggested should be collected are not included in the tables of the Tuscan network (e.g. the strength and direction of the winds, the humidity of the air and its pressure, or special events such as extraordinary tides, comets, or the appearance of new stars). Only the "Degrees of Heat and Cold in the Air" and the "constitution and face of the Sky" are usually included in the records sent to Antinori.

Analyses of the other manuscripts produced in close temporal proximity to the establishment of the network and its activities offer insights into the perception of the instrument's potential for analysing the natural world.

A study of the few extant letters that Riccioli wrote from Bologna to accompany his tables reveals some intriguing details. First, it can be observed that the 'ampoules,' accompanied by instructions for data collection, were sent to Milan via the rector of the Collegio di Santa Lucia in Bologna, where Riccioli taught.[29] Second, upon receipt of the thermometers, Riccioli informed Antinori of his wish to receive a hermetically sealed ampoule, sim-

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[26] As previously stated, Viviani proposed that barometric tubes be sent to various other regions in addition to thermometers. However, this request was not followed up. See note 25.

[27] In this regard, consider the words of Urbano Davisi in his edition of Galileo's *Trattato della Sfera*: "[…] e similmente si potrà comi stromenti di detta sorte e fatti con l'istessa proportione, sapere il caldo e freddo di qualsivoglia Provincia, o luogo, essendosi fatta per inanzi l'osservatione […]." Cavalieri, 1690, p. 239.

[28] Robert Hooke, "For the making a more accurate history of the changes of weather," [1663], RS, *Cl.P/20/24*.

[29] "Già un pezzo fà il nostro P. Rettore ha mandato a Milano la scattolina con la lettera." Riccioli to Antinori, 2 January 1655, *Gal. 307*, 95r, published in DIS II, pp. 343-344.

ilar to those recently delivered for the measurement of cold. This ampoule was to be filled with "*elixir vite*" or "spirit of vitriol." The purpose of this instrument was to enable the Jesuit from Bologna to conduct experiments to determine whether the spirit in question would pass through the glass and whether the glass had pores or not.[30] This is a clear example of Riccioli's own work and not of the whole network. Nevertheless, it illustrates the possible impact on the natural philosophical level generated by the transit of the thermometer within its receivers.

A testimony close to the time of the network's creation is also provided by Prince Leopold de' Medici. In 1657, the Grand Duke's brother wrote to Giovanni Alfonso Borelli (1608-1679) suggesting, if not the purpose for which the network had been created, at least one of its possible functions:

> In order to compare these observations, it would be proper for the Most Serene Duke to order his religious correspondents, who take into account the observations of the thermometers and other daily observations of the constitutions of the air, to send them the rules of the hours in which they should observe them, and of what they should observe, *so that from the different constitutions of the airs on our sides we may better understand every more significant accident of these quicksilver instruments*.[31]

In a lost letter, Borelli presented Leopold with the problem of mercury, which seemed to behave differently than usual in the barometric tube when the environment was more humid. According to the Prince, the thermometer could be used to better understand this problem. Furthermore, the meteorological network could provide valuable insights for the work of the Accademia del Cimento in its investigations into the constitution of the air, which, as the Leopold's words indicated, was already a central focus of the network.

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30 "[…] desidererei un ampolla piena di qualche estratto spiritosissimo, come a dire di Elixir vite o di Spirito di vitriolo, ma sia piena et sigillata col sigillo Hermetico, cioè col vetro come quelle che ha mandate per le canne del freddo e ciò per esperimentarsi se col tempo quello umore transpira per il vetro, e certificare alcuni di questi filosofi se il vetro ha pori o no." Ibid. For further insight into this topic and the relationship between Riccioli and Florence during this period, see Ruggero Pace Gravina's doctoral thesis: Pace Gravina, 2024. In his thesis, Pace Gravina also identifies a possible feedback effect of Riccioli's demands on Florentine research.

31 "Saria ben cosa aggiustata che il Ser.mo G. Duca per confrontare bene queste osservazioni ordinasse, et ai suoi corrispondenti religiosi che tengon conto delle osservazioni de termometri, et altre ancora giorno per giorno delle costituzioni dell'aria con mandare ad essi la norma delle ore, nella quale la devono osservare, e di quello devono osservare acciò che dalla costituzione diversa delle arie a noi laterali si potessi poi meglio congietturare ogni accidente più considerabile di questi strumenti dell'argento vivo." Leopold to Borelli, 15 December 1657, BNCF, *Gal. 282*, 2r-3v. Italics and translation are my own.

Three weeks later, for similar reasons and following discussions with the Grand Duke, Vincenzo Viviani proposed sending barometric tubes with thermometers "to lower Romagna, Lombardy, and other regions [...] where the tramontane of the season and the *marino* of summer exert effects that are contrary to those observed in our country and in others, particularly as regards the production of humidity and warmth in the air."[32] Among the proposals for experiments preserved in the Galileo collection is an undated sheet in Viviani's own handwriting. The document proposes the use of thermometers and "similar" instruments to determine whether there is a difference between "the ice of different countries and places much more northern and southern than ours."[33]

Finally, it should be noted that in 1667 the *Saggi* presented thermometers as "instruments for discovering the alterations of the air that result from heat and cold."[34] If nothing else, this aspect substantiates John P. McCaskey's reflections on the concept of temperature and its dependence on the thermometer.[35]

The surviving records do not provide precise information about the intentions behind the establishment of the network or the effects of the data collection. They do, however, reflect the complexity of the practices, topics, and issues that the instrument carried with it. The long journey of the thermometer included numerous regions and contextual shifts, from Tuscany to Milan, Parma, Bologna, Innsbruck, and Warsaw.[36] In this silent journey, the thermometer brought with it a standardised practice (Antino-

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32 "Quanto all'abbassar et alzare dell'argento vivo, fino a che io non venga persuaso da più potenti ragioni, non so staccarmi da' miei concetti significati già in parte al Ser.mo Gran Duca, con altro di poi a V.A.S., oltre a quel che appresso m'è sovvenuto. Estimerei bene, per comprovazione più spedita, il mandar di questi tali stromenti, insieme con i termometri, nella Romagna bassa, nella Lombardia et altrove qui intorno, dove, per quel che io intendo, il tramontano di questo tempo et il marino d'estate e così altri venti che regnino, operano effetti contrarij a ciò che segue nel nostro et in altri paesi e particolarmente circa al produrre umidità e caldezza nell'aria," Viviani to Leopold, 5 January 1658. BNCF, *Gal. 275*, 53. Italics and translation are my own.

33 "Far esaminare nella freddezza con termometri e simili se i ghiacci di paesi diversi e posti ne' luoghi dei settentrionali e meridionali assai più di noi, si trovi differenza." BNCF, *Gal. 269*, 81r. Published in DIS I, p. 434. The translation is my own.

34 "[...] "strumenti per conoscer l'alterazioni dell'aria derivanti dal caldo e dal freddo," *Saggi*, 1667, p. i. Translation in Middleton, 1971, p. 92.

35 McCaskey, 2020.

36 These destinations were probably primarily religious and connected to Luigi Antinori's personal networks. The thesis of a mainly religious circuit is corroborated by Leopold's letter to Borelli, quoted above, in which the prince refers to the "religious correspondents [of the Grand Duke] who take account of the thermometers' observations."

ri's instructions) and a multitude of potential questions about the nature and constitution of air, the glass from which it was made, and the functioning of the instrument itself.

The plethora of tables produced in different years and places in the early stages of the Florentine thermometer's development illustrates the attempt at "supervision through time and space" which Lorraine Daston so powerfully emphasises.[37] A strikingly uniform and systematic effort to collect and present data through 'at-a-glance' images is evident in the tables of the Medici network. However, the case analysed by Daston – the production of weather tables following Hooke's 1663 speech – represents a somewhat more mature stage. At this point, new thermometers were being designed and manufactured with the intention of perfecting an instrument that had ceased to be a novelty. Hooke's instructions were more detailed and comprehensive, and it can be surmised that they were driven by clearer objectives.

In both cases, the tables do not seem to have led to the identification of specific regularities or patterns. With regard to the Florentine case, the difficulty of deriving a "rule" from the set of data is made explicit in the *Saggi*, which after introducing the reader to certain types of thermometers and the hygrometer, states:

> It is true that no certain rule can be given in these matters, for they can vary because of many circumstances, not only with the season and the wind but also with the region and the country itself, so that the properties of the above-mentioned winds sometimes change.[38]

The book is remarkably cautious in its approach and avoids presenting any theoretical conclusions, even those that some academicians had already reached before its publication. However, the lack of evidence showing that the data was subjected to any real analysis makes the above statement worthy of serious consideration.

Nevertheless, while the documents from the Florentine archives largely confirm Daston's theses in this respect, they also reveal new and different elements. In the Tuscan case, the material instrument plays a predominant role. The thermometer, which had just been manufactured for the first

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[37] Daston, 2015.

[38] "Vero è che di queste cose non si può dare una certa regola, potendo elleno variare per moltissimi accidenti non solo della stagione e dell'aria, ma eziandio de' luoghi e de' paesi stessi, per ragion de' quali i giudizzi di detti venti alcuna fiata si mutano." *Saggi*, 1667, p. xv. Translation in Middleton, 1971, pp. 100-101.

time, was the most important component of the network. It was made by a single craftsman (the so-called "Gonfia")[39] in the service of the Grand Duke in several uniformly calibrated pieces and then sent to the various correspondents. The standardisation of data collection came primarily from the standardisation of the instrument. The thermometer was sent to individuals who were likely unaware of its existence, bringing with it a host of concerns and questions that finally began to be answered in the years following Hooke's speech in 1663.

An instrument that was not depicted or described on paper, but was tangible and identical for all, began to cross borders and enter different contexts, along with a letter that explained its placement, the time of its use, and the manner of its operation. When data collection failed to reveal regularities or patterns in the course of meteorological phenomena, the thermometer brought regularities and patterns in the manner in which they could be observed.

Second Act. The journey of a gift between diplomacy, personal networks, and curiosity: from Florence to Paris, via Poland

The Paris Observatory archives preserve the oldest documented thermometric measurements ever made in France.[40] The manuscript, discovered by Abbot Maze in 1895,[41] is a collection of observations made by Boulliau in Paris between 25 May 1658 and 19 September 1660 using a Florentine thermometer. The register is a daily record, with several observations made at different intervals throughout the day (with occasional short gaps in the record). It consists of four columns giving the date of the observation, the time it was made, the temperature measured by the thermometer, and notes on weather conditions, including wind direction, the presence of rain, snow, thunderstorms, hail, and other details. Between 25 March and 19 May 1659, there are two additional columns, which I will discuss later (Fig. 9). Boulliau carried out this activity almost daily for over two years, suggesting a circumstantial rather than a fleeting interest, triggered by the arrival in Paris of news of the thermometer and then of a few specimens.

39 Zanetti, 2023.

40 Boulliau, "Ad Thermometrum observationes anno 1658 Parisiis; thermometrum Florentiae fabricatum," BOP, *B5-12*.

41 Maze, 1895a.

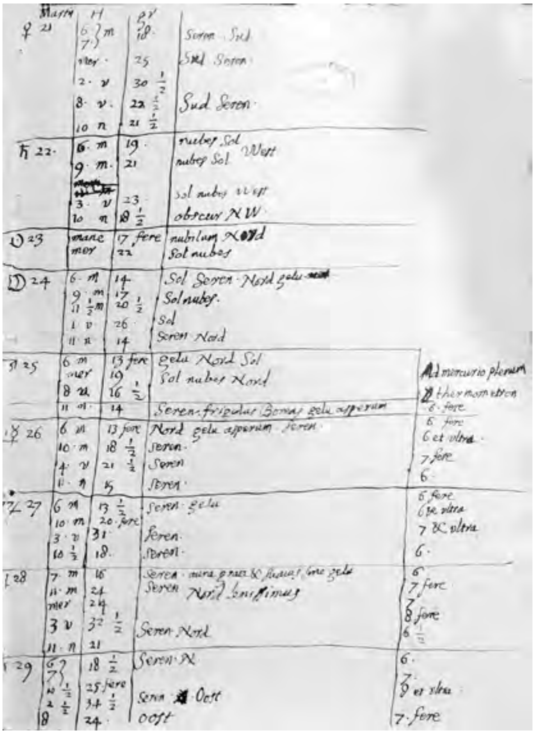

Fig. 9 – A page from Boulliau's register of observations (March 1659). BOP, B5-12, 32v.

Boulliau's register has been of interest to historians studying the development of meteorology in the seventeenth century, particularly in the first half of the twentieth century.[42] More recently, his data have been used in research into the history of climate.[43] Maze's study and subsequent research identified the provenance of Boulliau's first thermometer. However, new in-depth research has brought to light previously undiscovered documents that provide a better understanding of the dynamics of the instrument's circulation, as well as the mechanisms that led the French astronomer to take an interest in the Florentine thermometers and use them in Paris.

The Polish milieu: Pierre Des Noyers, Paolo del Buono, and Tito Livio Burattini

The first Florentine thermometer was sent to Boulliau from Warsaw by Des Noyers, the secretary to Maria Luisa Gonzaga-Nevers (1611-1667), Queen of Poland.[44] Boulliau and Des Noyers met at least twice in Paris between 1650 and 1655 through Johannes Hevelius (1611-1687).[45] Their correspondence was intense, with almost weekly exchanges. Over 600 letters have survived. Although their exchanges mainly concerned political news,

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[42] In addition to Maze's work, see Birembaut, 1958; Boffito, 1927; Middleton, 1966, pp. 35-38.

[43] Camuffo et al., 2020; Rousseau, 2013.

[44] Maze, 1895b, pp. 230-232.

[45] Nellen, 1994, p. 228 ff. On the relationship between Des Noyers and Boulliau, see also Mallet, 2021.

they also contained information of a more varied nature. Des Noyers was primarily a political figure, but he was also in contact with several scholars residing in Poland, including Valeriano Magni (1587-1671) and Tito Livio Burattini (1617-1680). He facilitated communication between French scholars such as Adrien Auzout (1622-1691) and Pierre Petit (1594-1677) and those in Poland. His extensive correspondence provides information on the technical innovations and the natural philosophical debates that were taking place Poland at the time, with interlocutors such as Mersenne, Pascal, Hevelius, Boulliau, and others.[46]

The earliest documented reference to a thermometer in the Des Noyers-Boulliau exchange is in connection with Paolo del Buono. In the spring of 1656, Boulliau was informed by his friend, then in Głogów, that Del Buono, "mathematician to the Grand Duke," was in Vienna and was making thermometers.[47]

Del Buono, like his brother Candido (1618-1676), was born in Florence and studied in Pisa under Famiano Michelini (1604-1665), a pupil of both Galileo in Florence and Benedetto Castelli (1578-1643) in Rome. An examination of Paolo Del Buono's correspondence of January 1655 with the Jesuit Father Antinori[48] suggests his involvement in the establishment of the Medici meteorological network. Antinori sent Del Buono the first tables that received from Parma and informed him that he had sent the thermometers to Warsaw and Innsbruck. Paolo Del Buono is the only one of Antinori's correspondents in Florence whose letters survive from the time when Antinori was engaged in the distribution of thermometers. He also played a significant role in the relations between Florence and Poland. Indeed, in 1655 Del Buono began serving Emperor Ferdinand III of Habsburg (1608-1657) after being recommended by Vittoria della Rovere (1622-1694), the Grand Duchess Consort of Ferdinand II de' Medici.[49] On 20 May 1655, he sent a letter from Bratislava to Ferdinand II, reporting on a recent meeting with Ferdinand III two days earlier. He stated that he had conveyed a message from the Grand Duke to the Emperor, and that he had discussed with him his invention for extracting water from mines.[50]

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46 On Des Noyers, see in particular: Mallet, 2021; Grell, 2019; Grell, 2013.

47 Des Noyers to Boulliau, 30 March 1656, BNF, *Fr. 13019*, 80r. Published in Des Noyers, 1859, p. 125.

48 Antinori to Del Buono, 4 and 9 January 1655, quoted in notes 11 and 15.

49 Della Rovere to Ferdinand III, 28 September 1654, BNCF, *Gal. 282*, 4r. Published in DIS II, p. 166.

50 The invention earned Del Buono a licence from Ferdinand III to work the mines he had drained using his method, keeping 90% of the ore extracted for his own use. Del Buono

The contents of Ferdinand II's letter to the Emperor are unknown, but Del Buono's letter refers to at least one previous one he had sent to the Grand Duke from across the Alps.[51] Del Buono's later messages to Florence refer to the "degrees of heat" recorded in Bratislava on the day of Leopold I's coronation as King of Hungary with the "instrument of heat and cold."[52] The exact identification of the thermometer used for the aforementioned measurements remains uncertain. It is uncertain whether this thermometer was the one sent by Antinori in December of the previous year, or whether Del Buono had brought an additional thermometer from Florence. It is also possible that he had already constructed a thermometer based on the Florentine one. Nevertheless, the fact that the letter also mentions wintertime measurements seems to rule out the latter hypothesis.

Information on the life and activities of Paolo del Buono is scarce, as is his surviving correspondence.[53] At some point during his time in Germany, Del Buono was appointed president of the Imperial Mint and travelled extensively to the imperial mines in the Carpathians, as well as those in Styria, Bohemia, and Upper Hungary, often with his student Geminiano Montanari (1633-1687). The surviving correspondence suggests that Del Buono maintained constant and significant communication with the Medici court even after he left Florence. However, it does not provide sufficient evidence to confirm or deny Del Buono's presence in Warsaw on the days in May when the thermometer readings recorded in the tables kept in Florence occurred.

Another Italian scholar lived in Poland during this period. Tito Livio Burattini[54] from Agordo (Belluno) moved to Krakow in the 1640s. After the coronation of Marie Louise Gonzaga-Nevers (spouse of Ladislaus IV and later of John II Casimir) in 1648, Burattini was appointed royal architect in 1650. Later, in 1652, he was awarded a contract for the lead and silver mines in Olkusz. He then became the Queen's treasurer and developed a close relationship with her secretary, Pierre Des Noyers. He took part in a number of important diplomatic missions. It is unclear whether he was involved in the measurements

to Ferdinand II, August 1655 and Del Buono to Leopold, 27 August 1655, BNCF, *Gal. 286*, 38r-v and *Gal. 275*, 38r-39v. Published in DIS II, pp. 247-249.

51 Del Buono to Ferdinand II, 20 May 1655, BNCF, *Gal. 286*, 24r-25r. Published in DIS II, pp. 221-222.

52 Del Buono to Leopold, 30 June 1655 and 27 August 1655, *BNCF, Gal. 286*, 26r-27r and *Gal. 275*, 38r-39v. Published in DIS II, pp. 232-233 and 247-249. The coronation of Leopold I as King of Hungary occurred on 27 June 1655 in St. Martin's Cathedral in Bratislava.

53 On Paolo del Buono, see Rotta, 2021, pp. 22-35; Middleton, 1969 and 1971, pp. 30-31; Nelli, 1759, pp. 104-107; Targioni Tozzetti, 1780, 1, pp. 438-442.

54 On Tito Livio Burattini, see Tancon, 2005; Targosz, 1977.

made in Warsaw in May 1655, but he was present in the city in July of that year.[55] Burattini and Del Buono are both important figures for understanding the spread of the 'Florentine' thermometer in Poland and its introduction in Paris, whether or not they were directly involved in its use in Warsaw.[56]

From Florence to Paris via Warsaw: Boulliau receives the first thermometer

As mentioned above, in the spring of 1656 Des Noyers informed Boulliau of Del Buono's construction of thermometers in Vienna. Des Noyers briefly introduced the instruments to his French acquaintance, explaining that the water in Del Buono's thermometers varied in height depending on whether it was heated or cooled. Des Noyers' lack of understanding of liquid-in-glass thermometers is evident at this point. He claimed that Del Buono's instruments behaved differently from standard thermometers, with the water column expanding when heated (owing to rarefaction) and contracting when cooled:

> He makes thermometers four and a half inches long, of which I have one, which show opposite effects compared to the others; the heat raises the water and makes it rarefied, while the cold lowers it and increases the sphere of the air.[57]

Des Noyers developed an interest in atmospheric phenomena. On his arrival in Poland, despite having no access to instruments, he began to make meteorological observations.[58] Des Noyers' description of Del Buono's gauges suggests that the thermometers which he later became familiar with were probably air thermometers. Therefore, it is most unlikely that he was involved in the measurements made in Warsaw using the Florentine thermometers, or that he received any specific information about them.

The Queen of Poland's secretary did not provide Boulliau with any additional information or illustrations. Moreover, there are no further references to thermometers in the extant correspondence until August 1657. The scant details from Głogów do not seem to have aroused Boulliau's

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55 Burattini to Hevelius, 1st July 1655, BNF, *NAL 1639*, 48r.

56 An examination of the handwriting of the notes in the table preserved in Florence reveals that it does not correspond to that of Paolo del Buono or Tito Livio Burattini.

57 "Il fait des thermomètres de 4 pouces et demi de longueur, don't j'en ai un, qui font leurs effets contraires aux autres; le chaud y fait hausser l'eau en la raréfiant, et le froid la fait abaisser et augmenter la sphere de l'air." Des Noyers to Boulliau, 30 March 1656, BNF, *Fr. 13019*, 80r. Published in Des Noyers, 1859, p. 125.

58 Des Noyers frequently included general notes on weather and temperature in his letters to Roberval, as noted by Targosz (Targosz, 1982, p. 159).

curiosity, and Des Noyers apparently had no further information to share with his friend. It was not until Burattini returned from Italy after travelling on behalf of Marie Louise Gonzaga-Nevers that the instrument began to attract interest.[59]

In 1657, Burattini returned with several instruments, including thermometers donated by Grand Duke Ferdinand II.[60] On 26 August, Des Noyers sent Boulliau a description of the Florentine thermometers that Burattini had brought with him:

> Mr Boratin (sic), whom the Queen had dispatched to Italy, has returned; he has brought back with him a number of mechanical beauties that I should like to share with you. There are hermetically sealed thermometers, which can be carried in a pouch, and are only about four or five inches long; there are also other inventions made of sealed glass, for comparing the weight of all liquids; others for measuring the lightness of wines; others for measuring the heat of a feverish person and the movement of the pulse; others for cooking eggs to the desired degree of doneness. The Grand Duke has gifted him with all this; he has also occasionally talked about you with Prince Leopold, who holds you in high regard.[61]

A considerable amount of paper was subsequently produced in connection with the thermometer. In the absence of a rapid and secure method of transmitting a physical specimen of the instrument to his Parisian colleague, Des Noyers sent him an illustration, a description of how it worked and, at Boulliau's request, an account of the steps required to make a similar instrument.

On 17 November, Des Noyers informed Boulliau, presumably at his request, that the instrument was too fragile to be transported in the customary manner and that it would undoubtedly have been damaged in tran-

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[59] Two letters written by Paolo Minucci to unidentified individuals help to define the temporal parameters of Burattini's sojourn in Florence. On 28 June 1656, Minucci indicated that Burattini was in Florence, while on 22 September of the same year he stated that "Signor Tito Livio left yesterday morning together with two German gentlemen." Minucci to unknown, 28 June and 22 September 1656. BNCF, *Gal. 285*, 17r-v and 18r-19v. Published in DIS II, pp. 356 and 362-364.

[60] Tancon, 2005, p. 62.

[61] "M. Boratin, que la reine avait envoyé en Italie, en est revenu; il a apporté quelques gentillesses de mécanique dont je voudrais vous pouvoir faire part. Il y a des termomètres scellés hermétiquement, qui se portent en la pochette et qui n'ont qu'environ quatre à cinq pouces de longueur; il y a d'autres inventions de verre scellé pour comparer la pesanteur de toutes les liqueurs; il y en a d'autres qui mesurent les vantosités qui sont les vins; d'autres pour mesurer la chaleur d'un fébricitant et le mouvement du pouls; d'autres pour faire cuire les oeufs sans qu'on puisse manquer de les mettre au degré de cuisson qu'on veut. Le grand-duc lui a fait présent de tout cela; il s'est aussi quelquefois entretenu de vous avec le prince Léopold, qui a pour vous beaucoup d'estime." Des Noyers to Boulliau, 26 August1657. BNF, *Fr. 13019*, 293. Published in Des Noyers, 1859, p. 342. The translation is my own.

sit.[62] The accompanying illustration, a simple pen sketch, was probably drawn by Des Noyers himself and served to illustrate to Boulliau the shape and size of the instrument for ease of reproduction. The drawing illustrates the division of the tube into 50 degrees (Fig. 10). According to Des Noyers, the inside of the tube was to be filled with a solution of "wine spirit that condenses in the cold and expands in the heat." Boulliau could ask an enameller to reproduce it, but the resulting specimen would necessarily differ from all the others. Indeed, the Grand Duke's thermometers were used to measure the difference between heat and cold in different regions and were therefore calibrated uniformly. Consequently, the reproduction would necessarily lack this Florentine-specific calibration.[63]

Fig. 10 – Des Noyers' drawing of the Florentine thermometer. BNF, *Fr. 13019*, 308r.

About two months later, Des Noyers returned to the subject, informing Boulliau that:

> The Grand Duke's thermometers are exactly like the one in the figure I sent you, made of very clear crystal and graduated by small enamel dots, but on the thermometer itself; the tens are slightly larger dots of white enamel. The thermometer should be hung with a small ribbon, not in the room where the air is more temperate, but outside a window, so that it is exposed to the air.[64]

Regrettably, Boulliau's letters to Des Noyers are no longer extant. Des Noyers's replies, however, indicate that by then the instrument had attracted considerable attention from the French astronomer. On 24 March 1658, the secretary to the Queen of Poland finally informed his friend that he had managed to send him one of the two specimens of the instrument in his possession.[65]

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62 "Si je vous pouvais envoyer un thermomètre de Florence, je le ferais de bon coeur; mais il se romprait assurément étant dans un paquet de lettres." Des Noyers to Boulliau, 17 November 1657, ivi, 305v-306r. Published in Des Noyers, 1859, p. 353.

63 "On met dedans de l'esprit-de-vin, qui se condense au froid et se dilate au chaud; toute la différence qui sera entre celui que vous ferez faire, c'est qu'il ne sera pas ajusté au point de ceux du grand duc, et qu'ainsi le vôtre ne correspondra à aucun autre," ivi, 306r, p. 354. A reproduction of the drawing (BNF, *Fr. 13019*, 308r) is not included in Des Noyers, 1859.

64 "Les thermomètres du grand-duc sont, justement, comme la figure que je vous ai envoyée, d'un cristal fort clair, et gradués par des petits point d'émail, mais sur le thermomètre même; les dizaines sont des points un peu plus gros d'émail blanc. Le thermomètre se pend avec un petit ruban, non pas dans la chambre où l'air est plus tempéré, mais dehors d'une fenêtre, afin qu'il soit à l'air," Des Noyers to Boulliau, 20 January 1658, BNF, *Fr. 13020*, 9r-v; published in Des Noyers, 1859, p. 376.

65 Des Noyers to Boulliau, 24 March 1658, published in Des Noyers, 1859, pp. 391-392. The original letter has not been located.

The thermometer would only reach Boulliau towards the end of May.[66] As a result of the long wait, Boulliau likely requested further information, as Des Noyers was still sending details of the construction and calibration of the instrument on 12 May.

Since you want to make thermometers on the model of the one I sent you, I'll tell you how to adjust them so that they are all at one point. The Grand Duke's enameller has one that he always keeps, which serves as a model for the others; he leaves it for some time in a bucket of ice with those that he wants to seal, which are already filled with wine spirit, in order to reduce this spirit to the amount corresponding to the degree of his model, adding or removing this spirit as necessary; and when they are reduced to the same degree, he seals them hermetically, so that, being all at the same point, one can judge the difference in heat in different places. He does not put coloured wine spirits in them, because over time they stain the glass and reduce the apparent quantity.[67]

Such detailed information on the method of thermometer construction in Florence would not be published until 1667 with the *Saggi*.[68] However, the information passed on by Des Noyers provides a clear illustration of the extent to which information about the Florentine instrument was disseminated in a more informal setting at this time.

On 24 May, the instrument was in the hands of Boulliau,[69] who promptly began a series of observations.[70] Between May and June 1658, he filled 68 pages with observations, noting the thermometer readings and making daily remarks on the weather.[71] The register has often been interpreted by scholars as evidence that Paris became part of the Medici meteorological

[66] Des Noyers to Boulliau, 16 June 1658, BNF, *Français 13020*, 52r-53r, published in Des Noyers, 1859, pp. 415-416.

[67] "Puisque vous voulez faire des thermomètres sur le modèle de celui que je vous ai envoyé, je vais vous dire comme on les ajuste afin qu'ils soient tous à un point. L'émailleur de m. le grand-duc en a un qu'il garde toujours, qui sert de modèle pour les autres; il le laisse quelque temps avec ceux qu'il veut sigiller, qui son déjà remplis d'esprit-de-vin, dans un seau de glace, afin de réduire cet esprit à la quantité correspondante au degré de son modèle, ajoutant ou òtant de cet esprit selon la nécessité; et lorsqu'ils sont réduits à un même degré, il les sigille hermétiquement, ce qu'il observe, afin qu'étant tous à un même point, on puisse juger de la différence de la chaleur en divers lieux. Il n'y met pas de l'esprit-de-vin coloré, parce qu'avec le temps il salit le verre et en diminue la quantité apparente." Des Noyers to Boulliau, 12 May 1658, BNF, *Fr. 13020*, 40r-v. Published in Des Noyers, 1859, pp. 405-406.

[68] *Saggi*, 1667, pp. II-XI.

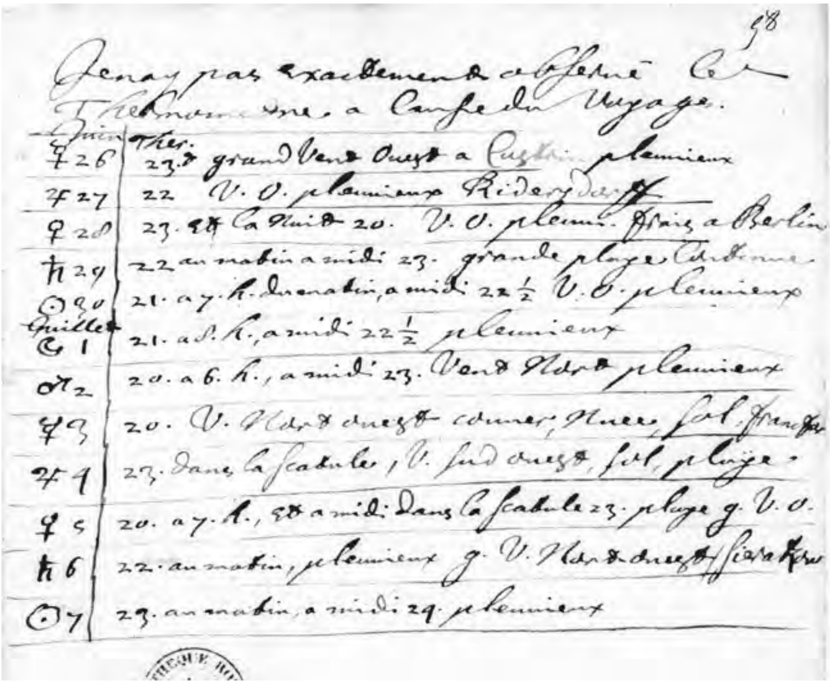
[69] Des Noyers to Boulliau, 16 June 1658, BNF, *Fr. 13020*, 52r-53r. Published in Des Noyers, 1859, pp. 415-416.

[70] BOP, *B5-12*.

[71] See also Camuffo et al., 2020.

network. However, there is no evidence that it was ever sent to Florence, and the structure of the tables it contains differs somewhat from those previously discussed. They are divided into three columns (day, degrees, sky conditions) and the column containing the temperature includes the time, often generic ('mane,' 'vesp.'), at which it was taken.

With the arrival of the thermometer in Paris, the subject of the instrument gradually receded into the background in the correspondence between Des Noyers and Boulliau. However, in their almost weekly exchanges, the two friends regularly recorded the temperatures they had observed with their thermometer in the locations where they were.[72] These records, at least in the case of Des Noyers,[73] were presented in the form of a small table placed at the end of the letter (Fig. 11). It should



58

Je n'ay pas exactement observé le Thermometre a cause du voyage.

Juin	Ther.
☿ 26	23. grand Vent Ouest a Custrin pluvieux
♃ 27	22 V. O. pluvieux Ridersdorff
♀ 28	23. et la Nuict 20. V. O. pluvieux. frais a Berlin
♄ 29	22 au matin a midi 23. grande pluye continue.
☉ 30	21. a 7. h. du matin, a midi 22½ V. O. pluvieux
Juillet ☽ 1	21. a 8. h., a midi 22½ pluvieux
♂ 2	20. a 6. h., a midi 23. Vent Nord pluvieux
☿ 3	20. V. Nord ouest couvert, Nues, sol. frais
♃ 4	23. dans la scatule, V. sud ouest, sol, pluye.
♀ 5	20. a 7. h., et a midi dans la scatule 23. pluye g. V. O.
♄ 6	22. au matin, pluvieux g. V. Nord ouest fort frais
☉ 7	23. au matin, a midi 24. pluvieux

Fig. 11 – One of the temperature recording tables sent by Des Noyers. BNF, *Fr. 13020*, 58r.

[72] See for instance Des Noyers to Boulliau, 16 and 23 June, 7 and 28 July, 4 and 25 August, 8 and 23 September and 1 October 1658. BNF, *Fr. 13020*, 52r-100r. Most of these letters were not included in Des Noyers, 1859. It should be noted that the volume in question often contains only partial transcriptions and no accompanying tables or drawings. See also Mallet, 2021, p. 188.

[73] As previously noted, Boulliau's letters to Des Noyers have been lost. Boulliau's transmission of data can only be inferred from the references Des Noyers makes to them in his replies.

be noted that the style of the table is very different from that previously considered.

Boulliau turns to Prince Leopold

Although they gradually stopped discussing thermometers, the topic suddenly resurfaced in Boulliau's communications with Prince Leopold.

Boulliau and Leopold de' Medici had been in contact since 1649, exchanging at least two or three letters a year.[74] Most of their discussions concerned astronomy, for Leopold's interest in the subject undoubtedly contributed to the establishment and consolidation of ties with the French astronomer. When Boulliau first wrote to Leopold about thermometers, they had already exchanged observations on eclipses and the comet of 1652. Leopold had also presented Boulliau with a telescope in 1651.[75]

It is not surprising, therefore, that Boulliau made a request to the Prince regarding the thermometers he had learned about. On 30 August 1658, Boulliau asked Leopold de' Medici to kindly provide him with a copy of all the different thermometers Des Noyers had described to him on Burattini's return to Poland.[76] The thermometers were sent to Boulliau by sea in December of the same year, in two different boxes and shipments, to ensure that at least one would arrive intact.[77]

A few months later, Boulliau wrote to the Prince that, once he received the instruments, he would use them to experiment with the constitution of the air and the various spirits of wine, promptly reporting the results. He then reported some measurements taken in Paris "in the hottest heat" and "in the harshest and most severe cold." He explained that the measurements had been taken with a thermometer that he had "received the previ-

[74] On Boulliau's network and his correspondence with Leopold de' Medici, see Hatch, 1998, 2009.

[75] Leopold to Boulliau, 30 March 1651, BNF, *Fr. 13039*, 38r.

[76] "Hisce porro literis Celsitudinem Tuam impensissime rogo, ut benevolentiam in me suam thermometra mihi donando demonstret, quae scilicet Serenissimus Magnus dux accurate fabrefieri curat, non solum autem quae aeris produnt temperaturam habere vellem, sed et illa, quibus immixti vino ventosi spiritus deprehenduntur. Addenda quoque erunt quae febricitantium calorem metiuntur, quaeque sorbilibus ovis apte riteque coquendis inserviunt," Boulliau to Leopold, 30 August 1658, BNCF, *Gal. 275*, 113r-115v.

[77] "Per via di mare, acciò meno patischino, invio a V.S. gl'istrumenti di vetro addimandati da lei. Ne mando due mute, et in due cassette, et in diversi tempi, acciò se una patisse qual che male incontro, possa sperarsi che l'altra giunga a salvamento." Leopold to Boulliau, 23 December 1658, BNCF, *Gal. 282*, 8r. Boulliau reported to Des Noyers, who replied: "[…] J'attend avec impatience votre lettre du 28 février, pour voir l'inventaire de ce que vous aura envoyé M. le prince Léopold," Des Noyers to Boulliau, 27 March 1659. Des Noyers, 1859, p. 501.

ous year from a friend in Poland," who had informed him that "it had been made in Florence." Finally, he added that he had observed very thin frost and ice even when the thermometer read 15 degrees, although the friend (Des Noyers) had warned him that above 14 degrees there was no frost and water did not turn to ice.[78]

In order to provide Boulliau with information about the thermometer he had received from Poland, Leopold asked Boulliau to send him a drawing of its dimensions, to tell him how many degrees it was divided into, and to add the report of an experiment. In particular, he asked him to place the thermometer in crushed ice, leave it for an hour and then observe how much and to what degree the liquid in the thermometer fell; or to leave it immersed for the time necessary for the liquid in the thermometer to fall to its lowest level.[79] Both Des Noyers' information and Leopold's request were based on observations and considerations made in Florence. Indeed, an undated document in a copyist's hand explains that:

> When placed in snow or ice, it [the fifty-degree thermometer] is regularly reduced to 13 1/2 degrees, although the coldest air in Florence reduces it to seven. And [...] when this instrument, kept in the open air in winter, is at 14 degrees, the water in the country usually freezes.[80]

Boulliau did not carry out the requested experiment. However, on 4 April 1659, he wrote to Leopold to announce that the instruments sent from Florence had arrived. The letter was accompanied by a life-size drawing. However, the instrument depicted was not the thermometer that Des

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78 "Vitreis illis organis, quae liberalitati tuae ac munificentiae debeo, ubi accepero, utar in experiundo apud nos tam aëris constitutionem, quam vinorum variorum spiritus, et alijs ad quae fabricata sunt adhibebo quodque illis deprehendero Celsitudini Tuae Serenissimae sum prompte significaturus. Thermometrum unum ex Polonia a quodam amico meo anno superiore accepi, quod Florentiae confectum mihi asseruit per intensissimos aestatis praeteritae aestus ad grad. 37. liquor in illo intumuit vicissimque Decembris elapsi diebus aliquot, aspero vehementeque frigore, quo Sequana concretus in glaciem est, ad grad. 7. liquor depressus apparuit. Hoc etiam adnotavi, pruinam cecidisse, ac tenuissimam glaciem visam esse, ubi liquor fuit ad grad. 15. compressus. Usque dum ad 14. g. subsedisset gelu non expectaveram, cum monuisset me amicus, supra illum gradum nec cadentem rorem in pruinam, nec aquam in glaciem concrescere." Boulliau to Leopold, 28 February 1658, BNCF, *Gal. 275*, 134r-135r. The two measurements mentioned in Boulliau's letter correspond to his register entries of 24 August and 17 December 1658. BOP, *B5-12*.

79 Leopold to Boulliau, 31 March 1659. BNF, *Fr. 13039*, 89r-v.

80 "Collocandosi nella neve o nel ghiaccio, suol ridursi regolarmente a gradi 13 1/2, tutto che l'aria più fredda di Firenze l'habbia ridotto anche a sette. E [...] quando questo strumento, tenuto all'aria aperta d'inverno, è a 14 gradi, allora l'acqua in campagna suol ghiacciare." "Memorie per l'uso di diversi strumenti," BNCF, *Gal. 269*, 230r. Partially published in DIS I, p. 465. The translation is my own.

Noyers had sent to Paris as Leopold had requested, but a similar one filled with mercury instead of spirit (Fig. 11).

Boulliau had actually had a thermometer-like glass instrument made, hermetically sealed and filled with mercury.[81] This is the instrument he drew in its true shape and size, and this is the instrument he wished to discuss. Indeed, he promptly explained to Leopold that, once the instrument had been prepared, he had hung it out in the open air and found that the mercury expanded with heat and contracted with cold, but not to the same extent as the spirit of wine contained in the thermometer.[82]

As anticipated, on 25 March Boulliau added two additional columns to his register. These columns, entitled "Ad mercurium plenum thermometrum," contain the results of measurements made with the newly manufactured instrument. Over the next eight weeks, the French astronomer recorded two measurements a day, one using the Florentine thermometer and the other using the instrument filled with mercury. The brevity of the recordings with the mercury-in-glass instrument and the notes sent to Leopold indicate that Boulliau aimed to compare the measurements obtained with the two instruments in question (Fig. 9 and 12).

A more complete understanding of the reasons behind Boulliau's aims can be gained by considering another element. In the period immediately preceding the transmission of the drawing of his new instrument to Florence, Boulliau had received from Des Noyers[83] a copy of a letter from Del Buono to Leopold, probably written more than a year earlier.[84] By this point in time, Boulliau was probably already in contact with a craftsman, following instructions previously sent to him from Poland. Nevertheless, it seems likely that it was Del Buono's letter that prompted him to fill the instrument with mercury. Indeed, Del Buono began his letter by alluding to experiments on vacuum and air pressure carried out at the Accademia del Cimento,[85] which he had learned about from Borelli. He then went on to

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81 "Ad thermometri itaque modum vitreum tubulum cum globulo appendice fieri, punctis distingui duabusque argenti vivi cum semisse unciis infusis inclusisque hermetice, ut dicunt, ab artifice sigillari curavi, ita ut aëri nullus meatus sit relictus." Boulliau to Leopold, 4 April 1659, BNCF, *Gal. 275*, 143v-145r.

82 "Sic paratum organum in aëre libero foris suspendi, notavique mercurium calore distendi, frigore vero constipari non pari tamen ac vini spiritus thermometro inclusi mensura," ivi, 145r.

83 Ivi, 143r-v.

84 It seems likely that the letter never reached its intended destination. On Del Buono's letter, see Middleton, 1969.

85 One of these experiments was the carp bladder experiment, which was conducted in Florence in August 1657. Based on this reference, Middleton correctly dated the letter to September-October 1657.

suggest further experiments and instruments for investigating the expansion and compression of air. In his correspondence with Leopold, Boulliau explained that Del Buono's observations on the properties of mercury and the movement of air had led him to a series of reflections. The issue of vacuum and air pressure, which Boulliau had not previously addressed in his work or correspondence, aroused the French astronomer's interest. In particular, he considered the explanations offered by the *horror vacui* and the weight of air for the suspension of mercury in Torricelli's experiment to be unproven. He also postulated that the *vacuum intermixtum* (i.e., the presence of minute empty spaces inside bodies) could not be denied and could account for the phenomena of rarefaction and condensation.

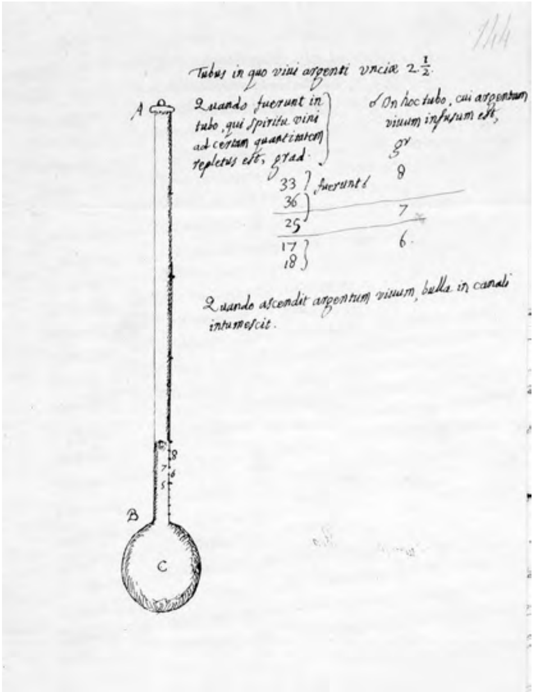

Fig. 12 – The drawing of Boulliau's instrument sent to Florence. BNCF, *Gal. 275*, 145r. Su concessione del Ministero della Cultura - Biblioteca Nazionale Centrale di Firenze. È vietata ogni ulteriore riproduzione con qualsiasi mezzo.

Boulliau was not only interested in theoretical speculation, but also sought to test his hypotheses empirically. The instrument he described to Leopold was not designed to measure heat and cold. Rather, its construction was motivated by the desire to investigate the possibility that the space left by the mercury remained filled with corpuscles of it.[86] An object physically identical to a thermometer, and built from information about how thermometers worked and were constructed in Florence, thus became a tool for investigating the problems raised by Torricelli's experiment.

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86 "Experiri itaque volui, an ex argento vivo corpuscula ad spatium illud ex parte replendum accurrere conijcere possem," Boulliau to Leopold, 4 April 1659, note 68.

The arrival of the instruments and the reading of Del Buono's letter led to a shift in discourse within the correspondence between Boulliau and Leopold. It was Boulliau who initiated a discussion on air pressure, vacuum, and the suspension of mercury in the tube in their conversation. Leopold responded by outlining the experiments that the Academy was carrying out or planning to carry out to study the influence of heat and cold, along with the height of the mercury column in the Torricellian tube. They also discussed the different behaviour observed in thermometers filled with different liquids. Leopold then sent Boulliau a brief manuscript treatise on vacuum written by Carlo Rinaldini (1615-1698). Boulliau replied to Rinaldini with a few observations and agreed that the role of air weight in supporting the mercury in the barometric tube should be dismissed. He substantiated this conclusion with evidence derived from his own observations. According to Boulliau, the observed rise and fall of the mercury in response to changes in temperature provided clear proof that the mercury was not pressed down by the weight of the air, but rather was rarefied and carried upwards by heat and condensed and thus lowered by cold.[87]

Boulliau's interest in the subject subsequently waned, perhaps partly because of the lack of prompt responses from Florence. However, the arrival of the thermometer prompted or, at least, facilitated the French astronomer's attention to hitherto unconsidered topics, brought him news of developments in Tuscany, and led him to discuss vacuum and air pressure not only with Leopold and Rinaldini, but also with Huygens.[88]

Conclusion

In recent decades, scholars have debated the emergence of the first scientific academies in Europe. They have sought to identify the factors that contributed to the emergence of new institutional and collegial realities focused on the experimental investigation of nature. This has mainly been achieved by analysing the respective contexts in which these institutions

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[87] "[...] Aliud praeterea, quo Mercurium in tubulo thermometro, spherulam appendicem habente, & hermetice sigillato, calore extendi, & ascendere, frigore autem constringi, & descendere cerniums, manifestum argumentum praebet non aeris pondere premi, sed calore rarefieri & sursum ferri; frigore condensari, & ideo subsidere," Boulliau to Rinaldini, 14 December 1659, BNF, *Fr. 13039*, 122v. Published in Rinaldini, 1682, p. 20.

[88] Boulliau to Huygens, 26 March 1660, UBL, *Hug, 45, 733*. Published in Huygens, 1888-1950, 3, pp. 49-51.

were established.[89] Nevertheless, examining these different contexts in isolation poses a challenge. This concerns the way in which these associations of scholars, so different from previous models and yet strikingly similar to each other, could have developed simultaneously in different locations. Unfortunately, in the early stages, there was little information disseminated directly through manuscripts, and even less in print. Consequently, any traces of possible exchanges or connections must be sought elsewhere.

In 2016, Mordechai Feingold drew attention to the peregrination of scholars across Europe and to their interactions in shaping the Continent's scientific landscape.[90] His work focused on what he called the "confabulatory life," namely, the diffusion of scientific knowledge through oral discourse. From this perspective, scientific instruments are less 'intangible' than oral speech. However, they are without words and, as with oral language, the traces they leave behind are often indirect and discernible only in the impact they may have had on the production of actions, ideas, images, and words.

The case of the Florentine thermometer illustrates the impact that the *peregrinatio academica* and the circulation of scientific instruments had on the establishment of a common European scientific framework.

During the period in question, other Florentine thermometers circulated beyond the Alps. In January 1665, Huygens informed Robert Moray (1608/9-1673) that, at an unspecified point in the past, Des Noyers had given him a thermometer crafted in Florence.[91] Furthermore, a Florentine instrument reached England in 1661, carried by Robert Southwell (1561-1695) on his return from a *grand tour* and subsequently shown to Robert Boyle (1627-1691).[92] In 1664, according to Renou, Philippe de la Hire (1640-1718) travelled to Florence and, on his return to Paris, commissioned Louis Hubin (d. 1749) to construct a thermometer with the intention of creating a device similar to the one he had seen in Florence.[93]

The instrument circulated during the period of the formation of the early modern scientific academies.[94] It brought with it practices, stimulated

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89 It is particularly noteworthy to cite studies that have significantly altered and broadened our understanding of the genesis and activities of the early scientific academies in Europe, such as Galluzzi, 1981; Shapin, Schaffer, 1985; Guerrini, 2015.

90 Feingold, 2016.

91 Huygens to Moray, 2 January 1665, RS, *EL/H1/43*, 44.r. Published in Huygens, 1888-1950, V, p. 188.

92 Middleton, 1966, pp. 38-39.

93 Renou, 1876, p. 7.

94 Upon receipt of the thermometer from Des Noyers, Huygens had recently been ap-

the need for experimentation where observation had always and above all been directed towards natural phenomena, opened up new channels of communication, and introduced new topics into already established dialogues.

The Florentine thermometer was a tangible demonstration of the Grand Duke's dedication and expertise in the field of natural philosophy. As a gift, it embodied the munificence of one of Europe's most celebrated patrons of science and the arts. The instrument's silent nature protected its senders and donors from potential tensions with the ecclesiastical authorities, while its tangible form safeguarded it against possible plagiarism. Consequently, it was more readily shared than written words, whether printed or handwritten.

In the formative years of scientific academies in Europe, the instrument facilitated the establishment of a common framework that was not yet fully defined, but began to standardise the modes, practices, and contents of investigations into nature.

Abbreviations

DIS I = *Le opere dei discepoli di Galileo Galilei. Edizione nazionale*, Abetti Giorgio, and Pagnini Pietro (eds.), Florence, Barbera, 1942.

DIS II = *Le opere dei discepoli di Galileo Galilei. Vol. II, Carteggio 1649-1656*, Galluzzi Paolo, and Torrini Maurizio (eds.), Florence, Giunti-Barbera, 1984.

Saggi, 1667 = *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 [i.e. 1667].

Archive sources

Florence, Biblioteca Nazionale Centrale di Firenze (BNCF), *Fondo Galileiano* (*Gal.*)

Leiden, Universitaire Bibliotheken Leiden (UBL), *Christiaan Huygens archive* (*Hug*).

London, Royal Society Library (RS), London, *Early letters collection (EL)*, and *Classified papers of the Royal Society (Cl.P)*.

pointed, or was about to be appointed, a Fellow of the Royal Society. He was also to play a pivotal role in the founding of the Académie Royale des Sciences in Paris. Boulliau, in turn, was to become a member of the Royal Society and, although he never had the opportunity to join the Académie Royale, he assiduously attended the Academy of Montmor during his time in Paris.

Paris, Bibliothèque Nationale de France (BNF), Paris, *Collection français* (*Fr.*), and *Nouvelles acquisitions latines* (NAL).

Paris, Bibliothèque de l'Observatoire de Paris (BOP), Collection *BOULLIAU.*

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