Víctor Pérez Álvarez

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Antiquarian Horology, Volume 39, No. 3 (September 2018), pp. 342–360

Volume 39, No. 3 (September 2018) contains the following articles

Front cover: The winding barrel click work of the turret clock of Wells cathedral. The clock is one of the three ancient English turret clocks discussed and compared in this issue by Keith Scobie-Youngs.

The universe on the table. The Buschman Renaissance clock of the National Maritime Museum

Víctor Pérez Álvarez*

The National Maritime Museum at Greenwich holds in its collections a Renaissance clock with astronomical complications made in Augsburg at the end of the sixteenth century. Beside the clock, the museum library holds its anonymous instruction booklet printed in Geneva in 1704. The clock is signed by Buschman, a prominent Augsburg maker, and is said to have belonged to John Casimir Vasa, king of Poland in the seventeenth century. This article discusses the authorship of the clock by comparing it with a twin clock from the same period signed by another maker. Whether it did indeed once belong to the Polish king is queried, with reference to his post mortem goods sale. This article uses written sources as well as the evidence from the clock itself, which was taken apart recently to study its history.

Introduction

About seven years ago, when I was working on my PhD thesis on the history of pre-pendulum horology in Spain, I visited the National Maritime Museum at Greenwich for the first time and a complicated instrument attracted my attention: a gilded Renaissance clock with an astrolabic dial on the top (Fig. 1). I carefully read the label, took some pictures (poor, due to the reflections on the glass cabinet), and after my visit kept thinking about the object. When I was about to finish my thesis, I applied for a Sackler Fellowship at the National Maritime Museum to research its history. My application was successful and the project was carried out from March to May 2017. I wish to thank the Museum for accepting my proposal and all staff members for their cordial reception, particularly Rory McEvoy, at that time the Curator of Horology, for his support and for taking the clock apart to enable us to study every part in detail.

In a paper presented at a conference, which is due to be published, I explored the clock as a 'luxury' astronomical instrument, discussed its value in use and how it was sold twice during its history.[1] My paper also looks at the clock as a sensorial object made to be seen, heard and touched. In the present article the clock is studied as a scientific instrument and its history is traced from the late sixteenth century, when it was made, to the present day, when it is exhibited in the Queen's House at Greenwich.

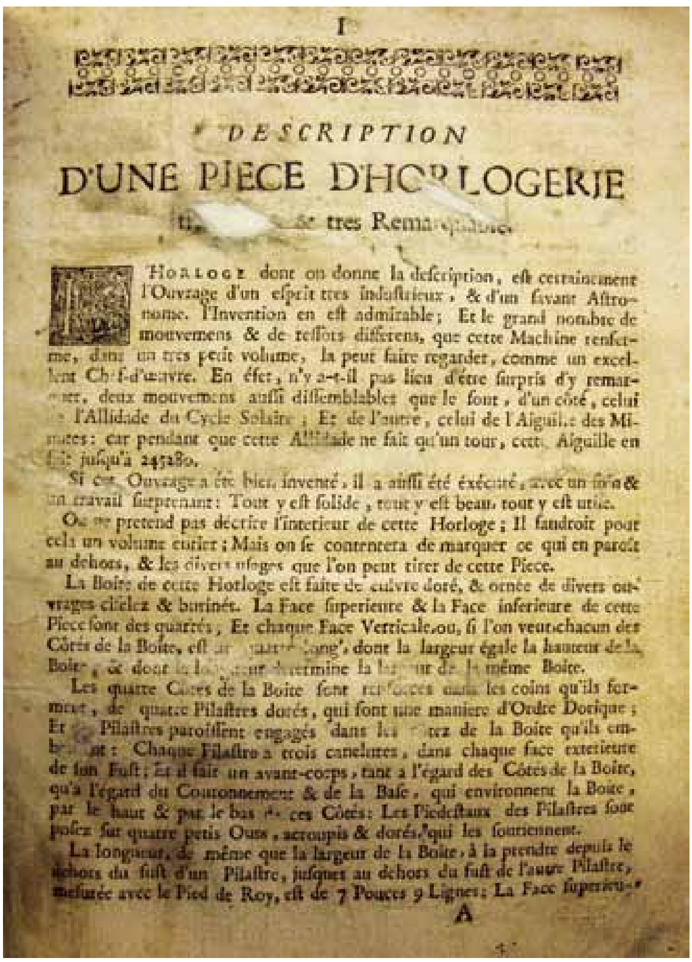
In both publications, two other related objects are considered. The first is a 15-page instruction booklet published in Geneva in 1704 to sell the clock after it had been refurbished in that city. The pamphlet describes the clock and explains how to use it but unfortunately does not include any illustration (Fig. 2). A copy is kept in the Caird Library of the National Maritime Museum.[2] The other object is a twin clock kept at the

*Dr. Víctor Pérez Álvarez (vpamm2016@gmail.com) defended his PhD thesis in December 2016 on the history of horology in Spain. Currently he is working on a monograph on the medieval clock of the Toledo cathedral and is carrying out a research project on the sixteenth-century clock and watchmaking trade in Madrid.

1. Víctor Pérez Álvarez, 'The 16th-century astronomical clock of the National Maritime Museum of Greenwich. Cultural study and sensorial analysis', Material Histories of Time, International Meeting held at the International Museum of Horology, La Chaux-de-Fonds, Switzerland from 29 November to 1 December 2017.

2. *Description d'une piece d'horlogerie tres rare & tres remarquable* (Genève: Pierre Jaquier, 1704) Greenwich, National Maritime Museum, Caird Library, PBC1310.

Fig. 1. Astronomical clock signed by Caspar Buschman of Augsburg, *c*. 1586. National Maritime Museum, Greenwich, Inv. nr. ZAA0011. Measurements: overall: 167 mm x 268 mm x 266 mm. Weight 12.65 kg. Below: Fig. 2. Instruction pamphlet of the Buschman clock, 1704. National Maritime Museum, Caird library. Above right: Fig. 3. Clock signed by Reinhold, almost identical to the Greenwich one. Landesmuseum Württemberg, Inv. 1973-25. Photo © and courtesy of Landesmuseum Württemberg, Stuttgart.



1

DESCRIPTION

D'UNE PIECE D'HO[illegible]LOGERIE

[illegible] tres Rema[illegible]

L'Horloge dont on donne la deſcription, eſt certainement l'Ouvrage d'un eſprit tres induſtrieux, & d'un ſçavant Aſtronome. l'Invention en eſt admirable; Et le grand nombre de mouvemens & de reſſorts differens, que cette Machine renferme, dans un tres petit volume, la peut faire regarder, comme un excellent Chef-d'œuvre. En éfet, n'y a-t-il pas lieu d'être ſurpris d'y remarquer, deux mouvemens auſſi diſſemblables que le ſont, d'un côté, celui [illegible] l'Allidade du Cycle Solaire; Et de l'autre, celui de l'Aiguille des Minutes: car pendant que cette Allidade ne fait qu'un tour, cette Aiguille en [illegible] juſqu'à 245280.

Si cet Ouvrage a été bien inventé, il a auſſi été éxécuté, avec un ſoin & un travail ſurprenant: Tout y eſt ſolide, tout y eſt beau, tout y eſt utile.

On ne pretend pas décrire l'interieur de cette Horloge; Il faudroit pour cela un volume entier; Mais on ſe contentera de marquer ce qui en paroît au dehors, & les divers uſages que l'on peut tirer de cette Piece.

La Boite de cette Horloge eſt faite de cuivre doré, & ornée de divers ouvrages cizelez & burinés. La Face ſuperieure & la Face inferieure de cette Piece ſont des quarrés, Et chaque Face Verticale, ou, ſi l'on veut, chacun des Côtés de la Boite, eſt [illegible] long', dont la largeur égale la hauteur de la Boite, & dont [illegible] la même Boite.

Les quatre Côtes de la Boite ſont [illegible] les coins qu'ils forment, de quatre Pilaſtres dorés, qui ſont une maniere d'Ordre Dorique; Et [illegible] Pilaſtres paroiſſent engagés dans les [illegible] de la Boite qu'ils em[illegible]: Chaque Pilaſtre a trois canelures, dans chaque face exterieure de ſon Fuſt; Et il fait un avant-corps, tant à l'égard des Côtés de la Boite, qu'à l'égard du Couronnement & de la Baſe, qui environnent la Boite, par le haut & par le bas [illegible] ces Côtés: Les Piedeſtaux des Pilaſtres ſont poſez ſur quatre petis Ours, acroupis & dorés, qui les ſoutiennent.

La longueur, de même que la largeur de la Boite, à la prendre depuis le dehors du fuſt d'un Pilaſtre, juſques au dehors du fuſt de l'autre Pilaſtre, meſurée avec le Pied de Roy, eſt de 7 Pouces 9 Lignes: La Face ſuperieu-

A

Fig. 4. Buschman clock, moon age and phase.

Fig. 6. The dragon.

Landesmuseum Württemberg in Stuttgart, Germany, and was formerly in the Fremersdorf collection.[3] (Fig. 3) Both clocks were made in the 1580s in Augsburg, they are almost identical but they are signed by different makers.

Dials

The Greenwich astronomical table clock is in a square gilt case standing on decorative feet in the form of four bears (Fig. 1). Both the case and the movement are in very good condition and only very few alterations have been carried out after it left the workshop in Augsburg. Its seven dials show several astronomical indications. The most important one is the astrolabic dial on the top, which, in addition to the position of the sun and the stars on the sky, shows the phases, the age of the moon and its angular distance with the sun (Fig. 4). On the top a steel hand shows the minutes and makes one turn every hour (Fig. 5). Behind the minutes hand is the moon pointer, which makes one turn every lunar day to show its height and its position on the ecliptic at the same time. The sun pointer shows the hours, the position of the sun in the

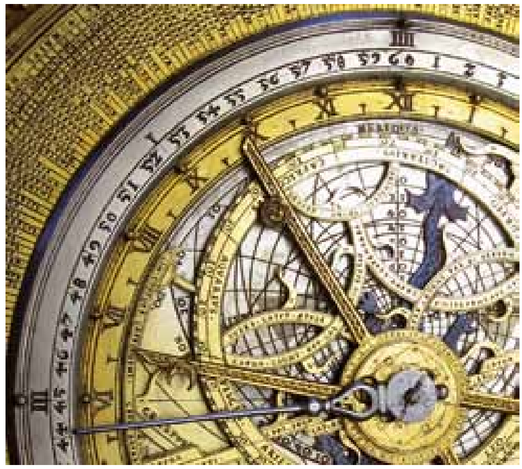


Fig. 5. Buschman clock, from the top to the bottom, steel minutes hand, moon phase and position, moon age and position of the sun, rete, dragon for the moon nodes.

sky and makes one turn every day. The rete shows the position and the magnitude of a selection of fixed stars and the ecliptic. Under the rete is the dragon, which shows the position of the moon nodes, which are the two points where its orbit crosses the ecliptic (Fig. 6). Only when the moon is on one of its nodes and it is lined up with the Sun and the Earth, an eclipse happens. This clock shows lunar and solar eclipses when the sun, moon and dragon pointers are aligned.

To describe the small dials, the 1704 pamphlet numbers the four sides anticlockwise, beginning with the side that shows calendar data (Fig. 7). The dial on the left shows the golden number and the epact corresponding to every year between 1586 and 1699. In order to know what the epact is, we must remember that a solar year is approximately 365¼ days and a lunar or synodic month about 29½ days; this means that 12 lunar months are about eleven days shorter than 12 solar months. If you need to know the age of the moon on a given day, add eleven days to the age of the moon on the same day of the previous year. 11 is the 'epact' number, which will be 22 for the following year, 3 for the next one, because you need to subtract 30 when the epact is bigger than this number, and so on. The epact numbers were

3. J. H. Leopold, *Die grosse astronomische Tischuhr des Johann Reinhold: Augsburg, 1581 bis 1592* (Luzern: Joseph Fremersdorf, 1974).

Fig. 7. Side 1. Left: epact and golden number, right: solar cycle, dominical letters and *indictio* ('ciclvs indictionis').

Fig. 8. Side 2. Planetary hours and days of the week in Latin and German: 'Lvnae Montag/ Martis Aftermo[ntag]/ Mercurivs Mitwoch/ Iovis Donerstag/ Veneris Freitag/ Satvrnvs Samstag/ Sol Sontag'.

Fig. 9. Side 3. Left: Climates; Rotating plate transcriptions: Outer rings: 'Qvantitas dierum' and 'Latitudo Poli'. Climates: 'Aequinoctialis/ Primvm climatis per Meorem/ Secvndi clim[a] per Sienem/ Terty clima per Alexandria/ Qvarta clima per Rhodis/ Quinta clima per Roma / Sexti clima per Boristhenem/ Septimi clima per Ripheos/ Octava clima/ Novvm clim[a]tis'. Right: length of the day and the night.

Fig. 10. Side 4: Alarm: 'Septentrio/ Oriens/ Meridies/ Occidens'; in different writing and from a later date: 'De minuit a midy'.

changed with the Gregorian reformation of the calendar, which are those shown on the dial of the Greenwich clock: 1, 12, 23, 4, 15, 26 and so on.[4]

The golden number is a period of 19 years that have exactly 235 synodic months, this means that the epact cycle starts again and the pattern of the moon phases repeats.[5] Each year has an epact and a golden number, which are useful to calculate the moon phases.

The dial on the right shows the dominical letter on the silver ring, the 28 year cycle on the outer fixed ring and the roman *indictio* on the inner plate. All are about the year and sun cycles. There are seven models of calendars named by seven dominical letters depending on which day of the week January 1st falls. For example, letter A is for the years that begin on Sunday, B for those that begin on Saturday, C for those that begin on Friday and so on. One year every four years is a leap year, and the 28 year cycle comes when seven leap years with different dominical letters are completed. The *indictio* is not an astronomical cycle, but a 15-year fiscal period from Roman times that was widely used in Antiquity and the Middle Ages to date documents and historical facts. The dominical letters ring is not connected to the movement and can be set by hand, the central index makes one turn every 28 years and the *indictio* disc makes one anticlockwise turn every 15 years.[6]

Side two of the clock has a pierced panel to let the quarter bell sound and a dial that shows the day of the week and the planetary hours, that is, which planet has its influence on each hour of the day. The pointer makes one turn per week. (Fig. 8)

Side three shows the length of the daylight depending on the latitude (Fig. 9). The disk of the left dial shows the climates, a set of parallels on the northern hemisphere used from Antiquity. The climates divide the Earth in strip-shaped areas depending on the length of the longest daylight of the year. They are separated by decreasing latitude distances from the equator to the pole. There is a difference of 30 minutes in the length of the maximum day between two adjacent climates. Therefore they are more related to astronomy than to geography. Ptolemy divides the northern hemisphere of the Earth in seven climates, each one named with a prominent city or geographic feature from it. Thanks to the new geographical discoveries of the fifteenth and sixteenth centuries, new climates were added to the north, like Ripheon and Danias.[7] Early modern cosmographers, like Waldseemüller[8] or Apian,[9] give the latitudes and the names for each climate, with changes depending on the author. That might allow us to know the source used to make the climates dial of the Greenwich clock. I have found that the climates names on the clock are those given by Waldseemüller,[10] who also points out that Ptolomeus did not give any name to the VIIIth climate as the lands contained in it are uninhabitable.

4. For more information about the epact and how the numbers changed with the Gregorian Reform, see Elly Dekker, ‘Epact tables on instruments: Their definition and use’, *Annals of Science,* 50 (1993), 303-324; pp. 304-5.

5. Dekker, ‘Epact tables’.

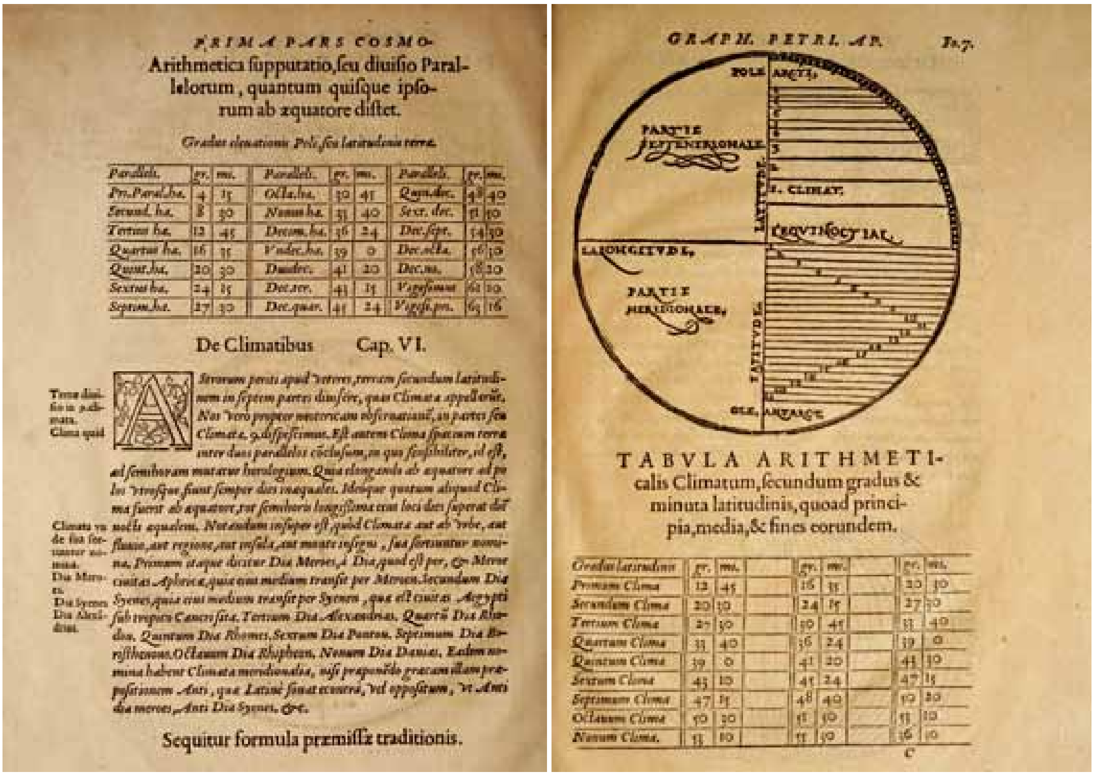
6. B. Richmond, *Time measurement and calendar construction* (Leiden: Brill, 1956), pp. 95–96.

7. Otto Neugebauer, *A History of Ancient Mathematical Astronomy* (Berlin: Springer-Verlag, 1975), pp. 725–6; Christine R. Johnson, *The German discovery of the world, Renaissance encounters with the strange and marvelous* (Charlottesville: University of Virginia Press, 2008), p. 62.

8. Martin Waldseemüller, *Cosmographiae introductio cum quibusdam Geometriae ac Astronomiae principijs ad eam rem necessariis. Insuper quatuor Americi Vespucii nauigationes. Uniuersalis Cosmographiae descriptio tam in solido q[uam] plano, eis etiam insertis quae Ptholomaeo ignota a nuperis reperta sunt* (Argentoracos: Joannes Grüniger, 1509), p. 8[v] and 13[v].

9. Petrus Apian, *Cosmographia Petri Apiani, per Gemmam Frisium apud Lovanienses Medicum et Mathematicum insignem, iam demum ab omnibus vindicata mendis, ac nonnullis quoque locis aucta, figurisque novis illustrata. Additis eiusdem argumenti libellis ipsius Gemmae Frisii* (Paris, 1553), p. 6[v]-7[r].

10. Waldseemüller, *Cosmographiae introductio*.



PRIMA PARS COSMO-

Arithmetica supputatio, seu diuisio Parallelorum, quantum quisque ipsorum ab aequatore distet.

Gradus eleuationis Poli, seu latitudinis terrae.

Paralleli.	gr.	mi.	Paralleli.	gr.	mi.	Paralleli.	gr.	mi.
Pri.Paral.ho.	4	15	Octa.ho.	30	45	Quindec.	48	40
Secund. ho.	8	30	Nonus ho.	33	40	Sext. dec.	51	30
Tertius ho.	12	45	Decim. ho.	36	24	Dec.sept.	54	30
Quartus ho.	16	25	Vndec.ho.	39	0	Dec.octa.	56	30
Quint.ho.	20	30	Duodec.	41	20	Dec.no.	58	20
Sextus ho.	24	15	Dec.ter.	43	15	Vigesimus	61	20
Septim.ho.	27	30	Dec.quar.	45	24	Vigesi.pri.	63	16

De Climatibus Cap. VI.

Terrae diuisio in climata. Clima quid

Astrorum periti apud veteres, terram secundum latitudinem in septem partes diuisere, quas Climata appellarũt. Nos vero propter maiorem obseruationem, in partes seu Climata, 9. dispescimus. Est autem Clima spacium terrae inter duos parallelos cõclusum, in quo sensibiliter, id est, ad semihoram mutatur horologium. Quia elongando ab aequatore ad polos vtrosque, fiunt semper dies inaequales. Ideoque quantum aliquod Clima fuerit ab aequatore, tot semihoris longissima eius loci dies superat diem noctis aequalem. Notandum insuper est, quod Climata aut ab vrbe, aut fluuio, aut regione, aut insula, aut monte insigni, sua sortiuntur nomina, Primum itaque dicitur Dia Meroes, à Dia, quod est per, & Meroe ciuitas Aphricae, quia eius medium transit per Meroen. Secundum Dia Syenes, quia eius medium transit per Syenen, quae est ciuitas Aegypti sub tropico Cancri sita. Tertium Dia Alexandrias. Quartũ Dia Rhodon. Quintum Dia Rhomes. Sextum Dia Pontou. Septimum Dia Borysthenous. Octauum Dia Rhipheon. Nonum Dia Danias. Eadem nomina habent Climata meridionalia, nisi praeponẽdo graecam illam praepositionem Anti, quae Latinè sonat econtra, vel oppositum, vt Anti dia meroes, Anti Dia Syenes, &c.

Climata vnde sua sortiuntur nomina. Dia Meroes. Dia Syenes. Dia Alexandrias.

Sequitur formula praemissae traditionis.

GRAPH. PETRI. AP. Fo. 7.

TABVLA ARITHMETIcalis Climatum, secundum gradus & minuta latitudinis, quoad principia, media, & fines eorundem.

Gradus latitudinis	gr.	mi.		gr.	mi.		gr.	mi.
Primum Clima	12	45		16	25		20	30
Secundum Clima	20	30		24	15		27	30
Tertium Clima	27	30		30	45		33	40
Quartum Clima	33	40		36	24		39	0
Quintum Clima	39	0		41	20		43	15
Sextum Clima	43	15		45	24		47	15
Septimum Clima	47	15		48	40		50	20
Octauum Clima	50	20		51	50		53	10
Nonum Clima.	53	10		55	10		56	10

c

Fig. 11. The climates according to Apian. Photo courtesy of Internet Archive.

Fig. 12. The climates dial on side 3.

Fig. 13. Sundials on the inner side of the bottom plate of the case.

I have compared the latitudes of the climates from the Buschman and the Reinhold clocks with the data given in Apian's *Cosmographia*.[11] (Fig. 11). In the first column group are the names of the climates as they are spelled on the Buschman clock. The latitudes are given in grades and minutes, although the dials on both clocks are made with insufficient resolution to read fraction of grades, so the minutes are an approximate guess. From the table it can be seen that the Reinhold clock follows the Apian latitudes much more closely. A close examination of the Buschman dial reveals that it is not accurately made, particularly the division of grades between 50° and 55° on the unnamed VIIIth climate. (Fig. 12) There is also a difference of more than one degree between the latitudes of the Ist, IInd and IIIrd climates of both clocks. The Buschman clock may follow a different source, or the maker may have paid less attention to this dial.

The disk that shows the climates makes one turn every year and has a fixed pointer

11. Apian, *Cosmographia,* 6^{v}, the latitudes are very similar to those given by Waldseemüller.

near to the edge that shows the position of the sun on the zodiac. The central pointer should be moved by hand to choose the latitude range in which the clock operates. The latitude (or the climate) and the season (or the sun's position on the zodiac) are the two variables that determine the maximum length of the day.

The right dial shows the hour of the day according to different forms of time reckoning. The outer fixed ring is a so called 'half clock' that reckons twelve hours twice from midday and from sunset. The black and silver ring shows the length of the day and the night depending on the season. In winter the black sector will be larger than in summer. The difference depends on the index position of the left dial. This form of hour reckoning was the so called 'Grosse Uhr' or 'Nuremberg Uhr' and was used by public clocks in Nuremberg and some nearby cities, like Regensburg, from the fourteenth century onward. The white sector is attached to the inner gilded ring, that reckons 24 hours from sunrise, and the black sector is attached to the outer gilded ring, that reckons the hours from sunset. The last one shows a form of time reckoning, known as the 'Whole clock' or 'Italian clock', as it was used in Italy and in other European areas, for example in Bohemia and Silesia.[12]

Side four contains the alarm dial and the pierced panel for the hour bell. (Fig. 10) The disc can be turned by hand to set the alarm and does not seem original to 1586, as it is made from silvered brass and it is poorly plated, in contrast with the high quality of the other parts. It shows inscriptions in French, in contrast with the planetary hours dial, on which the inscriptions are in German.

The mechanically driven dials are complemented by a set of four sundials engraved on the inner surface of the bottom plate of the case, which serves also to protect the escapement and the movement from damage and dust. To reach and to operate them, the plate needs to be detached from the clock (Fig. 13). Here we find four sundials, three for different latitudes and one with a variable angle gnomon to be used in latitudes between 39° and 54°. The plate includes a table containing the latitudes of ninety-six cities and a compass to orient the sundials.

Movement

In the 1970s, J. H. Leopold published a very detailed study of the movement of the Reinhold clock and compared it with the Buschman clock from Greenwich, and included pictures and diagrams.[13] Repeating this information here would be almost a copy and paste operation, therefore I will highlight just some interesting technical features.

The movement holds three trains (Fig. 14) and an alarm mechanism (Fig. 15). The going train has a verge and balance escapement originally with a bristle regulator. The balance seems original, but the verge and the escapement wheel are later replacements (Figs 16 and 17). These parts usually are the first ones to become worn and then to be replaced, but in this case the addition of the balance spring, probably around 1700, might have required replacing the escape wheel as the oscillation frequency of the balance would have changed. Also the bristle regulator was adapted to the balance spring. The Museum holds a box with screws and other old and newly made replacement parts from the clock movement, including a very early broken balance spring that may be the original one (Fig. 18).

The train seems to have been repaired in the past, as the contrate wheel had been tightly bushed, and the escape wheel and the verge are in almost mint condition. After slightly readjusting the position of the balance cock, the going train ran by winding the mainspring for less than a quarter of turn,

12. Víctor Pérez Álvarez, 'El descubrimiento y la difusión del reloj mecánico en la Europa bajomedieval. Una perspectiva general' in Jesús Criado Mainar, Juan José Borque Ramón (eds.), *El «Relox viejo» de Veruela. Un testimonio de la relojería mecánica bajomedieval* (Zaragoza: Diputación de Zaragoza, Institución Fernando El Católico, 2015), pp. 45–47; Gerhard Dohrn-van Rossum (translationThomas Dunlap), *History of the hour. Clocks and modern temporal orders* (Chicago: The University of Chicago Press, 1996), pp. 113–117; Klaus Maurice, *Die deutsche Räderuhr*. Vol. I (München: Verlag C. H. Beck, 1976), p. 33; Gustav Bilfinger, *Die Mittelalterlichen Horen und die Modernen Stunden* (Stuttgart: Verlag von W. Kohlhammer, 1892), pp. 161–252.

13. For the details of the movement see Leopold, *Die grosse astronomische Tischuhr*.

Fig. 14. Going and striking trains.

Fig. 15. Alarm mechanism. When the movement is assembled the whole alarm mechanism fits into the hours bell.

Fig. 16. Escapement wheel.

without balance spring and with no oil.[14]

The striking trains lack some parts, including the twelve and twenty four hour count wheels and both flywheels and their arbors. Some newly made replacement parts kept in the box were mounted in the movement, but none of the striking trains can be operated because there are no flywheels. The alarm mechanism (Fig. 15) is complete and works well.

14. The clock was not oiled as a conservation measure.

Fig. 17. Balance wheel. The bristle regulator was adapted to the balance spring.

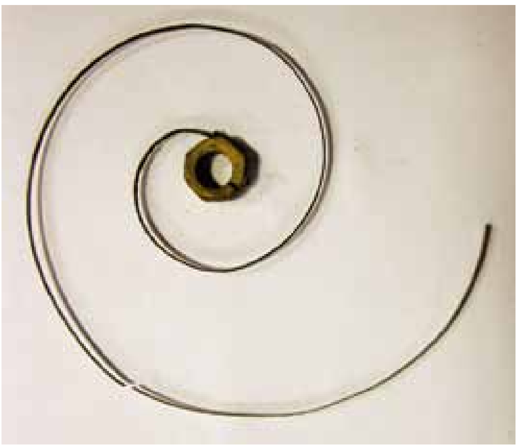


Fig. 18. Old broken balance spring.

Fig. 19. The complete chain.

Fig. 20. Fusee with round thread.

All trains, except the alarm mechanism, are chain driven, as stated in the 1704 instruction booklet. Two very old fusee chains were kept in the spare parts box, one broken and one in good condition, which was mounted on the going train barrel (Fig. 19). Both undoubtedly pertain to the clock, as they hook perfectly well in their respective barrel and fusee holes. Two fusees have round threads suggesting the previous existence of lines (Fig. 20), the other one seems a later replacement as it has square thread and is very clumsily made. The Reinhold clock has also two round thread fusees for gut lines and one square thread fusee for chain. According to Leopold, the last one was originally round and was transformed at a later date, as the unused hole for the line on its base shows.[15] But there is also evidence that the Buschman clock had chains from the beginning. First, the two holes in the fusees to let the hook spin at the end of the running period of the clock and to keep the chain straight. Second, there are no unused holes in the barrels as there would have been if lines preceded the chains. We may hypothesize that the supposedly previous lines could have been substituted for chains in Geneva in 1704, but they are very different from the sophisticated ones made in Switzerland at this period.[16]

15. Leopold, *Die grosse astronomische Tischuhr*, p. 71, fig. 42.

16. I thank Rory McEvoy for his decisive comments on this particular matter.

Fig. 21. The 1586-1699 and 1700-1799 epact dials.

Fig. 22. Pineapple punch on the sundials plate, the city mark of Augsburg.

The clock has been repaired many times in its history. The most relevant refurbishment may have been in 1704, when the clock was technically updated to be sold in Geneva. It was probably then that the balance spring was added. In addition, a new epact dial plate starting in the year 1700 was nailed to the old one, which ran from 1586 to 1699 (Fig. 21).

One of the last known interventions on the clock took place in 1967 by Philip Coole, expert on antiquarian clocks and watches, who was in charge of the horological collections of the British Museum from 1958 until his premature death in 1969.[17] Alan Stimson, under the guidance of Philip Coole, made some missing hands and other movement parts.[18] The parts from the separate box that were mounted in the clock in 2017 may have been made in 1967 by Stimson, who probably planned to restore the clock to working order but was unable to finish his project. That would explain the stripped down parts and the tight bushings in the contrate wheel pivots.

Authorship

The clock was made in Augsburg and on the sundials plate shows the pineapple mark of the city (Fig. 22). In addition, we know that the clock will have been made around 1586, the earliest year on the epact dial (Fig. 21). The astrolabe rete confirms this date. The longitude of the stars increases 1° every 71,6 years because of the precession of the equinoxes. This allows us to calculate the date of the astrolabe by comparing the longitude of a particular star on the rete with its longitude at a known date. Let's take Spica, which is very near to the ecliptic and whose longitude is quite easy to read.[19] In 1900 the Spica

17. T. P. Camerer Cuss, 'Philip Coole', *Antiquarian Horology* (March 1970), 6/6, 347–348.

18. Alan Stimson, former curator at the National Maritime Museum, filed the minute hand of the astrolabe following a design by Philip Coole. I thank Mr Stimson for this information. The file card of the clock kept at Greenwich confirms that it was moved to the British Museum on 27/09/1967 for examination and cleaning.

19. Henry Michel, *Traité de l´astrolabe* (Paris: Librairie Alain Brieux), 1977, p. 142.

longitude was 202,3° [20] and on our clock it is at 198° on the ecliptic, so there is a difference of 4,33°. By multiplying it by 71,6 you get 310,25, the years between both positions of Spica. Therefore 1900-310,25=1589,75 which can be rounded to 1590, the approximate date the astrolabe is calculated for.

The authorship seems obvious at first glance, as the clock is signed on the astrolabe tympanum by Caspar Buschman (Fig. 23), a member of a clockmakers family whose workshop in Augsburg remained active at least until the eighteenth century. Three sixteenth-century Buschmans from Augsburg were named Caspar: Caspar I (1512–89), Caspar II (1536–1613) and Caspar III (1563–1629). According to the date of 1586 given by the epact dial, the signature may correspond to any of these three. According to Bobinger, the Greenwich clock was made by Caspar II,[21] whereas Klaus Maurice suggests Caspar I or II, as Caspar III inherited the smiths' elegibility from his father only in 1591.[22] Another possibility should be considered. The clock meets the characteristics that a masterpiece should have according to the regulations of the Augsburg clockmakers' guild.[23] If it is a masterpiece by a Buschman, it should be attributed to Caspar III, but never to his father or his grandfather because they were masters from earlier dates. According to the guild regulations the son of a master clockmaker could get the master's title and run his own workshop at the age of 20. The available data show that the actual youngest candidates were 23 and the average age was 28.[24] Caspar Buschman III was born in 1563,[25] this means that he was 23 in 1586, the first year shown by the Greenwich clock on its epact dial.

Fig. 23. Astrolabe plate with the latitude and the signature of Caspar Buschman.

But serious doubts about the authorship arise when we compare the clock with other scientific instruments by Johan Reinhold and Georg Roll, two leading Augsburg makers from the last quarter of the sixteenth century, particularly with the Stuttgart clock signed by Reinhold, made in 1581 and refurbished in 1592 (Fig. 3). It shows almost the same information on the dials except for the moon nodes, strikes the same signals,[26] and the movements of both clocks are almost identical. The structures and the dimensions of both cases are the same as well. Only a few differences can be found on some ornaments, for example the feet of the Stuttgart clock are not bears, but they are not original.[27] The case has also four sundials engraved on the bottom plate where the signature of Johan Reinhold is.

20. See previous note.

21. Maximilian Bobinger, *Kunstuhrmacher in Alt-Augsburg* (Augsburg: Rösler, 1969), pp. 99–100

22. Klaus Maurice, *Die deutsche Räderuhr*. Vol. I, p. 176.

23. Eva Groiss, 'The Augsburg clockmaker's craft', in Klaus Maurice, Otto Mayr (ed.), *The clockwork universe. German clocks and automata 1550–1650* (New York: Neale Watson Academic Publications, Inc., 1980), p. 85; Bobinger, *Kunstuhrmacher*, p. 17.

24. Groiss, 'The Augsburg clockmaker's craft', p. 62.

25. Bobinger, Kunstuhrmacher, p. 14.

26. Leopold, *Die grosse astronomische Tischuhr,* pp. 45, 47, 51.

27. Volker Himmelein, 'Uhren und Wissenschaftliche Instrumente', in *Welt im Umbruch. Augsburg zwischen Renaissance und Barock. Band II: Rathaus* (Augsburg: Stadt Augsburg, 1980), p. 438.

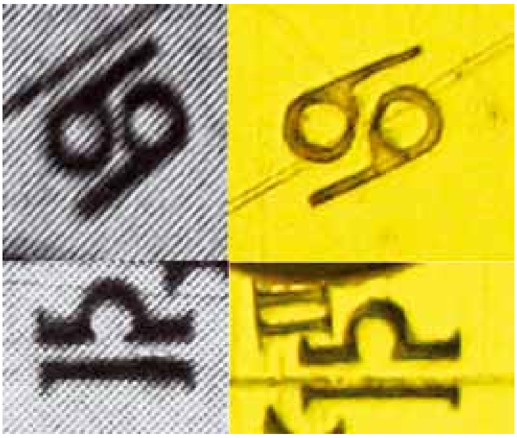


Fig. 24. Libra and Cancer symbols from the sundials' plates of the Greenwich (right) and the Stuttgart (left) clocks, the latter taken from Leopold, *Die grosse astronomische Tischuhr*, p. 35.

The Greenwich sundials have no signature but they have the Augsburg pineapple. The sundials plates from both clocks are almost identical except for the upper right dial and the cities mentioned in the latitudes table. A preliminary study of some punches from both plates has revealed significant information. I have taken some macrophotos of the Greenwich clock punches and compared them with the photos of the Stuttgart clock published by John Leopold.[28] The Cancer symbol for the summer solstice seems identical in both plates (Fig. 24). It is made with two '9' symbols horizontally arranged and both have straight shafts, while in instruments from other makers they tend to be slightly curved. The Libra symbol for the equinox seems to be made with the same punch as well. The right angle of the upper line is much sharper than the left one in both cases. All Libra and Cancer symbols of both plates have the same characteristics. This is a preliminary analysis and further comparisons should be made between other punches of the sundial plates and from other parts of the clocks, but that seems enough to establish that both plates come from the same workshop and maybe the entire clock, in spite of the different signatures. In the opinion of Maurice, Reinhold, as a scientific instrument maker, made the sundials and the astrolabe and Buschman finished the clockwork.[29] But Reinhold may have made the entire clock and then Buschman just signed it a few years later. It would not be the only known clock whose authorship is questioned in spite of its being signed. For example the oldest European clock in Japan, a diplomatic gift by the king of Spain around 1611, is signed by Hans de Evalo in Madrid in 1581, but in 2013 X-ray analysis revealed an older signature hidden by the Evalo cartouche.[30]

Different skills were required to make domestic clocks like the Greenwich one and different craftsmen from different workshops might collaborate to make one object. Usually the movement is made by a clockmaker and the case by a silversmith. The Greenwich clock, in addition, required scientific instrument making skills that not every clockmaker had. This may help to explain why the sundials and maybe the astrolabe can be attributed to the Reinhold workshop and the movement to one of the Caspar Buschmans.

Biography of the Buschman clock

The earliest information we have about it is contained in the object itself. We only know that it was made in Augsburg around 1586. There are no inscriptions, emblems or other symbols that hint at its first owner. The case is decorated with leaves and pomegranates, the four bear-shaped feet being the only relevant figurative elements (Figs 7–10). Lions are often used as feet in table clocks in the sixteenth century, but bears are unusual. They appear on the coats of arms of some cities and people whose names and surnames apparently include the root of the word 'bear' or '*bär*' in German, for example Berlin, or Bern in Switzerland.[31] But unless new sources about the clock are found, we do not have

28. Leopold, *Die grosse astronomische Tischuhr,* p. 35.

29. Maurice, *Die deutsche Räderuhr*. Vol. I, pp. 169, 176.

30. David Thompson, Johan Ten Hoeve, 'A Flemish clock at the Shogun's Shrine', *Antiquarian Horology* (December 2014), 35/4, 1063–1076.

31. Werner Vogel, *Berlin und seine Wappen* (Berlin: Ullstein, 1987), p. 20; Peter Meyer (ed.), *Berner – deine Geschichte* (Bern: Büchler Verlag, 1981), p. 129.

enough evidence to establish whether the bears have any meaning or are just ornaments.

According to the 1704 pamphlet the clock belonged to John Casimir II Vasa, king of Poland between 1648 and 1668. The text reads as follows:

> *L'Horloge dont on vient de faire la Description est à vendre. Cette Piece apartenoit à Casimir V^e^., Roy de Pologne, qui ayant abdiqué le Royaume, se retira à Paris, où il fut Abbé de St. Germain. Elle fut vendue à Paris après la mort de ce Prince, qui arriva l'An 1672. Elle est presentement à GENEVE, chez les Sieurs Marchant Maitres Horlogers, ausquels ceux qui auront dessein de l'acheter, pourront s'adresser.*

In 1668 John Casimir abdicated and spent the rest of his life exiled in Paris, where he became abbot of Saint-Germain-des-Prés and of Saint-Etienne of Nevers until his death in 1672.[32] Fortunately, his post-mortem goods inventory still exists and describes thirty eight clocks and watches, in addition to compasses, astrolabes and terrestrial globes.[33] Of the clocks described, these three come closest to matching the Greenwich clock:

> A clock that strikes the hours, half hours and quarters, it shows the moon phases, the days of the week, the twelve signs of the zodiac, the seven planets, the movement with small chains, on an ebony pedestal. The case is made with gilded brass, pierced and with an eagle on the top.

> A big alarm repetition clock that strikes the hours, half hours and quarters, that needs winding every day. It shows the twelve figures, the twelve months of the year and the holidays, with an astrolabe. It is on an ebony pedestal … the movements are in a square gilded brass case.

> A square clock in a square gilded brass case that shows the hours, half hours and quarters, the twelve zodiac signs and the seven planets.

The first and second descriptions can be discarded as the Greenwich clock has no eagle on its top and does not repeat the hours. The third description matches our clock, but in the sixteenth and seventeenth centuries there were many table clocks with these features, particularly in courtly contexts and *Wunderkammern* (cabinets of rarities). To identify unambiguously a particular existing object in an old inventory we need an accurate description that includes features that only this object has.[34] For example, for the Greenwich clock it would be useful to have a mention of the four bears, the two calendar pointers or the Caspar Buschman signature. Indeed, if the clock of the third entry is the Greenwich one, its description is surprisingly poor in comparison with the first and the second entries.

The clock itself shows evidence of having been in or near Paris at least in the seventeenth century. The astrolabe tympanum is for 48° latitude (Fig. 23), that of Paris, and the dial plate of the alarm, which does not seem original, has inscriptions in French (Fig. 25). Further evidence that the clock has been in France or maybe in Switzerland are the inscriptions scratched on the four side plates by a clockmaker who took it apart, which read 'Premier cotté', 'Second cotté' and so on (Fig. 26). In addition, during the dismantling process of the movement, six fragments of French playing cards from the mid-

32. W. Tomkiewicz, 'The reign of John Casimir: Part II, 1654–68', in W. F. Reddaway, J. H. Penson, O. Halecki, R. Dyboski, *The Cambridge History of Poland* (s. l.: Cambridge University Press, 1950), p. 531.

33. Ryszard Szmydki, *Vente du mobilier de Jean-Casimir en 1673. / Wyprzedaz mienia po Janie Kazimierzu w roku 1673* (Warszawa: Wydawnictwo Neriton), 1995, p. 42.

34. Some years ago I identified a clock owned by Isabella of Castile in 1504, in two inventories of the goods of the Dukes of Burgundy, dated 1467 and 1486. The definitive proof was the exact number of pearls and rubies mentioned. Víctor Pérez Álvarez, 'From Burgundy to Castile. Retracing and reconstructing a fifteenth-century golden clock', *Antiquarian Horology* (June 2015), 36/2, 248–254.

Fig. 25. Alarm dial plate with French inscriptions.

Fig. 26. 'Premier cotté' scratched above the solar cycle dial on the side 1.

Fig. 27. Fragments of a jack of diamonds playing card.

seventeenth century were found between the wheels and under one bridge.[35] (Fig. 27) These are identified as Paris pattern, which does not mean that they were necessarily used in Paris, but reinforces the hypothesis that the clock had been there or nearby.

The British Museum holds a tabernacle clock made in Poland in 1648 by the Polish clockmaker Lucas Weydman that may also have belonged to John Casimir (Fig. 28). However, although it has been carefully studied, there is no conclusive evidence to support this. The iconography of the case may make reference to the death of Wladislaw IV, the predecessor of John Casimir, who would have taken it with him to Paris, and it would then have been sold after his death in the 1673 sale. Like the Greenwich clock, it was in France at least from 1686 to 1836, according to the inscriptions and signatures found on the movement,[36] but none of the clocks described on the John Casimir goods inventory matches unambiguously the existing object at the British Museum.[37] Both clocks that supposedly belonged to the Polish king had been in Paris in the seventeenth century, but none of them can be linked to him with certainty.

35. Paul Bostock, 'Playing-cards found in a historical clock at The Royal Observatory, Greenwich', *The Playing-card. Journal of the International Playing-Card Society*, (2017), 45/4, 202–204; I thank Paul Bostock, chairman of the Worshipful Company of Makers of Playing Cards, for his helpful and constructive visit to the horological workshop of the Royal Observatory when the playing cards were discovered.

36. J. H. Leopold, *British Museum Catalogue of Pre-Pendulum Clocks*, (unpublished). I thank the British Museum curators of horology, particularly Laura Turner, for letting me check this catalogue; Wiesława Siedlecka, *Polskie zegary* (Wroclaw: Zaklad Narodowy im. Ossolińskich, 1988), pp. 67–68; Hugh Tait, Clocks and watches (London: British Museum, 1983), p. 28; Herbert Alan Lloyd, *The collector's dictionary of clocks* (London: Country Life, 1964), p. 206.

Fig. 28. Table clock by Lucas Weydman, possibly owned by John Casimir of Poland. British Museum, 1867,0716.4 ©Trustees of the British Museum.

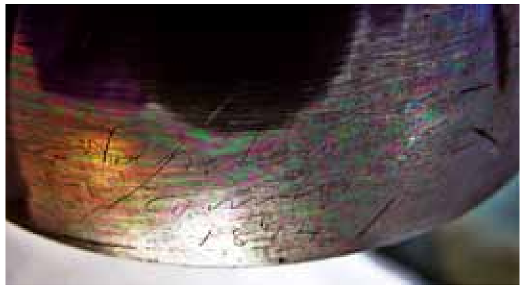


Fig. 29. Inscription on one of the bells reading 'Napoleâo, Coimbra, 1894'

As pointed out before, the first document that links the Greenwich clock to John Casimir is the anonymous description printed in 1704, about thirty years after the king's death, a period short enough to know the history of the object. The clock was then for sale in Geneva and the aim of the pamphlet was to advertise it to a wider public. If the object had belonged to a king it might be worth more money. This leads us to another question: was it actually connected to the Polish king or was mentioning the royal provenance just a marketing strategy?

The subsequent history of the clock is barely known. During the 2017 study, a signature was discovered on various parts of the movement which reads: 'Napoleâo, Coimbra, 1894' (Fig. 29). Some of the signed parts are inaccessible unless many other parts are first removed, which means that this must have been a clock- or a watchmaker who serviced the clock. As I found no mention of him in the obvious dictionaries,[38] I posted the question on Rete, a mailing list devoted to the history of scientific instruments.[39] Gilberto Pereira, from the University of Coimbra replied immediately.[40] He spoke with Antonio Ferreira, a watchmaker born in 1937 who started working at the 'Relojoaria Ferreira' in Coimbra[41] in 1948, when he was only eleven year old. There he knew an old watchmaker named Napoleâo who had been working there for a long time. He must be the same person as Eliseu Napoleao Augusto Neves, watchmaker and member of the 'Associaçiao dos Artistas de Coimbra' in 1891.[42] Nothing else is known about this Portuguese

37. Philip Coole, of the British Museum, studied the clocks described in the John Casimir inventories, as his curiosity had been sparked by the Weydman clock. One of the problems he faced was the ambiguity of the texts that make it very difficult to know how exactly each clock was. Moreover, this complicates their possible identification with still existing clocks. See Philip G. Coole, 'The Casimir inventories', *Horological Journal* (August 1964), 107, pp. 14–15 (September 1964), 107, pp. 20–21 (October 1964), 107, pp. 24–26.

38. G. H. Baillie, *Watchmakers and clockmakers of the world* (London: N. A. G. Press Ltd., 1982); Tardy, *Dictionnaire des horlogers français* (Paris: Tardy, 1972); Brian Loomes, *Watchmackers and clockmakers of the World* (London: Robert Hale, 1989); Luís Basanta Campos, *Relojeros de España y Portugal: diccionario bio-bibliográfico* (Pontevedra, Museo de Pontevedra, 1965).

39. http://www.mhs.ox.ac.uk/join/rete/ Rete is managed by the Museum of the History of Science, Oxford.

40. I am very grateful to Dr Gilberto Pereira, curator of scientific instruments at the Science Museum of the University of Coimbra, for his helpful information.

41. Rua Ferreira Borges, 108, Coimbra, Portugal.

42. José Mota Tavares, Fernando Correia de Oliveira, *Relógios e relojoeiros quem é quem no tempo em Portugal* (Lisboa: Ancora editora, 2006), p. 57.

clockmaker nor about the then owner of the clock, but it indicates that the clock was in Coimbra at the end of the nineteenth century.

Some years or decades after being serviced in Coimbra, the clock became part of the Mensing collection. Anton Mensing (1866–1936) was a collector and dealer of antiquities, including scientific instruments. He purchased entire lots of objects, for example the Heilbronner collection auctioned in 1922.[43] Mensing sold objects from his collection in several auctions, the last one was sold in an auction in 1937 after his death. This included the Buschman clock, and the sale catalogue contains its oldest known photograph.[44] The clock may have been acquired by Mensing after 1924, as it does not appear in the sale catalogue of that year.[45] Nothing is known about its provenance. In the 1930s Sir James Caird was collecting objects and books for the new National Maritime Museum at Greenwich and its library. Maggs brothers, who ran a family business of antiquarian books and manuscripts, were working for him and in 1936 travelled to Paris to the International Exhibition and purchased books, maps, navigational and scientific instruments,[46] including the Buschman clock and the 1704 instruction booklet forming part of the same lot. According to the Museum file card, it was presented by Sir James Caird in 1937 and cost £500.

In January 1967 Joseph Fremersdorf, the then owner of the Reinhold clock, by chance came across the catalogue of the 1937 Mensing sale and was surprised to see the photo of the Buschman clock because it resembled his Reinhold-signed clock. He wrote to Henri Michel showing him his interest in the object and in order to know who its current owner was. Fremersdorf knew of the existence of the 1704 booklet also from the 1937 catalogue and told Michel that he was ready 'to pay any amount for it'.[47] Michel replied to him that he had no idea who owned the Buschman clock and the pamphlet. After this, Fremersdorf sent him a copy of the pamphlet.[48] Probably he had discovered that the twin clock from the Mensing collection was then at Greenwich.

The file card of the Buschman clock kept at the National Maritime Museum does not mention the Fremersdorf collection and his Reinhold-signed clock, but some information contained on it might be connected with him. According to the card, the clock was transferred to the British Museum on 27 September 1967 for examination and cleaning and once again in October 1973. Philip Coole, who as we have noted worked at the British Museum from 1958 to 1969, studied the clock and made some gear diagrams. During these years he collaborated with J. H. Leopold on other projects,[49] and probably this allowed Leopold to know of the existence of the Buschman clock in Greenwich and to compare it with the Reinhold one from the Fremersdorf collection.[50] Fremersdorf had found the instruction booklet by 14 March 1967 and

43. Anthony J. Turner, 'Paris, Amsterdam, London: The collecting trade and display of early scientific instruments, 1830–1930', in Peter de Clercq, ed., *Scientific Instruments: Originals and Imitations; the Mensing collection* (Leiden: Museum Boerhaave, 1999), p. 36.

44. The National Maritime Museum keeps the page of the catalogue with the photo of the clock. I have been unable to find another copy.

45. Max Engelmann, *Sammlung Mensing: altwissenschaftliche Instrumente* (Amsterdam: Frederik Muller & Co, 1924), pp. 48–51.

46. Kevin Littlewood, Beverley Butler, *Of ships and stars: maritime heritage and the founding of the National Maritime Museum* (Greenwich/London: Athlone Press and the National Maritime Museum, 1998), p. 81; Maria Blyzinsky, 'The history of the collection', in Elly Dekker (coord.), *A catalogue of the globes and armillary spheres in the National Maritime Museum Greenwich* (Greenwich: NMM, 1994), p. 17.

47. Belgium, Centre National d'Histoire des Sciences, Correspondance et notes de Henri Michel, 1060 Correspondance Michel-Fremersdorf, 24 January 1967. Michel's correspondence and notes are available online at www.astrolabium.be.

48. Ibid., 14 March 1967.

49. T. P. Camerer Cuss, 'Philip Coole', *Antiquarian Horology* (March 1970), 6/6, 347–48.

50. Leopold, *Die grosse astronomische Tischuhr*.

only six months after that, the Buschman clock was sent to the British Museum. The closeness of the dates suggests that both facts were connected.

In 1973 the clock was once again sent to the British Museum, undoubtedly to enable John Leopold, who was then a regular visitor to the Horological Students Room, to include it in his monograph about the Reinhold clock owned by Fremersdorf which was published the next year.

Some conclusions

The Buschman-signed astronomical clock is one of the oldest horological objects in the National Maritime Museum collections and it is in very good condition as it still has most of its original elements. Its case is beautifully carved and thickly gilded. The movement is superb, every part is carefully finished and the different metals used to make them and the way they are organised are intended to create beauty.

In addition to the high quality of its workmanship, the clock has other interesting points, for example the accompanying 1704 pamphlet, which includes its description, instructions for use and the name of a distinguished previous owner. It is unusual to find a Renaissance scientific instrument with documents of this sort, which help us to write the biography of the object and how it has been valued throughout its history.

In this article we have explored different aspects of the clock at three moments in its history: its origins in Augsburg at the end of the sixteenth century, its refurbishment and sale in Geneva at the beginning of the eighteenth century, and its recent history as a museum object. It is interesting to see how the object has been valued at these three moments. In 1586 it was a luxury gadget for wealthy people interested in astronomy and astrology, in 1704 in Geneva its value was increased by connecting it to a deceased celebrity and in the twentieth century (and probably earlier) it was an outstanding collectable historical object.

Many sixteenth-century astronomical clocks made in South Germany can still be found in museums and collections around the world, but this does not necessarily mean that they were the most common type of clocks in the Renaissance. Non-luxury domestic clocks existed as well but when they all became technologically obsolete, only the luxury ones became collectable objects and the functional ones were more likely to disappear. This may distort our view about the numerical relevance of these clocks in relation with others. Some of the German clocks from this period have a similar size and shape as the Greenwich one. Particularly interesting is the existence of an almost identical clock signed by another maker. More cases of almost identical clocks from the same period signed by different authors have been mentioned previously and many more may have existed. This is a good starting point for future research on how different workshops collaborated and how technical knowledge circulated. In addition we should ask ourselves about the real meaning of the authorship of clocks, scientific instruments and other art and craft works in general.

Photo credits

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