GERARD MERCATOR'S THREE ASTROLABES

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ABSTRACT: No scientific instruments made by Gerard Mercator (1512-1594), the great cartographer, were known to exist, though it is recorded that he made astrolabes and other brass artefacts. In early 1992, the present author identified an unsigned astrolabe in Florence as being made in Mercstor's Duisburg workshop. By 1994, the 400th anniversary of Mercator's death, two further astrolabes had been identified as being by his hand. They are in museums in Augsburg and Brno. This paper describes the method of identification of these unsigned instruments, culminating in the discovery of Mercator's monogram on the rim of the astrolabe in Brno.

Introduction

No instruments by Mercator were known to exist until the first identification was made in Florence by the author in early 1992, though it is recorded that he did make astrolabes and other instruments[1]. Two further astrolabes were discovered as a result of work on the first. It must be rare to establish an attribution for an instrument and then later to have the attribution confirmed by the maker himself through a hitherto unexplained monogram. It shows in a startling manner that the methodology employed on the Florence instrument is sound.

The methodology used to attribute the astrolabes to Mercator involves detailed examination of all aspects of an instrument, the brass, the engraved

[1] A.S. OSLEY, *Mercator: A Monograph on the Lettering of Maps, etc in the 16th Century Netherlands with a Facsimile and Translation of his Treatise on the italic hand and a Translation of Ghim's* Vita Mercatoris (London, 1969), p. 186. See also MARCEL WATELET (ed.), *Gérard Mercator Cosmographe le temps et l'espace* (Antwerp: Mercatorfonds Paribas, 1994).

letters and numbers, the mathematical features, the star names and positions, the decorative elements. In the case of Mercator, only his maps and globes were available for comparative study, and their evidence comes through the medium of printing. The engraved copperplates provide the link with the engravings on the brass instruments, but of course in mirror image. The printing process removes the sharpness of the edges and the depth of cut produced by the burin, but the style and skill are fully apparent. Very little documentary evidence exists to establish the provenance of instruments. The Mercator astrolabe in Florence can be identified in a late-eighteenth-century museum inventory, but cannot be distinguished in earlier ones, where the descriptions are not sufficiently detailed. For the other two, there is no provenance before their acquisition by the museums. The instruments themselves, therefore, provide the only clues to their maker.

The first Mercator astrolabe to be identified is in the Istituto e Museo di Storia della Scienza, Florence[2]. It is unusual because it has a double-sided map plate[3]. This has a North polar projection on one side reaching to the Tropic of Capricorn, while the other side is a South polar projection to the Tropic of Capricorn only. The engraving characteristics found on this plate are markedly similar to some products of the Mercator workshop. Not only that, but a critical examination of the rest of the instrument showed that, apart from one latitude plate, the remainder is most likely to be in the hand of Gerard Mercator himself. The odd latitude plate, made for the latitude of Florence, is from the workshop of Giovan Battista Giusti. It can be shown that Giusti made the astrolabes commonly associated with Egnazio Danti (1536-1586), cosmographer to Duke Cosimo II of Florence[4]. Danti published his *Trattato dell'uso et della fabbrica dell'Astrolabio* at Florence in 1569, the same year that Cosimo (1519-1574) was

[2] Istituto e Museo di Storia della Scienza, Florence, inventory no. 1098. International Checklist [hereafter IC] no. 490. SHARON L. GIBBS, Janice A. HENDERSON, and Derek de SOLLA PRICE, *A Computerized Checklist of Astrolabes* (New Haven, Conn.: Yale University Department of the History of Science, 1973).

[3] This astrolabe is fully described in G. L'E. TURNER and E. DEKKER, 'An Astrolabe attributed to Gerard Mercator, c.1570', *Annals of Science*, 50 (1993), 403-443. This paper will be referred to subsequently as Turner and Dekker. See also G.L'E. TURNER, *Renaissance Astrolabes and their Makers* (Variorum Collected Studies Series CS766), (Aldershot: Ashgate Publishing Ltd, 2003), chapters 5, 6, 7, 8, 9.

[4] TURNER and DEKKER, Section 3.

created Grand Duke I of Tuscany. It is likely, therefore, that the Florence Mercator astrolabe was acquired during a period close to 1569.

While the Florence instrument was being studied, two more astrolabes were identified as closely similar. On the evidence supplied by examination of all three astrolabes, and by comparison with astrolabes and maps of contemporary craftsmen, only the Mercator workshop could have produced these instruments. The astrolabe in Augsburg is of exactly the same size at that in Florence, and the engraved information on the back is identical[5]. The Brno astrolabe is slightly smaller[6], and it is signed with a monogram. This is located on the bottom edge below the hour symbol 12 on the limb, and reads 'GMR', standing for: Gerardus Mercator Rupelmundanus (see Figure 1)[7]. Gerard Mercator was born at Rupelmonde, and referred to himself by this style on his productions from 1536.[8]

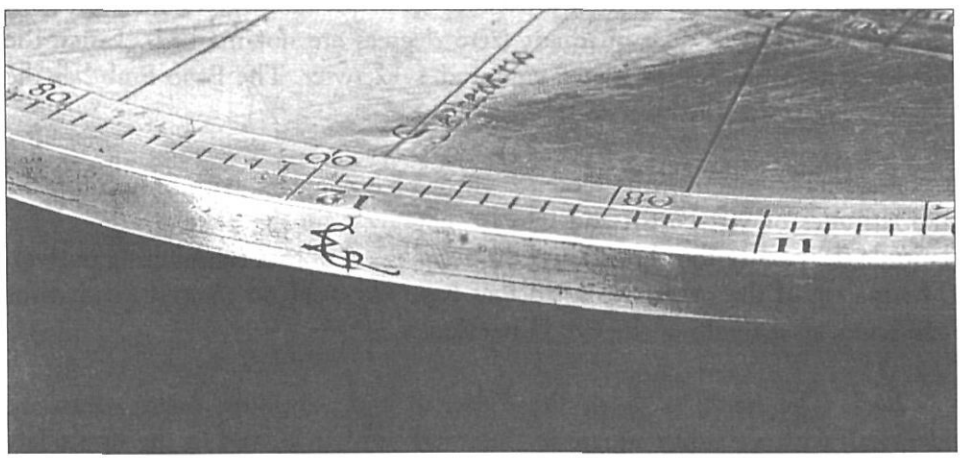


Fig. 1 The monogram of Gerardus Mercator Rupelmondanus.

[5] Städtische Kunstsammlungen, Augsburg, Germany, inv. no. 3537 (IC 4609).

[6] Moravská Galerie, Brno, Czech Republic, inv. no. 24-385 (IC 4608).

[7] For examples of his signature, and information on his maps and caligraphy, see A.S. Osley (note 1).

[8] Gerard Kremer had Latinized his name to Mercator by the time he enrolled at the university of Louvain on 29 August 1530. See R.W. KARROW, Jr, *Mapmakers of the Sixteenth Century and their Maps* (Chicago, 1993), p. 276. Karrow provides a full listing of Mercator's cartographic output, starting with the terrestrial globe he engraved for Gemma Frisius c.1536, pp. 376-406.

The astrolabes described

All three astrolabes will now be described as a group, with remarks on points of difference. The key information is given in Table 1, and their main parts are shown in Figures 2-7.

The astrolabes are made of gilt brass. Associated with the Florence instrument are five original latitude plates, and a further one made in Florence in about 1570. A seventh plate is engraved with projections of the Earth from the North and South Poles. The other two astrolabes each have a single latitude plate. In all three of the astrolabes the mater can accept only one plate at a time. The latitudes for which the plates are made are listed in Table 2.

Limb. The limbs on all three astrolabes are divided in degrees, marked, from the top, 90°-10° in each quadrant (zero degrees are not marked). Inside the degree scale is one for 24 hours, engraved 1-12 twice. The Brno limb has the degree scale inside the hour scale.

Mater. The mater of the Florence astrolabe is engraved with projections for the latitudes of 90° North and 0° Also engraved are the planetary hours for latitude 0° (twenty-four hours) and the astrological houses (numbering twelve). The maters of the other two astrolabes have engraved on them a quadratum nauticum, or diagram of the wind directions.

Back. The backs of both the Florence and Augsburg instruments are identical, with a shadow square in the lower semicircle, and in the upper left quadrant a diagram for conversions between equal and unequal hours (also called planetary or temporary hours) based on the times of sunrise and sunset; the right quadrant is blank. On the Brno astrolabe this quadrant is not blank, being filled with a diagram for measuring time in unequal hours based on the Sun's altitude; the left quadrant has its hour conversion diagram like the other two, but it is a mirror image and turned through 90°. In other respects it is the same as the others. Around the edges of all three are divided scales for degrees, the zodiac, and the calendar. The calendar is eccentric with respect to the zodiac.

Table 1 The key information on the three astrolabes. Measurements in millimetres.

Location	Florence	Augsburg	Brno
IC number	490	4609	4608
Inventory no.	1098	3537	24385
Signature	none	none	GMR
Diameter	316	317	278
Plates, latitude	5	1	1
Plate, latitude, extra	1	-	-
Plate, map	1	-	-
Plate diameter	293	293	258
Star pointers	50	50	48
Stars named	42	42	40
Ecliptic diameter	202	202	177
1st point Aries	10.3	10.2	10.3
Limb width	11.4	12	9.5
thickness	6.2	5.3	6
Alidade length	316	317	276
width	15	13	7 to 5
thickness	3.5	4	3.5
Rule length	316	317	278
width	13	15	12.4
thickness	4.2	3.4	3.5

Table2. The plates with the astrolabes.

	Florence	Augsburg	Brno
1.	36°/ tablet of horizons	45°/48°	49°/51°
2.	39°/42°		
3.	45°/48°		
4.	51°/54°		
5.	57°/60°		
6.	map plate		
7.	43°/43° by Giusti, Florence		

Plates. The original plates with the Florence instrument are engraved for latitudes every 3° between 36° and 60°, and one has a tablet of horizons. These, and the latitude plates on the other two astrolabes, are each engraved with almucantars at 2° intervals, and azimuths at 5°. The sixth plate is made for the latitude of Florence, 43°, and it is not from the same workshop as the rest of the astrolabe. Because the instrument was to be used in Florence, a plate for 43° was made by a craftsman of the city, Giovan Battista Giusti[9]. The fabrication of this plate, although skilled, is not to the same very high standard as the rest. The maters of all three astrolabes can accommodate but one plate at a time, contrary to the usual practice. This makes for a better fit, and it may explain why the other two instruments have just the one plate with them; any others could have been lost over the centuries. The Brno plate has a projection for the latitude of 49°, unlike the others. This is backed by a projection for 51°, so giving a deliberate 2° difference; the others are at 3° intervals, normal for the climates and their extensions. Augsburg has one plate for 45°/48°, which matches one of the Florence plates. Brno does not match any in the Florence set, and, by inference, Augsburg. The 2° latitude range covers the region from Antwerp (modern value 51° 13′) to Paris (48° 50′). The form of words indicating the latitude on each projection is: *Ad latit* (Florence and Augsburg) / *Latitudo* (Brno); *Trop* [Cap] (Florence and Augsburg) / *Tropicus Capricorni* (Brno). This supports the presumption that the Florence and Augsburg astrolabes were made at about the same time.

A remarkable feature on the Florence plates is the burnishing of the gilding in alternate segments of the unequal hours. Such a decorative conceit is very rarely to be found, and means that the instrument came from a first-class workshop, and that it was probably made for a notable customer.

[9] For the attribution to Giusti, see TURNER and DEKKER, Section 3. For Giusti's workshop, see G.'E. TURNER, 'The Florentine Workshop of Giovan Battista Giusti, 1556- c. 1575', *Nuncius: Annali di Storia della Scienza*, 10, fasc. 1 (1995), 131-172.

Fig. 2 The front of the Florence astrolabe

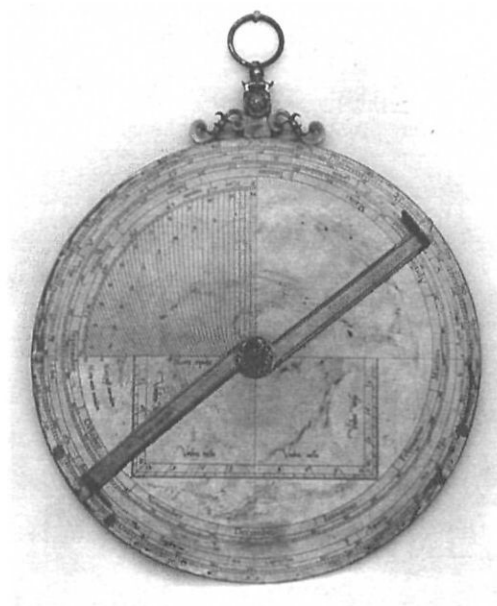


Fig. 3 The back of the Florence astrolabe

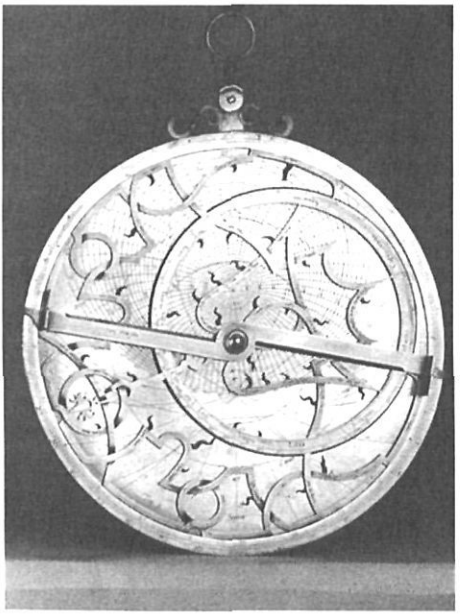


Fig. 4 The front of the Augsburg astrolabe

Fig. 5 The front of the Brno astrolabe

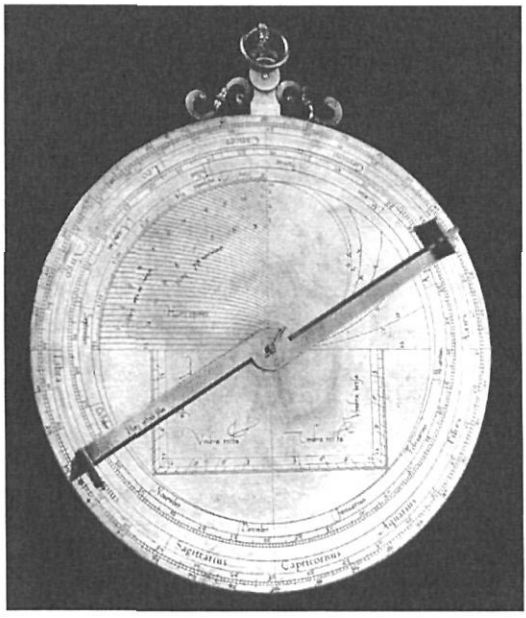


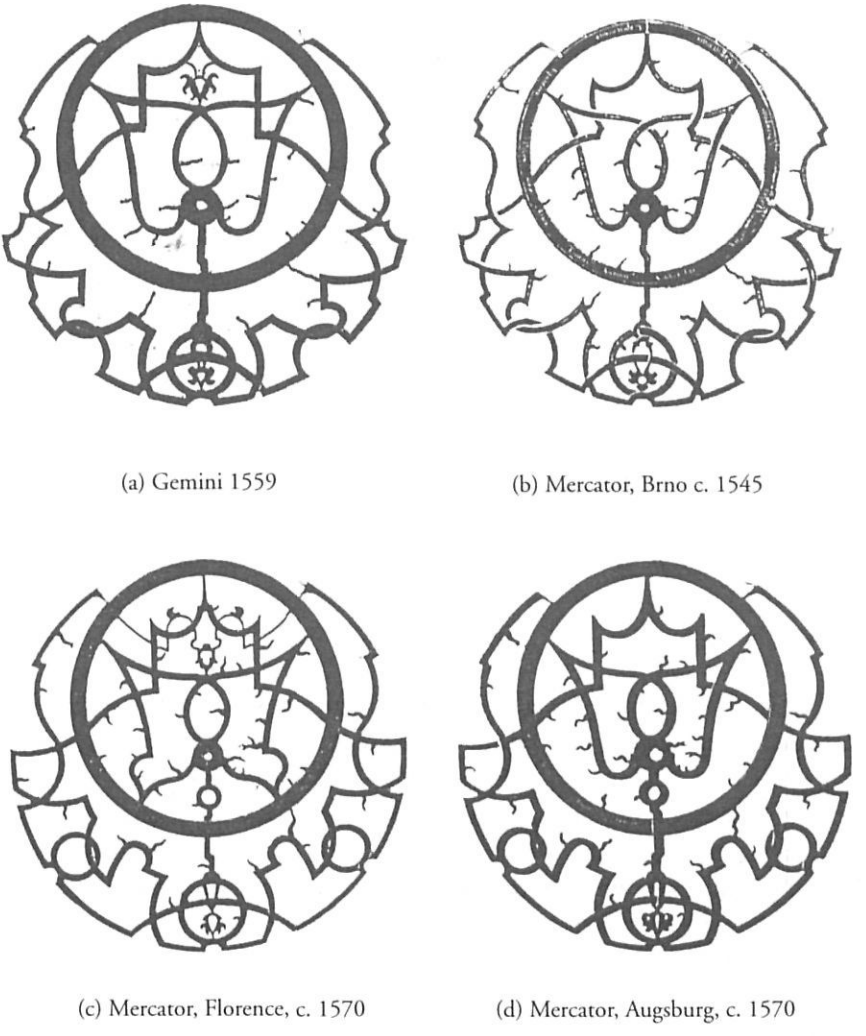
Fig. 6 The back of the Brno astrolabe

The maps with the Florence astrolabe are engraved on both sides of a copper disc, the land mass and decorative elements are gilded, while the seas are left as copper. This has blackened through long contact with the atmosphere. One side is a North polar projection to the Tropic of Capricorn, while the other side is a South polar projection cut off at the Tropic of Capricorn. This side has more space for engravings of monsters and sailing ships. On both sides the outer rim is divided into degrees, marked every five from 5° to 360°. The prime meridian runs through the Azores, a few degrees West of the Canaries, and through the magnetic pole, *Polus Magnetis*, at longitude 180° and latitude c. 74°. The meridians and the parallels are engraved for every 10°. The longitude scale is on the outer rim, marked by punched numbers every five degrees from 5° to 360°. The latitude scale is along the prime meridian and is marked every ten degrees from 10° to 90°. Both sides of the plate show the polar circles, *Circulus Arcticus* and *Circulus Antarcticus*, the equator, Circulus Aequinoctialis, and the two tropics, *Tropicus Cancri* and *Tropicus Capricorni*.

Fig 7. The map plate of the Florence astrolabe

Rete. The retes are in the 'tulip' strapwork pattern typical of the Flemish astrolabes of the sixteenth century. The Florence rete has some extra flourishes within the ecliptic circle, otherwise it is the same as Augsburg. The Brno rete is not identical to the other two; it bears a closer resemblance to the retes of Thomas Gemini,[10] a Flemish engraver working in London from about 1540 to 1562 (see Figure 8 for comparative silhouettes of the retes).

[10] For Thomas Gemini, see G.L'E. TURNER, *Elizabethan Instrument Makers: The Origins of the London Trade in Precision Instrument Making* (Oxford: OUP, 2000), pp. 12-20, 95-111.



(a) Gemini 1559 (b) Mercator, Brno c. 1545

(c) Mercator, Florence, c. 1570 (d) Mercator, Augsburg, c. 1570

Fig. 8 The rete patterns of the three Mercator astrolabes and one Gemini astrolabe

The retes on both the Florence and Augsburg astrolabes bear the names of the same 42 stars or groups of stars. The Brno instrument has 31 stars in common with those engraved on the Florence and Augsburg instruments with the same names. Of the remaining, 1 is not named, but is in the correct position for *Lanx septemtrionalis* (β Lib); 3 stars are common, but have different names; 1 has the same name, but refers to a different star (ι Cet). Additionally, the Brno

rete has 5 stars that are completely lacking on the others. On all three retes there are seven pointers for Ursa Major, and Cauda Capricorni has a bifurcated pointer. For the constellation Gemini, two stars are marked on the ecliptic circle, but these are not included on the Brno instrument. Two stars on the Brno astrolabe show careless, but all too human error in their positions. 'Orion: dex: hum:' (α Ori) has been given a Declination of -6° instead of +6°. 'Crus aquary' (δ Aqr) is displaced in Right Ascension by 30°, and in Declination by 10° (RA 307.38°, Dec -7.02° not RA 337.39°, Dec -17.56°).

The Brno rete provides the evidence that the laying out of the strapwork and star pointers was performed on the back. For an engraver not used to making astrolabes, the reversal of star position on to the back of the rete is bound to demand extra concentration. The mistakes in positioning these two stars are very simple ones. Six degrees to the wrong side of the ecliptic circle; 30°, starting from the wrong sign of the zodiac, and missing the ten, so measuring -7° instead of -17°. Could this have been a result of converting from the ecliptic co-ordinates of Copernicus to the equatorial co-ordinates used to mark out the astrolabe?

Alidade. On the Florence alidade one of the arms is divided with a scale 0-10 labelled *Horae ortus solis.* The sights have a notch at the top and a pinhole below. On either side of each sight is a wing, one with a hole and the other with a dot; the hole in one sight faces a corresponding dot on the other, for aligning on the Sun. The Augsburg alidade is similar, but with no decorative lines. The sights are rectangular with both pinhole and dot at each end. For Brno, the alidade is tapered in width; it is marked as before on the other two. The sights have a slit and pinhole at each end.

Rule. The Florence rule has both arms divided 0°-70°N and 0°-20°S. Scales are labelled *Declinatio septent: /Declinatio merid:*. The rules for Augsburg and Brno are the same as Florence, but with no decoration. Measurements of the alidades and the rules on the Florence and Augsburg instruments raise the possibility that they were made at the same time.

Pin. For Florence, the central fastener is a bolt, with incised triangular motif on the head and a foliate roundel on the nut. The washer has an acanthus and rose motif around its rim. For Augsburg it is a rod and wedge, with the head turned in concentric circles; the same for Brno, with a plainer circular head.

Throne. The thrones on all three astrolabes are the same: they are formed by a bar attached to the limb and supported by two S-shaped brackets with elaborate decoration. The ring at the top swivels above a bracket that moves in a shackle left or right. The boss is foliate on the Florence instrument and plain on the others. The pendant attached to the ring has a grotesque face on either side. The face and brackets are cast from the same mould. They seem to be stylized dolphins, a sea mammal whose form has had a perennial appeal in all manner of decoration. The dolphin is found as a support in architectural features such as the corbel or bracket.

Monogram. On the Brno astrolabe, the monogram 'GMR' has the G engraved in the way that is very typical of Gerard Mercator. The capital G is formed by cutting the semicircle first, followed by the vertical stroke, which leaves part of the circle protruding to the right below the vertical stroke. If this is an early piece, one of the first astrolabes made by Gerard, then it might well have contained errors that he was not proud of. Since it was usable to one who was aware of its faults, he put his initials on it in order to mark it as not for sale: purely personal to him.

Epoch. A careful measurement of the mean value and standard deviation in Right Ascension point to an epoch consistent with 1550 for the Florence astrolabe, and, because of its very close similarity, for the Augsburg astrolabe as well.[11] It is also known that Mercator's celestial globe of 1551 was plotted for the epoch of 1550.[12] It is the Copernican theory of precession explained in *De Revolutionibus* (1543) that was applied to produce the star positions, through an excess in longitude of 20° 55′ with respect to the Ptolemaic date (epoch AD 137).[13] Taking this value, a table has been made comparing the values of Right Ascension and Declination calculated from Ptolemy with measured values from the Brno astrolabe. This shows that the agreement is close. The values for the epoch of 1550 could not have been applied *before* about 1545, which is therefore the theoretical lower limit. If Mercator made the astrolabe between 1545 and 1550 he could have chosen an epoch of 1550. Dr Dekker has pointed

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[11] Data computed by Dr Dekker and published in TURNER and DEKKER, Appendix 2.

[12] TURNER and DEKKER, Section 7, and footnote 48.

[13] *Nicholas Copernicus Complete Works: On the Revolutions*, translation and commentary by Edward Rosen (Baltimore and London, 1978), Book III, chapters 11 and 12 (pp. 141-4).

out that Mercator's terrestrial globe of 1541 has 48 stars marked on it calculated on the pre-Copernican theory, which is 1° *less* than the figure for the precession used for the 1551 globe and the three astrolabes. The leading mathematician and astronomer of the period in the Low Countries was Gemma Frisius (1508-1555) of Louvain, with whom Mercator was associated. Dr De Smet has shown that Gemma Frisius had a close link with Poland through that country's ambassador to The Netherlands, Johannes Dantiscus (1485-1548), who was patron to Gemma. In Gemma's book, *De radio astronomico et geometrico* (Antwerp, 1545), there is enthusiasm for *De Revolutionibus*: 'il se réfè plusieurs fois à Copernic et de manière fort élogieuse'[14]. Naturally, the latest information obtained by Gemma would have been available to Mercator.

When were the astrolabes made?

Evidence from the Rete Pattern

As has been pointed out, the rete patterns of the Florence and Augsburg astrolabes are the same. The Brno rete, however, has a closer kinship with two astrolabe retes made by Thomas Gemini of London that are dated 1559[15]. Thomas Gemini (originally Lambert, Lambrit, or Lambrechts), was born in eastern Flanders at Lixhe (Lieze) in about 1510, which is really an educated guess. He died in London in June 1562. He had migrated to Blackfriars, London in around 1540, and set up as an engraver, printer, and instrument maker. Gemini is known chiefly for his edition of Versalius's Fabrica that he published in London in 1545 with the title *Compendiosa totius anatomie delineatio*. For this he received a pension from King Henry VIII. In 1555, he published maps of Spain and of England, and in the same year published Leonard Digges's *Prognostication of Right Good Effect*. What is important about Thomas Gemini (the name he assumed in his London period) in the present context are the similarities between his style and that of Gerard Mercator. Gemini was a highly skilled engraver, and his calligraphy owes everything to that expounded and taught by Gerard Mercator.

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[14] A. DE SMET, 'Gemma Frisius et Nicolas Copernic', *Der Globusfreund*, Nr. 21-23, October 1973 (for 1972/73/74), pp. 72-80 (p. 75). KERROW (note 8), pp. 205-15, lists Gemma's production of globes and books.

[15] Museum of the History of Science, Oxford, dated 1559, and dedicated to Queen Elizabeth of England, inv. no. 42223 (IC 575); Istituto e Museo di Storia della Scienza, Florence, dated 155 [last numeral omitted], inv. no. 1093 (IC 489). For Gemini, see note 10.

Thomas and Gerard, being much the same age, may have trained together in the workshop of Gaspar van der Heyden, a goldsmith of Louvain, who produced in 1536, with the co-operation of Mercator, a globe for Gemma Frisius. Mercator acquired tools in 1540, and from then on worked at Louvain independently of Van der Heyden and Gemma Frisius.[16] This is also about the time that Thomas Gemini is thought to have left Flanders for London. During the 1540s, Mercator is known to have made mathematical instruments, and the group of instruments made for the Holy Roman Emperor Charles V points to his high degree of skill. It must be stressed that the style and quality of the work by Thomas Gemini is such that he could have learned it only at Louvain before his London period. One would expect that he travelled with ideas for instruments (of which 7 are known, 4 being astrolabes), so that his rete pattern, examples of which date from the end of the 1550s, could have originated from 1540. Mercator could have kept in mind over a few years the same rete pattern.

For Mercator, the decade began with his terrestrial globe (1541) and ended with his celestial globe (1551). During this period his calligraphy settled down into the style he kept through the rest of his life, which was spent in Duisburg from 1552. A careful scrutiny of the gores that form these two globes prompts the impression that the engraving on the Brno astrolabe resembles more the globe of 1541 than it does that of 1551.

The Horary Quadrant

The back of the Brno astrolabe has two horary diagrams, the upper left is for conversion between equal and unequal hours, and the upper right (blank on Florence and Augsburg astrolabes) is the horary quadrant for finding the time in unequal hours from the Sun's altitude. For equal hours the day/night period is divided into 24 equal hours. Unequal hours are formed by dividing the day and night periods each into 12 hours, which become equal to each other only at the equinoxes. Clocks keep equal hours, but many sundials, from Roman times into the seventeenth century, are constructed to read unequal hours. The diagram of unequal hours and its approximate readings, except at sunrise, noon, and sunset, is fully analysed mathematically by Dr Archinard.[17]

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[16] TURNER and DEKKER, Section 5.

[17] Margarida ARCHINARD, 'The Diagram of Unequal Hours', Annals of Science, 47 (1990), 173-90

The horary quadrant occurs in the medieval period, but an earlier Islamic source is likely, and it has been pointed out that a ninth-century Baghdad text, recently discovered in Cairo, describes the horary quadrant[18]. Western astrolabes are not infrequently provided with this quadrant, possibly through inertia or as decoration: it had become expected, traditional even, or looked nice in an otherwise blank space. On the astrolabe it was always small, and is inherently inaccurate, getting much worse as the user moves to higher latitudes (e.g., above 30°). Its presence on an instrument of the accuracy that Mercator intended his to have is anomalous. The other diagram, for the interconversion of equal and unequal hours, is useful because the astrolabe measures the equal hours and many monumental sundials the unequal, and so it is these that people would be used to. Mercator chose to leave a blank space on his masterpiece and its close kin, so the presence of the diagram on the Brno astrolabe points to an earlier period in Mercator's life.

The Astrolabes at Florence and Augsburg

There are several independent pieces of evidence that, taken together, focus a date for two of the astrolabes to quite a narrow span of years. The sheer controlled skill of the engraver's hand, and so many characteristic letter forms, point to Gerard Mercator's second period, which was at Duisburg. The style has settled down by the time of the celestial globe (1551), and found its great expression with the world map of 1569.

The map plate does not appear to be in the hand of Gerard, and a case has been put forward that this was engraved by the second son, Rumold.[19] He was born c.1546, and by 1565, at the beginning of his twenties, he would have been mature enough to produce the map plate. This is the period in the run-up to the publication of the world map, when Gerard would have needed additional help because of the volume of work. From the evidence of his own signed map of the world published in 1587, Rumold was highly skilled, and his hand seems to match that of the map plate's engraver.

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[18] D.A. KING, *Islamic Astronomical Instruments* (Variorum Reprint CS253) (London, 1987), chapter 1, p. 9.

[19] TURNER and DEKKER, p. 430, Section 6.2.

The role of Egnazio Danti in Florence is almost certainly an important reason for the presence there of a Mercator astrolabe. He was appointed Cosmographer to Duke Cosimo de'Medici in 1562, and designed a globe and 29 wall maps between 1564 and 1575 for the *Guardaroba* in the Palazzo Vecchio[20]. In 1569 he published a treatise on the astrolabe. Cosimo de'Medici came to power in 1537. Through skill, luck, and force of arms he was created the first Grand Duke of Tuscany on 27 August 1569. He was now 50, and his Cosmographer, whose *Trattato* on the astrolabe had just been published with a dedication to Cosimo showing the six balls of the Medici over a globe of the Earth, was 33 years old. Clearly in great favour, Danti was, in 1571, granted permission to live in the Palazzo Vecchio. Unfortunately for Danti, Cosimo died on 21 April 1574, and was succeeded as Grand Duke by his son Francesco (1541-1587), who disliked Danti and summarily dismissed him on 28 September 1575.

Danti's presence in Florence between 1562 and 1575 sensitized the court to cosmography, and one would expect to find here the reason for a copy of Mercator's world map to have been purchased at Antwerp on 1 November 1569 for delivery to Florence.[21] Although the local craftsmen were reasonably competent, they were no match for the renowned cartographic and craft centre: Flanders. At the time of the crowning of the first Grand Duke of Tuscany in 1569, what would be more appropriate than to acquire from the world's finest astrolabe maker an example of his art? After all, Gerard Mercator had made mathematical instruments for the Holy Roman Emperor himself, and Cosimo was rising in the courtly circles of Europe.

All things considered, the date of *circa* 1570 seems to fit this astrolabe of Gerard Mercator and his Duisburg workshop. The Augsburg astrolabe is the same size and has the same back as the Florence instrument, has the same star names, but differs in having a less elaborate rete and it is not gilded. Another common feature is in the sizes of the alidades and rules. The Florence alidade and the Augsburg rule have the same width (15mm) and the same thickness (3.5/3.4mm); the Florence rule and the Augsburg alidade have the same width

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[20] ETTORE and Alessandro CECCHI, *Palazzo Vecchio e i Medici: Guida Storica* (Florence, 1980), pp. 303-10.

[21] See TURNER and DEKKER, p. 437.

(13mm) and the same thickness (4.0/4.2mm).[22] It is tempting to believe that these parts were made at the same time. The weight of evidence means that a date near 1570 is also reasonable for the Augsburg astrolabe.

The Astrolabe at Brno

The Brno astrolabe was most probably made earlier than the others. The calligraphy is slightly different, suggestive of an earlier date. If one examines the style of the engraved letters and numbers on Mercator's globes of 1541 and 1551, one readily sees many small variations in the layout of the letters, and the decorative flourishes, which are more pronounced in the earlier globe and on the Brno astrolabe. The pattern of the Brno rete has a greater similarity to the retes cut by Thomas Gemini, who left Louvain for London in about 1540, than it has to the other two Mercator astrolabes. Then there is the choice of stars and star names on the rete, which has a number of layout mistakes in its construction. The mispositioning of two star pointers, and forgetting to engrave the name of the star on one pointer, suggest a certain unfamiliarity with the details of the construction of astrolabes. The unequal hour diagram in a quadrant left blank on the other two instruments is yet another pointer to an earlier date. It is not an accurate device, and if the unequal hour is required, then it is much better to take the reading on the astrolabe of the equal hour and then convert by means of the diagram engraved on the left-hand quadrant that is to be found on all three of Mercator's astrolabes. The use of the epoch of 1550 for the laying out of the rete stars shows that the Copernican theory had already reached Louvain, which it did by 1545.

It is the calligraphy that points strongly to a date during the 1540s for the Brno astrolabe, and various other features do not contradict this proposal. If correct, then the Brno astrolabe was made in Mercator's Louvain workshop, while the astrolabes now at Florence and Augsburg were made in the Duisburg workshop.

Dimensions of the Instruments

Any craftsman wishing to make an instrument like an astrolabe, sundial, or globe, would select a suitable size in a measure familiar to his workshop. Thus

[22] See Table 3. The thickness measurements were made in a few places to provide a guide. The alidades and rules do not have a completely uniform thickness.

in England, Humfrey Cole's large astrolabe of 1575 is 24 English inches in diameter, and globes are customarily 3, 9, 12, 18, or 24 inches in diameter. Mercator's astrolabes are about one foot in diameter, and his globes are over one foot in diameter. But which foot? In the sixteenth century, Mechelen (Malines) near Louvain was the most influential city of the Low Countries, and its foot is equivalent to 278mm. Van der Heyden came from this city, and Mercator lived there after his university years at Louvain. Van der Heyden's globes of 1536 and 1537 have diameters of 370mm, exactly $1^{1/3}$ Mechelen feet. Mercator's 1541 and 1551 globes have diameters of 420mm, equivalent to $1^{1/2}$ Mechelen feet. The Brno astrolabe has a diameter of 278mm, exactly one Mechelen foot. The other two astrolabes, made in Duisburg on the Rhine, have diameters of 316mm and 317mm, and the Rhineland foot is equivalent to 315mm.[23]

Acknowledgements

I have pleasure in acknowledging my indebtedness to my co-author of a previous paper, Dr Elly Dekker. I am also grateful for the co-operation of the directors and curators of the museums holding the Mercator astrolabes. Professor Paolo Galluzzi, and Dr Mara Miniati, of the Istituto e Museo di Storia della Scienza, Florence; Dr Renate Eikelmann, Augsburg; Dr K. Holesovsky, Brno.

[23] Globe diameters from KARROW (footnote 7), 377, 382, 384. Measures from Horace DOURSTHR, *Dictionnaire Universel des Poids et Mesures anciens et modernes* (Brussels, 1840; 3rd edn, 1976).