THE DISCOVERY OF GERARD MERCATOR'S ASTROLABES

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Introduction

Gerard Mercator was born on 5 March 1512 at Rupelmonde in Flanders, and died on 2 December 1594 at Duisburg in Germany. Therefore 1994 is being marked as the 400th anniversary of his death. From 1530, when he entered the University of Louvain, he studied philosophy and theology; however, on graduating he turned to astronomy and mathematics working under the guidance of Gemma Frisius. He determined to transform cartography, which was vital for the exploration of the world that followed the discoveries of Christopher Columbus. Mercator became a highly skilled engraver, cut copperplates of his italic scripts, engraved the gores for his first globe in 1536, and in 1537 published his first map. His revolutionary contribution to cartography, one of the great inventions of all time, was his world map of 1569 drawn using the cylindrical projection he devised. It is this map, meant for ships' navigators, that continues to be familiar to many people today. Mercator is famed, secondly, for the great collection of maps he designed, engraved, and published during the later part of his life. The entire collection was published by his son Rumold in the year after Gerard Mercator's death as the "Atlas : or Cosmographical Meditations on the Structure of the World". This was the first time that a collection of maps had been given the name Atlas.

No instruments made by Gerard Mercator were known to have survived until the present writer identified an astrolabe, early in 1992, in the Istituto e Museo di Storia della Scienza, Florence; it is unusual because it has a double-sided map plate.[1] 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.[2] Danti published his *Trattato dell'uso et della fabbrica dell'Astrolabio* at Florence in 1569, the same year that Cosimo (1519-1574) was created Grand Duke of Tuscany on 27 August by the Pope in Rome. It is likely, therefore, that the Florence Mercator astrolabe was bought for the occasion.

While the Florence instrument was being studied, two more astrolabes were identified as closely similar.[3] 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. The Brno astrolabe is slightly smaller, 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. Gerard Mercator was born at Rupelmonde, and referred to himself by this style on his productions from 1536.[4]

The astrolabes described

The astrolabes are made of brass, with the Florence example gilded. Associated with this 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.

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 (un)equal 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. On the Augsburg instrument the sides are labelled *Longitudo minor*; *Longitudo maior*; *Latitudo meridiana*; *Latitudo ſeptentrionalis.* Superimposed are 32 radial lines each labelled in Dutch with the wind directions. The Brno mater is similar to Augsburg, but rotated through 180°; the winds are not named except for the cardinal points.

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.

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.[5] 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').

A remarkable feature on the Florence plates is the burnishing of the gilding in alternate segments of the unequal hours and on some other parts. Such a decorative conceit has been remarked on only one other astrolabe (also Flemish), and means that the instrument came from a first-class workshop, and that it was probably made for a notable customer.

The Florence astrolabe's maps are engraved on 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*.

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. Both have pointers for 50 stars; Brno has pointers for 48 stars.[6] The Brno rete is not identical to the other two; it bears a closer resemblance to the retes of Thomas Gemini, a Flemish engraver working in London from about 1540 to 1562.[7]

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. Also two stars are in the wrong position through simple errors in calculation, for example a Declination of -6° instead of +6°, and -7° instead of -17°.

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; the brackets 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 typical manner 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.

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.[8] Thomas Gemini (originally Lambert, Lambrit, or Lambrechts), was born in eastern Flanders at Lixhe (Lieze) in about 1510. 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 Vesalius' *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 is the similarity 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.

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 cooperation 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. 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 reputation and 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.

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.[9]

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 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 analyzed mathematically by Dr Archinard.[10] The horary quadrant that appears on the upper right of the Brno astrolabe occurs in the medieval period, and it is inherently inaccurate, getting much worse as the user moves to higher latitudes (e.g., above 30°). 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.[11] 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.

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 II in 1562, and designed a globe and 29 wall maps between 1564 and 1575 for the *Guardaroba* in the Palazzo Vecchio. In 1569 he published a treatise on the astrolabe. Cosimo de'Medici came to power in 1537. With 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 introduced

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. 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, and 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

It can be argued that the Brno astrolabe was made earlier than the others. In fact, it may have been the first, or one of the first, astrolabes made by Mercator in his Louvain workshop. 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 is closely similar to the retes cut by Thomas Gemini, who left Louvain for London in about 1540; the other two Mercator astrolabes have quite noticeable differences in the pattern. Then there is the choice of stars and star names on the rete, which has a number of layout mistakes in its construction. 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 star positions on all three astrolabes can be shown to be according to the new theory of Copernicus published in 1543, and which reached Gemma Frisius in Louvain quite rapidly. This gives a lower limit of about 1545 for the Brno astrolabe.

There is yet another significant piece of evidence to show that the Brno astrolabe was made in Louvain and not in Duisburg, and this is in the size of the instrument. It is customary for globes and instruments to be made with dimensions in convenient units of the local standard measure. For example, globes can be 6, 9, 12, 15, 18, etc inches in diameter; reflecting telescopes have mirrors with a focal length of 1, 1½, 2, 3, 7, etc feet. Mercator's astrolabes are about one foot in diameter, while his most famous globes are 1½-foot in diameter. But which foot ? In the sixteenth century, Mechelen 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. Taking the standard of one Mechelen foot at 278mm, and one Rhineland foot at 315mm (as used at Duisburg), the following table can be constructed.

Standards of length used by Mercator		
Van der Heyden, Globe 1536	370mm	16 Mechelen inches
Van der Heyden, Globe 1537	370mm	16 ditto
Mercator, Globe 1541	420mm	18 ditto
Mercator, Globe 1551	420mm	18 ditto
Mercator, Astrolabe, Brno, *c.*1545	278mm	12 ditto
Mercator, Astrolabe, Augsburg, *c.*1570	317mm	12 Rhineland inches
Mercator, Astrolabe, Florence, c.1570	316mm	12 ditto

It is the calligraphy that points to a date during the 1540s for the

Brno astrolabe, and the standards of length strongly support this. If correct, then the Brno astrolabe was made in Mercator's Louvain workshop during the period 1545 to 1550, while the astrolabes now at Florence and Augsburg were made in the Duisburg workshop around 1570.

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Notes

1. This astrolabe is fully described in Gerard L'E. Turner and Elly Dekker, "An Astrolabe attributed to Gerard Mercator, *c.*1570", *Annals of Science*, 50 (1993), pp. 403-443. This paper will be referred to subsequently as Turner and Dekker. Instituto 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).

2. Turner and Dekker, Section 3.

3. Städtische Kunstsammlungen, Augsburg, Germany, inv. no.3537 (IC 4609). Moravská Galerie, Brno, Czech Republic, inv. no. 24-385 (IC 4608). All the astrolabes are described in G.L'E. Turner, "The Three Astrolabes of Gerard Mercator", *Annals of*

Science, 51 (1994), pp. 329-353.

4. 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.

5. See G.L'E. Turner, "The Florentine Workshop of Giovan Battista Giusti, 1556-*c.*1575", *Nuncius : Annali di Storia della Scienza*, 10, pt 1 (1995), in press.

6. The stars are listed in Turner and Dekker, pp. 438-439, and in Turner, "The Three Astrolabes", p. 344.

7. For Thomas Gemini, see C.D. O'Malley in *Dictionary of Scientific Biography*, v (New York, 1972), pp. 347-349.

8. Museum of the History of Science, Oxford, dated 1559, and dedicated to Queen Elizabeth of England, inv. no. 36.6 (IC 575); Instituto e Museo di Storia della Scienza, Florence, dated 155 [last numeral omitted], inv. no. 1093 (IC 489).

9. See the reproductions from originals in the Bibliothèque royale at Brussels, *Les Sphères terrestres & célestes de Gérard Mercator 1541 et 1551* (Brussels, 1968), Preface by A. de Smet.

10. Margarida Archinard, 'The Diagram of Unequal Hours', *Annals of Science*, 47 (1990), pp. 173-190. Professor J.D. North confirms the unsatisfactory nature of this diagram, see his *Stars, Minds and Fate : Essays in Ancient and Medieval Cosmology* (London and Ronceverte, West Virginia : Hambledon Press, 1989), pp. 221-2.

11. Turner and Dekker, p. 430, Section 6.2.