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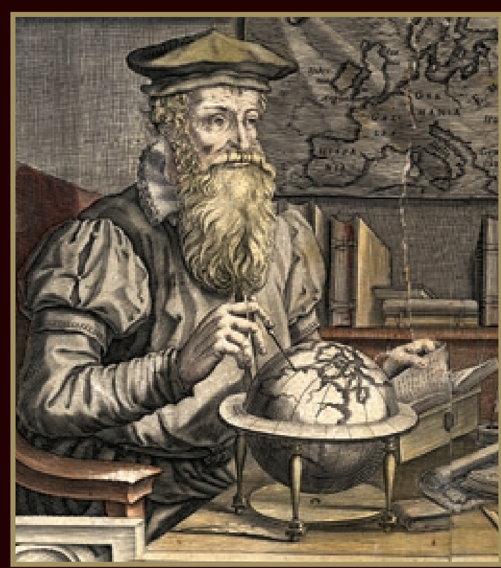
THE Renaissance in Astronomy

BOOKS, GLOBES AND INSTRUMENTS OF THE 16TH CENTURY

An exhibition by the Royal Astronomical Society and the Museum of the History of Science to mark the 500th anniversary of the birth of Gerard Mercator



The anniversary of Mercator's birth is an invitation to take an alternative look at 16th-century astronomy. Historians of science have generally made astronomical theory, and in this period planetary theory in particular, the focus of their attention: this was the century in which Copernicus published his account of the heavens, where the earth moved as a planet in the solar system. The titles of seminal works tell their own story, from J.L.E. Dreyer's *History of the Planetary Systems from Thales to Kepler* at the beginning of the 20th century, to the work of that most influential thinker about science in the late century, Thomas Kuhn, *The Copernican Revolution: Planetary Astronomy in the Development of Western Thought*. When Englishmen were given a part in the story, it was through the contribution of Francis R. Johnson, *Astronomical Thought in Renaissance England*. Thinking and theorising were the essence of astronomical work.

We can view Mercator's career as an integration of learning and skill. He was a cartographer, cosmographer, astronomer, engraver, printer and instrument-maker. If we no longer focus on planetary theory, we can see all these disciplines within a more inclusive account of 16th-century astronomy, one more in keeping with the working lives of the practitioners themselves.

Thought and theory are integral to astronomy, of course, and have to be part of the story told here. Copernicus must still have a central role. But presenting theory in an exhibition, however necessary to make sense of the narrative, is not to use the medium most effectively and emotively. Exhibitions are best at presenting objects, and craft is evident at every turn in the material record of Renaissance astronomy. Its objects – books, globes and instruments – were made by craftsmen in workshops and print-shops that were valued as sites of astronomical practice.

Claudius Ptolemy: Astronomy and Cosmography

The exhibition contains an example of the first printed edition of Ptolemy's *Almagest* (Venice, 1515) [1], the most sophisticated and influential astronomical treatise to survive from antiquity. It was produced by Peter Liechtenstein, a German printer who established a press in Venice towards the end of the 15th century. He was from Cologne, an early centre for printing (where England's first printer, William Caxton, had learnt the trade) and had printed other works of astronomy and astrology. This Latin translation of *Almagest* had been made from Arabic by Gerard of Cremona in the 12th century.

Also on display [14] is one of the most remarkable embodiments of the Ptolemaic planetary system, with its combinations of circles for calculating the positions of the planets in their wandering paths around the stationary earth. This is the *Astronomicum Caesareum* of Peter Apian, mathematician and cosmographer of Ingolstadt, who, like a number of the principal characters in this story, ran a printing press. This work was as much a constructed paper instrument as it was a printed book, with an 'equatorium' (an instrument for calculating planetary positions) for each of the planets.

Almagest was far from being Ptolemy's most published work in the period: by the time it appeared in print, there were already a number of editions of his *Geographia*. The common title for Ptolemy's 'Geography' in the 16th century was *Cosmographia*, and it is sometimes said that it was a 'mistake' that this title was so frequently used. An incorrect translation it may have been, but the publishers and printers of the many editions knew what they meant by the discipline of 'cosmography' and Ptolemy's work fitted this very well. It dealt with the coordinate grid for location on earth (latitude and longitude) and the relationships between time and place, while linking these variables with what was observed in the heavens.

Cosmography dealt with the presentation of the entire cosmos: the heavens and the earth together and the spatial relationship between them. Its products – the 'presentations' – took a range of forms: maps, globes, spheres, sundials, textual descriptions and even, in the case of a 16th-century project for part of the Palazzo Vecchio in Florence, a whole room with maps covering the walls and the constellations of the heavens on the ceiling. The maker of an instrument in the exhibition [21], the cosmographer Miniato Pitti, played an important part in the design of this room.

Cosmography had an astronomical component, dealing with the stars, the sun and their motions. Cosmographical astronomy taught that the imaginary circles used to manage the geography of our stationary earth – equator, tropics, lines of latitude and longitude – correspond to and are derived from equivalent circles in the movement of the heavens (the celestial equator, the tropics of Cancer and Capricorn, and the astronomical co-ordinates of declination and right ascension). Cosmographers were familiar with the starry heavens and how their appearance varied with the observer's location on earth; only the specialist mathematical astronomers had to tangle with the more challenging motions of the planets other than the sun and to read *Almagest*.

Almagestū CL. Ptolemei
Pheludiensis Alexandrini Astronomoꝝ principis:
Opus ingens ac nobile omnes Celorū motus continens. Felicibus Astris eat in lucē: Ductu Petri Liechtenstein Coloniēsis Germani. Anno Virginei Partus. 1515. Die. 10. Ja. Venetijs ex officina eius dem litteraria.
* *
*

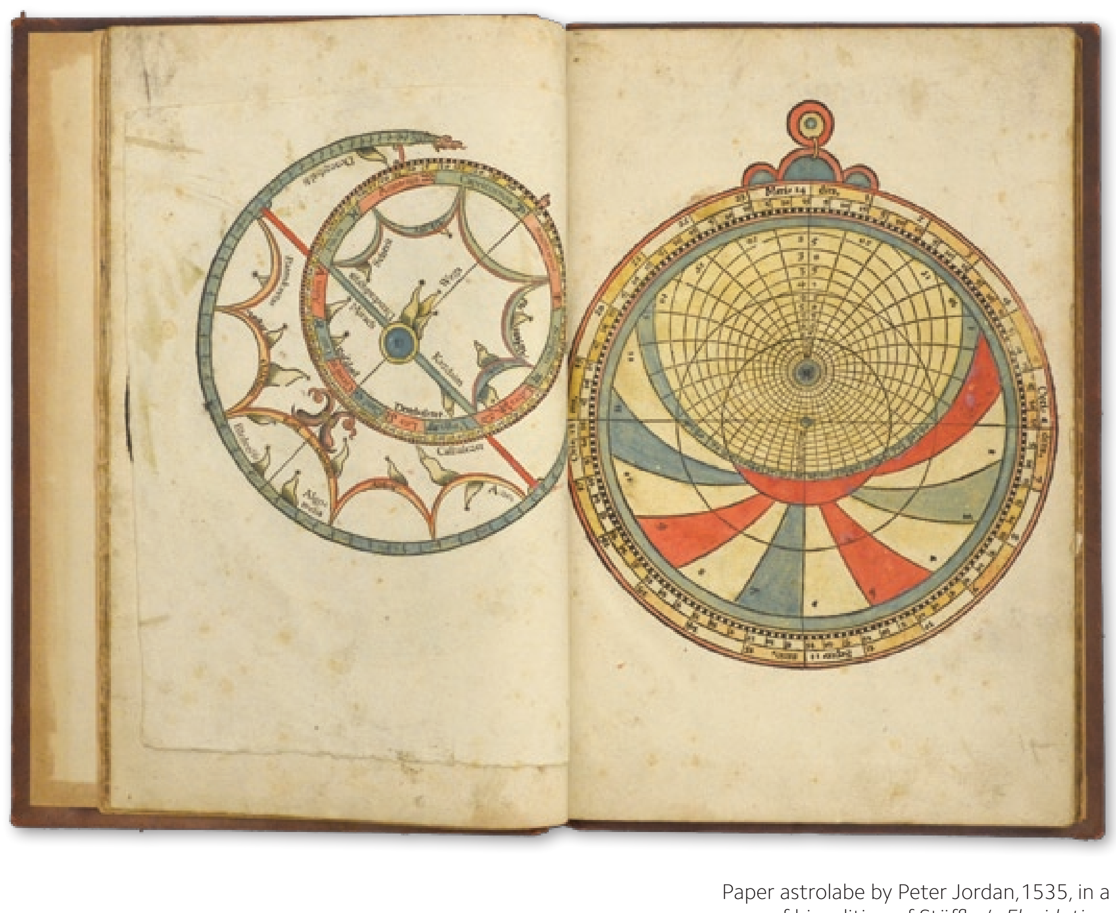
From the title-page of Claudius Ptolemy, *Almagest* (Venice, 1515)

Johann Stöffler and the Astrolabe

It is appropriate to the exhibition, with its emphasis on craft, that the first book of original astronomy published in the 16th century dealt with an instrument, the astrolabe, approached as something to be made and used [2]. This was *Elucidatio fabricae ususque astrolabii*, by Johann Stöffler, professor of mathematics at the University of Tübingen. It was published in Oppenheim in 1513 – earlier than any printed edition of the *Almagest* – and the printer was the mathematician Jakob Köbel. Stöffler was a globe- and instrument-maker who published on cosmography and wrote a commentary on Ptolemy's *Geography*. He deals in turn with the construction and use of the astrolabe, and this set a pattern, already used in medieval treatises, for many printed accounts of instruments that appeared in the 16th century.

There were also many editions of Stöffler's *Elucidatio* and one on display [3], printed in Mainz in 1535 by Peter Jordan, includes a lovely, coloured paper astrolabe. No doubt it was meant to be cut out and assembled. A printed paper astrolabe in the exhibition [11], which has been cut out and mounted on a wooden base, takes us to a city with a more sustained contribution to the story of astronomical craft, Nuremberg. Here the workshop and print-shop of Georg Hartmann had a large output and a widespread influence, not least because his printed instruments could be produced in numbers and distributed cheaply. Hartmann was another mathematical writer who was a printer and a globe- and instrument-maker.

The exhibition also has a brass astrolabe by Hartmann [9], made in Nuremberg in 1527, and from the same city an astrolabe by Johann Wagner [10] and portable sundials by Hartmann [12], Johann Gebhart [13] and Christian Heiden [26]. It is not surprising that it would fall to a printer of Nuremberg to produce the *De revolutionibus* of Copernicus.



Paper astrolabe by Peter Jordan, 1535, in a copy of his edition of Stöffler's *Elucidatio*

Books, Globes and Instruments in the Exhibition

1. Claudius Ptolemy, *Almagest* (Venice, 1515)
2. Johann Stöffler, *Elucidatio fabricae ususque astrolabii* (Oppenheim, 1513)
3. Paper astrolabe by Peter Jordan, Mainz, 1535, included in his edition of Stöffler's *Elucidatio*
4. Armillary sphere by Carlo Plato, 1588, Rome, MHS inventory no. 45453
5. Celestial globe by Johann Schöner, c.1534
6. Johann Schöner, *Globi stelliferi, sive sphaerae stellarum fixarum usus et explicationes* (Nuremberg, 1533)
7. Johann Schöner, *Tabulae astronomicae* (Nuremberg, 1536)
8. Johann Schöner, *Opera mathematica* (Nuremberg, 1561)
9. Astrolabe by Georg Hartmann, Nuremberg, 1527, MHS inventory no. 38642
10. Astrolabe by Johann Wagner, Nuremberg, 1538, MHS inventory no. 40443
11. Astrolabe by Georg Hartmann (wood and paper), Nuremberg, 1542, MHS inventory no. 49296
12. Diptych dial by Georg Hartmann, Nuremberg, 1562, MHS inventory no. 81528
13. Lower leaf of a diptych dial with city view of Nuremberg, by Johann Gebhart, Nuremberg, c.1550, MHS inventory no. 58226
14. Peter Apian, *Astronomicum Caesareum* (Ingolstadt, 1540)
15. Nicolaus Copernicus, *De revolutionibus orbium cœlestium* (Nuremberg, 1543)
16. Georg Joachim Rheticus, *Narratio prima* (Basel, 1566), printed with the second edition of Copernicus, *De revolutionibus*
17. Terrestrial and celestial globes by Gerard Mercator, 1541, 1551
18. Gerard Mercator's copy of Nicolaus Copernicus, *De revolutionibus orbium cœlestium* (Nuremberg, 1543)
19. Peter Apian and Gemma Frisius, *Cosmographia* (Antwerp, 1584)
20. Astrolabe (cosmographical mirror) and universal altitude sundial by Gillis Coignet, Antwerp, 1560, MHS inventory no. 53211
21. Altitude sundial and horary quadrant by Miniato Pitti, Florence, 1558, MHS inventory no. 44865
22. Astronomer's rings by Gualterus Arsenius, Louvain, 1567, MHS inventory no. 48126
23. Astrolabe by Regnerus Arsenius, Louvain, 1565, MHS inventory no. 53558
24. Erasmus Reinhold, *Prutenicæ tabulæ coelestium motuum* (Tübingen, 1551)
25. Horary quadrant and altitude sundial by Christian Heiden, German, 1553, MHS inventory no. 38947
26. Diptych dial by Christian Heiden, Nuremberg, 1569, MHS inventory no. 80277
27. Polyhedral dial by Nicolaus Kratzer, London, c.1525, MHS inventory no. 54054
28. Robert Recorde, *The Castle of Knowledge* (London, 1556)
29. Astrolabe by Thomas Gemini, London, 1559, MHS inventory no. 42223
30. Tycho Brahe, *Astronomiae instauratae mechanica* (Nuremberg, 1602)

Further information on all these objects may be found on the Museum's website, where there is an on-line version of the exhibition with all the individual labels (www.mhs.ox.ac.uk/exhibits/the-renaissance-in-astronomy). The Museum's objects also appear in a searchable database of the collection (www.mhs.ox.ac.uk/collections/search).

Loans

We are grateful to the following institutions for loans to the exhibition:
Royal Astronomical Society, London: item numbers 1, 5, 6, 7, 8, 14, 15, 16, 24, 28 and 30
Royal Museums Greenwich: item number 17: GLB0096 (http://collections.rmg.co.uk/collections/objects/19783.html) and GLB0097 (http://collections.rmg.co.uk/collections/objects/19784.html)
Special Collections Department, University of Glasgow Library: item number 18: Sp Coll Hunterian Cz.1.13 (http://special.lib.gla.ac.uk/exhibns/month/apr2008.html)

Thanks

We are grateful to the Barbara Whatmore Charitable Trust and to Trevor Philip & Sons Ltd, London, for generous contributions towards the costs of loans to the exhibition.

Johann Schöner in Nuremberg

Johann Schöner was a mathematician, astronomer, cosmographer, printer and globe-maker of great esteem and influence in the early 16th century. Born in Karlstadt near Würzburg, he was a priest in Bamberg, where he had a printing press and produced maps and globes, and from 1526 he taught mathematics in Nuremberg, where he became a Protestant.

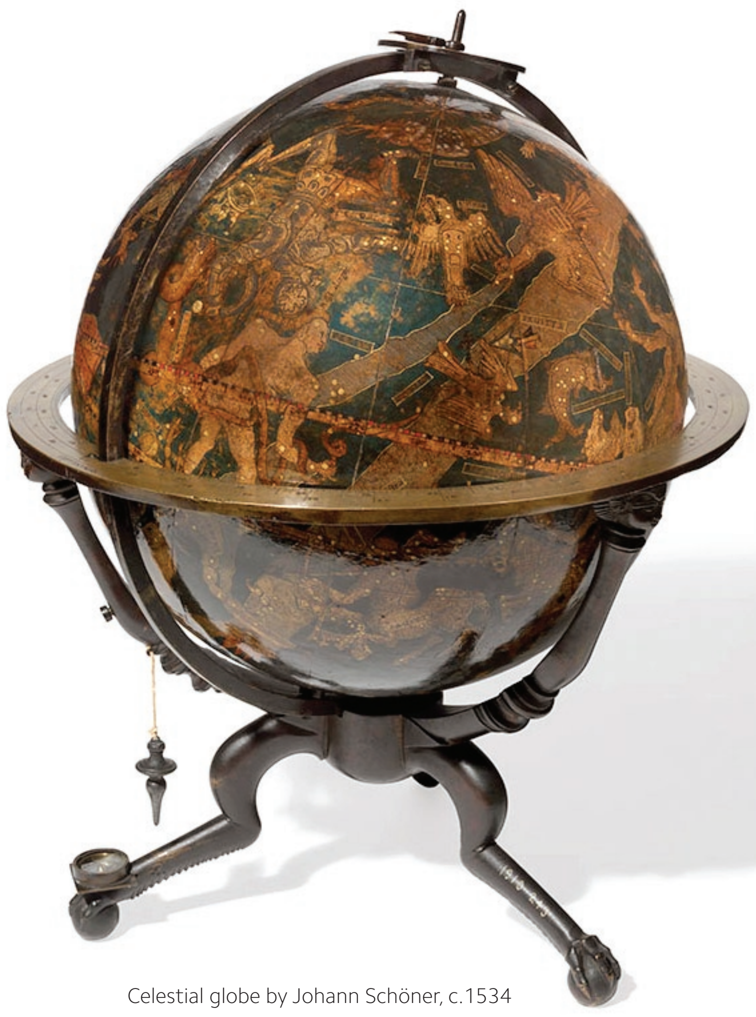
It was in Nuremberg that Schöner befriended, as a guest in his home, a young mathematics professor from the Lutheran stronghold of Wittenberg, Georg Joachim Rheticus. When Rheticus made his famous journey north to Frauenberg, where Nicolaus Copernicus was a canon of the cathedral and was known to have a novel astronomical theory, he was persuaded to do so by Schöner and encouraged by Georg Hartmann. He brought a letter of introduction from Schöner and among the books he took as presents were Ptolemy's *Almagest* and Schöner's edition of Regiomontanus's tract *De triangulis*.

One of the outstanding objects in the exhibition is the celestial globe made by Schöner in c.1534 [5]. It is one of only two examples of the earliest extant printed celestial globe, this one being mounted in a stand dated 1535; the woodcuts from which they were printed had been completed by 1533. Like many of the books on display, it is on loan from the Royal Astronomical Society, but unlike the books, the globe is not scheduled to return at the end of the exhibition but will remain on display in Oxford. It is not Schöner's first printed globe: he made smaller celestial and terrestrial globes in 1515 as a pair, indeed the first pair of globes ever produced. Pairing a celestial and a terrestrial in this way created a new invention in cosmography, in its attempt to deal with the relationship between the heavens and the earth. No example of the 1515 celestial globe survives.

The celestial globe of c.1534 also had a terrestrial companion and Schöner published short tracts describing them in 1533. A rare example of the tract on the celestial globe [6], *Globi stelliferi, sive sphaerae stellarum fixarum usus et explicationes*, shows the woodcut illustration of the stand, which coincides closely with the globe on display. A later edition, included in Schöner's *Opera mathematica* of 1561, adds the constellations to the surface [8].

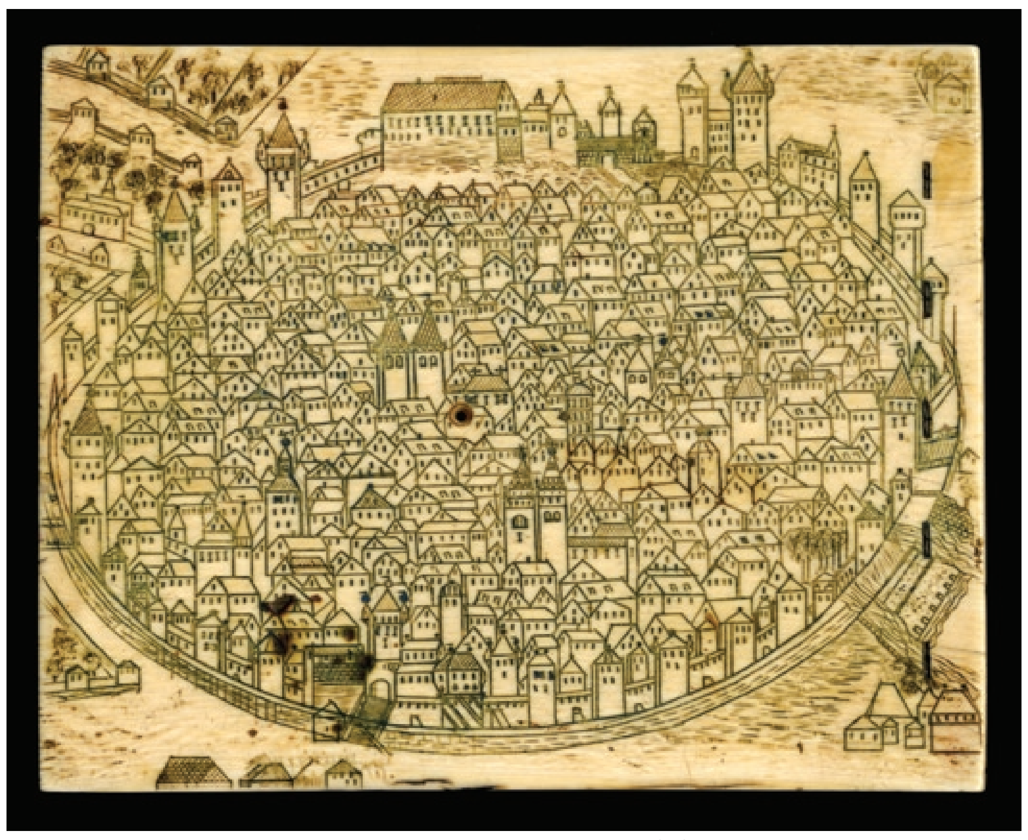
The copy of Schöner's *Tabulae astronomicae* of 1536 [7] illustrates the connections of 16th-century astronomy and its important position in Reformation Germany. To his tables Schöner adds a tract by Regiomontanus. A commendatory preface addressed to Schöner is a contribution by the leading Lutheran theologian and scholar Philipp Melanchthon. The book was published in Nuremberg by the celebrated printer Johannes Petreius, who had collaborated with Schöner as his editor on a number of mathematical works, including other tracts by Regiomontanus.

Melanchthon had been a student of Johann Stöffler and contributed a poem to the *Elucidatio*, his master's book on the astrolabe. He had instruments by Hartmann. Christian Heiden had been a pupil of Melanchthon in Wittenberg and presented him with a sundial in 1553, the year he made the quadrant on display [25]. Melanchthon taught and encouraged Rheticus, appointing him to his chair in Wittenberg. He composed the inscription for Schöner's tomb in Nuremberg, when he died in 1547.



Celestial globe by Johann Schöner, c.1534

Rheticus, Copernicus and Reinhold



Lower leaf of a diptych dial with a representation of Nuremberg, by Johann Gebhart, c.1550

Copernicus permitted Rheticus to publish a first account, the *Narratio prima*, of his theory that the earth was a planet moving annually around a central sun and rotating daily as it moved. The tract was addressed to Schöner, whose name appears with that of Copernicus on the title-page of 1540. On display in the exhibition [16] is the version that accompanied the second edition of *De revolutionibus*, published in Basel in 1566: *De libris revolutionum Nicolai Copernici narratio prima, per M. Georgium Ioachimum Rheticum ad D. Ioan. Schoenerum ... scripta*.

Rheticus returned to Wittenberg in 1541, carrying the precious manuscript Copernicus had entrusted to his care, with the understanding that it would be published. Rheticus had new responsibilities as dean of the faculty of arts but he found time to publish the trigonometric part of the manuscript, in a book on triangles dedicated to Hartmann. He addressed the instrument-maker and printer: 'Such a learned man as you will love this author equally for his brilliance and his learning.' Rheticus managed to travel to Nuremberg in 1542, where he visited Schöner and Hartmann and entrusted Copernicus's work to the print-shop of Petreius, who completed its publication the following year.

There are two copies of the first edition of *De revolutionibus* in the exhibition, one [15] opened at the woodcut print of what would become perhaps the most famous diagram in the history of astronomy, with the sun, 'Sol', boldly placed at the centre of the cosmos.

The astronomers who come later in the exhibition display a range of responses to the Copernican hypothesis but, as it happens, although there were a very few wholehearted affirmations of the Copernican 'cosmology' (i.e. as a physical truth and not just a mathematical hypothesis), no such author is represented here. Erasmus Reinhold, for example, who had been appointed by Melanchthon to the astronomy chair in Wittenberg, published up-to-date astronomical tables, his *Prutenicæ tabulæ coelestium motuum* in 1551 [24], having used Copernicus's theory for his calculations but without accepting its physical truth.

Gemma Frisius in Louvain

The mathematician, cosmographer, and globe- and instrument-maker Gemma Frisius, of the medical faculty of the University of Louvain, read of Copernicus's theory in the *Narratio prima* of Rheticus. Like Reinhold, he saw the potential for a more exact mathematical astronomy, whether or not the central hypothesis was taken to be true: 'Nor does it concern me whether the earth is said to revolve, or whether it stands still.'

A well-known engraved portrait of Gemma shows him seated at a table strewn with drawing instruments and tools. Behind him are shelves filled with books, as well as an armillary sphere, a quadrant and an astrolabe. Both his hands are on a celestial globe of his own making. Astronomy is practiced through craft as well as calculation.

In a succession of editions from 1529, Gemma had edited and expanded the popular *Cosmographia* of Peter Apian [19], which contained several paper instruments with moving parts – much simpler than Apian's *Astronomicum Caesareum* and much more widely distributed. So he was already concerned with cosmographical instruments when the distant influence of Schöner drew him into globe-making. Gemma's Antwerp publisher, Roeland Bollaert, had a good trade in selling globes by Schöner, but demand outstripped supply and he persuaded Gemma to move into globe production. Gemma acknowledged his debt to Schöner for many of the features he adopted – not least the cosmographical device of pairing a celestial globe with a terrestrial of the same size.

Gemma's workshop in Louvain also produced brass astronomical instruments and two are included in the exhibition, by a pupil who signed himself as Gemma's nephew ('nepos'), not always adding his own name as 'Arsenius'. The astrolabe [23] is engraved 'Regnerus Arsenius Nepos Gemmæ Frisij fecit Louanij anno 1565' and the astronomer's rings [22] simply 'Nepos Gemmæ Frisij Louanij fecit 1567'. Both designs derive from Gemma's astronomical work and both were clearly made in his own workshop.

Astronomer's rings designed by Gemma Frisius and made by Gualterus Arsenius, Louvain, 1567

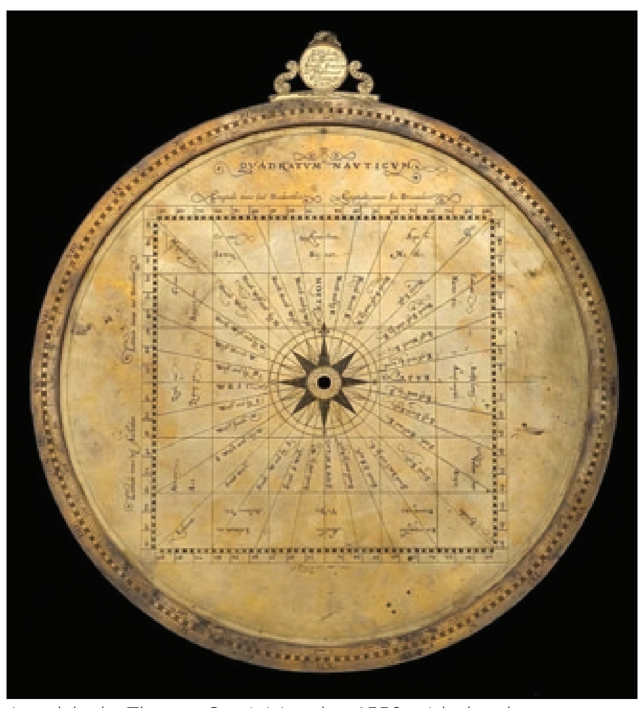
Gerard Mercator and his Influence

Gemma Frisius had a much more famous graduate from his workshop than his young nephew, for he taught, employed and collaborated with Gerard Mercator, who was to become the greatest cosmographer of the 16th century. It was appropriate for someone with a background in the Louvain tradition that Mercator made maps, terrestrial and celestial globes, and astronomical instruments such as astrolabes, thus encompassing a wide range of the craft of cosmographical astronomy. He also took the cosmographical book further than his predecessors, introducing the name 'atlas' for the result.

Mercator is represented in the gallery by two outstanding objects, both generously lent for the exhibition. One, from the Royal Museums Greenwich, is a pair of globes [17] made by Mercator in Louvain, the terrestrial in 1541 and the celestial a decade later. They are described by the leading globe historian Elly Dekker as 'the most important pair of globes made in the sixteenth century.' Following the example of Gemma, Mercator's terrestrial globe also has astronomical features – the circle of the ecliptic and a number of stars – giving it a dual function and making it more properly speaking a 'cosmographical' globe. Original with Mercator, however, are 'loxodromes' or 'rhumb lines', representing the paths traced by following a constant compass bearing and therefore relevant to navigation.

The second object can be said to be key to the entire exhibition: Mercator's own copy of the first edition of Copernicus's *De revolutionibus* [18]. It is on loan from the University of Glasgow Library and contains annotations by Mercator, who was the first owner. It shows that Mercator, a cosmographer and instrument-maker, saw his astronomy extending to engage with the most innovative and challenging work of his time.

Among the contents of the exhibition's final showcases is evidence of the development – relatively slow – of a serious English concern with astronomy in the 16th century. Gemma and Mercator played a part through John Dee, who spend time with them in Louvain around 1547, returning to England with two Mercator globes and Gemma's astronomer's rings. Skilled immigrants were vital to the establishment of astronomical craft in England. It is appropriate that the example of an 'English' polyhedral sundial on display [27] from early in the century is by an astronomer from southern Germany, Nicolaus Kratzer, while the astrolabe from the mid-century [29] is by a native of the Low Countries, Thomas Gemini, who was probably trained in Louvain.



Astrolabe by Thomas Gemini, London 1559, with the plates removed to reveal a 'nautical quadrant', typical of Flemish astrolabes and employing the form of Italic script developed as an engraving style by Mercator

Tycho Brahe is the exhibition's final example of an astronomical craftsman. His planetary system is represented in Mercator's posthumously-published *Atlas*, but Tycho gave his opinion in 1600 that Mercator's globes had been displaced by those of van Langren and Blaeu. Tycho kept abreast of such things. He was an instrument-maker himself, though not for trade, and maintained a workshop. He had a large celestial globe for recording the progress of his observations. The first edition (1598) of his *Astronomiae instauratae mechanica* [30 is the Nuremberg edition of 1602], where he described his instruments, was produced by his own printing press. In the book he discusses Gemma's astronomer's rings and the astrolabe. It is fitting, in the context of this exhibition, that he purchased brass plates he planned to use for his own design of astrolabe on a visit to Nuremberg.