THE CELESTIAL GLOBE OF GERBERT D'AURILLAC: ITS PLACE IN THE HISTORY OF CELESTIAL CARTOGRAPHY

by Elly Dekker

Independent scholar interested in celestial cartography and astronomical instruments.
vanbueren-dekker@planet.nl

This paper examines how the celestial globe designed by Gerbert d'Aurillac at the end of the 10th century fits into the long history of mapping the stars. After a short explanation of the two main branches of celestial cartography, the construction of a semi-sphere with sighting tubes, described in a letter of Gerbert to Constantine of Fleury, is first examined. This semi-sphere calls to mind the antique grid of parallel circles. A crucial feature of this grid is the pair of the 'arctic' and 'antarctic' circles for the Greek latitude of 36°. This grid is also utilised in two texts related to globe making, in a manuscript written in the first half of the 12th century, following a copy of the letter of Gerbert to Constantine. The first of these texts refers in its last line to Gerbert and Hyginus, the second text mention only Hyginus. The reason for using the antique grid in these texts is that in the descriptive tradition the grid provides the guide lines on which the constellations are to be placed on the globe. Finally, we reflect on the thesis by Marco Zuccato, who suggested that Gerbert borrowed the design of his celestial globe from a now lost book written by Dunāsh ibn Tamīm al-Qarawī, a philosopher, physician and astronomer. It is shown that the concepts underlying Gerbert's spheres do not conform to Arabic ideas on globe making, and that therefore this thesis cannot be maintained.

Keywords : celestial cartography, celestial globe, Gerbert d'Aurillac.

Gerbert d'Aurillac

Biographical details of Gerbert d'Aurillac are fairly well-known (Riché, 1987). He was born around 950 in the south of France. He received his primary education in the Benedictine monastery of St. Gerald d'Aurillac and thereafter studied for three years in the cathedral school of Vich, near Barcelona. At an early age Gerbert distinguished himself as a teacher, and was asked to tutor the future emperors Otto II (973–983) and Otto III (980–1002). The latter supported his election as Pope Sylvester II in 999. From 972 until 995, Gerbert pursued a career in teaching. Under his charge the cathedral school in Reims became a leading European centre of learning. In particular the design of astronomical models for teaching the liberal arts attracted the attention. Richer of Saint-Remy, one of Gerbert's pupils, has described in all four spheres (Latouche, 1937, vol. 2, nos. 50-53, p. 58-63):

- No. 50: a celestial globe (*Sperae solidae compositio*)
- No. 51: a semi-circle with sighting tubes (*Intellectilium circulorum comprehensio*)
- No. 52: a sphere for explaining the (orbital) properties of the planets (*Sperae compositio planetis cognoscendis aptissima)*
- No. 53: a sphere for teaching the constellations (*Aliae sperae compositio signis cognoscendis*).

Gerbert lived in a time of changing scientific perspectives, and therefore the question arises what astronomical knowledge was actually applied in designing these models. Before discussing this a short review of the history of celestial cartography is in place.

Cartographic traditions

Medieval knowledge of the celestial sphere was initially based on a tradition that developed from the work of the Greek astronomer and mathematician Eudoxus who lived in the 4th century BC. His work survives in *The Phaenomena*, a didactic poem written by the Greek poet Aratus during his stay at the court of the Macedonian king Antigonus II Gonatas. In it, he describes 51 constellations. In a later stage, these constellations were linked to myths that helped to memorize the various stellar configurations. The earliest treatise on astronomical myths has been attributed to Eratosthenes, another Greek mathematician, living in the 3rd century BC. Also descriptions of the positions of stars inside constellations were added, in order to facilitate observations by the naked eye. The popularity of Aratus's poem in Roman education is testified by Latin translations by Cicero, Germanicus and Avienus. The textbook *De Astronomia* of the Roman author Hyginus is also closely related to the texts of Aratus and Eratosthenes. Greek scholia based on the texts of Eratosthenes were translated into Latin before the turn of the 3rd century. In the 8th century an independent Latin translation of Aratus's text with scholia was made in the north of France, known as *Aratus latinus*, of which a number of reworkings were made (Dekker, 2013, p. 1-4).

The astronomical knowledge incorporated in these works is sometimes labelled as Aratean or classical, but from the point of view of celestial cartography it distinguishes itself by the way in which the positions of stars are recorded, and for that reason I have called it the descriptive tradition. The cartographic method used in this tradition is not very accurate, because the locations of the stars depend on how the constellation figure is actually drawn. The constellation Orion from an illustrated manuscript, probably composed in Santa Maria de Ripoll in 1056 (Vatican, Biblioteca Apostolica Vaticana, Reg. lat. 123, fol. 199v.), serves as an example (Blume, Haffner, Metzger, 2012, Band I.1, p. 488-495, and Band I.2, p. 328). In the accompanying text it is said that there are three stars in the sword. This confused the illuminator since Orion is equipped with two swords. The three stars are placed in the wrong sword, which a later reader/user has tried to correct by crossing them out. More often than not stars are not marked on constellations in illustrated astronomical manuscripts belonging to the descriptive tradition. On the oldest extant globe of ca. 6.5 cm diameter in the descriptive tradition constellations (fig. 1) 48 constellations are marked but here also stars are absent (Dekker, 2013, p. 57-69). This did not deter the users because the main function of globes in the descriptive tradition was to further the understanding of the cosmos through teaching the constellations and their risings and settings.

The mathematical tradition of celestial cartography so-called because the positions of the stars are expressed in mathematical coordinates started also in antiquity, in particular with the work of the Greek astronomer Hipparchus. His successor, the Alexandrian astronomer Ptolemy, tells us that Hipparchus had a celestial globe (Toomer, 1984, p. 327). Unfortunately, this globe and his star catalogue are lost, explaining why all maps and globes in this tradition are based on the star catalogue in Ptolemy's handbook *Syntaxis Mathematica*, known in the Latin West as the *Almagest* (Dekker, 2013, p. 10-14). From the end of the 8th century on a number of Arabic translations were made of Ptolemy's work. With the Arabic expansion in the 9th century some of these arrived in the Iberian Peninsula. These Arabic versions were used for the Latin translation made by Gerard of Cremona around 1175 (Kunitzsch, 1974).

As Ptolemy describes in the *Almagest*, in the mathematical tradition the stars are first stamped on the sphere, using their mathematical coordinates from the star catalogue, and thereafter the contours of the constellation figures were added. From a cartographic point of view this is far more satisfactory. The accuracy of the stellar positions allowed the globe to be used as analogue computer for solving problems in spherical trigonometry.

In addition to Arabic works, also astronomical instruments were transmitted to the West. The most well-known of these is the astrolabe, which appears first in Muslim Spain and later in the Latin West. Globes followed another pattern. Arabic globes were circulating in the 11th century in the Iberian Peninsula. This is attested by the Arabic celestial globe in the collection of the Bibliothèque national de France, shown in fig. 2 (Dekker and Kunitzsch, 2008/9). This rare globe was made in Spain around 1080 and its iconography reveals an early Eastern tradition of globe making, and hence exemplifies the transmission of knowledge from the Middle East to Spain. The impact of Arabic globe making in the Latin West came much later, and predominantly through Latin treatises of globe making in the mathematical tradition. Around 1250-1270, Qusṭā ibn Lūqā's globe treatise was translated in Catalan at the court of Alphonsus X. Around 1300 a Latin translation of this treatise was made. Also another Latin treatise, *Tractatus de sphaera solida*, was then produced, possible also of Arabic origin (Dekker, 2013, p. 337-343).

Against this back drop the question arises whether Gerbert's design of a celestial globe was based on the standard Greco-Roman astronomical thought presented in many illustrated manuscripts circulating in his days, or whether it was influenced by the Greco-Arabic mathematical know-how arriving in Spain. Does his design really show the impact of an Arabic model, as has been suggested (Zuccato, 2005a, 2005b)?

Gerbert's semi-sphere with sighting tubes

In order to answer this question, it is instructive to have a close look at the construction of the semi-sphere with sighting tubes, which is described in detail in a letter from Gerbert to Constantine of Fleury, the later abbot of St.-Mesmin-de-Micy (1011), because it clearly shows the underlying thought of Gerbert's astronomical reasoning (Riché P. and Callu J.P., 1993, Vol. II, pp. 680–687 and Lattin, H. P., 1961, p. 36–9). Mostert records 10 copies of this letter, the oldest of

Figure 1. Antique globe, 1st century BC. Courtesy of Galerie J. Kugel, Paris.

Figure 2. Arabic celestial globe of ca. 1080. Paris, Bibliothèque nationale de France, département des Cartes et plans, Ge A 325.

which was written in Corbie at the end of the tenth century (Mostert, 1997). Another copy, not listed by Mostert, is in a manuscript in Darmstadt (Universitäts und Landesbibliothek, ms 1020, fol. 59r–60v), where the letter is combined with other texts instructive for a better understanding of Gerbert's celestial globe. The manuscript dates to the first half of the twelfth century, and a note added in the early fifteenth century suggests that it was written in St Jacob abbey in Liege: *Liber Monasterii Sti Jacobi Leodiensis, cuius titulus est helpericus abbas de compoto.* Before discussing these other texts, let us examine the letter of Gerbert to Constantine.

Gerbert's instruction starts with making a solid sphere of wood and drawing five parallel celestial circles on it such that these circles are at a distance of 6, 11, and 15 units or parts of 6° from two opposite poles of the sphere (fig. 3, left upper corner). This sphere is subsequently cut into halves and one half is hollowed out. Next, holes are made in the middle of the five parallel circles and through the points N and S, seven in all. Each hole serves to hold a sighting tube (fig. 3, left lower corner). To use the semi-sphere, its curved part is placed upwards (fig. 3, right), and the two tubes along its diameter are aligned with the polar axis with the help of a star located at the north pole. If one were not sure which of the northern stars would be the 'pole star', Gerbert advises to take a sighting tube, centre it on the star concerned, and fix the tube's position. If the star concerned is indeed the 'pole star', it will remain there all night. If it is another one, the star concerned will move after a short while and disappear from the range of the tube.

In Gerbert's day the pole star (α UMi) was about 7° from the North pole. It has been suggested that Gerbert refers here to another, rather weak star, 32H Camelopardalis. This suggestion is supported by a drawing of Gerbert's semi-sphere (fig. 4) in the 11th century manuscript Paris, BnF, ms lat. 7412, fol. 15r. A similar drawing of Gerbert's semi-sphere is in London, British Museum, ms Old royal 15.B.IX, fol. 77r (Wiesenbach, 1991, p. 140). The drawing shown in fig. 4 is entitled *HEMISPERIUM* and the text written between the tubes, *SEPTEM FISTULAE SEMI PEDALES*, shows that indeed Gerbert's semi-sphere with sighting tubes is meant here. Wiesenbach has shown that the drawing in the bottom right corner (see fig. 5 for a close up) is intended to demonstrate how to find the time at night with the help of a star clock invented by Pacificus of Verona (Wiesenbach, 1993). He argued convincingly that the star clock built by Gerbert for the emperor Otto III in 997 during his stay in Magdeburg was a copy of Pacificus's instrument. Although the star clock and Gerbert's semi-sphere are not directly related, they have in common that both have to be directed to the north pole before they can be put into use. This connects the drawing in the right corner of fig. 4 with its main figure. The sighting tube in the drawing in the right corner is not directed towards the pole star (α UMi), but to a star called *computrix*, which Wiesenbach has identified with 32H Camelopardalis. A person with sharp eyesight would be able to see it, especially when using a sighting tube, but for the averaged, inexperienced student it must have been difficult to observe.

The 'arctic' and 'antarctic' circles

The design of the semi-sphere recalls the scheme of parallel circles as it was described in antiquity by, for example, the Greek astronomer Geminus and the Roman author Hyginus, both living in the 1st century BC. The most characteristic feature of this scheme is the pair of 'arctic' and 'antarctic' circles which by definition separate respectively the ever-visible and ever-invisible stars from those that rise and set. For that reason these circles depend on geographical latitude. In the treatise *De nuptiis Philologiae et Mercurii,* its Latin author Martianus Capella (fl. c. 410–420) introduces the 'arctic' and 'antarctic' circles as circles grazing the edge of the northern and southern horizon (Dick, 1925, VIII.18). This treatise was available in Gerbert's library (Riché, 1987, Annexe). In fig. 6 these circles are drawn for the Greek latitude 36°.

Poulle seems to think that Gerbert's 'arctic' and 'antarctic' circles at 36° from their respective poles should be understood as modern polar circles, which are at a distance of 24° from the poles (Poulle, 1985, p. 604). He dismissed Gerbert's circles at 36° as a grave error. But were Gerbert's circles really meant to be at a distance of 24°? Surely, Gerbert could have known the precise meaning of the parallels at a distance of 36° from the poles. By looking through a tube directed to the 'antarctic' circle one would not see the sky, showing that the circles at 36° from their respective poles do not coincide with the 'arctic' and 'antarctic' circles of his own latitude. Therefore, this 'antarctic' circle in the design of the semi-sphere served no purpose but was probably maintained for reasons of symmetry. As discussed below, for making a globe, the 'antarctic' circle is not superfluous. However that may be, the question is why Gerbert did not use the astronomically more meaningful 'arctic' and 'antarctic' circles valid at his own latitude.

In this connection, it is of interest to note that Gerbert's configuration of parallel circles reappears in the so-called sphere of William of Hirsau (c. 1030–91), a Benedictine monk from St Emmeran, became later

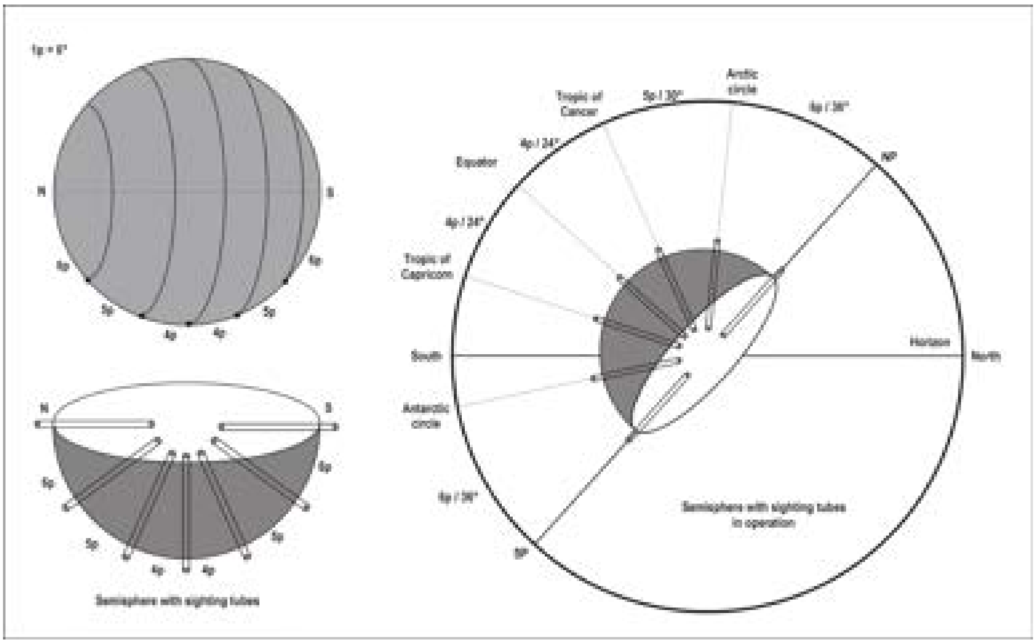

Figure 3. Gerbert's semi-sphere with sighting tubes.

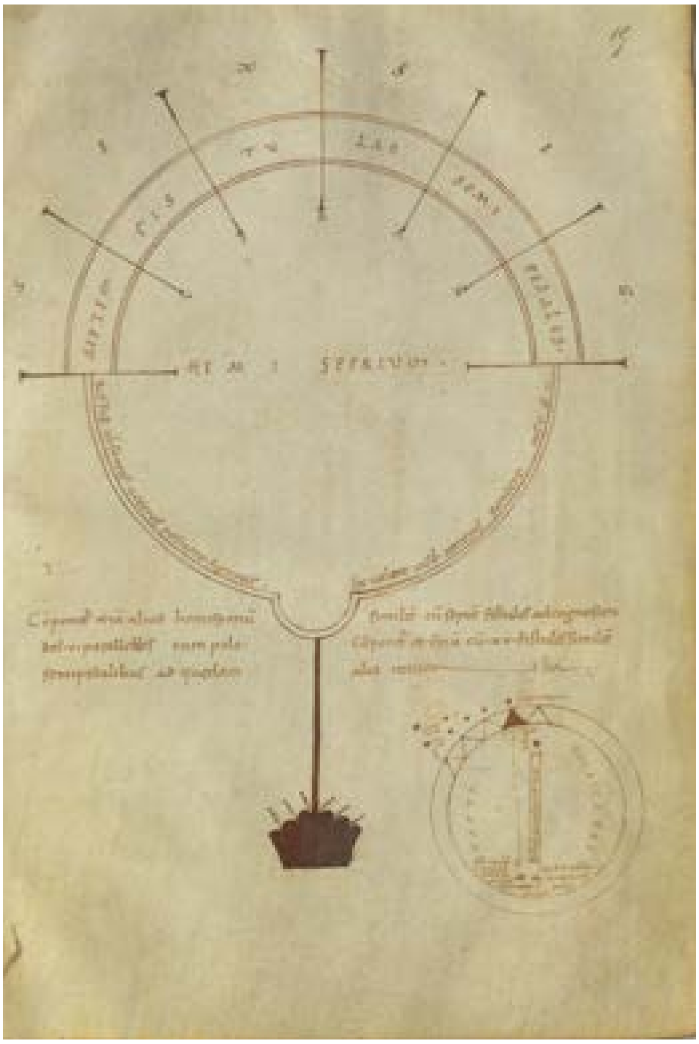

Figure 4. Drawing of a semi-sphere with sighting tubes.
Paris, Bibliothèque nationale de France, département des Manuscrits, ms lat. 7412, fol. 15r.

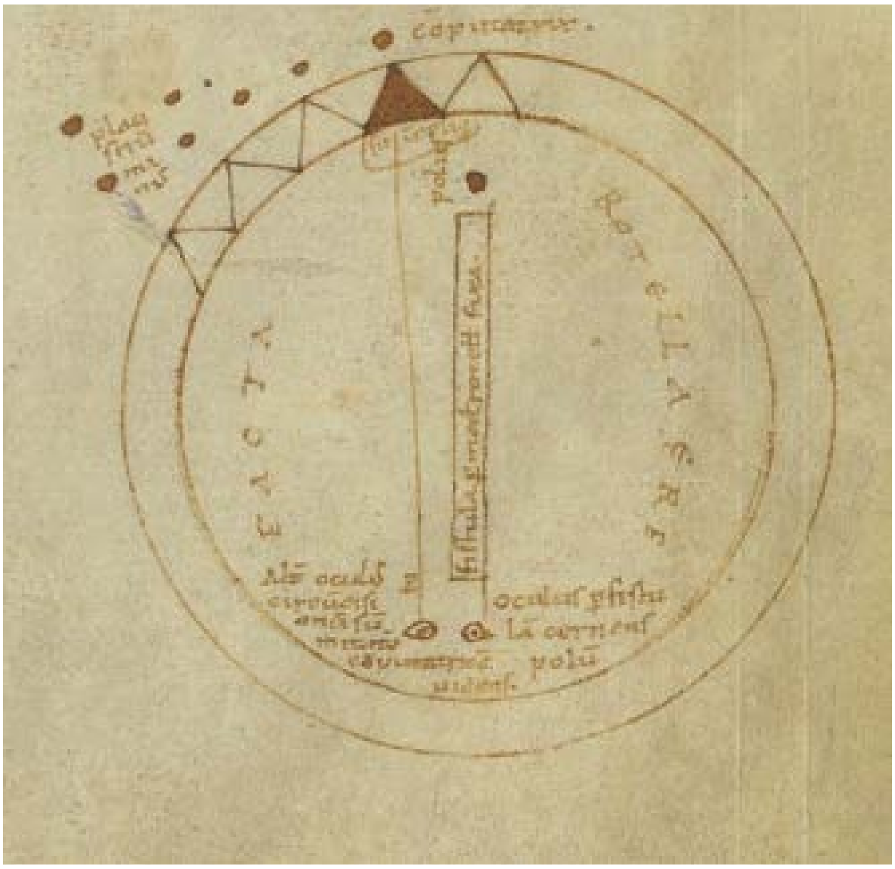

Figure 5. The star clock invented by Pacificus of Verona.
Paris, Bibliothèque nationale de France, département des Manuscrits, ms lat. 7412, fol. 15r.

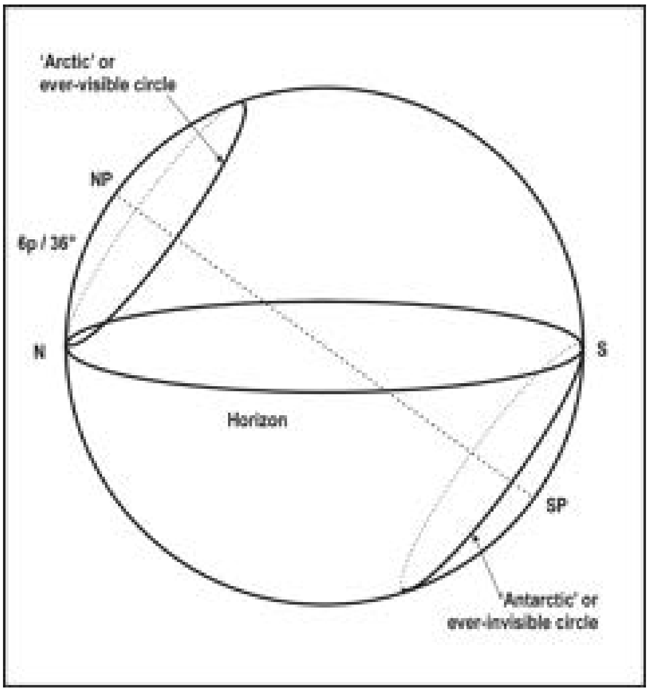

Figure 6. The 'arctic' and 'antarctic' circles
for geographical latitude 36°.

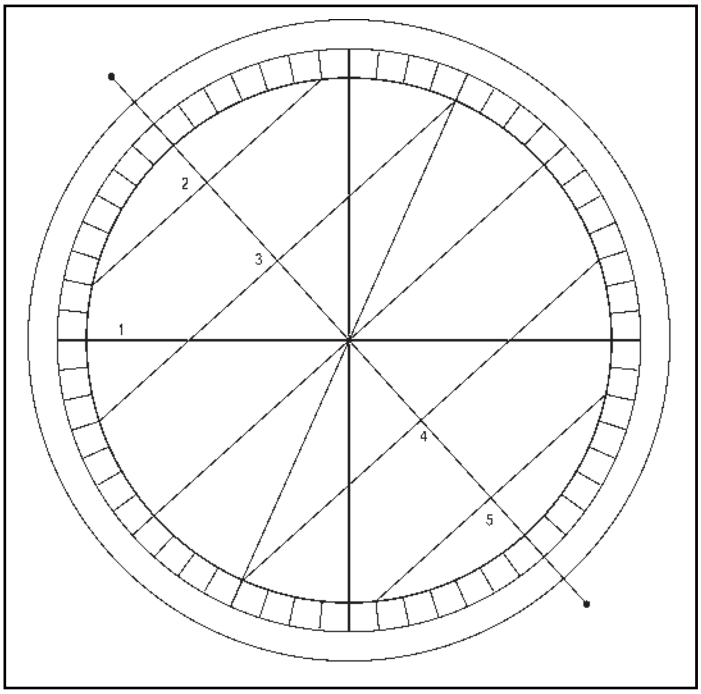

Figure 7. Reconstruction of the grid on the Sphere
of William of Hirsau.

abbot of Hirsau (Wiesenbach, 1991). On top of the pedestal of the statue is a disc of 60cm in diameter, with a sculpture of the poet Aratus, as the text in the outer ring testifies: *SYDEROS MOTUS RADIO PERCURRIT ARATUS* (Aratus has shown the course of the stars with the staff). The fact that Aratus is depicted, and not Ptolemy, shows that the Greco-Roman astronomical thought still dominated the Latin West in the 11th century. The actual instrument is at the other side of the disc. It consists of a grid cut in stone and there are locks for holding sighting tubes. A reconstruction of the grid is shown in figure 7. The text in the outer ring, *CLYMA CYCLI CARDO CELI LOCUS EXTIMA SIGNI MULTUA AD HEC USUS PATET HINC SUB ACUME VISUS* (The climate, the parallel circles, the celestial poles, location and limits of the signs, and a multiple of uses is offered by this side of the disc), explains its structure and use. Compared with Gerbert's construction William's sphere is an improvement in the sense that it has a fixed mounting for a geographical latitude of 48°. William probably knew what Gerbert did not, namely that the height of the north pole above the horizon equals the geographical latitude of a place. This property became generally known in the Latin West with the introduction of the astrolabe at the turn of the tenth century, too late for Gerbert to know it. Of special interest for the present discussion is that William also engraved circles at a distance of 36° from the poles, confirming that these circles in Gerbert's model are not an error in design. Hence the question remains why Gerbert, and William after him, did not use the astronomically more meaningful 'arctic' and 'antarctic' circles valid at their own latitude.

Tracing constellations

Tracing constellations on celestial circles is a very ancient notion which came into being at a time when mathematical coordinates were still unknown. Geminus explains that the imaginary parallel circles can be perceived only by the positions of the stars, 'by observations made with the *dioptra*' (Evans and Lennart Berggren, 2006, p. 151 and Aujac, 1975, p. 23). When Gerbert's semi-sphere is aligned with the polar axis, the five sighting tubes in the intersections between the local meridian and the five imaginary parallel celestial circles will point to the equator halfway between the poles; the tropics at a distance of 24° from the equator, and the 'arctic' and 'antarctic' circles at a distance of 36° from the respective poles. The constellations located on the grid of parallel circles would pass by one by one in the course of a year. By using lists of constellations described, for example, by Hyginus, as located on the grid of parallel circles, the semi-sphere would serve as a means for learning to recognise the constellations in the night sky (Dekker, 2013, p. 83, Table 2.3). For the identification of the constellations on the Greek 'arctic' circle, as described in these lists, the sighting tube must be directed to a distance of 36° from the north pole. It would not have made sense to point the sighting tube to a polar distance of 24° or 48°. It is therefore likely that the circles at a distance of 36° from the poles in Gerbert's model, and that of William of Hirsau, were meant to represent what they are: the Greek version of the 'arctic' and 'antarctic' circles, and not an error but part of Gerbert's design. One can now understand why parallel circles were emphasised in Gerbert's models. But what is the link with his celestial globe?

Gerbert's celestial globe

Richer's description of two of Gerbert's models (nos. 51 and 52) explicitly mention the grid of parallel circles, and the description of no. 53 refers to that of no. 52. We may therefore assume that the grid of parallel circles was also engraved on the celestial globe (no. 50). Unfortunately, Richer of Saint-Remy does not provide details on its construction, apart from the fact that the sphere is made of wood and that it is inclined to the horizon (Latouche, 1937, vol. 2, p. 58). Some information on mapping is provided in a letter, which Gerbert wrote at the end of 988 or the beginning of 989 to Remi, a monk of Trier, in which he offered him a choice:

Sed si nimia cura fatigaris habendi, simplici fuco interstinctam, circa marcias kl. eam expecta. Ne si forte cum orizonte, ac diversorum colorum pulchritudine insignitam praestoleris, annuum perhorrescas laborem (Riché and Callu, 1993, Vol. II, p. 363).

Clearly, Gerbert considers here two kinds of globes: (I) a simple one divided by red colour and (II) a more elaborate one with a horizon and multiple colours. It is not clear whether *simplici fuco interstinctam* of sphere (I) refers to the main celestial circles that would have been marked on the surface of the sphere or to the constellations which could then have been presented by simple line drawings. In contrast, the phrase *diversorum colorum pulchritudine* of sphere (II) is very likely referring to constellation figures. It seems therefore reasonable to assume that Gerbert made globes with the constellations drawn onto the sphere.

In this connection the two texts in Darmstadt ms 1020, following the letter to Constantine are of interest. The first seven lines of the first text on fol. 60v–61v (*incipit: Summa meae cartae brevis est divisio sperae*) describe the division of the sphere into five

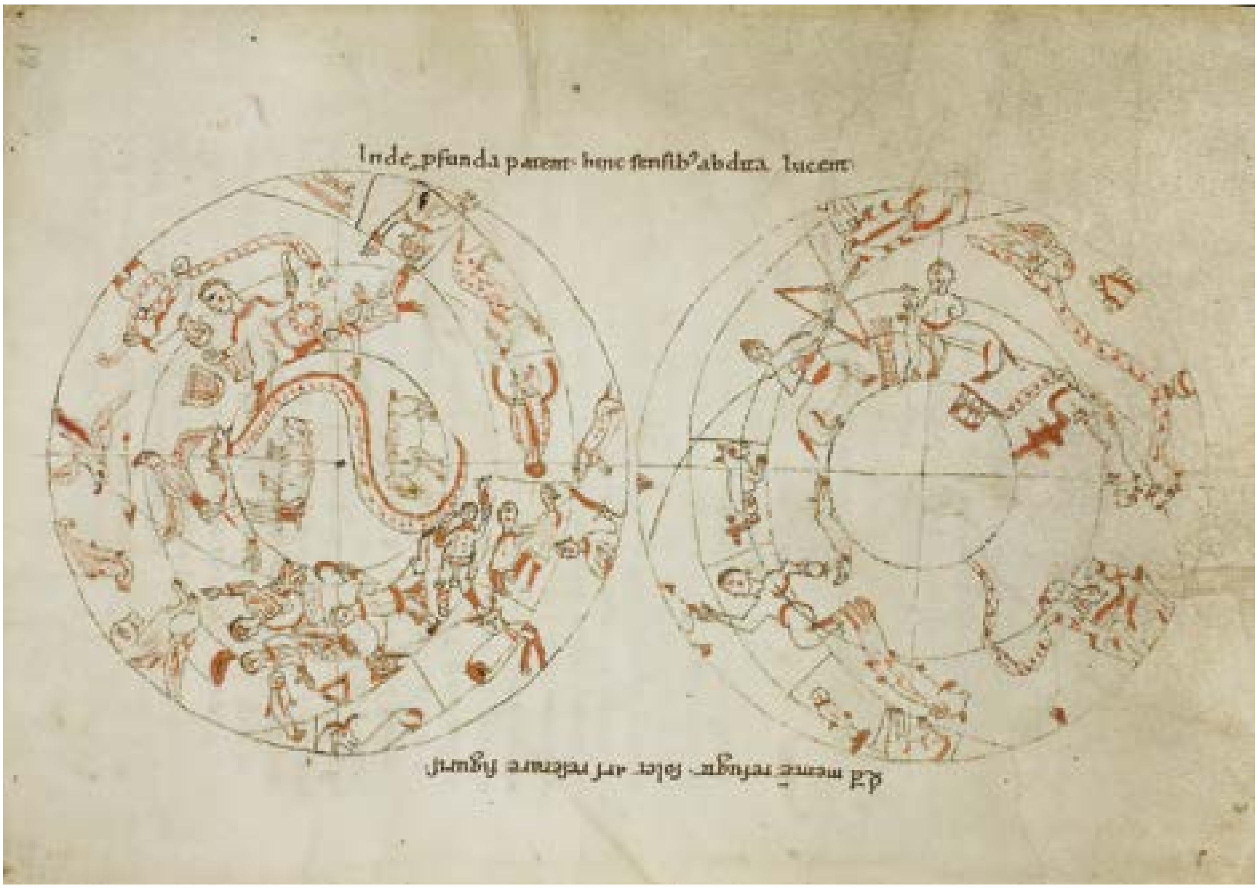

Figure 8. The Darmstadt pair of hemispheres.
Courtesy of the Universitäts-und Landesbibliothek, Darmstadt, ms 1020, fol. 61r.

Figure 9. The position of Cygnus on the northern hemisphere.
Courtesy of the Universitäts-und Landesbibliothek, Darmstadt ms 1020, fol. 61r.

zones based on the same grid as Gerbert used for his instrument with sighting tubes (Dekker, 2013, p. 189). The text continues with describing the constellations. In the last line (*explicit: Hec ita Gerbertus cui testis et auctor Higinus*) the author of the Darmstadt text links the description of the celestial sphere to two authors: Gerbert and Hyginus.

The second text of interest in ms 1020 (fol. 61v) describes the construction of a celestial globe (*incipit: Speram celi facturus ducas circulum per medium globum*). This construction is also based on the antique grid. It also specifies the colures, that is, semicircles passing through the north and south poles and through respectively the equinoctial and solstitial points, and a zodiacal band which extends 12° north and south of the ecliptic, that is, twice the value quoted in Antiquity. For more details the reader is here also referred to Hyginus (*explicit: Cetera necessaria sperae docet higinus*).

In the middle of the first text (fol. 61r) is a pair of celestial hemispheres (fig. 8), with the texts alongside the maps: *Inde p(ro) funda patent hinc sensib(us) abdita lucent* (Here secrets become plain, here shine things hidden from the senses) and *Q(uod) mente(m) refugit solet ars reserare figuris* (What escapes the mind, art uses to disclose through (painted) figures). The constellations here referred to are carefully drawn but stars are not indicated.

The mapping of these Darmstadt maps is consistent with Hyginus's descriptions of the constellations. For example, Hyginus describes the position of Cygnus as *Aestivus autem circulus rostrum eius a reliquo corpore dividit, cauda iungitur extrema cum capite Cephei* (Viré, 1992, p. 99). On the map (fig. 9) the summer tropic clearly separates his beck from the rest of his body and the tip of his tail touches the head of Cepheus. In reality the tail of Cygnus and the head of Cepheus are about 20° apart. Since this erroneous feature is found exclusively in Hyginus's treatise, its occurrence on the map corroborates the use of Hyginus's text.

Maps traditionally connected with the descriptive tradition have their roots in antiquity and are of two kinds: hemispheres centred on the summer and winter colures and bounded by the equinoctial colures, and planispheres centred on the north celestial pole and extending to the 'antarctic' circle (Dekker, 2013, chapters 3.1 and 3.2). The Darmstadt hemispheres share with these traditional maps that the five parallel circles are drawn together with the colures and the zodiacal band. However, the Darmstadt maps are centred on, respectively, the north and south poles and bounded by the equator and therefore present a new format. This medieval creation, which the author linked to Gerbert, could have been brought about by Gerbert's celestial globe. Indeed, had a copy of Gerbert's celestial globe survived, it may have looked like the Darmstadt hemispheres.

Globe making in the descriptive tradition

For making a celestial globe in the descriptive tradition, the five parallel celestial circles and the colures were used as the guide lines on which the constellations were arranged. Eudoxus listed the constellations located on the five parallel celestial circles and the colures (Dekker, 2009, p. 144-146). Eudoxus could determine the constellations located on the colures by observation after he had fixed the locations of the equinoxes and solstices in the midpoints of the relevant zodiacal constellations. All he had to do is to observe which non-zodiacal constellations were in the local meridian at the moment that the midpoint of the relevant zodiacal constellation was observed in it (Dekker, 2008, p. 220-221). The data on the parallel circles could also have been obtained by observation without measuring equipment because the points of rising and setting of the Sun on the horizon form a measuring device that enables one to decide how a star is situated relative to the parallel circles. Thus

- stars grazing the horizon in the North are located on the 'arctic' or ever-visible circle
- stars rising in the point of summer sunrise are located on the Tropic of Cancer
- stars rising in the East are located on the equator
- stars rising in the point of winter sunrise are located on the Tropic of Capricorn
- stars grazing the horizon in the South are located on the 'antarctic' or ever-invisible circle

Stars rising and setting in between these various points on the horizons are located between the corresponding circles. Thus by carefully observing the risings and settings of the constellations one can find out which constellations are located on which celestial circles, and arrange them accordingly on the grid of a celestial globe. The prominence of the ancient grid in Gerbert's models suggests strongly that this was the way in which Gerbert made his celestial globe.

Zuccato's thesis

In 2005, Marco Zuccato argued that Gerbert for the construction of his celestial globe borrowed some Arabic elements (Zuccato, 2005b, p. 763). His thesis

Figure 10. Drawing of a globe in Paris, Bibliothèque nationale de France, département des Manuscrits, latin 12957, fol. 63v.

is based on three assertions. First, he goes to great length to show that a now lost treatise discussing the construction of celestial spheres by Dunāsh ibn Tamīm al-Qarawī, a tenth-century Hebrew physician and astronomer writing in Arabic, and working in Tunisia, could have been circulating in Catalonia at the time of Gerbert's stay in 967–70. Next he links this treatise to Gerbert by insisting that in describing Gerbert's celestial globe, Richer of Saint-Remy is referring to a horizon ring or *armilla*. Finally, Zuccato claims that 'there is no evidence that a horizon ring was ever employed in Latin demonstrational celestial spheres, nor that there is any mention of a horizon ring in Latin descriptions of spherical demonstrational instruments before Gerbert' (Zuccato, 2005b, p. 760).

The first question that comes to mind is whether the text of Richer of Saint-Remy really refers to a horizon ring or *armilla*. The relevant lines of the description of Gerbert's celestial globe are:

Quam cum duobus polis in orizonte obliquaret, signa septemtrionalia polo erectiori dedit, australia vero dejectiori adhibuit; cujus positionem eo circulo rexit, qui a Graecis orizon, a Latinis limitans sive determinans appellatur, eo quod in eo signa quae videntur ab his quae non videntur distinguat ac limitet. Qua in orizonte sic collocata, ut et ort urn et occasum signorum utiliter ac probabiliter demonstraret, rerum naturas dispositis insinuavit, instituitque in signorum comprehensione. Nam tempore nocturno ardentibus stellis operam dabat, agebatque ut eas, in mundi regionibus diversis obliquatas, tam in ortu quam in occasu notarant. (Latouche, 1937, vol. 2, p. 58-61).

This text seems to be a short explanation of the function of the horizon circle, which is not significantly different from what one can find, for example, in Hyginus's treatise *De Astronomia*. It says that the sphere is placed with its poles obliquely to the horizon in order to show which constellations are visible and which not. It does not in any way refer explicitly to a material horizon. Yet, it is clear that in Gerbert's letter to Remi, mentioned above, a material horizon is implied, but does this necessarily mean that this would have been a horizon ring or *armilla*?. As Geminus explains: "The position of the horizon is, of course, perceived with the aid of the sphere's stand' (Evans and Lennart Berggren, 2006, p. 159). What kind of stand is indicated here is uncertain, but to judge from various illustrations from antiquity it could be a support without auxiliaries such as a meridian ring (Dekker, 2013, p. 4, 12, and 192). A meridian ring was not needed since in antiquity all globes were made for a latitude of 36°. The orientation of the globe could be made with the help of the 'arctic' and 'antarctic' circles as shown in fig. 6. In Book IV.2.2, Hyginus explains that if one adjusts the globe such that the circle called 'arctic' is always visible and the 'antarctic' circle is never seen, one finds that 5/8 of the tropic is above and 3/8 is below the horizon, which applies to a latitude of 36° (Viré, 1992, p. 127). Of course, Gerbert could not have used this method. Instead he used the pole star and sighting tubes for adjusting the semi-sphere as discussed above. The sphere for teaching the constellations (no. 53: *Aliae sperae compositio signis cognoscendis*) is equipped with a tube for indicating the celestial pole (Latouche, 1937, vol. 2, p. 62-63). Also the celestial globe described by Notker Labeo (950 –1022), a Benedictine monk and head of the convent school, is to be directed to the pole star (Wiesenbach, 1991, p. 141). There is no indication that Gerbert knew how to adjust globe for geographical latitude by means of a horizon and meridian ring. Indeed, Gerbert nowhere mentions the meridian ring, which is an important part of the mounting of Arabic globes because with it one can set the globe for a required geographical latitude. Therefore, I am not really convinced by Zuccato's reading of Richer's text.

One may also question Zuccato's assertion that horizon rings do not figure in Latin descriptions of spherical demonstrational instruments before Gerbert. Illustrations of globes were circulating in the Latin West from the ninth century on. The picture in fig. 10 shows a celestial globe from an Aratean treatise, written in the north of France, possibly Corbie, early in the ninth century (Paris, BnF, ms lat. 12957, fol. 63v.). The sphere is mounted in a meridian ring supported by the central column, and the north pole is indicated by a clamping screw at the meridian ring. Six other columns support a horizon 'ring'. Given that two columns are drawn in front of the sphere and two behind it, this picture may well present a real globe. This does not necessarily mean that such globes really existed in the Latin West, but it demonstrates that the type of mounting with meridian and horizon ring, which Zuccato labels as being exclusively Arabic, was known in the Latin West before Gerbert turned his attention to globe making.

Another, more important objection to Zuccato's thesis is that the concepts underlying Gerbert's globe do not conform to Arabic ideas on the function of the horizon ring. As Zuccato correctly stresses, with the introduction of a horizon ring 'the Aratean arctic circles become redundant and useless' (Zuccato, 2005b, p. 759) because the globe can be adjusted for different terrestrial latitudes and, when properly done, the constellations that are always visible are easily demonstrated. An examination of extant Arabic globes made before 1500 shows that there are only great circles engraved on the sphere: the equator, the ecliptic, and the meridians through the ecliptic poles (Dekker, 2013, p. 323-336). The tropics and the 'arctic' and 'antarctic' circles are conspicuously absent. There is no reference whatsoever to the antique grid. Nor is this grid mentioned in early Arabic treatises on the use of the celestial globe. Indeed, the grid employed and transmitted by Gerbert is not part of the mathematical tradition, which characterises Arabic globe making from the ninth century on, and therefore it is unlikely that Gerbert was familiar with an Arabic globe or a description thereof or knew Dunāsh's work on celestial spheres.

Conclusion

All identifiable characteristics of Gerbert's astronomical models conform to the Greco-Roman descriptive tradition as outlined by the Latin astronomical literature available in his day. There are no traces of an Arabic impact in Gerbert's texts. Although it is tempting to present Gerbert's celestial globe as a key element in the transmission of Arabic science from Spain to the Latin West, such a thesis should be dismissed.

The prominence of the ancient grid of celestial circles in his models strongly suggests that for constructing his celestial globe Gerbert used the method of globe making in the descriptive tradition. Gerbert's spheres were the first demonstrational instruments based on the Aratean literature made in the Latin West for teaching the structure of the universe.

Gerbert's astronomical models attracted the attention of his contemporaries. The sphere of William of Hirsau, the description of a globe in ms 1020 with accompanying celestial maps, and the celestial globe described by Notker Labeo show the impact of Gerbert's venture in making astronomical models. After 1300, these medieval efforts in globe making gave way to the construction of celestial globes in the mathematical tradition.

Bibliography

Aujac G., 1975, *Géminos. Introduction aux phénomènes*, Paris, Les Belles Lettres.

Blume D., Haffner M., Metzger W., 2012, *Sternbilder des Mittelalters. Der gemalte Himmel zwischen Wissenschaft und Phantasie Band I: 800–1200*, Berlin, Akademie Verlag.

Dekker E., 2008, « A 'Watermark' of Eudoxan Astronomy», *Journal for the History of Astronomy*, vol. 39, p. 223-238.

Dekker E., 2009, « Featuring the First Greek Celestial Globe », *Globe Studies* (English version of *Der Globusfreund*), vol. 55/56 (for 2007/2008), p. 133-152

Dekker E. and Kunitzsch K., 2008/9, « An Early Islamic tradition in globe making », *Zeitschrift für Geschichte arabisch-islamischen Wissenschaften*, vol. 18, p. 155-212.

Dekker E., 2013, *Illustrating the Phaenomena: Celestial cartography in Antiquity and the Middle Ages*, Oxford, University Press.

Dick A., 1925, Martianus Capella. *De nuptiis Philologiae et Mercurii, Liber* VIII, Leipzig, Teubner.

Evans J. and Lennart Berggren J., 2006, *Geminos's* Introduction to the Phenomena: *A Translation and Study of a Hellenistic Survey of Astronomy* , Princeton and Oxford.

Kunitzsch P., 1974, *Der Almagest. Die Syntaxis Mathematica des Claudius Ptolemäus in arabisch-lateinischer* Überlieferung, Wiesbaden, Otto Harrassowitz.

Lattin H. P., 1961, *The Letters of Gerbert with his Papal Privileges as Sylvester II*, New York, Columbia University Press.

Latouche R., 1937, *Richer. Histoire de France (888–995)*, Paris, Les Belles Lettres.

Mostert M., 1997, « Les traditions manuscrites des oeuvres de Gerbert », in Charbonnel N. and Iung J-E., *Gerbert L'Européen* , Actes du colloque d'Aurillac 4–7 juin 1996, Société des lettres, sciences et arts 'La Haute-Auvergne', *Mémoires* 3, p. 307–24.

Poulle E., 1985, « L'Astronomie de Gerbert », in Barabino G., *Gerberto: scienza, storia e mito: atti del Gerberti symposium, Bobbio 25–27 Juglio 1983*, Bobbio, *Archivum Bobiense. Studia* II, p. 597-617.

Riché P., 1987, reprinted in 2006, *Gerbert d'Aurillac: Le pape de l'an mil*, Paris, Arthème Fayard.

Riché P. and Callu J.P., 1993, *Gerbert d'Aurillac, Correspondence*, 2 vols, Paris, Les Belles Lettres.

Toomer G. J., 1984, *Ptolemy's Almagest*, London, Duckworth.

Viré G., 1992, *Hygini De Astronomia*, Stuttgart and Leipzig, Teubner.

Wiesenbach J., 1991, « Wilhelm von Hirsau: Astrolab und Astronomie im 11. Jahrhundert », *Forschungen und Berichte der Archäologie des Mittelalters in Baden-Württemberg*, vol. 10/2, Stuttgart, p. 109–56.

Wiesenbach J., 1993, « Pacificus von Verona als Erfinder einer Sternenuhr », in Butzer P.L. and Lohrmann D., *Science in Western and Eastern Civilizations in Carolingian Times*, Basel, Birkhäuser Verlag, p. 229–50.

Zuccato M., 2005a, « Gerbert's Islamicate Celestial Globe », in Nuvolone F., *Gerberto d'Aurillac-Silvestro II Linee per una sintesi. Atti del Convegno Internazionale. Bobbio, Auditorium di S. Chiara, 11 Settembre 2004*, Bobbio, p. 167–186.

Zuccato M., 2005b, « Gerbert of Aurillac and a Tenth-Century Jewish Channel for the Transmission of Arabic Science to the West », *Speculum*, vol. 80, p. 742–63.