

The planisphere: a brief historical review

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Planispheres usually consist of two circular discs of cardboard or plastic. The lower one shows a circular map of the sky and is free to spin about a small bolt placed through either the north or the south celestial pole. The upper disc contains an oval-shaped window that allows that portion of the heavens visible from a specific spot on Earth, at a specific time, to be segregated from the map. This paper investigates their design and origins and traces their development through recent astronomical history.

Introduction

The planisphere is an extremely common instrument and most astronomers, both professional and amateur, have at least one in their collections. The basic characteristics of its design are illustrated in Figures 1 and 2.

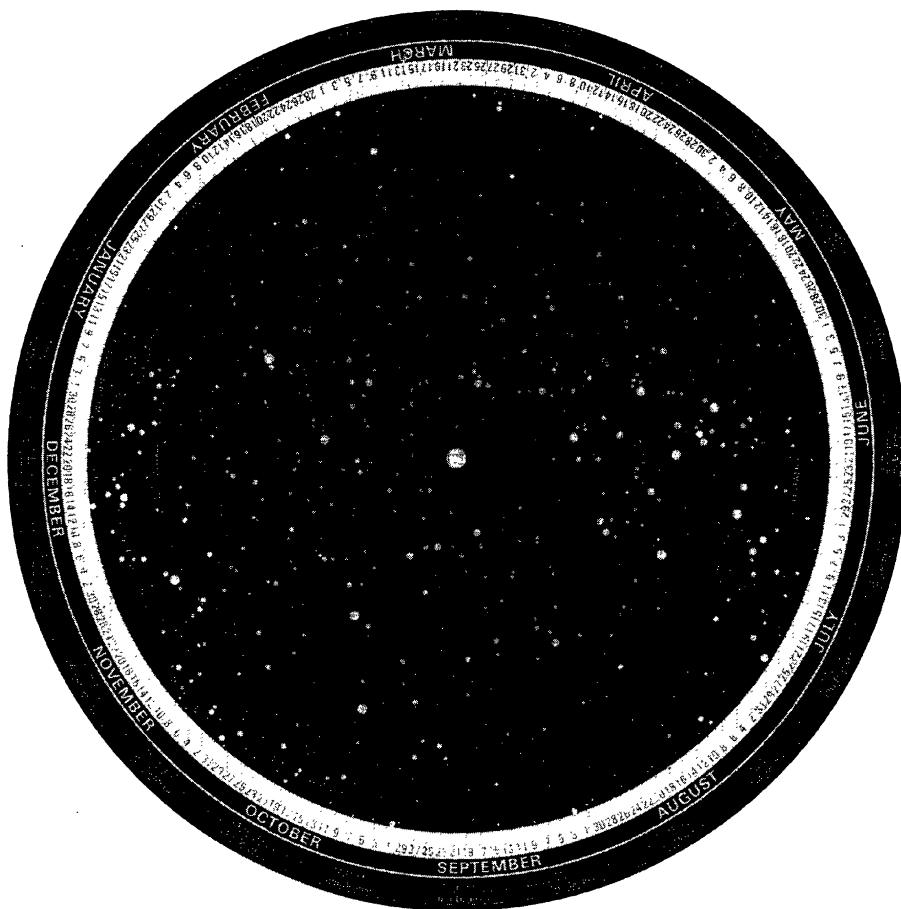
An observer sees the starry heavens rather like the inside of an inverted bowl. Unfortunately any attempt to represent this spherical surface by a flat map will introduce distortions. No projection from a spherical surface to a plane flat surface can avoid this. The aim of the planisphere designer is to select those observable features of the constellation patterns in the sky that the eye regards as the most important (the constellation shapes and the horizontal and vertical alignments of specific stars for example) and then to use a projection that represents these as realistically as possible.

The map shown in Figure 1 is extremely simple and convenient to produce as it follows the projection used in the usual star atlases. The plot is polar in right ascension and declination. Lines of equal right ascension are represented by straight lines on the plane star map and these radiate uniformly from the North Celestial Pole and are spaced 30 degrees apart, an interval corresponding to two hours of Right Ascension. For simplicity the circumference is also marked off in degrees, starting at zero at the First Point of Aries. The third scale around the circumference is marked in days and months of the year, starting with March 21 at the First Point of Aries. All scales increase in the clock-wise direction.

The loci of points having the same declination are represented on the star map by circles which are centred at the North Celestial Pole. These have radii that are directly proportional to $(90^\circ - \text{declination})$. In Figure 1 these circles are drawn at 30° intervals.

Figure 1. The base plate of a planisphere designed for an observer at latitude 51.5° north (i.e. London, Bristol and Cardiff). The circular star map contains about 750 stars, these being all the naked-eye stars brighter than about fourth magnitude and having declinations between the north celestial pole ($+90^\circ$) and -50° . Lines of equal stellar declination and right ascension are marked on the map, as is the celestial ecliptic (the path of the Sun across the sky and the mean path of the Moon and the planets) and the Milky Way. The constellations are clearly named as are about 70 of the brightest stars.

The months and days of the year are marked around the circumference of the map, and the outer ring gives the clockwise run of the right ascension of the stars in both hours and degrees from the First Point of Aries (the vernal intersection of the celestial equator with the ecliptic).



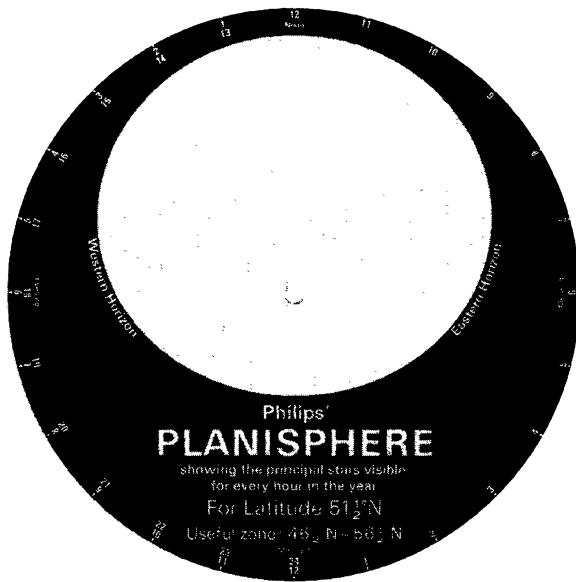


Figure 2. The upper plate of the same planisphere as Figure 1. The large bolt at the centre attaches this plate to the lower one through the north celestial pole. The hours of the day are marked evenly around the circumference. The elliptical hole, which delineates the observable part of the celestial sphere, has its minor axis passing through the line joining noon and midnight. This line passes through the north celestial pole. The 'noon' intersect of this line with the ellipse is the south point on the observer's horizon. The 'midnight' intersect is the north point. Note that the east and west points are not on the major axis but are both displaced round towards the north. They lie at the ends of the line that is perpendicular to the minor axis and passes through the north celestial pole. The southern horizon is thus much longer than the northern one.

The major axis of the 'elliptical' window is at right angles to the minor axis and also passes through the observer's zenith (i.e. the point on the sky that is directly above). 'For latitude 51.5 North' refers to the latitude for which the instrument was designed. Note that the instrument can be used for observer latitudes that are 5 degrees higher or lower than the design latitude without significant loss of accuracy.

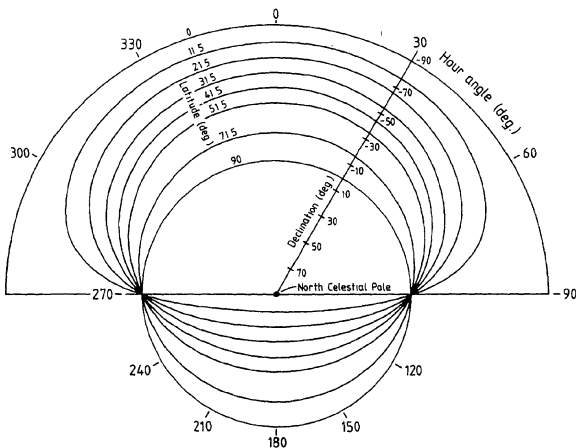


Figure 3. The shapes represent the windows in the upper plates of planispheres, these being drawn for observers at latitudes of 90, 71.5, 51.5, 41.5, 31.5, 21.5, 11.5 and 0° respectively. The central point of the diagram is the North Celestial Pole. The numbers around the diagram represent hour angles. The window is such that the north point on the horizon is at the bottom (hour angle 180°) and the south point is at the top. The western horizon is on the left and the eastern horizon is on the right.

A similar series of shapes (but this time for every 5° of latitude between 90° and 0°) was drawn on the tablet of horizons of Prince Henry's 1574 astrolabe in the British Museum, London.

The window in the upper plate has a shape that is usually described as 'elliptical'. This is a misnomer and is only strictly true for an observer at the North Pole where the 'ellipse' is actually of zero eccentricity and is circular. The window plate for a latitude 51.5 North planisphere is shown in Figure 2.

The shapes of the windows for a range of latitudes are shown in Figure 3. These are obtained by solving the equations of the spherical triangle that has the North Celestial Pole, the zenith and a point on the observer's horizon as its three corners. Let the observer be at a latitude of ϕ . The declination, δ , of a point on the observer's horizon that has an hour angle h is given by

$$\tan \delta = \cos h / \tan \phi$$

The hour angle is the angle marked around the circumference of Figure 2. It increases in the clockwise direction from 0° at the south point. The window in the upper planisphere disc, for a person on the equator, is semicircular. Needless to say this observer would find the planisphere to be of little use. As one moves northwards on the Earth's globe, the window becomes more rounded and more ellipse-like. In fact at high latitudes ($\phi > 45^\circ$) the correct shape is hardly distinguishable from an ellipse.

Consider the window for a latitude of 51.5°. This elliptical shape is such that the centre of the 'ellipse' is at the observer's zenith. (Objects at the zenith have a declination equal to the observer's latitude.) The minor axis of the ellip-

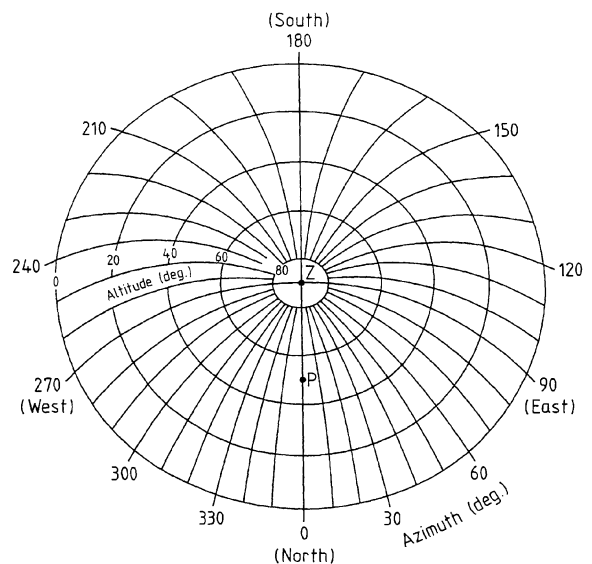


Figure 4. The window of a 51° north planisphere is marked with lines of equal altitude and azimuth. Many astrolabes had plates showing similar figures. A more recent (Second World War) example was produced by the USA Hydrographic Office under the authority of the Secretary of the Navy in March 1942 (H.O. No. 2102-C). This was entitled the *Rude Star Finder and Identifier*. The star map could be covered with a series of seven transparent discs (for seven different latitudes), each drawn with horizon 'ellipses' and marked with lines of equal altitude and azimuth.

Altitude-azimuth gratitudes of a similar nature have been produced by H. Robert Mills for the 56-cm Daily Telegraph Star Chart, and for planispheres of latitudes 51° N and 56° N (see *Occasional Notes* ON8 and ON8a). Robert Mills has also produced an altitude-azimuth overlay for the BAA's *Chart of the Heavens*. This had a stereographic projection and was thus similar in layout to the rete of a mediaeval astrolabe.

tical shape passes through the zenith and the North Celestial Pole. A star at the north point of the window would have a declination of $+38^\circ.5$, and one at the south point a declination of $-38^\circ.5$. Note that $38^\circ.5$ is the co-latitude, $(90-\phi)^\circ$. The major axis passes through the zenith and is at right angles to the minor axis.

The human eye is especially sensitive to deviations from the vertical and horizontal. The 'best' projection for the base-plate map would thus try to make the stars that appear to the observer to be on the same horizontal line in the sky (i.e. a line parallel to the horizon), or the same vertical line in the sky (i.e. perpendicular to the horizon) appear on an equivalent straight line on the flat-plane projection.

This is where the planisphere has problems. Over short distances the horizontal and vertical straight lines on the sky are equivalent to lines of equal azimuth and altitude respectively. Figure 4 represents a planisphere window for an observer at 51° north. The lines crossing the window are lines of equal altitude (this being the angular distance up from the horizon) and azimuth (the angular distance moving from the north point on the horizon, measured moving towards the east). It can be seen that these lines are strongly curved whereas the eye would see stars on them as being on straight lines. The azimuth curvature is most pronounced near the southeast and southwest horizon and this affects our conception of the relative positions of stars one above the other. The curvature of the altitude lines is ubiquitous and this affects our concept of which stars line up parallel to the horizon.

There is also a second problem in as much as similar areas of the visible sky are not represented by similar areas on the map as revealed through the planisphere window. The sky near the horizon occupies much more of the map in the southwest – south – southeast regions than it does in the northeast – north – northwest regions.

The history of the planisphere and its precursors

The word planisphere clearly refers to the mapping problem of converting the sphere of the sky into the plane, flat surface of the lower board of the instrument.

Today's planisphere is very probably directly related to the ancient planispheric astrolabe. This astrolabe was possibly invented by the Greeks about the second century BC (Hipparchus certainly described the theory of the stereographic projection) and it has been suggested that Ptolemy in the second century AD was acquainted with the instrument.¹ Saunders,² however, puts it slightly later placing its origin in Alexandria (Egypt) in the 3rd and 4th centuries AD. Webster³ and Gunther⁴ note that the earliest precise description of the astrolabe occurs in the manuscripts of the Alexandrian scholar John Philoponus, dating from about 530 AD. (This date is subject to some discussion, Gunther⁴ quoting it as about AD 642 but Michel⁵ and Archinard⁶ sticking with the early sixth century.)

The astrolabe was perfected by the Arabic and Persian astronomers and was in quite common usage amongst the astronomical community by the 9th century. Even Chaucer⁷



Figure 5. A typical astrolabe rete, courtesy of Harold N. Saunders, *All the Astrolabes*, Senecio Publishing Company, Oxford, 1984. This is the probable precursor of the planisphere star map. The rete shows the positions of only thirty-three stars. The addition of more stars would make the rete too complicated, and you must remember that it was being used as a clock and not as a guide to the stars. A typical planisphere map would show over 700 stars.

wrote a book about it. The main use of an astrolabe was to tell the time of day or night by measuring the altitude of the Sun or specific stars. It became the clock giving devout Muslims the time for prayer, a compass for obtaining a bearing on Mecca and an instrument for finding the positions of stars. Museums such as the Museum of the History of Science, Oxford and the National Maritime Museum, Greenwich have superb collections of hand-crafted brass astrolabes. We are more interested in the much cheaper pasteboard models and these were produced in considerable numbers between 1500 and 1750. These printed designs had to be cut out and were often made up by amateurs.

The astrolabe–planisphere transition required two basic steps. The first was to convert the rete into a solid star map. The astrolabe rete was a brass disc, most of which had been delicately cut away (see Figure 5). The centre pivot hole of the rete marks the position of the celestial pole and the brighter stars are indicated by named pointers. The celestial path of the Sun is represented by an ecliptic ring and this is usually divided into the twelve signs of the zodiac, thus forming a calendar.

The star pointers on the astrolabe rete were positioned using a range of different projections. The most common was the stereographic. This is best visualized by considering an observer at the south pole of the Earth, looking at the stars in the northern hemisphere of the sky through a supposedly transparent Earth, the north celestial pole being at the centre of the observer's field of view. The observer's sky view is then projected into the plane of the Earth's equator, this then being the plane of the map. This map has a non-linear declination scale, the radial distance of any celestial point from the north celestial pole being proportional to $\tan(45 - \delta/2)$.

The astrolabe rete usually contains the positions of about two dozen stars. The planisphere replaced the cut-away rete by a solid circular sky map. This was also centred on the north celestial pole but the projection was much simpler; instead of the tangent function given above, the radial declination scale was linear, this being just like the polar maps drawn in today's star atlases.⁸

Most astrolabes were provided with a plate known as the 'tablet of horizons'. This was nothing more than a series of curves drawn on a flat circular plate, the centre of the plate being the celestial pole. The tablet of horizons indicated the position of the observer's horizon against the projection of the celestial sphere, for observers at a range of different geographic latitudes. These curves were similar to the curves shown in Figure 3. Some astrolabes even went so far as to have horizon curves for every degree of latitude from say 6° to 66° (see Figure 6). Astrolabes were multi-latitude instruments. In moving from the astrolabe to the planisphere the multi-latitude aspect was lost. Instead of a host of horizon curves, a typical planisphere usually makes do with one. The region inside this curve is then cut out to produce the window seen in Figure 2.

The production of astrolabes practically ceased in Europe by the middle of the 18th century and the much simpler cardboard planispheres took over. A few typical examples are shown in Figure 7.

Planispheres are cheap, handy objects that are mass-produced. A typical example is the Philips range. Today this is produced in two sizes, these being 25 and 14 cm in diameter. Because the planisphere becomes inaccurate when used at a latitude more than 5° away from its prescribed latitude, most manufacturers make a range. A catalogue in a recent issue of *Sky and Telescope*⁹ offered planispheres for latitudes 32°.5 south and 22, 30, 35, 40, 45, and 50° north. British planispheres are usually produced for latitude 51°.5, (the latitude of London, Bristol and Cardiff). They would still work reasonably well for latitudes up to Newcastle (55°) and Edinburgh (56°) but observers in Inverness (57°.5) and Wick (58°.5) would start to have problems.

A big country like, say, Brazil requires a slightly different approach.¹⁰ Freitas Mourão's planisphere has a rotating star map centred on the south celestial pole and extending to declination +75°. This can be folded under a series of four different horizon plates for latitudes -5° (Manaus), -15° (Brasília), -25° (São Paulo) and -35° (Buenos Aires).

The Philips planisphere of today is little changed from the version produced by the same publishers over a hundred years ago. Plastic has simply replaced card.

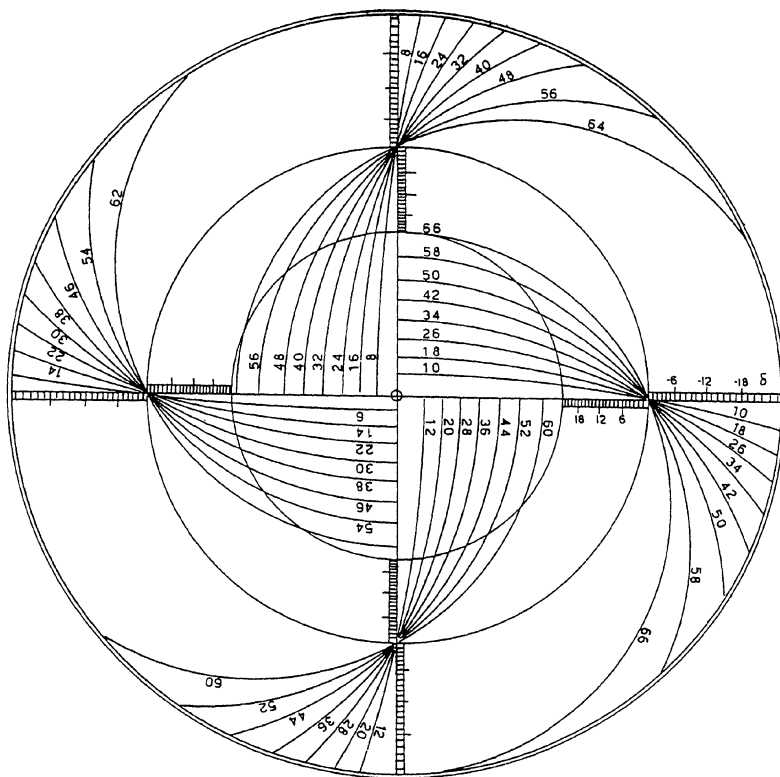


Figure 6. A very complex tablet of horizons for a host of different latitudes (courtesy of Harold N. Saunders, *All the Astrolabes*, *op cit*). The north celestial pole is at the centre of the diagram. Two things must be remembered when comparing this figure with Figure 3. Firstly Figure 6 is drawn for a stereographic projection and secondly, as the curves are symmetrical about the north-south line, only half of each curve has been drawn.

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References and Notes

- 1 see *The Planispheric Astrolabe*, 1976, National Maritime Museum, Greenwich, p. 8.
- 2 Saunders H. N., 1984. *All the Astrolabes*, Senecio, Oxford, p. 2.
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- 7 Chaucer, Geoffrey, 1391. *A Treatise on the Astrolabe*. (A modern edition of this book was edited by Skeat and published in London in 1872.)
- 8 see, for example, Tirion W., 1981. *Sky Atlas 2000.0*, Cambridge University Press, chart 2.
- 9 *Sky & Telescope*, December 1993.
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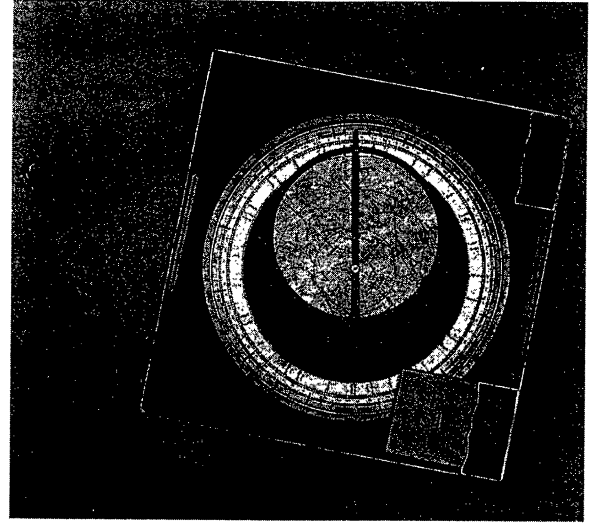
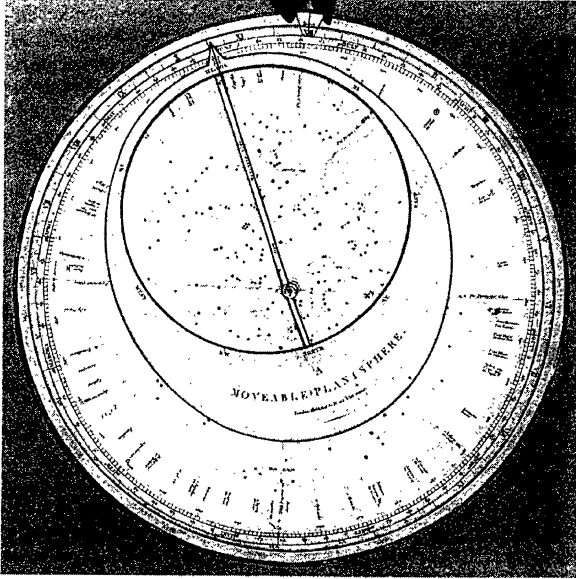


Figure 7. A selection of planispheres produced over the last 150 years.

7a. (left, top): A *Moveable Planisphere*, produced for the latitude of London and published by J. Cary, The Strand, London.

7b. (left, below): An early version (circa 1880) of Philip's Planisphere, showing the principal stars visible for every hour of the year, again made for the latitude of London (51° 5' N). George Philip & Sons, at that time, referred to themselves as 'geographical publishers', and traded from 32, Fleet Street, London.

7c. (above): A *Drawing-Room Planisphere*, enlivened with the biblical quotations, 'the heavens declare the glory of God, and the firmament sheweth his handiwork' (Psalms 19:1) and 'I will consider thy heavens, even the works of thy finger' (Psalms 8:3).

7d. (below): The fourth edition of an *American Planisphere* for latitude 40° (Philadelphia, Denver, San Francisco). This was adapted to Burritt's *Geography of the Heavens*, and was made by Henry Whittall of Philadelphia. It was produced in 1856, and sold by Mason Brothers of New York.

