PLANETARY HOURS

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'Planetary hours' is a term quite often seen on dials and related instruments of the 16th century or earlier, particularly on portable dials and continental wall dials. Generally, the term has been taken by most modern writers to be synonymous with temporary or seasonal hours, dividing the daylight period into 12 equal 'hours'. Because the term 'planetary hours' brings with it connotations of astrology, now discredited as unscientific and not worthy of consideration, it is normally ignored and one of the other terms used instead. However, if the origins of planetary hours are studied in more detail it can be seen that they started out as having a different, and astronomically valid, basis to the other forms of unequal hours. The use of this earlier definition has not been widely studied.[1]

'Unequal Hours'

There are numerous synonyms for hour systems which divide the daylight period on a given day into 12 equal periods, giving rise to much confusion for novice diallists as they study old dials, books and manuscripts. These terms include

- Unequal hours
- Temporary hours
- Temporal hours
- Seasonal hours
- Antique hours
- Jewish hours
- Welsch (*i.e.*, foreign) hours
- Zodiacal hours
- *hora artificiales*
- *horæ inequales*

and so on. Thus it would not seem necessary to introduce another term, planetary hours, meaning exactly the same thing. Also, note that these hours are only unequal over the seasons; on a given day all 12 daylight hours, starting at sunrise and ending at sunset, are equal although of a different duration to the night-time hours. Thus the term 'seasonal hours' is preferred here to 'unequal hours'. One hour can be defined as the time it takes for the sun to pass through one-twelfth of the diurnal arc. The sequence is continued through the night, so that the sunset-sunrise interval is divided into 12 hours, which (except at the equinoxes) are of different duration to the daylight hours. By contrast, the normal equal hours are the time it takes for the vertical through the sun to pass through 15° of the equatorial circle (*i.e.*, 1/24th of a day).

One of the main reasons why the medieval diallist may have been interested in planetary hours is through their supposed astrological influence. The hours of the day were said

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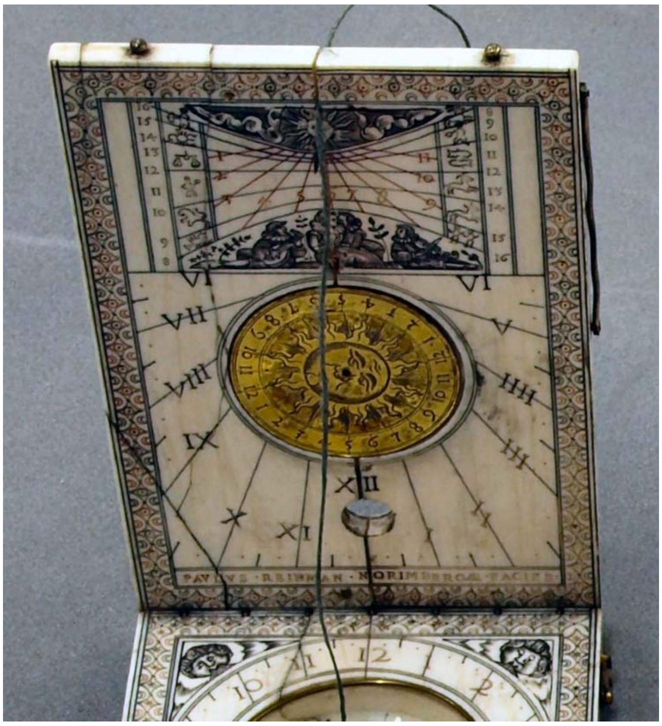
Fig. 1a. Example of (left) dial with (seasonal) planetary hours at San Benigno Canavese in Piedmont and (right) a planetary table at the Palazzo Spade, Italy.

to be ‘ruled’ by the seven astrological planets (which included the Sun and Moon), in the Ptolemaic sequence of their apparent period of revolution about the stationary Earth, in decreasing order: Saturn ♄, Jupiter ♃ , Mars ♂, Sun ☉, Venus ♀, Mercury ☿ and Moon ☾. The days of the week have names derived from the ruling planet of the first hour. Starting on Saturday with Saturn as the first hour, throughout the 24 hours of the day and night the sequence runs three times plus the next three hours and ends with Mars as the last hour. Continuing the sequence gives the Sun as the ruling planet for the next day (Sunday). The last hour of Sunday is Mercury and the first hour of the next day is therefore Moon (Monday), The day names continue in this way until the end of the week and Saturn is the first hour again. This familiar sequence of the days of the week has its origin in Roman times when the Jewish week of seven days came into use in the Christian calendar and the coincidence with the seven astrological planets led to the adoption of the first hour as names for the days. The sequence has continued without alteration, special arrangements being made at the changes from the Julian to the Gregorian calendar. However, the names of the Roman deities Mars, Mercury, Jupiter and Venus have been replaced in the Teutonic languages by their Norse near-equivalents Tui, Woden, Thor and Freya. Tables of these planetary sequences can still be seen on some old continental wall dials (Fig. 1a) or on 17^{th}-century portable dials (Fig. 1b). In these cases, though, the associated planetary hours are the seasonal ones, rather than the true ecliptic ones.

The vertical dial (delineated for seasonal hours) shown in Fig. 1a is one of four dials on a building at San Benigno



J Davis

Fig. 1b. An ivory diptych dial by Paul Rieman of Nuremberg (after 1602) with a (seasonal) planetary hour scale as one of its subsidiary scales. Courtesy of the Whipple Museum, Cambridge, inv. no. 1687.

Canavese in Piedmont. The other three are for French (*i.e.* equal), Italian and Babylonian hours. The seasonal hours are numbered 1–12 and the initial letters for the days of the week appear on either side at the top. The alternately-coloured bands for each day contain the planetary hour symbols in the sequence described above. To use the dial the day of the week is found in the initial letters and the coloured band for that day is followed round until it meets the gnomon shadow. On Fig. 1a the shadow falls in the sector between lines 9 and 10, the tenth hour. Suppose the weekday is Friday (initial V for Venerdi), the band for that day shows the symbol for the moon which is therefore the ruling planet at that time.

(Ecliptic) Planetary Hours

The earliest description of planetary hours (at least, as known to the authors) is attributed to Sacrobosco’s *Tractatus de Sphæra.*[2] Written around 1240,[3] ‘*The Sphere*’ became the standard astronomy starter text for several centuries, attracting many commentaries which extended its usefulness. In it, Johannes de Sacrobosco (also known as John of Holywood, see Biographies) notes that ‘a natural hour is the space of time in which half a sign rises’. Since the zodiac signs are distributed at 30° intervals around the ecliptic and there are always 6 signs above the horizon, this means that a planetary hour (also known sometimes known as a zodiacal hour) is the time for 15° of the ecliptic to rise above the horizon. Although, like seasonal hours, there will always be 12 hours from sunrise to sunset, these ecliptic planetary hours will be of unequal duration during the day with the distribution of the durations depending on the time of year. As a consequence, the 6^{th} hour will not, in general, equate to midday. The detailed characteristics of ecliptic planetary hours are discussed later in this paper.

The complicated characteristics of true ecliptic planetary hours make them very difficult to use on a sundial, though it can be done. In the late-medieval period, it seems that diallist/astrologers (which included such respected names as Regiomontanus) wanted to display planetary hours but without the complications. Thus they made dials with lines labelled for planetary hours but using the simpler definition for the seasonal hours. Planetary and seasonal hours became synonymous: the original ecliptic definition was gradually lost. The English-language edition[4] of a mystical work by Heinrich Agrippa (written in 1509, first published in 1531 and published in English in 1631) contains the passage:

> “…….almost all Astrologers divide all that space of time from the Sun rising to setting into twelve equall parts and call them the twelve hours of the day; then the time which followeth from setting to rising, in like manner being divided into twelve equall parts, they call the twelve hours of the night, and then distribute each of those hours to every one of the Planets according to the order of their successions…….but in the partition of the hours some do different, saying, that the space of the rising and setting is not to be divided into equall parts,

and that those hours are not therefore called unequal because the diurnal are unequal to the nocturnall but because both the diurnal and nocturnal are even unequall amongst them-selves……..for as in artificial hours, which are always equall to themselves, the ascension of fifteen degrees in the equinoctiall constituteth an artificial hour: so also in planetary hours the ascension of fifteen degrees in the Eclipticke constituteth an unequall or planetary hour, whose measure we ought to enquire and find out by the tables of the oblique ascensions of every region."

The distinctions drawn between the three time systems are clear: although most astrologers at that time were dividing the daytime and night-time intervals into equal (seasonal) hours, some were still using the planetary hours based on the rising of the ecliptic, giving hours which vary in length throughout the day and night. 'Artificial hours' are the normal equal hours of apparent solar time based on the rising of the equinoctial (the celestial equator).

Geoffrey Chaucer, writing his *Treatise on the Astrolabe* at the very end of the 14th century, explicitly labels the spaces between the seasonal hour lines of his astrolabe drawing with the planets.[5] In section 12 of the *Treatise*, ("Special declaracioun of the howres of planetes") he explains how to convert the sun's altitude measurement on a specified date to the appropriate (seasonal) planetary hour. In his *Canterbury Tales*, Chaucer uses both planetary hours and the more 'modern' equal hours for timetelling as well as using planetary and zodiacal references to imply dates.[6]

A nineteenth-century analysis of Chaucer's works by A.E. Brae[7] goes so far as to call Sacrobosco's definition of an 'unequal' (planetary) hour as a 15° rise in the ecliptic as a "grossly absurd mis-description" and "monstrously untrue" so clearly all memory of ecliptic planetary hours had been lost in Victorian Britain.

Only a very few descriptions of ecliptic planetary hours can be found in the early-modern period and it is not until the scholarly study of sundials by Joseph Drecker[8] in 1925 that a proper analysis was published. Since then, a few modern authors, notably Fer de Vries,[9] have noted their existence.

Another definition of planetary hours due to Peter Apian and reported by his son Philip is discussed later.

These multiple definitions of planetary hours beg a number of questions. For example,

- were ecliptic planetary hours ever really used?
- are there any instruments (extant or in drawings) using ecliptic planetary hours?
- when, or over what period, did the change-over from the ecliptic to the seasonal definition of planetary hours occur?
- are there any modern uses of planetary hours (of either form) that could be exploited?
- how do you recognise the type of planetary hours used on old sundial, quadrants, *etc*.?

The Mathematics of Ecliptic Planetary Hours

As mentioned earlier, the durations of planetary hours are based on the rising of 15-degree intervals of the ecliptic (in celestial longitude) and are unequal, both from day to day and within one day. The annual path of the sun is confined to the ecliptic (within very narrow limits) and its position in the sky due to the diurnal rotation of the earth can be taken as an indicator of the planetary hour. Two intersecting great circles on the sphere (in this case the ecliptic and the horizon) mutually bisect each other, so that as the sun sets a point on the ecliptic 180º distant is rising, and the sunrise-sunset period (the diurnal arc of the sun) is divided into 12 intervals of 15º of rising longitude. The system of planetary hours commences at sunrise and from then until 15º of the ecliptic have risen is hour 1. Hour 2 runs from 15º to 30º and so on until hour 12 ends at sunset. The night-time hours also run from 1 to 12, hour 1 commencing at sunset and hour 12 ending at sunrise, but here only the daytime hours are considered. The hours are not subdivided; each represents a period of certain astrological influences.

The zero point of the longitude is the First Point of Aries, the position the sun occupies at the northern hemisphere spring equinox. At the summer solstice the sun's longitude is 90º, 180º at the autumn equinox and 270º at the winter solstice.

The inequalities in the hours are caused by the inclination of the ecliptic to the celestial equator (the obliquity angle of 23.5º). The declinations of points on the ecliptic vary between +23.5º (north of the celestial equator) and –23.5º (south), depending on the longitude. The azimuth on the horizon of a point on the ecliptic which is rising depends on its declination, so that through the sequence of 15º ecliptic points their azimuths at rising are continually variable, and the angle at which the ecliptic intersects the horizon is also variable. The maximum inequalities occur at the equinoxes.

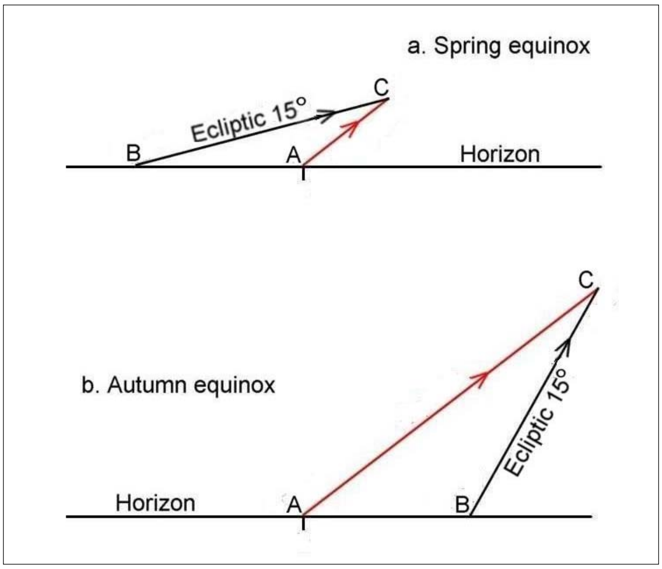


Fig. 2. Seasonal effects on the rate of rise of the ecliptic above the horizon.

Fig. 2 shows schematically the effect of these changes upon the interval between the rising of successive 15º ecliptic points. Fig. 2a is drawn for the spring equinox when the declination is increasing and the azimuth change is to the north. The rising azimuth of an ecliptic point is at A and that of the next 15º point is at B. Between A and B the point A will have risen to C, and it is obvious that the arc AC is less than the 15º of BC on the ecliptic. The conditions for decreasing declination (azimuth changing to the south) is shown in Fig. 2b, where the arc AC is now greater than 15º. In each case the arc AC represents the change in the hour angle measured at the pole of the sky, and the inequalities in the planetary hours are the consequences. Note that in Fig. 2a the ecliptic makes a shallow angle with the horizon and the angle in Fig. 2b is much steeper.

From longitude 90º to 270º the declination is decreasing, so the effect of Fig. 2b is always present to a greater or lesser extent when the longitude which is rising is within this range. Similarly, the effect of Fig. 2a occurs for the longitude range 270º to 90º. The overall effect of the combination of these factors is a set of hour lines of varying shapes, and the lines for longitudes 270º to 90º are a reversal of those for longitudes 90º to 270º.

To plot the planetary hours on a sundial it is necessary to know the latitude and the hour angle and declination of the sun, from which the coordinates of points on the dial can be found. The following method is used to perform this, using the latitude and the daily longitude of the sun.

Notation:

φ	Latitude
ε	Obliquity of ecliptic, taken as 23.5º.
λ_s	Longitude of sun.
δ_s	Declination of sun.
λ_r	Longitude of rising point of ecliptic, in multiples of 15º > λ_s
δ_r	Declination of λ_r
$h(\lambda_r)$	Hour angle of λ_r at rising.
Δh	Difference of hour angle corresponding to increase of 15º in λ_r
h_s	Hour angle of sun.
N	Nodus height for gnomonic projection on a horizontal dial.
x, y	Coordinates of sun on this.

Formulae:

δ_s	$\arcsin(\sin\lambda_s \sin\varepsilon)$	1
δ_r	$\arcsin(\sin\lambda_r \sin\varepsilon)$	2
$h(\lambda_r)$	$-\arccos(-\tan\varphi\tan\delta_r)$ (always negative)	3
Δh	$\arccos\{(\cos(\lambda_r-\lambda_s) - \sin\delta_s\sin\delta_r)/(\cos\delta_s\cos\delta_r)\}$ (always positive)	4
h_s	$\Delta h + h(\lambda_r)$	5
K	$(\sin\varphi\sin\delta_s + \cos\varphi\cos\delta_s\cos h_s)$	6
x	$N\cos\delta_s\sin h_s/K$	7
y	$N(\cos\varphi\sin\delta_s - \sin\varphi\cos\delta_s\cos h_s)/K$	8

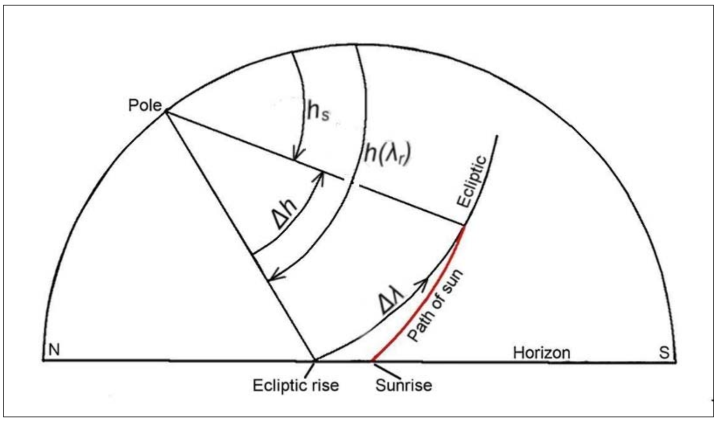


Fig. 3. The derivation of the ecliptic planetary arcs for the latitude of 51.5° N.

To examine the properties of the planetary hours the latitude of London (51½º) has been selected. The diagram of Fig. 3 shows the relationships of the various arcs, labelled with the symbols shown in the notation. Since sunrise, the sun has followed the path shown in red, centred on the pole of the sky. The ecliptic arc is centred on the ecliptic pole, 23.5º distant.

It is difficult to visualise the appearance of the hour lines on the sky. Fig. 4 may help: the lines are shown in terms of altitude and bearing on a horizon-based Mercator projection. The lines drawn are for solar longitudes 90º–180–270º, (summer to winter solstice) and would need reversal as a mirror image for the other half-year. Note the variable separations and that the earlier and later lines are approximately parallel to the horizon. For a large part of its length line 11 is very close to the horizon, within four degrees of altitude. The only positions of hour 6 which coincide with the meridian are those for the solstices.

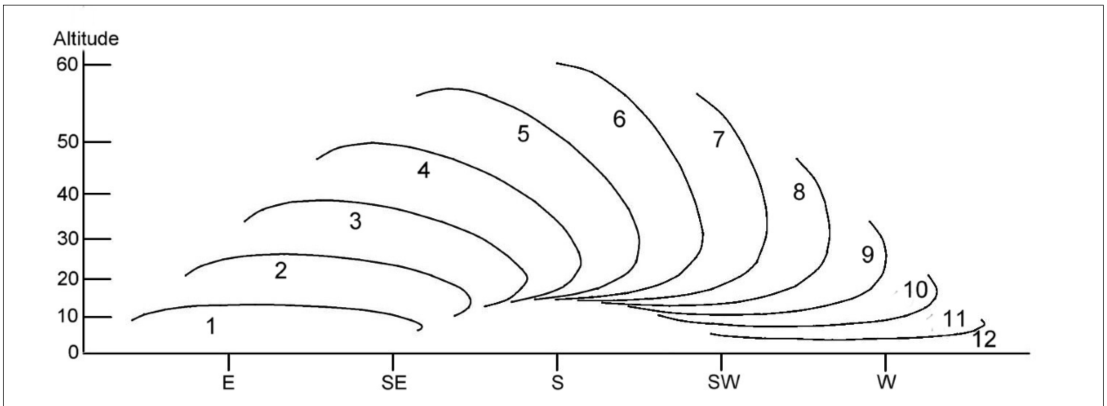


Fig. 4. The appearance of the ecliptic planetary hours on the sky, based on the Mercator projection.

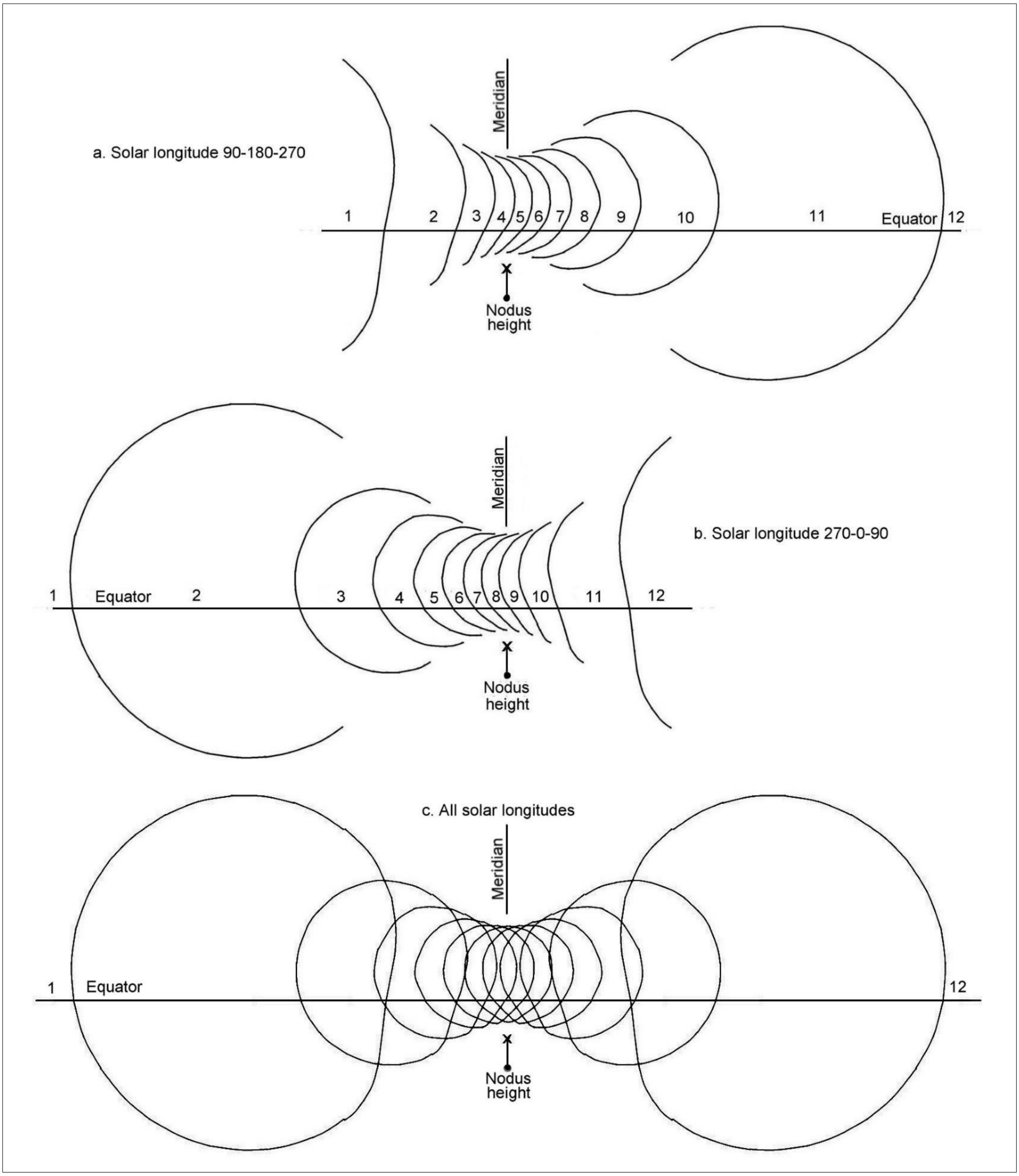


Fig. 5. The ecliptic planetary hours lines on a horizontal dial using the gnomonic projection. (a) for the Autumn half of the year, (b) for the Spring half and (c) combined for the whole year. The X *marks the location of the vertical gnomon with the nodus height shown.*

The appearance of the lines on the gnomonic projection of a horizontal sundial (viewed from the south) with a vertical gnomon and shadow-casting nodus is shown in Fig. 5a for longitudes 90–180–270º, with the equator indicated. Sunrise and sunset cannot be shown on this projection, and only the lines for the end of hour 1 and the beginning of hour 12 are present. The sub-nodus position is shown by a cross and the nodus height is indicated. Radial distance on the projection is proportional to the tangent of the zenith distance (90º – altitude) which accounts for the exaggerated spread of lines near the horizon. Fig. 5b shows the projection for the longitudes 270–0–90º half of the ecliptic, the reversal of the other half.

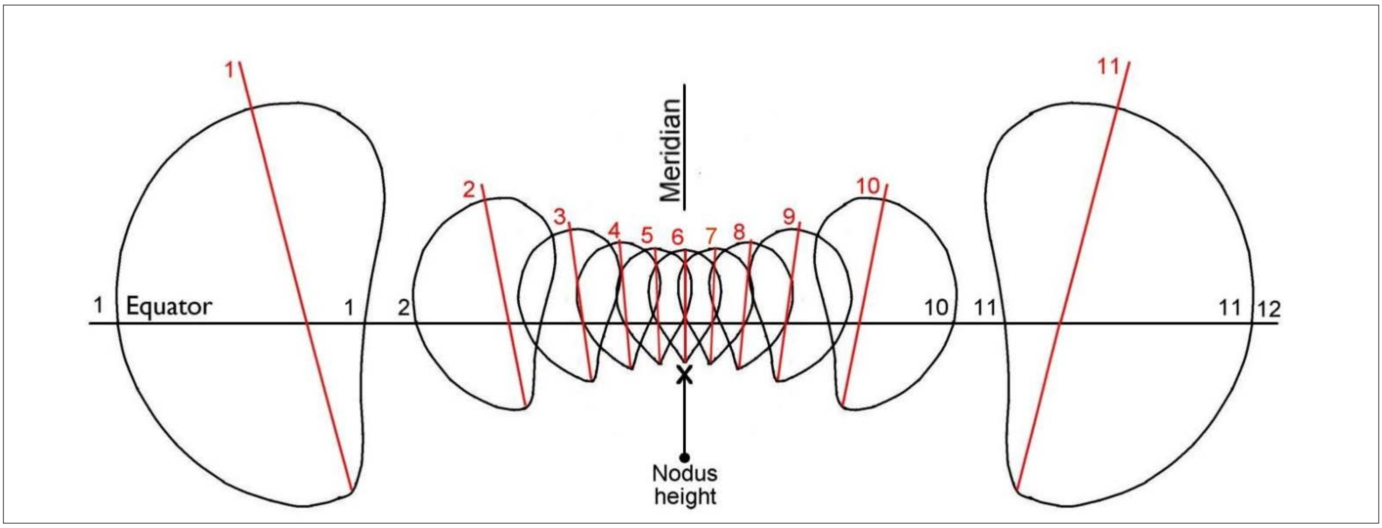


Fig. 6. A horizontal dial with ecliptic planetary hours for a latitude of 32°. The red lines represent the seasonal hours. The X *marks the location of the vertical gnomon with the nodus height shown.*

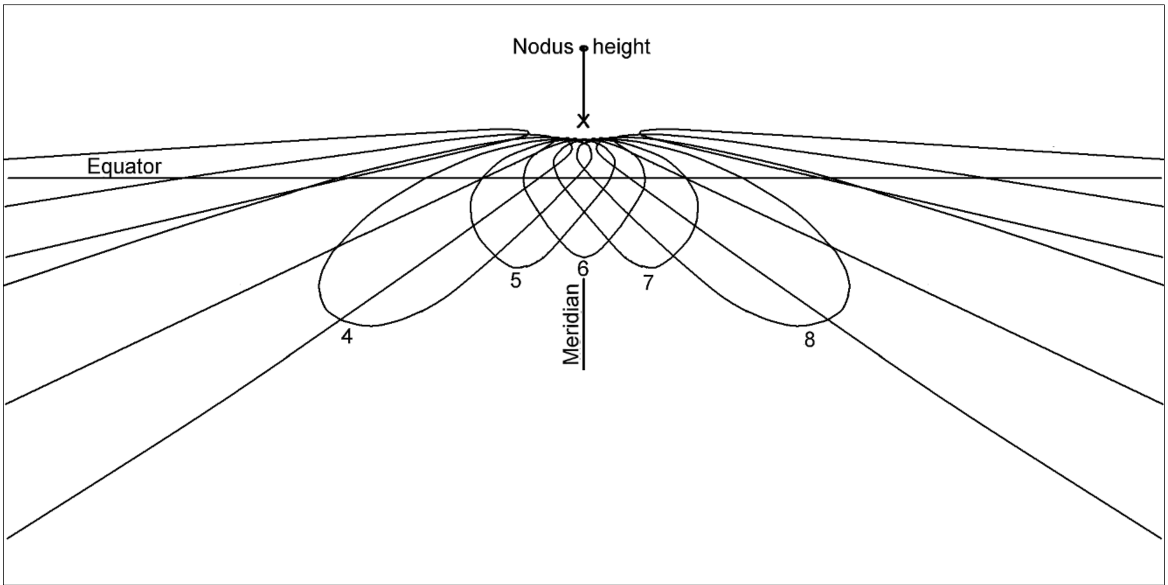


Fig. 7. A south-facing vertical dial showing planetary hours for latitude 51½º.

The combination of the hour lines for all longitudes is shown in Fig. 5c. It is obvious that such a dial with overlapping hour lines would be very difficult if not impossible to read. On the drawing it was found quite impracticable to label the lines with the appropriate hour numerals! The alternative would be to provide separate dials for each part of the year.

The system of these planetary hours is thought to have originated in lower Mesopotamia, at a latitude of perhaps 32°. Fig. 6 is a horizontal dial drawn for this latitude. Although the overlap of the lines is reduced, the appearance is still very confusing. The red lines on Fig. 6 represent the equally-spaced seasonal hours and it is not surprising that eventually the seasonal hours displaced the complexity of the old planetary hours in astrology and assumed their name.

For public display of planetary hours it is likely that vertical sundials would be preferred. In common with equal-hour south-facing dials, those parts of lines which lie north of or close to the east or west points cannot be shown. Fig. 4 indicates that this excludes a large section of hour lines 1 and 11 and smaller parts of lines 2, 3, 9 and 10. Fig. 7 is a south-facing vertical dial for latitude 51½°. Around the time of the winter solstice (closest to the cross marking the sub-nodus) the lines are very compressed and would be virtually unreadable. Fig. 8 is a south-facing dial for latitude 32º. Here, although the winter lines are better separated, the early and late hours are even more truncated (only 5, 6 and 7 are fully shown) and the high altitude of the sun in summer implies that a vertical dial to carry the full extent of the lines would need to be excessively tall. Vertical dials for planetary hours are not really a practicable proposition.

The Romans were very dependent upon astrology in their daily lives and many Greco-Roman dials are known. The majority appear to carry delineations for seasonal hours: can any of them be interpreted as planetary hours?

Tables of planetary hours which correlate them with local apparent solar time as shown on an equal-hour sundial can be prepared for every day of the year. Extracts from such a table are given by de Vries,[9] from a work by Crätschmairum (1626).[10]

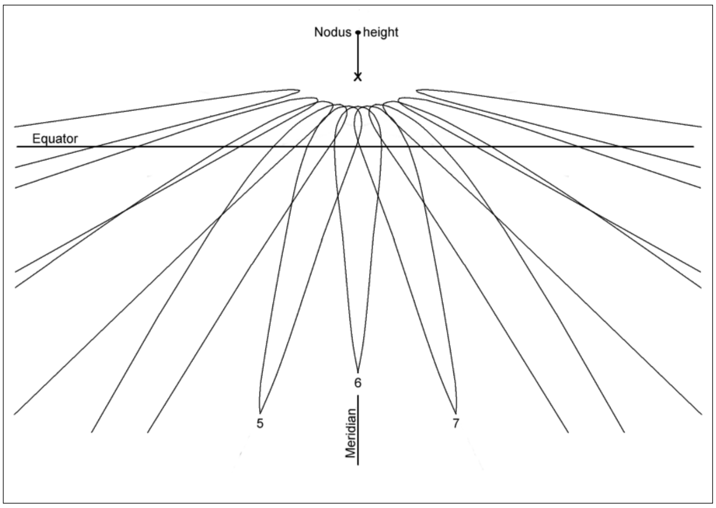


Fig. 8. A south-facing vertical dial showing planetary hours for latitude 32°.

The Planetary Hours on the Apian Triens

The zenith-centred stereographic projection of the triens showing the PLAN and JUDE (planetary and Jewish or seasonal) hours (Fig. 9) occurs among a number of other illustrations published by Philip Apian but due to his better-known father Peter.[11,12] This is the only example of this definition of planetary hours known to the authors. The triens projection is folded in half along the meridian AH and each line carries hour identifications for the morning and afternoon hours. Other features are a note of the design latitude (AD POLE ELEV. 47.48.49 GR.), a scale of degrees around the limb, lines of declination of the sun for the start of each zodiacal sign, an altitude scale (GRAD. ALTITUDE), and two apertures for sighting the sun. Alongside the meridian the zodiacal signs are identified and the declination range of each is divided into three.

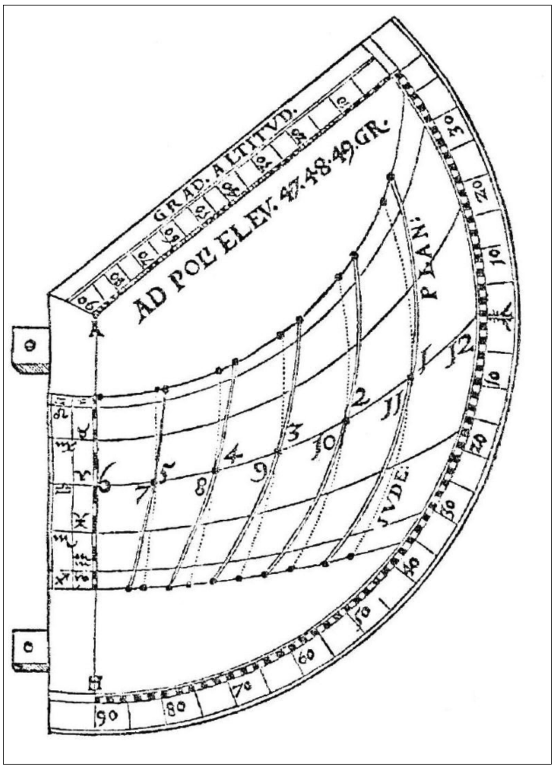


Fig. 9. A version of a 'triens' by Peter Apian delineated for planetary ('PLAN') and seasonal ('JVDE') hours.[12] It uses the horizontal stereographic projection.

From analysis of the positions of the PLAN hours it is found that they represent arcs of great circles which pass through the celestial equator at intervals of fifteen degrees and also through the north and south points of the horizon. On a horizontal dial they appear as straight lines parallel to the meridian.

For use, the triens would be fitted with a plumb-bob and cord passing through an aperture at A. With the instrument held vertically, the sun is sighted through the apertures and the altitude of the sun read from the freely-hanging cord on the limb scale. A bead on the cord is then set to this reading on the altitude scale and moved around until it meets the arc of declination appropriate to the zodiacal sign of the sun's current position. The planetary hour or the seasonal hour is found from the position of the bead among the hour lines, knowing whether the sun is before or after the meridian. The azimuth of the sun (measured from the east or west points of the horizon) can be found from the intersection of the limb scale with the cord.

On the stereographic projection of Fig. 9 the planetary hour arcs are centred on a line orthogonal to the meridian passing through the apex of the projection (representing the zenith) at distances and radii (where R is the radius of the arc of degrees):

$$y = \mathrm{R}\cos\varphi/\tan h$$
$$r = \mathrm{R}/\sin\{\arctan(\tan h/\cos\varphi)\}.$$

If continued beyond the declination lines they would intersect the meridian at point H, the projection of the south point of the horizon. On a horizontal dial the north and south points of the horizon are at infinity and the hour lines are parallel to the meridian and spaced at $N\tan h_s/\cos\varphi$,

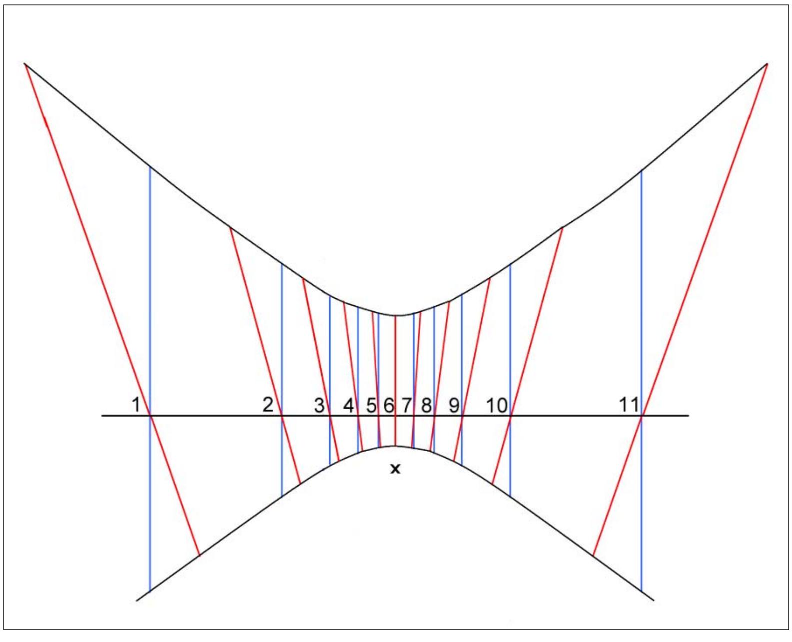


Fig. 10. Comparison of seasonal hours (red lines) and Apian planetary hours (blue lines) on a horizontal dial for latitude 51½°.

with a vertical gnomon and nodus height N. On a south-facing vertical dial the lines radiate from the base of a horizontal gnomon at angles $\arctan(\tan h_s/\cos\varphi)$ from the noon line.

Comparison of Seasonal Hours and Apian Planetary Hours

Although no such dial is known to the authors, it is possible that some dials apparently with seasonal hours are actually delineated for Apian hours. The appearance of both on a horizontal dial for latitude 51½° is shown in Fig. 10 with red lines for seasonal and blue for Apian hours. Both sets pass through the 15-degree points on the celestial equator, but the seasonal hours are inclined to the meridian instead of parallel. This inclination is dependent on the latitude, becoming less at lower latitudes and (to take the extreme case) for a location on the equator, where the semi-diurnal arc is always 90º and the poles are on the horizon, the seasonal, Apian, equal, Italian and Babylonian hours would all coincide in lines parallel to the meridian. But the ecliptic planetary hours would appear as distorted figure-eight shapes, as shown in Fig. 11.

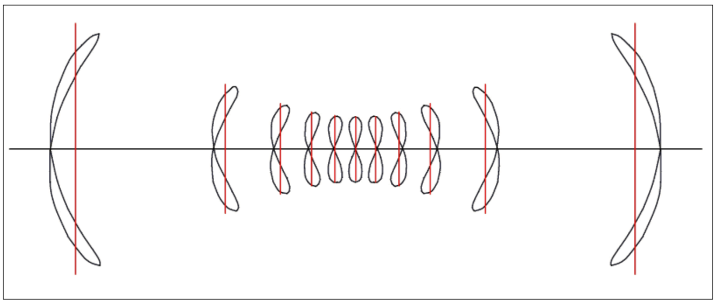


Fig. 11. A horizontal dial for a location on the equator. The distorted figure-eight shapes are the ecliptic planetary hours: the red lines indicate the seasonal and Apian hours.

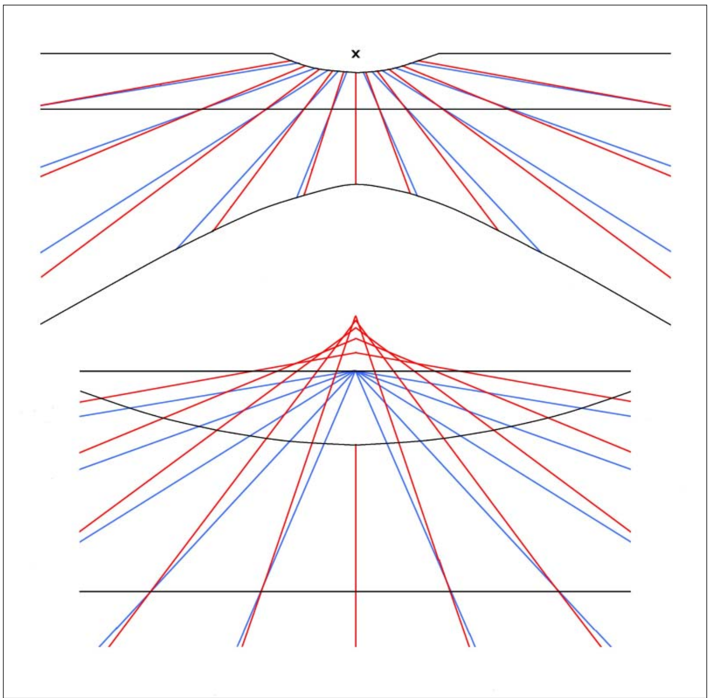


Fig. 12. Comparison of seasonal hours (red lines) and Apian planetary hours (blue lines) on a vertical south-facing dial at latitude 51½º. The upper diagram shows as much of the layout as can be conveniently included: the lower diagram is an enlargement of the central section showing how the lines intersect.

Seasonal and Apian hours on a south-facing vertical dial for latitude 51½° are shown in Fig. 12. The distinction between the two sets is not very obvious and for a real dial careful measurement might be necessary. One distinguishing feature is that the Apian hours if extended intersect in a point on the projection of the horizon, but the seasonal ones have no common intersection, as shown in the enlarged central section on Fig. 12.

Of course the majority of vertical dials will not face due south, having greater or lesser declining angles, but the above rule concerning the line intersections will still apply. The dial shown in Fig. 1a declines about 12° west and is drawn for seasonal hours.

Other Instruments:

The British use of seasonal hours appears to have been relatively limited. We have previously described[13] two horizontal dials by Isaac Symmes which carry them and two examples on unusual altitude dials by Humphrey Cole are known.[14] These use the shadow of a 45-degree gnomon to find equal hours and seasonal hours.

Conclusion

It is not really possible to give definite answers to most of the questions posed above. No dials carrying ecliptic planetary hours have come to the notice of the authors, but manuscript diagrams have been located.[9] If ever they were used, it seems possible that planetary hours were superseded in Roman times or earlier, and the extract from Agrippa indicates that in his time they were considered obsolete. It is difficult to envisage any current use for planetary or seasonal hours but some modern dials may carry them merely for interest. The hints given in this article may help to resolve any problems with identification of hour lines on old dials.

Brief Biographies

Heinrich Cornelius **Agrippa** von Nettesheim (1486–1535)[15] was a German occultist, natural philosopher and medical writer. He is also described as a magician, theologian, astrologer and alchemist. He was an exact contemporary of Nicholas Kratzer, whom he met at the University of Cologne and later, in 1510, in the English Court of Henry VIII, where Agrippa was a servant of Louis of France.[16]

Peter Apian (1495–1552, Petrus Apianus) was born in Saxony and studied at the University of Leisnig. He was a mathematician, cosmographer and also a printer of high-quality geographic and cartographic works. He is best-known for his 1524 *Cosmographicus Liber*, a work renowned for its diagrams with working volvelles. Also of importance is his *Instrument Buch…* (1533) describing the construction of astronomical instruments. One of his 14 children was Philip Apian (1531–1589) who was also a mathematician and who did much to promote the work of his father. For a list of their works, see Zinner.[17]

Sacrobosco (c. 1195–c.1256, John of Holywood) was a monk and astronomer who taught at the University of Paris. He is believed to have been born in England, though there is considerable mystery about the full details of his biography.[3] He is credited with introducing the Hindu-Arabic number system into Europe and he also accurately described the defects of the Julian calendar centuries ahead of its replacement by the Gregorian one. His short book *Tractatus de Sphaera* ('The Sphere', c.1230) was hugely influential throughout the medieval period as an introduction to astronomy, providing a readable description of the Ptolemaic universe.

ACKNOWLEDGEMENTS

We are grateful to Nick Orders for photocopying parts of Drecker's book from the BSS Library. Walter Hofmann provided much assistance searching for extant Continental wall dials. The photograph of the San Benigno Canavese dial (Fig. 1a) was kindly supplied by Francesco Caviglia.

REFERENCES and NOTES

1 There are honourable exceptions, particularly the recent articles by Fer de Vries and the earlier scholarly book by Joseph Drecker (see refs 8 and 9).
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