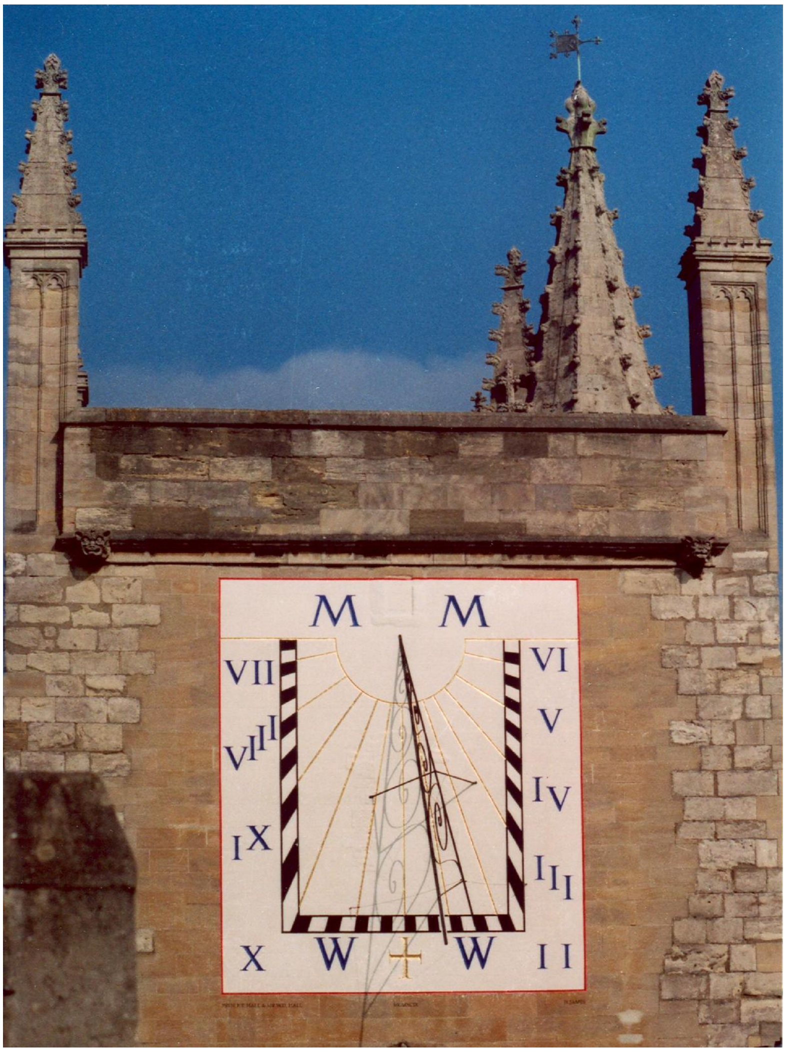
The British Sundial Society



BULLETIN

VOLUME 17 (i) MARCH 2005

Front cover: The Millennium Sundial on the Muniment tower of New College, Oxford. Carved by Harriet James, it declines 10° west of south and measures 15 × 17 feet. The 'MM' for the year 2000 is inverted to give 'WW' for William of Wyckham, founder of the college. The style and layout of the numerals imitate those shown in prints of a 1696 dial on the same site.
With the permission of the Warden and Scholars of New College, Oxford.

Back cover: from St. Kenelm Church, Minster Lovell, Oxon. (Photo: A.O. Wood)

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VOLUME 17 (i) - MARCH 2005

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BULLETIN

OF THE BRITISH SUNDIAL SOCIETY

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VOLUME 17 (i) - MARCH 2005

EDITORIAL

Once again our authors have displayed the width of their interests, and their versatility, from which all of us can benefit. In this issue we have something historical (Saxon Dials) and something of aesthetic charm (Time Courtyard in an Italian convent). We have some original designs: (ecliptic, equatorial and 'flagpole') and Moondial, breaking new ground in the celestial sphere. Frank Evans has written-up last autumn's Sundial trip to Italy, making it as interesting a read for those who were present as for those who were not. I am specially pleased to publish material from authors who have not previously published in the Bulletin. Keep it up!

A Correction

I have been asked by Martin Jenkins to make a small correction in his account of the meeting of NASS, published in the December 2004 Bulletin. The change is required in Bull. BSS. Vol. 16(iv) page 153, first column. Fred Sawyer writes "…..it seems to suggest that the dial I described was invented by Thijs de Vries; this is incorrect. The helical polar dial is my design. By way of giving some historical context for my talk, I mentioned *another* polar dial that Thijs de Vries had described to me many years ago---this was a polar dial with a cycloid gnomon and linear-spaced hour divisions arranged along the east-west line. I then explained that in response to Thiijs' letter, I developed a dial which uses a helical gnomon and has linear-spaced hour points along the meridian. This placement of the hour points on the meridian is what leads to the wide array of alternative equations of time that apply to one form of this dial. In another form, the meridian hour points also permit the design of a dial whose gnomon (or dial plate) moves daily in a fashion similar to an analemmatic dial, but in this case the movement actually incorporates the correction to yield a mean time reading."

MOONDIALS AND THE MOON

MICHAEL LOWNE

INTRODUCTION

Previous articles in BSS *Bulletins*[1-16] have discussed examples of moondials and the attempts to show the solar time by the night-time position of the moon. The purpose of this article is to examine some attributes of moondials and their limitations, and to suggest improvements which may enable a moondial to tell solar time with an accuracy approaching that of a simple sundial. Many aspects need to be considered, such as the properties of the moon and its monthly orbit around the earth, and the response of the human eye to the low intensity of moonlight.

SOME BASIC PRINCIPLES

In our time-keeping system, 12 noon in *apparent solar time* is defined by the transit of the sun across the north-south meridian. The function of an ordinary sundial is to derive the hour-angle of the sun (the angle in time by which it is east or west of the meridian measured at the pole of the sky) and to apply this to 12 noon to indicate the time of day. A moondial can measure the hour-angle of the moon, but the transit occurs later day by day throughout the period from one new moon to the next (a lunation) and there is no fixed relation of the transit to solar time as with the sun. We can however imagine 'moon time' depending on the moon's hour-angle, with its own 'noon' at meridian transit. Moon time continually gets slower on solar time, losing at an average rate of about two minutes an hour. The key to the problem of obtaining time from the moon is a knowledge of the solar time at which the moon transits on any occasion. In the $2x12^h$ system, the time of moon transit is equivalent to the interval which has elapsed since 12 noon or 12 midnight and is in effect the amount by which moon time is slow on solar time. Historically, this time difference was found from the age of the moon in days counted from new moon as day 1. Various methods were used to apply the difference as an additive correction to the moon time indicated by the gnomon shadow, to derive solar time.

TYPES OF MOONDIAL

Four methods of applying the necessary correction to the moon time can be identified among existing moondials. The tabular method supplies daily corrections depending on the age of the moon. Some small portable dials have a separate volvelle on which the age is set enabling the solar time to be read off against the moon time shown by the dial. In a graphical method circles or spirals, one for each day of the lunation, carry scales of times which incorporate the daily correction, enabling the solar time to be read directly from the gnomon shadow. Adjustable moondials have a chapter ring which can be rotated to a setting appropriate to the moon's age and again the time can be read directly. For all dials the age could be found from the *epact* (one day less than the age on January 1) for each year, or from dates of moon phases published in various popular almanacs.

DIALS WITH CORRECTION TABLES

Readers will be familiar with the table which appears on the Cambridge Queens' College dial[4,5,7,8,12,13] shown in Table 1. The upper and lower rows represent the age of the moon in days, counted from the day of new moon which is called day 1. The top row represents ages up to day 15 (full moon) and the lower row the ages after full, from 16 to 30. The centre row has a sequence of daily time corrections which increase by intervals of 48 minutes from 0^h48^m to 12^h0^m. This choice of interval will be discussed later. Only one row of corrections is needed because in the $2x12^h$ time system they repeat after full moon. As explained above, the correction is to be added to the time shown by the gnomon shadow to obtain the solar time. As an example, if the dial shows the moon time to be 3^h30^m on the ninth day of the moon whose correction is given as 7^h12^m, the solar time is $3.30 + 7.12 = 10^h42^m$. If the sum exceeds 12^h, then 12^h is to be subtracted to give the time in the $2x12^h$ system. Instead of a table some dials have a scale of moon ages and transit times from which the required correction may be read. This is sometimes arranged so that fractions of a day in the age may be taken into account, as shown on a reproduction Henry Wynne (c.1685) dial[15]. This refinement is not likely to make any significant improvement to the derived time.

A double-horizontal dial by Elias Allen now in the Science Museum has a curious feature. A subsidiary time scale for the moondial is 4

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0:48	1:36	2:24	3:12	4:00	4:48	5:36	6:24	7:12	8:00	8:48	9:36	10:24	11:12	12:00
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

Table 1. The correction table on the Queens' College dial.

hours slower than the main dial graduation and the table of corrections is increased by 4 hours to compensate. The reason for this construction is not apparent.

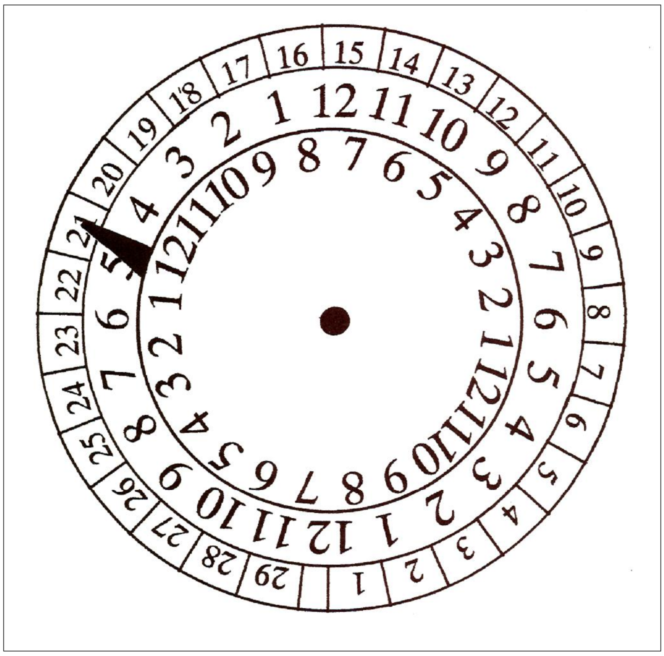

Fig. 1. A replica moondial volvelle.

THE VOLVELLE METHOD

Fig.1 is a replica of a typical lunar volvelle as found on some small portable dials. The outer circle is the age of the moon based on a 29½-day lunation. The rotating inner circle with $2\text{x}12^h$ times carries a pointer which is set to the age, and the solar time can then be read on the middle time circle, adjacent to the dial moon time on the inner circle. In Fig.1 the age is set to day 21: if the moon time is 4 the solar time is about 8.30pm and if moon time is 9, solar time is about 1.30am. Obviously such a volvelle is by no means a precision instrument, an accuracy of about twenty minutes or half an hour is the best that can be attained.

GRAPHICAL DIALS

Dials with moon age and time rings usually have 15 rings, labelled with the age of the moon from 1 to 15 and repeated from 16 to 30. After full moon at day 15 the times repeat in the $2\text{x}12^h$ system, as with the tabular method. The maker will have applied the necessary corrections to the time graduations contained in each ring by arranging the indicated time on the meridian to read the tabular transit time appropriate to the age for each ring. For example, the ring for age 10 days would read 8^h0^m at the normal 12^h position and the indication of the gnomon shadow on this ring will give the apparent solar time. Some of the large double-horizontal dials by Henry Wynne carry the day-and-time scale in addition to moondial rings[15]. In moonlight the narrowness of the rings would make them difficult to follow round the dial from their age labels without inadvertently changing to the wrong one. The numerals are only about 5mm high and would not be easy to read except near the time of full moon.

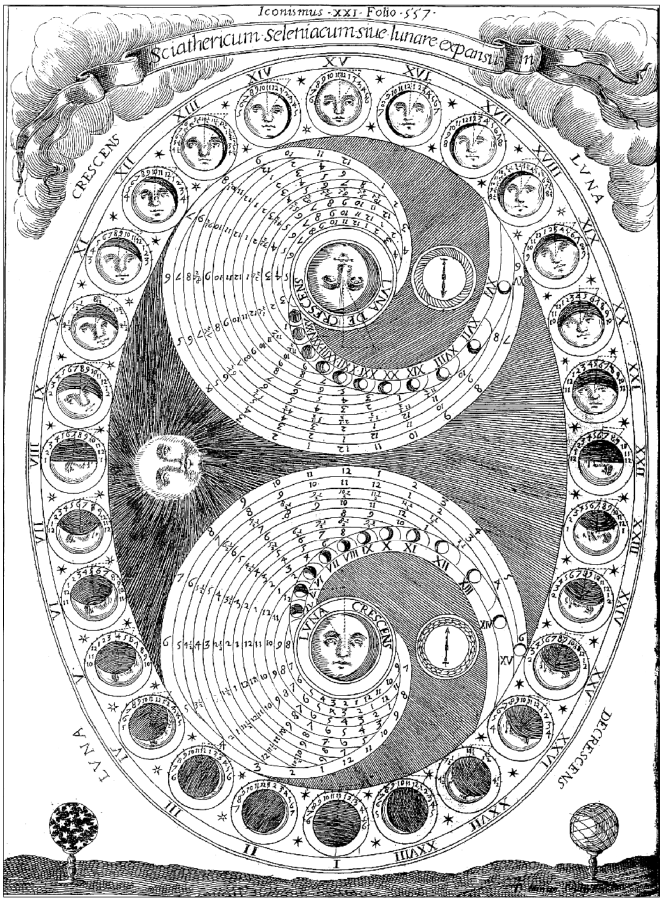

Fig. 2. Kircher's Sciathericum seleniacum.

A dial by Kircher discussed by Schneider[9] (the *Sciathericum Seleniacum,* shown in Fig. 2) uses drawings of the phase, the day-by-day appearance of the moon, to deduce the age and hence the appropriate spiral to use. This method could be accurate near the quarter-moons when the daily change in the appearance is most rapid. However, near full moon the appearance changes only slowly. At two days either side of full the unilluminated area is about 5% of the whole disc and only about 2% at one day from full. Such small departures from circular are not obvious. The moon appears to be 'full' for a few successive nights and the age is uncertain. Schneider has redrawn the dial to avoid some inconsistencies in the design.

A slate dial dated 1803 by Isaac Morris[14] has circles for the age of the moon and instead of time marks in each ring has spirals for each hour of solar time. It is read by following round the circle for the age of the moon until the gnomon shadow is reached at an hour spiral and then following this to the centre or outer rim where the time figures are located. A mistake has been made in the numbering of the age rings by running days 1-15 inwards and days 16-30 outwards: both sequences should run inward so that day 16 is paired with day 1 and so on just as in Table 1. A dial with age rings and time spirals described by Fantoni[1] is a modern version of the Morris instrument.

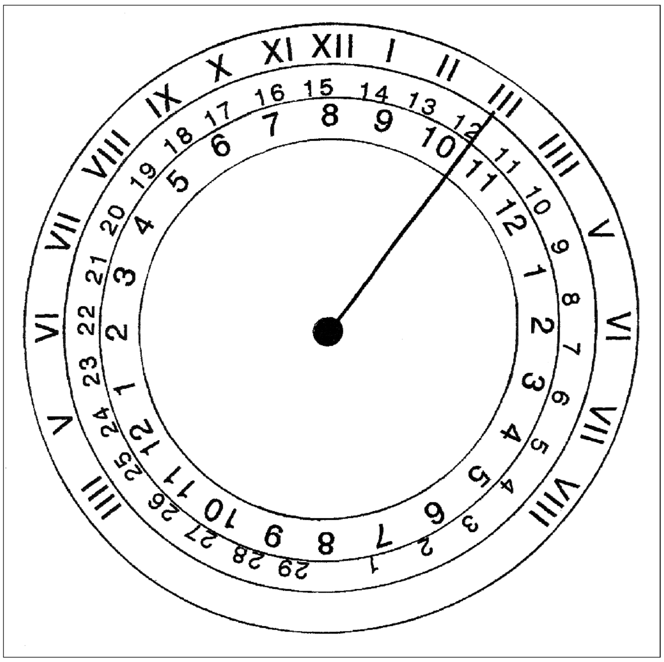

Fig. 3. Schematic horizontal adjustable dial.

ADJUSTABLE DIALS

Most small horizontal adjustable moondials are combined with a sundial, as shown in a schematic layout of a typical dial face in Fig. 3, drawn for latitude 51° north. The outer ring with Roman numerals is the sundial, the middle one the moon ages and the inner one is the rotatable moondial chapter ring. The normal polar gnomon is fixed on the XII line, and the central area is usually occupied by a magnetic compass. In use, one or other of the markers for the hour of 12 is set to the moon's age for that day. The solar time of transit is then on the meridian adjacent to XII on the sundial and the other graduations are at the appropriate places to read the solar time directly from the gnomon shadow. There is however an anomaly in such dials: the moon hour marks are necessarily evenly spaced at 15° intervals and so cannot match the unequal spacing of the projection of the hour lines on a horizontal plane. Times are correct on the meridian and at 6^h hour-angle but between those positions have errors. On Fig. 3 the moon age is set to day 10 and the transit time is near 8, in agreement with Table 1. The diagonal line represents a gnomon shadow showing 3pm on the solar dial, 3 hours west of the meridian. The solar time is therefore 8^h+3^h or 11pm, but the moondial reads 10.30pm, about half an hour wrong. The error increases at lower latitudes, under similar conditions a dial for 35° north would be wrong by an hour.

A horizontal moondial (Fig. 4) described by Bion[17] in the 18th century makes an apparent attempt to correct this projection error. Both the inner rotatable hour scale and the age scale are plotted on the normal horizontal projection

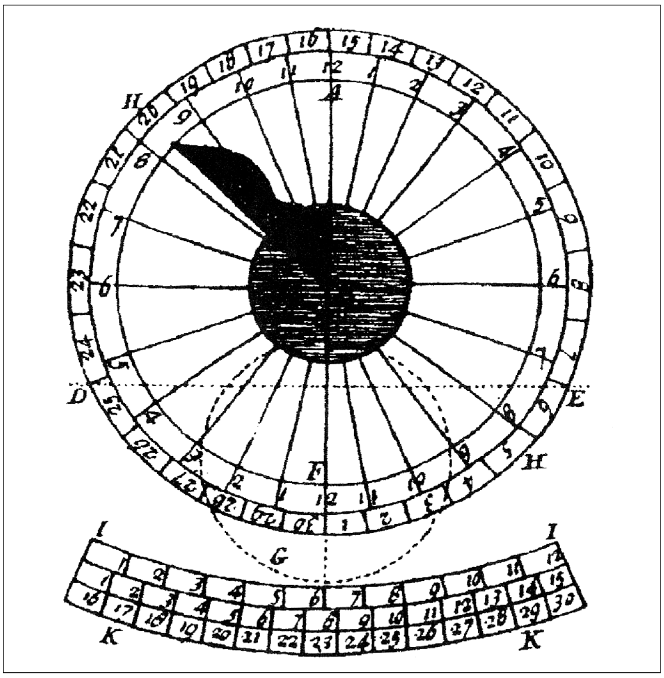

Fig. 4. A moondial by Bion.

and so are unevenly spaced, being compressed around 12^h and days 1-30 and 15-16. To set the dial, a 12 time mark is placed against the moon's age. The construction ensures that the dial is correct at moon transit and at midnight, but at other times can be seriously wrong: the rotated hour lines with 12^h displaced from the meridian cannot match the projection of the hour circles. Errors of an hour or more occur throughout a lunation: the only situation when the dial reads even approximately correctly at all times is when the moon transits at or near midnight. This dial was also discussed by Schneider[9] but his suggestion that the hour and moon circles should be centred on the dotted circle is not understood. It is clear from Bion's text that this circle and a dotted line are construction features. The dial also carries a correction table (only the hours are given) enabling solar time to be found from the moon if 12^h is set to the meridian, or indeed could be used with any other dial.

A curious French-made brass dial (c.1700) is in the collection of the National Maritime Museum (AST0169)[18]. The time and age circles use the same projection as the previous instrument but the gnomon is fixed to the rotating time plate. In setting the dial to the moon's age the gnomon is displaced out of the meridian, which will destroy the declination-independent property of a polar gnomon. Again the only time when the dial will work correctly is when the moon transits near midnight and the gnomon is oriented north-south.

An equiangular equatorial dial will avoid this projection difficulty. Oronce Finé (1560)[19] has a combined sundial and moondial (Proposition XIX, reproduced in Fig. 5) arranged in this way and adjustable for latitude. The setting quadrant is graduated for the co-latitude, not the latitude. Presumably there is also a dial on the lower face for use when the moon has a southerly declination. The sequence of rings and the method of operation is the same as for the previous instruments. The central area of the dial may be a device which, by rotation of the time ring, can be adjusted to match the visual appearance of the moon's phase and so set the time scale appropriately. The needle-like gnomon

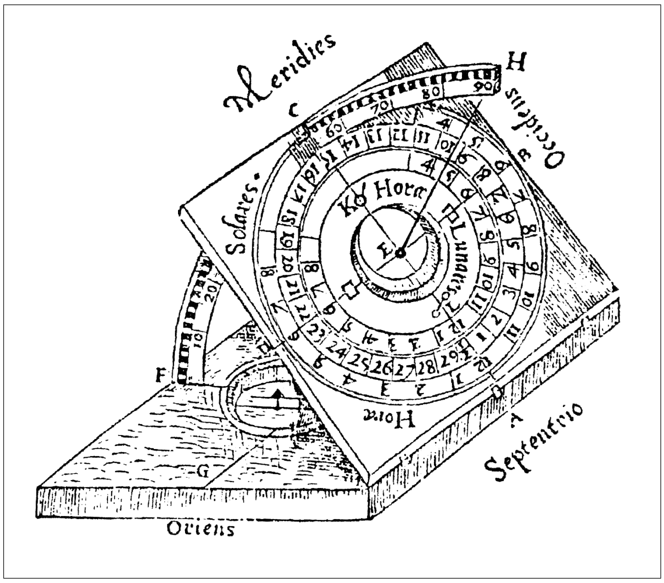

Fig. 5. Sun and moondial by Oronce Finé.

seems too thin to cast a good shadow in moonlight and the illumination will always be weakened by the oblique angle of the light to the equatorial plane, severely so at low declinations, and will disappear entirely when the moon is on the equator.

It will be noticed that all the moondials described are of the polar-gnomon form. This operates without knowledge of the declination, and so is appropriate for a moondial where that of the moon is generally unknown. There is no correlation between the age of the moon and its declination. All provide corrections for moon ages throughout the whole lunation, although early and late in the lunation the moon is not bright enough to use for time-telling.

THE ERRORS OF THE TABLES

Thus far it has been tacitly assumed that corrections depending on the moon's age will satisfactorily derive solar time. This however is very far from being correct. To show this the Cambridge dial table times are compared with some published transit times. Fig. 6a is the difference (in the sense tabular *minus* true) between the times for every other day throughout one particular lunation from one new moon to the next, and Fig. 6b is a similar comparison for another lunation six months later. It is at once obvious that the times in the table are badly in error: there can be differences of an hour or more between them and the true times,

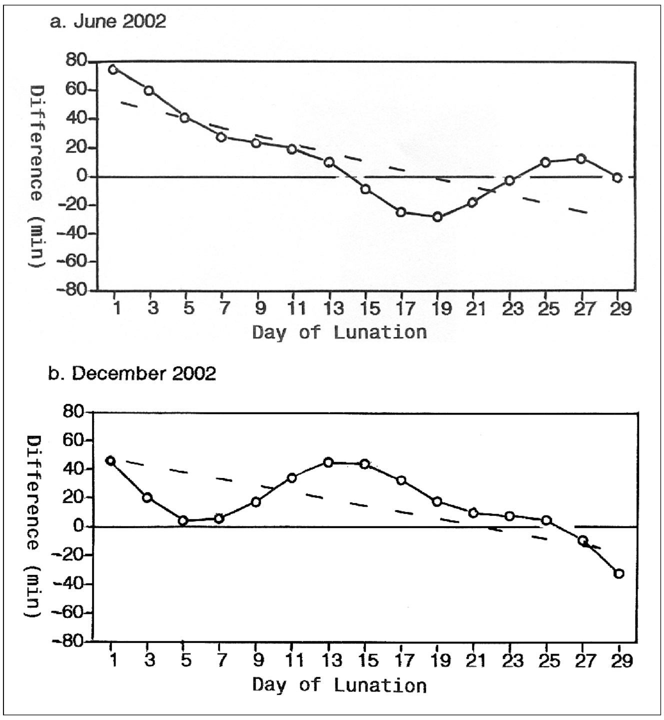

Fig. 6. Comparison of Cambridge dial table with actual transit times.

and the errors are not the same from one lunation to another. The accuracy of a set of data can be evaluated by the *standard deviation* (symbol σ). It is the square root of the average of the squares of the individual deviations from the correct figure and is also known as the *root-mean-square deviation.* It is expressed as ±(value). Comparison of the table times and the true transit times over a period of ten years (125 lunations) gives σ = ±36 minutes. With a normal distribution of errors 38% should lie within ½σ of the true value (18^m in this case), 68% within 1σ (36^m), and 95% within 2σ (72^m). Although these errors are substantial we must realise that in the days when the majority of moondials were constructed the age of the moon was the only readily-accessible means of obtaining even an approximate transit time. Authors of the past were probably well aware of the likely errors, the time found by a moondial is often referred to as "the hour of the night" as if implying that accuracy to the hour was all that could be expected.

There are three ways in which the errors in the table are apparent. The most obvious is a cyclical variation throughout the month: the graphs have peaks and troughs. These resemble the well-known 'Equation of Time', the difference between apparent and mean solar time and indeed have similar origins in the elliptical nature of the moon's orbit and the inclination of the orbit to the equator. The overall effect in the case of the moon cannot be readily compensated as with the sun, where with sufficient accuracy the equation of time may be regarded as constant from year to year for many years in succession.

The first entry in the Table for day 1, the day of new moon, is 0.48, equivalent to a transit time of 12.48pm. This is clearly wrong: at new moon the sun and moon are in conjunction and (within limits) cross the meridian together. If new moon occurs early in the day, moon transit will be later than that of the sun by up to half a day's motion, and, if late in the day, moon transit will be before that of the sun. The average transit time of new moon over the ten-year period mentioned above is 12.01pm ±15m.

The third error is shown by the dashed lines on Figs. 6a and 6b which represent the trend of the daily differences. There are downward slopes to the lines showing a systematic tendency of the errors throughout the lunation. This arises from the way the daily values of the table have been calculated. During a lunation the moon makes a complete circuit of the sky relative to the sun, thereby losing 24 hours on solar time. A lunation takes on average 29½ days so, rounding this to 30 days, the amount by which the transit gets later day-by-day (the 'daily retardation of transit') is taken to be 24÷30=0.8 hour or 48 minutes, the interval given by the Queens' College dial table. Other correction tables use the lunation period of 29½ days and divide that into 24 hours giving a daily retardation of 48.8 minutes. Neither is correct. During a lunation the earth turns (from west to east) on its axis 29½ times, but in the same time the moon goes round the earth once in the same direction, cancelling one of the diurnal rotations and returns to the meridian only 28½ times. The correct calculation for the average retardation is therefore $24^h \div 28½ = 50½$ minutes. The precise value given in astronomical text-books is 50min 28sec.

It seems ironic that this simple mistake has for centuries been perpetuated on moondials and in the many explanatory articles written about them without being noticed! The error of 2½ minutes compared with the 48-minute interval of the tables may appear hardly significant but when working from day to day the difference is cumulative. Apart from other errors, counting forward from new moon as in the Cambridge dial the discrepancy will amount to 18 minutes at the time of first quarter, 36 minutes at full moon and nearly an hour at last quarter.

It may be objected that on this reasoning there will be a day in a lunation on which the moon does not transit the meridian. This is however quite correct: if on a certain day the moon transits at a few minutes before midnight, the next transit, coming (on average) 24 hours and 50½ minutes later, occurs just after midnight, obviously not on the next day but on the next but one. Thus the missing day is accounted for. The transit-less day is generally but not always the day of full moon. The ten-year average time of transit on the day before full moon is 11^h35^mpm $\pm16^m$ and that of the next transit is 12^h25^mam $\pm16^m$, in the night following the day of full moon. The tables imply that the average transit time of the full moon on day 15 is 12 midnight, but this is not correct.

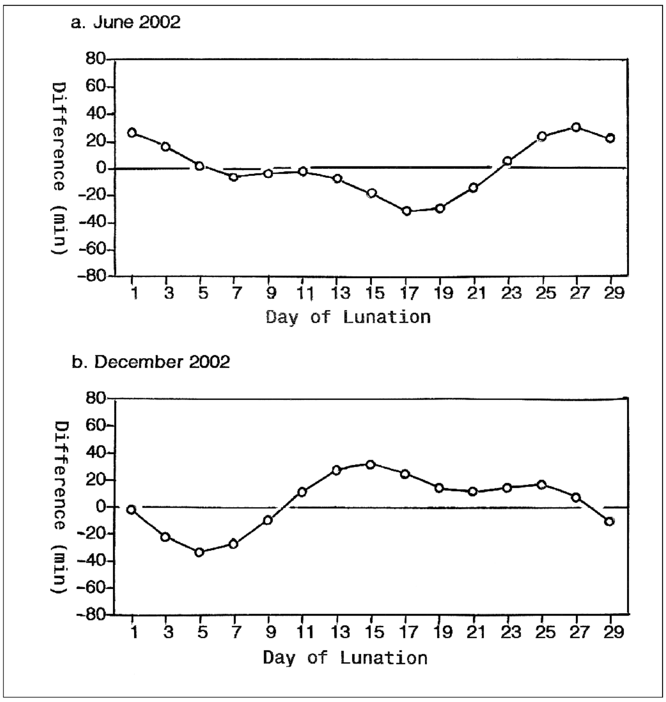

Fig. 7. Comparison of 50½ minute interval table with actual transit times.

Figs. 7a and 7b show the improvement in the agreement of tabulated transit times with daily intervals of 50½ minutes when compared to the actual times. Only the peaks and troughs of Figs. 6 remain; the slopes have been eliminated. The ten-year deviation is reduced to ±28 minutes.

THE ORBIT OF THE MOON

The large discrepancies between the true transit of the moon and the uniform values given by the tables can be explained by consideration of the moon's orbit relative to the earth. The elliptical orbit has an eccentricity more than three times greater than that of the earth around the sun, resulting in large changes of velocity. The gravitational field of the sun causes distortions in the elliptical motion and relatively rapid changes in the orbital parameters. The orbit is inclined to the ecliptic at 5.1° and the points where the moon's orbit intersect the ecliptic (the nodes) are in motion going right round the ecliptic in 18.6 years, so that the inclination of the moon's orbit to the equator varies between a maximum of (23.4+5.1) = 28.5° and a minimum of (23.4-5.1) = 18.3° in the cycle. The position of perigee, the closest approach to the earth where the orbital velocity is greatest, is also in motion making one complete revolution round the orbit in 8.8 years, in the opposite direction to that of the motion of the nodes. The position of the moon and hence its transit time cannot be accurately portrayed by any simple tabular means. Some high-precision tables of the moon published in 1919[20] required no less that 1500 separate terms! Even if the moon's orbit altered only as slowly as that of the earth around the sun, there would still be changes in the transit times from month to month: at the same ages the orbital position of the moon would be different from one lunation to another.

SOME IMPROVED CORRECTION METHODS

Clearly for a successful moondial a more accurate indication of the actual time of the moon's transit is needed. For the very simplest purpose the average transit interval of 50½ minutes can be used, giving rise to the values of Table 2. This has alternate intervals of 50 and 51 minutes, backward and forward from the day of full moon which is called day 0. The average times for transits either side of full moon mentioned above are adopted as the origins. Days -1 to -8 are days before full and days +1 to +8 are days after full. The transit times are to be used throughout the *nights* which follow the numbered days. Thus the transit on the night of day -4 (four days before full) is 9^h03^mpm, and that for the night of the second day after the day of full moon (+2) is 2^h06^mam. The table is limited to 8 days either side of full: there is generally insufficient moonlight to use a dial outside those limits, approximately the times of first and last quarter. This point will be discussed later. Times found by this method will be subject to errors similar to those shown in Fig. 7, with deviations of around ±16 minutes near full moon but rising to ±25 minutes at the quarter-moons because the daily retardation will not in general be the average value of 50½ minutes. The changing orbital velocity of the moon causes the retardation to vary between about 40 minutes and more than 60 minutes.

When using tables such as Tables 1 or 2 the transit times are referred to the sun and therefore in principle need correction for the solar equation of time if the mean time is required. In practice this is hardly worth while, the errors in the tables are comparable to or larger than the equation of time. Statistically the $\pm28^m$ error of the $50½^m$ table would only be reduced to about $\pm26^m$.

The daily transit time of the moon can be obtained from various publications. In the UK probably the most easily accessible is *Whitaker's Almanack:* try a public library. The time is given for every day of the year in the monthly pages of astronomical data, in 24-hour Universal Time (UT, equivalent to GMT) and applicable to the meridian of Greenwich. For locations within the limits of the British Isles it will also be the *local mean time* of transit. Other countries may have their own similar annual volumes. Although many astronomical web sites give moon data, I am not aware of any which provide the transit times (but I should be pleased to hear of one!). For any specified location the 'Heavens Above' site (www.heavens-above.com) gives the time of maximum altitude, which should be within about five minutes of the transit time, depending on the rate of change of the moon's declination. The mid-point between the times of moonrise and set printed in daily papers will give the time of transit to about ten or fifteen minutes.

Day:	-8	-7	-6	-5	-4	-3	-2	-1	
Transit:	5:41	6:32	7:22	8:13	9:03	9:54	10:44	11:35	
Day:	0	+1	+2	+3	+4	+5	+6	+7	+8
Transit:	12:25	1:16	2:06	2:57	3:47	4:38	5:28	6:19	7:09

Table 2. An improved correction table based on 50½ minutes.

THE EFFECT OF LONGITUDE

When using a published table of transit times, the continual loss of time by the moon implies that it may be necessary to take into account the longitude of the location of the dial with respect to the longitude for which the table is compiled. For every 15° change of longitude east (west) the *local time* of transit will be earlier (later) by about two minutes. Within a limited range such as that of the British Isles this is unimportant. If however the site is some distance from the longitude for which the transit time is given, the correction may be worthwhile. The times derived from the dial are in *local mean time* and need correction to the longitude of the standard meridian to give *zone times.*

THE GEOCENTRIC PARALLAX OF THE MOON

The hour-angle of the moon from which the time is to be determined should be referred to the centre of the earth, but the observer is on the surface, 6400 km off-centre. The average distance of the moon is 384000 km. The resulting parallax displacement causes the moon to appear lower in the sky than its true geocentric position (except if it is in the zenith). The maximum effect occurs when the moon is on the horizon: the apparent depression from the true position is then about one degree. The full calculation of parallax needs to take into account the actual distance and declination of the moon at the time, but adequate accuracy for a moondial can be obtained from:

Parallax in hour-angle = $4^m.\cos\phi.\ \sin h$

where ϕ is the latitude and h the hour angle. Fig. 8 is derived from this formula and shows the values in one-minute bands, depending on latitude and

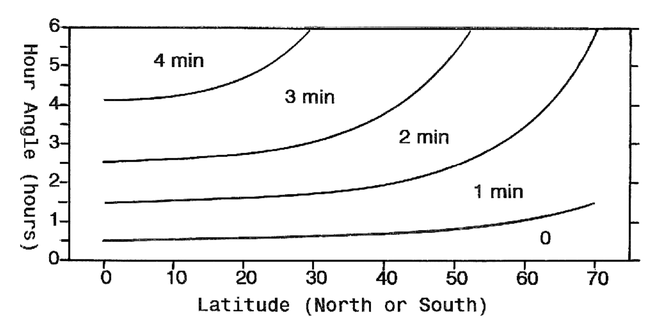

Fig. 8. The correction for lunar parallax.

hour-angle. The parallax correction is to be added to the indicated time if the moon is east and subtracted if west of the meridian. In the latitude of Britain the maximum is generally two minutes but could rise to three minutes on the South coast. Nearer the equator the correction can be as much as four minutes.

THE READABILITY OF A DIAL UNDER MOONLIGHT CONDITIONS

The visibility of the gnomon shadow and the readability of the dial graduations will be affected by several factors:

1. The brightness of the moon.
2. The angle at which the moonlight strikes the dial surface.
3. The reflectivity of the surface.
4. The contrast between the surface and the time graduations.
5. The performance of the human eye in conditions of faint light.
6. The presence of local artificial lighting which may obliterate the gnomon shadow.

Obviously moonlight is much fainter than sunlight, but it may perhaps not be realised how much fainter. Even the full moon is half a million times fainter than the sun! In photometric units sunlight has a luminous intensity of 130000 lumens/square metre (lm/m^2) and that of the full moon is (on average) 0.26 lm/m^2, approximately equivalent to the illumination from an ordinary candle at a distance of 2 metres. The moon's surface has very poor reflectivity, only about 7% of the incident sunlight is reflected. At the first and last quarters moonlight is only about one-tenth as bright as at the time of full moon. The variation in brightness is shown in Fig. 9, in terms of the celestial longitude of the moon from the sun with the quarter- and full moon positions indicated. The illumination from the full moon is set to 100%. The values are average intensities, the variations in the distance of the moon from earth affect the moon's apparent brightness by up to ±20%. Near the time of last quarter the moon is about 10-15% fainter than when near first quarter. From the graph it is clear that the light is reduced to such an extent before first and after last quarter-moon that it will be most unlikely to provide a reliable shadow.

The illumination of a dial surface will depend on the cosine of the angle from perpendicular at which the light strikes it. At 60° incidence it will be reduced to a half and at 75° to only a quarter.

The surface reflectivities of dials, affecting the visibility of the gnomon shadow, vary within wide limits. A white-painted dial might reflect perhaps 80-85% of the incident light but one made of slate or weathered metal will reflect probably less than 10%. The readability of the dial will be much influenced by the contrast of the graduations against the surface background. Black figures and lines on a white ground will have excellent high contrast but with incised lines on a slate or metal dial the contrast can only be low.

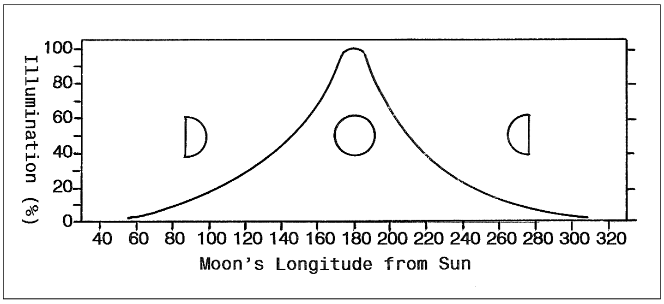

Fig. 9. The illumination from moonlight relative to full moon.

VISION IN MOONLIGHT

The human eye has two visual systems: bright-light colour--sensitive *photopic vision* and weak-light *scotopic vision* which does not respond to colour. There is no abrupt change from one to the other, over a wide range of illumination both may be operating *(mesopic vision)* but with much reduced sensitivity in photopic vision. On going from a brightly-lit room to a darker environment the pupil of the eye opens to admit more light. Nevertheless vision is at first very poor, but improves as the light-sensitive chemical *rhodopsin* builds up in the retina: this is called *dark adaptation* and may take half an hour or more to develop fully. The resolution (ability to distinguish fine detail) of scotopic vision is significantly worse than that of photopic vision. Under bright light the eye can resolve detail of about two or three arc-minutes, equivalent to about two or three tenths of a millimetre at a reading distance of 300mm. Some people can do better. At the brightest part of the mesopic range a resolution of perhaps 5-10 arc-minutes can be attained. As the light weakens only scotopic vision operates and resolution becomes worse until at very weak light levels it may be only a degree or so. It is probable that for typical conditions moonlight will lie in the mesopic range at full moon but may require pure scotopic vision at quarter-moon. The contrast of an object against its background will also have a marked effect upon the eye's ability to discriminate detail under weak light. In bright light detail can be seen when the contrast is only a few percent but weak light needs high contrast. A moondial should have the highest possible contrast, such as would be provided by black figures on a white ground.

The loss of resolution at the low light levels of moonlight will have a direct effect on the necessary size of the dial numerals. At the time of full moon, high-contrast black-on-white numerals of about 3 or 4mm should be readable at a distance of 300mm but 10 or 12mm numerals are necessary at the quarter-moons. In effect this last value sets the required size of the numerals on a moondial, but would need to be increased for lower contrast and also to allow for illumination angles away from the perpendicular.

The eye is very good at detecting linear features. Time line widths of about 1mm or less can be seen at full moon but at the quarters about 2½-3mm widths are necessary, adjusted as before for lower contrast and the illumination angle.

THE LIMITS OF THE AVAILABILITY OF MOONLIGHT

In addition to the brightness and age of the moon some other constraints are relevant to the use of a moondial. It is not likely that the moon will provide sufficient illumination when close to the horizon near moonrise or moonset. The light will be dimmed by atmospheric absorption, in the case of a horizontal dial the light will fall obliquely and there may well be local features causing obstruction. A practical limit might be that the moon should be at least ten degrees above the horizon. In twilight after sunset and before sunrise the illumination from the sky will swamp the gnomon shadow and from the photometric properties of twilight it seems that in typical conditions the sun must be at least ten degrees below the horizon for the gnomon shadow to be detectable. Limits can therefore be set to the useful ranges of a moondial: the moon's phase should be no more than eight days before or after full, the sun must be at least ten degrees below the horizon and the moon ten degrees or more above. The moon is available for all the dark-sky time for only two or three nights around the time of full moon and at other times is restricted. For example, in general the first-quarter moon sets and the last-quarter rises around midnight. Calculations show that in a typical lunation the moon is available for about two-thirds of the dark-sky time. This however refers only to the period from first to last quarter when the moon is bright enough and effectively only half of the lunation is usable. Astronomers in eastern Britain reckon that, taking account of clear and part-clear nights, about one-third of night-time sky is cloudless, a value which may well be less in the western parts, but greater in more favourable climates. Multiplying these three factors of two-thirds, half and one-third leads to the dispiriting conclusion that, viewed as a long-term general average, the moon can be used for time-keeping for only about one-ninth of the total dark-sky time.

A moondial described by Thiessen[16] does not rely on a gnomon shadow and extends the useful range of the dial by sighting on the moon visually and using the known angle between sun and moon to obtain the hour-angle of the sun and hence the solar time. In this way the crescent moon and other phases can be used in twilight when the sun is below the horizon but the sky is too light for the moon to cast a shadow. As the derived time is referred to the sun it will be in apparent solar time and will need correction for the equation of time. For strict accuracy the correction for parallax should also be applied.

IMPROVED DIALS

It is obvious that, in general, moondials leave much to be desired as instruments of good time-keeping. Nevertheless, by attention to the matters which have been outlined above it is possible to construct dials of good accuracy. Three experimental dials have been made.

In the course of an hour the moon moves 15° westward by the earth's rotation and approximately ½° eastward by its own orbital motion, losing about 2 minutes every hour. A dedicated moondial should have the hour markings spaced at intervals of 14½° in hour-angle, not 15°. However, the 2^m/hour is an average value: the hourly loss of time can vary between about 1½ to 2½ minutes.
The first dial shown in Fig. l0 is a moondial overlay for a 250mm diameter horizontal garden sundial in 50.9° north latitude. The time-value indicated by the gnomon shadow is to be applied to the transit time, subtracted if the moon is east and added if west of the meridian, to obtain the solar time.

The dial shown in Fig. 11 is an adjustable equatorial instrument. The time marks can in this case be uniformly spaced at 14½° per hour and the concave semi-cylindrical scale ensures that the area where the gnomon shadow falls is never far from perpendicular to the moonlight. The time ring rotates in guides centred on the polar gnomon (a metal rod) and a pointer is used to set the moon's true transit time on to the meridian: this can of course be done in advance by daylight or by lamplight. To conform with published transit times the dial is calibrated in the 24^h system. The small scale at the bottom of the time ring for setting the transit time is divided in ten-minute intervals and can readily be set to two minutes. The time scale is divided in twenty-minute intervals with only the even-numbered hours identified. To assist their readability at all ages the time markers are tapered from 2.5mm wide down to 0.5mm. The diameter of the gnomon rod needs to be no less than one/fiftieth of the radius of the dial. The shadow indicates the local mean time which needs correction to standard zone time, or the transit time could be set to take account of the longitude difference from the standard meridian so that the dial reads zone time directly. In Fig. 11 the transit is set to 0200 and the shadow of the gnomon rod indicates the time as 2140.

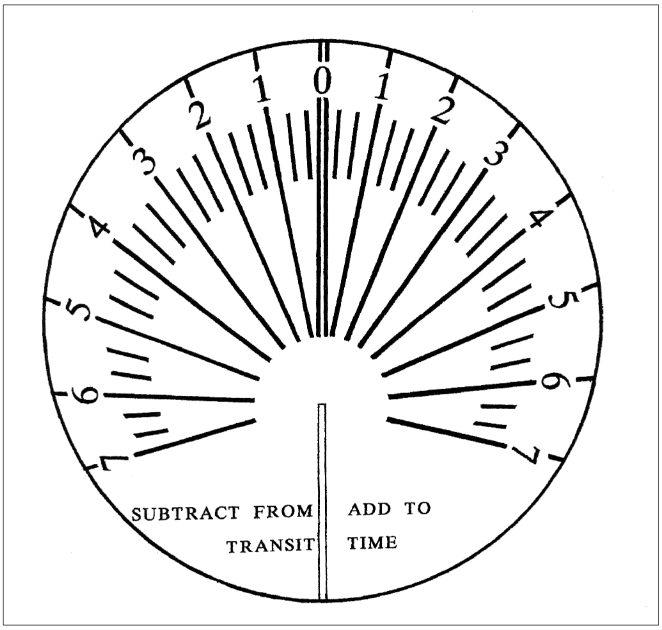

Fig. 10. A moondial overlay for a horizontal sundial.

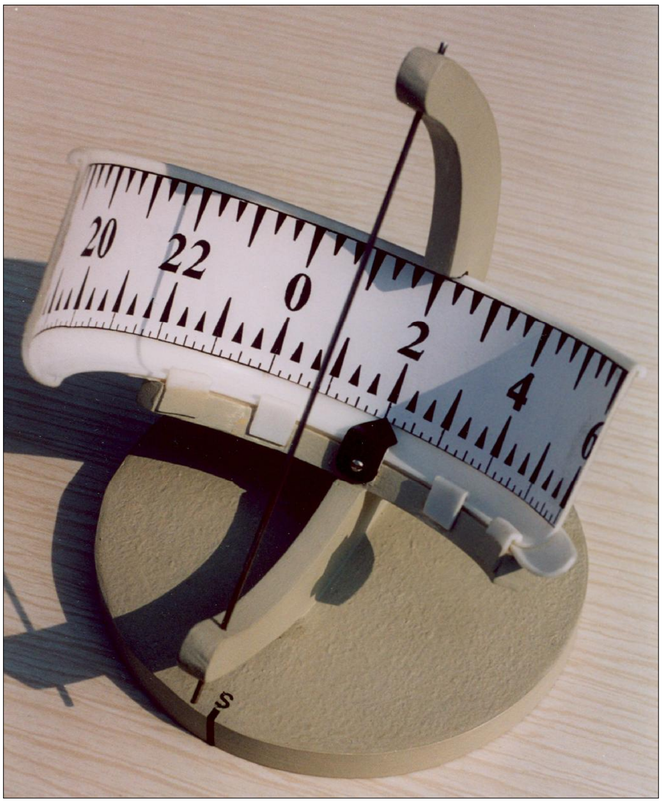

Fig. 11. An adjustable dial with cylindrical scale.

The thickness of the time lines on this and the previous dial necessary to ensure their visibility in moonlight limits the accuracy of a reading to about ±3 minutes.

In the event that an accurate transit time is not available the age of the moon is carried on a scale on the outside of the time ring (Fig. 12). Setting the age to a pointer positions the time scale according to the 50½-minute daily intervals of Table 2, but of course the derived time is then subject to errors such as are shown in Figs. 7a and 7b.

Fig.13 shows a duplex instrument designed as a sun and moondial. It has a rotatable disc in the equatorial plane, with calibration (in the 24^h clock) for the sundial running $6\text{-}12\text{-}18^h$ at 15° per hour around half the face and for the moondial $18\text{-}0\text{-}6^h$ at 14½° per hour around the other half. This produces the discontinuities which are seen at 6^h and 18^h. A pointer at the south enables the transit time of either moon or sun to be set to the meridian, corrected if required for longitude and in the case of the sun for the equation of time. In Fig. 13 the moon transit is set to 19.30. The reading method was inspired by the Pilkington *Sol Horometer*[21] and consists of an open box which rotates independently of the dial plate. It has a slot at one end and a black line of the same width on a white ground at the opposite internal end. In use the box is adjusted until the light passed by the slot falls on the black line and is no longer visible. This is sur-

Fig. 12. Age of moon scale on cylindrical dial.

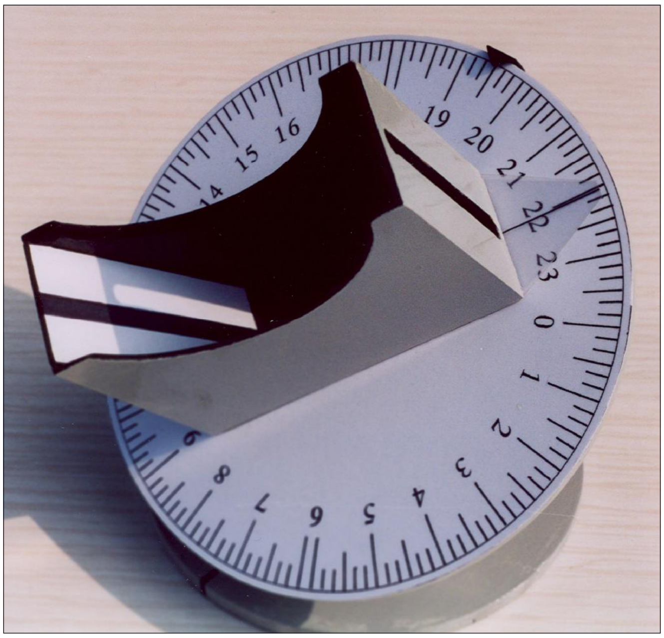

Fig.13. A duplex sun and moondial.

prisingly sensitive, in sunlight and with a bright moon the setting accuracy is about half a minute, better than the dial (with ten-minute divisions) can be read, and even at quarter-moons setting can be made to a minute or two. In fact the moonlight passing the slot is detectable for about ten days before or after full moon, the box helps to reduce the effects of light pollution. The time is indicated by the index line carried on the box front. At night with a bright high moon the time can be read directly but otherwise requires the use of a pocket flash-lamp (which some may consider to be cheating). The dial plate is 160mm in diameter, the box length is 100mm and the slot and black line width 6mm. To accommodate the full range of declinations of the moon the slot length is 75mm: when the sun or moon is at a high or low declination only the ends of the black line receive light passed by the slot.

This construction enables a direct comparison to be made of the relative accuracy of the sun- and moondial. From series of readings I find that the standard deviation of time from the sundial is ± 1.3 minutes which will be compounded of setting and reading errors and no doubt small construction inaccuracies. The deviation of the times from the moondial is ±1.8 minutes and the claim that a moondial (used with an accurate transit time) can approach the accuracy of a simple sundial is justified.

CONCLUSION

While it would be unfair to condemn moondials of the past as useless, it is evident that their utility is much more restricted than is perhaps generally realised, in terms of accuracy, ease of reading and the availability of moonlight. Pocket dials may well have been of some use to night-time travellers. One might think that dial-makers would have been well aware of the defects and limitations of their instruments, particularly the high-class makers such as Allen and Wynne and their large fixed dials. Quite possibly customer demand was responsible for their continued production. The proud owner may have been eager to explain his dial to friends and visitors in the daytime but is not likely to have made much practical use of it during night-time hours.

ACKNOWLEDGEMENTS

Help in the production of the article has been provided by Christopher Daniel and John Davis, to whom I am most grateful.

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EQUATORIAL EQUINOCTIAL SUNDIAL

W. S. MAY

The construction of this sundial is based on the use of two car flywheel starter tings of slightly different diameter welded together, one within the other at 90°. The rings are available commercially with a smooth circular surface on the inner face and, of course, teeth for the starter pinion to engage on the outer surface. As can be seen in Fig. 1, these rings are supported on a third, flat, steel piece rolled semi-circular. This latter is slotted to set for latitude, and welded to the starter rings. The three steel pieces were nickel plated after welding. The stainless steel gnomon lies on the axis of the equatorial ring.

Fig. 1. The complete equatorial dial.

The time scale is marked on to a rolled brass 'flat' which fits closely inside the equatorial ring and slides relative to it to enable it to be set to correct to mean time according to the equation of time. And here is the clever bit, which is perhaps unique to this dial. Because the equation of time is the result of adding two sine waves, one with a period of one year (the elliptical path of the earth) and one with a period of six months (the tilt of the earth's axis), it is possible to set the position of the time ring with a crank pin and slot mechanism. Referring to Fig. 2, the brass time ring is moved by a pin mounted eccentrically on a spindle (turned by outer knurled knob), to adjust for the elliptical orbit of the earth. The above spindle works in an eccentric hole in the second spindle (turned by inner knurled knob) which adjusts for the tilt of the earth's axis. Thus the two corrections are added to set the time ring correctly to the equation of time.

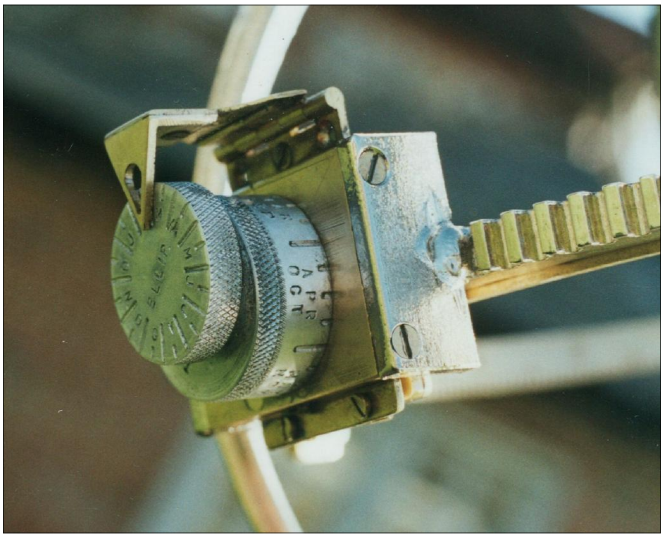

Fig. 2. Close-up of the equation of time mechanism.

The elliptical orbit spindle requires one revolution per year but the earth's tilt requires two revolutions per year, and the knobs are marked with the months accordingly, with the correct phasing. Graduations are half months (elliptical orbit) and quarter months (earth's tilt), requiring interpolation when setting to date.

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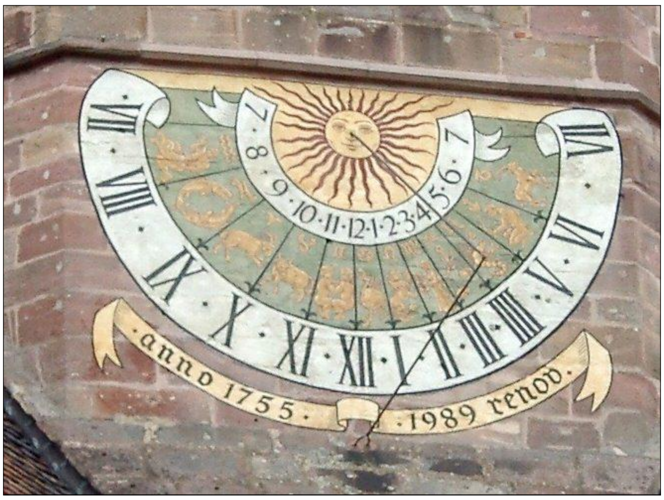

Photo: M. Cowham

Soultz, Alsace, France. An attractive large dial mounted high on the church tower.

A FLAGPOLE SUNDIAL

SVEN OLOF LARSSON

When reading about the design of an azimuthal sundial in the *BSS Bulletin* 16(ii), I come to think of a design I did a couple of years ago. The reason of having a flagpole sundial is to enable a quick and easy reading when time for hoisting or lowering the flag for each date. The dialplate in Fig. 1 and the appearance in Fig. 2. The actual time can be found by using the actual date and then determine where the shadow time for hoisting or lowering the flag is shown for the actual date thicker lines. As seen in Fig. 2 the problem of determining the exact position starts is difficult. A similar problem has been in an earlier issue[2]. Using some kind of sun-sight[1], the dialplate rotated 90 degrees and using the direct angle to the sun instead. A vernier scale could possibly be used for a more accurate reading. It noted that the dialplate is made for a specific latitude. The one in the figures is made for Karlskrona in Sweden.

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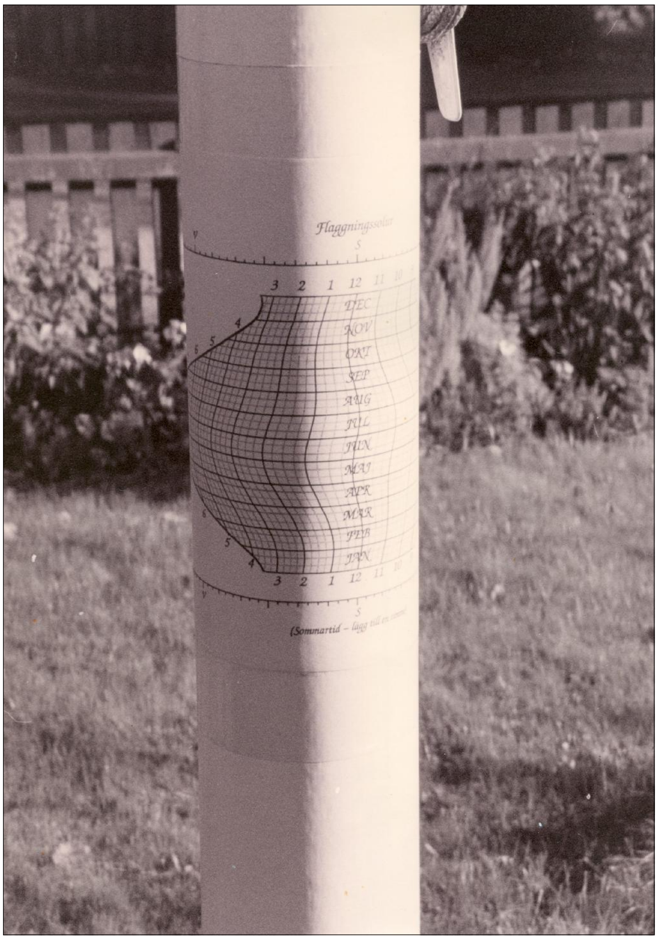

Fig. 2. The flagpole sundial.

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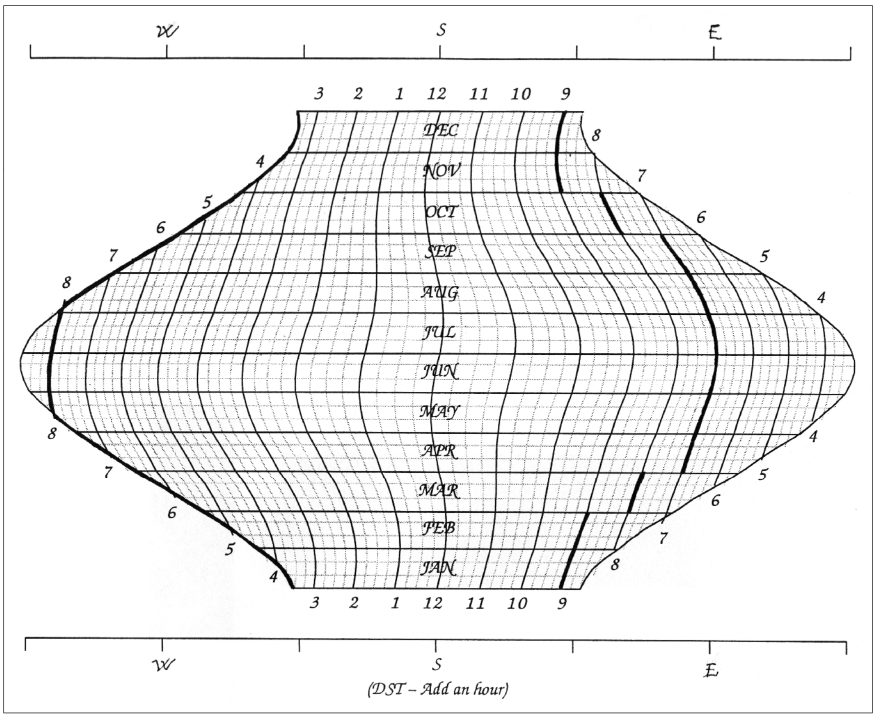


Fig. 1. The dialplate showing the time for hoisting or lowering the flag.

THE COURTYARD OF TIME OF CASCINA PICCHETTA, CAMERI, PIEDMONT

ROSARIO MOSELLO AND GUIDO DRESTI

INTRODUCTION

A “cascina” was a form of land management established by the Romans when the Po Plain first began to be exploited agriculturally, the fertility of the land determined by a favourable climate and an abundance of running and spring water. It comprised an area of cultivated land and a farmhouse in the imperial form of the “villa”[1], a kind of *domus* or townhouse, a rural adaptation of the Italic house, made up of a building surrounded by a low wall, preceded by a central atrium with side rooms opening onto a courtyard with an *impluvium* or water pool.[2] It underwent modifications over the centuries as different population groups succeeded each other, and in relation to changing technological and agricultural conditions. Sometimes the *cascina*, while retaining its primary function, which was to control and manage the farming activity, was also used by its owner as a villa, a kind of holiday home, where he could leave behind the hard work of every day and enjoy nature and the landscape in the peace and quiet of the countryside.

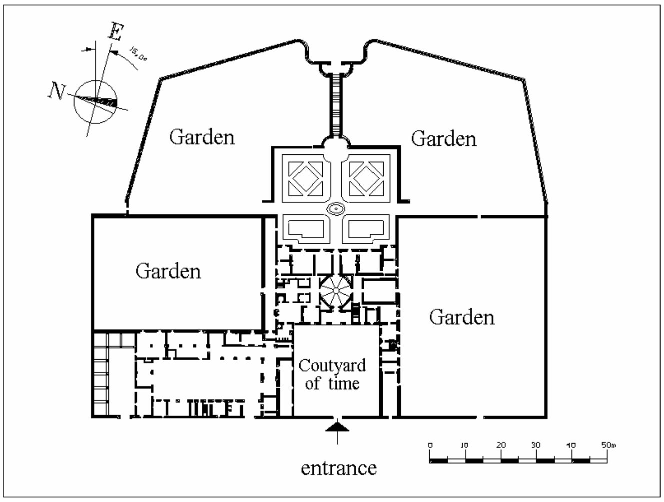


Fig. 1. Plan of the Cascina Picchetta and gardens.

This is what happened to Cascina Picchetta in the district of Cameri in the province of Novara, which for some years now has been the headquarters of the Ticino Valley Natural Park, where the building is located. It was bought by Lucretia Chiocharia, the daughter of a Milan aristocrat, with the consent of her husband, Francesco Cid, in September 1575. The building is described in the documents drawn up for the sale as “*palatium dictum la Picheta*”, the term *palatium* indicating that the building was to be used not only for agricultural purposes but also as a country residence[3].

During the following centuries the *cascina* changed hands several times, and its structure was altered until it took on its present appearance at the beginning of the 17th century (Fig. 1). Of particular interest for the purposes of this article is the fact that the villa was used as a house for Jesuit priests to come on vacation, having been given to the order in 1649 by Nicolao Cid through the intercession of his son Francesco, himself a Jesuit.[3]

Fig. 2. The complex of the Courtyard of the Clocks.

After the Jesuit order was suppressed in 1733 by Pope Clement XIV,[4] the property passed to the Crown, and was subsequently bought in 1770 by Marquis Pietro Antonio Natta d’Alfiano, who was interested mainly in exploiting the land for farming, but who also, over a thirty year period, made the structural alterations which have remained to the present day. These consisted primarily in closing off the central space of the villa by the creation of the sumptuous octagonal reception hall on the ground floor and the cupola which rises above it, and alterations to the front entrance which transformed it into a portico with columns (Fig.2).

The complex was bought in 1989 by the Consortium of the Ticino Valley Natural Park, which planned to restore the building and adapt it to serve as the headquarters of the Park and to be accessible to the public. An important part of the restoration work will involve the courtyard in front of the main entrance to the villa, where the octagonal room is located. The study of this courtyard is the subject of our article.

There are six sundials on the walls of the courtyard, which form the side wings of the villa, three on the south-facing wall and three on the north-west facing wall (Figs. 3-5). Although in a very poor state of preservation, the dials are

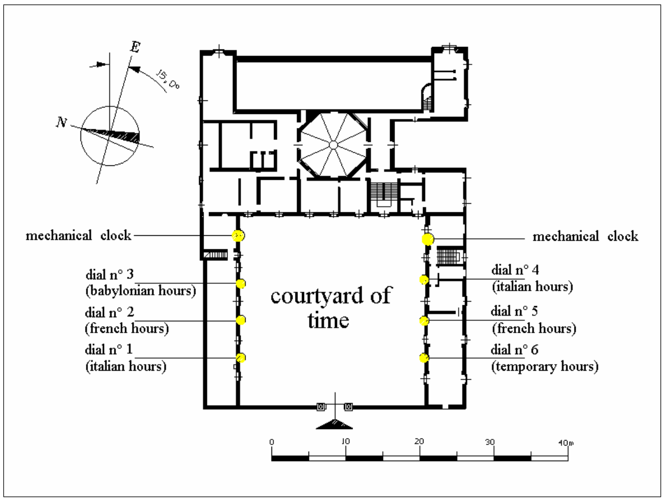


Fig. 3. Plan of the courtyard, showing the location of the six sundials and the two mechanical clocks.

still reasonably legible and carry traces of more than one layer of markings. The courtyard owes its attractiveness not only to the harmonious structure of the central body of the villa, overlooked by the cupola and the *tiburio*, but also to the presence of two mechanical clocks on the façades of the two side towers.

Six sundials and two mechanical clocks in one courtyard are obviously too much of an attraction for us not to wonder about their origin. In this article we shall describe the present state of the sundials and the clocks, and hazard some guesses as to their origins and function in the context of how the villa was used, in the hope that this information may be helpful for the restoration work in progress.

METHOD OF CALCULATING SUNDIALS

It was not always easy to interpret the hour lines on the dials because of the deterioration of the dial face, caused by weathering and also in some cases by hour lines of different systems being superimposed. The lines that we were able to interpret, or at least see and recognise as constituent parts of the dial, are highlighted in the photographs of each dial. After deciphering the lines *in situ* and from photographs, we calculated the hour lines according to the hour system of measurement that emerged, using a modern computer programme[5] and taking into account the topographical data of the walls, the size of the dials and the gnomon. This method confirmed our first diagnosis of the type of hour system used, and also provided useful information for the restoration of the dials.

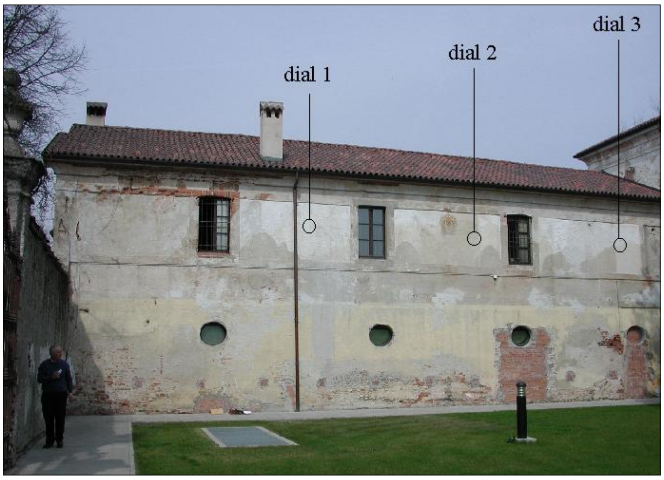


Fig. 4. South-east facing wall in Courtyard of the Clocks, with numbers and locations of the dials.

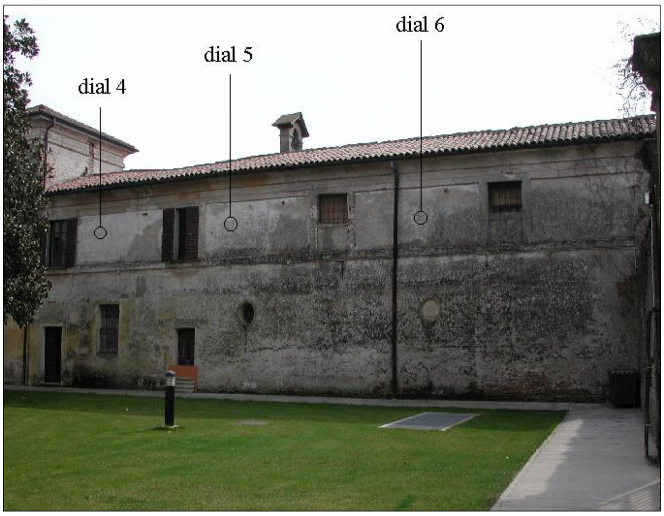


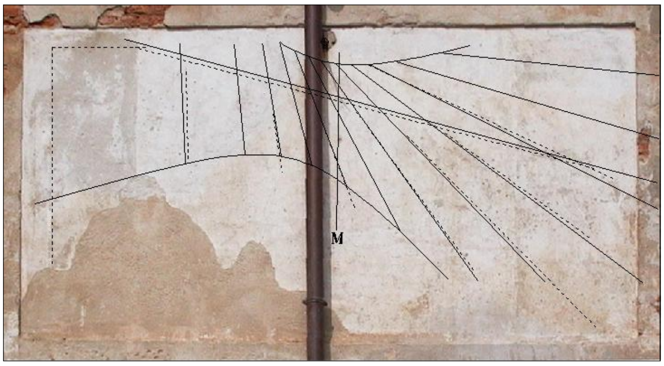
Fig. 5. North-west facing wall in Courtyard of the Clocks, with numbers and location of the dials.

The geographic coordinates of Cascina Picchetta measured from official maps on a scale of 1:25000 give latitude f = 45° 30' 21"; longitude λ = 8° 40' 16". To measure the declination we used a wooden board fitted with two spirit levels, enabling the board to be placed parallel to the earth's surface, and a 9 cm long steel gnomon fixed perpendicularly to the board to cast the sun's shadow. By placing the edge of the board flat against the wall and checking its horizontality, we marked the shadow point at the prearranged time of true solar noon on 27 March. We subsequently made several measurements at approximately 20-minute intervals, to obviate any unevenness of the walls and to have more data to compare. Measurements of this kind involve a greater number of calculations, but they do make it possible to get the right declination of the wall. The mean of the measurements thus performed was 15.17°, approximated to 15° east, which was the value we used for all the calculations of the dials on this south-east facing wall. The opposite wall, facing north-west, is not quite parallel to the other one, differing by 1.27°, so that its declination is 166.27° west, approximated to 166° west. The size of the dials is approximately 1.90 x 3.80 m.

The existing gnomons are of the orthogonal type, perpendicular to the wall; one is missing, but the type of dial where it was placed suggests that it was polar. The gnomons are around 30 cm long. When the dials were constructed (17th century) the metric system had not yet been introduced, so the length of the gnomons may have been half a *braccio lungo* (long arm) of Novara, equal to about 33 cm.[6]

DESCRIPTION AND RECALCULATION OF THE SUNDIALS

The dials are positioned at the height of the first floor, three on the south-east facing wall, three on the north-west facing wall. To facilitate their description we have numbered them from 1 to 3 (south-east wall) and from 4 to 6 (north-west wall), as shown in Figs. 3-5. The hour lines on each dial have been marked with dotted line by retouching the photographs.



. 6. Dial no. 1; lines still visible (dotted line) and computer reconstruction (full line) are marked.

Dial no. 1

The equinoctial line, the noon line and eight hour lines can be traced on this dial (Fig. 6, dotted line). The gnomon is perpendicular to the wall and has been bent. There are no inscriptions, numbers or signs of the zodiac. The dial is bisected by a drainpipe. The bottom left side has traces of scratches remaining from a fresco which may have depicted some motif connected with time. Taken as a whole, the barely visible hour lines show with a fair degree of certainty that the Italian hour system was used.

We then made a graphic reconstruction of the dial using the data taken from the wall and the geographic data of the locality. Our reconstruction shows that the equinoctial line and the noon line coincide, but the hour lines are rotated by about half an hour; in fact, the noon line, the equinoctial line and the 6 p.m. hour line all have to pass through the same point, while in the original layout the intersection was at 5.30 p.m. This means that the original dial used "bell tower" ("*da campanile*") Italian hours, i.e. hour XXIV was fixed half an hour after sunset, which is when the darkness effectively begins. We therefore recalculated the hour lines for this type of hour system (full line in fig. 6); if compared with the lines still visible on the dial, the correspondence is excellent.

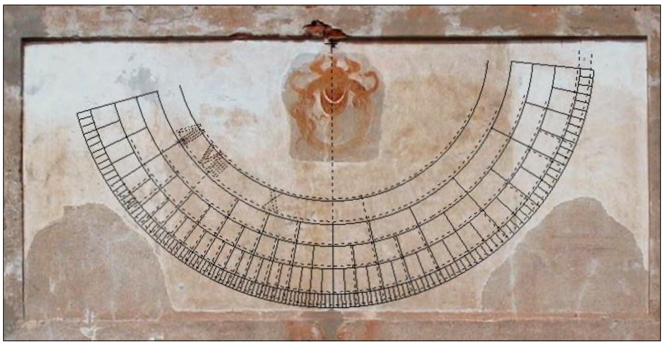


Fig. 7. Dial no. 2; lines still visible (dotted line) and computer reconstruction (full line) are marked.

Dial no. 2

This dial is definitely of more recent construction and is in a better state of preservation. It may have been created after Napoleon imposed French time on the whole of Northern Italy in the first half of the 19th century. A number of details are distinguishable on this dial: it is subdivided into five concentric circles, on each of which the hours are divided into half hours, then quarter hours, and lastly five minute intervals, the hour lines going from 6 a.m. to 5 p.m. (Fig. 7). The gnomon is missing, but we can be sure that on this type of dial it was polar. A coat of arms is clearly visible in the centre, and at the bottom of each side there are other decorative motifs on the theme of time. This dial was very accurate, and could consequently be used as a reference for all the others, perhaps even for the mechanical clocks on the towers. The photograph of this dial and its computer-generated graphic reconstruction show a perfect match (Fig. 7).

Dial no. 3

This dial (Fig.8) was the hardest one to decipher, both because of the superimposition of different hour systems and its errors of construction. The left side of the dial is laid out with the Babylonian system, while the right side displays a series of numbers indicating the Italian hour system. Babylonian hours have been superimposed on these lines. The

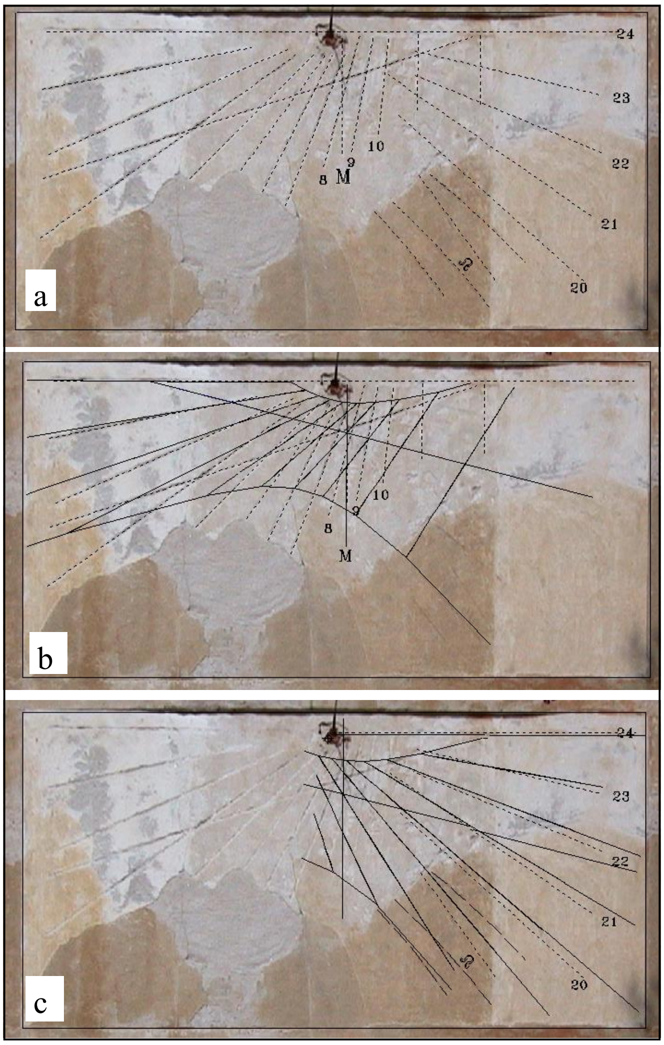


Fig.8. a. (top) Dial no. 3; lines still visible are marked. b. (centre) Dial no. 3, lines still visible (dotted line) and computer reconstruction (full line) of the left side (Babylonian hours). c. (bottom) Dial no. 3, hour lines still visible (dotted line), diurnal lines (long dotted lines) and computer reconstruction (full line) of the right side (Italic hours).

most striking error is in the equinoctial line, whose slope, in a dial facing south-east, cannot go up from left to right but should go down. The error emerges clearly in a comparison of still visible lines and the reconstruction (Fig. 8b), as does the fact that the Babylonian hours do not match perfectly on the right side of the noon line. This may be due to faulty restoration carried out over the centuries. The right side of the dial is occupied by Italic lines (Fig. 8c). A vertical line with an engraved "M" is the noon or meridian line. To the bottom right the sign of the zodiac of Leo (23 August) is clearly visible, as well as part of the corresponding diurnal line. Fragments of other two diurnal lines are visible. Traces of decoration can be distinguished on the left side. The gnomon is orthogonal.

The dials described so far are on the south-east facing wall. A fourth rectangle, distinguishable on the left in Fig. 4, is not a sundial, but contains figures and decorations which are, however, still on the theme of time.

Fig. 9. Dial no. 4; lines still visible (dotted line) and computer reconstruction (full line) are marked.

Dial no. 4

Of the dials on the north-west facing wall, the fourth is the best preserved (Fig. 9). Four hour lines are clearly visible, marked with the numbers 21-22-23-24, indicating the Italian hour system, and there is also an equinoctial line. The small number of hour lines remaining, also seen in the next two dials, is the result of the unfavourable exposure of the wall, which is illuminated by the sun only from 4 p.m. to 6 p.m. approximately. The gnomon is orthogonal to the wall and is in the wrong place. The bottom right part of this dial also shows the decorative frieze which runs round the three walls of the courtyard. We were able to make a graphic reconstruction of the dial using the data available; the reconstruction and the actual lines show a perfect match (Fig. 9).

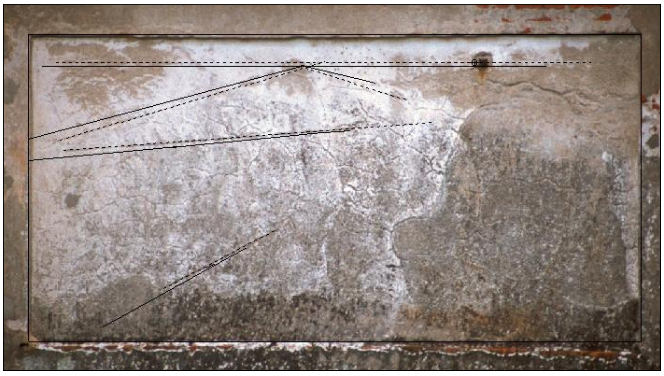


Fig. 10. Dial no. 5; lines still visible (dotted line) and computer reconstruction (full line) are marked.

Dial no. 5

Very few lines are visible on this dial, and only on one of them is there a number or a symbol, which is undecipherable (Fig. 10). However, the reconstruction clearly shows that this is a dial using the French hour system, also because there is already a dial using the Italian system on this wall (no. 4). It cannot be the Babylonian system either. The remaining possibilities would be temporary hours or

French hours, but the superimposition of the drawing on the photograph gives more credibility to the supposition that French hours are used. Once again, to the right of this dial there are traces of decoration. The gnomon is orthogonal. The reconstruction and the lines existing on the dial show an excellent match.

Fig. 11. Dial no. 6; lines still visible (dotted line) and computer reconstruction (full line) are marked.

Dial no. 6

This dial also displays very few lines, and there are no numbers or symbols which can tell us exactly what kind of hour system was used here (Fig. 11). However, we believe that the creator of these sundials wanted to represent the various types of hour system on the different dials. If we try a graphic reconstruction for the temporary hour system, we get a good agreement with the few lines remaining on the dial. We accordingly think that this dial used the temporary hour system. The gnomon is once again perpendicular to the wall. At the bottom right we can almost make out the figure of a sleeping person with his or her head resting on one arm, with a clock nearby. This dial too is defaced by a drainpipe.

The mechanical clocks

The mechanical clocks on the side towers of the courtyard (Fig. 12) can probably be dated to the late 18th or early 19th century. They are in a very poor state of preservation. Of about 1 metre diameter, they have an hour hand and a minute hand. The face of the clocks carries a double series of numbers, an inner series in Roman numerals for the hours from I to XII, and an outer series in Arabic numerals marked off at 5 minute intervals. Unfortunately the interior mechanism has been completely lost, and so far research has not unearthed any documents which can provide details of the clocks.

CONCLUSIONS

The reconstruction of the sundials in the courtyard of Cascina Picchetta highlights the skill with which they were made, and throws light on the purpose which this space was intended to have in the villa complex. The purely technical error in the layout of the third dial is of little importance, and was in any case corrected by the superimposition of an Italian hour dial, clear signs of which remain on its right side.

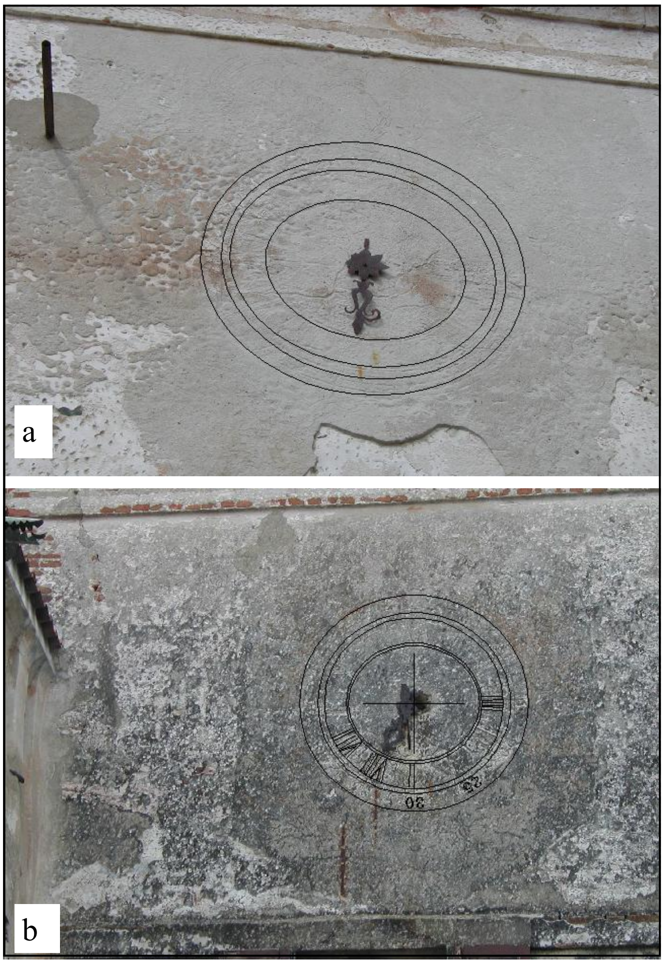


Fig. 12 a. (top) Mechanical clock located on the south-east facing tower and b. (bottom) on the north-west facing tower.

If we look at the sundials as a whole, taking note of the ornamental motifs as well, it seems obvious that the entire courtyard was designed to be devoted to time and its passing, a common theme in 17th and 18th century culture, especially in the religious sphere. This intention is emphasised by the number and size of the dials, the care with which the different hour measurement systems in use at the time were employed, and the involvement of the unsuitable north wall, almost as if the makers of the dials wanted to show off their technical skill. And while the decorative elements are sometimes difficult to decipher due to their very poor state of preservation, they clearly include features connected with the passage of time, such as hour-glasses, a person sleeping with a clock behind him, alternating with floral and ornamental motifs.

It is hard to avoid associating the high degree of skill required in making these sundials, and the emphasis on the passage of time, with the fact that for a long period in the 17^{th} century the Jesuits used the Cascina for vacational purposes. The Jesuits were well-known for their application to the study and teaching of science, for centuries playing an essential role in these fields. We can better appreciate the importance of this role by remembering that the Roman Catholic Church for centuries had total control in scientific matters, as in many other aspects of society, a demonstration of its concern that new discoveries should not come into conflict with the revealed truth of the Bible and areas of life that the Church regarded as its exclusive province. The Jesuits were also highly skilled in astronomy and gnomonics. An emblematic figure in this sense was Athanasius Kircher (1602-1680), who entered the Order at 16, and was for decades a teacher of mathematics and oriental languages at the Jesuits' Roman College; he was also the founder of a famous museum and author of many works including treatises on gnomonics.[7,8]

In the absence of any records which mention the construction of the dials, we may imagine that one of the many eminent priests enjoying a vacation at Cascina Picchetta decided to create one or more sundials, an absolutely normal activity in the 17^{th} and 18^{th} centuries. This maker, or others emulating him, gradually filled two walls with dials, showing off his technical skill in the use of the different hour systems. The two mechanical clocks, which blend in with the symmetrical layout of the architecture and the sundials, were undoubtedly installed at a later time, probably after the villa was bought by the Marquis Natta d'Alfiano (1779), who made major alterations to the building. It was probably at this time that the second sundial underwent a major overhaul, which resulted in a high precision dial with a resolution of less than five minutes. This entailed the construction of an adequate network of hour lines, still visible today, and the addition of a polar gnomon, at the expense of the uniformity of design and style which previously would have been common to all six dials. The reason for this departure is to be sought in the necessity for regulating the mechanical clocks, which in their early days were not at all accurate, varying in their precision by as much as 15 minutes a day[9]. Moreover, the error was liable to increase as the days went by, so that in a short time the clock was totally unreliable. The error associated with the measurement of time by a well-constructed sundial like this one is certainly smaller, less than 5 minutes a day, and with no accumulation of the error over a period of days. This helps us to understand why sundials were used regularly to set mechanical clocks, a task performed by the man responsible for winding and maintaining them, known in Italian as a *temperatore*.

Subsequent changes[3] may have affected the decoration, but did not alter the leading motif outlined on the courtyard walls, which can still be distinguished today. The walls may now be faded with the ravages of much weathering, but they can still communicate their message, and as we look round the courtyard it is not difficult to imagine it as it was three centuries ago, partly covered by a pergola of vines, with benches, a well in the middle and a shrine against one wall, an elderly priest taking the air with his breviary in his hand; or perhaps, on an August evening, echoes of the conversation of a few of the visitors, accompanied by a glass or two of wine…

The message from these walls is uncompromising, now as it was three centuries ago: time passes quickly, in the quiet countryside as in the bustle of the city; it consumes the seasons and inexorably marks off the days of our lives. It is important that the restoration work now in progress should be done in full awareness of the unique cultural inheritance displayed on the outside walls of the villa, returning it to pristine condition while observing the rules of gnomonics.

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FURTHER COMMENTS ON THE SUNDIAL OF ST. MARY'S STOKE D'ABERNON, SURREY

K H HEAD

In the Bulletin for October 1999[1] I described the sundial on the wall of the Saxon church of St Mary, Stoke d'Aubernon, in Surrey, which replaced a much earlier dial that fell down in 1933. I have recently found another fragment of information about the original dial, but this only raises further questions.

The present dial, with the inscription below it, is shown in Fig.1. Five years ago I had no information about the earlier dial, other than sketches by Mrs. Gatty[2] and P M Johnson[3]. In my article I asked whether anyone could shed any light on its date of origin. There was no response so I wrote to David Scott, who was then contributing a series of articles on sundials in Anglo-Saxon England[4]. He very kindly

Fig. 1. The sundial at Stoke D'Abernon.

Fig. 2. Photograph c.1920 of the First World War Memorial with the dial visible in the top right corner.

wrote to me a some length, giving his comments and suggestions, which can be summarised as follows.

1. The present dial is undoubtedly a modern replica of a typical Saxon dial of about the seventh century, i.e. the time when the church was built (it is mounted on the surviving original Saxon wall).

2. The date of the original dial is less certain, but Mr. Scott conjectured that it probably dates from about the twelfth century, i.e. when the Normans added the north aisle to the church, (the century before the renowned ancient memorial brasses were made). He thought that it was an early angled-gnomon type, which did not reach England until the return of the crusaders from the Middle East, and the pattern of marking (as seen in the sketches) seemed to confirm this.

This is the only information we had about the original dial, until now. A few months after publication of my article, our then Rector showed me a photograph of the First World War memorial, in the form of a Calvary, in its original situation by the south porch (Fig. 2). In the top right-hand corner, the original dial can be seen, confirming the earlier sketches but apparently providing no new information. The area of the wall round the dial is shown enlarged in Fig. 3. The photograph was probably taken in the early 1920s but nobody can tell me exactly when. In 1947 the Calvary was moved to the churchyard area.

Last year a former churchwarden compiled a magnificent book of photographs of memorials to those from Stoke D'Abernon who had fallen in the two world wars - memorials situated in other countries as well as in the UK. The

Fig. 3. Enlargement of Fig. 2 showing the dial.

Fig. 4. Photograph of the dial from a recent book of local memorials.

photograph shown in Fig. 2 is included, and there is also another picture of the same subject, taken at a later date from a different angle, which I had not seen before. The sundial appears again, and is shown enlarged in Fig. 4. The interesting feature about this view is that it shows very clearly that the face of the original dial was not vertical, but inclined slightly upwards. This was not at all obvious from the earlier picture (Fig. 2), although with hindsight the inclination is detectable in Fig. 3.

Is this an unusual feature of these early dials? Does it help to explain the origin of this dial and to determine its date? I would be grateful if some knowledgeable member could provide further information.

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ITALY 2004

FRANK EVANS

Unlike other members, Rosie and I arrived in Italy from Malta and its stifling heat to be greeted by the pleasantly cool Rome air. We were also met by a wonderfully warm welcome from other BSS denizens of the airport who were awaiting transport to our hotel. On departure our total number was less than the coach driver had been given and he stolidly refused to move for half an hour. “The driver has a difficulty” was to become a theme of our time in the capital. He finally yielded to the idea that some members may have arrived at the other Rome airport and eventually delivered us to the Hotel Albani, our base for the next four days.

The hotel! It was a psychedelic dream. A huge chandelier hung in a stair well at the entrance, clearly lighting some cave below, there were abundant white marble steps, walls in orange, mauve and lime green, carpets in geometric design and wideawake colours, glass panels that tempted you to walk through them, and a maze of lifts and curving corridors. But the bedrooms had good showers with plenty of hot water and some even had balconies. Across the street from our bedroom we could see the grounds of the Villa Albani filled with birdsong and graffiti reading “Berlusconi terrororista”.

The next day, Sunday, we began what was soon to prove a walking holiday, setting off apace for the Pincio Park and the Gallery Borghese. In the park we found an east declining dial, recently deliberately restored to its original inaccuracy. Above it, a gargoyle stared at us open mouthed. Would a cuckoo emerge therefrom at noon, as some wags averred? Lunch was taken at the small zoo in the park before we trailed out along the highway to a charming street, the *Via dei Tre Orologi.* And, sure enough, there was a cube with dials on three sides, crowned with a stone sphere.

The Borghese museum itself was a handsome villa stuffed with wonders, Caravaggio and Botticelli led the painters and Bernini and Canova, the sculptors. We loved Canova’s growling Cerberus, the three-headed watchdog of the nether regions, and marvelled at the transformation of Daphne into a tree as she fled from rapacious Apollo, all in finely detailed marble. The villa walls bore many mosaics formed from tiny ceramic pieces; however, all was not always as it seemed as some apparent mosaics proved warm to the touch and were actually drawn frescoes. The whole collection was stunning.

The afternoon was spent on a coach tour of Rome. Our guides were Mario Catamo and our patron, Sir Mark Lennox-Boyd, who speaks fluent Italian thus enabling him to engage vigorously with the driver who, true to his type, had difficulties with the route. We passed the grandiose monument to united Italy’s first king, Vittorio Emanuele, for which many Romans had wished a friendly bomb in 1944, before continuing to the blessedly traffic-free *Colosseum*. We did not join the two hour queue to enter but stood amused at a human statue nearby who skilfully turned his absolute stillness into a joke on the rattle of a coin in his tin. On past the huge Roman baths of Caracalla to the Garibaldi monument and a fine view of the capital before we descended to the *Aqua Paula* fountains and then the tiny circular *Tempieta* church, situated in the floor space of a larger church, and thence home for supper. It had been a very full first day.

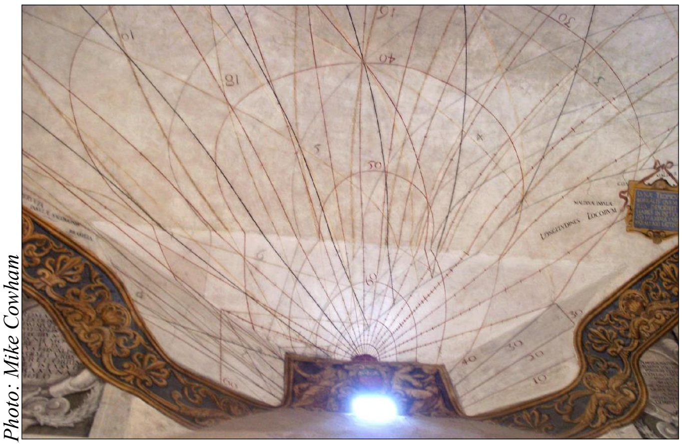


Photo: Mike Cowham

The lines of the ceiling dial in the Palazzo Spada.

On Monday morning we attacked the complexity of the immense catatropic or mirror dial painted on the ceiling of the *Palazzo Spada* (not ‘Spade’ but ‘Sword’, the family name). A verbal description of this masterpiece of Father Maignan can only fail. In this house, having tested our neck vertebrae on the ceiling dial, we were addressed by the benign President of the *Consiglio di Stato*, which controls the administrative code of Italy, overseeing the legality of parliamentary acts. His words were translated by Bruno Caracciolo, one of our Italian members who had been press-ganged into helping out as he spoke good English. The *Palazzo Spada* houses a handsome court room for the purposes of the *Consiglio*. Walking on we passed the rival sixteenth century *Palazzo Farnese* with its frontage by

Photo: Mike Cowham

Photo: Tony Moss

At Meridiana. Top: the solar system model. Bottom: the scene on the inside of the staircase.

Michelangelo. It contains the French Embassy. Then through the flower market of *Piazza Fiori* (we longed to stop) to reach our coach. We were bound for Oliveto, the as yet unfinished house of our patron, some forty miles north east of Rome. Situated among beautiful hills, the last of which we climbed on foot to reach the house, it featured Sir Mark and Lady Arabella Lennox-Boyd and a most sumptuous lunch which they had prepared. But first we must see the extraordinary inside of a tower laid out as an inverse cube dial with a mirror dial on the ceiling. It was large, hugely impressive and the work of Sir Mark himself together with his step-daughter who had painted the background. We easily imagined the laborious months it had taken to prepare.

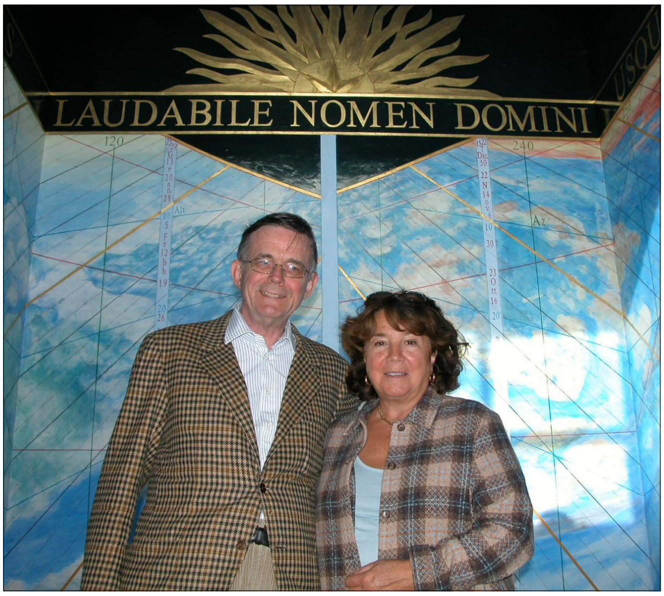


Photo: Tony Moss

Our hosts at Meridiana: Mark and Arabella Lennox-Boyd.

There followed a short visit to the ancestral home of Lady Arabella in the village before our return to the hotel.

The *Horologium Solarium Augusti* (Tuesday) was in fact the obelisk of the Egyptian, Psammetic II, and not of the Emperor Augustus at all. And it may not have been a *horologium* either. It has been moved to the front of the Italian Parliament and its ancient function bears a question mark although it now has a recent noon line. No question, though, about the meridian line in the *Basilica di Santa Maria degli Angeli e dei Martiri.* The baths of the Emperor Diocletian, still standing today, were converted into this church twelve hundred years later by Michelangelo. Their stability suggested the erection of a meridian line and this was realised in 1701 by Bianchini, its purpose being the exact timing of the equinox. Close beside it was another short meridian line bisecting a nesting succession of elipses. These traced the daily movement of the Pole Star through a sight in a north window while tracking the star's approach to the celestial pole from the years 1700 to 2100. Emerging from the church we noted the Marcus Aurelius column and the Trajan column, the latter honoured by the world's letter cutters and calligraphers, glimpsed in passing.

After lunch, to the Vatican, where we joined one of the numerous queues to go into the basilica. Two of our number joined a queue stating "No lift" and, mistakenly thinking this would give quick entry into the cathedral, found themselves toiling to the top of the dome, a climb of a hundred and thirty metres up with no turning back. They returned pale but proud.

Photo: Mike Cowham

Ponte Vecchio Bridge dial in Florence.

On Wednesday we left Rome for Florence and Ravenna, a six hour coach drive. In Florence there was little time for sightseeing but we walked to the *Santa Maria Novella* to view the remnants of the instruments installed by the Dominican monk, Ignatio Danti, in 1574 on what was his convent church. These were the bracket which had once supported an astronomical quadrant projecting to the south and on the opposite corner an armillary sphere perhaps somewhat overlooked by our party. The bracket had direct east and west dials. They were instruments of high intent, designed to show not merely the time but the moment of equinox and, by repeated annual observations, the length of the year. Danti's eventual year-length was about three minutes out. They made him a bishop.

During our short stop we could claim to see the *Ponte Vecchio* and the *Duomo* (Florence Cathedral) with its glorious free-standing campanile. And so, on to Ravenna and our modest hotel

Ravenna is well served by the railway, as we were intrigued to see from our window on awaking on Thursday. But today we were bound first for the Ravenna National Museum where we saw the remains of a Roman dial once borne on the shoulders of Hercules. Alas, all that remains of him after the earthquake of 1591 is his stone left leg. The dial, too, is in pieces. From the museum we walked to the octagonal Basilica of *San Vitale*, an absolutely stunning Byzantine church, filled with coloured mosaic, said to be the finest outside Istanbul. Our eye was particularly taken by the Empress Theodora, the lovely but dangerous woman portrayed standing by her husband Justinian who, in the sixth century, had completed the church. Odd to think that at an early stage in her career you could have taken this powerful woman out for dinner for the price of the meal and a little present.

Then to the Domus of Stone Carpets, an assortment of Roman mosaic floors, many surviving almost complete. Trust someone to say what a pity the Romans had not finished them.

A pair of columns in the *Piazza del Popolo* proved to be further timepieces, one a marker for a meridian line, the other engraved as an immense dial in the form of a shepherd's dial but showing only noon through the year in Italian hours. But its gnomon was missing following a hurricane in 1898. We next visited the tomb of Dante ("It's an inferno in there" declared the usual suspects) before continuing to the Classense Library. Here there was a cornucopia of small dials and instruments, some brought forward especially for our viewing. And for the calligraphers amongst us there were some manuscript books with Carolingian scripts to enjoy.

After a pleasant lunch back at the hotel, we went a mile or two out of Ravenna to Classe and the church of *Sant' Apollinare*. This vast accoutred barn has an apsidal east end in gold and green mosaic portraying St. Andrew with sheep; Italian mosaic was becoming almost monotonously breathtaking. In the church are the remains of the first bishop of Ravenna. We were looking still at the sixth century and yet another amazing architectural survival.

Returning to the present we visited Mario Arnaldi's ingenious dial of 2001, achieved in collaboration with the mathematician Gianni Ferrari, a pretty conceit whereby the sun in its course shines through successive holes in a curved wall to give the time of day. Finally we went on to view another of Mario's dials, a large tiled wall dial dated 1997, east declining, with lots of information about regular hours, Italian and Babylonian hours, the sun's azimuth, the equation of time, the Jewish calendar and so on. Had it been in Rome it would by now have been covered with graffiti and fly-posters. In Ravenna it just looked splendid.

At dinner, it being Trafalgar Day, our seaman chairman proposed a toast to the 'Immortal Memory', presumably of a certain Vice Admiral. There were no French colleagues with us to take offence and the Spanish amongst us declared that it was the French who were defeated on that day and not the Spaniards, who were merely present.

Perhaps the most important day of our trip was the next

Photo: Tony Moss

Bologna: the meridian line running close to a pillar.

day, Friday, for we were to see Cassini's great meridian line in the church of *San Petronio* in Bologna. Accompanying us were fellow diallist Giovanni Paltrinieri and yet another and very well informed guide, Silvia Vallerin. We began with a sight of the thirteenth century Papal offices, now occupied by the mayor of the town followed, in the *Piazza Maggiore,* by the statue of Pope Gregory XIII, aka Gregory the Calendar.

In the *Palazzo Pietramellara* was the only meridian line we saw which had once had a trackway to bear a focussing lens; the fixing points of the track were still visible. Apparently there were also once graduations to mark the Pole Star's orbit but these are no longer to be seen.

Outside was a statue of the physiologist Luigi Galvani (1737-1798), pioneer of galvanism and electrifier of frogs' legs. Even the stony amphibian legs were represented in the statue although here, inevitably, motionless.

In a very full morning we next visited the historic Anatomy Theatre of the University. The Medical Faculty of Bologna has a long and distinguished history but in medieval times functioned under the restrictive eye of the Church. Dissections of human bodies were permitted in Bologna (but not, for instance, in Padua) within strict limits. A spy hole high up enabled a monk of the Inquisition to secretly view the proceedings. At the head of the marble dissecting table was an elevated and august seat. The present writer stepped forward to explain that its occupant was called the Reader, a title still in use in British universities and not only in medical faculties. The Reader read from a hallowed text such as the Roman anatomist, Galen, while his deputy, the Demonstrator (another surviving university title) displayed the organs referred to. Outside in the corridor numerous coats of arms decorated the ceiling, the armorial bearings of undergraduates of long ago.

And then we came to the Basilica of *San Petronio*, home of Cassini's famous meridian line. The line, which supplanted one by Danti, has been described exhaustively elsewhere and one can only comment on the great precision it has been shown to display. The sun hole in the roof is obvious. The ingenuity of the layout of the line, missing one of the great pillars by a whisker, is clear. We know that the line is level since it was mastered by a water trough giving a horizontal surface. And it is the largest meridian line in the world at over sixty eight metres. It is impressive.

The line, installed in 1655, has been adjusted, first by Cassini himself in 1695 and subsequently by the astronomer Zanotti in 1776. And by the way, the writer has a picture, downloaded from the net where it was placed by a charitable Italian diallist (again Mario Arnaldi, we suspect), of the sun on the noon line and the date, 11 August 1999, at the solar eclipse.

The traditional BSS group photograph. Photo: Tony Moss.

The museum of church treasures aroused much interest and once again the calligraphers rejoiced at the sight of ancient song books, huge manuscript books

The dial in Abano town square, showing Galileo with telescope on the gnomon.

with square notes in the ancient fashion, written on four lines rather than the modern five. The script, we are credibly informed, was Italian Gothic of the early fifteenth century, with illuminated initial letters and lots of gold leaf.

After such a busy morning the party needed lunch and a democratic decision was taken to sit on the stone ledge outside *San Petronio* and eat the food provided for us by the hotel. Some of the generous supply of goodies found its way into the hands of local beggars as an undisciplined drift began towards a café across the street offering coffee instead of the healthy bottled water stored in our carrier bags.

Reassembling, we proceeded to the mother church of the Dominican Order. Here is the tomb of St. Dominic himself, who died in Bologna in the thirteenth century. Its ambience was explained to us by one of the brothers, Fra Tarcisio. We also viewed yet another meridian line, again constructed by Danti, no less. Unlike his *San Petronio* line it is short, so short that it crosses the floor and climbs up the doorpost to reach its winter termination.

Then once again we returned to the twenty first century as we journeyed to the Quarter Savena to see a dial created by Giovanni Paltrinieri which he was pleased to describe to us. The dial was large, with a gnomon elevated to catch the sun above the surrounding buildings. It foreshadowed the more elaborate dial by this maker in Abano Terme which is described below. Standing at the edge of the thirty six metre dial plate is a column topped by a sphere whose shadow travels a straight line marked on the ground, at the equinox.

Saturday found us far from home, travelling to Este and stations north on a round trip of perhaps a hundred and fifty miles. Passing through the flat fenland country bordering the Adriatic we called first at Pomposa Abbey. It was Benedictine and a visit to the museum, the former dormitory of the monks, suggested that the monastic rule demanded night access into the church chancel. An insignificant door at one end of the museum was locked but a return to the abbey church revealed a fine flight of night stairs flanking the high altar which led upwards, inevitably, to the other side of the locked door. Medieval monks, rather like the Romans, rarely altered their building plans and it was soon possible to descry the refectory, chapter house, warming room and western range. Further afield was what we were told was the abbot's court house, he being a great landlord as well as a cleric. Oh, and in the dormitory there was an interesting marble 'D' formation dial with twelve equal divisions and a gnomon hole at the top.

Este is a walled town whose present buildings appear mostly to lie outside the wall. Within the walls lie a public garden, a fairy-tale castle and the *Atestino* museum, formerly a villa. We had come there to see one particular object of interest, the small portable dial from the first century which has received a careful examination by Mario Arnaldi and Karlheinz Schaldach (who many will remember as our guide on our 1997 German trip). The dial is of the type known as a shepherd's dial. It is ivory, 61.5 mm high and marked with date lines and hour lines. It was discovered, associated with a Roman doctor, in a necropolis in 1884 but its purpose was for long not recognised. Mario holds that such a dial is too good for shepherds and it should rather be called a "physician's dial".

Este offered a clock in the market place with only an hour hand and, on the other side of the clock tower, a simple declining dial marked for the solstices but without numbers. (The body responsible for controlling restorative work has not permitted a full reconstruction,)

From Este we continued northwards to Arquà and the house of Petrarch. We found ourselves among steep hills in a totally rural landscape. The house itself was lovely. It featured an airy covered balcony looking down on a well-kept garden. Within, the principal room is decorated with wall paintings and a ceiling divided into small squares, each containing a formal design. Petrarch must have been comfortable during the four last years of his life spent here.

Outside, street sellers offered tempting fruit, and pomegranates blushed in scarlet confusion from surrounding trees. Our party was entranced by the whole effect and wished they knew more about Petrach. Enquiry revealed that his Italian was about as hard to read by modern Italians as Chaucer's English is to us. The two are contemporary.

The very last dial of our tour was at Abano Terme ('Terme' is 'Spa') where a second dial of Giovanni Paltrinieri is found. Compared with his Quarter Savena dial this one is in glorious technicolour. It too is vast, with an elevated gnomon. Breaking the line of the gnomon is an armillary sphere. Time lines and a meridian line are laid out on a grey stone surface which on the south side bears a circle of zodiacal symbols. The gnomon is grooved along its length, sighting the Pole Star. The sides of the gnomon are highly decorated, acknowledging Galileo and an earlier natural philosopher, Pietro d'Abano. To one side is a large floor diagram showing the four ancient elements named, in Latin, Earth, Air, Fire and Water interspersed with the characters Warm, Cold, Humid and Dry. Lines unite these elements and are labelled either Affinity, Opposition or Repulsion. The whole composition is a diagram summarising much of medieval thought.

Finally we returned to Ravenna and dinner, which was followed by our usual end of session entertainment, upon which it is now a firmly established tradition not to report.

And on Sunday we all went home.

A SALUTATION TO DAVID YOUNG
(With apologies to Lord Macaulay)

CHRISTOPHER DANIEL

Sir Mark Lennox-Boyd of Gresgarth
In nine months he swore
He'd see Society members
On a guided sundial tour.

So who would organise the trip
To Italy and Rome,
To see La Meridiana
His fine Italian home?

Then out spake David Young,
Once Secretary he'd been:
"Oh, I'll arrange the BSS
To be upon the scene".

So out flew many Members,
Most English in descent,
Some from the North in Lancashire
And some from down in Kent.

There was Kevin and Irene Barrett
And Tony and Mary Belk,
Both from the shores of England
Nigh the taste of a seaside whelk;

Jack Bromiley and Marginson
(His Christian name is James),
Down from the Northern counties
And across the River Thames.

There was Frank and Rosie Evans
And Brian and Maureen Moss
And Brian's brother Tony:
They galloped down the Foss!

There came Wilf Dukes and Parsons
(Geoff, as you should know)
And Patrick Powers and Catherine,
All set to "fight the foe";

Jill Wilson, Hilary Hart,
And the Woottons came as well;
Mike Shaw and Margaret Stanier,
Intent the ranks to swell.

There followed Graham Stapleton,
Jean Thornton, she came too
And also Leonard Honey,
Bearing rings to Honey due.

Then David Young, alas, announced
He could not make the tour:
So who would take the standard
And who would go before?

Then out spake Michael Cowham,
With Valeria at his side:
"Oh, I will bear the banner
And I will be your guide."

Thus gathered the Brittanic sundial horde
And from the Stansted gate they poured
Into the air their chariots roared
And away to Rome with 'fire and sword'!

*** *** ***

Outside the mighty walls of Rome
The Italia lines did wait.
In serried ranks the impressive team
Were standing by the gate.

Mario Catamo, Riccardo Anselmi,
Bruno Caracciolo – were there in fine array,
Paula Càtera and Barbara Mastracchio,
All were awaiting the onslaught of the day.

Here Claudio Catuzzi, Lucio Baruffi
And Giancarlo Rigassio joined the valiant line,
All waiting for the great event
With a signal or a sign.

*** *** ***

As I surveyed the sundial scene,
With Doria of Sherpian fame,
Her arrowed bow and shield between,
Another horde there came.

The Ogdens from yon Irish shores
Had landed with a smile,
Andrew and Liz they were,
With a dash of Irish guile;

From the distant land of Canada
By Ontario's famous lake
Flew the Petries, Don and Jackie,
For a Roman sundial's sake;

And Guenter and Christel Burger,
From Bavaria they came,
With barbarians from Germania,
The Kunaths of that name:

Jutta of gentle nature
And Peter the driving force,
Who hailed me with a clarion call:
"I'll drive you down of course!"

And then appeared fair Ilse,
A Fabian was she,
From the Austrian country,
(A land without a sea.)

Then forth came Andres Majo Diaz
From the Catalonian land,
With Maria Majo Diaz
And *they* would make a stand.

*** *** ***

And so the Barbaric sundial tribes
Were gathered for their tour
With the finest of Italia
Who would show them cities four.

Round Rome's most glorious city,
The tribes were driven forth,
Viewing sundials and meridians,
Aligned from South to North.

Thence northwards to Oliveto
Where the throng would stay a while
To see La Meridiana
And Mark's reflective dial.

Here Mark and Arabella
Received the gnomonic line,
In beautiful surroundings,
With food and local wine.

Again the hordes drove northwards,
To Florence, a city fair,
Thence onwards to Ravenna
By nightfall to repair.

But here in northern Italy
Had gathered a greater host:
Paolo and Fulvia Alberi Auber
From Trieste's nearby coast;

And Giovanni Paltrinieri,
Of gnomonista fame,
Whose dials around Bologna
Are embellished with solar flame.

With Mario Arnaldi and Umberto Fortini,
Who took the Apian way,
And Sylvia Valerin
Who talked with us all day.

Ah! What a splendid sundial tour
For the Angles and the rest:
No thanks can be sufficient
For Italia's very best!

And when the hordes will flee for home
They will remember the tour of Rome;
They will remember Ravenna too
And I believe that so will *you*!

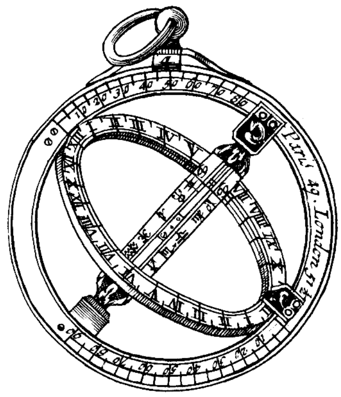
***

Author's note:

The above verses are loosely based on Lord Macaulay's epic poem "Horatius" and were very hastily penned on the evenings of Friday and Saturday 23/24 October 2004, to meet the 'deadline' for the after-dinner 'cabaret'. Seven more verses have since been included in an attempt to make this particular 'epic' complete. Whether the verses scan or not is immaterial, since, in this instance, speed was more important than quality! The author wishes to thank Sir Mark Lennox-Boyd, Mario Arnaldi and David Young, without whom there would have been no tour and no 'epic'.

DIAL DEALINGS 2004

MIKE COWHAM



This is my annual look back at dial sales over the past year. I have not necessarily picked the most expensive nor the most impressive dials but those that have interested me, particularly if they have interesting or unusual features. I will list the items in the order in which they appeared, and the prices quoted are hammer price plus buyer's premium.

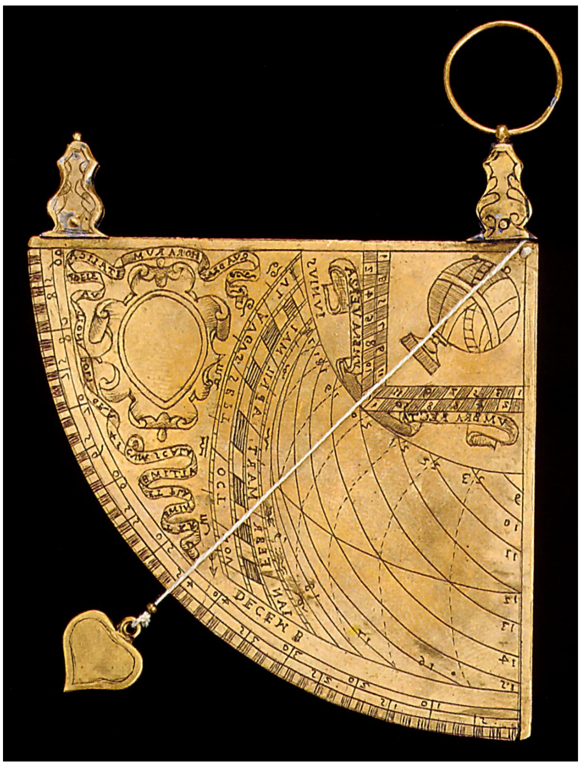


Fig. 1. Italian Hour Horary Quadrant.

Christies South Kensington, 8 April.

There were several fairly standard dials in this sale but one, a Horary Quadrant, was somewhat special: Fig. 1. It was a brass quadrant, probably from Italy, and was calibrated in Italian Hours, (those ending at sunset). The sights on the top edge were bold and unusual and the plummet was an attractive heart shape. As with all good quadrants it had a shadow square at its apex, decorated inside with a globe. Although estimated £2000-3000 it realised just £1434.

Bonhams, 3 June.

A rather small picture of this dial in their catalogue attracted my attention: Fig. 2. It was an oval gilt brass and silver Horizontal Dial with Perpetual Calendar made by ***Wolfgang Hager, Wolffenbuttel***, and was dated 1704. Dials by Hager are always well executed and are not particularly common. Its slender gnomon was of the 'pop-up' type as the lid was opened. Inside the lid was an attractive Perpetual Calendar showing the season, date, zodiac sign and three saints days for each month. It sold for a reasonable £1434. A standard silver Butterfield Dial in the same sale made just £741.

Fig. 2. Oval Dial by Wolfgang Hager.

Fig. 3. Garden Dial by Thomas Tompion from Wrest Park.

Sotheby's, 15 June.
This sale was dominated by one very special dial, a Horizontal Dial by Thomas Tompion of London. There are very few Tompion dials in existence. He was our most famous clockmaker, but occasionally he also supplied a sundial for setting his clocks. One of his best known works is at Bath with the clock inside the Pump Room and the dial just outside. This dial sold by Sotheby's was supposedly made for Wrest Park in Bedfordshire: Figs. 3 & 4. I make no apology for showing the front cover of the Sotheby's catalogue with the wonderful Tompion gnomon, a work of art in its own right. The catalogue gives a full description of the dial, better than I am able to do, but I did notice one rather strange feature; the dial plate was not the same thickness right across - it was tapered. On the south side it was 8mm thick and on the north 25mm thick. This taper across the

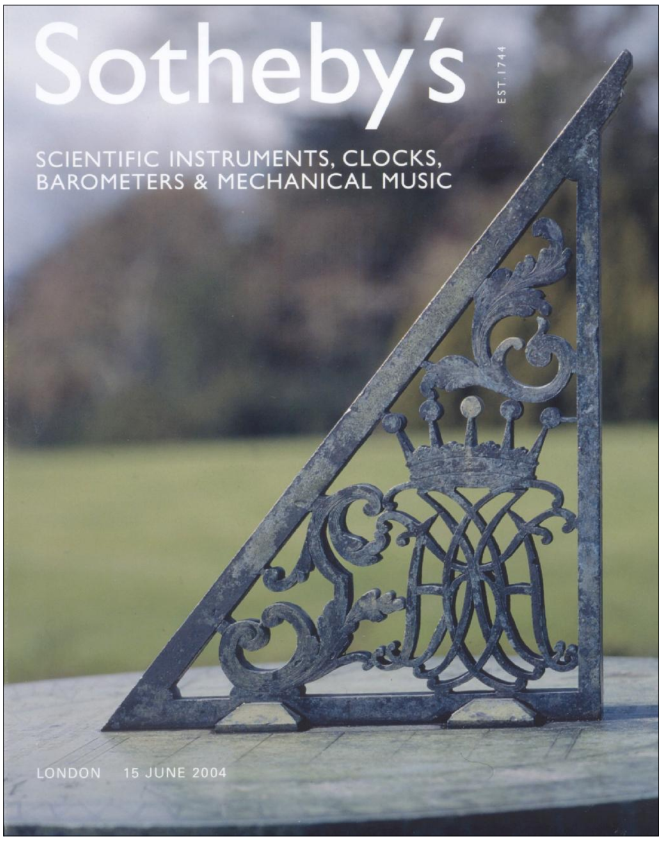


Fig. 4. Front Cover of Catalogue showing the marvellous Tompion gnomon.

diameter of around 532mm represents a tilt of 1.83°. Was the dial made for one latitude and then moved to another? No! I don't think so. It would have taken forever to cut down a 1" thick plate to taper to 8mm. It was certainly a deliberate feature. What we don't know is exactly why! My guess is that Tompion used the delineation of a former dial to lay out his hour lines and then compensated for the difference by tilting the whole in this way. I was not able to check the delineation so I am unable to say if the original layout was for London, 51° 32'. If so, the new latitude would not correspond to Wrest Park but to somewhere around Derby. Its pedestal was a little damaged but the dial itself was in excellent shape, with Equation of Time tables that were still legible. It was a magnificent dial and there may never be another like it sold at auction. I thought that its estimate was rather low at £80,000 - £100,000 expecting to see it sell for as much as £250,000. In the event it made a satisfactory £173,600.

Christies, South Kensington, 30 June.
This was again a sale with one very special piece, an Astronomical Compendium in gilt brass signed ***CHRISTOFFERVS SCHISSLER ME FECIT AVGVSTE ANNO DOMINI 1556***: Fig. 5. All Schissler instruments are very sought after and his Compendiums are justly famous. A Compendium is a collection of astronomical instruments all

in one box. It usually includes a Compass, Sundial, Nocturnal, Perpetual Calendar, Lunar Conversion Tables, Gazeteer and much more. This one was in excellent condition and was originally from the Rothschild Collection. It doubled its lower estimate making £122,850.

Fig. 5. Astronomical Compendium by Schissler.

Bonhams, 6 October.

In their sale on 25 February, Bonhams had a rather special Universal Equinoctial Ring Dial, in silver, by Elias Allen, c1635: Fig. 6. Its reserve was obviously set too high and it remained unsold. This original estimate had been £15,000 - £20,000! It was re-offered in their October sale and sold for a bargain price of £3466. Allen was probably the first manufacturer of this type of dial, having worked closely with Rev. William Oughtred who had just published his booklet, 'The Description of the General Horological Ring'.

Fig. 6. Silver Ring Dial by Elias Allen.

Sotheby's, New York, 13 & 14 October. Masterpieces from the Time Museum, Pt 4, Vol 2.

This really has to be one of the year's top sales. It featured some great horological masterpieces by makers such as Thomas Mudge, John Arnold, Thomas Earnshaw, Abraham Louis Breguet, and Ferdinand Berthoud. It can be deduced from these names that it was a sale of precision timepieces and chronometers. The second part of the sale was devoted to Scientific Instruments, which really means sundials, hour glasses and other time telling devices. It would take pages to describe all of the dials so I have just picked out just five of them here.

Fig. 7. Rock Crystal Pillar Dial by Wolfgang Fugger.

Figs. 7 & 8 show a very special Pillar Dial by Wolfgang Fugger in 1563. It is made from silver with partial gilding and its body is of rock crystal. Considering its age its condition is perfect. Inside the dial is stored a long scroll with a full year's calendar written on it. The hour scale in engraved on a silver inner

Fig. 8. Calendar on Scroll inside Fugger Dial.

cylinder, being nicely protected by the tube of rock crystal. I am not sure if the refraction of light caused by this outer tube has been allowed for in the dial calibrations. It was sold for $78,000, nearly four times its top estimate.

Fig. 9. Ivory Diptych Scaphe Dial by Hans Ducher.

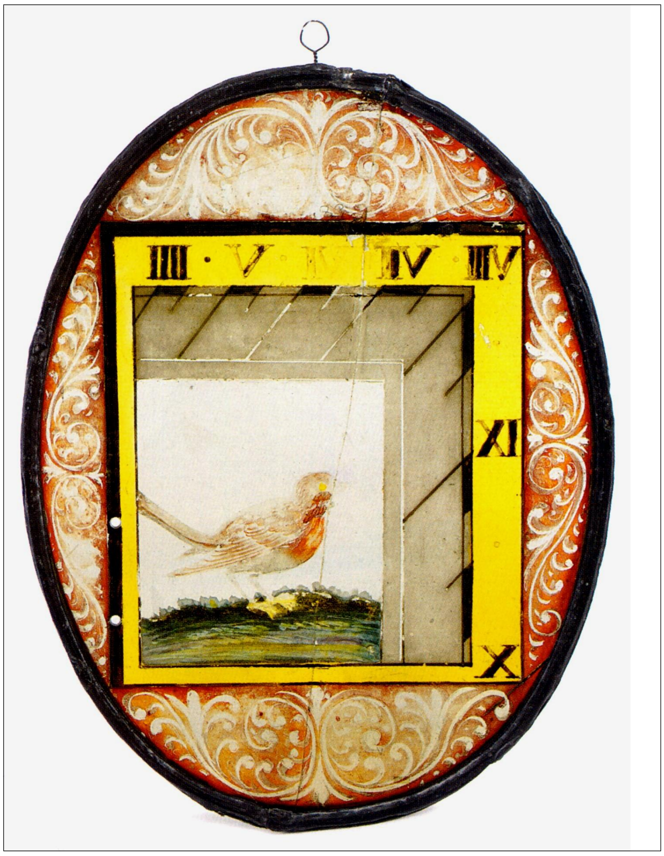


Fig. 10. Stained Glass Dial, probably by John Oliver.

The item that really took my fancy was an Ivory Diptych Dial by Hans Ducher of Nuremberg, dated 1595: Fig. 9. This case was round, 4cm dia., with a scaphe dial set into its lower leaf showing just Italian Hours from a simple vertical pin gnomon. I have not seen a dial like this before. On the inside of its lid were the words 'COMPASS VS PROPE FERRVM NON RECTE ASSIGNARE POTEST' (This compass will not indicate correctly near iron). This dial sold for $8400, doubling its estimate.

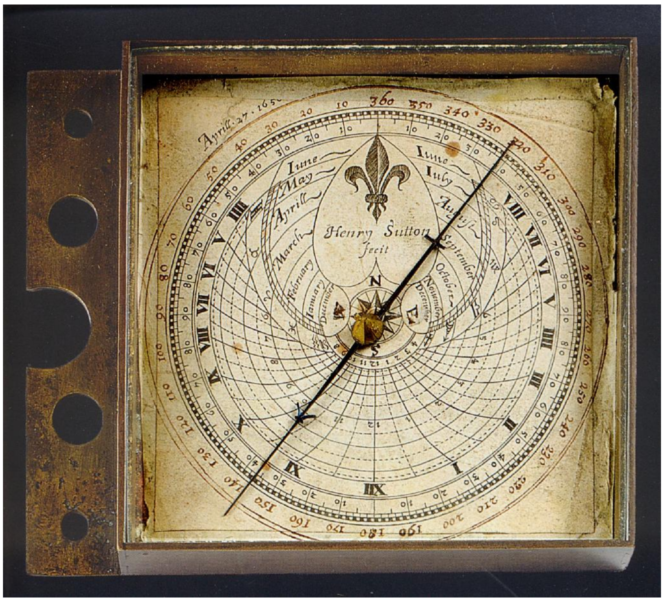


Fig. 11. Magnetic Azimuth Dial by Henry Sutton.

There has been a lot of interest lately in Stained Glass Dials, mostly due to the good efforts of John Carmichael. It was therefore interesting to have one of these very rare objects offered in this sale: Fig. 10. This dial shows what we all believe to be a robin and was probably made by John Oliver in England around 1640. Sotheby's expert had catalogued it as "possibly Swiss?", 17th Century. As you will see the dial is pictured from the outside. It is really an east decliner. Estimated at just $400-$500 it made $3000.

Henry Sutton was well-known for his quality instruments. In particular he was known to have made some relatively cheap, but accurate, ones using paper scales pasted onto wood. His large wooden quadrants may be seen in several museums. Very few survived, the paper being very fragile. However, he also engraved the plates for making compass cards. This next dial is a Magnetic Azimuth Dial, which is part of a Plane Table Compass: Fig 11. A similar dial by Walter Hayes was described in an earlier Bulletin.[1] The Sutton dial is dated April 27, 1650 (or 1656). For some reason the dial did not even reach half of its lower estimate selling for just $1680. I wish that I had been bidding for it......

Fig. 12. Unsigned Horizontal Dial with 12 subsidiary dials.

After all the portable dials that I have shown I feel that it is now appropriate to show a garden dial. This one is a little unusual, having a central dial with 12 small subsidiary dials around its edge, similar to the dials of Melville: Fig 12. However, this dial was made from brass rather than slate. It was unsigned, but was delineated for London. Its subsidiary dials were labelled with the following towns:- PARIS, ROME, MOSCOW, TEHRAN, CALCUTTA, PEKING, SAN DIEGO, MEXICO, PHILADELPHIA, BUENOS AYRES, RIO DE JANEIRO & MADEIRA. It sold for $7800, over three times its top estimate.

ACKNOWLEDGEMENTS

I would like to thank the following for allowing me to use their photographs. Christie's South Kensington for Figs. 1 & 5. Bonhams London for Figs. 2 & 6. Sotheby's London for Figs. 3 & 4. Sotheby's New York for Figs. 7, 8, 9, 10, 11 & 12. These pictures remain their copyright.

REFERENCES

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AFFILIATION TO THE ROYAL ASTRONOMICAL SOCIETY

The Council is pleased to report that the Royal Astronomical Society has granted affiliation to our Society. This gives us added status amongst the learned societies and there are advantages of shared facilities, particularly the use of the RAS offices at Burlington House, Piccadilly (near to the Royal Academy), and free access to their very large library for reference purposes. The library contains one of the best astronomical collections in the world, and needless to say, has many rare books and other material on Dialling. Their popular well illustrated membership journal, Astronomy and Geophysics, can be made available at a reduced subscription to BSS members. For our part, we will promote the RAS whenever we can, and their members can more easily learn about our events.

The RAS was founded in 1820 and is a focal point for astronomy in the UK. From the 1920s the study of geophysics - the science of Earth as a planet - has increasingly been part of the Society's remit as well. About one sixth of the 3000 members are geophysicists. The membership is drawn from professional researchers, students, keen amateurs, and people working in education and the media, and others who share the aims of the Society.

The RAS organises an annual National Astronomy Meeting which takes place over four to five days in March or April, and, like the BSS, moves to different university venues each year. In addition, regular monthly meetings are held at Burlington House from October to May.

Council urges members to make use of the research facilities in the library at Burlington House. Currently negotiations are under way to possibly open the library occasionally on Saturdays for the benefit of members and visitors. For a society like ours, one may expect to have some members who are also members of the RAS. This is indeed the case, and both organisations hope to have more members in common, after all, we are all dealing with solar astronomy in one form or another!

The affiliation is governed by a simple one-page Memorandum of Understanding, and copies are available from the Secretary.

SIR ISAAC NEWTON SUNDIAL UNVEILED AT LEICESTER UNIVERSITY

JOHN DAVIS

A new version of the Sir Isaac Newton sundial, first described in the Bulletin in 2002[1], was unveiled at Leicester University on 20 October 2004. The sundial stands as the central feature in a small garden area outside a new building housing two national research centres: the Space Research Centre and the Multidisciplinary Centre for Mathematical Modelling.

Photo: Leicester University Media Unit

Fig. 1. Sir Michael Atiyah, sculptor Vanessa Stollery, Isaac Newton and the author.

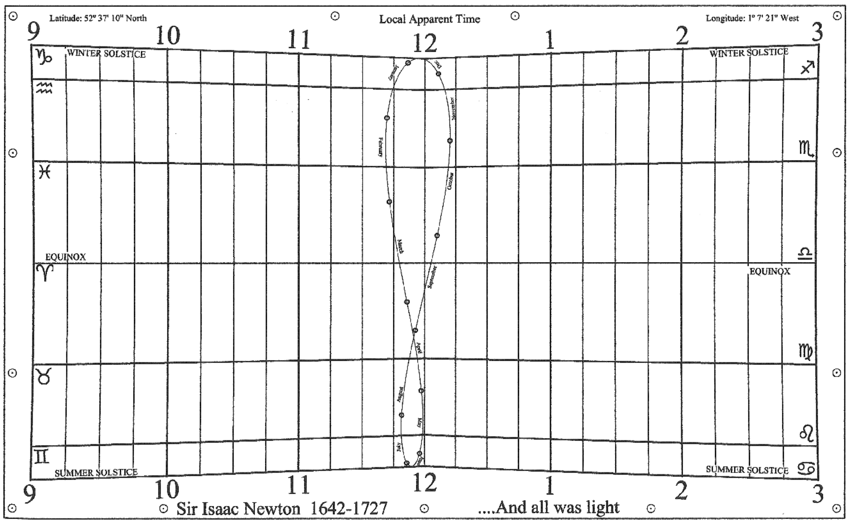

Fig. 3. A 2D drawing of the dialplate for the Leicecester Newton sundial. It indicates Local Apparent Time and has a slight pin-cushion appearance as the distance from the nodus hole to the equinox/noon position is slightly less than the radius of the dial cylinder.

The building is named after, and was officially opened by, Professor Sir Michael Atiyah (Fig. 1). Sir Michael is currently the Chancellor of Leicester University and was president of the Royal Society from 1990 to 1995. He is one of the county's most prominent mathematicians, having recently been presented with the Abel Prize (the mathematical equivalent to a Nobel Prize) by King Harald of Norway. It was particularly appropriate that he should unveil the sundial as his past posts include being the first Director of the Isaac Newton Institute for Mathematical Sciences at Cambridge University, Master of Trinity College Cambridge (Newton's own college) and Savilian Professor of

Fig. 2. Newton by arc-light as foundryman Lawrence Edwards welds the statue together.

Geometry at Oxford University; a post once held by Henry Briggs, designer of the 1629 east dial at Merton College, Oxford[2]. Leicester University is quite close to Woolsthorpe Manor, Newton's birthplace.

The dial was selected for the location by pro-Vice Chancellor Professor John Holloway, who saw the prototype in a gardening magazine. Whereas the first two versions of the dial were made in cold-cast bronze resin, the requirements of a prestigious public site on a busy university campus called for a more robust version in pure bronze. The same silicone-and-fibreglass mould could still be used, but this time to make a full-size model in red wax. This was then used in the lost-wax casting process with molten bronze, a process carried out by the sculptor and foundryman Lawrence Edwards at the Butley Mills Studios in Suffolk. The casting was made in several pieces which were then MIG welded together (Fig. 2).

The disadvantage of the bronze technique is that it contracts by around 5% on cooling, changing some of the key design dimensions. Also, the weight of the wax model caused the radius of the cylindrical dialplate to increase slightly so that the 'prism' nodus was not on its axis, although it was still possible to position the axis along the polar direction. This was not a major problem as it simply required the hour and declination lines to be recalculated for the new geometry. Instead of forming a rectangular grid on the unwrapped dialplate (i.e. in 2D), they took on a slight pin-cushion appearance (Fig. 3). Although not obvious, the vertical date lines, as well as the horizontal declination lines, have a slight curvature. No doubt the resulting shape will cause some head-scratching amongst future occupants of the Michael Atiyah building as the dial seems to be a standard equatorial one unless a ruler is taken to it!

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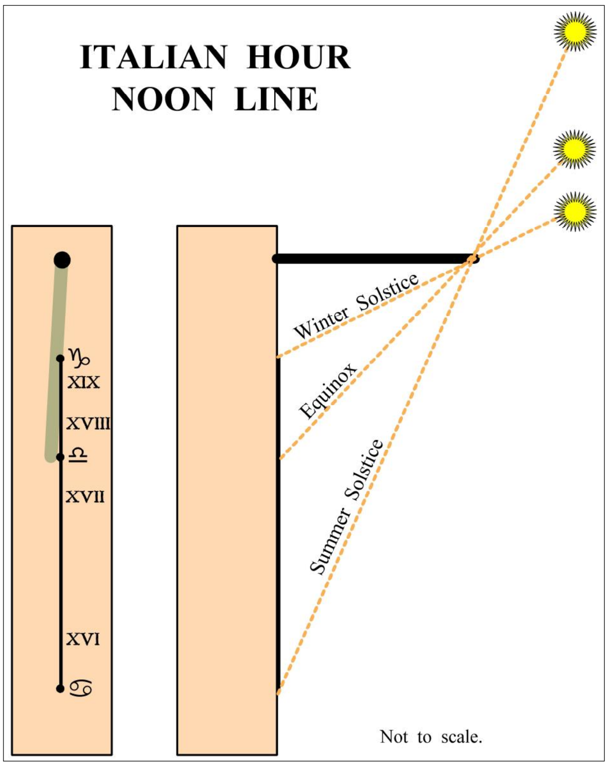
PILLAR DIAL WITH MERIDIAN LINE CALIBRATED IN ITALIAN HOURS

MIKE COWHAM

During the BSS Tour of Italy we came across a rather puzzling Meridian Line on a pillar in Piazza Del Popolo in Ravenna. It is on one of two columns erected under Venetian domination in 15th century. This 'Italian Hours Meridian Line' was added to one of the pillars by Professor Teodoro Bonati in 1795. The dial is now without its horizontal gnomon, which was lost in a hurricane in 1868. The vertical scale is calibrated only for the moment of local noon, (ignoring the Equation of Time). The calibrations seem to make little sense until it is fully appreciated how Italian hours differ from our modern time-reckoning system.

Italian hours divide the day into 24 equal parts (or hours), but the day does not start at midnight as we do, but at sunset, (or more correctly half an hour after sunset, the moment of 'Ave Maria'). This means that at the equinox, dawn will be 11½ hours later at 11:30 hours, noon at 17:30 hours and the following sunset at 23:30 hours. At other times of the year the hours of dawn and noon will vary due to the changing day lengths.



Therefore, at noon on the equinox, the time will be 17:30, at the summer solstice it will be 15:30 and the winter solstice 19:30 hours, working from ***the previous sunset.*** The displacement of the half-hour being due to the new day starting half an hour after sunset.

AN ECLIPTIC CALENDAR DIAL

"... on Earth as it is in Heaven ... "

JOHN FOAD

INTRODUCTION

The nodus of a normal horizontal or vertical dial can be used to tell not only the time, but also the date, against a set of declination lines. A more specialised device, designed to tell the date alone, was shown by John Moir[1] with his delightful 'Origami Sun Calendar'. This ingeniously folded sheet of card allowed a stationary shadow to fall on a conical date scale. Another more mechanical design was described by Allan A. Mills in his article on the Cooke Heliochronometer[2]. All such approaches to showing the date suffer however from one shortcoming: that the scale is highly compressed at the Solstices, and is entirely non-linear.

In trying to devise a dial that would show the date against a linear scale, I came up with the design that I am describing here. As an unexpected bonus, I gained a better understanding of the behaviour of the Ecliptic Plane.

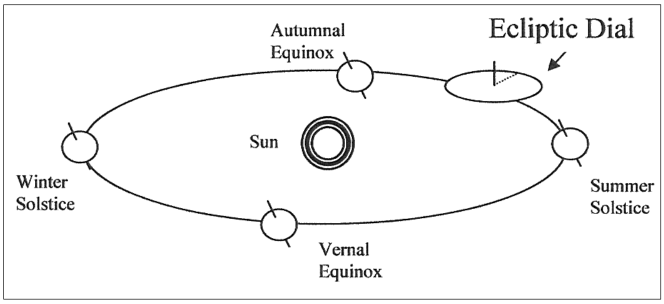


Fig. 1. A dial in the plane of the Ecliptic.

PRINCIPLE

For someone standing in space, outside the Sun-Earth system, it is easy to envisage a dial in the plane of the ecliptic, with a central vertical gnomon pointing to the Ecliptic Pole, as in Fig. 1. And it is easy to see that the shadow of the gnomon will indicate the Celestial Longitude of the sun. The shadow moves around the dial once in a year, and thus can be made to yield the date.

But I am not standing in space. I live at a latitude of 51° on the surface of a sphere that is rotating rapidly about an inclined axis. How on Earth, if you will pardon the pun, can I get my dial to lie in the plane of the Ecliptic?

In fact it is not as hard as it may seem. We know two things about the dial. First, the gnomon must lie at 23.5° to the Earth's axis. Secondly, by definition, the Sun must lie in the plane of the dial. So if we constrain the dial so that however it moves, the gnomon is 23.5° from the Earth's axis, and if we then adjust the dial until the Sun's rays just graze its surface, we must have succeeded.

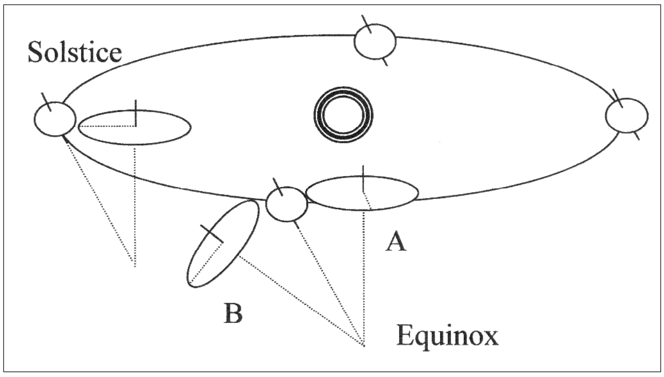


Fig. 2. Ambiguity away from the Solstices.

Except for one thing. At the solstices we are fine, as shown in Fig. 2. But anywhere else, for example at an equinox, there are two possible orientations for the dial that satisfy the conditions. At A the dial is where we want it. At B, it is not. And yet at both A and B, the gnomon is at 23.5° to the axis, and the sun is in the plane of the dial.

This ambiguity is associated with the fact that the sun's declination is the same for example in March as it is in Sep-

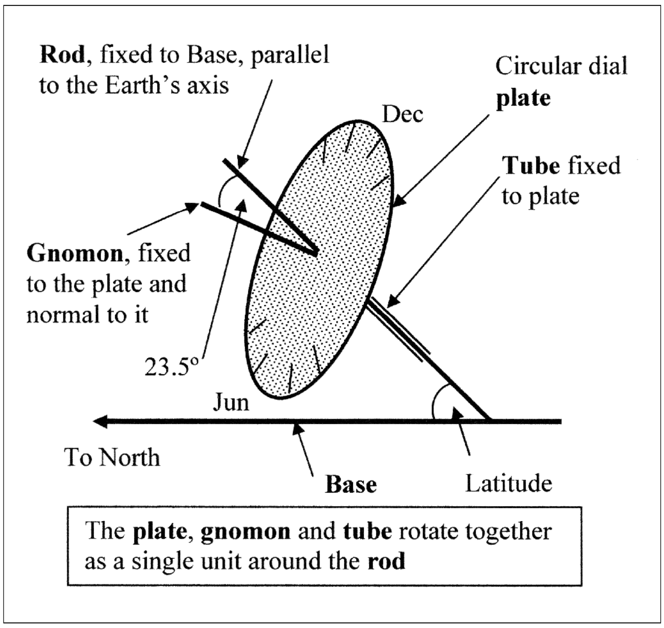


Fig. 3. Basic dial design.

tember, and we cannot tell, from the declination alone, which half of the year we are in. It is a dilemma from which, as far as I can see, any attempt to tell the date from a single observation of the sun must suffer. In practice we know if it is Spring or Autumn, and it is only around the solstices that it is a problem. My dials will always offer two possible dates, and you need some common sense to know which is the right one.

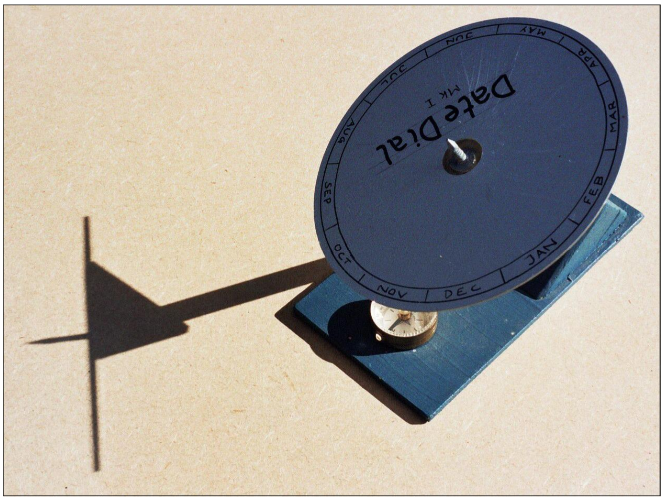


Fig. 4. Mark I: The dial in its simplest form. The shadow of the gnomon can be seen, offset by 23.5° from the shadow of the polar axis. The shadow of the gnomon cannot be observed on the dial plate, but would indicate a date of early October.

A BASIC DESIGN, AND THE ECLIPTIC

A design which achieves this, in its simplest form, is shown in Fig. 3, and a photograph of a rough model is at Fig. 4. The same idea of a tilted plate was used by Thomas A. Hughes in his Sidereal Sundial[3]. In Hughes' design the plate acted as a gnomon for setting a separate equatorial dial on which the time was indicated. In the present case, the tilted plate itself forms the dial. The date scale is inscribed around the circumference, with the date of the Summer Solstice at its lowest point. This ensures that the inclination of the plate is greatest at noon on the Summer Solstice (when the shadow of the gnomon falls at the lowest point of the disc) and least at the Winter Solstice.

Even in the crude form of the dial in Fig. 4, with only the months marked around the edge, the model can provide us with a real insight into the position of the ecliptic at any time, and how it alters through the day and through the year. Not being an astronomer, and thus being naïve in these matters, I always thought the ecliptic was the same as the daily path of the sun through the sky, as seen from here on earth. I was therefore surprised to find where the ecliptic really lies. The first point, which should be obvious but was not to me, is that the ecliptic as seen from here is always an arc of 180º, unlike for example the path of the summer sun, which covers at my latitude nearly 270°, from approximately North East through South to North West. Take next the movement of the ecliptic on one day. Fig. 5 below shows it at sunrise and sunset at the Vernal Equinox. That these two are different was a surprise enough. That the noon position is nothing like halfway between them was really puzzling. By noon the equinox has twisted round (due of course to the rotation of the earth), intersecting the horizon at about 116º on the east side and 64º on the west. This means that the mid-day sun is not even at the midpoint of the visible arc. As I thought about it, using Fig. 1 as an aid, and experimenting with the simple dial of Fig. 4, I eventually began to understand the reasons, and I found that very satisfying. It is only in this way that I have been able to start to come to terms with the behaviour of the Ecliptic!

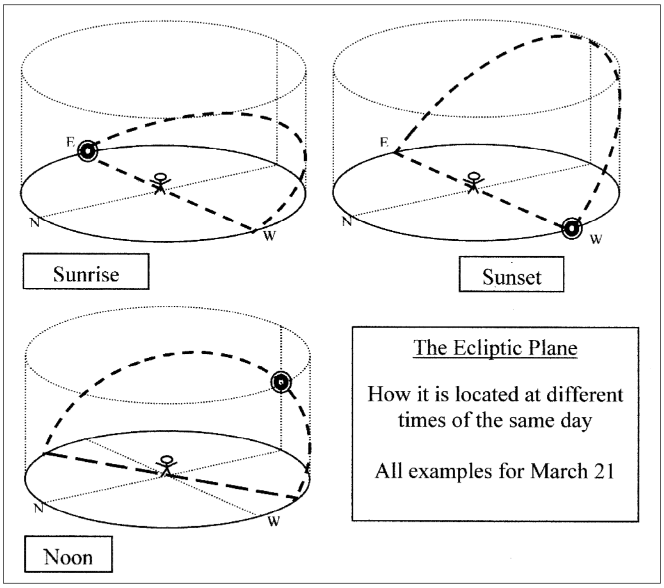


Fig. 5. The movement of the Ecliptic Plane.

Of course it is at night, when looking for the planets, that an amateur really wants to find the ecliptic. A more knowledgeable stargazer will recognise the constellations that mark out the zodiac, but for those who are unable to do this, the dial can help by night just as well as by day. With the simple version of Mark I, at say 11 pm on 15 December, just turn the dial until "DEC" points to where the sun would be at 11 am, and the disc will show where the ecliptic, or the zodiac, lies at night. In the Mark VI dial, described below, a more accurate position can be achieved by setting the cursor to 15 December and to 11 pm, and again the disc will show the plane of the ecliptic at that time.

(Since my first explorations into the behaviour of the ecliptic, I have acquired a modern version of an astrolabe, supplied with an excellent manual describing its use[4]. This also indicates the location of the ecliptic at any time, and is strongly recommended to anyone who is interested in taking this line of enquiry further. The astrolabe can be supplied personalised to your exact longitude and latitude. Two versions are available, one closely following the original format, and a modern one which replaces the zodiac signs with the corresponding dates, omits the unequal hours lines, and includes the equation of time. Both are well worth getting.)

THE EQUATION OF DATE

The dial shown in Fig. 4 has only the months indicated. To increase the accuracy, we could mark the dates evenly around the circumference, with each day taking an angle of (360/365.25)º. The dial would then indicate what I call the Apparent or Indicated Solar Date, where the year is divided into 365.25 Apparent Solar Days, in each of which the Sun appears to move an equal angular distance around the Earth. We of course use Mean Solar Dates, where again there are 365.25 Mean Days in a year, but each is of 24 hours duration. Apparent Solar Days, by contrast, last more than 24 hours at aphelion, and less at perihelion, when the Earth moves faster around the Sun.

By analogy with the Equation of Time, an Equation of Date can be used to derive the Mean Date from the Indicated Solar Date. Because the dial plate lies always in the plane of the Ecliptic, there is no effect due to the inclination of the Earth's axis. The only cause of deviation is the Earth's elliptic orbit, and the graph of the EOD is a simple sine curve (see Fig. 6). The zeroes are at perihelion and aphelion, and the maximum and minimum are mid-way between. The maximum correction is about 46 hours.

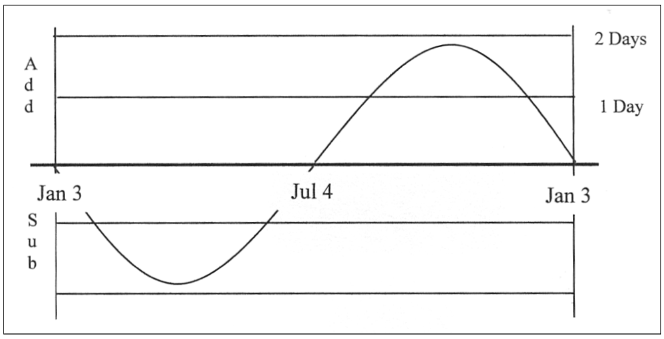


Fig. 6. Sketch of the Equation of Date. "Add" and "Sub" mean "Add to or Subtract from the Indicated Date". January 3 and July 4 are taken as the dates of Perihelion and Aphelion respectively.

The Equation of date can be applied in a number of ways.

1. A table or graph can be used to find the correction, plus or minus so many hours or days, depending on the Indicated Date.
2. Because the Indicated Dates are evenly spaced around the circumference of the dial plate, the plate can be rotated a short way in either direction against a calibrated concentric scale to apply the necessary correction.
3. The days can be spaced unevenly around the plate, closer together at aphelion, and more widely separated at perihelion, reflecting the actual angular position of each date.
4. With the days evenly spaced, the gnomon can be positioned not at the centre, but offset by one thirtieth of the radius towards the date of perihelion. The shadow of the gnomon then moves faster around the scale at perihelion, and slower at aphelion, in a way that correctly adjusts for the unequal angular separation of the Mean Days.
5. Alternatively but equivalently, we can leave the gnomon in the centre of the circle of the longitude scale, but inset a circular evenly spaced date scale with its centre shifted by one thirtieth of its radius towards the date of aphelion. This scheme was used on the Back Plate of many astrolabes. An example can be seen in Fig. 7.

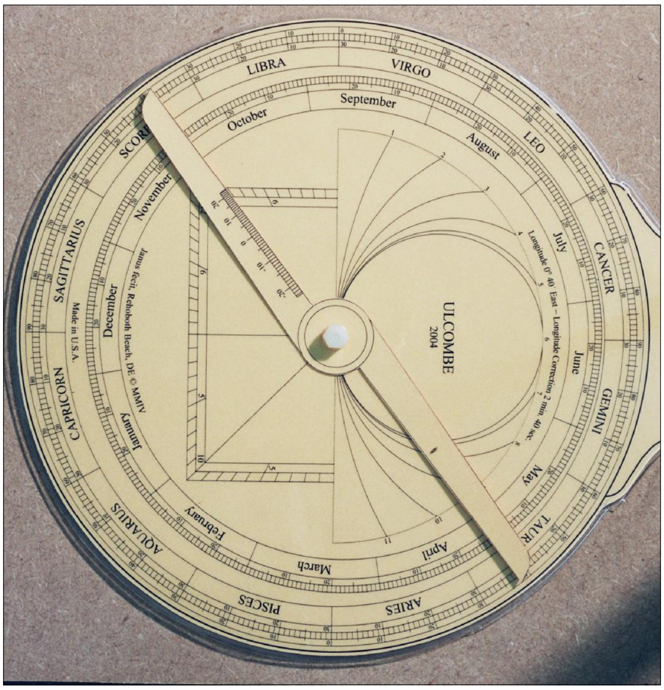


Fig. 7. Back plate of a "Janus" astrolabe, showing the offset calendar circle.

AN IMPROVED DESIGN

By the very nature of the dial in Fig. 4, when it is correctly set, there is no visible shadow of the gnomon on the disc, although its position can be assessed reasonably well by turning the disc to and fro around the best setting. One way of overcoming this problem is to use an adaptation of the Benoy dial principle (see for example Tony Wood's article[5] in the Bulletin for September 2003). If the central transparent cylinder of the Benoy design is replaced by a truncated cone, as can be seen in Fig. 8, it acts as a prism and bends the cusp of light down on to the surface of the dial plate.

Fig. 9 shows the dial in operation. The cusp is very bright and does not photograph well, but has a sharp point which can be read to about 1º. The dates are set out around the dial using Method 3 above, so that the Mean Date can be read directly. The innermost ring of figures shows the Ecliptic Longitude of the sun, and the outer ring shows the Zodiac, with the sigils positioned at the "first point" of each Sign.

Although the longitude scale is linear (and the Mean Dates are also extremely close to being linear), the dial is not equally accurate at every point. In fact of course the mechanism is no more than a device for measuring the declination of the sun, and as such shares the problem of traditional dials, arising from the fact that the declination changes very slowly around the Solstices. The Mark VI dial (Figs. 10 to 12) can be set with greater accuracy.

Fig. 8. Mark III - The adapted Benoy principle.

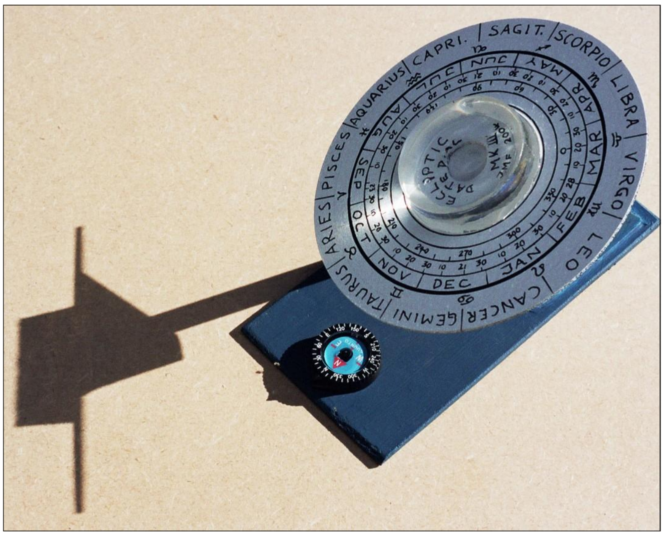


Fig. 9. The Mark III dial in use.

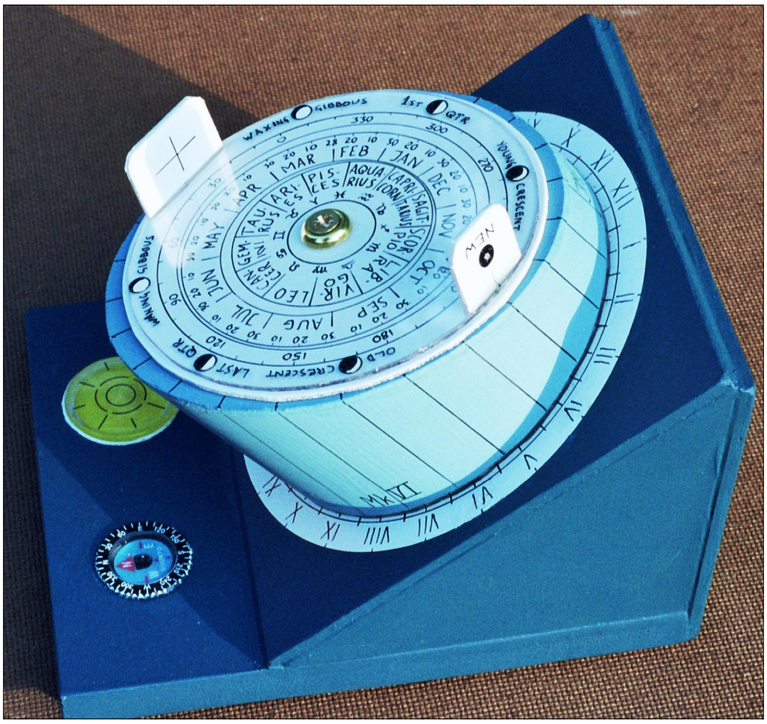


Fig. 10. Mark VI – Showing the cross-hairs setting, at about 3:00 pm GMT on October 22.

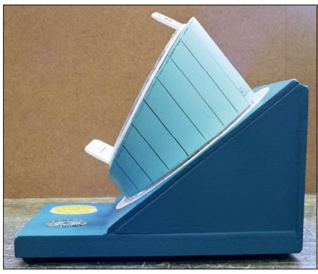


Fig. 11. Mark VI set to Noon at the Summer Solstice.

Fig. 12. Set to Noon at the Winter Solstice.

Mark VI has a base, to be set horizontally and pointing North. Fixed to this is a sloping support making an angle with the base equal to the co-latitude. Rotating on this sloping surface is an 'ecliptic wedge', consisting of a section of a right circular cylinder, with its top cut off so as to make an angle of 23.5º with its base. The ecliptic longitude is inscribed counter-clockwise around a circular scale set in the elliptical top of this wedge, and the Summer Solstice is now positioned at the highest point. The dates are inscribed on an offset circular scale inside the longitude scale by Method 5, so that they indicate the Mean Solar Date directly. Rotating freely on the upper surface of the wedge is a transparent disc with a cursor for reading the longitude and date scales. Fixed to the disc is a small plate containing a pinhole in line with the cursor, and cross hairs marked on a corresponding surface opposite.

Since the sloping support surface lies in the equatorial plane, it is provided with a Chapter Ring as as can be seen in Fig. 10, to allow the device to tell the time as well as the date. Guide lines on the elliptical top and curved side of the wedge allow the position of the cursor to be followed down to the Hour Scale.

With this design, it is no longer necessary to judge just when the sunlight is grazing the surface of the disc. Instead, the pinhole casts a spot of light onto the cross hairs, and by independently rotating the wedge (for vertical positioning) and the pinhole disc (for horizontal positioning) we can achieve considerable accuracy. The overall accuracy of course depends also on how well the dial has been made and set up, and I cannot claim any great skills in this direction. It would be nice to see a version made by a skilled mechanic, and to find in practice what accuracy could be achieved.

ACCURACY

Michael Lowne[6] has investigated the theoretical accuracy of the dial. He bases his estimate on the fact that the sighting device (the pinhole and cross-hairs) is very sensitive, and when the dial is left stationary, the daily motion of the sun can be detected in 20 or 30 seconds, corresponding to about a tenth of a degree. From this he has assumed a maximum setting error of 0.15º. The dial measures both the longitude and the declination of the sun. The longitude error is taken as 0.15°, or about 0.15 days. The declination changes at a maximum rate of 0.4º a day at the equinoxes, but hardly at all at the solstices. At the equinoxes therefore the maximum error is 0.15 / 0.4 , or 0.375 of a day, but it increases dramatically towards the solstices. Finally the drift of the date over the four-year leap-year cycle contributes a maximum error of 0.4 days (reading March 1 as February 29 in a leap year, and subtracting one day from every reading thereafter).

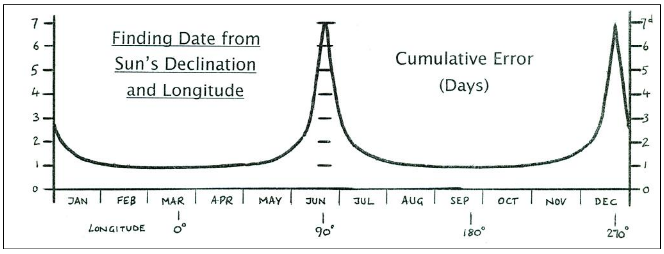


Fig. 13. Graph of the theoretical accuracy of the Mark VI dial.

Taking the worst case, where none of the sources of error cancel each other out, Michael sums the error factors and arrives at a maximum error of about plus or minus one day, for a couple of months each side of the equinoxes, rising sharply to possibly seven days at the solstices. The formula is

Maximum error in days:

$0.15 / (\sin \varepsilon \cdot \cos L) + 0.15 + 0.4$

The results are shown graphically at Fig. 13.

THE PATH OF THE MOON

As a final note, Mark VI can also be used as a Moon Dial with a difference. For we can make it tell not the time by the light of the moon, nor its phase on this day or that, but the path of the moon across the sky by night or by day. We all know how the full moon rides high in the sky on frosty winter nights, but is low on the southern horizon in summer. We can show this with the dial, and also explore when and why it is that the moon in its first or its last quarter goes sometimes high overhead, and sometimes low. The dial can tell us in what direction, and at what time, the moon will rise and set, and when it will be due south, and how high it will then be in the sky.

Fig. 14. Moon phases on the pinhole plate.

The moon is always within 5º of the ecliptic, so the ecliptic disc gives a good approximation to the moon's position. We mark the phases on the cursor plate – New Moon at the pinhole, towards the sun, and First Quarter, Full Moon and Last Quarter counter-clockwise around from there. If we then, for example, set the cursor to the Winter Solstice, and rotate the ecliptic wedge, we can see how the winter full moon moves around the sky on the highest part of the wedge, close to the orbit of the Summer Solstice sun. Set the cursor to the Vernal Equinox, and it is the first quarter moon that flies high in the spring, reaching its peak in the south just at sunset; while the last quarter moon, in the south in the early morning, "makes but winter arches".

CONCLUSIONS

A design has been shown which indicates directly the Celestial Longitude of the sun. From this the Mean Date can be calibrated on a linear scale. The dial is theoretically accurate as a calendar to about plus or minus one day for eight months of the year, and to about one week even at the solstices.

Various methods are shown for converting the Longitude to the Mean Date, and the way it was done on the earliest astrolabes is found to be probably the simplest and most elegant.

A second use of the dial is as a teaching aid to allow one to understand the movement of the Ecliptic Plane as seen from Earth, by night as well as by day. This is by no means obvious, and manipulating the disc can help to make it clearer.

The behaviour of the moon in its different phases, and at different seasons, can also be demonstrated. The Mk VI dial can show approximately the path of the moon, the direction and time of its rising and setting, and the time and altitude of its southing.

Finally it may be mentioned that knowing only the date, the device can act as an accurate sun compass and self-orienting sundial.

POSTSCRIPT

While this article was in press, I was told about the book by Jenkins and Bear[7] which also describes an "Ecliptic Dial". Theirs is not a sundial, and does not aim to show the current date or time, but it does show the paths of the sun and moon, and the location of the ecliptic plane. In fact it is the best presentation of the position and movement of the ecliptic that I know, and the book is very strongly recommended to anyone interested in following up on this aspect.

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THE DIALLIST'S APPRENTICE

I've a personal plan to be a Sundial man
A maker of world-wide renown.
I'll have all the gear, and not be too dear,
I'll make sundials for all round the town.

I've scanned Mrs Gatty till it drove me batty
The challenge was clear – to go forth!
So I copied a few, just like others I knew,
Though I'm never quite sure which is North.

I listen to talks, join in Mass-dial walks
And swallow the Bulletins whole.
If the Sun isn't shining I presume it's 'declining'
And still I confuse Zenith with Pole.

But I haven't a clue if my Due South is True
So my pedestals are never quite straight.
And when there's a tree where one ought not to be
I get into a state that I hate.

My numbers, they say, go round the wrong way
And often my gnomons are bent.
My motto's in Greek, which none of us speak,
And no one is sure what is meant.

But my best little dial has passed every trial
It's there on the church on the hill.
They've sited it well, above a large bell –
Just three ladders up and then out on the sill!

If you come down our street you'll know where to call
By the fifteen foot gnomon high up on the wall.
We don't open windows – it would break up the line.
A bit stuffy in summer, though in winter it's fine.

With my apprenticeship done, I'll be out in the Sun –
Setting dials, though I make this assertion:
If you don't like my fee, I'll make one for free,
Don't worry, I'm that sort of person.

Elm S Slows

NEWLY DISCOVERED SAXON DIALS
AND THEIR PROSPECTS FOR THE FUTURE

TONY WOOD

The status of Saxon dials is a minefield. Although forming a small (about thirty) and distinct corpus sufficient doubts about specific dials exist making it difficult to assign them definite Saxon status. The Society thinks it better to record them in both the Fixed Dial Register and Mass Dial Register on vague stylistic grounds rather than chronological ones. They date from the eighth century (Bewcastle, Cumbria) to the eleventh and seem to have disappeared with the Norman Conquest. It would appear that late Norman church buildings made no provision for timekeeping by sundial and so scratch dials came to be made, relatively crude carvings compared with the earlier Saxon dials. It has been suggested[1] that these Saxon dials appeared on churches following the rebuilding or demise of early abbey or priory foundations and certainly the dial stone would have been a separate artefact, easily movable and possibly originally mounted in a wooden based structure as not all Saxon foundation buildings were made of stone.

The dials here constitute possible new discoveries or recognition of Saxon status to a previous 'mass dial'.

Fig. 1. St Michael & St Martin, East Leach Martin, Gloucs.

1. St Michael and St Martin, Eastleach Martin, Gloucestershire.

The adjoining parishes of Eastleach Martin and Eastleach Turville managed to build their churches on opposite banks of the river forming the parish boundary and so have finished up a hundred yards apart with a delightful walk over the bridge in a picturesque village. Martin is now redundant and Turville is the parish church for all. Thanks to my sharp-eyed walking companion who guides me round the Cotswolds 'What's that up there?' revealed a Saxon dial amongst the gloomy porch rafters and timberwork (Fig. 1). Somewhat defaced by a socket hole, it is clearly Saxon and seems not to have been previously reported. The mental note to return and photograph was not fulfilled for over two years and then required a considerable number of exposures whilst perched on a ladder trying to avoid beams and at the same time organising some light up there over the door within the porch.

The dial is typical Saxon with five radial lines originating from near the top of a relief circle and the lines being crossed at their ends. It is damaged and worn; the socket hole mentioned above must have arisen from an earlier porch construction. Here we have possibly the fifth Saxon dial in the county; those at Daglingworth and Saintbury are well known and the Coates and Stowell dials are also probably Saxon.

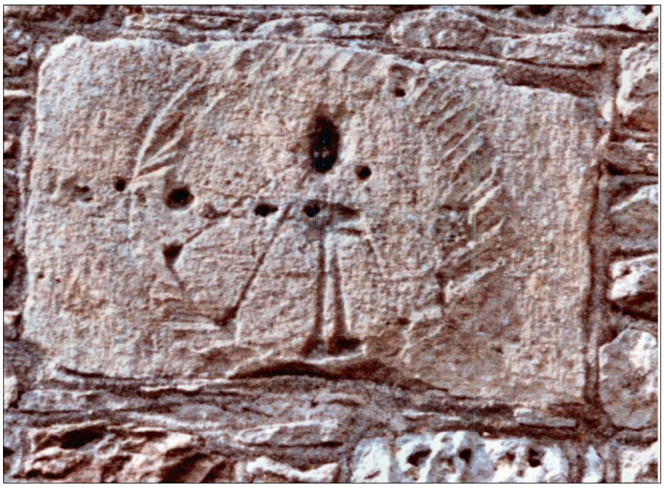

Fig. 2. St Denys, Stanford-in-the-Vale, Oxon.

2. St Denys, Stanford-in-the-Vale, Oxfordshire (previously Berkshire).

This dial is well known and photographed (Fig. 2). At least three separate reports have been sent in by members and Ted Hesketh's archive report from the 1970s notes that the dial is 'quite large'. It is indeed somewhat larger than most mass dials but it is by examining the design that one concludes that its origin may be Saxon.

Photo: I Butson

Fig. 3. All Saints, Shirburn, Oxon.

There is a complete surrounding circle, in relief, but almost chiselled away – it looks like an attempt to obliterate a more pronounced relief circle. Was this an example of superstitious removal of a 'magic symbol'? An alternative scenario might be that the relatively ornate Saxon dial suffered the same fate as stained glass and statues in the Puritan era. The gnomon hole is again near the top of the circle, not central and there are five lines still visible. The whole dial however has been subject to the alterations which involve large holes horizontally across, constituting a 'four holes in a row' type of mass dial using the original gnomon – at least that is one interpretation. Currently it is placed to the left of a buttress which puts it in shadow for the greater part of the morning. It must have been moved from another location; again, did it come from a monastery, abbey or priory?

3. All Saints, Shirburn, Oxfordshire.

Mass dials with mottoes are unknown so the arrival of Ian Butson's report on the dial at Shirburn (Fig. 3) aroused interest and suspicion. This rather large (600mm diameter) and faint dial has two circles at the perimeter with the remains of an inscription in Latin '- - ET SVNT ·'. The markings comprise a central 'hole' with a horizontal line through, a noon line and two lines marking 30° sectors in the lower right quadrant. With a little imagination similar lines can be detected lower left. The Daglingworth and Saintbury dials in Gloucestershire have a similar horizontal diameter and divisions.

The only other 'motto round the edge' dials known are at Stow in Lincolnshire (small fragment) and Orpington in Kent (Fig. 4) where a large fragment of dial has an Anglo-Saxon inscription similarly placed and also Latin and runic characters on the dial face. In the north of England are Saxon dials with inscriptions, but again in Anglo-Saxon rather than Latin and alongside the dial rather than round the perimeter.

Although Saxon dials are reasonably distinctive there is quite a variation in style with some having the gnomon dis-

Fig. 4. All Saints, Orpington, Kent.

Photo: R Sylvester

Fig. 5. St Cuthbert, Bewcastle, Cumbria.

placed above the centre of the circle whilst others have a central hole and diametral line. The relief carving of the perimeter is common but not universal and another small group of Saxon dials is distinguished by ornate carvings. The division of the circle is usually by a small number of radial lines but the very early dials of Bewcastle, Cumbria, (Fig. 5) and Dalton-le-Dale, Co. Durham,[2] have twelve divisions. The corpus is well established and it should now be possible to establish stylistic groups related in time or geography.

A note on the dial at All Saints, Orpington in Kent.

The dial was uncovered in 1958 and is now 'cemented in place, unfortunately upside-down, in a new arcade'[3]. The main interest is in the three inscriptions, viz:-

i) Runic characters
ii) Latin
iii) Old English

The three Runic characters are not decipherable in any meaningful sense, the Latin word could be 'OROLOGIVM' or 'ORALOGIUM' i.e. 'sundial' but the central letters are missing so this is speculative. The Old English inscription is clear and extensive around the perimeter. Dr Page, (Cambridge) translates it[3] as 'to tell/count and to hold for him who knows how to seek out how'.

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ITALY EXTRA

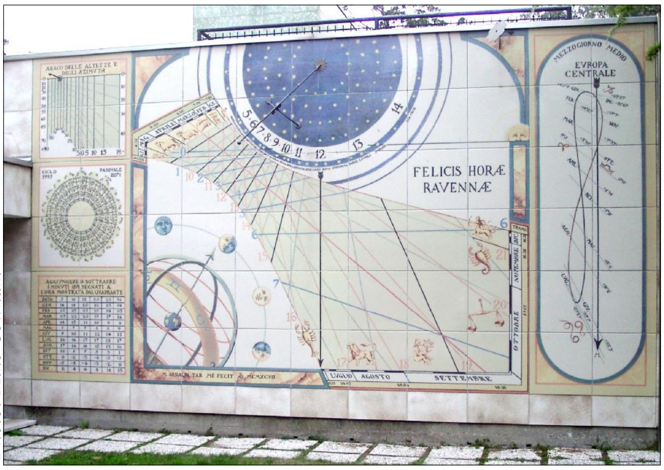

Photo: Mike Cowham

Planetarium dial by Mario Arnaldi, Ravenna.

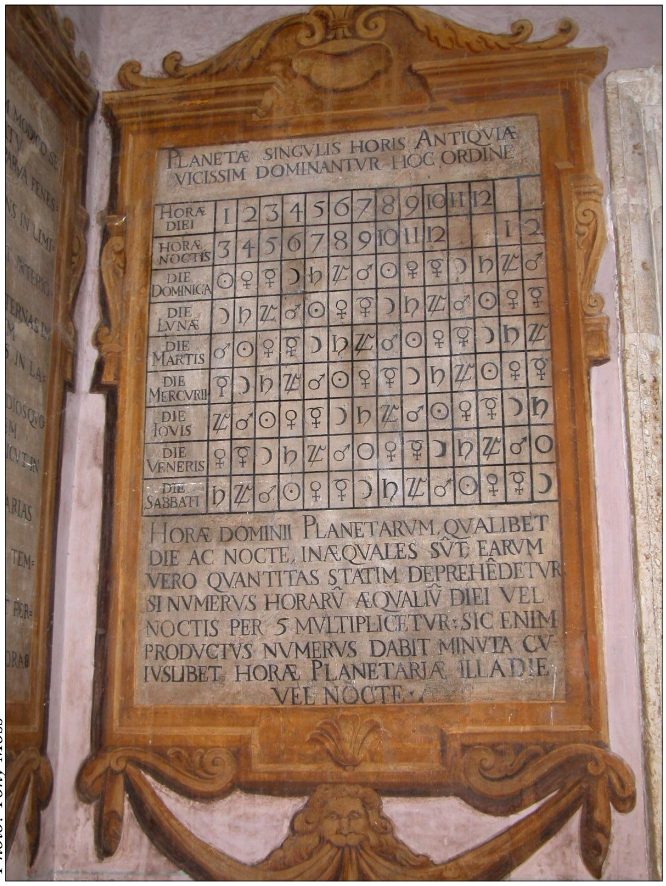

Photo: Tony Moss

Planetary hour table at the Palazzo Spade.

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