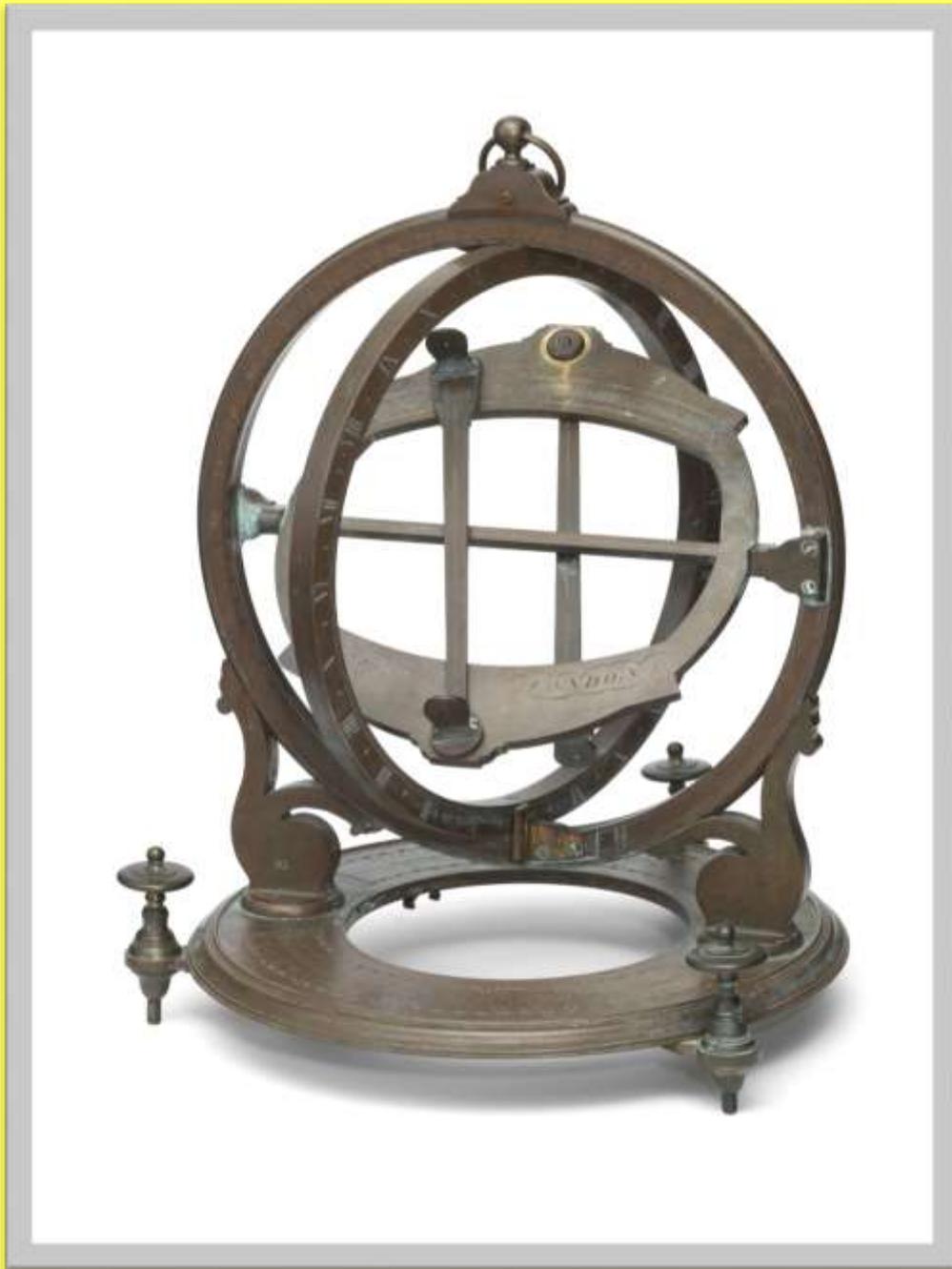
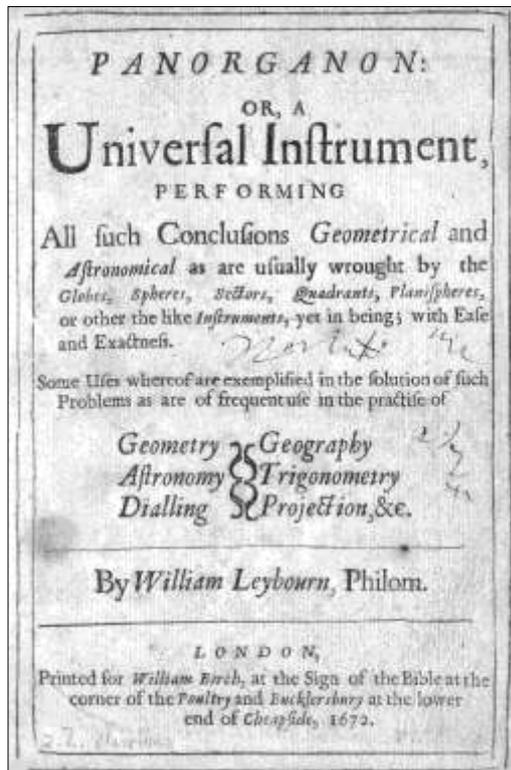
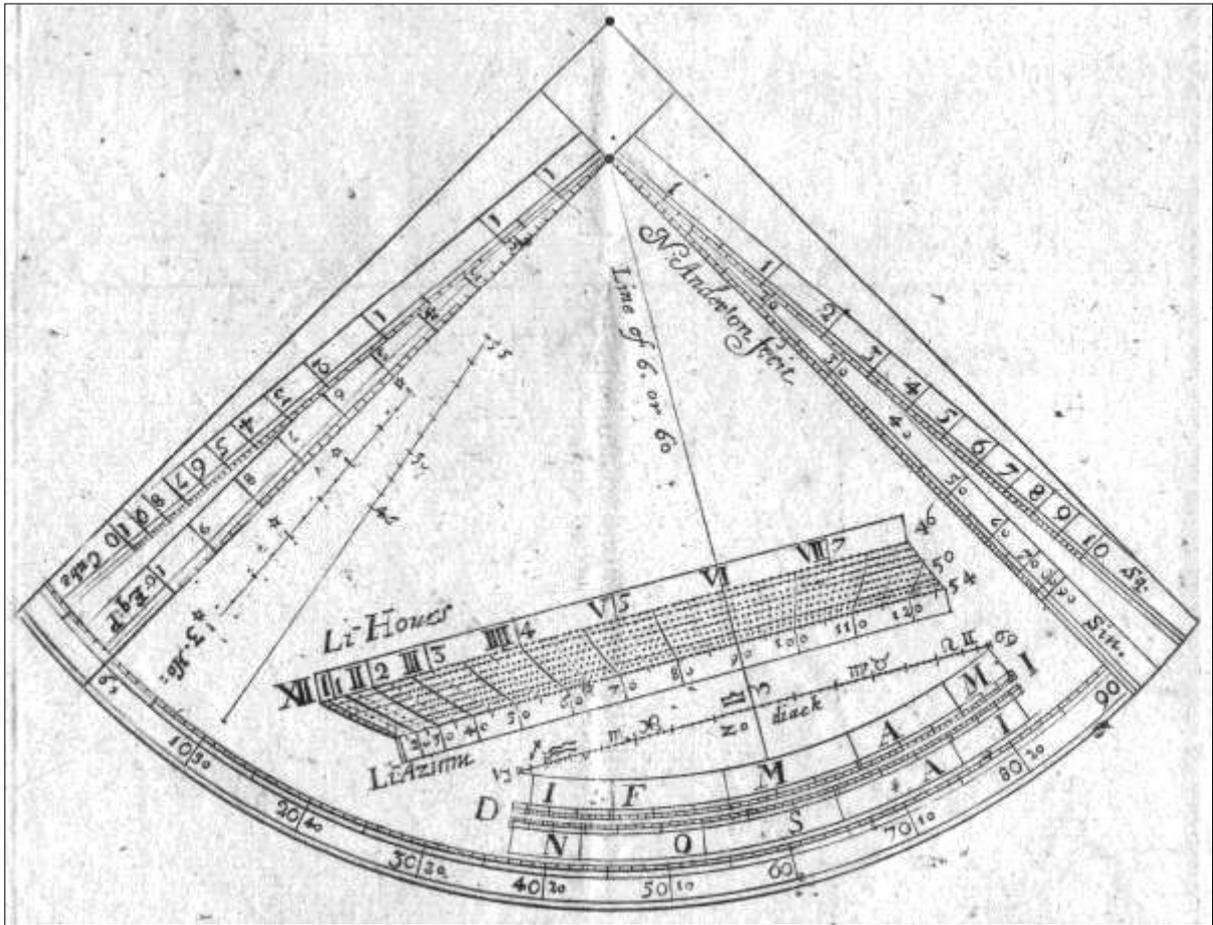


The British Sundial Society  
**BULLETIN**



VOLUME 29(iii)  
September 2017



The illustration above and the title page on the left are from the 1672 book by William Leybourn describing the Panorganon, a form of quadrant, and its many uses, including telling the time from the altitude of the sun.

From the point near the top of the instrument there would have been a plumb line with a bead that could be set as required. Its reverse side has additional scales for use with various stars.

The book has 126 pages and includes a full-page portrait of William Leybourn at the front.

Details of this, and many more old books, are now on the BSS website at

<http://sundialsoc.org.uk/publications/old-sundial-books/>

Mike Cowham

**Front cover:** An interesting standing ring dial by J. Sisson, described by David Hawker on pages 41–3. Photo copyright Christie's Ltd.

**Back cover:** The gnomon of a new dial in Mullaghmore, Co. Sligo, Ireland, itself part of a memorial to those who once lived in a deserted village nearby. For details of the memorial's construction and the fascinating and touching story behind it, see Michael Harley's article on pages 46–7. Photo copyright Joe McGowan.

# BULLETIN

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### EDITORIAL

There are many excellent articles in this issue of the *Bulletin*, beginning with Woody Sullivan's account of using my favourite Italian *meridiana* in a novel way.

A number of articles in recent issues have stemmed from enquiries made to the BSS Help and Advice service. In the current issue, an original enquirer, Brian Huggett, has written about a nicely crafted mean time equatorial dial that he has made. It is always good to receive an article from a new member and we look forward to many more.

Sue Manston's article on a slate dial by Griffith Davies began as a reply to another Help and Advice enquiry. Most of what we know about this dial is based on an engraving

of it made by a professional engraver who was clearly not too knowledgeable about delineating sundials.

Some articles are based on talks given at Conferences and Newbury meetings and we encourage speakers to send the editorial team their write-ups too so that the whole membership can benefit.

David Brown's account of a 'A Missed Opportunity' serves as a reminder that photographs of sundials spotted while on holiday can often be turned into articles for the *Bulletin*. In this case, the photographs were taken from a canal that he was travelling along.

*Frank King*

# MODERN OBSERVATIONS USING THE 1702 MERIDIAN LINE OF THE BASILICA OF SANTA MARIA DEGLI ANGELI E DEI MARTIRI (ROME)

WOODRUFF SULLIVAN, MALLORY THORP,  
GUADALUPE TOVAR and JENNIFER LOOK

*This article is based on the talk given by the first-named author at the 2016 BSS Conference in Liverpool.*

The giant meridian lines that can still be found in a handful of major cathedrals in Italy and France have long fascinated the first author. At solar noon an aperture high in the south wall of each church admits a spot of sunlight that crosses the meridian line at different locations dependent on the season. In the Spring term of 2015 the opportunity arose to lead (together with art historian Lane Eagles) a program of studies in Rome for seventeen undergraduates of the University of Washington, Seattle. Through lectures, readings, and visits to field sites in and near Rome, we studied the many interactions among art, science and religion over the centuries. Students also learned about sundials through constructing and using their own personal dials.

In particular we studied the history, art, architecture and astronomy of Santa Maria degli Angeli e dei Martiri (latitude 41° 54' 11" N, longitude 12° 29' 51" E), a unique basilica that arguably has the finest extant meridian line of them all.<sup>1</sup> In this church each student observed one or more solar noons over the term. Once back in Seattle, the authors analysed these and other observations in order to determine accurately the obliquity of the ecliptic (the 'tilt' of the Earth's axis) and the expected difference from values measured three centuries earlier. Also determined were accurate values for the length of the year and the time of vernal equinox, historically important for determining the date of Easter.

## Historical Setting

### *Giant meridian lines*

During the 17th and 18th centuries many meridian lines were constructed in churches, palaces, mansions and astronomical observatories.

Constructing them is straightforward in principle. A small aperture high in a roughly south-facing wall or in a ceiling admits a spot of sunlight. When the sun is highest in the sky each day, at solar noon, mark on the floor where the solar image falls.<sup>2</sup> As the seasons pass and the sun moves north and south in the sky, the series of marks will describe

a north–south line, each point on the line corresponding to two dates of the year, one between the winter and summer solstices as the sun moves north, and the other during the following six months. Next make the north–south line permanent by laying a brass strip in the floor and label it with signs of the zodiac as well as special calendar dates.<sup>3</sup> The line can be further marked with more scientific quantities such as the sun's altitude angle and declination, or a linear scale in metres or other units. Now in successive years one can determine calendrical information from *where* on the line the solar image crosses, as well as the precise time of solar noon by *when* it crosses.

The motivation to build large meridian lines in churches was first to establish calendrical quantities such as the length of the year and the time of vernal equinox, both vital to the Church for establishing the changeable date of Easter and other religious holy days.<sup>4</sup> But at the same time, one could study more subtle effects such as atmospheric refraction, or the obliquity of the ecliptic, which was suspected to be slowly changing (see the Analysis section). In addition, the *time* of transit provided an accurate measure of the equation of time and could be used daily to set local civil time, as well as the times for services.

Although most meridian lines were never used for any scientific work, created rather for prestige or controlling civil time, others contributed significantly to the astronomical knowledge of the day. The 1999 book *The Sun in the Church* by John Heilbron is the definitive historical study of meridian lines in churches.<sup>5</sup> The first one of note was built by Paolo Toscanelli (1397–1482) in 1468 for the Cathedral of Florence. The location of its aperture, fully 90 metres up in the famous dome, means that the solar image reaches the floor only near the summer solstice. The most scientifically fruitful was built in the Bologna Basilica of San Petronio in 1655 by the astronomer Giovanni Cassini (1625–1712), before he moved to Paris for the bulk of his career. Another notable extant meridian line is that of St Sulpice church in Paris, built in 1743 by Pierre Le Monnier (1675–1757). Though simple in design, the scale, precision, and elaborate artwork of these meridian lines reveal the admiration church officials had for the science of their time.



Fig. 1. Looking towards the northwest transept of Santa Maria degli Angeli e dei Martiri, Rome. The 30-metre high vaulted ceiling is a remarkable remnant of the original Diocletian baths of AD 306. Photo: Sullivan.

### *Santa Maria degli Angeli e dei Martiri*

The beginnings of Santa Maria degli Angeli e dei Martiri in Rome are either AD 306 or 1561, depending on one's point of view. At the latter time Pope Pius IV (reigned 1559–65) authorized the construction of a church on the site of the ruins of the ancient huge baths (~300 metres on a side!) built by the Emperor Diocletian and dedicated in 306. The repurposing of this site expressly illustrated the triumph of Christianity over Roman paganism – the first Emperor to convert to Christianity was Constantine, only two decades after Diocletian. The name of the basilica, referring to 'martyrs', was to honour the many slaves who died building the baths.

The Pope hired none other than Michelangelo (1475–1564), then aged 86, to design the basilica. Ever the innovator, he incorporated surviving portions of the ancient baths into his design. The result was that 30-metre high vaults and huge hallways (only a small portion of the former baths) were transformed into a majestic nave and transept (Fig. 1).<sup>6</sup> He also chose to make the church's exterior the most radical in Rome by keeping it unadorned and looking like an ancient ruin, as it still does today.<sup>7</sup>

### *Bianchini's meridian line*

A century after the Gregorian calendar reform of 1584, various experts felt that it still needed fine-tuning. Pope Clement XI (reigned 1700–21) thought that his prestige could be enhanced if Rome acquired its own large meridian line. He thus commissioned the polymath Francesco Bianchini (1662–1729), a sometime colleague of Cassini's,

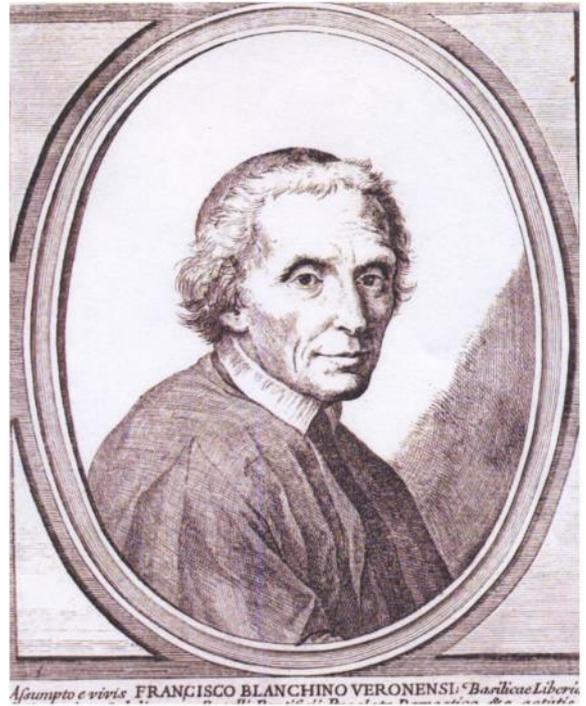


Fig. 2. Francesco Bianchini (1662–1729).<sup>11</sup>

to build one in whichever Roman church he found most suitable. Bianchini (Fig. 2) considered even St Peter's, but its scale was too large. He finally chose Santa Maria degli Angeli because its geometry worked and its 1400-year history guaranteed that its walls had completely settled.



Fig. 3. Looking south along about two-thirds of the length of the meridian line. The southern aperture (close-up in Fig. 5) can be seen as a dark feature cut through the architrave, to the lower right of the windows at the top; its height is 20.3 metres above the floor. Photo: Sullivan.

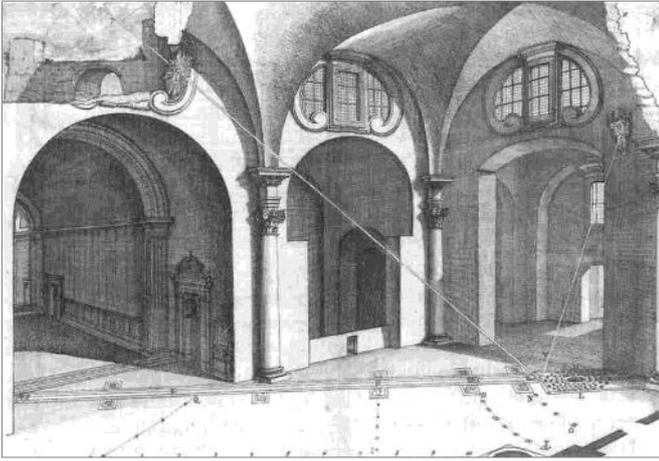


Fig. 4. Schematic diagram of the basilica, showing the light paths from both the southern aperture (to the right) and the northern (Polaris) aperture.<sup>10</sup>

Over a remarkably short time in 1702 Bianchini built what many contemporaries hailed as the most beautiful, useful and interesting meridian line in Europe (Figs 3 and 4). The aperture<sup>8</sup> is at a height of 20.344 metres on the south wall (Fig. 5), which then means that the brass meridian line (of width 3.4 cm within a broad marble band) has a summer-to-winter length of 37 metres as it slices across the transept. Fig. 6 shows the basic geometry of how the solar image falls on the meridian line over the year, the huge scale of this scientific instrument allowing a very accurate measure of solar declination. The meridian line is not



Fig. 5. The southern aperture. A major revision of the basilica interior in the mid-18th century introduced an architrave, complete with its accommodating cutout section. Light from the sky can just be seen through the aperture (diameter about 2–4 cm). Photo: Sullivan.

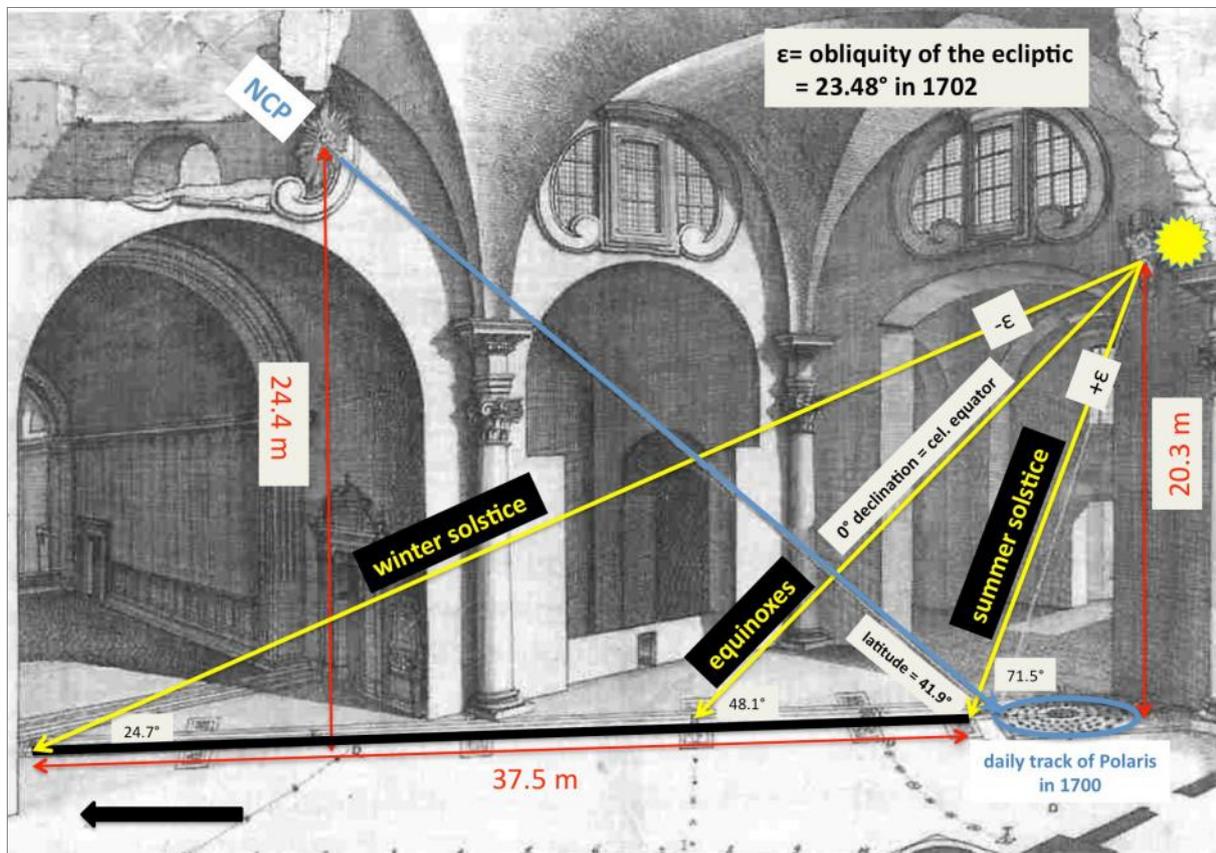


Fig. 6. Explanatory features (overlaid on Fig. 4) illustrating the usage of the two apertures and the annual change in declination of the sun. The North Celestial Pole (NCP) aperture allowed light from Polaris (shown as a blue line) to describe a daily ellipse on the floor as indicated.

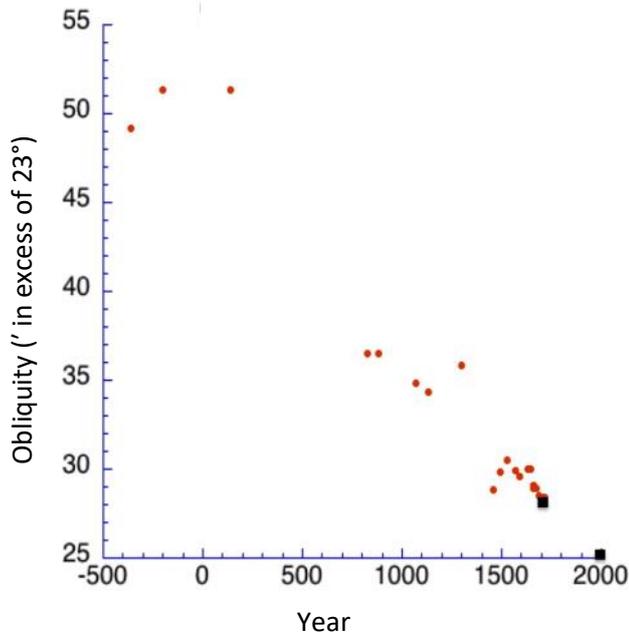


Fig. 7. Historical measurements of the obliquity of the ecliptic, as known circa 1700. The black squares refer to Bianchini's 1703 value and the result of the present study. Plot based on tables in Heilbron.<sup>5</sup>

sequentially labelled with the dates of the year, but does feature ornate panels depicting the constellations of the zodiac, two scales related to the angle of the noontime sun from the zenith, and a half-dozen plaques commemorating various events, each at the correct position for the date of the event. The earliest is dated 20 August 1702, when the Pope himself came to inspect his new meridian line.

Besides the meridian line intended for solar observations, Bianchini added several unique features. The first was the ability to set up a small refractor telescope along the line, in order to measure accurately the altitude angle and transit times not only of the sun, but also of stars and planets. Bianchini could observe the brightest stars even in the daytime to determine accurately their celestial positions with respect to the sun.<sup>9</sup>

The movable small telescope could also observe *to the north*, specifically the star Polaris, through a second high aperture facing north (Fig. 6). This enabled a measurement of latitude, and was the inspiration for a unique set of nested ellipses marked on the floor near the southern end of the meridian line (Fig. 18; see the section on Polaris).

Over the first 15 months of the meridian line's existence (September 1702 to December 1703), Bianchini observed everything he possibly could: 53 days of solar transits, bright stars such as Sirius and Arcturus, planets, Jupiter's moons, eclipses of the moon (but not on the meridian), and Polaris to the north. He quickly published these observations in a book dedicated to the Pope,<sup>10</sup> concluding that the best overall value for the length of the year (as determined much earlier by others) was in accord with that adopted by the Gregorian reform, as well as obtaining a precise value



Fig. 8. The students and instructors of the Program in the Spring of 2015, posing in front of St Peter's dome while visiting the Tower of Winds in the Vatican. Photo: Tour guide.

for the obliquity of the ecliptic. He and others continued to use the meridian line for much of the 18th century.<sup>11</sup>

#### *The obliquity of the ecliptic — does it change over time?*

Astronomers in the 17th and 18th centuries argued about whether or not the obliquity of the ecliptic  $\epsilon$ , the 'twenty-three and a half degree' tilt of the Earth's axis with respect to the plane of the Earth's orbit, was in fact changing over the centuries. If indeed it was changing, what was causing the change, and when might it stop, or reverse its course? The data in hand were as shown in Fig. 7. One had three groups of values: ancient authorities such as Ptolemy at roughly  $23.8^\circ$ , Islamic astronomers ca. AD 1000 at  $\sim 23.6^\circ$ , and more accurate and numerous recent measures at  $23.5^\circ$ . At face value it looked like a significant decline, but how much stock should one put into the comparatively crude pre-telescopic values? And why were late 17th century astronomers disagreeing amongst themselves as to the correct contemporary value? Some even trusted meridian lines more than the telescopes of the day. Not until the end of the 18th century did a consensus develop that the decline was real, that it was due to the gravitational effects of Jupiter and Saturn on the bulge of the Earth's equator, and that its value was  $47''$  per century.<sup>12,13</sup>

One key motivation for our own observations at Santa Maria degli Angeli was to see whether or not we could determine the early 21st century value of  $\epsilon$  with sufficient accuracy actually to detect its decline since the time of Bianchini three centuries before. We of course knew that the decline has been  $2.4'$ , but did not know beforehand whether or not we could detect so small a change.

#### **Our Observations**

During the Spring of 2015 our class (Fig. 8) observed as many transits of the solar image at Santa Maria degli Angeli as schedules and weather would allow. An

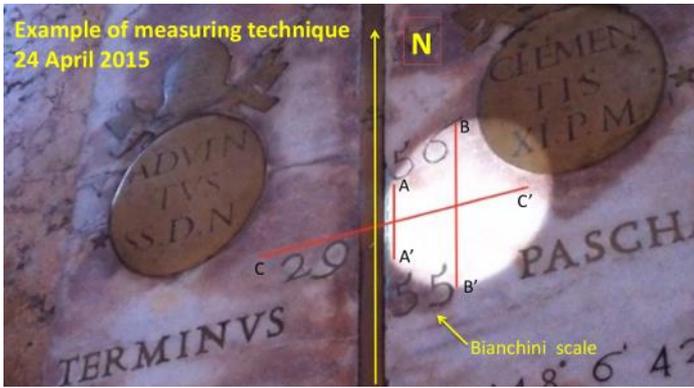


Fig. 9. A frame from our movie of 24 April 2015 to illustrate the image analysis technique for solar image position. During our Spring term the solar image typically moved with a speed of  $\sim 9$  cm/min and had a width of  $\sim 20$  cm. The scales of Bianchini can be seen: on the left '29' refers to a solar zenith angle of  $29^\circ$  and on the right '55' refers to  $\tan(\text{zenith angle}) = 0.55$ . The entire 3-minute movie can be found by searching within YouTube for 'obliquity data' (including the inverted commas).

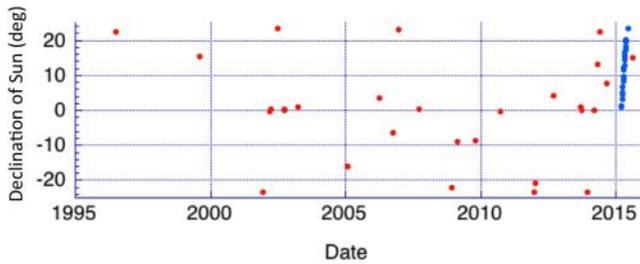


Fig. 10. The 54 observations in our dataset, scattered over the period 1996–2015: red points are taken from images by others and blue are from our campaign in Spring 2015.



Fig. 11. Examples of other images used in our study. Note the different sizes and shapes and angles of view. The image size at the winter solstice is  $\sim 110 \times 45$  cm. Credits: 21 December 2013 and 25 April 2014 (C. Sigismondi, YouTube); 4 June 2014 (anonymous); 20 April 2015 (a frame from one of our movies).

observation consisted of a 2–3 minute movie at solar noon of the moving solar image. Fig. 9 shows a frame from a typical example of these movies; the full movie can be found by searching within YouTube for 'obliquity data' (including the inverted commas). In the end we gathered 23 days of usable data over the period 23 March to 19 June 2015.

In order to supplement our springtime dataset, we scoured publications and the Internet for any usable still images or movies of meridian solar images. These images were of variable quality, but usually satisfactory. Altogether this yielded 31 more observations, for a total of 54 over the span 1996 to 2015 (Fig. 10).<sup>14</sup>

For a given day we measured the declination of the sun by the position on the meridian line where the solar image crossed.<sup>15</sup> Because the images are taken from a wide variety of angles with respect to the meridian line, our usual method of image analysis used the facts that the spot of light (a) is elliptically shaped,<sup>16</sup> and (b) moves perpendicular to the meridian line at solar noon.<sup>17</sup> In Fig. 9 lines AA' and BB' span the solar image in two different places and are constructed parallel to the meridian line.<sup>18</sup> The line CC', the perpendicular bisector of both AA' and BB', then intersects the meridian line at the desired location. In practice this was done for two images (when available) on each day, on either side of the meridian line; the two results were then averaged. Fig. 11 gives examples of images taken by others at different locations on the meridian line, on various dates from a variety of angles; note the different shapes and brightnesses of the images.

Bianchini supplied us with a linear scale all along the meridian line<sup>19</sup> and with our method we estimate that we could measure a solar image's centre to  $\pm 4$  mm, which corresponds to an error of  $\sim \pm 0.6'$  at the summer solstice, decreasing to  $\sim \pm 0.1'$  at the winter solstice. The measured solar declination for a given day was then found from the algorithm shown in Fig. 12. Note that we had to correct (as

### A Sample Datum: 24 April 2015

Basic equation on the meridian:

$$\text{declination of sun} = \text{latitude minus solar zenith angle}$$

latitude of Santa Maria degli Angeli =  $41.903^\circ$

measured transit position on the line: 55.60 on Bianchini's scale

$\tan(\text{zenith angle}) = 0.5560$

solar zenith angle =  $29.074^\circ$

refraction correction to zenith angle =  $+0.0087^\circ$

**measured declination of sun =  $+12.820^\circ$**

compare with known value =  $+12.837^\circ$

difference =  $0.017^\circ = 1.0'$

Fig. 12. The algorithm for determining solar declination from a measurement on the meridian line, starting with data from Fig. 9.

did Bianchini, using values measured by Cassini) for the fact that light is bent downwards as it refracts through the Earth's atmosphere. This means that any object viewed through the atmosphere appears higher in the sky (larger altitude angle) than it really is. In Rome the noontime sun altitude varies from  $25^\circ$  in the winter to  $72^\circ$  in the summer, which means that the solar image is 'lifted' by amounts between 2.2' (winter) and 0.4' (summer). Although the exact amount of refraction depends on temperature and pressure, adopting standard values of  $20^\circ\text{C}$  and 1.0 atm was adequate given other errors in our data.

Fig. 13 plots the difference for each day between our measured solar declination and the known value for the same day. The standard deviation of the dataset is 0.9', which provides a good estimate of how well we were able to measure declinations. This error arises from many possible causes, but only about one-half of it is due to the determination of the centre of the solar image. The remainder is probably due to the actual geometry of the aperture/wall/floor/meridian line differing from what we assumed. In addition, there are unfortunately no 'tick marks' on the line, only the large, ornate numerals alongside (Fig. 9). We chose the *centre* of each numeral to be the exact location to which it referred, but there could well be individual or systematic errors in where these numerals are placed.<sup>20</sup>

Sigismondi has investigated many properties of the meridian line;<sup>21</sup> for instance, he finds that its direction deviates 4.5' to the east of north. Although important for any timing observations, this has minimal influence on the north-south locations of transit positions. More problematic is that over the past two decades the exact position of the aperture has unfortunately been slightly

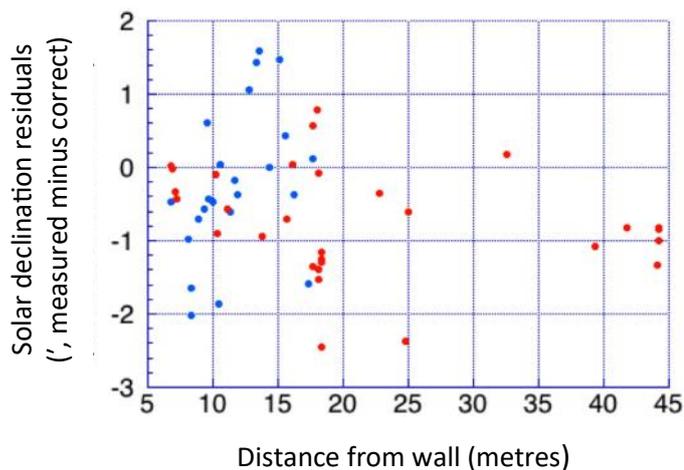


Fig. 13. The difference between our determination of solar declination and almanac values, versus distance from the wall along the meridian. The leftmost data correspond to summer solstice at the southern end of the meridian line and the rightmost winter solstice at the northern end; the equinoxes occur at a distance of 18.2 metres from the wall. Red points are taken from images by others and blue are from our campaign in Spring 2015.

changed by various persons! An examination of our residuals (measured declination minus correct declination) as a function of time over the years, however, shows no detectable correlation with the history of these changes. In the end, as often with experiments, all we can say is that there exist various known and unknown causes for our measurement errors.

### Analysis

Every year the solar declination has a *roughly* sinusoidal variation with period of one year, starting at the vernal equinox, and with an amplitude for the curve equal to the obliquity of the ecliptic. The actual mathematical formulation for the annual variation, however, is complex. The formulation accounts for the obliquity, the elliptical shape of the Earth's orbit, and the Earth's variable speed along that orbit through the seasons. A series of six trigonometric equations allows one to calculate, for any specified date, a predicted declination of the sun to an accuracy of much better than 1'.<sup>22</sup>

Having this mathematical form of how declination through a year varies (our *model*), we then asked the question: for our set of 54 measured declinations over a period of 19 years, which 'best-fit' values of the following three quantities minimize the differences between the model and the data?

- P the mean length of the (tropical) year (from one vernal equinox to the next)
- $T_{VE}$  the exact time of the vernal equinox (when the solar declination =  $0.00^\circ$ )
- $\varepsilon$  the obliquity of the ecliptic

A statistical technique called nonlinear least squares (specifically the Levenberg-Marquardt algorithm) allows one to solve simultaneously and optimally for the above three quantities even for a dataset such as ours with very non-uniform intervals between observations. Fig. 14 shows

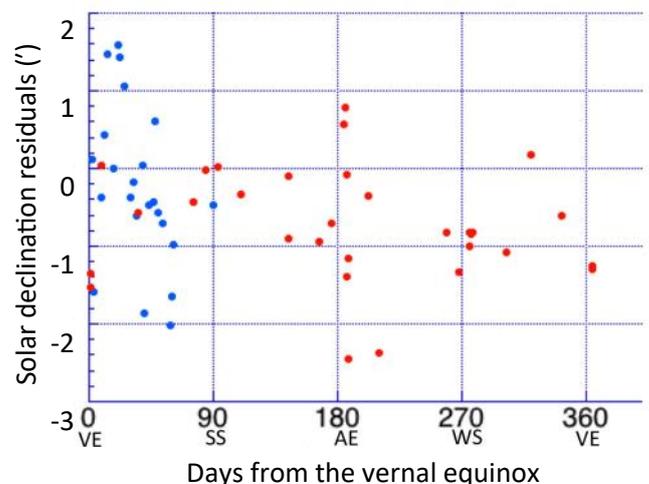


Fig. 14. The difference between our measurements of solar declination and the declinations of the best-fit model versus days from equinox. The equinoxes and solstices are indicated. Red points are taken from images by others and blue are from our campaign in Spring 2015.

the residuals between our best-fit model values of declination and the 54 measured data points. The error estimate (standard deviation) of our best fit model is  $\pm 1.1'$ .

Our best-fit solution is:<sup>23</sup>

$P$  365.2421832 days =  $365^d 5^h 48^m 56^s \pm 136^s$ , which is 11 seconds longer than today's accepted value (and 5 seconds less than Bianchini's adopted value)

$T_{VE}$   $1^s \pm 28^s$  earlier on average than the accepted values for each of the years

$\epsilon$   $23.42274^\circ = 23^\circ 25.36' \pm 0.26'$ , which is  $0.9'$  smaller than the accepted value for the current epoch

Using our best-fit model, all of the 1996–2015 years are folded together in Fig. 15 over one year starting at the vernal equinox; the discrepancies (of typical size  $\pm 1'$ ) between the model and the data points are much smaller than the size of the dots in the plot.

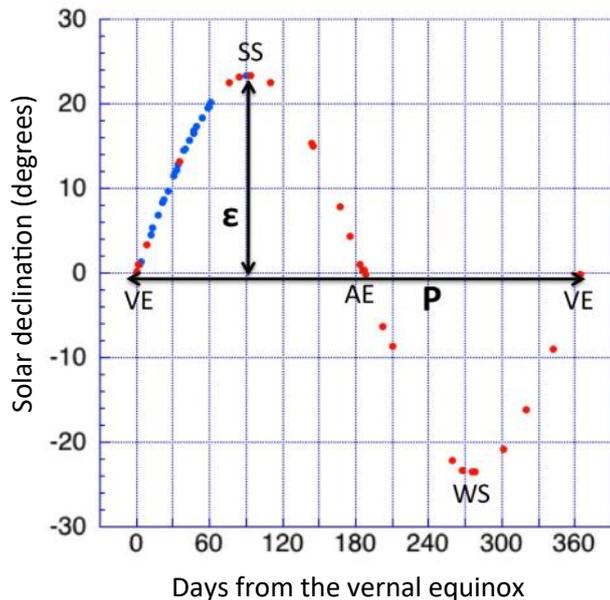


Fig. 15. Solar declinations versus days from equinox (both best-fit values), starting at the vernal equinox. The 54 data points over 19 years have been folded into a single year according to the best-fit value for the length of the year (the time span from one vernal equinox to the next, shown as  $P$ ). The amplitude of the quasi-sinusoidal curve is the obliquity of the ecliptic,  $\epsilon$ . Red points are taken from images by others and blue are from our campaign in Spring 2015.

Bianchini's value for  $\epsilon$  in 1702–03 was  $\epsilon = 23^\circ 28.58'$ .<sup>24</sup> In the three centuries since the meridian line was built, modern astronomy tells us that the value of  $\epsilon$  has declined by  $2.40'$ , whereas our analysis yields a decline of  $3.2' \pm 0.3'$  from Bianchini's time (Fig. 16). The fact that our derived value for the decline differs from the known value by considerably more than our formal estimate of random error indicates a systematic bias of some sort. Once again, small errors in the assumed church geometry, or in placement of numerals along the meridian line, as discussed in the previous section, would be sufficient.

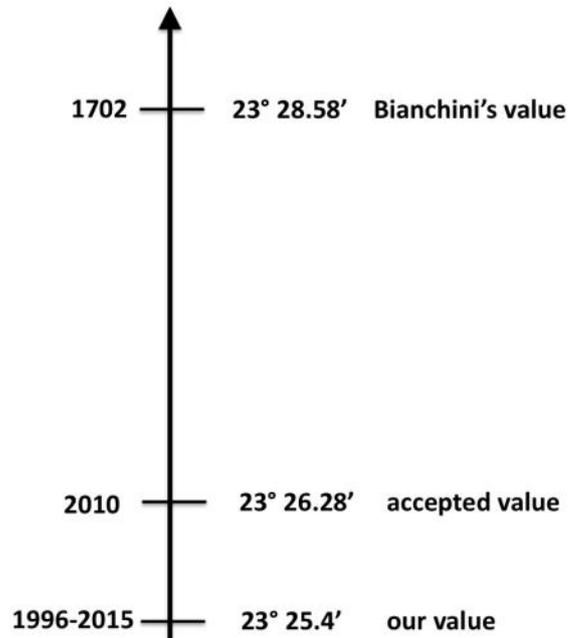


Fig. 16. Our measured value for the obliquity of the ecliptic  $\epsilon$ , compared with the accepted value of 2010 (representative of our dataset) and Bianchini's larger value of 1702. Compare Fig. 7.

Nevertheless, we have indeed successfully demonstrated that  $\epsilon$  is considerably smaller today than when the Santa Maria degli Angeli meridian line was constructed.

Note that our methodology of measuring  $\epsilon$  is distinctly different from that of Bianchini (and all others), who focused on measuring solely the extreme declination values at the winter and summer solstices.<sup>25</sup> Our procedure, using mathematical techniques invented long after Bianchini's era, employs samples taken at random times throughout the seasons as the solar declination varied annually over two decades. Earlier determinations of  $\epsilon$  in effect measured only the maximum and/or minimum of the curve shown in Fig. 15 and did not constrain at all the path of the sun during the remainder of the year. In contrast, our method,



Fig. 17. The aperture for the North Celestial Pole and Polaris. The centre of the vertical slot is about 24.4 metres above the basilica floor and 0.91 metres to the west of the meridian line. See Fig. 6. Photo: Catamo and Lucarini.<sup>1</sup>

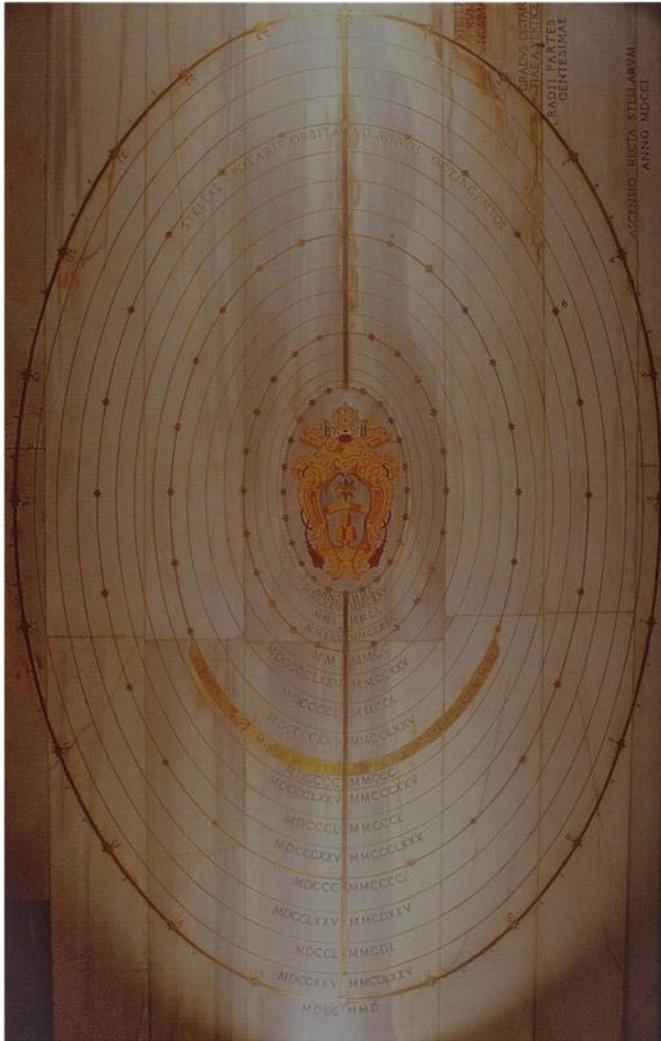


Fig. 18. The seventeen nested precession ellipses located near the southern end of the meridian line. Each ellipse is dated with Jubilee Years, including AD 1700/2500 (the outermost, with dimensions of  $4.4 \times 3.0$  metres) and AD 2100 (the innermost). The coat of arms of Pope Clement XI is in the centre, including a large star located at the projection of the North Celestial Pole through the northern aperture. Photo: Catamo and Lucarini.<sup>1</sup>

although its individual observations are considerably less accurate than typical solstice observations, is based on knowledge of the mathematical form of the entire curve. The two approaches are nicely complementary.<sup>26</sup>

### Polaris and the Precession Ellipses

As mentioned before, a unique second aperture was also provided so that observations to the north were possible. An aperture (Fig. 17) high above the floor (24.39 metres) was mounted such that the north star Polaris could be observed with a small telescope near the southern end of the meridian line and displaced 0.91 metres to the west (Figs 6, 18 and 19). Bianchini used this to determine his latitude, and also argued (somewhat disingenuously) that this northern aperture allowed him to determine the precise time of midnight, needed for the timing of various services. We could not observe Polaris *à la* Bianchini because the window behind the aperture is unfortunately now blocked.



Fig. 19. Measuring the dimensions of the precession ellipses (looking north). Note that their major axes run 0.91 metres to the west of the meridian line. Photo: Sullivan.

Instead we turned our attention to the related and unique set of nested ellipses located near the southern end of the meridian line (Fig. 18).<sup>27</sup> Although these ellipses were never historically used for any observations, their design is fascinating.

In Bianchini's time Polaris was located  $2.30^\circ$  from the North Celestial Pole (NCP), in other words its north polar distance (NPD) was  $2.30^\circ$ . Each (sidereal) day Polaris thus described a circle on the sky centred on the NCP and of radius  $2.30^\circ$ . But the NCP, which is the extension of the Earth's rotation axis, does *not* remain fixed with respect to the stars but, rather, every 26,000 years describes on the celestial sphere a wide, roughly circular path whose radius is equal to  $\epsilon$ , the obliquity of the ecliptic. This phenomenon is called the precession of the equinoxes and has been well known since ancient times.<sup>28</sup> Precession means that the position of the NCP steadily moves through the heavens. Since Bianchini's time the path of the NCP (Fig. 20) has brought it (by chance) ever closer to the star we call Polaris. Its NPD is today  $0.68^\circ$ , in the year 2100 it will be at its closest (NPD =  $0.45^\circ$ ), and thereafter will increase for many millennia.

Bianchini did not make any contribution to the study of precession, but he cleverly used the phenomenon to illustrate the power of astronomy and the longevity of the Church. The ellipses of Fig. 18 represent the projections on the floor of the daily circle of Polaris as they would be observed through the northern aperture at 25-year intervals from AD 1700 to 2500! These dates correspond to 33 of

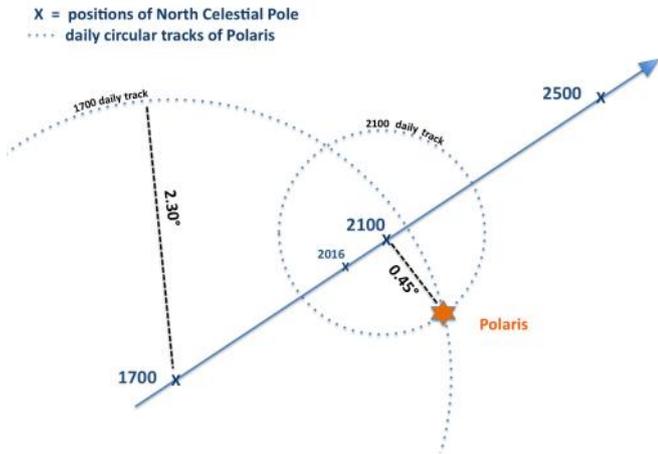


Fig. 20. The phenomenon of precession. A short portion of the precessing path of the North Celestial Pole (NCP) is shown, extending over AD 1700 to 2500, the period covered by Bianchini's ellipses. The daily circuit of Polaris about the NCP is shown at its largest (1700) and smallest (2100). Diagram not to scale.

the celebratory Jubilee Years in the Roman Catholic calendar.<sup>29</sup> Bianchini, however, was able to get by with only 17 ellipses because of the good fortune that the NCP will be closest to Polaris in a Jubilee Year, namely 2100. Then, assuming symmetry between the 400 years before 2100 and those afterwards, he labelled each ellipse with two years equidistant from 2100: for example, 1700/2500, 1725/2475, 1750/2450...2075/2125, and finally 2100 by itself.

We made detailed measurements of the dimensions of the nested ellipses, including the 17 major and minor axes (Fig. 19). The axes of the largest (1700/2500) and smallest ellipses (2100) are  $4.406 \times 2.976$  metres and  $0.897 \times 0.563$  metres. The geometry shown in Fig. 21 then allowed us to calculate the values of Polaris's NPD that Bianchini

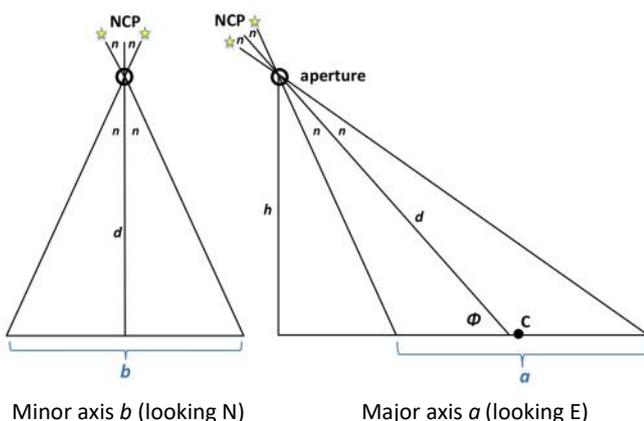


Fig. 21. The geometry of the major axis  $a$  and minor axis  $b$  of each precession ellipse on the floor, as determined by Polaris's north polar distance ( $n$ ) (the radius of Polaris's daily path), the height of the aperture  $h$ , and the latitude  $\phi$ .  $C$  is the centre of the precession ellipse, which is offset from the projection of the North Celestial Pole (end of line  $d$ ).

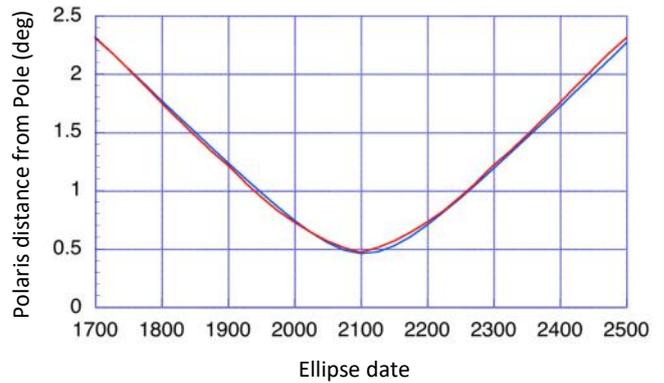


Fig. 22. The varying distance of Polaris from the North Celestial Pole over the period covered by Bianchini's ellipses. The blue line shows modern values and the red line Bianchini's values as deduced from the ellipses of Fig. 18.

apparently predicted and used to draw his ellipses.<sup>30</sup> In Fig. 22 the curve defined by these 33 values is compared with modern precession theory. Bianchini's values of NPD are always within  $0.05^\circ$  (corresponding to  $\sim 1$  cm error for a typical ellipse axis), but steadily diverge with time, primarily because he did not account for the very effect discussed at length in earlier Sections, namely the changing value of  $\epsilon$ , which also affects precession.

We also checked the shape of the largest ellipse in detail and found it to be slightly non-elliptical in the sense that, for its axis ratio,<sup>31</sup> it bulges out too much (by  $\sim 1.5\%$ ) at locations intermediate to the two axes. Bianchini's design incorporates another interesting geometrical effect: the centre of each projected ellipse does not coincide with the projected NCP (indicated by the large star in Fig. 18; also see Fig. 21). The ellipse centres are not marked on the floor, but we determined them from our axis measurements. We find that our determined centres for successively larger ellipses indeed progressively shift southward away from the NCP point, as they should, but the amount of shift is too small. For example, his offset for the largest ellipse is only 9 cm versus the correct 39 cm; perhaps he made the shift smaller for aesthetic reasons, i.e., to keep the nested ellipses more closely centred on the star.<sup>32</sup>

### Closing Remarks

There exists a surprising abundance of astronomical phenomena that can be revealed by careful consideration of sunlight passing through a hole in a wall and falling upon a long calibrated line. In the present study it has been possible, with a mathematical analysis of 54 measured solar declinations spread over the seasons and over two decades, to confirm that the obliquity of the ecliptic has indeed grown smaller since Bianchini determined his value in 1702 (Fig. 16). Our dataset has further allowed accurate determinations of the length of the year and the time of vernal equinox. The accuracy of the precession ellipses associated with the meridian line has also been studied for the first time. Notwithstanding some difficulties, these

observations are further proof that, after three centuries, the marvellous Santa Maria degli Angeli meridian line remains a remarkably accurate scientific instrument.

## ACKNOWLEDGEMENTS

We thank those who supplied the raw solar images for our study, namely (1) the University of Washington (UW) students who participated in the Spring 2015 Program ‘Science, Religion and Art in Rome over Two Millennia’, and (2) the many persons whose movies and images are posted on the Internet or published.<sup>33</sup> John Heilbron, Frank King and Costantino Sigismondi made valuable reviews of an earlier version of this article. Vital information about the meridian line and its history was provided by Sigismondi and Mario Catamo. Lane Eagles, the co-instructor of the Program, was very supportive of the project, as was the Director of the UW Rome Center, Sheryl Brandalik. The Rev. Don Franco Cutrone’s cooperation allowed out-of-hours access to the basilica. Finally, Eric Agol’s expertise and software (normally used to hunt for periodicities to discover exoplanets) were essential for the mathematical analysis.

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2. The spot of sunlight is actually an image (upside-down) of the sun. The entire church in effect has become a huge *camera obscura*, or pinhole camera. For example, during a partial solar eclipse in 2006, the solar image observed at Santa Maria degli Angeli had a significant ‘lunar bite’ taken out of it!
3. The described procedure is only for brief explanatory purposes — it was not that actually used to construct the meridian lines.
4. The date of Easter was (then and now) actually defined relative to an *ecclesiastical* vernal equinox, defined as always 21 March, and an *ecclesiastical* full moon, defined by a certain formula that only approximately tracks the astronomical moon. Despite this, one wanted to check the usefulness of this definition by continually monitoring the actual times of vernal equinoxes.
5. J. Heilbron: *The Sun in the Church: Cathedrals as Solar Observatories*. Harvard University Press, Cambridge, Mass. (1999). In 2012 Heilbron gave the Andrew Somerville Memorial Lecture to the BSS on this topic. The history discussed in the present paper relies heavily on Heilbron. In 1997 Charles Aked gave an earlier Somerville Lecture on meridian lines in general: *BSS Bulletin* **97.3**, 24–8 (July 1997).
6. About 1750 L. Vanvitelli renovated the entire church, including interchanging the original nave and transept.
7. D. Karman: ‘Michelangelo’s “minimalism” in the design of Santa Maria degli Angeli’, *Annali di Architettura*, **20**, 141–52 (2008).
8. The size and precise location of the aperture (originally of 2 cm diameter) have unfortunately not remained constant over the years.
9. Observations of bright stars and planets on the meridian were possible to the south through a large window behind the aperture.
10. F. Bianchini: *De Nummo et Gnomone Clementino*, part of Bianchini, *De Kalendario et Cyclo Caesaris ac de Paschali Canone...*, Francisci de Comitibus, Rome (1703).
11. For example, see F. Bianchini: *Astronomicae, ac Geographicae Observationes Selectae*, Ed. E. Manfredi, Romanzini, Verona (1737).
12. Heilbron (ref. 5) nicely describes the history of all the measurements of the obliquity. His tables on pp. 63, 135, 136 and 239 form the basis of Fig. 7.
13. One consequence of the declining value of the obliquity is that the positions on the meridian line of the solstices are slowly approaching each other! Over the past 300 years the summer solstice (southern end) has moved 1.5 cm northwards and the winter solstice has moved 8 cm southwards. A second consequence is that, to the nearest tenth of a degree, the value for  $\epsilon$  should actually be quoted today as 23.4°, not 23.5°. The accurate value now is 23.43733° (2015.0), declining 0.000130° per year. Current theory indicates that obliquity oscillates between ~22° and ~24.5°, with a quasi-period of ~40,000 years.
14. Of the 31 other observations, seven are in Catamo and Lucarini (2002) (ref. 1) and ten have been posted online (e.g., YouTube) or published by C. Sigismondi. The handiest way to find the Sigismondi reports with data or images we used is at [arXiv.org](http://arXiv.org) — search for the following article numbers: 1106.2948, 1106.2976, 1109.3558, 1201.0510, 1202.1071, and 1412.6096.
15. We did not make accurate measurements of the *timing* of each solar noon.
16. The spot of light is the gnomonic projection of the solar disc onto the horizontal plane of the floor.
17. At solar noon the sun is at its highest altitude angle of the day with a motion almost exactly east–west.
18. The definition of the edge of each solar image is problematic because the angular sizes of the sun and aperture (as seen from the meridian line) lead to a fuzzy penumbra rather than a sharp cutoff. Since we only needed to determine the *centre* of the solar image (rather than its width), we strove only to be consistent in defining the upper and lower edges for lines AA’ and BB’ in Fig. 9. Because the aperture’s angular size is much smaller than that of the sun, the size of the fuzzy penumbra is determined by the former. For detailed discussion see F. King, ‘Francesco Bianchini, a study in fuzz (or what John Heilbron didn’t tell you)’, talk at the 2013 BSS Conference in Edinburgh, *BSS Bulletin* **25(ii)**, 53 (June 2013).
19. The scale, which can be seen in Fig. 9 at a value of ~55.6 for the solar image centre, equals 100 cot (altitude of sun); one unit = height of aperture / 100 = 20.344 cm.
20. As an example, one-quarter of a numeral’s height corresponds to an error of ~2.5’ at the summer solstice, decreasing to ~0.4’ at the winter solstice.
21. Notes 1 and 14; private communications (2016–17).
22. P.K. Seidelmann (ed.). *Explanatory Supplement to the Astronomical Almanac*, p. 670, University Science Books, Mill Valley, Cal. (1992, second edition).

23. These values, the results from a greatly improved analysis, replace the preliminary values reported by Sullivan at the 2016 BSS Conference at Liverpool.
24. See ref. 10, pp. 48 and 77.
25. For example, Sigismondi (2014, *arxiv.org* paper number 1412.6096) re-analyzes Bianchini's 1701 winter solstice data.
26. Our method also would in principle allow one to lay out an accurate day-by-day date scale along the line without having to observe on 365 days.
27. See ref. 5, pp. 160–4 and ref. 1 (Catamo and Lucarini), pp. 75–81.
28. This precession, which is analogous to the wobbling of the axis of a spinning top, is primarily caused by the gravitational attraction of the moon on the equatorial bulge of the Earth. The NCP does not precess in an exact circle, as often stated, because of the steadily changing value of  $\epsilon$ .
29. In the Jubilee Year of 2000 a major restoration of the Santa Maria degli Angeli meridian line and precession ellipses was undertaken; other aspects of the basilica were also substantially improved (for example, a major statue of Galileo was added).
30. We do not know which precession equations Bianchini used to calculate the changing NPD of Polaris 800 years into his future. It is unlikely that his calculated values were accurate enough to pin down the minimum NPD of Polaris to a single particular year. He probably found the minimum to be near 2100 and then happily adopted exactly 2100 because it had three desirable properties: a Jubilee year, a century year, and an even number of centuries from a starting point of 1700, only requiring a two-year shift from the construction date of the meridian line. (It turns out that modern calculations in fact predict a minimum in March 2100!)

31. The ratio of minor to major axis for each ellipse is simply  $\sin(\text{latitude}) = 0.668$ .
32. Sigismondi (ref. 1, pp. 61–2) has in addition determined that the major axes of the ellipses are not aligned to true north, but are 3.0' east of north.
33. The primary contributors were C. Sigismondi (ref. 14) and M. Catamo and C. Lucarini (ref. 1). Others whose names can be identified from the Internet are: N. Bruni, J. Giesen, N. Heckenberg, C. Muccini, R. Num, V. Reijs, and M. Rocco.

Left to right:

**Jennifer Look** has now received her bachelor's degree in Biology and works for Pure Engineering in California. **Guadalupe Tovar** and **Mallory Thorp** have received their bachelor's degrees in Physics and Astronomy, and will be doing postgraduate



studies in Astronomy at the University of Washington (UW) and the University of Victoria (Canada), respectively. **Woody Sullivan** has just retired from the UW faculty after teaching and researching for 40 years in the fields of Astronomy,

Astrobiology, and History of Science. He has designed many sundials in the Seattle region, further afield in the USA, on the planet Mars, and tattooed on his wrist.

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## HOW LONG WAS I WALKING?

GRAHAM STAPLETON

A query printed in *The Athenian Mercury* of 13 February 1692/93<sup>1</sup> itemised a walk across Stuart London. Noticing the disparity of the various clocks on churches and public buildings along the route, the correspondent puzzles as to how long it took to complete the journey. This piece has subsequently been quoted as evidence of the poor standard of timekeeping in public clocks of the era. It reads in full:

*“I was in Covent Garden when the clock struck two, when I came to Somerset-House by that it wanted a quarter of two, when I came to St. Clement’s it was half an hour past two, when I came to St. Dunstan’s it wanted a quarter of two, by Mr. Knib’s Dyal in Fleet-street it was just two, when I came to Ludgate it was half an hour past one, when I came to Bow Church, it wanted a quarter of two, by the Dyal near Stocks Market it was a quarter past two, and when I came to the Royal Exchange it wanted a quarter of two: This I aver for a Truth, and desire to know how long I was walking from Covent Garden to the Royal Exchange?”*



Fig. 1. Excerpt from Ogilvy and Morgan's 1676 City of London Map, showing locations of Mansion House, St Mildred Poultry and the King's Head Tavern.

Whilst public timekeeping may have been in a state of disarray, it would surely be an extraordinary coincidence that all of the clocks were showing a quarter or half hour, rather than the more likely disparate range of minutes. Perhaps the author had a satirical intent, but it actually seems to be a numerical problem, capable of being solved –

| Location                |                 | Yards   | Sundial time | Duration (Minutes) | Actual time | Clock error (Minutes) |
|-------------------------|-----------------|---------|--------------|--------------------|-------------|-----------------------|
| St Paul's               | Covent Garden   | 561.56  |              | 7.2                | 1.40 pm     | +20                   |
| Somerset House          | Strand          |         |              | 4.0                | 1.47 pm     | -2                    |
| St Clement Danes        | Strand          | 314.96  |              | 4.2                | 1.51 pm     | +39                   |
| St Dunstan in the West  | Fleet Street    | 332.13  |              | 4.2                | 1.55 pm     | -10                   |
| Mr. Knib's dial         | 68 Fleet Street | 194.88  | 1.58 pm      | 2.5                | 1.58 pm     | -                     |
| St Martin Within        | Ludgate         | 425.08  |              | 5.4                | 2.03 pm     | -33                   |
| St Mary le Bow          | Cheapside       | 684.59  |              | 8.7                | 2.12 pm     | -27                   |
| Dyal near Stocks Market | Poultry         | 223.97  |              | 2.9                | 2.15 pm     | -                     |
| Royal Exchange          | Cornhill        | 276.46  | 2.15 pm      | 3.5                | 2.18 pm     | -33                   |
| Total yards:            |                 | 3013.63 |              |                    |             |                       |
| Total miles:            |                 | 1.71    | Total time:  | 38.4               |             |                       |

Table 1. Distances and calculated travel times between the given locations. Averaged from the known elapsed time and distance travelled between the two sundials (highlighted).

albeit making any number of assumptions. As there are two sundials (which naturally we assume to be reliable), and the distance between them known, a possible duration for the entire route can be calculated.

All of the buildings mentioned still exist and are readily located on a map,<sup>2</sup> but for the locations of the sundials, I am reliant on the map annotated by Anthony Turner.<sup>3</sup> 'Mr. Knib's Dyal', on the premises of the notable clock-maker Joseph Knibb, is easily identified as a shop on the east side of Whitefriars Street (then known as Water Lane), running south from Fleet Street.<sup>4</sup> The sundial (which is mentioned as if it was a familiar landmark) would appear to have been a great decliner facing slightly south of west. Sadly I have not discovered any image of the dial to confirm this.

The location of the dial near the 'Stocks Market',<sup>5</sup> is much more ambiguous. The site of the market is now the location of the Mansion House. Given the tumultuous nature of London's streets, a dial on a market cross seems unlikely. A south-facing dial (declining slightly east of south) would be of the greatest use and hence most probably it was upon one of the buildings east of St Mildred's church (Fig. 1). I have traced only two engravings of the market, neither looking in the required direction.<sup>6</sup> Poultry came to be a street with a long association with clockmakers, but it was an early home of the Clockmakers' Company at the King's Head Tavern.<sup>7</sup>

To solve the puzzle, I measured the distance between each of the points using online mapping.<sup>8</sup> This gave the overall distance and crucially, the distance between the two dials.

Using the times by the (assumedly accurate) two dials as the lapsed time, an average speed was calculated. This average speed was then proportionally added to, or subtracted from the known points, giving a duration between each point and the inaccuracy of the supposed clock readings.

Thus the answer – apparently waiting since 1693 – is a trifle over 38 minutes (Table 1). By way of comparison, I used the Journey Planner on the Transport for London site.<sup>9</sup> A similar route was tried, and the average pace gave a time of 40 minutes. I would suggest, however, that aside from numerical variables, the earlier journey would have been much beset by bad paving, hawkers, trulls and beggars.

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# A SUNDIAL SERENADE

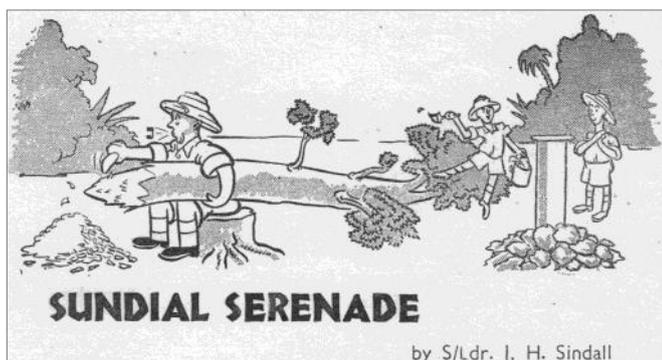
Wg Cdr JAMES HEPBURN SINDALL DSO RAF

With a little editing by KEVIN KARNEY

*This poem was read by Kevin Karney at the 2017 BSS Conference in Oxford.*

**D**uring the Burma campaign in 1945, James Sindall was stationed at the Kalyan airfield some 50 miles North East of Bombay. The base had been home to a bomber squadron earlier in the war and later to a squadron of Tempests and Spitfires. But, when these moved forward towards the battle for Burma, the airfield was left empty of aircraft. The remaining complement of ground staff, struck with the intense heat of India, lack of activity and homesickness, succumbed to general boredom, and a turn towards gnomonics was required to bring relief.

The Sundial Serenade was published in the March 1944 edition of the *Journal of the Air Forces, India and Far East Edition*.



It all began when the units went,  
And they hadn't filled the establishment.  
There were a few of us left, you see,  
To clear up the mess, so it fell to me  
(as the senior bloke with experience)  
To show the C.O. who had bags of sense  
But was straight from school (Admin), and so  
Wasn't quite sure of the way to go.

We had a good man in the Orderly Room,  
And the O.C.M.T. wasn't really a goon,  
The Signals were coping, the Canteen was there,  
As a unit, not super, but certainly fair.

\* \* \*

So dawned the day when the Powers That Be  
Were informed that the station from rubbish was free,  
And if They Were Pleased and had the intent,  
They could post in some bodies – but none were sent,

And to we who lived in a simple way,  
It seemed that the atmosphere of Bombay  
Had made them forget us, who were so far  
Away from the gins of the Harbour Bar.

So resigned to our fate, we looked around  
For something to do, and a driver found,  
That a skin of a snake, if properly treated,  
(A blow on the head is initially meted)  
Was the thing to send home, for they haven't got shoes,  
(Can we really believe the Japanese news?)

\* \* \*

The troops were content, there was hardly a mumble,  
But we're never happy unless we can grumble  
At something unusual, and so without fail,  
We cursed B.P.O. messing round with our mail.

The Officers found that the evenings were long,  
(You can't go to town if you're near Chittagong),  
We weren't, but we might just as easily been  
For the lights of Bombay were too far to be seen.

So we sat down to think what was best to be done,  
There were plenty of ravens, but who had the gun!  
And to throw stones at pi-dogs is fun as it stands,  
But they soon get the gen and it's hard on the hands.

\* \* \*

It was then that a sundial was mentioned, the one  
Who thought of it said that he knew that the sun  
Wasn't really intended to brown off the knees  
Of the erks who had recently come overseas...

A site was chosen outside the Mess,  
I can't think why it was there, unless  
The griff was to let the bearers (Camp)  
Obtain the time by Hurricane lamp

At all events, we got a beam  
And stuck it in, but it would seem  
That all the earth for miles around  
Was full of rocks, or so we found.

Eventually it stood alone,  
Though he who hit his thumb would moan,  
And on the top was nailed a card,  
The distance from the ground, one yard.

(The pointer earned for one renown,  
He felled it down, and pared it down).

There was not much more to be done,  
Except to mark the hours by sun  
Which, when completed, seemed to rights  
And we settled down to more dull nights.

It wasn't long before we thought  
That bricks, like battlemented fort  
Arranged around the base would make  
It look less bare and doubtless cramp  
The style of pi-dogs, (it is no lamp).

And so constructive work began  
With blue dope added from a can  
White paint was 'borrowed' from the Store,  
(There's plenty if we want some more).

And powdered brick of reddish tint  
Was scattered round, no need to stint,  
We even got some broken flint,  
Which made a pathway or surround,  
To finish off the Sundial Mound.

Where 'ere you be, whatever season  
You will agree there is no reason  
Why you should sit around and moan,  
When one way now to you I've shown  
To pass the time, as we have found,  
Until the day you're Homeward Bound<sup>1</sup>

\* \* \*

Now you may think the work was done,  
Providing always that the sun  
Continued to appear when due,  
So we our toil with pride could view.

But even then we didn't wait,  
And started in upon a plate  
Which indicated without fear,  
Just how we felt as being here.

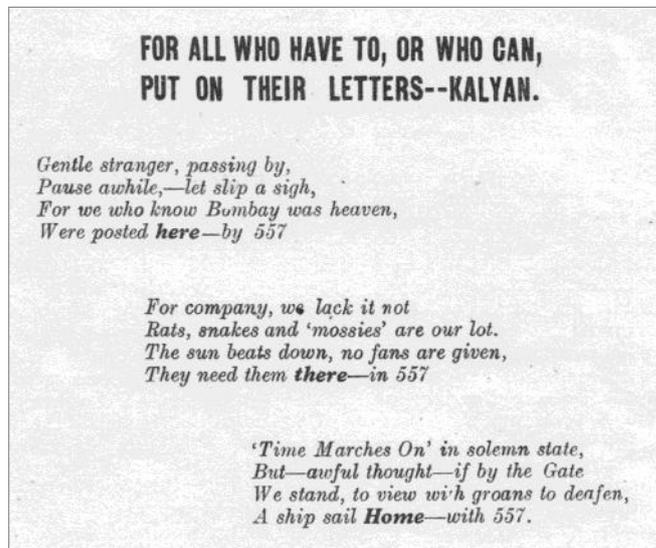
This time we really were quite good,  
And asked the S.D.O. for wood

Which he supplied – I thought I'd faint  
When he actually OFFERED a can of paint.

Two coats of black were then applied,  
And words, (for which we did decide  
That those to whom it might refer  
Would rather laugh than rage prefer),

In letters white, for all to see,  
Were painted with unholy glee.

I have no doubt you'd like to know  
Just what we said – well read below....



The request for publication of the poem was formally made to the Editor with another few lines of doggerel...

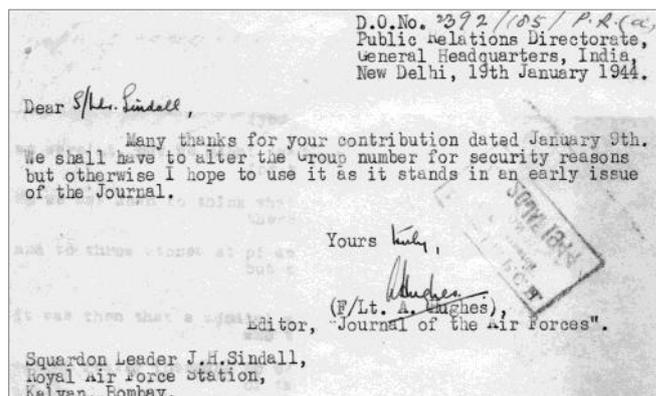
Dear Editor

I'm sending you a little work of mine,  
Which you might like to put in the Journal, if it's fine  
Enough for all the 'erks to read, and, maybe, those  
High Few  
Who work amidst such splendour, in South Block, on  
Floor two.

I hav'nt passed it through the Group, you do not  
indicate

That action of that sort is what I really ought to take,  
So if I've made a 'black' of sorts by sending it straight  
in,  
You'll understand it's due to so much solitude and  
gin...

See the formal response...



| <b>Glossary</b> |  |
|-----------------|--|
| OCMT            | Officer Commanding Motor Transport.  |
| Erk             | Aircraftman (from cockney 'erkräft).   |
| Griff           | Reliable information or news.  |
| BPO             | Base Post Office.  |
| Blue dope       | Paint. The term 'dope' was originally used for the material used to water-proof and make tight the canvas used on canvas-covered planes. |
| Hurricane lamp  | Kerosene light with an asbestos glowing mantle.  |
| Pi-dog          | Indian Pariah Dog ( <i>Canis lupus familiaris</i> ) is the aboriginal dog of India.  |
| SDO             | Service Delivery Organization or Squadron Duty Officer.  |

The only security measure taken by the Delhi bureaucrats was to change Squadron 227 to Squadron 557!

### Historical Note

Kalyan Airfield was abandoned after the war. The land was owned by the Defence Ministry of the Indian Government but the ownership was transferred to the Airports Authority of India. The site was once considered for the construction of a second airport for the Mumbai Metropolitan Region.

A search for the Sundial Mound at the location of the airstrip (19.178477° N, 73.138853° E) revealed that, by

2003, the whole area was given over to agriculture. Although the trace of the runway can still be made out, no mound was found.

### ACKNOWLEDGEMENT

This poem is reprinted by kind permission of Wing Commander Sindall's son, Squadron Leader Tim Sindall.

### NOTE

1. This verse was not included in the published version.

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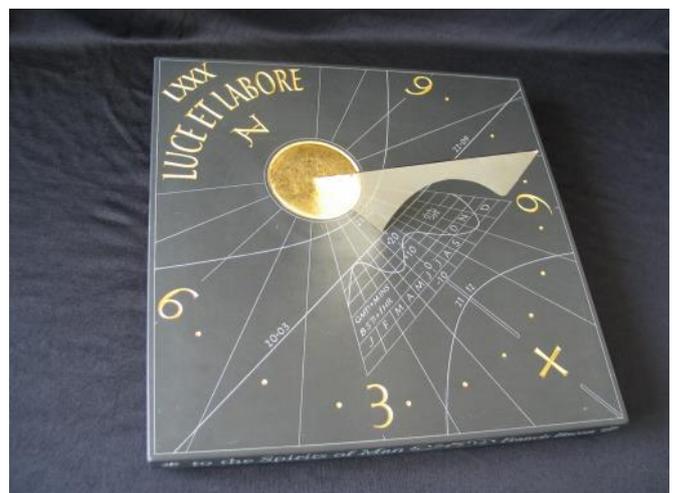
## NEW DIALS (1)

### An 80th Birthday Sundial

I was asked by a client to create a large stone inscription (1 metre long) of Sir Francis Bacon's well-known introduction to his essay 'Of Gardens'.<sup>1</sup> It was to hang on the exterior wall of his father's garden to mark his 80th birthday. The client 'discovered' in the course of discussions that I make sundials, with the result that that became the focus of attention. As an added bonus, he could have the Bacon quotation as well, since it readily divided into four phrases to suit a four-sided horizontal sundial (Fig. 1). The stone is 3 cm thick Welsh slate, measuring 40 cm square in a diamond format, lettering V-cut, some features gilt (Figs 2 and 3). The gnomon is 3 mm brass with a nodus notch. Seasonal declination curves are labelled, and the EoT graph makes use of the separation of the hour and half-hour lines. The LXXX date and monogram of the recipient border the motto of Wye College, an agricultural research institution in Kent, now closed, which he attended many years ago.



Fig. 1. The Francis Bacon quotation around the vertical perimeter of the sundial.



Figs 2 and 3. Two views of the completed sundial.

### NOTE

1. Sir Francis Bacon (1561–1626), Jacobean statesman and author.

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# SUNDIALS IN THE SCIENCE MUSEUM, GENEVA

DOUG BATEMAN

Geneva has many museums, ranging from the humanitarian (the Red Cross) to the extravagant (Patek Philippe watches), but perhaps the broadest is the science museum, Musée d'histoire des sciences de la Ville de Genève. The museum is located in the *Villa Bartholoni*, built in 1830 as a summer residence for Parisian bankers Constant and Jean-François Bartholoni, and extensively restored between 1985 and 1992. The villa itself is located in a large park overlooking Lake Geneva. The collection covers astronomy, microscopy, meteorology and electricity. There is a fine orrery by Rowley and a regulator clock by Shelton.

A particular theme is the provision of hands-on exhibits for surveying, and there are sundials outside, with three examples shown here in Figs 1–3. Within the building are



Fig. 2. A conventional globe dial where the gnomon is rotated to be in line with the sun. Note the platform for children to stand on.



Fig. 3. A large analemmatic dial with a long meridian line. Lake Geneva is in the near distance.



Fig. 1. An unusual horizontal dial that is in fact an altitude dial. The dial plate is rotated to the date (as near as can be estimated) and the time read from the relevant curve. This dial has links to Fred Sawyer's second talk at the 2017 BSS Conference in Oxford, in which he explained solar decliners, a form of vertical altitude dial.<sup>1</sup>



Fig. 4. One of several display cases of sundials, this with quadrants, altitude dials and a navicula.

display cases, several featuring sundials. The cabinet shown in Fig. 4 includes a navicula from England, which according to the talk by John Davis at the 2017 BSS Conference<sup>2</sup> was purchased in 1993 at considerable expense!

## REFERENCES

1. F. Sawyer: 'Solar decliners, or sundials CLARAFied', *BSS Bulletin* 29(ii), 45 (June 2017).
2. J. Davis: 'The Navicula: made in Medieval East Anglia?', *BSS Bulletin* 29(ii), 15–23 (June 2017).

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**CHARLES MILLER  
ADVERTISEMENT  
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THIS PAGE**

# IN THE FOOTSTEPS OF THOMAS ROSS

## Part 20: The Other Dials of Lennoxlove

DENNIS COWAN

The Lady of Lennoxlove (Fig. 1) is a fabulous multiple dial and has been the subject of at least two articles in the *Bulletin* and has to be my most favourite dial. She appeared in Part 3 of this series of articles,<sup>1</sup> and was more recently extensively covered by Alastair Hunter in his article ‘A Scottish Sundial Holding Secrets’ in June 2016.<sup>2</sup>



Fig. 1. The Lady of Lennoxlove.

But there are other dials at Lennoxlove. In volume 5 of *The Castellated and Domestic Architecture of Scotland*,<sup>3</sup> Thomas Ross mentions two other dials at Lennoxlove, which he knew as Lethington Castle.

The first is a horizontal dial that sits just to the north of the Lady’s garden. Ross provides no sketch and merely says:

“A round horizontal dial with a baluster shaft [Fig. 2] stands in front of this ancient castle; it is undated, but on its metal face is engraved DAVID LYON SCULPSIT.”

As can be read above, Ross identifies it as a “round horizontal dial” but as can be seen from Fig. 3, it is clearly octagonal. It is almost certainly the same dial, however, as although the markings are only just legible today, the



Fig. 2. The horizontal dial and pedestal.



Fig. 3. Detail of the horizontal dial.

engraving described by Ross can be seen. There are Roman numerals from 4 am to 8 pm read from the inside on an inner ring. Outside that another ring includes hour, half- and quarter-hour lines, outside of which is a minute scale with ten-minute intervals named. Additionally, “for latitude 56 degrees” can be identified on the dial, which is correct

for Lennoxlove. Unfortunately these engravings did not photograph well!

David Lyon is not a known maker, but Webster's *Signature Database*<sup>4</sup> has a record for a barometer maker named Lyon operating out of Edinburgh in 1772. In addition, there is a Hunter Lyon (son or brother perhaps) also operating out of Edinburgh from 1793 to 1803. He was an optician and it is known that both barometer makers and opticians also dabbled in sundials. There is a possibility, therefore, Edinburgh being less than twenty miles from Lennoxlove, that our David Lyon is the one mentioned above or perhaps part of this family.

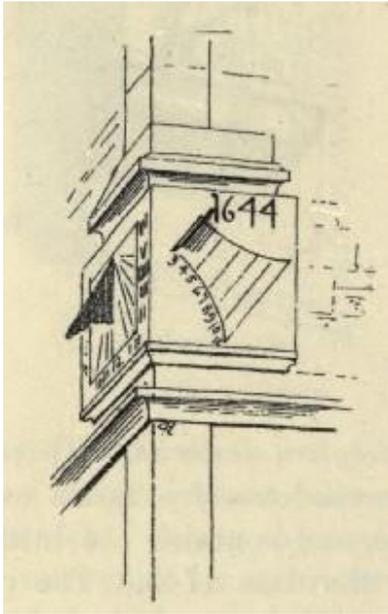


Fig. 4. Ross's sketch of the south and east vertical dials incorrectly showing the east face gnomon on the 3 am hour line.

As to the other dial identified by Ross, he comments:

*"On the south-east corner of the latest part of the castle may be seen the dial shown in [Fig. 4]. The date (1644) shows that this portion of the building was erected after Lethington passed from the Maitlands into the possession of the ancestors of the present proprietor, Lord Blantyre."*<sup>5</sup>

His sketch at Fig. 4 is clearly in error, as it shows the east face gnomon on the 3 am hour line. The photograph of the dial today (Fig. 5) shows the gnomon correctly positioned on the 6 am line, where it looks as though the date of 1644 has been re-engraved. The south face of the dial has Roman numerals whereas the east face has Arabic numerals.

This dial is on the left-hand edge of the building underneath the security camera and directly above the Lady in the left foreground of Fig. 6.



Fig. 6. Lennoxlove with the Lady in the left foreground and the south and east vertical dials (circled) above her and underneath the security camera.



Fig. 5. The south and east vertical dials today with the probably re-engraved date.



Fig. 7. The south and west vertical dials (circled) above the lamp on the corner of the house.

There is another dial at Lennoxlove which was not known to Ross. It is similar in design to the previous dial, but has south- and west-facing dials sitting as it does on the south-west corner of the house above the lamp (Fig. 7). Again, like the south-east dial, the south face has Roman numerals whilst the west face has Arabic numerals (Fig. 8).



Fig. 8. Detail of the south and west vertical dials.



Fig. 9. The south-east and south-west dials together.

Finally, Fig. 9 shows the close proximity of these last two dials.

#### REFERENCES and NOTES

1. D. Cowan: 'In the footsteps of Thomas Ross Part 3: The sundials of James Gifford', *BSS Bulletin* 24(iv), 6–9 (December 2012).
2. A. Hunter: 'A Scottish sundial holding secrets', *BSS Bulletin* 28(ii), 7–13 (June 2016).
3. D. MacGibbon and T. Ross: *The Castellated and Domestic Architecture of Scotland*, David Douglas, Edinburgh (1892).
4. <http://historydb.adlerplanetarium.org/signatures/>
5. Since 1946, Lennoxlove has been owned by the Dukes of Hamilton.

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## PETER-JOCHEN KUNATH

Peter-Jochen Kunath studied mathematics at Bonn University. His professional career, from 1970 to 2011, was as a systems engineer for mainframe computers with IBM.

It was in the early 1970s that he discovered his passion for sundials occasioned by two publications from the sundial pioneers Erich Pollähne, Germany (an article in *Der Spiegel*) and Lothar M. Loske, Mexico (the book *Die Sonnenuhren*).

Over the years he calculated a multitude of dials which were then made out of wood, iron or marble. He also built sundials himself using wood, acrylic glass, glass or PVC rigid foam board. Additionally, he made numerals, lines and zodiacal signs from plastic film.

He was a member of the *Deutsche Gesellschaft für Chronometrie* (German society for measuring time), The British Sundial Society and the North American Sundial Society. Furthermore he attended meetings of the sundial working group of the Austrian astronomical association and some BSS sundial safaris.



Peter and I got to know one another just ten years ago. Our discussions about very different sundial topics were always fruitful and it was interesting to philosophise with him about the spirit of time or the meaning of life. Peter's credo was: *Alter forscht* (Old age explores).

It is especially worth mentioning that Peter was winner of the *Bulletin* 'Most Enjoyed Article' award in 2012 for his contribution on Henry Moore's unusual equatorial dial.<sup>1</sup> He collected 2,013 Latin aphorisms and inscriptions on European

sundials, translated them and edited them into a small booklet.

*Una ex his erit tibi ultima*

*Eine von diesen wird für dich die letzte (Stunde) sein*

*One of these will be your last (hour)*

Peter died aged 72 in April 2017, and I lost both a sundial colleague and a friend.

Ortwin Feustel

1. P. Kunath: 'Lost and found: the long journey of an unusual sundial', *BSS Bulletin* 24(iv), 2–5 (December 2012).

## NEW DIALS (2)

### Polar Sundial in Darwin

At the 2016 BSS Conference in Liverpool, Geoff Parsons reported on a polar sundial in Darwin.<sup>1</sup>

Sundials Australia constructed this sundial as part of Darwin's commemoration of the Centenary of the Anzac (Australian and New Zealand Army Corps) disastrous military landing at Gallipoli on 25 April 1915. Anzac Day is Australia's major military remembrance day, more highly commemorated here than Remembrance Day on 11 November.

The Darwin City Council's initial request for a horizontal sundial would not have been satisfactory for the low latitude of Darwin (12.5°), so we suggested a polar sundial that commemorated significant military dates as more useful.

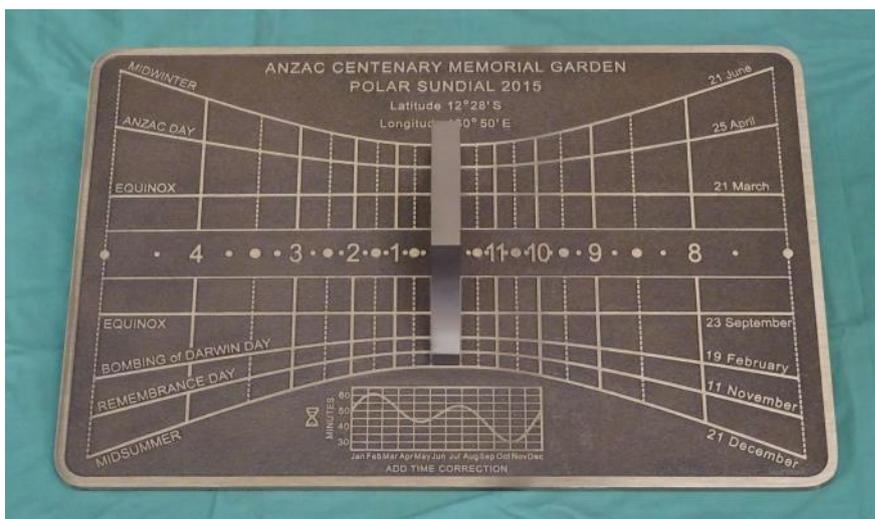


Fig. 1. The finished Darwin polar dial cast in gunmetal bronze, with gnomon in place.

This sundial (Fig. 1) was cast in gunmetal bronze using the patternmaking and casting techniques I discussed at the 2010 BSS Conference at Exeter.<sup>2</sup> It measures 550 mm × 370 mm with a nodus block 100 mm × 100 mm and 20 mm thick.

Fig. 2 shows John Ward machining holes in the cast bronze dial plate to attach the solid block gnomon securely while Fig. 3 shows these holes in detail and Fig. 4 shows detail of the block gnomon.

The dial was installed in the newly-created Anzac Centenary Memorial Garden (see Figs 5 and 6), and the opening ceremony took place on 25 April 2015. The council employee who coordinated with us over this sundial reported with delight the surprise people had seeing the tip of the nodus shadow passing along the 25 April dateline.



Fig. 2. John Ward machining holes in the cast bronze plate.



Fig. 3. Holes machined in dial plate for attaching the gnomon block.

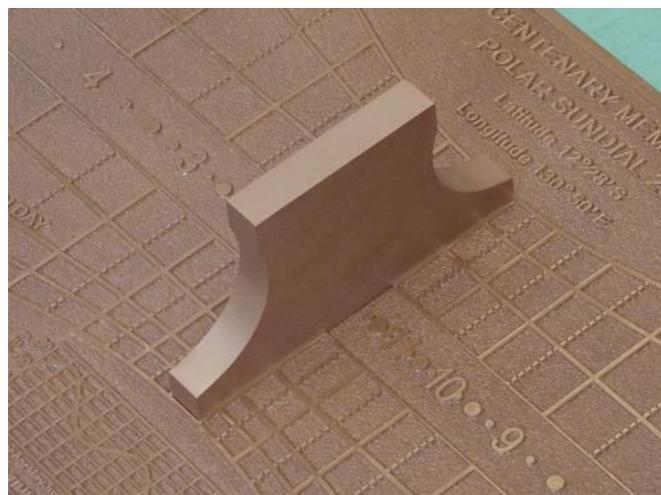


Fig. 4. Detail of the block gnomon.



Fig. 5. The sundial on its pedestal in the Anzac Centenary Memorial Garden. Photo: Aaron Trenfeld.



Fig. 6. The polar sundial, side view. Photo: Aaron Trenfeld.

## REFERENCES

1. Conference report: *BSS Bulletin* 28(ii), p.44 (June 2016).
2. Conference report: *BSS Bulletin* 22(ii), p.35 (June 2010).

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## A Missed Opportunity

David Brown

During a recent narrowboat holiday on the Stratford-upon-Avon canal, I was delighted to see what looked like a sundial on the pediment of a prominent new building in a development on the outskirts of Birmingham (Fig. 1). The locale is called Dickens Heath, a new village within the Metropolitan Borough of Solihull in the county of West Midlands. Closer inspection on foot showed it to be very

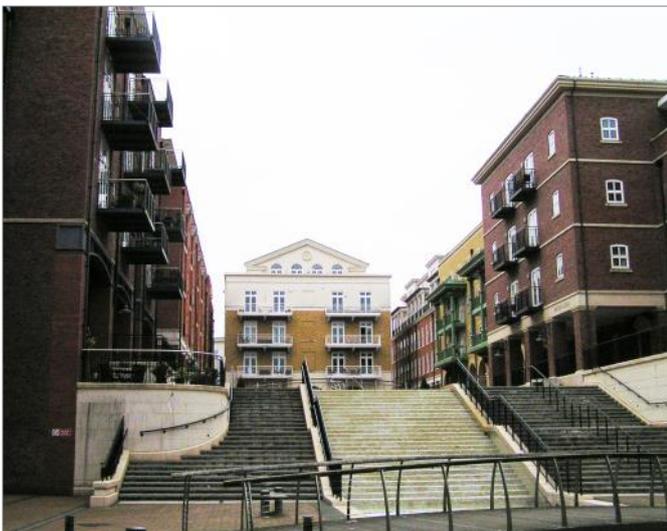


Fig. 1. The sundial on a pediment at Dickens Heath, Solihull, as seen from the canal.



Fig. 2. Detail of the 'sundial'.

much wanting in accuracy (Fig. 2). Measurement of the wall's declination using Google Earth shows that it declines 59° East. I am hoping to discover the architect and sundial designer in the hope that they might be persuaded to put matters right.

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## READERS' LETTERS (1)

### Sundial at Picton, New Zealand

Reading the Holiday Pictures note about the sundial on Flagstaff Hill, New Zealand in the June issue (*BSS Bulletin* 29(ii), p.8), I recollected one horizontal sundial I visited in Picton, New Zealand several years ago (Fig. 1).

There is a nice history described at the *waymarking.com* website,<sup>1</sup> and one notable detail that may be of interest to BSS members is that the sundial was made by Troughton & Simms, London (Fig. 2).



Fig. 2. Troughton & Simms maker's mark.

Accounts suggest that the sundial was purchased in 1871 with the aim of establishing the official timepiece of Picton. A year later it was placed in the grounds of Holy Trinity Church, and in the 1960s it was moved to the back of the church. In 1987 it was vandalised and lost its gnomon, but two years later this was replaced using photographs of the original as a reference point (Fig. 3).



Fig. 4. Dial plate detail near the noon gap.



Fig. 1. The dial plate.



Fig. 3. The replacement gnomon.

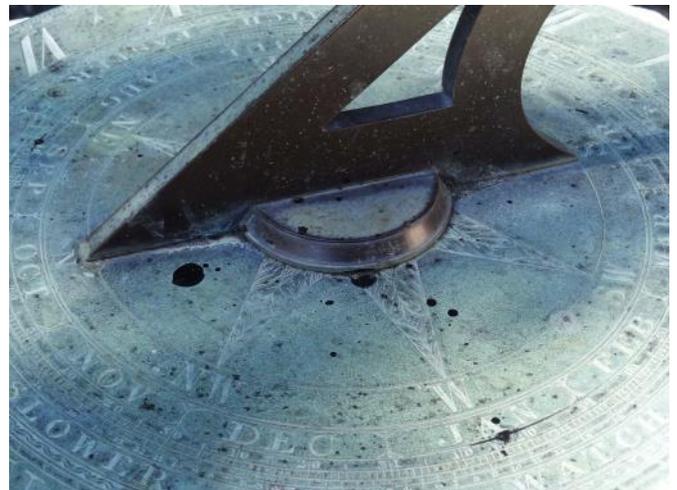


Fig. 5. Dial plate detail near the base of the gnomon.



Fig. 6. An unsatisfactory position for a sundial.

The brass dial plate includes an eight-point compass rose and an equation of time Watch Faster/Slower ring, parts of which are shown in Figs 4 and 5. The hours are divided into 2-minute units.

The current location of the sundial is not the most appropriate for telling the time – during a large part of the day this time-keeping device is in the shadow of the building and an oak tree (Fig. 6).

#### REFERENCE

1. [http://www.waymarking.com/waymarks/WMAT15\\_Holy\\_Trinity\\_Anglican\\_Church\\_Sundial\\_Picton\\_South\\_Island\\_New\\_Zealand](http://www.waymarking.com/waymarks/WMAT15_Holy_Trinity_Anglican_Church_Sundial_Picton_South_Island_New_Zealand)

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## Postcard Potpourri 40 – Glamis Castle

Peter Ransom

Two pictures of the same dial this time, from postcards 63 years apart. The older one (on the right) is interesting as on the back someone has written the following:

*Sundial at Glamis Castle. This is one of Mr F's negs: I am going out to get it some day soon. In the waterfall cards the detail is not to be seen in the high lights. In P.O.P it comes out all right. I have this in Ozo, mounted.*

The card is postmarked July 6 1904, but there is no publisher's detail on it.

The other one (below) is dated 20 August 1967 and is a 'Collo Colour' postcard published by Valentine and Sons, Ltd. The message on the back doesn't mention the dial, however.



This multi-faceted dial (SRN 1489) dates from 1670 and has c. 80 dials! Made of sandstone, it stands 6.5 metres high and is mentioned in Mrs Gatty's *Book of Sun-Dials* and Andrew R. Somerville's *The Ancient Sundials of Scotland*.

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# A POP-UP SUNDIAL FOR WROXTON

DAVID BROWN, GRAHAM STAPLETON and JACKIE JONES

The fun of creating a (very) temporary analemmatic sundial on Crosby beach around one of Antony Gormley's figures as a public lead-in to the 2016 BSS Conference in Liverpool<sup>1</sup> was the motivation behind a similar creation for the 2017 Conference in Oxford. The ideal site would have been in the city centre, but given the busy nature of that place and that it is no longer easier to gain forgiveness than permission for unapproved activities, it was clearly not viable to carry out a project anywhere around there. Graham Stapleton did some research: the conference hotel grounds and the adjacent village of Wolvercote seemed unsuitable and unlikely to provide an audience as had happened at Crosby, so he looked further afield. A search through the BSS Register for nearby settlements with two or more sundials, but with accessible open space and a significant population, was not successful. However, he had spotted that the Oxfordshire village of Wroxton, although further away from Oxford than ideal, has an unusually large number of sundials: the BSS Register shows that eight have open access, three others are visible, and another is private. It was supposed that the village was well-tuned to accept another, if only temporary.



Fig. 1. Sundial Farmhouse, Wroxton and sundial SRN 3959.

Suitable sites with horizontal grassy areas were hard to come by. Sundial Farmhouse (Fig. 1) has a small vertical sundial above the doorway and a few metres away is another vertical dial (Fig. 2). The grassy area nearby looked good at first on Google Earth but Street View showed it to be steeply sloping. A grassy triangle at a road junction was



Fig. 2. The 1752 sundial at Wroxton Old Post Office (SRN 3960).

too far away from the village centre. The only other possibility was at the local Primary School, so we asked whether we could lay out a sundial on an area to the east of the school building. This location would have the additional bonus of the dial being an educational resource for the pupils, as well as being accessible to the village. Correspondence with the Head Teacher was protracted, but permission was given with the proviso that the sundial be set up in holiday time. The Conference was due to start on the afternoon of Friday 21 April, which was also the last day of the school holiday, so that morning was earmarked for installing the sundial and the invitation to join in the fun was sent out through the BSS Newsletter as well as to the school. The village website was also informed.

Some advance preparation had to be done: How could the sundial be marked out on the grass, and how could it be aligned anyway if the sun did not appear on cue on 21 April?

It would be possible to paint the hour points, date scale, and other elements of the sundial using stencils and spray paints, but grass needs to be cut from time to time, so the life-time of the sundial would be almost as short as that at Crosby beach. Painting on a tarmac area would give a more permanent sundial, but that option had been dismissed by the school. An alternative method would be to have the components painted on some sort of weather-proof material, then fixed by pegs to the ground. By chance, on a visit to an IKEA store in Bristol to collect kitchen units, I spotted a sheet of red plastic board 4 mm thick in their help-yourself recycle area. This was quickly squirrelled

away in my car. It proved easy to cut to size with very little left over. Painting was done – not very expertly, alas – with black car-body lacquer spray-paint, using the home-made stencils I had to hand that in the past have served me well for carving details for several stone analemmatic sundials.

As for alignment, Google Earth came into play again. A tarmac path separating a suitable area of grass from the school building has an edging that can be easily seen in the plan view (Fig. 3). Its alignment was measured using the ruler function of Google Earth and found to be very close to that of the meridian, so failing an appearance of the sun, that edging could be a very handy reference line.

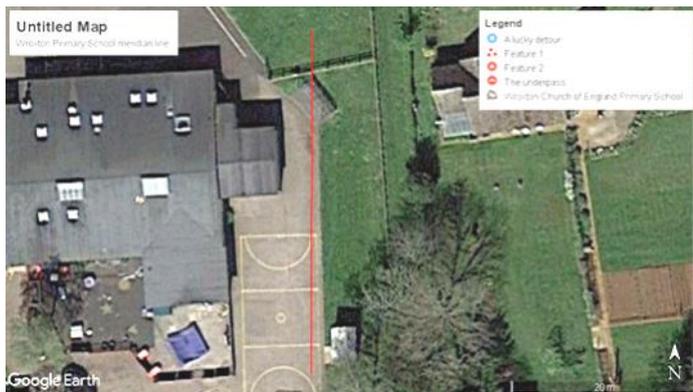


Fig. 3. Google Earth plan view of the site with a meridian line (red) close to the grass area.

On the appointed day the party of Jackie Jones, Rob Stephenson and I (having travelled together by car from Oxford) were joined at the site by Derek Humphries who had responded to the Newsletter invitation. No-one from the school appeared. True to frequent form on such occasions, there was no sight of the sun, so use was made of the Google Earth data on the nearby path edging to get the meridian line established. Perhaps the grass was due to have its pre-term trim, but the grass was longer than expected. Nevertheless, the push-in anchoring nails helped to press the sundial components down. Full use had been made earlier in the week of Helmut Sonderegger's



Fig. 4. Laying out the sundial using marked wooden laths.



Fig. 5. The finished pop-up sundial at Wroxton Primary School.

excellent software Alemma<sup>2</sup> to extract data for marking out a couple of wooden laths with the  $x$  and  $y$  co-ordinates of the hour points, so it was a straightforward and quick job to position the hour points (Fig. 4). Holes drilled through the plastic allowed 6-inch nails to be pushed through into the ground for fixing the elements in place. Cardinal points and Bailey points (sunrise and sunset markers) were also added. It took about half an hour to lay out the sundial from start to finish (Fig. 5). It would have been good to have been able to test it, but the sun didn't co-operate. Copious notes on how to use the sundial and the sunrise and set markers were posted through the school letterbox, together with the sundial layout data so that if the sundial had to be moved to another area of the grounds, or temporarily removed to allow mowing of the grass to take place, then information would be to hand. The laying-out battens were also left at the school. In an hour or so we were back at the Oxford hotel to prepare for the Conference.

After several weeks, when nothing had been heard from the school, I collected the components – still on the grass, but with many of the components in irrelevant places. No doubt there will be another occasion where the kit that I now have will come in handy for another pop-up sundial; perhaps to fulfil Graham's suggestion that the installation of even a temporary sundial at each of our conference venues might yet become a custom. If anyone knows of a suitable site in Norwich, we could perhaps have another go at exciting the public about sundials.

## REFERENCES

1. J. Jones: 'A sundial in the sand', *BSS Bulletin* 28(iii), 34–5 (September 2016).
2. 'Alemma' software for analemmatic sundials from Helmut Sonderegger. [www.helson.at/sun.htm](http://www.helson.at/sun.htm)

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# AN INTERESTING SLATE SUNDIAL BY GRIFFITH DAVIES, FRS

SUE MANSTON

This is the story of how a poor Welsh farm boy, with little formal education, became a noted actuary and was given a medal for his sundial.

Griffith Davies (Fig. 1) was self-educated and did not speak English until he was twenty-one. He was employed at times by the Bank of England, the East India Company and the Guardian Assurance Company. He was a member of many learned organisations including the Society of Antiquarians and the London Mathematical Society.



Fig. 1. Griffith Davies, FRS.<sup>1</sup>

Davies was born Gruffydd Dafydd on 28 December 1788 at Ty Croes, Hafod Boeth, in the parish of Llandwrog, Caernarfonshire.<sup>1</sup> His father, Owen Dafydd, was an illiterate farmer and quarryman who worked in the Welsh slate quarries. The family was poor and lived in a very isolated spot with no school in the parish of Llandwrog or any of the adjoining parishes. Davies's father, like most of his neighbours, had never been taught to read in any

language, but his mother, Mary Williams, could read the Welsh language reasonably well. Davies's first instruction was at a Welsh Sunday School, conducted by a man who worked in the slate quarries. This man faced considerable opposition from locals who thought that learning to read was not proper employment for a Sunday. Davies considered himself very indebted to this man and he soon acquired the art of spelling and reading in the Welsh language.<sup>2</sup>

When he was about seven a school for teaching English opened in an adjoining parish. Davies attended this school, a distance of two miles away across rugged country, for five or six quarters, at the rate of 2s 6d per quarter. He was beginning to read English well, but by the age of eight or nine he had to leave school and help his father on the land. Then, at the age of 12, he was again sent to school, this time to an English day-school established in his parish. But the bad harvests of 1800 and 1801 meant he was again taken from school and hired to a distant relative on a neighbouring farm, to drive horses and plough land.

At the age of 14 he became permanently employed in the slate quarries. Having passed through apprenticeship he began to earn a man's wages, support himself and save a little money. So by the age of 17 he attended an English day-school at Caernarfon where he made considerable progress in spelling, reading and writing the English language. He also discovered that he had an aptitude for mathematics.

When his savings were exhausted he returned to work in the slate quarries, spending his spare time making calculations on slates. But he aspired to something higher than mere manual labour and was determined to go to England in search of employment. In September 1809, at the age of 21, he sailed from Caernarfon to London, where he attended a school at Cambridge Heath, Hackney Road. He was advised to improve his writing and grammar, but it was mathematics that really fascinated him.

In January 1810 Davies was engaged as the arithmetical tutor at a school in the neighbourhood of Sadler's Wells, at a salary of £20 a year with board and residence. He remained there until the summer of 1811 when, as a result of reorganisation, his services were no longer required. He then opened a school of his own, teaching mathematics and allied subjects. At the same time he continued his own

studies; he joined the Mathematical Society whose extensive library was of great benefit to him.

Among his pupils was a gentleman connected with an Assurance Office who wanted to study the theory of life assurance. The then President of the Mathematical Society recommended Davies as a person likely to be able to give him instruction. Davies had no knowledge whatever of life assurance, but he set himself to work to attain proficiency in annuities and assurances. His studies in actuarial and assurance work led him to discover new methods of assessing premiums and to give assurance work a scientific basis. He developed a method of sharing earnings between partners in a bargain when some of them had been absent from work during the month.

Another of his pupils at the school was Sir John Franklin, the Royal Navy officer and celebrated explorer of the Arctic, who came to improve his knowledge of navigation.

In 1816 Davies moved his school to Cannon Street where he taught chiefly mathematics. He now began to teach gentlemen holding the appointment of actuaries to Life Offices, and he even made calculations for some of those institutions. As he had now become familiar with the theory and practice of life assurance, he was encouraged to become an actuary himself. He introduced himself to William Morgan of the Equitable Life Assurance Society and requested that Morgan examine him on his skills and furnish him with a certificate of actuarial competency. He was, however, unsuccessful in his first application to become connected with an Assurance Office.

In December 1819 he was advised to submit to the Society of Arts a “sundial of a peculiar kind” engraved on slate by him some years earlier. This dial showed the following:

1. The hour of the day in London.
2. The hour of the day at Peking.
3. The sun’s place in the ecliptic, and the curves traced out by the shadow of the summit of the gnomon at the entrance of the sun into each of the twelve signs of the zodiac.
4. The day of the month.
5. The sun’s declination.
6. The time of the sun’s rising.
7. The time of the sun’s setting.
8. The length of the day.
9. The Babylonish hour, or time from the sun’s rising.
10. The sun’s altitude.
11. The sun’s azimuth.
12. The equation of time to mean noon.
13. The day and hour when the sun is vertical at several places situated between the tropics.
14. The proportional quantity of solar rays falling obliquely on a given surface, as compared with the quantity falling vertically on a like portion of surface.

In the summer of 1820 Davies was awarded the large silver medal of the Society, presented by its then President, the Duke of Sussex.

In 1821 Davies was invited to give advice and assistance to a company about to be formed under the name of the Guardian Assurance Company, and in 1823 he was appointed as a permanent actuary of that company, an appointment he held for nearly a third of a century. By 1825 his reputation as an actuary had become established and he was consulted by various Assurance and Annuity Societies in England, Scotland, Ireland, Europe and America.

In 1829 the East India Company asked Davies to audit the accounts of the Bombay military funds, and in the following year he was asked to do similar work for the Madras and Bengal military funds. He was elected FRS on 16 June 1831. By 1843 Davies was extremely well-off and had more private work than he could cope with, being involved as a consulting actuary in several legal cases. He was the first member of the Institute of Actuaries to be elevated to a Fellow of that institution and had been invited to become its President – but he declined, mainly owing to his ill health.

Griffith Davies was widely respected for his honesty, piety, charity and benevolence. He remained devotedly attached to the religious faith of his early days as a “Welsh Calvinistic Methodist”. In 1837 he became an elder of his church in Jewin Street, Cripplegate, where services were held in Welsh. He married an English woman, Mary Holbut, in 1812 and had four daughters, only one of whom, Sarah, survived to maturity. His wife died in 1836, and he married again in 1841. His second wife was a Welsh widow, Mrs Glynne, who had three sons; they had one child, a son who grew up bearing his father’s name.

In the winter of 1847 Davies was afflicted with severe influenza which left him with chronic bronchitis for the rest of his days. He suffered a stroke in December 1854 and died on 21 March 1855. He was buried at Abney Park cemetery in Stoke Newington, London Borough of Hackney.

### **The Slate Sundial**

In his submission to the Society of Arts, Davies wrote:

*“the inventor submits his dial to the consideration of the Society, more on account of its novelty as a work of art, and the lowness of the price for which such dials may be engraved on slate as compared with brass, than for any peculiarity in the theory of its construction.”*

His submission included a sketch of his sundial, calculations, notes and a covering letter from his address at 43 Cannon Street, dated 8 December 1819, in which he said:

*“I HAVE constructed a Sun-Dial of a peculiar description, and engraved it on a Welsh slate, 27 inches square and an inch thick.*

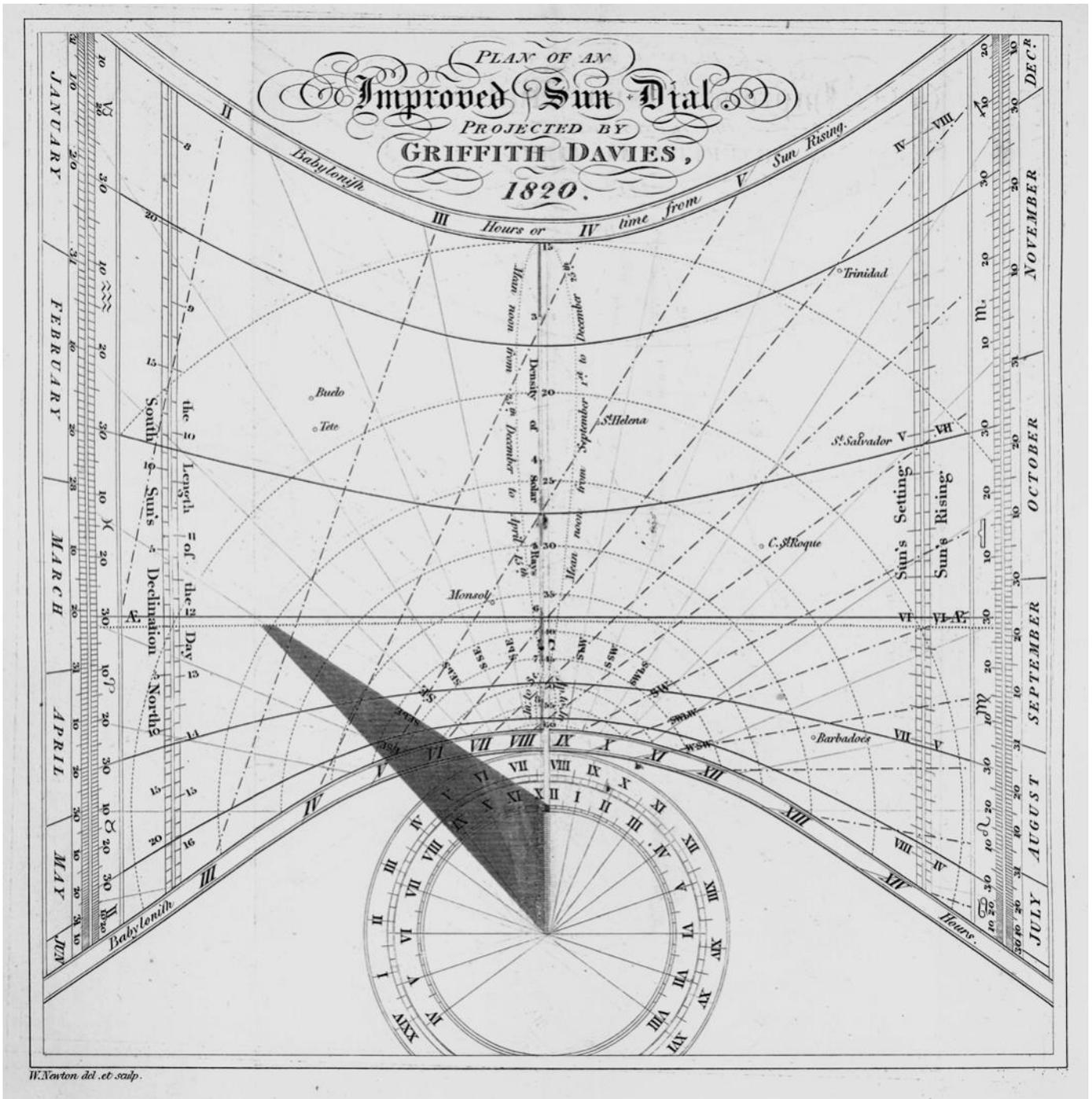


Fig. 2. Engraving of Davies's Sun Dial by W. Newton.<sup>3</sup> Courtesy of University of Reading Library.

"If such should come within the object of the Society of Arts, &c., I shall feel happy in bringing it for their inspection at any time they may think proper to appoint."

Details of all the awards made in 1820, including Davies's large silver medal, were published in the *Transactions of the Society for the Encouragement of Arts, Manufactures, and Commerce* in 1821.<sup>3</sup> This publication contains an engraving (Fig. 2), made by W. Newton, entitled "Plan of an Improved Sun Dial projected by Griffith Davies, 1820".

The sundial was engraved by Davies on Welsh slate, 27" square and 1" thick. It was designed for a latitude of 51° 32' North, the approximate latitude of his school of mathematics in Cannon Street, London EC4. The gnomon was a

simple right-angle triangle with a polar style. It was made of solid brass and was fixed to the slate by two legs which were fastened underneath by screws. Unfortunately, Davies did not state the thickness of the gnomon.

Items 1–14 above are now considered in more detail.

1. The hour of the day in London is shown by the inner ring of the circular dial at the bottom of the engraving. This shows the hours from 4 am to 8 pm. Davies noted that allowance must be made for the thickness of the gnomon. He also stated that morning hours from 6 am to noon are shown by the shadow of the left edge of the gnomon; afternoon hours from noon to 6 pm are shown by the shadow of the right edge of the gnomon; and the hours

before 6 am in the morning and after 6 pm in the evening are shown by the shadows of the contrary edges of the gnomon. We can deduce, therefore, that his dial had a noon gap and that the hour lines, including those for the back hours, were correctly delineated.

2. The hour of the day at Pekin is shown in the outer ring of the dial. The time in Pekin is 7hr 45m ahead of London.

3. The sun's place in the ecliptic, and the curves traced out by the shadow of the summit of the gnomon at the entrance of the sun into each of the twelve signs of the zodiac: seven declination lines are shown, along with the signs of the zodiac.

4–8. Scales showing the day of the month, the sun's declination, the times of the sun's rising and setting, and the length of the day are found at the sides of the dial.

9. The Babylonish hour, or time from the sun's rising is shown by lines which are marked from II to XIV. Davies noted that the shadow of the left tip of the gnomon falls on the lines to the left of the meridian line, and the shadow of the right tip of the gnomon falls on the lines to the right of the meridian line. This results in a horizontal line across the noon gap.

10. Circles show the sun's altitude from 15° to 60°, in 5° increments. The morning circles are marked by the shadow of the left tip of the gnomon; the centre of these circles is the left foot of the gnomon. In the afternoon, the circles are marked by the shadow of the right tip of the gnomon, and the centre of these circles is the right foot of the gnomon. The circles are labelled, from 15° to 60°, in the noon gap.

11. There are ten lines on each side of the dial showing the sun's azimuth.

On the left-hand side they are: EbN, E, EbS, ESE, SEbE, SE, SEbS, SSE, SbE, S (the first three are not labelled). These lines originate from the left foot of the gnomon, and the azimuth is shown by the shadow of the left tip.

On the right-hand side the lines are: S, SbW, SSW, SWbS, SW, SWbW, WSW, WbS, W, WbN (the last three are not labelled). These lines originate from the right foot of the gnomon, and the azimuth is shown by the shadow of the right tip.

Readers with sharp eyes may have noticed that the labels for SW, SWbW and WSW are incorrectly engraved on the Babylonian hour lines.

12. The equation of time to mean noon is marked by an analemma on the meridian line, either side of the noon gap. It is marked "Mean noon from 25th December to April 15th" on the upper left-hand side, "Mean noon from September 1st to December 25th" on the upper right-hand side, "Ju. to Se." on the lower left, and "Ap. to Ju." on the lower right.

13. Eight places are marked on the dial to show the day and hour when the sun is vertical at that point (the sub-

solar point). Such places must lie between the tropics and be less than 90° from London. For example, St Helena is marked on the dial at a declination of 16° S and a time of 6° W. My atlas confirms that these are indeed the correct co-ordinates for St Helena. So we know that when the tip of the gnomon is on the dot marked St Helena then the sun is directly overhead there.

There are five places whose co-ordinates appear to be correct (all five are on the right-hand side of the dial):

St Helena, 16° S, 6° W (South Atlantic)

Trinidad Island, 20° S, 30° W (Brazil)

St Salvador, 13° S, 38° W (Salvador, Brazil)

Cape St Roque, 5° S, 35° W (Brazil)

Barbadoes, 13° N, 60° W (Caribbean)

The three places on the left-hand side of the dial (all in Africa) are more problematic:

Tete is in Mozambique on the Zambezi River. It appears to be at 14° S, 30° E on the dial, but is actually at 16° S, 34° E. So it is not quite in the correct place on the dial.

Buelo appears to be at 15° S, 29° E on the dial. These co-ordinates are near Lusaka, Zambia, but I could not find Buelo here (or anywhere else for that matter). I wondered whether it was Bulawayo in Zimbabwe which is 20° S, 29° E. Say "Boo-ay-low" to yourself and see whether you think it may be a mispronunciation of Bulawayo. Even so, the co-ordinates are not quite correct. Maybe Davies's knowledge of African geography and spelling was not as good as his South American.

Monsol appears to be at 2° S, 11° E on the dial. Monsol was the capital of the Anziku Kingdom, a central African state of the modern Republic of Congo. The state was centred around Pool Malebo (4° S, 16° E) which is a very shallow lake on the Congo River. Brazzaville and Kinshasa are on opposite shores of the lake. There is no sign of Monsol on the present-day map.

Why Davies chose these particular places to put on his dial remains a bit of a mystery.

14. The proportional quantity of solar rays falling obliquely on a given surface, as compared with the quantity falling vertically on a like portion of surface:

Davies makes three caveats for this item:

(i) that a small portion of the earth's surface may be considered as a plane,

(ii) that all solar rays which fall on such a surface may be considered as parallel to each other, and

(iii) that the density of solar rays is not affected by the comparatively small distance of one part of the earth's surface from the sun, and that of another part.

Imagine a square portion of the earth's surface placed at right-angles to the solar rays (Fig. 3). One edge of this square is denoted by CB. 100% of the solar rays fall on this square.

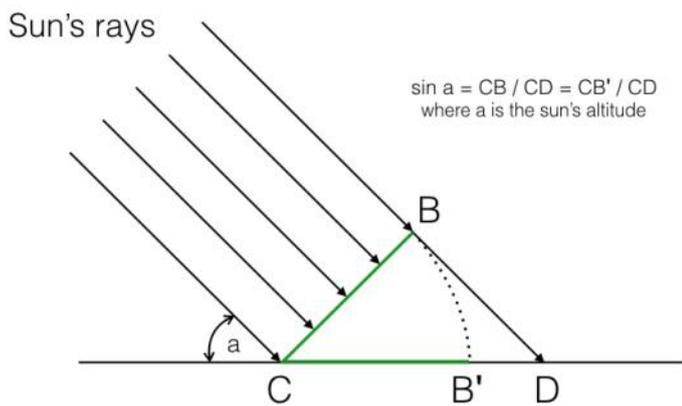


Fig. 3. The proportion of solar rays falling obliquely on a given surface, as compared with the quantity falling vertically on a like portion of surface, is equal to the sine of the sun's altitude.

Next, lay this square down along the horizontal, represented by  $CB'$  ( $CB' = CB$ ). The same amount of solar rays that fell on the square  $CB \times CB$  now fall obliquely onto a rectangle whose area is  $CB \times CD$ . So the proportion of the solar rays that are falling on a "like portion of surface" (that is, a square with sides of  $CB$ ) is  $CB / CD$ , and this is equal to  $\sin a$ , where  $a$  is the sun's altitude.

For example, at the summer solstice,  $a = 62^\circ$ , so 88% of the sun's rays fall on the square. At the winter solstice,  $a = 15^\circ$  and 26% of the sun's rays fall on the square. So the proportion varies throughout the year.

The scale showing "Density of Solar Rays" is marked along the meridian (3–8, denoting three-tenths to eight-tenths).

### Other Observations

There is a dotted declination line just below the equinox line, at  $1^\circ$  North. The shadow of the gnomon's tip is placed on this line, so it is likely that this is a worked example to show where the shadow would be at 8:45 am on 22 March.

There are a few things that are incorrect on Newton's engraving, such as:

- Tete is not quite in the right place.
- Three of the azimuths are marked on the Babylonian hour lines.
- The Babylonian hour lines do not have a step across the noon gap.
- The azimuth lines do not originate from the correct points.

Also, I wonder why the top corners of the dial are not on the engraving. It would have made sense to continue the date scales upwards to meet the winter declination line.

Having read Davies's notes and seen his diagrams, tables, calculations and attention to detail, I feel sure that his original slate dial would be accurate, and that any errors on the engraving were made by Newton alone.

Even so, Newton's engraving does capture the spirit of this very interesting dial. Sadly we don't know whether the dial is still in existence, so if anyone knows its whereabouts please let the BSS know.

### ACKNOWLEDGEMENTS

Many thanks to Frank King for his enthusiasm and advice.

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1. Llewelyn G. Chambers: 'Griffith Davies (1788–1855) F.R.S. Actuary', *Transactions of the Honourable Society of Cymmrodorion*, 59–77 (1988).
2. 'Memoir of the late Griffith Davies, Esq., F.R.S.; abridged from a more extended one, by his Nephew Thomas Barlow', *The Assurance Magazine and Journal of the Institute of Actuaries*, 2(4), 337–348 (1855).
3. *Transactions of the Society for the Encouragement of Arts, Manufactures, and Commerce*, 38, 147–160 and Plate 31 (1821).

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profession, she joined a multinational computer manufacturer, first in customer support, then product management, and finally marketing & advertising. Sue is a member of the Berkshire Guild of Weavers, Spinners & Dyers; she is also a basketmaker and has had her work displayed in several exhibitions. She lives near Wokingham with her husband and two cats. She can be contacted at [smanston@hotmail.co.uk](mailto:smanston@hotmail.co.uk).

## READERS' LETTERS (2)

### Port Jackson and Richard Melville's Dial

I can add a comment about the listing of place names on the Melville slate dial described by Mike Cowham in the June issue (*BSS Bulletin* 29(ii), 36–7): Port Jackson is Sydney Harbour, named by Captain Cook in 1770 and settled by the First Fleet in 1788, led by Captain Arthur Phillip.

I cannot contribute any suggestions as to why these 'two locations' are shown as being an hour apart; that is a straight mistake by the sundial maker. New Zealand is two hours ahead of Sydney, as listed in Mike Cowham's article.

Further information can be found at

[https://en.wikipedia.org/wiki/Port\\_Jackson](https://en.wikipedia.org/wiki/Port_Jackson)  
and

<https://www.britannica.com/place/Port-Jackson>

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# PORTABLE DIAL IN A CALENDAR BOX

MIKE COWHAM

Portable dials frequently have some form of calendar attached. The dial in this article is set into a box that has quite a complex calendar system around its outside.

The dial itself is fairly plain and is unsigned but is almost certainly English (Fig. 1). It is the exterior of the box which is the most interesting part, with all surfaces covered with calendrical or similar information. These scales are printed on paper adhered to the box then protected by a coat of varnish. From its markings it probably dates from 1792, in the reign of King George III, and this is the earliest date shown on the scales. The box is 3" diameter and 1½" overall height (78 mm × 37 mm). Beneath the dial, in the main box, there is a small space for carrying perhaps a few coins, tablets or even snuff.

I will take each part in turn and explain what it is showing.

## The Box Lid

The lid of the box is illustrated in Fig. 2.

The outer ring has the 12 months of the year, each showing the number of days in that month. Four of the months have additional information as follows:

- |               |   |                    |
|---------------|---|--------------------|
| March 31.     | – | Spring Q'. beg. 20 |
| June 30.      | – | Summer Q'. beg. 21 |
| September 30. | – | Autumn Q'. beg. 24 |
| December 31.  | – | Wint' Q'. beg. 21  |

Then below each month are shown between three and five Saints' days or other important events. For example, June has the following:

- |    |                           |
|----|---------------------------|
| 1  | K.C. III. Born            |
| 11 | S <sup>t</sup> . Barnabas |
| 21 | Longest Day               |
| 24 | S <sup>t</sup> . John Bap |
| 29 | S <sup>t</sup> . Peter    |

The next ring inwards has "Dominical Letters from 1792 to 1832."

This shows the years from A to G, with A reading:

- |    |                 |
|----|-----------------|
| A. | 1797. 1809.     |
|    | 15. 20. 26. 37. |

The next ring shows the seven days of the week and months of the year that fall on these, such as:

- |            |          |
|------------|----------|
| APL. JULY. | Saturday |
| JAN. OCT.  | Sunday   |
| MAY.       | Monday   |

In the very centre is a revolving disc with the seven dominical letters around it and dates above each letter (in the green band), such as:

- |                |
|----------------|
| 5. 12. 19. 26. |
| E.             |



Fig. 1. The dial in its box with the lid removed.



Fig. 2. Calendrical information on the lid of the box.

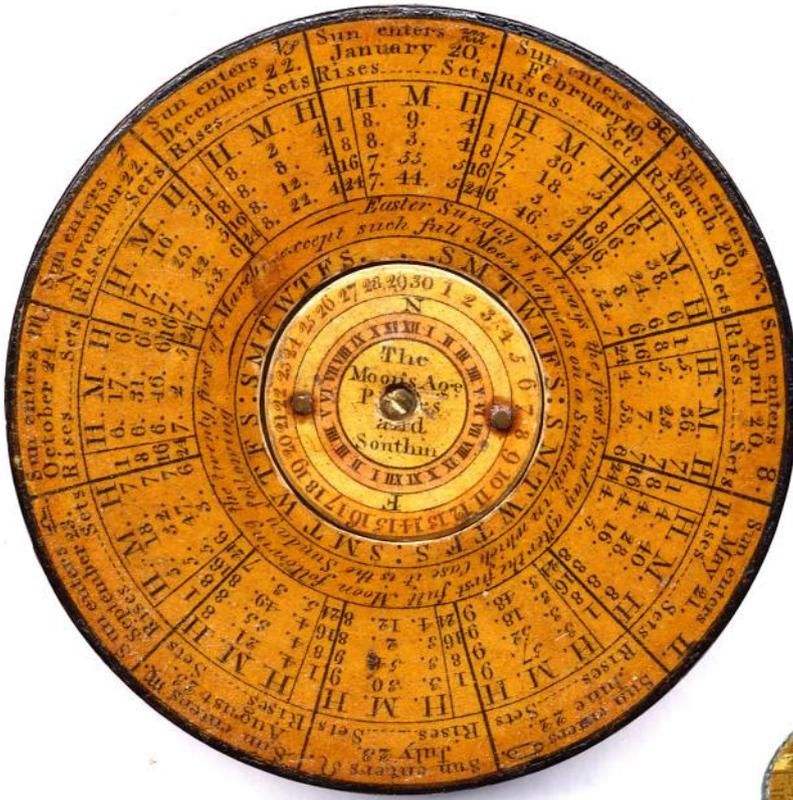


Fig. 3. The underside of the box.

At its centre is written: "The Dominical Letters and Days of the Month".

**The Box Underside**

The underside of the box is shown in Fig. 3.

The outer ring has the twelve zodiac signs with the dates of entry, such as:

Sun enters ♀ May 21.

and

Sun enters ♋ June 22.

Below this are the words "Rises - - - Sets" above the next ring's columns where the times of rising and setting are shown as in Fig. 4. This is perhaps a little confusing as for the times of sunset, the minutes need to be deducted from the hours shown rather than added as for sunrise.

Below this is written in two lines:

*Easter Sunday is always the first Sunday after the first full Moon following the twenty first of March except such full Moon happens on a Sunday, in which Case it is the Sunday following.*

There is then a ring of the days to be read against the rotating centre. These days are shown as "S M T W T F S .:", repeated four times.

The central rotating dial shows: "The Moon's Age Phases and Southin."

Around its edge are days 1 to 30 with N (New) and F (Full), set outside the XII points on a 24-hour dial.



Fig. 4. Times of sunrise and sunset in May.



Fig. 5. The calendar box with its lid in place.



Fig. 6. How time at any place shown may be determined. Here XII Noon has been set to London time, so in Kep. Island and in New Zealand it is about XII Midnight. New Zealand is also shown as 11745 miles N.E. of London.

|  |                        |  |                          |
|--|------------------------|--|--------------------------|
| Paris S.S.E.215.<br><b>London.</b><br>Madrid S.S.W.700.        | Noon.<br><b>XII.</b>   | <i>Keop: Ifland.</i><br>N. by E.10880.<br>New Zealand.<br>N.E.11745.                 | Midnight.<br><b>XII.</b> |
| Lisbon S.S.W.<br>985.<br>Canary Ifles                          | <b>XI.</b>             | Great<br>South Sea.  | <b>XI.</b>               |
| Azore.<br>Ifles..  | <b>X.</b>              | N. Britain.<br>N.E.8830.   | <b>X.</b>                |
| Brazil.<br>S. Salvador<br>S.W.6000.                            | <b>IX.</b>             | N. Holland.<br>E.9310.   | <b>IX.</b>               |
| Surinam S.W.<br>3840.<br>Carribbe Ifles.                       | <b>VIII.</b>           | China<br>Pekin N.E.<br>4320.   | <b>VIII.</b>             |
| Quebec W.3000.<br>Philad. W.byN.<br>3430.<br>C. Horn S.W.8890. | <b>VII.</b>            | Canton.<br>N.E. by N.5880.<br>Batavia E.7309   | <b>VII.</b>              |
| Florida<br>S. Augustine<br>W.3690                              | Morning.<br><b>VI.</b> | Siam E.5040.<br>Tibet E.3780.  | Evening.<br><b>VI.</b>   |
| Mexico<br>W.by S.6844  | <b>V.</b>              | Delly E.3720.<br>Surat E.4330.<br>Bombay E.4000.                                     | <b>V.</b>                |
| California<br>S. Juan. W.                                      | <b>IV.</b>             | Rufsian Tartary<br>Tobolski.<br>N.E.2160.  | <b>IV.</b>               |
| Great<br>South Sea   | <b>III.</b>            | Ispahan E.2460<br>Morocco S.S.W.1449<br>Aleppo E.1860                                | <b>III.</b>              |
| Otabeite.<br>N.W. by N. 9590.                                  | <b>II.</b>             | Jerusalem S.E.by E.<br>2352<br>Petersb. N.E. 1300.<br>Constantinople.<br>E.S.E.1547. | <b>II.</b>               |
| Great<br>South Sea   | <b>I.</b>              | Dantzick E.N.E.961<br>Vienna E. by S.700<br>Rome S.E. by E.887                       | <b>I.</b>                |

Table 1. Markings around the outside of the box with the lid set to noon in London.

### The Box Periphery

Around the edge of the lid are the hours I–XII, I–XII divided by halves, quarters and half quarters, while the lower part of the box shows various places in the world (Fig. 5). Table 1 gives a complete list of the markings on the periphery of the box, the lid being on the right of each column. As well as showing the place it also shows the nearest direction and distance in miles from London by a Great Circle route. It seems strange that New Zealand is “N.E.” of London, but this is the shortest route to that country.

The lid may be rotated above the lower part of the box so that if the time is known at any one place, this time can be set over that place and the time at any other place can then be determined quite simply. An example is explained in Fig. 6.

Overall, it is a most interesting calendar box.

### The Dial

The dial itself has not been competently calibrated (Fig. 7). Its gnomon is at 45° and the hour spacing goes from 15° near XII to as much as 20° near VI. This, in fact, puts the two VI’s to the south of the centre line by about 10°. One



Fig. 7. The chapter ring and gnomon showing the errors in its calibration.

unusual feature is the central bar which is asymmetric, but a rather interesting idea! On either side of the centre, it is vaguely ‘S’ shaped, but in the same direction in both the east and west. These parts are made from brass with silvering whereas the compass bowl itself is just brass.

However, the attractively hand-coloured paper in the compass bowl is nicely produced (Fig. 8), but being printed, it may originate elsewhere. It appears to be glued to another piece of paper which may have been the original compass plate.



Fig. 8. The calibration of the compass bowl.

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# A DIY GARDEN HELIOCHRONOMETER

BRIAN HUGGETT

My wife and I enjoy visiting gardens, in part to gain inspiration for our own. Such outings led me to consider installing a sundial in our garden. Knowing little about sundials, I inspected those we encountered and was dismayed to discover that none agreed with my watch. Even those that claimed to reflect clock time required additional consultation of a table or graph.

“What we need,” I said to my wife, “is a sundial from which clock time can be easily read by anybody.”

“Why don’t you invent one?” she replied.

My subsequent enquires led me to understand that in order for a sundial to correspond with a properly-adjusted clock, it must take account of five factors:

- The latitude of the sundial.
- The longitude of the sundial.
- The north-south orientation of the sundial.
- The Equation of Time (EoT).
- British Summer Time (BST).

During the winter of 2016/17, I designed and built a sundial to take account of these factors (Fig. 1). Rather to my surprise, it has turned out to display the time within a minute or so of the time shown by my watch. In this article, I will describe how each of the above factors was addressed

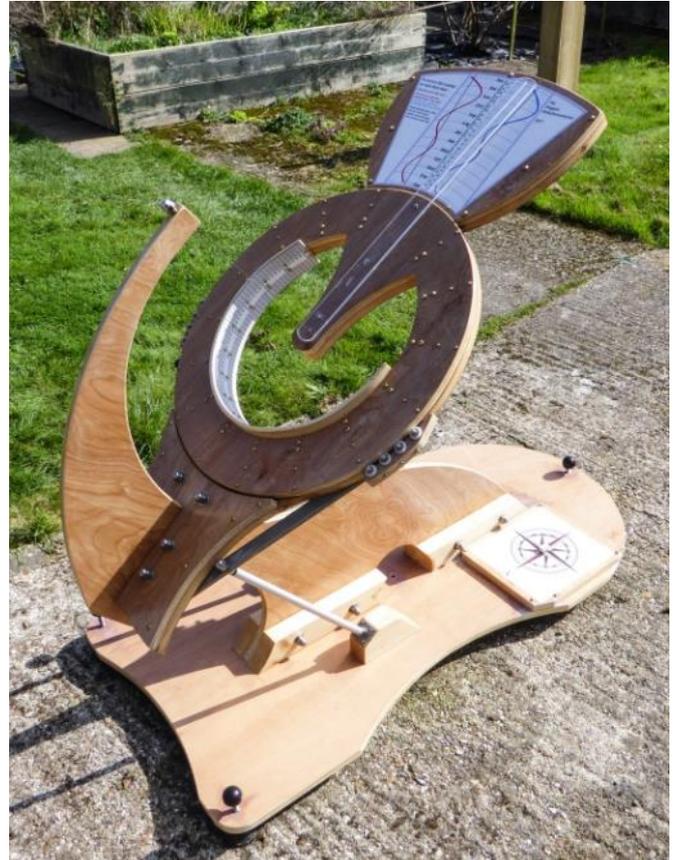


Fig. 1. The heliochronometer.

in the design of the sundial, together with some of the practical issues that arose

The primary components of my sundial are labelled in Fig. 2. My first decision concerned the type of sundial. I chose to make an equatorial sundial because graduations on the time scale have equal spacings – one hour is always  $15^\circ$  of the circle on which the time graduations are marked. Corrections for longitude, the EoT and BST can therefore be made by simply rotating the dial plate/time scale.

## The Latitude of the Sundial

The latitude of my garden is  $50.94^\circ$  N ( $51^\circ$  for practical purposes) and my sundial is specifically designed for that latitude. The dial plate is fixed at the co-latitude of  $39^\circ$  to the horizontal, which leads to the plane of the dial plate being parallel to the plane of the Earth’s equator (Fig. 3). I did not wish to add too many design complications to an experimental project. Clearly, however, it would have been possible to incorporate a mechanism that would permit the



Fig. 2. The primary components of the heliochronometer.

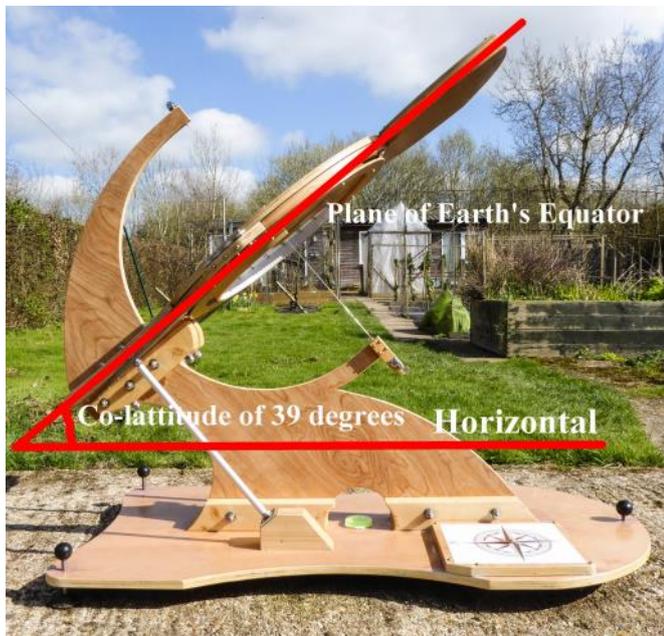


Fig. 3. The heliochronometer is designed specifically for the latitude of my garden.

dial plate to rotate about an east–west axis and thus allow the sundial to be used at other latitudes.

### The Longitude of the Sundial

Clock time in relation to where I live is either the mean solar time at Greenwich (GMT) or that time plus one hour (British Summer Time or BST). My garden is at a longitude of  $1.178^\circ$  W. This means that when it is solar noon on the Greenwich Meridian, it is 4.7 minutes before solar noon in my garden. Once again, for simplicity, my sundial is designed specifically for my garden. The timescale is, therefore, fixed such that solar noon in my garden would cause the gnomon shadow to fall at 4.7 minutes past 12:00 on the time scale if there were no corrections for the EoT or BST. As the graduations on the time scale have equal spacings, it would be straightforward to adjust for other longitudes by detaching the time scale from the dial plate annulus (DPA) and reattaching it with an appropriate rotation.

### The North–South Orientation of the Sundial

The current (2017) magnetic declination of my garden is  $0.9^\circ$  W. The sundial's alignment is achieved by having a compass rose on its baseplate, the north–south axis of which is parallel to the longitudinal axis of the sundial (Fig. 4). A red line is marked on the rose with a thin black line running along its centre. That red line is rotated by  $0.9^\circ$  anti-clockwise relative to the longitudinal axis of the sundial – hence it aligns with magnetic north. A large (100 mm), free floating, compass needle can be placed on a pivot at the centre of the rose. By rotating the whole sundial, the compass needle can be aligned with that red line, causing the longitudinal axis of the sundial to point towards geographic north. This method worked adequately in practice, although it could only be used when the air was

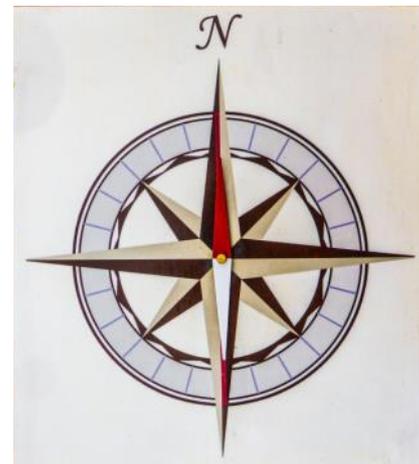


Fig. 4. The compass rose, showing the red, magnetic north, alignment line and the compass needle.

absolutely still because a breath of wind moved the needle. It was possibly more by luck than judgement that an accurate north–south orientation was achieved using a compass needle. I now understand that this is not the preferred method for diallists. Owing to the accuracy of modern clocks, it is, of course, possible to align a dial to the geographic meridian by making all other relevant adjustments to the dial and then orientating it such that it reads the expected time.

### The Equation of Time

The mechanism for the EoT adjustment was the greatest challenge in meeting my initial criterion of making a sundial from which clock time could be easily read by anybody. My attempt to achieve this employs a graph of the EoT that is mounted beyond the southern extremity of the DPA (Fig. 5). The DPA, and hence the time scale attached to it, can rotate in the plane of the dial plate relative to the rest of the sundial's structure. An acrylic



Fig. 5. The dial plate and EoT graph.

pointer is attached to the DPA such that it rotates with the DPA. By rotating the DPA to align the slot in the acrylic pointer with the current date on relevant time curve, the DPA, and hence the time scale, is moved to compensate for the EoT (Fig. 6).

### British Summer Time

My sundial adjusts between GMT and BST by having two EoT graphs that are set 15°, or one hour, apart. These are positioned symmetrically on each side of the longitudinal axis of the dial plate (Fig. 6).



Fig. 6. The EoT and BST adjustment scale. The acrylic pointer is set for 15 March (or 15 January).

### Some Practical Issues

The description above has summarised the manner in which relevant adjustments occur to allow my sundial to display clock time. I explore some of the practical issues below as a series of questions and answers:

*How is the time scale positioned in relation to the dial plate annulus bearing in mind the longitude, EoT and BST corrections?*

Fig. 7 shows the alignment of the time scale at the points where the time scale is intersected by the longitudinal and lateral axes of the dial plate annulus.

*Can the time scale be easily read when the sun is south of the celestial equator and hence, in the northern hemisphere, shining on the underside of the dial plate?*

The time scale is positioned at right angles to the plane of the dial plate, attached to the inside surface of the dial plate annulus. This means that sunlight can shine upon the time scale from either above or below the dial plate. The same scale can thus be easily read from the top of the sundial on sunny days, all the year round.

*Can the time scale be read around the time of the equinoxes?*

The dial plate annulus forms a complete circle. This is necessary because the graphs for the EoT and BST corrections are mounted at the southern end of the dial

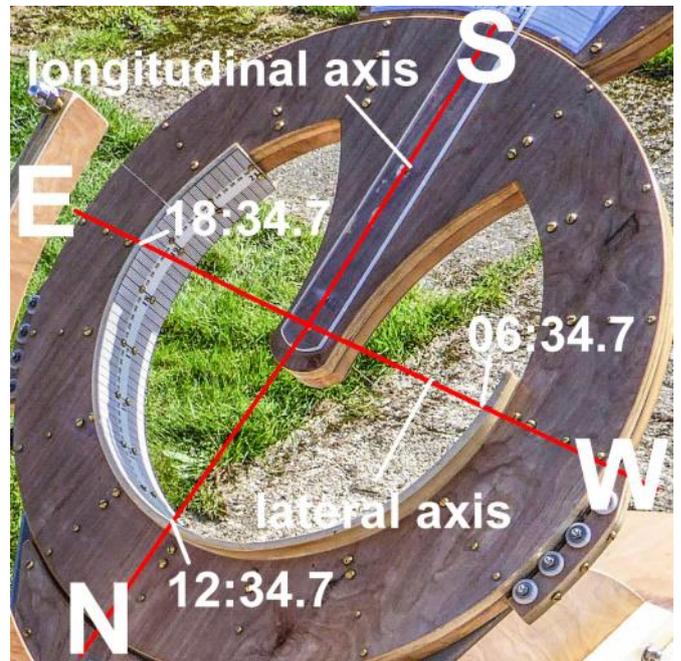


Fig. 7. The alignment of the time scale at the points where the time scale is intersected by the longitudinal and lateral axes of the dial plate.

plate. As a consequence, the inside face of the dial plate annulus will be in its own shadow on days close to an equinox.

Fig. 8 shows a cross-section of the dial plate annulus at the instant of an equinox. The plane of the diagram is that defined by the sun and the wire gnomon. With the sun in the equatorial plane, all sunrays (shown in green) are parallel to the dial plate annulus.

Three sample sunrays are shown. The central one strikes the outside rim of the dial plate annulus and is blocked. All surfaces within the thickness of the dial plate annulus are therefore in shadow.

The two flanking sunrays are not blocked until they meet the wire which serves as the gnomon. The shadow of this wire will fall on the parts of the time scale which protrude above and below the dial plate annulus. The time can therefore be read successfully.

Note that the time scale cannot be a full circle because it would be obscured by its own shadow on days close to an equinox. In order to avoid that problem, a section of the time scale has been omitted. The time scale runs from 6 am to 9 pm. Most of its absent section would, for much of the year, represent the hours of darkness at the location where I

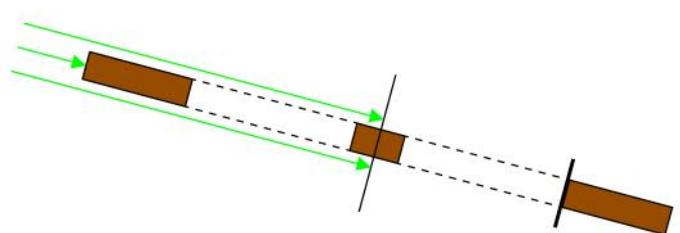


Fig. 8. Diagram showing how the time scale protrudes above and below the main dial plate structure.

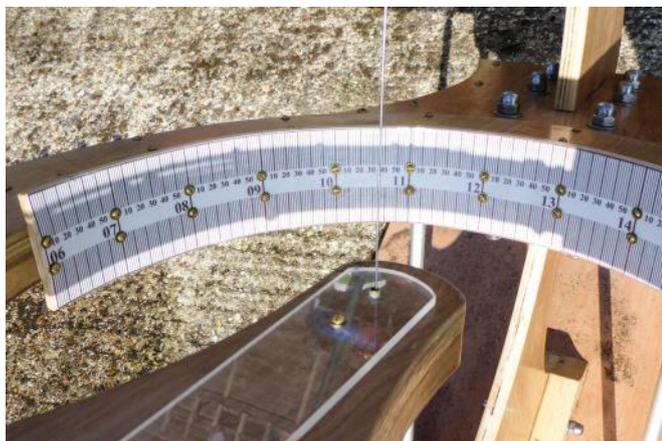


Fig. 9. The shadow on the time scale at around the time of the spring equinox.

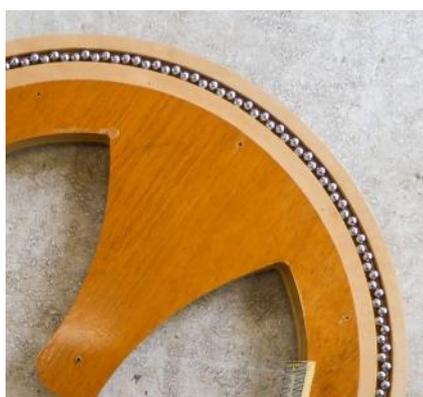


Fig. 12. The ball bearings that allow the rotation of the dial plate annulus (shown prior to final assembly).

Fig. 13. Nylon wheels on stainless steel bearings support the rotating section of the dial plate.



live. The shadow cast by the time scale onto itself means that, on days close to an equinox, the time can only be read between 9 am and 6 pm. The shadow on the timescale near the time of the spring equinox is shown in Fig. 9.

#### *How is the sundial levelled to the horizontal?*

The sundial stands on three feet that are adjustable using screw threads (Fig. 10). Having three points of support allows the sundial to stand on uneven ground. It also simplifies the levelling process. The level is checked by placing a spirit level, designed for record player turntables, onto the baseboard (Fig. 11).

#### *What is the mechanism that allows the dial plate annulus to rotate?*

The dial plate annulus rides on stainless steel ball bearings that are located in a groove between the moving section of the dial plate annulus and the static section of the dial plate structure (Fig. 12).



Fig. 10. One of the three adjustable feet.



Fig. 11. A spirit level, designed for record player turntables.

The rotating section of the dial plate is supported in its position, and guided in its rotation, by nylon wheels on stainless steel bearings (Fig. 13). These were designed to support the sliding doors of a shower.

#### *How did you avoid the shadow cast by the gnomon being too wide, and how did you keep a long, thin gnomon straight?*

Reducing the thickness of the gnomon is one obvious approach to making its shadow as narrow as possible, but it is difficult to keep a very thin rod straight. My sundial uses 0.8 mm stainless steel wire for the gnomon that is tensioned between its support points. This means that the gnomon can both be thin and totally straight.

A guitar machine head made an excellent tensioning mechanism for the gnomon wire (Fig. 14).

One minute on the time scale is 0.85 mm in width. The time period between graduations is two minutes. As the sun has an angular diameter of  $0.5^\circ$ , the width of the shadow cast by the gnomon onto the time scale is also the equivalent of two minutes in time. The umbra of the shadow spans the equivalent of about one minute (Fig. 15).

#### *How did you draw the scales and the compass rose?*

The scales were all designed and drawn on a computer and then printed on photo-quality paper. The main compass graphic was a free image taken from the Internet.



Fig. 14. The guitar machine head.



Fig. 15. The shadow of the gnomon on the time scale at around 14:09. The blue circle highlights a red alignment mark on the scale at 34.7 minutes past 12:00.

There is a small red alignment mark (circled in Fig. 15) at the top of the scale at 34.7 minutes past 12:00. This aligns with the longitudinal axis of the dial plate at its northern end, as explained above. Unfortunately scales printed on photographic paper have proven insufficiently durable. Printer ink does not dissolve in varnish, and so they seem well protected from rain. Printer ink, however, fades in sunlight. I intend, therefore, to replace all the printed scales with ones that are printed onto vinyl. I am happy with the design of the time scale and compass rose, but will use the opportunity provided by scale replacements to enhance the graphics of the EoT and BST adjustment scale. Those enhancements will include:

- Highlighting the dates for the changes between GMT and BST (the last Sunday in March and in October).
- Rendering in a different colour or style the sections of each EoT adjustment graph that are never used.
- Increasing the number of date arcs to improve accuracy in setting the acrylic pointer.

*How did you bend the wood for the time scale?*

The pine strip-wood on which the time scale is mounted was immersed in water overnight. It was then bent around a former by pressing it onto the former, a section at a time, using a hot domestic iron. The strip-wood, secured around the former, is illustrated in Fig. 16. Each section was screwed to the former with the wooden blocks shown. The circular sections of the former were made from the wood that had been cut from the centre of the dial plate. They were, therefore, of the correct diameter for the time scale.

*How did you cut all the circles and arcs of various sizes needed for the sundial?*

I made a very simple jig that allowed my jigsaw to cut circles (Fig. 17). The screw attaches the jig to the centre of any circle to be cut and acts as a pivot for the jigsaw to rotate around. Any diameter of circle can be cut by drilling a hole for the screw at an appropriate place on the bar.



Fig. 16. The strip-wood for the time scale, secured around the former.



Fig. 17. The jig for the jigsaw.

Mine is not a scrolling jigsaw, but that does not seem to matter if the blades used have a small depth, front to back.

*Where can I obtain further information about your sundial?*

This article is written for the *BSS Bulletin*, so I have assumed a good understanding by the reader of the underlying physics and mathematics. Had I read a similar article in the autumn of 2016, however, I would not have fully understood it. For that reason, I produced a web page that expands on the above with very detailed descriptions of how the sundial functions and why. See: <http://www.short-humour.org.uk/Heliochronometer/Heliochronometer.htm>.

**Brian Huggett** is a retired mental health social worker. He enjoys growing vegetables, performing as a singer/guitarist and writing under the pen name of Swan Morrison: <https://www.linkedin.com/in/shorthumoursite/>.



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# A STANDING RING DIAL BY J. SISSON

DAVID HAWKER

At a pub lunch, one of my work colleagues casually mentioned that he had a sundial in which I might be interested. He explained that it had been given to him by a friend who didn't want it. It had been in the friend's garden lying on its side and overgrown with brambles. It had subsequently been languishing in my colleague's garden shed for two years. Without much anticipation, I asked him to send me some photographs which he duly did commenting that the maker's name engraved on it was either J. Fyson or J. Sifson. I was astonished to see a rather special-looking portable (table top) sundial (Fig. 1).

Not being quite sure of the correct dial description, I sent the photographs to John Davis. He replied that it looked like a very interesting and unusual standing ring dial and that the maker was likely to be either Jonathan or Jeremiah Sisson who used a long 's' followed by a normal 's' in their name and that they worked early to mid-18th century.

My work colleague kindly let me borrow the dial to study it properly and it is described below. The maker's inscription does, in fact, show J. Sisson, with a long and a short 's' (Fig. 2) followed by 'London'. From Jill Wilson's *Biographical Index of British Sundial Makers*<sup>1</sup> it can be seen that Jonathan Sisson (c. 1690–1747) worked from around 1722 in London whilst his son Jeremiah took over the business around 1747–9.

The dial sits on a base with adjustable feet and the large hole in the centre of the base should, of course, house a compass with levelling bubbles. Sadly, the owner has no



Fig. 1. Standing ring dial by J. Sisson.  
Photo copyright Christie's.



Fig. 2. Maker's name J. Sisson on alidade ring.

knowledge of ever having seen this item. On the base is mounted a vertical support ring surrounding a moveable latitude ring. Pivoted to the inside of the latitude ring is an hour ring inside of which is a further ring, shaped from a plate and mounted with two alidades.

The base is engraved with a Watch Faster/Watch Slower chart which provides clues to the age of the dial. It must have been made before the calendar change of 1752, as the sun/watch equal dates are: 4 April, 6 June, 20 August and 13 December (now all 11 days later). John Davis suggested also looking for the Equation of Time maxima and minima and comparing them with values in a database of various published tables.<sup>2</sup>

The dates and times as marked on the dial and shown below are a perfect match with a table that John Flamsteed produced and that was published by John Smart in 1702:

|            |           |              |
|------------|-----------|--------------|
| 29 January | + 14m 49s | (Watch fast) |
| 4 May      | - 4m 13s  | (Fig. 3)     |
| 15/16 July | + 5m 46s  |              |
| 23 October | - 16m     | (Fig. 4)     |

As these tables were not superseded until the mid-1730s it is likely that the dial precedes that period and that it was probably made by Jonathan rather than Jeremiah Sisson.

## Description

### Base

The base is 8¾" outside diameter and on its underside are four small threaded rods with horseshoe-shaped attachments (actually three extant, one missing). These were determined to be 'wing' screws used to attach the compass plate. There are also four guide plates allowing the main, inner, part of the base to turn. Connected to the outer rim are three adjustable feet, each attached by two small brass screws. Two of these fixing screws are missing.

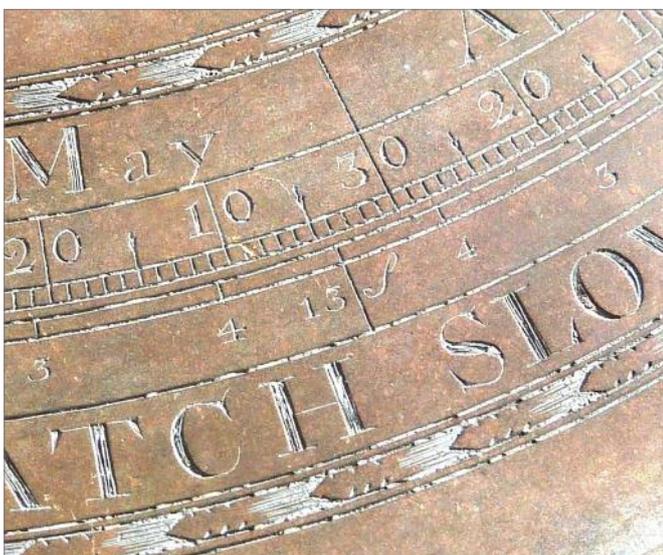


Fig. 3. Watch Faster/Watch Slower table showing the greatest deviation of 4 minutes 13 seconds watch slow compared with the dial on 4 May.



Fig. 4. Watch Faster/Watch Slower table showing the greatest deviation of 16 minutes [0 seconds] watch slow compared with the dial on 23 October.

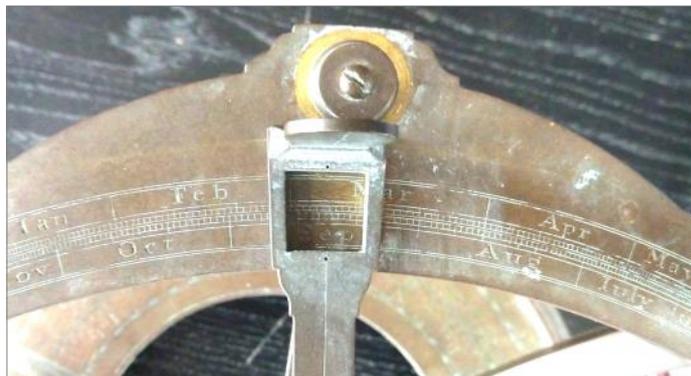


Fig. 5. Month markings on the alidade ring.

The inner base, which can turn relative to the supporting rim, is engraved with the Watch Faster/Watch Slower table. There is a hole in the centre 4½" in diameter where the above-mentioned compass with, probably, levelling bubbles should be mounted. On this base are mounted the two main supports for the sundial.

### Fixed Outer Ring

The fixed vertical outer ring is also 8¾" outside diameter and is supported by two sturdy mounts. At the top is a finial with a lifting ring. On the inside of this fixed ring is the latitude ring. This ring should rotate within the fixed ring in order to set the latitude. However, it is seized and I could not find any easy way to free it.

### Latitude Ring

One side of the latitude ring is engraved with degrees, from 0° to 90° in both directions divided in half-degree intervals. The other side is engraved with divisions drawn radially from a point on the ring at around 45°. The markings go from 0 to 90 and are for altitude measurement.

### Hour Ring

The hour ring is pivoted inside the latitude ring at the zero degrees and 180° positions. It can move through 90° from inside the latitude ring. There is a stop when it is at 90° from the latitude ring; it is then set up for use.

It is engraved with hour markings in Roman numerals going clockwise from 12 at the zero-degree pivot round to 12 at the 180° pivot, and then continuing round from this point up to 12 again at zero degrees. The markings are in two-minute intervals with a diamond lozenge at the 30-minute mark.

The hour markings are on the same side of the dial as the latitude degree markings on the latitude ring.

### Alidade Ring

Mounted on a bar crossing the diameter of the latitude ring at the 90° position is a third ring made from a pierced flat plate that rotates inside the hour ring. From the outer points of this ring are attached two pivoted arms or alidades, one on each side of the plate. These alidades cross the ring to the other side and both have small perpendicular plates at

either end, one with a pin hole at the moving end and one with a target mark at the pivot end. Each bar has a cut-away portion at the pin-hole end with a centre line and small holes for attaching an indicating wire (missing) for aligning with engraved markings on the ring plate (Fig. 5).

On one side of the plate, the engraved markings give months, arranged in an arc from January to May and returning on the same arc from June to December. The centre area has been rubbed where the alidades had, at the time when I borrowed the dial, been attached incorrectly. The months are divided into days and the divisions reduce in size from the centre to the left and right extremities of the arc (Fig. 5).

On the other side of the ring there is a similar arc, the top half of which has declination markings showing: in the centre an 'Æ' (Equator); on the left-hand side, 'SD' (South Declination); and on the right-hand side, 'ND' (North Declination). The markings on this arc are from 0 at the centre to 20 at SD and similarly to 20 at ND in the other direction. These units are divided into equal intervals of one half. Below this arc is another with the signs of the zodiac. To the right of centre are three sectors, in reducing size, each with 30 divisions. The first has the signs for Aries and Virgo, the second for Taurus and Leo and the third for Gemini and Cancer. From the centre to the left are: Libra and Pisces, Scorpio and Aquarius, and Sagittarius and Capricorn (Fig. 6).



Fig. 6. Declination and zodiac markings on the alidade ring.

### Condition

The latitude ring of this sundial is firmly seized on to the support ring. Releasing the screw in the top finial, which relieves a fixing plate, does not help. It is difficult to see how the latitude ring has been constructed and consequently how it might be removed for cleaning. At the moment this does not look possible without damaging the dial.

### Materials and Construction<sup>3</sup>

The composition of the various rings and components of the dial were analysed by X-ray fluorescence (XRF).<sup>4</sup> All the components gave a very similar result of a leaded brass containing approximately 70% Cu, 27% Zn and 2% Pb. Small levels of impurities were mainly 0.2% Sn; 0.1% Ag; 0.05% Ni; and 0.3% Fe with a trace amount of Sb. This is

rather a high-quality specification for the period. The consistency of the results shows that all the materials came from the same source and are original. The surface now shows a significant level of patination. The standard of workmanship and finish is very high with smooth surfaces without any signs of blow-holes or casting flaws and with very crisp, square edges to the plates. The engraving, too, exhibits a very controlled use of the burin.

### Conclusions

It would seem that this dial may be quite rare. A specialist at one of the auction houses said that he had only ever seen one other standing ring dial with an alidade and that was by Rowley (1668–1728; Master of Mechanics to George I)<sup>5</sup> in a private collection. Jonathan Sisson is known to have made theodolites<sup>6</sup> and perhaps this association with alidades inspired the design of this sundial. The dial is not overburdened with elaborate decoration and the majority of the engraving can be seen to be functional. Most standing ring dials, which were often made as presentation pieces for heads of state, are known as 'mechanical ring dials' and feature a watch dial mechanically coupled to the setting of the hour ring.

The moral is: when someone down the pub nudges you in the ribs and says " 'ere, I've got a sundial. Do you want to see it?", never say "No".

### ACKNOWLEDGEMENTS

My thanks to Michael Rehling and Christine Anderson for giving me the opportunity to study this sundial. I am grateful to John Davis for considerable help in preparing this article.

The Fig. 1 photograph is by kind permission of Christie's. This is the copyright of the auction house and must not be reproduced without their permission.

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2. J. Davis: 'The equation of time as represented on sundials', *BSS Bulletin* 15(iv), pp.135–44 (December 2003).
3. This section was contributed by John Davis.
4. The instrument was a Thermo-Scientific Niton XL3t GOLDD+ using a 50 keV primary beam and a silicon drift detector, calibrated against the CHARM set of certified reference materials for heritage copper-alloys. The test time was 65 seconds per analysis.
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6. A.D. Morrison-Low: *Making Scientific Instruments in the Industrial Revolution*, Ashgate, Aldershot (2007), p.262 and elsewhere.

For a portrait and CV of the author, see *Bulletin* 25(iv), December 2013. He can be contacted at [david@hawkerdials.co.uk](mailto:david@hawkerdials.co.uk).

# THE ESPERANCE STONEHENGE IN AUSTRALIA

JOHN WARD and MARGARET FOLKARD

Early in March 2017 John Ward and his wife Audrey drove their Volkswagen Caddy van from Adelaide in South Australia to Perth in Western Australia (Fig. 1). The return trip was around 7,000 km. Needless to say, en route they saw many things and had lots of exciting experiences.

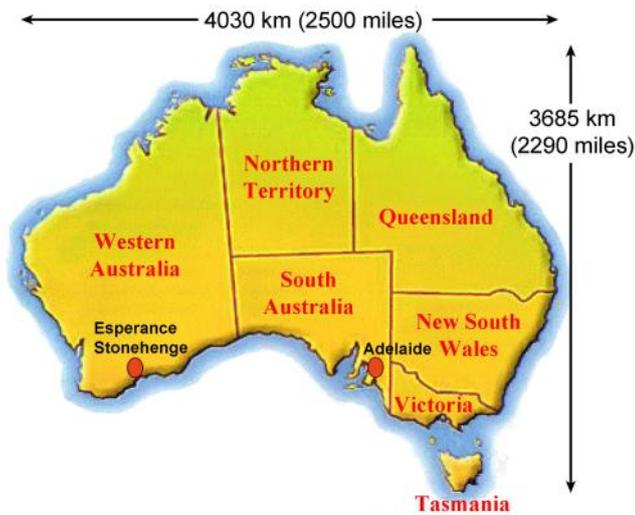


Fig. 1. Map of Australia showing Esperance and Adelaide.

One highlight was meeting a grandson at Kalgoorlie which has the biggest gold pit in Australia, large enough to be seen from space. It is about 3.5 km long, 1.5 km wide and 570 metres deep! From there it was on to Perth where they



Fig. 2. John beside the armillary sphere which Sundials Australia constructed in 1998. Photo: Audrey Ward.



Fig. 3. Esperance Stonehenge from the air.<sup>2</sup> Photo courtesy Kim and Jillian Beale.

climbed the Swan bell tower and had a go at bell ringing on the old bells which have been re-located from St Martin in the Fields in London. Turning south from Perth, they visited Binningup (latitude  $33^{\circ} 09' S$ , longitude  $115^{\circ} 42' E$ ) and checked out the bronze armillary sphere sundial 1200 mm in diameter which Sundials Australia made in 1998 (Fig. 2).

Forever onwards until they reached Esperance (latitude  $33^{\circ} 49' S$ , longitude  $121^{\circ} 52' E$ ). About 18 km outside Esperance is the famous (in Australia) 'Esperance Stonehenge' (Figs 3–5). They met and spoke at length to the owners of this monument, farmers Kim and Jillian Beale. As the Wards paid their way in they swapped a copy of the book *Sundials Australia*<sup>1</sup> for a copy of Kim Beale's book *The Building of Esperance Stonehenge 2011*<sup>2</sup> which contains a wealth of pictures and information describing this creation and is beautifully illustrated in colour.

Esperance Stonehenge is a full-size replica of the original Stonehenge in the UK, as it would have looked around 1950 BC. It consists of 2500 tons of Esperance Pink Granite, quarried adjacent to the Beales' property in



Fig. 4. Plan view of Esperance Stonehenge.<sup>2</sup>  
Photo courtesy Kim and Jillian Beale.



Fig. 5. Esperance Stonehenge (with cows!).<sup>2</sup>  
Photo courtesy Kim and Jillian Beale.

Esperance, Western Australia, and is made up of 137 individual stones.

The ten Trilithon Stones in a horseshoe pattern (see Fig. 4) weigh between 38 and 50 tons each, standing with the 18-ton lintels to a height of 8 metres. Inside the Trilithon Horseshoe stands another horseshoe of 19 Blue Stones (each weighing either 2.25 tons or 3.25 tons), and the Trilithon Stones are surrounded by a circle of 30 Sarsen Stones weighing 28 tons each and standing almost 5 metres high including the 7-ton lintels on top. Between the Sarsen Circle and the Trilithon Stones is a full circle of 40 smaller stones, referred to as the Bluestone Circle.

In front of the tallest Trilithon Stones is the Altar Stone, weighing 7 tons. The whole structure is aligned with the summer solstice sunrise (the longest day of the year, 22 December) for Esperance. Heel Stones (Fig. 6) are positioned on this line to allow the sun's rays to pass through to the Altar. Sunset on the winter solstice (the shortest day of the year – 21 June) lies along the same line as the summer solstice sunrise. Each of the two events of

the Summer Sunrise and Winter Sunset, creating the Solstice Line through the structure, lasts less than two minutes.

### Construction

Construction of Esperance Stonehenge began in January 2011 with earthworks and preparing footings. 120 cubic metres of concrete were used in the footings, along with mesh and reo bar. The five rectangular footings under the Trilithons measure  $6.2 \times 2.6 \times 0.6$  metres on four of the pairs and the two biggest stones stand on a footing  $7.3 \times 2.6 \times 0.6$  metres. The outer circle stands on a footing 2 metres wide by 0.4 metres deep, the trilithona. The 40 large stones have a wire-cut base and stand on top of the footings, which is 200 mm below ground level.

On 22 February, transport and erection commenced, using a 140-ton crane, two 988B loaders and two floats. The finish of the stones was achieved with a jet burner which is a diesel-fuelled tool operated by a large air compressor. This gives a very hot flame (5000–6000° C), very much like an oxy torch, which fuses the surface asperities leaving a highly tactile finish.

The positioning of the Bluestone horseshoe inside the Trilithons and the Bluestone Circle was done prior to the placement of the Altar Stone.

After the stonework within the Sarsen circle was completed, Kim spent many hours measuring and marking the positions for the 30 Sarsen Stones. At this point it was critical that the diameter of the circle and the centre of each of the Sarsen Stones was exact, so that the lintels sat correctly on top. The Sarsen stones were erected in two days with the use of one loader, and the roll-out lawn was laid at the same time.

Winter had arrived by now and construction stopped in June for 11 weeks owing to boggy conditions.

After the ground dried out, positioning of the 30 7-ton lintels was completed in two days using a 20-ton crane, with the last lintel in the structure being set in place at 3.15 pm on 26 October 2011.



Fig. 6. Heel Stones show the alignment of the solstices.<sup>2</sup>  
Photo courtesy Kim and Jillian Beale.



Fig. 7. John and Audrey inside Esperance Stonehenge. Photo courtesy Kim Beale.

The two Heel Stones were positioned on the Solstice Line prior to the December solstice in 2011.

John and Audrey (who are shown in Fig. 7) were very impressed with this massive structure. John strongly

recommends that all BSS visitors to Australia include Esperance in their itinerary as well as visiting Sundials Australia in Adelaide. Margaret hasn't been to Esperance yet but hopes to go there soon.

#### ACKNOWLEDGEMENTS

We thank Kim and Jillian Beale for permission to copy information about, and photographs of, this incredible structure in the present article.

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## NEW DIALS (3)

### Sundial on Mullachgearr Memorial, Mullaghmore, County Sligo

Mullaghmore is a well-known holiday destination on the west coast of Ireland. One of the most beautiful locations in Ireland, it has a harbour and a famous sandy beach which is perfect for surfing and many other water sports. Close by is the now-deserted village of Mullachgearr, near to which, about 60 years ago, a man named Freddy McHugh was living alone. He was very poor and one bitter, frosty winter evening, on his way home from the local shop, he sat down to rest by the roadside. He was found there by a neighbour and died shortly after in the County Home. Later his home was found to be almost devoid of wooden furniture; he had burnt it for warmth when there was nothing else. Even the bed was partially dismantled to this end. Freddy's grave is unmarked and there is no trace now of his existence save in the minds of the few who knew him.

Moved by his story, the Mullaghmore Residents and Heritage Group decided, on 17 January 2013, to erect a memorial in memory of both Freddy and the other, now almost forgotten, people of Mullachgearr.

The monument (at 54° 28' N, 8° 28' W) consists of a low, hollow, cylindrical dry-stone wall, similar to the dry-stone walls of the surrounding area (Fig. 1). On top of this is a sandstone capstone six feet in diameter, which incorporates an inset sundial. Around the perimeter of the capstone is inscribed in Irish: *I gcuimhne ar Freddy agus ar mhuintir Mullach Gearr* [In memory of Freddy and the people of Mullachgearr]. The top surface is divided into sections on which the names of Freddy and the villagers of Mullachgearr are memorialised. Carved emerging from the perimeter of the stone are three heads and a skull. The skull primarily represents the famine victims of the area, one of the heads represents a Mullachgearr woman, *Peggy Mor*,



Fig. 1. The dial in course of construction; sculptor Brendan McGloin is in the centre. Photo copyright Joe McGowan.



Fig. 2. Christian Meyer with the completed dial. Photo copyright Joe McGowan.



Fig. 3. The gnomon. Photo copyright Joe McGowan.

while the other two are historical figures from the area. A time capsule, containing messages and artefacts from those who contributed towards the cost of the memorial, has been placed in the void under the capstone. By doing so, participants have retained ownership of the memorial and future generations will take pride in the fact that their forbears' messages are part of the completed memorial.

The sundial (Fig. 2) was chosen as symbolic of the passing of time and the connection between the generations. There is neither a beginning nor an end to time; we are all connected to the past just as the future is connected to us. It also reminds us that we all exist in each other's shadow.

Carved from Donegal limestone by Christian Meyer, the inset 13¾" diameter sundial has an 11" high stainless steel gnomon perforated with Celtic interlacy (Fig. 3). The dial

indicates local sun-time which differs from clock time by about one and a half hours during the summer. The hour lines are continuous across the dial face, starting at the root of the gnomon and terminating at the chapter ring, which has Roman hour numerals carved in relief. The gnomon, designed by Christian Meyer, is ¾" thick and was made by SF-Engineering, Co. Sligo.

The sundial was unveiled on Easter Monday, 17 April 2017 (Fig. 4).



Fig. 4. Joe McGowan, Project Co-ordinator (speaking) at the unveiling of the Mullaghmore Memorial. Photo copyright Jacqueline Skinner.

#### ACKNOWLEDGEMENTS

I am indebted to Joe McGowan, the Project Co-ordinator, for drawing this dial to my attention. Most of the above text has been copied from an information plaque at the site.

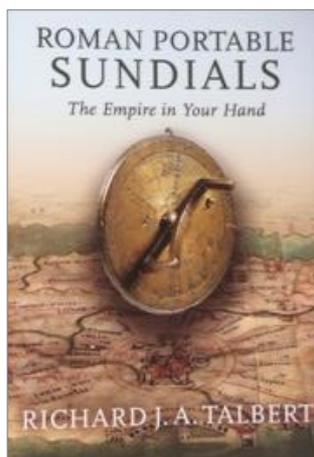
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## NEW BOOK

**Roman Portable Sundials: The Empire in your Hand** by Richard J.A. Talbert. ISBN 978-0-190-27348-4. 235 × 165 × 28 mm hard covers, 264 pp, 99 b/w halftones; 65 b/w line drawings. Published February 2017 by Oxford University Press, London. RRP: £41.49. Also available as an Ebook.

In the first chapter Talbert gives a brief introduction to timekeeping in the ancient world, with extensive notes and references to further reading, and then describes some portable sundials in use in the Roman Empire. He devotes several pages to the type that has most commonly survived, using as his example the dial in the Oxford Museum of the History of Science that was the subject of an article in a recent *Bulletin*.<sup>1</sup>

In the 89-page-long second chapter, the sixteen portable dials from the Roman period that Talbert terms 'geographical' (those on which geographical names and related latitude figures appear) are described in considerable



detail. Maps, photographs, line drawings, and bibliographies relevant to each dial are also provided.

Talbert suggests that the placenames and latitudes that appear on these 'geographical' dials have 'unique potential significance as indicators of an educated public's geographical awareness and worldviews', and explores these indicators in Chapter 3, while in Chapter 4 he considers who might have commissioned or used this type of portable dial, and for what purpose. Again, there are maps and extensive footnotes and references.

The final chapter, 'Post-classical Comparisons', is followed by an appendix entitled 'The Aquincum Fragment: a sundial maker's manual?', a Gazetteer, and an impressive general Bibliography to complement the footnotes found throughout the book.

1. F.H. King: 'Analysis of a Roman portable dial', *BSS Bulletin* 27(iii), 22–29 (September 2015).

CHN

# OLD SUNDIAL BOOKS

A Survey by Mike Cowham and Fred Sawyer

## THOMAS STRODE, A NEW & EASIE METHOD TO THE ART OF DYALLING

London 1688

A New and Easie  
**METHOD**  
TO THE  
**ART**  
OF  
**DYALLING.**

CONTAINING

I. All Horizontal Dyals, all Upright Dyals, Reflecting Dyals, Dyals without Centres, Nocturnal Dyals, Upright Declining Dyals, without knowing the Declination of the Plane.  
II. The most Natural and Easie Way of Describing the Curves-Lines of the Sun's Declination on any Plane.

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**The like never before Published.**

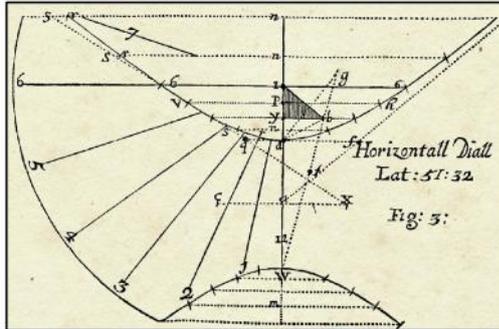
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By **THOMAS STRODE**, Esq; of Maperton  
in the County of Somerset.

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L O N D O N

Printed, by H. C. for J. Taylor, at the Ship, and T. Furborough, at the Ball, in St. Paul's Church-Yard, MDC LXXX VIII.



Construction of a Horizontal Dial

### CHAP. II.

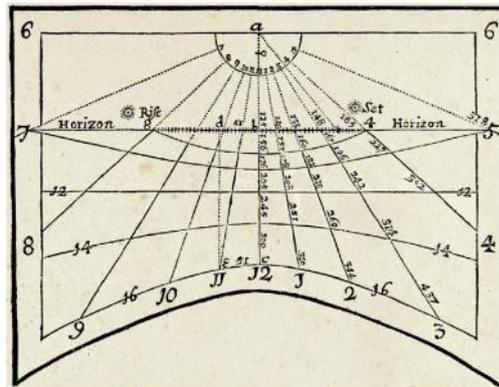
The Nature of Sines, Chords, Tangents and Secants, with a Table of them for each Degree.

### CHAP. III.

How from this Table, and a Diagonal Scale, or Scale of Equal Parts, to make an Horizontal Dial for any Latitude.

### CHAP. IV.

How to make any Erect Dial from the Horizontal, whether it be a Direct South Dial, or a Declining.



A Direct South Vertical Dial

### CHAP. V.

How to describe the Tropiques and other Circles of Declination of the Sun on a Plain Dial, the elevation of the Pole, and the Sun's Declination being given, first Geometrically, then Arithmetically.

### CHAP. VI.

How to find the Inclination of the Plane.

*Soli Deo Gloria.*

"A New and Easie METHOD TO THE ART OF DYALLING" is a small format book by Thomas Strode commencing with two advertisements:

**N**avigation, and all the Parts of the Mathematicks, are taught in *English* and *French* by Mr. Reeve Williams, at the *Virginia Coffee-House* in *St. Michael's-Alley*, in *Cornhil*, near the *Royal Exchange*, *London*.

**A**LL sorts of Globes, Spheres, Maps, Sea-Plats, Mathematical Projections, Books and Instruments, made and sold by *Philip Lea*, Globe Maker, at the *Atlas* and *Hercules* in *Cheapside*, next the corner of *Friday-street*.

*Removed from the Poultry.*

### CHAP. I.

*Of Dyalling in General.*

**D**yalling is an Art teaching how to Measure the time of the Day, by the Shade of the Sun.

The Heavens, with the Sun and Stars, go round the Earth every Twenty four Hours, with an Equal Motion. Two Points of the Heavens are Immovable, which are called the Poles; and there is an Imaginary Line passing from one Pole to the other, which is called the *Axe of the World*. The Circle which cuts the *Axe* at Right-angles, and divides the Heavens into two Equal Parts between the said Poles, is the *Equinox* or *Equator*, which (as every great Circle) is divided by Astronomers into 360 Equal Parts, called *Degrees*; of which the Sun goes 15 *Degrees* each Hour: Every *Degree* is divided into 60 *Minutes*, as by the *Globe* may be seen.

Number of Pages: 71

Page Size: 7 1/4" x 5 1/4"

Illustrations: Many

This is a typical page from the extensive survey of English language sundial books from the 17th (and even late 16th) to early 20th centuries, prepared by Mike Cowham and Fred Sawyer, now available on the BSS website at

<http://sundialsoc.org.uk/publications/old-sundial-books/>

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