# The transit of Venus, 2012 June 5–6

Peter Macdonald

The transit of Venus on 2012 June 5–6 is visible to some extent from almost all of Europe. This paper summarises the circumstances of the transit in the British Isles and overseas and considers the frequency of such phenomena.

## Introduction

On 2012 June 5–6 there occurs a transit of Venus across the face of the Sun, the second in the current pair of transits, with just the egress being visible from the British Isles. The transit occurs at Venus' descending node with the planet crossing the northern part of the Sun's photosphere. For a geocentric observer ingress occurs on June 5 at 22h 10m UT (= Universal Time, which is used throughout this paper) and egress on June 6 at 04h 50m.

Figure 1 illustrates the path which Venus appears to take across the Sun for a geocentric observer. In this paper, figures depicting the solar disk have celestial north at the top and Venus moving from left to right. The planet appears as a small black disk approximately 1/32 of the Sun's diameter, and its position is shown at intervals of one hour.

Table 1 gives the geocentric phases. The angle P is reckoned from the north point of the solar disk through east, while the quantity $d_m$ represents the least distance between the centres of the disks of Venus and the Sun expressed in units of the solar *radius*, and is positive because Venus passes to the north of the Sun's centre. Eighteen minutes elapse between exterior and interior contacts. With Venus passing closer to the Sun's centre than in 2004, the geocentric duration of 6h 40m is 27 minutes longer than on that occasion while the geocentric quantity $|d_m|$ is 0.07 smaller than at the previous transit.

The circumstances have been computed from the elements given in *Transits* by Jean Meeus.[1] The difference ΔT between Dynamical Time (TD), a uniform time system, and Universal Time (UT), which is based on the Earth's rotation, is subject to irregular variations. These are unpredictable and can be determined purely by observation. For the future, this difference can be no more than an estimate, and a value of ΔT = +1m 07s has been adopted here.

**Table 1. Geocentric phases of the Venus transit of 2012 June 5–6**

| | *UT* | *P* | *Least distance of centres* | |
|---|---|---|---|---|
| | *d h m s* | ° | ′ ″ | $d_m$ |
| Ingress, exterior contact | 5 22 09 37 | 40.7 | | |
| Ingress, interior contact | 5 22 27 34 | 38.2 | | |
| Mid transit | 6 01 29 36 | 345.4 | 9 14.4 | +0.59 |
| Egress, interior contact | 6 04 31 38 | 292.7 | | |
| Egress, exterior contact | 6 04 49 35 | 290.1 | | |

Apparent semidiameter of Sun 15′ 45″.7
Apparent semidiameter of Venus 29″.1

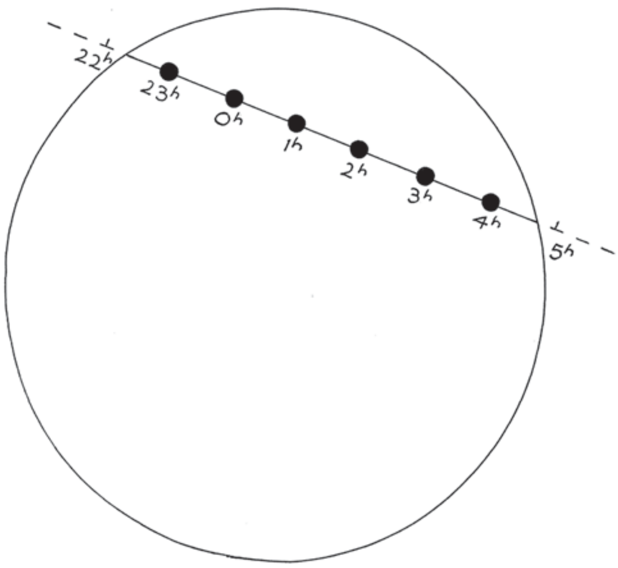


**Figure 1. The path of Venus across the Sun on 2012 June 5–6 for a geocentric observer.**

## Visibility of the transit

Figure 2 illustrates the area of visibility of the transit, which may be seen from wherever the Sun is above the horizon. The complete transit is visible from Greenland (except the southern tip), northern parts of Scandinavia, much of Asia, the eastern part of Australia, New Zealand, Alaska, north-western parts of Canada and arctic regions. As the Sun's declination is almost 23°N, in latitudes higher than 67°N it remains above the horizon throughout the day and the entire transit is visible, irrespective of longitude. Mid-transit at local apparent noon occurs about longitude 157°E, while mid-transit at local apparent midnight takes place around longitude 23°W.

Over most of Europe, eastern Africa, western parts of Asia and western Australia the Sun rises with Venus al-

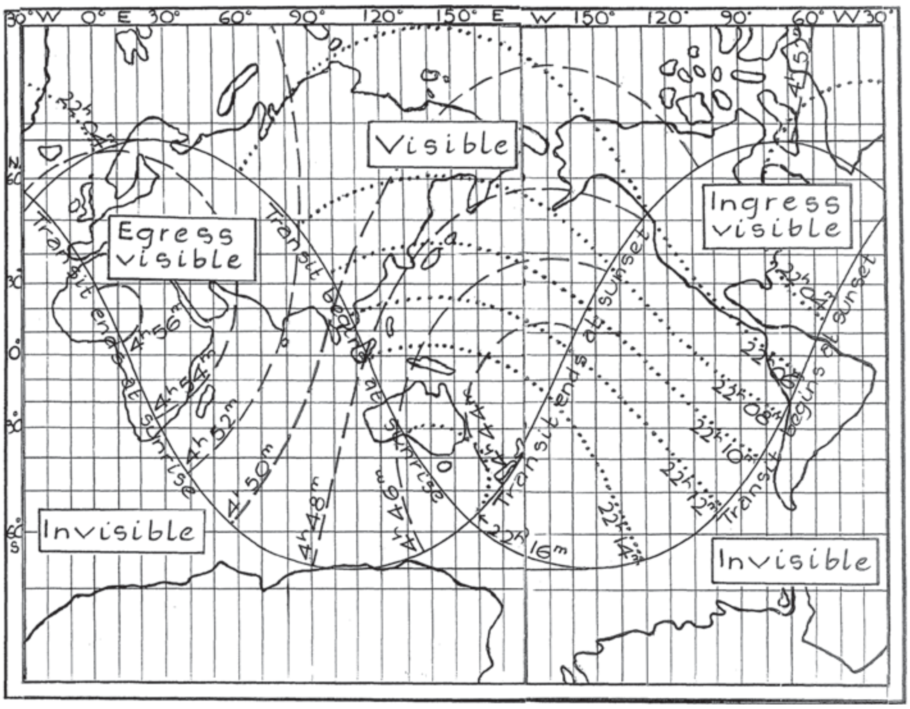


**Figure 2. Sketch map showing the area of visibility of the transit over the surface of the Earth.**

ready in transit so that just the egress may be seen. In eastern Canada, the contiguous United States, Central America, the northwestern part of South America and the southern tip of Greenland the Sun sets with the transit in progress so that just the ingress is visible. In the small triangular area encompassing Iceland the Sun sets and rises during the transit so that Venus continues on the Sun during the local night. From this region both the ingress and the egress are visible and it is possible to see sunset in the evening with Venus already on the solar disk, and then to observe sunrise the following morning with the transit still in progress. In the small triangular area towards the Antarctic the Sun rises and sets during the transit so that Venus remains on the Sun throughout the local day. From this region neither the ingress nor the egress is visible but it is possible to see sunrise during the morning with the transit already in progress and then to observe sunset in the evening with Venus still on the solar disk. From all other parts the transit is invisible.

Due to parallax, the times of the contacts vary according to the observer's location and may differ by up to almost seven minutes from the geocentric phases, ingress (exterior contact) taking place on June 5 between 22h 03m.1 (UT) and 22h 16m.2 and egress (exterior contact) occurring on June 6 between 04h 42m.9 and 04h 56m.2. From the Figure it is possible to obtain the exterior contacts for any location. For example we see that at Sydney the entire transit is visible, ingress occurring on June 5 at 22h 16m and egress on June 6 at 04h 44m. Similarly at Greenwich where the Sun rises with Venus already on the disk, just the final stages of the transit are visible, egress occurring on June 6 at 04h 55m; while at Washington DC, where just the initial stages of the transit are visible, ingress takes place on June 5 at 22h 04m, the Sun setting with the transit still in progress.

Finally, it may be seen that from the western part of the Iberian peninsula no part of the transit is visible. (At Madrid the Sun rises with Venus partly on the disk, between interior and exterior contacts at egress.) Also because of parallax, the chord which Venus appears to describe across the Sun is displaced with the observer's location. The value of $d_m$ varies from +0.57 in far North America to +0.61 in Australasia. Figure 3 illustrates the effect of this displacement for observers at Nome (Alaska) and Sydney. At the former location the duration of the transit is some fourteen minutes longer than at the latter.

Table 2 gives some local circumstances. The angle V is measured anticlockwise from the vertex while the Sun's azimuth is reckoned from north through east. It is interesting to note how at Reykjavik the Sun sets on June 5 with the transit already in progress and then rises some three and a half hours later on June 6 with Venus still on the disk. Because they are situated to the east of the International Date Line, for observers toward the far west of North America and in the western Pacific islands the entire transit occurs on June 5, local time.

## The transit in the British Isles

In the British Isles the Sun rises very early on the morning of June 6 with Venus already well advanced onto the solar disk, so that just the final stages of the transit are visible. The time of egress varies by less than one minute across the whole group of islands, exterior contact taking place at 04h 54m.4 in Shetland and at 04h 55m.0 in Cornwall. However, the times of sunrise vary considerably, ranging from about 02h 45m in Shetland to about 04h 15m in Cornwall. Consequently, at Lerwick the Sun attains an altitude of 11°.4 at egress (exterior contact) while at Penzance it reaches just 4°.6 at exterior contact, interior contact taking place at an altitude of 2°.2, just over twenty minutes after sunrise. From Figure 4 it is possible to obtain the time of sunrise for any location, for example we see that at Edinburgh the Sun rises at 03h 30m and at

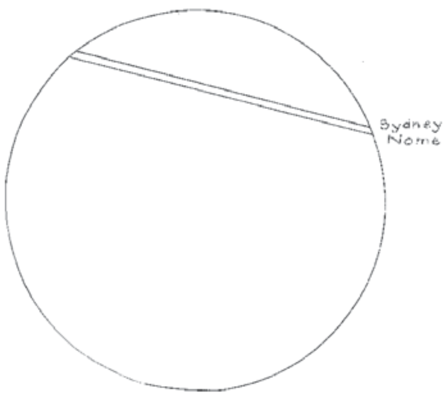


**Figure 3. The displacement of the chord due to parallax for observers at Nome and Sydney.**

## Table 2. Local circumstances of the 2012 transit

| | *Sunrise* | | *Ingress, exterior contact* | | | | *Ingress, interior contact* | | | | *Mid transit* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *UT* | *Sun's az.* | *UT* | *P* | *V* | *Sun's alt.* | *UT* | *P* | *V* | *Sun's alt.* | *UT* | *P* | *V* | *Sun's alt.* |
| | *h m* | ° | *h m s* | ° | ° | ° | *h m s* | ° | ° | ° | *h m s* | ° | ° | ° |
| *British Isles* | | | | | | | | | | | | | | |
| Belfast | 03 51 | 47 | – | | | | – | | | | – | | | |
| Cardiff | 03 58 | 50 | – | | | | – | | | | – | | | |
| Edinburgh | 03 30 | 45 | – | | | | – | | | | – | | | |
| Greenwich | 03 45 | 50 | – | | | | – | | | | – | | | |
| Lerwick | 02 46 | 37 | – | | | | – | | | | – | | | |
| Liverpool | 03 46 | 48 | – | | | | – | | | | – | | | |
| Penzance | 04 14 | 52 | – | | | | – | | | | – | | | |
| *USA* | | | | | | | | | | | | | | |
| Mauna Kea Obs. | | | 22 10 05 | 40.6 | 179.5 | 86 | 22 27 45 | 38.1 | 249.0 | 87 | 01 26 14 | 345.3 | 260.6 | 47 |
| Nome, Alaska | | | 22 06 46 | 41.7 | 50.2 | 47 | 22 24 21 | 39.3 | 45.0 | 48 | 01 27 19 | 345.4 | 325.2 | 42 |
| Washington DC | | | 22 03 56 | 41.2 | 344.8 | 26 | 22 21 35 | 38.7 | 343.0 | 23 | – | | | |
| *Canada* | | | | | | | | | | | | | | |
| Ottawa | | | 22 03 47 | 41.3 | 352.2 | 26 | 22 21 25 | 38.9 | 350.2 | 23 | – | | | |
| *Iceland* | | | | | | | | | | | | | | |
| Reykjavik | 03 10 | 24 | 22 03 33 | 42.0 | 22.2 | 5 | 22 21 15 | 39.6 | 21.2 | 4 | – | | | |
| *Australia* | | | | | | | | | | | | | | |
| Perth | 23 11 | 64 | – | | | | – | | | | 01 32 17 | 345.9 | 129.0 | 23 |
| Sydney | | | 22 16 04 | 39.9 | 176.0 | 13 | 22 34 08 | 37.2 | 175.8 | 16 | 01 30 23 | 345.7 | 159.9 | 33 |
| *New Zealand* | | | | | | | | | | | | | | |
| Wellington | | | 22 15 38 | 39.6 | 195.3 | 20 | 22 33 42 | 36.9 | 195.8 | 22 | 01 29 18 | 345.5 | 179.8 | 24 |
| *Japan* | | | | | | | | | | | | | | |
| Tokyo | | | 22 10 49 | 41.6 | 102.5 | 31 | 22 28 33 | 39.1 | 100.4 | 35 | 01 29 39 | 345.8 | 31.3 | 70 |
| *China* | | | | | | | | | | | | | | |
| Beijing | | | 22 10 01 | 41.9 | 94.1 | 14 | 22 27 48 | 39.4 | 92.6 | 17 | 01 30 40 | 345.9 | 39.5 | 52 |

## Table 2, continued

| | *Egress, interior contact* | | | | *Egress, exterior contact* | | | | *Sunset* | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *UT* | *P* | *V* | *Sun's alt.* | *UT* | *P* | *V* | *Sun's alt.* | *UT* | *Sun's az.* |
| | *h m s* | ° | ° | ° | *h m s* | ° | ° | ° | *h m* | ° |
| *British Isles* | | | | | | | | | | |
| Belfast | 04 37 02 | 291.1 | 322.5 | 4 | 04 54 44 | 288.7 | 321.5 | 7 | | |
| Cardiff | 04 37 17 | 291.1 | 326.0 | 4 | 04 54 58 | 288.7 | 325.0 | 7 | | |
| Edinburgh | 04 37 00 | 291.1 | 322.2 | 6 | 04 54 40 | 288.7 | 321.1 | 9 | | |
| Greenwich | 04 37 20 | 291.1 | 327.1 | 6 | 04 55 00 | 288.7 | 326.0 | 8 | | |
| Lerwick | 04 36 44 | 291.1 | 319.1 | 10 | 04 54 23 | 288.7 | 317.7 | 11 | | |
| Liverpool | 04 37 10 | 291.1 | 324.4 | 5 | 04 54 51 | 288.7 | 323.4 | 8 | | |
| Penzance | 04 37 19 | 291.1 | 326.4 | 2 | 04 55 01 | 288.7 | 325.5 | 5 | | |
| *USA* | | | | | | | | | | |
| Mauna Kea Obs. | 04 26 33 | 292.6 | 221.5 | 6 | 04 44 34 | 290.0 | 220.5 | 2 | | |
| Nome, Alaska | 04 31 01 | 291.5 | 263.8 | 23 | 04 48 43 | 289.1 | 261.5 | 22 | | |
| Washington DC | – | | | | – | | | | 00 31 | 300 |
| *Canada* | | | | | | | | | | |
| Ottawa | – | | | | – | | | | 00 48 | 304 |
| *Iceland* | | | | | | | | | | |
| Reykjavik | 04 36 02 | 291.0 | 309.8 | 4 | 04 53 44 | 288.6 | 308.8 | 6 | 23 42 | 336 |
| *Australia* | | | | | | | | | | |
| Perth | 04 29 04 | 294.1 | 117.7 | 35 | 04 46 54 | 291.4 | 119.6 | 35 | | |
| Sydney | 04 26 16 | 294.2 | 148.0 | 23 | 04 44 17 | 291.5 | 148.4 | 20 | | |
| *New Zealand* | | | | | | | | | | |
| Wellington | 04 25 24 | 294.2 | 155.7 | 4 | 04 43 34 | 291.5 | 154.9 | 2 | | |
| *Japan* | | | | | | | | | | |
| Tokyo | 04 29 55 | 292.4 | 237.2 | 63 | 04 47 30 | 289.9 | 232.3 | 59 | | |
| *China* | | | | | | | | | | |
| Beijing | 04 31 58 | 292.2 | 280.2 | 72 | 04 49 28 | 289.7 | 267.7 | 71 | | |

Greenwich at 03h 45m, while from Figure 1 may be estimated the position of Venus on the solar disk at that or at any other instant. Thus while the transit is visible for more than two hours at Lerwick, barely forty minutes elapse between sunrise and egress (exterior contact) at Penzance. An essential requirement for observers in the British Isles is a clear north-eastern horizon. [Observers are reminded that all the above times are UT, and that one hour should be added for British Summer Time].

This is the second of the current pair of transits. That in 2004 was the first to be *wholly* visible in the British Isles since 1283 and was 'announced' in 1896 by Johnson,[2] who gave the circumstances of some future transits. It was observed by many, including the author under perfect conditions at home,

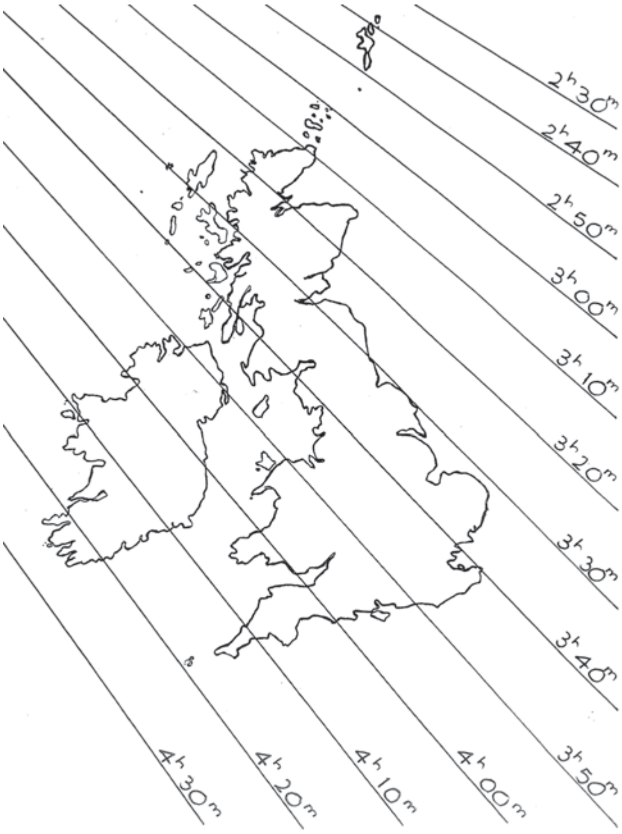


**Figure 4. The variation in sunrise over the British Isles during the 2012 transit.**

and an extensive report of observations undertaken both in the British Isles and overseas was published in a commemorative issue of the Association's *Journal*.[3] My earlier papers[4,5] give more information about it. Some scientific comment regarding the observation of this most recent transit has been provided by Dr Richard McKim *et al*.[6]

Table 3 lists transits of Venus between 1283 and 2498. The date of each is given together with the instant of mid-transit for a geocentric observer (which may be in error by a few minutes for more distant events due to an uncertainty in the values of ΔT, which are those recommended by Morrison & Stephenson,[7]) and the extent of visibility in the British Isles. In this paper, the change of calendar is reckoned from the Gregorian reform in 1582. Of the next pair of transits, it may be seen that that in 2125 is partly visible, while the next to be entirely visible is not due until 2247. My booklet *Eclipses at London 1951–2160*[8] lists transits of Venus visible from the British Isles during the much longer period from 1001–3000.

**Table 3. Transits of Venus 1283–2498**

| | Mid-transit UT h m | Visibility in the British Isles |
|---|---|---|
| 1283 May 23 | 15 48 | Visible |
| 1396 Nov 23 | 19 27 | Ingress visible |
| 1518 May 26 | 01 57 | Egress visible |
| 1526 May 23 | 19 12 | Ingress visible |
| 1631 Dec 7 | 05 19 | Invisible |
| 1639 Dec 4 | 18 26 | Ingress visible |
| 1761 June 6 | 05 19 | Egress visible |
| 1769 June 3 | 22 25 | Ingress visible |
| 1874 Dec 9 | 04 07 | Invisible |
| 1882 Dec 6 | 17 06 | Ingress visible |
| 2004 June 8 | 08 20 | Visible |
| 2012 June 6 | 01 30 | Egress visible |
| 2117 Dec 11 | 02 48 | Invisible |
| 2125 Dec 8 | 16 01 | Ingress visible |
| 2247 June 11 | 11 33 | Visible |
| 2255 June 9 | 04 38 | Egress visible |
| 2360 Dec 13 | 01 43 | Invisible |
| 2368 Dec 10 | 14 45 | Ingress visible |
| 2490 June 12 | 14 16 | Visible |
| 2498 June 10 | 07 24 | Visible |

## Series of transits

Transits of Venus occur rarely and are grouped into easily recognisable series. It is well known that transits happen in pairs, and presently each pair is separated from the next by an interval of more than one hundred years. Figure 5 shows the paths of Venus across the Sun for a geocentric observer during this current pair of transits.

For a transit to occur, Venus must reach inferior conjunction within a day of passing through one of its nodes. The nodes are the two points where the planet's orbit intersects the plane of the ecliptic. The heliocentric longitudes of the nodes are slowly varying functions of time. They are sensibly constant at any particular epoch and currently they are 77° (ascending) and 257° (descending). The Earth attains these longitudes around December 9 and June 7 respectively in each year and transits are only possible on or about these dates. Due to their gradually increasing longitudes the nodes are progressing slowly through the seasons and transits are becoming later in the year – by 3500 they will occur at the solstices. In the present case Venus reaches inferior conjunction on June 6d 1h, passing through the descending node at 17h, just sixteen hours later. Figure 6 illustrates the passage of the planet through the node. The ecliptic is represented by the dotted line and the path of Venus, whose position is shown every three hours, by the dashed line. For the duration of the transit this is replaced by a solid line. Because the transit is not central (*i.e.* Venus does not cross the Sun's centre), the instant of mid-transit does not coincide with that of inferior conjunction.

Venus reaches inferior conjunction every 584 days (approximately nineteen months) and completes 152 such synodic revolutions in 88,756 days. In the Gregorian calendar such an interval is equivalent to 243 years plus 1, 2 or 3 days, depending on the number of intervening leap years, and corresponds to 395 of Venus' sidereal revolutions (fixed star to fixed star), to within about a day. So at the end of this period Venus and the Earth have returned very nearly to their former positions, not only with respect to each other but also with respect to the node, and transits repeat with a great similarity. Transits separated by this interval are said to belong to the same series. At each return the path which Venus appears to take is slightly displaced. Currently, this displacement of the chord is in a southerly direction at both nodes of the planet's orbit. This has been the case for several millennia and it will continue long into the future, but after many more millennia, eventually, for transits taking place at Venus' descending node the southward displacement of the chord is replaced by a northward one.

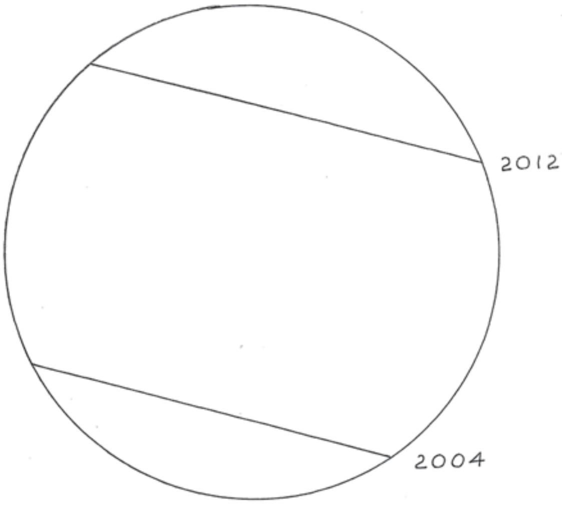


**Figure 5. The current pair of transits in 2004 and 2012 for a geocentric observer.**

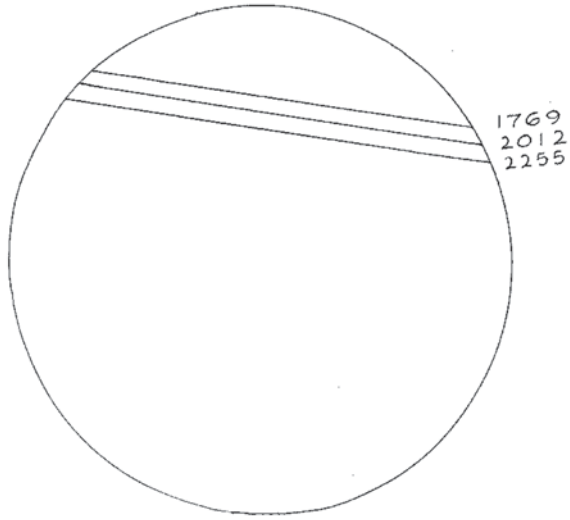


**Figure 7. The displacement of the chord after a period of 243 years for a geocentric observer.**

The present transit is the seventh in a series which comprises 47 members, which began in 554 when Venus just grazed the northern limb of the Sun's photosphere. The southward displacement of the chord will continue until several almost central transits occur during the sixth and seventh millennia, after which the path which Venus takes across the Sun is displaced in the opposite direction, the series ending with a transit across the Sun's northern limb in 11732. In contrast to the transit in 2004 whose series contains 29 members and spans 6804 years, the current series extends over 11178 years. Figure 7 illustrates the displacement of the chord after a period of 243 years for a geocentric observer during three consecutive transits in the present series.

There is also a much shorter period of 5 synodic revolutions which amounts to 2920 days. This corresponds to 8 years minus 2 days (or 8 years minus 1 day if the interval includes a non bissextile century year), and approximates within two days to 13 sidereal revolutions of the planet. Although not so close an alignment as in the former case, transits often occur in pairs at intervals of 8 years. The paths are parallel, but at the second transit the chord is displaced by about 24' to the south at the ascending node or by about 20' to the north at the descending node. After two returns the displacement is either 48' or 40', which exceeds the Sun's diameter of 32'; hence it is not possible for three transits to occur within sixteen years. Also, when Venus passes within about 8' ($|d_m|<0.50$) of the Sun's centre at the ascending node or within about 4' ($|d_m|<0.25$) at the descending node, at the inferior conjunctions occurring eight years either side, the planet misses the solar disk and no transit occurs.

Several lists of Venus transits have been compiled. Towards the end of the eighteenth century a table of transits occurring between 900 and 3000 was computed by Delambre and published by Lalande.[9] This list contains 35 transits including three (902, 1145 and 1388) which do not exist. It also misses the transit in 2976. There are, in fact, 33 transits of Venus during this period. A list of transits from –2999 to 3000 was given by Meeus,[10] who introduced the alphabetical system for identifying each series, which uses upper case characters for transits occurring at the ascending node and the lower case for those at the descending node. This system has been retained here and in my earlier paper.[5]

**Table 4. Panorama of transits, 1283–3000**

| *ascending node (Nov/Dec)* | | *descending node (May/Jun)* | |
|---|---|---|---|
| *Series* | | *Series* | |
| *C* | *B* | *b* | *c* |
| | | | 1283 |
| | 1396 | 1518 | 1526 |
| 1631 | 1639 | 1761 | 1769 |
| 1874 | 1882 | 2004 | 2012 |
| 2117 | 2125 | 2247 | 2255 |
| 2360 | 2368 | 2490 | 2498 |
| 2603 | 2611 | 2733 | 2741 |
| 2846 | 2854 | 2976 | 2984 |

With the advent of electronic computing techniques, the opportunity has been taken to publish lists of transits which extend over much longer periods. Two further tables have been produced by Meeus; from -1999 to 4000[1] and from –3999 to 8000.[11] Finally, Prof. Aldo Vitagliano of Naples University calculated a list of Venus transits for 100,000 years[12] but this is beyond the scope of this paper. Her Majesty's Nautical Almanac Office website[13] has produced an excellent series of world maps showing the visibility of each transit from 1032 until 2611.

The present transit belongs to series c and we can tell at a glance that it takes place at the descending node. Table 4 presents a 'panorama' of tran-

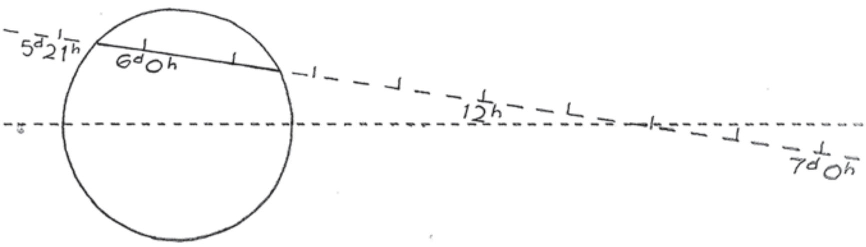


**Figure 6. The passage of Venus through the descending node in 2012.**

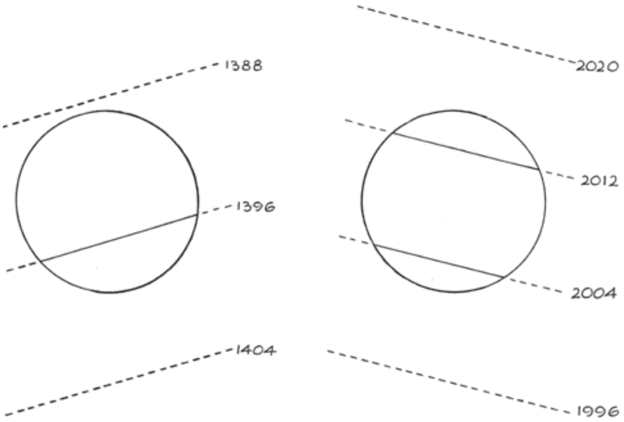


**Figure 8. The proximity of Venus to the Sun at November and June inferior conjunctions around the time of the single transit in 1396 and the double transit in 2004 and 2012.**

sits between 1283 and 3000, grouped according to their series. The 1631 transit is the first of series C while that in 2854 is the last of series B. By reading vertically we can follow the progress of each series, while reading horizontally gives the chronological sequence. In any period of 243 years there are either one or two transits at the ascending node and one or two at the descending node.

Figure 8 shows the proximity of Venus to the Sun at the November inferior conjunctions around the time of the most recent 'single' transit in 1396 and at the June inferior conjunctions around the time of the current 'double' transit in 2004 and 2012, and illustrates how transits may occur either singly or in pairs. In the first case, near its ascending node, Venus passes slightly beyond the Sun's northern limb at inferior conjunction on 1388 November 26, just failing to make a transit. Eight years and five inferior conjunctions later on 1396 November 23, Venus' path is displaced by 24' to the south and the planet crosses the solar disk passing 7' south of its centre. After another eight years, at inferior conjunction on 1404 November 21 a further southerly displacement of 24' shifts Venus' path well beyond the Sun's southern limb and no transit ensues.

In the second case, near its descending node, Venus passes considerably south of the Sun's southern limb at inferior conjunction on 1996 June 10. After eight years, at inferior conjunction on 2004 June 8 the planet's path is displaced by 20' to the north and a transit occurs with Venus passing 10' south of the Sun's centre. After another eight years at inferior conjunction on 2012 June 6 Venus' path is displaced by a further 20' to the north and a second transit takes place with the planet crossing 9' north of the Sun's centre, but after a further eight years Venus passes too far beyond the Sun's northern limb for a transit to be possible at inferior conjunction on 2020 June 3.

Since 1518 there have been two transits at each node, occurring at intervals of 8, 105½, 8 and 121½ years. This is the situation now and it will continue until 3000. But because there may be either one or two transits at each node, other intervals are possible; for instance when series B ends there will be just one transit at the ascending node giving the sequence 129½, 8 and 105½ years.

The distribution of transits over a period of 12,000 years may be ascertained from the table presented by Meeus.[11] From this it may be seen that many variations are possible, for example between the years –426 and 424 there was just one transit at each node, occurring at regular intervals of 121½ years. During historical times transits taking place at opposite nodes have always been separated by more than a century, but from 5171 intervals of 97½ years occur. Also, during the currency of this table, the longest interval between transits is 137½ years but after 7942 an even longer interval of 145½ years will take place. In the distant future other intervals may be possible, and in any event, by then the paths of successive transits occurring at the ascending node will already be shifting northward.

## Historical notes

No record exists of a transit having been observed before the invention of the telescope. The possibility that the inferior planets might occasionally pass in front of the Sun was not considered until the early part of the seventeenth century, when Kepler predicted transits of both Mercury and Venus for 1631. The transit of Mercury on November 7 was observed from Paris by Gassendi, but Venus crossed the Sun during the European night and eluded observers. Kepler believed that the next transit of Venus would not occur until 1761, but the young English astronomer Jeremiah Horrocks (1619?–1641) calculated another transit for 1639 which he observed from Much Hoole, a village near Preston in Lancashire. William Crabtree, a colleague whom Horrocks had notified of the event, also saw the transit from Manchester. A popular account of Horrocks' observation of this 'first' transit has been given by Allan Chapman[14] and there is also a more comprehensive study of Horrocks' achievements set against the background of seventeenth century science by

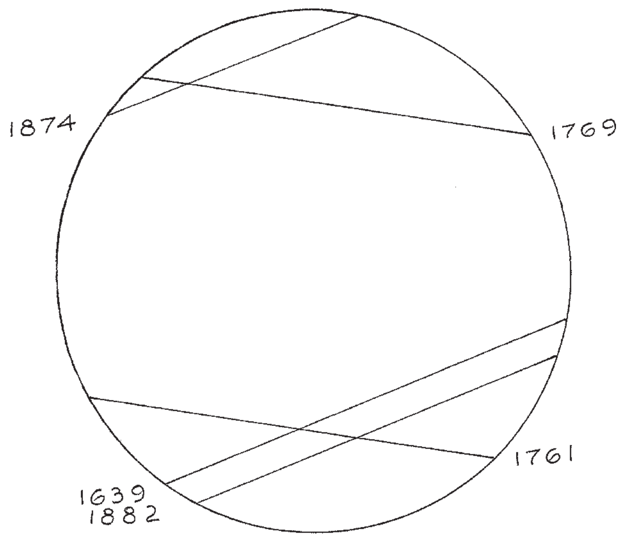


**Figure 9. The historical transits from 1639 to 1882 for a geocentric observer.**

the same author.[15] It is remarkable that two transits occurred during Horrocks' short life.

Of the six transits which are known to have been observed, it is believed that the first was seen by just Horrocks and Crabtree. Those in the eighteenth and nineteenth centuries were the subject of scientific investigation, principally in the attempt to determine the solar parallax, and hence the astronomical unit. The results of observations made by expeditions during the transits in 1761 and 1769 have been thoroughly documented by Woolf.[16]

In anticipation of the nineteenth century pair of transits, a popular review of past and coming transits was published by Proctor.[17] The transit in 1874 was the first which could be studied by photography, and expeditions were despatched to several locations. An interesting account of the American expedition has been given by Janiczek & Houchins.[18] Even with the aid of photographic plates the results of observations proved to be largely unsuccessful, and well before the next transit was due, consideration was being given to finding alternative ways in which to obtain the Sun's distance. Of that 1882 transit, just the initial stages were visible in the British Isles, the ingress taking place during the early afternoon with the Sun setting before mid-transit. Although conditions were generally unfavourable, some observers were fortunate in seeing Venus on the Sun, though with varying degrees of clarity, as indicated in their reports.[19,20]

This transit, being visible throughout from the eastern United States, inspired J. P. Sousa to compose his march *Venus*. Though rarely performed today, a recording of this little known work has been issued on CD.[21] Figure 9 illustrates the paths of Venus during the historical transits from 1639 until 1882 for a geocentric observer. Most recently, the transit in 2004 was seen, probably by millions, from Europe, Asia, America and Australasia.

Of course, as Venus presents a sizeable disk, it is quite possible that the planet had already been seen in transit during historical times, especially if the Sun was low or behind a thin layer of cloud; indeed Johnson[2] suggests that a record of such an observation may survive from ancient times: 'The reader's attention may just be called to a broken Assyrian tablet in the British Museum, concerning Venus. The following succession of broken lines occurs: 'the planet Venus' … 'it passed across' … 'the Sun' … 'across the face of the Sun.' It may be just possible to fill up each hiatus in a manner not to refer to a transit. But it reads somewhat like the record of one, which, it seems, must be before the 16th century BC.'

## Remarks

Transits of Venus occur so infrequently that they are among the rarest of all planetary phenomena – rarer even than mutual occultations of naked eye planets. Since the year 1 there have been 25 of the former but 43 of the latter[22] of which just one, the occultation of Mercury by Venus recorded at Greenwich on 1737 May 28, is known to have been observed.[23] Six Venus transits are known to have been observed, of which the last three have been photographed.

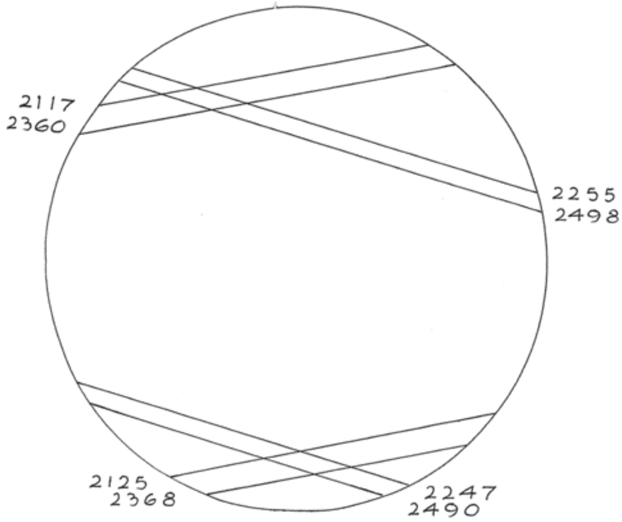


**Figure 10. Future transits from 2117 to 2498 for a geocentric observer.**

Besides crossing in front of the solar disk in transit, Venus may also pass directly behind the Sun and be occulted by it. With the planet towards its greatest distance from the Earth, the ecliptic limits are much greater and an occultation is possible if superior conjunction is reached within about seven days of the passage through a node. Consequently, at each transit season there is an associated run of occultations taking place at intervals of eight years. The present run contains ten occultations and commenced on 1976 June 18, when Venus passed behind the Sun's northern limb. The occultation on 2016 June 6 is almost central, and the run ends on 2048 May 28 when the planet is hidden by the Sun's southern limb. Although such occultations are purely of theoretical interest, that of 1984 June 15 has been investigated by Ghorbal.[24]

Extremely rarely, it may be possible to see Venus at inferior conjunction, even when no transit is taking place. The total solar eclipse of 1769 June 4 occurred just a few hours after Venus crossed the Sun and any observers within the total track, which stretched from Greenland across arctic regions, could have seen the planet's black disk projected against the Sun's corona in a 'coronal transit' which, of course, is no transit at all. An even more remarkable case, cited by Maor,[25] occurs as Venus reaches inferior conjunction on 2263 June 6, when a total eclipse of the Sun is visible from the Pacific Ocean and North America. On this occasion Venus fails to make a transit, passing just beyond the Sun's northern limb, but close enough for observers within the track of totality to see her black disk against the corona, even though the nearest actual transit occurs eight years earlier in 2255.

The most recent transit on 2004 June 8 was visible from beginning to end in the British Isles – the first to be so since 1283 May 23.

Looking ahead, Figure 10 illustrates the paths of Venus during future transits from 2117 to 2498 for a geocentric observer. The transit on 2117 December 11 is invisible from Europe, but may be seen to its greatest advantage from Australia and New Zealand, just possibly by someone who is alive today. Observers in Central and South America are the best placed for the transit on 2125 December 8, although it is partly visible from western Europe. In the British Isles ingress occurs during the early afternoon, exterior contact taking place at 13h 21m and interior contact at 13h 46m. The time of sunset ranges from about 15h 00m in Shetland to about 16h 20m in Cornwall, so that in the extreme southwest mid-transit at 16h 00m should just be visible. At Edinburgh and Greenwich the Sun sets at 15h 39m and 15h 51m respectively.

The transit of Venus on 2247 June 11 is visible in its entirety from the whole of Europe and Africa, and is the next to be completely visible from the British Isles. Ingress (exterior contact) occurs at 08h 47m and egress (exterior contact) at 14h 20m. Least distance of centres takes place at 11h 34m. It is interesting to note that both transits of Venus in the twenty fifth century are visible throughout from the British Isles.

Finally, it is requested that observations of the transit of 2012 June 5–6 be sent to the Director of the Mercury and Venus Section.

**Address:** 46 Vista Way, Harrow, Middlesex, HA3 0SL

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