

Charles Todd's observations of the transits of Venus

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Abstract

The scientific importance of the 1874 transit of Venus is evidenced by the number of international expeditions undertaken in order to observe it, with their goal being the determination of the astronomical unit. Charles Todd, the first Government Astronomer and Superintendent of Telegraphs in South Australia, observed the transit from Adelaide with a newly purchased 203-mm (eight inch) Cooke equatorial. Although ingress was clouded out, Todd successfully observed the egress, and noted evidence for Venus' atmosphere as the planet moved off the Sun's disc. This had first been noticed during the transits of 1761 and 1769, but the effect was not widely known to observers of the 1874 transit. For the 1882 transit Todd travelled to Wentworth, where he was one of few observers in Australia to be favoured by clear skies.

Keywords: 1874 transit of Venus, 1882 transit of Venus, C Todd, Adelaide, Wentworth

1 THE IMPORTANCE OF TRANSITS

In a speech given at a dinner organized by the Philosophical Society of Christchurch, Major H S Palmer, RE, head of the English expedition to observe the 1874 transit of Venus, described the importance of the event (The Transit of Venus, 1874a:11): "As Sir George Airy once feelingly remarked to me, "We don't mind the stars, Major Palmer, and we can get on pretty well with the sun and planets, but the moon is the greatest plague of all." Palmer proceeded to describe the importance of observations of the moon in determining longitude for the navigation of ships at sea. Lunar theory failed to accurately predict where the moon would be and "...the chief reason, there can be little doubt, of this extraordinary apparent misbehaviour on behalf of the moon is, that we do not accurately know the earth's distance from the sun..." (ibid.). It was anticipated that, by meeting the main scientific objective, the transit of Venus would also "... afford the means of perfecting the lunar theory and thus improving the science of navigation, and adding to the safety of commerce." (The Transit of Venus, 1874a:12).

It had been realized by the mid-1800s that Encke's value for the solar parallax of $8''.571$, derived from observations of the transits in 1761 and 1769, was too small, and so the observations of the 1874 transit were accorded great scientific and practical importance.

2 CHARLES TODD

European settlement in the Colony of South Australia was established in 1836. Charles Todd (Figure 1) was the first Government Astronomer and Superintendent of Telegraphs in South Australia, arriving in Adelaide from England in 1855 at the age of just 29. Previously he had held positions at the Royal Observatory, Greenwich, and the Cambridge Observatory (Edwards, 1993; Elliot, 2004; Symes, 1976).

The construction of a network of telegraph lines took up the majority of his time, most notably the Overland Telegraph, which by crossing Australia from south to north provided in 1872 the first telegraphic connection between Australia and Europe (e.g., Clune, 1955; Harcourt, 1987; Moyal, 1984; Taylor, 1980).

Systematic astronomical work began in 1867, facilitated by the loan of a Simms transit from the Melbourne Observatory, however Todd did observe the transits of Mercury of 1861 November 12 and 1868

November 5 from Adelaide. The observations were reported as having been made with a 57 mm (Todd, 1862) and 64 mm (Todd, 1869) aperture Dollond telescopes, respectively, though this may have been one and the same instrument.



Figure 1. Sir Charles Todd, 1826-1910 (Courtesy: Mitchell Library, State Library of New South Wales).

In 1872, the South Australian *Register* carried an article about the upcoming transits (The Transit of Venus, 1872), noting that

It appears that the Governments of Great Britain, France, Germany, and Russia have unitedly undertaken to obtain the required observations of the phenomenon, and that 46 stations have been selected for this purpose ... 33 in the northern

hemisphere, and 13 south of the Equator ... It will be observed that Adelaide is not included among the selected stations. This is to be regretted, because the purity of our atmosphere during the summer is proverbial, and because ... the transit will take place here at noon.

It is interesting to speculate whether the fact that no international expedition was to be made to Adelaide may have been a factor in the decision to fund the purchase of a new telescope for the Observatory to observe the transit, although the successful completion of the Overland Telegraph and the acclaim it brought was probably a more important factor. In any case, provision was made in the South Australian Colonial Government's budgetary Estimates of 1872 and 1873 for a transit room, anemometer tower, and an office for the Observatory. The transit room initially housed the Melbourne Observatory's Simms transit, the Adelaide Observatory acquiring its own Troughton and Simms transit instrument in 1881 (Edwards, 1993).

The Estimates of 1873 provided £800 for an equatorial telescope, and the Estimates of 1874–1875 contained £500 for a building to house it. It was not until 1874 that the Observatory's first Assistant Astronomer, Alexander Ringwood, who had previously worked as a surveyor on the Overland Telegraph line, was appointed. The equatorial (Figure 2) was by made by Cooke & Sons of York, with Airy, then Astronomer Royal, assenting to Todd's request to supervise the manufacturing of the telescope (Todd, 1884). The equatorial had an object glass (aperture) of 203 mm and a focal length of 3.04 m. Todd (*ibid.*) reported "There was considerable delay in erecting the dome, but I fortunately succeeded in mounting the telescope and getting it into good adjustment in time to observe the transit of Venus in December, 1874". Edwards (1993) interpreted this to mean the dome was not completed until sometime after the transit, however newspaper reports from the time reveal that this was not the case.

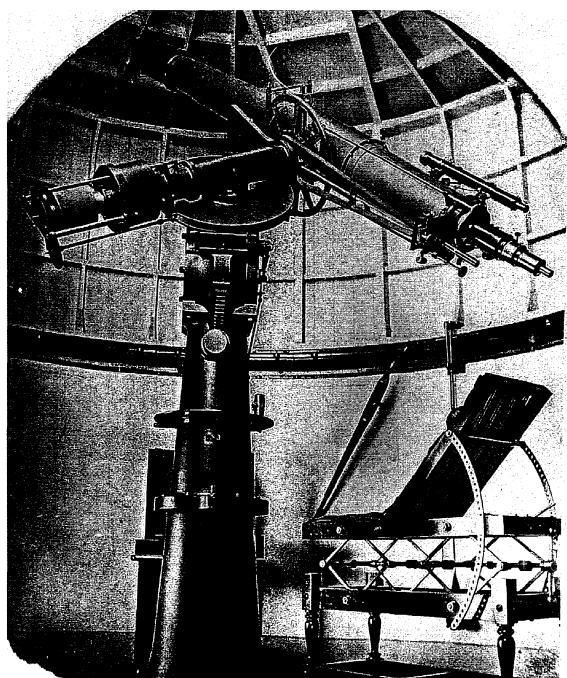


Figure 2. The 203-mm equatorial by Cooke & Sons of York (Courtesy: State Library of South Australia, SLSA: B 12156).

The *Observer* newspaper (The Transit of Venus, 1874b) reported that the telescope

... has been erected upon a massive iron pedestal resting upon a tower of solid masonry, having a deep foundation so as to prevent any vibration from external causes. Nothing short of an earthquake can disturb its repose. It is protected above by a dome weighing over two tons [1814 kg] capable of being shifted horizontally, the base being supported upon cannon balls running in a kind of grooved railway.

Meanwhile, the *Chronicle* (The Transit of Venus, 1874a:12) waxed: "The pedestal stands on a brick pier 6 feet [1.83 m] in diameter, built in cement, with a concrete base. The dome is cylindrical, turning on cannon balls, and although weighing over two tons, it runs so easily that a child might turn it." The equatorial and the dome are pictured in Edwards (1993). The last of the Observatory buildings was demolished in 1978, with the Observatory site now the location of Adelaide High School. Plaques in the foyer of the High School and on the school grounds commemorate the astronomical and meteorological work undertaken by Government Astronomers Todd and G F Dodwell (Edwards, 1994) and their assistants.

3 THE 1874 TRANSIT OF VENUS

The morning of 1874 December 9, a Wednesday, did not augur well for observations of the transit from Adelaide, with complete cloud cover and gusty southwest winds. First external contact, expected at 11:04 a.m. Adelaide mean time (which was $9^{\text{h}} 14^{\text{m}} 21^{\text{s}}.3$ ahead of Greenwich mean time), with the Sun at an elevation of ~ 74 degrees, was clouded out. Shortly after, however, the clouds started dispersing: when Todd first saw the planet it had advanced onto the Sun by about one sixth of its diameter (The Transit of Venus, 1874a, 1874b). Todd observed with the aperture of the equatorial reduced to 102 mm and using a double filar micrometer eyepiece, with a power of 140.

The *Chronicle* (The Transit of Venus, 1874a) reported that timekeeping was arranged as follows.

During the transit of the planet a chronograph was placed in the equatorial dome, on which the sidereal [*sic*] clock in the transit room recorded its time every second, and a key by the observer's side enabled him also to record on the chronograph the instants of contact.

Mr F S Crawford, the Government Photolithographer, took a few un-enlarged photographs shortly after mid-transit. Todd forwarded the negatives to the Royal Astronomical Society, though suspecting they "... possess no practical value." (Todd, 1883, 1884). He observed that the photos showed a "... somewhat flattened oval image of the planet ..." (*ibid.*), but noted that this was not apparent when looking at the planet through the telescope.

Micrometric measurements were made of the planet's position as the transit proceeded, with the skies remaining clear for the egress.

With regard to the 'black drop', of which so much has been written, I wish I had never heard of it, as looking eagerly for its appearance and not seeing what I expected was certainly calculated to bias my judgement as to the precise instant of internal contact. As the planet closed up to the Sun's limb

it seemed to be but very slightly, perhaps a little disturbed; but I saw nothing like the representations of the 'black drop'. There was, I thought, a slight oscillatory movement (of course only apparent) of the planet to and from the limb, which made it excessively difficult to fix positively the exact instant of contact, neither the Sun's limb nor the planet being sharply defined, but the time first noted by me, viz. 3h. 4m. 42.07s., was when I thought the continuity of the sun's limb or the fine streak of light appeared to be broken, although the planet did not appear to be quite in contact, but rather seemed to be connected with the sun's limb by a most minute protuberance or fine filament, too small to be shown in any drawing. At 3h. 4m. 54.54s. the contact seemed to be full or tangential. Perhaps the true instant lies between the two times noted. I can hardly say to which I would attach the greater weight, and as a true record of my impressions at the time I give you the two times and the circumstances under which they were noted...

As the planet moved off, or a few minutes after internal contact, the distortion was obvious (much the same as in the mock transits I had arranged previously for practise) on the side adjoining the edge of the sun, where the planet appeared to be elongated or drawn out into a short wide band. This was especially noted at 3h. 5m. 22s. and at 3h. 6m. 35s., but taking the whole phenomenon, I feel perfectly safe in saying there was no black drop. (Todd, 1883, 1884).

From Adelaide, the elevation angle of the Sun was ~46 degrees at third contact (internal contact at egress) and ~40 degrees at fourth contact (external contact at egress). The times given here, and elsewhere in this paper, for the observations used the system, in common use until 1925, of starting the astronomical day at 12 noon, local time.

3.1 Venus' Atmosphere

Todd continued in his report

I was not prepared to find a portion of the planet off the sun remain distinctly visible and sharply defined, admitting of a fair measurement of its diameter being taken at 3h. 9m. 33.6s. Mr. Ringwood, my assistant, whom I called to the instrument, also saw it. The planet — that is, the segment off the sun's disc — appeared to be surrounded and to be seen through, as though enveloped in a faintly luminous nebulous haze or a purplish hue inclining to violet on the planet towards the sun.

The discovery of Venus' atmosphere is widely credited to Mikhail Lomonosov, who observed a similar phenomena from St. Petersburg during the transit of 1761 and interpreted it as being caused by the atmosphere of Venus. Cruikshank (1983) states

Lomonosov ... noted a gray halo surrounding the planet as it was partially silhouetted against the Sun and correctly inferred that Venus has an atmosphere. Many other observers of the same event noted the halo and also that at second contact the small black disc remained connected to the Sun's limb with a black thread; when the thread broke, Venus already stood well on the disc. Lomonosov correctly concluded ... that these phenomena were caused by an atmosphere surrounding the planet, though others who saw the

effects did not draw the same inference. Lomonosov's discovery was published in Russian in St. Petersburg and was not widely known. Yet his descriptions and inferences are clear, and he is rightly credited with the discovery of the Venus atmosphere.

Maor (2000), for example, notes that Lomonosov's report, published in Russian, did not become known in the west until 150 years later, and that prior to this the discovery of the Cytherean atmosphere was credited to William Herschel, from his interpretation of the lack of permanent features on Venus being due to clouds (see also Newcomb, 1910), or to Herschel and JH Schroeter (see, e.g., Struve, 1954). Newcomb (1910) notes Herschel's observations, and also reports the observations of halos around Venus near inferior conjunction "... first noticed by David Rittenhouse, of Philadelphia, while observing the transit of Venus on June 3d [sic], 1769 ..." and also seen by Mädler in 1849 and Lyman in 1866. However, Fegley (2004), citing Woolf (1959), states that "... several observers observed a halo around Venus as it entered and exited the Sun's disk. Thomas [sic] Bergman in Uppsala and Mikhail Lomonosov in St. Petersburg, independently speculated that the halo was due to an atmosphere on Venus."

Torbern Bergman was one of four scientists who viewed the transit from Uppsala (Woolf, 1959), and his observations are described (in Latin) in the *Philosophical Transactions of the Royal Society* (with his name appearing as "Thorbern"). In part he states: "Imprimis, Venerem atmospha circumdatam observasse credimus; sequentibus nixi rationibus. Scilicet, ante completam immersionem, seu adhuc quarta circiter parte diametri Veneris extra marginem Solis existente, tota Venus visa est; nam pars extra prominens debili lumine erat cincta, uti Fig. 1 monstrat." (Bergman, 1762), which may be translated as:

From the beginning, we believed that we observed Venus surrounded by an atmosphere for the following reasons. Evidently, before total immersion, with about a quarter of the diameter of Venus outside the edge of the sun, all Venus was seen; the external portion was surrounded by a faint light, as Fig. 1 shows.

The paper contains six figures, two showing Venus near ingress and four near egress. In the Figure 1 referred to above, a halo is visible around the portion, ~20% of the diameter of Venus, outside the Sun's disc. The same effect is seen at egress, with Figure 2 of Bergman's paper showing a halo surrounding the portion of the planet exterior to the Sun's disc midway between third and fourth contacts. Bergman's Figure 3 shows ~80% of the planet's diameter outside the Sun's disc, with two partial halos extending from the Sun's edge around ~70 degrees of the planet's circumference. The remaining figures concern observations of the black drop effect.

Other observers, for example Dunn (1762), claimed evidence for a Venusian atmosphere from the indistinct edge of the planet while it was completely on the Sun's disc, or from observations of the black drop. It is now established that the black drop effect, also visible for Mercury, despite its lack of atmosphere, in both Earth- and space-based observations (Schaefer, 2000, 2001; Schneider, Pasachoff and Golub, 2004) cannot be ascribed to Venus' atmosphere.

It is interesting to note that Struve (1954), in discussing Lomonosov's observations of a "blister" on the Sun's edge preceding third contact, concludes "... it seems inescapable that the blister seen by Lomonosov cannot be reasonably accepted as proof of the existence of an atmosphere." Struve continues:

Of course, it is now well known that when Venus is several degrees from the sun its atmosphere can be observed as a faint, narrow luminous ring around the planet. This faint luminosity was not observable in the telescopes of Lomonosov's day. However, when Venus is entering or leaving the sun at transit, the ring is more conspicuous. David Rittenhouse saw it at the 1769 transit ... But this phenomenon is not bright enough to account for Lomonosov's observation. (Struve, 1954)

It would therefore appear that Bergman's observations provide more convincing evidence for an atmosphere around Venus. In any case, these early observations were unknown to observers of the 1874 transit: "Accordingly, many of the observers were quite taken by surprise to find that when Venus was partly on and partly off the sun, the outline of that part of her disk outside the sun could be distinguished by a delicate line of light extending around it." (Newcomb 1910).

3.2 Other Observations

The results of a number of other observations are reported in the *Observer* (The Transit of Venus, 1874b). Todd included results from the observations of F C Singleton, T D Smeaton, and A W Dobbie in his report to the Royal Astronomical Society, though noting the "... from uncertainty in the determination of time they may not be of great value ..." (Tupman, 1878; Todd, 1883, 1884). Singleton observed from the Observatory grounds with a 76-mm achromatic telescope.

Smeaton, a keen amateur (Waters, 1996) and, for some time the Manager of the Bank of South Australia, observed the transit with a 89-mm equatorial of Cooke & Sons from his house in North Adelaide. Smeaton noted "The dark planet was seen against the bright sky when half off the sun, and edged with a bright margin. This I interpret as the twilight of Venus, proving the presence of an atmosphere. This bright edge gave the planet quite a solid appearance, contrasting strangely with its flat disc-like aspect when wholly on the sun." (The Transit of Venus, 1874b).

Dobbie, a keen amateur astronomer and telescope maker (see, e.g., Edwards, 1994; Orchiston and Bembrick, 1995; Orchiston 1997; Waters, 1996) observed with an 216-mm silvered glass reflector at his residence "... about 880 yards north and 3,740 yards east ..." (800 m north and 3.4 km east) of the Observatory. Tupman (1878) reports Dobbie's location as "3,740 yards" east, with a footnote stating this is the distance given in Todd's original report. However, Todd (1883, 1884) clearly gives 3740 yards, which is consistent with Dobbie's residence being in the suburb of College Park, as reported following the 1882 transit (see section 4.2). The difference is not sufficient to make any appreciable change to Dobbie's residual given in Table 1.

3.3 Results

The Chronicle advised: "Of course our readers will

understand that some considerable time will be required to work up the observations, so as to obtain complete results, as a great deal of labour will be necessary before these results can be arrived at." (The Transit of Venus, 1874a:12). This proved to be something of an understatement.

Table 1. Adelaide Mean time for internal contact at egress, weights accorded to the observations, and residuals from the best-fit solution obtained by Tupman (1878).

| Observer | Recorded time | | | Weight | Residual s |
|-----------|---------------|---|------|--------|---------------|
| | h | m | s | | |
| Todd | 3 | 4 | 48.3 | 2 | +1.0 |
| Singleton | 3 | 4 | 41 | 1 | +8.1 |
| Dobbie | 3 | 5 | 5 | 0 | -17.0 |
| Smeaton | 3 | 5 | 6 | 0 | -16.1 |

Under pressure from the British Parliament (Airy, 1877; Meadows, 1974), Tupman's preliminary results from the British expeditions (observations of ingress at Honolulu, Rodriguez, Kerguelen and New Zealand, and of egress at Mokattam and Suez, Luxor, Rodriguez, and Kerguelen) were published in 1877, with a determinations of mean solar parallax from ingress observations of 8".739, the egress observations yielding 8".847, and a weighted mean giving 8.760". A provisional result from the observations of American expeditions, by D.P. Todd (no relation to Charles!), of 8".883 ± 0.034, did not appear until 1881 (see, e.g., Dick, Orchiston and Love, 1998).

Tupman's analysis was criticised by E J Stone (1878), Her Majesty's Astronomer at the Cape of Good Hope, who from the same observations derived 8".884 ± 0.037, a figure which also happened to be in much better agreement with Stone's previous calculations of the solar parallax from other observations (Evans, 1988; Stone, 1878).

Tupman subsequently made a fuller analysis, incorporating the British expeditions and a large set of other observations, including those made in Australia. He accorded each observation a weight of 2, 1, or, if the observation could not be trusted, 0. Given Todd's description of his observations (above), Tupman (1878) took the mid-point between the two times (Table 1), but gave the observation double weight due in part to the detailed description, and also the reliable determinations of time and observing location. Singleton's observation from the Observatory grounds was given a weight of 1, whereas Dobbie's and Smeaton's were discarded, a decision validated by their larger residuals from the resulting solution (Table 1).

Tupman derived a solar parallax of 8".845 from twenty observations of ingress, and 8".846 from 41 observations of egress (i.e., neglecting those given a weight of 0). He concludes "Although the ... results of Ingress and Egress present such an unexpected agreement, it cannot be said that the mean 8".8455 is entitled to much confidence, since all the observations would be fairly well satisfied by any mean solar parallax between 8.82" and 8.88"." (ibid.).

4 THE 1882 TRANSIT

As a result of the difficulty in reducing the data from the 1874 observations, and the inconclusiveness of those results obtained, the December 1882 transit was not observed with the same enthusiasm (e.g., Janiczek and Houchins, 1974; Meadows, 1974; Sheehan, 2004). Ingress occurred before sunrise in Australia and New

Zealand, and egress was to take place only shortly after sunrise in Adelaide. The Adelaide Hills lie to the east of Adelaide and, realizing that "... the sun might possibly be obscured by the clouds which frequently hang over the hills ...", Todd (1884) decided to travel to a site further east to observe the transit, eventually deciding on Wentworth, at the junction of the Murray and Darling rivers in western New South Wales.

4.1 Preparations

The observing party left Adelaide on November 27 by train, changing at Morgan to a steamboat, and arriving at Wentworth on December 2. Todd chose a site "near the gaol, about a mile out of the town" (*ibid.*). The gaol, built between 1879 and 1881, closed in 1927 and is now a popular tourist attraction. An enclosure of galvanized iron was erected around the equatorial and azimuth transit, with a brick pier built for the latter. Due (ironically) to cloudy weather over the next few nights, it was only possible to take one set of transit observations for time, and that on December 8, after the transit. However, as the chronometers were checked daily with the Adelaide Observatory by the exchange of telegraph signals, Todd was confident his recorded times were reliable. The meridian transit of 13 stars on the evening of December 8 was used to determine the difference in longitude from the Adelaide Observatory, with a longitude of $9^{\text{h}} 27^{\text{m}} 37^{\text{s}}.18$ east of Greenwich being determined (using the revised determination for Adelaide's longitude described in section 4.2). The latitude, $34^{\circ} 6' 24.7''$, was determined from observations of eleven meridian altitudes, taken with a sextant by surveyor J W Conolly.

Todd observed with "... an excellent equatorial, having an aperture of $4\frac{1}{2}$ in. [114 mm], purchased for the Observatory from the late Mr B H Babbage, who brought it from England after the death of his father (Mr Charles Babbage [1791-1871]), to whom it originally belonged." (Todd, 1884). A report in the *Chronicle* claimed the telescope had an even more illustrious heritage: "... an equatorial telescope, having an object-glass of a $4\frac{1}{2}$ -inch diameter, which was lately the property of Mr Charles Babbage, the distinguished mathematician, by whom it was purchased on the death of Sir William Herschel [in 1822]" (*The Transit of Venus, 1882a*).

Benjamin Herschel Babbage (1815-1878) was the oldest son of Charles and Georgiana (nee Whitmore). His middle name bears evidence to the close friendship of his father with John Frederik William Herschel (1792-1871), son of Sir William. B H Babbage left England for Italy in 1842, and emigrated to Adelaide in 1851. He was the first Surveyor General and Assayer of the Colony, mapping large areas of northern South Australia, and helping determine the route for the southern section of the Overland Telegraph (Tee, 1983). Babbage also had an interest in astronomy (Waters, 1996) and is reported as having observed the 1874 transit (*The Transit of Venus, 1874a:12, 1874b*), possibly with the same telescope!

4.2 Observations

Of his observations, Todd (1884) reported:

The sun rose in an unclouded sky on the day of the

transit, and the atmospheric conditions were all one could desire. Just before the time of internal contact, the limb of Venus became somewhat distorted and ragged or woolly, appearing to be slightly drawn out towards the edge of the sun, and the sun's limb was occasionally boiling and tremulous; but I think I succeeded in getting the times of the different phases of internal contact A, B, C (as shown in the accompanying drawings [Figure 1]), with as great exactness as the nature of the observation will admit.

Phase A occurred at $17^{\text{h}} 30^{\text{m}} 15^{\text{s}}$ Wentworth mean time: "At this time few very fine ligaments appeared to connect the limb of the planet with that of the sun, and the streak of light round the limb was not again continuous although the planet was well on the disc" (*ibid.*). At Phase B, 43.6 seconds later, "The ligaments, which have gradually been thickening since the last time noted, have closed up, and the contact now seems tangential" (*ibid.*). Phase C, at $17^{\text{h}} 32^{\text{m}} 7^{\text{s}}$, "Planet evidently partly off the sun's limb now, as shown in the sketch" (*ibid.*). Todd's sketches are reproduced in Figure 3. Third contact occurred with the Sun at an elevation of ~ 8 degrees.

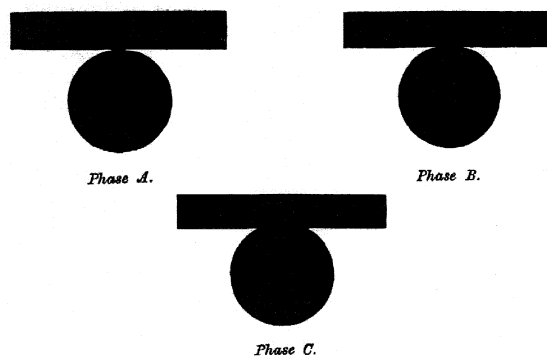


Figure 3. Sketches of the phases of egress as observed by Todd from Wentworth, December 1882 (after Todd, 1884). See the text for details of the phases.

Adelaide was effectively clouded out, with glimpses of the egress being obtained through fleecy clouds. Ringwood, who had previously observed the egress of Mercury during the transit of 1878 May 6 (Todd, 1878), attempted to observe using the full aperture of the Cooke equatorial (*Transit of Venus, 1882*). The time recorded for internal contact, $17^{\text{h}} 16^{\text{m}} 25^{\text{s}}$ Adelaide mean time, with the Sun at an elevation of ~ 6 degrees, was noted as being "very uncertain" (Todd, 1884), with an uncertainty of 20 or 30 seconds (*Transit of Venus, 1882*). Ringwood noted again seeing evidence of Venus' atmosphere (*ibid.*). Dobbie, one of a number of other hopeful observers, mounted a 165-mm Newtonian on the roof of his house at College Park, but was unsuccessful in viewing the transit due to clouds (*The Transit of Venus, 1882b*).

Todd was almost certainly the westernmost observer to provide accurate observations of the egress, which in principle made them of some importance in analysis using Delisle's method. The only other Australian observations included in the British analysis were two observations from Melbourne and one from Hobart (*The Transit of Venus, 1882, 1888*).

The Overland Telegraph line was used in 1883 January to determine the longitudes of Australian, and

thence New Zealand stations. This was done with the assistance of Captain Leonard Darwin, RE (son of Charles Darwin), who had been part of the unsuccessful British expedition to Brisbane. "Captain Darwin while in Australia determined the difference of personal equation between the Australian observer and himself, and then returned via Singapore. Signals were exchanged between Captain Darwin at Singapore and Mr Barrachi [of the Melbourne Observatory] at Port Darwin on eight nights, and the results are very accordant" (The Transit of Venus 1882, 1884). The revised longitude for Adelaide, $9^{\text{h}} 14^{\text{m}} 20^{\text{s}}.08$ East of Greenwich, was used in determining the longitude of Wentworth which was used in the subsequent analysis of results (Todd, 1884).

The determination of Australian longitudes by telegraph was commemorated by a stone plinth and plaque in Liberty Square, Darwin. As the original was removed and subsequently lost sometime in the mid-twentieth century, a replica of the Port Darwin Astronomical Observation Pillar was unveiled in March 2000.

4.3 Results

The British Government Committee's analysis, directed by Stone, yielded a solar parallax derived from egress observations of $8''.855 \pm 0.036$, and an overall result, combining ingress and egress observations, of $8''.832 \pm 0.024$ (The Transit of Venus 1882, 1888).

With the publication of the American result, $8''.842 \pm 0.011$, by Harkness, and the German result, $8''.883 \pm 0.022$, by Auwers, Stone (1892) revisited his results, reporting a value based solely on observations of internal contacts of $8''.850 \pm 0.022$ and concluding "The results given by the other contacts observed in 1882 agree within the probable errors of their determinations with those obtained from the Internal Contacts." (Dick, Orchiston and Love (1998) note that these probable errors are 74% of the mean, or standard, error that is now in common use.)

Ultimately, the utility of the transits of Venus in determining the solar parallax (Dick, Orchiston and Love, 1998; Janiczek and Houchins, 1974; Meadows, 1974; Sheehan, 2004) can be judged by the fact that the accepted value is $8''.794148$.

5 CONCLUSIONS

Charles Todd, Government Astronomer of South Australia, made useful observations of egress at both the 1874 and 1882 transits of Venus. Todd was one of many observers in 1874 surprised to find evidence for Venus' atmosphere. The discovery of the Cytherean atmosphere is widely credited to Mikhail Lomonosov, although this has been questioned by Struve (1954). The independent, and perhaps more compelling, discovery by Torbern Bergman would appear to be deserving of more credit.

In addition to the transits of Venus, Todd and his assistant observers made a number of other observations of astronomical phenomena (Edwards, 1993; Elliot, 2004). Todd's many other duties prevented him from devoting as much time to astronomy as he would have liked, and one of his regular reports to the Royal Astronomical Society contains the plaintive plea "Please remember, when thinking how little I do, that I am also [from 1870] Postmaster-General and Superintendent of Telegraphs" (Todd, 1878). The various honours and accolades he

received attest to the fact that his many achievements were duly recognized (Edwards, 1993; Symes, 1976). Perhaps most recently, Todd was pictured on the Australian pre-stamped envelope issued to mark the 125th anniversary of the completion of the Overland Telegraph.

Todd was (in)famous for his love of puns. For example, "When asked whether a postal service could be provided at Orrorroo, Todd replied that it would not be worthwhile as there were only two letters in Orrorroo" (quoted in Waters, 1996). Todd would therefore probably have enjoyed the humorous account of observations of the transit by Geoffrey Crabthorn (1874), which included lyrics to accompany the popular tune "Willie, We have missed you" (by Stephen Foster, who also wrote "Oh! Susannah", "De Campdown Races", "Swanee River" and others). The first verse reads:

Oh! Venus, is it you Ma'am,
Seen, seen at last?
The skies at length are blue, Ma'am,
That were so overcast.
The clouds began to break,
And with joy I watched the sun,
For I knew you were behind them,
And the transit had begun,
Making on its face a spot
In the disc of dazzling light;
Oh, Venus, we have missed you;
Welcome, welcome sight!

These words will perhaps resonate more deeply with some astronomers after 2004 June 8 and 2012 June 5/6!

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