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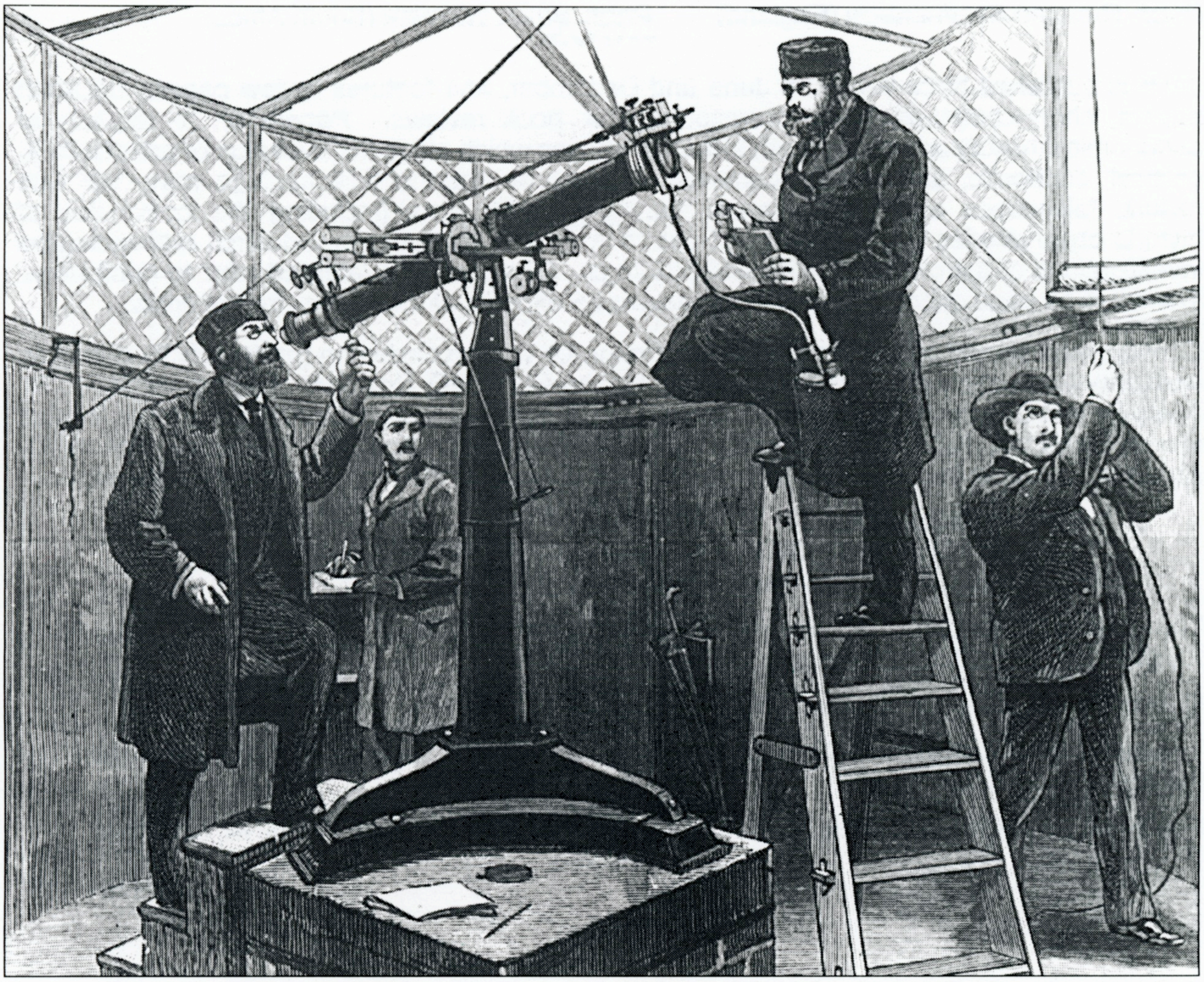

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Cover: The heliometer observations in Hartford. At the telescope: Müller (left) and Deichmüller (right), Bauschinger taking notes in the background, Dölter is operating the dome slit (Frank Leslie's Illustrated Newspaper, made available by the Connecticut Historical Society). See pages 13-14.

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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.

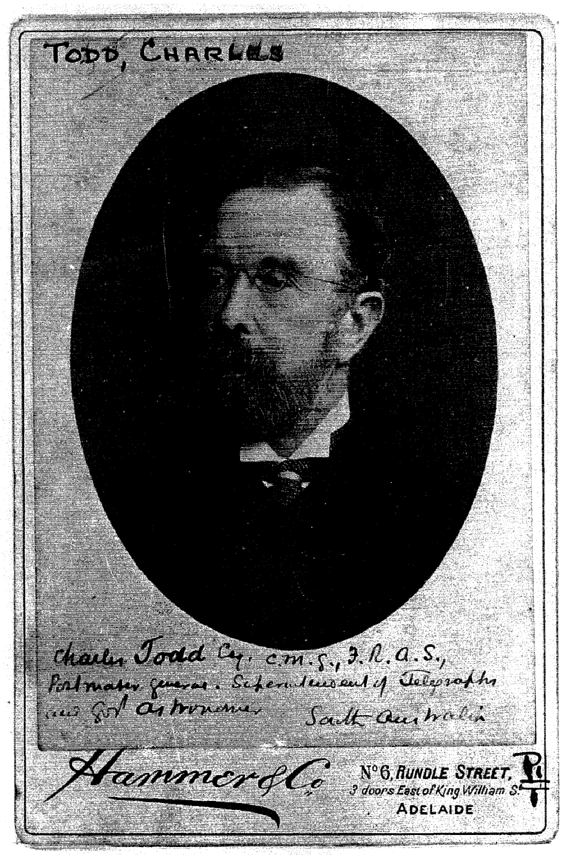

Figure 1. Sir Charles Todd, 1826-1910 (Courtesy: Mitchell Library, State Library of New South Wales).

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.

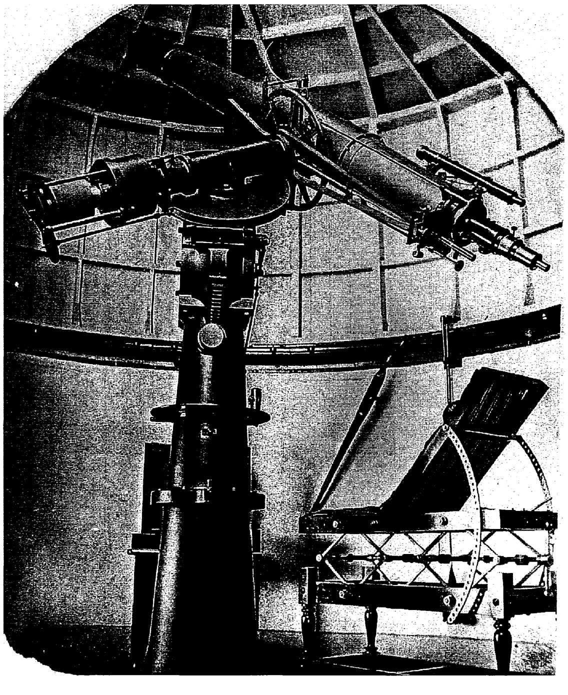

Figure 2. The 203-mm equatorial by Cooke & Sons of York (Courtesy: State Library of South Australia, SLSA: B 12156).

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 south-west winds. First external contact, expected at 11:04 a.m. Adelaide mean time (which was $9^h 14^m 21^s.3$ 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 siderial [*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 Photo-lithographer, 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 J H 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 atmosphera 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 h m s	Weight	Residual 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 $9^h\ 27^m\ 37^s.18$ east of Greenwich being determined (using the revised determination for Adelaide's longitude described in section 4.2). The latitude, 34° 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 4½ 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 4½-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 $17^h\ 30^m\ 15^s$ 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 $17^h\ 32^m\ 7^s$, "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.

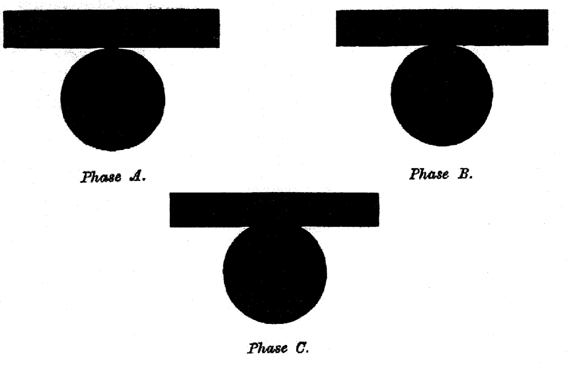

Figure 3. Sketches of the phases of egress as observed by Todd from Wentworth, December 1882 (after Todd, 1884). See the text for details of the phases.

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, $17^h\ 16^m\ 25^s$ 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, $9^h\ 14^m\ 20^s.08$ 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 Orroroo, Todd replied that it would not be worthwhile as there were only two letters in Orroroo" (quoted in Waters, 1996). Todd would therefore probably have enjoyed the humorous account of observations of the transit by Geoffry Crabthorn (1874), which included lyrics to accompany the popular tune "Willie, We have missed you" (by Stephen Foster, who also wrote "Oh! Susannah", "De Camptown Races", "Swannee 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!

6 ACKNOWLEDGEMENTS

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The German transit of Venus expeditions of 1874 and 1882: organization, methods, stations, results

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Abstract
The first major Government-funded German scientific enterprise was triggered by a smaller one to observe the total solar eclipse of 1868. The photoheliograph built for this occasion was later used for transit of Venus observations, together with three similar instruments. Furthermore, five small Fraunhofer heliometers were used to visually measure the position of Venus on the solar disc. The 1874 expeditions went to Tschifu in China, Kerguelen, Auckland and Mauritius Islands, to Isfahan (Persia) and to Luxor (Egypt). The low accuracy achieved from the photographic observations led to the abandonment of such studies in the next transit. The 1882 transit expeditions went to Hartford (Connecticut), Aiken (South Carolina), Bahia Blanca (Argentina), Punta Arenas (Chile), and Royal Sound (South Georgia Island). Meticulous calibrations of the heliometers were carried out before and after the transits, and final results of contact timings, photographic and heliometric observations were only published in 1896.

Keywords: *Venus transits 1874 and 1882, German expeditions, photographic observations, heliometric observations*

1 INTRODUCTION

In 1868, the science writer Aaron Bernstein, whose popular books on the natural sciences would later inspire young Albert Einstein, sent a petition to the parliament [Reichstag] of the North German Federation (the German Empire would only come into existence 3 years later). His suggestion was to organize and support a German expedition to observe the total solar eclipse of August 18. After a feasibility study by Wilhelm Foerster, the Director of the Berlin Observatory, referees' comments from various observatory directors and astronomy professors, and some discussion in parliament, the project was granted 16,000 thalers (equivalent to 48,000 marks after the 1873 currency change), and expeditions were sent to Aden (South Arabia) and to Mulwar, a village near Bijapur (India). The recently-founded Astronomische Gesellschaft served as the controlling authority, and the (somewhat scarce) results were later published in its *Vierteljahrsschrift* (Bruhns, 1872). Nevertheless, this activity carried the seed of the next major project: an attempt to observe transits of Venus from various places on Earth. When this application was filed with the Federal Council, a detailed outline was requested, and scientists were nominated to carry out this task. Thus the *Commission für die Beobachtung des Venusdurchgangs* came into existence in 1869, and would cease its activities about 30 years later, when only two out of the original nine members were still alive, after having organized about ten expeditions, published six volumes totalling 3600 pages, and spent about 780.000 marks—an equivalent of about 12 million present-day dollars.

2 INSTRUMENTATION AND METHODS OF OBSERVATION

It seems that August Winnecke and Arthur Auwers (Figure 1) developed first plans in 1869. They had become friends in 1854, when Winnecke was studying in Göttingen, and Auwers was not yet 16 years old, but already an active observer. Now Winnecke had left his job in Pulkovo (Russia) for health reasons and was carrying out private research in Karlsruhe (he would later become the first Director of Strassburg Observatory), while Auwers was an Astronomer at the Prussian Academy of Sciences. Carl Christian Bruhns, Director of Leipzig Observatory, who had organized the 1868 solar eclipse project, soon joined the team. Bruhns and Auwers planned to file simultaneously—through the Prussian and Saxonian academies—applications to the respective Ministries that would pass them on to the Council of the North-German Federation [Bundesrath des Norddeutschen Bundes], asking for support. Although Auwers' application was delayed, the Council reacted favourably, but required a detailed research plan and a cost estimate, and requested that State Governments should suggest names of scientists to carry out these tasks to the Office of the Federal Chancellor. In this way, a 'Commission' was established, which was composed of the three initiators, and in addition the Directors of Bonn, Berlin, Gotha, and Hamburg Observatories (Friedrich Argelander, Wilhelm Foerster, Peter Andreas Hansen, and George Rümker) as well as the great-ducal Chancellery Officer Friedrich Paschen of Schwerin (Mecklenburg). The latter, a student of Gauß, was well-known for his geodetic work. After the foundation of the German Empire in 1871 January, two astronomers from southern states were added: Eduard Schönfeld from Mannheim Observatory and Ludwig Seidel from Munich Observatory.

Two methods could be applied to determine the solar parallax. The visual method involved measuring the motion of Venus across the solar disc by means of heliometers. Since the instruments should be comparable in size, a series of quite old-fashioned Fraunhofer heliometers (and those produced by his successor Utzschneider) of 3½ feet focal length was slightly modernized to facilitate the reading of the settings by the Repsold company. The photographic method was based on taking a series of momentary exposures of Venus transiting the Sun by means of a photoheliograph; the plate analysis would be carried out after the return in Schwerin (later Leipzig), where measuring facilities were available. The instrument used for the solar eclipse at the Aden station was thought to be suitable, although the image scale was increased by about a factor six by means of an optical device made by Schröder (Hamburg). Three more instruments were ordered, to be used at different stations. In addition, the expeditions carried conventional refractors for the observations of contacts, chronometers, transit and universal instruments for the determination of longitude and latitude, models for training contact timings and heliometer settings, and various meteorological instruments.

Figure 1. The president of the German Venus Transit Commission, Arthur Auwers (Shane Archives, University of California, Santa Cruz).

The Fraunhofer heliometers had apertures of 34 lines (75 mm) and focal lengths of 3½ feet (1067 mm). Heliometer A of Breslau (Wroclaw) Observatory was used at Tschifu and Aiken, heliometer B of Gotha (later Strassburg) Observatory was used at Betsy Cove and Bahia Blanca, heliometer C of Göttingen Observatory at Port Ross and Punta Arenas, and heliometer D of Berlin Observatory at Mauritius and Hartford. A slightly-different heliometer E, built for Wilhelm Olbers and kept at Hamburg Observatory, was used in Luxor and South Georgia. Heliometers B and C still survive in the respective Observatories, while E is now in the Deutsches Museum Munich.

The Steinheil photoheliographs had slightly different apertures, focal lengths, and focal magnifications. Heliograph A is the original Astronomische Gesellschaft instrument (two-lens aperture: 161.6 mm, 1905 mm focal length, magnification 6.1×) and was used at Betsy Cove; heliograph B (two-lens, 163 mm, 1905 mm, 6.25×) was used at Tschifu; heliograph C (four-lens, 106.8 mm, 1981 mm, 5.5×) was used at Port Ross, and heliograph D (four-lens, 106.8 mm, 1981 mm, 5.4×) was used at Ispahan. Heliograph C is kept at the Dr Remeis Observatory in Bamberg; heliograph A (minus its objective lens, but with a special mounting designed for it by P A Hansen) still survives, and is in the Astrophysikalisches Institut Potsdam.

The photographic observations were straightforward: after a plate was inserted, the shutter was released and a very short exposure of the Sun was taken (the instruments had, except in the case of the Hansen mounting, no equatorial mounting and no tracking provision). More effort was taken concerning the preparation, development and fixing of the photographic plates, and both dry and wet plates were employed.

3 THE EXPEDITIONS OF 1874

Members of expedition I (Tschifu) were astronomers Wilhelm Valentiner (Leiden, Netherlands), Carl Adolph (Elberfeld, today Wuppertal), Eugen Reimann (Ratibor, Upper Silesia) and photographer Carl Kardaetz from Französisch-Buchholz (a village near Berlin). Assistants were the mechanic Friedrich Deichmüller (Leipzig) and painter Oskar Eschke (Berlin). Besides the passengers, there were 107 boxes, with a total weight of 14 tons. The two-month trip from Southampton to Shanghai with a stopover in Bombay was made by British steamers, and the remaining distance was travelled on a small US ship. Tschifu was reached on October 27.

The station was erected on a piece of land enclosed on three sides by a wall, while on the fourth side there was a steep slope (Figure 2). The crew of the corvette SMS *Arcona*, which was stationed in East Asian waters, assisted with the setup.

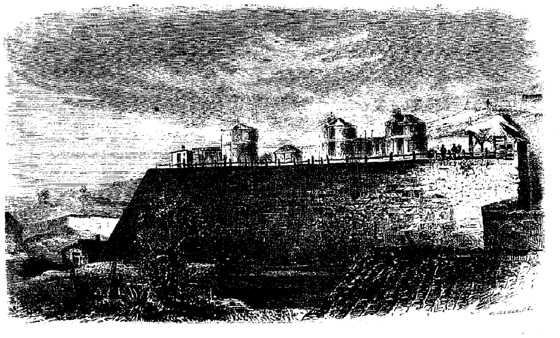

Figure 2. The observing station in Tschifu (Jahrbuch der Illustrirten Deutschen Monatshefte).

A letter from Kardaetz (1874) describes the decisive time at the Tschifu station as follows:

> The day before we were thoroughly frightened because of the weather. No one could sleep during this night. We were lucky, at 3 a.m. the wind changed direction, chased the clouds away, and we had the most marvellous sunrise. At 7 a.m. everyone was on the spot. Baron von Reibnitz, commander of SMS Arcona, said: "This spot looks like the deck of an armoured frigate which is cleared for action." All ships in the harbour were dressed, all consulates and many private houses flew flags, the Chinese in town burned fireworks since morning, therefore begging for clear skies. The requests have been granted, since we had quite clear skies for about two hours. At the end of the phenomenon, with the last photographic plate, it was like cut off, the sky was completely covered with clouds. In the morning of the following day, we had snow and hail.

Members of expedition II (Betsy Cove, Kerguelen Island) were Carl Börgen, Director of the Naval Observatory in Wilhelmshaven, Arthur Wittstein (Munich), Ladislaus Weinek (Budapest, on temporary leave at the photographic test station in Schwerin), zoologist and photographer Theophil Studer (Berne, Switzerland), photographer H Bobzin, and mechanic Carl Krille (both from Schwerin).

Since British and US astronomers had also established stations on Kerguelen, different locations were chosen to minimize the chance of a clouding out:

the British were in Christmas Harbour to the North, the US scientists in Royal Sound to the South, and the Germans chose Betsy Cove within Accessible Bay on the eastern side of the Island. The Kerguelen expedition was part of a two-year research voyage of the steamer corvette SMS *Gazelle*, which also carried out oceanographical, geographical, botanical, and zoological studies. The *Gazelle* left Kiel harbour on June 21, sailed to Cape Town, and anchored in Betsy Cove on October 26 (Figure 3). One day later, the search for a suitable place began, and Börgen (1898) noted that

> At the southern side of the Cove the ground slowly rises to a hill, which piles up in steep rocks in the last 40 feet. At half-way we noted a number of crosses painted in white, which indicate the graves of the whalers who lost their life here. The only somewhat dry spot which was flat as well was found above the graves on the foot of the above-mentioned rocks, and we decided to choose this point.

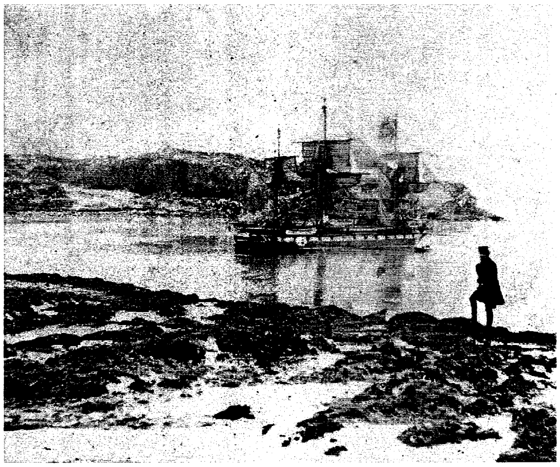

Figure 3. Kerguelen Island. Corvette SMS. *Gazelle* in Betsy Cove, Weinek in the foreground (Universitäts-Sternwarte Göttingen).

Construction was carried out with the help of the *Gazelle's* crew (Figure 4), and two of the naval officers also participated in the observations (Figure 5). Weinek (1911) noted his impressions of the voyage and the transit in a lengthy manuscript. His report of the activities at the time of the transit are quite illustrative:

> In the evening of December 8, it was still raining; on the 9th, the day of the phenomenon, the sun rose in a clear and pleasant sky. The ingress should occur shortly after 6 ½ a.m., the egress at 11 a.m. A few minutes before the event, everybody hastened to his place, the astronomers to their telescopes, the photographer to the darkroom. Börgen stood at the heliometer, Weinek at the refractor, and Wittstein at a 3 ½ foot telescope. … In the meantime, the sky became covered with a quite thick white veil; above the snow-covered mountains in the west darker clouds were looming. Venus, a small black disc 1/30th of the sun's diameter, slowly started to move into the sun. We waited with tension for the inner contact of the two rims, since if we succeeded in observing it we could say that we did not come in vain to these barren regions. The critical moment is approaching, another glance at the ticking chronometer to verify the second which is counted in thought. Venus seems to intend to detach from the solar rim, a bridge is forming still, it becomes thinner, and finally it breaks in two. This was the moment to be observed, and we were joyful to have established it. … While Venus is now standing freely inside the sun, the astronomer's work changes; distance measurements of Venus from the solar centre, or more correctly, distance measurements of both rims, first by eye with the heliometer, and second, with the photographic telescope, where the light records the positions of Venus again and again. Börgen stayed at the eyepiece of the heliometer, while Wittstein continuously read the scale of the objective; whereas Weinek and Crille rushed to the photoheliograph, where the first carried out the exposure, while the second took care of the changing of plates, which were prepared by Bobzin and Studer in the darkroom. We were pleased with the work achieved, especially since the observation of the inner and outer egress of Venus succeeded completely. After December 9, muddy and stormy weather prevailed, and we had to wait until December 19 to photograph the sun again.

Figure 4. The station on Kerguelen Island. Domes of refractor and heliometer on the left side, darkroom cabin and photoheliograph dome on the right (Universitäts-Sternwarte Göttingen).

At the end of January, the station was dismantled and the return trip was begun. On February 26, Port Louis on Mauritius was reached, where the astronomers took a mail-steamer, while the *Gazelle* continued her trip around the world (together with zoologist Theophil Studer), finally reaching Kiel in 1876 April.

Figure 5. The scientists and two officers of the Kerguelen expedition. Front row, sitting, from left: sea officer, Krille, Bobzin; standing, second row: sea officer, Studer, Börgen, Wittstein, Weinek (Estate of H Buchwald, made available by W Fuchs, Hamburg).

Expedition III (Port Ross, Auckland Island) consisted of two astronomers, Hugo Seeliger (Bonn) and Wilhelm Schur (Strassburg), two photographers, Hermann Krone and Guido Wolfram (both from Dresden), and two assistants, mechanic Hermann Leyser Jr. (Leipzig) and Johannes Krone (Dresden).

Most of the participants travelled in a British steamer from London, which took fifty-three days to reach Melbourne, where they were already expected by Seeliger and two officers from the Imperial Admirality. Five days later, the chartered French barque *Alexandrine* transported the expedition members, boxes and a wooden house (that was made in Australia) to Auckland Island. The station was built on the beach at Terror Cove, near the settlement of Port Ross. One Krone photograph (Figure 6) shows the house and domes, another the photoheliograph inside its dome (Figure 7), and a third is a paper copy of an Auckland Island plate of the Venus transit (Figure 8). Since all original plates of the German expeditions were destroyed during an air raid in World War II, this is possibly the only record of such a photographic observation made by German expeditions.

Figure 6. The station on Auckland Island (Agfa Photo-Historama).

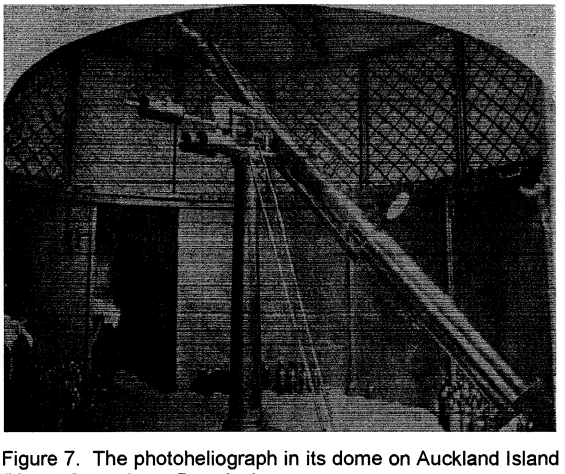

Figure 7. The photoheliograph in its dome on Auckland Island (Krone-Sammlung, Dresden).

The Auckland Island station remained active from 1874 October 18 to 1875 March 6. One of Seeliger's (1898) last entries in the official diary states:

> March 5. The last things belonging to the lodge are brought on board. During our last visit to the island, the pillar of the passage instrument, on whose stone plate Mr. Krone Jr. has incised the words *German Expedition 1874*, was recommended to the special protection of the shepherd who lives on the island.

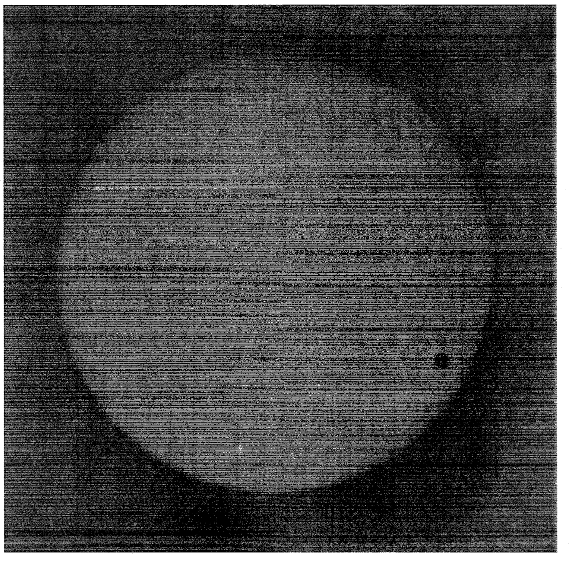

Figure 8. An Auckland photograph of the Venus transit (Krone-Sammlung, Dresden).

The best look into the activities of this expedition (Figure 9) is provided by the photographs, reports, and poems of Hermann Krone, one of the pioneers of photography in Germany. He wrote for various newspapers and journals, produced and sold three photographic series *Die Auckland Inseln*, and around the turn of the century wrote several volumes of poems. Two of these, properly entitled *Father and Son on a Trip Around the World*, deal with the events that were twenty-five years in the past, and in their rhyming emulate the Odyssey.

Figure 9. The members of the Auckland expedition. Front row, from the left: Seeliger, Schur, Krone jr., Leyser, back row: Wolfram, Siegel, Becks, Krone sr. (Agfa Photo-Historama).

The purely visual expedition IV (Solitude, Mauritius) consisted of two astronomers, Moritz Löw (Berlin) and Carl Frederick Pechüle (Hamburg), and two assistants, mechanic Hermann Dölter (Strassburg) and castellan Dietrich Heidorn of Göttingen Observatory. Mauritius had been chosen to have at least one 'meteorological reliable' observing place in the Southern Hemisphere, in case the expeditions to Kerguelen and Auckland Islands—which were prone to storm, rain and snow—would fail. The party went by train and ship to Aden, and then by mail-steamer to Port Louis. A free area with an uninhabited country house, 'Solitude' (Figure 10), was chosen in the south-east of the island near the railway to Mahébourg, since Lord Lindsay had installed his private expedition at Belmont in the north-east. Contrary to expectations, the weather was bad, but a few heliometer measurements were obtained.

Figure 10. Mauritius expedition members and natives in front of the dwelling-house Solitude. Between the central pillars, from left to right: Heidorn, Löw, Pechüle, Dölter (Universitäts-Sternwarte Göttingen).

The purely photographic expedition V (Ispahan, Persia) comprised four persons, photographer Gustav Fritsch, Assistant at the Anatomical Institute of Berlin University, astronomer Ernst Becker (Berlin), and two more photographers, Franz Stolze (Berlin) and Hugo Buchwald (Breslau – now Wroclaw). The party went by train through the Baltic provinces to Zarizyn (now Wolgograd), took a steamer down the Volga to Astrakhan, across the Caspic Sea to the Persian port of Rescht, and then a caravan of fifty-eight animals to Teheran. After an audience with the Shah, the scientists continued their trip to Isfahan, where a 'Garden palace' outside the city was used as a lodge, and the instruments were set up in the vicinity (Figure 11). An extract from a somewhat sarcastic report by Fritsch (1875) for an illustrated newspaper runs as follows:

> Soon a building was raised on the western part of the platform which excelled through its simplicity, when compared with the nearby castles of Shah Abbas, of a weird architectural style, resembling most closely a shielded battery. A person looking into the open space above the rampart with poor illumination may have thought to discover the muzzle of a heavy gun – the objective of the heliograph, which, however, aimed at the sun in a harmless way. A look inside in bright sunlight showed how the expedition members served the gun [see Figure 12], and how on command "Fire" the momentous shutter was released, which exposed the sensitized plate. Humour did not leave the expedition, except on that fateful day, when unfaithful Venus during its suspect approach to the sun threatened to veil herself completely. Sombre distress prevailed in the small room, until, using the rare light moments twenty useful photographic plates of the phenomenon were taken. The plates will hopefully form a valuable contribution to the material of the expedition, and we will therefore remember with some satisfaction the place near Ispahan, which carries on a base, not unlike a gigantic gravestone, the engraving: Deutsche Venus-Expedition 1874. May the stone soon be considered as a holy grave among the Muhammadans, and may remain unmoved for times to come.

Figure. 11 The station of the Persian expedition at the garden palace Baugh-i-Zerescht near Isfahan (After *Illustrirte Zeitung*, Leipzig).

Auwers himself went to an expedition to Luxor near Thebes in Egypt, financed by the Berlin Academy of Sciences. Here he observed the transit in company with the Pulkovo astronomer Wilhelm Döllen. The 'German-Russian' station was near the stations of the two British parties (Auwers 1878). The heliometer used by Auwers was the one made by Fraunhofer for Wilhelm Olbers, and was borrowed from Hamburg Observatory.

Figure 12. Members of the Persian expedition at the photoheliograph, from left to right: Stolze, unknown person, Fritsch, Buchwald, Becker (After *Illustrirte Zeitung*, Leipzig).

4 THE TIME BETWEEN THE TRANSITS

The photographic observations, into which some committee members had put much hope, turned out to be disappointing. With one exception, the heliographs did not have a parallactic mounting, since the exposure times had been chosen so short that the Sun was imaged sharply also with a stationary telescope. It had been ignored that the air turbulence would cause a strong deformation of the images. Foerster precisely describes the matter in his memoirs (Foerster 1911):

> During the preparations, we had to try hard to restrict the effects of sunlight on the photographic plate to the most minute time, and we succeeded not to overstep the exposure time of a plate of one ten-thousandth of a second. Only in this way could we obtain sharply limited images of the solar disc and the details on it. When we proceeded to the exact measuring of the photographic solar images of our Venus expeditions of 1874, it was found that the photographic momentous exposures of the sun images are completely unsuitable for the finest measuring results, and this is because of the enormous fluctuations, which had not been known until then, which the propagation direction of the light rays suffers because of the continuous variations of the states of the different atmospheric layers.

The solar limb was poorly defined, and the image of Venus appeared deformed, sometimes five-sided. Commission President Auwers, as a 'classical' astronomer suspicious of the 'modern' technique of photography, decided without much protest from his Commission colleagues to cancel photographic observations during the 1882 transits. This would also save a lot of money (the 1874 expeditions—five to often remote sites, versus four in 1882—cost almost four times as much as the latter ones).

5 THE EXPEDITIONS OF 1882

Favourable places for the 1882 Venus transit were found in the Western Hemisphere, and it was decided to have two northern and two southern stations, two in the United States (at Hartford, Connecticut, and Aiken, South Carolina), and two in South America (at Bahia Blanca in Argentina, and Punta Arenas in Chile). In addition, the German Polar Expedition of the First International Polar Exploration Year was on the island of South Georgia (south of the Falkland Islands), and was also equipped with a dome and the Hamburg heliometer.

Expedition I (Hartford) consisted of astronomers Gustav Müller (Potsdam) and Friedrich Deichmüller (Bonn), astronomy student Julius Bauschinger (Munich) and technical assistant Hermann Dölter (Diedenhofen – now Thionville). The Secretary of State for Connecticut had offered "... the southern part of the Capitol grounds..." for the station, but because of a restricted horizon and possible disturbance by a curious public this was politely declined. Instead, an offer by Trinity College professors was accepted to erect the station on the campus grounds outside the city, and the observers also found a place there where they could stay. A long official report by Müller (1898) describes the activities at the station, and illustrations give a very good impression of what it looked like (Figure 13) and the activity during the transit (Figure 14). After a time of heavy frost, it was thawing the day before the transit. It then rained during the night, and in the morning the sky was overcast. One hour after ingress, the first heliometer measurements could be made, but clouds also disturbed the egress.

Expedition II (Aiken) consisted also of four persons, astronomers Julius Franz (Königsberg, now Kaliningrad), Hermann Kobold (Konkoly Observatory, Hungary), astronomy student Adolf Marcuse (Berlin), and mechanical assistant F Carl (Würzburg). Franz (1884) has provided a detailed report. The party went by steamer to New York and then by train to Aiken, South Carolina. "This little town with only 2000 inhabitants is rapidly growing and, since it is considered as a health resort, is visited by many foreigners because of its mild climate." The station was built on the northern edge of the city (Figure 15). A long period of clear weather ended on December 5, and the night before the transit it was raining. In the morning, the sky was covered, but the clouds became thinner. Three sets of measurements were made, and the station was closed on December 22. The sea trip back to Hamburg was made on the steamer *Cimbria*, which sank on its next Atlantic crossing!

Members of expedition III (Bahia Blanca) were Ernst Hartwig, Assistant at Strassburg Observatory, Bruno Peter, Observer at Leipzig Observatory, Walter Wislicenus, astronomy student in Strassburg, and H Mayer, Mechanic of the Physico-Mathematical State Collection in Munich. Peter's (1884) report, written in Spanish, gives a detailed description of the trip, the station, and the observations. A steamer brought the members from Hamburg to Buenos Aires, and a small warship of the Argentine Navy took them to Bahia Blanca. A little farm west of the settlement owned by Domingo Pronzati was chosen, "... the occupied terrain was encircled with a fence to shield it from animals which grazed freely in the pampa ...", and the domes were erected in the vicinity of the house (Figure 16).

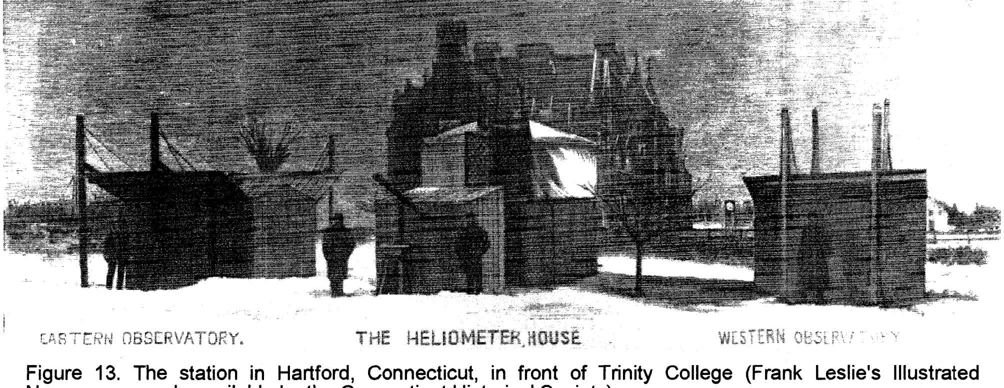

Figure 13. The station in Hartford, Connecticut, in front of Trinity College (Frank Leslie's Illustrated Newspaper, made available by the Connecticut Historical Society).

On the day of the transit, the Sun rose in a layer of cloud, but ten minutes before first contact the clouds dissipated and the contact was observed; however, the second was lost by new clouds. During a clear stretch, two sets of measurements were taken, then strong wind brought forth new clouds and it started raining. Then the Sun reappeared, measurements were continued, and egress was observed.

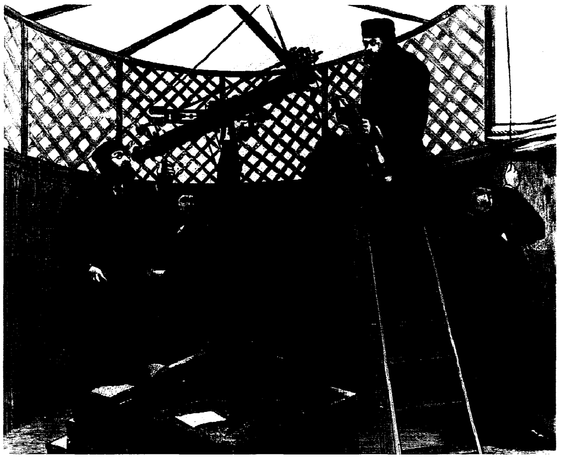

Figure 14. The heliometer observations in Hartford. At the telescope: Müller (left) and Deichmüller (right), Bauschinger taking notes in the background, Dölter is operating the dome slit (Frank Leslie's Illustrated Newspaper, made available by the Connecticut Historical Society).

Members of expedition IV (Punta Arenas) were astronomers Friedrich Küstner and Paul Kempf from Berlin, geologist Gustav Steinmann from Strassburg, and mechanic Friedrich Schwab from Marburg. Auwers decided on short notice to join the expedition, along with his servant Bohne. A steamer brought the party to Montevideo, and they took another one to Punta Arenas. Auwers (1883) gave many details in an address to the Academy:

> The town has at present only about one thousand five hundred inhabitants, and is only a group of little wooden houses scattered copiously on the sloping green lawn. Their appearance in primitive forms and partly in the natural colour of weather-beaten wood, partly, including the peculiar light-house which forms the most prominent object on the beach, with a fantastic colourful paint, fits perfectly into the landscape.

The station was erected near the light-house (Figure 17), and the team started to practice observations with an artificial Venus transit model (Figure 18). Auwers describes the critical hours:

> Indeed, in the afternoon of [December] 5, rain started to pour with such a standard strength that hope sank deeply. The rising sun illuminated a transparent blue sky, only swarms of small cumulus arose behind the Cordillera and were driven by moderately strong western wind over Punta Arenas.

First contact occurred, and twenty minutes later, the important second one: "Just when the light thread will reach the solar limb, a thick cloud moves in front of it, and when it had passed one and a half minutes later, Venus stands completely inside the solar limb." In spite of this disappointment, many heliometer observations were carried out, and the two egress contacts were observed.

Figure 15. The station in Aiken, South Carolina. The heliometer dome is to the left, a small refractor shelter is in front. A wooden hut in the background houses the pendulum clock, a cabin with two slits contains the passage and universal instruments; a geodetic pillar is in the foreground. The refractor dome is to the right. From left to right: unknown person, Carl, Franz, Marcuse, Kobold. (Archive of the Berlin-Brandenburg Academy of Sciences).

Expedition V (South Georgia) was an extraordinary project. Already before 1874, the pioneer of German polar research, Georg von Neumayer, had given advice to the Commission concerning possible southern observing stations, and since the southern expedition of the German Polar Commission of the first International Polar Year 1882/83 was installed on the island of South Georgia, it was obvious to also equip it with suitable astronomical instrumentation. The station (Figure 19) was installed at Moltke Harbor (named after the steam corvette SMS *Moltke* that carried the expedition) in the Royal Sound, which was occupied by eleven people between 1882 August 20 and 1883 September 6. Observations were carried out by Carl Schrader, an observer at Hamburg Observatory, assisted by mathematician Peter Vogel, physicist Otto Clauß, and engineer E Mosthaff.

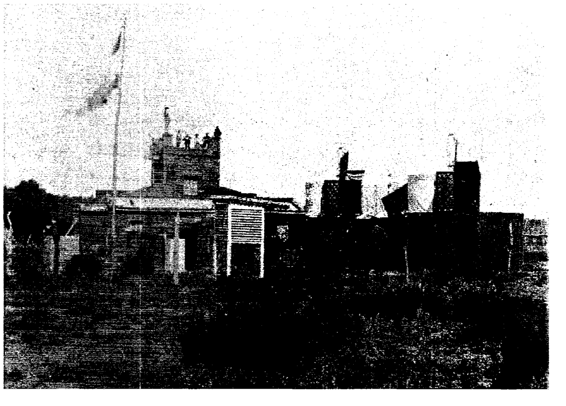

Figure 16. The station in Bahia Blanca, Argentina, showing also the house of Sr. Pronzati and some of its inhabitants. Wislicenus, Meyer and Peter (from left to right) are near the telescope; Hartwig's head is seen in the slit of the refractor dome (right) (Archive of the Berlin-Brandenburg Academy of Sciences).

The transit occurred in clear skies but presumably strong air turbulence as the observing log notes "very strong storm", and Mosthaff reports:

> The observation of the Venus transit on December 6 was especially favourable, which, in spite of strong storm, which endangered the rotating dome so that it had to be kept by three or four men with ropes, gave a quite favourable result because of the

> fact that the weather remained bright all day long, and the sun remained uncovered. (Mosthaff and Will 1884):

Auwers' comments indicate obvious errors in recording, setting and scale-reading, as well as poor calibration of the Hamburg Observatory heliometer, and he notes that the observations of the South Georgia station were of little use, that is they could not improve the result based on the 'official' heliometer stations of 1874 and 1882.

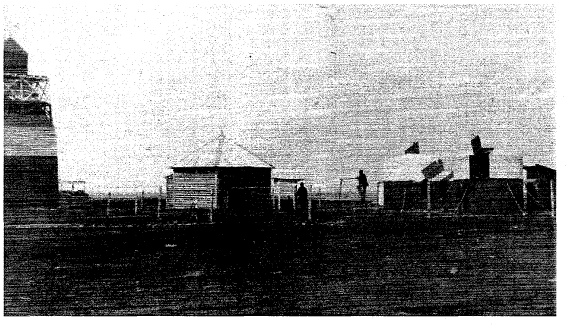

Figure 17. The station in Punta Arenas, Chile (Archive of the Berlin-Brandenburg Academy of Sciences).

Figure 18. The members of the Punta Arenas expedition in front of a Venus transit model on a pillar. From left to right: Kempf, Küstner, Auwers, Steinmann, Schwab, Bohne (Archive of the Berlin-Brandenburg Academy of Sciences).

6 ANALYSIS OF THE MATERIAL

The transit of 1882 meant the end of the proper observations, but by no means the end of calibrations, or investigation of the properties of the heliometers at different temperatures etc., that were carried out at Berlin and Strassburg Observatories. Six quarto volumes totalling 3,600 pages were edited by Auwers between 1887 and 1898, and these contained instructions, reports, measurements, reductions, and finally the overall results of the project. Auwers painstakingly presented the complete material, even including uncomplimentary remarks by expedition members (for example: "Our splendid medicine-chest and the even more splendid user's manual obviously leave us in the lurch, here like in all other cases.", along with Auwers' footnote: "Ed. could not omit anything ... The composition of the chest and the manual had been done by a medical man, with several years experience of travel in other continents and uncivilized countries"). Auwers painstakingly analysed all observations, visual contacts, photographic positions, and heliometric settings. He also filed all of his correspondence in a meticulous way, so that at present 110 files exist (only one has been lost), filled with letters and drafts, manuscripts and proofs, invoices and receipts, sea charts and steamer timetables, as well as some photos, often marked with stamp of receipt and inventory number. But this is only one side of the picture. Some expedition members wrote popular reports (we have given some examples above), and a few surviving private letters from Fritsch to Foerster (who had familial ties) show that Auwers' apparently arrogant as well as book-keeping manners were certainly not appreciated by everyone—although it should be said that only such a person could successfully carry out so vast a project, involving many scientists and assistants with differing tempers and temperaments.

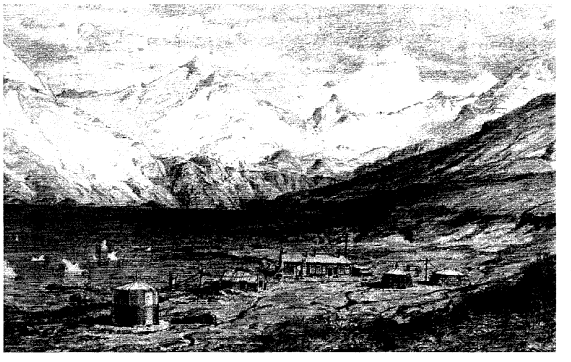

Figure 19. The station at Moltke Bay, Royal Sound, South Georgia (drawing by Mosthaff; Neumayer 1890/91).

As seen by the general public, the project was a resounding success, and this is reflected in a letter the Emperor wrote Auwers on 1884 July 4:

> When in the years 1874 and 1882 the transit of the planet Venus in front of the solar disc was approaching – a celestial phenomenon which is extraordinarily important for many research purposes, and which will only occur again after more than a hundred years – whose full utilization was depending on a collaboration of many astronomers in different remote points on earth, Germany also participated in this project by sending several scientific expeditions. Effectively supported by my navy, these expeditions occupied a series of stations which were especially important for the observation of this phenomenon, the first time in the range between the Chinese coast, Persia and Egypt on one hand and the borders of the Antarctic on the other, the second time between the north and the southern tip of America. Under your [Auwers] prudent and devoted guidance, German science managed in a high degree to win success and appreciation in a field of earth-embracing activities, in which in previous times Germany had to stand down in similar occasions as compared to the achievements of other nations. The more vivid was the interest, with which I have followed the ventures of German science for the observation of the phenomenon since their beginnings; the more joyful is the satisfaction with which I consider their resultful [ergebnißreich] conclusion. Herewith I pay my tribute to your merits for this success, as well as to the true co-operation of all which have contributed to such a success; I furthermore express my thanks for the help and hospitality encountered in a high degree by our scientific expeditions, and which was rendered to them not only by compatriots living abroad, but also by many people of other nations… (Wilhelm I, 1884):

What did that "resultful" outcome look like? One has to browse carefully though Auwers' 3600 pages. He collects, corrects and analyses all contact observations, without attempting to determine a solar parallax according to Halley's method (Auwers, 1887–1898, VI: 49). The results of photographic observations of the four stations of 1874 are given (op. cit.:186), and a parallax value of 8″.810 ± 0.120 is derived. The detailed analysis of all heliometer observations follows (op. cit.:714), from which Auwers derives a value of 8″.8796 ± 0.0320. The photographic result is closer to the modern value of 8″.794148 within its—disappointingly large—errors, while the 'more accurate' heliometric value appears to be 1% too large. Obviously the heliometer observations suffered from uncorrected systematic errors (which were overlooked even by diligent Auwers), the cause is difficult to establish today.

7 CONCLUDING REMARKS

Around the time when Auwers finished the manuscript of the last volume, somewhere else in Berlin two little-known astronomers, Gustav Witt and Felix Linke, discovered a minor planet on a plate taken at the popular Berlin Urania Observatory. This planet, later named Eros, had a path that at times brought it close to that of Earth. Thus it offered the same advantage as Venus, without having its disadvantages, that is a poorly-defined disc in front of the solar disc, that had to be observed during daytime in poor seeing. At its opposition of 1900, a new and improved value of the solar parallax was derived, and interest in transits of Venus as a research tool rapidly vanished.

8 ACKNOWLEDGMENTS

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10 APPENDIX 1: OBSERVING STATIONS

In the accompanying table, the geographic longitudes and latitudes of the German observing stations (in °, ′ and ″) are given. References indicate volume and page of the Auwers report; comments indicate drawn plans of the stations. Notes on the stations are taken from Auwers (1887-1898) and additional sources:

Tschifu, China: the site belonged to the merchant Clarke of the Ferguson Company, in the immediate neighbourhood of the Beach Hotel. After the transit observations, foundations had to be removed; a pole was buried at the site of the heliometer, and next to it a bottle with the names of the expedition members (Auwers, 1887-1898, I:307).

Betsy Cove, Kerguelen Island: the foundations were left in position.

Port Ross, Auckland Island: the pillar of the passage instrument, on whose stone plate Mr Krone Jr. has incised the words "German Expedition 1874", was recommended to the special protection of the shepherd who lives on the Island (Seeliger 1898). There is one sentence and one picture in the book of Allen (1997:145): "All that remains is the brick plinth on which they placed their apparatus." A triangular base of 5-6 layers of red brick is seen on page 103 in Allen's book.

Solitude, Mauritius: the station on the site belonging to count Rochecouste is determined by the pillar which belongs to the triangulation network of Mauritius. The co-ordinates refer to the passage instrument.

Ispahan, Persia: the station was on the site of the garden palace Baugh-i-Zerescht between Ispahan and the southern suburb Djulfa. On the plate of the foundation of the heliograph, the inscription "Deutsche Venus-Expedition 1874" was incised, and an agreement was reached with the administrator of Baugh-i-Zerescht to keep this place undisturbed for the following eight years—furthermore, the Persian Government declared to take care of the preservation (Auwers, 1887-1898, I: 309, and Fritsch, in Auwers, 1887-1898, II: 403).

Luxor near Memphis, Egypt: I have designated this as expedition 1874 (VI), since designation VI is never used in official documents. This is the "German-Russian Station" by Auwers and Döllen. Auwers' passage instrument was 464.78 m W and 497.37 m S of the obelisk in front of the Luxor temple (Auwers 1878:144). The longitude of the station is calculated using the correction given in (op. cit., I:309).

Hartford, Connecticut: there is a marker stone designating the place of the heliometer. Since Auwers (op. cit., I:463) states "... nothing is mentioned about a marking of the point ...", it is obvious that the marking was done by Trinity College scientists. Its inscription reads: "Transit of Venus/December 6, 1882/German Imperial Commission./Lat. 41° 44′ 47″/Long. 4h 50m. 46.4s. W." The marker was moved a few feet from its original location almost 50 years ago to make way for the construction of an engineering building. Both the marker and building remain in place (information provided by P Knapp; photo provided by M Johnson).

Aiken, South Carolina: the owner of the site, Mr Henry Smith, has agreed to take care of the pillar of the passage instrument; it was covered with a stone plate inscribed with: "Venus-Durchgang 1882/Deutsche Expedition II/Länge 5h 26m 52s.6 W./Breite 33° 33′ 51″" (Auwers, 1887-1898, I: 463).

Bahia Blanca: to fix the observing site, a pole was buried 2.3 m south of the heliometer; its distance from the SW corner of Sr. Domingo Pronzati's house (Figure 18) is 37.4 m.

Punta Arenas: Auwers (op. cit., I:465) mentions that the wooden houses were destroyed by fire, and new houses were built on the site of the station; a wall covers the pillars. A re-measurement by J Lederer, made in 1897, could not be included in Auwers' report.

Royal Bay, Moltke Harbour, South Georgia. I have designated this as expedition 1882 (V), since the designation V is never used in the official documents: No information on 'markers' is available from German sources, because the station was actually abandoned. The area was visited several times, a detailed report of the visit in 1982 January is given by Headland (1982), where also a map can be found. The ruins of the Moltke Harbour station are described. The collapsed iron skeleton of the 'Venus cupola' is clearly visible, and shown in a photograph.

Expedition	Station	Longitude	Latitude	Elevation	Ref.	Comments
1874 I	Tschifu	121 23 36.6 E	+37 32 48.1	12 m	I:308	
1874 II	Betsy Cove	070 11 04.6 E	- 49 09 13	17 m	I:308	plan II:186
1874 III	Port Ross	166 13 27.9 E	–50 32 14.4	4 m	I:309	plan II:190
1874 IV	Mauritius	057 40 00 E	–20 25 51.0	85 m	I:309	
1874 V	Ispahan	051 40 03.3 E	+32 38 16.2	1530 m	I:309	
1874 (VI)	Luxor	032 38 09.3 E	+25 41 40.7	?		see notes
1882 I	Hartford	072 41 34.5 W	+41 44 48.3	?	I:463	
1882 II	Aiken	081 43 05.7 W	+33 33 50.9	200 m	I:463	plan III:77
1882 III	Bahia Blanca	062 18 16.2 W	–38 42 49.0	20 m	I:465	
1882 IV	Punta Arenas	070 54 08.7 W	–53 09 39.3	10 m	I:465	
1882 (V)	Royal Bay	036 01 04.6 W	–54 31 00	?	I:466	see notes

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The 1882 transit of Venus observed in Italian observatories

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Abstract
The Italian Government did not provide financial support to Italian astronomers so that they could organize expeditions to places where the 1882 transit of Venus could be observed both at ingress and egress, so all observations had to be made from Italy, where the phenomenon was only partially visible. On December 6, the ingress should have been visible in Rome at about 2.30 p.m., in very unfavourable circumstances. Nonetheless, observations were made at the Observatories of Milan, Turin, Moncalieri, and Palermo; at the University Observatory and the Royal Navy Observatory in Genoa; at the Observatories of the Collegio Romano, Campidoglio and Gianicolo in Rome; and at the Capodimonte Observatory in Naples. Both spectroscopic and visual observations were made.

Keywords: *1882 transit of Venus, Italian Observatories, spectroscope*

1 INTRODUCTION

The success of the Italian party that went to India to observe the 1874 transit of Venus (Pigatto & Zanini, 2001) convinced Giuseppe Lorenzoni and Pietro Tacchini[1] that the Italian Government would finance at least two expeditions to geographical places where both the ingress and egress of the 1882 transit would be observable. During their sole mission of 1874, the Italian astronomers were the only ones to make use of the spectroscope, and they used that transit to gain experience, with the next transit in mind. In the process, they demonstrated that spectroscopic observations produced precise contact times, especially of the external contacts. The Italian expedition of 1874 was also successful because of the scientific friendship and collaboration between Lorenzoni and Tacchini, so they expected that an astronomer would represent Italy at the 1881 October 6 international conference in Paris that was arranged in order to discuss and outline general instructions for observations of the 1882 transit. Instead, the two friends were bitterly disappointed when this did not eventuate, and the reason for this seemingly inexplicable decision makes a funny story that deserves to be told.

On 1881 September 23 the Minister of Public Education wrote a circular letter to the directors of Italian observatories: "Economic reasons prevent this Ministry from delegating one of our clever astronomers to represent Italy at the Paris International meeting, promoted by the French Government in order to study the problems concerning the transit of Venus over the Sun." (Minister P.E., 1881). The Minister decided to send "... as a representative, the same Italian delegate to the International meeting of Electricity, which contemporaneously is held in Paris, that is the illustrious professor Gilberto Govi". The Minister (ibid.) asked the astronomers to give suggestions and necessary instructions to him "... in order to make his difficult task easier." On September 30 Lorenzoni replied:

> It is completely unknown to the undersigned what the Royal Government's intention is concerning the role that Italy will play in the observation of the next transit of Venus ... if it is decided that Italy is not going to take part in this enterprise, an Italian commissioner's presence at the meeting evidently will be useless except for solemnizing the declaration of Italy's abstention. (Lorenzoni, 1881).

However, Lorenzoni demonstrated that he had not completely given up hope by suggesting what the Italian commissioner should take into account during the transit meeting. In particular, he should advise the meeting that the Italian astronomers were acquainted with standard visual and spectroscopic methods of contact observations.

Tacchini was extremely upset, and in a letter to Lorenzoni he wrote:

> The Ministry's letter about the transit of Venus had the same effect on me as a poultice poorly applied: as soon as they decided that money was lacking, it was necessary for the Ministry to be completely out of this matter. Once the Ministry decided to be represented at the meeting, the astronomers, above all, had to be invited, in order to avoid making a fool of the Ministry by nominating an outsider as a makeshift and then asking us to give him suggestions! These are ridiculous tricks fit for a Ministry without rhyme or reason ... It is sure that we will make a bad impression due to the stupidity of our Government. (Tacchini, 1881).

Despite these protests, Professor Govi, a physicist and Italian member of the *Bureau International des Poids et Mesures*, ended up representing the Italian Government at the Paris meeting. It is quite possible that political reasons may have been behind this absurd decision, as relations between Italy and France were strained following France's occupation of Tunisia (where thousands of Italians lived and worked) earlier in the year. It was a very delicate diplomatic situation, and the lack of any Italian representative at the astronomical meeting could have been interpreted by the French as a further stiffening of Italy's attitude towards the 'Tunisian problem'.

After the Paris meeting, this whole affair was never spoken of again, and Italian observatories arranged to observe the transit at home, even though the conditions would be very unfavourable, mainly because of the season of the year.

2 OBSERVATIONS OF THE TRANSIT MADE AT ITALIAN OBSERVATORIES

The 1882 transit was observable in Italy and western Europe only during the ingress phase (first and second contact), whereas the entire event was visible from central America and South America.

In 1877, Elia Millosevich calculated the mean time of ingress for the longitudes and latitudes of Turin, Naples, Venice, Rome, Padova, Florence, Bologna, Milan and Palermo, using geocentric data (Venus and Sun conjunction in right ascension at GMT) derived from Leverrier's astronomical tables. These data, together with the eastern and western angles of Venus's path with respect to the solar north, gave the observers the places on the solar limb where the contacts would take place (Millosevich, 1877).

On 1882 December 6, the ingress was observed at about 2.30 p.m. Rome Mean Time (RMT) in very unfavourable conditions because of cloudy or foggy skies and an early sunset, just two hours later (i.e. before the egress phase). No observations were made at Padova Observatory because of dense fog. Table 1 summarizes the places where observations were made, the instruments used and the associated observers, on the basis of published scientific reports.

The directors, Schiaparelli, Dorna, Garibaldi, Magnaghi, De Gasparis, and Cacciatore sent a short note about their observations to Tacchini, who communicated these initial results to the Accademia dei Lincei (Tacchini, 1883) and published them in the *Memorie della Società degli Spettroscopisti Italiani* (Tacchini and Millosevich, 1883). Some of the above astronomers also published their own scientific reports in different journals (see References).

2.1 Brera Observatory

In Milan (Figure 1), the astronomers were only able to observe the second ingress contact, and even then through passing clouds. Giovanni Schiaparelli used a Gregorian reflector by Short that had belonged to the Brera Observatory since its foundation in 1762. Because of its antiquity, the mirrors had partially lost their reflecting capacity, so it was possible to observe the Sun directly without using a coloured glass or a helioscopic eyepiece (Schiaparelli, 1882, 1883). The low elevation of the Sun (~13°) and a foggy horizon also helped. In spite of atmospheric turbulence, Schiaparelli obtained a good quality image with a 48 magnification eyepiece, and was able to appreciate the skill of this famous English telescope-maker. Figure 2 shows a Short reflector similar to the one used by Schiaparelli. When half of Venus's disc was on the Sun, Schiaparelli could see a bright arc around the planet's dark portion outside the Sun, and he attributed this phenomenon to a Venusian atmosphere. He also observed that the bright arc, even if thinner, persisted once the planet was completely on the Sun. Schiaparelli recorded the second contact, when the two cusps joined together (see Figure 3) and a very thin bright stripe appeared.

Giovanni Celoria observed with a Gregorian Dollond reflector and a 50 magnification eyepiece, and like Schiaparelli he noted the same bright halo outside the solar disc. The third observer, Michele Rajna, had to reduce the magnification from 150 to 75 on his telescope because of clouds and atmospheric turbulence, and he only observed the second contact.

The Brera Observatory astronomers used a Froshdam chronometer, and their results were in good agreement, in spite of their small telescopes. No one saw the black drop phenomenon (Schiaparelli, 1883).

2.2 Turin Observatory

Alessandro Dorna, Director of Turin Observatory, used the same equatorial reflector he had used during the 1874 transit in India (Figure 4). This instrument was installed in the new dome of the Observatory (see Figure 5). Passing clouds, atmospheric turbulence, and fog disturbed the observation, but Dorna observed a dark ligament connecting the planet to the solar limb. He also noted that "... on its limb Venus appeared brighter than in the centre, as if a less opaque medium existed there." (Tacchini & Millosevich, 1883:3).

Table 1. Italian observatories where the 1882 transit was observed

Place	Instruments	Observers
Milan Brera Observatory	600 mm focal length Short reflector 120 mm aperture Dollond reflector: 75 mm aperture Ramsden refractor	Schiaparelli Celoria Rajna
Turin Observatory	1920 mm focal length Fraunhofer refractor 1530 mm focal length Dollond refractor 1030 mm focal length Dollond refractor	Dorna Charrier Castino
Moncalieri Observatory	100 mm aperture Merz refractor	Denza
Genoa University Observatory	Terrestrial and astronomical refractors	Garibaldi Porrata
Genoa Observatory of the Hydrographic Bureau of the Royal Navy	Not mentioned	Magnaghi
Rome Collegio Romano Observatory	250-mm Merz refractor 150-mm Cauchoix equatorial refractor	Tacchini Millosevich
Rome Campidoglio Observatory	115.4 mm aperture Merz refractor 94 mm aperture Merz refractor 65.2 mm aperture French refractor 68 mm aperture Ramsden refractor	Respighi Di Legge Giacomelli Prosperi
Rome Gianicolo Observatory	108 mm aperture Merz refractor 91 mm aperture Sécrétain refractor	Ferrari Hüninger
Naples Capodimonte Observatory	Not mentioned	De Gasparis Brioschi Nobile Contarino Angelitti
Palermo Observatory	72 mm Ramsden meridian circle 9 cm Fraunhofer refractor Ramsden refractor Merz refractor	Cacciatore Zona Delisa Riccò

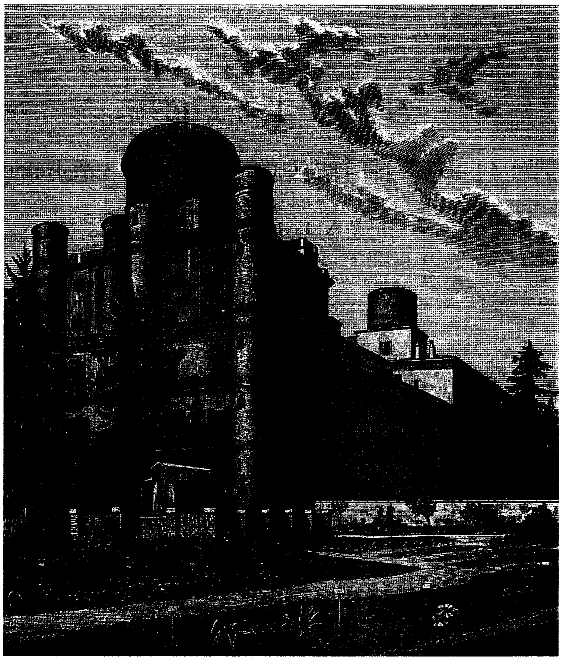

Figure 1. Engraving showing Milan Brera Observatory at the end of the XIX century. The astronomers observed the transit from the terrace.

2.3 Collegio Romano Observatory

In Rome (Figure 6) it was sunny all morning, but the Sun was obscured by large clouds at 2.30 p.m. RMT, shortly before the transit. Nonetheless, Tacchini decided to use a reticle spectroscope mounted on the Merz refractor, while Millosevich would observe Venus in the standard visual way with the 150-mm Cauchoix and 130 magnification (Figure 7). As Tacchini had stated since 1874, the spectroscopic method had the advantage of showing the planet's black disc above the red chromosphere just before the first contact happened, whereas with traditional visual observations Venus was invisible before first contact, so it was necessary to monitor the solar limb and continuously verify the position angle of the contact in order not to miss it.

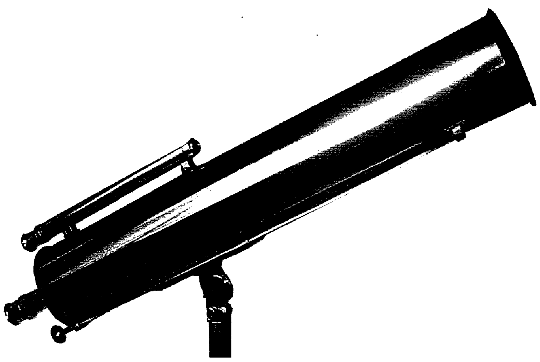

Figure 2. A Short reflector like that used by Schiaparelli (Museo *La Specola*, INAF-Astronomical Observatory of Padova-I).

The spectrum could not be observed if the Sun was obscured by passing clouds, but Tacchini noted that

> On the other hand, even if the observations of these contacts in Italy were of very little importance as far as the solar parallax determination was concerned, it was a duty in front of the science to try spectroscopic observations, even if the probability of not succeeding could be very large. There is even more reason why the spectroscopic method has to be used: this method is not taken into account by the foreign missions mainly because it is practically unknown and very few devote themselves to spectroscopic observations of the Sun; in addition, Mercury and Venus transits are too rare for practising the spectroscopic method. (Tacchini and Millosevich, 1883:6).

It was a thrilling moment for Roman observers, for although a cloud obscured the Sun just five minutes before the first contact, luckily it quickly moved and Tacchini was able to observe "... the planet's limb on the tips of the living chromospheric small flames..." (ibid.). From that moment, it was sufficient for the slit to be kept tangential to the solar limb and to control the planet's motion towards the AB edge as shown in the drawing ("*Fig. 4*") in Figure 8. "Only in this way could we be sure to note the true first external contact. Instead, this is impossible with the ordinary method: in this case the first contact is the time in which the observer notices the notch produced by the planet on the solar limb." (Tacchini and Millosevich, 1883:7).

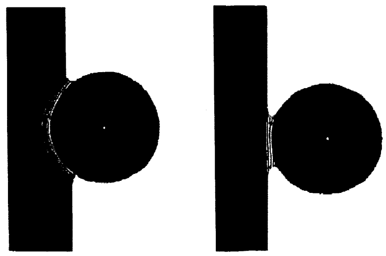

Fig. 1. Fig. 2.

Figure 3. Drawings of Venus ingress and second contact by Schiaparelli (Fig. 1 and 2 from Schiaparelli, 1882: 665).

As a matter of fact, a very very small notch, impossible to observe in the ordinary way, is sufficient to produce a thin black line along the solar spectrum (see Figure 11 in Pigatto & Zanini, 2001:50). Tacchini had realized that sunspots very near to the solar limb were visible in the spectroscope, but that it was impossible to notice them in the ordinary way, either by observing directly or by using projection. He was able to observe the second contact as far as the red arc of the chromosphere recovered its size, when the planet was completely over the photosphere. Just as in 1874, he was also able to see the solar spectrum growing dark near and around the C and B lines, as the planet was crossing the slit perpendicular to its path, a phenomenon—he wrote—due to the atmosphere of Venus. He also derived a value of 67″.253 for the mean spectroscopic diameter of Venus.

Millosevich, who collaborated with Tacchini as adjunct astronomer from 1879, after the transit calculated the corrections to be made to the difference of the apparent equatorial co-ordinates of Venus and Sun, related to the observations performed at the Collegio Romano. He concluded that the spectroscopic method was much more precise than the ordinary one as far as the first contact was concerned. He also compared the times of the second contact recorded by Italian astronomers following the instructions given by the International Conference of

Paris (International Conference, 1881), and verified that they were in good agreement and were comparable to those derived from the spectroscopic method (Tacchini and Millosevich, 1883:13-19).

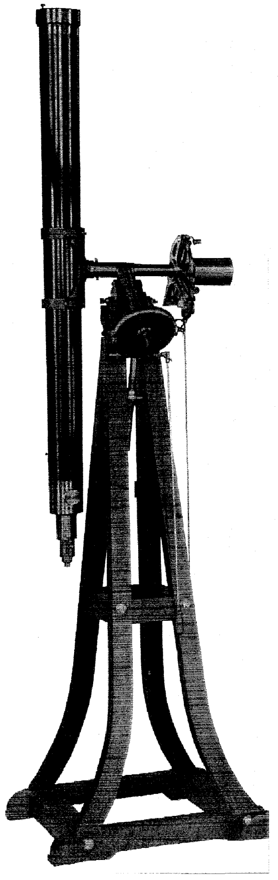

Figure 4. Fraunhofer equatorial refractor used by Dorna both in 1874 and 1882 transit of Venus (Photograph, Padova Observatory Archives).

Contact times recorded at the Collegio Romano Observatory and a number of other Observatories are listed in Table 2.

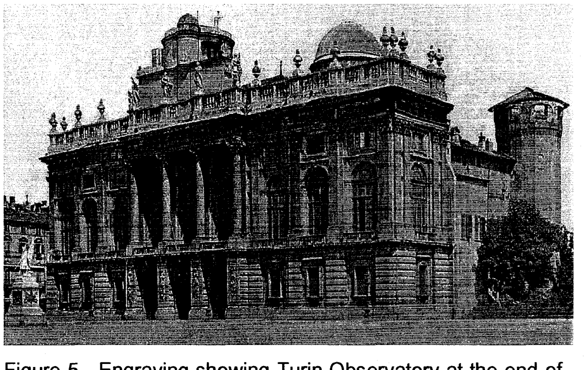

Figure 5. Engraving showing Turin Observatory at the end of the XIX century with the new dome in the background.

2.4 Campidoglio Observatory

Lorenzo Respighi, Director of the Observatory, was ready to observe the contacts with the spectroscope. However, being afraid of loosing the contacts because of the bad condition of the sky, he replaced the spectroscope with a micrometric eyepiece. The times of the contacts recorded by him and his three collaborators were in close agreement. All observed a weak luminous halo around the dark body of Venus. Respighi tried to explain this, separating out effects due to the planet's atmosphere from others due, for example, to the solar corona over which the planet's dark body was projected before its complete entrance onto the solar disc. He believed that it was very unlikely that absorption bands could be observable in the spectroscope, taking into account the very thin layer of Venus's atmosphere and the refraction of the solar light through it. This opinion was open criticism of Tacchini who—as mentioned above—saw such bands in 1874. After the internal contact, Respighi measured Venus's diameter with his micrometer, obtaining a value of 66″.36, but he questioned its reliability as it was derived in bad atmospheric conditions (Respighi, 1883:4).

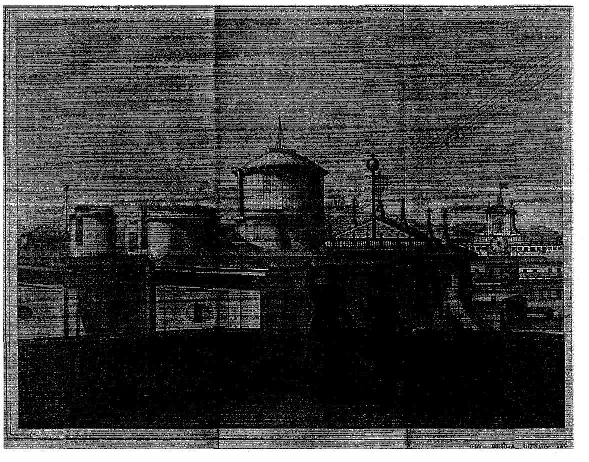

Figure 6. Engraving showing Collegio Romano Observatory in Rome in the second half of the XIX century.

2.5 Palermo Observatory

Although they were conscious of the relative unimportance of their observations, the astronomers at Palermo were still prepared to observe the transit. Gaetano Cacciatore wrote in his note to Tacchini that they observed through passing clouds, recording the second contact when the black ligament broke, and that their data were in good agreement. Annibale Riccò observed with the spectroscope, but he missed the contacts as he had had little practice with this instrument. Like Tacchini, he observed a fleeting darker band near the B and C lines of the solar spectrum when Venus was crossing the slit of the spectroscope. He also believed that this was due to the planet's atmosphere (Tacchini and Millosevich, 1883:23).

2.6 Other Observatories

Annibale De Gasparis, Director of Capodimonte Observatory in Naples, wrote a very short note to Tacchini: "The transit of Venus over the Sun was observed in Naples as well as in our Observatory. The sky gave us the pleasure of being clear for about an hour. Because of our poor-quality telescopes, we couldn't record the first contact in a realiable way… I won't send you other reports from us, as the agreement is not at all satisfying, or so it seems to me." (Tacchini and Millosevich, 1883:20). This short and dry report, without any information about observers or instruments, Brioschi's contact excepted, evidently hid a strong disagreement between the Director and his astronomers. In fact, Arminio Nobile (1883), an astronomer at the Observatory, wrote a short note in *Astronomische Nachrichten* where he mentions other two observers (there were five in all).

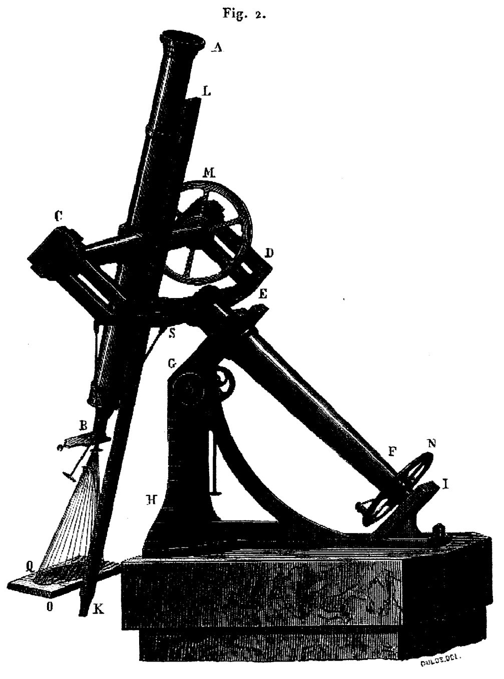

Figure 7. Cauchoix refractor used by Millosevich (from Secchi, *Le Soleil*, 1875, I:9.).

The Jesuit Stanislao Ferrari became Director of Collegio Romano Observatory after Secchi's death, but had to move away when the new Italian State appropriated all the buildings in 1879. He then built a small private observatory on Gianicolo hill (Monaco, 2000), where he observed the transit. He published his results in *L'Osservatore Romano* and in *Astronomische Nachrichten* (Ferrari, 1883). His first contact anticipated those of the other Roman astronomers by more than 20 seconds, so Millosevich thought that his data were completely unreliable.

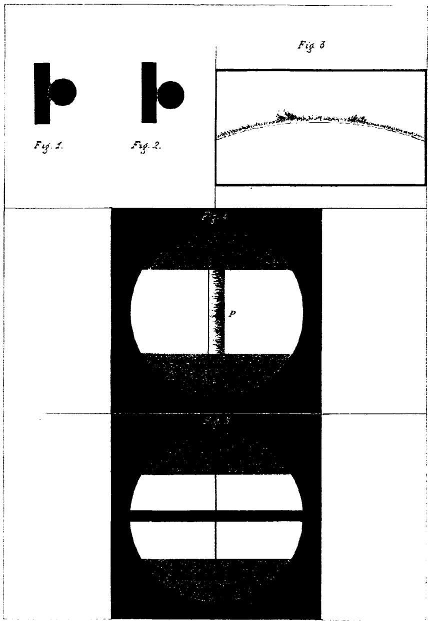

Figure 8. Drawings of the observations performed by Millosevich (Fig. 1 and 2, ordinary method) and Tacchini (Fig. 3, 4, 5, spectroscopic method). (From Tacchini and Millosevich, 1883, table CXLVIII).

Table 2. Data from Italian observatories: times for internal and external contacts at Venus ingress reduced to Rome Mean Time.

Ingress at Rome MeanTime	
External contact	Internal contact
$2^h\ 48^m\ 54^s.43$ (Rome C.R.- spectroscopic method)	$3^h\ 9^m\ 34^s.79$ (Rome C.R.- spectroscopic method)
$2^h\ 49^m\ 48^s.14$ (Rome C.R.- ordinary method)	$3^h\ 10^m\ 10^s.14$ (Rome C.R. - ordinary method)
$2^h\ 49^m\ 9^s.74$ (Rome C. - ordinary method)	$3^h\ 10^m\ 5^s.43$ (Rome C. - ordinary method)
$2^h\ 49^m\ 20^s.53$ (Rome C. - ordinary method)	$3^h\ 9^m\ 27^s.01$ (Rome C. - ordinary method)
$2^h\ 49^m\ 38^s.40$ (Rome C. - ordinary method)	$3^h\ 10^m\ 5^s.40$ (Rome C. - ordinary method)
$2^h\ 49^m\ 32^s.40$ (Rome C. - ordinary method)	$3^h\ 9^m\ 59^s.90$ (Rome C. - ordinary method)
$2^h\ 48^m\ 27^s.10$ (Rome G. - ordinary method)	$3^h\ 9^m\ 36^s.12$ (Rome G. - ordinary method)
	$3^h\ 10^m\ 8^s.00$ (Rome G. - ordinary method)
$2^h\ 49^m\ 32^s.5$ (Turin. - ordinary method)	$3^h\ 10^m\ 5^s.0$ (Turin – ordinary method)
$2^h\ 50^m\ 13^s.0$ (Turin. - ordinary method)	$3^h\ 10^m\ 13^s.0$ (Turin – ordinary method)
$2^h\ 51^m\ 3^s.0$ (Turin - ordinary method)	$3^h\ 10^m\ 4^s.0$ (Turin – ordinary method)
$2^h\ 49^m\ 31^s.0$ (Moncalieri - ordinary method)	$3^h\ 9^m\ 54^s.4$ (Moncalieri – ordinary method)
–	$3^h\ 10^m\ 33^s.5$ (Milan – ordinary method)
–	$3^h\ 10^m\ 32^s.5$ (Milan – ordinary method)
–	$3^h\ 10^m\ 31^s.0$ (Milan – ordinary method)
$2^h\ 48^m\ 39^s.1$ (Palermo - ordinary method)	$3^h\ 9^m\ 26^s.4$ (Palermo – ordinary method)
$2^h\ 49^m\ 22^s.6$ (Palermo - ordinary method)	$3^h\ 9^m\ 38^s.5$ (Palermo – ordinary method)
$2^h\ 48^m\ 39^s.3$ (Palermo - ordinary method)	$3^h\ 10^m\ 19^s.3$ (Palermo – ordinary method)

C.R. = Collegio Romano; C. = Campidoglio; G. = Gianicolo

Finally, Father Francesco Denza of Moncalieri Observatory communicated his results to the newspaper *L'Unità Cattolica*, n. 288 of 1882, then he sent two short notes to *Monthly Notices of the Royal Astronomical Society* (Denza, 1883a,b). Denza recorded the second contact as the black drop detachment, and reported a value of 67″.12 for Venus's diameter. He considered this value as unreliable, because of the atmospheric turbulence experienced at the time of his observation.

3 CONCLUSION

The results achieved by Italian observatories were of poor quality, largely because of the generally bad observing conditions. However, Italian astronomers did their best, after lack of funds prevented them from organizing a mission to South America, as Lorenzoni and Tacchini had planned. The final mockery for the disappointed astronomers arrived three months later. On 1883 March 13, the Ministry of Public Education sent a letter to Lorenzoni informing him (and Italian astronomers) that

> … in Santiago as well as in Punta Arenas the great astronomical phenomenon of December 6 had been happily observed … According to the news freshly published at the capital of Chili three scientific parties, one from Germany, one from Brazil, and the third from England, successfully observed the transit of Venus in different places of the Magellan Straits". (Ministry P.E., 1883).

Evidently the Ministry believed that Italian astronomers were incapable of collecting information from their foreign colleagues, and that specialized journals in astronomy did not exist.

Concerning the spectroscope, Tacchini believed that it was only Italian astronomers who had used this instrument to observe the transit, but perhaps he had not seen the note by French astronomer, Charles Trépied, who observed the transit from Alger. Trépied missed the ingress contacts because of clouds, but was able to observe the planet on the solar disc with a Thollon spectroscope during a very short appearance of the Sun. He tried to see if a selective absorption due to the Venusian atmosphere could be observed, as Tacchini had already seen during the 1874 transit. Trépied (1883) wrote that with the slit both crossing the planet's disc and tangential to its limb, he did not see any change in the solar spectrum.

4 NOTES

1. Giuseppe Lorenzoni (1843-1914) and Pietro Tacchini (1838-1905) were respectively appointed Directors of Padova Observatory and Rome's Collegio Romano Observatory in 1877 and 1879.

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The 1882 Belgian transit of Venus expeditions to Texas and Chile – a reappraisal

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Abstract
In 1871, the Belgian astronomer Houzeau suggested applying a new heliometric device to measure the position of Venus transiting the solar disc. This "heliometer with unequal focal lengths" produces a large and a small solar image, as well as a large and a small image of Venus. Making the small solar and the large Venus image coincide would yield a measure of the distance of the centres of both objects. Two separate stations equipped with similar instruments may provide a value for the solar parallax. After being appointed Director of the Royal Observatory of Belgium in 1876, Houzeau obtained support to organize two Belgian expeditions to observe the 1882 December 6 transit of Venus: one to San Antonio (Texas) and the other to Santiago (Chile). The observations were quite successful, but it took some time to take into account the effects that influenced the measurements, in order to determine the parallactic displacement. While the result was not overwhelmingly convincing, the experiment nevertheless was a fresh approach to determining the solar parallax. This enterprise was the first major expedition in the history of Belgian science.

Keywords: *Transit of Venus, Belgian expeditions, heliometer with unequal focal lengths, solar parallax, Houzeau, Niesten, Vergara*

> "It is fortunate for humanity that the greatness and power of nations is not measured by the extent of the regions that constitute it; just like the talent and the energy of people is not measured by the number of feet of their height ..." (Zegers 1883).

1 THE DRIVING FORCE BEHIND THE EXPEDITIONS: J-C HOUZEAU

The above words of Luis Zegers, the self-appointed historiographer of the activities in and around Santiago de Chile to observe the 1882 Venus transit, form the beginning of his chapter on the Belgian activities. Clearly, however, the project was started through the initiative of just one person, Jean-Charles Houzeau. In 1871, the *Bulletin* of the Belgian Academy of Sciences included a note by him, dated Kingston (Jamaica) 1871, titled "On a method to measure in a direct way the distance between the centres of the Sun and of Venus, during the transits of that planet." Houzeau was an eminent astronomer, arduous topographer, fervent writer and newspaper editor, and at that time the owner of a banana plantation, and in this note he drew attention to a novel and ingenious way of determining the solar parallax. That his note did not pass unnoticed is proven by another one, published just one year later, where he tries to refute some objections put forward by George Airy (Houzeau 1872). Houzeau's drive to turn his project into reality was certainly one of the reasons he later accepted the offer to become Director of the Royal Observatory in Brussels. During the six years of his Directorship "... the activity of the Observatory was truly prodigious. Stimulated by the example of its chief, the personnel worked with a veritable enthusiasm ..." (Lancaster 1889). And it was certainly his feeling of accomplishment, but also the problems with the administration of the Royal Observatory and his aggravating sickness, that led to his resignation soon after the project was carried out.

Extensive biographies of Houzeau are available, including a monumental one by Houzeau's collaborator, Lancaster (1889), others by Rankin (1984) and Evans (1990), and a very recent detailed study by Verhas (2002), so we can restrict ourselves to a short sketch of his life. Jean-Charles Houzeau de Lehaie (Figure 1), who was born in Mons in 1820, was a prodigious writer on scientific and social topics from an early age. For a while, he lived and studied in Paris, but in 1848, Adolphe Quételet, founder of the Royal Observatory of Belgium, accepted him first as a volunteer, then as a paid Assistant. During the social upheavals of 1848, Houzeau took a firm Republican stand and had to resign his post, leave Belgium, and range about Europe, working in various libraries and writing books on geography. In 1854 he was recalled to Belgium to work on the triangulation of the Kingdom, but when this project was interrupted in 1857 he left on the sailing ship *Metropolis* for New Orleans, arriving there in late 1857.

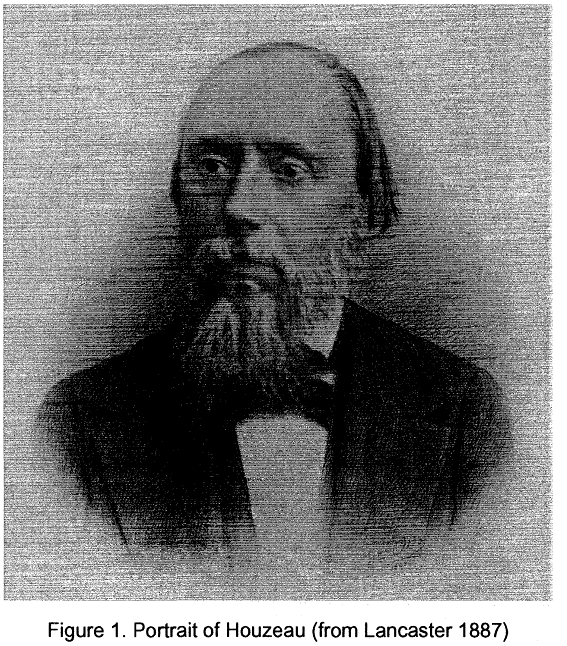

Figure 1. Portrait of Houzeau (from Lancaster 1887)

He first visited San Antonio, Texas, in 1858 May, and stayed there till 1862, apart from almost a year that he spent surveying in a region to the south of Dallas. When the Civil War broke out, he crossed the Mexican border in 1862 March. After his return to New Orleans, he served as one of the editors of the newspapers *Union* and *Tribune*, which were mainly read by Afro-Americans. In 1868 March he left New Orleans, and in June settled in Jamaica. There he cultivated a plantation, founded a school for young natives, and carried out studies in natural sciences and astronomy, mainly for his *Uranographie Générale* (which also involved a trip to Panama, in 1875). When Adolphe Quételet died in 1874, King Leopold II overrode objections of his ministers and appointed Houzeau as Director of the Royal Observatory. Houzeau took up his post in 1876 June, and was deeply involved in the reorganization and relocation of the Observatory to the suburb of Uccle/Ukkel. He resigned from the Directorship at the end of 1883, but continued to work on his voluminous astronomical bibliography. In 1888 July, he died from the consequences of malaria that he had contracted more than twelve years earlier.

2 THE OUTLINE OF THE PRINCIPAL INSTRUMENTS

Two examples of Houzeau's heliometer with unequal focal lengths (Figure 2) were built by Grubb of Dublin at the initiative of Houzeau and according to plans outlined by Louis Niesten (see Houzeau, 1871). Descriptions are given in Anonymous (1898), Houzeau (1884b), and Van Boxmeer (1996).

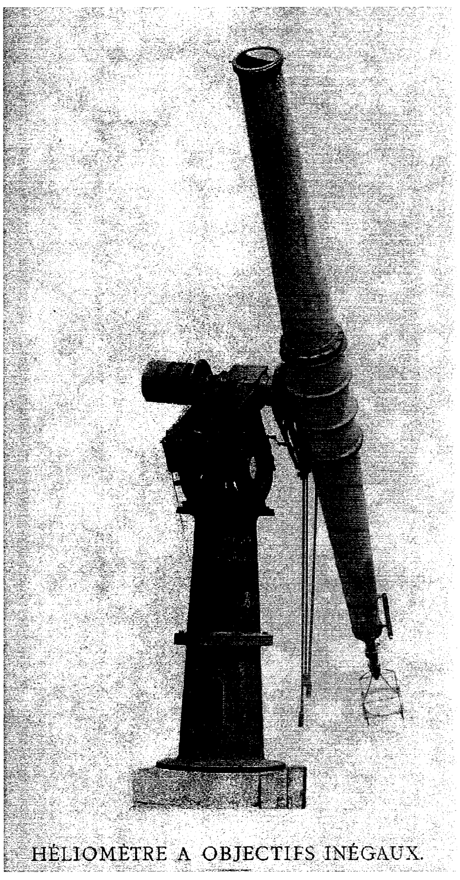

Figure 2. The heliometer with its projection screen on its parallactic mounting (from Houzeau 1884)

The instrument has a half-objective of 220 mm diameter and 4.34 m focal length, and a half-objective of 30 mm diameter and 0.14 m focal length, which actually forms part of the eyepiece unit of the telescope (Figures 3 and 4). The pair of objective lenses was acquired by Quetelet in 1844 from the lens-maker Cauchois in Paris. The eyepiece projects a solar image on a screen (Figure 5), which was made in 1882 at the Observatory. The projected large solar image has a diameter of 160 mm on the screen, while the diameter of Venus is about 5 millimetres. The short-focus objective produces a solar image a little bit smaller than that of Venus. The relative position of both objectives can be changed by means of a graduated micrometer screw that moves the small lens. This permits one to produce a precise coincidence of the small image of the Sun and that of Venus (Figure 6). The difference in micrometer reading between the positions 'small Sun centred on crosshairs, being the centre of the large Sun' and 'small Sun centred on large Venus', properly calibrated, gives a measure of the distance between the centres of both objects during the transit.

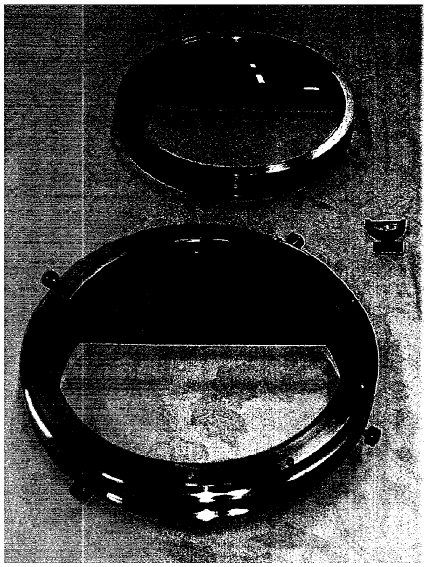

Figure 3. Two large and one small half-objectives. Photograph by C Sterken

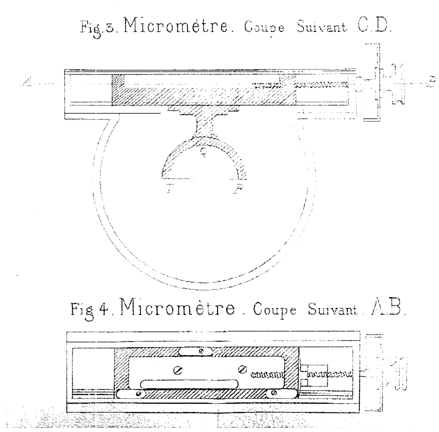

Figure 4. The small half-objective on its micrometer sledge (construction plan by L Niesten; from Houzeau 1884)

The measurements were done in such a way that one observer centred the 'large Sun' on the screen by fine motion of the telescope, a second one centred the 'small Sun', first on the crosshair and subsequently on the Venus image, and a third one read the micrometer settings and the times (and recorded the observations).

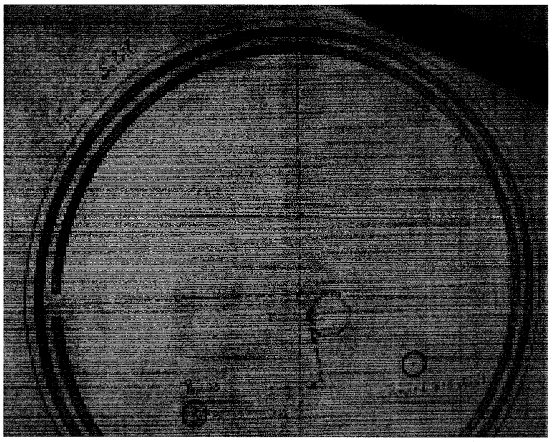

Figure 5. A close-up of the surviving projection screen surface, showing the centring circles for the large solar image ("Grand Soleil"), the silhouette of the dark "Vénus", and the appearance of the small Sun centred on the dark Venus ("Vénus et petit Soleil"). Furthermore, the smallest distance of the centres of both objects is marked ("distance minima" [*sic*]). Photograph by C. Sterken

Both of the large and small half-objectives (the large ones secured on fixed brass mounts), a projection screen, at least one tube and major parts of a mounting, and two eyepiece units with micrometer screws for the small objectives, survive at the Royal Observatory of Belgium. The optical items and the screen (with a sketch of a Venus transit as seen with such an instrument) are on display at the Museum of the Royal Observatory.

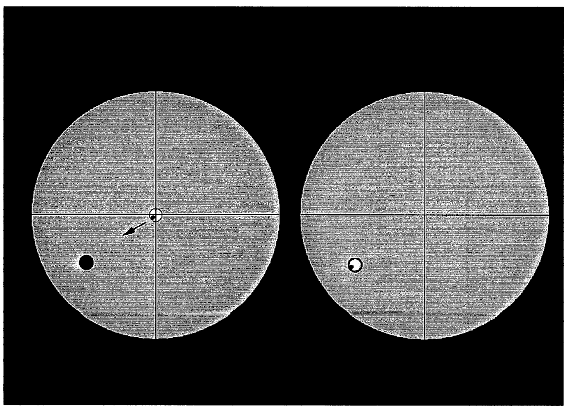

Figure 6. The principle of measurements with the heliometer with unequal focal lengths (adapted from sketches given by Houzeau 1871)

3 AN OVERVIEW OF THE BELGIAN EXPEDITIONS

Two expeditions of the Royal Observatory of Belgium (ROB) were carried out, one to San Antonio, Texas, and the other to Santiago in Chile. We give here a brief overview of the expedition members and the equipment, as well as biographical sketches of the expedition members.

3.1 Texas Mission

3.1.1 Members

J C Houzeau, Director of the ROB, mission leader.
A Lancaster, Meteorologist-inspector, ROB.
E Stuyvaert, Adjunct Astronomer, ROB.

3.1.2 Telescopes

Heliometer with unequal focal lengths (AL).
Merz refractor, 110 mm aperture, 125× (JCH).
Fraunhofer refractor, 75 mm aperture, 90× (ES).
The initials in brackets indicate the observers who used the instruments for contact observations; during the actual transit, all members were working with the heliometer.

3.1.3 Biographical notes

Albert Lancaster (1849–1908) (Figure 7) reorganized the climatological network of stations in Belgium and in 1898 was appointed Scientific Director of the Meteorological Service, a post that he retained until the end of his life. Together with Houzeau, he wrote *Traité Elémentaire de Météorologie*, and the legendary *Bibliographie Générale de l'Astronomie* (Anonymous 1980; Mourlon 1908).

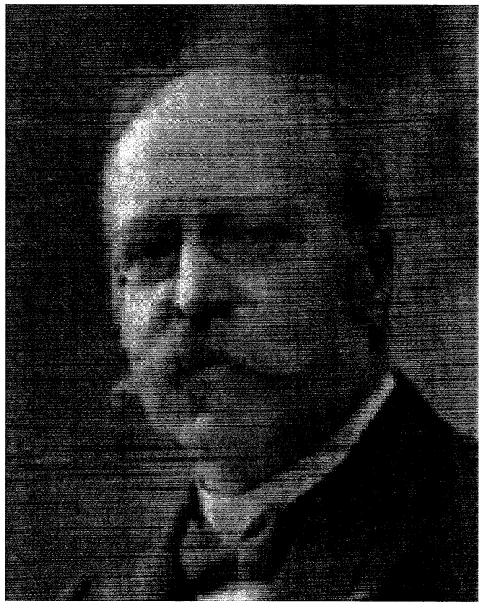

Figure 7. Albert Lancaster (from Lagrange 1908)

Charles-Emile Stuyvaert (1851–1908) entered the Royal Observatory in 1879 as a voluntary, and became Astronomer in 1881. He did surface studies of Venus, Mars, Jupiter, and Saturn, determined cometary positions, observed lunar occultations, and was especially interested in lunar surface studies; in the process, he made drawings and prepared a lunar globe (Stroobant 1909).

3.2 Chile Mission

3.2.1 Members

Louis Niesten, Astronomer, ROB, mission leader.
Charles Lagrange, Adjunct Astronomer, ROB.
Joseph Niesten, Lieutenant of Artillery.

3.2.2 Telescopes

Heliometer with unequal focal lengths (JN).
Dollond refractor, 110 mm aperture, 140× (LN).
Troughton & Simms refractor, 90 mm aperture, 160× (CL),
The initials in brackets indicate the observers who used the instruments for contact observations; during the

actual transit, all members were working with the heliometer.

3.2.3 Biographical notes

The following biographical data are taken from Zegers (1883) and supplemented by Anonymous (1932, 1980).

Louis Niesten (1844–1920) (Figure 8) was born in Visé near Liège, and made his first studies in the Military Academy; he rose to the rank of Artillery Captain, but left military service in 1877 to work as a scientist. Zegers mentions many papers by Niesten on the physical properties of Jupiter and Mars, on comets, asteroids, and double stars, as well as of a transit of Mercury. In 1884 he became Astronomer and Chief of the Service of Mathematical Astronomy. In 1898, he succeeded Charles Lagrange as Scientific Director of the Astronomical Service, a post that he retained until 1900.

Figure 8. Louis Niesten; drawing at the time of his Chilean mission (from Zegers 1883).

Charles Lagrange (1851–1932) (Figure 9) was born in St. Josse-ten-Noode/Brussels. He also took first studies in the Military Academy, became an Artillery Lieutenant in 1874, but moved to the Observatory in 1878. Zegers also mentions theoretical and observational studies, as well as a history of the physical sciences in Belgium between 1830 and 1880. In 1897, he became Director of the Astronomical Service, a post that he left a year later to dedicate his life to historical research, mainly on the chronology of the biblical prophets. He was also a notable Professor at the École Militaire, and wrote several works on the philosophy of science.

Joseph Niesten, born in Visé near Liège in 1847, entered military school in 1867, and became a Lieutenant of Artillery in 1870. Since he also took part in astronomical projects at the Royal Observatory, and because of his practical and theoretical knowledge of astronomy, the War Ministry agreed that he should join the astronomical expedition led by his brother.

A map of the topography of the San Antonio Station is given in Houzeau (1884b), Résultats, Plate 2, and this is reproduced here as Figure 10.

Figure 9. Charles Lagrange, undated photograph (from Anonymous 1980)

4 THE BELGIAN EXPEDITION TO SAN ANTONIO, TEXAS

Houzeau departed for the United States on 1882 June 30, while Lancaster left Antwerp on July 22 on the steamer *Waesland* (of the Belgian Red Star Line), along with the equipment of the expedition. The Atlantic crossing to New York took 11 days and 22 hours. There he found instructions from Houzeau and the New York Belgian consul on how to proceed. On August 12 the instruments were loaded on the steamer *San Marcos*, destination Galveston, and from that port they were transported by railroad to San Antonio, where they arrived on August 30 in perfect condition.

While in Washington, Lancaster (1882) visited the Naval Observatory and the Signal Office (telegraphy and meteorological observations), and the Smithsonian Institution. Then he travelled by rail through Kansas and Colorado to San Antonio, where he arrived on September 2.

The Belgian transit observatory was located in the back garden of a rented wooden house "... in an isolated situation ..." (Houzeau 1884b) that faced the Staff Post and the Quadrangle of 'Government Hill' (its present-day name, Fort Sam Houston, was only assigned in 1890). Evans and Olson (1990) suspect that the house (which no longer exists) was "... probably on the south side of Grayson Street, in the block between the streets now called North Palmetto Avenue and Pierce Street. The telescope piers were approximately 640 feet south and 950 feet west of the clock tower in the Quadrangle."

Houzeau (1884b) was an experienced topographer, and he published a list of measurements of buildings and other features of San Antonio in his final report, while a copy of a hand-drawn map giving a bird's eye view of San Antonio is found in the archive of the Royal Observatory of Belgium.

We owe the most detailed description of the Texas observations to Lancaster (1882):

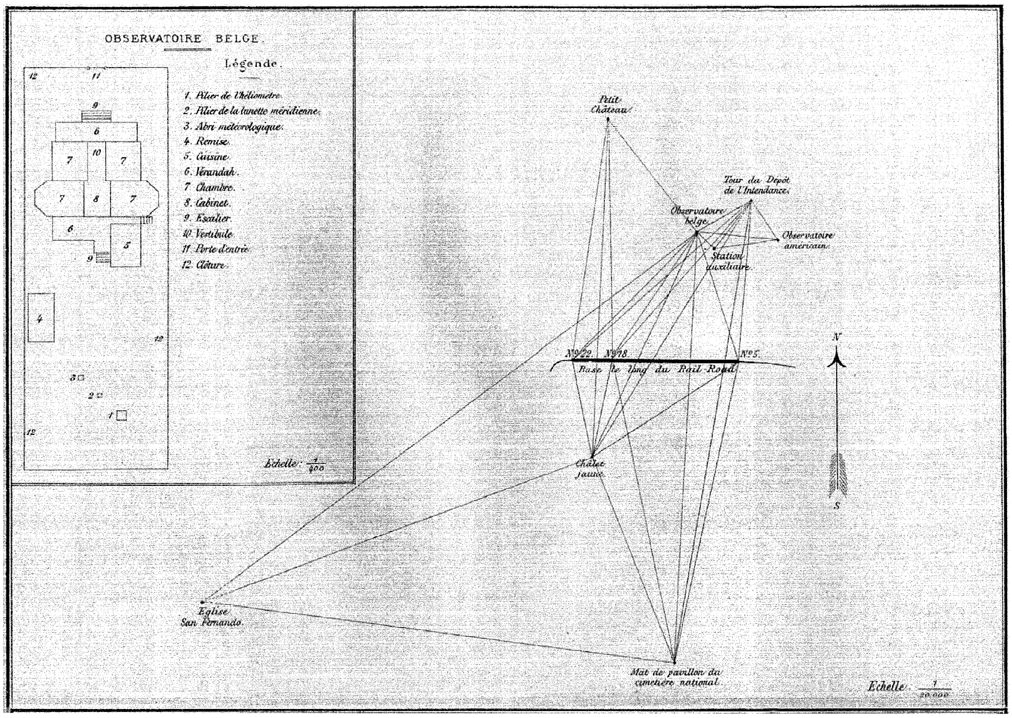

Figure 10. Outline of the house of the Belgian mission in San Antonio, and visual bearings (from Houzeau 1884)

San Antonio is the headquarter of the troops which are stationed in Texas, and the barracks are on Government Hill, 7 km NE of the city, at an isolated and elevated location, where the view passes a huge horizon and where also the Belgian station was installed ... The Belgian flag floats in the wind at a small distance of that of the grand American republic. [Lancaster then gives a few details about the city, the inhabitants, and the evening dinners outside on the Plaza de las Armas.]

On the 5th, slight cirrus gave us some fears, but at nightfall there was no trace left. The night from the 5th to the 6th was very good till 5 in the morning, at 5 1/2, rapid clouds showed up and covered the sky in a few moments. All our instruments were ready since the evening, and pointed to the direction where Venus should appear in front of the sun. At 6 ¼ in the morning, M. Houzeau went to the American station to compare the chronometers.

The moment of first contact approaches, the sky is always covered, and remains so till about 9 a.m.; then the clouds appear to be less thick, some hazy brightenings show up here and there, and our hope returns.

Suddenly we see the solar disc through a thin cloud; but another one covers it immediately, and this hope and anguish goes on for 30 minutes. At around 9 ½, a brightening which is larger than the previous ones permit to point at Venus between the clouds, 12 minutes before the moment of the minimum distance of centres. From that moment on we can make micrometric measurements, with a few interruptions, till the end of the transit. These measures which form the main body of our observations are 124 in number, and some refer to the time when the planet was closest to the solar center ... At 1h 14m and 1h 34m we observed the two last contacts on a sky which was almost free from clouds. And everything was finished!

But in his extensive obituary, Lancaster (1889) provides information about Houzeau's state of mind on the morning of the transit when the sky was overcast: "Houzeau did not say anything, but his face became very pale; not a muscle of his face moved; we understood that he was undergoing a deep inner trouble. He returned to our little house and laid down on the floor, as he liked to do it, and said to us that we should notify him if some change in the sky conditions should arise."

And there is another line in Lancaster's obituary (ibid.) relating to the Texas expedition that merits citing since nothing is found in the official reports: "Soon after his [Houzeau's] return to Belgium [in 1876], he re-married with his sister-in-law, the widow B Discry, who accompanied him on his trips to Jamaica in 1878, and to Texas in 1882, and who cared for him, from the first days of his sickness to which he would finally succumb, with an unlimited devotion."

5 THE BELGIAN EXPEDITION TO SANTIAGO DE CHILE

Luis Ladisláo Zegers, a physicist at the Universidad de Chile, wrote a 'noticia histórica' on the observations carried out in Santiago and its vicinities. He accessed a lot of correspondence and newspaper clippings, talked with Belgian and US scientists, and actively took part in the French transit expedition as an assistant. Zegers is best known today because of his use of Röntgen's newly-discovered X-rays for medical purposes in Chile only a few months after their first application in 1895 (Zegers and Salazar 1896). Let us briefly mention that Zegers' (1883) book does not inform us about the activities of the Chilean National Observatory on 1882 December 6, since this was obviously restricted to the "... authorized word of its director ...", José Vergara. Instead, Zegers quotes from Vergara's newspaper articles of the forthcoming event, gives a long history of the National

Observatory, deplores its present state of decline, and then very briefly lists contact timings derived by Chilean personnel at the Observatory ("... we owe these data to the kindness of the director of the National Observatory ..."). And this remained, according to our knowledge, the only printed result of the transit of Venus observed by the Chilean National Observatory staff. For a detailed history of the Chilean National Observatory, the reader is referred to Keenan *et al.* (1985).

The Belgian project started with an exchange of letters, transmitted by Zegers (1883:168) between Houzeau and the Director of the Chilean National Observatory, José Ignacio Vergara (Figure 11):

Figure 11. The director of the Chilean National Observatory, José Vergara (from Zegers 1883)

Brussels, October 16, 1881

To the Director of Santiago Observatory.

Mr. Director:

Since the Belgian government has decided to send a scientific commission to Chile for the observation of the next transit of Venus in December 1882, I take the honour to recur to your kindness in order to obtain some information with respect to the installation of our instruments.
They comprise a large equatorial of 0.18 m aperture and 4.30 m focal length, which is especially designed for the observation of the transit, and a meridian telescope for supplementary observations. Under which conditions can we easily find in the surroundings of Santiago a convenient place to build shelters, and to put up the instruments?

The Belgian commission will depart from Europe in about August 1882, and consequently will arrive in the month of October.

I hope, Mr. Director, that you excuse the liberty by which I request your benevolence, and I beseech you to accept my anticipated thankfulness, and the expression of all my consideration.

J.C. Houzeau
Director of the Royal Observatory in Brussels.

This was answered as follows:

December 24, 1881

To Mr. J.C. Houzeau, Director of the Royal Observatory in Brussels.

Mr. Director:

I have received your important letter of October 16 of this year, in which you communicated that the Belgian Government has decided to send to Chile a scientific commission with the aim to observe the next transit of Venus, and in which you ask me about the possibility to find a convenient place in the surroundings of Santiago for the instruments that this commission will bring along.

In answering with true joy to your mentioned letter, it is especially pleasant, Mr. Director, to be able to signal to you that the said commission will find in this capital all the facilities which it can expect for the performance of its duty in this important mission, both from the side of the government as well as from that of the single inhabitants, and that consequently it will therefore not encounter any difficulty to establish its observatory in the place which it considers most advantageous.

Being authorized by the Minister of Public Education, I can immediately offer you in the same place that is occupied by the Observatory in whose charge I am, not only the necessary space for this purpose, but also the use of the offices, that of one of the three equatorials, and that of the meridian circles of this institute. If you accept this offer, the Commission does not need to bring the meridian telescope that you have announced.

The equatorials of this observatory are made by Fraunhofer, by Würdeman and by Repsold, and measure, respectively, 0.11, 0.16 and 0.23 m in aperture and 1.40 m, 2.60 m, and 4.25 m in focal length. The lenses of the last one are the work of Mr. Merz.

I have seen in some correspondence that the Belgian commission will not be the only one arriving from Europe in order to observe that phenomenon, and since I must assume that these commissions will chose special points to establish their observatories, not only the purpose of these should be considered, but also, in order to prevent the possible case that the atmospheric condition prevents work in a given location, I take the liberty to announce in addition that whatever point will be chosen by [the commission] of that Republic, the same facilities will be found that I have indicated to you with respect to Santiago. I hope that, if you have the opportunity, that you can use to communicate the previous facts to the above-mentioned commissions.

With the sentiments of my distinguished consideration, I take the honour to offer myself to you, Mr. Director, as your zealous and certain servant.

José Ignacio Vergara.

In fact, other researchers from abroad did come to Chile: the French would establish their observing station at Cerro Negro, an area near the town of San Bernardino, a few kilometres south of Santiago; the Americans in the park (now called Parque O'Higgins) in Santiago; and the Germans and Brazilians in Punta

Arenas, the (then) only major settlement in the southernmost twelfth region of Chile. Details are found in Duerbeck (2004a,b).

The Belgian Chilean party consisted of Louis Niesten, Astronomer at the Royal Observatory of Brussels (chief of mission), Charles Lagrange, Adjunct Astronomer at the same institution, and Louis' brother Joseph Niesten, an Artillery Lieutenant on leave from the War Ministry. Details are given in Houzeau and Niesten (1883) and in Houzeau (1884b). A forty-five day trip on the steamer *Denderah* (of the German *Kosmos* line) brought them from Antwerp to Valparaiso, and following a five hour railway trip they arrived in Santiago on 1882 September 2.

A few days after arrival, the Belgian commission began to install its instruments in an annex of the National Observatory (Figure 12) "... somewhat to the south and facing the large tower that contains the new equatorial ..." (Zegers 1883:173). In the name of the Sociedad Nacional de Agricultura, the Director of the Quinta Normal, René F. Le-Feuve, offered the Belgian astronomers living quarters near the Observatory grounds.

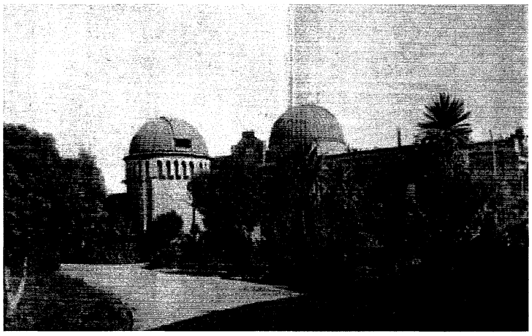

Figure 12. The Chilean National Observatory in the suburb of Quinta Normal in Santiago (provided by H Alvarez)

December 6, the day of the transit, was perfectly clear: "Since dawn, a clear sky – only a few clouds above the snowy peaks of the Andes – promised a wonderful day ..." wrote Niesten in his diary (Houzeau 1884b). Indeed, 606 measurements of the position of Venus were taken with Houzeau's heliometer, and additional observations were made with refractors. The latter ones showed the phenomenon that had already plagued the eighteenth century observers, the notorious 'black drop effect' that appears at second and third contacts (Figure 13) and makes accurate timings of internal contacts virtually impossible. Nonetheless, Louis Niesten wrote Zegers (1883:177) that "The measurements were carried out with the outmost easiness, and with a great precision ...", and Zegers added: "When the heliometric results of the two Belgian stations, that of Texas and that of Chile, will be combined, the Belgian astronomers will without doubt achieve to determine the value of the solar parallax with a completely novel method which will establish itself with all signs to be an excellent one."

After completing their observations, the party went by railway to Santa-Rosa, crossed the Cordillera on muleback, and again by train to Rosario, where a steamer took them to Buenos-Aires. After shorts stays in Montevideo, Rio de Janeiro and Petropolis, they returned on the steamer *Sénégal* (of the Messageries Maritimes) via France to Belgium, happily ending "... the first scientific expedition organized by Belgium ..." (Houzeau and Niesten 1883).

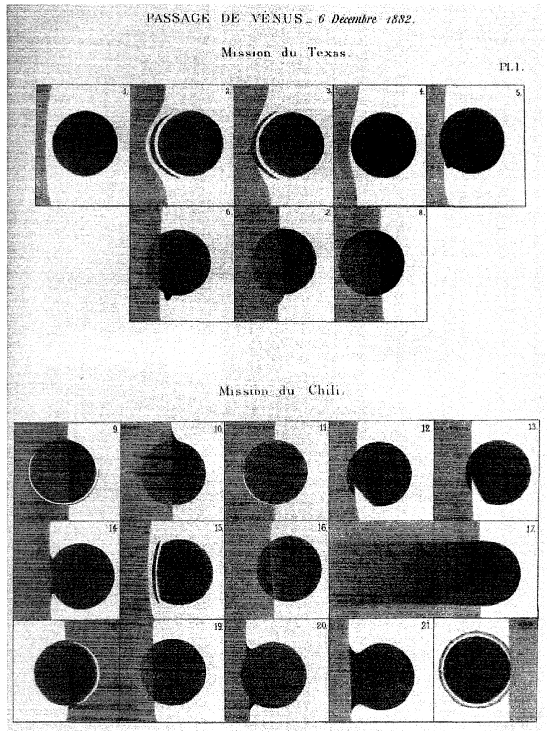

Figure 13. Visual black drop observations, recorded by E Stuyvaert in San Antonio and by C Lagrange in Santiago de Chile (from Houzeau 1884).

6 RESULTS

Two years after the transit, Houzeau (1884a,b) published reports on the campaign. A lot of—partly unforeseen—corrections had to be applied to the measurements: for example, the crosshair of the heliometer used in Santiago had been damaged on the trip, and had to be replaced by one which was not properly adjusted, thus corrections for eccentricity had to be carried out. The small Sun and Venus had of course different zenith distances, thus differential refraction corrections had to be applied, which amounted to different values in both locations, and these values directly influenced the resulting parallax value. Houzeau, as did all other investigators, used a preliminary model of the Sun-Venus-Earth system with an assumed solar parallax of 8″.86, and from the observations he worked out the corrections to the assumed values. Unfortunately, his observations carried him even further from the true value: his final result was 8″.911±0.084 for the solar parallax. While the parallax value can be taken as one based on a new and independent method, and thus something that can be regarded as a true achievement, Houzeau was less happy about the unexpectedly large error, which he mainly blamed on the poor sky conditions in San Antonio.

7 CONCLUSION

In the history of astronomy, the nineteenth century transits do not occupy the same rank of importance as those of the eighteenth century. While in the sequel of the eighteenth century transits, there was no immediate way to replace the method by another one, the refinement of other, concurring methods in the second half of the nineteenth century—even when the 'transit season' was underway—led to a critical evaluation of different approaches to determine the astronomical unit, which is perhaps best exemplified in Newcomb's varying views on how to handle the problem of solar parallax (see Dick *et al.*, 1998). And when a suitable minor planet—Eros—was discovered, which provided all the advantages and none of the disadvantages, the method of Venus transits fell into oblivion. There was no twentieth century Encke who tried to homogenize the nineteenth century results. But the importance of the solar parallax, which was seen as just one element in the system of astronomical constants, was clearly recognized by some leaders in the field. Astronomers like Harkness (1891) and Newcomb (1895) set out to determine such a system, built on foundations that Houzeau had earlier laid when he compiled the first—and perhaps the most extensive and erudite—compilation of 'astronomical quantities' in one of his *opera magna*, the "Vade-Mecum de l'Astronome" (Houzeau 1882). So we recognize in Houzeau a unique person, someone who was both a compiler and a researcher, a Republican and a 'Royal astronomer', a Belgian and a cosmopolitan.

8 ACKNOWLEDGMENTS

Many colleagues have supported our research on the transit of Venus expeditions and we want to express our particular gratitude to Pierre Alexandre, Archivist at the Royal Observatory of Belgium, Ukkel; Professor Hector Alvarez, Departamento de Astronomia, Universidad de Chile, Santiago; Mrs Maria Eugenia Gomez, Librarian at the European Southern Observatory, Santiago; Mrs Hilde Langenaken, Calculator at the Royal Observatory of Belgium; and Hans-Emil Schuster, Hamburg. One of us (CS) acknowledges the Belgian Fund for Scientific Research (FWO) for a travel grant that allowed him to present this paper at the 25th General Assembly of the IAU in Sydney.

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APPENDIX I GEOGRAPHICAL INFORMATION ABOUT THE BELGIAN OBSERVING STATIONS

Station	Longitude	Latitude	Elevation	Location
San Antonio, Texas	98°27'45" W	+29°26'33"	228 m	Fort Sam Houston
Santiago de Chile	70°41'45" W	–33°26'42"		Garden, Obs. Nac.

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'The Grange', Tasmania: survival of a unique suite of 1874 transit of Venus relics

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Abstract
One of the two US expeditions in Australia for the 1874 transit of Venus was based in Campbell Town, Tasmania. While the transit was observed from this site and some of the photographs taken were used in the subsequent investigation of the solar parallax, its main claim to fame is the physical vestiges of the transit programme that have survived there through to the present day. These comprise foundations for instruments, two piers associated with the photographic telescope, and one of the prefabricated observatory buildings. In addition, a copy of a photograph of the transit is preserved in the Queen Victoria Museum and Art Gallery in nearby Launceston. Collectively these form a unique suite of 1874 transit of Venus relics, and are of international importance.

Keywords: *Campbell Town, Tasmania, transit of Venus, astronomical relics*

1 INTRODUCTION

During the eighteenth century, transits of Venus were seen as ideal tools with which to investigate the value of the solar parallax, and hence that fundamental yardstick of Solar System astronomy, the astronomical unit (or AU). Consequently, expeditions were dispatched to the far reaches of the globe, but conflicting results were obtained. This directed attention to the next pair of transits, in 1874 and 1882.

The Americans mounted one of the most ambitious 1874 transit of Venus campaigns, with expeditions dispatched to three northern stations and five southern ones (Dick *et al.*, 1998). One of the latter was intended for the Crozet Islands, but inclement weather conditions prevented a landing and so a decision was made to relocate to Australia. A US station was already planned for Hobart, Tasmania, and the relocated party eventually accepted an invitation from Dr William Valentine to establish their observing station at his luxurious home, 'The Grange', in Campbell Town, 110 km to the north of Hobart as the crow flies (see Orchiston and Buchanan, 1993; Smith and Jetson, 1994).

Leading the Campbell Town party was Captain C W Raymond from the U.S. Army Corps of Engineers, assisted by First Lieutenant S E Tillman (also from the Corps of Engineers) and three American civilians employed as photographers (Newcomb, 1880). During the transit, they were also aided by three Launceston volunteers. One of these was local school-teacher, Alfred Barrett Biggs, who would go on to become one of Tasmania's most distinguished amateur astronomers (see Orchiston, 1985).

2 THE CAMPBELL TOWN TRANSIT STATION

2.1 The Instruments

Instruments used at the Campbell Town transit station were: a horizontal photographic solar telescope, a transit telescope, a 5-in (127-mm) Clark refractor, a sidereal clock, three box chronometers, a chronograph, five thermometers, a barometer, and equipment for measuring terrestrial magnetism.

The 'heart' of the research effort was surely the solar telescope, which was designed to take three different sets of photographs of the transit: of the ingress contacts, of Venus on the disc of the Sun during the transit, and of the egress contacts. The plate-holder (which supported the photographic glass plates) was mounted on a solid cylindrical metal pier (Figure 1), and protected from the elements by a simple prefabricated flat-roofed wooden 'Photographic House', which also included facilities for preparing and developing the photographic plates.

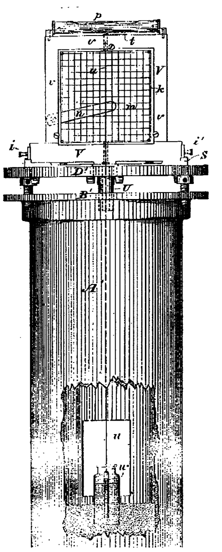


Figure 1. The photographic telescope plate-holder (after Newcomb, 1880).

Precisely 38 feet 6.625 inches (11.75 metres) due south of the photographic plate-holder was another metallic cylindrical pier. This supported a heliostat and collimator lens, which captured the Sun's rays and focussed them on the glass plate in the Photographic

House. Immediately south of the heliostat pier was a tripod containing a weight drive that allowed the heliostat to track the Sun (see Figure 2). Between the heliostat and the photographic plate-holder was a measuring rod (used to determine the focal length of the telescope), and this was supported and protected from the elements by a wooden framework and roof. For part of its length, this simple structure also protected a tube through which the light of the Sun passed while *en route* to the photographic plate. The overall arrangement of this horizontal solar telescope is shown in Figure 3.

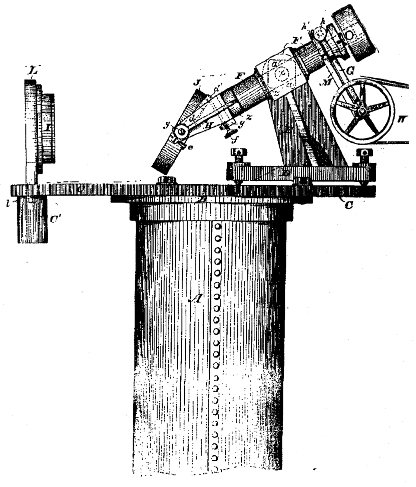


Figure 2. The photographic telescope heliostat and collimator lens (after Newcomb, 1880).

Also located along the N-S axis occupied by the photographic telescope was the Stackpole broken-tube transit telescope, which was mounted on a solid brick foundation inside a simple, wooden, sloping-roofed 'Transit House'. A typical Stackpole transit telescope is shown in Figure 4; this instrument was used to determine the latitude and longitude of the transit station, and also to maintain an accurate local time service.

The third of the prefabricated wooden buildings was the Equatorial House, which housed the equatorially-mounted Clark refractor that was used for visual and micrometric monitoring of the transit, and recording lunar occultations (for longitude-determination purposes) before and after the transit. Unlike the transit telescope, the Clark refractor did not require a brick or stone pier or support, as the base of the metallic column that supported the equatorial head contained three small but sturdy tripod legs that rested directly on the wooden floor of the Equatorial House. Figure 5 shows a surviving 1874 transit of Venus Clark telescope that was on display at the U.S. Naval Observatory in Washington D.C. in 1997.

The entire 1874 US transit of Venus programme was a major logistical exercise, and also involved very considerable expenditure. Even the fitting out of one transit station was financially non-trivial: as Table 1 indicates, the instruments at the Campbell Town site cost well in excess of US$4,200, which in today's currency equates to nearly US$50,000, a truly astronomical sum.

2.2 Setting up the Transit Station

When Raymond disembarked from the US man-of-war *Swatara* at Hobart on 1874 October 1 he had not decided on a new site for his transit station, but after consulting local officials and Dr R L J Ellery, Director of Melbourne Observatory, he accepted Dr Valentine's suggestion of Campbell Town. It offered various advantages:

> It is connected with the city of Hobart Town by one of the finest roads in the world—a solid, smooth, macadamized road, built by convicts in the days when Van Dieman's Land [the original name for Tasmania] was a penal colony—so that instruments and material could be transported to the station with rapidity and safety. It occupied nearly the highest available ground on the island, and is unpleasantly celebrated for dry weather during the summer months, so much so that the inhabitants are sometimes distressed for water, and agriculture is carried on with difficulty. Meteorological records, which I examined at Hobart Town, indicate it as the driest locality on the island … and show clear weather on December 9 for at least nine years preceding. It is separated by hills from Hobart Town, so that local storms are not likely to extend from one place to the other. It is about eighty miles distant from the station at Hobart Town. (Raymond, n.d.:377).

Raymond and Tillman reached Campbell Town by mail coach on October 10, nearly two months before the all-important December 9 transit, leaving ample time to set up the various instruments and prefabricated observatory buildings. These arrived by wagon-train October 13, and by this time a paddock near Dr Valentine's house had been selected as the site for the transit station. It was level, several acres in extent, and was

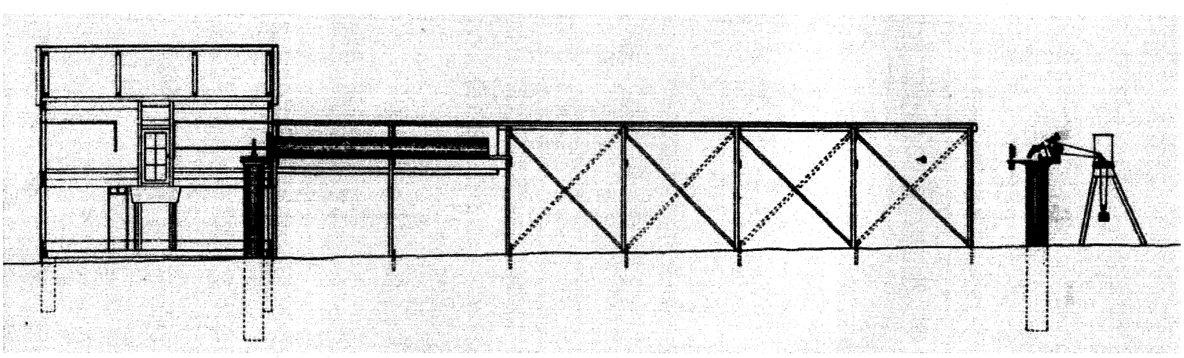


Figure 3. Schematic side elevation of the photographic telescope. From left to right: the Photographic House (with developing room, and the plate holder and pier), superstructure supporting and protecting the measuring rod, the heliostat and collimator lens (with pier) and the tripod and heliostat drive. (adapted from Newcomb, 1880).

Table 1: Instruments at the Campbell Town transit station (adapted from Dick, 2003: 248)

Instrument	Manufacturer	Cost (US$)
Photographic telescope	Alvan Clark & Sons (Cambridge, Mass.)	525
Refracting telescope	Alvan Clark & Sons	1200
Transit telescope	Stackpole Bros (New York)	1370
Chronograph	Alvan Clark & Sons	500
Astronomical clock	E. Howard & Company (Boston)	275
Sidereal chronometer	T.S. & J.D. Negus (New York)	?
Mean time chronometer	Geroge E. Porter (Boston)	?
Thermometers	?	?
Barometer	?	?
Theodolite	Stackpole Bros	200
Engineer's level	Stackpole Bros	175
Dip circle	Edward Kahler	?

> … admirably adapted to our purpose. The ground rose gently towards the west, the direction of the prevailing winds, and on that side a small grove furnished a very efficient shelter without limiting the range of our telescopes. The sky was visible in every direction almost to the horizon. The soil was a firm loam, and beneath it, at a distance of from two to four feet, is the solid bed-rock, a tough volcanic stone consisting of Hornblende, pyroxene, and silicates of alumina, and furnishing a perfect foundation for our piers. (ibid.)

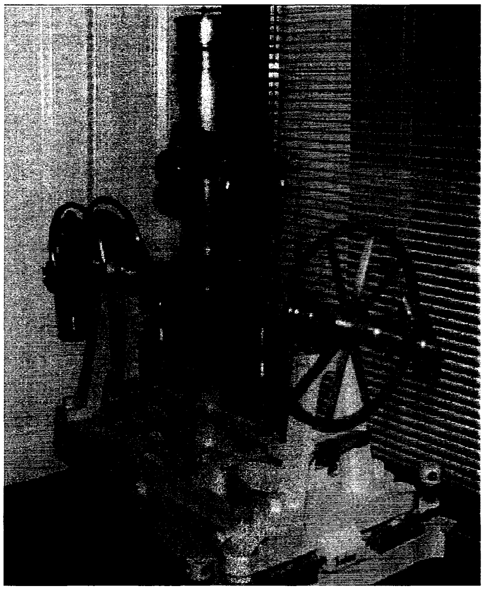


Figure 4. Stackpole broken-tube transit telescope at the U.S. Naval Observatory.

In a detailed, unpublished account, Raymond (n.d.) documents how his party systematically went about setting up the transit station. First to be erected was the Transit House, which was completed on October 19. At the same time, the hole for the transit pier was dug. This was

> … about four feet eight inches [1.42 metres] in depth. All the loose stone was removed from it, and the bedrock was carefully cleaned and leveled with concrete. The pier was then constructed with brick, laid in Portland cement. At first considerable water from the adjacent high ground settled in the pier hole; but this difficulty was obviated by inclosing [*sic*] the pier to the height of about eighteenth inches in a bottomless wooden box and surrounding this box with concrete. (Raymond, n.d.:378).

Figure 6 illustrates the general features of the pier, as outlined by Newcomb (n.d.) in his specific instructions to each of the transit parties. Just one day later (October 20) the transit telescope was installed. The chronograph followed on the 23rd, and was operational on the 26th.

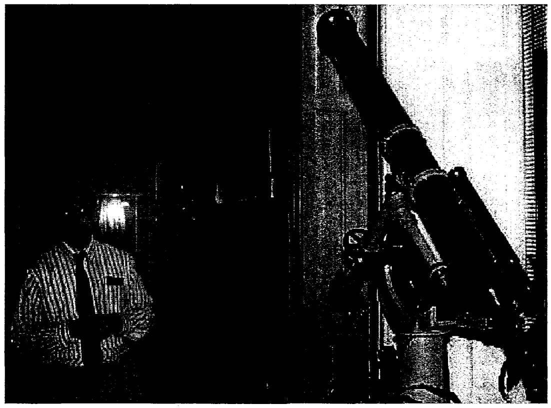


Figure 5. 5-in Clark refractor and US astronomical historian and transit of Venus authority, Steven J Dick, at the U.S. Naval Observatory in 1996.

While some members of the team were busy with the Transit House, others were setting up the Equatorial House. This was also completed on October 19, and the Clark telescope was installed.

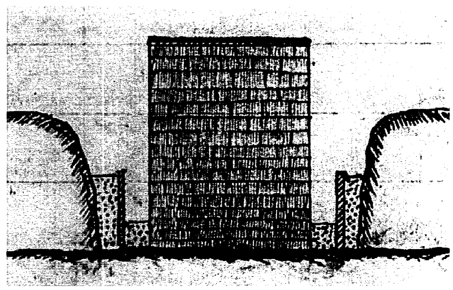


Figure 6. Installation of the transit telescope pier (after Newcomb, n.d.:10).

Finally came construction of the Photographic House and photoheliograph, which proved to be a much more time-consuming and challenging task. On October 20 the positions of the two piers were determined, and holes for them were dug. Raymond (n.d.:380) reports that in excavating these holes,

> … the solid rock was found about three feet below the surface. The piers had therefore to be cut off in order to bring their upper surfaces to the proper levels. Each hole was then lined with a bottomless

> wooden box. The piers were then fastened temporarily in these boxes with wooden wedges ... [and] were then accurately adjusted in position. When the adjustment had been perfected, the spaces around the piers were filled with concrete, and finally the piers themselves were filled with concrete to within about one foot of their tops.

With the exception of the bottomless box, which was designed to prevent the inflow of groundwater, Raymond followed closely the instructions and diagram (Figure 7) provided by Newcomb (n.d.:11) in his notes for the different transit parties. On October 24 the Photographic House was erected, and by November 4 the photographic telescope was operational and the first test images of the Sun were taken. Finally, on November 7 the measuring rod and its cover were installed.

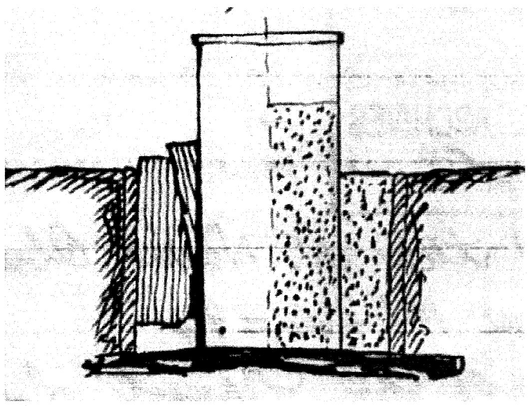


Figure 7. Installation of the photographic telescope pier.

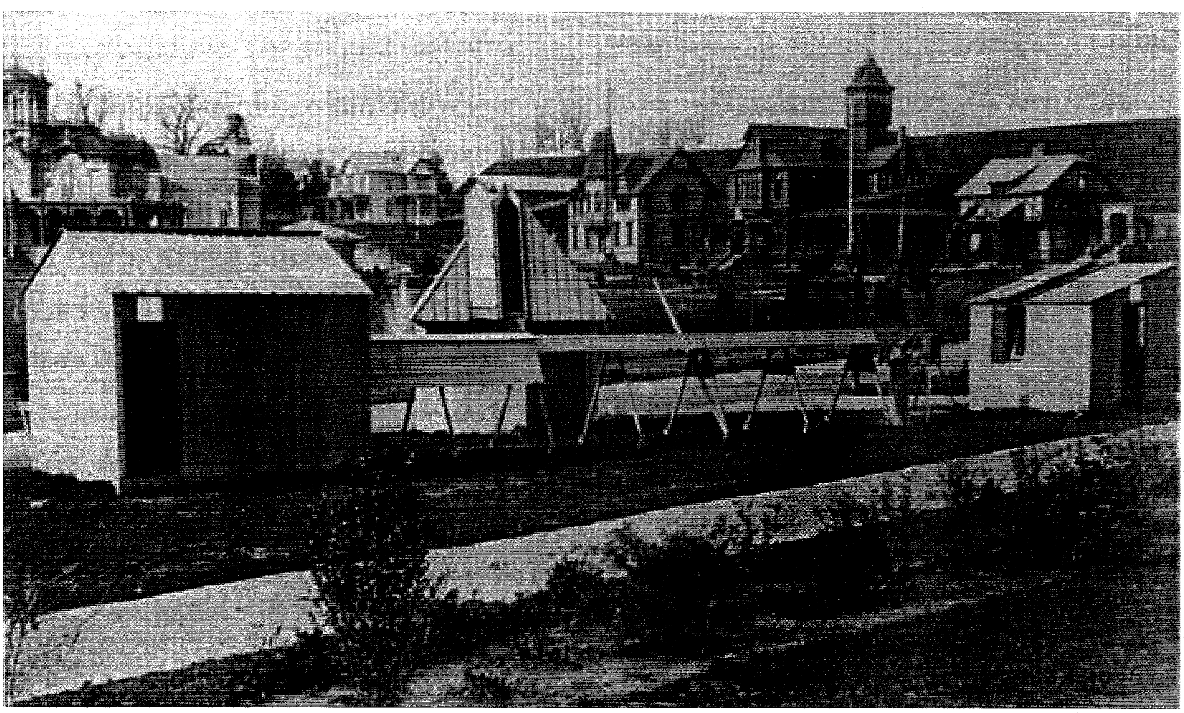
The other transit facility set up at Campbell Town was a Clock Room, which was located in Dr Valentine's house. The house was a substantial brick construction, and since a room was chosen that had just one window and was protected from direct sunlight by a wide veranda there were only small diurnal changes in temperature. On October 16 the sidereal clock was bolted to a thick brick partition wall and set in motion. Also installed in this room were a sidereal chronometer, a mean time chronometer, two thermometers, and the barometer (Raymond, n.d.:380). The Clock Room also doubled as an office for the transit party.

Once the observing station was fully operational, members of the transit party were kept busy right up until the day of the transit monitoring and checking on all the equipment, making practice solar observations, maintaining the time-service, and conducting astronomical observations for latitude and longitude. Derived co-ordinates of the site (after Raymond, n.d.: 379) were:

Latitude 41° 55′ 42.5″ S
Longitude 9^h 02^m 25^s West from Washington

Elsewhere in his account of the transit expedition, Raymond (n.d.: 390) gives a latitude of 41° 55′ 42″.0 ± 0.16 S.

Raymond did not supply a description, so we do not know the precise appearance of the Campbell Town transit station. However, photographs of other US 1874 transit stations exist, and these show what the prefabricated Transit, Photographic and Equatorial Houses looked like. Figure 8 is particularly helpful in this regard, as it shows a 'typical' transit station, which was constructed specifically for the 1876 US Centennial Exhibition in Philadelphia—but with genuine examples of the three Houses, the heliostat and drive mechanism. We can safely assume that the prefabricated Houses at Campbell Town were identical or very similar in overall appearance.



Houses (left to right), and the structure extending from the Photographic House towards the heliostat and drive (after Dick, 2003:252).

Table 2: Contact times of the 9 December 1874 transit at Campbell Town

Contact	Local Time		
	h	m	s
First contact (external contact at ingress)	11	35	27
Second contact (internal contact at ingress	12	04	53
Mid-transit	13	56	01
Third contact (internal contact at egress)	15	46	55
Fourth contact (external contact at egress)	16	16	23

2.3 Observations of the Transit

Campbell Town was ideally placed for observers of the transit, as the entire event was visible (weather-permitting). Table 2 (after Abbott, 1874) indicates the transit began late morning local time, and ended late in the afternoon, but well before sunset. The total duration of the transit was just over 4 hours and 40 minutes.

After all these fine preparations, the transit party awake to a sky full of rain clouds on 1874 December 9, and the time first contact was scheduled it was raining quite heavily. Nonetheless, all members of the party were at their assigned positions as "... the rain was pouring hopelessly outside." (Raymond, n.d.:386), but at 12:15 p.m. local time the rain suddenly ceased and the Sun could be seen dimly through passing clouds. Raymond looked through the Clark telescope, and there was Venus near the limb of the Sun but well past second contact. Meanwhile, Tillman was in charge of the Photographic House, and the heliostat and drive were immediately installed and activated, and then photographs of the Sun were taken whenever breaks in the clouds permitted.

Heavy rain and strong winds terminated all observations at about 1 p.m., and lasted for 50 minutes, when the sky cleared a little. Tillman's team obtained further photographs whenever the Sun was visible, and Raymond managed to obtain some micrometric measures of Venus's position through the Clark refractor. Raymond also observed the third contact. At this time, clouds were drifting over the Sun, and Venus "... seemed to me *gradually* to assume the pear shape ... No shooting out of the planet toward the sun's limb at or near the time of contact was observed." (ibid.). Given the generally inclement weather, this was a positive result, and the photographers fared even better, obtaining 55 full disc photographs of the Sun (Figure 9) and 77 of the third and fourth contacts.

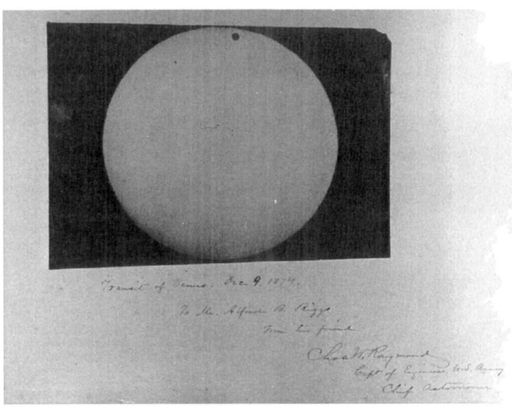


Figure 9. Photograph taken at the U.S. station at Campbell Town, showing the transit in progress (Courtesy: Queen Victoria Museum and Art Gallery).

2.4 Calculation of the Solar Parallax

With the notable exception of the Chatham Islands party, all of the US stations obtained useful transit photographs (see Dick *et al.*, 1998: Table 2), even though most experienced far from ideal weather. Now came the challenge of analysing all of the observations and producing a value for the solar parallax. Visual and photographic observations of the contacts were discarded, largely because of the notorious 'black drop effect' (see Schaefer, 2001), and the focus shifted to the full-disc photographs of the Sun taken in the course of the transit. In 1881, D P Todd from the Nautical Almanac Office published an interim value for the solar parallax of $8''.883 \pm 0.034$, but for various reasons (summarized in Dick *et al.*, 1998:241-242) the analysis was not completed and the final result was never published.

Instead, William Harkness proceeded to publish a value of $8''.842 \pm 0.0118$ based on US photographs obtained during the 1882 transit (*Annual Report*, 1889: 424-425), and he and Newcomb were only able to improve on this in the 1890s by re-analysing earlier data on the understanding that the solar parallax was intricately linked to such parameters as the lunar parallax, the constants of precession and nutation, the parallactic inequality of the Moon, the masses of Earth and Moon, and the velocity of light. Their values of $8''.809 \pm 0.0059$ and $8''.800 \pm 0.0038$ (Harkness, 1894; Newcomb, 1895) are remarkably close to the currently-accepted value of $8''.794148 \pm 0.000007$, which was ratified by the IAU in 1976.

3 SURVIVING RELICS

3.1 The photographic telescope piers

When the Americans abandoned their Campbell Town site after the transit, they left the two photographic telescope piers *in situ*, and these exist today as rather novel gate posts at the entrance to 'The Grange' property from the Midland Highway (Figure 10). Reference to Figure 3 reveals that the heliostat pier was of slightly larger diameter than the pier which supported the plate holder, and this is reflected in the relative sizes of the two gate posts: the right hand gate post in Figure 10 has an external diameter of 309 mm (12".2) and is the pier from the Photographic House, while the left hand gate post, with an external diameter of 356 mm (14"), represents the heliostat pier. Both piers are made of riveted 9.5 mm ($^{3}/_{16}$") plate steel, and extend 1.32m (4' 4") above ground level. The date when the piers were relocated from the 'Observatory paddock' to the driveway entrance has not been documented, but it must have post-dated Valentine's death (which occurred in 1876).

3.2 The 'Observatory paddock'

The gate post piers were originally located in what today is colloquially known as the 'Observatory paddock', which is to the north and slightly east of Dr Valentine's homestead (see Figure 11). This more-or-less level paddock currently contains field evidence of three different structures, that one would automatically hope to associate with the Transit House, heliostat pier (and drive), and the Photographic House, and their approximate positions relative to one another and to the homestead are shown in Figure 11.

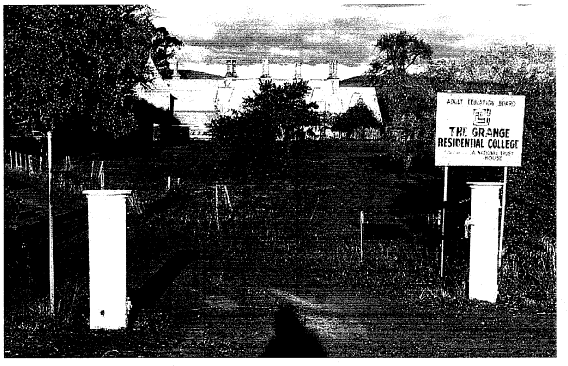


Figure 10. The entrance to 'The Grange', with Dr Valentine's homestead in the background. The novel gate posts are the piers that originally supported the heliostat (left) and the photographic plate-holder (right).

The most northerly of the three structures is a solid brick pier of rectangular cross-section (Figure 12), with the long axis aligned east-west. This pier measures 717 × 616 mm (2' 4".25 × 2' 0".25) and extends 775 mm (2' 6".5) above ground level. Approximately 38 metres (136') to the south there is a conspicuous low concrete foundation, which only extends ~15 cm above ground level and measures 1.47 × 1.07 metres (4' 10" × 3' 6"), with the long axis oriented in the east-west direction. As Figure 13 indicates, the western part of the top of the foundation has been built up with mortar. The most southerly of the three structures is an area of cobblestones measuring approximately 3.05 × 3.35 metres. Very near its northern boundary there is a conspicuous stone-lined depression that is the right diameter to accommodate the larger of the gatepost piers (Figure 14). Moreover, this depression is ~11.75 metres (or 38' 6.625") from the low concrete foundation, which just happens to be the distance that separated the two photographic telescope piers at the US transit of Venus stations.[1]

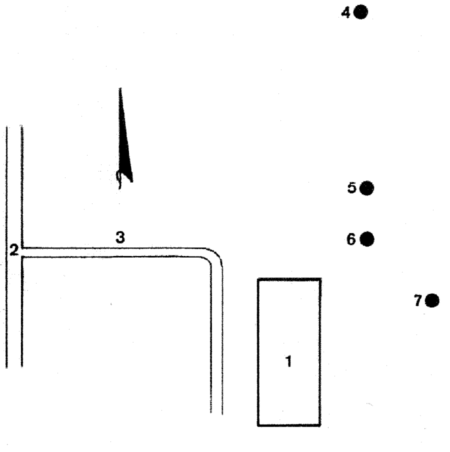


Figure 11. Sketch plan (not to scale) showing The Grange homestead (1), location of the gate posts (2), entrance driveway (3), three structures in the 'Observatory paddock' (4-6) and the summer house (7).

The accumulated evidence suggests that the three structures, from north to south, respectively relate to the Transit House, the Photographic House and the heliostat pier (and drive),[2] and there is little doubt that the most northerly structure is indeed the remains of the transit telescope pier (see Raymond, n.d.; Newcomb, 1880. See, also, Figure 6). But the identification of the second field structure is not so simple. If this low foundation was associated with the Photographic Telescope, then why is there no field evidence of the conspicuous hole that would have been left when the plate-holder pier was torn out of the ground and relocated to the entrance of The Grange's driveway? Perhaps because the built-up cement area of the low foundation represents the remains of the hole, which was subsequently filled in. Unfortunately, we have no close-up photographs of any foundations associated with *in situ* 1874 plate-holder piers, but they would have been similar in general appearance to those found with heliostat piers. Figure 15 shows the heliostat pier and foundation at the Chatham Islands (New Zealand) transit station, and if we mentally remove the pier then the two-tiered foundation bears a close resemblance to the Campbell Town field evidence. Supporting this interpretation is an area of surface boulders just south of the low foundation, which would seem to represent the rocks that Raymond (n.d.) mentions encountering in the course of excavating the holes for the photographic telescope piers.

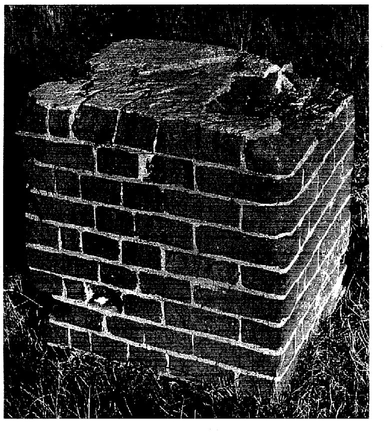


Figure 12. Remains of the pier that supported the transit telescope.

But even if we accept the above identifications—which seem eminently reasonable—there is still a problem, and that is the anomalous positioning of the transit telescope pier. We have no 1874 photographs of the Campbell Town transit station or site descriptions by Raymond (n.d.) or Newcomb (1880) to judge from, so we must be guided by the configurations of other Southern Hemisphere US 1874 transit stations. Scaled layouts of the Hobart and Queenstown transit stations (the latter in neighbouring New Zealand) have been published (Dick, 2003:258; Orchiston *et al.*, 2000:35), and these show a consistent pattern of N-S aligned Photographic House, heliostat pier, and Transit House, *in that precise order*, with the pier of the transit telescope positioned 4.9 metres and 4.2 metres to the south of the heliostat pier respectively. A photograph of the 1874 Nagasaki transit station published by Janiczek and Houchins (1974:370) shows the middle of the Transit House ~4.7 metres from the heliostat pier, while Koorts (2003:201) lists 4.27 metres as the distance of "... a typical southern station of an American observation post in 1882." If these figures are indicative, then the transit telescope pier at Campbell Town should be anywhere from 4 to 5 metres *south* of the heliostat pier hole, not far to the north of this feature and the Photographic House foundation as is in fact the case. If the transit telescope pier is *in situ*, and has not been relocated since 1875 February (when the Americans sailed from Hobart), it's current position cannot easily be explained. In fact it makes absolutely no sense, for to have functioned optimally it was important that the Transit House was close to Dr Valentine's residence, so that the chronometers could be transferred from the Clock Room to the transit telescope whenever observations were to be made.

Figure 13. Remains of the foundation for the pier that supported the photographic plate-holder.

3.3 The Equatorial House

Whereas the relative locations of the Equatorial House, heliostat pier, and Transit House are generally predictable at the American 1874 transit of Venus stations, there was no 'standard' position for the Equatorial House. Sometimes this was located due east or west of the Transit House (as, for example, at Queenstown), while at other sites it was located between the Transit and Photographic Houses, either to the east or the west of the line joining these two structures. Furthermore, because the Clark refractor did not require a subsurface instrument pier or footing, we should not expect to find any field evidence of the original location of the Equatorial House at Campbell Town (or any of the other transit stations). But what we do know is the current whereabouts of this Equatorial House.

Figure 14. Hole associated with the heliostat pier.

It happened that Dr Valentine was a keen amateur astronomer, so when the Americans quit Campbell Town they expressed their thanks for his genial hospitality by giving him the Equatorial House. They also showed their gratitude to Alfred Barrett Biggs, who assisted in the Photographic House, by presenting him with the Transit House. Biggs subsequently relocated to Launceston where he became Tasmania's foremost astronomer (see Orchiston, 1985), and for the next twenty-five years the ex-Campbell Town Transit House served him well as one of two observatories that he operated. Some time after his death in 1900 it was dismantled and no longer exists.

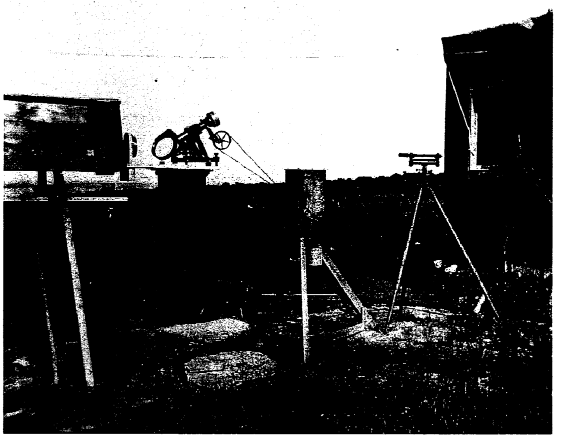


Figure 15. Chatham Islands heliostat, pier and drive, and to the extreme right part of the Transit House photographed by W H Rau (Courtesy: Alexander Turnbull Library, Wellington, New Zealand: F-55746-½).

Valentine also was able to indulge his passion for astronomy after the Americans departed, and he installed an 8.5-in (216-mm) Browning-With reflector in the Equatorial House. By a strange quirk of fate, after his demise in 1876 this instrument found its way to one of Biggs's observatories in Launceston. At some later date, the 3.1 metre diameter Equatorial House was converted into a summer house and relocated to near the tennis court at 'The Grange', which is where it remains today (see Figures 16 and 17). Currently it comprises five of the eight original octagonal wall units, each measuring 1.98 metres (6' 6") high and either 1.27 metres (4' 2") or 1.32 metres (4' 4") in width. The wall units have Oregon (*Pseudotsuga menziesii*) bottom plates, wall plates, studs, noggs and diagonal bracing, and are clad with vertical planks which in 1986 March were identified by staff at the CSIRO's Division of Chemical and Wood Technology as *Pinus lambertiana* or Sugar Pine. Both tree species are endemic to the USA, and common in the mountains of Oregon and California. Some of the pieces of framing timber exhibit incised Roman numerals (Figure 18), a practice which was used by the Americans to help facilitate easy and rapid erection of these prefabricated buildings at the various transit stations. One wall unit differs markedly from the others in that it contains a window. This has a wooden frame measuring 838 mm in height and 508 mm in width. There is no doubt that this is an original feature as a photograph of the US 1882 transit of Venus station at Santa Cruz, Argentina, includes an Equatorial House with an identical window. As with other US Equatorial Houses, the one at Campbell Town originally had a wooden floor, but when the summer house was set up this was removed and replaced by an octagonal concrete slab.

Various surviving photographs of US 1874 and 1882 Equatorial Houses show that these featured a four-sided triangular wooden dome, with a single wooden shutter, but the Campbell Town dome has at some stage been removed and replaced by a modern rustic roof, which during the 1960s was clad externally with wooden shingles (Gary Price, pers. comm., 2004). However, the basic design of the summer house, and the presence of a circular steel dome ring around the wooden plate above the octagonal wall units (Figure 19), betray its original astronomical nature. This dome ring is 3 metres (10') in diameter, and made up of 15 individual neatly butted lengths of track, each with an inverted U-shaped cross-section. On opposite sides of the building, two large metal cleats (Figure 20) have been screwed to the inside of the wall plate, and given Tasmania's windy climate these would have served to anchor the dome when the observatory was not in use, and perhaps to secure the shutter during observing runs.

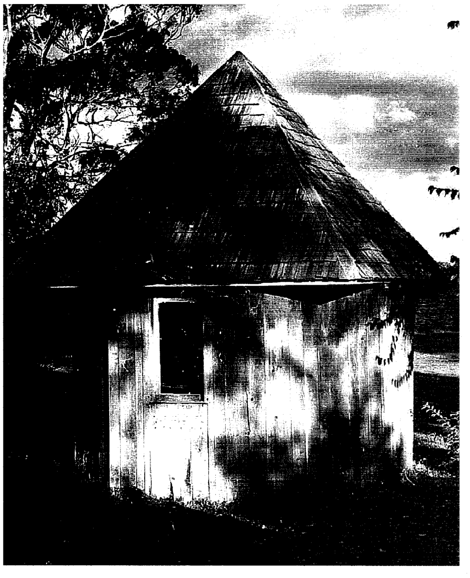


Figure 16. The Equatorial House has been converted into a summer house at Campbell Town.

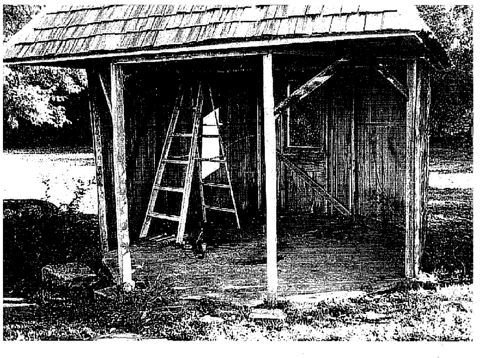


Figure 17. Interior of the summer house, showing constructional details.

3.4 The transit photograph

During the transit, the Campbell Town party succeeded in taking 55 photographs of Venus on the Sun's disc and 77 of the egress contacts, and a print of one of the 'disc' photographs survives in the Queen Victoria Museum and Art Gallery, Launceston, and has been reproduced here as Figure 9. Titled "Transit of Venus, Dec. 9, 1874." and inscribed "To Mr. Alfred B. Biggs From his friend Chas. W. Raymond Capt. of Engineers, U.S. Army Chief Astronomer", this photograph was sent to Biggs as a memento of the transit and to show gratitude for his valued assistance in the Photographic House.

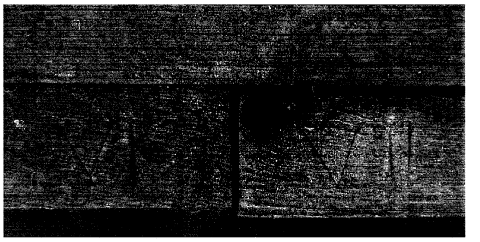


Figure 18. Examples of pieces of framing timber with incised Roman numerals.

4. CONCLUDING REMARKS

Campbell Town, in Tasmania, was the site of one of the eight temporary stations set up by the US to observe the 1874 transit of Venus, and although far from ideal weather was experienced there, photographs taken while the planet was on the Sun's disc and during the two egress contacts played an important part in the overall analysis.

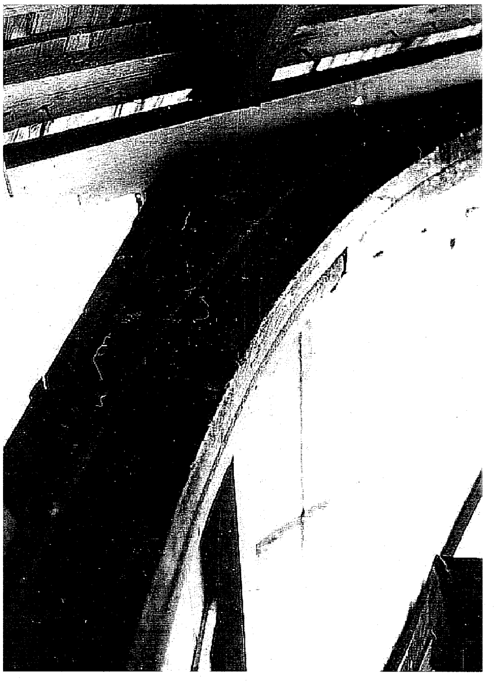


Figure 19. View of the expanded wall plate carrying the metal track upon which the dome originally rotated.

However, Campbell Town has another, even more significant, claim to fame in that an amazing assemblage of transit of Venus relics is preserved at this site. These comprise the two piers associated with the horizontal photographic telescope (and field evidence associated with both of these), the remains of the Equatorial House, and the transit telescope pier (the current position of which is an enigma). While relics at other 1874 and 1882 US transit of Venus stations were still extant in the mid-twentieth century (e.g. see Koorts, 2003), these Tasmanian relics would appear to be the only ones that have survived through to the present day. Furthermore, the photograph of the transit in the Queen Victoria Museum and Art Gallery has special significance as searches of relevant US archives and observatories have failed to reveal the existence of any other photographs of the 1874 transit taken by the various official US transit parties. This print therefore is unique, and as if to further highlight its importance, it would appear that not a single photographic plate from any of the 1874 transit parties has survived.

Tasmania therefore has a unique collection of 1874 transit of Venus relics. These are of international significance, and constitute part of our nineteenth century world astronomical heritage. As such, it is essential that their importance is fully recognized, and that they receive appropriate attention from those trained in the care and maintenance of historical and industrial archaeological remains. While the piers and various instrument foundations are in reasonable condition, and remedial conservation and restoration can be carried out if required, the Equatorial House has suffered serious borer damage and this does not bode well for its long-term survival.

Figure 20. One of the metal cleats used for anchoring the dome.

5 NOTES

1. Gary Price (pers. comm., 2004) reports that in 2002 an exploratory archaeological examination of this cobblestone area suggested that it once served as the floor of a milking shed or byer, a view reinforced by the discovery of a short length of half-field-tile drain that would have carried water away from the building when the floor was washed down. Near the conspicuous 'pier' hole was another slightly smaller hole, suggesting that the heliostat pier and an adjacent post functioned as the two sides of a cow bale.
2. In our earlier preliminary report on these relics (Orchiston and Buchanan, 1993:23-24), we came up with a quite different interpretation, in that we suggested the low foundation shown here in Figure 13 was "... a foundation for the stand that supported the heliostat drive." Meanwhile, at the time of our original field survey of the site (in 1982), the cobblestone area was overlain by a thin cement covering, and we associated this with "... the floor of the Photographic House." This covering, which was disintegrating, has since been removed, exposing what we now believe to be the hole associated with the heliostat pier. Access to archival material (including transit station photographs) in Australia, New Zealand and the United States over the past decade or so has led to a dramatic increase in our overall familiarity with US 1874 and 1882 transit of Venus stations, and we feel confident about the identifications made in the present paper.

6 ACKNOWLEDGEMENTS

We are grateful to the present owners of The Grange, Gary Price and June Tyzack, for their co-operation, and to Dr Steve Dick (NASA), Ms Sharon Gibbs and Mr Michael Musick (National Archives and Records Service, Washington) and Dr Jugo Ilic (Division of Chemical and Wood Technology, CSIRO) for their assistance. Finally, we wish to thank the Queen Victoria Museum and Art Gallery (Launceston) and the Alexander Turnbull Library (National Library of New Zealand, Wellington) for permission to publish Figures 9 and 15 respectively.

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The Melbourne Observatory Dallmeyer photoheliograph and the 1874 transit of Venus

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Abstract
An improved form of De La Rue's photoheliograph built by Dallmeyer was installed at Melbourne Observatory in time to observe the 1874 transit of Venus. Photographs obtained included some made with De La Rue's version of Janssen's rapid sequence photographic camera. A succession of adverse circumstances has led to the preservation of the photoheliograph at Melbourne, unaltered from its nineteenth century form. It is expected to be usable again in its original domed building for the 2004 transit of Venus.

Keywords: *Dallmeyer photoheoliograph, Melbourne Observatory, 1874 transit of Venus, astronomical photography, heritage preservation.*

1 INTRODUCTION

Warren De La Rue was a wealthy nineteenth century English amateur astronomer and pioneer photographer (Dreyer and Turner, 1987:154-157). In 1857 he devised the photoheliograph, an adaptation of a telescope for recording heliograms or photographs of the Sun (King, 1979:226; Phillips, 1992:27). In an age when pocket telephones can capture, transmit, and display images we may think this nothing special, but recording celestial images of any sort was a leading technological challenge in the formative days of astronomical photography (see Lankford, 1984; de Vaucouleurs, 1961).

The first Daguerrotype showing sunspots was taken by Foucault and Fizeau in 1845 April (Abrahams, 2004), and experimental lunar photographs made in the 1870s with wet plates at the prime focus of the Great Melbourne Telescope were regarded at the time as the best ever taken (Baracchi, 1914a). Five photoheliographs of an improved design by De La Rue were made for the Royal Observatory, Greenwich, by J H Dallmeyer of London, in preparation for the eagerly-awaited 1874 transit of Venus (Howse, 1975).

2 THE MELBOURNE OBSERVATORY PHOTOHELIOGRAPH

Melbourne was the capital of the gold-rich Colony of Victoria. Its astronomical observatory was already Australia's foremost, equipped with the world's largest fully-steerable reflector, the ill-fated Great Melbourne Telescope (Gascoigne, 1996). A Dallmeyer photoheliograph was delivered on 1874 August 28 and installed in a new domed building at the Observatory shortly before the transit. The Government Astronomer's own copy of one of the Observatory's annual reports (White, 1875:5) has a handwritten marginal note indicating that the photoheliograph was purchased for £364 (more than double a junior professional's annual salary at that time), so it was certainly not a gift from England.[1]

This instrument still exists. It has a flint-first air-spaced objective with an aperture of 102 mm and a focal ratio of f/15. In its original state, a secondary 'Rapid Rectilinear' type lens projects a 100-mm diameter solar image onto a ground-glass screen for focusing, or onto the 6-inch (152-mm) square glass photographic plate. A two-part cast iron triangular webbed pillar supports a Fraunhofer-type equatorial mount that is adjustable for latitude, and has slow motions, setting circles and a falling-weight clock drive. The year '1869' is scribed on the polar axis. The tube can be rotated as a whole against a degree scale in position angle, allowing the plate to be aligned with the Sun's rotational axis. The total mass is about 464 kg.

Other Dallmeyer photoheliographs of similar vintage were present in British possessions at the time. For instance, Sydney Observatory had a photoheliograph with a similar optical tube assembly (now in Sydney's Powerhouse Museum) but a much earlier style of equatorial mount (see Russell, 1892). There was also a photoheliograph at the Cape Observatory in South Africa (Warner, 1979), and another, called Dallmeyer No. 4, in India (Kochhar, 1991). Howse's (1975) brief description of each of the five Greenwich instruments does not indicate if the Melbourne photoheliograph was one of them.

3 OBSERVATIONS OF THE TRANSIT

As Victoria would be in sunlight throughout the 1874 transit (weather permitting), Melbourne Observatory Director, Robert L J Ellery (1883), planned an ambitious programme involving four separate observing stations and eight different telescopes. Modest refractors and a single reflector were assigned to the three remote stations, located at Mornington, Sandhurst (now known as Bendigo) and Glenrowan, while at Melbourne Observatory Ellery and his associates planned to use the Dallmeyer photoheliograph, an 8-in (203-mm) Troughton & Simms refractor, the 48-in (1.22-m) Great Melbourne Telescope, and a small altazimuth surveying instrument (Greig, 2001).

At Melbourne much of the transit was successfully observed (ibid.), and the photoheliograph was used to take 37 whole disk photos of the Sun on wet plates. A team of four (presumably engineering students) handled the plates, operated the instrument and recorded actions and times under the control of W C Kernot, who later became the foundation Professor of Engineering at the University of Melbourne.

A Janssen Rapid Photography Attachment[2] was fitted to the photoheliograph near the time of transit contacts (White, 1875:9). This invention was designed to take a sequence of photographs around an annular area of a circular wet plate that was rotated between exposures. The Attachment used at Melbourne was different from those used with the Sydney and Indian photoheliographs, although all were made by Dallmeyer and based on a simplified design provided by De La Rue (1874). The Melbourne version was contained within a flat wooden box (184-mm wide and 20-mm thick) arranged to fit in the slot normally used for the plate-holder, and because of space and construction time constraints took only 20 exposures per 6-inch diameter plate rather than 60. It was operated by a small crank handle. The Sydney device and one uncoated glass disk for it survive at the Powerhouse Museum, Sydney (N Lomb, pers. comm., 2004).

All of these instruments had electrical contacts to allow the instant of each frame exposure to be recorded on a chronograph. They could take a series of photographs much faster than could be achieved using the photoheliograph's own shutter and the rather cumbersome standard wet plate holders. About 180 images were recorded with the Janssen Attachment at Melbourne near the contact times during the 1874 transit of Venus (White, 1875:9), so at least nine plates were exposed.

A woodcut of the transit observations with the Melbourne photoheliograph (Figure 1) shows interesting detail such as a barrel chronograph with a Huygens parabolic pendulum governor, a box chronometer with the lid open, a temporary plate-changing enclosure, and most interestingly, Kernot reclining in a position not generally required for ordinary solar photography once the focus has been set on the ground glass. Moreover, he appears to be in the off-axis position necessary for visual alignment of the disk of Venus within the eccentric frame field of the De La Rue device.

No information is to hand about how the Janssen Attachment came to be in Melbourne in 1874 or what became of it afterwards. It is not mentioned in the Annual Report from Melbourne Observatory that includes a brief description of observations of the 1882 transit of Venus, nor does it feature in Ellery's (1883) detailed report on the 1874 transit that was published in the *Memoirs of the Royal Astronomical Society*.

In 1875 March Ellery took all "... the photograms of the transit... " (Board of Visitors, 1875:3) and other related Victorian observations and calculations with him when he departed for England on a year's leave of absence, and these data were used by Tupman in his overall analysis of transit observations made at British possessions around the world. His final result, however, left much to be desired: "Although the above 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." (Tupman, 1878:455).

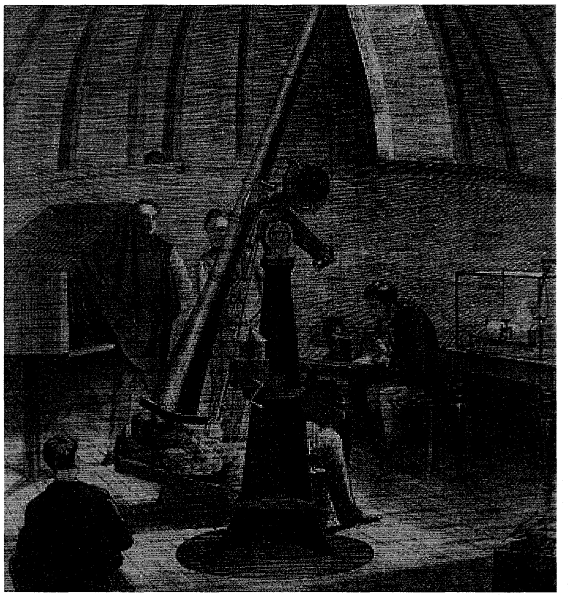

Figure 1. Woodcut from the *Australasian Sketcher* of 30 December 1874, showing the Photoheliograph Room at Melbourne Observatory during the 1874 transit of Venus. The observer is W.C. Kernot. Parts or maybe all of the barrel chronograph on the right still exist. (after Greig, 2004; cf. Haynes *et al.*, 1996: Figure 4.5).

4 POST-TRANSIT SOLAR OBSERVATIONS

After the transit, the photoheliograph continued in daily use to photograph the Sun, weather permitting, from 1874 to 1895. Dry plates were introduced in 1883. Accumulated negatives were sent to London in 1885 March, arriving with only 13 of the 1,712 plates broken (Ellery, 1885:6).

Figure 2 shows the photoheliograph in 1885, after the dome was braced in June but before introduction of the 200-mm image diameter used with similar instruments at South Kensington and elsewhere. Later a new dust-excluding centre section carrying the focal plane shutter, cross wires, and secondary magnifier (Figure 3) was constructed in the Melbourne Observatory workshop (Ellery, 1891:5), along with other improvements (Ellery, 1892:4).

An economic depression in 1892 led to photographs being taken only on days when sunspots were visible, both to economize on materials and to try to cope with enforced staff retrenchments.

The photoheliograph was used less frequently after Ellery's retirement in 1895 (Baracchi, 1896-1914), but the photographs were still sent to England. The 100-mm image diameter was eventually restored (Baracchi, 1896:4), but a return to 200 mm was offered with a proposal for Melbourne to be a station in an international solar research programme (Baracchi, 1908:9). A new automatic time exposure shutter was made, along with a new lower brass tube having a 10-inch plateholder to give a 2°.5 field for coronal photography. These went with the photoheliograph on an expedition to Bruni Island near Tasmania for the eclipse of 1910 May 9 (Baracchi, 1910:4). Unfortunately, light rain fell throughout totality there.

In 1911 the Melbourne photoheliograph was taken on a successful expedition to Vavau in Tonga for the solar eclipse of April 29 (Baracchi, 1914a). After 1914, surviving records from the Melbourne Observatory are sparse. However, solar photographs from Mauritius, Dehra Dun, Melbourne and Harvard were used to fill gaps in order to get an almost unbroken record for the Greenwich photoheliographic study (ROG, 1976) that produced the famous 'Butterfly Diagram' showing the change in sunspot latitudes as the 11-year solar cycle progressed (Phillips, 1992:27)

5 CLOSURE OF THE OBSERVATORY AND DISPOSAL OF THE PHOTOHELIOGRAPH

From the reports of the Melbourne Observatory by Ellery (1860-1895) and Baracchi (1896-1914; 1914a), it is clear that the Observatory performed well in astrometry, time-keeping and signalling, geodesy, metrology, geomagnetic recording, meteorology, tidal studies, seismology, and instrument development, but its activities in geodesy, meteorology, seismology and terrestrial magnetism were eventually taken over by other government bodies. Meanwhile, visitors to Victoria, persons with a genuine interest in astronomy, and apparently others with influence, continued to be admitted to the Observatory at night (despite published bans on night-time visits), seriously reducing the time that staff could devote to scientific research (see Perdrix, 1961). As if to compound this, regulation of trade weights and measures became a responsibility of the Observatory after Federation of Australia in 1901, despite its minimal relevance to observational astronomy. Furthermore, the allocation of Astrographic Catalogue and Chart work accepted by the Observatory (Turner, 1914) proved far more burdensome than expected.[3] Finally, the Observatory's primary services to the public and to shipping—time-keeping and time-signalling—slowly became less important in the 1920s and thereafter as transmission and reception of radio time signals on local and global scales improved and clocks and watches became more reliable and affordable.

The Great Melbourne Telescope was a liability to maintain (Perdrix, 1992) but it nevertheless remained in use for visitors right up to the start of WWII in 1939 September (W. Fiddian, pers. comm., 2004), when it was finally laid up. Extra-meridional observations at the Observatory always had low priority, and led to little in the way of discoveries. Meanwhile, a doubling of artificial skyglow every decade (see Clark, 2003: Figure 1) was increasingly hampering observations of faint objects at night. Resources dried up in the Great Depression and were never properly restored, and by 1940 the Observatory was doomed. It was officially closed down in 1944, while WWII was still in progress (Perdrix, 1961), and the wholesale disposal of everything began with sales and gifts to other observatories, transfers to other government departments and agencies, and public sales. In the end, whatever was left was ordered by bureaucrats to be smashed, burnt and dumped, and this happened with few exceptions.

Figure 2. The Photoheliograph in its dome at Melbourne Observatory, from a 10-inch by 12-inch glass plate negative. The plate-holder shown is the one for 6-inch square plates. The tube section between the tapered lower end and the cradle is the original one, as shown in Figure 1. This section survives but now has no shutter (if it ever had one) and no secondary lens. The steel bracing strips were fitted to the dome in June 1885, so the photo is later than that.

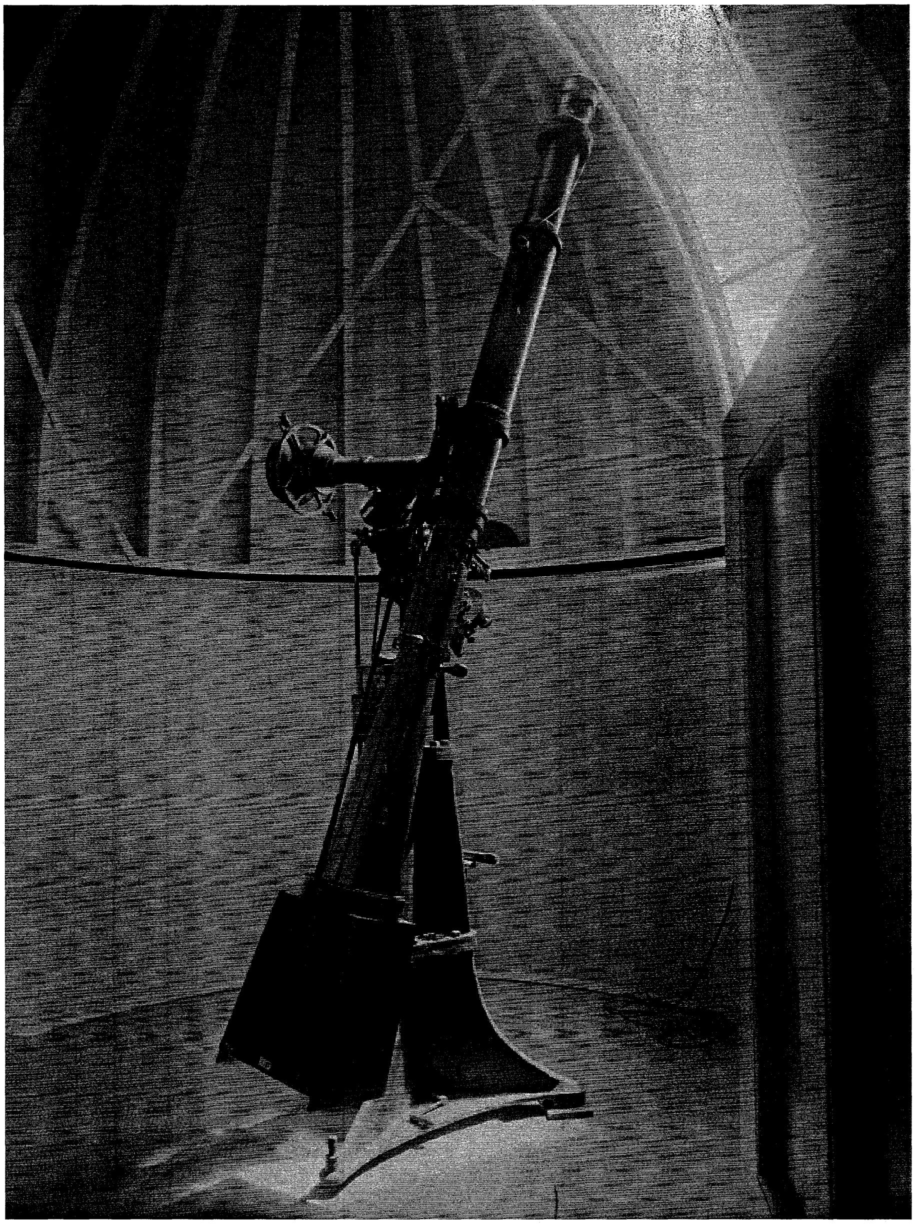

Figure 3. The Photoheliograph, from a 6-inch by 8-inch glass plate negative. The new (1891) 'central' tube section has an adjustable focal plane shutter and bevel gears for convenient secondary focus adjustment. The camera fitted in place of the original plateholder at the lower end of the tapered brass tube has a plateholder for 10-inch square plates. High magnification shows 'J. H. DALLMEYER' (probably) above 'LONDON' on the camera nameplate. A separate large conical brass tube with a 10-inch square plateholder survives. The objective cap has a cord-operated shutter. The lead counterbalance near it is extant. Two open-ended spanners rest on the driving weight behind the pillar. (One spanner survives.) The camera, supplied in 1886 (Ellery, 1886:7), extended the tube enough to require northwards displacement of the pillar. A triangular stone plinth was installed later. The floor had dry rot and was removed (Ellery, 1891:4), dating the photo to 1891 or not much earlier.

6 THE PHOTOHELIOGRAPH IN PRIVATE OWNERSHIP

Apparently other observatories showed no interest in the Dallmeyer photoheliograph, so it was advertised for sale by public tender. The only bid, a modest one by a local amateur astronomer named Les Claphan, was accepted in 1946, in spite of his condition that the instrument should stay in its domed building at the Observatory during his lifetime. At the time, Claphan was the Director of the Solar Section of the Astronomical Society of Victoria (ASV), and also served as the Science Museum's Curator of the Telescope (i.e. the 200-mm Troughton and Simms refractor that was also left on site; its dome and that of the photoheliograph are only metres apart).

Claphan claimed that in 1946 he had discovered a method of predicting the longitudes of sunspot activity on the basis of planetary alignments, and access to the Troughton & Simms telescope allowed him to check and refine his predictions. Claphan's Deputy Curator, Bob Bryant, was a photographic technologist and he was able to get the photoheliograph working with glass plates in 1948. One of the authors (BC) became involved in 1957, and soon after this, Bryant introduced modern sheet film, which required neutral density filters and an aperture stop to avoid overexposure. One to three photographs a week were taken and supplied to Claphan right up to his death in 1961. Subsequently, BC tried to investigate what was known of Claphan's methods but the task was difficult and inconclusive. By the mid-1980s, sufficient home computing power and extensive observational data made large numerical simulations and analyses practicable. Planetary periods were indeed present in the solar data, as were many others, but no trace of the modulation of alignment periods by ellipticity of orbits was found. The apparent successes of Claphan's predictions were therefore mere coincidences within longitude and formation-time tolerances he thought occurred naturally.

Claphan was secretive about his work, and had refused to submit his method for publication in the belief that a research paper by a non-professional would be rejected, but his ideas would eventually be claimed by others. This led to controversy within the ASV, and Claphan responded by denying most ASV members access to the photoheliograph. As a consequence of the dispute, the Museum transferred care of the Troughton & Simms telescope to the ASV in 1962, and insisted that the photoheliograph be removed from its building. This offended Claphan's widow, so instead of offering the instrument to the Museum—as Claphan had originally intended—she sold it at cost to Bryant and BC, who had nowhere to store it, however. It was soon on-sold at cost to the Department of Physics at Monash University, which was planning a new observatory at the time. In time, the academics involved realized that an historic specialized instrument like this could not be readily modified for the types of research intended, and its on-going storage became an increasing problem. BC repurchased the photoheliograph in 1966 (again at cost), and has stored it at home ever since (apart from a few days when it was on public display in 1974 and 1976).

7 CONCLUDING REMARKS

At the time of writing, the photoheliograph's original domed room has not had a usable telescope mounted in it for over forty years but, at last, work is just about to start on reinstallation, by courtesy of the Royal Botanic Gardens, Melbourne, present custodian of the former Melbourne Observatory site. Consideration will be given to the use of full-aperture Hα filters and CCTV as benign auxiliaries in due course. The intention is to enhance the last surviving astronomical function of the Observatory, showing visitors sights of the Universe.

The Melbourne Observatory Dallmeyer photoheliograph is one of Australia's most significant 1874 transit of Venus instruments, and but for Claphan's contentious theory it might not have survived at all. But even had it survived in different circumstances, it would probably have ended up with extensive modifications (such as the fitting of computerized drives and large-aperture lightweight Cassegrain optics for night-time use). Fortunately it *has* retained its nineteenth-century configuration unmodified, and as such is a heritage instrument of considerable national and international importance. Its preservation is now an overriding consideration.

Meanwhile, the search continues on how the Janssen Attachment came to be in Melbourne and what subsequently became of it, given the key role that this invention played in the development of motion-picture technology. It would be wonderful if the 1874 Janssen-De La Rue plates from Melbourne Observatory still exist, as they would have to be among the earliest animatable photographic sequences ever made of astronomical objects.

8 NOTES

1. Not long before, the instruments from a British eclipse expedition were presented to Melbourne Observatory by Sir Norman Lockyer "... for use hereafter in your hemisphere ..." (Ellery, 1873:9). This generous gift included "... one large long focus rectilinear photographic lens by Dallmeyer ...", which could be a description of the optical tube assembly of a photoheliograph. No record has yet been found of what happened to any of these instruments after they reached Melbourne Observatory.
2. Lucassan (2004) shows a rapid sequence photographic camera by Jules Janssen (1824–1907) and a transit of Venus. However the transit animation is not from the lost Daguerrotype plate made by Janssen in 1874 in Nagasaki but from one of three extant test plates of a simulated transit made in Paris (F. Launay, pers. comm., 2004). The mechanism of the Janssen Apparatus drove two slotted disks and the plate to give the series of exposures. De La Rue's version was less complicated.
3. The Astrographic Chart (to 14th magnitude) remains unfinished but the Catalogue (to 9th magnitude) is now available on a CD ROM called 'AC 2000.2', e.g. from the U.S. Naval Observatory, Washington DC.

9 ACKNOWLEDGEMENTS

The authors are grateful to Dr Françoise Launay (Meudon Observatory), Dr Nick Lomb (Sydney Observatory) and Bill Fiddian (Ballaarat Astronomical Society) for their assistance, and to Brian Greig for kindly providing Figure 1.

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Dr Wayne Orchiston is archivist and historian at the Australia Telescope National Facility and a Research Associate at the Anglo-Australian Observatory in Sydney. His research interests lie mainly in Cook voyage, Australian and New Zealand astronomical history, with emphasis on comets, early radio astronomy, historically-significant telescopes, the development of early astronomical groups and societies, and transits of Venus. He has published extensively, including the books *Nautical Astronomy in New Zealand. The Voyages of James Cook* (1988) and *Astronomical Instruments and Archives from the Asia-Pacific Region* (2004, co-edited by R. Stephenson, S. Débarbat and Nha Il-Seong). Wayne is a committee member and former chair of the IAU Working Group on transits of Venus.

The IAU Transits of Venus Working Group. 3: progress report

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This Progress Report follows the introductory report on the Working Group, which was published in the December 2002 *ICHA Newsletter* (pp. 30-34) and in the *Journal of Astronomical History and Heritage* (see Orchiston *et al*., 2002, below). With the up-coming June transit, it is no surprise that there has been a worldwide flurry of recent interest in transits of Venus.

As would be expected, various historic re-enactments of earlier transit observations have been arranged for June 2004. The National Trust of Australia (New South Wales) has arranged for observations to be carried out at Woodford, in the Blue Mountains west of Sydney, a site used by one of the Sydney Observatory transit expeditions in 1874. In South Africa, Willie Koorts has arranged for observations to be made at Wellington, the site where the 1882 US transit party was based, and where women from the Huguenot Seminary for Girls also carried out observations. From Touws River (known as Montagu Road until 1883), the site of the 1882 British expedition to South Africa, the local tourism office is busy arranging a Transit Festival and observations from this site, where the hand-inscribed piers of the expedition have survived. At the former "Royal Observatory" in Cape Town, where David Gill observed the transit, re-enactments are planned, which will involve the public and particularly school groups. Sara Schechner (Curator of Harvard University's Collection of Historical Scientific Instruments) is organizing a re-enactment at Harvard of John Winthrop's observations of the 1769 transit of Venus from Cambridge (Mass.). Winthrop also observed the 1761 transit (from Newfoundland), and some of the instruments from both transits may be used in the re-enactment. Meanwhile, Rolf Willach (Switzerland) is planning to view the transit through an historic eighteenth century heliometer.

Peter Broughton (Canada) has compiled a list of transit of Venus plaques, with the aid of various colleagues around the world, and on 2003 March 22 provided a list on H-ASTRO. Since then, others have supplied further examples, and we end up with the following list:

- 1639: Horrocks, at Carr House, near Much Hoole, UK
- 1639: Crabtree, in 'The Cliff' district of Manchester, UK
- 1769: French-Spanish expedition, in the Casa del Cultura, San Jose del Cabo, Baja California Sur, Mexico
- 1769: Cook, at Venus Point, Tahiti
- 1874: US expedition, in Queenstown, New Zealand

1874: British expedition, at the Hulihee Palace, Kailua-Kona, Hawaii
1882: German expedition, at Trinity College, Hartford, Conn., USA
1882: British expedition, at the All Saints Garrison Church, Burnham, New Zealand
1882: Marth, Stevens and Thornton, in Touws River, South Africa
1882: On the summit of Transit Hill, Lord Howe Island, Australia

Peter Broughton also reports that "... a plaque will definitely be erected in St. John's, Newfoundland, to recognize the observations near there by John Winthrop on 6 June 1761 ... the initiative is coming from the RAS of Canada ... [and] Professor Frederick Smith of the Memorial University of Newfoundland has determined the site as Kenmount Hill (see JRASC, **97**:291 for details)." Meanwhile, in South Africa, Willie Koorts and some colleagues plan to install a plaque and sundial at Wellington, South Africa, to commemorate transit of Venus observations made there in 1882.

Various museums, observatories, planetariums, and science centres have arranged special transit of Venus displays, and in addition to those already mentioned in the previous report these include an exhibit titled "Chasing Venus: observing the transits of Venus, 1631–2004" which opened at the National Museum of American History in Washington, D.C., on March 23. This was organized by the Smithsonian Libraries, with support from the Peter Gruber Foundation, NASA, and the U.S. Naval Observatory. At Harvard, Sara Schechner is organizing a display for the permanent gallery featuring instruments used by John Winthrop and Harvard students to observe the 1761 and 1769 transits, and both the National Trust's Woodford Academy in Australia and the Wellington Museum in South Africa are busy planning temporary transit of Venus displays. NASA organized a Sun-Earth day on 19 March, in connection with the upcoming transit of Venus, and the following web site contains details of the various activities:

http://www.sunearth.gsfc.nasa.gov/sunearthday/2004/index_vthome.htm

There is also a plethora of transit of Venus special lectures, seminars, workshops and conferences. The key conference is IAU Colloquium 196 "Transits of Venus: New Views of the Solar System and Galaxy", organized by Gordon Bromage and Don Kurtz from the University of Central Lancashire in Preston, UK (where the Conference will be held). C41/ICHA is well-represented, with Suzanne Débarbat (France), Steven Dick (USA), Julieta Fierro (Mexico), Wayne Orchiston (Australia), Jay Pasachoff (USA), and Luisa Pigatto (Italy) on the Scientific Organising Committee; Peter Hingley (UK) on the Local Organising Committee; Allan Chapman (UK) as a Keynote Speaker; and Steven Dick, Wayne Orchiston and Richard Strom (Netherlands) as Invited Speakers. For further details of this Conference see the following web site:

http://www.transit-of-venus.org.uk/conference

Immediately prior to the IAU Colloquium, Paul Marston (also from the University of Central Lancashire) has organized a weekend residential conference on "Jeremiah Horrocks and Transits Ancient and Modern" for amateur astronomers and interested members of the general public. C41/ICHA members speaking at this event are Allan Chapman, Mary Brück (Scotland), and Wayne Orchiston.

On 2004 January 9 a seminar was held in Germany to mark the 65th birthday of Dieter B Hermann, Director of the Archenhold Observatory and a renowned astronomical historian, and Hilmar Duerbeck gave a paper on "Big science at the Kaiser's time: the German Venus transit expeditions". Each year, Sydney Observatory features its prestigious annual *By the Light of the Southern Stars Lecture*, and on 2004 March 26 Wayne Orchiston lectured on "Transits of Venus: Uncovering the Human Face of History". Last September he gave a paper on Cook's 1769 transit expedition at the Annual Convention of the Antique Telescope Society in Denver (USA), and the following month presented a research seminar at the University of Washington (Seattle) on the 1769 and 1874 transits. On May 7 the Australian Science History Club will hold a one-day seminar on "The Transit of Venus" at Sydney Observatory, and speakers include Wayne Orchiston and Nick Lomb (C41/ICHA member, and Curator of Astronomy at the Observatory). On June 1, a transit of Venus colloquium will be held in Utrecht, Holland, and in South Africa, an international conference will be held in the Pilanesberg National Reserve to coincide with the transit. A public lecture is planned for nearby Sun City the night before the transit, which will then be viewed from the Bakubung Game Lodge (for details see: http://www.tuningfork.co.za). In July, Sara Schechner will deliver the Helen Sawyer Hogg Public Lecture of the Royal Astronomical Society of Canada and the Canadian Astronomical Society on John Winthrop and the transits of Venus.

Further to the list of references that appeared in the December 2002 *Newsletter*, other transit of Venus publications we have noted are:

Brück, H., 1992. Lord Crawford's Observatory at Dun Echt 1872-1892. *Vistas in Astronomy*, **35**:81-138 [pages 88-89 and 111 deal with the ToV expedition to Mauritius].

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Duerbeck, H.W., 2004a. The 1882 transit of Venus—as seen from Chile. *Orion*, **2**(321):10-15.

Duerbeck, H.W., 2004b. The beginnings of German governmental sponsorship in astronomy: the solar eclipse expeditions of 1868 as a prelude to the Venus transit expeditions of 1874 and 1882. In *Development of Solar Research*, 2003 Colloquium of the Working Group for the History of Astronomy, in press.

Duerbeck, H.W., 2004c. Venusdurchgänge zu Kaisers Zeiten: die Deutschen Expeditionen von 1874 und 1882. *Sterne und Weltraum*, **43**(June): 34-40.

Gent, R. van, 1993a. De Nederlandse Venus-expedities van 1874 en 1882. *Zenit*, **20**:332-337.

Gent, R. van, 1993b. *De reizende astronoom: Nederlandse sterrenkundige expedities naar de Oost en de West*. Leiden, Museum Boerhaave.

Hudon, D., 2004. A (not so) brief history of the transits of Venus. *Journal of the Royal Astronomical Society of Canada*, **98** (6), in press.

Koorts, W.P., 2003. The 1882 transit of Venus and the Huguenot Seminary for Girls. *Monthly Notices of the Astronomical Society of South Africa*, **62**:198-211.

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McDonald, P., 2002. The transit of Venus on 2004 June 8. *Journal of the British Astronomical Association*, **112**:319-324.

Orchiston, W., 2004. New South Wales observations of the 1874 transit of Venus. *Anglo-Australian Observatory Newsletter*, **104**:12-14.

Orchiston, W., Dick, S., Gurshtein, A., and Pigatto, L., 2002. The C41/ICHA Transits of Venus Working Group. 1: An introduction. *Journal of Astronomical History and Heritage*, **5**:185-188.

Simaan, A., 2002. *La Science au Péril de sa Vie. Les Aventuriers de la Mesure du Monde*. Paris, Vuibert & Adapt [a section of this book deals with the French 1761 and 1769 transit of Venus expeditions].

Simaan, A., Blamont, J., Cannat, G., Delaye, Y., Laudon, M., Luminet, J.-P., Sellers, D., et Roode, S. M. van, 2003. *Vénus Devant le Soleil. Comprendre et Observer un Phénomène Astronomique*. Paris, Vuibert & Adapt.

Smith, F.R., 2003. Observation of the 1761 transit of Venus from St. John's, Newfoundland. *Journal of the Royal Astronomical Society of Canada*, **97**: 291-293.

Young, A.T., 2001. Venus and refraction. *The Observatory*, **121**:176-178 [about contact timings and the 'black drop' effect].

Zuidervaart, H., 1999. *Van 'Konstgenoten' em Hemelse Fenomenen: Nederlandse Sterrenkunde in de Achttiende Eeuw*. Rotterdam, Erasmus Publishing [Ph.D. Thesis, University of Utrecht; the transits are treated in Chapters 12-17].

The 2004 June issue of the *Journal of Astronomical History and Heritage* will be devoted to transits of Venus, and will contain the following papers:

Clark, B.A.J. and Orchiston, W. The Melbourne Observatory Dallmeyer photoheliograph and the 1874 transit of Venus.

Duerbeck, H.W. The German transit expeditions of 1874 and 1882: organization, methods, stations, results.

Edwards, P. Charles Todd's observations of the 1874 and 1882 transits of Venus.

Orchiston, W., and Buchanan, A. 'The Grange', Tasmania: survival of a unique suite of 1874 transit of Venus relics.

Pigatto, L. and Zanini, V. The 1882 transit of Venus observed in Italian observatories.

Sterken, C., and Duerbeck, H.W. The 1882 Belgian transit of Venus expeditions to Texas and Chile—a reappraisal.

All of these papers (except Clark and Orchiston) derive from the WG4 (Transits of Venus) meeting at the 2003 July General Assembly of the IAU in Sydney.

Meanwhile, the next issue of the *Journal of Astronomical Data* (*JAD* 10, to appear at the end of 2004) will have a special Transit of Venus section. Foreseen contributions are:

Gent, R.H. van. Transits of Venus bibliography.

Misch, A. & Sheehan, W. The 1882 transit of Venus reanimated.

Orchiston, W. The nineteenth century transits of Venus: an Australian and New Zealand overview.

These are provisional titles and have yet to be finalized. Since *JAD* is issued on CD, contributions containing extensive observational data, tables, colour and B&W images, archive listings, etc., are especially welcome, but also standard historical articles are accepted. Since the papers go through a refereeing process, submission before July 1 is encouraged, but late submissions are possible if the editors are informed about the contents and approximate size of the contribution by July 1. The editors are Chris Sterken (csterken@vub.ac.be) and Hilmar Duerbeck (hduerbec@vub.ac.be).

Those wanting to find already-published papers about different transits of Venus should consult the excellent bibliography prepared by Robert van Gent:

http://www.phys.uu.nl/~vgent/venus/venustransitbib.htm.

And for a comprehensive transits of Venus web site, with plenty of historical information, readers are referred to the following URL:

http://www.transitofvenus.org

In the previous Newsletter we erroneously reported that the Scientific Instruments Society was jointly developing a transit of Venus web site. In fact, this web site is the work of the SIC Transit of Venus Committee of the Scientific Instrument Commission of the IUHPS/DHS. We regret this error, and look forward to working closely with the Commission and its Committee. Sara Schechner reports that the web site is still under construction, and contains a searchable database of linked instruments, people, places, and transits with relevant photographs. The site is organized as follows, and encourages people to contribute to it:

- Introduction—what is a transit of Venus, and who observe it?
- Stories—highlights from our resources
- Browse—explore the online collection through categories, people, places, and dates
- Search—a free-text search for detailed questions
- Links—online resources, museum exhibits and events, and web sites devoted to the 2004 transit of Venus
- Contributors—view the contributors to the site and find out how to add your own resources to this web site.

The IAU Historic Radio Astronomy Working Group. 1: progress Report

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This new Working Group was established at the 2003 July IAU General Assembly in Sydney, with a view to:

(1) assembling a master list of surviving historically-significant radio telescopes and associated instrumentation found world-wide;
(2) documenting the technical specifications and scientific achievements of such instruments;
(3) maintaining an on-going bibliography of publications on the history of radio astronomy;
(4) monitoring other developments relating to the history of radio astronomy.

This was a joint initiative of Commissions 40 (Radio Astronomy) and 41 (History of Astronomy), and as such the new WG comes under the umbrella of both Commissions and Divisions X and XII.

Coincident with the formation of the WG at the General Assembly were 1.5 days of meetings about the history of radio astronomy, organized jointly by Commissions 40 and 41. Given Australia's pioneering efforts in international radio astronomy, it was only natural that such sessions should form part of the programme at the Sydney GA, and it was pleasing to see that they drew capacity audiences. Science Meeting 2, on "The Early Development of Australian Radio Astronomy", ran all day on July 21, and attracted the following oral and poster papers:

Sullivan, W. A half-century of Australian radio astronomy, 1939-1988: from wartime radar to the Australia Telescope.
Minnett, H. Fifty years of radio science and its applications.
Murray, J. The Penrith and Dapto solar radio spectrographs.
Robinson, B. Joe Pawsey and his influence on the development of Australian radio astronomy.
Slee, B. Early Australian measurements of radio source structure.
Robinson, B. Early observations of the H-line in Sydney.
Murray, J. Development of the Murraybank multi-channel H-line receiver.
McLean, D. The solar radio astronomy program at Culgoora: an historical overview.

Suzuki, S. The Culgoora Spectropolarimeter.
Duncan, R.A. History of the determination of Jupiter's rotation period.
McAdam, B. From Molonglo Cross to MOST: a scientific appraisal.
Batchelor, B., Brooks, J., & Sinclair, M. Receiver development for the Parkes Radio Telescope.
Milne, D., & Whiteoak, J. The impact of Frank Gardner on the first years of research with the Parkes Radio Telescope.
Finlay, E., & Jones, B. The 30 MHz array at Fleurs.
Robinson, B. URSI (Sydney) 1952: the first international meeting of radio astronomers.

Most of these papers dealt with the work at the various CSIRO Division of Radiophysics field stations and at Parkes, although Bruce McAdam gave an excellent review paper about the University of Sydney's Molonglo Cross. Apart from Woody Sullivan's introductory overview—which effectively set the scene for the day—all of the papers were prepared by retired radio astronomers who were actively involved in Australian radio astronomy at one time or another during the period 1945–1988. In addition to the various papers, a video about Grote Reber was screened during lunchtime. This Science Meeting was organized by Miller Goss, Dave Jauncey, Ken Kellermann, Wayne Orchiston (Co-Chair), and Woody Sullivan (Co-Chair).

For those wanting yet more, Wayne Orchiston and Bruce Slee organized Science Meeting 5 on "Pioneering Observations in Radio Astronomy", which was held on the morning of July 22. This featured the following oral and poster papers:

Kellermann, K. Grote Reber: maverick scientist and father of radio astronomy.
Radhakrishnan, V. Olof Rydbeck and early radio astronomy in Sweden.
Sullivan, W Wurzburg dishes: German WWII radar antennas vital to early radio astronomy in every country but Germany (and Australia).
Orchiston W. Dr Elizabeth Alexander: first female radio astronomer?
Goss, M. Ruby Payne-Scott (1912-1981): Australian pioneer in radiophysics and radio astronomy.
Kardashev, N. and Matvennko, L.I. The early development of USSR radio astronomy.
Goss, M., McGee, R., and Slee, B. The discoveries of Sagittarius A in New South Wales in 1951 and Sagittarius A* in West Virginia in 1974.
Morimoto, M. Early Japanese mm-wave observations and their impact on international radio astronomy.
Débarbat, S. Fifty years of radio astronomy in France.
Jauncey, D., Lovell, J.E.J., Koyama, Y., Fey, A.L., Edwards, P.G., Aller, M.F., Aller, H.D., Klein, M.J. and the GAVRT Team. Interstellar scintillation observations: back to the future.
Orchiston, W., Chapman, J., Parsons, B., Sharp, P., Slee, B. and Wilcockson, B. Interpretation of the historic Dover Heights field station: an ATNF heritage project.

In addition to the two specialized sessions mentioned above, other historic radio astronomy papers were given in Science Meeting 1 (on a possible 500–2000 yr. old SN in the Crux-Centaurus region recorded in Maori 'star lore'), and Working Group Meeting 1 (an account of the ATNF's Historic Photographic Archive and development of a digital database). It is hoped that all Australian-related papers from these various meetings will be brought together in a book.

Meanwhile, publications on the history of radio astronomy that have appeared since 1998 include:

Birthday dish [40th Birthday of the Parkes Radio Telescope]. *Sky & Space*, **14**(5):18-27 (2001).

Bracewell, R.A., 2002. The discovery of strong extragalactic polarization using the Parkes Radio Telescope. *Journal of Astronomical History and Heritage*, **5**:107-114.

Davies, R.D., 2003. Fred Hoyle and Manchester. *Astrophysics and Space Science*, **285**:309-319.

Finley, D.G., and Goss, W.M. (eds.), 2000. *Radio Interferometry: The Saga and the Science*. Green Bank, National Radio Astronomy Observatory (Workshop Number 27).

Kellermann, K.I., and Moran, J.M., 2001. The development of high-resolution imaging in radio astronomy. *Annual Review of Astronomy and Astrophysics*, **39**:457-509.

Menon, T.K., 2001. The discovery of the first HI shell in the Galaxy. In A.R. Taylor, T.L. Landecker and A.G. Willis (eds.). *Seeing Through the Dust. The Detection of HI and the Exploration of the ISM in Galaxies*. San Francisco, ASP (Conference Series, Volume 276). Pp. 23-26.

Moran, J.M., 1998. Thirty years of VLBI: early days, successes, and future. In J.A. Zensus, G.B. Taylor and J.M. Wrobel (eds.). *Radio Emission from Galactic and Extragalactic Compact Sources*. San Francisco, ASP (Conference Series Volume 144). Pp. 1-10.

Orchiston, W., 2001. Focus on history of Australian radio astronomy. *ATNF News*, **45**:12-15.

Orchiston, W., 2004a. From the solar corona to clusters of galaxies: the radio astronomy of Bruce Slee. *Publications of the Astronomical Society of Australia*, **21**:23-71.

Orchiston, W., 2004b. Radio astronomy at the short-lived Georges Heights field-station. *ATNF News*, **52**:8-9.

Orchiston, W., 2004c. The rise and fall of the Chris Cross: a pioneering Australian radio telescope. In W. Orchiston, R. Stephenson, S. Débarbat and I-S. Nha (eds.). *Astronomical Archives and Instruments in the Asia-Pacific Region*. Seoul, Yonsei University Press. Pp. 157-162.

Orchiston, W., and Slee, B., 2002a. The Australasian discovery of solar radio emission. *AAO Newsletter*, **101**:25-27.

Orchiston, W., and Slee, B., 2002b. The flowering of Fleurs: an interesting interlude in Australian radio astronomy. *ATNF News*, **47**:12-15.

Orchiston, W., and Slee, B., 2002c. Ingenuity and initiative in Australian radio astronomy: the Dover Heights hole-in-the-ground antenna. *Journal of Astronomical History and Heritage*, **5**:21-34.

Orchiston, W., Chapman, J., and Norris, B., 2004. The ATNF Historic Photographic Archive: documenting the history of Australian radio astronomy. In W. Orchiston, R. Stephenson, S. Débarbat and I-S. Nha (eds.). *Astronomical Archives and Instruments in the Asia-Pacific Region*. Seoul, Yonsei University Press. Pp. 41-48.

Radhakrishnan, V., 2001. The first twenty years. In A.R. Taylor, T.L. Landecker and A.G. Willis, (eds.). *Seeing Through the Dust. The Detection of HI and the Exploration of the ISM in Galaxies*. San Francisco, ASP (Conference Series, Volume 276). Pp. 6-18.

Robinson, B., 1999. Frequency allocation: the first forty years. *Annual Review of Astronomy and Astrophysics*, 37, 65-96.

Robinson, B., 2001. Reminiscences of early 21-cm research at the C.S.I.R.O. In A.R. Taylor, T.L. Landecker and A.G. Willis, (eds.). *Seeing Through the Dust. The Detection of HI and the Exploration of the ISM in Galaxies*. San Francisco, ASP (Conference Series, Volume 276). Pp. 19-22.

Robinson, B., 2002. Recollections of the URSI 10th General Assembly Sydney 1952. *The Radio Science Bulletin*, 300, 22-30.

Steinberg, J.-L., 2004. Les cinquante ans de Nançay. *L'Astronomie*, **118**:5-9.

Sullivan, W.T., 2000. Kapteyn's influence on the style and content of twentieth century Dutch astronomy. In P.C. van der Kruit and K. van Berkel (eds.). *The Legacy of J.C. Kapteyn*. Dordrecht, Kluwer. Pp. 229-264.

Sullivan, W.T., 2001. The cultural value of radio astronomy. In R.J. Cohen and W.T. III Sullivan (eds.). *Preserving the Astronomical Sky*. San Francisco, ASP. Pp. 369-376.

Tarter, J., 2001. The search for extraterrestrial intelligence (SETI). *Annual Review of Astronomy and Astrophysics*, **39**:511-548.

Westerhout, G., 2001a. The pioneers of HI. In A.R. Taylor, L T. Landecker and A.G. Willis (eds.). *Seeing Through the Dust. The Detection of HI and the Exploration of the ISM in Galaxies*. San Francisco, ASP (Conference Series, Volume 276). Pp. 3-5.

Westerhout, G., 2001b. The start of 21-cm line research: the early Dutch years. In A.R. Taylor, T.L. Landecker and A.G. Willis (eds.). *Seeing Through the Dust. The Detection of HI and the Exploration of the ISM in Galaxies*. San Francisco, ASP (Conference Series, Volume 276). Pp. 27-33.

We are keen to build up a definitive bibliography on the history of radio astronomy, and would like to hear of other recent publications—particularly in languages other than English—which are not included in the above list (e-mail details to: Wayne.Orchiston@csiro.au).

An up-coming conference with a significant historical radio astronomy component is "The New Astronomy: Opening the Electromagnetic Window and Expanding our View of Planet Earth. A Meeting to Honor Woody Sullivan on his 60th Birthday". This will be held at the University of Washington, Seattle, from 16 to 18 June 2004, and a separate notice (including the URL of the web site) appears elsewhere in this report. Confirmed contributors of radio astronomy or SETI-type papers are Bruce Balick, Ron Bracewell, Chris Chyba, Marshall Cohen, Steve Dick, Frank Drake, Miller Goss, Mott Greene, Alastair Gunn, Karl Hufbauer, Richard Jarrell, Ken Kellermann, Wayne Orchiston and Bruce Slee, Richard Strom, and Dan Werthimer.

With the passing of the years, increasing numbers of radio astronomy pioneers are being taken from us. Those who have died within the last three years include Semion Braude (Ukraine), Frank Gardner (Australia), Robert Hanbury Brown (UK and Australia), Victor Hughes (UK and Canada), Harry Minnett (Australia), Grote Reber (USA and Australia), Gordon Stanley (Australia and USA), Kevin Westfold (Australia), and Don Yabsley (Australia). Obituaries for Gardner and Minnett are in active preparation, while for Hanbury Brown, Reber, Stanley, Westfold and Yabsley refer to the following publications:

Browne, G., and Burge, E., 2001-2002. Kevin Charles Westfold 24 August 1921–3 October 2001. *Trinity Today*, Number 59 [Electronic Newsletter of Trinity College, University of Melbourne. URL: http://www.trinity.unimelb.edu.au/publications /trinitytoday/].

Hanbury Brown, R., 1991. *Boffin. A Personal Story of the Early Days of Radar, Radio Astronomy and Quantum Optics*. Bristol, Adam Hilger.

Kellermann, K., 2003. Obituaries: Gordon James Stanley. *Physics Today*, **56**(2):74-75.

Kellermann, K., 2003. Obituaries: Grote Reber, 1911–2002. *Bulletin of the American Astronomical Society*, **35**:1472-1473.

Kellermann, K.I., 2003. Obituary. Grote Reber (1911-2002). *Nature*, **421**:596.

Kellermann, K.I., Orchiston, W., and Slee, B., n.d. Gordon James Stanley and the early development of radio astronomy in Australia and California. Submitted to *Publications of the Astronomical Society of Australia*.

Orchiston, W., 2004. Solar radio astronomy at the short-lived Georges Heights field station. *ATNF News*, **52**:8-9. [About Lehany and Yabsley]

Orchiston, W., and Slee, B., 2002. Vale Gordon Stanley. *ATNF News*, **46**:3.

Tyson, J.A.., 2003. Obituaries: Grote Reber. *Physics Today*, **56**(8):63-64.

Hanbury Brown's autobiography is captivating reading, and far more scintillating than any obituary!

Semion Braude was Ukraine's foremost radio astronomer, and Gregory Tsarevsky kindly arranged for his colleagues to provide us with biographical notes which were used in compiling the following brief account.

> Semion Yakovych Braude was born on 28 January 1911 in Poltava, Ukraine, and in 1932 graduated from the Kharkov Institute of Physics, Chemistry and Mathematics (now the Kharkov National University), where he had studied physics. He subsequently obtained a Ph.D. (1937) and Doctor of Technics (1943). From 1933 until 1955 he worked at the Institute of Physics and Technology of the Academy of Sciences of Ukraine, rising to Department Head (1949-1955). In 1955 he was appointed Scientific Deputy Director of the Institute of Radio Physics and Electronics Engineering, NASU, and from 1980 to 1987 was Head of the Department. From 1987 until his death he was a Councillor for the Directorship of the Institute.
>
> Braude's initial research fields were radio-location and radio-oceanography, but in 1957 he turned his attention to radio astronomy. He then established an observatory in the Kharkov region where he and his colleagues erected a number of high-yield broadband decametric radio telescopes, the largest and best-known being the UTR-2. He

was behind the URAN Project, which involved a VLBI network of decametric antennas that was used for a high-resolution survey of selected radio sources. He was an important pioneer in decametric radio astronomy.

Over the years, Professor Braude published more than 270 monographs and papers, and received many honours from both the Ukraine and the USSR. He was a man of talent, wide erudition, inexhaustible energy and capacity to work, rare charm and kindness. He was sociable and witty, and will be remembered by everyone who was lucky to commune with him. With his passing, on 29 June 2003 at the age of 92, the scientific community lost an outstanding radio astronomer.

Finally, like other C40 members we were shocked to hear of Lucia Padrielli's death on 22 December 2003. Lucia was Chair of Commission 40 when plans for the formation of our WG were in train, and she gave us her whole-hearted support and encouragement. We extend our condolences to her family, her colleagues and her institute.

The IAU Historical Instruments Working Group. 1: progress report 2003–2004

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A key development since the WG3 (Historical Instruments) Working Group meeting was held at the 2003 July IAU General Assembly in Sydney is that the Board of the Antique Telescope Society has kindly agreed to publish some of the papers from that meeting in 2004 and 2005 issues of the *Journal of the Antique Telescope Society (JATS)*. The following authors plan to submit their papers to *JATS*:

- Johnson, K. A glimpse at the astronomy heritage of the Science Museum, London.
- Kaptüg, V.B., Chubey, M.S., Vereshchagin, S.A., and Sokolov, Y.A. On recovery and research work at the Russian Struve station on Gogland.
- Lomb, N. Historically significant astronomical instruments at Sydney Observatory.
- Nakamura, T. Early historic telescopes preserved in Japan.
- Orchiston, W. History of the 'Catts Telescope': a nineteenth century 20-inch Grubb reflector.
- Pigatto, L., Tomasella, L., and Zanini, V. Telescopes at the Astronomical Observatory of Padova, Italy. From the last refractor to the first reflector.
- Shankland, P.D., and Orchiston, W. Lost and found: saga of the historic Clark refractor at the U.S. Naval Academy.
- Watson, F. James Gregory and the invention of the Cassegrain telescope.

The paper by Kaptüg *et al.* has special significance to C41/ICHA as it relates to the IAU resolution passed in 1994 about identification, documentation, and preservation of surviving instruments and sites connected with the measurement of the arc of the meridian made by F G W Struve. For an overview of this important project, which is co-ordinated by the International Institution for the History of Surveying & Measurement, see Jim Smith's article on pages 38-42 in *ICHA Newsletter* No. 4 (December 2002).

A recent publication of interest to Working Group members is *Astronomical Instruments and Archives From the Asia-Pacific Region* (2004), details of which appear elsewhere in this report. Included are nine papers on ancient astronomical instruments from China, India, Indonesia and Korea, an astrolabe in the National History Museum in Mexico City, and nineteenth century optical and radio telescopes from Canada and Australia, respectively.

One of the papers in the above-mentioned book is by Sarah Nha (a daughter of Working Group Chair, Professor Nha Il-Seong), and deals with the web site set up by our Working Group to inventory historically-significant astronomical instruments world-wide. The URL is:

http://www.nhamuseum.org/WG

Although members of the new Committee (approved at the Sydney IAU General Assembly) are currently in the process of making some structural modifications to the web site, any C41/ICHA member who has relevant information on historically-significant astronomical instruments is encouraged to contact Sarah Nha and discuss including these instruments in the database. Her e-mail address is: christin@chollian.net

As a policy decision, Committee members of the Working Group have decided to attend various astronomical and scientific instrument meetings during the current IAU triennium, and describe the Working Group's research programme and the database. Wayne Orchiston presented the first of these papers when he attended the 2003 Annual Convention of the Antique Telescope Society, in Denver (USA). His PowerPoint presentation is available upon request (e-mail: wo@aaoepp.aao.gov.au), but be warned, it is a 10Mb file that contains many coloured images.

The 2000–2003 Triennial Report of C41/ICHA published in *ICHA Newsletter* No. 4 (December 2002) included a list of references dealing with historic astronomical instruments published during that period. Relevant books and papers published since that list was prepared include:

Ackermann, S., 2003. Light on Byzantium – a universal sundial in the British Museum. In C. Entwistle (ed.). *Through a Glass Brightly – Studies in Byzantine and Medieval Art and Archaeology Presented to David Buckton*. Oxford, Oxbow Books. Pp. 16-21.

Beech, M., 2002. The mechanics of cometaria. *Journal of Astronomical History and Heritage*, **5**:155-163.

Beretta, M., Galluzzi, P., and Triarico, C. (eds.), 2003. *Musa Musaei. Studies on Scientific Instruments and Collections in Honour of Mara Miniati.* Florence, Biblioteca di Nuncius Studi e Testi XLIX. [This contains many relevant papers.]

Bobis, L., and Lequeux, J., 2003. *François Arago & l'Observatoire de Paris*. Paris, Obervatoire de Paris.

Bonoli, F., Miniati, M., Greco, V., and Molesini, G., 2002. Telescope optics of Montanari, Cellio, Campani and Bruni at the "Museo della Specola" in Bologna. *Nuncius*, **2**:467-475.

Brosche, P., 2002. Köhler's sternphotometer von 1786. *Beiträge zur Astronomiegeschichte*, **5**:152-158.

Debauvais, F., and Befort, P.-A., 2002. *Cueillier les Etoiles. Autour des Astrolabes de Strasbourg.* Strasbourg, Editions Ligne à Suivre.

Dick, S.J., 2003. *Sky and Ocean Joined. The U.S. Naval Observatory 1830-2000.* Cambridge, Cambridge University Press.

Dupré, S., 2003. Galileo's telescope and celestial light. *Journal for the History of Astronomy*, **34**:369-399.

Gaab, H., 2002. Johann Philipp von Wurzelbau (1651–1725). *Beiträge zur Astronomiegeschichte*, **5**:47-114.

Hooijmaijers, H., 2003. De omzwervingen van een telescoop. *Gewina*, **26**:40-45.

Hoskin, M.A., 2003. Herschel's 40ft Reflector: funding and functions. *Journal for the History of Astronomy*, **34**:1-32.

Le Guet Tully, F., and Sadsaoud, H., 2003. La création de l'observatoire d'Alger. *La Revue (du Museé des Arts et Métiers)*, **38**:26-35.

Lindner, R.P., 2003. Rebuilding astronomy at Michigan: from Hussey to Goldberg. *Journal of Astronomical History and Heritage*, **6**:107-119.

Maddison, R., 2003. Some typical design features of late eighteenth century Gregorian reflectors. *Journal of the Antique Telescope Society*, **25**:17-22.

Malet, A., 2003. Kepler and the telescope. *Annals of Science*, **60**:107-136.

Mörzer Bruyns, W.F.J., 2003. *Schip Recht Door Zee. De Octant in de Republiek in de achttiende eeuw.* Amsterdam, Edita Knaw.

Nankivell, G.R., 2002. The Cooke Photovisual Objective and the 22.9cm refractor at the Carter Observatory, New Zealand. *Journal of the Antique Telescope Society,* **24**:4-8.

Orchiston, W., 2002. From Crossley to Carter: the life and times of an historic Cooke refractor. *Journal of the Antique Telescope Society,* **24**:9-24.

Orchiston, W., 2003. Amateur telescope making in Australia. An historical perspective. In W.J. Cook (ed.). *The Best of Amateur Telescope Making Journal. Volume 2*. Richmond, Willmann-Bell. Pp. 208-239.

Osterbrock, D.E., 2003. Don Hendrix, master Mount Wilson and Palomar optician. *Journal of Astronomical History and Heritage*, **6**:1-12.

Pettersen, B.R., 2002. Christopher Hansteen and the first observatory at the University of Oslo, 1815–28. *Journal of Astronomical History and Heritage*, **5**:123-134.

Satterthwaite, G.E., 2003. Airy's zenith telescopes and "the birth-star of modern astronomy." *Journal of Astronomical History and Heritage*, **6**:13-26.

Shankland, P.D., and Orchiston, W., 2002. Nineteenth century astronomy at the U.S. Naval Academy. *Journal of Astronomical History and Heritage*, **5**:165-179.

Talbot, S., 2002. The astroscope by James Mann of London. The first commercial achromatic refracting telescope c.1735. *Bulletin of the Scientific Instrument Society*, **75**:6-8.

Talbot, S., 2003. The first telescope dynameter as designed and constructed by Jesse Ramsden. *Bulletin of the Scientific Instrument Society*, **77**:8-9.

Turner, A.J., 2002. The observatory and the quadrant in eighteen-century Europe. *Journal for the History of Astronomy*, **33**:373-385.

Turner, G. L'E., 2003a. The Italian-hour nocturnal. *Annals of Science*, **60**:249-268.

Turner, G. L'E., 2003b. *Renaissance Astrolabes and their Makers*. Aldershot, Ashgate Publishing.

Véron, P., 2003. L'équatorial de la tour de l'est de l'Observatoire de Paris. *Revue d'Histoire des Sciences*, **56**:191-220.

Whitesell, P.S., 2003. Detroit Observatory: nineteenth-century training ground for astronomers. *Journal of Astronomical History and Heritage*, **6**:69-106.

Zuidervaart, H.J., 2003. "Zo'n mooie machine, waarvan de kwaliteit door alle astronomen wordt erkend." Een biografie van een vrijwel niet gebruikte telescoop. *Gewina*, **26**:148-165.

Particularly useful are the bibliographies prepared by the Scientific Instrument Commission of the IUHPS/DHS, as these include many astronomical entries, and readers are referred to the following web site:

http://www.sic.iuhps.org/in_bibli.htm

Another invaluable resource, especially for those with an interest in the history of the telescope is the web site

http://www.europa.com/~telscope/telebibl.txt

which was assembled by C41/ICHA member and former Antique Telescope Society President, Peter Abrahams.

The IAU Historical Instruments Working Group. 2: Harvard's Collection of Historical Scientific Instruments and its astronomical treasures

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Located in the new wing of the Science Center of Harvard University, the Collection of Historical Scientific Instruments contains one of the finest university collections of its kind in the world. With close to 20,000 artifacts dating from the early fifteenth century to the present, the Collection covers a broad range of disciplines, including astronomy, navigation, horology, surveying, geology, meteorology, mathematics, physics, biology, medicine, chemistry, experimental psychology, and communications. Noteworthy among these are scientific instruments that Harvard purchased in London with the help of Benjamin Franklin in 1764 after a disastrous fire destroyed the College's philosophical apparatus in the old Harvard Hall. The historical value of the instruments is greatly enhanced by original documents preserved in the Harvard University Archives and by over 6,500 books and pamphlets in the Collection's research library that describe the purchase and use of many of the instruments.

Of particular interest to historians of astronomy are instruments used by John Winthrop, Hollis Professor of Mathematics and Natural Philosophy, to observe the Transits of Venus in 1761 from Newfoundland and 1769 from Cambridge. These include clocks, telescopes (Figure 1), heliometers, and astronomical quadrants (Figure 2). These and related instruments were also used by Winthrop's successor, Samuel Williams, to observe the total solar eclipse of 1780 (during which Williams was the first to record Bailey's beads) and to survey the boundaries between New York, Massachusetts, and Canada. The Collection also has two exquisite grand orreries by Benjamin Martin of London and Joseph Pope of Boston (Figure 3), a Martin cometarium, the largest collection of sundials in North America, some early astrolabes (Figure 4) and globes, and the earliest Hadley's quadrant known.

The work of the Harvard College Observatory during the nineteenth century is documented in the Collection by a superb group of astronomical regulators, including many by William Bond and Son that delivered standard time to New England and the railroads. We also have the Observatory's first and second meridian circles by Troughton and Simms; early photometers used by HCO Director Edward C. Pickering; Henry Draper's 28-inch, silver-coated glass mirror used in the early observations of star spectra that culminated in the Henry Draper Catalog of spectral classifications; and the tailpiece of the 24-inch Bruce Doublet telescope used to make the photographic plates of the Great Magellanic Cloud from which Henrietta Leavitt derived the period-luminosity relation of the Cepheids.

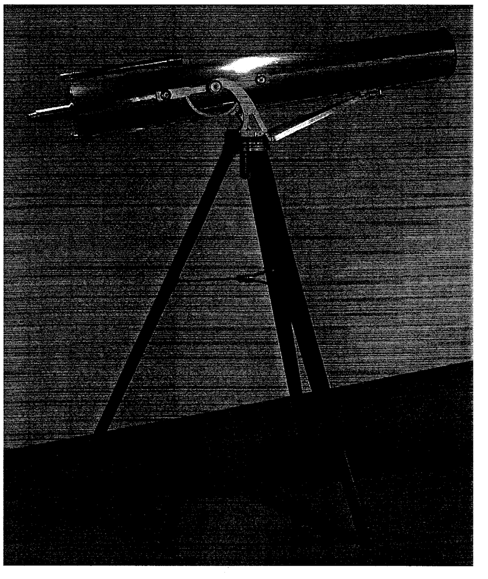

Figure 1. Four-foot Gregorian reflecting telescope made by James Short, London, *c.* 1768 under the supervision of Benjamin Franklin and used by John Winthrop to observe the transit of venus in 1769 from Cambridge, Massachusetts.

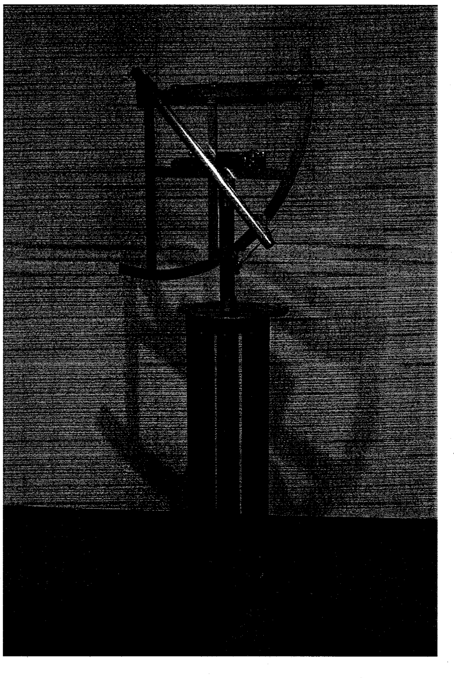

Figure 2. Astronomical quadrant by Jeremiah Sisson, London, *c.* 1765, also purchased with Franklin's help after the fire of 1764 and used by Winthrop to observe the transit of Venus in 1769.

Instruments of note from twentieth century laboratories at Harvard include the cloud chamber in which Jabez Curry Street discovered the cosmic muon (Figure 5), Theodore Lyman's spectrographs, apparatus used in the Pound-Rebka experiment to measure the gravitational redshift of light, and a spectro-heliometer designed for Sky Lab. Our collections continue to grow!

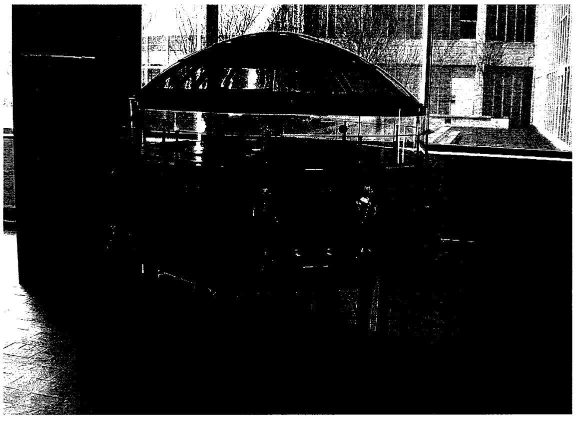

Figure 3. Grand orrery completed in 1786 after ten years of work by Boston clock maker, Joseph Pope. The cosmic sphere sits on the shoulders of cast brass figures representing Science and the State: Isaac Newton, Benjamin Franklin, and James Bowdoin (the Governor of Massachusetts). The orrery was purchased for Harvard in 1788 by public lottery.

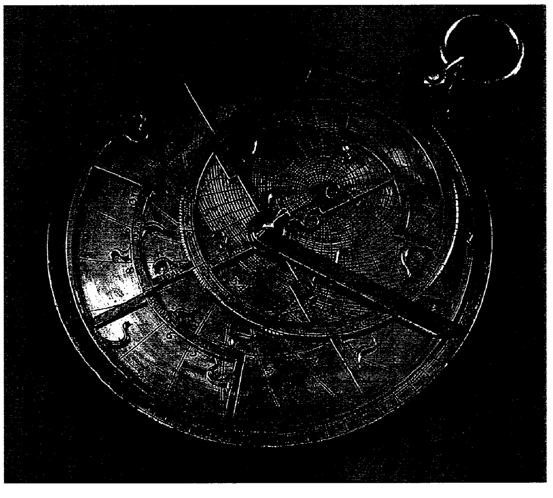

Figure 4. The oldest instrument in the CHSI is this astrolabe by Jean Fusoris, Paris, *c.* 1400.

Although Harvard University has been acquiring scientific instruments for teaching and research for over 300 years, it was not until 1947 that a serious attempt was made to preserve its historical apparatus as a resource for students and faculty. Here credit must go to David P Wheatland and I Bernard Cohen. Since the first exhibition of instruments was held in 1959, the Collection has grown rapidly both from within the University and from private donations. The Collection of Historical Scientific Instruments became affiliated with the Department of the History of Science in 1989. Like many other Harvard collections, its primary purpose is teaching and research, providing students and scholars with the opportunity to examine and work with artifacts that have made science possible.

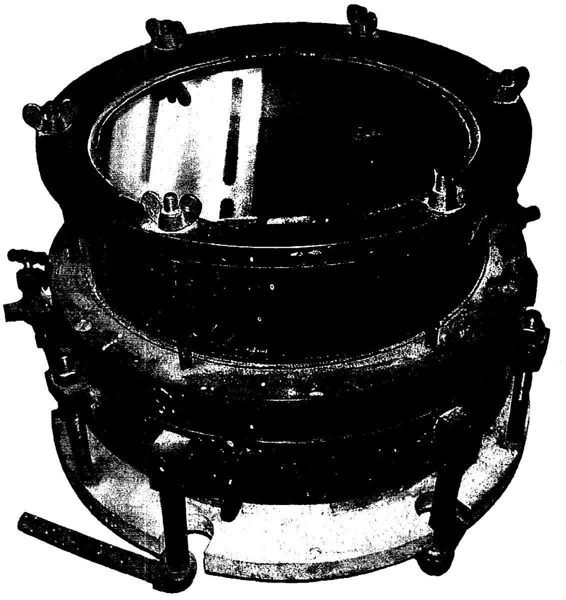

Figure 5. Cloud chamber built in 1936 by Harvard physicist, Jabez Curry Street, for the study of cosmic rays, and in which he first detected the muon.

The Collection has two public museum galleries (located in Science Center 136 and 251), a research library and instrument study room (Science Center 250), a conservation laboratory, and classroom. Curatorial offices are located in Science Center 251c. Please call ahead (617-495-2779) for library and gallery hours. We are wheelchair-accessible.

For more information, please contact the author.

The IAU Astronomical Archives Working Group. 2: progress report

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One of the features of the 2003 July IAU General Assembly in Sydney was a half-day meeting devoted to astronomical archives. The WG1 Meeting attracted a good audience, and featured the following papers.

Jessica Chapman presented a paper co-authored by Wayne Orchiston and Barnaby Norris about the Historic Photographic Archive at the Australia Telescope National Facility (ATNF) in Sydney. This contains a unique photographic record of the development of radio astronomy in Australia from 1945 to the present day, as seen through the eyes of the photographers at the CSIRO's Division of Radiophysics and later the ATNF. After summarizing the types of images preserved in the collection, Jessica discussed the current project to create a digital library of the most important images.

Brenda Corbin could not come to Sydney, so Steven Dick presented her paper about recent projects concerning the archives at the U.S. Naval Observatory. Brenda discussed the interest shown by people in the Library, partly as a result of the up-coming transits of Venus, and she discussed the Observatory's involvement in the 1874 and 1882 transits. Photography occupied a special place at this time, and she noted that some of the original plates are preserved at the Observatory. For further information, Brenda can be reached at: corbin.brenda@usno.navy.mil

Adam Perkins (Cambridge University Library) also was unable to attend the General Assembly, so his paper was represented by Richard Stephenson. Adam began by recalling what happened to the Royal Greenwich Observatory archival collection after it was moved from Herstmonceux to Cambridge just prior to the close of the Observatory. The RGO Archives span more than three centuries, and are now the responsibility of the Library's Department of Manuscripts. The collection includes documents from various overseas observatories, and many important record lots, including the Board of Longitudes archives and the Airy papers. More information about this important collection can be obtained from Adam (email: ajp21@cam.ac.uk).

Wayne Orchiston presented a paper about the Tebbutt Collection in the Mitchell Library, which is part of the State Library of New South Wales in Sydney. Although he was amateur, Tebbutt was Australia's foremost nineteenth century astronomer, and he carried out an amazing range of observations, published prolifically, and maintained a voluminous correspondence with amateur and professional astronomers from around the world. Tebbutt's records are an invaluable resource for those researching the history of Australian astronomy during the period 1850-1915, but they also throw useful light on aspects on overseas astronomy. Wayne discussed the different types of records found in the Tebbutt Collection, and gave various examples of how data in different records could be used for historical research.

Tsuko Nakamura gave a paper on the current status of the project to establish a general inventory of astronomical archives preserved in Japan. Till now, the project has focussed on archives predating 1870, but in the future it will be expanded to cover more recent records. Many of the early archives are in the form of hand-written documents. A book has already been published about the project, and it is hoped that another progress report will be given at the Prague General Assembly in 2006. In the interim, Tsuko is happy to provide further information (e-mail him at: tsuko@cc.nao.ac.jp).

Suzanne Débarbat and Laurence Bobis (the Curator at Paris Observatory) discussed the "Alidade Project", which was initiated by Nandou Daliès, one of their predecessors. The idea was to establish an inventory of astronomical archives in French repositories, and this project has been carried out in collaboration with other relevant institutions, such as the Académie des Sciences. A recent development has been the application of computers to this Project. The inventory for the Paris Observatory is more or less complete, and can be found at the following web site: La.Bibliotheque@obspm.fr

Luisa Pigatto presented a paper she prepared with Maurizio Salmaso and Valeria Zanini on the letters written by Laurenzoni and Tacchini during the period 1870-1904 and preserved in the archives of Padova Observatory. Both scientists were well-known, particularly in the field of solar astronomy, and along with Secchi played an important part in the development of astrophysics. From the letters, the authors were able to show how this field evolved in Italy during the second half of the nineteenth century, and they emphasized the value of such archives in making better known certain facts concerning some important events.

Magda Stavinchi presented a paper that she and V Mioc prepared about how, in Romania, monasteries have served a vital role in the long-term preservation of astronomical archives. They gave examples of some of the notable archives found in these monasteries, mostly located in the northern part of the country, and noted that such archives mainly record astronomical events that were observed in Romania.

Mary Brück and Karen Moran (the Librarian at the Royal Observatory Edinburgh) prepared a poster paper about the Crawford Collection at the Observatory. This contains around five thousand items, including many old documents and rare books. Most of the collection came to the Observatory as a gift from the 26th Earl of Crawford; other acquisitions derived from Babbage, of computer fame. For more information about the Crawford Collection and the ROE Library contact Karen (e-mail: ksm@roe.ac.uk).

Iralki Simonia prepared a poster about astronomical archives preserved in Georgian institutions. These include some very old documents, with contain a range of information that could be of use to historians of astronomy. Irakli's poster included a number examples, supported by photographs of selected pages from some of the manuscripts.

A key development since the Sydney General Assembly is that Dr Chris Sterken and Professor Hilmar Duerbeck have kindly agreed to publish papers from the Archives WG Meeting in a 2004 issue of the *Journal of Astronomical Data (JAD)*, along with some of the papers from the archives session at the 2000 Manchester GA. *JAD* is an electronic journal, and can be accessed via the following web site:

http://www.vub.ac.be/STER/JAD

The journal is also issued annually on a CD, and at this stage, the following authors have already agreed to submit their papers to *JAD*:

Ansari, R. Astronomical archives in India.

Corbin, B. Archives in the U.S. Naval Observatory—recent projects.

Débarbat, S., and Bobis, L. The Alidade Project — work in progress.

Dick, W. German astronomical archives.

Moran, K., and Brück, M. The Crawford Collection at the Royal Observatory Edinburgh.

Nakamura, T. Progress report on the Japanese astronomical archives project.

Orchiston, W. An introduction to the astronomical archives of Australia and New Zealand.

Orchiston, W. Highlighting the history of Australia astronomy: the Tebbutt Collection in the Mitchell Library, Sydney.

Pigatto, L., Salmaso, M. and Zanini, V. The Lorenzoni-Tacchiini correspondence in the Padova Observatory Archive. The 'true' history of Italian astronomy in the second half of the nineteenth century.

Simonia, I. Old Georgian astronomical manuscripts.

Stavinschi, M. and Mioc, V. Storing astronomical information in the Romanian territory.

Wilkins, G. The archives of the Norman Lockyer Observatory.

Meanwhile, we have noticed the following recently-published papers about astronomical archives:

Ansari, R., 2002. Practical astronomy in Indo-Persian sources. *'Indian Journal of History of Science*, **37**:255-265.

Débarbat, S., 2003. The IAU, astronomical archives and commission 41 and the ICHA. *Journal of Astronomical History and Heritage*, **5**:181-183.

Another location where papers on astronomical archives can be found is the Proceedings of the conference on astronomical history held in Cheongju (Korea) in July 2002. *Astronomical Instruments and Archives From the Asia-Pacific Region* (Seoul, Yonsei University Press, 2004), edited by Wayne Orchiston, F. Richard Stephenson, Suzanne Débarbat and Nha Il-Seong, contains the following archives-related papers:

Jeong Seong-Hee. Calendar-making in seventeenth to nineteenth century Korea and the present archives (pp. 177-180)

Lee, J.-B. and Nha, I.-S. The long-term project of astronomical archives in Korean history (pp. 35-39)

Oh Gil Sun. Creating ancient star maps using a computer (pp. 165-176)

Ohashi, Y. Medieval Indian astronomical instruments and archives (pp. 125-128)

Orchiston, W., Chapman, J. and Norris, B. The ATNF Historic Photographic Archive: documenting the history of Australian radio astronomy (pp. 41-48)

One further 'publication' relating to astronomical archives deserves to be mentioned, and this is a CD-Rom that was issued by the University of Bologna in 2003. Edited by Marina Zuccoli and Laura Peperoni from the Departments of Astronomy and Economics, respectively, this concerns a project titled "Science for Everyone. From Bologna's Astronomers' Documents to their Books", which aims to teach people about the old Astronomical Observatory (which is now an museum), the Archives (where the astronomers' manuscripts are preserved) and the Library (which houses books used and/or published by the Observatory's astronomers). The CD explains what the University's astronomical archive is, how it was formed, and how people may access it. Useful lists of manuscripts, letters, and books housed in the Department of Astronomy at the University are also given. We thank Marina and Laura for kindly providing us with a copy of the CD-Rom, and Luisa Pigatto for preparing this account.

Two other developments will also be of interest to members. The U.S. Naval Observatory recently sent twenty-four manuscript volumes of Hertzsprung's measurements of photographic plates to the Hertzsprung archives in the Department of Science at Aarhus University in Denmark, and Klaus-Dieter Herbst is working on a multi-volume publication that will include all known astronomical letters to and from Gottfried Kirch.

Finally, we are excited by a new archives-related initiative that C41/ICHA has become involved with. The International Union for History and Philosophy of Science has recently obtained funding for an international project titled "World History of Science Online: Databases of Bibliographical and Archival Sources". From the start, the IAU has been a Supporting Applicant for this project, and we anticipate that our Working Group will be closely involved in helping develop the astronomical components of the databases, in collaboration with the Library and Information Services in Astronomy group (LISA), which comes under the umbrella of IAU Commission 5 (Documentation and Astronomical Data).

Erratum

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Caption for Figure 5.

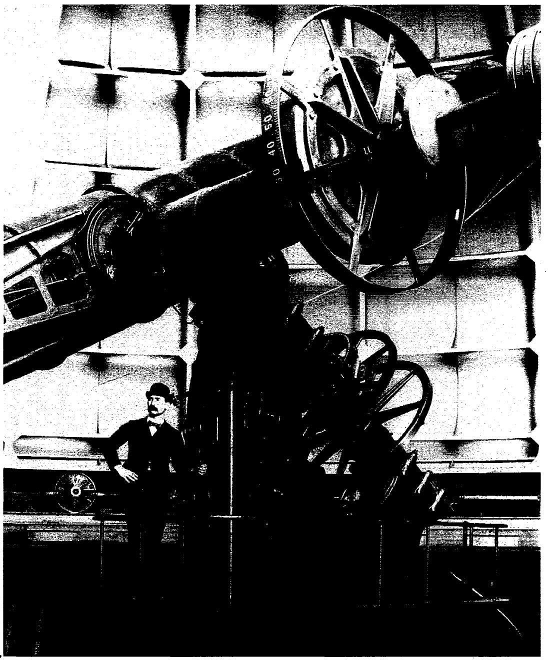

Figure 5. Allen L Colton at the controls of the Lick Observatory 914-mm refractor (*c.* 1895) (Courtesy of the May Lea Shane Archives of the Lick Observatory).

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