JOHN ISAAC PLUMMER AND THE 1882 TRANSIT OF VENUS

John Isaac Plummer (1845-1925) worked at Orwell Park Observatory from 1874 until 1890 as Colonel Tomline's professional astronomer. The majority of his astronomical work and publications concerned positional studies of comets; however, his observation of the transit of Venus on 06 December 1882 was undoubtedly one of the highlights of his career. Although research by members of OASI has uncovered much about his life and work, until the early 2010s little was known of his observation of the transit beyond the bare fact of his participation in a government expedition organised for the purpose. In 2012-13 I uncovered several sources which shed further light on this aspect of his work; this article draws together the current strands of knowledge of the subject.

PREPARATIONS

By the second half of the 19th century, astronomers had used Kepler's third law to relate the orbital periods and radii of the planets and had developed techniques for estimating the absolute distance from the Earth to the Sun in order to fix the scale of the entire solar system. Observation of a transit of Venus provided a reasonably accurate method of determining the mean Earth-Sun distance. The method was an indirect one which relied on estimation of the times of contact, when the limb of Venus appeared to just touch the solar limb. In fact, four contact events were generally distinguished:

1st contact: on ingress, the disk of Venus off the solar disk. The instant when the limbs of the two bodies first appeared to touch.

2nd contact: on ingress, the disk of Venus on the solar disk. The instant when the limbs of the two bodies last appeared to touch.

3rd contact: on egress, the disk of Venus on the solar disk. The instant when the limbs of the two bodies first appeared to touch.

4th contact: on egress, the disk of Venus off the solar disk. The instant when the limbs of the two bodies last appeared to touch.

The geometry of a transit is such that due to the effects of parallax, observers positioned across the surface of the Earth witness slight differences in the apparent path of the planet across the face of the Sun and thus report different times for the phenomena of contact. The observed contact times can be analysed to estimate the mean distance from the Earth to the Sun (the analysis is not for the mathematically faint-hearted!)

In 1881, the Royal Society appointed a committee to advise the government on arrangements for observing the forthcoming transit. Photography of the previous transit (09 December 1874) had not lived up to the hopes of many astronomers as the images turned out to be blurred due to atmospheric unsteadiness; the committee therefore recommended that observations be made by eye[1]. (In addition, the committee noted that there was insufficient time left to develop new techniques and construct associated instruments to enable more accurate observations to be obtained.) Reliance on eye observations meant that, in addition to professional astronomers, many amateur observers were also able to contribute to the endeavour.

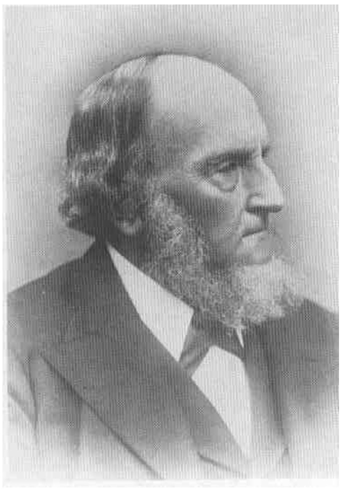

Figure 1. Edward James Stone (1831-97).

Later in 1881, the government appointed an Executive Committee, under the direction of Edward James Stone (1831-97, see figure 1), Radcliffe Observer at Oxford, to oversee the arrangements. The Committee anticipated receiving many observing reports and it thus became imperative to standardise observing conditions as far as possible so that a common framework of analysis could be employed. To this end, the Committee issued a set of observing instructions which was later considered at an international conference in Paris in October 1881. The conference produced a set of instructions (see [1881a] for an English translation) largely based upon those of the Committee, and the latter issued a supplement, which was widely distributed, e.g. [1882a]. Key points of the instructions were as follows:

[1] The recommendations of the committee contrasted with those provided for the benefit of American astronomers by a commission authorised by Congress [1882o]. The Americans proposed to rely primarily on photographic techniques.

- The observer should use a refractor with an aperture of 150mm. Larger instruments should be stopped down. Instruments as small as 100mm could be used provided that they were "perfect". If using a reflector, it should have an aperture of at least 175mm.
- The observer was requested to provide evidence of the optical quality of his instrument. This should include the appearance of a bright star when the eyepiece was pulled and pushed either side of the point of focus and the ability of the telescope to separate double stars and to reveal granulations on the surface of the Sun.
- The observer should use a first-surface reflecting prism to enable safe observation of the solar disk and a neutral-tint wedge between eyepiece and eye to control the apparent brightness of the field of view. Two approaches were specified to standardise the latter so that all observations of contact events were made in fields of similar brightness. The observer could employ an eyepiece with very fine parallel wires, spaced at an apparent distance of 1", and adjust the position of the wedge so that the wires could be readily used to estimate angular separations at or near the limb of the Sun to an accuracy of 0.1". However, this procedure was delicate and, as a more robust approach, the observer could instead choose simply to adjust the wedge to half-way between the setting at which, in a sky unobscured by cloud, the limb of the Sun could be observed with comfort and that at which it could just be seen clearly and distinctly; having memorised the resulting appearance of the image, he should use the wedge to achieve similar brightness in observation of the transit.
- The observer should use a *negative* or a *Steinheil's simple achromatic positive eyepiece*[2]. Use of a double-image eyepiece or a Dawes solar eyepiece was deprecated (except as below in the case of the former).
- The observer should use a magnification of 150x (even if definition was poor).
- Phenomena around the times of contact could be complex and, in an endeavour to improve the consistency of results, the instructions attempted as follows to define precisely what the observers should attempt to time. The definitions concentrated on 2nd and 3rd contact, which were expected to provide the most accurate results:
    - At ingress: *the time of the last appearance of any well-marked and persistent discontinuity in the illumination of the apparent limb of the sun near the point of contact.*
    - At egress: *the time of the first appearance of any well-marked and persistent discontinuity in the illumination of the apparent limb of the sun near the point of contact.*

  The phrase *well-marked and persistent* was intended to guard against observers reporting times when there was only a suspicion of a slight disturbance, perhaps due to atmospheric unsteadiness. If the black drop or similar feature were visible, the observer was instructed, in addition to the preceding, if the feature appeared as dark, or nearly so, as the outer edge of the planet, to record the time of greatest darkness. Of course, not all observations might fit exactly with the descriptions provided in the instructions and, in this case, the observer was to describe what he saw, with drawings, and provide timings.
- The observer with a double-image micrometer eyepiece was encouraged to measure the angular distances between the limbs of Venus and the Sun after 2nd contact and between the cusps of Venus at egress. However, he was cautioned when doing so against jeopardising timings of 2nd or 3rd contact.
- The observer was to specify the maker's name and number of the chronometer used. He should check its accuracy against the heavens for a few days before and after the transit.
- Great care was to be taken to ensure accuracy in recording time from the chronometer. (The instructions noted that mistakes had occasionally been made by observers reading seconds from the "tail" of the seconds hand rather than the "head".)
- The observer should permanently mark the location of his observing site.
- Each observer should write his observing report independently and forward it to the Royal Society at Burlington House. In the case of government expeditions, copies of the reports were to be sent, the original being lodged with local officials until receipt of the copy was acknowledged, at which point the original could be mailed.

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[2] Carl August von Steinheil (1801-70) was a German physicist, inventor, engineer and astronomer. The eyepiece named after him is a doublet with a flint-glass lens towards the objective and a crown-glass lens towards the observer, together forming a weak positive lens with low chromatic aberration.

The Committee organised observing expeditions from England to the following locations: Jamaica, Barbados, Bermuda, the Cape of Good Hope, Madagascar, New Zealand and Brisbane. Other astronomers stationed widely around the globe also contributed to the British effort. Such a widely-spaced set of observing stations provided a good baseline for analysis of results and had the important benefit of increasing the chance of some observers benefitting from clear skies.

Each observing expedition sent from England comprised a chief observer, a second observer and an assistant from the military. No documentation has been found describing how members of the expeditions were selected. However, the three chief observers dispatched to the West Indies were chosen from the ranks of astronomers in private employment in Britain. Thus, chief of the Jamaica expedition was Dr Ralph Copeland (1837–1905), employed by the Earl of Crawford (1847-1913) at Dun Echt Observatory, Aberdeenshire, chief of the Barbados expedition was Charles George Talmage (1840–86), employed by Joseph Gurney Barclay (1816-98) at his private observatory at Leyton[3], and Plummer was appointed chief of the Bermuda expedition. Copeland was by far the most accomplished astronomer of the three, with a notable record of publications and discoveries. He went on to become third Astronomer Royal for Scotland, 1895-1905. However, Plummer was not least of the three, the diversity of his work and his publication record being considerably superior to those of Talmage. Figures 2 and 3 respectively show Copeland and Plummer; to date, no photograph has been located of Talmage.

Figure 2. Dr Ralph Copeland (1837-1905)

Tomline was doubtless delighted at Plummer's appointment; indeed, given his status in society, wealth and connections, it is possible that he engineered it. His obituary in the Lincolnshire Chronicle [1889a] noted that *he "kept an astronomer" because he conscientiously believed it to be his duty to employ his money in every direction in which human activity demanded recognition and the cooperation of men of wealth…* He may have viewed the lending of Plummer to the government to lead the Bermuda expedition as, in a small way, discharging his duty and he likely appreciated the prestige associated with the appointment.

Figure 3. John Isaac Plummer (1845-1925).

Second observer at Bermuda was Lieutenant Charles Burnaby Neate (1846-1916). Neate joined the Royal Navy in 1860 at age 13; he progressed through the ranks and retired in 1891 with the rank of commander, after which he worked for a further 15 years for the Port of Dover. Although not primarily an astronomer[4], he clearly had a significant interest in the science. He was a veteran of the 1874 transit, which he had observed from Point Venus, Rodrigues Island [1881b]. His Admiralty record [1916a] shows that, on 06 January 1882, he was granted permission to join the transit of Venus expedition from May of the year, being authorised to draw full pay for the duration. Later, his record noted that, on 10 July 1882, he *left at own request to proceed to Radcliffe Observatory for work in regard to transit of Venus*. Reassuringly, he was not disadvantaged by his astronomical service, the record further noting: *Transit of Venus expedition allowed as full service for all purposes*.

The assistant at Bermuda was Sergeant Dobing RAM [1883a]. In fact, Dobing appears to have been a last-minute substitution: *The Times*, a few days prior to the transit, listed the assistant as Captain Washington, RE [1882g].

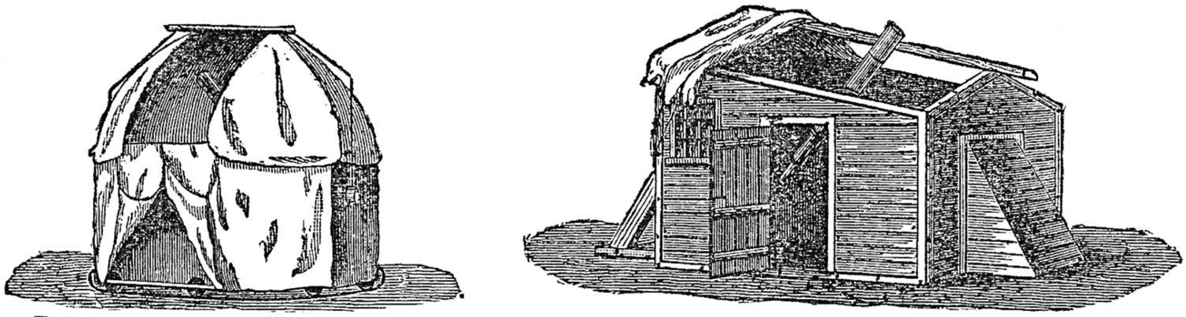
Captain G. Mackinlay, RA, second observer in the Jamaica team, wrote a detailed account [1883d] of the expedition including the preparations before the observers set sail. His description, summarised as follows, is likely typical of all the expeditions. Previous transits had demonstrated the importance of consistency in the estimation of event times. Accordingly, all observers, regardless of experience, assembled at the Radcliffe Observatory, Oxford, in summer 1882. There, Stone explained the instructions for observing the transit and, to provide an opportunity for practice, arranged for three telescopes to be positioned 180m distant from a model of the Sun and Venus. The model represented the apparent motion of the planet across the solar disk but had no means of

[3] See the article by the late Ken Goward, FRAS on Barclay, his observatory at Leyton and its similarities to Orwell Park: http://www.oasi.org.uk/OPO/Leyton/Leyton.shtml.

[4] Neate appears to have no publications to his name in the astronomical literature.

representing the brightness of the Sun or the atmosphere of Venus. The observers practiced recording the times of apparent contact of the limbs of the model Sun and Venus, finding the results to be *very fairly accordant*. Some astronomers, on the other hand, were profoundly sceptical of this approach, believing that over-reliance on such training prior to the 1874 transit had in fact vitiated the results of several observers who had strained to record what they had been taught to observe rather than what they actually saw.

Later, each team came again to the Radcliffe Observatory and stayed for about a month, allowing team members to practise setting up and using the telescopes and other apparatus and to pack equipment ready for transportation. The primary instruments of each expedition were two 150mm equatorially mounted refractors and an altazimuth transit instrument. Of course, the instruments required shelter from the elements, provided in the form of wooden huts or tent-like structures, each fitted with a wooden floor. There appeared to be some tailoring of the temporary buildings to accommodate the instruments which they housed; thus the Bermuda expedition included a *hexagonal wooden hut, with revolving dome eight feet in diameter* (see figure 8), which does not accord with Mackinlay's sketches (figure 4) of the observing huts for Jamaica. Unsurprisingly, the total equipment requiring transportation with each team was considerable; Mackinlay stated that it amounted to *47 large packages and boxes*.



ROTATING HUT-TENT—SHUTTER OPEN. RECTANGULAR WOODEN HUT—ROOF OPEN, TARPAULIN TIED BACK.

Figure 4. Observing huts from Mackinlay [1883d].

Before leaving the UK, the observers researched the climate and possible observing locations at their intended destinations. The criteria used for selection of observing stations were (1) probability of a clear, unclouded sky, (2) a healthy location, so that the observers did not run a high risk of being incapacitated through fever and (3) easy accessibility, to minimise costs and time pressures.

Records of the Royal Greenwich Observatory (RGO) [1892a] show that, on 29 September 1882, shortly before departing for Bermuda, Plummer collected a chronometer, *Kullberg 59S*, for use there.

THE EXPEDITION

It is not known when or in which vessel Plummer set sail across the Atlantic to reach Bermuda. However, the island's *Royal Gazette* [1882b] listed him and Sergeant Dobing entering the colony via the capital and main port, Hamilton, on 23 October 1882, having journeyed from New York aboard the mail steamer *Orinoco* (figure 5). Plummer travelled as a cabin passenger; Dobing steerage. Neate arrived aboard the *Orinoco* at St. George, on the north tip of the island, on 07 November [1882d].

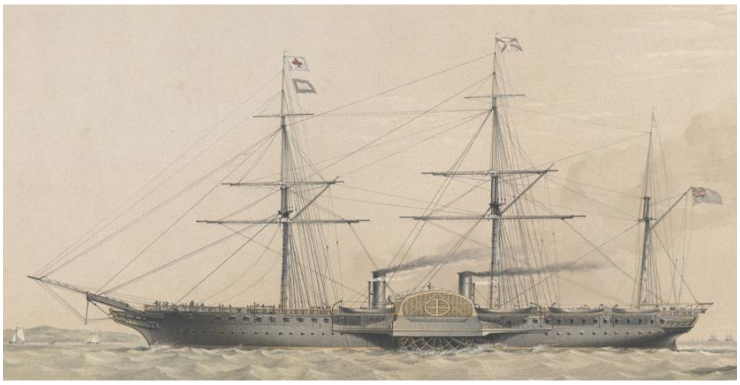


Figure 5. The *Orinoco*, from a coloured lithograph by H J Buchan commemorating the ship's launch in 1852.

Plummer and Neate chose to establish their observing station in the *immediate vicinity* [1882c] of Gibbs Hill lighthouse (figure 6) on the southern coast of the island. (The beacon became operational in 1846 and is famous for its cast iron construction.) They would likely have relied upon the labour of military personnel stationed in the colony for the transport of their equipment and construction of the observing station. The transit telescope and equatorials would have required substantial concrete foundations. As noted earlier, the instructions to observers included a directive to mark permanently the location of the observing station; construction of a concrete base upon which to mount instruments would have been a ready means of achieving this. (It is intriguing to speculate whether any trace of the observing site remains nowadays.)

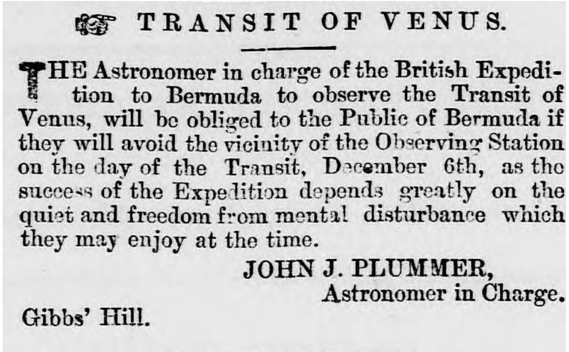
Figure 6. Gibbs Hill lighthouse.

Once the observing station was established, one of the important duties of the observers was to determine its position accurately, as this formed a key factor in the analysis of results. Latitude could be determined relatively straightforwardly from observations of the altitudes of known stars (for example using Talcott's Method, much employed by Plummer several years later while working at Hong Kong Observatory). However, in order to determine longitude accurately from the stars, a reference time was required at the observing station. Neate was responsible for provision of reference time at Bermuda, a responsibility he discharged by means of "chronometer runs" to New York [1887a], to access master chronometers kept accurate by observations at Washington Observatory. Assuming that Neate's "chronometer runs" were typical of the genre, he would have transported several chronometers to New York, where they would have been synchronised with the master timekeepers and their rates compared with those of the latter. He would then have transported them to Bermuda, where in turn they would have been used to synchronise and to determine the error of the chronometers to be used in observations. The *Royal Gazette* listed Neate making a return trip to New York, likely for this purpose, on 09 and 19 November [1882e, 1882f]. He may also have transported chronometers to/from New York on his initial journey to Bermuda via the city and on finally leaving the island. (The chronometer Kullberg 59S, borrowed by Plummer from the RGO, does not feature in observing reports from the island and thus may have been used on chronometer runs.)

The results by Plummer and Neate concerning the location of the observing station are intriguing. The *Royal Gazette* [1882m] indicated that the observers enjoyed mixed results: referring to the previously-accepted coordinates of the location, the paper noted that *while the longitude has been confirmed as being sufficiently exact; the latitude has been found considerably in error, showing that Bermuda stretches almost half a mile more into the southern sea than was formerly believed…* The report of the Executive Committee [1887a], adopting the determination by Plummer and Neate, quoted the coordinates as $4^h\ 19^m\ 20.45^s$ W, 32° 14' 46.6" N. A modern value for the position of the lighthouse (Google Earth, 08 July 2013) is $4^h\ 19^m\ 20.33^s$ W, 32° 15' 10.0" N; while the longitude agrees very well with the estimate by Plummer and Neate, the latitude corresponds to a location approximately 0.4 miles further north. Perhaps, therefore, Plummer and Neate were in error in their determination of the latitude and the earlier value, which they had sought to correct, was, in fact, accurate[5].

[5] There is a resonance here with Plummer's difficulties in determining the longitude of Orwell Park Observatory. See his biography at http://www.oasi.org.uk/OPO/JIP_bio.pdf, section 14.

Once Plummer and Neate had determined the position of the observing station, they would have kept busy practicing using the instruments. There was likely considerable local interest in the activities of the observers, and they would have had to host countless visits by local people. (At Jamaica, Mackinlay [1883d] reported on local interest as follows: *Considerable interest in the object of the expedition was shewn by residents in Jamaica, but soon all visitors had to be refused till after the Transit, though there still remained rather more than a fortnight*.) Excitement must have mounted greatly as 06 December drew near. Indeed, with one day to go, Plummer placed an advertisement in the *Royal Gazette* [1882h] asking the public to avoid the observing station on the day of the transit (figure 7).



TRANSIT OF VENUS.

THE Astronomer in charge of the British Expedition to Bermuda to observe the Transit of Venus, will be obliged to the Public of Bermuda if they will avoid the vicinity of the Observing Station on the day of the Transit, December 6th, as the success of the Expedition depends greatly on the quiet and freedom from mental disturbance which they may enjoy at the time.

JOHN J. PLUMMER,
Astronomer in Charge.

Gibbs' Hill.

Figure 7. Request to the public to avoid the observing station on 06 December.

OBSERVATIONS

The report [1887a] of the Executive Committee summarised the accounts by Plummer, Neate and the other observers of the transit. Plummer observed with a 150mm Cooke equatorial, a Steinheil positive eyepiece providing a magnification of 177x and the clock Dent 2015. Clouds were passing at the time of 1^{st} contact and he had to make such frequent changes between the thin end of the wedge and direct vision that, in subsequently writing his report, he was unsure whether or not he was employing the wedge at the instant when he first spotted the limb of Venus. Having discerned Venus, he then employed the thin end of the wedge to follow its motion, enabling him to estimate the instant (at an earlier time) of 1^{st} contact itself. Almost four minutes later, he observed an aureole all around Venus, which persisted until 2^{nd} contact. The width of the ring varied between 1" and 1.5". He recorded the times of three more events during the ingress phase: 2^{nd} contact, believing his estimate to be accurate to within three seconds; the first appearance of sunlight between the limbs of the Sun and the planet, describing it as a *sudden and marked phenomenon*; and the instant when sunlight between the limbs appeared *perfect and bright*. He witnessed the black drop effect, noting that it became less marked between the latter two times. Immediately after the ingress phase, the Sun was clouded out.

Dense cloud was present at the time of 3^{rd} contact and Plummer observed without using the wedge. He timed the phenomena at egress corresponding to those which he had timed at ingress. However, the image was *boiling greatly* and *very faint indeed* and suffered from *much tremor in the limbs, both of Venus and the Sun*, and he did not consider his timings *of any value unless confirmed*. Things were slightly improved by the time of 4^{th} contact, and he stated that it was *well observed* and his timing of it was accurate to three or four seconds or better.

Neate observed with a 150mm Naylor equatorial, a magnification of 180x and clock Arnold and Dent 715. Other than around the time of 2^{nd} contact, he used the wedge at its nominal position to make timings. His description of his observations started just after 1^{st} contact, when he observed fine light shading on the following limb of Venus. When the planet was approximately half upon the disk of the Sun, he described the following limb as bright; around this time, he also observed a luminous ring around the planet, approximately 2" in breadth at its widest. He found it difficult to estimate the time of 2^{nd} contact, in part due to fleecy clouds (necessitating use of the wedge at minimum obscuration) and in part due to the black drop effect. For a few seconds immediately after 2^{nd} contact, cloud necessitated continuous adjustment to the setting of the wedge; approximately nine seconds after the event, the band between Venus and the Sun changed colour from dark to dusky brown; it persisted for another 20 seconds then disappeared.

Of course, Neate's observations of 3^{rd} contact, like Plummer's, were hampered by dense cloud and he did not consider his egress timings to be of any great accuracy. He saw no aureole during egress. In contrast to Plummer, who was confident in his timing of 4^{th} contact, Neate was not, and provided both a "suspected" and "definite" timing for the event.

Table 1 compares timings reported by the Bermuda observers with modern calculations[6] of event times (all rounded to the nearest second); the comparison does not reveal any surprises. Plummer's time of 1^{st} contact is 14 seconds later than calculations suggest, Neate's 33 seconds later. Plummer studied the motion of Venus immediately after first discerning it in order to estimate the time of 1^{st} contact, and his approach appears to have

[6] Calculated times are obtained from an enhanced version of Montenbruck and Pfleger's algorithm *Ecltimer* [1994a]. Positions of solar system bodes are provided by the NASA JPL reference ephemeris DE-405; contact times are assumed to refer to the cloud-tops of Venus; and the value of ΔT (=ET-UT) is set to -5.4 seconds (interpolated from the values listed in Meeus [2009a]).

been reasonably effective. In contrast, it is unclear how Neate estimated 1st contact and it may be that his timing, some 19 seconds later than Plummer's, is simply when he first noticed the limb of the planet intruding upon the solar disk. The reported times of 2nd contact (geometrical) by the two observers are within six seconds of one another and both are 20 seconds or more in advance of the calculated time. The "black drop" must have made timing of the event difficult. Plummer's estimate of 3rd contact (geometrical) agrees well with calculation, but Neate's is 44 seconds after the latter; again the "black drop" effect may be responsible for the observers reporting such discordant times (although Plummer, in his report, mentioned the phenomenon around 3rd contact, Neate did not). Both observers' estimates of the time of 4th contact are several tens of seconds earlier than calculation indicates; this situation is not unexpected. Overall, Plummer's timings agree with calculations much better than Neate's, perhaps a reflection of the fact that he was a professional astronomer whereas the latter was not.

	Times of Phenomena (UT)		
Contact	**Calculated**	**Plummer**	**Neate**
1st	14:03:23 [7]	14:03:37	14:03:56
2nd	14:24:05	Geometric contact: 14:23:45. First visibility of sunlight surrounding whole limb of Venus: 14:23:59. Last visibility of "black drop" effect: 14:24:13.	Geometric contact: 14:23:39. "Black drop" effect; band apparently linking Venus to solar limb changed colour and became lighter: 14:23:48. Band apparently linking Venus to solar limb disappeared: 14:24:08 (approx).
3rd	19:47:24	First visibility of "black drop": 19:47:03. Last visibility of sunlight surrounding whole limb of Venus: 14:47:19. Geometric contact: 19:47:34.	Geometric contact: 19:48:08.
4th	20:08:12	20:07:27	Suspected: 20:07:09. Definite: 20:07:14.

Table 1. Modern calculations of contact times and timings reported by Plummer and Neate.

The *Royal Gazette* [1882j, 1883c] listed three additional observers in Bermuda: the Chief Justice and Mr Barr observed at the Public Buildings using the Colonial Telescope and Captain Clapp observed at Ireland Island. Although their observations were reported to the Royal Society, they were not included in the report of the Executive Committee and no record of them has to date been found.

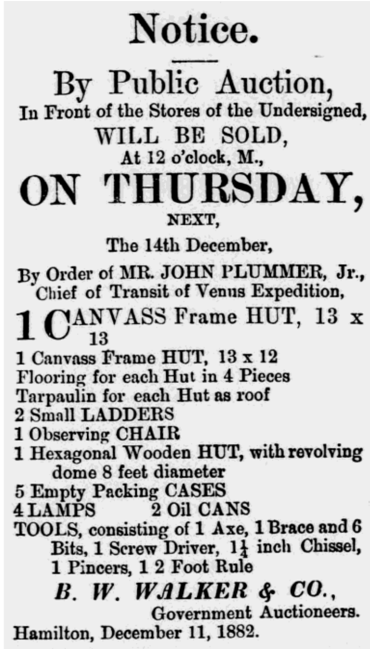
HOMECOMING

Neate left Bermuda the day after the transit [1882k] departing aboard the *Orinoco* for New York; his Admiralty record noted his return to England on 24 December 1882. Plummer first arranged to auction (figure 8), on 14 December 1882, surplus equipment of the expedition [1882i, 1882l] and then, on 21 December [1882n], left the island aboard the *Orinoco* bound for New York. From there, shortly after Christmas, he travelled to England aboard the steamship *City of Brussels*[8] (figure 9). He must have looked forward to the transatlantic journey: he had been away from home for over two months and the liner offered the prospect of luxurious travel as a cabin passenger among the wealthy and influential of the age. Unfortunately, the journey turned out to be more eventful than he could have anticipated! His description of the passage, recorded in the *East Anglian Daily Times* [1883a] and repeated in the *Royal Gazette* [1883b], provides a vivid narrative:

[7] [1882m] quotes the contemporary prediction of 1st contact as 16 seconds earlier than the observed time; assuming the latter is that of Plummer, the prediction would be only two seconds earlier than modern calculations indicate.

[8] The ship was a holder of the record for the fastest Atlantic eastbound voyage, 1869-73.

We left New York on December 28th, and experienced very severe weather for the first half of our voyage. We then encountered a severe gale, in which our maintopsail [sic] *was carried away. The weather then abated, and all went well up to the time of our arrival at Queenstown on Saturday. At noon we left Queenstown under most favourable circumstances and expected to arrive in the Mersey about noon on Sunday. About five o'clock on Sunday morning we were within a short distance of the NW lightship, which is the extreme light from the mouth of the Mersey. Here we were arrested in consequence of meeting with a thick fog blown from the land by a SE wind, and which had detained vessels in the Mersey for a considerable time previously. A good look-out was kept on deck, and the captain and two other officers were on the bridge. About seven o'clock in the morning the fog horn of a steamer was heard and was replied to by the "City of Brussels". In a very short space of time, however, the form of a vessel which turned out to be the "Kirby Hall", screw steamer, 2700 tons burden, from Glasgow, was seen approaching with what appeared to be considerable velocity, and before the "City of Brussels" could get under weigh or do anything to avoid a collision, she was struck on her starboard bow, and a hole was cut in her side. The concussion felt on board was much less than might have been supposed; it was in fact scarcely alarming. At the desire of Captain Land, the "Kirby Hall" put off a short distance and was lost sight of in the fog. The injury to the "Brussels" was so severe, and the water gained so rapidly in her hold, that all hands were at once ordered to lower the boats. In a space not exceeding a quarter of an hour, five boats were lowered ready to receive the passengers and crew. In the mean while the majority of the passengers were awakened from their berths, and speedily dressed in what came nearest to hand. There was little or no confusion; indeed, the passengers did not appear to realize the extreme danger in which the ship was placed. One gentleman positively assured me that after he was awakened by the steward he fell asleep again, and I myself dressed very deliberately and proceeded on deck about ten minutes after the collision. My assistant then informed me that there was 14 ft. of water in the hold, and when I saw some of the passengers whom I had always looked upon as steady and self-possessed were putting on lifebelts, I felt that matters must be serious, and I procured a lifebelt for myself. By the exertion of the captain and purser the ladies were speedily hustled on board the boats, and they were followed at no great interval of time by the rest of the passengers, and such portion of the crew as was necessary to take charge of the boats. Doubtful how long it would be before it would be absolutely necessary to take to the boats, I made a rush below and secured my cash-box, which contained valuable papers as well as money, but I was not permitted to take it with me. I had barely time to extract a valuable bill, lock the box, and place it on the seat in the smoke room. I mounted the bulwarks and followed some of the passengers, who were getting into one of the boats. I believe I was the last cabin passenger who left the ship. There were severa1 steerage passengers, including Sergeant Dobing, RAM, assistant to the Expedition. As soon as we got into the boats we could see how much the ship had sunk, and we could judge how speedily she was likely to go down. All five boats put off to a safe distance from the ship, leaving on board what was supposed to be a few, but in reality about 17 officers and crew. For fear of injury to the boats, it seemed impossible to rescue these, and the moments of suspense were probably the most terrible experience any of us had ever felt. Those left on board had really been employed in endeavouring to launch a sixth boat, which being a heavy one, and the crew being reduced in number, was more than they were able to manage. Having vainly cried for help, they for the most part took to the rigging, and when the ship heeled over to starboard, in all probability jumped for their lives as she sank. Several were now seen clinging to the spars and other wreckage, and two boats, already well filled, approached to take them off. Upon one of the spars were the captain and three others. They were rescued by a boat which had discharged her passengers already upon the "Kirby Hall", and was returning to the scene of the wreck, assisted by the boat in which I happened to be. Having seen the whole of these safely in the boats, we proceeded to the "Kirby Hall", and found her in a considerably damaged condition, but sufficiently sound to produce a comfortable feeling of safety. For some time the boats, now relieved from their numerous passengers, cruised about in the hope of finding some others, but owing to the thick fog, and perhaps to the distance to which the "Kirby Hall" had receded, none were found. My own interest was taken up at this time with endeavours which were being made to rescuscitate* [sic] *two men, the second officer and carpenter, who had been brought on board in a drowning condition. In spite of all efforts they unfortunately succumbed. The muster of the crew and passengers was then taken, and it was found that eleven in all were missing. All hope of finding others alive was given up. Happily, however, the fog lifting for a few minutes enabled us to see clinging to the masts of the "Brussels", which having righted were considerably above water, the form of another survivor. A boat was speedily sent to his rescue, and thus the tale of deaths was reduced to 10. We had now to wait, with what patience we could, for the fog to lift, which it did after the lapse of about ten hours. The "Kirby Hall" was then got under weigh, and proceeded to Liverpool.*



Notice.

By Public Auction,
In Front of the Stores of the Undersigned,
WILL BE SOLD,
At 12 o'clock, M.,
ON THURSDAY,
NEXT,
The 14th December,
By Order of MR. JOHN PLUMMER, Jr.,
Chief of Transit of Venus Expedition,

1 CANVASS Frame HUT, 13 x 13
1 Canvass Frame HUT, 13 x 12
Flooring for each Hut in 4 Pieces
Tarpaulin for each Hut as roof
2 Small LADDERS
1 Observing CHAIR
1 Hexagonal Wooden HUT, with revolving dome 8 feet diameter
5 Empty Packing CASES
4 LAMPS 2 Oil CANS
TOOLS, consisting of 1 Axe, 1 Brace and 6 Bits, 1 Screw Driver, 1¼ inch Chissel, 1 Pincers, 1 2 Foot Rule

B. W. WALKER & CO.,
Government Auctioneers.
Hamilton, December 11, 1882.

Figure 8. Notice of auction.

Without wishing to throw any blame upon the officers of the ship, which of course must be a matter for judicial investigation, one could not help but see that she was very much under-manned, having only four deck hands on board, and being unable to launch even a single boat to aid in the rescue. The fact that five boats ware launched and manned from the "Brussels" in a space of time not exceeding 20 minutes, speaks greatly in favour of the steadiness of the men, the capacity of the officers, and the quietness and freedom from panic shown by the passengers themselves. It is a matter of intense regret that another boat was not at hand to take off the rest of the crew.

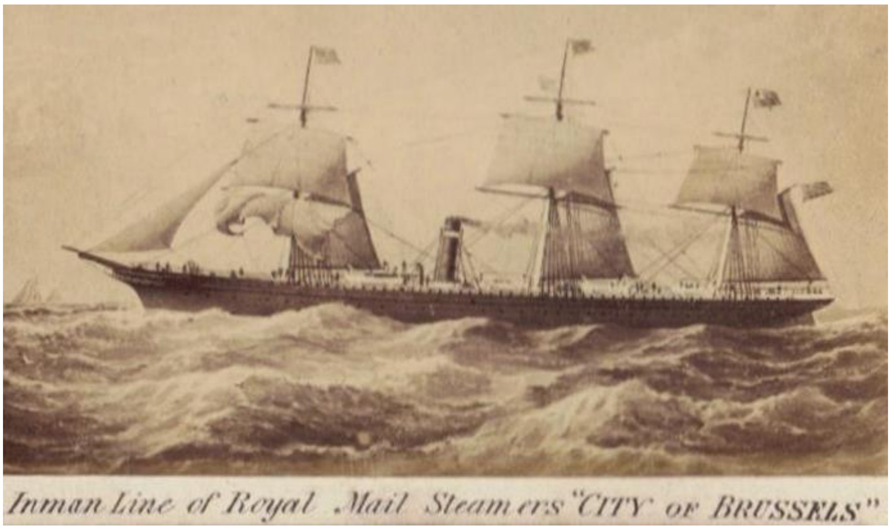


Figure 9. A postcard showing the *City of Brussels* in her original form - she was extensively modified and refitted over the years [2013a].

Fortunately, although all the passengers' baggage, papers, and effects were lost, the observers' reports of the Transit of Venus had been mailed from New York and arrived safely in England by another steamer [1883c].

RESULTS

Although summary reports from observers of the transit started appearing in print only a few days after the event (e.g. [1882m]), gathering together all the reports and fully analysing the data was a monumental undertaking and it was not until 1887 that the Executive Committee published its final report [1887a]. Stone took responsibility for the analysis, and Henry Carpenter, an astronomer at Dun Echt, undertook most of the arithmetic calculation. As in previous transits, the black drop and atmospheric unsteadiness confounded many observers and Stone struggled in many cases to select, out of several reported event times, the appropriate one upon which to base the analysis.

Despite the difficulties, Stone and Carpenter eventually arrived at an estimate of the mean Earth-Sun distance of 148,960,000 km ±400,000 km. The modern estimate [1992a] of the quantity is 149,597,870.66 km. With the exception of observations of 4^{th} contact, the residuals of Stone's analysis for the timings by Plummer and Neate are all relatively low in comparison with those of their peers implying, in broad terms, that their results were of good accuracy.

In fact, however, although governments and individuals around the globe invested considerable resources in observation of the 1882 transit, the technique was already falling into disfavour as a means of estimating the mean Earth-Sun distance. The black drop and atmospheric unsteadiness which prevented precise determination of the instants of apparent contact of the limbs of the Sun and Venus together limited the accuracy of the method. As a result, astronomers had already begun to turn to other methods, such as the parallax of Mars at opposition, to provide more accurate estimates (see e.g. Sellers [2001a]). The 1882 transit was the last used by professional astronomers to estimate the scale of the solar system.

FOOTNOTE

At the time of writing, the most sought-after documents in connection with the transit, the original observing reports by Plummer and Neate, are proving elusive, being present neither in the archives of the Royal Society nor the RGO. Efforts to locate them are currently centred on the Dun Echt archive.

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07 September 2013