John Tebbutt and observational astronomy at Windsor Observatory

Wayne Orchiston

During the nineteenth century, John Tebbutt (1834–1916) was the doyen of Australian astronomy and a prominent figure in international positional astronomy. From his modestly-equipped Windsor Observatory, near Sydney, he single-handedly carried an amazing observational load over more than half a century, with emphasis on comets, variable stars, double stars, minor planets, planets, eclipses, transits of Mercury and Venus, lunar occultations and Jovian satellite phenomena. He discovered two of the Great Comets of the nineteenth century, and a nova. In addition, he actively popularised astronomy, maintained a local time service and a meteorological station, carried out studies of tides and floods, and was intimately associated with the founding of some of Australia's earliest formal astronomical groups. Tebbutt published almost 390 scientific papers and notes in Australian and international journals, as well as two books, two chapters of books, and a stream of booklets, including Windsor Observatory *Annual Reports*. He is proof that it was still possible for a talented, dedicated amateur astronomer working in virtual geographical and intellectual isolation to make a valuable contribution to forefront astronomical research during the nineteenth century. His is a remarkable story of achievement, which can only serve to inspire present-day astronomers, amateur and professional alike

Introduction

John Tebbutt (Figure 1) was one of the world's most remarkable nineteenth century amateur astronomers.[1] Entirely self-taught, from the geographical and intellectual isolation of his Windsor Observatory near Sydney, Australia, he carried out a wide-ranging observing programme, publishing prolifically in local and overseas journals, actively popularising astronomy, maintaining a local time-service and a meteorological station, and monitoring local floods and freshes.[2] In 1862 he discovered a nova,[3] and in 1861 and 1881 two of the 'Great Comets' of the century. In 1882 he formed Australia's first national astronomical group of any kind, the short-lived Australian Corps of Comet Observers, and in 1895 when the New South Wales Branch of the British Astronomical Association was founded he served as its inaugural President.[4]

Figure 1. John Tebbutt, 1834–1916 *(Orchiston Collection).*

Although offered the post of Government Astronomer of New South Wales and Director of Sydney Observatory in 1862, Tebbutt chose to remain an amateur,[5] and quickly went on to build an international reputation. By 1869, Windsor Observatory was deemed important enough to be listed in the *Nautical Almanac*, and later in the century it was reliably reported by a scientific colleague in Germany – arguably the leading nation for positional astronomy – that '...there are two men in Australia who were of wide fame in Europe: one was Baron von Mueller [the Melbourne botanist], and the other John Tebbutt.'[6] As a further indication of his international eminence, in 1905 Tebbutt was only the third recipient of the Royal Astronomical Society's Jackson Gwilt Medal and Gift.[7]

Despite a remarkable record of achievement extending over more than half a century, in more recent times Tebbutt's name was largely unknown to Australian astronomers until a crater on the Moon was named after him in 1973 and his face and Windsor Observatory were chosen to feature on a new $100 Australian banknote issued in 1984. Two years later, his great-grandson began restoring the two surviving Windsor Observatory buildings, and these were opened in 1989 as a unique museum of astronomy.

John Tebbutt now has a secure place in Australian scientific and astronomical history, and has been described as 'The undisputed jewel in the crown of Australian amateur astronomy...'[8] and as '...an example of what may be achieved by an amateur observer with modest instrumental equipment applied in a methodical manner to the fundamental problems of astronomy.'[9]

This paper is the first in a series about Tebbutt's observational astronomy, and 'sets the scene' for these later papers by providing relevant biographical details, plus information on the instrumentation and library that were used for these observations and conversion of the raw data into research papers and popular newspaper articles. It also discusses Tebbutt's observational 'apprenticeship', which culminated in the purchase of his first telescope, construction of the first Windsor Observatory building, and publication of his observations for the first time in international astronomical journals.

The paper ends with a discussion of his wide-ranging observational programme and ensuing publications, and overviews his observations of comets, variable stars, double stars, minor planets, planets, eclipses, transits of Mercury and Venus, lunar occultations and Jovian satellite phenomena.

Tebbutt: the man

On 1834 May 25 John Tebbutt was born to John and Virginia Tebbutt in the historic farming township of Windsor, 30 miles northwest of Sydney, and grew up in comparatively affluent surroundings. He was effectively an only child, for his younger sister died in infancy. Young Tebbutt attended local church schools where he excelled, and his inquiring mind soon turned to scientific and mechanical pursuits and ultimately to astronomy.

At age fifteen he completed his formal schooling and began working full-time on 'The Peninsula Estate', his father's 250-acre farm which was situated on the eastern outskirts of Windsor and almost completely surrounded by the flood-prone Hawkesbury River and its tributary, South Creek (see Figure 2).[10] On 1857 September 8 he married Jane Pendergast, and over the years they had one son and six daughters. John Tebbutt lived most of his life at Windsor, and died there on 1916 November 29.[11]

As a man, Tebbutt was a hard taskmaster. Haynes *et al*. found that 'Time and precision became, for him, almost an obsession, and friends who arrived late for an appointment risked his permanent displeasure.'[8] He was also a stickler for accuracy and honesty, despised drunkenness and gambling, and frowned on horse-racing and other 'sins'.[12] Because of his own internationally recognised achievements in astronomy he ended up with unrealistic expectations of others, and when they could not live up to the ideals that he aspired to he would sometimes display a degree of intolerance.[13] Yet he was always prepared to help genuine inquirers with information about astronomy and meteorology, and was known for his quick responses (generally within 1–2 days) and eagerness to assist those with a sincere interest in science.[14]

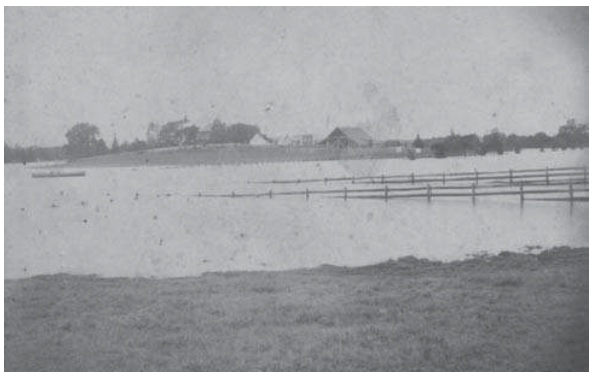

Figure 2. When South Creek was in flood The Peninsula Estate was isolated from Windsor. This early photograph shows the Tebbutt homestead (among the trees), two of the Windsor Observatory buildings and a large barn *(Orchiston Collection)*.

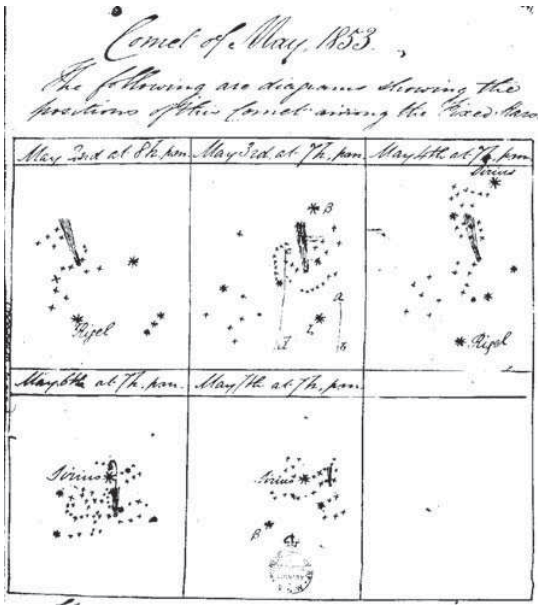

Figure 3. Tebbutt's drawings of Comet C/1853 L1 (Klinkerfues) in his first observing journal *(Courtesy: Mitchell Library, Sydney)*.

Tebbutt rarely reveals his innermost feelings in his published writings, but his 1894–96 observing journal does contain one remarkable non-astronomical diversion that is worth reproducing here in full:

> 'Poor Jacko, my pet magpie and a remarkably intelligent bird, was unfortunately killed by one of the dogs... He was an exceedingly clever imitator, and my constant companion at the Observatory day and night for the past seven years. I buried him yesterday under the ladder which leads up to the maximum shade thermometer. On this ladder he was accustomed frequently to roost and when not asleep invariably saluted me on my passage to and fro between the main observatory and the round equatorial room. I was wonderfully attached to the poor bird and I feel his loss very keenly. Hence this little tribute to his memory.'[15]

This paints a rather poignant picture of an aging astronomer sharing his nightly vigils with a friendly old magpie. For the serious amateur working in isolation astronomy could be a lonely preoccupation.

An observational apprenticeship

John Tebbutt records in his *Astronomical Memoirs* that it was through the education he received from Rev Stiles and frequent contact with his old tutor, Mr Quaife, that his tastes were initially directed towards science.[16] His special interest in astronomy escalated towards the end of the 1840s as a result of continuing contact with Quaife and reading some popular books on astronomy by the London astronomer, Hind, and it then dawned on him

> '...that the universe was really a mechanism of the highest order, and being, as I have already said, mechanically inclined, I began to turn my attention to celestial mechanism. Thus began my love for astronomy, and I became fired with an ambition to do real work in its behalf.'[17]

In 1853 May, this 'armchair' interest underwent a sudden

metamorphosis with the appearance of a conspicuous naked eye comet (C/1853 L1), and Tebbutt's career as an observational astronomer was launched. He observed this celestial visitor with a small marine telescope provided by his father, and recorded his observations and accompanying drawings in what was to be the first of many observing journals (Figure 3).[18]

Later in the year he added a secondhand sextant to his tiny stable of astronomical equipment, which included the family's grandfather clock. At about the same time, he improvised a crude mounting for the little marine telescope and began sunspot observations using the projection method. In this way he was able to confirm the rotational period of the Sun on the basis of his own observations.

An unusually large group of spots was visible on the Sun in 1854 May, and after observing this Tebbutt wrote an account of it that was published in the *Sydney Morning Herald* newspaper.[19] In so doing, he commenced a practice that he would pursue throughout his life: that of using the media to offer the general public accounts of his own observations and discoveries, and information on forthcoming astronomical events or objects which might be of interest.

So by the comparatively young age of twenty, Tebbutt was committed to a life of astronomy, and

> 'Henceforth he lived in an atmosphere of moving planets. The science of astronomy became his ruling passion; all else to him went by the board, and he had perpetually in his mind, while pursuing his study of the starry heavens, a working model of the universe, whose mysteries it was the purpose of his life to unfathom.'[20]

The occurrence of a total solar eclipse on 1857 March 26 with a path of totality that passed directly through Windsor and Sydney provided Tebbutt with another opportunity to bring astronomy before the public via the newspapers. Unfortunately, the day turned out cloudy and no observations were obtained, but Tebbutt's efforts placed him squarely in the public eye.[21]

In 1858, Comet C/1858 L1 (Donati) attracted Tebbutt's attention, and two years later he observed Comet C/1860 M1 (the Great Comet of that year). Both were naked eye objects, and Tebbutt determined their positions with his sextant and then went on to compute their orbital elements and publish these in the local newspapers. For good measure, he then calculated the orbit of the 1853 May comet, using his own crude observations as positional data.

In those distant times before electronic computers, such calculations were time-consuming and intellectually demanding. Many years later, Tebbutt recounted how he came by the requisite mathematical knowledge: while still a teenager he read some popular articles on comets, and they

> '...brought home to him how sadly deficient he was in mathematical knowledge, and how essential mathematics were to anyone seeking to make progress in astronomical studies.
>
> He accordingly resolved to master what mathematics he could. He began with algebra, following on with geometry and trigonometry. Interest increased as he advanced. When he reached the field of the higher problems he felt he would succeed. The stars looked down on him with different meanings in their faces. Day and night the heavens conversed with him in the newly-discovered speech.'[22]

This really was a remarkable accomplishment for a young man working in virtual academic isolation.

Other objects and events to attract Tebbutt's astronomical attention during the 1850s were fireballs and meteors, Jupiter's satellites, lunar eclipses, lunar occultations of stars, the variable stars Algol and ç Carinae, aurorae, and the zodiacal light.[18] This catholic approach to observational astronomy was to be a notable feature of his later astronomical career, once he was properly equipped to make a useful contribution to the science.

In 1861 came the discovery that was to propel Tebbutt's name into the annals of astronomical history. Let us quote from his *Astronomical Memoirs*, which reflects some of the excitement of the moment even though it was written more than forty years after the grand event:

> 'On the evening of May 13, 1861, while searching the western sky for comets, I detected a faint nebulous object near the star Lacaille 1316 in the constellation Eridanus. In my marine telescope the object appeared much diffused, and it was with the greatest difficulty that I measured its distance from three well known fixed stars. The object was hardly distinguishable in the small telescope attached to the sextant ... Every comet hunter knows how necessary it is to the carrying out of his work to have at hand a copious catalogue of nebulae, but this valuable adjunct I unfortunately did not possess. I could not, however, find the object in the limited catalogues at my command. I accordingly made up my mind to watch it ... I rose on the following morning to examine it, but failed to detect any change in its position ... The evening of the 15th was cloudy, but on the following evening the nebula was found to occupy sensibly the same position as on the night of discovery. I had now almost given up hope of its proving to be a comet. Cloudy weather prevailed till the evening of the 21st, when ... I now noted such a change in position as caused me to remark in my journal that 'I was almost persuaded of the cometary nature of the nebula'... On the following evening, the 22nd, I again ... found that it had very sensibly changed its position. There could, therefore, now be no doubt as to the cometary nature of the object of my solicitude ...'[23]

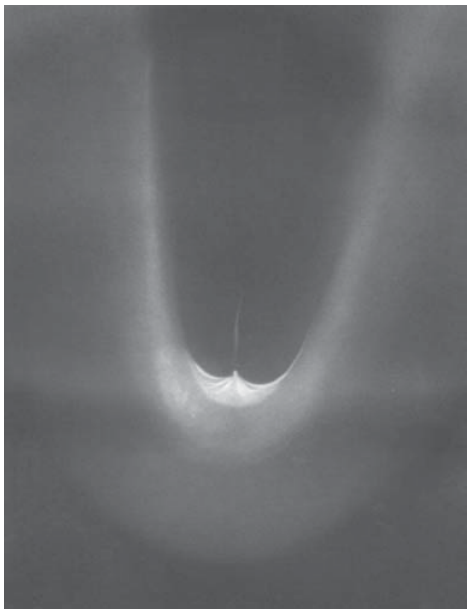

Figure 4. Drawing of the intricate head of Comet C/1861 J1 (Tebbutt) as seen by de la Rue on 1861 July 2 in a 13in [330mm] Newtonian reflector *(from the frontispiece of Guillemin's* The World of Comets*, 1877).*

The announcement of the discovery appeared in the Sydney newspapers on May 25, thus serving as a novel twenty-seventh birthday present for the talented young astronomer from Windsor.

After moving into northern skies – beyond the range of Australian telescopes – Comet C/1861 J1 (Tebbutt) turned out to be one of the most magnificent celestial visitors of the nineteenth century, and at its prime fea-

tured an ever-changing head (Figure 4) and a prominent tail that extended for more than 100 degrees. For a time, the Great Comet of 1861 (as it became known) was visible in broad daylight.[24]

This discovery inspired Tebbutt to purchase an astronomical telescope, erect an observatory, and dedicate his life to astronomy. His 'apprenticeship' was over.

Instrumentation and library

On 1861 November 14, just three months after bidding farewell to his comet, Tebbutt purchased an 8.3cm refractor from a Sydney firm. In 1873 he provided a useful description of this telescope:

> 'This instrument is the work of Chas. Jones of Strand Street, Liverpool, England; the clear aperture of the object glass is 3¼ inches [8.3cm] and its focal length about 48 inches [1.22m]... The telescope is provided with a brass tripod stand with altitude and azimuth movement ... The telescope has a finder of about 11 inches [27.9cm] focal length and 7/8 inch [2.2cm] clear aperture. It is also furnished with a terrestrial eyepiece with extra tube, [and] six negative eyepieces with powers varying from 30 to 120...'[25]

Tebbutt then pressed on with the construction of an observatory, and this was completed by the end of 1863. It comprised a simple rectangular wooden building with a central tower for the Jones refractor (Figure 5). The main observatory room had two transit piers, one at each end of the building, and associated with each pier were wall and ceiling shutters that opened to expose a narrow band of sky. A small prime vertical room was appended to the south side of the building in 1867, and provided with a pier for a portable transit telescope.[26]

In order to determine the latitude and longitude of his observatory and establish a local time service, Tebbutt ordered a 5.3cm transit telescope from the Sydney scientific instrument maker, Angelo Tornaghi, and this arrived in 1864 September. He also purchased a box chronometer, and continued to make use of the family's grandfather clock, which was known to keep reliable time. The new transit telescope was normally kept in the main observatory building under one of the north–south aligned roof shutters, and was used to regulate the clock and chronometer. Tornaghi also provided two ring micrometers for the Jones refractor, and Tebbutt completed the fitting out of his observatory by purchasing a full set of meteorological instruments.[27]

Further telescopes were added to the fold over the years, and with them new observatory buildings. In 1872 Tebbutt purchased a fine equatorially-mounted 11.4cm Cooke refractor, which he described in 1887:

> 'Its object glass has a clear aperture of 4½-inches [11.4cm] and a focal length of 70 inches [1.78m]. It is mounted according to the Fraunhofer [German Equatorial] method and is adjustable to any latitude. When it came into the possession of the writer it was mounted on a firm wooden tripod ... At the lower or northern end of the polar axis is the hour circle, five inches [12.7cm] in diameter. It has a double set of divisions on its edge, and when clamped revolves with the polar axis, and when unclamped it revolves on the axis by means of a milled head ... The hour circle is divided on brass to two minutes of time, and these divisions are again read off by a microscope and vernier to five seconds. The declination circle is five and a half inches [14cm] in diameter and is divided on its brass edge to 30′ and subdivided by two verniers to single minutes. The telescope is provided with the usual arrangements for clamping and slow motion in right ascension and declination.'[28]

Figure 5. John Tebbutt and his original Windsor Observatory building, constructed in 1863 and extended in 1867. The stands in the foreground held meteorological instruments, and the ladder on the extreme left was Jacko's favourite perch until his premature death on 1895 August 7 *(Orchiston Collection)*.

The telescope came with a dew cap, and a finder of 3.5cm aperture and 38cm focal length,[29] two diagonal eyepieces, a transit eyepiece, a comet eyepiece, a terrestrial eyepiece, six negative eyepieces (with powers ranging from ×55 to ×400) and solar filters. Since there was no micrometer, Tebbutt adapted the two ring micrometers made for the Jones telescope,[30] but in 1879 he acquired a new position filar micrometer made expressly for the telescope by Thomas Cooke & Sons.[31]

Initially the Cooke telescope was housed in the tower observatory, but in 1874 Tebbutt transferred it to a new free-standing circular wooden observatory that was erected near the original building. This new facility was 3.7m in diameter,[28] and the conical dome was constructed in two sections of different pitch, each with eight segments and made of wood covered with canvas. This second observatory is shown in Figure 6, and it was a thoroughly acceptable home for the Cooke refractor. The only major drawback was that the telescope lacked a drive,[31] and this would prove to be a limiting factor when it came to attempting certain kinds of micrometric observations (as had also been the case with the Jones refractor).

Five years later (in 1879) a substantial brick building was constructed to the south of the original wooden observatory and due west of the 1874 observatory, and this contained a dome room, transit room, prime vertical room, computing room and a library. As Figure 6 indicates, this new observatory had considerable architectural merit and visual appeal. Austin *et al.* have carried out an architectural appraisal of the building, and conclude that it is '...an example of classical Georgian with its small entrance portico and well proportioned plan. John Tebbutt being associated with geometry has undoubtedly left this inherent with his buildings

Figure 6. Windsor Observatory in 1880 from the northwest, showing (left to right) the original building, the circular wooden observatory built for the Cooke refractor, and the 'substantial brick building' constructed in 1879 *(Courtesy: Royal Astronomical Society)*.

... Where any contradictions occur such as the small fenestrations and roof form over the equatorial room, these are purely functional elements derived from the needs of the building. The whole complex is the outcome of function and this is typical Georgian architecture.'[32]

A new building called for new instruments, so Tebbutt purchased a 7.6cm Cooke transit telescope for the transit room, and later, in 1882, a new chronometer by John Poole joined this telescope and the old Parkinson and Frodsham chronometer in the transit room. Meanwhile, the Cooke refractor was relocated to the new dome, and in 1882 a new square bar micrometer made by Thomas Cooke & Sons arrived, replacing the earlier Cooke micrometer and the two rings micrometers made by Tornaghi.[33]

Finally, in 1886 Tebbutt took possession of an even larger telescope, a 20.3cm Grubb refractor (Figure 7),[34] of which he has provided a detailed description:

> 'This consists of a fine equatorial refractor of eight inches [20.3cm] clear aperture, and 9 feet 7 inches [2.92m] focal length... The pillar supporting the equatorial consists of two massive hollow cylinders of cast iron, one standing on the other. The lower casting is securely bolted to a pier ... The upper casting is bolted to the lower one, and admits at the same time of a small azimuthal adjustment by means of a tangent screw. To the upper cylinder is secured another massive casting containing the socket for the polar axis: it also contains the clock, whose driving weight is within the cylindrical pillar. This casting consists of two parts fitted in such a way as to admit of the usual adjustment for latitude within a very wide range. The mounting is that known as the Fraunhofer or German. The telescope tube is in three parts and of rolled steel. The hour circle is at the upper extremity of the polar axis, and the declination circle next to the telescope cradle, being respectively 8.6 [21.8cm] and 13.0 [33cm] inches in diameter. They are divided, the former to 2 minutes of time and read off to 10 seconds by the vernier, and the latter to 10′, read off by opposite verniers to 30". The latter is very conveniently read off from the eye end of the telescope by means of a tube with lenses and a prism. The illuminating lamp is suspended at the counterpoise extremity of the declination axis. The light passing up this hollow axis and falling on a set of reflectors in the telescope cradle, serves for illuminating the micrometer threads, the graduated limb of the declination circle and a transparent position circle at the eye end of the telescope. The telescope has a filar micrometer of the best description ... a Dawes solar eyepiece and four negative eyepieces whose magnifying powers are 131, 175, 224 and 340.'[35]

The four micrometers used with the 11.4cm Cooke were adapted to this new telescope.

Tebbutt now had what many professional astronomers by international standards would regard as minimal equipment,[36] although the Grubb telescope was comparable to the largest refractors found in the Australian colonial observatories of the day. Tebbutt installed this telescope in the vacant circular wooden observatory, but this proved rather cramped quarters for so large an instrument and eventually the ravages of white ants forced the issue and demanded its demolition. In 1894 it was replaced by a more commodious brick observatory of 5.5m diameter that was build on the same site (Figure 8).[37]

In addition to its instrumentation, Windsor Observatory possessed a library which Tebbutt believed '… few private establishments can boast of.'[38] This comprised a goodly selection of astronomical books and monographs, runs of journals, and an extensive collection of reprints.[39] It was partly through an extensive international exchange network with 168 institutions, societies and individuals in thirty-three different countries and involving his Windsor Observatory *Annual Reports*, other booklets and reprints of his papers that Tebbutt was able to build up this magnificent resource. By the end of the nineteenth century all of the world's major observatories were providing Windsor Observatory with gratis copies of their publications, which says a great deal about Tebbutt's international reputation.

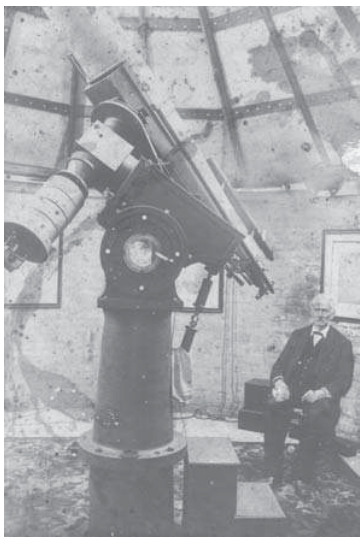

Figure 7. Photograph of John Tebbutt and the Grubb telescope, taken on 1915 May 11, a year and a half before his death *(Orchiston Collection)*.

Serious observational astronomy

Introduction

After installing the Jones refractor and Tornaghi's transit telescope in his brand new Windsor Observatory in 1863, Tebbutt at last felt he was ready to do

> '...something respectable for astronomy. At the outset I resolved to devote myself to systematic observations of occultations of stars by the moon, of eclipses of Jupiter's satellites,

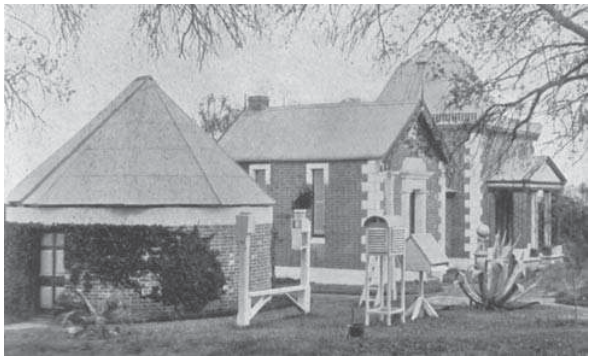

Figure 8. View of two of the three Windsor Observatory buildings in 1906 from the east-north-east, showing (left to right) the brick building constructed for the Grubb refractor (which replaced the 1874 wooden building on the same site that is shown in Figure 6) and the main building of 1879 *(Orchiston Collection)*.

> and of positions of comets, with attention to phenomena of an occasional character.'[40]

The 'phenomena of an occasional character' which particularly interested him were transits of Mercury and Venus, and solar and lunar eclipses. The only other celestial object that he decided to keep under scrutiny was the unusual variable star, Eta Argus (now known as Eta Carinae). However, his observational targets were expanded considerably with the acquisition of the Cooke telescope and yet again when the Grubb refractor was installed at Windsor Observatory. Unlike the two smaller telescopes, the Grubb telescope was furnished with a drive, which made micrometric observing much easier. In addition, the increased light grasp allowed Tebbutt to follow comets for longer and to carry out successful observations of fainter double stars and minor planets.

Carrying out the observations was simply part of the story. It was also necessary to compute the local occurrence times of certain events (e.g. lunar occultations and eclipses) beforehand, and after most telescopic work came the task of reducing the observations and preparing them for publication. In the case of cometary positions and the subsequent orbital computations the amount of labour involved was prodigious, yet until 1881 Tebbutt carried out all of these calculations himself. Thereafter, it was only with difficulty that he found computers competent to assist,[41] until the Government surveyor, Joseph Brook, and fellow amateur astronomers R. T. A. Innes and C. J. Merfield came to his aid late in the century. When Macdonnell summarised Tebbutt's lifelong observational achievements, he specifically referred to the onerous nature of these calculations: 'The reductions connected with the work which has been so systematically carried out for the last 40 years involve an immense amount of labour...'[42]

From the time he purchased the Jones refractor, Tebbutt carried out astronomical observations every single year until his official 'retirement' at the end of 1903 (when he was seventy years of age), and intermittently thereafter through to 1915, just one year before his death. During his busiest years, he observed on a large percentage of clear nights,[43] yet he somehow also found the time and energy for family life, and to run his farm and attend to his business interests in Windsor.

Given these circumstances, one is almost overwhelmed by the variety of observations that Tebbutt undertook during his long career as an amateur astronomer (see Table 1). Although he had catholic tastes, his main emphases were on cometary, planetary and minor planet positions; Jovian satellite phenomena timings; double star position angles and distance measurements; lunar occultation timings; variable star magnitude estimates; and what he called 'phenomena of an occasional character' (such as eclipses, transits of Mercury and Venus, lunar occultations of planets, planetary conjunctions, and occultations of stars by planets). He also participated in international searches for the postulated intra-Mercurial planet, Vulcan.

These were precisely the types of programmes that many professional astronomers and serious amateur astronomers tended to focus on during the second half of the nineteenth century, although there was increasing interest in the research opportunities offered by applying photography and spectroscopy to astronomy.[44] Over the years Tebbutt acquired a number of books and many reprints on the so-called 'new astronomy', astrophysics, so he was all too aware of these developments, but they did not tempt him. Instead, he remained true to positional astronomy, and was seen by some of those who outlived him as

> '...one of the few remaining links that connect the astronomy of today [i.e. 1917] with the older form that Airy and his school recognised and practised [during the nineteenth century]. The late Mr. Tebbutt, as a loyal member of that school, worked hard to record positions, [and] to deduce orbits...'[45]

Comets

Of all celestial objects, comets were undoubtedly Tebbutt's favourite target, and there are two different facets to his work that we must consider. Firstly, he knew that by using his micrometers to precisely determine the positions of known comets, he and others could use these measurements to calculate the orbital elements and thereby contribute significantly to cometary astronomy. Secondly, he quickly discovered that systematic comet-searching could be rewarding, for it not only produced new targets for those committed to cometary science but also brought the discoverer considerable kudos – and kudos *was* important to John Tebbutt.

Baracchi has described Tebbutt's cometary work as 'remarkable',[46] and this is an apt evaluation. Between 1853 and 1916 he followed 59 different periodic and non-periodic comets (see Table 2), and in addition he searched unsuccessfully for known comets in 1889, 1890, 1892, 1894, 1896, 1898, 1900 and 1901.[47]

Once he was furnished with proper instruments, Tebbutt's usual procedure was to obtain micrometric positions of each comet from the time it first became visible at Windsor or news of its discovery was received, until it disappeared from southern skies or became too faint to detect any longer. Many comets were observed on every possible clear night, and followed for extended intervals. Tebbutt became so proficient in cometary observation that this sphere of astronomy was sometimes left entirely to him by the Australian professional observatories.[48]

Table 1. Tebbutt's observational astronomy, 1853–1915

Year	CP*	DS	LE	LP	LS	JS	MP	PP	SE	TM	TV	VS
1853	×											
1854												×
1855												
1856												
1857									×			
1858	×		×									
1859	×											
1860	×											×
1861	×								×			
1862	×											×
1863					×							×
1864	×				×	×						×
1865	×											×
1866			×		×	×						×
1867			×		×	×						×
1868					×	×			×			×
1869			×		×	×		×				×
1870			×		×	×			×			×
1871									×			×
1872												×
1873			×		×	×						×
1874	×		×		×	×					×	×
1875	×			×	×	×						×
1876					×	×			×			×
1877			×		×	×	×					×
1878	×				×	×		×	×	×		×
1879	×		×			×	×	×				×
1880	×	×	×		×	×	×	×				×
1881	×	×	×		×	×		×		×		×
1882	×	×			×	×	×	×	×			×
1883	×											×
1884	×	×										×
1885	×	×	×		×	×	×	×				×
1886	×	×		×	×	×		×				×
1887	×	×	×		×	×	×	×				×
1888	×	×		×	×	×	×	×				×
1889	×	×			×	×	×					×
1890	×	×			×	×	×		×			×
1891	×	×	×		×	×	×	×		×		×
1892	×	×			×	×		×				×
1893	×	×		×	×		×	×				×
1894	×	×		×	×			×		×		×
1895		×			×	×	×	×				×
1896		×			×	×	×					×
1897	×				×	×	×	×				×
1898	×				×	×	×	×				×
1899	×	×			×	×	×	×				
1900		×		×	×	×	×	×				
1901	×	×			×		×	×				
1902	×	×			×	×	×					
1903	×						×					
1904	×						×	×				
1905		×						×				
1906		×		×								
1907		×										
1908					×	×						
1909	×	×										
1910	×											
1911		×										
1912	×											
1913		×										
1914												
1915		×										

Key:
CP = Cometary positions
DS = Double stars
LE = Lunar eclipses
LP = Lunar occultations of planets
LS = Lunar occultations of stars
JS = Jovian satellite phenomena
MP = Minor planets
PP = Planetary positions
SE = Solar eclipses
TM = Transits of Mercury
TV = Transits of Venus
VS = Variable stars

The first comet that Tebbutt observed micrometrically was the periodic comet 109P/Swift–Tuttle, in 1862, and in an obvious case of unbridled over-enthusiasm he submitted five short papers on these measures and the derived orbital elements to *Astronomische Nachrichten, Monthly Notices of the Royal Astronomical Society*, and *Transactions of the Philosophical Society of New South Wales*.[50] These were his very first contributions to professional scientific journals. They were certainly not to be his last.

The longest series of micrometric observations Tebbutt obtained for any one comet was of Comet C/1898 L1 (Coddington–Pauly) on 103 nights in 1898–1899,[51] but the comet that he observed most frequently was Comet 2P/Encke, which is distinguished by having the shortest orbital period of any known comet. As a result, with the passing of the years this became an all-too-familiar visitor at Windsor Observatory, and Tebbutt observed it on eight different occasions between 1862 and 1904 (inclusive). He was the first to observe the comet during its 1878 and 1888 apparitions and is credited with the recovery on each occasion, while in 1898 he shared this honour with the New Zealand astronomer, John Grigg.[52]

In the case of twelve of the comets that he observed, Tebbutt used his own positional data to compute the orbital elements. This was a considerable accomplishment, and in 1902 one of his Sydney contemporaries wrote:

> '...the place of highest honour in Cometary Computation in Australia belongs to Mr. Tebbutt. For nearly forty years he must have had that field entirely to himself. From intimate acquaintance with Mr. Tebbutt and his work for the past fourteen years & more, I can say I hardly know whether to admire more his universally recognised accuracy & refinement of his observational work, or the mathematical skill ... of his work – during all these years – in the field of Cometary calculation.'[53]

In addition to following known comets, Tebbutt searched for new ones. As we have seen, he was responsible for the discovery of the Great Comet of 1861, and in 1881 he detected a second Great Comet (see Figure 9) almost twenty years to the day after his 1861 discovery. Because of rapid developments in astronomical photography and spectroscopy at the time, Comet C/1881 K1 (Tebbutt) made a major contribution to cometary astronomy.[54] Later in 1881, Tebbutt discovered a second comet (C/1881 N1), only to learn that it had been found earlier by a northern hemisphere observer.

Variable stars

The second most important area of observational astronomy to which Tebbutt contributed was variable stars, even though he only made extensive observations of two different objects.[55] One of these was η Argus (or η

Figure 9. Etienne Léopold Trouvelot's painting of Comet C/1881 K1 (Tebbutt), after it became a feature of northern skies *(Courtesy: Chapin Library, Williams College, Mass.).*

Carinae as it is now known) and the other R Carinae. Because a larger aperture was never called for, Tebbutt made all of the telescopic observations with his Jones refractor.

Eta Carinae is an extremely unusual variable star, and is of great interest to astrophysicists. It is one of the most massive and luminous stars in our Galaxy and is the standout example of a small class of variable stars known as 'luminous blue variables' (LBVs).[56] In 1843, when young Tebbutt was just nine years old, it outshone almost all other stars in the southern sky at visual magnitude –1. By 1850 it had begun to fade, slowly at first, but more rapidly from 1860, and by 1864 it was close to the limiting magnitude visible with the unaided eye. Between 1854 and 1898 Tebbutt made 241 magnitude estimates of η Carinae, contributing significantly to our knowledge of its unique and unpredictable light curve (but at that time there was little interest in understanding the dynamics of the star itself). One of the most interesting features of his light curve is the minor increase in magnitude recorded in the late 1880s, which some astronomers correlate with the 'equatorial features' present in HST images of η Carinae and associate with an S Doradus-type outburst.[57]

Tebbutt also observed the variable star R Carinae, which is a Mira type variable, and on the basis of the 450 individual magnitude estimates he made between 1880 and 1898, plus those obtained by others, he was able to derive a period of 311 days.[58] This differs little from the currently-accepted value of 308.58 days. A light curve based on Tebbutt's published and unpublished observations has been generated, and is shown here in Figure 10; twenty-two different minima are represented.

While Tebbutt's observations of these two variable stars are valuable, perhaps his most amazing achievement was the discovery of Nova V728 Scorpii 1862.[59] What is remarkable is that he made the discovery quite by accident in 1877 while re-analysing some of his own 1862 observations of Comet 109P/Swift–Tuttle. Despite the strange circumstances, there seems little doubt that Tebbutt did indeed unwittingly observe a nova, and after considering the evidence Professor H. H. Turner concluded: 'It may confidently be said that Mr. Tebbutt was too good an observer to have made a mistake.'[36]

Tebbutt also carried out occasional observations of a few other variable stars, and during the 1870s investigated a number of stars whose variability was in question at the time.

Table 2. Numbers of comets observed by Tebbutt, 1853–1912[49]

Year	*No.*	*Year*	*No.*	*Year*	*No.*
1853	2	1881	2	1893	2
1858	1>	1882	3>	1894	3
1859	1	1883	1	1897	1
1860	1	1884	3	1898	2>
1861	1	1885	1	1899	3
1862	2	1886	5	1901	1
1864	1	1887	1	1902	1>
1865	2	1888	4>	1903	2
1874	1	1889	3	1904	1
1875	1	1890	2	1909	1>
1878	1	1891	2	1910	1
1879	1	1892	4>	1912	1
1880	1				

Note: An '>' indicates that a comet was observed through into the following year.

Double stars

Double stars constitute a third class of astronomical objects for which Tebbutt made a useful contribution. Various astronomers combined his numerous micrometric measures of position angle and separation with comparable data obtained at earlier times by others to derive orbital parameters for selected double stars.

Tebbutt carried out his first micrometric double star observations in 1880 with the Cooke refractor, but was able to

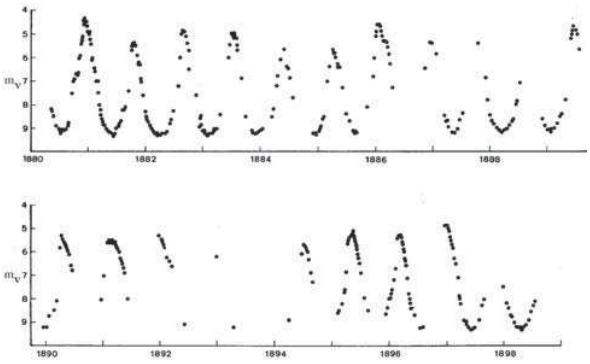

Figure 10. Light curve of R Carinae, 1880–1898, based on Tebbutt's observations.

Table 3. Numbers of different double stars observed by Tebbutt, 1880–1915[60]

Year	No.	Year	No.	Year	No.
1880	6	1890	7	1901	28
1881	12	1891	8	1902	54
1882	16	1892	14	1905	5
1884	1	1893	1	1906	1
1885	18	1894	11	1907	13
1886	1	1895	17	1909	7
1887	29	1896	8	1911	5
1888	28	1899	2	1913	2
1889	3	1900	26	1915	11

greatly expand this programme with the arrival of the Grubb telescope. He continued to observe double stars through to 1915, just one year before his death (see Table 3), making a great many observations in the years 1900, 1901 and 1902 in particular. Some of the observations made during the 1890s were at the specific request of overseas professional astronomers.

In all, Tebbutt observed 133 different double stars, his most popular targets being α Centauri, p Eridani, γ Coronae Australis, γ Centauri, β Muscae and Lacaille 2145. All of the stars Tebbutt observed were known doubles; unlike his Sydney Observatory colleagues he did not systematically search for new double or multiple stars.

Minor planets

Tebbutt was able to contribute to minor planet astronomy by providing published micrometric positions that were used by professional astronomers interested in refining the orbital parameters. He never engaged in any systematic searches for new minor planets, as some amateur astronomers were prone to do.

His first minor planet observations were of 4 Vesta in 1877, using the Cooke telescope, but these observations became much more numerous after he acquired the Grubb telescope in 1886.[61] Between 1877 and 1904 he at one time or another tracked twenty-three different minor planets, and used his micrometers to record their positions relative to selected reference stars. His favourite targets were 1 Ceres, 2 Pallas, 3 Juno, 4 Vesta, 6 Hebe and 11 Parthenope.

Planetary positions

A fifth area to which Tebbutt contributed was planetary positional astronomy. Between 1869 and 1905 he carried out micrometric observations of three different sorts of phenomena: mutual conjunctions of planets; conjunctions of planets and accurately-catalogued stars; and occultations of stars by planets. By far the most commonly-observed were conjunctions of planets and stars, and between one and four of these was observed almost every year from 1885 to 1901, inclusive.[61]

These conjunctions and occultations had the potential to reveal planetary positions with considerable accuracy, and this was particularly important in the case of the outer planets, Uranus and Neptune, whose orbital characteristics still posed problems. However, Tebbutt did not discriminate: he observed phenomena associated with all of the known planets except Mercury, but most common were stellar conjunctions involving Jupiter and Uranus.

Figure 11. One of Tebbutt's drawings of the 1874 transit of Venus *(after Tebbutt, 1883 in ref. 63).*

Transits of Mercury and Venus

Of the various 'phenomena of an occasional character' which interested Tebbutt, his observations of solar and lunar eclipses and transits of Mercury and Venus were of greatest significance.

Transits of Venus are rare events. Two occurred in the nineteenth century, in 1874 and 1882, and both were potentially visible from Australia. Tebbutt realised that his observations, when combined with others, could be used to investigate that fundamental solar system yardstick, the astronomical unit (AU), the mean distance from the Earth to the Sun. During the nineteenth century, accurate determination of the AU was one of the challenges of world astronomy.[62]

As it turned out, Tebbutt successfully observed the 1874 event (see Figure 11), and his contact times formed part of the dataset used by Tupman to derive a solar parallax of 8.84553.[63] In marked contrast, on the vital day in 1882 the sky was '...completely overcast with dense dark cloud, through which there was not the slightest prospect of obtaining a glimpse of the Sun.'[64]

Somewhat less spectacular in appearance and much less important were transits of Mercury, and Tebbutt observed four of these between 1878 and 1894, paying particular attention to possible evidence of a planetary atmosphere. The diagnostic halo round the planet was not detected during any of the transits, and nor was there any sign of a possible Mercurian satellite.[65]

Solar and lunar eclipses

Solar and lunar eclipses are visually alluring events, but they also allow checks to be made on the Moon's orbit. Probably both factors explain Tebbutt's interest in these events, and as we have seen he first attempted to observe a solar eclipse – in this case a total solar eclipse – in 1857, but was thwarted by clouds. Although this was the only total solar eclipse visible from Windsor during his lifetime, he did succeed in observing nine different partial solar eclipses between 1857 and 1891, and fifteen different lunar eclipses.[66]

In addition to recording the times of the various contacts for both types of events, during lunar eclipses Tebbutt also recorded the times when the Earth's shadow intersected various craters, and was particularly interested in colour variations at totality.[67]

Table 4. Numbers of Jovian satellite phases observed by Tebbutt, 1866–1902[68]

Year	No.	Year	No.	Year	No.
1866	18	1878	27	1890	41
1867	21	1879	19	1891	31
1868	5	1880	14	1892	14
1869	2	1881	3	1895	24
1870	3	1882	4	1896	43
1873	7	1885	15	1897	32
1874	11	1886	27	1898	11
1875	14	1887	46	1899	23
1876	17	1888	75	1900	8
1877	8	1889	26	1902	23

Jovian satellite phenomena

Yet another area of astronomy to which Tebbutt contributed was in the observation of Jovian satellite phenomena. Four different types of events were involved: eclipses, transits, shadow transits and occultations. Tebbutt knew that all four types of observations could be used by professional astronomers to investigate the orbital dynamics of the satellites.

Tebbutt began observing Jovian satellite phenomena in earnest in 1866, and continued to contribute observations through to 1902 (see Table 4). Before the acquisition of the Grubb telescope in 1886 he tended to confine his observations to eclipses, but thereafter he added occultations and transits to his repertoire. The most productive consecutive years were during the period 1886-1897.

While Tebbutt generally confined his Jovian studies to the satellites, from time to time he was seduced into observing and recording some of the distinctive markings on the planet's disk. For a short time in 1880 he monitored the colour of the Great Red Spot and timed its transit across the central meridian of the planet, and in 1896 he followed the development of two distinctive dark spots that appeared in the North Tropical Zone.[69]

Lunar occultations of stars

Another area of observational astronomy to which Tebbutt was particularly committed was the timing of lunar occultations of stars, and he was aware that such observations could be used to provide a valuable check on anomalies in the Moon's orbit. He also realised that occultation data could be used to establish the longitude of the Windsor Observatory.

Tebbutt timed his first lunar occultations in 1863, and with the founding of the Windsor Observatory the following year they became a regular feature of his observing programme. Such observations were carried out in thirty-three different years during the thirty-nine year period, 1864–1902 (inclusive) – see Table 1. Although very respectable totals were recorded every year between 1885 and 1900, by far his most productive years were 1896 and 1897 with total annual 'phases' of 161 and 134 respectively.[70]

In 1901, Elkington pointed out that through these lunar occultation observations '...the position of Windsor [Observatory] has been more accurately determined than that of any other place in New South Wales.'[71] As a result of his painstaking lunar occultation work over many years Tebbutt succeeded in making Windsor Observatory one of Australia's fundamental geodetic reference points.

Lunar occultations of planets

One final area of astronomy to which Tebbutt contributed was the observation of lunar occultations of planets, and on eight occasions between 1875 and 1906 he was fortunate enough to witness such events and record the disappearance and appearance times (see Table 1). On a number of occasions he also observed unusual optical effects.[72]

Most of these observations were carried out after the acquisition of the Grubb telescope, and all of the naked eye planets were involved except for Mercury.

Publications

To John Tebbutt, observing was a means to an end: to provide colleagues, and particularly professional astronomers, with useful data. Publication therefore was the obvious climax of any viable observational project. In this regard, he was particularly productive, as Table 5 illustrates.

In this Table, the dominance of Tebbutt's cometary work stands out. It is also significant that those programmes ranking two and four in terms of total published papers (i.e. Jovian satellite phenomena and lunar occultations of stars) were less important in terms of internationally significant research results than many of the entries below them in the table. On this score, transits of Venus have the lowest ranking of all, yet Tebbutt made a particularly valuable contribution in 1874.

Another way of looking at Tebbutt's published output is to consider all of the papers that appeared under his name in different astronomical journals. As Table 6 indicates, during the course of his astronomical career Tebbutt published 388 different research notes and research papers. Most of these were short and descriptive and simply recorded observational raw data, but in the case of his cometary work Tebbutt sometimes included orbital elements derived from his own observations. In addition, a few papers represented in Table 6

Table 5. Number of published papers by Tebbutt dealing with different areas of astronomy[73]

Area of astronomy	No of papers
Comets	162
Jovian satellite phenomena	33
Planets	33
Occultations of stars	32
Variable stars	30
Double stars	29
Minor planets	27
Solar eclipses	9
Lunar eclipses	9
Occultations of planets	8
Latitude/longitude	8
Transits of Mercury	7
Transits of Venus	5
'Other'	14
Total	406

Table 6. Number of Tebbutt's publications per journal, 1862–1915[73]

Astronomical Journal	1
Astronomische Nachrichten	149
Astronomical Register	9
Journal of the British Astronomical Association	20
Monthly Notices of the Royal Astronomical Society	125
Memoirs of the Royal Astronomical Society	1
The Observatory	47
Publ. of the Astron. Society of the Pacific	6
Southern Science Record [published in Melbourne]	3
Trans. of the Phil. Society of NSW and its successor, *Journal and Proceedings of the Royal Soc. of NSW*	27
Total	388

are non-observational, dealing with historical astronomical themes or with aspects of meteorology or tidal studies, but these amount to less than 2% of the total.

Table 6 indicates that Tebbutt's papers appeared in three local and eight international journals. All of the overseas journals were reputable ones, *Astronomische Nachrichten* and *Monthly Notices* being the leading publication outlets at that time for professional astronomers (though some would argue that this was to change at the end of the nineteenth century when *Astronomische Nachrichten* was eclipsed by the *Astronomical Journal*, the *Astrophysical Journal* and *Publications of the Astronomical Society of the Pacific*). In Australia, Tebbutt had to resort to the publications of the local Royal Society and a general scientific journal, the *Southern Science Record*, given the absence of any specialist astronomical journal at that time.

While the figures in Table 6 are certainly impressive, they do not tell the whole story, for as was the custom in nineteenth century science, Tebbutt published some of his papers in duplicate (or occasionally even in triplicate) in two (or three) different journals. For example, of the 125 papers which appeared in *Monthly Notices of the Royal Astronomical Society*, 39 of them (31%) also appeared in *Astronomische Nachrichten*. Likewise, about 25% of his papers published in *The Observatory* also appeared in *Astronomische Nachrichten*, and some papers published locally by the Philosophical Society (later the Royal Society) of New South Wales also suffered this fate. However, Tebbutt rarely sought duplicate publication venues after 1885.

After identifying all such duplications and triplications, we can determine the total number of *individual* papers and research notes that Tebbutt wrote. His lifetime tally was 323, which is still a prodigious output and one that many a present-day scientist would be proud of.

But even this does not signify his total output, for over the years Tebbutt also published a number of astronomy-related books and booklets at his own expense, and these were widely distributed to Australian and overseas institutions, scientific colleagues and others. The first of these private publications to appear was a 74-page soft-cover book titled *History and Description of Mr. Tebbutt's Observatory, Windsor, New South Wales* which was published in 1887. This was followed by Windsor Observatory *Annual Reports* for the years 1888 to 1903 inclusive, booklets ranging in length from 19 to 33 pages, which summarised the instruments at and the astronomical activities of the Windsor Observatory. This was an ambitious undertaking for an amateur, but reflected Tebbutt's professional approach to astronomy and his realisation that the wide circulation of such publications was surely an effective way of promoting his work and his observatory. To some extent, this was also the motivation behind the preparation of his *Astronomical Memoirs*, which appeared in 1908 as a 132-page soft-cover book. With the passage of time, this became a collectors' item, and it was reprinted, with additional supporting material, in 1987 (although the publication date is incorrectly listed as 1986). The cover features a colourful David Malin image of a well-known spiral galaxy (see Figure 12), and is a far cry from the plain cover of the original edition.

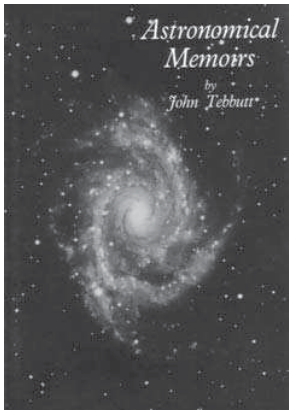

Figure 12. A black and white reproduction of the cover of the 1986 reprint of Tebbutt's *Astronomical Memoirs*, featuring one of David Malin's colourful galaxy images.

In addition to these eighteen astronomical books and booklets, Tebbutt also wrote a number of booklets on the astronomy–religion interface,[74] published eight monographs documenting his meteorological observations,[75] and produced astronomy chapters for two different books.[76] When all of these published works are considered alongside his very numerous newspaper articles, we are looking at a phenomenal output – especially for a solitary self-taught amateur astronomer – and '...a monument to Mr. Tebbutt's untiring energy and unremitted diligence.'[41]

Concluding remarks

For the last three decades of the nineteenth century, John Tebbutt was Australia's leading astronomer, amateur or professional, and he enjoyed a considerable local, national and international reputation.

As an amateur astronomer, he had few international peers. From humble beginnings and minimal instrumentation, he improved his situation as his increasing means allowed until his Windsor Observatory was in a position to compete effectively with larger government-funded northern hemisphere observatories. Through exchanges with many of these, he built up an outstanding research and reference library that he used extensively.

With unbounded energy and total dedication, he made optimal use of his modest astronomical equipment and was able to contribute significantly to cometary, double star, minor planet, variable star and Jovian satellite astronomy and to the international transit of Venus programme in 1874. He discovered two of the 'Great Comets' of the century, was responsible for three recoveries of Comet 2P/Encke, discov-

ered a nova, and provided lunar occultation observations that were used in establishing the geodetic framework for New South Wales. Further information on his observational achievements will be presented in later papers, but it is particularly appropriate that this introductory paper should be written in 2003, exactly one hundred years after his 'official' retirement from observational astronomy (even if he actually continued to make intermittent observations to within a year of his death in 1916).

Although technically an amateur, in that he received no remuneration from astronomy, Tebbutt was regarded as a professional astronomer by most Australian astronomers and as the doyen of Australian astronomy. His observatory rivalled those maintained by the colonial governments in New South Wales, Victoria, South Australia and Western Australia; he observed the same types of astronomical objects and celestial events as they did; and published in the same international journals – but far more frequently as his lifetime total of nearly 390 individual papers and research notes testifies. To these must be added his books, booklets and chapters of books, in all a phenomenal output for a single individual.

Over the years, Tebbutt was a strong supporter of the Royal Astronomical Society and the British Astronomical Association, and in recognition of his pre-eminent status in Australian astronomy was elected founding president of the New South Wales Branch of the latter Association when this was formed in 1895. Back in 1882 he had formed Australia's first national astronomical group, a Corps of Australian Comet Seekers, but this was an anachronism and after struggling to survive folded one year later.

Along with the likes of Gale and Roseby in Sydney and Biggs in Launceston, Tebbutt was an Australian pioneer in the popularisation of astronomy. Through his innumerable contributions to Sydney newspapers, his popular lectures and his occasional viewing nights at Windsor Observatory the general public gradually grew more astronomically literate, and a number of individuals who would later make names for themselves were wooed into amateur astronomy. Although a busy man, Tebbutt managed to maintain a voluminous correspondence. He always had time to reply to those with serious inquiries, and was renowned for the encouragement he gave to beginners in astronomy.

During the last three decades of the nineteenth century, Tebbutt was a power-broker in New South Wales astronomy, and his advice and support were sought by amateur and professional astronomers alike from within Australia and from overseas. As such, he was the idea rôle model for those amateur astronomers aspiring to greatness, but his high profile came with a price for he became increasingly estranged from Russell, the Government Astronomer of New South Wales, and by 1891 a bitter feud existed between the two men.

In any assessment of Tebbutt's contribution to Australian science it is important to remember that for more than half a century he also maintained a time-service for the citizens of Windsor, ran a meteorological station and published data in local newspapers and in a series of monographs, recorded local floods and freshes, and for a short while carried out local tidal studies. In addition to his astronomical achievements, he should be seen as an Australian pioneer in the field of meteorology, and his wide-ranging scientific contributions reinforce Ashbrook's perception that he '...was trying with some success to run a one-man Greenwich Observatory in the Southern Hemisphere.'[77]

While we may applaud his efforts, Tebbutt was frustrated by what might have been, and in 1875 he contributed the following perceptive comments to the pages of the *Sydney Morning Herald* newspaper:

> 'I am gratified to find that what little I have, under God's blessing, been enabled to do, is of some service to science, but I feel that what has been accomplished is only a fraction of what should be done to represent Windsor in the astronomical world. Sublunary matters and a somewhat delicate state of health prevent me from bestowing that attention on the subject which it deserves. I have long lived in the hope of meeting someone who, with a certain amount of leisure at his command, could assist me in my work, partly out of love for the science, and partly for a remuneration. If such an one can be found, I shall feel myself in a position to add to my instrument appliances, and so make my work more effective. It is almost needless to remark that there is a wide and fruitful field open to the enthusiast in our southern skies.'[78]

It is illuminating to imagine just how much more Tebbutt might have achieved had such an assistant materialised. Yet despite this apparent setback, Tebbutt proved to be '...the first great Australian born astronomer...',[79] and for more than half a century he was able to make a major contribution to Australian astronomy. As the retired Government Astronomer of Victoria, Robert Ellery, wrote in 1901: 'To Mr. Tebbutt's enterprise, persevering and well-directed personal work belongs no small share of Australia's contribution to astronomy during the last thirty years.'[80]

Despite this, few tangible rewards came Tebbutt's way during life, although since his death a crater on the Moon has been named after him and he has featured on an Australian banknote. The refurbished John Tebbutt Observatories at Windsor now operate as a commemorative museum to one of Australia's most remarkable amateur scientists.

In closing this paper I can do no better than to quote the distinguished British astronomer, Professor H. H. Turner, who in 1918 wrote:

> 'John Tebbutt was one of those enthusiastic non-professional astronomers who, with instrumental appliances of the humblest order [by world standards] and no outside help, made an indelible mark on our records.'[36]

Turner corresponded with Tebbutt for many years, but the two only met in 1914 when the British Association for the Advancement of Science held its eighty-fourth meeting in Australia and a carload of astronomers – Turner and the Astronomer Royal included – made the pilgrimage to Windsor to meet a delighted yet frail John Tebbutt. Just two years later he was dead.

Acknowledgments

I wish to thank Wayne Hammond (Williams College), Peter Hingley (RAS Library), Ethleen Lastovica (formerly Librarian at the South African Astronomical Observatory), Dr Nick Lomb (Sydney Observatory), Jim Park (Melbourne), John Tebbutt (great-grandson of the astronomer) and staff at the Mitchell Library (Sydney) for their assistance. I am particu-

larly grateful to the Mitchell Library, the Royal Astronomical Society and the Chapin Library (Williams College) for permission to publish Figures 3, 6 and 9.

Address: Anglo-Australian Observatory and Australian Telescope National Facility, PO Box 296, Epping, NSW 2121, Australia. [wo@aaoepp.aao.gov.au]

References and notes

The following abbreviation is used: TL = Letters to J. Tebbutt, bound manuscript letters in the Mitchell Library, Sydney.

1 There is an extensive bibliography on Tebbutt, but two readily-accessible overviews are Orchiston W., *Astron. Now*, **2**(5), 11–16 (1988) and White G. L., *Proc. Astron. Soc. Austr.*, **3**, 408–411 (1979).

2 For overviews of Tebbutt's astronomical, meteorological and tidal observations see Tebbutt J., *Astronomical Memoirs*, Sydney, 1908 and Orchiston W., *Southern Stars*, **29**, 215–244 (1982), while information about Tebbutt's important role in popularising astronomy is provided in Orchiston W., *Austr. J. Astron.*, **7**, 33–66 (1997).

3 Re the nova discovery see Ashbrook J., 'John Tebbutt, his observatory, and a probable nova', in J. Ashbrook, *The Astronomical Scrapbook. Skywatchers, Pioneers and Seekers in Astronomy*, 66–71, Cambridge (Mass.), 1984 and White, *op.cit.* (ref. 1).

4 The history of the Comet Corps is recounted in Orchiston W., *J. Astron. Soc. Vict*oria, **35**, 70–83 (1982), and the early history of the BAA NSW Branch is discussed in Orchiston W., *J. Brit. Astron. Assoc.,* **98**, 75–84 (1988) and in Orchiston W. & Perdrix J., *J. Brit. Astron. Assoc.,* **112**, 68–77 (2002).

5 For an account of the Government Astronomer of NSW offer see Orchiston W., *Austr. J. Astron.*, **2**, 149–158 (1988).

6 See Macdonnell W. J., *J. Brit. Astron. Assoc.,* **15**, 80–86 (1904).

7 RAS President, Professor H. H. Turner, announced at the 1905 AGM of the Society that 'The Jackson–Gwilt Gift and Medal have been awarded to Mr. John Tebbutt of Windsor, New South Wales, for his important observations of comets and double stars, and his long continued services to astronomy in Australia, extending over forty years. there can be no reason why I should not recall to your memory that Mr. Tebbutt began astronomical work in 1854, and is only now relinquishing it at the age of seventy, that amid surroundings which gave him little encouragement he has made regular and systematic observations during half a century, including, for instance, those of some 1400 occultations of stars by the moon, and valuable measures of double stars; that he has contributed over eighty papers to the *Monthly Notices*: and has, moreover, discovered several comets, including the notable ones of 1861 and 1881, the orbits of which he computed from his own observations.' (cited in Tebbutt, *op. cit*., ref. 2, 80–81).

8 Haynes R. *et al.*, *Explorers of the Southern Sky: A History of Australian Astronomy*, Cambridge University Press, 1996

9 *J. Brit. Astron. Assoc.,* **34**, 45 (1923)

10 When his seventy-six year old father died on 1870 December 20, thirty-five year old John Tebbutt inherited the Peninsula Estate. Five years earlier, a wealthy uncle had died, leaving a significant portion of his estate to his talented nephew (see the genealogy in Tebbutt J., *Astronomical Memoirs*, 103, Windsor, 1986; and 'Will of Thomas Tebbutt', Tebbutt Papers, Mitchell Library, Sydney (MSS.5588)).

11 John Tebbutt was pre-deceased by his wife and three of his daughters (see the genealogy mentioned in ref. 10). His estate was valued for probate at £69,364 (see Wood H., 'Tebbutt, John (1834–1916)', in G. Serle & R. Ward (eds.), *Australian Dictionary of Biography. Volume 6. 1851–1890. R-Z*, 251–252, Melbourne, 1976), and his funeral was a major event for Windsor, attracting representatives of the NSW State Government, the RAS, the BAA and the Royal Society of New South Wales (see 'Death of Mr. John Tebbutt', in Tebbutt J., *Astronomical Memoirs*, 145–149, Windsor, 1986). Soon after Tebbutt's death his son donated the Windsor Observatory library and most of the astronomical records to the Mitchell Library in Sydney. The 'Tebbutt Collection' comprises more than one hundred volumes of manuscript notebooks, observing journals, calculations, meteorological and other data, and private correspondence, and is an incomparable resource for those studying the history of nineteenth and early twentieth century Australian astronomy and meteorology.

12 Tebbutt J., *The Broad and Narrow Way. An Address, Delivered Before the United Religious Mission*..., Windsor, 1875

13 This is revealed, for example, in his attitude towards fellow-astronomers, Dr William Bone and Sydney Observatory Director, Henry Russell (see Orchiston W., *Southern Stars*, **32**, 111–128 (1987) and Orchiston W., *AAO Newsl.,* **95**, 8–11 (2000) and Orchiston W., 'Tebbutt vs Russell: passion, power and politics in nineteenth century Australian astronomy', in S. M. R. Ansari *(ed.)*, *History of Oriental Astronomy*, 169–201, Dordrecht, 2002).

14 This message comes through time and again when one reads the volumes of inward letters in the 'Tebbutt Collection' in the Mitchell Library. By way of typical example, when W. Swindlehurst wrote Tebbutt on 1877 January 18 requesting information on sextants and astronomical books he received an almost instant reply, to which he responded on February 3: 'I am sure that I do not know what to say to sufficiently thank you for your exceedingly kind reply to my first letter. I certainly hoped to receive a few lines from you – but such a full friendly epistle, so full of good natured advice and useful hints I really had not dreamed of receiving.' (Swindlehurst W., letter to John Tebbutt dated 1877 February 3, in TL; his underlining).

15 Tebbutt J., untitled journal, 1894–96, MS, Mitchell Library, Sydney (A3756), entry for 1895 August 7

16 Tebbutt, *op. cit*., ref. 2, 9

17 Tebbutt, *op. cit*., ref. 2, 10

18 See Tebbutt J., *Observations made ... at the Peninsula, near Windsor, in the Colony of New South Wales, 1853–59*, MS, Mitchell Library, Sydney (A3745-1).

19 Tebbutt J., *Sydney Morning Herald*, 1854 May 13

20 Houghton T. H., *J. Proc. Roy. Soc. NSW*, **51**, 7 (1917)

21 *The Town and Country Journal*, 1889 November 2

22 *The Australasian*, 1893 August 26. In his *Astronomical Memoirs* (ref. 2, 14) Tebbutt remarks on how his father was concerned that these intensive mathematical studies would ruin his health.

23 Tebbutt, *op. cit*., ref. 2, 14–16

24 For a detailed account of this comet see Orchiston W., *Irish Astron. J.*, **25**, 167–178 (1998).

25 Tebbutt J., letter to E. Dunkin dated 1873 April 18, in RAS Letter Archives. The telescope tube was brass.

26 For the founding of this observatory see Orchiston W., *J. Brit. Astron. Assoc.,* **98**, 287–293 (1988), while the addition of further buildings and telescopes at Windsor Observatory is discussed in Orchiston W., *J. Antique Tel. Soc*., **21**, 11–23 (2001).

27 In setting up Windsor Observatory as a meteorological station Tebbutt was simply mimicking the practice in vogue at the time in the government observatories of Melbourne and Sydney, where meteorology was seen as part of the normal charter of a professional astronomical observatory – for details, see Orchiston W., *Search*, **19**, 76–81 (1988).

28 Tebbutt J., *History and Description of Mr. Tebbutt's Observatory*..., 8–9, Sydney, 1887

29 Tebbutt J., untitled description of the Windsor Observatory, 1873, in Tebbutt J., untitled journal, 1873–79, MS, Sydney, Mitchell Library (A3783)

30 Tebbutt J., *op. cit*., ref. 2, 37–38

31 Tebbutt J., untitled journal, 1896–98, MS, Sydney, Mitchell Library (A3757)

32 Austin, Tollis, Weiss & Youden, Tebbutt's Observatory Peninsular [*sic*] Estate Windsor, Sydney, School of Architecture and Building, University of New South Wales (copy in the Mitchell Library, Sydney, PXD 110^{-1}). It may be no more than a coincidence, but it is interesting that this basic design, with the main dome at one end, meridian and transit rooms leading off this, and an office/library facility beyond that, is identical to the floor plan of the Leipzig University Observatory constructed in 1861 (see Donnelly M. C., *A Short History of Observatories*, **99**, Eugene, 1973) – although Tebbutt's new observatory was, of course, on a much more diminutive scale.

33 Tebbutt J., *op. cit*., ref. 28, 10. This micrometer was ordered because Tebbutt had concerns about the previous Cooke micrometer and the two Tornaghi micrometers: 'The illuminating arrangement [of the original Cooke micrometer] has always given complete satisfaction, but there being no means of exhibiting bright threads on a dark field, all faint objects were until the close of 1881 observed by means of the ring-micrometers previously referred to. It is, however, well known to astronomers that it is only under certain conditions which cannot always be secured, that differential measures with this form of micrometer yield satisfactory results.' (*ibid*.)

34 This telescope was built to the order of Dr William Bone of Castlemaine, Victoria, in 1882, and aspects of its history are docu-

mented in Orchiston, 1987, *op. cit*., ref. 13; Orchiston W., *Austr. J. Astron*., **7**, 89–114 (1997) and Orchiston W. & Bembrick C., *Austr. J. Astron*., **7**, 1–15 (1997).

35 Tebbutt J., *op. cit*., ref. 28, 14–15

36 Turner H. H., *MNRAS*, **78**, 252–255 (1918)

37 Tebbutt J., *Report of Mr Tebbutt's Observatory, The Peninsula, Windsor, New South Wales, for the Year 1893*, **3**, Sydney, 1894

38 Tebbutt J., *op. cit*., ref. 2, 112

39 The Windsor Observatory library holdings, as at 1887, are listed in Tebbutt, *op. cit*., ref. 28, 47–74, and each year thereafter, new acquisitions were listed in successive Windsor Observatory *Annual Reports*. The library contained works in many languages other than English, and in order to keep up with astronomical developments published in French and German, John Tebbutt taught himself both of these languages – see Elkington H., *The Speaker*, **2**(2), 40–42 (1901).

40 Tebbutt J., *op. cit.*, ref. 2, 30

41 *The Sydney Quarterly Magazine*, **6**, 164–170 (1889)

42 Macdonnell W. J., *op. cit*., ref. 6. Just how much Tebbutt managed to accomplish is highlighted when we consider Sheepshank's warning: 'It is not enough that a splendid building is filled with magnificent instruments directed by a consummate astronomer; he must have at his disposal numerous subordinate assistants for observation and compilation...' (cited in Dewhirst D. W., *Vistas in Astron.*, **28**, 147 (1985)). Far from having 'numerous subordinate assistants', Tebbutt could not boast a solitary one!

43 Between 1863 and 1903, there was only one conspicuous hiatus when Tebbutt almost abandoned observational astronomy and that was between 1871 June and 1873 March when he was ill and moved to Parramatta (near Sydney). During this period he only had occasional weekend access to his observatory, but as his health improved so too did his appetite for astronomy and for a larger telescope. It was while living at Parramatta that he purchased the Cooke refractor.

44 See Clerke A., *A Popular History of Astronomy during the Nineteenth Century*, London, 1893.

45 This obituary note was taken from *The Observatory*, **40**, 141 (1917).

46 Baracchi P., 'Astronomy and geodesy in Australia', in G. H. Knibbs *(ed.), Federal Handbook Prepared in Connection With the Forty-Eighth Meeting of the British Association for the Advancement of Science, Held in Australia, August, 1914*, 352, Melbourne, 1914

47 In some instances, Tebbutt had been provided with incorrect positional data; other comets were simply too faint to be detected with his telescopes, or were inconveniently located in the sky.

48 For example, in 1892 Melbourne Observatory's Robert Ellery wrote to Tebbutt: 'The Andromeda Comet [17P/Holmes] is just within our reach but we are not observing it as we know you are looking after it.' (Ellery R. L. J., letter to John Tebbutt dated 1892 November 22, in TL). This was by no means an isolated example.

49 Annual totals are based on Tebbutt's *Annual Reports*; Tebbutt J., *op. cit*., ref. 2; and Tebbutt J., *MNRAS*, **71**, 224–226 (1910), *J. Brit. Astron. Assoc.,* **23**, 139–140 (1912) and *Astron. Nachr.*, **193**, 313–314 (1913).

50 In his *Astronomical Memoirs* (ref. 2, 27), Tebbutt proudly announces that the two little papers in *Astronomische Nachrichten* and the single paper in *Monthly Notices* '…constituted my first attempt to bring my work before the professional astronomers of the northern hemisphere.'

51 See Tebbutt J., *Report of Mr. Tebbutt's Observatory, The Peninsula, Windsor, New South Wales, For the Year 1899*, Sydney, 1900. Cometary designations used here are after Marsden B. & Williams G. V., *Catalogue of Cometary Orbits 1996*, Cambridge (Mass.), 1996.

52 Vsekhsvyatskii S. K., *Physical Characteristics of Comets*, Jerusalem, 1964. For details of Grigg's cometary astronomy see Orchiston W., *J. Brit. Astron. Assoc.,* **103**, 67–76 (1993).

53 Roseby T., letter to the RAS Secretary dated 1902 December 3, in RAS Letter Archives

54 For a detailed account of this comet see Orchiston W., *Irish Astron. J.*, **26**, 33–44 (1999).

55 For a detailed account of Tebbutt's variable star observations see Orchiston W., *Irish Astron. J.*, **27**, 47–54 (2000). The very first research paper that Tebbutt wrote was titled 'On the desirability of a systematic search for, and observation of variable stars in the Southern Hemisphere' (see Tebbutt J., *Trans. Phil. Soc. NSW*, 126–139 (1862-65)), so it is ironic that he never actually engaged in a search for new variable stars.

56 For an excellent review of LBVs see Humphreys R. M. & Davidson K., *Publ. Astron. Soc. Pacific*, **106**, 1025–1051 (1994). The precise nature of LBVs is still being debated – e.g. see van Genderen *et al*., *Astron. & Astrophys*., **304**, 415–430 (1995).

57 See Morse J. A., Humphreys R. M. & Damineli A. *(eds.)*, *Eta Carinae at the Millennium*, San Francisco, 1999. This outburst was also recorded by Henry Russell – see Russell H. C., *J. Proc. Roy. Soc. NSW*, **22**, 76–78 (1888).

58 Tebbutt J., *MNRAS*, **56**, 351–352 (1896)

59 See Tebbutt J., *J. Proc. Roy. Soc. NSW*, **11**, 197–202 (1877)

60 The annual totals in this table are based on Tebbutt's *Annual Reports*, and Tebbutt J., *MNRAS*, **46**, 50–55 (1885), *MNRAS*, **66**, 547 (1906), *MNRAS*, **68**, 396 (1908), *MNRAS*, **70**, 655 (1910), *MNRAS*, **72**, 563 (1912) and *MNRAS*, **76**, 36 (1915).

61 See Tebbutt's *Annual Reports* and data in Tebbutt, *op. cit*., ref. 2.

62 See Clerke, *op. cit.*, ref. 44; Dick S., Orchiston W. & Love T., *J. History Astron*., **29**, 221–255 (1998).

63 Tebbutt's 1874 transit of Venus observations are reported in Tebbutt J., *Astron. Nachr.*, **85**, 173–176 (1875) and *Mem. RAS*, **47**: 89–92 (1883). For Tupman's analysis of observations made in various British Empire countries see Tupman G. L., *MNRAS*, **38**, 429–457 (1878).

64 Tebbutt J., letter to the RAS Secretaries dated 1882 December 9, in RAS Letter Archives

65 See Tebbutt J., *J. Proc. Roy. Soc. NSW*, **12**, 226–227 (1878), *MNRAS*, **42**, 103–104 (1882), *Astron. Nachr*., **128**, 25–28 (1891) and *Astron. Nachr*., **137**, 93–94 (1895).

66 See Tebbutt, *op. cit*., ref. 2; Tebbutt J., untitled journal, 1864–69, MS, Mitchell Library, Sydney (A3747); Tebbutt J., untitled journal, 1873–79, MS, Mitchell Library, Sydney (A3783); Tebbutt J., *Journal for Astronomical Observations*, The Peninsula, Windsor, NSW, 1879–81, MS, Mitchell Library, Sydney (A3749); Windsor Observatory *Annual Reports*; newspaper articles and published papers.

67 For example, see Tebbutt J., *Sydney Morning Herald*, 1881 January 10, and Tebbutt J., *Journal for Astronomical Observations*, The Peninsula, Windsor, NSW, 1890–92, MS, Mitchell Library, Sydney (A3754).

68 The annual totals in this table are based on data in Tebbutt's published papers.

69 See Tebbutt J., *MNRAS*, **41**, 331–332 (1881) and *J. Brit. Astron. Assoc.,* **7**, 59–62 (1896), respectively.

70 Each individual disappearance or reappearance of a star is referred to as a 'phase'.

71 Elkington, *op. cit*., ref. 39, 42

72 For example, see Tebbutt J., *Publ. Astron. Soc. Pacific*, **6**, 23–24 (1894).

73 The totals are based mainly on entries in Tebbutt, *op. cit*., ref. 2, 118–132, and papers published subsequently. Note that the 'Papers' column in Table 5 does not give the total number of individual papers that Tebbutt published, as some papers deal with more than one topic. This explains the different bottom line totals in Tables 5 and 6.

74 For example, see Tebbutt J., *The Testimony Which Astronomy Furnishes to the Attributes of The Creator*, Sydney, 1878.

75 These were titled *Meteorological Observations Made at the Private Observatory of John Tebbutt...* or *Results of Meteorological Observations...*, and were published in Sydney in 1868, 1874, 1877, 1882, 1886, 1891 and 1898. The eighth and final volume was published posthumously in Windsor in 1916, and bears a slightly different title: *Results of Meteorological Observations at Mr. Tebbutt's Observatory The Peninsula, Windsor, New South Wales, during the Period 1898–1915*.

76 For example, see Tebbutt J., 'On the progress and present state of astronomical science in New South Wales,' in *The Industrial Progress of New South Wales: Being A Report of the Intercolonial Exhibition of 1870, at Sydney; Together With a Variety of Papers Illustrative of the Industrial Resources of the Colony*, 617–632, Sydney, 1871.

77 Ashbrook, *op. cit*., ref. 3, 66

78 Tebbutt J., *Sydney Morning Herald*, 1875 March 27

79 Houghton, *op. cit*., ref. 20, 6–7

80 Ellery R. L. J., 'A brief history of the beginnings and growth of astronomy in Australasia', in *Report of the Eighth Meeting of the Australasian Association for the Advancement of Science*, 9, Melbourne, 1901

Received 2003 January 17; accepted 2003 September 03