

WANDERINGS OF THE ‘SIMPLY PERFECT’ BURNHAM TELESCOPE

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Abstract: S.W. Burnham’s 6-inch Clark refractor, in service from 1870, quickly became famous as a potent double star catcher. It was the instrument he used for the site survey of Lick Observatory in 1879. Sold to Washburn Observatory, it travelled to Caroline Island with Edward Holden to search for Vulcan during the total solar eclipse of May 1883. Back in Madison, it was used by George Comstock for his measurements of refraction and aberration. In the late 1950s it was used at the Knuijt Observatory in Appleton, Wisconsin. Travels and transformations of this famous telescope have spread its parts widely as astronomical relics, and it even remains in active service today.

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1 INTRODUCTION

It is not often that astronomers mention their telescopes in the titles of publications since more often than not a telescope is to an astronomer as a saw is to a carpenter: the saw might be important, but it does not share credit for the work. Yet Sherburne W. Burnham (1838–1921; Figure 1; Barnard, 1921; Frost, 1921) gave one of his very early scientific publications the title “A third catalogue of 76 new double stars, discovered with a 6-inch Alvan Clark refractor.” (Burnham, 1873). If there is something naïve about the title, there is also justifiable pride in the discoveries that had managed to elude professionals with much larger telescopes.

No less than Robert Aitken (1864–1951; van den Boss, 1958), who dedicated the first edition of his binary stars book to Burnham, declared Burnham’s early papers to be “... the beginning of the modern period of double star astronomy.” (Aitken, 1935: 20). Joel Stebbins (1878–1966; Whitford, 1978) once remarked that quite aside from double stars, Burnham’s significance for astronomy was underestimated. Burnham, Stebbins (1944: 185) said,

... initiated the practice of using a telescope during all of a good clear night. Previous to his time this procedure had been little followed anywhere in the world.

Edwin Frost (1866–1935; Struve, 1937; Frost, 1921) made a very similar comment. Barnard (1921) confirms this, reporting that in their years observing together at Lick Observatory, Burnham would work until midnight, pause for a snack and coffee, then observe until dawn. Burnham’s earliest all-night vigils were probably spent searching for double stars in his backyard observatory with his 6-in (15.2-cm) Alvan Clark refractor, which he would describe years later as “... simply perfect.” (Burnham, 1900: x). But Burnham’s double star searches were only the beginning of this telescope’s remarkable history of travels and transformations, as this paper will reveal.

2 CHICAGO

Burnham (1900, cf. 1906) tells us the essential details of how he acquired the legendary 6-in telescope in the introduction to his 1900 double star catalogue, where he also outlines the history of his double star research. It was not his first telescope, but his third. The first he had acquired in London in 1861: a 3-in (7.6-cm) refractor on an altazimuth mount, which was not very useful, he says, for astronomical observing. Some years later, shortly after the end of the U.S. Civil War, Burnham became more seriously interested in

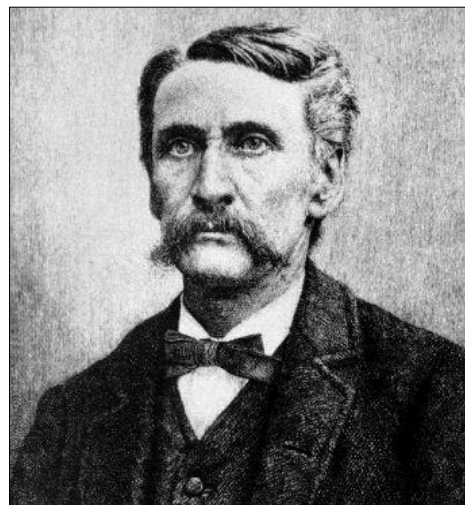


Figure 1. Sherburne W. Burnham, the original owner of the Burnham 6-inch Clark refractor (en.wikipedia.org).

astronomy and purchased a 3.75-in (9.5-cm) Fitz refractor on an equatorial mount. The Fitz was “... good enough to be of some use ...” (Burnham, 1900: vii), but left him wanting something better as his interest in astronomical observing deepened.

In the late 1860s, Burnham lived quite near the Dearborn Observatory of the Old University of Chicago (long before their 18.5-in (47-cm) Clark refractor was relocated to Northwestern University in Evanston). His proximity to the observatory

—of which he would later serve as unpaid Acting Director—probably offered the connection that made possible his meeting in 1869 with Alvan Clark, the already famous telescope-maker, who had travelled to Iowa for the solar eclipse of 7 August and was returning to Massachusetts via Chicago. As a result of that meeting, Burnham tells us, he ordered from Clark a 6-in refractor on an equatorial mounting, leaving all design to Clark's judgement, but "... stipulating only that its definition should be as perfect as they could make it ..." so as to achieve optimal performance, given the aperture, on double stars (Burnham, 1900: viii). According to several sources, including Burnham's colleague and close friend Edward Emerson Barnard (1857–1923; Sheehan, 1995), the cost, was \$800 (Barnard, 1921).

Burnham took delivery on his bespoke telescope from Clark in 1870. Originally the mounting lacked a clock drive, but Burnham ingeniously contrived one (Barnard, 1921). He wrapped a rope around the polar axis and attached a weight to pull the rope, creating a torque on the axis. The weight rested on sand, which escaped from a hole in its container and allowed the weight to fall at a controllable rate. It was a crude mechanism but avoided expensive clockwork. Burnham's double star measurements with the 6-in Alvan Clarke telescope were always fairly crude, being estimates by eye of the separation and position angle (his later, more exact, work was done with telescopes equipped with micrometers, as at Washburn and Lick Observatories). The question of how much value Burnham added to his instrument comes up in the matter of its later sale to the University of Wisconsin. The mounting probably lacked setting circles as well since they are later mentioned as another improvement. But even without clock and circles, in its brand new state, it must have been a beautiful instrument. The tube is a cylinder formed of blackened wood staves wrapped in a dark wood veneer with a deep finish. The objective cell and tailpiece are brass, which would have nicely complemented the dark tube.

Burnham's first double star discovery came on 27 April 1870 (Eggen, 1953), which indicates that he had the telescope in operation quite soon after receiving it. But Burnham tells us his double star work effectively began in 1872. The years of 1870 and 1871 no doubt comprise the steeper part of the learning curve as Burnham worked with his fine new instrument and acquired familiarity with the double star catalogues available to him in the Dearborn Observatory library, which would have included those of Frederick Georg Wilhelm von Struve (1793–1864; Batten, 1988), Otto Wilhelm von Struve (1819–1905; Nyren, 1906), and John Frederick William Herschel (1792–1871; Buttman, 1970). In fact, Burnham's need for the series of double star catalogues

arose directly from his work with the 6-in refractor, as he tells us (Burnham, 1906). Burnham entered astronomical circles as a Fellow of the Royal Astronomical Society in 1874, and also was being noticed by the public at home. The *Chicago Tribune* criticized the neglect of the largely idle Dearborn telescope by pointing out how it was upstaged by the "... novice Burnham." (Fox, 1915: 4). It is said that the future astronomical empire-builder, George Ellery Hale (1868–1938; Adams, 1939), then in his early teens, visited Burnham's backyard observatory to admire the Clark refractor (Osterbrock, 1976). If that visit helped inspire Hale toward his career of building ever larger telescopes (Wright, 1994), then Burnham's 6-in telescope has had historical leverage far out of proportion to its size.

Burnham's 6-in Alvan Clark refractor was a rather small telescope for a research instrument, and with the passage of time its scientific significance would prove to be out of proportion to its size. By 1874 in the United States alone there were telescopes, refractors all, with apertures up to 26 inches (at the U.S. Naval Observatory) in use by professional astronomers. Burnham's productivity—he would eventually discover more than 400 new double stars with his 6-in telescope—far outpaced the better-equipped professionals and was a product of several factors, including his own work ethic, which kept him working those long nights even as he maintained his day job as a professional stenographer. He also was willing to search for double stars despite an attitude among professional astronomers that there was little potential for new discoveries. An (erroneous) intuition that a double star is a very rare occurrence might have suggested to astronomers that the existing catalogues should have nearly exhausted them, so any search for additional ones would prove futile. This may be a case where Burnham, as an outsider, came to astronomy free of the prejudices that constrained the thinking of the professionals. Or perhaps, as a hobbyist, Burnham felt free to follow pursuits that personally interested him, but might look unproductive to professionals.

But Burnham's success also came about because he and his telescope were literally made for each other. In requiring the most perfect possible definition in the Clark objective lens, Burnham was complementing the keen capacity of the eyes he was born with. Indeed, the acuity of his vision was legendary. "If a star disc deviated an almost infinitesimal quantity from the circular, his eye detected it at once ..." declared William de Wiveleslie Abney (1843–1920; Hearnshaw, 2014), then President of the Royal Astronomical Society, upon awarding the Gold Medal to Burnham in 1894, and "... the catalogues of double stars which he has given us amount to no fewer than nineteen ..." (Abney, 1894: 279, 277).

These catalogues contained 1,274 double stars that he had observed—although by then with the use of much larger telescopes. Note, also, that these nineteen publications were research papers and therefore quite different from Burnham's later general catalogues, of 1900 and 1906.

In discovering double stars it was essential to have access to previous catalogues in order to know whether a given double star was already known. Burnham's limited library led him to visit observatories whenever he could and to take notes from the sources that might be available there. It was on such a visit to the U.S. Naval Observatory in 1874 that he made the acquaintance of Edward Singleton Holden (1846–1914; Campbell, 1919), then an Assistant Astronomer to the USNO Director, Simon Newcomb (1835–1909; Campbell, 1924). Holden, an ambitious astronomer of a bibliographic bent, and Burnham seem to have hit it off well at their meeting, which began a long and complicated friendship with many collaborations, but ending in enmity (Osterbrock et al., 1988). Holden would also be the instigator of the Burnham telescope's most extravagant travels.

3 MOUNT HAMILTON

Newcomb and Holden were early advisors to the Lick Trust, the members of which were planning the Lick Observatory, which would eventually host the world's largest refractor (at that time), the 36-in Clark. When the question arose of testing the quality and steadiness of the astronomical 'seeing' on the peak of Mount Hamilton, where the Observatory would take form, Holden and Newcomb recommended Burnham for the task. The resolution of closely spaced stars is a test not only of the observer's eye and the telescope's quality, but also of the steadiness and clarity of the atmosphere, so an expert double star observer was a perfect choice to evaluate the conditions at the proposed site of the new Observatory. Burnham was interested in the job, but, like many an amateur astronomer, he had his day job to consider and family responsibilities too. He agreed to a fee of \$500 plus expenses, in return for which he and his 6-in Clark refractor would spend two months at Mount Hamilton, report on the suitability of the site, and have the honor of initiating astronomical research at the site of the great Observatory to come (ibid.).

Burnham set up his 6-in telescope in a rough wood-and-canvas structure near the peak of Mount Hamilton, and observed double stars from 17 August until 16 October 1879. By then his telescope was equipped with setting circles and a clock drive. At the expense of the Lick Trust, the new Clark clock drive replaced the early, improvised device mentioned by Barnard. After his time on the mountain, during which he received an inspection visit by Simon Newcomb, Burn-

ham pronounced the quality of the site to be excellent. Then having blazed the trail for one of the most important and productive observatories of the coming decades, he packed up his telescope and shipped it back to Chicago (ibid.; Eggen, 1953; Frost, 1921).

4 WASHBURN OBSERVATORY

By mid-March 1881, Edward Holden had given up his post at the U.S. Naval Observatory and relocated from Washington D.C. to Madison, Wisconsin, where he had accepted the position as Director of the new Washburn Observatory, which was still a work in progress. His immediate predecessor had been the famous astronomer James C. Watson (1838–1880; Figure 2; Comstock, 1895a), who had been lured to the University of Wisconsin away from his position as



Figure 2: James Craig Watson, first Director of Washburn Observatory (courtesy: Department of Astronomy, University of Wisconsin-Madison).

Director of the Detroit Observatory of the University of Michigan, in Ann Arbor. Watson accepted the post in October 1878 and had arrived in Madison in January 1879 just in time to oversee the installation of the 15.6-in (39.6-cm) Clark refractor that Governor Cadwallader C. Washburn (1818–1882) had ordered as the primary instrument of his new observatory, which he was building for the University of Wisconsin. Watson's tenure was cut short by his sudden death in November of 1880, but in that brief time he both built and opened several doors through which Burnham's Clark telescope would soon pass.

Watson's fame arose in part from his prolific work discovering asteroids—he held the world record at the time having discovered 22 of them.

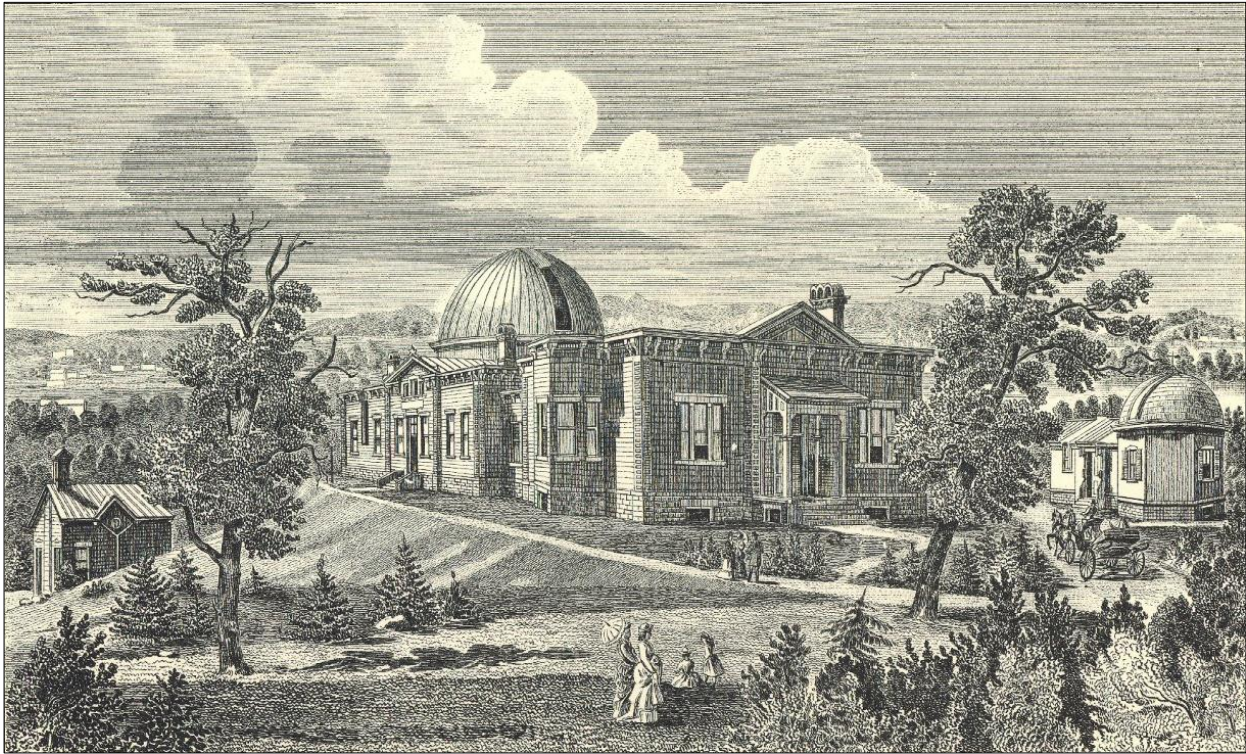


Figure 3: A view of Washburn Observatory, showing the Student Observatory to the right of the main building, and the Solar Observatory, to the left of the main building (courtesy: Department of Astronomy, University of Wisconsin-Madison).

He had also been in the news since the middle of 1878 for his apparent discovery of the intra-Mercurian planet Vulcan. But the ensuing controversy over Vulcan was intense (see Baum and Sheehan, 1997), and Watson took steps to vindicate his work in the shaping of the new Observatory. He began constructing, drawing on his personal wealth, a complex and unusual instrument that he hoped would allow him to confirm the existence of Vulcan without being constrained to observe only during total solar eclipses. In brief, a heliostat (a tiltable mirror rotating on a polar axis), would reflect light through a polar-aligned tunnel following the southern slope of Observatory Hill leading to a small building at the foot of the hill that would house a subterranean telescope. That telescope would be able to look, via the steerable mirror, into the daylight sky east and west of the Sun, and Watson's theory was that with this arrangement he would be able to see Vulcan, confirm its existence, and determine its orbit. Despite its real mission, to find Vulcan, it was always called the Watson Solar Observatory. This project, like nearly everything else in the Washburn Observatory of late 1880, was incomplete at his death (see Figure 3).

Watson also decided to build, again at his own personal expense, a small, separate observatory just east of the main observatory building. This was to be a Student Observatory, housing smaller versions of the larger research instruments in the main building. This structure was also incomplete when Holden, recruited by Governor Washburn to fill Watson's shoes, arrived in Madison.

Holden (Figure 4) was an unusual astronomer of great erudition and wide interests, although an enthusiasm for astronomical observing was not among his virtues. He was, however, a skilled (if somewhat authoritarian) organizer who perceived well the importance of staffing the new Observatory with experienced and dedicated observers who could begin delivering respectable results. Holden turned immediately to his friend Burnham, who was nearby in Chicago and was a dependable worker. Holden convinced Governor Washburn to pay Burnham's salary for six months in spring and summer at an effective annual rate of \$2000, which was generous and comparable to Holden's own salary. So Burnham arranged to take leave of absence from his job as a recorder with Judge Drummond of the U.S. District Court in Chicago. He moved to Madison, was given lodging in the main Observatory building, and by 8 April 1881 took up duties as an Assistant Astronomer, working with Holden on the 15.6-in telescope and its Clark micrometer for double star measurements. Burnham also brought along his trusty 6-in Clark refractor, and when he departed in August this telescope remained in Madison, in the Student Observatory.

Just as he had done before coming to Madison, Holden maintained a lengthy correspondence with the Lick Trustees, advising them on various particulars of creating and running an observatory. He was clearly and genuinely interested in the success of the project as well as the prospect that he might become Director of the

world's first mountain-top observatory, which would also be the home of the world's most powerful research telescope. He arranged for himself and Burnham to spend some weeks at Mount Hamilton during October and early November 1881, where they would install the Repsold meridian circle that Holden had advised the Lick Trustees to acquire (Holden and Burnham, 1882). While they were there, Burnham used a 12-in (30.5-cm) refractor that was already installed on Mt. Hamilton to observe the 7 November transit of Mercury (the 36-in telescope being still some years in the future). Meanwhile, Burnham's 6-in Clark refractor remained at Washburn Observatory.

Holden and Burnham both departed Mount Hamilton after the transit, returning to Madison and Chicago respectively, but Burnham did not collect his 6-in Clark from Madison and take it back to Chicago. Why did he leave it in Madison mounted in the Student Observatory? As would soon become apparent, Holden had plans for the Burnham telescope, so he surely encouraged leaving it and reported its status as "... on loan ... for use in ordinary instruction ..." from Burnham (Holden, 1882: 8). In fact, Holden hoped that Burnham would quit his job in Chicago and remain on the staff at Washburn Observatory. If Burnham was giving this move serious consideration, then he might have been inclined to leave his telescope where it stood until the matter was resolved.

But it could also be at this juncture that Burnham had decided to retire from astronomy (Eggen, 1953), even though he was only 43 years of age. Perhaps he had tired of the astronomer's life, after spending the previous six months as a full-time observer at Madison, plus the trip to Mount Hamilton for the November transit. Probably the insecurity of the position in Madison, funded basically by a personal grant from Governor Washburn, whose health was failing, worried him. Although Holden would have kept Burnham at Washburn Observatory if at all possible, in August 1881 he wrote Governor Washburn that Burnham declined to risk by further absence his position with Judge Drummond (Holden, 1881). Whether he hoped to return to Madison some day or planned to give up astronomy entirely, Burnham must have decided that he had no further need for a personal telescope. Whatever Burnham's thinking, his Alvan Clark telescope would never return to Chicago—at least not intact.

By January 1882 Holden had convinced Burnham to sell the 6-in Clark refractor to the University of Wisconsin and had convinced the Board of Regents to purchase the telescope from Burnham "... who offers it at a very moderate price ..." of \$1,200 (Holden, 1882: 8). Holden had advised the Board that this was a good deal since Burn-

ham had paid \$1,400 for it. Since, in fact, it seems that Burnham had actually paid Clark \$800 for the telescope, the discrepancy is significant! It might be that the reported \$800 figure was, in effect, a deposit Burnham paid to Clark rather than a full payment for the telescope, with the balance of \$600, paid on delivery perhaps, and unreported by contemporaries. But this seems unlikely. Or perhaps the \$1,400 figure was Holden's estimate of the value of the telescope after improvements made by Burnham, such as circles, clock drive



Figure 4: Edward S. Holden, second Director of Washburn Observatory (courtesy: Department of Astronomy, University of Wisconsin-Madison).

and an improved mounting. Holden was also probably trying to obtain a good deal for his friend and recruit him to the Washburn staff, which could have influenced his generous assessment. In any case, the price was accepted by both parties, and the Burnham telescope became a permanent fixture at Washburn Observatory.

It is occasionally said that Burnham regretted parting with his 6-in telescope, and that is not hard to imagine. But after 1881 he never really needed a personal telescope again since he had his choice of positions, and eventually he spent time at several major Observatories, namely Washburn, Lick and Yerkes. And he retained his day job in Chicago for many of the years that he was observing at Yerkes Observatory, while following a demanding schedule of commuting to Williams Bay every weekend for observing. He could have made his life much easier by purchasing another backyard telescope, but he did not. He clearly loved working with the 'big glass'.

Yet it is also not difficult to hear a note of fond reminiscence, if not quite regret, in his 1900 *Gen-*



Figure 5: Washburn Observatory view from the southwest with the Solar Observatory in the foreground (courtesy: Department of Astronomy, University of Wisconsin-Madison).

eral Catalogue where he comments on the various telescopes that he had used for his double star work. When he mentions the 6-inch Clark, he says:

It is hardly necessary to say, in view of the discoveries made with it and given in this catalogue, that its performance on the most difficult objects was simply perfect. Many of the stars discovered with it are by no means easy to measure with the largest telescopes now in use. Some of the most rapid and interesting binaries in this catalogue were discovered with this instrument. It now belongs to the Washburn Observatory of the University of Wisconsin. (Burnham, 1900: x).

5 TESTING WATSON'S THEORY

Holden felt bound to implement Watson's Solar Observatory plan (i.e. using a heliostat to reflect light down a tunnel to an underground telescope) in order to test its ability to detect intra-Mercurian planets, should they be there, and he was ready to do so by the summer of 1882. He needed a telescope small enough to place in the cellar of the Solar Observatory building at the base of the polar axis tunnel and with good enough optical performance to reveal a very small planetary disk against the daytime sky. The Burnham telescope was what he needed. Relatively large, bright

planetary disks, such as that of Jupiter, can be seen against the daytime sky with the aid of a telescope. But the alleged Vulcan would not be nearly so bright, nor would its disk be very large. For the tests, Holden selected stars among the Pleiades cluster that have apparent brightnesses comparable to that reported by Watson for the elusive Vulcan. Holden aimed at night by setting the heliostat (which he borrowed for the purpose from Samuel Langley) on the meridian at the declination of the Pleiades, then, leaving the heliostat undisturbed, he tried to see the stars of the Pleiades in the daylight sky using the heliostat-telescope combination at the time when they were known to be transiting the meridian. But he could see nothing. Moreover, in the cellar where the telescope was mounted, there were problems with moisture and air currents in the tunnel that sloped up the hill to the heliostat (Figure 5).

In his report to the Board of Regents Holden (1882) explained his attempts, and these also appear in a brief publication, where he mentioned the 6-in Clark refractor, "... which has made a history for itself already." (Holden, 1883b: 112). The results were disappointing, of course, although not entirely unexpected because, as Holden noted, others had tried similar schemes, and also without success. Moreover, because of the



Figure 6: Holden's Caroline Island observing station (after Holden, 1884: Figure 5 following page 22).

moisture and other problems of a subterranean telescope, it was also not practical to use Watson's device to attempt direct spectroscopy or imaging of the Sun. Holden and the Burnham telescope gave Watson's ideas 'a fair shake', but vindication eluded them. Holden chose to publish the results in a German journal—the only place where they appear aside from in the Regents' Report—but not in the prestigious *Astronomische Nachrichten*, where he had published previously and would often again. Placing the unhappy result in a less-consulted journal was probably a gesture of deference to Watson's memory by giving the failure a low profile in the USA. The primary utility of the Solar Observatory building, before and after Holden's tests, was mainly to provide lodging for an Observatory Assistant.

6 THE CAROLINE ISLAND EXPEDITION

The first solar eclipse expedition by Washburn Observatory astronomers was an ambitious one, with the bills paid by the U.S. Government and the National Academy of Sciences. The destination of the U.S. expedition to observe the total solar eclipse of 6 May 1883 was Caroline Island, near Kiribati in the South Pacific,¹ more than 5,000 miles and many weeks of travel from Wisconsin. In fact, Holden did not initiate the enterprise but was asked to take the place of Charles Young (1834–1908; Frost, 1913), the Princeton astronomer, as leader. Such a project suited Holden's military background and organizational disposition well, and he meticulously planned and documented the expedition (Holden, 1884). Among the variety of scientific instruments along

on the trip, which also had meteorological and geological goals, was the Burnham telescope, which, of course, was now part of the Washburn Observatory instrument stable. Undeterred by the failure of his tests of Watson's instrument, the basic concept of which he rightly suspected, Holden planned to test again for Vulcan or any other intra-Mercurian planets in the sky near the Sun rendered visible during the totality of the eclipse. This would require a nimble instrument to scan for dim, uncharted objects during the nearly five and a half minutes of totality. Holden does not tell us what kind of mounting he used, but the Clark equatorial mounting would have been useless at just 10° south of the Equator, as would a clock drive, so he probably made do with a simpler, more portable mounting (Figure 6).

The expedition members and their equipment embarked from New York City on 2 March 1883 and sailed westward via a series of ships and a portage across the Isthmus of Panama to their rendezvous with the U.S. Navy's sailing steamer, sloop-o-war *USS Hartford*, under the command of Captain C.C. Carpenter, at Callao, the port of Lima, Peru. The *USS Hartford* departed Callao for Caroline Island on 22 March and sighted the Island on 20 April. On the 20th and 21st, seamen from the ship rowed their whaleboat through the coral reefs, and settled the scientists on the archipelago with their "... bulky cases under rather exceptional difficulties." The *USS Hartford* sailed on to Tahiti on the 22nd, and by the 24th Holden (1883a) reported that his equipment and shelter were complete, and that the Burnham telescope was ready for its assault on the Southern sky. The

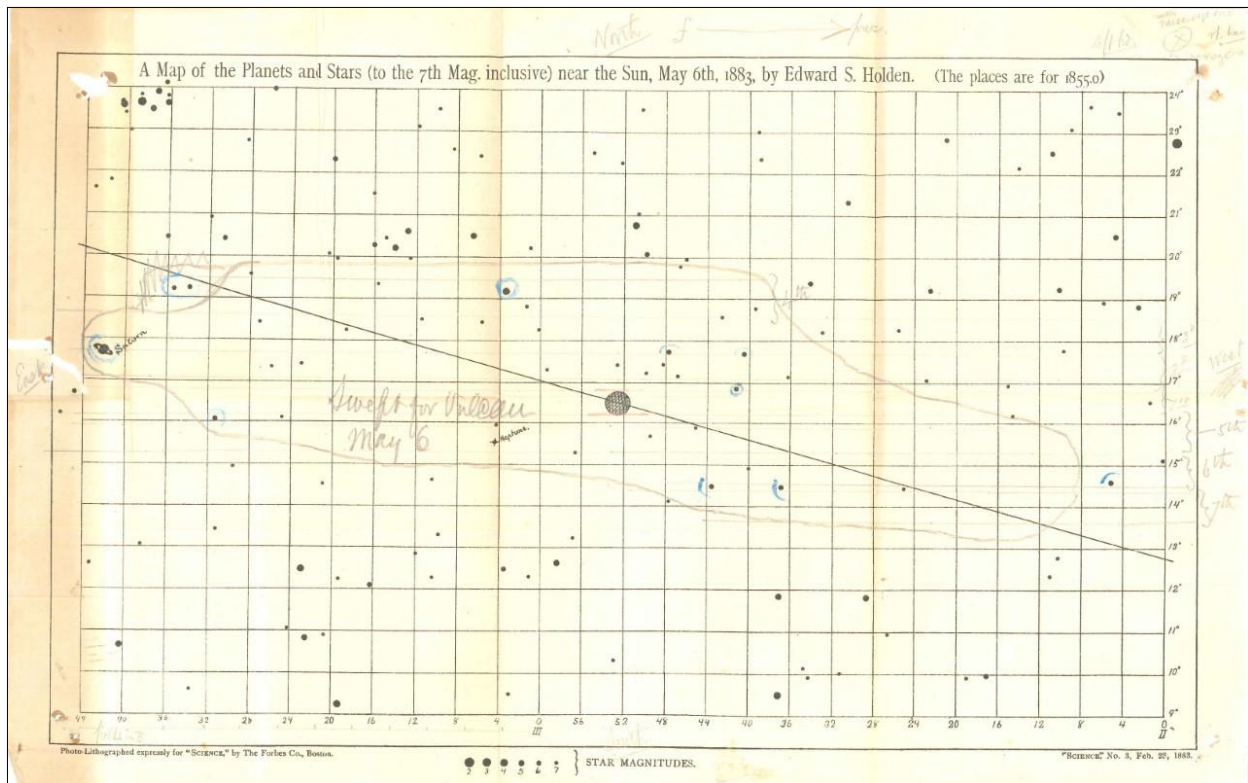


Figure 7: Star chart used by Edward Holden during his search for Vulcan on Caroline Island during the May 1883 total solar eclipse. His notations outline the area of the sky he scanned with the Burnham telescope (courtesy: University of Wisconsin Archives).

USS Hartford returned to Caroline Island on 8 May to take aboard the men and equipment for their return to the United States, via the Hawaiian Islands and San Francisco, where Holden and company arrived on 11 June.

While they were on Caroline Island, the eclipse party had clear weather during the eclipse, so Holden was able to make his final observations in a bid to vindicate Watson. But Holden (1883a) found nothing, and he reported that "... no star as bright as 5th mag. was visible in the space covered by my sweeps ..." in the zones scanned east and west of the totally eclipsed Sun (Figure 7). A French solar eclipse expedition also was based on Caroline Island, and one of their astronomers, Johann Palisa (from the Imperial Observatory in Vienna), also scanned the sky for suspicious objects during totality and saw nothing. Holden (1884: 101) concluded that the non-existence of Vulcan or other intra-Mercurial planets was "... definitely settled ...", and that there would be no point in conducting further searches for them at future solar eclipses. He was quite right about that.

The Burnham telescope had another role during the Caroline Island expedition, and that was the same task that had already made it famous: the discovery of new double stars. Observing with Johns Hopkins University physicist Charles S. Hastings (1848–1932; Uhler, 1938), Holden discovered 23 new double stars in those southern zones of the sky they had time to study: "... two or three hours of each clear night (with a few

exceptions)." (Holden, 1884: 97). He also reported the discovery of five new red stars. All of this in so little time indicates, he said, the great value of an extended observing program in the Southern Hemisphere. He suggested the Chilean and Peruvian Andes, both of which would, of course, later become important observatory sites.

In comparing his double-star magnitude estimates with those of Hastings, which, he noted, show a systematic difference, Holden made the odd statement that Hastings' estimates should be preferred over his own because "I was not familiar with the appearance of stars in the 6-inch telescope." (Holden, 1884: 98). It is not surprising, perhaps, that he had not used the 6-in telescope much at Madison in the recent past since he had access to the much larger 15.6-in telescope, but it seems odd that he should suggest that Hastings would be better at estimating magnitudes through an instrument that he, presumably, had never used. There was another 6-in telescope taken on the expedition, but it was not brought by Hastings and seems to have been intended for spectroscopy. Moreover, Holden mentions the 6-in routinely and without qualification in his expedition observing note-book amid the double star records, so it seems all but certain that he used the Burnham telescope for those observations.

Holden took advantage of his repatriation at San Francisco to pay a visit to the developing Lick Observatory. There is no record to suggest that he took the Burnham telescope with him, so presumably it returned to Madison as freight some

time that summer. Burnham also travelled with the Lick Observatory Crocker expedition to Cayenne, French Guiana, for the December 1889 solar eclipse, but there is no record that the Burnham telescope went along on loan to Lick Observatory.

The only other eclipse expedition involving the Burnham telescope was to North Carolina for the 1900 solar eclipse with Washburn Observatory's Albert Stowell Flint (1853–1923; Stebbins, 1923), but there is no record of how it was used there. That the Burnham telescope stayed at home for the eclipse expeditions during the Directorship of Joel Stebbins (from 1922 to 1948) is not surprising because the scientific goals of those trips involved wide-field photometry of the solar corona and used very simple collimating tubes instead of telescopes in front of the photoelectric photometers. So presumably the Burnham telescope resumed its location in the Student Observatory and its role as a telescope for student observers.

7 BACK IN MADISON

Near the end of 1885, Holden left Washburn Observatory for the University of California, where he served for a while as President until the completion of Lick Observatory in June 1888, where he then took over as Director. His departure produced an interregnum period at Washburn that was only resolved when George Cary Comstock (1855–1934; Figure 8; Stebbins, 1938), who had actually accompanied Watson from Ann Arbor and worked on and off at the Observatory with Holden, was named on-site Director in June 1887, but with oversight from the eminent Asaph Hall (1829–1907; Hill, 1908) of the U.S. Naval Observatory. That arrangement would end when Comstock became Director in his own right in 1889. Comstock set to work defining research programs for all of Washburn's major instruments: the 4.5-in Repsold meridian circle, the 15.6-in Clark equatorial and the Burnham telescope.

Comstock became interested in a novel method of studying two inescapable effects that observational astronomers must cope with: the refraction of light in our atmosphere and the aberration of starlight. At a practical level, quite aside from their physical significance, these two effects amount to corrections that astronomers must apply as accurately as possible if the reduced relative positions and motions of stars are to be correct. The refraction (or bending) of the light from a star has the general effect of making objects appear higher above the horizon than they really are. The magnitude of the effect varies from zero near the zenith to a considerable fraction of a degree near the horizon. Aberration of starlight produces an annual periodic displacement in the position of a star of more than 20 arc seconds depending on its location in the sky with respect to the direction of the Earth's orbital mo-

tion.

To launch a new inquiry into these effects, Comstock proposed to use an optical arrangement using a prism (for which he would soon substitute mirrors), called a Loewy apparatus after its inventor, the French astronomer Maurice Loewy (1833–1907). The Loewy apparatus, in effect, allows a telescope to simultaneously look in two directions, separated by 120° . It also transformed the task into a differential measurement between the two stars rather than an absolute measurement with respect to meridian and horizon. With funding from the Watson Fund of the National Academy of Science, Comstock (1895b) improved on the original Loewy design and constructed his own version of the device, which he mounted in front of the objective of the Burnham



Figure 8: George C. Comstock, third director of Washburn Observatory (courtesy: Department of Astronomy, University of Wisconsin-Madison).

telescope. Burnham's double star work was, Comstock mentions, adequate testimony to the telescope's excellence. At the eyepiece end of the telescope he mounted an astronomical micrometer. He could then directly measure the angular separation of two very widely spaced stars.

Observing pairs of stars with such large angular separations required major modifications to the dome of the Student Observatory, where the Burnham telescope was mounted, because the slit opened only to a limited stretch of sky in an arc perpendicular to the horizon. Comstock's solution was to modify the dome by dividing its hemisphere into two semi-domes, one of which (the half containing the original slit and shutter assembly) he removed. Then he constructed an-

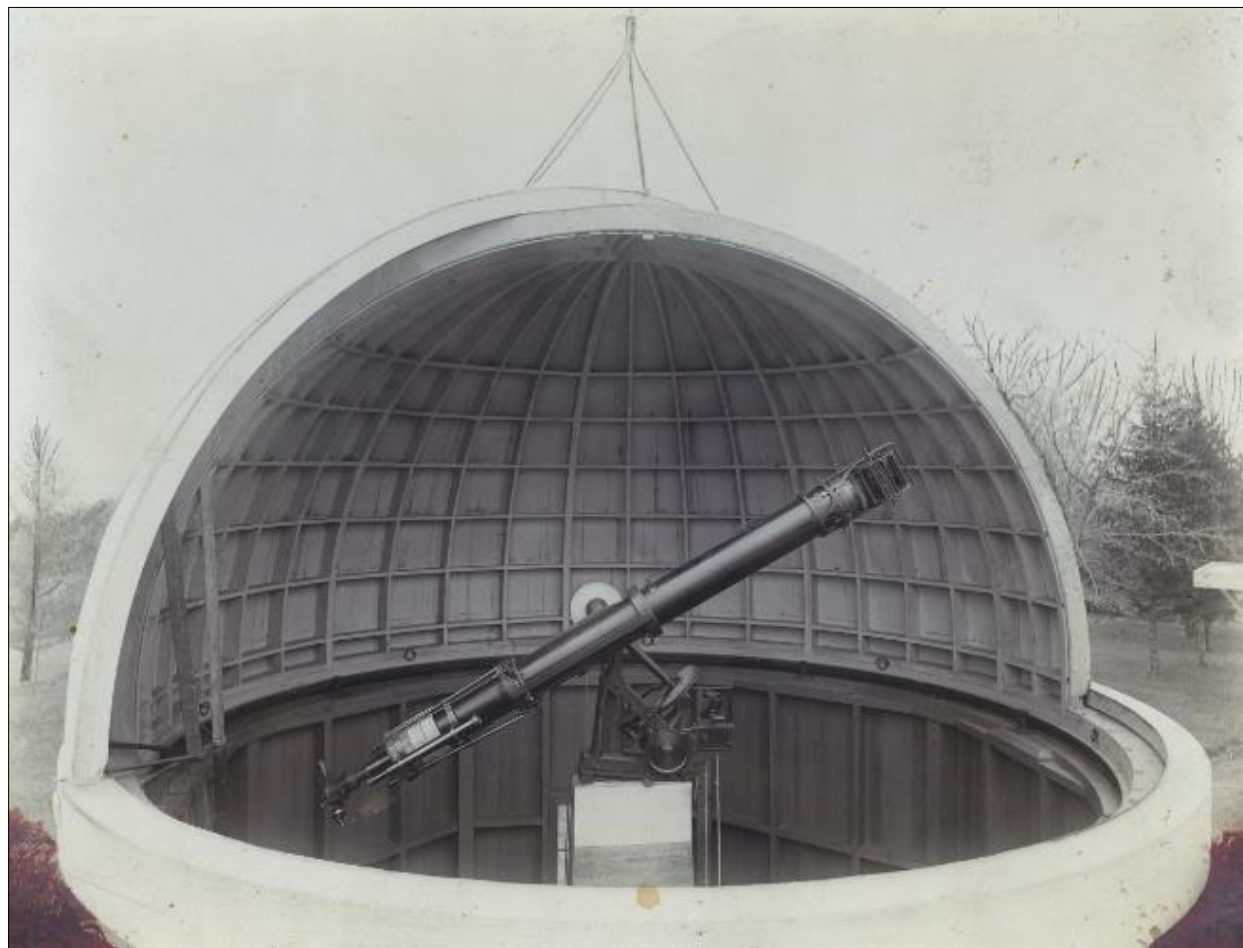


Figure 9: The Burnham telescope mounted in the Student Observatory equipped with the Loewy device in front of the objective. At this stage it still has the original wooden tube. The Clark mounting, made for Chicago's latitude, has been corrected by shims. Note the clock drive, probably the one paid for by the Lick Trustees, also in Fig. 10. Note also the semi-dome arrangement (courtesy: Department of Astronomy, University of Wisconsin-Madison).

another semi-dome of slightly larger radius and mounted it on a track concentric with and just outside of the original dome track. Thus the inner half dome would nest within the outer and, when rotated to maximum overlap, revealed fully half of the sky above the horizon and allowed pointings of the telescope that, with the Loewy device in place, spanned very large angles. The operation of the Loewy device required that it be able to rotate about the optical axis of the telescope, so Comstock had to arrange controls for this motion at the eye end of the telescope. This arrangement of telescope and dome is shown in Figure 9. This is the only existing photograph known that shows Burnham's telescope with the original wooden tube and Clark mounting.

By Autumn of 1889, Comstock reported that the modified observatory and telescope were ready and that he had begun observation trials to refine his as-yet 'imperfect' understanding of the theory of the Loewy optics. But in October he encountered a major setback owing to an attack of iritis, which was severe enough to require ophthalmological surgery and a temporary cessation of his observing activities. As it turned out, he could not begin the planned observations until

after his eyesight recovered, and after he saw parts of volumes six and seven of the *Publications of Washburn Observatory* through the press, and after he spent part of the next summer touring European observatories.

Once he finally got the program underway, in September 1890, Comstock observed with the Burnham telescope steadily until July 1892 to accumulate his data, and he then spent about two years reducing and analyzing them. For refraction, his result amounted to formulae for corrections, including humidity of the air, to the standard refraction tables of Bessel and of Pulkowa Observatory, of which he judged the latter superior. He also published a new value for the constant of aberration, which he concluded to be $20.443 \pm 0.010''$, and "... one of the best determinations of the constant of aberration made up to that time." (Stebbins, 1938: 164). Comstock made note of the 'singular coincidence' that omitting correction for systematic personal error would result in the value $20.499''$, "... which is very closely the mean of the more recent determinations of this quantity by other methods." (Comstock, 1895b: 203). Since the latter value is closer to the modern accepted value, and by quite

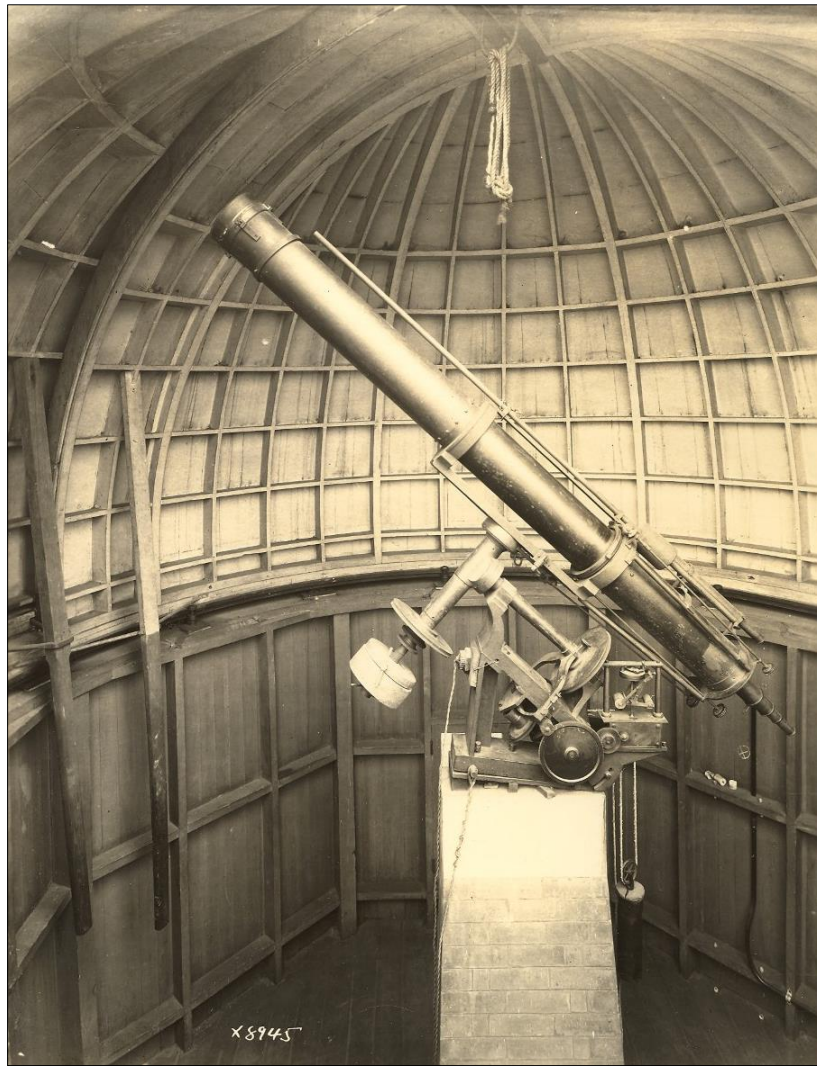


Figure 10: The Burnham telescope on the Clark mounting in the Student Observatory after conversion to the metal tube. Undated but not before 1908, when the conversion was done. The semi-dome arrangement was still in place (courtesy: Department of Astronomy, University of Wisconsin-Madison).

a bit more than his own error, it would seem that correcting for systematic personal error was counterproductive in this case.

With Comstock's refraction and aberration work, the research career of the Burnham telescope effectively came to an end in 1892. S.W. Burnham himself retired in 1902 from his job as Clerk of the U.S. District Court in Chicago, but he continued his observational work at Yerkes Observatory until 1914. Meanwhile the 6-in Clark telescope continued to be a valued instrument at Washburn Observatory judging by the subsequent history of its transformations. Presumably it continued in use as a telescope for astronomy students and astronomers-in-training. The semi-domes remained in place long after the conclusion of Comstock's Loewy device work and are still evident in photos taken as late as 1908, perhaps leaving open the possibility of further wide-angle observations. The semi-dome arrangement was eventually reverted to the conventional slit and shutter configuration, but the date is unknown.

The first major transformation of the Burnham telescope came in 1908 with the replacement of the telescope tube. The objective cell containing the 6 inch lens was removed from the original wooden tube and moved to a tube made of riveted sheet steel. Similarly, the brass tail-piece attaching the focuser and eyepiece were moved over to the new tube. The original components Clark had assembled thus began to part company. The motivations for this change are not recorded, but it seems probable that Comstock had concerns about the physical integrity of the old tube, the wood veneer perhaps separating from the structural staves after so much handling and variation in temperature and humidity during its traveling years. The new assembly took its place on the Clark mount in the Student Observatory (Figure 10), and the wooden tube went into storage at the Observatory.

George Comstock retired as Director of Washburn Observatory in 1921, the same year that S.W. Burnham died in Chicago. Comstock's suc-

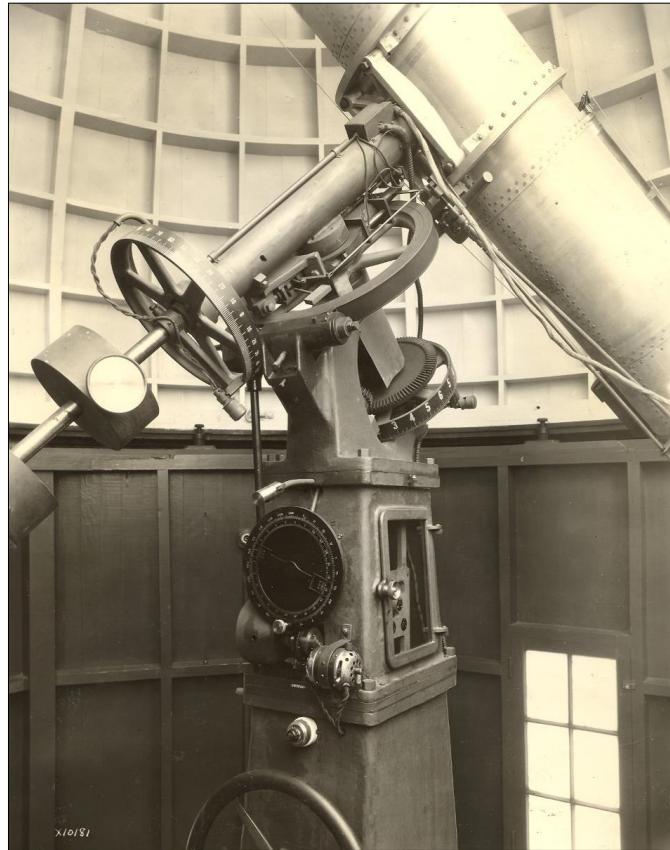


Figure 11: The 10-inch Fecker refractor on the new Romare mounting in the Student Observatory. The Burnham telescope had been on this mounting for testing before the Fecker took its place. A cast iron pier replaced the stonework pier that supported the Clark mounting. (courtesy: Department of Astronomy, University of Wisconsin-Madison).

cessor was Joel Stebbins, who had pioneered photoelectric photometry in Urbana at the University of Illinois Observatory. Stebbins began planning improvements to the Washburn telescopes even before he took up residence in the summer of 1922. In the coming years Stebbins removed the fine old Repsold meridian circle, which was quickly becoming obsolete in the dawning days of photographic astrometry and was in any case irrelevant to the Stebbins research program. The former meridian room, the observatory's west wing, became a class-room. Stebbins also replaced the original Clark equatorial mounting of the 15.6-in Clark refractor. That mounting had been problematic from the beginning, and much better designs were available to ease the finding and tracking of faint photometry targets. By a stroke of remarkable good luck, Stebbins had available at Madison the skilled and ingenious mechanical engineer Oscar E. Romare (1875–1932). Romare, a talented and energetic immigrant from Sweden, had come to the University of Wisconsin Engineering School in 1920 after many years at Yerkes Observatory, where he had designed and built telescopes and various astronomical devices. After Stebbins' arrival, Romare soon became very important around Washburn Observatory, and he built photoelectric instruments, participated in

eclipse expeditions, and also designed telescope mountings.

As a prototype for the new mounting for the Washburn 15.6-in refractor, Stebbins had Romare design and build a smaller version for the Burnham telescope incorporating modern (by the standards of the 1920s) controls. The new equatorial mounting, fabricated by M.H. Kidder of the University Shops, was in place by early 1927 and judged a success. A weight-driven clock drive, designed by Romare, which could run the telescope for hours without attention, was engaged and disengaged by a button-operated electric clutch. The telescope could be driven in slow motion electrically on both axes. An integrated dial, driven by the clock, on the north face of the pier eased aiming by indicating both the sidereal time and the hour angle of the telescope. It was "... by far the most elaborately equipped instrument of its size in the world ..." in the judgement (no doubt reflecting Stebbins' own) of the local student newspaper (Kulp, 1927: 267). Stebbins actually had a newer, heavier telescope in mind for the new mounting: a 10-in Fecker photographically corrected refractor (Figure 11). For the moment, however, the Burnham telescope's role was to test Romare's designs for the 15.6-in new

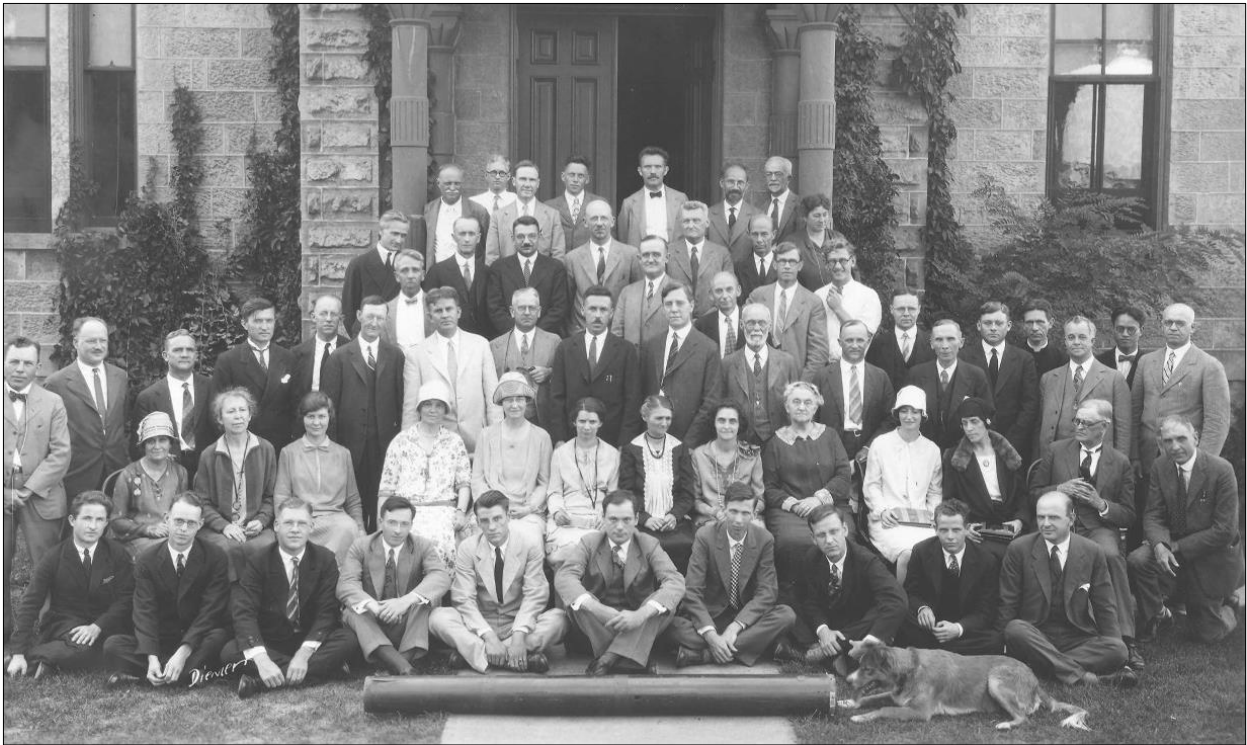


Figure 12: Group photo from the September 1927 AAS meeting in front of the Washburn Observatory east entrance. The wooden tube of the Burnham telescope lies in the foreground. Joel Stebbins, then director, is in the center of the second row from the top; on his immediate left is his predecessor, George Comstock; Philip Fox is in the light suit seventh from our left in the longest standing row (courtesy: Department of Astronomy, University of Wisconsin-Madison).

mounting, a project that was not completed until 1933 (delayed by Romare's sudden death in an automobile accident in April 1932). With the advent of this new mounting, the Burnham telescope's original Clark mounting parted company with the objective and tailpiece and joined the wooden telescope tube in storage.

8 THE AAS MEETING IN SEPTEMBER 1927

From 1917 to 1927, Stebbins (Director of Washburn Observatory since 1921) was the Secretary of the American Astronomical Society, and later he would serve that organization as President (1940–1943). George Comstock, teacher and predecessor to Stebbins, was President of AAS from 1925 to 1928 and he still maintained a home near Madison. So as the home to both the President and Secretary, it is no surprise to find that the AAS meeting of 6–8 September 1927 was held in Madison, Wisconsin, and hosted by Washburn Observatory.

Although the AAS was founded at and had met repeatedly at Yerkes Observatory, at Williams Bay in southern Wisconsin, this was the first meeting in Madison (about 70 miles away), so in addition to the usual scientific and organizational business, attendees were interested in touring the Madison area, sailing on the local lakes, walking the University campus, and, of course, getting a look at the Washburn Observatory. An unsigned account of the meeting describes the afternoon inspection visit of Washburn Observa-

tory on Wednesday, 7 September, where "... perhaps the main item of interest was Burnham's famous six-inch refractor, now remounted but with the old mounting on exhibition as a historical relic." (Thirty-eighth meeting, 1927: 481). That account prints a typical AAS meeting group photograph, in this case in front of a fraternity house where many of the attendees were lodged. But there was another group photo taken at the meeting, which was taken in front of the east entrance of the Observatory, no doubt on the occasion of the tour (Figure 12). This shows 61 people (including most of the 48 AAS members attending), one dog, and what looks at first sight like a stove pipe poised in the foreground. But in fact this 'stove pipe' was the wooden tube of the Burnham telescope, which must have been of as much interest to the visitors as the original mounting (but the latter was probably too bulky to take outside for the photograph). The dog in the photograph is probably the Stebbins family dog, Tycho. What item of interest Stebbins stashed inside the tube to ensure Tycho's attention is not recorded.

9 THE ADLER PLANETARIUM

By April 1928, Washburn Observatory records indicate that the 10-in Fecker refractor had taken the place of the steel-tubed Burnham telescope, which had still been in the Student Observatory at the time of the AAS meeting the previous fall, on the new Romare mounting. The steel-tubed Burnham would then have joined the

Clark wooden tube and mounting in storage.

Meanwhile in Chicago, the planning for America's first planetarium, under the leadership of philanthropist Max Adler (1866–1952), was under way. From the very beginning of the planetarium project, Adler was personally responsible for what would become one of the planetarium's specialties, namely a fine collection and museum of antique and historical astronomical instruments (Taub, 1995). The astronomer tapped to become the Adler Planetarium's first Director was Philip Fox (1878–1944; Stebbins, 1944), the Director of Northwestern University's Dearborn Observatory, the home of the 18.5-in Clark telescope with which Burnham had done some of his early work. Fox and Stebbins had known each other for many years and had been 'neighbors' along the Washburn-Yerkes-Dearborn Observatory axis since Stebbins arrived in Madison in 1922. As the Adler Planetarium neared its opening, which came in May 1930, Fox, who had been at the 1927 AAS meeting and seen the Burnham relics, wrote to Stebbins in June 1929



Figure 13: Original wooden tube of the Burnham telescope now part of the astronomical instrument collection at Adler Planetarium (photo by the author with permission of Adler Planetarium).

to ask if he would consider contributing the Burnham telescope for display at the new astronomical museum (Fox, 1929).

The appropriateness of returning the Clark tube and mounting of the Burnham telescope to Chicago had already occurred to Stebbins, and that produced a slightly embarrassing situation. In response to Fox's inquiry, Stebbins revealed that he had already made an offer to the Rosenwald Museum (as Chicago's Museum of Science and Industry was commonly known then), and the offer was accepted, although "... of course I intend to keep the objective to be used on stars for as long as it will serve." (Stebbins, 1929). They agreed in subsequent letters that if the Director of the Rosenwald, Waldemar Kaempffert (1877–1956), would release Stebbins from his offer, then the old tube and mounting could go to the new Adler Planetarium. Kaempffert then complied with Fox's request. Construction at the Planetarium was still under-way in early 1930, but by April 1930 Stebbins had shipped the orig-

inal wooden tube and Clark mounting with clock drive to Fox, where they entered the instrument collection as items on loan. The Burnham items must have been some of the earlier artifacts in the collection, aside from the Mensing instruments acquired by Max Adler himself. It is not clear whether Fox and Stebbins were aware that the wooden tube might have been the last of the tapered wooden telescope tubes to be made by the Clarks (Warner and Ariail, 1968). The objective lens and tailpiece attached to the new steel tube remained in Madison, in storage at Washburn Observatory. So the Burnham telescope's parts diverged even farther (Figure 13).

10 STORAGE AND SOJOURN

It appears that the metal-tube Burnham remained in storage from 1928 until 1956—at least there are no log books or records for it during that time. Joel Stebbins had retired in 1948 and was succeeded by his younger colleague Albert Whitford (1905–2002; Osterbrock, 2004). Whitford was managing some major transitions for Washburn Observatory, including a new, rural observatory site with modern instruments, Pine Bluff Observatory. At the organizational level, the Observatory was making the transition from what was primarily a research institution into a fully fledged and rapidly growing University Astronomy Department. And finally, the astronomers, their offices, laboratories, and shops were preparing to move to a new wing of the Physics building, Sterling Hall.

The 15.6-in telescope remained on its Romare mounting in the old Washburn Observatory dome, where its primary purpose became use by astronomy classes and the general public, but the Student Observatory was about to be abandoned.

Before its final relocation, the Burnham telescope came out of storage to make one more trip away from Madison. In 1956, an energetic amateur astronomer from Appleton, Wisconsin, Jerome J. Knuijt (1959: 410), "... went to the Washburn Observatory to see Burnham's 6-inch refractor, but learned that this fine instrument had been put in storage." Knuijt had constructed his own rather impressive and unusual observatory in his hometown, which, coincidentally, featured a split-hemisphere dome similar to the arrangement Comstock had used on the Student Observatory for the refraction and aberration work with the Burnham telescope. Knuijt clearly impressed Whitford, who arranged for him to borrow the Burnham telescope for his personal use back in Appleton. Knuijt, using his own mountings, paired the Burnham with a 6-in reflector to make direct comparisons of the visual performance of the two types of telescopes (Figure 14).



Figure 14: Jerome Knuijt at his Appleton, Wisconsin, observatory with the Burnham telescope, which is piggy-back on a larger telescope (courtesy: University of Wisconsin Archives).

11 RETURN TO MADISON

In 1958 Albert Whitford left Washburn Observatory to become Director of Lick Observatory. His successor was Arthur Dodd Code (1923–2009), who came to Madison from California Institute of Technology, but had worked for a year at Washburn earlier in his career. The Burnham telescope returned to Madison from Appleton in late 1959. In summer that year the new Astronomy Department had moved from the old observatory building to the top floor of the new east wing of Sterling Hall. During the construction of the new wing of the building, provision was made by the architects for the installation of a planetarium and telescopes on the roof, including concrete columns extending vertically from the foundation up to rooftop level where they could support telescopes. Code (oral history interview with the author, 31 August 2001) was of the opinion that those telescope-supporting columns were the reason that the east wing of Sterling Hall did not collapse after the truck bomb attack of August 1970.

On the westernmost column, under a new dome, the Burnham refractor was reunited with the Romare mounting, where they remain today.

Meanwhile, parts of the 10-in Fecker refractor went into storage. The Sterling Hall site suffers from serious light pollution and, being in the midst of campus, various rooftop heating and cooling systems degrade the seeing. But its location is nearly ideal for use by astronomy students, which is one of the reasons why Holden bought it from Burnham in the first place. The Romare clock drive and control system were replaced with more modern hardware in 2008, and the objective was cleaned and collimated a few years ago (Figure 15). These roles, travels, and transformations are testimony to the durability and versatility of a classic achromatic refractor, which remains in active use today nearly one and a half centuries later. Thanks to the expertise of the Clark shop long ago and the custodianship of several generations of astronomers, the optical performance of the Burnham telescope remains as 'simply perfect' as ever (Figure 16).

12 NOTES

1. Note that Caroline Island is a small isolated coral atoll in Polynesia, near Kiribati, and is not part of the much better-known Caroline Islands thousands of kilometres to the west.

13 ACKNOWLEDGEMENTS

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Figure 16. Original brass tailpiece with Clark's engraving (photo by the author with permission of the Department of Astronomy, University of Wisconsin-Madison).

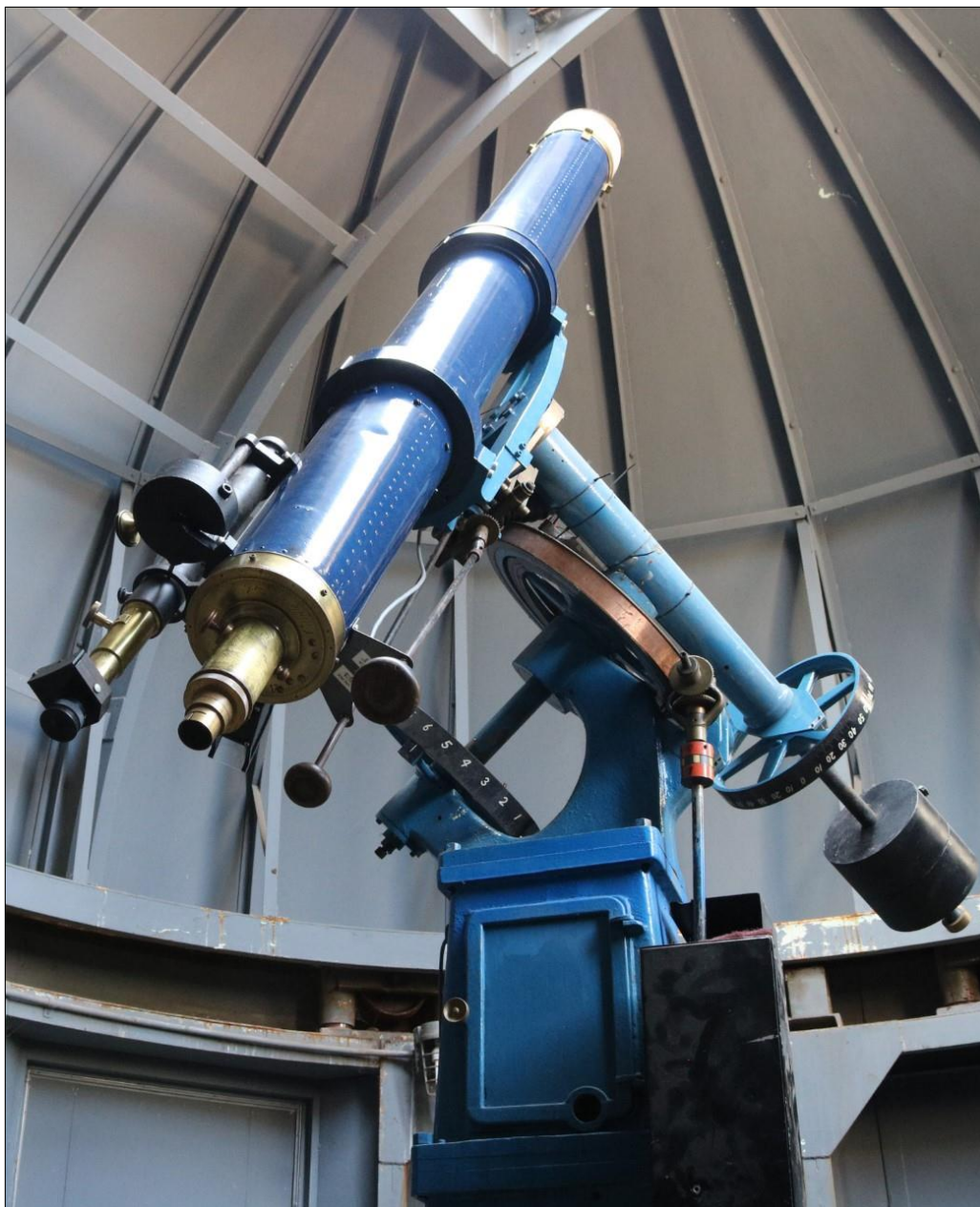


Figure 15: Contemporary view of the Burnham telescope in the dome on Sterling Hall (photo by the author with permission of the Department of Astronomy, University of Wisconsin-Madison).

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