Journal of Astronomical History and Heritage

Volume 6 No. 2 Number 12 2003 December

ASTRAL PRESS

Journal of Astronomical History and Heritage

JAH² is published twice-yearly, in June and December, and features review papers, research papers, short communications, correspondence, book reviews. Papers on all aspects of astronomical history are considered, including studies which place the evolution of astronomy in political, economic, and cultural contexts. Papers on astronomical heritage may deal with historic telescopes and observatories, conservation projects (including the conversion of historic observatories into museums of astronomy), and historical or industrial archaeological investigations of astronomical sites and buildings. All papers are refereed prior to publication. There are no page charges and authors receive 25 offprints of their paper free of costs.

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Website: http://www.astralpress.com.au

The annual subscription to Volume 6, 2003, is AU$75.00 or Stg£27.00 for institutions, AU$44 or £17 for individuals.

Published by Astral Press, Registered Office, 4 Mead Grove, Floreat, WA 6014, Australia.

ISSN 1440-2807

Cover: Earliest known image of Detroit Observatory by Jasper Cropsey, 1855. Original painting held at Bentley Historical Library. Courtesy: Bentley Historical Library, University of Michigan. See page 69.

Journal of Astronomical History and Heritage 6(2):69-106 2003

Detroit Observatory: nineteenth-century training ground for astronomers

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Abstract
Detroit Observatory was founded in 1854 at the University of Michigan in Ann Arbor, Michigan, USA, by Henry Philip Tappan, the University's first President. In 2004, the University celebrates Detroit Observatory's sesquicentennial year. Tappan named his creation the "Detroit Observatory" to honour the city's major benefactors. Tappan, who was inaugurated in 1852, was a visionary leader in the history of higher education. The creation of an astronomical observatory was one of his first steps toward the integration of a new scientific course with the traditional classical course of study, following the Prussian model of higher education. Tappan's observatory was built in the frontier state of Michigan at a modest cost, yet it was equipped with the best European and American instruments available. The facility was impressive, but Tappan's success in launching the University of Michigan to the forefront of American astronomical science was achieved through the recruitment of the renowned Prussian astronomer, Franz Brünnow, of the Berlin Observatory. The instruction in precision astronomy Brünnow offered to American students produced some of the most notable astronomers of the era, which led to the recognition of an 'Ann Arbor School of Astronomy'. Subsequent Directors and Assistants, including James Watson, Mark Harrington, J Martin Schaeberle, and Asaph Hall Jr., produced students with exceptional talent in astronomy, geodesy, surveying and meteorology. Michigan's talent pool was then widely deployed across the nation. This paper documents and preserves this history, and serves as a focal point for celebrating in 2004 the 150-year milestone in Detroit Observatory's fascinating history.

Keywords: *Detroit Observatory, University of Michigan, Franz Brünnow, James Watson, nineteenth-century astronomy, U.S. Lake Survey*

1 INTRODUCTION

In 2004, the University of Michigan celebrates the 150th anniversary of the founding of Detroit Observatory (Figure 1) in Ann Arbor. There is much to recognize in Detroit Observatory's distinguished history: its creation in 1854 by the University of Michigan's inaugural president, Henry Philip Tappan; the vision and generosity of its major benefactors from the City of Detroit; the impressive telescopes, including a 15.2 cm (6-inch) meridian circle made by Pistor and Martins of Berlin, and a 32.1-cm (12.625-inch) refractor by Henry Fitz of New York City; the discovery at the Observatory of twenty-one minor planets by James Watson, and two comets by Martin Schaeberle; the timekeeping service provided by Detroit Observatory during the mid-nineteenth century for the Great Lakes region; the longitude determination made in 1861 in collaboration with the United States Lake Survey, which became the fundamental reference point for all subsequent land surveys from Detroit across the Western states; and the fact that the building, its original telescopes, and many pieces of original apparatus have persisted intact over the course of the Observatory's 150-year history, in spite of the predilection of Midwestern American universities to raze old buildings to make way for new facilities.

The distinguishing facts of Detroit Observatory's rich history are becoming more widely known. What is less known is the Observatory's impressive record as a training ground for some of America's most prominent nineteenth-century astronomers. This paper documents and chronicles the breadth and depth of the impact made in the United States by students trained at Detroit Observatory during the nineteenth century. The individuals selected for inclusion in this article represent only a small fraction of the students trained at Detroit Observatory, and no implication is intended by the exclusion of other meritorious alumni and alumnae.

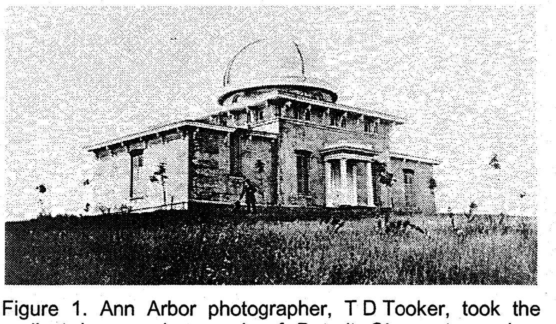

Figure 1. Ann Arbor photographer, T D Tooker, took the earliest known photograph of Detroit Observatory, circa 1858 (Courtesy: Bentley Historical Library, University of Michigan).

2 FOUNDING OF DETROIT OBSERVATORY

When the University of Michigan relocated to Ann Arbor in 1837 from its original location in Detroit, Ann Arbor was a town of about 2,000 citizens. In many ways, it was still a frontier town, surrounded by log cabins and newly-cleared farm fields. Cattle grazed on the pastoral forty acres the town donated to attract the University away from Detroit. There were no campus buildings until 1840 when four identical professors' houses were constructed. By 1850, the graduating class included only twelve students, and seven buildings were completed (Figure 2). An absentee Board of Regents governed the University, but it had become clear that the University required the presence of full-time leadership.

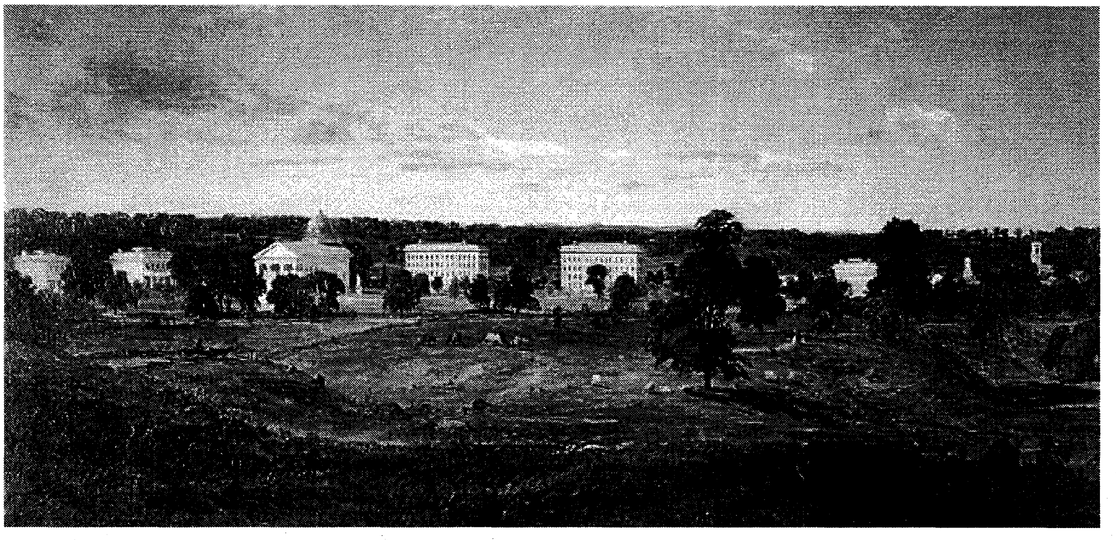

Figure 2. This 1855 landscape painting of the University of Michigan campus by Hudson River School artist, Jasper Cropsey, was done while he was visiting his friend, Henry Tappan. During the same visit, Cropsey also painted the Detroit Observatory, and it is the earliest known image of the Observatory. Both original paintings are in the Bentley Historical Library (Courtesy: Bentley Historical Library, University of Michigan).

Henry Tappan (1805-1881) was recruited from New York in 1852 to be the University's inaugural President. He was a prominent philosopher and educator who had served on the faculty at the University of the City of New York (now New York University). He brought to Michigan a progressive vision, based on the model of education espoused by French philosopher, Victor Cousin. Coincidentally, the educational plan for the State of Michigan, which was ratified in 1835, was influenced by Cousin's ideas. In his inaugural speech, Tappan shared the details of his vision, which was to supplement the standard classical course of study with a scientific course. As a top priority in implementing the plan, Tappan wanted to erect an astronomical observatory as the University's first dedicated scientific facility.

Henry Walker, a prominent citizen of Detroit, was in the audience the day Tappan articulated his vision. After the speech, Walker stepped forward to offer assistance in raising funds to erect an observatory. The collaboration Tappan and Walker established was the ideal reciprocal relationship: Tappan would have his observatory and telescopes for instructional use and basic research, and Walker and others across the Great Lakes region would benefit from a timekeeping service that an observatory with a fixed telescope and a trained astronomer could provide. Walker was heavily invested in the Michigan Central Railroad, which was rapidly laying down tracks across the State. He was also involved in banking, and was a leader among the intellectual elite of Detroit. A time-keeping service would keep Walker's trains on schedule and prevent collisions, which tragically happened with unfortunate regularity. It would also help ensure that financial markets closed simultaneously, to prevent competitive advantage.

Tappan and Walker's vision and collaborative effort helped to launch the Great Lakes region into the intellectual, technological, industrial, and commercial forefront. Today, historians of higher education recognize Tappan as the progenitor of the research university. In a recent speech, University of Michigan Provost, Paul Courant (2003:5) characterized Tappan and Walker's alliance of academy and commerce as being "...uniquely American, [having] persisted to produce a set of institutions of learning and research that are quite extraordinary."

3 INSTRUMENTS AMONG THE BEST IN THE WORLD

Detroit Observatory was one of the best-equipped observatories in the world when it was completed in 1854. The facility was quite exceptional, especially when consideration is given to its remote location in the frontier State of Michigan, the fledgling status of the University's scientific curriculum, and the Observatory's overall low cost.

Walker's desire for an Observatory was so great that he provided the entire sum required to purchase the best meridian circle telescope available in the world. He also used his influence among Detroit's intellectual and wealthy citizens to raise the remainder of the funds needed for the Observatory. The distinguished donors included Lewis Cass, Governor of Michigan; Zachariah Chandler, Mayor of Detroit; E C Litchfield, a lawyer and banker who later endowed the Observatory at Hamilton College in Upstate New York, and Bela Hubbard, Litchfield's brother-in-law, who was a distinguished scientist and explorer on Douglass Houghton's geological survey of Michigan. Tappan named his new Observatory in honour of these citizens of Detroit, whose generosity made the project possible.

3.1 The Fitz Equatorial Refracting Telescope

In 1853 February, Tappan travelled with Walker to New York City, where they met with Henry Fitz Jr. at his telescope shop. Fitz was the first American telescope maker of note, and until he gained a reputation in the 1840s, the best telescopes were exclusively made in Europe. Tappan and Walker placed an order with Fitz for a 30.5-cm (12-inch) achromatic refracting telescope with an equatorial mounting (Figure 3). Fitz was behind in filling his orders and did not have the telescope ready when Detroit Observatory's new Director, Franz Brünnow, arrived from Berlin in 1854 July, so Fitz provided a telescope on loan. Fitz finally delivered a new telescope in 1854 December, but Brünnow rejected it because the mounting was deficient. Fitz's innovative new mounting was made of cast iron to provide superior strength at a lower cost, but Brünnow was not impressed and insisted that the mounting be cast in traditional bell metal. In 1857 November, Fitz finally delivered a telescope that Brünnow would accept.

When it arrived in Ann Arbor, the Fitz telescope was among the largest refractors in the world, with an objective lens of 32.1 cm (12.625 inches) clear aperture. The instrument's wooden tube, which provided a 5.38 m (17 foot 8 inch) focal length, was constructed of pine covered with strips of mahogany veneer, and flanked on each side by wooden flexure rods for stability. Seven positive and six negative eyepieces were included, the highest magnifying power being 1200 times. Accessories included a ring-micrometer, 'sunshades', a filar micrometer, and a finder telescope of 5.72 cm (2.25 inch) clear aperture. A clock drive provided slow motion control.

By 1907, astronomers had lost confidence in wood as a stable material for telescope tubes, because it was too easily influenced by changes in temperature and relative humidity. The decision was then made to replace the wooden tube with one made of steel, and also to replace the flimsy clock drive with a better one by Warner & Swasey. In 1997, the refractor was restored to its 1907 condition, and a scale model of the telescope with its wooden tube and flexure rods was constructed to document its original details, and to interpret the 1907 modifications to visitors.

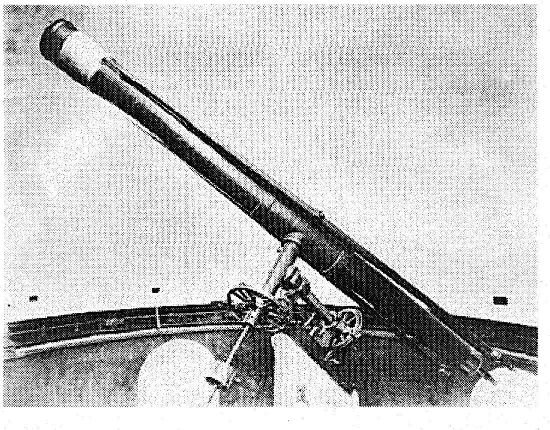

Figure 3. Detroit Observatory's 32.1-cm Fitz refracting telescope (Courtesy: Bentley Historical Library, University of Michigan).

Today, the original 32.1-cm objective lens is widely believed to be the largest surviving lens made by Fitz that has not been refigured by another telescope maker.

3.2 The Pistor & Martins Meridian Circle

In the 1850s, meridian circle telescopes, which were used for timekeeping, longitude determinations, and precision astronomy, were available only in Europe. After Tappan and Walker ordered the refractor from Fitz, Walker left New York for Detroit, and Tappan proceeded on to Europe as previously planned. He intended to personally examine the European system of higher education, and he also wanted to visit various observatories to obtain recommendations for the purchase of a meridian circle.

After visiting observatories at Greenwich, Rome, and Munich, Tappan went to the Berlin Observatory, where he met with the renowned astronomer Johann Encke and his assistant Franz Brünnow. They enthusiastically recommended the instruments of Pistor & Martins, and clockmaker C F Tiede, both of Berlin. Tappan was convinced, and he placed his order with the condition that Brünnow inspect the instruments for accuracy before they were shipped to America. Brünnow's admiration of the instruments later prompted Tappan to offer him the inaugural Directorship of Detroit Observatory.

The Pistor & Martins meridian circle (Figure 4) was a work of art, and exacting in its specifications. Its tube, mounted between two limestone piers, had a 2.44 m (eight foot) focal length and 15.2 cm (6 inch) diameter lens. Its two circles, each 96.5 cm (three feet two inches) in diameter, were finely divided on an inlaid band of silver to two-minute intervals, and equipped with four microscopes on each circle to read the finely-inscribed lines. Oil lamps provided indirect light to illuminate spider lines in the reticle, and an adjustable interior aperture controlled the amount of light that could enter. A spirit level covered in leather to equalize the temperature, and two collimating telescopes mounted on limestone piers at the north and south ends of the telescope room, facilitated the precise alignment of the telescope. Directly beneath the telescope was a metal basin into which mercury was poured to provide a perfectly level mirror. A star reflected in the mercury pool helped determine the nadir and the zenith. Another mercury basin that rolled on a narrow gauge track on the floor was used for reflex observations. A reversing carriage on a larger gauge track was used to flip the telescope 180 degrees in its mount. This made possible observations first to the north, and then to the south. The observational data were then compared to identify any error in the instrument. For the observer's comfort, a couch on wheels was provided, with an adjustable back to facilitate the proper level of incline. For daytime observations, a parasol mounted on a trolley was provided. This large black screen, with an adjustable aperture in the middle and controls to adjust for elevation and angle, prevented sunlight from interfering with the observations.

The Ann Arbor instrument is the only one of thirteen meridian circle telescopes made by Pistor & Martins to survive intact in its original mount anywhere in the world, and is the oldest surviving meridian circle in America.[1] Pistor & Martins made meridian instruments for the major German observatories at Leipzig, Bonn, and Berlin (two), the observatories at Leiden, Copenhagen and Palermo, the U.S. Naval Observatory, the U.S. Naval expedition to Chile in 1849, Amherst College in Massachusetts, Dudley Observatory at Albany (New York), Dunsink Observatory in Ireland, and Detroit Observatory. Brünnow personally installed three Pistor & Martins meridian circles, at the Dudley, Dunsink, and Detroit Observatories.

The meridian circle made by Pistor & Martins in 1856 for the Dudley Observatory is currently in storage at the New York State Museum, but only a few pieces survive, and the empty brass tube was badly damaged by a blowtorch. The 1865 meridian circle telescope of the U.S. Naval Observatory is no longer extant, nor is the instrument from the expedition to Chile. The Dunsink instrument is gone, as is the Amherst College meridian circle. The instrument made for Leiden Observatory is on display at the Boerhaave Museum in Leiden (The Netherlands), and the meridian circle from the Observatory at Bonn is on display at the Deutsches Museum in Munich. Copenhagen's instrument is on display at the Steno Museet in Ärhus, Denmark, and the instrument from the Berlin Observatory was destroyed, but its lens and Berlin's 1867 meridian circle are at the Astrophysikal Institut in Potsdam. Finally, the meridian circle at Palermo was modified nearly beyond recognition and placed on a different pier, prior to its recent restoration.[2]

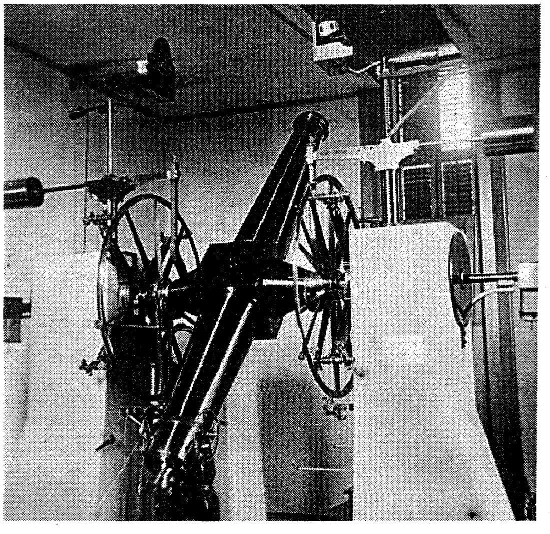

Figure 4. Detroit Observatory's Pistor & Martins meridian circle telescope. The astronomical clock by C F Tiede is mounted on the limestone clock pier (behind the left circle) (Courtesy: Bentley Historical Library, University of Michigan).

4 DETROIT OBSERVATORY ARCHITECTURE

For the design of the Detroit Observatory building, Tappan turned to a former colleague at New York University. Professor Richard Bull, who taught mathematics, surveying, astronomy, architecture and constructional methods, possessed the unique combination of astronomical and architectural knowledge needed to successfully design an observatory (Whitesell, 1998:87-88). Observatories that were designed by individuals unfamiliar with astronomy typically failed to meet specific scientific requirements. For example, a pair of famous architects, Andrew Jackson Downing and Calvert Vaux, designed the Dudley Observatory in Albany, New York. While the architecture was pleasing, the plans had to be radically modified during construction in order to provide the required distance between the collimating telescopes (Whitesell, 1998:90-94).

Professor Bull was the ideal person to design an observatory, given his academic training and practical understanding of astronomy. He was an experienced amateur astronomer, and for a number of years determined astronomical time for the City of New York at his private observatory (Whitesell, 1998:89).

University of Michigan Chemistry Professor, Silas Douglas, supervised construction of Detroit Observatory, a duty he similarly performed for several other campus construction projects. The University selected as the site a 1.62-hectare (4-acre) hilltop located 800 m (half a mile) from the Campus, and work commenced in 1853 and was completed the following year. The floor plan was typical of nineteenth-century observatories (see Loomis, 1874a and 1874b), consisting of a two-storey central mass topped by a revolving dome, and two one-storey wings, one for the meridian circle and the other for the Director's office and library (Figure 5). The main building was 9.75 m (32 feet) square and 7.3 m (24 feet) high, with a solid brick pier ascending through its centre into the dome above to provide a stable base for the refracting telescope. The building was designed to avoid touching the pier.

The walls of the building were solid brick covered with stucco that was scored to resemble individual blocks of stone. Pigments were added to the wet stucco, and the resulting effect was that every scored section was a different shade resembling granite. White and black paint was finely spattered on the stucco to resemble the sparkles in granite, and the mortar joints were painted white. From a distance, the building appeared to be made of stone. Inside, similar faux finishes were used to fool the eye, such as grain-painting of the pine woodwork to make it look like more expensive oak, and blue-grey stucco on the central telescope pier that was scored to look like blocks of limestone and striped with black paint to accentuate the mortar joints. (Whitesell, 1998:100-103) Solid limestone piers were obtained from a quarry at Sandusky, Ohio, to provide stability for the meridian circle, two collimating telescopes, the clock, and the refracting telescope.

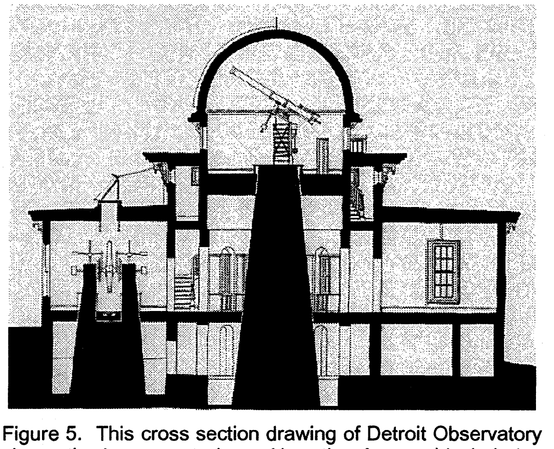

Figure 5. This cross section drawing of Detroit Observatory shows the instrument piers. Note that for graphical clarity, the refracting telescope is shown in an east/west (rather than the proper north/south) position (Courtesy: Detroit Observatory Collection).

To keep the dome lightweight and breathable, it was constructed of wood, lined with cotton canvas and paper, and protected on the exterior by tin plates. A continuous rope was pulled to rotate the dome. Originally, the dome revolved on five cannonballs, but there was no provision made to space these and when they inevitably clustered together the dome had to be lifted in order to reposition them a distance from one another. This proved to be cumbersome, as did the original shutter, which was rolled up and over the back of the dome to provide a slit for observing. Equally irksome was the observer's chair, which was attached to the dome and rotated along with it. In 1890, all of these features were altered: railroad-style wheels replaced the cannonballs, a new shutter opened to the side, and a free-rolling observer's chair was obtained. The hatches on the roof of the meridian circle telescope wing were opened by means of a crank attached to cables that passed through the roof to the exterior side of the hatch covers.

Over the years, several additions were constructed to expand the Observatory complex. In 1868, a Director's residence was added to the Observatory's west wing (Figure 6), into which James Watson (see Section 7, below) moved his entire extended family. By the turn of the nineteenth century, the Observatory's telescopes were outmoded, and more powerful telescopes were needed to keep pace with advancing technology. The Astronomy Department then successfully secured funding for a new wing, and equipped it with a 95.3-cm (37.5-inch) reflecting telescope. The residence was demolished in 1954 to make way for expansion of an adjacent dormitory, and the 1907 addition was razed in 1976 when it was condemned due to termite damage. The original 1854 building was placed in the National Register of Historic Places in 1973, and then saved from the wrecking ball in 1976 through the efforts of local preservationist John Hathaway, Astronomy Professor Hazel (Doc) Losh, and others dedicated to the cause.

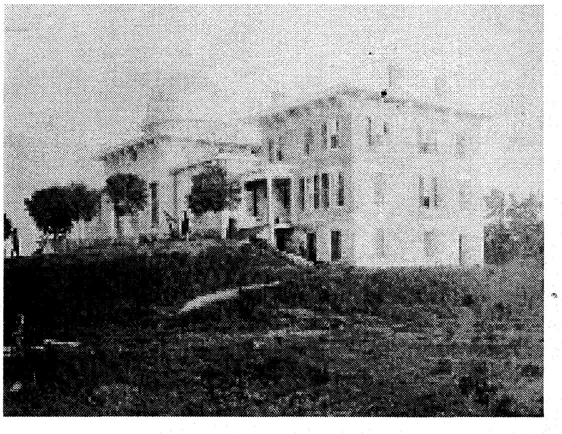

Figure 6. While serving as second Director of Detroit Observatory, James Watson added a Director's residence in 1868. Watson is standing in front with a small telescope, and his wife, Annette, is at the front porch (Courtesy: Author's Collection).

In 1997, the Detroit Observatory building and telescopes were restored, with exacting attention paid to historical detail. The award-winning result[3] is an Observatory that immediately transports the visitor back to the 1850s. Students and visitors can now examine the facility within which Michigan astronomers provided instruction, conducted research, made scientific discoveries, provided a time service, determined the longitude that established the fundamental reference point for the survey of the Great Lakes, and prepared students for a variety of careers.

5 PRUSSIAN PRECISION: THE RECRUITMENT OF FRANZ FRIEDRICH ERNST BRÜNNOW

Director, Detroit Observatory 1854–1863 [1821–1891]

Franz Brünnow (Figure 7), a German-born and trained astronomer, was the first foreigner to receive appointment as Director of an American observatory, and introduced his students to German astronomical methods, which stressed precision in both spherical and observational astronomy. When he was appointed in 1854 as the inaugural Director of Detroit Observatory, Brünnow was the first Faculty member to hold the Ph.D. degree, and his appointment immediately launched the University of Michigan to the forefront of American astronomical science.

The significance of Brünnow's contribution to American higher education and astronomy has been likened to the contributions of Alexander Agassiz in natural history (Bruce, 1987:87). Upon the seventy-fifth anniversary of the founding of the University, an alumnus trained at Detroit Observatory, Robert Woodward (see Section 9.5, below), commented on the significance of Brünnow's contributions:

> ... in the science of astronomy, including all its branches, Americans have been the leaders for more than fifty years. Two schools have been founded in America, the first by Professor Benjamin Pierce of Harvard University and the second by Professor Brünnow of this University. It was Brünnow who introduced in America before 1860 the methods of the illustrious Gauss and the incomparable Bessel, the German astronomers who laid the foundations of modern spherical and observational astronomy. From Brünnow are descended some of the most distinguished American astronomers. (University of Michigan, 1915:135).

Brünnow's expertise in astronomy was an excellent fit with the innovative scientific curriculum Tappan introduced in 1852–1853. Freshmen studied algebra, geometry, and history; sophomores concentrated on trigonometry and conic sections, descriptive and analytic geometry, mensuration and navigation, natural history, German, history, and rhetoric; juniors studied natural philosophy, German, drawing, perspective and architecture, calculus, rhetoric, civil engineering, and chemistry; and seniors took civil engineering, chemistry, animal and vegetable physiology, and geology. Interestingly, astronomy was offered through the classical rather than the scientific course to third term juniors.

What distinguished Michigan from other institutions was Tappan's newly-instituted graduate programme, that students could enter following receipt of a Bachelor's degree. This course included astronomy. Students who wanted to pursue a course in higher astronomy began in their senior year and continued for four semesters, taking them one year beyond graduation. Brünnow's course in higher astronomy included:

- Spherical Astronomy and Theory of the Instruments
- Calculation of the Orbits of Celestial Bodies
- Numerical Calculus; Theory of Interpolation; Method of the Least Squares
- Physical Astronomy; Calculation of the Special

and General Perturbations of the Heavenly Bodies.

This rigorous theoretical and highly-technical training, and practical experience through hands-on use of the meridian circle and refracting telescopes, was not available to students at other comparably-equipped observatories in America.

Figure 7. Franz Brünnow, 1821–1891 (Courtesy: Bentley Historical Library, University of Michigan).

Franz Brünnow was born on 1821 November 18 in Berlin, the son of Johann Brünnow, a German Privy Councillor of state, and Wilhelmine Weppler. He was educated at the Friedrich-Wilhelm Gymnasium in Trier, and at the University of Berlin (where he studied mathematics, astronomy, and physics). In 1843, upon completion of his thesis "De Attractione Moleculari", he received the Ph.D. degree. He was appointed Director of the private Bilk Observatory at Düsseldorf in 1847, where he authored an important paper on De Vico's comet (see Brünnow, 1849). He was honoured the following year with a Gold Medal from the Amsterdam Academy.

In 1851, Brünnow was appointed at Berlin Observatory as First Assistant to Johann Encke, replacing Johann Galle when Galle became Director of Bresslau Observatory. Brünnow was trained by Encke as part of a distinguished group of young astronomers that included Galle, Carl Bremiker and Heinrich d'Arrest. Brünnow was present when Galle discovered Neptune on 1846 September 23, based on predictions made earlier by French astronomer Urbain LeVerrier. Brünnow's most important work, *Lehrbuch der Sphärischen Astronomie*, or *Handbook of Spherical Astronomy*, was published in 1851, and he personally translated the text into English in 1865. Other translations were later published in Spanish, French, Russian, and Italian. This text established Brünnow as an astronomer of international renown. From 1851 to 1854, he served as Assistant Director of Berlin Observatory under Encke.

It was in Berlin in 1853 that Brünnow met University of Michigan President, Henry Tappan, and Tappan later recruited Brünnow as inaugural Director of Detroit Observatory. Brünnow arrived in Ann Arbor in 1854 to assume his new duties, and three years later, in 1857, he married Tappan's only daughter, Rebecca. Years later, Tappan reflected on the Observatory he created as being the achievement at Michigan that was his greatest source of pride, and said that his daughter's marriage to Brünnow made him feel thus "wedded" to the Observatory.

Brünnow's arrival at the University was newsworthy, and was quickly attached to boastful statements concerning the University's eminence. Undergraduate student, William Anderson, wrote to a friend on 1854 August 21:

> I sent you a catalogue of the University of Michigan, of which I am an unworthy member, and which I may tell you ranks very high among the educational institutions of America. There are very great improvements going on here. We have built an observatory here and have called one of the best astronomers in the world to take charge of it, namely Dr. Brünnow of Berlin Prussia. On his way here he stopped at some of the [?] colleges and caused many of them to envy the University of Michigan its good fortune on obtaining the services of such a man. His name will bring a large procession of students ... (Anderson, 1854).

Brünnow's academic career was characterized by high standards and ideals, extremely hard work, and amazing perseverance. The study of double stars was an obsession of his, with particular attention paid to 85 Pegasi, the measure of which he calculated in 1870. Brünnow started the University of Michigan's first scholarly journal, *Astronomical Notices*, to publish the discoveries and research findings made at Detroit Observatory, as well as contributions sent in by other astronomers. He studied the motions of minor planets, and published several studies, including "The General Perturbations and Elliptical Elements of Vesta" and "Tables of Victoria."

Few students were sufficiently prepared in higher mathematics to receive instruction from Brünnow, and in the early years following his arrival, he sometimes lectured to just one student. That student was James Watson, who later succeeded him as Director of Detroit Observatory. Students held Brünnow in high regard, but his thick German accent made him the unfortunate target of student pranks and taunting. History Professor, Andrew White, later reminisced about this, during his years as President of Cornell University: "There was in him a quiet simplicity which led those who knew him best to love him most, but it occasionally provoked much fun among the students." (White, 1905:274). Yet, Brünnow's writing was flawless in English and in German.

Between 1858 and 1869, numerous university observatories collaborated with the U.S. Lake Survey on longitude determinations in the Great Lakes region, and Detroit Observatory was an important participant. Brünnow (1861:17-18) first determined the longitude of Detroit Observatory in 1858 from occultations of the Pleiades, and two years later, in 1860 May, while he was at Dudley Observatory, Watson worked with the U.S. Lake Survey to determine the longitude by an exchange of arbitrary telegraph signals. The method was less accurate than use of an electric telegraph and chronograph, but it was the most advanced method available at the time. However, the results were not entirely satisfactory, and when Brünnow returned to Ann Arbor from Dudley Observatory he brought along a chronograph made by William and George Bond of Harvard College, and obtained approval from the University Regents to install a telegraph line from Detroit Observatory to the nearby Michigan Central Railroad depot. Observations were performed in 1860 April and May in co-operation with the Lake Survey, and personal equations were checked in June. This collaboration with the Lake Survey resulted in the establishment of Detroit as the fundamental reference point for all positional determinations made by the Lake Survey in the Great Lakes region (Loomis, 1874b:527-528). In addition, the Detroit longitude was eventually used to connect longitude determinations between observatories all the way to the West Coast. (see Whitesell, 2000).

Brünnow resigned from the University in 1863 in direct response to the controversial and much-contested dismissal by the Regents of President Tappan. Although he spent only nine years in America, Brünnow left his mark on the history of American astronomy, and is considered to have been one of the best of the small band of astronomers active in America during the mid-nineteenth century.

In 1865, he was appointed Astronomer Royal of Ireland, Andrews Professor of Astronomy at the University of Dublin, and Director of Dunsink Observatory. At Dunsink, he continued his research on stellar parallaxes, which he published in his *Astronomical Observations* (1870) and *Researches Made at Dunsink* (1873). In 1869 he was elected a Fellow of the Royal Astronomical Society, and in 1871, with John Stubbs of Trinity College, he expanded and updated the classic text, *Brinkley's Astronomy*. Failing eyesight forced his resignation in 1874. He retired to Switzerland, and in 1889 settled in Heidelberg (Germany) to be with his son, Rudolph. Poor eyesight precluded any scientific work, so he occupied himself through his considerable musical talents. He once remarked that had he not pursued astronomy, he ought to have devoted himself entirely to music.

Brünnow's death in Heidelberg on 1891 August 20 at age sixty-nine was unexpected, although he had been seriously ill in June of that year. He was making preparations for a trip to Switzerland when he developed a blood clot in his leg, which led to a fatal stroke.

6 BRÜNNOW'S STUDENTS, 1854–1863

Students were attracted to the University of Michigan from great distances for the opportunity to receive instruction from the renowned astronomer, and some of Brünnow's students went on to lead distinguished careers. Among them were Asaph Hall Sr., discoverer of the moons of Mars; DeVolson Wood, founder of the engineering courses at Michigan; Cleveland Abbe, the eminent meteorologist; Orlando Wheeler, engineer with the U.S. Lake Survey; Stillman Robinson, engineer, professor and inventor; and James Watson, second Director of Detroit Observatory and discoverer minor planets.

In addition, the astronomer Charles Young learned German astronomical methods from Brünnow (Russell, 1927:206), although he never attended the University of Michigan. In 1858, Young and Brünnow participated with the U.S. Lake Survey in the longitude determinations for Hudson, Ohio, Ann Arbor and Detroit (Whitesell, 2000:147). Later, Young accompanied Watson on astronomical expeditions to Iowa and China, built a distinguished reputation, and became Professor of Astronomy at Dartmouth and Princeton Universities.

6.1 Asaph Hall Sr., attended 1856 [1829–1907]

Asaph Hall Sr. distinguished himself in astronomy in diverse ways, but he is best known for his discovery in 1877 of the two moons of Mars. Another notable achievement was his discovery of the motion line of the apsides of the orbit of Hyperion, one of Saturn's satellites.

It was at the University of Michigan in 1856, while studying under Brünnow, that Hall first began a serious study of astronomy. For personal and financial reasons he did not remain at Michigan very long, but he later made a remarkable contribution to Michigan's astronomy programme when his son, Asaph Hall Jr., served from 1892 until 1905 as fourth Director of Detroit Observatory. The name 'Asaph Hall' is therefore associated with Detroit Observatory through both father and son.

Asaph Hall Sr. was born at Goshen, Connecticut, on 1829 October 15 to Asaph and Hanna Hall. His early education was at Norfolk Academy, and was supplemented and stimulated by his father's extensive library. Hall then attended Central College in McGrawville, New York, in 1855. He financed this education by making repairs to College buildings, capitalizing on his skill as a carpenter. While at Central College, he met Angeline Stickney, his instructor in geometry and German, and they were married at Elkhorn, Wisconsin, on 1856 March 31. They set out that same day for Ann Arbor, where they intended to stay for three or four years while Asaph attended school. The marriage produced four children; Asaph Jr., the youngest, was born on 1859 October 6.

Brünnow was so impressed by Hall Sr. that he arranged for the brilliant young student to continue his studies without paying tuition fees when he complained of financial difficulties. The Halls considered staying in Ann Arbor, but after only three months they moved to Shalersville, Ohio, to live with Angeline's aunt. There they earned their board, with Asaph working in the fields and Angeline in the house. Asaph then took a teaching position at the Shalersville Institute, and in about a year they saved sufficient funds to repay family debts, freeing Asaph to return to college. Brünnow attempted to entice Hall back to Ann Arbor, but he decided instead to relocate to Cambridge, Massachusetts, where George Bond, Director of Harvard College Observatory, needed an assistant.

Before commencing work at Harvard College

Observatory, Hall first went to Plymouth Hollow in Connecticut to work as a carpenter, in the hope of saving sufficient funds for them to settle in Cambridge, while Angeline lived with his mother at Goshen, Connecticut. The Halls moved to Cambridge in 1857 August, but continued to struggle financially. Asaph earned a dollar for each Moon culmination he observed for the Army engineers, and for computations he made for the Nautical Almanac. His persistence and ability impressed Bond, and Hall was permanently hired and placed on salary. Independently, he continued his studies, which included Brünnow's text, *Lehrbuch der Sphärischen Astronomie* (which he was able to read because Angeline taught her husband German). In 1858, Hall published his computations of the orbital elements of a comet in the *Astronomical Journal*. In 1862, he was appointed an Astronomer at the U.S. Naval Observatory, and the following year he became Professor of Mathematics with the U.S. Navy.

Hall's greatest contribution to astronomy took place on 1877 August 11. Night after night he had used the U.S. Naval Observatory's 66.6-cm (26-inch) refractor to methodically search for any sign of the satellites of Mars, which had long been thought to exist. It was during the early morning hours that he first noticed a faint star-like object near Mars. He spotted it again on August 16, and he and his assistant, George Anderson, detected a second, inner, moon the next day. He named the moons Deimos and Phobos. On August 18 the news was telegraphed, the observations were confirmed, and the discoveries were announced to the world (National Cyclopaedia of American Biography, 1893). In 1878 Hall was awarded the Gold Medal of the Royal Astronomical Society for this discovery, and other awards he received during his lifetime included the Lalande and Arago Prizes from the National Academy of Sciences and the Cross of the Legion of Honour of France.

During his eminent career, much of which was spent in service with the U.S. Navy, Hall travelled on many astronomical expeditions, including to Plover Bay near Bering Strait in 1869 to observe a solar eclipse, Sicily (1870) for a solar eclipse, Vladivostok (1874) for the transit of Venus, Colorado (1878) for a solar eclipse, and Texas (1882) for another transit of Venus. In recognition of his achievements, he received honorary degrees from Hamilton College (Ph.D.), Harvard (AM) and Yale (LL D) in 1879, and another from Harvard (LL D) in 1886. He resigned from the Navy in 1891 – as retirement regulations required – with the rank of Rear Admiral, but remained at the U.S. Naval Observatory completing various projects until he accepted an appointment as Professor of Mathematics at Harvard in 1896. He remained there until his final retirement in 1902, and died at Annapolis, Maryland, on 1907 November 22 at the age of seventy-eight.

6.2 DeVolson Wood, Class of 1859 [1832–1897]

DeVolson Wood is considered to be the founder of the courses in engineering at the University of Michigan (Cooley, 1947:87). He was born at Smyrna, New York, in 1832, and spent his early life on the family farm. Wood was a creative, clever, and expansive thinker. He graduated from Albany Normal School, enrolled at Rensselaer Polytechnic Institute in Troy, New York, and graduated in 1857 with a degree in civil engineering. It was at this time that he conducted a serious study of a solar eclipse, predicting well in advance the precise moments of ingress and egress. Wood then made his way to Ann Arbor, introduced himself to Tappan, and was fortunate in his timing: Professor Peck had not yet returned from a leave of absence, and Tappan needed a substitute. When Peck failed to return, Wood became permanent, and was appointed Assistant Professor of Physics and Civil Engineering.

While teaching at Michigan, Wood pursued graduate studies along with James Watson (see Section 7, below), studying under Brünnow and others. Both Wood and Watson received Master's degrees in 1859 – the first advanced degrees ever granted by the University. That same year, Wood also received a Master's degree from Hamilton College at Clinton, New York, most likely facilitated by Brünnow's close association with C H F Peters, Director of the Hamilton College Observatory. In 1859, Wood was promoted to full Professor of Physics and Engineering.

Students at the University could pursue the traditional classical course or the scientific course. The scientific course offered students scientific and practical training while they simultaneously pursued classical training in fields such as history and English. During their first two years, students in the scientific course studied mathematics through trigonometry and descriptive geometry, history, English language and literature, surveying, and drawing. In the third year, they studied practical engineering in the first semester, and then devoted the second semester to practical astronomy, analytic investigations of the resistance of materials, motors, machines, and construction. In this way, engineering students were taught some astronomy, and if they desired further training and practical experience they could pursue this at the master's level through Brünnow.

While at Michigan, Wood had visionary ideas about advancing the scope of engineering education, but he subsequently accepted the Chair of Engineering at Stevens Institute of Technology in Hoboken, New Jersey, and stayed there for the remainder of his working life. He died in New York City on 1897 June 27.

6.3 Cleveland Abbe, attended 1859–60 [1838–1916]

Cleveland Abbe is a legendary figure in the history of meteorology, and was the first American to provide regular weather forecasts based on daily telegraphic reports and synoptic maps. He was born in New York City on 1838 December 3 to George and Charlotte Abbe. He received his early education at the New York Free Academy, graduated in 1857, and went on to pursue a Master's degree, which he completed in 1860. To help meet his educational expenses, he worked as a Tutor in Mathematics at Trinity Grammar School in 1857–1858, at the State Agricultural College (Michigan State University) in Lansing in 1859, and at the University of Michigan in 1859–1860. When Abbe graduated from the Free Academy in 1857, every astronomer he consulted suggested that the best place to study astronomy in the United States was under Brünnow (*Michigan Alumnus*, 1903). Abbe followed this recommendation, and in 1859 he was successful in obtaining an appointment at the University of Michigan as Instructor in Physics and Civil Engineering under Professor Wood. While teaching, Abbe seized the opportunity to study astronomy under Brünnow.

Abbe was disappointed when Brünnow left Michigan in 1859 to assume leadership of Dudley Observatory, but was likely even more disappointed when he returned to Michigan in 1860. This prompted a reshuffle of the staff that left no slot for Abbe, and the Regents were forced to terminate his appointment at the end of the academic year. Abbe then accepted a position with the United States Coast and Geodetic Survey, and from 1860 to 1864 worked in Boston under Brünnow's professional adversary, Benjamin Gould (Whitesell, 1998:149-151). He then spent two years at Pulkova Observatory in Russia under Otto Struve, which established him as the only nineteenth-century American known to have studied science in Russia (see Bruce, 1987:290). Abbe returned to the US and spent the next year as an aide at the U.S. Naval Observatory.

After many years of training and practical experience, in 1868 Abbe settled into an established role as Director of Cincinnati Observatory. During his time in Michigan and Boston he had developed an interest in atmospheric refraction, and at Pulkova Observatory he had concluded that atmospheric conditions significantly influenced observations with the meridian circle to such an extent that atmospheric data must be factored into the calculations. Not enough was known about meteorological science at that time, and Abbe resolved to pursue it further. In his first report on the state of Cincinnati Observatory, he proposed a collaboration with the Cincinnati Chamber of Commerce and Western Union Telegraph Company in order to create a telegraphic system for the distribution across Ohio of daily weather maps and forecasts prepared at the Observatory. His vision was that this service would eventually extend across the country and widely serve both commercial and agricultural interests. In 1869 September he released the first official public weather forecast in the form of the Cincinnati Weather Bulletin, and this profound innovation became the model for the national weather service that is maintained to this day. Abbe's daily weather bulletins earned him the nickname 'Old Probabilities'.

The year 1869 certainly proved to be a busy one for Abbe. In addition to the aforementioned meteorological developments, he designed a new building for the Cincinnati Observatory and selected a new site for it. The new Cincinnati Observatory was constructed in 1873 at Mt. Lookout, to the northeast of the city. (see Cincinnati Historical Society, 1944). This building, and another constructed in 1904, have survived through to the present day, and now serve as the Cincinnati Observatory Center. The 1873 building shares several elements in common with Detroit Observatory, no doubt because of Abbe's familiarity with the Ann Arbor structure. The distinctive rotunda surrounding the central telescope pier replicates Detroit Observatory's unusual archways, while the brick walls are covered with grey stucco scored to look like blocks of stone and striped in black to simulate the mortar joints, a treatment identical to that used at Detroit Observatory. The author has not found such features in any other American observatories of the same period.

Abbe's meteorological innovations spurred others with an interest in meteorology to co-ordinate their efforts towards creating a national weather service. In 1870, Abbe's idea was put into effect, and in 1871, he was appointed as a civilian Assistant in the office of General Meyer, the Chief Signal Officer. Abbe took the lead in co-ordinating an international consortium for weather observations, which led to the establishment in 1873 of the Daily Bulletin of Simultaneous International Meteorological Observations.

In addition to weather forecasting, Abbe was interested in co-ordinating standard time across the country to ensure that weather data were consistently collected. He published his *Report on Standard Time* in 1879, which led to the creation in 1884 of four standard time zones for use by the railroads. Abbe was similarly innovative and persistent in advancing meteorological science through the study of oceans and rivers, standardization of thermometry and barometry, use of kites and balloons for data gathering, and studies of atmospheric electricity and earthquakes. In 1871 he instituted a system of visible signals to disseminate weather information: coloured flags were hoisted atop buildings and displayed on passing trains, while bells, whistles and other devices all communicated cautionary weather forecasts.

Abbe published nearly 300 research papers during his career, on topics related to meteorology, astronomy, geography, geology, physiography, and chemistry. One publication of particular note was titled "On the improvements of the elements of a comet's orbit: Brünnow's Method based on one of Brünnow's lectures."

When the National Geographic Society was founded in 1888, Abbe was among the thirty-three founding members. He received many honours and awards during his career, including the Symons Gold Medal from the Royal Meteorological Society in 1912 and the Hartley Gold Medal from the National Academy of Sciences in 1916. He received honorary LL D degrees from the University of Michigan (in 1888) and the University of Glasgow (1896), and Mount Abbe in the Fairweather Range, Alaska, is named in his honour.

In 1895 Abbe retired to a position as Lecturer at Johns Hopkins University, and remained there until his death at Chevy Chase, Maryland, on 1916 October 28 at the age of seventy-eight. One of his three sons, Cleveland Abbe Jr., became a noted meteorologist and scientific editor.

6.4 Orlando Belina Wheeler, Class of 1862 [1835–1896]

Orlando Wheeler (Figure 8) was born to Belina and Malinda Wheeler on 1835 November 29 in Lodi Township, Michigan, not far from Ann Arbor. He is next mentioned, in 1856, as a teacher at Brighton District School (*History of Livingston County Michigan*, 1880:212).

Wheeler soon enrolled at the University of Michigan, and graduated with the Class of 1862, receiving both AB and BS degrees. He studied astronomy under Brünnow, along with fellow classmate James Watson, and was an assistant to Brünnow in his final year of studies and also following graduation (*Michigan Alumnus*, 1896). In 1879 the University awarded him an honorary degree in civil engineering.

Figure 8. Orlando Wheeler, 1835–1896 (Courtesy: Bentley Historical Library, University of Michigan).

Wheeler devoted the first twenty years of his career to service with the United States Lake Survey, from 1862 August until the survey was completed in the summer of 1882. During this period, he seized many opportunities to undertake collaborations with his fellow-students and colleagues from the University of Michigan. For example, his name regularly appears in the literature relating to the determination of the longitude of observatories. For the 1864 longitude determination of Fort Edward, located at the head of Green Bay in Wisconsin, Wheeler served as the Lake Survey observer in Chicago, James Watson made intermediate observations at Ann Arbor, Colonel William Raynolds and Stillman Robinson (Wheeler's classmate at Michigan – see Section 6.5, below) were at the Lake Survey's observatory in Detroit, and Charles Young was at Fort Howard (Comstock, 1882:627). In 1880 October, Wheeler worked with William Payne (see Section 8.2, below), who attended the University of Michigan in 1863–1864, on the determination of the longitude of the Carleton College Observatory (Payne, 1881). Wheeler used a Pistor & Martins transit instrument in 1869 to determine the latitude of Toledo, Ohio (Comstock, 1882:635).

In 1865, while serving under Colonel Raynolds, Wheeler and Robinson developed a novel solution to the problem of communicating between triangulation stations. The distance between stations ranged from 81 to 145 kilometres (50 to 90 miles), and it was difficult to communicate with field parties over this distance. Wheeler and Robinson developed the heliograph, which sent Morse code messages using a heliotrope, or small reflecting mirror, by interrupting the reflection to correspond with the dots and dashes of the code (Comstock, 1882:318).

When an office position became available in 1871 in the Lake Survey's Meteorological Department, Wheeler assumed these duties, and was also placed in charge of water level computations. In 1874, perhaps to escape prolonged deskwork and in order to indulge his astronomical interests, he took leave of absence from the Lake Survey to serve under Asaph Hall Sr. as Assistant Astronomer on an expedition to Vladivostok to observe the transit of Venus. Four years later, in 1878, he took a second leave to observe the total eclipse of the Sun with a group stationed at Central City, Colorado, and was then deployed by the Lake Survey to assist with determination of the Mexico-Guatemala boundary. In 1882, he served under Lieutenant Samuel Very of the United States Navy on a transit of Venus expedition to Santa Cruz, Patagonia. He relocated to St. Louis, Missouri, in 1884 to serve as Assistant Engineer with the Missouri River Commission, and died in St. Louis, Missouri on 1896 June 3.

In 1928, Wheeler's wife and children established the Orlando B Wheeler Fellowship and Publication Fund in Astronomy at the University of Michigan.

6.5 Stillman Williams Robinson, Class of 1863 [1838–1910]

Stillman Robinson was born at South Reading, Vermont, on 1838 March 6 to Ebenezer and Adeline Robinson. His early education was in the South Reading schools. To help meet his living expenses and save for college, he served an apprenticeship as a machinist from 1849 until 1853. He received a degree in civil engineering from the University of Michigan in 1863, and like others in his field of study went to work for the U.S. Lake Survey. In 1864 he collaborated with Watson, Wheeler, and Young to determine the longitude of Fort Howard, Wisconsin. That same year, Robinson published an article in the *Journal of the Franklin Institute* on Brünnow's magnetic break circuit.

The University of Michigan recruited Robinson away from the Lake Survey in 1866 to serve as an Instructor in Engineering under Professor Wood, and he remained at Michigan until 1870 when the Illinois Industrial University (now the University of Illinois) lured him as Professor of Mechanical Engineering and Physics. In 1878, Robinson transferred again, this time to a similar role at Ohio State University, where he remained until his retirement in 1895. In 1887 he served as a consulting engineer for the mounting of the Lick Observatory 91.4-cm (36-inch) telescope, at the time the largest refractor in the world. This was to be his last astronomical project. He died suddenly at his home in Columbus, Ohio, on 1910 October 31. He was seventy-two years old.

7 JAMES CRAIG WATSON: ASTRONOMER AND ENTREPRENEUR[4]
Director, Detroit Observatory 1863–1879 [1838–1880]

James Watson (Figure 9) was Brünnow's most promising student at Detroit Observatory, and he eventually became the Observatory's second Director. Watson was born near the village of Fingal, in Ontario, Canada, on 1838 January 28. His father was a farmer and carpenter, and he also taught school, passing along to local children and his own three sons and daughter the knowledge he gained through books.

Figure 9. James Watson, 1838–1880 (Courtesy: Bentley Historical Library, University of Michigan).

In 1850, Watson's father fell on hard times and was forced to abandon his house. The family relocated to Ann Arbor for the educational opportunities it could offer the children. Watson's father found work at a small factory, and James took on various menial jobs, learning quickly by observing. Soon he became a skilled machinist, and displaced a less competent factory engineer. Meanwhile, he seized every spare moment to study Latin, Greek, and other subjects, and he excelled at mathematics. When the factory closed, he was reduced to selling apples and books at the railway station, which he found so humiliating that he soon ran away to Detroit, and was about to sail off on a Great Lakes trade ship when he was recognized and convinced to return home.

At the young age of fifteen Watson entered the University of Michigan, graduating with honours in 1857. He was Brünnow's first (and sometimes only) student in astronomy, and in 1859 was the first student to receive an advanced degree, when he obtained his Masters in astronomy. Both theoretical and practical astronomy interested Watson, but his mechanical talents led him to telescope-making and lens-grinding and polishing, guided by his translation from the German of Prechtl's *Praktische Dioptrik*, and by his correspondence with American telescope maker Henry Fitz.

Watson was regarded as brilliant. He was facile with numbers, and he used this skill to great advantage in the study of astronomy. Under the tutelage and mentoring of Brünnow, he was staged for an outstanding career. When Brünnow was questioned as to why he would teach a class of only one student he replied, "That class consists of Watson." (Obituary…., 1892). Yet, Watson's reputation was repeatedly tarnished by his obsession with the pursuit of financial gain.

Following Watson's graduation in 1858, Brünnow made him Assistant Astronomer, a position he held while completing his graduate studies. Watson went on to make a name for himself by discovering twenty-one minor planets at Detroit Observatory, and another, Juewa, on 1874 October 10, while in Peking (China) to observe the transit of Venus. His discovery during 1868 of six different minor planets was a remarkable achievement, and two years later won him the Lalande Gold Medal of the French Academy.

Watson's success at discovering minor planets was due to his remarkable memory and command of detail. He prepared detailed charts with the positions of stars located near the ecliptic, and these helped him recognize objects not previously identified. After his death, tables on Watson's minor planets were computed and published according to his wishes, and were generously funded in his will. Some minor planets proved so elusive that it took many years for them to be relocated.

During his lifetime, Watson published numerous research papers and reports on astronomy. Most notable was his 1868 textbook, *Theoretical Astronomy*, which contained little original material yet was considered exceptional in its thorough coverage of the subject, drawing as it did from a great many different sources.[5] The text challenged all but the most exceptional astronomy students.

Professor Pierce of Harvard, who was also Superintendent of the U.S. Coast Survey, funded his friend Watson in 1869 to perform research on the lunar tables. The existing tables in the *American Ephemeris and Nautical Almanac* needed improvement for use in practical navigation, and Watson supervised a team of Michigan alumni to perform the complicated computations, an enterprise that continued for five years. While the outcome was satisfactory, the tables were never published and were lost (University of Michigan, 1958a:450).

Practical topics not related to astronomy were also subjects Watson pursued. In 1870, he went into the book and stationary business in Ann Arbor, and three years later purchased Dr A W Chase's lucrative Ann Arbor Printing and Publishing Company (Watson, 1873c) in partnership with local businessmen.

While Brünnow was at Dudley Observatory in 1859–1860, Watson had charge of Detroit Observatory, and when the Regents called Brünnow back to Michigan – at the urging of the Detroit donors – Watson was enraged and made his feelings known through an article published in the newspaper. Watson wanted the post for himself. Instead, the Regents offered Watson the positions of Professor of Physics and Instructor in Mathematics (to assist DeVolson Wood), which Watson initially declined but eventually decided to accept. But, relations with Wood proved difficult, and Watson made several attempts to locate another position. He even volunteered to become a field officer in the U.S. Signal Service – with the stipulation that he be made a Major or Lieutenant Colonel (Watson, 1861). Watson's financial problems worsened to the point where the Regents were on the verge of dismissing him, but action was delayed because of his "...earnest pleas, protestations and promises." (Beakes, 1906:31).

When Brünnow resigned in 1863, in response to Tappan's dismissal from the University, Watson saw an opportunity to realize his ambition to become Director of Detroit Observatory. He proceeded to nominate himself for the post, and sought letters of recommendation from Benjamin Gould, Elias Loomis, William Chauvenet, Joseph Winlock, Benjamin Pierce, J M Gillis, and other prominent scientists. His strategy was successful, and in 1863 August he succeeded his mentor as Director.

Subsequently, Watson was repeatedly criticised because he would not admit visitors or students to the Observatory. For example, the following note appeared in the bi-weekly student paper *The Chronicle* in 1874 May:

> During the present week the juniors have been granted the privilege of making their long-wished for visit to the observatory. A passing glance at pale Luna and girdled Jupiter was allowed each man as his row slided along the seat, and then his only sight of the big telescope during his four year's course of study was over. Thinking we understand the connection of the Observatory with the University, a protest is just against such complete isolation of its advantages from those students who do not intend to spend life in formulating their way through space. (University of Michigan, 1874:199).

To negative opinions expressed about him, Watson was indifferent, holding himself aloof from others and devoting his energies to his work. In a biographical memoir penned after his death, Comstock of Washburn Observatory wrote of Watson:

> He had bitter enemies and they circulated reports, to the discredit of his personal character, which went uncontradicted and gained undeserved credence. It cannot be denied that a measure of truth attended many of these statements, but they were habitually distorted and magnified all out of proportion. (Comstock, 1888:284).

That Watson was vain is indisputable. The notebooks he kept while he was a student at Michigan are repeatedly signed by him every few pages in elegant handwriting. Sometimes the signature appears numerous times, as if he were practicing his autograph. Watson viewed his penmanship as an asset, and this paid off on at least one occasion, when he landed a job as a clerk to help earn money for expenses during college. In one place in his notebook, he signs "James Craig Watson, Astronomer Royal", which is a designation reserved for only the most renowned astronomers of Europe. In a draft description of a telescope he proposed to make, Watson wrote:

> The Hon. James C. Watson, one of the greatest astronomers that this country has ever produced to whom immeasured devotion to science owes some of its greatest blessings. Astronomy under his patronage has reached a summit rarely attained.
>
> The Telescope which the Hon. James C. Watson, LLD, F.R.S., F.A.S., &c &c &c proposes to make is of the Gregorian construction and will bear a magnifying power of 1200 Times! Great indeed!!! 1200! 1200! (Watson, n.d.:62).

Physically, Watson was described as being vigorous and healthy, but he reached 240 pounds toward the end of his life. He was, religiously, a fundamentalist, believing that it was impossible for a mathematician to be an atheist (*American Journal of Science*, 1881:65).

Watson was elected to the National Academy of Sciences in 1867, to the Royal Academy of Sciences in Catalina, Italy, in 1870, and to the American Philosophical Society in 1877. He received numerous honorary degrees, including Ph.D.s from Leipzig (in 1870) and Yale University (1871), and a Doctor of Law from Columbia College (in 1877).

During his lifetime, Watson participated in several important astronomical expeditions. In 1869, he accompanied a number of other prominent astronomers to Iowa to observe a total eclipse of the Sun (Figure 10). Watson's party included his former student George Merriman (see Section 8.1, below), by then Assistant Professor of Mathematics at the University; Donald McIntyre, Treasurer of the University, financier, former Regent, and amateur astronomer; Professor John Van Vleck of Wesleyan University, a civil engineer, son of a former University of Michigan Regent, and amateur astronomer;[6] Van Vleck's assistant, William Johnston; Professor E C Pickering[7] of Massachusetts Institute of Technology; Professor Henry Morton[8] of University of Pennsylvania; and Watson's wife Annette, who capably assisted her husband.

Figure 10. James Watson led a solar eclipse expedition to Burlington, Iowa, in 1869. Left to right: E C Pickering, Donald McIntyre, James Watson, William Johnston (Van Vleck's assistant), John Van Vleck, and George Merriman (Courtesy: Collection of Leonard Walle).

In 1870, Watson travelled to Sicily to observe a total eclipse. Then, in 1878 July, he participated in another solar eclipse expedition to Separation, Wyoming (Figure 11), for which he borrowed a 10.2 cm (4-inch) Clark refracting telescope from the Michigan State Normal School (now Eastern Michigan University). Many famous astronomers and scientists travelled to the western frontier for this eclipse, including Henry Draper of New York and the famous inventor Thomas Edison. Thirty-one year old Edison intended to test his new tasimeter[8] by measuring the temperature of the solar corona during the eclipse (see Baum and Sheehan, 1997:196).

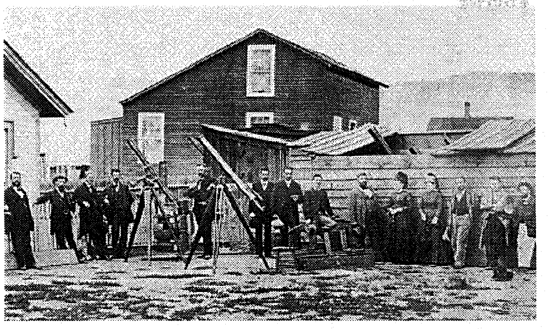

Figure 11. Watson and his wife Annette (fourth and fifth from the right) accompanied other prominent astronomers to Wyoming in 1878 to observe a total eclipse of the Sun. Thomas Edison (second from right) was along to test his new tasimeter (Courtesy: Collection of Leonard Walle).

It was in Wyoming, while searching for objects near the Sun during the eclipse, that Watson became convinced he had discovered two intra-mercurial planets. He hoped that one of these was Vulcan, the existence of which was first postulated by the French astronomer LeVerrier. In 1859 a French physician, Lescarbault, thought he observed this planet as it transited the Sun, and subsequently many astronomers sought to document the existence of Vulcan. Watson was one of these, and he corresponded with LeVerrier in order to obtain the predicted transit times. Conditions during a total solar eclipse presented astronomers with an ideal opportunity to look for Vulcan.

Watson announced his discovery by telegraph from Wyoming, and was inundated with mail by the time he returned to Ann Arbor. Lewis Swift, who was stationed at Denver during the eclipse, also claimed to have seen Vulcan, but the positions reported by the two astronomers conflicted. Most astronomers believed the two had mistaken stars for the elusive planet. Watson's claim was controversial, to say the least, and he was never able to confirm his sighting, even though he devoted significant energy to proving his claim, right up until his death in 1880. The controversy was finally put to rest in 1929, with the conclusion that Vulcan does not exist (see Baum and Sheehan, 1997).

In 1874, Watson and his wife went to Peking (now Beijing) to observe the transit of Venus, and they then continued around the world from east to west. While in Egypt, at the request of the Khedive, Watson surveyed the base line of that country, measured the pyramids, and taught mathematics to an officer of the Royal Guards. For these contributions, he was decorated as a Knight Commander of the Imperial Order of the Medjudieh of Turkey and Egypt, and was loaned a houseboat and crew for a trip up the Nile (Beakes, 1906:10; 13-14).

An opportunity arose in 1878 for Watson to become Director of the University of Wisconsin's new Washburn Observatory. Newspaper accounts suggest that Watson was wooed by both Wisconsin and Michigan "...with an ardor nowadays reserved for football coaches." (Bless, 1978:2). Wisconsin won the contest. At Washburn, Watson undertook new initiatives using his own funds, such as the construction of a students' observatory and a solar observatory of his own design (which he intended to use in a search for the elusive intra-Mercurial planets).

Watson died unexpectedly of peritonitis in Madison on 1880 November 22; he was only forty-two years of age. Letters received by the University from around the country mourned the tragic loss and praised the brilliant astronomer. Many gathered in Ann Arbor for the funeral, and Watson was buried at Forest Hill Cemetery, near Detroit Observatory. Andrew White (President of Cornell University and former History Professor at Michigan) wrote on Watson's death:

> I came to form a very high estimate of his genius and services. The breadth and depth of his knowledge and the hearty way in which he imparted it laid a great charm on me. (Watson, 1881).

Many were surprised to learn the extent of the savings that Watson had amassed from his extensive business activities. Although he had been criticized for devoting too much time to personal gain over scholarly pursuits, in his will he expressed his devotion to science by designating a bequest to perpetuate scientific excellence. He left a considerable sum to the National Academy of Sciences (to which he was elected a member in 1868) for orbital calculations associated with minor planets he had discovered, and he established a medal to recognize significant discoveries or other contributions to astronomical science. The Watson Medal is still awarded today. Inexplicably, Watson's will provided relatively little for his widow, elderly mother, and brothers.

8 WATSON'S FIRST STUDENTS

Watson's teaching methods were both praised and criticized, but he was popular with his students, though not necessarily for laudable reasons. Watson's full attention was paid only to those students who were eager to learn about astronomy, yet his charming discourse in lectures, his full voice, and his reputation for being an easy grader attracted flocks of students.

8.1 George Benjamin Merriman, 1864 (by examination) [1834–1918]

George Merriman (see Figure 10) held many important positions in astronomy, for which he was trained under James Watson at Michigan. He was born at Pontiac, Michigan, on 1834 April 15 to Isaiah and Caroline Merriman. Following preparatory school, he enrolled at Ohio Wesleyan University in 1855, but he returned home the following year when his father became ill and eventually died. He studied law, passed the Michigan bar exam in 1860, and was admitted to practice, and then resumed his studies at Ohio Wesleyan in 1861, graduating in 1863. He immediately pursued graduate studies at the University of Michigan, where he received a Master's degree upon examination in 1864. From 1864 to 1866, he served as Assistant Astronomer for the U.S. Naval Observatory expedition to Chile. No doubt, Watson recommended him for this post.

Merriman returned once again to Ohio Wesleyan and received a Master's degree in 1866. That same year, he was recruited back to Ann Arbor as Assistant Professor of Mathematics and Assistant to Watson at Detroit Observatory, and he remained at Michigan until 1875. During this time he accompanied Watson on the 1869 solar eclipse expedition to Mt. Pleasant, Iowa (see Figure 10). In 1871, he switched his instructional focus to physics, under the eminent Professor George Williams. When Williams retired in 1875, mathematics and physics were combined into one Department, and Merriman departed for a Professorship in Mathematics at nearby Albion College, where he taught for two years.

From Albion College, he moved in 1877 to Rutgers College in New Jersey, where he was Professor of Mathematics and Astronomy. He moved again in 1891 to Middlebury College in Vermont, to a comparable position, and relocated yet again in 1894, this time to Lawrence University in Wisconsin. His final move took place in 1899, when he became an Assistant at the Nautical Almanac Office in Washington. He died in Washington, DC, on 1918 April 3.

8.2 William Wallace Payne, non-graduate 1863–1864 [1837–1928]

William Payne graduated in 1863 from Albion College, located 81 kilometres (50 miles) west of Ann Arbor. After graduation, he travelled to Ann Arbor to study law, eventually receiving his law degree in 1866 from the Chicago Law School. Payne was not the first astronomer to pursue the study of law as a fallback career. Among the astronomers trained at Michigan, Merriman as well as Kintner and Comstock (see Sections 9.1 and 9.9, below) all studied law. But, Payne had a keen interest in astronomy, sparked when he was a boy by reading Smith's *Astronomy*. While studying law at Michigan, Payne spent time at Detroit Observatory with James Watson, where he learned about the astronomical instruments and the details of Watson's intensive minor planet programme (Fath, 1928:268).

Payne was born at Somerset, Michigan, on 1837 May 19 to Jesse and Rebecca Payne. As a boy, he worked on the family farm and attended country schools, where he developed a great interest in and facility with mathematics. He started teaching at age seventeen, but returned during the summers to work on his father's farm. His struggle to support himself through school no doubt raised his anxieties about his future ability to make a living through the science he loved.

In 1868 he moved to Mantorville, Minnesota, to practice law with a college friend, but he soon returned to teaching, which he preferred, working his way up to Superintendent of Schools for Dodge County, Minnesota. In 1871 he moved to Carleton College, in Minnesota, to accept a Chair of Mathematics and Natural Philosophy. Payne was determined to have an observatory at Carleton, and to prepare for this undertaking he spent a summer at Cincinnati Observatory with Ormond Stone in order to gain skill in the operation of astronomical instruments and to learn about the design of observatories. The design Payne submitted for Carleton's observatory was approved, and construction was completed in 1878.

Payne began a time-service even before the Observatory was completed, and time balls around the region were eventually controlled by a signal from the Carleton College Observatory. In 1880, Lieutenant Wheeler of the U.S. Lake Survey assisted Payne in determining the longitude of the Observatory, which was an essential prerequisite for an accurate time service. Over the years, the time service expanded, and it became indispensable to the district and to the regions west of Minnesota, including Iowa, Nebraska, the Dakotas and Montana – altogether encompassing 8,937 kilometres (5,541 miles) of railroad line (Payne, 1881).

In 1882, Payne started publication of the *Sidereal Messenger*, which later evolved into *Astronomy and Astrophysics*, and subsequently, under different editorship, into the *Astrophysical Journal*. In 1893, he created *Popular Astronomy*, which he described as being "plainly worded and untechnical in language." This astronomy magazine continues publication today.

The fact that Payne carried off the construction of two fully-equipped observatories, a time-service, academic instruction, and the creation and editing of important astronomical publications is an incredible achievement for an individual acting largely alone. He worked tirelessly, with great dedication, encouraged throughout by Carleton's President J W Strong. When Payne retired in 1908, he ceased teaching but immediately launched into the creation of a time service for the Elgin Watch Company in Illinois, for whom he designed yet another observatory. He died at Elgin on 1928 January 29, at age ninety-one.

9 WATSON TRAINS STUDENTS TO MEET THE SCIENTIFIC NEEDS OF THE 1870s

The United States faced enormous geographical change following the Civil War in the extent, shape, and prospects of its territorial holdings. It acquired Alaska in 1867, and in 1869 the 'golden spike' completed the transcontinental railroad, thereby facilitating access by exploration parties to previously impenetrable regions of the US and its new territories. International commerce was revolutionized when the Suez Canal opened, providing direct passage between the Mediterranean and Red Seas.

In response to national growth and related changes, higher education entered a period of significant redefinition to "...meet the now imperative needs of an expanding industrial nation and of a developing national power." (Rudolph, 1962:242). New scientific schools, such as the Massachusetts Institute of Technology and a school of engineering at Princeton, were created to accommodate programmes in applied and pure science, to expand upon the scientific training previously provided nearly exclusively by the U.S. Military Academy and the Rensselaer Polytechnic Institute. Between 1870 and 1873, more than fifty new scientific schools were started (Elliott, 1996:108).

In this new environment, enrolments in scientific and technical fields at the University of Michigan steadily grew. Unfortunately, despite an enthusiastic President, the University was unsuccessful in creating a new scientific school until funding eventually materialized in 1895. The outfall was the loss of key Faculty member DeVolson Wood to the new Stevens Institute of Technology, and Wood's protégé, Stillman Robinson, to the Illinois Industrial University. Nonetheless, Michigan produced many outstanding scientists, engineers and surveyors during the 1870s.

Astronomy was an essential element of surveying and navigation, which made James Watson an integral part of the team that trained students in engineering, mathematics, and physics (e.g. see Figure 12). Following graduation, students were in demand to serve with the national surveys, which acted as graduate and field schools for a whole generation of aspiring astronomers, surveyors, and naturalists. Some students undertook fieldwork during summer vacations to help pay college expenses. Others assisted Watson on projects funded by the U.S. Coast Survey and the Nautical Almanac Office.

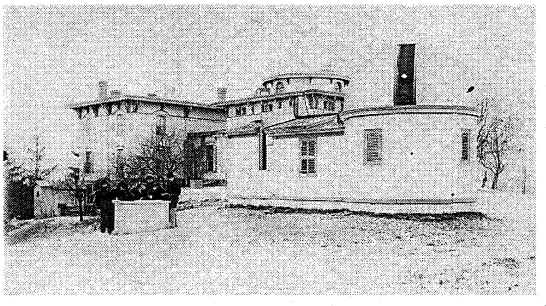

Figure 12. Michigan students gathered behind the Students' Observatory with sextants in hand and textbooks open, ready for instruction in use of the instrument. Detroit Observatory is in the background (Courtesy: Collection of Leonard Walle).

Many astronomers and surveyors trained by Watson at Michigan during the 1870s went on to lead distinguished careers.

9.1 Charles Jacob Kintner, Class of 1870 [1848–1921]

Charles Kintner (Figure 13) was born in the town of Boone, Harrison County (Indiana), on 1848 April 19 to Jacob and Elizabeth Kintner. His youth was spent in rural farm life, on a 243 hectare (six-hundred acre), unique – to Indiana – antebellum plantation-style complex of buildings his father built, called Cedar Farm. The family placed a high value on education, and at an early age Charles Kintner resolved to pursue that path.

The natural world particularly captured Kintner's attention. He saw in nature its beauty and its mysteries, and it helped him recognize the value of an education:

> ...I discovered at an early age that the glorious tints of the morning sun as seen upon the 'cloudlets' have no beauty to the boy who is forced to follow the drudgery of farm life. ...I learned in early life to look with envious eyes upon the short hours of labor which fall to the lot of city people and resolved to obtain an education and follow professional life. (University of Michigan, 1870a).

At age seventeen, following a preparatory course at New Albany, Indiana, Kintner headed north to the University of Michigan to join the Class of 1870. He pursued a course in chemical and civil engineering. In the archives of Michigan's Bentley Historical Library is a bound collection of "Specimen Drawings" sketched by Kintner and his classmates (University of Michigan, 1870b). Kintner's sketch is of the North and South College buildings on the Michigan campus, and it is perhaps the finest, most detailed sketch of the group, with the most exacting use of perspective. Following graduation, he was appointed by Watson as Assistant at the Observatory, a position he held until 1877. During that time, he was active in local affairs, serving as the City Recorder in 1876, and running unsuccessfully in a close race for County Superintendent of Schools. Watson had served as City Recorder as a younger man, so he doubtless guided his student into these activities.

In 1876, when Watson came under attack in the *Ann Arbor Currier*, Kintner wrote a letter to the Editor of the rival *Ann Arbor Register* in defence of his mentor. The "scurrilous" attack written under an assumed name complained that visitors were not permitted entry to the Observatory, and that the Professor spent all of his time pursuing "...miserable little asteroids." Kintner (1876) defended Watson as a dedicated man of science who worked tirelessly, contributed greatly to scientific knowledge, and served as a dedicated teacher.

Kintner's opportunity for scientific adventure came in 1877 when he was appointed Assistant Astronomer in the United States Corps of Engineers under Lieutenant George Wheeler. There is little doubt that Watson recommended Kintner for this position. The Wheeler Survey of the Western States was first organized in 1869 to map the geological features of the West for military purposes. The project was expanded in 1872 with a Congressional appropriation of $75,000, and the project was dubbed the 'Geographical Survey West of the One Hundredth Meridian', shortened by most to the 'Wheeler Survey'. By 1879, another $800,000 was invested. Kintner's two years with the Survey saw him to the end of the monumental project. His appointment as Assistant Astronomer began at the base camp in Ogden, Utah, in 1877 May and ended at Washington, DC, where he reduced the observations he made throughout the Rocky Mountains.

Figure 13. Charles Kintner, 1848–1921 (Courtesy: Bentley Historical Library, University of Michigan).

Following the tradition started at the University of Michigan by faculty explorer Joseph Steere, Kintner wrote a series of fascinating letters from the

West for publication in the *Ann Arbor Register*. It is no coincidence that Watson was one of the proprietors of the *Register*. The ten letters Kintner wrote were published in their entirety in a 1966 issue of the *Utah Historical Quarterly* (see Bidlack and Cooley, 1966), and were packed with adventure and the rich details of everyday life in the West that were craved by readers back in the Midwest. Kintner brought the rugged Western terrain to life with his vivid descriptions of such things as daily life in a surveyors' camp; the soil, crop yields and prices, irrigation methods; weather and climactic events; the Mormon enclave at Salt Lake City; both the awe and fear native Americans stirred up in him; geological features and historical landmarks; and wildlife spotted along the trail. He had a special talent for descriptive prose: his account of ripe strawberries found along the trail was mouth-watering. About Salt Lake City he wrote:

> The scenery is truly beautiful and the great lake lies shimmering and glistening in the sunlight like a great sea of mercury, while the deep blue background made up of the mountains over a hundred miles [161 kilometres] away adds very much to the effect, but best of all is the sight of the hundreds of comfortable homes that look like mere specks in the distance and the comforting thought that here is room for thousands of our fellow beings to earn a livelihood if they will but labor. (Bidlack and Cooley, 1966:69-70).

True to the personal pledge he made to himself as a boy, when the Wheeler Survey disbanded in 1879 Kintner pursued an office job in the city as a patent lawyer. He advanced through the ranks of the Patent Office in Washington, DC, from Assistant Examiner up through the civil service grades to Chief Clerk under the Commissioner of Patents. In 1893 he was promoted to Principal Examiner in Charge of Electrical Patents, and was later made Secretary of the Civil Service Board of the Patent Office. He resigned in 1897 to pursue the practice of patent law and electrical engineering, first in Philadelphia and then in New York. Kintner also produced and patented several electrical inventions.

Upon retirement, he returned to Ann Arbor, where his health deteriorated (Carter, 1921:262). He died at home on 1921 July 7.

9.2 William Francis McKnight Ritter, Class of 1871 [1846–1917]

William Ritter (Figure 14) was born in Milton, Pennsylvania, on 1846 June 23. The details of his early life remain elusive, but in 1870, he enrolled at the University of Michigan. He graduated in 1871, and received his Master's degree in 1874. Ritter was a favourite student of James Watson, and they shared in common a special facility with mathematics. Through Watson, Ritter became interested in computing the orbits of minor planets, work that was painstaking and exacting.

In the archives of Michigan's Bentley Historical Library are the detailed computations that Watson performed – perhaps assisted by Ritter and other students – for the orbits of minor planets that he discovered. Each computation consists of up to a ream of paper, each sheet completely covered with detailed calculations. In Watson's papers, evidence is found that he received much pressure from the scientific community to complete these time-consuming calculations. Watson was disgruntled by the lack of compensation for the laborious process, and the lack of understanding and appreciation by the University and others regarding the significance and importance of the endeavour. Later in life, Ritter devoted much attention to the study of perturbations of minor planets, and his book, *New Method of Determining the General Perturbations of the Minor Planets*, was published in 1896. In the acknowledgements, he credits assistance from his classmate and friend, Monroe Snyder (see Section 9.3, below).

Figure 14. William Ritter, 1846–1917 (Courtesy: Bentley Historical Library, University of Michigan).

Ritter served as Assistant Observer at Detroit Observatory under Watson from 1871 through 1876. In 1874 he was given management responsibility for the Observatory when Watson went to Peking to observe the transit of Venus and continued on a voyage round the world. During Watson's long leave of absence, the Ritters lived in the Director's residence at the Observatory, and the Watsons regularly corresponded with them. The Ritter and Watson families established a family tie when Annette Watson's sister, Della Waite, married Ritter's brother, Dr Thomas Ritter.

In 1876, Ritter left Ann Arbor for the U.S. Naval Observatory, where he remained until 1887. His work at the Nautical Almanac Office was in close association with George Hill. Ritter died at his home in Pottsgrove, Pennsylvania, on 1917 November 6 at the age of seventy-one.

9.3 Monroe Benjamin Snyder, Class of 1872 [1848–1932]

Monroe Snyder (Figure 15) was born on 1848 March 13 at Quakerstown, Pennsylvania. His early education was at the Bucks County Normal and Classical School in Quakerstown. Following two years at Pennsylvania College in Gettysburg, he spent two years teaching school while recovering from ill health. He then returned to college, but after one term transferred to the University of Michigan in order to study theoretical astronomy under James Watson. He graduated with the civil engineering Class of 1872, and formed a close friendship with William Ritter that persisted throughout their careers.

In 1873, when Watson was asked by the Central High School in Philadelphia to recommend an astronomer to direct their Observatory, he suggested Snyder, who was happy to accept the post (University of Michigan, 1872b). Snyder served as Instructor of Astronomy and Assistant Professor of the Higher Mathematics, and simultaneously as Professor of Physics at the Artisan's Night School of the Philadelphia Central High School. The Observatory was in a moribund state, but Snyder invigorated it, and with its instruments he was able to make important contributions to astronomical science. He received a Master's degree from the University of Michigan in 1875.

Figure 15. Monroe Snyder, 1848–1932 (Courtesy: Bentley Historical Library, University of Michigan).

Snyder observed the transit of Mercury in 1878, and developed a new method of observing the transit of planets across the Sun (University of Michigan, 1872a). In 1882, the Philadelphia Observatory served as a transit of Venus station, and Snyder's long-time friend William Ritter (by then at the Nautical Almanac Office) joined him for the observations (Seen through a hazy sky, 1882:2). By 1897, Snyder had worked his way up to the Head of the Department of Mathematics and Astronomy and Director of the Philadelphia Observatory. His published research included a study of "Radium in Spiral Nebulae and in Star Clusters".

Snyder's achievements captured the attention of the community, and he was successful in acquiring funding for a new observatory building and instruments. Unfortunately, the new Philadelphia Observatory was nearly totally destroyed by fire in 1905.

Snyder served as Secretary to the United States Electrical Commission in 1884, the year they held an Exhibition in Philadelphia. It was during this year that he first proposed the formation of a National Board to oversee Physical Standards. Although this plan was widely applauded by many leaders in science, it was not until 1901 that Snyder's vision was finally acted on through creation of the National Bureau of Standards (Obituary…., 1933). He was made a Fellow of the Royal Astronomical Society the following year.

Snyder's career was long and distinguished, and he did not forget the great teachers who influenced him. For the fortieth reunion of the Class of 1872, which he was unable to attend in 1912, he wrote:

> Particularly remember me to those of the old class of six who took Watson's course on "Have faith, gentlemen. Have faith." ...each of them has had a much wider horizon since the sunshine of Watson's smile beamed permanent encouragement through the mists of youth. (University of Michigan, 1912:18).

For the fiftieth reunion, in 1922, he continued to express sentiments about his old professors:

> May I, on this notable occasion, pledge you to the remembrance of three great teachers whose imagination and forward look kindled the highest in us-Cocker, Winchell, Watson. To know them was to imbibe the university spirit for a life-time. (University of Michigan, 1872b:9).

Snyder died on 1932 September 28, at age eighty-four.

9.4 Otto Julius Klotz, Class of 1872 [1852–1923]

Otto Klotz (Figure 16) distinguished himself in the history of Canadian science as Director of the Dominion Observatory. His formal scientific training was largely at Detroit Observatory under James Watson.

Klotz was born on 1852 March 31 in Preston, Ontario. Preston was located in what was then known as Upper Canada, a remote area where his father, Otto, served as a prominent notary public and an advocate for free public education. Klotz was educated at the local school, and then won scholarships to the Berlin High School and the celebrated Galt Grammar School. At the University of Toronto he pursued the study of astronomy, mathematics, and science, but he transferred to the University of Michigan in 1870 for more concentrated study in these subjects, graduating in 1872. In Ann Arbor, he met his future bride, Marie Widenmann, daughter of the German consul at Ann Arbor. They married in 1873 December.

After graduation, Klotz followed a course typical of many of Watson's graduates: he entered government service with the U.S. Lake Survey and the Coast and Geodetic Survey. But, he soon returned to his native Canada, passed the examination for Dominion topographical surveyor, and in 1879 was appointed by the Canadian Government as a surveyor in the unexplored regions of Western Canada. His early work also involved several boundary determinations, including the Alaska boundary (see Green, 1982:49-53). Since this work required astronomical techniques, Klotz was granted the title of Astronomer. His expertise led to contributions to the determination of the Greenwich-to-Montreal longitude in 1892. In 1902, following the establishment of an underwater cable that linked Vancouver, British Columbia, with Australia and New Zealand, Klotz was assigned the responsibility of determining the first trans-Pacific longitude. This completed the longitudes encircling the globe, with only one-fifteenth of a second of error in the entire circuit. This impressive undertaking earned Klotz several honorary degrees, including an LL D from the University of Toronto, Sc.D. from the University of Michigan (in 1913), and LL D from the University of Pittsburgh (1916).

Figure 16. Otto Klotz, 1852–1923 (Courtesy: Bentley Historical Library, University of Michigan).

Klotz was methodical in his work, and in his daily life. A daily journal began on 1866 August 16 and kept until a few days before his death is held in the Ottawa Public Archives; it reveals much about his life and career, and contains a fascinating account of the Alaskan boundary dispute.

Canada did not have a fixed observatory at this time, so longitude work and the rating of chronometers was done from a small transit house. Klotz and his colleague, William King, agitated to change this, and when they received support from the Minister of the Interior, this led – in 1905 – to the erection of the Dominion Observatory, in Ottawa, Ontario. King was appointed Director, and Klotz his First Assistant. Klotz then turned his attention to seismological work and the study of terrestrial magnetism, fields in which he made many important contributions, including the publication of his *Seismological Tables* (1916), which became a valuable reference work. He also devised a means of determining the epicentre through stereographic projection.

After King's death, action toward appointing a replacement was delayed, perhaps by wartime prejudice against Klotz's German ancestry (Jarrell, 1988:103-104), but Klotz was ultimately appointed Director and Chief Astronomer of the Dominion Observatory, a position he held for the remainder of his career. While in Europe in 1922, his health failed, and following a year of health challenges, he died on 1923 December 28.

9.5 Robert Simpson Woodward, Class of 1872 [1849–1924]

Robert Woodward (Figure 17) produced some of the most important research on geophysics ever published in America. He excelled at mathematical physics, but he applied this expertise broadly to encompass the Earth's mass, shape, size, rotation, tides, atmosphere, internal temperature, earthquakes and volcanoes, and density.

Woodward was born on a farm in Rochester, Michigan on 1849 July 21 to Lysander and Peninah Woodward. His father, who at one time was an unsuccessful candidate for Governor of the State of Michigan, took a scientific approach to farming, and passed on these interests to his son.

As a boy, Woodward attended Rochester Academy, and then worked as a clerk in a general store in Rochester in 1866. Determined to pursue a collegiate course, he studied independently for two years to prepare for enrolment at the University of Michigan, where he concentrated on mathematics, astronomy, and engineering. He and Klotz were in the same class, and they received their civil engineering degrees in 1872.

Woodward spent his summers doing fieldwork with the U.S. Lake Survey. Following graduation, he pursued this work full time as Assistant Engineer, and remained in this role for the next ten years until the survey of the Great Lakes was nearly completed. He worked under General Comstock performing primary triangulations for the determination of latitude and longitude.

From 1882 to 1884, Woodward joined Professors Asaph Hall Sr. and William Harkness as Assistant Astronomer with the United States Transit of Venus Commission. Eight field parties were deployed to observe the 1882 transit, four in the United States and four in foreign countries (Wright, 1926:117; see Dick *et al.*, 1998). Hall's team was stationed at San Antonio, Texas. Following the transit, Woodward was engaged in the laborious work of measuring photographic plates to determine a more precise value of parallax. In 1884, he relocated to the U.S. Geological Survey as Assistant Astronomer. In short order, he was appointed Geographer, and then Chief Geographer in charge of the Division of Mathematics. This was an invigorating environment for him, and during his six years at the Geological Survey he produced the most important scientific papers of his career. The topics included the conditioned cooling of a homogeneous sphere, and the possible laws of arrangement of density in the Earth's mass.

Figure 17. Robert Woodward, 1849–1924 (Courtesy: Bentley Historical Library, University of Michigan).

To the regret of his colleagues at the Geological Survey, Woodward departed in 1890 to join the U.S. Coast and Geodetic Survey. The lure was an opportunity to devise a means of testing the efficiency of various forms of apparatus used by the Survey for precise triangulation. In particular, he turned his attention to the calibration of steel tapes, and devised a method that was adopted and remained the standard method for decades to follow (Memorial of Robert Simpson Woodward, 1926). He also prepared geographical tables for the Smithsonian Institution.

In 1893 Woodward joined Columbia University as Professor of Mechanics and Mathematical Physics. Two years later he became Dean of the College of Pure Science. His congenial personality and facility with administrative matters made him well suited to academia. His success prepared him for his next distinguished position, as President of the Carnegie Institution in Washington, DC, in 1905, a position he held for the next sixteen years.

Woodward received numerous honorary degrees, including two from the University of Michigan (Ph.D. 1892, LLD 1912). He was also a member, and in many cases an officer, in the top American scientific and academic organizations. In addition, he served for forty years, from 1884 to 1924, as Associate Editor of the journal *Science*.

Woodward's career was distinguished, yet he expressed regret at not following his true passions. In 1917, he wrote to the captain of his graduating class at Michigan:

> Curiously enough, although I have sought since 1872 to practice engineering, the world has not permitted me to do so. On the contrary, it has taught me the severe but perhaps wholesome lesson that unless one is very inefficient or very selfish he may not do what he would wish but he must do what society demands of him. Hence I have been working chiefly during these years for other people, while the astronomy, physics, and engineering to which I am most attached have had to be pursued rather as avocations than as vocations. (Woodward, 1917).

Woodward died in Washington on 1924 June 29 at the age of seventy-five.

9.6 Horatio Nelson Chute, Class of 1872 [1847–1928]

James Watson's students pursued various scientific careers, but at least one student, Horatio Chute, distinguished himself as a teacher of physics.

Horatio Nelson Chute (Figure 18) was born on 1847 December 26 at Malahide, Ontario (Canada) to Walter and Catherine Chute. His early education was at the local district school, and he then enrolled at Woodstock College in Ontario. He taught briefly at a country school, then served as Principal of the Aylmer schools from 1866 to 1869, and was Assistant Professor of Latin at Woodstock from 1869 to 1870 before transferring to the University of Michigan in 1870 on the recommendation of a Michigan graduate with whom he taught at Woodstock. Chute received his bachelor's degree in 1872, and continued on for his Masters, which he received in 1875. His senior thesis was a detailed study titled simply "Coal." During his graduate studies, he served as Assistant in Astronomy at Detroit Observatory from 1872 to 1873 under James Watson.

To support his family, Chute found employment at Ann Arbor High School in 1873. He was appointed first as Instructor in Science and Mathematics and later in Physical Sciences. This marked the beginning of what was to be a long and distinguished teaching career that spanned forty-nine years, until his retirement in 1922. His lengthy service, enthusiasm for teaching, devotion to his students and distinctive long beard (which he sported even during his early college years), all made him a legend in Ann Arbor.

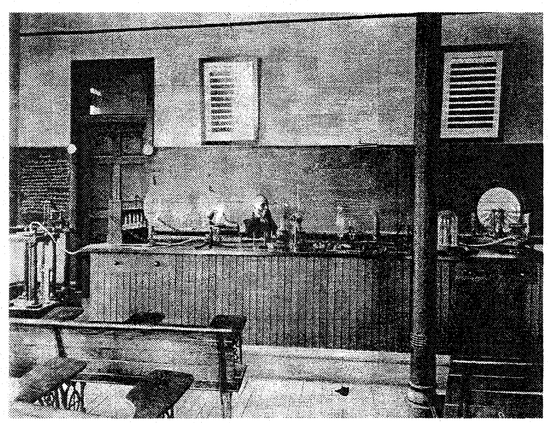

Figure 18. Horatio Chute, 1847–1928, in his laboratory classroom at Ann Arbor High School (Courtesy: Bentley Historical Library, University of Michigan).

When Chute began teaching at Ann Arbor High School he initiated a new emphasis on instruction in physics. Harvard College began accepting a unit in physics in 1873 as an entrance requirement, and other colleges quickly followed this example. Soon, a unit in high school physics was a widespread graduation requirement, and Chute's classroom was crowded with students.

In his first year at Ann Arbor High School, Chute's laboratory equipment consisted of "...one glass tube and a few pieces of worn out mechanism..." (Chute n.d.), but the ill-equipped laboratory placed under his charge was soon outfitted with the best available equipment, including ripple tanks, Wheatstone bridges, a spectroscope, a pendulum clock, and even a 10.2-cm (4-inch) refracting telescope and an observatory to house it (Buell, 1962).

Chute demanded the attention of his students, and was a stickler for precision, clarity, and neatness. Yet, he was a favourite with students. One of his associates wrote: "How can one re-create on paper the complex of brilliance, force, thoroughness, wit, logic, industry, clowning, sharpness, and kindness that was 'Chute,' all embodied in a little man, during much of his adult life hidden behind a cascade of black whiskers?" (Duff, 1958). Another wrote: "...he devoted himself so wholeheartedly to his task that he awakened a feeling of respect and emulation in his students which may frequently have been of far more value in their education than any facts of physics which they may have acquired." (Chute, n.d.).

Chute distinguished himself far beyond the city limits of Ann Arbor through the publication of several physics textbooks that became classics in the field: *Chute's Practical Physics* (1889); *Elements of Physics* (1892) – which was co-authored with University of Michigan Physics Professor, Henry Carhart – and *A Laboratory Guide to Accompany Carhart and Chute's First Principals of Physics* (1913).

His career at Ann Arbor High School was punctuated by a great calamity that took place on the morning of 1904 January 31, when a student walking across the school campus in the early morning hours noticed that the fire in a stove was out of control. It spread quickly, and the building was soon engulfed in flames:

> From the windows on the northwest corner there shot a tongue of flame which swept 15 feet over the sidewalk and to a level with the curbing, and then curved about and covered the north end of the school as if it were an immense fan... (Duff, 1956:2).

The alarms sounded, and fire-fighters arrived at the scene. Teachers from the school arrived soon after, and by a plan organized and led by Chute, more than one hundred teachers and students carried books and laboratory apparatus from the building. In all, about 8,000 books and the majority of the apparatus were saved. When a new school was constructed, Chutes' seniority and stature as a teacher in an important discipline influenced the establishment of a physics laboratory that was rivalled by few others in the country.

Along with the famous educator John Dewey, and others, Chute was responsible for the establishment in 1886 of the Michigan Schoolmaster's Club, and served as its inaugural President. He was also a member of the American Association for the Advancement of Science. When Chute decided to retire in 1922, the Principal was unable to convince him to stay for a fiftieth year. His resignation was accepted, and the Board of Education recognized him with an honorary high school diploma, because he had never actually graduated. Chute was spending winter with relatives in Clearwater, Florida, when he died on 1928 March 11 at the age of 80. He was posthumously honoured through creation of the Horatio N Chute Medal, which is still awarded annually to a high school student demonstrating outstanding citizenship.

9.7 John Henry Darling, Class of 1873 [1847–1943]

John Darling graduated from the University of Michigan in 1873 with a degree in civil engineering, and received an honorary Doctoral degree in 1915 in recognition of his distinguished career as an engineer.

He was born on 1847 April 15 in Lake Ridge, Michigan, to Henry and Matilda Darling. His father served as a member of the Michigan Legislature, and in 1851 was responsible for championing a law that elevated the prominence of scientific subjects in the classical curriculum. Following graduation from the University of Michigan in 1873, Darling was employed by the U.S. Lake Survey as Assistant Engineer from 1873 to 1882. During the field season, he performed primary triangulations along Lakes Ontario and Erie, and from Lake Michigan into the State of Illinois. During the winter he performed mathematical computations at the Detroit office. He also participated in the survey of the Mississippi River. In 1878, when the Lake Survey was short of funds, Darling took six-month leave to travel in Europe.

When the Lake Survey was completed in 1882, Darling took a position as a draughtsman in Major Allen's office at St. Paul, Minnesota, working on river and harbour improvement projects. Then, in 1884, he moved to Duluth, where he continued his residence the remaining fifty-eight years of his life. In Duluth, he was employed as an Engineer for the United States Government, specializing in the design and construction of water-related engineering projects. He became so well known, and so universally popular in Duluth that he was installed as a member of the Duluth Hall of Fame in 1930. He was described as "...a quiet, kindly, cultured gentleman..." (Gingrich, 1942:533).

Although Darling was an engineer, his occupation is listed in the University of Michigan's Alumni Catalogue as 'astronomer'. Astronomy was a great interest of his, and when he retired from his engineering career in 1913, he devoted himself entirely to astronomy. His was not a casual interest: in 1917, he constructed a well-equipped private observatory at considerable personal expense. He announced to the citizens of Duluth, and wrote in an inscription carved over the front door of the Darling Observatory, his desire that the facility promote "...a popular knowledge of the noble science of astronomy." (Gingrich, 1942:534). His observatory was equipped with a 22.9-cm (9-inch) refracting telescope, which was regularly made accessible to individuals and groups for observing. When Darling became too elderly and infirm to independently operate his observatory, he hired an assistant to carry on his activities for the cultural and educational benefit of the citizens of Duluth.

In his ninety-fifth year, the editors of *Popular Astronomy* paid Darling a compliment by publishing a brief article he authored titled "Meteor's and the Moon's Surface" (Darling, 1942). He died at age ninety-six, seven months after writing this article. In his will, the Darling Observatory was bequeathed to the State Teachers College of Duluth, with the caveat that they continue to provide access to the public. The building was utilized according to his wishes through into the 1960s, and was subsequently demolished.

9.8 Charles Leander Doolittle, Class of 1873 [1843–1919]

Charles Doolittle (Figure 19) was born on 1843 November 12 in Ontario, Indiana, to Charles and Cecilia Doolittle. He enlisted for service in the Civil War, and was fortunate to work in an area of personal interest: making astronomical observations for the U.S. Northern Boundary Commission. After returning to his hometown in 1866, he enrolled at the University of Michigan, and graduated in civil engineering with the Class of 1873. His training at Detroit Observatory was received under James Watson.

Figure 19. Charles Doolittle, 1843–1919 (Courtesy: Bentley Historical Library, University of Michigan).

From 1873 to 1875, Doolittle was employed with the Northern Boundary Survey, handling field assignments as well as office work, first at Detroit and later at Washington, DC. When his wife died in 1875, Doolittle relocated to Lehigh University at South Bethlehem, Pennsylvania, where he served as Professor of Mathematics and Astronomy. He remained in this position until 1895, when he transferred to a comparable position at the University of Pennsylvania. An unexpected bequest to the University provided for construction of a new observatory, which was named the Flower Observatory after the donor. Doolittle held the position of Director of Flower Observatory until his retirement in 1912, and was succeeded by his second son, Eric Doolittle. His first son Charles also followed his father's interests, making a career with the Nautical Almanac Office at Washington, DC, while another son, Alfred, became a Professor of Mathematics.

During his career, Doolittle distinguished himself in precision astronomy through his observations to determine variations in latitude. At Lehigh University's Sayre Observatory, he used a portable zenith telescope he obtained as surplus from the U.S. Coast and Geodetic Survey. The meridian circle instrument available to him at Flower Observatory offered far greater precision, yet the accuracy of the observations Doolittle initially made with the zenith telescope demonstrated his skill as a precision astronomer (Tucker, 1919).

One of the more spectacular events in Doolittle's astronomical career was his attempted observation of Halley's Comet in 1910 May – thanks to an invitation from the Philadelphia Aeronautical Recreation Society – from the basket of a balloon that had ascended to 6,500 feet. Unfortunately the clouds, even at that elevation, were so dense that the Comet was totally obscured from view (Will view comet ..., 1910:2; Balloon party missed comet, 1910:20). The press regularly interviewed Doolittle on scientific topics, including the possible presence of life on Mars, and he even speculated on the future state of the Earth's structure. Charles Doolittle died on 1919 March 3.

9.9 George Cary Comstock, Class of 1877 [1855–1934]

George Comstock (Figure 20) was another of the students trained by Watson who went on to distinguish himself as a national leader in astronomy.

Comstock was born in Madison, Wisconsin, on 1855 February 12 to Charles and Mercy Comstock, and spent his youth in Madison and Kenosha, Wisconsin, and Sandusky, Ohio. In 1869 the Comstock family moved to Adrian, Michigan, where George completed his secondary education. He gained admission to the U.S. Naval Academy, but his mother's concern over the dangers of a military career convinced him to enrol instead at the University of Michigan. The family then moved to Ann Arbor so that George could reside at home.

At the University, Comstock became a protégé of James Watson. Following the financial panic of 1873, Watson made arrangements through General Marr of the U.S. Army for Comstock to earn some money for college expenses by working as a Recorder for the United States Corps of Engineers on the surveys of Lakes Ontario, Erie and Superior, and of the Mississippi River. Comstock worked as a Surveyor during the summer and attended the University the other six months of the year. After graduation in 1877 he continued his work on the Mississippi River survey for a year, and then worked with Watson at Detroit Observatory as his private assistant, in association with Assistant Astronomer Martin Schaeberle (see Section 10, below).

In 1878, Comstock accepted appointment as Assistant US Engineer on the improvement of the Mississippi River. That same year, Watson was selected to be the inaugural Director of the Washburn Observatory, and this prompted Comstock's return to his hometown in 1879 as Watson's Assistant. Watson died unexpectedly in late 1880, but Comstock remained at Madison under the new Director, Edward Holden. Comstock spent the remainder of his scientific career at Wisconsin, with short leaves for teaching assignments as Chair of Mathematics and Astronomy at Ohio State University from 1885 to 1887, and for a summer at Lick Observatory in 1886. Although he intended to stay in California following his summer at Lick, instead he accepted the Directorship of Washburn Observatory when Holden became Director of Lick Observatory in 1886.

Comstock studied law at the University of Wisconsin to prepare for a fallback career. He was conservative and cautious, and he realized that astronomy might not always provide a reliable source of income. He received his Juris Doctor degree in 1883 and was admitted to the Wisconsin bar, although he never practised. He viewed his legal studies as perhaps the most valuable training of his education, because it taught him to apply his knack for precision to his speech and his mental processes. Comstock's surveying work with the U.S. Lake Survey gave him the expertise that led to his *Textbook of Field Astronomy for Engineers*, published in 1908.

His distinguished career is evidenced in his numerous publications, including contributions to the *Publications of the Washburn Observatory* and his seminal works on the determination of the aberration constant and atmospheric refraction. He devised various pieces of scientific apparatus, including a slat-screen device to enhance use of the meridian circle telescope, and a double image micrometer. His painstaking work on double stars led him to detect the proper motion of stars as faint as the twelfth magnitude. This prompted Comstock to reach the conclusion that the Milky Way was an absorption effect, a theory that appeared astute at the time but was subsequently disproved.

By 1899, Comstock's reputation led to his being offered the prestigious Directorship of the Nautical Almanac Office, a position he declined in favour of remaining at Washburn Observatory. In 1897, he was among the astronomers who founded the American Astronomical Society, an organization with which he held numerous offices, including President (from 1925 to 1928). Comstock was a popular instructor, teaching with dedication and inspiring his students to follow his example of hard work, high standards, and determination. He was elected to the National Academy of Sciences in 1899, and received honorary Doctoral degrees from the University of Illinois and the University of Michigan in 1907.

In retirement, the Comstocks lived in Beloit, Wisconsin. George Comstock died at Madison on 1934 May 11.

Figure 20. George Comstock, 1855–1934 (Courtesy: Mary Lea Shane Archives of the Lick Observatory).

10 J MARTIN SCHAEBERLE
Class of 1876
[1853–1924]

Martin Schaeberle (Figure 21), a German-born astronomer trained in the USA, discovered three comets, was one of the inaugural astronomers at Lick Observatory, and invented the Schaeberle solar camera to develop his theory of the solar corona.

Schaeberle was born Johann Martin Schäberle on 1853 January 10 in Oeschelbronn, Würtemberg, Germany, and immigrated to the United States as an infant in 1854 with his parents, Anton and Christina Schäberle. In America, his name changed to John Martin Schaeberle, and family and friends called him Martin. A master saddle maker by trade, Anton Schaeberle, settled in Ann Arbor, joining many other emigrants from Würtemberg who had arrived earlier (Emigration document, 1854).

Following his early education in Ann Arbor, Martin Schaeberle travelled at age fifteen to Chicago to serve an apprenticeship in a machine shop. It was in Chicago that he gained an interest in astronomy. His mechanical skills enabled him to make mirrors for reflecting telescopes, and he spent clear evenings on the roof of the hotel he called home making observations. The great Chicago fire of 1871 October caused the termination of his 3-year apprenticeship, and he returned to Ann Arbor, completed his high school course in four months, and then enrolled at the University of Michigan to study engineering and mathematics. He used telescopes of his own construction to make observations at the private observatory he built in 1872 in an alley behind a commercial building in downtown Ann Arbor. Watson's curiosity about Schaeberle's observatory prompted him to drop by one evening to see it. Schaeberle wrote to his brother:

> My own observatory is in constant use, observations being made by myself every clear night. The observations are mostly on the minor planets of which the Prof. [Watson] discovers occasionally. Two weeks ago last Saturday he [Prof. Watson] unexpectedly came to me in the evening while I was observing. And I need scarcely tell you that he was surprised to find what an instrument I had. After using the very highest powers possible he declared the diffraction excellent and made the remark that I could make very valuable observations with it. Since that time he has been hard at work putting up rooms and a work shop at the [Detroit] Observatory where he intends to have me stay to make telescopes etc. at odd hours. You would not recognize my observatory now either inside or outside. The dome is painted sky blue both inside and outside. The lower part is painted white, inside it is papered with pasteboard, and also painted white. I have just begun another instrument called the Transit Instrument which is used to determine time accurately; it will be placed in a separate building which I intend to place on the east side and close up to my present observatory and connected with it by a door so that to enter it one must pass through the main part. (Schaeberle, 1877).

Schaeberle soon became Watson's favourite pupil, and following receipt of his degree in civil engineering in 1876, he became Watson's Assistant. Two years later he was promoted to Instructor in Astronomy, and continued to serve on the Astronomy Faculty until 1888.

Figure 21. J Martin Schaeberle, 1853–1924 (Courtesy: Collection of Robert Schaeberle).

Using a 20.3-cm (8-inch) reflecting telescope of his own design and manufacture housed in his private observatory, on 1880 April 7 Schaeberle discovered the second comet of that year. The following year, on July 14, he discovered the fourth comet of 1881 with the Fitz comet-seeker at Detroit Observatory. Details of the discovery are recorded in a letter written by one of his students:

> With another woman student I had been working under Mr. Schaeberle's supervision in the smaller [Students'] observatory until the wee hours of the night and we were about to close up when someone suggested that a conjunction of the major planets would be visible later. We were anxious to see it and Professor Schaeberle with the patient, kindly courtesy which was characteristic of him offered to stay. While he was waiting for us he took a little portable telescope which was standing in the yard—I think they called it a "comet seeker"—and began to look around the heavens. Presently he hurried into the observatory and asked to use the telescope. We found that he had seen a comet and learned later that he received an award of several hundred dollars for the discovery. But the money didn't seem to interest him as much as the comet. (Greathouse, 1925).

On 1893 April 16 Schaeberle discovered a third comet, for which the Astronomical Society of the Pacific awarded him a medal (see Figure 22).

Figure 22. The comet medal presented to Schaeberle by the Astronomical Society of the Pacific in 1893 (Courtesy: Collection of Robert Schaeberle).

Under Watson's tutelage, Schaeberle received instruction in the German astronomical methods that Watson had learned from Brünnow, which stressed spherical and positional astronomy. This approach was well suited to Schaeberle's interests and abilities in precision astronomy, and this led Schaeberle to compute the ephemerides and perturbations of minor planets Watson discovered for publication in the *Berliner Jahrbuch*.

When Watson left Michigan in 1878 to become inaugural Director of Washburn Observatory, Mark Harrington (see Section 13.1, below) took his place, but since Harrington's primary interest was in meteorology, this meant that Schaeberle was able to take responsibility for the bulk of the astronomical work at Detroit Observatory. When Harrington asked for a year's leave in 1886 on account of illness, Schaeberle was appointed Acting Assistant Professor, and his salary was increased to Harrington's Directorial rate.

In 1888, Schaeberle seized an opportunity to become one of the inaugural astronomers at the newly-founded Lick Observatory on Mt. Hamilton (California), and he remained there for ten years, responsible for observations with the Repsold meridian circle. In 1889 a total solar eclipse that crossed northern California captured his attention and prompted him to make plans to go to Cayenne, French Guiana, in 1889 December to observe the next one. In a desire to formulate a mechanical theory of the solar corona, which would expand on the prevailing magnetic theories, he devised a long-focus camera to take photographs of the Sun during solar eclipses. His design was a photographic telescope of 12.2 m (40 foot) focal length, driven by clockwork, which was portable so that it could easily be taken to remote locations. The Schaeberle camera produced the best photographs of the solar corona produced to that time, one of which revealed a Sun-grazing comet that would otherwise have gone undetected. Schaeberle travelled with his camera to Mina Bronces (Chile) in 1893 and to Akkeshi (Japan) in 1896 in order to observe total solar eclipses. He independently organized the expeditions, and recruited and trained local civilians to assist him. Astronomers continued to take the Schaeberle camera on eclipse expeditions up until 1932, when H D Curtis exposed the last coronal plates at Fryeburg, in Maine.

Schaeberle's persistent visual observations led to his discovery in 1896 of the elusive thirteenth-magnitude companion of Procyon, the 'Little Dog Star', using the great Lick refractor. He devoted himself entirely to astronomy, working diligently and methodically with disciplined, organized, work habits. He was always punctual, unusually tolerant of other points of view, and was particularly attentive to his physical health through regular exercise. He was well liked and respected, and often chose to remove himself from political disagreements. He set his ideals higher than is typically attainable, and when he came to a decision after careful contemplation and consideration of all factors, he held steadfastly to his beliefs (Tucker, 1924; Reichel, 1959).

When Edward Holden resigned as Director of Lick Observatory in 1897, Schaeberle was the obvious choice to be Acting Director. He held this position until 1898, gaining the high regard of his colleagues, and expected to be made Director. But, the Lick Trustees made a political move and instead appointed James Keeler. Schaeberle could not accept this perceived injustice, so he left Mt. Hamilton and returned to Ann Arbor, despite the protestations of his colleagues. Of his resignation, he wrote:

> The regents of the University of California urged me to withdraw my resignation and, offered me a year's leave of absence with full pay, but I could not accept their kind offer as I feel satisfied that my present course is the proper one for me to take. (Schaeberle, 1898).

Schaeberle never held another formal appointment. At first, he travelled around the world, and he then decided to carry on his astronomical work from an observatory he built at the family residence on Second Street, Ann Arbor. He constructed a 61.0-cm (24-inch) reflecting telescope, mounted equatorially, that he planned to equip with a modified bolometer to detect far-infrared radiation from the Sun and stars. Unfortunately, while drilling a hole to make a modification to the telescope, he broke his cherished mirror. In the 1930s, astronomers at the University of Michigan found one half of the discarded mirror leaning up against the Schaeberle's old barn, and they obtained it to use as an off-axis parabola for infrared spectrometry.

Schaeberle was one of the founding members and first Secretary of the Astronomical Society of the Pacific. In 1898, the University of California conferred upon him an honorary Doctor of Law, which was preceded by an honorary M.Sc. from the University of Michigan in 1893. Over the course of his career, Schaeberle published more than 100 research papers in scientific journals, some of which contained ingenious methods for determining instrumental constants.

Martin Schaeberle died suddenly and unexpectedly on 1924 September 17, while doing light yard work at his Ann Arbor home.

11 EXPLORATION OF ALASKA TERRITORY AND THE ARCTIC REGION

In the nineteenth century, great attention was paid to exploration of the Alaska territory and the Arctic region. Expeditions were organized for the exploration and identification of resources and commercial opportunities, and expedition leaders were typically trained scientists with an interest in gathering scientific data and identifying new species. Such expeditions garnered immense geographical knowledge, and amassed vast quantities of hydrological, meteorological, astronomical, and geomagnetic data. They also resulted in bountiful collections of insects, plants, birds, small animals, invertebrates, fish, rocks and minerals, and they advanced scientific knowledge in the areas of palaeontology, physical geography, meteorology, astronomy, geodesy, and ethnology.

Scientists were needed to staff the expeditions, and it was to universities that expedition leaders often turned to recruit their teams. While Director of Detroit Observatory, James Watson received numerous requests for names of suitable graduates to participate in such expeditions. These offered Michigan graduates excitement, adventure and a chance to utilize their skills and contribute to scientific knowledge, but there was also potential for danger – even death.

The United States acquired the Alaska territory in 1867, following two years of systematic exploration of the region. Interest in the area grew naturally from westward expansion, and also through a plan to establish an intercontinental telegraph. The Western Union Telegraph Company succeeded in connecting the Atlantic and Pacific coasts by telegraph in 1861, and a transcontinental railroad followed, although its completion was delayed until 1869 by the Civil War. When Cyrus Field's efforts to lay a telegraph cable across the Atlantic Ocean met with repeated failure, his thoughts turned to other possibilities for achieving his goal. The distance between the Alaskan coast and Russian territory across Bering Strait was a mere 65 kilometres (40 miles), which offered an intriguing alternative route.

Robert Kennicott, an explorer and naturalist from Chicago, was engaged to lead an exploratory mission to examine possibilities. But, news came in 1866 that the Atlantic cable was successfully laid, so Kennicott abandoned this portion of his mission. He died that same year, but his friend, William Dall, continued the scientific exploration of the Alaskan territory. Dall's official missions were to perform a hydrographic survey that would facilitate commerce, and to identify a cable-landing site for a telegraphic connection with Japan, but his true interest was in advancing scientific knowledge of the region.

There was keen interest in Arctic exploration as well. The quest for a North-West Passage, an Open Polar Sea, and a North-East Passage to reach the Orient from Europe began in America as early as the arrival of the first colonists, and persisted into the nineteenth century. Willem Baffin, John Ross, William Parry, John Franklin, and others conducted early explorations of the Arctic. The last link of the North-West Passage was achieved in 1850, followed by the North-East Passage in 1879, and the North Pole was finally reached in 1909.

During the decades of the 1850s through 1870s, explorers such as Elisha Kane, Charles Hall, and Adolphus Greely mounted expeditions to search for the missing Franklin party, and in pursuit of the North Pole. Their connections with officials at the U.S. Coast Survey and the Nautical Almanac Office led them to contact James Watson and Mark Harrington at Detroit Observatory for assistance in recruiting capable students to join their scientific corps.

11.1 Marcus Baker, Class of 1870 [1849–1903]

Marcus Baker (Figure 23) was one of the students enlisted for duty in Alaska. He was one of the most distinguished scientists trained by Watson at Detroit Observatory. His long career was launched when Watson recommended him for a post as an Astronomical Assistant for the United States Coast and Geodetic Survey's exploratory expedition to Alaska in 1873, and culminated in his role in 1888 as one of the thirty-three original founders of the National Geographic Society.

Figure 23. Marcus Baker, 1849–1903 (Courtesy: Bentley Historical Library, University of Michigan).

Baker's life began on 1849 September 23 near Kalamazoo, Michigan, where he was born to John and Chastina Baker. He grew up on the family farm, attended the District school, and in 1862 was sent to the Union School at Kalamazoo. In 1866 September he enrolled at Kalamazoo College and then transferred to the University of Michigan as a junior in 1868. It was at Michigan that he met James Watson. Baker was one of Watson's most accomplished students, and was offered employment following graduation in 1870 to assist with the preparation of Watson's Lunar Tables.

In 1870 September, Baker took an appointment as Professor of Mathematics at Albion College for one academic year. He then returned to Michigan in 1871 as an Instructor in Mathematics, working with Professor Ulney. In 1873 March, following a recommendation from Watson, Baker accepted appointment as Assistant Astronomer with Dall's U.S. Coast Survey expedition to Alaska. The position was made vacant when Mark Harrington decided to return to Ann Arbor to take a position as Assistant Professor of Geodesy, Zoology, and Botany. Baker was exceptionally well liked, and was described by Dall as having a "...kindly and cheerful nature and lively enthusiasm [that] captured our affections at the start." (Dall 1904:40).

His journey to Alaska began in Washington, DC, where Baker prepared for the trip by practising observations under the direction of Julius Hilgard, the Assistant in charge of the Coast Survey (Watson, 1873a). In 1873 March, he set out for San Francisco by way of Ann Arbor, Kalamazoo, and Kansas (where his future bride resided). Following Baker's first glimpse of the Pacific Ocean, Dall's group left San Francisco on 1873 April 28, arriving in Unalaska on May 20, then setting off in June for Alta Island in the Aleutian chain. Baker spent the summer in the islands, charting positions along the island coasts and harbours, correcting old charts, making magnetic declination determinations, gathering scientific data on tides and weather, and collecting natural history and ethnology specimens. Much of the information he gathered was utilized to prepare the *Coast Pilot of Alaska*.

After six months on assignment in Alaska, Baker took an hiatus in San Francisco, where he independently reduced unpublished data on terrestrial magnetism that had been collected between 1740 and 1880. The results of this painstaking work constituted a significant advance in scientific understanding. Baker then applied to join Watson's transit of Venus expedition to Peking, but discovered that the team had already been finalized (Watson, 1873b), so he decided to return to Alaska for another tour of duty, leaving in 1874 April. First he worked on a hydrographic survey of the coast from Sitka to the Bering Strait, and then in 1874 December he seized the opportunity to return to Kansas to marry Sarah Eldrid. But, Alaska was not yet out of his system, for he made a third trip there in 1880.

In 1886, Baker severed his connection with the U.S. Coast and Geodetic Survey to join the United States Geographical Survey. But, before this transition he was asked (in 1882) to establish a magnetic observatory at Los Angeles. With the Geographical Survey, he took a leadership role in shaping the topographic mapping of southern New

England and other regions. As Secretary and Editor, he made significant contributions to the Board of Geographic Names, a group created by President Harrison to regulate nomenclature. Mount Marcus Baker in the Fairweather Range and the Baker Glacier in Alaska were both named in his honour.

Baker also took an active role in the determination of several important border questions, including the Venezuela boundary controversy, for which he compiled a historical atlas and other materials that were essential to resolving the dispute. In 1902, he prepared a comprehensive *Geographic Dictionary of Alaska*, which proved to be an invaluable resource for cartographers and geographers.

Baker served as President, Secretary, and Editor of the Philosophical Society of Washington, and toward the end of his life was appointed Assistant Secretary of the Carnegie Institution. On 1903 December 12 he died very suddenly from heart failure while at his residence in Washington, DC. He was only fifty-four years of age.

11.2 Samuel Sharpless Green, Class of 1871 [1846-1941]

Samuel Green was born on 1846 November 13 to William Lamborn and Sarah (Sharpless) Green. When he enrolled at the University of Michigan, he was living at Media, Pennsylvania. In Ann Arbor, he studied under James Watson at Detroit Observatory. Apparently, he was one of Watson's favourite students, because when Arctic explorer captain C F Hall asked Watson to recommend an astronomer for an expedition to the North Pole, Watson recommended Green. Hall's telegram to Watson dated 1871 May 19 read:

> Can you recommend to Arctic Committee National Academy Science a competent astronomer for North Pole Expedition salary one hundred dollars per month and all expenses paid urgent need of a skillful energetic & willing volunteer to communicate with or report to me at once for preparatory training Coast Survey Washington. (Hall, 1871)

Watson sent his reply (collect) the same day:

> Yes. I can recommend Samuel S Green now with me. He is robust, active, well educated and will accept the place. Please advise me of your further wishes. He can report at once. (Watson, 1871)

Green immediately travelled to Washington for training, but on 28 May, Green wrote to Watson regarding his serious doubts about the expedition and its leader.

> ...there are other discouraging circumstances: the expedition seems to be very poorly organized. There is a want of confidence in Capt. Hall; the captain is an uneducated man, he knows but little about navigation and I do not think he is a man who would preserve discipline, upon which so much depends. ... Prof. Baird told me this morning that he would not consent for a son or relation of his to go on the expedition as at present organized, as it will be extremely hazardous... ... Prof. Hilgard told me... ...further that Capt. Hall killed a man on one of his expeditions and was only acquitted of the crime on the ground of want of jurisdiction. (Green, 1871)

Green's instinct was to decline the position. He wrote to Watson "...two men of considerable astronomical practice and experience have already declined the place after having once accepted it." In fact, Green did resign, which proved to be a fortunate decision. Hall and his expedition party did achieve a new record for distance north—only 748 kilometres (464 miles) from the North Pole—but the Hall expedition was a disaster.

Hall died aboard his ship *Polaris* under mysterious circumstances in the fall of 1872. When *Polaris* became stranded in the ice, nineteen crew members became trapped on a huge ice floe. They drifted for seven months, and suffered through terrible privation, until they were rescued about 2,903 kilometres (1,800 miles) from their starting point by a passing ship. Those left on *Polaris* were forced to abandon ship, and they suffered tremendous hardships and starvation. Five died, and the ice floe shrank to a tiny platform before they miraculously reached the Labrador coast, where they found a camp of friendly Inuits at Etah. A whaling ship rescued them that Spring.

The Navy's inquiry into Hall's death concluded that he died of a stroke. But, ninety-seven years later, Hall's biographer, Dartmouth College Professor Chauncey Loomis, became suspicious. Evidence he uncovered made him suspect Hall was murdered. Loomis had Hall's body exhumed from the frozen Greenland tundra, and an autopsy confirmed he died of acute arsenic poisoning. (Parry, 2001:296-305; Berton, 2000:408) Those responsible for the crime remain unknown.

After Green resigned from the expedition, he was an instructor in physics at Swarthmore College for a year, then returned to Ann Arbor to complete a Master's degree in 1874, and returned to Pennsylvania as an instructor at Quaker's College in Swarthmore. After a year of study at Berlin and Heidelberg, Germany, he returned to Swarthmore College in 1878 as Professor of Physics and Chemistry, where he remained on the faculty until 1886. Green retired to Florida and worked as a librarian at the public library in Bartow. He died in Florida in 1941 at the age of ninety-five.

11.3 Edward Israel, Class of 1881 [1859–1884]

Edward Israel's fascinating life was tragically short, but his contributions to science were remarkable and heroic. Israel, a native of Kalamazoo, Michigan, was born on 1859 July 1, the son of a wealthy and prominent family of that college town (At Israel's home, 1884:2). His father, Menz Israel, was the senior partner of a prosperous dry-goods firm.

Edward Israel (Figure 24) attended public schools at Kalamazoo, where he distinguished himself for his love of study and his tendency to pursue original investigations. He entered the University of Michigan in 1877, where his exceptional aptitude for mathematics caught the attention of Mark Harrington. Harrington personally provided instruction to Israel, who was far ahead of the other members of the class. Harrington wrote:

Figure 24. Edward Israel (1859–1884) is third from the right in the front row in this etching of Greely's Arctic expedition party (after Greely 1888, I: facing page 39).

> He read with me Watson's *Theoretical Astronomy*, a work so advanced as to be beyond the range of most college students, and even to offer in places serious difficulties to the professional mathematician or astronomer. Mr. Israel not only read the entire work in a half year, but he seemed entirely unconscious that he was doing anything extraordinary. (*Cyclopedia of Michigan*...., 1890:284).

Israel graduated from the University of Michigan in 1881. His scientific contributions were in both astronomy and meteorology, which is not surprising given that his mentor, Mark Harrington, went on to be the inaugural Chief of the U.S. Weather Bureau.

At the time Israel graduated from the University, Lieutenant Greely of the United States Cavalry was forming his team for the nation's first polar expedition. Greely needed an astronomer for the mission, so he sought a recommendation from Detroit Observatory. Harrington recommended Israel, who was selected over all others. Israel enthusiastically accepted this unique opportunity, and the University recognized his talents by permitting him to join the expedition prior to the end of the semester, yet graduate with his class. Israel reported to the United States Signal Service office at Washington, DC, in 1881 May for a month of practical instruction in use of the instruments, and learned to perform computations to help prepare him for the expedition.

Israel was the youngest member of the Greely Arctic Expedition (1881–1884), and the only one with a Jewish heritage. He was appointed at the rank of Sergeant, and was responsible for the astronomical observations and expected to assist with the meteorological observations.

The polar expedition was part of a larger plan adopted by the International Geographical Congress at Hamburg in 1879, with the goal of establishing a network of circumpolar stations where scientific observations could be carried out and data collected. Congress made the appropriation for the expedition in 1881 March, to establish scientific stations in the area of Lady Franklin Bay. Greely's station was to be located at the most northerly point, at Discovery Harbor (latitude 81° 44' North and longitude 64° 45′ West).

Greely and his twenty-four man team set out from St. John, Newfoundland, on the steamer *Proteus* on July 4, and entered Lady Franklin Bay a month later. They established a base camp and named it Fort Conger to honour Senator Omar Conger of Michigan who sponsored the bill that funded the expedition. At Fort Conger, the first thing Israel did, even before setting up his astronomical and magnetic observatory, was to determine the longitude and local time of the station. Once this was done and the observatory was erected, he set about making daily astronomical observations (weather-permitting) and collecting weather data. The expedition met with many successes, and perhaps the most significant geographical milestone was the achievement by Lieutenant James Lockwood of a new northern latitude record when he reached 83° 24′ on 1882 May 13.

But, in the harsh climate of the polar region there are few certainties, and life continues to hang in the balance. Relief ships that were expected to bring provisions failed to arrive in 1882, and again in 1883, and the Greely party was forced to travel 645 kilometres (400 miles) to the south, arriving at Cape Sabine in 1883 September. Alas, the provisions they expected to find cached at this location were not there. They hoped for rescue at this more accessible location, but the relief ship did not arrive before winter set in. Provisions were rationed with precision and care, yet members of the party suffered unbearable privation that winter, and one by one they died of starvation and exposure. By April, the survivors were reduced to consuming small quantities of lichens found under the snow, and spent their time huddled together for warmth in three-man buffalo hide sleeping bags (Figure 25). With the passage of time, they became less and less able to perform even the most routine of tasks.

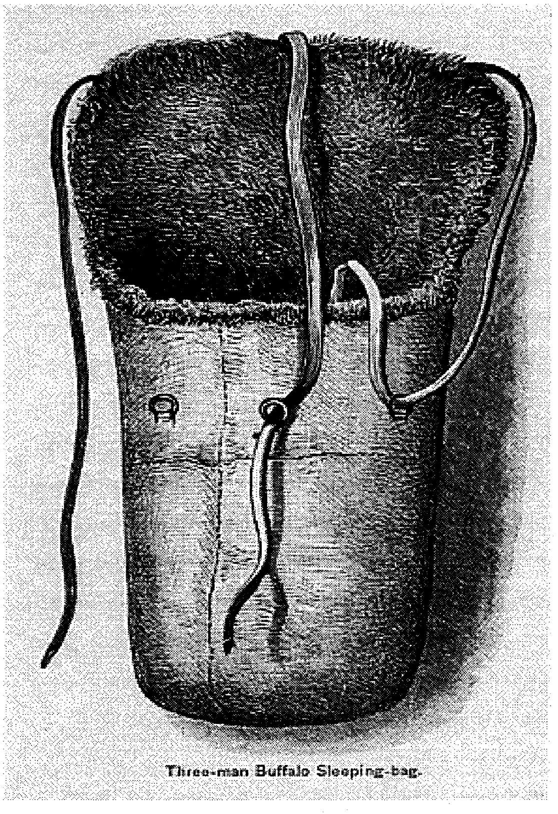

Figure 25. Arctic sleeping bag of the type Edward Israel shared for warmth with Arctic expedition leader Lte Adolphus W Greely (after Greely 1888, I: 212).

Israel, as one of Greely's favourites, received tender care and attention. When his health took a worrisome turn, a raven was seen at the camp and was killed for food. Greely gave four ounces of this scarce meat to Israel in the hope that it would help sustain him, but to no avail. Three days later, Greely (1888:519) wrote: "Israel cannot long survive the horrors of this hated place...", and the following day (1884 May 25) he wrote: "My God, this life is horrible! It is burdensome, and it plunges one into the lowest depths of despair." (Greely, 1888:520). On May 27, just after midnight, Israel died "very easily." Greely (ibid.) wrote:

> After losing consciousness—about eleven hours before his death—he talked of food, restaurants, &c. Everyone was his friend. He had no enemies. His frankness, his honesty, his noble generosity of nature had won the hearts of all his companions. His unswerving integrity during these months of agony has been a shining example...

Nearly four weeks later, on June 22, a rescue party arrived to take the seven survivors home, one of whom died during the journey.

Israel's abilities as a scientist were highly respected and valued by Greely and the other team members. The data Israel gathered were praised when examined after the expedition. About Israel's work, it was said: "...[his] computations indicate great care, even in the smallest details, exhibiting a greater degree of precision than is necessary..." (Greely, 1888:61). Israel's contributions are locked into history in the form of the important data he gathered, and in Greely's written mention of his superb abilities and personal qualities in the published account of the expedition. Israel's memory is also kept alive in his hometown of Kalamazoo, where his body was returned for burial. A State of Michigan historical marker was erected near his grave in 1972 to honour 'Edward Israel, Arctic Pioneer'.

12 BOTANICAL COLLECTIONS AND THE U.S. LAKE SURVEY

Congress established the Survey of the Northern and Northwestern Lakes (*aka* U.S. Lake Survey) in 1841, but its work began in earnest in 1851. Large teams of trained engineers and surveyors were needed to gather data in order to accurately map the Great Lakes region. Land crews performed primary triangulations, while others using various watercraft made depth soundings. Between 1863 and 1882, when the Lake Survey was completed, more than fifty percent of the civil assistants employed by the Lake Survey were students or graduates of the University of Michigan.[10] Some students worked as field assistants during the summer break, for experience or to earn money for college expenses, or both. Others took leaves of absence from their studies to earn funds so that they could continue on towards graduation. Still others launched their careers after graduation as employees of the Lake Survey.

The extensive contributions made by University of Michigan students to the surveying needs of the Lake Survey have already been documented. A more obscure yet important contribution made by some of these students was the collection and documentation of Michigan's botanical species. Orlando Wheeler and other civil assistants of the U.S. Lake Survey actively collected botanical specimens during the course of their fieldwork. One Michigan-trained surveyor, Ossian Simonds, became a famous landscape architect, and designed the University's Arboretum. In the field, botanical specimens were assembled and labelled, and data were recorded for each plant on small squares of readily available birch bark rather than on the usual paper labels. Today, many of these specimens are preserved in the University of Michigan Herbarium. For a fascinating account of the Lake Survey's contribution to nineteenth-century US botanical collecting see Voss, 1978.

13 INTRODUCING THE CONSUMATE INTERDISCIPLINARIAN

During the mid-nineteenth century, scientists had the opportunity to explore numerous disciplinary areas, because the boundaries between sciences were not rigidly defined. This is clearly evidenced in the case of 'astronomical' observatories, which in addition to traditional astronomy, generally also espoused time-keeping, meteorology, trigonometrical surveying, seismology, geomagnetism, and sometimes even tidal studies.

Scientific expeditions were necessarily limited in size, so it was advantageous for team members to serve multiple roles, such as providing both astronomical and meteorological data. One particular scientist trained at Detroit Observatory, who took interdisciplinarity to the extreme, was Mark Harrington. His interests were diverse, his curiosity hard to quell, and his energy and enthusiasm took him to the pinnacles of success. Yet, his career and his life both ended tragically.

13.1 Mark Walrod Harrington, Class of 1868 Director, Detroit Observatory 1879–1892 [1848–1926]

Mark Harrington (Figure 26) was an accomplished botanist, meteorologist, astronomer, and university president, and he pursued several other scientific disciplines, as well. He was born on 1848 August 18 in Sycamore, Illinois, to James and Charlotte Harrington. His father was a practicing physician. Mark showed great aptitude in school, and at the young age of twelve years he enrolled at Northwestern University near Chicago, where students were needed to fill spaces vacated by those engaged in the Civil War. After five years he transferred to the University of Michigan, and received his degree in 1868. He stayed on at Michigan for graduate studies, and received his Master's degree in 1871.

Harrington was a favourite of Michigan faculty members Joseph Steere and Alexander Winchell, and worked in the laboratory and museum on projects involving geology, botany, and zoology. He was particularly interested in botany, and diligently gathered and prepared specimens for the herbarium. He developed into an inspiring teacher, and in an effort to fascinate his students he suggested the use of microscopes in the botanical laboratories. In 1868 he led a group of students on a field trip to Lake Superior, and upon his return assumed his first paid position, as an Instructor of Mathematics.

In 1871, Harrington lectured on geology at Oberlin College in Ohio, and then had the opportunity to join William Dall on a U.S. Coast Survey scientific expedition to the Aleutians as Astronomical Aid. Watson opened this door by recommending Harrington for the post when Dall wrote to him asking for the name of a suitable young astronomer. Dall subsequently wrote: "I am much pleased with the prospect of having as a companion, a gentleman so highly recommended by yourself and so competent to do good work." (Dall, 1871). The expedition's objective was to examine the coast from Cook's Inlet to the end of the Aleutian Chain, and to the north as far as Cape Romanoff. Along the way, they planned to make longitude determinations, take bathymetric soundings, make astronomical and meteorological observations, take barometric measurements of various mountains they might have time to ascend, and collect animal, geological, and botanical specimens.

Harrington accepted the assignment and departed for San Francisco to meet up with Dall. In the course of this journey he truly enjoyed the scenery encountered, and a highlight was a visit to Salt Lake City to see the Morman enclave. But he became lonesome and bored in Alaska. Writing to Steere from Ilinlink, Unalaska, he complains: "We shall lie here all winter, and a miserable little hole it is." (Jones, 1978:119). But, there was one thing in particular in Alaska that truly appealed to him, and that was the opportunity to study the weather.

Figure 26. Mark Harrington, 1848–1926 (Courtesy: Bentley Historical Library, University of Michigan).

Winchell called Harrington back to Ann Arbor in the fall of 1872 to a Professorship in Geology, Zoology and Botany, and he arrived with a great many rare specimens, but the most interesting 'curiosity' was a 15-year old Aleutian boy. Perhaps Harrington was following his friend's example, because Steere had previously returned to Ann Arbor from the Philippines with a similar ethnographic 'specimen.' In 1876, Harrington developed a new course in pharmaceutical botany that emphasized the identification of drugs extracted from vegetable matter and the detection of adulterants. The course was required for students in the University's new School of Pharmacy.

Secure in a steady job, Harrington returned home to Illinois to marry Rose Martha Smith on 1874 June 30, and in 1876, with a two-year leave of absence in hand, they left for Europe where he planned to study German and learn "...the best methods in botany and comparative anatomy." His studies began at Kew Gardens near London, where he completed a study of ferns collected by Steere and published the results in 1878 in the *Journal of the Linnean Society*. This was a significant event, as it was the first research paper published by a Michigan faculty member based on the University's botanical collections (University of Michigan, 1958b:1446), and in recognition of this important publication Harrington was elected a fellow of the Linnean Society of London. In 1876 he moved to Leipzig, where he studied German and worked at various botanical gardens. The following year, he received a Ph.D. from the University of Leipzig.

After a short visit to their home in Sycamore, Illinois, the Harringtons again went abroad, Rose to Paris, and Mark to Peking, where he accepted an appointment as Professor of Astronomy and Mathematics at the Cadet School of the U.S. Foreign Office and Director of the T'ung wen Quan (Royal Observatory). This new position offered a better salary than his post in Michigan, from which he resigned.

Due to his ill health and Rose's loneliness, they decided to return to America in 1878, and Mark was appointed to a Chair in Natural Science at Louisiana State University. However, things obviously did not work out there, for the Harringtons soon returned home to Illinois, and it was there that he published an analysis of the tropical ferns collected by his friend Steere in the early 1870s.

In 1879 March, Harrington accepted President Angell's offer to return to Ann Arbor as the third Director of Detroit Observatory, given Watson's imminent departure for the Washburn Observatory. It is likely that Professor Winchell recommended him for the job, but Angell's appointment as Minister to China may have had some bearing as well. Harrington and Angell carried on a personal correspondence during the latter's residence in China, and in 1894 Angell arranged for Harrington to receive an honorary Doctor of Law degree.

During his tenure as Director of Detroit Observatory, Harrington's interests in botany and meteorology remained strong, so he decided to concentrate on meteorology and leave Schaeberle largely in charge of astronomy. Weather instruments were soon purchased, and a wind vane and anemometer appeared on the roof of the Observatory.[11] Weather records were kept and sent to the State Board of Health at Lansing. Harrington also acquired two seismoscopes, and added seismological studies to the Observatory's repertoire. In addition, in 1884 he founded the *American Meteorological Journal*, the nation's first journal dedicated solely to meteorology.

When the Federal Government reorganized its meteorological structure in 1881, Harrington left Ann Arbor to accept the post of inaugural Chief of the U.S. Weather Bureau. One consequence of this was that the University eliminated its course on meteorology, and the subject was never again offered by the Department of Astronomy.

At the Weather Bureau, Harrington led many research initiatives. Perhaps one of the most interesting was a study published in 1895 titled *Surface Currents of the Great Lakes as Deduced from the Movements of Bottle Papers During the Seasons of 1892, 1893, and 1894*. Commercial interests prompted this study. It was observed that flotsam and jetsam from shipwrecks travelled along predictable routes, and knowledge of these surface currents would permit vessels to maximize the advantage of the drift. Around the Great Lakes, Harrington deployed five thousand glass bottles into which he placed instructions to inform the Weather Bureau of the precise location and date of recovery. Only thirteen percent of the bottle papers were returned, but the data from these led to an increased understanding of surface currents. Even today, Harrington's study is viewed as a significant reference for research on Great Lakes surface currents being performed by the National Oceanographic and Atmospheric Administration (Schwab, pers. comm., May 2003).

Harrington was a gifted scientist, but he did not excel in the rigid, militaristic environment that was well established within the U.S. Signal Service, the predecessor to the Weather Bureau. In spite of his many successes and the innovations he introduced, by 1895 his position at the Weather Bureau was seriously undermined. When he was asked to resign he declined, so he was removed by action of President Grover Cleveland. His path then took him to Seattle, where he was appointed as President of the University of Washington. But shortly after his appointment, the State of Washington entered a period of political turmoil, and history repeated itself: Harrington was dismissed. His replacement resigned after six months, following altercations with the Faculty and Regents.

As always, Harrington bounced back, finding employment again with the U.S. Weather Bureau as a Section Director in San Juan, Puerto Rico. But, his physical and mental health was beginning to fail, and he was transferred to New York, where he retired. His book, *About the Weather* (1899), was published at this time, and was very well received.

But, something was amiss with Harrington's 51-year old mind. One evening in 1899 October he told his wife and son that he was going to dinner in New York, and simply disappeared. Over the course of the next ten years his family did not see him or know of his whereabouts.

It transpired that in early 1909 Harrington applied for shelter at a police station in Newark, but was unable to identify himself, so he was transferred to the Morris Plains Asylum in New Jersey. His son Mark, then a Master's candidate in anthropology at Columbia University, located his father after seeing a short note in the *New York Times* about a very learned man in an insane asylum who did not know his identity. Harrington spoke seven languages, and expounded eloquently on scientific topics, which caught people's attention and aroused curiosity.

A reporter, by pulling together past newspaper clippings, was able to determine that Harrington left New York in 1899 for China, where he suffered a long illness, but he eventually recovered and worked as a tutor to save money for the trip home. In 1902, he was living in a cheap boarding house in Chicago. In an interview with a reporter, he described from his scientific point of view the time he spent among hobos who "...migrate as regularly and completely as the birds, only they do not pass the Gulf Coast." (Jones, 1978:134). He also complained that "...universities do not want a man over fifty..." (Scholarly man's plight ..., 1902:2). At the time, the reporter did not realize that Harrington had abandoned his family, and the article escaped the notice of anyone aware of his disappearance. Later on, Harrington worked on a sugar plantation in Louisiana, and then worked as a log roller in Washington State in 1901, living in a one-room cabin he built, in which he surrounded himself with books and scholarly materials. During this time, he compiled an almanac for Alaska containing climatic and geological data, and he also worked as a labourer in a shipyard.

After a remarkable yet tragic life, Mark Harrington died at the Morris Plains Asylum on 1926 October 9.

14 WOMEN MAKE THEIR MARK

The University of Michigan did not permit the enrolment of women until 1870. The topic generated intense debate across the nation, and in Ann Arbor Tappan believed that women were a disruptive element. His own daughter was a capable student who pursued advanced study, but she attended a local school for young ladies. University students and faculty were generally sympathetic to the admission of women, but once women were admitted, it became apparent that the sentiment among townspeople was decidedly anti-women. The fear was that the University would become less attractive to students, and local business would suffer.

By 1870, the University decided to proceed with what some referred to as the "dangerous experiment", and just one woman enrolled that year. The number increased to 112 within five years, and nearly doubled over the next decade. By 1895, there were nearly 600 women at the University of Michigan. Although the majority entered the literary college, many pursued medical studies, including James Watson's sister, Catherine, who was one of the first women at Michigan to receive a degree in pharmacy when she graduated in 1876.

Once admitted, many of the women who attended the University during the nineteenth century distinguished themselves in their subsequent careers. One impressive example is Alice Freeman Palmer, Class of 1876, who became President of Wellesley College. Many of the educated women of that era found career opportunities at the women's colleges, such as Vassar and Wellesley, where the environment generally was hospitable. A digest of Michigan's women graduates compiled in the mid-1890s (see Thwing, 1895:552) identifies nine particularly successful women, including astronomer, Mary Byrd.

14.1 Mary Emma Byrd, Class of 1878 [1849–1934]

Mary Byrd (Figure 27) transferred to Michigan from Oberlin College in Ohio as a junior, graduated in 1878, and then pursued a career in astronomical science at Smith College. Byrd received her instruction in mathematics and astronomy at Michigan from James Watson and others. Of her experience at Michigan, she later wrote in response to a 1924 alumnae survey: "One of my keenest memories of college days at Ann Arbor is that the women students were unwelcome. The professors themselves, so far as I knew personally, were always courteous and considerate." (Attaway and Barritt, 2000:18).

Byrd was born in 1849 in LeRoy, Michigan (Attaway and Barritt, 2000:122), the daughter of Elizabeth Byrd, but grew up in Lawrence, Kansas (University of Michigan, 1878). Her father was a Congregational minister and staunch abolitionist who was descended from Jonathan Edwards, the noted religious philosopher and author of *Freedom of the Will*, which had a major influence in the scholarly life of Henry Tappan. Byrd's father moved the family to Kansas in 1855, where one of her mother's brothers was a prominent judge and member of Congress for a term. Mary Byrd possessed rare personal traits, including an intense resolve and inflexible moral standards, which she may have inherited from her philosopher father.

Figure 27. Mary Byrd, 1849–1934 (Courtesy: Bentley Historical Library, University of Michigan).

Following her graduation from Michigan in 1878, Byrd taught Latin, Greek and mathematics at Wabash, Indiana, and served as a high school Principal at Atchinson, Kansas, for several years. She then took a position at Harvard College Observatory, where she worked with astronomers such as E C Pickering and Henry Draper, and with a number of women who distinguished themselves in astronomy. Most prominent of these were Antonia Maury, who discovered that Beta Aurigae was a close binary star; Mina Fleming, who discovered that bright lines in the spectra of some stars indicated they were variable (Reed, 1892:167); and Anna Winlock, daughter of Harvard astronomer Joseph Winlock, who literally grew up at the Observatory. Anna began by computing the Cambridge zones while a schoolgirl, but did not complete the task until 1896, a devotion that consumed her for over twenty years and earned for her the high regard of colleagues. When she died in 1904, having only reached her late forties, Mary Byrd (1904) wrote a biographical sketch that locks into history Winlock's achievements and her dedication to science; it also demonstrates Byrd's close relationship with her departed friend. Byrd's associations at Harvard were important elements in her development as an astronomer, and she particularly valued the mentoring she received from E C Pickering, who was well known for his conviction that women should receive support and recognition in the scientific world (Jones and Boyd, 1971:413-417).

After several years at Harvard, Byrd relocated to Carleton College to teach mathematics and astronomy. And under the supervision of William Payne, she also provided time signals twice daily for the region's railroads. During this time, she pursued doctoral studies in astronomy, and received her Ph.D.

from Carleton in 1904. Her abilities then caught the attention of Smith College, and they succeeded in attracting her as Director of their new Observatory. She remained at Smith College for nineteen years, and eventually become their first Professor of Astronomy.

Byrd was recognized at Smith for her hands-on teaching methods. In 1899, she published her first textbook in astronomy, titled *Laboratory Manual in Astronomy*. Her second textbook, *First Observations in Astronomy*, appeared in 1914, written as a practical guide for the student with limited means or access to equipment. The book included instructions for making a sundial using a wooden ruler, a block of wood, a paper dial, and a carpenter's level. Other tools or instruments deemed essential for the astronomy student were a straight edge, a pocket compass, a steel scale, a transparent protractor, an orrery, a celestial globe, opera glasses and a small telescope. Byrd cautioned against the idea that a telescope was the first order of business for the energetic student:

> Magnifying power for studying the heavens is perhaps best given at first by opera-glasses. Those having a power of two or three diameters show detail on the moon, and resolve some double stars and star clusters. A telescope is the last, rather than the first instrument to be obtained. The danger is that it will be only a pretty toy, but even as a plaything it has its uses, and one can be put together with little expense... Instead, however, of making the tubes, much labor is saved by using mailing tubes, or tin tubes, of suitable size. (Byrd, 1914:11).

Three of Byrd's letters to the President of Smith College, Clark Seelye, are preserved in the Smith College archives, and they reveal the problems that she and other Directors of small college observatories faced, but they particularly characterize the challenges at a woman's college. Byrd desperately appealed for an assistant. She pointed out that she was operating the observatory alone, maintaining the equipment, making observations and teaching, and that she had to work twelve-hours days, without any vacations, just in order to keep up. These pleas eventually had the desired effect, and she was able to appoint a Smith College graduate, Harriet Bigelow, as her Assistant (see Section 14.2, below).

One of Byrd's most important contributions to astronomy, beyond her many years of college teaching and production of two text books, was her determination of the longitude of Smith College Observatory. According to Reed (1892:167), this was "... probably the only longitude campaign ever conducted wholly by women ...", and during this undertaking she teamed with Mary Whitney, who later succeeded Maria Mitchell as Director of Vassar College Observatory.

In 1906, Byrd resigned her position at Smith College as a protest against funds the College was accepting from benefactors such as John D Rockefeller and Andrew Carnegie, because she considered them to be "tainted." Deemed a "conspicuous anti-capitalist" by the media ("Tainted money at Smith," 1906:8), Byrd remained silent when the College received a series of gifts from Rockefeller, but her personal convictions became overwhelming when the Carnegie gift was announced, although it was not designated for the astronomy programme. She felt strongly that educational institutions compromised their freedom of expression on economic problems when they accepted large financial gifts from wealthy private benefactors. She retired in disgust. In submitting her resignation, she questioned "... the methods by which certain large personal fortunes were built up, and her own need for protest, even at sacrifice of her position, against such sources for college funds." (Hoblit, 1934:497).

With her principles intact, Byrd returned to her hometown of Lawrence, Kansas, where she remained active in astronomy and completed a further textbook, titled *First Observations in Astronomy*. In the acknowledgements, she extended thanks to a jeweller in Lawrence named Marks, for "... courtesy in sending accurate time by telephone render[ing] it possible to test a home-made transit instrument, and to determine longitude from local observations." (Byrd, 1914).

Byrd then relocated to New York City, and served as a Lecturer in Astronomy at Normal College and Hunter College in 1913–1914 (Dr Byrd at Normal, 1913:9). She later retired to Dunedin, Florida (Attaway, 2000:122), and died in Lawrence, Kansas, on 1934 July 30 at the age of eighty-five.

14.2 Harriet Williams Bigelow, Ph.D. 1904 [1870–1934]

Harriet Bigelow (Figure 28) received her Ph.D. in astronomy at the University of Michigan in 1904. Her educational preparation was influenced by study under Asaph Hall Jr. at Detroit Observatory, and also by Mary Byrd at Smith College Observatory. Considering the influence of such distinguished mentors, it is no surprise that Bigelow had an impressive career as a teacher and a researcher.

Born on 1870 June 7 in Fayetteville, New York, Harriett Bigelow was the daughter of the town's Presbyterian pastor. Her early education was in the Fayetteville and Pitcher community schools. The family relocated to Utica, New York, in 1878, where she attended the Utica Free Academy, graduating in 1889. She then enrolled at Smith College, where she studied astronomy under Mary Byrd. Her initial interest in astronomy was completely serendipitous: "My dormitory window faced the observatory, and I thought it would be fun to help turn the dome around." (Williams, 1934:435). She graduated in 1893.

Bigelow made an impression on Mary Byrd, and was employed as her Assistant in 1895. At the time, Bigelow was teaching at the Granger Place School in Canandaigua, New York, but she was enthusiastic about returning to Smith College. Her move to Smith in 1896 marked the beginning of a career to which she devoted the remainder of her life.

Her work at Smith College was interrupted only by her pursuit of a doctoral degree at the University of Michigan. Asaph Hall Jr., the Director of Detroit Observatory from 1892 until 1905, trained Byrd in the use of the Pistor & Martins meridian circle telescope. Her dissertation, published in 1905, was titled *Declinations of Certain North Polar Stars Determined with the Meridian Circle*. She became an expert in the determination of instrumental errors.

Following the completion of her doctoral work, Bigelow returned to Smith College as Instructor in Astronomy, and when Byrd resigned n 1906 she was promoted to Associate Professor and Director of the Observatory. In 1911 she advanced to full Professor. For the duration of her career, she carried on the tradition Byrd established at the Observatory, and like Byrd, she focused on quality instruction through hands-on observations, and respect for the mental discipline required to pursue the scientific method. Both women believed their job was "...not to turn out astronomers, but to make the girls intelligent about the universe in which we live." (Williams 1934:436). It was also important to Bigelow that every student master the English language, so that they could express their ideas in clear, proper written form.

Figure 28. Harriet Bigelow, 1870–1934 (Courtesy: John Dann).

Bigelow was active both on campus and beyond, through service to the College and to organizations such as the American Astronomical Society and American Association of Variable Star Observers. She organized at Smith the first informal meetings of women astronomers from the Eastern part of the United States, and she worked tirelessly for her science.

In 1934, following years of devoted service, Bigelow asked for sabbatical leave, and to her delight it was granted. Her desire was to spend a year of unfettered travel, free from academic responsibilities, and she made her way to Japan, then to China, and on to Manila, where she stayed six months. She then decided to visit observatories in South Africa before returning home, but between Bali and Java was found unconscious, having suffered a stroke. She never regained consciousness, and died two days later, on 1934 June 27, in a hospital in Surabaya, East Java (Williams, 1934:437).[12] Her ashes were sent home to America.

15 MICHIGAN ASTRONOMERS MIGRATE TO CALIFORNIA

During the 1880s, the pathway for students trained at Detroit Observatory shifted away from service on the topographical surveys and national engineering projects. Instead, a pattern developed, and soon became apparent, that established the University of Michigan as a training ground for astronomers at Lick Observatory (Osterbrock, 2003). The appeal of this fabulously-equipped Observatory was compelling, and Martin Schaeberle was the first to go west, leaving Michigan in 1888 to serve as one of the inaugural astronomers. But, the Michigan-California connection actually began well before Schaeberle's appointment.

James Watson was keen on becoming the inaugural Director of Lick Observatory, and began his lobbying in 1876 February, soon after Michigan's Eugene Hilgard (who was Professor of Mineralogy, Geology, Zoology, and Botany) left Ann Arbor to take up a position at the University of California. Eugene happened to be the brother of Julius Hilgard, Superintendent of the U.S. Coast Survey, whom Watson also knew. Watson corresponded with Eugene about his interest in the Lick Directorship, and in his reply Eugene noted that local salaries were decidedly better than those in Michigan, and he advised: "Be sure to find another planet soon, and Mr. Lick will want you just for the sake of having it called after himself!" (Watson, 1876). Through his connection with both Hilgards, and others, Watson gained the friendship of Joseph Henry, Secretary of the Smithsonian Institution, who wrote to the Lick Observatory Trustees nominating Watson for the Directorship. He then wrote Watson: "It will give me great pleasure to hear that they accept the nomination. If they do, as I have said in my letter to them, I doubt not you will soon make the name of the Lick Observatory familiarly known in every part of the civilized world." (Watson, 1877).

Progress at Lick Observatory was slow, but R S Floyd, the Superintendent in charge, regularly consulted Watson on constructional matters and sought his recommendations as to which telescopes to purchase. In 1880, Floyd sent Watson a photograph of Mt. Hamilton, about which Watson replied:

> [The photograph] gives me a good idea of the location of the Observatory, the slope of the mountain, &c. Mrs. Watson thinks the outlook would be superb, and a mountain residence such as you will provide not so much of a hermitage as some would suppose. We can see that the carriage road has a very easy grade. Perhaps when the time comes I may enroll my name as one of the candidates for the Directorship of your Observatory, and that too notwithstanding the ties that bind me here. I am for the best scientific opportunity while I live. (Watson, 1880).

Little could Watson have imagined that his life would end prematurely just three months after writing this letter, at the young age of forty-two.

The California-Michigan axis is fully examined in the third paper in this series (Osterbrock, 2003), but to facilitate the transition to that paper, one more Lick astronomer trained at University of Michigan during the nineteenth century, Sidney Townley, needs to be introduced.

15.1 Sidney Dean Townley, Sc.D. 1897 [1867–1946]

Sidney Townley received his early training at the University of Wisconsin under George Comstock, graduated in 1890, and went on to graduate training at Lick Observatory, where he was the first student to receive the newly created Hearst Fellowship. But, when Lick Director, Edward Holden, committed the Fellowship funds to Schaeberle in 1893 for a solar eclipse expedition to Chile, Townley was forced to seek employment elsewhere. Using his connections with Comstock and Schaeberle, he secured a position as an Instructor in Astronomy at the University of Michigan, and over the course of his subsequent, impressive career, he crossed paths with many other Michigan alumni who were trained at Detroit Observatory.

Townley was born on 1867 April 10 at Waukesha, Wisconsin, not far from Madison, to Robert and Mary Townley. His father was a minister who encouraged hard work and intellectual thought. Upon completing his high school studies, Townley's proficiency at mathematics landed him the job of clerk at the local bank. He saved his wages and enrolled at the University of Wisconsin in 1886, from which he graduated four years later with distinction, membership in Phi Beta Kappa, and one of four available graduate fellowships. His interest in astronomy did not begin until his second year at Wisconsin, and was heightened when he was given a room at the Washburn Observatory, for which he paid by working as an Assistant in the dome and helping with the time-service operation. His expertise in astronomy developed quickly under the guidance of George Comstock, who at the time was Director of the Observatory.

After graduating, an opportunity to visit his brother in California in 1891 sparked Townley's interest in Lick Observatory. Comstock provided a letter of introduction to Holden, and Townley was very impressed by the tour that Holden provided. When it came time to consider Ph.D. programmes, Townley applied to Lick Observatory and Harvard University, but he was successful in receiving an offer only from Lick (Osterbrock *et al.*, 1988:178-79). Following the loss of this Fellowship in 1893, Townley relocated to Ann Arbor to pursue graduate studies while teaching astronomy to undergraduates.

When he was a student at the University of Wisconsin, Townley started the tradition of keeping a detailed diary, to record his thoughts on everything from daily life to prohibition (Townley, 1940). At Detroit Observatory, he kept logbooks with the same regularity, and these contain a comparable level of detail (Townley, n.d.). He became widely recognized for his editorial skills, and served as editor of several scholarly journals, including the *Bulletin of the Seismological Society of America* and the *Publications of the Astronomical Society of the Pacific* (Aitken, 1946:195). During his career, he published more than 100 research papers on practical astronomy, variable stars, latitude variations, earthquakes, and other topics. He was also a photographer, and the photo albums he kept while in Ann Arbor are today an invaluable historical resource for those studying the town and the campus.[13] His research at Detroit Observatory from 1893 to 1898 was on variable stars and comets using the 32.1-cm Fitz telescope, but he also employed the meridian circle. His notebooks give an indication of the influence of his mentors, because he mentions the use of "Schaeberle's method" and refers to the sections of Brünnow's *Spherical Astronomy* that cover differential refraction.

In 1896, Townley took a one-year leave from Michigan to study in Germany, travelling to Berlin, Leipzig, and Munich, which were locations of major observatories. Upon his return to Ann Arbor, he taught astronomy for two more years, and received his Sc.D. degree from Michigan in 1897 for a dissertation on the "Orbit of Psyche." At this time, he accepted an offer to teach at the University of California-Berkeley under Armin Leuschner (see Osterbrock, 2003), which led to his appointment as Director of the International Latitude Station at Ukiah, California, from 1903 to 1907. His work at Ukiah directed his attention to the study of geodesy, and particularly seismology – following the 1906 California earthquake. In 1907, Townley relocated to Stanford University where he moved up the professorial ranks from Assistant to full Professor by 1918. His appointment at Stanford continued until his (mandatory) retirement in 1932 at age sixty-five, although he remained an active observer. He died in Stanford on 1946 March 18 at the age of seventy-nine.

16 CONCLUSION

Science and technology advanced at a rapid pace during the nineteenth century. University of Michigan President, Henry Tappan, was prescient in his understanding of the times and the role he envisioned for higher education. He believed that the advancement of science and technology for national prosperity and the betterment of society could best be achieved through intellectual cultivation. At his inaugural speech, he said:

> We aim not merely to equal, but even to surpass the old nations of the world, in our manufactures, our steamboats, and our railroads. We level the forests in a day, lay down our tracks, and startle the old world with the sounds of our engines ... substantial railroads in every direction ... lead the astonished traveler through villages, towns and cities, which have sprung up by the magic of that industry whose divine mission it is to change the wilderness into fruitful fields ... Let us make men as well a houses and railroads. Let us have eternal thoughts circulating among us as well as gold and silver. (Tappan, 1852:51).

The 'friends of science' in Detroit respected Tappan's vision and supported it, and Tappan acknowledged their financial support by naming the observatory after their city. Tappan's Detroit Observatory was the best-equipped observatory in the nation, and the recruitment of Franz Brünnow offered American students the most advanced instruction in astronomy available in America. Brünnow's appointment as the first foreign Director of an American observatory also served to heighten awareness in Michigan that prejudice against foreigners was unfounded.

Detroit Observatory contributed to the education of many of the nation's most accomplished nineteenth-century astronomers, surveyors, meteorologists, mathematicians, and physicists. It also impacted on generations of students who followed other career paths. The influence imparted by Detroit Observatory on young minds during the nineteenth century persisted for decades to follow. Evidence of this is found in the letters students wrote the University on the occasion of their class reunions. Robert Woodward, graduate of the Class of 1872, who became a distinguished geophysicist and President of the Carnegie Institution, identified the Faculty as the most important influence on University of Michigan students. He wrote:

> Some of us are old enough, also, to remember the wonderful material and intellectual progress made during the last forty years, since the graduation of the class of 1872, and how favorable have been the circumstances for the great development of this University, taking part as it has in the progress of the nineteenth century. It has been asserted that greater progress was made in that century by our race than in all previous history. But the greatest of all the influences behind the University is to be found in the great men [and women] among its Faculties. (University of Michigan, 1915:136).

Detroit Observatory stands today as a physical legacy of Henry Tappan's vision for higher education, and as a nearly perfectly-preserved nineteenth-century scientific laboratory. The historical telescopes and interpretative exhibits inform visitors about the scientific research performed by University of Michigan Faculty, and the quality of the training they offered to students.

17 ACKNOWLEDGEMENTS

I am grateful to John Perdrix and Dr Wayne Orchiston for making possible this special issue of the *Journal of Astronomical History and Heritage*, which celebrates the University of Michigan Detroit Observatory's sesquicentennial in 2004. I also thank the invited contributors, Drs Don Osterbrock and Rudi Lindner, for their papers on twentieth-century astronomers trained at Detroit Observatory. I greatly appreciate the support of University of Michigan Provost, Paul Courant, and Associate Provost, Janet Weiss, who champion Detroit Observatory, and Drs Homer Neal, James Duderstadt, and Fred Neidhardt, and Mrs Anne Duderstadt, who championed the restoration. And, I thank the University of Michigan Libraries for access to their wealth of information: the Bentley Historical Library (especially Karen Jania, Malgorzata Myc, and Kerry Connole), Jo Keller of the Public Health Library, and Carol McKendry and her staff at Buhr Library. In addition, I am grateful to the Mary Lea Shane Archives of the Lick Observatory and the Smithsonian Institution Archives for information and images. I am indebted to University of Michigan Faculty Drs Edward Voss, John Dann, and the late Russell Bidlack; Dr Marsha Ackermann, Eastern Michigan University; Dr David Schwab, National Oceanographic and Atmospheric Administration; Leonard Walle; Julie Truettner; Gerald Rees; Robert Schaeberle and Bernd Schlanderer, ancestors of Martin Schaeberle; Robert Keith, ancestor of Orlando Wheeler; and Karen Wight for technical assistance with the images. I dedicate this article to the late John R Hathaway for launching the successful effort in the 1970s to save Detroit Observatory from demolition, and to his family, who carry forward his dedication to the preservation of Detroit Observatory. And, I salute with profound respect the contributions of Henry Tappan and Franz Brünnow in creating Detroit Observatory in 1854, and James Watson for carrying forward the foundation they built. The opportunity to explore the minds and preserve the legacy of such notable personalities is a distinct privilege.

18 NOTES

1. The Ann Arbor meridian circle's original equipment survives complete, with the exception of its parasol and reflex basin, three of its microscopes, and its two collimating telescopes (replicas were made in 1997), which were stolen in the 1980s.
2. The author identified the location of these meridian circle telescopes in 1997, and has inspected the instruments at New York State Museum, Boerhaave Museum, and the Steno Museet. For their kind assistance, thanks are extended to Nancy Langford, Dudley Observatory and Geoffrey Stein, New York State Museum; Dr Steven Dick and Brenda Corbin, U.S. Naval Observatory; Dr George Greenstein, Amherst College; Dr Ian Elliott, Dunsink Observatory; Dr Rob van Gent, Boerhaave Museum; Dr Gerhard Hartl, Deutsches Museum; Dr Hans Buhl, Steno Museet; Jörg Zaun, Technische Universität Berlin; Dr Ileana Chinnici, Palermo Observatory, and Dr Paolo Brenni, University of Florence.
3. The restoration of Detroit Observatory (1994–1998) received the following awards: Award of Honour, American Institute of Architects-Michigan; Award of Merit, American Association for State and Local History; Preservation Award, Michigan Historic Preservation Network; Preservation Project of the Year, Historic District Commission, City of Ann Arbor, Michigan; Certificate of Recognition, University of Michigan History and Traditions Committee; Pyramid Award for Best Restoration Project Team, Washtenaw Contractors Association-Michigan.
4. This biographical sketch of Watson is an edited version of Chapter 11 of the author's book, *A Creation of His Own: Tappan's Detroit Observatory* (Whitesell, 1998). The author has in progress a full-length biography of Watson, preliminarily titled, *Michigan's Astronomer Royal, James Craig Watson, 1838-1880.*
5. Watson's personal copy of this book is now held in Detroit Observatory's collections. The book was given to Martin Schaeberle by Mrs Watson after Watson's death, then passed to Schaeberle's nephew, then returned to the Observatory library during W J Hussey's Directorship, and recently returned to the Observatory by the University of Michigan Libraries at the request of the author.
6. The Van Vleck Observatory at Wesleyan University is named after John Van Vleck.
7. E C Pickering went on to become Director of Harvard College Observatory in 1877.
8. Henry Morton became the inaugural President of the Stevens Institute of Technology at Hoboken, New Jersey.
9. The "class of six" included Snyder, Otto Klotz and Robert Woodward. Snyder could not recall the names of the others.
10. Data were compiled by the author from (Comstock, 1882:45-47) and (University of Michigan, 1923).
11. Many of Harrington's meteorological instruments and weather records have survived, and are in the Detroit Observatory's collections.
12. Bigelow's death date is erroneously reported as 1934 June 29 in *Publications of the Astronomical Society of the Pacific*, **46**:242 (1934).
13. Townley's photograph albums containing images he took while a student in Ann Arbor are held at the Bentley Historical Library, University of Michigan.

19 REFERENCES

The following references were consulted with such frequency that they are not routinely cited throughout the research paper:

Appleton's Cyclopaedia of American Biography. Appleton & Company, New York (1889).

Biographical Dictionary of American Science. Greenwood Press, Westport (1979).

Dictionary of Scientific Biography. Charles Scribner, New York (1970).

Hinsdale, Burke A., 1906. *History of the University of Michigan*. University of Michigan, Ann Arbor.

National Academy of Sciences. *Biographical Memoirs*.

National Cyclopaedia of American Biography. White & Company, New York (1893).

Tuttle, Charles R., 1873. *General History of the State of Michigan: With Biographical Sketches, Portrait Engravings, and Numerous Illustrations*. Tyler & Co, Detroit.

University of Michigan, 1923. *Alumni Catalogue of the University of Michigan 1837-1921*. University of Michigan, Ann Arbor, Michigan.

University of Michigan. Class Records. Bentley Historical Library, University of Michigan.

University of Michigan, 1958. *Encyclopedic Survey*, I-IV.

University of Michigan. *Michigan Alumnus*. University of Michigan.

University of Michigan. *Michigan University Book*. Richmond, Backus & Company, Detroit.

University of Michigan, 1837–1915. *Proceedings of the Board of Regents* (various volumes).

Aitken, Robert G., 1946. Sidney Dean Townley, 1867-1946. *Publications of the Astronomical Society of the Pacific* **58**:193-195.

American Journal of Science, **21**:65-80 (1881).

Anderson, William D., 1854. Letter to Hamilton Higginson, dated August 2. William D. Anderson Papers. Bentley Historical Library, University of Michigan.

At Israel's home. *New York Times*, July 18 (1884).

Attaway, Doris E., and Barritt, Marjorie Rabe, 2000. Women's Voices: Early Years at the University of Michigan. Bentley Historical Library, University of Michigan.

Balloon party missed comet. *New York Times*, May 22 (1910).

Baum, Richard, and Sheehan, William, 1997. *In Search of Planet Vulcan*. Plenum Press, New York.

Beakes, Samuel W., 1906. *Past and Present of Washtenaw County Michigan*. Clarke Publishing Co, Chicago.

Berton, Pierre, 2000. *Arctic Grail*. Lyons Press, New York.

Bidlack, Russell E., and Cooley, Everett L. (eds), 1966. The Kintner letters: an astronomer's account of the Wheeler Survey in Utah and Idaho. *Utah Historical Quarterly* **34**:62-80, 169-182.

Bless, Robert C., 1978. *Washburn Observatory 1878-1978*. University of Wisconsin, Madison.

Bruce, Robert V., 1987. *Launching of Modern American Science 1846-1876*. Alfred A. Knopf, New York.

Brünnow, Franz F.E., 1849. *Mémoire sur la comète elliptique de Vico*. C. G. Sulpke, Amsterdam.

Brünnow, Franz F.E., 1861. Determination of the longitude of Ann Arbor by telegraphic method. *Astronomical Notices* **27**:17-18.

Buell, Mahlon H., 1962. Some Remarks on the Teaching of Physics in Ann Arbor High School, 1873-1958. A paper presented at the Physics-Chemistry-Astronomy Conference of the Michigan Schoolmasters' Club in Ann Arbor, May 11.

Byrd, Mary E., 1904. Anna Winlock. *Popular Astronomy* **12**:254.

Byrd, Mary E., 1914. *First Observations in Astronomy*. Rumford Press, Concord.

Carter, Charles S. (ed), 1921. *History of the Class of '70*. Published by the Class.

Chute, Horatio N., n.d. Unattributed and undated newspaper clipping. DB Vertical File, Bentley Historical Library, University of Michigan.

Cincinnati Historical Society, 1944. *Centenary of the Cincinnati Observatory, November 5, 1943*. Cincinnati.

Comstock, George C., 1882. *Report Upon the Primary Triangulation of the United States Lake Survey*. Government Printing Office, Washington, DC.

Comstock, George C., 1888. Biographical memoir of James Craig. *The Sidereal Messenger* **7**:273-286.

Cooley, Mortimer E., 1947. *Scientific Blacksmith*. University of Michigan Press, Ann Arbor.

Courant, Paul N., 2003. Why Liberal Education Endures in the World of the Bottom Line. Alumni Collection Address, Swarthmore College, June 7.

Cyclopedia of Michigan: Historical and Biographical. Western Publishing and Engraving Co., New York and Detroit (1890).

Dall, William H., 1871. Letter to James C Watson, dated April 23. In James C. Watson papers, Box 1, Correspondence 1871. Bentley Historical Library, University of Michigan.

Dall, William H., 1904. Marcus Baker. *National Geographic Magazine* **15**(1):40-43.

Darling, John H., 1942. Meteors and the Moon's surface. *Popular Astronomy* **50**:169.

Dick, S.J., Orchiston, W., and Love, T., 1998. Simon Newcomb, William Harkness, and the nineteenth-century American transit of Venus expeditions. *Journal for the History of Astronomy* **29**:221-255.

Donnelly, M.C., 1972. *A Short History of Observatories*. University of Oregon Press, Eugene.

Dr Byrd at Normal. *New York Times*, March 30 (1913).

Duff, Lela, 1956. Ann Arbor High School in its earliest days: Fire-and the Phoenix. *Ann Arbor News*, October 17.

Duff, Lela, 1958. *The Pioneer School. Some Chapters in the Story of Ann Arbor High School*. L. Duff, Ann Arbor.

Elliott, Clark A., 1996. *History of Science in the United States: A Chronology and Research Guide*. Garland, New York.

Emigration document dated 1854 April 29. In Oeschelbronn Archives, Germany (sent to the author courtesy of Bernd Schlanderer).

Farmer, Silas, 1884. *The History of Detroit and Michigan*. Silas Farmer & Co., Detroit.

Fath, E.A., 1928. William Wallace Payne. *Popular Astronomy* **36**:267-270.

Gingrich, Curvin H., 1942. John H. Darling, 1847-1942. *Popular Astronomy* **50**:533-535.

Greathouse, Mary M. Curtis, 1925 (UM BA '82; AM '83). Letter from Rosslyn, Virginia to Michigan Alumnus Magazine, dated May 2. Bentley Historical Library, University of Michigan.

Greely, Adolphus, W., 1888. *Report of the Proceedings of the United States Expedition to Lady Franklin Bay, Grinnell Land. I*. Washington, DC.

Green, Lewis, 1982. *Boundary Hunters: Surveying the 141st Meridian and the Alaska Panhandle*. University of British Columbia Press, Vancouver.

Green, Samuel Sharpless, 1871. Letter dated 1871 May 28 to James Watson. James C. Watson papers, Box 1, Correspondence 1871, Bentley Historical Library, University of Michigan.

History of Livingston County Michigan. Everts & Abbott, Philadelphia (1880).

Hoblit, Louise Barber, 1934. Mary E. Byrd. *Popular Astronomy* **42**:496-498.

Jarrell, Richard A., 1988. *The Cold Light of Dawn: A History of Canadian Astronomy*. University of Toronto Press, Toronto, Ontario, Canada.

Jones, Bessie Z. and Boyd, Lyle G., 1971. *The Harvard College Observatory: The First Four Directorships, 1839-1919*. Belknap Press, Cambridge, Massachusetts.

Jones, Kenneth L., 1978. Mark Walrod Harrington (1848-1926): botanist, astronomer, meteorologist ... *Michigan Academician* **11**:115-137.

Kintner, Charles J., 1876. The Observatory. *Ann Arbor Register*, May 31.

Loomis, Elias, 1874a. Observatories in the United States–I. *Harper's New Monthly Magazine* **48**:25-52.

Loomis, Elias, 1874b. Observatories in the United States–II. *Harper's New Monthly Magazine* **49**:518-531.

Memorial of Robert Simpson Woodward. *Bulletin of the Geological Society of America* **37**:115-134 (1926).

Michigan Alumnus **3**:45 (1896).

Michigan Alumnus **9**:419 (1903).

Obituary: Franz F.E. Brünnow. *Monthly Notices of the Royal Astronomical Society*, 1892. **52**:230.

National Cyclopaedia of American Biography, 1893 **22**:287-288.

Obituary: Monroe B. Snyder. *Monthly Notices of the Royal Astronomical Society* **93**:231-232 (1933).

Osterbrock, Donald E., 2003. The California-Michigan axis in American astronomy. *Journal of Astronomical History and Heritage* **6**:120-136.

Osterbrock, Donald E., Gustafson, John R., and Unruh, W.J. Shiloh, 1988. *Eye on the Sky: Lick Observatory's First Century*. University of California Press, Berkeley.

Payne, William W., 1881. Time service of Carleton College Observatory, at Northfield, Minnesota. *Science* **2**:445.

Reed, Helen Leah, 1892. Women's work at the Harvard Observatory. *New England Magazine* **12**:165-177.

Reichel, Max, 1959. Der astronom John Martin Schaeberle. *Aus Schönbuch und Bäu* **11**:2.

Rudolph, Frederick, 1962. *The American College and University: A History*. Vintage Books, New York.

Russell, John A., 1927. *Germanic Influence in the Making of Michigan*. University of Detroit. Detroit.

Schaeberle, J. Martin, 1877. Letter to his brother Fred. Robert Martin Schaeberle, dated 9 December. Original in possession of the author.

Schaeberle, J. Martin, 1898. Letter to the Editor. *Popular Astronomy* **6**:254.

Scholarly man's plight. Ex-Chief Harrington of the Weather Bureau is looking for manual labor in Chicago *New York Times*, May 30 (1902).

Schwab, David, 2003. Personal communication with the author (May).

Seen through a hazy sky. *New York Times*, December 7 (1882).

"Tainted" money at Smith. *New York Times*, May 17 (1906).

Tappan, Henry P., 1852. *A Discourse, Delivered by Henry P. Tappan*. University of Michigan, Ann Arbor.

Thwing, Charles F., 1895. What becomes of College women. *North American Review* **161**:546-561.

Townley, Sidney D., n.d. Observer's Notebook. Observatory Records, Box 13, Bentley Historical Library, University of Michigan.

Townley, Sidney D., 1939. Diary of a student of the University of Wisconisn, 1886 to 1892. Stanford University.

Tucker, Richard H., 1919. Charles Leander Doolittle. *Astronomical Society of the Pacific* **31**:103-104.

Tucker, Richard H., 1924. John Martin Schaeberle: an appreciation. *Publications of the Astronomical Society of the Pacific* **36**:312-313.

University of Michigan, 1870a. Class Records 1870. Unattributed Clippings, Box 13, Folder 1870, Bentley Historical Library, University of Michigan.

University of Michigan, 1870b. Class of 1870, specimen drawings. Bentley Historical Library, University of Michigan.

University of Michigan, 1872a Class of 1872 Records. Class notes submitted by Monroe B. Snyder. Bentley Historical Library, University of Michigan.

University of Michigan, 1872b. Class of 1872, Fiftieth Anniversary. Bentley Historical Library, University of Michigan.

University of Michigan, 1874. *The Chronicle*, V, September 1873–June 1874. Ann Arbor, Michigan.

University of Michigan, 1878. 1878 Class Album, margin note. Bentley Historical Library, University of Michigan.

University of Michigan, 1912. Class of 1872, Fortieth Anniversary 1912. Bentley Historical Library, University of Michigan.

University of Michigan, 1915. Class note by Robert S. Woodward. Memorial of the Seventy-Fifth Anniversary of the Founding of the University of Michigan. University of Michigan, Ann Arbor.

University of Michigan, 1958a. Encyclopedic Survey, II. Ann Arbor, Michigan.

University of Michigan, 1958b. Encyclopedic Survey IV. Ann Arbor, Michigan.

Voss, Edward G., 1978. *Botanical Beachcombers and Explorers: Pioneers of the 19th Century In the Upper Great Lakes*. Ann Arbor (Michigan Contributions from the University of Michigan Herbarium, 13).

Watson, James C., 1861. Letter from James C. Watson to Lte Gillis, dated September 16. James C. Watson Papers, Box 1, Correspondence 1861, University of Michigan, Bentley Historical Library.

Watson, James C., 1871. Telegram from Watson to C.F. Hall, dated May 19. James C. Watson papers, Box 1, Correspondence 1871, Bentley Historical Library, University of Michigan.

Watson, James C., 1873a. Letter from Watson to William H. Dall, dated February 29. Smithsonian Institution Archives.

Watson, James C., 1873b. Letter from Watson to J.E. Hilgard, dated December 26. James C. Watson papers, Box 1, Correspondence 1873, Bentley Historical Library, University of Michigan.

Watson, James C., 1873c. Two-page legal agreement signed by A.W. Chase, dated August 1. James C. Watson Papers, Box 1, Correspondence 1873, Bentley Historical Library, University of Michigan,

Watson, James C., 1876. Letter from E.W. Hilgard to Watson, dated February 23. James C. Watson Papers, Box 1, Correspondence 1876, Bentley Historical Library, University of Michigan.

Watson, James C., 1877. Letter from Joseph Henry to Watson, dated July 13. James C. Watson Papers, Box 1, Correspondence 1877, Bentley Historical Library, University of Michigan.

Watson, James C., 1880. Letter from Watson to R.S. Floyd, dated August 24. Mary Lea Shane Archives of the Lick Observatory, University of California, Santa Cruz.

Watson, James C., 1881. Letter from Andrew D. White to Henry S. Frieze, dated January 2. James C. Watson Papers, Box 1, Correspondence 1881, Bentley Historical Library, University of Michigan.

Watson, James C., n.d.. Jotting Book. James C. Watson Papers, University of Michigan, Bentley Historical Library.

White, Andrew Dickson, 1905. *Autobiography of Andrew Dickson White, Volume 2*. Century Co, New York.

Whitesell, Patricia S., 1998. *A Creation of His Own: Tappan's Detroit Observatory*. University of Michigan Press, Ann Arbor.

Whitesell, Patricia S., 2000. Nineteenth-Century Longitude Determinations in the Great Lakes Region: Government-University Collaborations. *Journal of Astronomical History and Heritage* **3**:131-157.

Will view comet from balloon. *New York Times*, May 20 (1910).

Williams, Marjorie, 1934. Harriet W. Bigelow. *Popular Astronomy* **42**:434-437.

Woodward, Robert S., 1917. Letter to Edwin A. Ayer, dated February 7. Class of 1872 Records, Correspondence from Robert S. Woodward, Bentley Historical Library, University of Michigan.

Wright, Fred E., 1926. Memorial of Robert Simpson Woodward. *Bulletin of the Geological Society of America* **37**:115-134.

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Journal of Astronomical History and Heritage 6(2):107-119 2003

Rebuilding astronomy at Michigan: from Hussey to Goldberg

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"... few and far between were the minds keen enough to perceive, and brave enough to insist, that the study of the observed fact must come first, with time-honored theories a weightless second." (Curtis, 1912:568).

Abstract
The University of Michigan astronomy programme, in research and teaching, was in terrible shape when W J Hussey returned to revive it in 1905. With support from the administration and an old friend, Hussey built a new, astrophysical observatory and planned a southern station to pursue his double star campaign. His successor, Ralph Hamilton Curtiss, developed a school of astronomical spectroscopy and saw the southern station, the Lamont-Hussey Observatory, in full operation. After Ralph Curtiss's early death, Heber Curtis continued, nurtured the McMath-Hulbert Observatory and wedded it to the University, and obtained the pyrex disc for a 2.49-m (98-inch) reflector. The Great Depression deprived the Ann Arbor pogamme of its momentum, but after World War II a new Director, Leo Goldberg, made the Department a formidable presence in American astronomical research and training.

Keywords: *Detroit Observatory, Lamont-Hussey Observatory, McMath-Hulbert Observatory, University of Michigan, W J Hussey, R H Curtiss, R Rossiter, D McLaughlin, H Losh, H D Curtis, R McMath, L Goldberg*

1 INTRODUCTION

Astronomy in a cloudy climate! This was not the most immediate need of a financially-pressed university administration, but it is nevertheless what the University of Michigan accomplished in the twentieth century. This is the story of the birth, growth, and maturity of the programme, from meagre beginnings and against great odds, both natural and human.

At the beginning of the century the Ann Arbor astronomy programme, based on the old 32.1-cm (12.625-inch) Fitz refractor and the 'Walker' meridian circle, was moribund. The Detroit Observatory was an historical curiosity, without pogamme or future promise. An outside review of work done by its Director, Asaph Hall Jr., with the meridian circle, a classic instrument of the older astronomy, was equivocal at best (Anonymous, 1904). Other observatories with large Fitz refractors had found it profitable to have the objective lenses refigured by the Clark firm, which had produced the much larger objectives for America's great observatories of the gilded age, Lick and Yerkes. The Fitz telescope's wooden tube, rigid enough for visual observations, rendered the instrument unfit for photography or spectroscopy, basic tools of the 'new astronomy'. Once the third largest telescope in constant use (see Whitesell, 2003), it now ranked nineteenth in size among US educational institutions.

As for the educational mission of the Observatory, one observer could look back and claim that "From Michigan have come, as is not so well known, one-fourth of our most distinguished astronomers ..." (Hussey, 1921). A number of them had become practitioners of the 'new astronomy', the most eminent at that time being Wallace Campbell, Director of the Lick Observatory. However, none of them had received training in photography or spectroscopy at Michigan, where the older positional astronomy ruled supreme and where there was neither spectrograph nor photographic apparatus. With the passage of time and lack of interest in astrophysics, Michigan had lost its position as a school for future astronomers.

2 W J HUSSEY AND THE ASTROPHYSICAL REVIVAL

The Michigan Regents sought someone to revive the field, and they looked to the Lick Observatory, where so many Michigan graduates had worked (Osterbrock, 2003). After 1898, when J M Schaeberle resigned his post at Lick and returned to Ann Arbor as a private citizen, he was available as counsel, but the Regents needed little advice, for two Michigan men had already made names for themselves at Lick, Wallace Campbell and William Joseph Hussey. Hussey had led the revolt that resulted in the ousting of Lick's first Director, Edward Holden, but as a scientist he was making a name for himself through his surveys and discoveries of double stars. Binary stars were much more central to astronomical research then than they are today, because their orbits provided an excellent way of determining stellar masses, which proved central to the study of stellar evolution. Campbell had rapidly become a leading figure in stellar spectroscopy, with a well-defined radial velocity programme and an enormous amount of energy. When Director James Keeler died tragically in 1900, all the outside referees agreed that Campbell was the man to direct the fortunes of the Lick Observatory. So when the Michigan Regents tried to lure him back to Ann Arbor he would have none of it: he had the equipment and climate that he needed, and was unwilling to leave behind the advantages of the great mountain observatory.

Hussey (Figure 1), however, was not in the same boat. His wife had old and close Michigan connections, and while she enjoyed the natural attractions of life on Mount Hamilton she knew that raising two young children there would prove difficult. Hussey, meanwhile, had directorial ambitions, and had already been in contact with the authorities at Stanford University in the hope of heading an observatory on their campus. He also felt that there was a real challenge in Ann Arbor: the challenge of doing good astronomy in an urban setting. 'Good astronomy' meant not only observing and research but also teaching, and teaching more than a very few graduate students was an impossibility at Lick. He believed that it was possible to have a productive research and teaching establishment near a university campus. As an engineering graduate of Michigan (in 1889), Hussey knew that astronomy was a required course in the engineering curriculum, so that many potential students were guaranteed from that side of the campus, and he thought it possible to raise interest in the letters college as well. His ideas and the wishes of the Regents were congruent. Hussey's value as a consultant also became clear when the Carnegie Institution had him survey sites in southern California, including Mount Wilson and Mount Palomar.

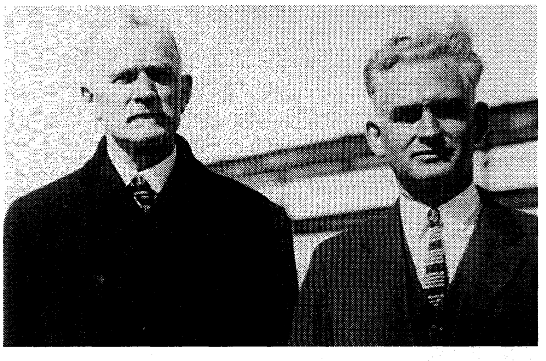

Figure 1. W J Hussey and R A Rossiter *en route* to England in1926 (Courtesy: Michigan Historical Collections, Bentley Library, The University of Michigan).

Levi Barbour, the Regent most concerned with the fate of the Detroit Observatory, was in contact with Hussey, and we can obtain a clear idea of Hussey's notions from a report he presented to Barbour in early 1904, probably in response to a feeler about his interest in the Ann Arbor Directorship. From it we can see that Hussey was by no means a disinterested party. He began by denigrating the existing equipment, and in particular the wooden tube and imperfect quality of the Fitz refractor. These rendered it impossible to teach astrophysics, or to undertake modern lines of research. For "... advanced instruction and extended investigations ..." it would be necessary to add powerful instruments to the Observatory. Hussey recommended that these additional instruments be a large refracting telescope, between twenty-four and thirty inches in aperture, a large reflecting telescope, between thirty and thirty-six inches in aperture, and a photographic refractor of ten inches aperture. Auxiliary equipment not then part of the Observatory apparatus would be necessary as well, in particular a spectroscopic outfit and a photometer. Beyond the equipment, it would also be necessary to set up an Observatory shop for the construction and repair of instruments, much like the model shop at Yerkes Observatory or the smaller one at Lick. The largest expense would be for the refractor, and the entire outfit, telescopes and domes, would cost $100,000 (Hussey, 1904).

Hussey appears to have had in mind the creation of a mountain observatory in the Ann Arbor setting, with the hope that the sacrifice in observing conditions would be more than met by the opportunity to render the observatory a powerful teaching institution with close links to the University. It would be like the Lick Observatory in many ways. First, there would be a large refracting telescope, and while Hussey did not spell out its research programme, he was very interested in prosecuting an organized survey for new double stars, for which he and Robert Aitken had used Lick's two refractors. Edward Emerson Barnard's wide-field photographs of the Milky Way, first with the Willard lens and later with the Bruce photographic refractor, had a profound impact on professional astronomers and proved the usefulness of such an instrument in the years before the invention of the Schmidt telescope. The large reflector would be a brother to Lick's Crossley reflector, which Hussey had once reviled but which, in the hands of James Keeler, had become a powerful research instrument well suited to photography (and, a few years later, nebular spectroscopy).

In less than a year the Regents reached an agreement, based upon an incremental building programme, and the Hussey era at Michigan began in the fall of 1905. In November he approached the Regents to request $28,750 for a 91.4-cm (36-inch) reflector and $34,000 for a 61-cm (24-inch) refractor, optics and mounting, as well as funds to enlarge the Observatory's machine shop (Hussey, 1905). By this time he appears to have settled on a much larger refractor than initially planned (one suited to pursue the search for double stars that he and Aitken had begun at Lick), a big reflector, for direct photography and spectrographic observations, and a solar tower telescope. For these he trusted the Ann Arbor site, still a distance north-east of the main campus, but he understood that not all the funds would be forthcoming at once. The big refractors of his time had been the gifts of wealthy donors, and George Ellery Hale had demonstrated just how an enthusiastic, determined, and skilled entrepreneur might win over the hearts of the wealthy (Osterbrock, 1997: 8-23, 42). Hussey had come from a farming family, but while a student at Michigan had befriended Robert Patterson Lamont, another engineering student (1891) and fellow boarder at 5 Packard Road, Ann Arbor. Hussey, Lamont, and a third Michigan friend, Ethel Fountain (who met Hussey again in California, and married him), remained close friends, and as Lamont's career at American Steel Foundries in Chicago took off, he did not forget his old college friends. Hussey expected to turn to Lamont, as Hale had turned to other wealthy Chicagoans. Lamont had in fact become interested in Hussey's double star campaign while visiting Lick in 1902, and they had even discussed the possibility of extending the survey to the southern hemisphere. In the meantime, the Regents approved the reflector (Figure 2), most of whose mechanical parts could be fabricated in the new Observatory shop. The contract for figuring the mirror went to the Brashear firm in Pittsburgh, while Hussey designed the mounting, which was based on Perrine's remounting of the Crossley reflector at Lick.

Hussey's training had been in engineering and the older, positional astronomy, and he lacked the basic knowledge of astrophysics that a newer generation of astronomy graduates possessed. He therefore chose his second staff member from among the recent Lick Ph.D.s, in the person of Ralph Hamilton Curtiss (Osterbrock, 2003, Rufus 1930). Curtiss (Figure 3) had completed an excellent dissertation under the direction of Wallace Campbell, in which he studied the Cepheid variable star W Sagittarii. In this dissertation he considered the radial velocity curve in terms of a spectroscopic binary system, the common interpretation of such stars at the time, and he discussed the techniques of reducing and analyzing the spectrographic plates. Curtiss then went to Allegheny Observatory, where he designed a precision spectrograph based in large part on the Mills spectrograph at Lick Observatory. Curtiss seemed ideal to Hussey, and in 1907 he arrived at Michigan and began to design the spectrograph for the new reflector.

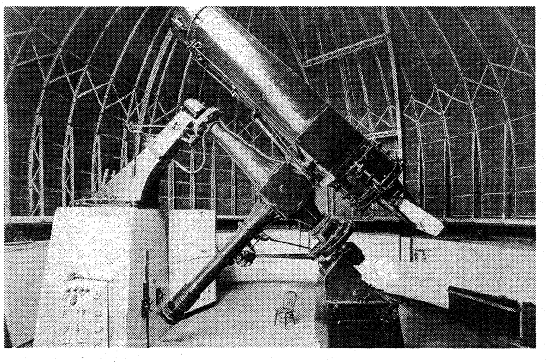

Figure 2. The 'Great Reflector' (Courtesy: Michigan Historical Collections, Bentley Library, The University of Michigan).

Hussey had thought of the revived Detroit Observatory as involving both research and teaching in a campus environment, and he worked assiduously to build interest in the field. When he arrived on campus, the enrolments in astronomy courses were about twenty students per term. Over the years he built up both undergraduate and graduate enrolments, so that by 1925 around 300 students per term were taking astronomy courses. This high student interest came at the price of what today would seem a very demanding teaching load (Rufus, 1943a: 459).

The 95.5-cm (37.5-inch) reflector went into service on 1911 January 31, when Ralph Curtiss obtained a spectrogram of Capella, and for a few months it was the third largest operating telescope in the world. Its entire career was dedicated to stellar spectroscopy, and Curtiss, future colleagues and graduate students were able to obtain high quality, measurable, spectrograms on every possible night of good seeing. Curtiss soon discovered that he was able to obtain reliable spectra of stars of magnitude 10.5, and in half to a third of the time required for the Yerkes 1-m (40-inch) refractor the Ann Arbor 'great reflector' produced spectra of equivalent dispersion and brightness. Over the years Curtiss found himself with a backlog of spectrograms to measure and reduce, and the combination of his teaching load, lack of assistants to reduce the observations, and puritan sense of duty rendered him far less productive at publishing research results than, for example, Otto Struve, the hard-driving Director of Yerkes Observatory.

The research programme directed by Curtiss fitted the possibilities of the Ann Arbor equipment well. His one-prism spectrograph had a relatively low dispersion, which suited stars of high luminosity with broad emission lines in their spectra. The natural candidates for observation were those bright, 'early type' B stars now known as Be stars. Over the years, the construction of a power plant, dormitories and the University hospital near the Observatory limited the usefulness of the 'great reflector', but improvements in photographic techniques, the aluminizing of the mirror in 1936, and improved emulsions, kept the telescope productive until 1974.

Soon after the reflector came into service, Curtiss began directing a series of doctoral dissertations from students who came, for the most part, from the Midwest, and whose later careers involved teaching at nearby colleges and small universities. Almost all of these dissertations were spectroscopic studies of peculiar stars: Zeta Ursae Majoris (Mizar), Beta Cephei (a Beta Canis Majoris variable), Beta Lyrae, S Sagittae (a Cepheid variable), Zeta Tauri and Phi Persei (both intriguing shell stars), Pi Aquilae (a star with violent atmospheric motions), Upsilon Sagittarii (a helium-rich star with a peculiar spectrum), and P Cygni (a star with an expanding envelope that displayed motions through absorption features at the violet edge of emission lines), all objects with much to offer students interested in the various stages of stellar evolution. These dissertations, which normally appeared in the *Publications of the Observatory of the University of Michigan*, presented the data carefully, and offered suggestions as to the interpretation of the absorption and emission line features.

Figure 3. Ralph Hamilton Curtiss (Courtesy: Michigan Historical Collections, Bentley Library, The University of Michigan).

What they lacked, and this was common for the era, was a theoretical framework setting these stars in a wider setting, either of stellar evolution or of energy production in the stellar interior. After

Eddington's publication of the mass-luminosity relationship in 1924, even the earlier giant-dwarf evolutionary model of Russell could not be employed in such studies. In any event, although Ann Arbor students could study advanced spectroscopy with Harrison Randall and his associates in the Department of Physics after 1910, physical theory was not part of the required advanced astronomy programme (see Zorn *et al.*, 1988). Nevertheless, Curtiss's students had all spent their required nights at the reflector, they had involved themselves faithfully not only on their own programmes but also on spectrographic programmes directed by Curtiss, and they had measured and reduced their observations themselves. They were all diligent and competent at this work. Curtiss's office was close to the 95.3 cm dome, and he knew just who was observing each night, what was on their menu, and how long they remained at their task.

Hussey remained committed to the construction of a large refractor with a view to continuing his search for double stars. In 1908, Lamont (see Figure 4) told Hussey to begin the planning for a 61 cm (24-inch) telescope, and he promised to finance its construction and operation. To this end Lamont paid for improvements to the machine shop and purchased a twenty-six acre plot of land to the east of the Detroit Observatory domes and deeded it to the University on the understanding that it would be used for an observatory. From 1908 to 1933 Lamont provided over $100,000 for Hussey's dream. That dream took a desirable turn south when, in 1910, Argentinian authorities offered Hussey the Directorship of the La Plata Observatory; his former Lick associate, Charles Dillon Perrine, had been Director of the Cordoba Observatory since 1907. Hussey jumped at the chance when Acting President Hutchins made it possible for him to divide his time between directing the Michigan and La Plata programmes. From 1911 to 1916 Hussey ran both programmes and made plans to bring the large refractor south, where there was little competition in the hunt for new double stars. In the meantime, he used the old La Plata refractor to add 312 new pairs to his personal list. The collapse of the Argentine economy during World War I, and increasing difficulties with the governing authorities, brought an end to this joint project, but Hussey was now determined to place his big refractor in the southern hemisphere, perhaps in Australia, perhaps in South Africa.

Hussey's absence made it necessary to add to the Ann Arbor staff. Curtiss wanted to hire another spectroscopist, one who would take an enthusiastic part in the Michigan programme as well as in his own research (and in those days, "his" was not a formal designation). The hiring of which Curtiss was most proud was a fellow Lick alumnus, Paul Merrill (Ph.D., 1913). Merrill spent two years in Ann Arbor but chafed at the weather and the impact of the new heating plant on the seeing. He began his life-long study of Be type stars and shared Curtiss's interest in these objects, but when the U.S. entered World War I Merrill went to the National Bureau of Standards and then on to the larger telescopes and better observing conditions of Mount Wilson Observatory. His former colleagues attempted more than once to bring him back to Ann Arbor as Director, but Merrill always found a polite reason to decline.

Figure 4. Robert Lamont (Courtesy: Michigan Historical Collections, Bentley Library, The University of Michigan).

Curtiss then ended up hiring his own graduates. The first Michigan addition was Will Rufus, an Albion College graduate who had spent some time as a missionary and educator in Korea. When the Korean government seized his telescope and demoted him to high school teaching, he returned to Michigan and completed a Ph.D. in 1915. He studied the spectra of ten stars of class R, commonly known as carbon stars, and attempted to determine their correct place in the spectral sequence (Curtiss, 1932:37). This was a first-rate piece of work, and Rufus continued spectroscopic work for a time on Cepheid spectra in conjunction with Curtiss's programme. However, in the 1920s his interest turned to the history of American and Far Eastern astronomy. Rufus remained on the Michigan staff until his death in 1946.

In the early 1920s Richard Rossiter (Ph.D. 1923) joined the full-time staff. Rossiter's thesis, also directed by Curtiss, was on the extraordinary eclipsing variable Beta Lyrae. Rossiter was able to demonstrate stellar rotation in this star, thus providing proof for a suggestion made earlier by Frank Schlesinger, and it is for this work that Rossiter is best known today (Struve and Zebergs, 1962:225-226). After Rossiter left Ann Arbor for the Lamont-Hussey Observatory in South Africa, Curtiss hired two of his students, Dean McLaughlin (Ph.D., 1927) and Hazel Marie Losh (Ph.D., 1924). McLaughlin's dissertation was on Algol, and in it he also confirmed a rotational effect, while Hazel Losh studied the shell star Zeta Tauri. After completing her dissertation, Losh had become a 'computer' at Mount Wilson Observatory, but she did not enjoy the tedium of the work. Both McLaughlin and Losh spent the rest of their careers at Michigan; Losh became the best-known instructor on campus, while McLaughlin became an international figure in the study of novae as well as a long-term Secretary of the American Astronomical Society. He received an offer to work at Lick Observatory, but chose to remain in Ann Arbor, and the position at Lick went to another promising young spectroscopist, Donald Menzel.

Soon after the end of World War I the location of Detroit Observatory became untenable, partly as a result of the spread of the campus and of the growing city of Ann Arbor. The setting had become completely urbanized, with light pollution, smoke pollution, and heated air currents affecting every aspect of research: it began to seem as if every star Curtiss observed was a carbon star! Hussey and Curtiss decided to separate the teaching and research aspects of the programme and to move the research instruments out of Ann Arbor, although not out of reach. Space in a new campus building, Angell Hall, was made available for a small teaching observatory, including a 25.4-cm (10-inch) refractor, a 38.1-cm (15-inch) reflector, and a small transit instrument, all of which were available by 1929. Fifteen miles north-west of Ann Arbor, on a small ridge near Base Lake and Peach Mountain, the astronomers planned to relocate the 95.3-cm reflector, the large refractor (upon its return from the southern hemisphere), and a large new reflecting telescope, 1.9 cm (75 inch) in diameter, for which the Regents began to seek funding from the legislature.

3 THE LAMONT-HUSSEY OBSERVATORY

During these years Hussey worked to obtain his big refractor. In 1908, while visiting Chicago to test the large castings for the reflector, Hussey and Lamont attended a world championship wrestling match, during which Lamont agreed to fund the project. Hussey had plans drawn up modelled on the 66-cm (26-inch) U.S. Naval Observatory refractor, but modified somewhat in light of improvements made to the mounting for the Swarthmore College refractor. The Detroit Observatory shop had machined many of the parts by the beginning of World War I. Obtaining the glass for the objective lenses was, however, a much harder task, and to some extent the choice of lens fabricators was a function of their ability to obtain the crown and flint lens blanks. The Clark firm preferred to obtain glass from Mantois in France, but the Parisian firm was unable to cast a suitable flint disc, despite numerous attempts. The Brashear firm, in Pittsburgh, reported success with crown and flint discs bought from Schott in Jena, and suitable blanks were available by the end of 1914. However, the British blockade made it likely that the glass would not reach American shores, and Lamont was unwilling to risk their loss.

During the War, the National Bureau of Standards became concerned about the supply of optical glass and sponsored some experiments with the intent of rendering the US ultimately independent of foreign suppliers. After the war, the Spencer Lens Company in Buffalo continued these experiments, but was unable to provide large enough discs for Michigan. Finally, fifteen years after Lamont's original authorization, Schott offered crown and flint discs of 68.6 cm (27 inch) diameter, and Hussey had them shipped to Pittsburgh, where John McDowell, Brashear's son-in-law, had taken over the firm. McDowell was also busy making the 66-cm (26-inch) lenses for the Yale University southern station's parallax refractor (recently destroyed in the terrible fire at Mount Stromlo). McDowell worked on both projects steadily, completing the Yale objective first. Figuring the Michigan lenses proved a very great challenge because the work took place during the winter and the Brashear shop was partially heated, so that there were layers of air currents at different temperatures all along the test corridor, some seventy-five feet long. McDowell and his assistant, Fred Hegeman, could figure the lens for only a few minutes at a time, then wait for the objective to cool, and then interpret the test results in light of the effects of the ever-changing air currents in the testing tunnel. The strain proved too great for McDowell, and he died in the shop. This tragedy threw the firm into confusion (and ultimately into the hands of J W Fecker, who took it over), and it was only in 1925 that Hegeman was able to complete the figuring. Curtiss, Hussey, and H D Curtis, Director of the Allegheny Observatory, confirmed the results of the final shop tests in person, and in Ann Arbor Hussey set up the mounting outside the 95.3 cm dome in order to observe actual stars before accepting the lens. It had taken twenty years from first vision to the first star tests.

Lamont and Hussey considered where to place their new refractor just as soon as the lens blanks had arrived in Pittsburgh from Jena. Hussey was no longer thinking about Argentina, but he was planning to make tests in Australia. However, Lamont convinced him to try South Africa first, and in the fall of 1923 Hussey left for South Africa, where he tested sites near Johannesburg and Bloemfontein. After two months of testing with a 25.4-cm (10-inch) refractor, Hussey was very satisfied with the Bloemfontein area. A site was available at Naval Hill, within the city limits but a few miles beyond the business district, and the height of the hill placed it beyond the reach of lights and smoke. A second site, on a hill some miles out into the veldt, was more attractive for astronomical purposes, but would be more expensive to develop. Ultimately the Naval Hill site became the home for the large refractor.

Hussey was no longer a young man, and he planned to take along a team of three observers to run the southern station. Chief of them was Rossiter, who would give up his spectroscopic work. Hussey selected the two other observers from among the Michigan graduate students, and they were Henry Donner, who had briefly worked as an engineer for General Electric, and Morris Jessup, also with an engineering background but now a graduate student in the astronomy programme. While Donner and Jessup trained on double stars with the old Fitz refractor and Curtiss again became Acting Director at Ann Arbor, the Husseys and Rossiters sent the refractor off to Bloemfontein in 1926 August and themselves sailed to London in September, *en route* to South Africa. Just when his decades-long plan was about to be realized, and after describing the expedition to meetings of fellow astronomers, William Joseph Hussey collapsed at dinner and died in London on 1926 October 28. He was 64 years of age.

Hussey's achievement was to revive astronomy at Michigan, to broaden the base of undergraduate enrollment and rebuild the graduate programme, to bring astrophysics into both teaching and research, and to improve the quality of the instrumentation and staff. He never let go his dream of returning to double star research, but circumstances delayed it for too long. In turn, however, his career as a diligent and creative administrator was distinguished, and it is far from clear that this role was not actually his real pride and joy in his mature years. He also grew as a person, from the bitter and vindictive plotter against Holden at Lick to the gentle and supportive statesman whose memory his students and colleagues revered (H. Donner, pers. comm., 1989).

With Lamont's support, Rossiter sailed on to South Africa and established the Lamont-Hussey Observatory in 1927. Jessup and Donner arrived later that year, and the observing programme began in earnest in the southern autumn of 1928. Jessup spent two years in Bloemfontein and Donner five (though returning again for a brief period in 1948), but neither of them completed their graduate studies in astronomy. Jessup briefly taught astronomy at Drake University in Des Moines, took on various engineering jobs, and gained notoriety for three books on flying saucers, volumes marked by great charm of expression and somewhat less scientific insight (e.g. see Jessup, 1955). Donner earned a Ph.D. in geology at Michigan and went on to a distinguished career at Case Western Reserve University in Cleveland, where he also served as an officer in the Cleveland Astronomical Society for many years.

Hussey had originally expected the double star programmes to last six years, but Rossiter never left South Africa, observing alone from 1933 until his retirement in 1952 (see Figure 5). When the onset of the Great Depression led Lamont to end his funding of the project, Rossiter arranged for financial assistance from the city of Bloemfontein and the Union Government, until the University of Michigan was able to resume full support of the Observatory in the 1940s (Figure 6). Somehow, every time it appeared that circumstances would close the Observatory and bring the telescope and observer home, Rossiter was able to keep the project going (Rufus, 1943b). He was a valued member of the astronomical community in South Africa. During his twenty-six years of solitary hunting in Bloemfontein, he discovered 5,534 double stars, an unequalled record of discovery.

In the early 1950s, Michigan graduate student (and later astronaut) Karl Henize used the Naval Hill site for his observations of Hα regions in the southern Milky Way (Figure 7), and during the close approaches of Mars to Earth in the 1950s Earl Slipher of Lowell Observatory adapted the 68.6 cm refractor for photographic work and obtained what were, at that time, among the best photographs ever taken of the red planet. Later, Frank Holden used the telescope to follow some of Rossiter's pairs. Michigan finally closed the Lamont-Hussey Observatory in the 1970s, as a political response to the South African regime. The 68.6-cm objective is now in storage, while the Observatory building on Naval Hill has become a popular children's theatre.

4 RALPH HAMILTON CURTISS

Since Ralph Curtiss had served as Acting Director of the Detroit Observatory and Departmental Chair during Hussey's absences in Argentina and South Africa, it was only natural for the President and Dean to appoint him as Hussey's successor. He continued to teach and supervise graduate students, and with the presence of McLaughlin and Losh the basic staff was now even more focused on stellar spectroscopy. Over the years Rufus taught more and more history, while Losh took over the undergraduate courses, which brought in almost 600 students per year.

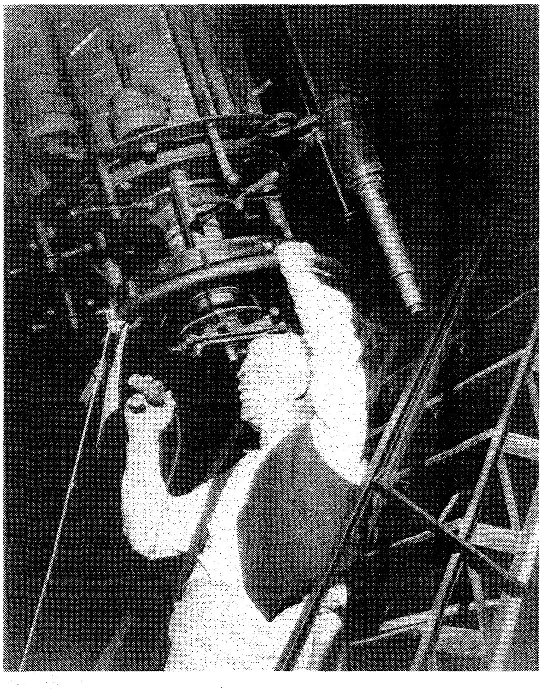

Figure 5. R A Rossiter at the eye end of the Lamont-Hussey refractor (Courtesy: Karl Henize).

Curtiss took just one sabbatical leave during his Michigan career, and he used it to visit Mount Wilson and Lick Observatories in 1925–1926, where he worked on his contribution to the *Handbuch der Astrophysik* (Curtiss, 1932). This was a remarkable synthesis of historical and scientific analysis. After a lengthy discussion of the historical background, Curtiss described the Draper classification, methods of refining the allocation of stars to various sub-classes, and issues arising from the study of line intensities. He pointed out that the problems of empirical classification had been largely resolved, while conceding that a theory connecting stellar spectra with "fundamental stellar characteristics" lay in the future. His conclusion was that future stellar classification schemes would be multi-dimensional and based upon physical principles. In this he foresaw the rise and success of the MKK system pioneered by W W Morgan at Yerkes Observatory (see Hearnshaw, 1986: 283-288).

Hussey, Curtiss, and Lamont had realized that the construction of the heating plant and the growth of the campus would require moving the research instruments to a rural site, and by the end of World War I they also recognized, as did Wallace Campbell and the Lick astronomers during the 1920s, that they needed a larger research instrument. The Base Lake site near Peach Mountain would be home not only to the returned Lamont refractor and the 95.3-cm reflector, but also to a larger, 1.83-m (72-inch) reflector, modelled after the Dominion Astrophysical Observatory telescope (Batten, 2003) that J S Plaskett and his colleagues had dedicated to spectroscopy (and whose mounting had been in part based upon the smaller Michigan reflector, thus making the planned Michigan telescope a grandchild of the Crossley reflector at Lick) (Fecker, 1927). As the Ann Arbor campus slowly but surely swallowed up the Detroit Observatory site, and as the hospital's needs grew to include the lands Lamont had deeded to the Observatory, the Regents began seeking funds for the new telescope from the state, and by 1929 the new site and Observatory comprised the most urgent University need placed before the legislature (Rufus, 1944a). However, the Great Depression struck the State revenues in that year, and a second personal tragedy struck the Observatory community when Ralph Curtiss died prematurely on 1929 December 25. He had put Ann Arbor back on the map of astronomical publication, and he had created a school of stellar spectroscopy, directing fifteen dissertations in twenty-two years. His was a programme of observational results, while theory was the province of Harrison Randall and the physicists. The Ann Arbor programme was empirical, thoroughgoing, and successful (McLaughlin, 1930).

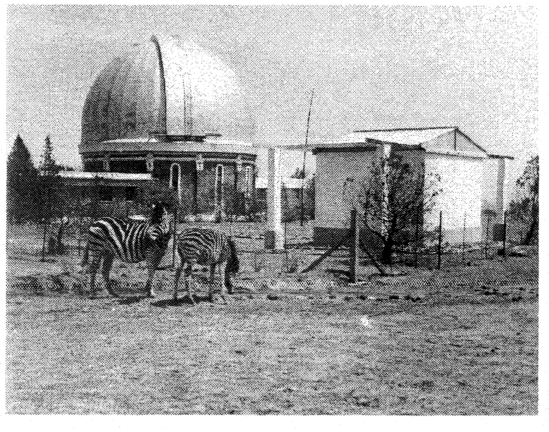

Figure 6. The Lamont-Hussey Observatory, with zebras (Courtesy: Karl Henize).

Curtiss left behind many unmeasured spectrograms and even a partially-unspent grant that would have paid for competent assistance. This fact highlights one of two persistent problems the Michigan pogamme faced in the early twentieth century (the other being money). Getting and keeping the right staff was not easy. Paul Merrill was perhaps the most promising young astronomer Curtiss and Hussey tried to keep, but Mount Wilson offered him a brighter future. Other hires did not turn out: for example, Sebastian Albrecht was an early hire, an original thinker but also a man who took little part in the assigned pogamme; Allan Maxwell came from Lick but turned from spectroscopy to theoretical astronomy (orbit calculations). Donald Shane and Frederick Leonard both came highly recommended but, in the end, refused job offers. There was an ingrained prejudice against hiring any foreign candidates, especially after the Great Depression began, but we must doubt whether Walter Baade actually would have been prepared to exchange Hamburg's weather for Ann Arbor's if offered the chance. Will Rufus turned his attention more and more to historical studies, and Hazel Losh became enmeshed in the freshman survey ("As for athletes, Bs for boys, Cs for coeds"). In the 1950s, Michigan graduate students were amazed when they consulted her dissertation on Zeta Tauri and discovered just how good it was. Her large enrollments and heroic efforts in the freshman course made it possible for others to devote themselves to graduate training. Another hire that turned out remarkably well was bringing Dean McLaughlin back from Swarthmore. In the late 1920s, Ralph Curtiss and McLaughlin were great strengths, but they were the *only* strengths in the Ann Arbor programme, and Ralph Curtiss died young.

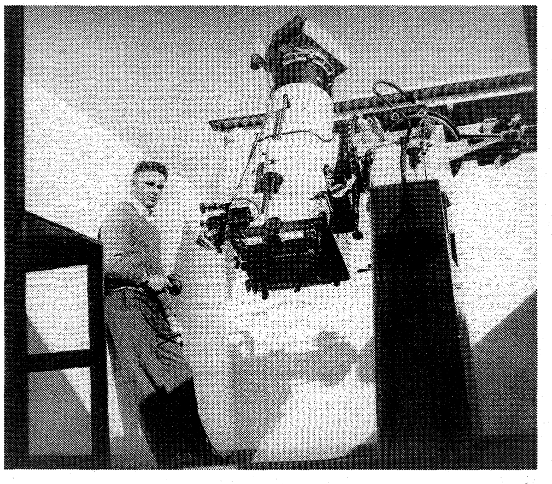

Figure 7. Karl Henize at the Lamont-Hussey Observatory (Courtesy: Karl Henize).

5 FIRST INTERREGNUM

After Curtiss's unexpected death at age 59, the Dean began a national canvass for a replacement. Paul Merrill was the recommendation of many, but he could not be lured back. A name that outside referees often mentioned was Heber Curtis (Osterbrock, 2003), a Michigan A.B. (in classics) who had completed a Ph.D. in astronomy at Virginia and went on to accomplish outstanding work at Lick Observatory on planetary nebulae and spiral nebulae. In the 'Great Debate' with Harlow Shapley, Curtis had upheld the view that spiral nebulae are external galaxies, island universes like our own, and he also believed that our Milky Way Galaxy was relatively small in size. He was right on the former point, but off the mark on the latter. In 1920, with a young family to support, he had accepted the Directorship of the Allegheny Observatory in Pittsburgh, but his research had come to an end with the poor instrumentation and mediocre climate of that industrial city.

The decade of the 1920s had seen Curtis move away from the forefront of research. Earlier in his career, he had taken an interest in Einstein's theory of relativity and had published the first paper in an astronomical American journal on the Special Theory of 1905. He kept in touch with the literature, both in German and English, and wrote further reviews of the General Theory as Einstein developed it. He took part in the abortive 1914 Lick expedition to Russia to measure the predicted displacements of stellar images near the eclipsed Sun, and he was in charge of the Einstein cameras at the Goldendale

(Washington) eclipse expedition in 1918. After a year's hard work measuring the plates and reducing the observations the results were questionable, and Curtis became an agnostic on the question. He found it impossible to accept the geometries of the various competing versions of General Relativity, and he refused to accept as definitive either the eclipse results reported by Eddington in 1919 or the more accurate results reported by Trumpler and Campbell in 1923. Curtis accepted the ether drift experimental results announced by Miller of Case Western Reserve University and the negative results for a gravitational redshift of lines in the solar spectrum reported by his Allegheny colleague and friend Keivin Burns. His involvement with an anti-Einstein rear-guard action led by Professor Poor of Columbia University did not advance his reputation, and by 1930 Curtis, no matter how well liked as a person, was no longer in the vanguard of the field.

Nevertheless, the Dean and President turned finally to Curtis after it became clear that Merrill was unavailable and that other candidates could not offer comparable administrative experience and skill using new equipment. There was no little irony in this choice, for Hussey had desperately wanted Curtis to join him in La Plata in 1911, but Curtis turned down offer after offer, confessing in the end that only such a position as Hussey's own at Michigan would entice him. When the Dean originally approached Curtis, he was not at all sure he wished to leave Pittsburgh. However, the enticements of building a new Observatory, at a better location, with a big reflector, all tilted the balance in favour of Michigan.

6 HEBER CURTIS, ANN ARBOR, AND LAKE ANGELUS

Curtis arrived in Ann Arbor in 1930 October, with great expectations, but the Great Depression was to all but dash these. Four months after his arrival, Robert Lamont, Secretary of Commerce and by now the most reviled member of Herbert Hoover's cabinet, wrote that he could no longer afford to support the Lamont-Hussey Observatory. Within the year falling state tax revenues led to severe cuts in the University budget. Curtis's own salary fell by 20%, and all plans for a new observatory had to be shelved. Here was another leitmotiv in the history of Michigan astronomy: strong financial backing turned fickle.

This is in a sense the real story behind our story. Lick Observatory had needed a larger telescope for at least a decade, but there were neither academic entrepreneurs, nor willing donors, nor wily lobbyists in a position to win it. A shrewd research strategy, such as Joel Stebbins's focus on photoelectric photometry at Illinois and then Wisconsin, could obtain support that was sufficient for a small, focused, research programme. The combination of an energetic, purposeful Director and an enthusiastic, expansive Administrator, such as the team of Otto Struve and Robert Maynard Hutchins at Chicago, could bring not only financial support but also rapid research results and the seizing of grand opportunities (the McDonald Observatory in Texas). Hussey had been able to make something of his opportunities at Michigan because he could dangle the Regents before Lamont and Lamont before the Regents. If the Regents went for the 'great reflector', Lamont would provide additional assistance in the form of the big refractor, equipment for the machine shop, land to protect the Observatory, funds to support a Belgian refugee (Paul Henroteau) for a time, and all else that the phrase 'good will' implied. However, Hussey's death loosened the tie, and the Depression severed it. The University was not the only Michigan cultural institution that suffered from a want of entrepreneurship and wealth. Neither the Detroit Institute of Arts nor the Detroit Symphony Orchestra did as well as competing institutions in Ohio and Illinois. The big money remained in the hands of the legislature, and the legislature's generosity was limited by the volatility of tax receipts, as the automobile industry contributed a greater and greater percentage of public revenues. Private donors existed, but their purses were smaller than the Observatory's needs.

Curtis's great success at Michigan came from a completely unexpected source. So far, two of Hussey's projects had come to fruition: the 95.3-cm telescope and its spectroscopic programme, and the Lamont-Hussey refractor and Rossiter's double star project. But Hussey's solar tower telescope never got under way, thanks to uncertainties about the development of the property, and the site soon became a nursing student dormitory. Instead, the solar project ended up coming to the University from outside. As Curtis put it,

> "I gambled on one of the most remarkable m[e]n I have ever met, Robert R. McMath, and have won the gamble with a $300,000 plant that is undoubtedly the best and most powerful solar observatory on the earth today… I am immensely proud of the McMath-Hulbert Observatory, the one big achievement of my rather humdrum career here." (Curtis, 1941).

In late 1924 Hussey had received a letter from Henry Hulbert, judge of the probate court in Detroit and an amateur astronomer, about means of observing the forthcoming total solar eclipse of 1925 January 24. Hussey provided some information about the path of the eclipse and the climate at various observing sites. By the date of the eclipse Hussey had joined Hulbert's party, which intended to observe and photograph the eclipse above the clouds over Geneva, New York, on board a balloon. High winds foiled the enterprise, but Hulbert and his friends, Francis McMath and his son, Robert McMath (1913 Engineering), both prosperous engineers, remained in touch with Hussey and Ralph Curtiss about their projects. In particular, the McMaths and Judge Hulbert began experimenting with cinema photography through the telescope, and they built a telescope at their private observatory at Lake Angelus, near Pontiac, Michigan. In 1929, Curtiss arranged for the Regents to appoint the trio Honorary Curators of Astronomical Observation, and Curtis, who had been a high school classmate of Judge Hulbert, urged them on. Their work became more and more advanced and their connection with the University became closer and closer, and in 1931 they decided to deed the McMath-Hulbert Observatory (as Curtis named it) to the University. Robert McMath (Figure 8), by now the driving force, became Director of the Observatory, and over the succeeding years the facility grew and added research faculty. By the end of 1941 there were 15-m (50-ft) and 22.9-m (75-ft) tower telescopes operating at Lake Angelus, with funding from the University, the McGregor Fund of Detroit (through the intervention of Judge Hulbert), and the McMaths, whose engineering and manufacturing skills aided in the development of the instrumentation.

Figure 8. Robert McMath and family with trophies (Courtesy: Michigan Historical Collections, Bentley Library, The University of Michigan).

During the first few years, the scientific work of the team received assistance from Edison Petit, seconded from Mount Wilson, and over time the McMath-Hulbert Observatory was able to photograph and measure motions in the Sun's atmosphere in the light of hydrogen and calcium through what Curtis – mindful of his classical background – dubbed the 'spectroheliokinematograph'. Curtis showed McMath-Hulbert movies at astronomical conventions, to the amazement and interest of solar astronomers, for whom a continuous record of activity in the solar atmosphere had been but a dream. One of the unexpected results of these observations was clear and repeated evidence of material in solar prominences falling back into the chromosphere; even after two showings, one expert continued to complain that the projectionist must have shown the film backwards (McMath *et al.*, 1943)!

The success of the Lake Angelus establishment led to a growth of its staff, including the appointment of astronomers Orren Mohler, a Michigan Ph.D., Keith Pierce (who later was in charge of the McMath Solar Tower Telescope at the Kitt Peak National Observatory), and Leo Goldberg, a recent Harvard Ph.D. It became rapidly apparent that the real path-breaking astronomical research at the University of Michigan was occurring at Lake Angelus, and the position of its Director, curators, and research staff became increasingly anomalous. Curtis welcomed the success and growth of the McMath-Hulbert Observatory, but he was alone among the Ann Arbor staff in that regard (Hulbert, 1944)

The connections with Lake Angelus proved useful in other ways. Judge Hulbert, although not a wealthy man, had well-off friends who had some funds available – even in the Depression. One of them, Tracy McGregor, gave $15,000 for a 2.49-m (98-inch) pyrex disc for the new reflecting telescope. By 1938 the disc was in Ann Arbor (Figure 9) and Curtis had drawn up plans for the mounting, but with mounting and dome estimated to cost half a million dollars it was clear that the project was impossible (for this was a time when salaries had yet to return to their 1930 levels). The 2.49-m telescope would have given Michigan, once again, the third largest operating telescope in the world, but that time never came. In the end, Curtis told Orren Mohler that it was probably for the best not to mount so large a telescope in so unpromising a climate (O. Mohler, pers. comm., 1978).

The graduate curriculum in the Department continued to reflect Curtiss's observational and empirical bent. Whereas Lick, Yerkes, and Harvard added specialists in theory to their staffs during the 1930s, Michigan's first such appointment was Leo Goldberg, in 1941, when he joined the McMath-Hulbert staff (but under the guise of his instrumental abilities). A typical graduate programme at Michigan in the late 1930s included advanced calculus, celestial mechanics and orbit theory; one course each in astrophysics, binary stars and spectrophotometry; two spectroscopy courses in the Physics Department; and Curtis's course on cosmogony, in which he expressed his ongoing doubts about relativity and the various theories of an expanding universe (Curtis, 1939a, 1939b, 1940a, 1940b).

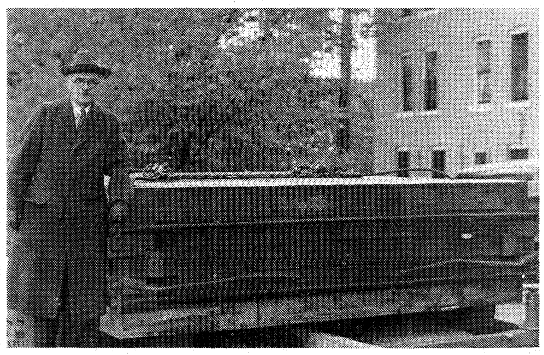

Figure 9. Heber D Curtis with the crate containing the 2.49-m pyrex disc (Courtesy: Michigan Historical Collections, Bentley Library, The University of Michigan).

Among the students of this era who passed through the Michigan programme on their way to productive research careers in astronomy were Orren Mohler, R M Petrie, Helen Dodson Prince, Albert Hiltner, and Arthur Wyse (who completed his Ph.D. at Lick). In one year, for an example of the training requirements, Wyse (Figure 10) took courses on variable stars and astrophysics with McLaughlin, solar physics with Rufus, photometry with McLaughlin and Robley Williams, and advanced laboratory spectroscopy with Harrison Randall. Wyse made a distinct impression on Curtis, as he did on everyone during his war-shortened career. No doubt his interest in planetary nebulae attracted Curtis, who had written the pioneering monograph on their morphology.

The research work of the Department continued. Curtis completed a study of galactic nebulae and external galaxies for the *Handbuch* (Curtis, 1933). This monograph contained a masterful summary of recent research on galactic nebulae, especially planetary nebulae, on which he had worked and written at Lick. But the largest section was devoted to spiral galaxies, and in particular to a review of the various theories that explained "... the excess of velocities of recession in the spiral class." Curtis was writing just on the cusp of the acceptance of the idea that the universe must be expanding, and his monograph is an interesting example of the transitional literature (see Ellis, 1990:101-105). Research at Ann Arbor also continued, led by McLaughlin (Figure 11). A stunning run of good weather allowed him to study the changes in the spectrum of Nova Herculis (1934), which led him to a comparative study of other recent novae and a monograph on the classification and evolutionary sequence of nova spectra, which became a standard work. McLaughlin was a careful observer and sophisticated interpreter of stellar spectrograms, and he built up a massive collection that focused on peculiar stars. Years later, Leo Goldberg referred to McLaughlin as "... the world's greatest expert on novae." (W. Liller, pers. comm., 2000)

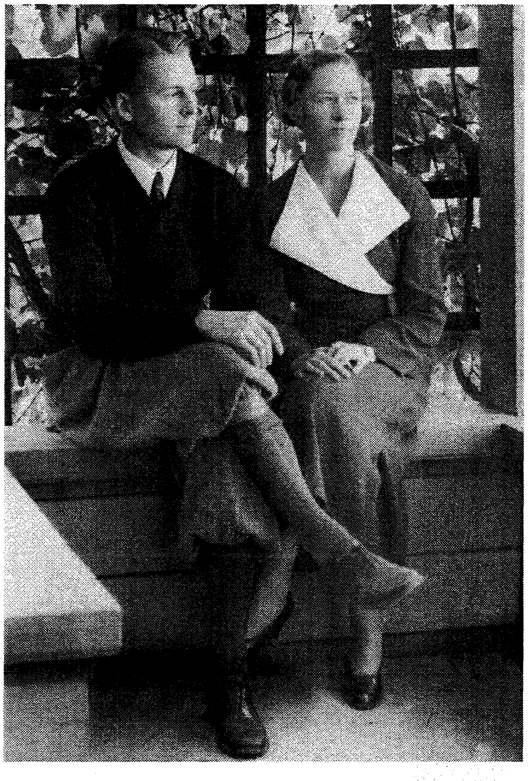

Figure 10. Arthur and MaryLyn Wyse (Courtesy: MaryLyn and Stephanie Wyse).

7 SECOND INTERREGNUM

By the end of World War II the situation at Ann Arbor had become critical. Heber Curtis died at the beginning of 1942, succumbing to the thyroid condition he had fought for twenty years. Rufus had acted as caretaker, and retired in 1945. Remaining were McLaughlin and Losh. The disparity between the small staff in Ann Arbor and the exuberant, productive team at Lake Angelus was embarrassing. The 95.3-cm reflector was out of date, and there was no sign of the funds necessary to complete the 2.49-m reflector. University expansion in the vicinity had rendered the facility quite possibly the world's only floodlit observatory! Meanwhile, the tower telescopes at the McMath-Hulbert Observatory were at the very forefront of solar research, with first-rate equipment which was lovingly cared for.

In personal terms, there were also misunderstandings between the two staffs. With the exception of Robert McMath, the Lake Angelus staff did not have the status and benefits of instructional rank. As McLaughlin put it, the Ann Arbor astronomers feared that the 'tail would wag the dog'. Realizing that a specific purpose had won Judge Hulbert and the McMaths their Observatory, he concluded that one reason the big reflector never materialized was that the Ann Arbor staff had never made clear just what campaign they proposed for it (McLaughlin, 1944).

The failure of the Ann Arbor staff to propose a new Director and Chairman led President Ruthven and Dean Kraus to rely more and more upon Robert McMath. He was, to some outsiders, "... the outstanding astronomer connected with the University ...", while to the administration he was the man who had won the funds for the 2.49-m disc *and* the solar observatory. In the end, his influence grew, for his co-operation in raising public and private funds for a new observatory was considered essential (Bowen, 1945, Hulbert, 1945).

All hinged on the choice of the new Director. Ira Bowen visited the campus in 1945 and made a series of recommendations to the Dean, but he showed no personal interest in the position. The problem was simple. The pogamme needed a strong Director, but no strong candidate would come without improved instrumentation for the programme, and the legislature would not guarantee the $800,000 now required to figure and mount the 2.49-m reflector. But to convince the administrators, legislators, potential colleagues, and potential students, a strong Director was needed. There had been some early talk of using the 2.49-m disc as a bargaining chip with which to enter a joint arrangement with another Observatory, either Yerkes or Lick, but neither institution had the funds to convert the disc into a working instrument (Rufus, 1945).

Figure 11. Dean McLaughlin (Courtesy: Michigan Historical Collections, Bentley Library, The University of Michigan).

The Gordian knot was cut in 1946 when the University abandoned the 2.49 m project in favor of a smaller and more versatile Schmidt telescope, along the lines of the Burrell Schmidt of Case Observatory, which J J Nassau was using to excellent effect. They also assigned funds to develop a rural site atop Peach Mountain, north-west of Ann Arbor, and they offered the Directorship to McMath, who declined (McMath, 1946a, 1946b). At the beginning of August, Dean Keniston called a 'summit meeting' involving the eminent astronomers and Observatory Directors, Harlow Shapley, Otto Struve, C D Shane, and J J Nassau, and later he consulted Henry Norris Russell and Bart Bok. The result of the conference was a decision to add theoretical astrophysics to the programme by appointing new staff, and to offer the Directorship to Bart Bok—who decided to turn it down after receiving a retention offer from Harvard.

At that point, Yale University offered Leo Goldberg a position, and promised him tenure. Goldberg had studied at Harvard and worked at the Observatory for five years before McMath and Curtis hired him for the solar observatory. He had excellent credentials in theory as a student of Donald Menzel, and also was well known as the co-author of an outstanding book (Goldberg and Aller, 1943). He had rapidly become McMath's right hand man and an important interpreter of the data pouring out of the tower telescope cameras. Yet it was only when an outside offer arrived that he received careful and favourable consideration from the University of Michigan hierarchy.

On 1946 November 1, Goldberg became Chairman of the Astronomy Department and Director of The University of Michigan Observatories. The Yale offer was an important one, in that the programme at New Haven was to be overhauled and modern astrophysics made its foundation. On the other hand, at that time private universities were not the great funders of science that they would later become, and both Michigan's record of war-related work and McMath's political connections made it likely that significant funds would be available in Michigan. Seen locally, University administrators recalled that after World War I there had been a substantial growth in student numbers and state appropriations, and there was every expectation, given the pent-up demand for education and research/development after a war twice as long and many times as demanding, that the State would again be generous. It proved a wise calculation on Goldberg's part.

8 LEO GOLDBERG AND THE SECOND REVIVAL

Within a short time, Goldberg's worth was proven. The 2.49-m disc went to England and became the foundation of the Isaac Newton telescope (ironically, it left the Americas only to land beneath equally cloudy skies)! The Curtis Schmidt telescope went into service on Peach Mountain (and later moved to Chile). Lawrence Aller and Freeman Miller joined the staff and revamped the astrophysics curriculum, bringing in their train a new generation of excellent graduate students. Goldberg joined the graduate students daily at 10:00 and 3:00 to have coffee (see Figure 12), and all faculty were expected to attend and to discuss the latest research as well as recently-arrived publications (P. Boyce, pers. comm., 2003). As another enterprising and successful saviour of an observatory wrote,

> "Goldberg's spectacular rise from a relatively little-known research worker in your own observatory to one of the most successful observatory directors in America has been one of the most interesting astronomical developments during the past two years." (Struve, 1948).

One of the markers of this resurgence was the symposium held at Ann Arbor to celebrate the dedication of the Curtis Schmidt telescope in 1950. The speakers included some of the most brilliant lights and influential scientists in the field of galaxy research. Walter Baade was the biggest catch, and Goldberg and Baade both conspired to arrange matters around what Baade called "really <u>fundamental</u> questions". In fact, it was at this symposium that W W Morgan and J J Nassau pointed towards evidence of spiral structure in our Galaxy, derived in large part from exposures obtained with Nassau's Schmidt telescope (Gingerich, 1985).

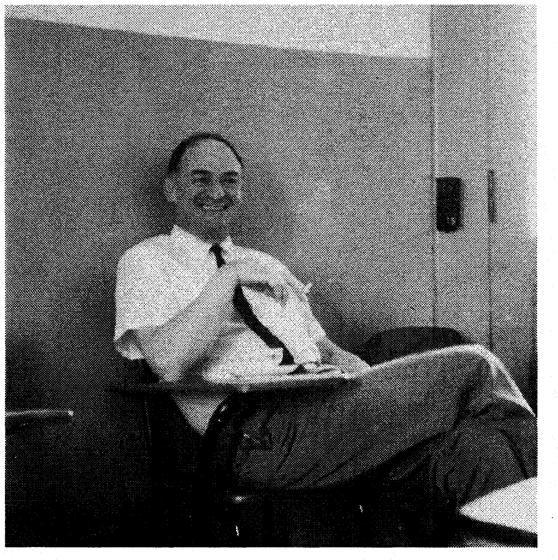

Figure 12. Leo Goldberg at the morning coffee klatsch (Courtesy: Harvard University Archives).

A second marker is the 1953 Michigan Symposium on Astrophysics. In the 1920s and 30s the Michigan Department of Physics had run an internationally-famous Summer School in Physics, which occasionally included astrophysicists among the speakers. A little later, in the mid-1930s, Harlow Shapley (who was the Director at Harvard) instituted a series of Summer Schools in Astrophysics at Harvard, with a similar international cast of luminaries. After World War II, however, the Harvard series came to an end, and, building on the success of the 1950 symposium, Goldberg arranged (with the help of a very early NSF grant) a Summer School starring Baade and a cast of astronomers at the peak of their productivity, plus "... at least one graduate student from each of the leading graduate schools in astronomy." (Gingerich, 1994:36). With the likes of Baade and George Gamow in daily attendance, the summer proved decisive for a generation of future scholars in the fields of galactic research, stellar evolution, and cosmology. Michigan was now a major player in the field, with Goldberg as an increasingly influential coach.

9 CONCLUSIONS

During the half century under examination, the Michigan programme benefited from the largesse of the State and especially from a number of private, well-off donors. None of them provided the massive capital infusions that a George Ellery Hale had won time and time again, but nevertheless they allowed for the success of focused research programmes: Curtiss's and McLaughlin's studies of peculiar stars, Rossiter's search for double stars and McMath-Hulbert's pioneering studies of activity in the solar atmosphere. The programmes were observational, and consequently there was much more discussion of equipment than explanation of observations in the Observatory publications. This lack of a strong theoretical base meant that when Ann Arbor's instrumentation failed to keep pace with other observatories, there was nothing to keep up the momentum, but when Michigan developed powerful instruments – as at Lake Angelus—the pogamme remained strong. The research cycle at Ann Arbor, in Carl Rufus's view seemed to be "... instrumentation, observational data, reductions and applications, progress in scientific theory." (Rufus, 1944b) However, theory was not forthcoming from Ann Arbor until Leo Goldberg's Directorship. Yet a dedicated programme was able to produce valuable and suggestive results, as in the long series of studies of Be stars and the McMath-Hulbert films. When Leo Goldberg took over, the pogamme grew in numbers, promise, and achievement, with new instruments, new hires and an invigorating approach. Hussey's dreams had come true.

10 ACKNOWLEDGEMENTS

Dr Patricia Whitesell kindly invited me to contribute this paper, which is derived from a more extensive study of the development of the astronomy programme at The University of Michigan. I wish to thank a number of colleagues for their assistance and helpful comments on earlier drafts of this paper. The late Professors Freeman Miller, Henry Donner, Albert Hiltner, Lawrence Aller, and Orren Mohler provided useful information; Professor Donner was particu-larly helpful in reconstructing the atmosphere of the Hussey years. The late Clinton Ford offered insights into the Michigan career of Heber Curtis. David DeVorkin commented at length on the 1989 lecture from which this study grew. For further assistance and inspiration I am grateful to Professors Donald Osterbrock, Patrick Seitzer, Nicholas and Margaret Steneck, William Liller, William Bidelman, Peter Boyce and Owen Gingerich. Professor Liller, whose Astronomy One class I recall with fondness, was especially helpful at suggesting revisions. I owe thanks to Dorothy Schaumberg of the Shane Archives at UCSC as well as to Francis Blouin of the Bentley Historical Library and the authorities at the Princeton and Harvard University Archives. I am grateful to Professor Irving Shapiro of the Harvard College Observatory for permission to study the later papers of Donald Menzel, Harlow Shapley and Leo Goldberg. I dedicate this paper to the memory of Professor Orren Mohler, a fount of information, a continued source of inspiration, and a saintly man.

11 REFERENCES

The following abbreviation is used:

MHC = Michigan Historical Collections, Bentley Historical Library, University of Michigan, Ann Arbor

Anonymous, 1904. The Detroit Observatory. *The Observatory*, **27**: 320-321.

Batten, A., 2003. The 1.8-m Plaskett Telescope in Victoria, B.C. In Orchiston, W., Stephenson, F.R., Debarbat, S., and Nha, I.-S. *Astronomical Instruments and Archives in the Asia-Pacific Region*. Seoul, Yonsei University Press. In press.

Bowen, I.S., 1945. Letter to Dean E.H. Kraus, dated February 12, in MHC.

Curtis, H.D., 1912. Rosa Ursina, Sive Sol. *Popular Astronomy*, **20**: 561-568.

Curtis, H.D., 1933. The nebulae. In G. Eberhard *et al.* (eds.), *Handbuch der Astrophysik, Bd. V:II*. Verlag Julius Springer, Berlin, 774-936.

Curtis, H.D., 1939a. *Notes on Cosmogony*. Ann Arbor.

Curtis, H.D., 1939b. Letter to the Graduate School, dated September 1, in MHC.

Curtis, H.D., 1940a. Letter to the doctoral committee for P.R. Annear, January 19, in MHC.

Curtis, H.D., 1940b. Letter to Dean Okkelberg, dated December 27, in MHC.

Curtis, H.D., 1941. Letter to R.A. Rossiter, dated January 30, in MHC.

Curtiss, R.H., 1932. Classification and description of stellar spectra. In G. Eberhard *et al.* (eds.), *Handbuch der Astrophysik, Bd. V:I*. Verlag Julius Springer, Berlin, 1-108.

Ellis, G.F.R., 1990. Innovation, resistance, and change: the transition to the expanding universe. In B. Bertotti *et al.* (eds.), *Modern Cosmology in Retrospect*. Cambridge University Press, Cambridge, 97-113.

Fecker, J.W., 1927. Letter to R.H. Curtiss, dated July 15 and 16, in MHC.

Gingerich, O., 1985. The discovery of the spiral arms of the Milky Way. In H. van Woerden *et al.* (eds.), *The Milky Way Galaxy*. Reidel, Dordrecht, 59-70.

Gingerich, O., 1994. The summer of 1953: a watershed for astrophysics. *Physics Today*, **47**(12): 34-40.

Goldberg, L., and Aller, L.H., 1943. *Atoms, Stars, and Nebulae*. Blakiston, Philadelphia.

Hearnshaw, J.B., 1986. *The Analysis of Starlight. One Hundred and Fifty Years of Astronomical Spectroscopy*. Cambridge University Press, Cambridge.

Hulbert, H.S., 1944. Letter to Dean E.H. Kraus, dated September 25, in MHC.

Hulbert, H.S., 1945. Letter to President A.G. Ruthven, dated February 1, in MHC.

Hussey, W.J., 1904. Manifold copy of report furnished Regent Barbour, dated March 7, in MHC.

Hussey, W.J., 1905. Letter to the Regents, dated November 17, in MHC.

Hussey, W.J., 1921. Letter to Mrs Cramer, dated March 30, in MHC

Jessup, M.K., 1955. *The Case for the UFO. Unidentified Flying Objects*. Citadel Press, New York.

McLaughlin, D.B, 1930. Ralph Hamilton Curtiss, 1880-1929, *Journal of the Royal Astronomical Society of Canada*, **24**: 153-158.

McLaughlin, D.B., 1944. Letter to the Observatory Staff, dated August 15, in MHC.

McMath, R.R., 1946a. Letter to Dean H. Keniston, dated April 10, in MHC.

McMath, R.R., 1946b. Letter to Dean H. Keniston, dated June 13, in MHC.

McMath, R.R., McMath, F.C. and Hulbert, H.S., 1943. The McMath-Hulbert Observatory. In Shaw: 483-489.

Osterbrock, D.C., 1997. *Yerkes Observatory 1892-1950: The Birth, Near Death, and Resurrection of a Scientific Research Institution*. University of Chicago Press, Chicago.

Osterbrock, D.E., 2003. The California-Michigan axis in American astronomy. *Journal of Astronomical History and Heritage*, **6**:120-136.

Rufus, W.C., 1930. Ralph Hamilton Curtiss, Astrophysicist. *Popular Astronomy*, **38**: 190-199.

Rufus, W.C., 1943a. The Department of Astronomy. In Shaw: 442-465.

Rufus, W.C., 1943b. The Lamont-Hussey Observatory. In Shaw: 476-483.

Rufus, W.C., 1944a. A statement of needs of the Astronomy Department, dated January 15, in MHC.

Rufus, W.C., 1944b. A statement urging immediate action, dated October 3, in MHC.

Rufus, W.C., 1945. Letter to Dean Hayward Keniston, dated June 22, in MHC.

Shaw, Wilfred B. (ed.), 1943. *The University of Michigan, An Encyclopedic Survey, Part III:I.* University of Michigan Press, Ann Arbor.

Struve, O., 1948. Letter to Robert McMath, dated April 8, in MHC.

Struve, O., and Zebergs, V., 1962. *Astronomy of the 20th Century*. Macmillan, New York.

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

Zorn, Jens, *et al.*, 1988. *On the History of Physics at Michigan*. Physics Department, The University of Michigan.

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Journal of Astronomical History and Heritage 6(2):120-136 2003

The California-Michigan axis in American astronomy

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Abstract.
From the beginning of the big-telescope era in American astronomy there has been a California-Michigan Axis of exchange of astronomers between these two states. Several of the earliest participants in it are identified, and their careers are briefly described; some of the reasons for which it came into existence and survived are discussed.

Keywords: *Berkeley Astronomical Department, celestial mechanics, Detroit Observatory, eclipse expeditions, galaxies, Lick Observatory, radial velocities, nebulae*

1 INTRODUCTION

Over the years since the beginning of the big-telescope era in American astronomy, roughly dating from the completion of the Lick Observatory 91.4-cm (36-inch) refractor on Mount Hamilton, California, in 1888, there have been many Michigan astronomers who went to California to do research, and many who went the other way too. Both state Universities had active astronomy programmes, and this traffic was natural. It was strengthened by several personal factors, as we shall see.

2 EARLY DAYS

Three early members of the California-Michigan axis were George Comstock, Martin Schaeberle, and Sidney Townley, all discussed in another paper in this issue (Whitesell, 2003). Comstock spent a summer at Lick Observatory in 1886, even before the big telescope was completed, and Townley was a graduate student there for one year in 1891–1892. Both departed from Mount Hamilton harbouring strong dislike of the first Lick Director, Edward Holden, who had failed to follow through on promises they believed he had made to them. This was to be a repeating motif throughout his Directorship. Comstock had expected Holden to recommend him as his successor as Director at the University of Wisconsin's Washburn Observatory, but fumed as he learned that the Lick Director-to-be had recommended three other astronomers, all more senior friends, instead. After they all turned it down, Holden did recommend Comstock, but by then the hard-working young assistant had already won it on his own (Osterbrock, 1984:64-65). Townley, on the other hand, had his meager Phoebe Apperson Hearst Fellowship terminated after just that one year, when Holden decided to switch the wealthy University of California donor's gift to support an eclipse expedition (Osterbrock *et al.*, 1988:178-180). Neither one of them trusted him after that, nor mourned him after he was forced out of his position less than a decade later after a fight initiated by a California-Michigan cabal, as we shall see.

3 ARMIN LEUSCHNER

Armin O Leuschner, the first graduate student at Lick Observatory, and later the founder and long-time head of the Berkeley Astronomical Department at the University of California, was born in Detroit in 1868 and completed his undergraduate work at the University of Michigan. Leuschner was born in a German-speaking home, and his father, an immigrant to America, died when Armin was quite young. His mother took him back to Germany, where he grew up in Kassel, attending school and then a Gymnasium (the German equivalent of an academic junior and senior high school). Leuschner's mother brought him back to Detroit in 1886, after his graduation, and as a native-born American citizen he entered the University of Michigan. With his Gymnasium education and knowledge he was far ahead of the other freshmen in most subjects (though not in English), and he easily earned his bachelor's degree in two years. He was especially good in mathematics, and was already interested in astronomy (Alter, 1953). Leuschner's teachers were Schaeberle, then an Acting Assistant Professor, and Mark Harrington, the Professor of Astronomy and Director of Detroit Observatory, on the Ann Arbor campus.

In 1888, just as Leuschner was completing his undergraduate work, Holden offered Schaeberle a position at Lick Observatory after Comstock had declined it, and the Michigan astronomer took it and was on the scene by 1888 July 1, when the Observatory officially went into operation as part of the University of California. Perhaps attracted by the lure of California and the Wild West, which German boys of his generation read about avidly in pot-boiler adventure novels, Leuschner followed him to Mount Hamilton as Lick Observatory's sole graduate student. Very probably Leuschner was also keen to begin research, for all his life he worked assiduously at it himself, and pushed it whole-heartedly at the University of California, in astronomy, and later in all sciences as a senior faculty leader and Dean of the Graduate School from 1913 to 1923 (Einarsson *et al.*, 1958:69-72). Harrington, who earlier had taught mathematics and almost every college subject, and had been a museum curator for a time, was editing and publishing a meteorological journal throughout Leuschner's years in Ann Arbor, and apparently had never done any research in astronomy. Whatever his reasons, Leuschner decided to follow Schaeberle to California in 1888 September rather than to stay in Michigan with Harrington (Osterbrock, 1984:75-6).

Holden was eager to have graduate students at Lick and welcomed Leuschner. There were no formal courses; the plan was that he would work as an assistant for various astronomers, to learn what they were doing, and would begin a thesis under Holden's guidance. The subject the Director assigned him was photographic photometry, an important topic, but Holden had never worked in it himself, and was incapable of showing Leuschner what to do, or giving any practical advice on methods and techniques. The Lick Director was an excellent library scientist who had written and published some very good review papers, but he had never done any new, creative research on his own. Leuschner soon recognized Holden's weaknesses, and spent an unhappy year at Lick. In his second year he stayed on the Berkeley campus for the first semester, taking mathematics courses which he liked, and some physics too. Then he went back to Mount Hamilton for the spring and summer but made little progress. In the fall of 1890 he became a Mathematics Instructor on the campus, against Holden's advice, and in the summer of 1891 he travelled to Harvard, and then on to Germany, discussing his attempted thesis with Edward Pickering, Heinrich Vogel, and Julius Scheiner, all important astrophysicists of that era. Then in 1892 Leuschner was appointed an Assistant Professor of Mathematics on the campus, and began teaching astronomy there as part of surveying for civil engineering students. Holden hated this development, for he wanted to be in charge of astronomy on the campus as well as on the mountain. He no doubt realized that Leuschner was becoming more popular than he was in Berkeley. They had several public quarrels, especially in the context of class visits to Lick Observatory, shepherded by Leuschner. He and Holden were both sensitive to imagined slights, and also quite capable of baiting each other before the students. When in 1894 Leuschner was named an Assistant Professor of Astronomy on the campus, their struggles became fiercer. By now Leuschner had given up on his original thesis topic. In the summer of 1896 he married Ida Denicke, the daughter of a wealthy, important Regent of the University, and the newlyweds went off to Berlin on a year's leave-of-absence that Leuschner had been granted in order to study there (Anonymous, 1896). He then tackled a whole new thesis on methods for computing the orbits of recently-discovered comets and asteroids, his main interest in astronomy, and with credit for the work he had already done at Lick and Berkeley, he earned his Ph.D. He returned to Berkeley in the fall of 1897 just as Ernst Denicke, his father-in-law, was helping force Holden out of the Lick Directorship and out of the University of California (Anonymous, 1897).

Leuschner (Figure 1), promoted to Associate Professor, began building up a strong Astronomy Department on the campus. He got along very well with James Keeler, the Director the Regents chose to succeed Holden; Leuschner as a graduate student assistant had worked briefly with him at Lick (where Keeler had been the staff member who specialized in spectroscopy until 1891) and later, also briefly, at Allegheny Observatory in Pittsburgh, where Keeler had gone as Director from 1891 to 1898. After Keeler's unexpected death in 1900, Leuschner kept on good terms with W W Campbell, Robert Aitken and William Wright (who had been one of his first students at Berkeley), the successive Lick Directors until 1938, when "the Chief" formally retired (Osterbrock, 1990). Over most of those years the UC graduate astronomy programme, with students dividing their time between Berkeley and Lick, was generally considered the best in America (Hughes, 1925). Leuschner, a convinced California-booster, retained many of his German traits all his life: his strong accent; his love of the outdoors, including a sacrosanct month-long family vacation each year at his 'camp', a summer retreat in Tuolome County near Yosemite; and writing at least one letter a week to his mother back in Germany. But during World War I, when anti-German feelings ran high in the United States, he proved his loyalty to his native land by applying for and receiving a commission as a Major in the Chemical Warfare Service, the branch of the Army that was then closest to science. Leuschner served for a year and a half, mostly as an organizer and facilitator in Washington in the National Research Council, which astrophysicist George Ellery Hale had brought into being to provide the science and weapons development programmes the army and navy needed.

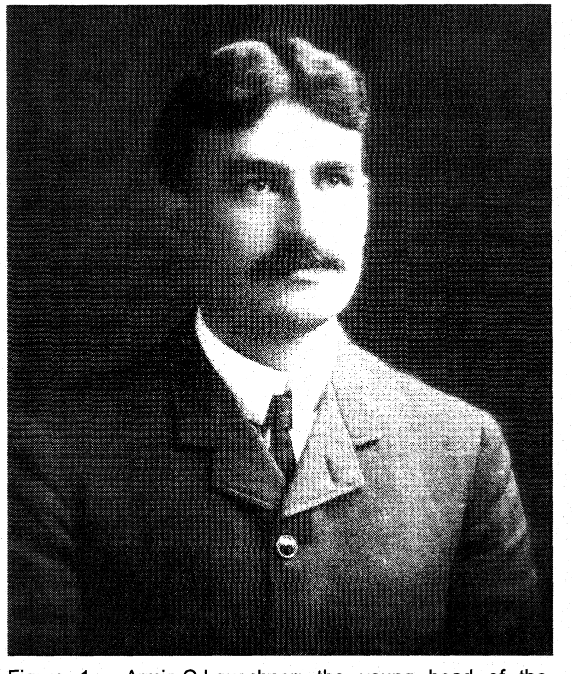

Figure 1. Armin O Leuschner, the young head of the Berkeley Astronomical Department (1903) (Courtesy of the Mary Lea Shane Archives of the Lick Observatory).

Leuschner's main interest in astronomy for his entire life was the calculation of the orbits of the smaller objects in the solar system, especially by the method which he had developed and demonstrated in his 1897 Berlin thesis. He insisted that all the graduate students in his Department know it well and use it. Frank Ross, one of his first Ph.D.s, who actually did his thesis in mathematics, afterward calculated the orbits for the first 'irregular' satellites of Saturn and Jupiter (with large eccentricities, high inclinations, and long periods), soon after they were discovered by William Pickering at Harvard and by Charles Perrine at Lick (Nicholson, 1961, Morgan, 1967). Ross was the Chief Assistant to Simon Newcomb, the 'grim dean of American astronomy' in Washington and a world authority on celestial mechanics. After becoming an expert in that field in his own right, Ross later switched to positional astronomy and then an optical designer, but Leuschner preferred his former students who stayed in celestial mechanics. Every student who passed through the Berkeley Astronomical Department took part in at least one race to beat Harvard, Berlin, or any other astronomical centre in determining the orbit of a newly-discovered object (Herget, 1978). Very soon after Clyde Tombaugh discovered Pluto at Lowell Observatory in 1930, Ernest Bower and Fred Whipple, then both graduate students at Berkeley, calculated the first orbital elements for it. Then, from the pre-discovery positions of Pluto that were found using that preliminary orbit, Seth Nicholson and Nicholas Mayall at Mount Wilson Observatory, both former Leuschner students, calculated a much-improved orbit for it, and Bowers then calculated the definitive orbit as his Ph.D. thesis in 1931 (Osterbrock, 1990).

Leuschner regarded it as natural to hire one of the best of the graduates of his own Department onto its faculty whenever a vacancy occurred in it. As a result, it was heavily weighted toward celestial mechanics. After he retired as Chairman in 1935, his first three successors in that office were Tracy Crawford, Donald Shane and Sturla Einarsson, all California Ph.D.s. Crawford and Einarsson had done theses in 'theoretical astronomy', as celestial mechanics was called at Berkeley, and continued in the faculty basically as teachers. Shane, who had done his thesis on stellar spectroscopy at Lick, had learned and taught himself astrophysics, and he left Berkeley to become Director of the Observatory after World War II (Vasilevskis and Osterbrock, 1989).

But Leuscher's heart embraced all astronomy; he supported all the students he could, especially if they were good. Lawrence Aller, who was born and grew up in far Northern California, was taken out of school and put to work by his father, but ran away from home and made his way to Berkeley. There Donald Menzel, then teaching on campus from Lick, met him and was so impressed by his knowledge of astronomy and interest in it that he succeeded in having Aller accepted as a special student at the University. Leuschner helped young Lawrence get a scholarship, and in addition hired him as a part-time gardener at his own home. Aller, a very good student, earned a bachelor's degree at Berkeley and took one year of graduate work there before moving on to Harvard to study astrophysics under Menzel, who had moved there in 1935. While doing his Ph.D. thesis on planetary nebulae, and later during World War II when he was working on the atomic-bomb project at Berkeley, Aller returned to Mount Hamilton whenever he could for a few nights of the nebular observing which he loved (Aller, 1993). He later became an outstanding theoretical astrophysicist and a member of the California-Michigan Axis, as a member of the University of Michigan faculty from 1948 until 1962.

4 WILLIAM WALLACE CAMPBELL

W W Campbell, as he always signed his scientific papers, the long-time Director of Lick Observatory, was an important part of the California-Michigan Axis. He was born in 1862 on a farm in Hancock County, Ohio, near Fostoria in the north-western part of the state. He was one of a large family of brothers and sisters, and his father, who was a skilled carpenter, died when young Wallace (as he was always known to his family and close friends throughout his life) was only four. From then on his mother had the main responsibility for their farm, and his sister Isabel, fifteen years older than he was, took most care of him when he was a little boy. As soon as he was old enough Wallace began helping with the chores, and then in the fields. He was very bright, especially in mathematics. The young boy was naturally left-handed at birth, but was made to learn to write and do other tasks with his right hand; as a result in adult life he was ambidextrous, for instance in using tools (Campbell, 1938). Campbell's heritage was all Scottish and he was proud of it; he and his wife named their three sons Wallace, Douglas, and Kenneth, all celebrated names in the history of Scotland. Many of his closest friends in later life also tended to have Scottish names, including Robert Bruce, a shipping agent in San Francisco whose services Campbell used extensively. Later, when the Lick Director had a well-deserved reputation for keeping a tight rein on the budget, he boasted of his frugality as a positive Scottish trait, though many of his staff astronomers who suffered under it considered him a tightwad (Wright, 1949).

After attending local Hancock County schools, Campbell entered Fostoria High School and graduated first in his class, which evidently numbered only six (Fostoria High School, 1880). His graduation oration was entitled "Every Man in His Place", and he had long ago decided that his own was not on the farm. He disliked the constant, mindless toil, though he loyally did his share. His high-school principal recognized his abilities and urged him to go on to university. First however, he worked for a year, probably at a job in Fostoria. Then in 1881, at the age of eighteen, he entered Ohio State University, but he only lasted for one term before dropping out and coming home. Probably he was insufficiently prepared and maybe he was homesick too. At any rate, he got jobs teaching at various local schools (in those days such schools typically only held classes for one term of four to six weeks, and graduation from high school was considered plenty of preparation for the teachers), and undoubtedly studied a lot too.

Then Campbell entered the University of Michigan, which in Ann Arbor was actually closer to Fostoria than Ohio State University was in Columbus. He had registered in the engineering course, but he did so well in it that he had time enough to study more mathematics on his own. Then a book he found in the University library changed his life in a completely unexpected direction. It was in the summer of 1885, between his junior and senior years, when he had accumulated enough money to stay in Ann Arbor and study rather than returning to a summer job near home. One day he picked up Newcomb's book, *Popular Astronomy*, and found it so interesting that he checked it out and took it to his room and read straight through it in two days and nights, according to his later story. By the time he reached the end of the book, he knew he wanted to be an astronomer for the rest of his life. Still practical however, Campbell kept his major in engineering but managed to take two additional courses in astronomy, one based on James Watson's book on *Theoretical Astronomy*, very probably taught by Harrington, the other on William Chauvenet's *Spherical Astronomy*, certainly taught by Schaeberle, with whom he also did some additional reading in astronomy (Campbell, 1938). Chauvenet was Holden's father-in-law, illustrating how small the world of astronomy was at that time.

Upon graduation with his B.S. degree in civil engineering, Campbell got a job as Professor of

Mathematics and Astronomy at the fledgling University of Colorado in Boulder. Perhaps, like Leuschner, he wanted a taste of the Wild West, but not quite as far from the University of Michigan as the younger German-American student had gone. At that time, and for many years afterwards, astronomy was considered much more a mathematical subject than a physical one, and was taught in a department of mathematics and astronomy almost everywhere. Campbell's extra reading had paid off for him, and he taught a lot of mathematics at Boulder, and only a little astronomy. Then when Schaeberle decided to leave the University of Michigan for his new research post at Lick in 1888, Campbell was offered the job as his replacement back in Ann Arbor as an Instructor in Astronomy at $900 a year. Eager to teach in his chosen field with no mathematics courses, he jumped to accept the offer, even though it meant a considerably lower salary. The University of Colorado wanted to keep him and in the end offered him $2,000 a year to stay. That made it harder to leave, but he knew he wanted to be an astronomer, not a mathematics teacher for the rest of his life in Boulder, so back to Michigan he went.

There Campbell again did very well as a teacher, but by then he knew he wanted to do astronomical research, and there was little chance for that at Detroit Observatory, except to calculate comet orbits or measure double stars. But he kept in touch with Schaeberle, and with his recommendation was permitted to spend the summer of 1890 as a volunteer Research Assistant at Lick Observatory. Holden had him work most of that summer with Keeler, who was then doing his pioneering (visual) spectroscopic measurements of the radial velocities of planetary nebulae and the Orion nebula (Osterbrock, 1984:62-103). Leuschner also worked with Keeler at times that summer, and these two assistants must have reminisced about their respective periods at the University of Michigan, which had just missed overlapping. But Campbell was much more interested in spectroscopy than the younger Leuschner was, and by the end of summer he had become a real expert in it.

Thus, less than a year later when Keeler resigned his Lick position to marry and move to smaller Allegheny Observatory as its Director, Campbell was the only logical candidate to replace him as the spectroscopist at Mount Hamilton. He was one of the few astronomers in the country who knew anything about the subject, and the only one who had personal experience with the Lick telescope and the spectroscope that Keeler had designed. Campbell (Figure 2) accepted the offer at once and soon converted the instrument into a photographic spectrograph, just what Keeler had built for his own continuing research in Pittsburgh. Photographic plates had become the detector of choice for astronomical data-taking, and Campbell and Keeler both started using them as soon as they could.

Campbell began his own astrophysical research on planets, nebulae, and stars with the Lick telescope and spectrograph. He started observing Mars at its close opposition in 1894, and proved to his own satisfaction that it had little if any water vapour in its atmosphere, certainly less than the amount in the Earth's atmosphere above the high, dry Mount Hamilton site. However the celebrated German astronomer Vogel, working with a smaller telescope in the damper climate of Potsdam thought he had seen water vapour in the spectrum of the red planet, and published a note politely questioning the unknown young American's result. Campbell was sure he was right (as he was) and struck back hard (Campbell, 1894a, 1894b). This controversy dragged on for several years, and from it Campbell developed a strong distaste not only for Vogel personally, but also for German professors as a group, whom he regarded as arrogant, closed-minded and dictatorial. Though he tried to repress this attitude in their presence, he never shed this prejudice (Osterbrock, 1984a:248-252).

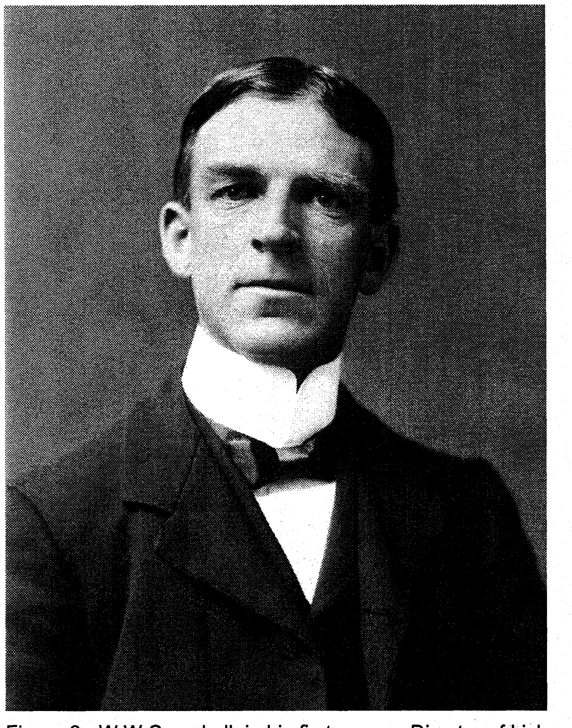

Figure 2. W W Campbell, in his first year as Director of Lick Observatory (1901) (Courtesy of the Mary Lea Shane Archives of the Lick Observatory).

On a much more pleasant note, Campbell had married Elizabeth Ballard Thompson in 1892 December, and in doing so added another member to the California-Michigan Axis. He had met his bride as a student in one of his mathematics classes in Colorado, which she entered the same year he joined its faculty. She had been born and grew up in Grand Rapids, Michigan, where her family were pillars of the community, her maternal grandfather a liberal Congregational minister, her father a successful businessman and investor who was called Colonel H E Thompson, meaning he had been an officer in the Civil War, or perhaps in a Michigan militia regiment. Bessie, as she was known to her family, friends and husband, had accompanied her mother and younger brother to Colorado where they lived several years in a vain attempt to save him from tuberculosis, a fashionable cure in that age. She attended the University of Colorado for four years, received her B.A. in 1890, and then taught mathematics for a year at Rockford College, a women's college in Illinois, where her mother had been a student a generation earlier (Preston, 1985; Surrey, 1985). Evidently Bessie and Wallace had corresponded after he left Boulder in 1888, and they became engaged in 1891 June when she came to Ann Arbor, heavily chaperoned, after the Rockford school year ended (Cheever, 1891; Thompson, 1891). No doubt they went on to Grand Rapids, where she stayed with her mother (her father had died) until Campbell returned for the wedding there just after Christmas in 1892 (Campbell, 1892). He had kept his courtship by correspondence secret from even his closest friends, and had told them he would never marry, so they were surprised as well as pleased to learn of his engagement from letters he sent after his arrival back on Mount Hamilton (Hussey, 1891; Lehman, 1891). But almost certainly that had been a pose he adopted to deflect their curiosity, and he had recognized Miss Thompson as his 'Mrs. Right' while he was still at Boulder. His new job at Lick Observatory paid well, a university house on Mount Hamilton came with it, and the book which he had written so industriously at the University of Michigan on practical astronomy for engineering students would help provide funds for their married life and future children.

Bessie, who after her marriage always used the name Elizabeth Ballard Campbell (rather than the then more conventional Elizabeth Thompson Campbell, because she did not want to become 'ETC', she always said), proved to be the perfect wife for the astronomer and future Director, then University President. She tactfully smoothed out most of his rough edges, was always friendly, diplomatic and outgoing with others, and at the same time was extremely supportive of him. Campbell became an inveterate organizer of eclipse expeditions to distant lands, always returning with valuable new data on the Sun, in the days when a hard-working, intelligent, part-time solar physicist could still make important new discoveries (Osterbrock, 1980). Bessie accompanied him on nearly every one of these expeditions, at first taking a hand in exposing plates with a smaller telescope or a spectrograph, and later taking over as organizer, supervisor, and provider of all the housekeeping arrangements – including doling out a medicinal dollop of good Scotch whisky to Wallace if he became too harried, apprehensive, and conscious of his own possible failure during the precious moments of totality (Campbell, 1903)! As he rose in power and responsibility at Lick Observatory she became the gracious hostess to important visiting astronomers, Regents of the university, and other dignitaries. She corresponded with Phoebe Apperson Hearst, the immensely wealthy Regent and financial supporter of many good causes, including Lick Observatory. Elizabeth's interests always coincided with Wallace's, but from a more elevated, wider point of view (Campbell, 1904).

Campbell's upward course was rapid. As a research astronomer he published many important papers on spectroscopy (Wright, 1949). He got along well with Holden, the first Director, but gradually began to see flaws in his leadership and his scientific abilities. In 1897 the faculty revolt in which Campbell played an important but hidden role, as we shall see, led to Holden's forced resignation and departure from Lick Observatory (Osterbrock, 1984b). Keeler, Campbell's mentor and good friend, came back from Allegheny in 1898 as the new Director, and rather than compete with him in spectroscopy, instead took over the Crossley reflector which as 'Holden's folly' had triggered the revolt. With it Keeler blazed a new path of research in nebular direct photography, which included his recognition of spiral 'nebulae' (which we know as galaxies today) as an important constituent of the universe (Osterbrock, 1984b:233-329). But he was ill with heart disease, and probably emphysema or lung cancer too, and died at an early age after only two years back on Mount Hamilton. By then, Campbell had done so much research that he was the only possible successor to the Directorship. He took over as Acting Director soon after Keeler's death, and was named to the full post, effective 1901 January 1, with no expiration date, and he held it until 1930.

Campbell's most important long-term research project was the radial-velocity programme which he conceived and started working toward under Holden, continued under Keeler, and brought to vigorous fruition during his own Directorship. Other astronomers had measured a few stellar and nebular radial velocities by the Doppler effect before Campbell began his programme, but their results were fragmentary and somewhat contradictory. He realized it was a very important problem and, with his engineering approach, designed and built first one, then a second spectrograph optimized for radial-velocity measurements and nothing else. He analyzed each possible source of error and did his best to eliminate it (Aitken, 1938). Campbell threw all the resources of the Observatory into it, with a corps of student assistants observing, measuring spectrograms, and reducing the measurements to radial velocities (Osterbrock *et al.*, 1988:130-148). The results flowed out and they were so impressive that Newcomb nominated Campbell for the first Nobel Prize in Physics (Newcomb, 1900, 1901). Campbell did not get it (Wilhelm Röntgen did, for his discovery of X-rays), but Newcomb's nomination indicates the importance this new method of measuring the radial components of the velocities of large numbers of stars had to the theorists of his generation.

The overall result of Campbell's massive radial-velocity programme was the measured velocities of thousands of stars of all spectral types all over the sky (he sent a telescope and observers to Chile to build an observatory to get the stars that never peeped above the horizon at Mount Hamilton). One of the unexpected results was how many stars, until then believed to be single, turned out actually to be close 'spectroscopic binaries', moving in orbits about one another, detected only by the periodic changes of their radial velocities (Moore, 1939). Perhaps the most important generalization that Campbell deduced from this was the systematic correlation of velocity dispersion (that is, random velocities of the stars) with spectral type, from the small velocity dispersion of hot, 'early-type' O and B stars to the large random velocities of cool, 'late-type' stars. In terms of those descriptive names, which had been assigned by earlier astronomers on the basis of an evolutionary picture of how stars aged, it seemed to show that stars were formed with small random velocities, which increased as they aged. Campbell's discovery was anticipated by the Dutch statistical astronomer, Jacobus Kapteyn, who first published his results, based in large part on Lick radial-velocity measurements, in 1910 (Kapteyn, 1910). Campbell described the results, which he had found independently, in his Silliman Lectures at Yale earlier that same year, which he then wrote up for publication in a book that did not come out until three years later (Campbell, 1913). In that book, he described in tedious detail how he had grasped this relationship, discussed it with other astronomers in the East and lectured about it before Kapteyn's paper appeared in print (which was no doubt true), but he did not mention – and may never have realized – that Kapteyn very probably had also described his discovery to other astronomers in earlier discussions and lectures before publishing it, as most scientists do. The correlation was sometimes referred to as the Kapteyn-Campbell effect (or vice versa), and was clearly an important clue for the study of star formation and evolution, but it was only decoded fully by Walter Baade, Lyman Spitzer, and Martin Schwarzschild in the 1940s and 1950s.

Campbell always remained a proud, loyal University of Michigan alumnus. When James Angell, the President who had officiated at his graduation in 1886 and had appointed him an Instructor in Astronomy in 1891, celebrated a quarter of a century on its faculty, Campbell prepared a letter congratulating him which he signed as a member of the class of '86, and also got William Hussey ('89) and Allen Colton ('89), both then on the Lick Observatory staff, to sign as well. Campbell added to the letter that Schaeberle ('76) was abroad (heading an eclipse expedition to Japan) or he would have signed too (Campbell, 1896). Then in 1905, the University of Michigan awarded Campbell an honorary D.Sc. degree. Campbell wrote Angell that he valued this honorary degree "... from my own University as highly as any degree [he] could obtain ...", and proved he meant it by completely rearranging the plans he had made to sail with his wife to Spain for an eclipse that summer, so that they could be in Ann Arbor on graduation day (Campbell, 1905). This, incidentally, was Campbell's second honorary D.Sc., for the Western University of Pennsylvania (now the University of Pittsburgh) had given him his first in 1900; the University of Wisconsin had also awarded him an LL.D. in 1902.

Campbell became President of the University of California in 1923 and had to give up astronomical research, but he retained the Lick Directorship. He moved to the President's house in Berkeley, leaving Robert Aitken in charge of operations on Mount Hamilton as Associate Director, but still played a major part in important decisions, especially new faculty appointments. Campbell also kept the Director's house on Mount Hamilton, which he and Elizabeth used as a retreat for occasional weekends. In 1930 when Campbell retired, he still kept the house on Mount Hamilton, but moved to an apartment in San Francisco. He was elected President of the National Academy of Sciences, and for four years he and his wife spent part of each one in Washington. Only in 1935 did he give up 'his' house on Mount Hamilton to Wright, the new Lick Director who succeeded Aitken. By then Campbell was becoming tired and ill; he suffered from aphasia and was losing his sight. Nevertheless, he and Elizabeth attended the class of 1886 fiftieth anniversary reunion in Ann Arbor, and he appeared to be one of the better-preserved members in the group photograph taken at the time (see Figure 3). But he worsened rapidly, and fearing he would become a sightless invalid committed suicide in 1938 (Aitken, 1938).

Figure 3. Fiftieth Anniversary Reunion group, UM Class of 1886 (1936). W W Campbell is third from left in the back row (Courtesy of the Mary Lea Shane Archives of the Lick Observatory).

Elizabeth lived on for many years after him. In 1946 she moved to the Pasadena area in Southern California where, in 1948, she attended and was honored at the dedication of the 5.08-m (200-inch) Hale telescope, along with Evalina Hale, the widow of George Ellery, for whom it was named (he had died in the same year as Campbell), Ida Leuschner, and Jessie Aitken (Herbig, 1948). In her later years Elizabeth Campbell collected and arranged her husband's personal letters and photographs, especially from the many Lick Observatory eclipse expeditions, and wrote a book-length manuscript based on them and her personal letters, diaries, and memories of all these astronomical field trips on which she had worked with him (Campbell, 1945). She died at the age of ninety-three in a sanatorium (an extended-care facility for senior citizens, in today's language) in San Gabriel (California, 1961).

5 WILLIAM HUSSEY

William J Hussey, another important figure in the California-Michigan Axis, was born in the same year as Campbell, and like him on a modest farm in northern Ohio. But Hussey's family lived near Mentor, a small town just east of Cleveland, well across the state from Fostoria. Like Campbell, Hussey had to work to earn enough money to enter the University of Michigan, in 1882, at age twenty. He too registered in the civil engineering course, and was in several classes with Campbell in his first two years there. But then Hussey dropped out for three years, working as a school teacher and principal, and as a surveyor for a railroad in the Northwest in summer, to get enough cash together for his final two years as a student at the University (Curtiss, 1926). When Hussey returned to start his junior year in 1887, Campbell was at Boulder teaching mathematics, but he came back to Ann Arbor in 1888, and had his friend as a student for one year there. Hussey compiled an outstanding academic record, and like Campbell completed his B.S. in engineering.

Then, after a summer as an Assistant in the Nautical Almanac Office in Washington, Hussey returned to the University of Michigan as an Instructor in Mathematics. When Campbell departed for his new faculty position at Lick in the summer of 1891, Hussey switched back to astronomy, and in 1891–1892 was briefly the unofficial Acting Director of Detroit Observatory (as an instructor) after Harrington left to become Head of the Weather Bureau in Washington. However Hussey's Acting Directorship was only an interim position until Asaph Hall Jr., son of the famous American discoverer of the two moons of Mars, was appointed Director on a 'permanent' basis.

Hussey, who had given a younger brother the advice that whatever job he had, he should always be planning for the next one, had evidently been doing just that himself. He certainly had told Campbell that he would be very interested in a job at Lick, if another opening developed there, and for a few weeks near the end of 1891 that very nearly happened. Henry Crew, a recent Ph.D. in physics from Johns Hopkins University, had been added to the Lick staff just after Campbell, but with no previous experience in stellar astronomy he was not doing very well. Holden decided that they both should work together in the dome on Crew's assigned nights with the telescope. Crew refused, considering it a form of surveillance, which it was. Holden, an imperious West Point type, insisted, and Crew, who believed in fighting for his rights, handed him a written letter of resignation, which he knew Holden would have to forward to the Board of Regents who governed the University of California. The Director, who always wanted to have a potential successor on hand for such eventualities, immediately told Campbell to telegraph his friend in Michigan and ask informally if he would take the job if Crew left (Campbell, 1891). He did, and Hussey telegraphed back, even more quickly, that he would come at once if necessary, but that after Christmas would be "more convenient" (Hussey, 1891). Then Holden telegraphed Timothy Phelps, Chairman of the Regents' Committee on Lick Observatory, that Crew had 'vacated' his position and that Hussey, who was then in charge of "... all the astronomy taught in Ann Arbor ..." would accept the job. It was urgent to appoint him at once, Holden said in his telegram, "... so that the work just begun [by Crew] may not be interrupted." (Holden, 1891). Phelps, an experienced old politician, listened to Crew and then advised Holden to let him observe on his own. The Director had no choice and Crew withdrew his resignation, although he probably began looking for another position then (Osterbrock, 1984b:101-105). He found one at Northwestern University and did resign from the Lick staff in the summer of 1892, but by then Hussey had accepted another job (Osterbrock, 1986).

He stayed at the University of Michigan until Asaph Hall Jnr arrived, and then headed to California in his new post as Assistant Professor of Astronomy at the very new Stanford University in Palo Alto. Although Holden had encouraged him to think in terms of a possible Lick job later, there was no opening when Crew departed. Hussey was not waiting for it; he had told the Lick Director that he would be very glad to go there and work under his direction but he could make no promises except in response to a firm offer (Hussey, 1892). In fact he was then already in touch with Stanford and soon afterward was offered the Assistant Professorship there, as their first astronomer (Swain, 1892). The new University had just opened its doors to students a year earlier, in 1891, and Hussey's advancement was rapid. After only one year he became an Associate Professor, and after one more a full Professor, in 1894. He was a good teacher, but there was no observatory; nor were there any research opportunities for him at Stanford. Later that year he presented President David Starr Jordan with a conceptual plan for a large Stanford Observatory with a 50.8-cm (20-inch) refractor, plus five 20.3-cm (8-inch) telescopes for student use, two smaller photographic telescopes, and a large solar spectrograph. Some day he hoped to see a 1.27-m (50-inch) refractor there, surpassing the Lick 91.4 cm and the Yerkes 1.02 m (40 inch), then still a few years from completion but much in the newspapers. He had scouted the region near the campus and found several sites for it, with less fog in spring than the high, cold, Mount Hamilton site. Hussey had a wildly optimistic cost estimate from John Brashear, the Pittsburgh telescope maker, claiming the 1.27 m could be built, complete with dome and rising floor, for $335,000, about half the cost of that for Lick

Observatory, plus estimates for less costly telescopes ranging from 1.14 m (45 inches) down to 41 cm (16 inches) (Hussey, 1894). Hussey still maintained excellent rapport with Holden, and arranged to go to Lick as a scientific visitor in the summer of 1892, when he lived and boarded in the Director's house (Holden, 1893; Hussey, 1893). At Mount Hamilton the Stanford astronomer did research on two comets, using small photographic telescopes with which the famous Edward Barnard was the primary observer (Hussey, 1895a). Hussey knew that Barnard was chafing under Holden's rule, and was likely to follow his friends and allies Burnham and Crew, both gone from Lick by then. Hussey would be ready to step into Barnard's shoes if he did go.

Finally Barnard, who was torn between wanting to get away from Holden and not wanting to leave the clear skies of California, did resign effective 1895 October 1, and departed for Chicago two years before Yerkes Observatory (where he was to continue research for the rest of his life) was ready for him. Holden had Hussey ready, willing, and able to leave Stanford for Mount Hamilton, starting on 1896 January 1 (Figure 4). His appointment began auspiciously; he and his wife stayed in Holden's house as his guests until they moved into the house they would have as their own (Holden, 1895; Hussey, 1895b). However, it all too soon turned into a nightmare, as I have related elsewhere (Osterbrock, 1984b). Hussey wanted to do research on double stars, observing with the Lick 91.4-cm refractor, the largest and most effective refracting telescope in the world at that time, and the smaller 30.5 cm (12-inch) refractor, but Holden soon assigned him to work with the Crossley 94-cm (37-inch) reflector, a recently arrived gift, whose donor had turned from observational astronomy under the cloudy skies of the north of England to theology. Holden considered the reflector the capstone of his administration as Director, but Hussey and most other professional American astronomers considered it a rickety "pile of junk." He objected, delayed, wrote long memoranda to Holden and the Regents, and leaked stories to the newspapers, but did nothing on the Crossley reflector. He wanted to be a research astronomer, not an antique rebuilder! Hussey had no intention of resigning, as Burnham, Crew, and Barnard had; he would fight it out with Holden. Hussey enlisted Campbell, who after several years of seeing Holden close up at Mount Hamilton was well aware of his flaws as a scientist and as a leader. Campbell did not come out into the open in the fight, but supported Hussey covertly. So did Perrine, then the Observatory's Secretary, who longed to be an astronomer and had grown to dislike the Director intensely. Perrine fed information from Holden's incoming and outgoing correspondence to Campbell and Hussey.

During the entire time he was at Lick, Hussey kept in close touch with Jordan, the Stanford President. The Lick astronomer had high hopes of returning to Palo Alto as Director of his planned observatory, with a large telescope there if Jordan could pry the necessary funds to build it from Leland Stanford's heirs (Hussey, 1896). The President wanted Hussey to come back, and encouraged him to fight Holden (whom he called "... that immoral and incompetent man.") all the way, as did John Branner, the Stanford Geology Professor (Branner, 1897, Jordan, 1897). To do so, Jordan recommend that Hussey consult E L Campbell (no relation to the astronomer), a lawyer who was a member of the Stanford Board of Trustees, for legal advice. He did, and the lawyer began collecting "evidence" (mostly statements against Holden), and made at least one surreptitious visit to Mount Hamilton. Schaeberle and Richard Tucker, the two senior astronomers at Lick, declined to take part in the struggle but made no move to save Holden either. All of Holden's imperious ways came back to haunt him; Leuschner only returned to Berkeley as the fight was ending, but Denicke, his father-in-law and a member of the Board of Regents, pressed the charges against Holden relentlessly. Holden resigned and fled to the East in the fall of 1897, never to return to California (Osterbrock, 1984b:156-173).

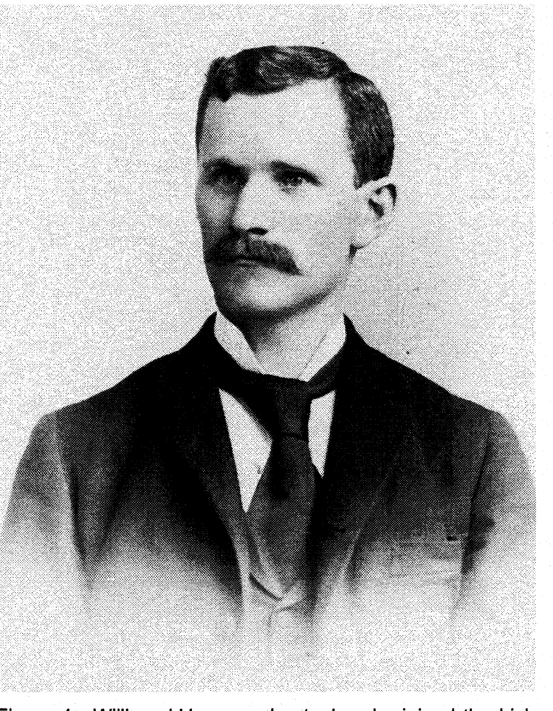

Figure 4. William J Hussey, about when he joined the Lick Observatory staff (*c.* 1896) (Courtesy of the Mary Lea Shane Archives of the Lick Observatory).

Schaeberle took over as Acting Director until the Regents, after a long delay, named Keeler as the next Director and he accepted and arrived on 1898 June 1. Schaeberle, who had been passed over for the Directorship, could not be dissuaded from resigning; he moved back to Ann Arbor almost immediately after Keeler's arrival. To the surprise of everyone on the mountain the new Director put himself in charge of the Crossley reflector, rather than continuing the spectroscopic research he had done so productively both at Lick and at Allegheny. Campbell went on with his radial-velocity and other spectroscopy, and peace returned to the mountain. Hussey, angling for the Directorship back at Michigan, agreed with his friends there that Hall was not a successful Director. He would come back himself, he wrote, only if the University of Michigan really wanted him and proved it by matching his salary at Lick, his two nights a week observing with the big telescope, his two student assistants, his practically non-existent teaching load, and only two 'popular' lectures a year (Hussey, 1898a).

Simultaneously he was lobbying for a job at Stanford, advising Jordan and Branner where they could pick up a good used 8-inch telescope cheaply, but adding that a larger one on a site he had found near the campus would be much better (Hussey, 1898b). One year later he sent Jordan a letter that he had received from a friend in Michigan to prove how much they wanted him back. Hussey added that if he did return to the University of Michigan, he would consider it useful training for his eventual appointment as the Director of the then still only conceptual Stanford Observatory (Hussey, 1899).

Keeler died in 1900 and Campbell, by then world famous in astronomy, became Director almost by acclamation. Hussey was still observing double stars, but he was no longer a confidant of his old friend. Once again Hussey wrote the Stanford President that everything was pleasant enough at Lick, but that he was still eager to come back to build an observatory in the hills above the Palo Alto campus (Hussey, 1901). But it never came about. In 1903, when Hale was trying to get the money from Andrew Carnegie to build a new 'Solar Observatory' (around a 1.52-m (60-inch) reflector) in California, Hussey was dispatched from Lick to investigate several potential sites for it, including Mount Wilson, Mount Lowe (near it), Palomar, and also a few in Australia and New Zealand. He concluded that Mount Wilson was the best place to put it, no doubt to Hale's profound relief, for he had been sure that it was the place to put the 1.52 m since 1896 (Wright, 1966:164-165). Two years later Hussey finally got one of the jobs he had always said he wanted: he was appointed Director of Detroit Observatory when Hall left Michigan to return to the Naval Observatory (Lindner, 2003).

6 ALLEN COLTON

A less familiar name in the early California-Michigan Axis was Colton, whose letter of resignation on 1897 August 18, triggered the final struggle that led to Holden's departure just one month later. Colton grew up in Ionia, Michigan, and attended the University of Michigan, where he studied astronomy and graduated in the same class of 1889 as Hussey (Colton, 1892; Campbell *et al.*, 1896). There he had Campbell as a teacher in his senior year, so the three of them were well acquainted with one another. After graduating, very probably Colton worked as an assistant to Harrington in his meteorological activities at Detroit Observatory, and he certainly went with him to the Weather Bureau in Washington. Holden had Colton appointed as an Assistant Astronomer and Secretary at Lick Observatory in the vacancy created by Crew's resignation, effective 1892 July 1, and urged him to come as quickly as he could, because he was badly needed at Mount Hamilton (Holden, 1892a). The Lick Director wrote Harrington a jocular letter apologizing for stealing yet another of his pupils (he was referring to Campbell and Leuschner), but continued on a more serious note, pointing out that there was much work for "... an excellent methodical fellow ..." like Colton, and that there were not many of them at Lick (Holden, 1892b). Harrington replied in similar style, joking that Holden had taken all of his employees but his cook, who would probably be next to leave for California. More seriously, he added that Holden had recognized the value of the University of Michigan as a training ground for young astronomers, and that though he was sorry to lose Colton he was confident that he had "... a very honorable career before him." Holden, by taking him, had "... afforded him a very excellent beginning for it." (Harrington, 1892).

However, Colton's main duty turned out to be assisting Holden in his programme of lunar photography with the long-focus Lick refractor (Figure 5). When Holden had come to Mount Hamilton as Director, he trumpeted the virtues of astronomical photography, but he had no previous experience in this new research field. He was too busy, too distracted, and even unwilling to appear to take advice from his subordinates who were experts in it, Burnham and Barnard. They resented his arrogant incompetence and each eventually declined to help him; Colton evidently appeared (from a distance) to be just the man he needed. Within a year Holden hired Perrine to take over the secretarial work, and Colton became the Director's full-time Photographic Assistant. He had plenty of previous experience, but the work was hard, with many large plates to develop after each night Holden observed, most of them poorly focussed, as Colton could see. In five years at Lick Observatory he was author or co-author of only five short scientific papers or notes. The one he considered most important was a three-page description of direct photographs of Jupiter taken using an enlarging lens with the refractor, on which he was listed as the third author. Holden, who certainly wrote the text for this note, stated that he, Campbell, and Colton had all worked together at the telescope, and that Colton had developed all the plates (Holden *et al.*, 1892). Probably the perfectionist, Colton, had taken most of the good ones. Holden's bumbling efforts at the telescope repelled him, and he was hoping to move on. He wrote Hussey he would be glad to transfer to a job at Stanford, dreaming of getting a Ph.D. some day (Colton, 1894). Evidently he did not realize that Hussey himself was trying to get a faculty job at Lick. By 1895 Colton was thoroughly discouraged and thinking of going back to Michigan (Colton, 1895). He even claimed Holden had admitted he knew that he was getting poor results but cynically told him that no one but the two of them would notice (Colton, 1897a). This seems to be a distortion, written only two months before the dam of his resentment burst in his bitter letter of resignation (Colton, 1897b), listing all his charges of incompetence and malfeasance against the Director. Holden had to forward it to the Regents with his rebuttal, in which he said he could give explanations of any of Colton's statements at any time they wished, but that many astronomers had said that the lunar maps he had produced were good ones. The struggle between the Lick Director and Burnham, Crew, Barnard, Hussey and now Colton had been going on for years, and the Regents had had enough. Prodded by Leuschner's father-in-law, Denicke, and some of the more recently-appointed Regents who had no vested interest in protecting Holden any longer, they gave him no choice but to resign. He had to go, and he did (Osterbrock, 1984b:164-171).

By then Colton was back in Michigan, his predicted long, honourable career over, though apparently he never admitted it, even to himself. In 1901, soon after Campbell was appointed Director, Colton wrote a long, friendly letter to him from Ann Arbor, congratulating him and saying he knew his old friend would succeed. He wanted to come back and "... prove that I am *good for something* in the astronomical line ..." His heart had been in his work at Lick, but it had been embittered by his experiences, his health was poor, and he could barely do anything. But he had taken some courses in physics at the University of Michigan, taught school in a little community for a time, and now wanted to return and redeem himself (Colton, 1901). Campbell, who knew Colton very well from the six months in 1892 when the two of them (both bachelors) and Townley (then Lick's only regular graduate student) had shared quarters and meals together at Mount Hamilton, was noncommital. He was glad to get Colton's cordial note and would always be happy to hear from him. Now that he was back in Ann Arbor, he should begin a research project of his own. (Campbell had published about eighty papers and notes in *his* first five years at Lick.) That would help him find a suitable job somewhere. As for Lick, all the staff positions were filled, and all the telescope time was being used effectively. He sent Colton his best wishes for the future (Campbell, 1901).

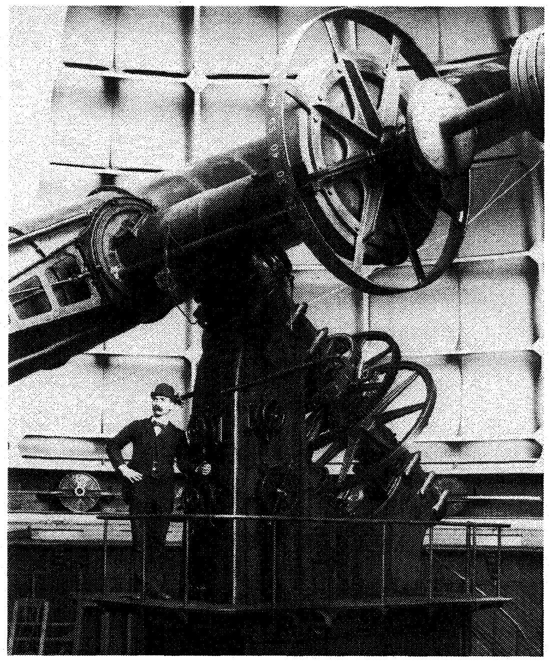

Figure 5. William J Hussey, about when he joined the Lick Observatory staff (*c.* 1896) (Courtesy of the Mary Lea Shane Archives of the Lick Observatory).

Colton's memory lived on for years at Lick; the old-timers learned his story via the grapevine, though it was never published in any of the official accounts of the Observatory. He did not get back into astronomy, but was living in Washington in the 1920s. In 1932 Heber Curtis heard from friends at the US Naval Observatory that Colton, then about seventy and "... up against it ..." in that dark Depression year, had been there, asking for piecework computing, but there was none to be had (Curtis, 1932).

7 RALPH CURTISS

Ralph H Curtiss was a member of the California-Michigan Axis who was educated in California and then ended up at the University of Michigan as a Professor of Astronomy and ultimately Director of Detroit Observatory. He was born in Connecticut, but as a child moved with his family to Redlands, California, east of Los Angeles. Curtiss was an excellent student who graduated from high school there at age sixteen, and then worked for a year before he entered the University of California. He was especially interested in physics, attracted by E P Lewis, the Professor who taught spectroscopy, but in his junior year switched to astronomy under Leuschner. In addition Curtiss (Figure 6) took some engineering courses, and by his senior year Leuschner considered him "... one of the best men we have ever turned out." (Leuschner, 1900). That

Figure 6. Ralph H Curtiss, as a senior on the Berkeley campus, soon before leaving to observe the solar eclipse in Borneo (from a San Francisco newspaper clipping, 1901) (Courtesy of the Mary Lea Shane Archives of the Lick Observatory).

year Curtiss was appointed an assistant and accompanied Perrine, by then a full-fledged Lick astronomer, to Padang, Borneo, to obtain spectrograms and direct photographs of the corona and chromosphere at a total solar eclipse (Moore, 1930). They were almost clouded out but got some useful data. Curtiss demonstrated that he was a careful, capable observer and received his B.S. in 1901 and a Lick Observatory Fellowship for three years of graduate study. It involved course work in astronomy, physics, and mathematics at Berkeley, and observing at Mount Hamilton. There he photographed and analysed comets with small telescopes, and also learned to use the Crossley reflector. For his thesis he standardized and optimized the methods for measuring spectrograms and measuring radial velocities from them (Curtiss, 1902). After receiving his Ph.D. Curtiss stayed on at Lick for another year and a half as a Fellow, then an Assistant under a grant from the Carnegie Institution, responsible for measuring and reducing the radial-velocity spectrograms sent back to Mount Hamilton from the southern-hemisphere station in Chile. By the time he left for a regular position at Allegheny Observatory in 1905, he was a world expert in measuring accurate stellar radial velocities, and a few years later he took this expertise on to Detroit Observatory (see Lindner, 2003).

8 HEBER CURTIS

Heber D Curtis, was an outstanding research astronomer in both California and Michigan. Born in Muskegon, Michigan in 1872, he was an excellent student in school there and in Detroit, where his family moved when he was seven. He took the classical course in high school, which included Latin, and was very good in mathematics, but did not take any science courses, although he was quite handy with tools, including the machine tools of his day. Undoubtedly his father, Orson Curtis, urged his son to study classics, not science, to follow in his own footsteps. Orson Curtis had been a student in classics at the University of Michigan when the Civil War broke out, and in the summer of 1862 volunteered for the Union Army. In December of that same year he was wounded in the Battle of Fredericksburg, Virginia, had his left arm amputated, survived the field hospital, and was sent home an instant hero. Moreover, his regiment, part of the Iron Brigade, became famous throughout Michigan (Curtis, 1891). Orson Curtis recuperated, then returned to the University of Michigan, graduated in 1865, and became a school teacher, and eventually a School Superintendent. Soon he was a leader in the Grand Army of the Republic, the Northern veterans' organization which in alliance with the Republican Party "waved the bloody shirt" and dominated national politics for many years. Orson Curtis ran for the Michigan State Senate once and was defeated, but then obtained a series of political patronage jobs in the U.S. Customs Service in Detroit. He wanted his first-born son to become the Professor of Classics he might have been if the Civil War, his abbreviated military career, and his wound had not turned him in a different direction.

Thus Heber Curtis went on to the classical course at the University of Michigan, and took all the Latin and Greek taught there, as well as two years of Hebrew, two of Assyrian, and one of Sanskrit. He earned his A.B. in 1892, and an A.M. in 1893, but in his four years at Ann Arbor Curtis never took a course in astronomy or physics, or even entered the campus Observatory (Aitken, 1943). Then Curtis went west, to become Professor of Latin and Greek at Napa College, a small Methodist institution near San Francisco. It had an 20.3-cm (8-inch) refracting telescope with a Clark lens, but no Professor of Astronomy. Curtis began using it to look at stars and was soon hooked on astronomy. Napa College was losing money rapidly, and in 1896 merged with the University of the Pacific, another small Methodist college then located in University Park, between Santa Clara and San Jose (now a teeming area in Silicon Valley). Curtis, an excellent teacher, was one of only three Napa faculty members who was retained, but as Professor of Mathematics and Astronomy. The University of the Pacific had an excellent 15.2-cm (6-inch) Clark refractor, which though smaller than the Napa 20.3 cm had graduated right ascension and declination circles, and a micrometer for measuring angular separations of double stars. Soon Curtis was in touch with Holden, at Mount Hamilton, visible from University Park on clear days. Holden sent the eager young Professor some suggestions, and in 1897 approved his request to spend six weeks of his vacation as a volunteer assistant and summer student at Mount Hamilton. Curtis, who had married in 1895 and already had one young daughter, moved up to spartan bachelor quarters in the little astronomy village for the month and a half. He learned to use the transit, meridian circle, and smaller telescopes, and helped the regular observers with the big 91.4-cm refractor. His winning personality, drive, persistence, and mechanical skills endeared him to all. Curtis became particularly friendly with Schaeberle and Campbell. Curtis also made a good impression on Holden, whom he soon realized was on his way out. The embattled Director left Mount Hamilton in 1897 September, not long after Curtis had returned to his students at the University of the Pacific.

That fall he decided, with his wife's support, to switch careers and become a professional astronomer. He was already studying on his own, but he realized that although none of the current Lick astronomers had more than bachelor's degrees, he would certainly need to earn a Ph.D. to prove that he was a 'real' astronomer and not a displaced classics scholar. In 1898 February Curtis applied for admission as a graduate student at Lick Observatory, to begin that summer. Schaeberle, now Acting Director, was very positive for him to come, but Leuschner objected vociferously (Schaeberle, 1898). Curtis should first register at Berkeley and take all the undergraduate astronomy courses (which he taught) or at least pass exams in them, Leuschner insisted, before he could be considered for graduate work at Lick. Keeler was named Lick's new Director just then, and he sided with Leuschner, whom he wanted as an ally on the campus. Keeler was not impressed by Curtis's training in languages, and had not seen him in action at the Observatory. The result was that Curtis stayed in his teaching job at the University of the Pacific and spent only part of the summer of 1898 at Lick (Leuschner, 1898). Then, taking his family with him, Curtis went to the University of Michigan for the whole of next summer to work with Hall, calculating the orbit of Comet Perrine 1898 I, discovered at Lick Observatory. He returned to University Park and one more year of teaching, spending his entire Christmas vacation at Mount Hamilton, working on the orbit.

By now Curtis was determined to start as a graduate student somewhere in 1900. He could have done so at Michigan, but Hall was generally considered a lightweight and Curtis knew that a degree from him would not help his career. He applied at the University of Chicago, where his brother Walter lobbied for him (Curtis, 1900). Forest Moulton, the young astronomy instructor on the Chicago campus, recommended Curtis strongly for a fellowship at Yerkes Observatory and Hale, its Director, tried to get it for him, but the University administration had already committed all they had for that year (Moulton, 1900; Hale, 1900). At Lick Keeler was still negative, and Curtis finally had to take what was undoubtedly his last choice, a two-year fellowship at the University of Virginia's McCormick Observatory in Charlottesville (Keeler, 1900). Ormond Stone, its Director (and sole staff member) was a kindly old classical astronomer who needed an assistant badly. Curtis's father, the wounded Union veteran who had orated against the 'Rebels' for years, must have hated the idea of his son going to Virginia to study.

Lick Observatory was sending a party to observe a total solar eclipse, whose track lay across the south-eastern United States that summer. Campbell and Perrine made up the Lick group, and Curtis, who had already gone east, joined them as a volunteer at their eclipse camp at Thomaston, Georgia. Perrine came down with dysentery on the unfamiliar, small-town Southern deep-fried cooking, but Curtis filled in expertly for him, helping Campbell line up all the cameras and spectrographs before the eclipse, and operate them during the brief moments of totality. All their data turned out well, and Campbell, greatly impressed by Curtis's practical skills, marked him for the future (Osterbrock, 1980).

Stone's skills may be judged from the fact that he came to the eclipse with a fairly large astronomical camera and took a photograph of the corona, but did not know how to develop it, and had to ask Campbell to do so for him. As the only astronomy graduate student at Virginia, Curtis lived with his family in a house near the observatory (on a height named Mount Jefferson), carried out a regular observing programme under Stone's supervision, learned what he could from him, and gained valuable experience in laboratory spectroscopy, working with physicist William Humphreys. Curtis sailed off to Borneo on a six-month-long eclipse expedition with Humphreys, but they were clouded out almost completely on the day of totality. Nevertheless in two years Curtis completed his Ph.D. thesis on the definitive orbit of Comet Perrine, the standard type of dissertation of those days. Campbell had promised Curtis a job on the Lick staff after he got his degree, and came through with it, although it took several more months before the young Director could provide a house for Curtis's family on Mount Hamilton (Curtis, 1902; Campbell, 1902).

Campbell was then in the beginning stages of his massive radial-velocity programme. Curtis became his trusted right-hand man, who worked closely with him in taking spectrograms at the telescope, measuring them, and reducing the measurements to yield radial velocities of the stars. The Lick observers discovered many spectroscopic binaries and in 1905 Campbell and Curtis published the first catalogue of these stars, listing data on all the 140 then known objects of this type, the largest number of them discovered at Lick. They discussed the percentages of spectroscopic binaries among stars of different spectral types. They also mentioned that the reflex motion of the Sun about the centre of mass of the solar system, largely due to Jupiter, is periodic with a range of 0.03 km/sec. That was much too small to be detected in other stars with their spectrograph then, they wrote, but might provide the method for finding possible planets around other stars in the future, as indeed it has in our time (Campbell and Curtis, 1905).

For the southern-hemisphere observing station in Chile Campbell built, in house, a 94-cm (37-in) reflecting telescope, the optics made by Brashear & Co. This reflector with its canvas dome cost about one-twentieth as much as the famous Lick refractor, but equalled it in light-gathering power. It was completed and tested on Mount Hamilton in early 1903, and Lick astronomer Wright and his assistant, Harold Palmer, a recent Lick Ph.D., then took it to Chile and erected it on San Cristobal, a hill on the outskirts of Santiago (Campbell, 1907). Soon they were obtaining good, measurable spectrograms of southern stars. The two of them did all the observing, working from lists provided by Campbell. They processed the spectrograms there, and measured as many of them as they could, sending the rest back to Lick for measurement there by Curtis (Wright, 1907).

Wright and Palmer had signed on for three years, and at the end of 1905 Campbell sent Curtis, with assistant George Paddock, a Virginia graduate student, to replace them. Curtis arrived at Chile in 1906 February, and two nights later he was already working at the telescope. Paddock did not arrive until three months later; until then Curtis observed on his own. Wright had done an excellent job in getting the telescope and observatory into operation; Curtis improved it greatly and systematized the work. He found the primary mirror badly tarnished, and resilvered it carefully, experimenting as he did so, ending up with an excellent coat and a tested procedure which was used at San Cristobal and at Lick for years afterward. Paddock was a quiet, morose character while Curtis was a whirlwind of activity who kept his assistant cheered up and working effectively for months, and then sent him off on brief vacations in Chile to recuperate from the long nights of observing (Curtis, 1909a). Curtis, a gregarious, talkative individual, quickly learned Spanish, which was easy for him with his knowledge of Latin and other languages. In Santiago he, his wife, and their three children lived very much in the Chilean community. For their first year in Santiago the two older children attended an English school, but after that they switched to a Chilean school and quickly became fluent in Spanish, as their younger brother did also, picking it up from his playmates around their home.

From 1908 Christmas through early 1909 January a large Pan-American Scientific Congress was held in Santiago, with delegates present from all over South and Central America, Mexico, and the United States. They read over six hundred papers on their research. Curtis, was named a Vice President of the Congress and gave three oral papers (all in Spanish). One was a review of current astronomical research in the southern hemisphere, a second on his own work on the radial velocities of large-proper-motion stars, and the third a summary report on the southern spectroscopic binaries he, Wright, Palmer, and Paddock had discovered at San Cristobal (Curtis, 1909b). Curtis undoubtedly showed many of the delegates around the observatory, and went on a five-day excursion by rail to southern Chile with nearly a hundred of them. According to him it was a continuous round of banquets, toasts, and cigars, all as guests of the Chilean Government.

Curtis and his wife, May, enjoyed living in Santiago, and though he had signed on for five years, he felt they might well decide to stay for ten (Curtis, 1908). However, in 1909 March Campbell summoned him back to Mount Hamilton (Curtis, 1909a). Perrine had accepted the Directorship of Cordoba Observatory in Argentina, and would be leaving Lick. He had been the observer assigned to photograph nebulae with the Crossley (91.4-cm) reflector since Keeler's death in 1900, and now Curtis was to replace him on 1909 July 1.

Keeler in his two short years as Director of Lick had systematically photographed nebulae with the Crossley reflector. Because of its speed and scale, it showed these objects in much greater detail than any visual observer had seen them, or than smaller cameras had recorded them. His greatest discovery had been the huge number of spiral 'nebulae', previously unknown or seen only as faint, fuzzy blurs; his direct photographs showed they were objects similar to M31, the well-known Andromeda 'nebula', smaller in angular size down to barely-resolved objects. Keeler grasped that these spirals were all physically similar, but at larger distances than M31, out to the furthest, apparently smallest ones. He thought they were all recently formed stars, still contracting and forming planets, as in Kant's, Laplace's, and Herschel's nebular hypotheses. After Keeler's death, Perrine had continued this programme. Educated as a secretary, he had no theoretical ideas in astronomy, and did little more than take better direct photographs with the Crossley, which he had improved. Perrine discovered two new outer satellites of Jupiter with the reflector, but had not gone beyond Keeler in understanding nebulae (Osterbrock, 1980).

Curtis (Figure 7) still further improved the mounting of the Crossley Reflector, and began his systematic study of nebulae. He carefully inspected all the plates Keeler and Perrine had taken of each object, and took more himself, if they were needed, to get a complete picture of each object. Curtis was much more scientific than Perrine (he read widely in German, English, and American journals), and tried to frame hypotheses which he could test in his collection of direct photographs. One class of objects he studied in detail was the planetary nebulae. He could see that they were mostly cylindrically symmetric, like rings, not spheres, each with a central star which was blue or hot. The planetary nebulae were at all distances, and hence appeared with all angular sizes, the apparently largest ones being the nearest. In the sky they were strongly concentrated in the galactic plane, but had high random velocities. Curtis therefore deduced that, in terms of the current very primitive picture of stellar evolution, the average planetary was even older than the average late-type star. Although he had little idea of the physics of these nebulae, he had isolated them as a class, and laid out the main lines of their nature as we understand them today. Curtis gave a very good summary of these ideas in a lecture in San Francisco in 1917 March (Curtis, 1917a), and he published his magnum opus on planetary nebulae in 1918; it defined the field for years (Curtis, 1918b).

Curtis was extremely friendly with everyone, and especially with all the Mount Hamilton residents from the Director to the janitor, and their families. He was the postmaster, a small job which meant he handed out the mail to everyone once a day, when the stage brought it up from San Jose. Curtis was the owner of one of the very few automobiles on Mount Hamilton; he maintained it himself, often during stops on the winding mountain road to get out his tool box and repair a part. When he drove up or down, he would always take others who wanted to go, to the capacity of his car. In 1912 he was President of the Astronomical Society of the Pacific (the term was then one year), and in 1915, when the American Astronomical Society held its first West Coast meeting, Curtis produced a little guidebook of astronomical exhibits at the Pan-Pacific Exposition (a World's Fair) then going on in San Francisco.

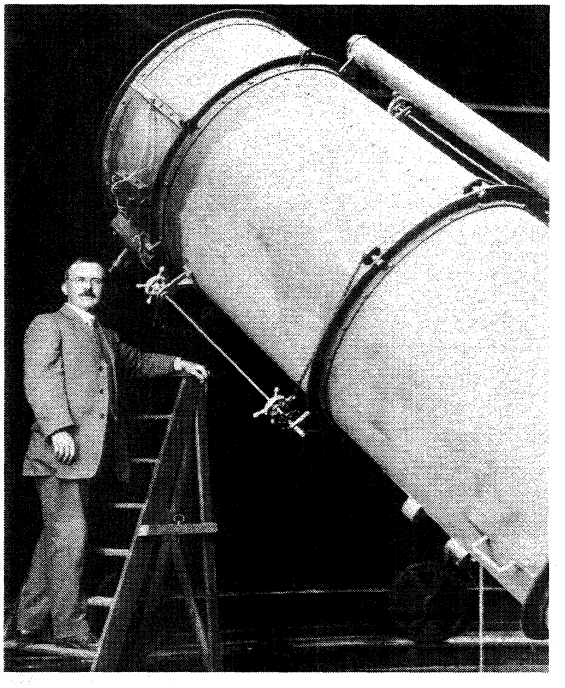

Figure 7. Heber D Curtis at the Newtonian focus of the Crossley reflector, Lick Observatory, *c.* 1915) (Courtesy of the Mary Lea Shane Archives of the Lick Observatory).

In 1913 Albert Einstein published a paper pointing out that according to his Special Theory of Relativity, light should be deflected in a strong gravitational field. The predicted amount at the edge of the Sun was 0″.87, and as Einstein emphasized, this should be observable at a solar eclipse. Curtis, an omnivorous reader of scientific journals saw this paper, studied it in detail, and wrote an excellent review of relativity theory for astronomers (Curtis, 1913). He undoubtedly brought it to Campbell's attention, who greatly enjoyed leading eclipse expeditions to the far corners of the globe. Campbell resolved to take a Lick group (including his wife, his mother-in-law, his three sons, and Curtis) to measure the deflection at the favourable solar eclipse in Russia in 1914 August. They brought their long-focus cameras with them to their station near Kiev, to photograph the star field surrounding the eclipsed Sun at totality, but were completely clouded out. Even worse, World War I broke out while they were in Russia. To get there they had travelled through Germany, now at war with Russia, but could not return that way. They barely managed to escape via Finland and Sweden, but had to leave all their instruments behind, in the care of Russian astronomers. Then in 1916 Einstein announced his new General Theory of Relativity. According to it, the deflection of light at the edge of the Sun would be 1″.75, double the amount predicted by the Special Theory of Relativity. Now it was even more important to make the observational test, and the next good chance would be during the upcoming solar eclipse at Goldendale, Washington, in 1918 June (Osterbrock, 1980).

By then America was in World War I too, and this was to change Curtis's life and scientific career greatly. Forty-five years old, and with four children, he was never in any danger of being drafted, but he wanted to 'do his bit'. Curtis was not a super-patriot like Campbell, who hated the 'Huns' and ached to punish their leaders and scientists, but he considered it his duty to do anything he could for his country. By 1917 August, Curtis was at San Diego, teaching navigation in a 'quickie' wartime school for merchant ship officers, as America became 'the arsenal of democracy'. He taught full-time, but he brought his astronomical data and notes with him and worked on research when he could. Campbell sent him more, as Curtis needed them. He had stopped observing, and was consolidating his ideas and writing up his results for publication. From San Diego, after a brief interval back on Mount Hamilton in 1918 February, Curtis moved to Berkeley where again he taught navigation as well as elementary astronomy to would-be naval officers. He wanted to get more directly involved in the war effort, and got a temporary appointment at the Bureau of Standards in Washington, in a group developing cameras for photographic mapping and intelligence collecting. He was there from 1918 August through 1919 April, well after the armistice, with several other astronomers and physicists from all over the country. His family had remained at Mount Hamilton all this time, and so though Curtis was doing his most important astronomical research on the run, he was also developing contacts and exchanging ideas with a wider group of scientists than he would ever have seen at Lick Observatory.

In 1918 the Lick photographic telescopes had not arrived back from Russia, and Campbell had to borrow less satisfactory lenses for the Goldendale eclipse. Curtis broke away from Berkeley briefly, and he and Campbell got the plates they needed, but the relativity effect was too small to be detected with the substitute cameras. Curtis spent great effort measuring and reducing the plates, and at one time thought they had disproved the General Theory of Relativity, but could neither confirm nor disprove the Special Theory. He prepared a paper along these lines for presentation at the ASP meeting in Pasadena in 1919 (Curtis, 1919a, b). However, Campbell, in England for a post-war astronomy meeting, learned that all the astronomers there believed that Arthur Eddington and Frank Dyson had measured the larger value of the light deflection at the very recent solar eclipse in Brazil and Africa, proving that the General Theory of Relativity was correct. Campbell cabled Lick that Curtis should delay publishing his paper (Campbell, 1919), as the probable errors reported in it were too large. Curtis, recognizing that it was "... better to be safe than to be sorry ...", withdrew the paper and it was never published (Curtis, 1919c). The errors in the English astronomers' measurements were very large, but their result was basically correct. From the Goldendale experience Campbell learned how to avoid the pitfalls in these light-deflection measurements, and by 1922, when all the Lick 'Einstein' cameras were back, he and Robert Trumpler obtained plates on which they measured the deflection at the limb of the Sun $1''.75 \pm 0''.09$, which confirmed the General Theory to high accuracy.

Studying the Crossley images of many spiral 'nebulae', Curtis realized that not only were they all one family, seen at different orientations at different distances, but also the most nearly edge-on ones all had dark rifts down their central axes. He recognized that this resulted from 'occulting' or 'absorbing' matter, similar to the 'dark nebulae' Barnard had photographed in the Milky Way. Curtis's interpretation was that the spirals were not true nebulae, composed of gas, but were vast star systems like our Milky Way, with the occulting material in their mid-planes. They were 'island universes' or galaxies. The individual stars in them were too faint to be resolved, indicating they were much more distant than the size of our Milky Way system.

Curtis gave an oral paper on this subject at a meeting at Stanford in 1917 April, in the same week the United States declared war on Germany (Curtis, 1917a). Confirmation came quickly, for G W Ritchey, working independently with the Mount Wilson 1.52-m (60-inch) reflector, reported the discovery of a 'nova' in the spiral NGC 6946. Curtis immediately saw that it must have been not an 'ordinary' nova like the well known ones in our Galaxy, but a much rarer, more luminous object like the bright nova S Andromedae which had flared up to seventh magnitude in M31 in 1885. At San Diego, looking over his own data from the vast Lick collection of direct photographs, Curtis found images of a few more of these relatively bright novae in other spiral 'nebulae', as Ritchey also did at Mount Wilson (Curtis, 1917c). They thus confirmed Curtis's picture (Curtis, 1917d). Vesto Slipher at Lowell Observatory had already measured extremely large radial velocities for a few of the brighter spirals; they proved these objects could not long remain in our star system, and probably had never been a part of it. Curtis further realized that the strange distribution of the spiral 'nebulae' on the sky, highly numerous around the galactic poles but not present at all near the galactic equator, could be understood as resulting from the strong 'occultation' (or absorption) of light by 'dark nebulae' (dust clouds) near the galactic plane (Curtis, 1918c).

Curtis now understood that the spirals were 'island universes' or galaxies like our own Milky Way. From his many plates he could estimate the total number of them in the sky, down to the faint magnitude limit of the Crossley reflector. The result he found, about 700,000, was larger than the previous estimates by Keeler and Perrine, based on their earlier surveys with less well-exposed photographs (Curtis, 1918a). Curtis published these papers on the evidence for this whole picture in 1917 and 1918, all written in moments he could spare from his wartime duties in San Diego, Berkeley, and Washington.

After the armistice, which effectively ended World War I in 1918 November, Curtis, with many other scientists, stayed in Washington several more months as their wartime projects wound down. His results on spiral nebulae as galaxies were known by word of mouth to many of his colleagues, and he lectured on them at a meeting in Washington in 1919 March. In that talk, entitled "Modern Theories of the Spiral Nebulae", Curtis presented a clear, logical discussion of "... the spiral nebulae as island universes ...", illustrated by many slides of his photographs and a few spectrograms (Curtis, 1919c).

Read today, it is completely convincing, and no doubt it seemed so to many in the large audience of scientists who must have been present. Others probably did not find it so, for they had all been brought up with the idea that the spiral 'nebulae' were stars and planetary systems in formation. It was hard for them to change their thinking. But the Lick astronomers were all convinced by then that Curtis was right.

Hale, who had been in Washington since 1916 and probably heard Curtis's lecture in 1919 March, arranged for him to give one of the two talks on "The Scale of the Universe" before the National Academy of Sciences in 1920 April, which we today call 'The Great Debate'. The other speaker was Harlow Shapley, who had been doing pioneering research at Mount Wilson on our Galaxy, and had published a short paper rejecting Curtis's conclusion that the spiral nebulae were stellar systems (Shapley, 1919). At the debate Curtis upheld his island universe 'theory'; Shapley spoke mostly of the distances to the globular clusters, but believed that "... the evidence ... [was] opposed to the view that the spirals are galaxies of stars comparable with our own." "In fact," he went on, "there appears as yet no reason for modifying the tentative hypothesis that the spirals are not composed of typical stars at all, but are nebulous objects." He was wrong, and Curtis was right, although on the question of the size of our Galaxy, Shapley was closer to our current view (Curtis, 1921, Shapley, 1921).

In later years Shapley depicted himself as having been a naïve astronomer pitted against a master of rhetoric and a skilled debater. Certainly Curtis had studied rhetoric in his classical course at Michigan three decades earlier, but in fact he gave a straightforward account of the observational evidence, not a Ciceronian oration. Shapley, on the other hand, had been trained as a journalist at the University of Missouri, and he knew better than Curtis how to simplify an argument to make it understandable to the senior scientists from all fields at the National Academy meeting.

In 1920 April, just a few days before the Great Debate, Curtis decided to leave Lick Observatory to accept the Directorship of Allegheny Observatory. His high visibility, especially in Washington in 1919, had brought him the offer. Earlier he had turned down the chance to return to the University of Virginia as Director of its Observatory in 1911. Curtis had wanted to continue his research, and Lick was clearly the place to do it, not Charlottesville. It seems incredible to us today that he should accept the Allegheny job less than a decade later, a poor, under-funded Observatory in Pittsburgh. But in those days a scientist was supposed to want to rise to head of his department. Knowing the inflexible Lick seniority system, Curtis could easily see that Aitken and then Wright were in line to succeed Campbell, in that order, and that he could not become Director there before 1942, when he would be seventy years of age. Also, in those days the Allegheny Directorship paid about twice as much as a senior Professor could hope to make. For Curtis, with four children to put through college, this was a significant factor indeed. These are the reasons Curtis gave for accepting the new job; in addition his experiences in San Diego, Berkeley, and especially Washington had probably made him realize the attractions of being part of a larger scientific community, rather than living out his life on an isolated mountain top.

Whatever the reasons for making the move, Curtis soon found that he could do little important research at Allegheny, which already suffered from severe light pollution, and where there was no money for new instruments or a larger staff. In 1930 he moved on to his Alma Mater, the University of Michigan, as Director of the Detroit Observatory (see Lindner 2003). At Lick Observatory, Curtis had done important research on solar eclipses, stellar spectroscopy and radial-velocity measurements, spectroscopic binaries, southern-hemisphere astronomy, planetary and diffuse nebulae, relativity and the gravitational deflection of light, and spiral galaxies. Today the 'bright novae' he identified in a few spirals are called supernovae, and astronomers use them to measure distances to distant galaxies much more accurately than he could; but he had realized back in 1917 that they were the keys to the intergalactic distance scale (Osterbrock, 2001).

9 CONCLUSION

Why was there a California-Michigan axis in American astronomy, and why did it thrive? It is easy to see from these case studies that the principal reason was that Universities of Michigan and California were two large state universities that were dedicated to graduate education and to research from their beginnings. Both States were relatively prosperous and populated by citizens who believed in education and research. Both Universities were accessible to poor would-be students with brains, drive, and ambition who were interested in science and astronomy. There were few other serious, large graduate programmes in astronomy, only Yerkes Observatory of the University of Chicago and, on a much smaller scale, the University of Wisconsin. And, once the first University of Michigan astronomers (Schaeberle, then Leuschner and Campbell) went to the University of California, then they brought younger colleagues from the University of Michigan with them, or encouraged their friends from Ann Arbor to join them.

10 ACKNOWLEDGEMENTS

I am indebted to my late friend, Orren Mohler, himself a product of Eastern Michigan University and the University of Michigan, later a Professor and Director of the latter's McMath-Hulbert Observatory, who made many observing trips to California, for first calling my attention to the California-Michigan axis in American astronomy and awakening my interest in it. I dedicate this paper to his memory. I am also most grateful to Patricia Whitesell and Rudi Lindner for sharing valuable source material and their highly insightful thoughts on the California-Michigan axis with me. In addition, I am grateful to Dorothy Schaumberg, Curator of the Mary Lea Shane Archives of the Lick Observatory, McHenry Library, University of California, Santa Cruz and to the archivists at the Bentley Historical Library, University of Michigan, Ann Arbor; the Stanford University Archives, Stanford, California; and the Bancroft Historical Library, University of California, Berkeley, for their efficient help in finding material for me which went into this paper. I have incorporated into Section 8 parts of the text of my earlier article on Heber Curtis published in *Mercury*

without references (Osterbrock, 2001), here edited, revised, and extended, with the sources given as references. I am grateful to Robert Naeye, Editor of *Mercury*, for encouraging me to do this.

11 REFERENCES

The following abbreviations are used:

BMNAS = *Biographical Memoirs, National Academy of Sciences*

PASP = *Publications of the Astronomical Society of the Pacific*

SLO = Mary Lea Shane Archives of the Lick Observatory. University Library, University of California, Santa Cruz

BHL = Hussey Family Papers, Bentley Historical Library, University of Michigan, Ann Arbor

Aitken, R.G., 1938. William Wallace Campbell 1862-1938. *PASP*, **50**:204-209.

Aitken, R.G., 1943. Heber Doust Curtis 1872-1942. *BMNAS*. **22**:275-294.

Aller, L.H., 1993. An astronomical rescue. *Annual Review of Astronomy and Astrophysics*, **33**:1-17.

Alter, D., 1953. Armin Otto Leuschner. *PASP*, **65**:269-273.

Anonymous, 1896. "Beauty Weds with Science. Nuptials of Miss Denicke and Professor Leuschner. A Year's Honeymoon", *San Francisco Call*, May 21 issue.

Anonymous, 1897. "Success at Berlin of a A Berkeley Professor — Degree Conferred Upon Him After A Year's Study in the German Capital," *San Francisco Call*, August 14 issue.

Branner, J.C., 1897. Letter to W.J. Hussey, dated September 2, BHL.

California, State of, 1961. Death certificate of Elizabeth B. Thompson, later Mrs. W.W. Campbell, printed public record.

Campbell, E.B., 1938. "Notes" [on her husband W.W. Campbell], an otherwise undated manuscript, SLO. The information which she reported on his childhood traits and schooling came to her from Campbell's sister Isabel.

Campbell, E.B., 1945. *In the Shadow of the Moon*. Undated, unpublished book-length typed manuscript. Different chapters were clearly completed at different times, and the year given here is my best estimate of when the last chapter was finished.

Campbell, W.W., 1891. Telegram to W.J. Hussey, dated November 23, SLO.

Campbell, W.W., 1894a. The spectrum of Mars. *PASP*, **6**:228-236.

Campbell, W.W., 1894b. Concerning an atmosphere on Mars. *PASP*, **6**:273-283.

Campbell, W.W., 1901. Letter to A.L. Colton, dated March 5, SLO.

Campbell, W.W., 1902. Letter to H.D. Curtis, dated June 18, SLO.

Campbell, W.W., 1903. Biographical information, an undated record in his 1903 correspondence file, SLO. This card was written by a secretary early in Campbell's directorship of Lick Observatory, undoubtedly from his notes or dictation.

Campbell, W.W., 1905. Letter to J.B. Angell dated May 6, SLO.

Campbell, W.W., 1907. Organization and history of the D.O. Mills expedition to the southern hemisphere. *Publications of the Lick Observatory*, **9**:5-12.

Campbell, W.W., 1913. *Stellar Motions, with Special Reference to Motions Derived from the Spectrograph*. Yale University Press, New York.

Campbell, W.W. and Curtis, H.D., 1905. First catalogue of spectroscopic binaries. *Lick Observatory Bulletins*, **3**:136-146.

Campbell, W.W., Hussey, W.J. and Colton, A.L., 1896. Letter to J.B. Angell dated June 18, SLO.

Colton, A.L., 1892. Telegram and letter to E.S. Holden. both dated July 6, SLO.

Colton, A.L., 1894. Letter to W.J. Hussey, dated September 6, BHL.

Colton, A. L., 1895. Letter to J.J. Gibson, dated March 4, Author's Collection.

Colton, A.L., 1897a. Untitled memo dated June 11, BHL.

Colton, A.L., 1897b. Letter to the President and Board of Regents of the University of California, dated August 18, SLO.

Colton, A.L., 1891. Letter to W.W. Campbell, dated January 27, SLO.

Curtis, H.D., 1900. Letter to G.E. Hale, dated June 9, Yerkes Observatory Archives, Williams Bay, Wisconsin.

Curtis, H.D., 1902. Letter to W.W. Campbell, dated June 9, SLO.

Curtis, H.D., 1908. Letter to R.H. Tucker, dated September 8, SLO.

Curtis, H.D., 1909a. Recent progress in the work of the D.O. Mills expedition. *PASP*, **21**:191-201.

Curtis, H.D., 1909b. Letter to W.W. Campbell, dated March 23, SLO.

Curtis, H.D., 1913. The theory of relativity. *PASP*, **23**:219-229.

Curtis, H.D., 1917a. The nebulae. *PASP*, **29**:91-103.

Curtis, H.D., 1917b. A study of absorption effects in spiral nebulae. *PASP*, **29**:145-146.

Curtis, H.D., 1917c. New stars in spiral nebulae. *PASP*, **29**:180-182.

Curtis, H.D., 1917d. Novae in spiral nebulae and the island universe theory. *PASP*, **29**:206-207.

Curtis, H.D., 1918a.. The number of the spiral nebulae. *PASP*, **30**:159-161.

Curtis, H.D., 1918b. The planetary nebulae. *Publications of the Lick Observatory*, **13**:57-74.

Curtis, H.D., 1918c. A study of the occulting matter in the spiral nebulae. *Publications of the Lick Observatory*, **13**:45-54.

Curtis, H.D., 1919a. The Einstein effect; eclipse of June 8, 1918. *PASP*, **31**:190. This is the abstract of the paper Curtis sent to the ASP meeting in Pasadena in June 1919, and submitted for publication then, but later withdrew and never published.

Curtis, H.D., 1919b. The Einstein effect; eclipse of June 8, 1918 (preliminary paper). This is the 8-page undated manuscript of the paper which he had read for him at the meeting, and sent to Campbell, but then withdrew, SLO.

Curtis, H.D., 1919c. Modern theories of the spiral nebulae. *Journal of the Washington Academy of Science*, **9**:217-227.

Curtis, H.D., 1921. The scale of the universe: Part I. *Bulletin of the National Research Council*, **2**:194-217.

Curtis, H.D., 1932. Letter to R.G. Aitken, dated September 26, SLO.

Curtis, O B., 1891. *History of the Twenty-fourth Michigan of the Iron Brigade: Known as the Detroit and Wayne County Regiment*. Winn & Hammond, Detroit.

Curtiss, R.H., 1902. Photographic observations of Comet b 1902 (Perrine). *Lick Observatory Bulletin*, **2**:99-104.

Curtiss, R.H., 1904. A proposed method for the measurement and reduction of spectrograms for radial velocities of celestial objects and an application to the variable star W Sagittarii. *Lick Observatory Bulletin*, **2**:19-40.

Curtiss, R.H., 1926. William Joseph Hussey. *Popular Astronomy*, **34**:605-612.

Einarsson, S., Crawford, R.T., Hart, W.M. and Lenzen, V.F., 1958. Armin Otto Leuschner. *University of California In Memoriam*, April issue, 69-72.

Fostoria High School, 1880. "Graduation Exercises", a printed programme dated June 4. Campbell is listed first among the three student orations, three others are listed for essays, and no other graduating students are named in the programme.

Hale, G.E., 1900. Letter to H.D. Curtis, dated June 11, Yerkes Observatory Archives, Williams Bay, Wisconsin.
Harrington, M.W., 1892. Letter to E.S. Holden, dated July 28, SLO.
Herbig, G.H. 1948, Astronomical meeting, Pasadena, June 28, July 1, 1958. *PASP*, **60**:219-224.
Herget, P., 1978. Armin O. Leuschner. *BMNAS*, **49**:129-147.
Holden, E.S., 1891. Telegram to T.G. Phelps, dated November 23, SLO.
Holden, E.S., 1892a. Two telegrams to A.L. Colton, dated June 30 and July 12, SLO.
Holden, E.S., 1892b. Letter to M.W. Harrington, dated July 7, SLO.
Holden, E.S., 1893. Letter to M. Kellog, dated March 11, SLO.
Holden, E.S., 1895. Letter to Mrs. E.F. Hussey, dated December 16, Bentley Historical Library, University of Michigan.
Holden, E.S., Campbell, W.W. and Colton, A.L., 1893. Negatives of Jupiter made with the great telescope of the Lick Observatory during the opposition of 1892-3. *Monthly Notices of the Royal Astronomical Society*, **53**:445-447.
Hughes, R.M., 1925. *A Study of the Graduate Schools of America*. Miami University Press, Oxford, Ohio.
Hussey, W.J., 1891. Telegram to W.W. Campbell, dated November 23, SLO.
Hussey, W.J., 1892a. Letter to E.S. Holden, dated January 11, SLO.
Hussey, W.J., 1892b. Two letters to J. Swain, dated February 20 and March 16, BHL.
Hussey, W.J., 1893. Letter to E.S. Holden, dated March 7, SLO.
Hussey, W.J., 1894. Letter to D.S. Jordan, dated December 8, with attached 17-pp. memorandum, Stanford University Archives, Palo Alto.
Hussey, W.J., 1895a. A study of the physical characteristics of Comet Riordane. *PASP*, **7**:161-185.
Hussey, W.J., 1895b. Letter to E.S. Holden, dated December 2, SLO.
Hussey, W.J., 1896. Letter to D.S. Jordan, dated March 9, BHL.
Hussey, W.J., 1898a. Two letters to W.W. Beman, dated May 30, and to E.A. Lyman, dated October 10, BHL.
Hussey, W.J., 1898b. Letter to D S. Jordan, dated March 8, BHL.
Hussey, W.J., 1899. Letter to D.S. Jordan, dated October 27, Stanford University Archives, Palo Alto.
Hussey, W.J. 1901. Letter to D.S. Jordan, dated December 12, Stanford University Archives, Palo Alto.
Jordan, D.S.., 1897. Four letter to W.J. Hussey, dated May 2, May 7, May 24, July 3, BHL.
Kapteyn, J.C., 1910. On certain statistical data which may be of some value in the classification of the stars in the order of their evolution. *Astrophysical Journal*, **31**:258-269.
Keeler, J.E., 1900. Two letters to H.D. Curtis, dated February 19, March 26, SLO.
Leuschner, A.O., 1898. Two letters to J.M. Schaeberle, dated April 5, April 15, SLO.
Leuschner, A.O., 1900. Letter to W.W. Campbell, dated December 27, SLO.
Lindner, R.P., 2003. Rebuilding astronomy at Michigan: from Hussey to Goldberg. *Journal of Astronomical History and Heritage*, **6**:107-119.
Moore, J.H., 1930. Ralph Hamilton Curtiss, 1880-1929. *PASP*, **42**:37-40.
Moore, J.H., 1939. William Wallace Campbell, 1862-1939. *Astrophysical Journal*, **89**:143-151.
Morgan, W.W., 1967. Frank Elmore Ross. *BMNAS*, **39**:391-402.
Moulton, F.R., 1900. Two letters to G.E. Hale, dated March 7, March 15, Yerkes Observatory Archives, Williams Bay, Wisconsin.
Nicholson, S.B., 1961. Frank Elmore Ross 1874-1960. *PASP*, **73**:182-184.
Osterbrock, D.E., 1980. Lick Observatory solar eclipse expeditions. *Astronomy Quarterly*, **3**:67-79.
Osterbrock, D.E., 1984a. *James E. Keeler, Pioneer American Astrophysicist: And the Early Development of American Astrophysics*. Cambridge University Press, Cambridge.
Osterbrock, D.E., 1984b. The rise and fall of Edward S. Holden. *Journal for the History of Astronomy*, **15**:81-127, 151-176.
Osterbrock, D.E., 1986. Failure and success: Two early experiments with concave gratings in astronomy. *Journal for the History of Astronomy*, **17**:119-29.
Osterbrock, D.E., 1990. Armin O. Leuschner and the Berkeley Astronomical Department. *Astronomy Quarterly*, **7**:95-115.
Osterbrock, D.E., 2001. Astronomer for all seasons: Heber D. Curtis, *Mercury*, **30**(May-June):24-31.
Osterbrock, D.E., Gustafson, J.R. and Unruh, W.J.S., 1988. *Eye on the Sky: Lick Observatory's First Century*. University of California Press, Berkeley.
Rufus, W.C., 1930. Ralph Hamilton Curtiss, astrophysicist. *Popular Astronomy*, **38**:190-199.
Schaeberle, J.M., 1898. Letter to H.D. Curtis, dated January 27, SLO.
Shapley, H., 1919. On the existence of external galaxies. *PASP*, **31**:261-268.
Shapley, H., 1921. The scale of the universe: Part I. *Bulletin of the National Research Council*, **2**:171-193.
Vasilevskis, S. and Osterbrock, D,E,, 1989. Charles Donald Shane 1895-1983. *BMNAS*, **58**:489-511.
Whitesell, P.S., 2003. The Detroit Observatory: nineteenth century training ground for astronomers and surveyors. *Journal of Astronomical History and Heritage*, **6**:69-107.
Wright, H., 1966. *Explorer of the Universe: A Biography of George Ellery Hale*. Dutton & Co., New York.
Wright, W.H., 1907. Introductory account of the D.O. Mills expedition. *Publications of the Lick Observatory*, **9**:15-22.
Wright, W.H., 1949. William Wallace Campbell 1868-1938. *BMNAS*, **25**:35-74.

Donald E Osterbrock is a retired research astronomer and former director of Lick Observatory, now an historian of American astronomy in the big-telescope era which began with Alvin Clark & Sons. He spent parts of two summers at the University of Michigan and its Observatory in 1951, as a visiting graduate student from Chicago, and in 1953, as a visiting postdoc from Princeton. He first saw and heard the subject of his most recent book, *Walter Baade: A Life In Astrophysics* (2001), in Ann Arbor in 1950, when Baade gave an invited paper on his research on galaxies at a symposium on the structure of the Galaxy there, in connection with the dedication of Michigan's Heber D Curtis Memorial Schmidt Telescope.

Review

The Enigma of Sunspots: A Story of Discovery and Scientific Revolution, by Judit Brody (Floris Books: Edinburgh 2002), 191 pp., ISBN: 0 86315 370 4, soft cover, £12.99, 149 × 197 mm.

The very source and fount of Day
Is dash'd with wandering isles of night

In Memoriam,
Alfred, Lord Tennyson

Though sunspots had occasionally been observed with the naked eye for many hundreds of years, they were only recognized as a regular feature of the solar disk following the application of the telescope to astronomy early in the seventeenth century. This recognition of transient 'blemishes' on the Sun, along with the discovery of Lunar mountains and craters around the same time, helped to overthrow the Aristotelian view of the cosmos, by demonstrating that celestial bodies were not perfect, unchanging and incorruptible and of a completely different nature to terrestrial matter. The Enigma of Sunspots tells the story of the discovery and interpretation of sunspots.

The treatment is largely chronological. Following a brief introduction, the early chapters touch on the solar myths of various ancient peoples and cover pre-telescopic observations, which were more common in the Far East than in Europe. The story proper, however, starts with the telescopic observations by Fabricius, Scheiner (and his student Cysat), Galileo, and Harriot which established sunspots as a regular feature of the solar disk. Following the initial flurry of discoveries and the debate over whether sunspots were really phenomena of the solar surface or small planets orbiting close to the Sun (which would have preserved the Aristotelian perfection of the heavenly bodies) there was relatively little further progress for the remainder of the 1600s and the early 1700s, not least because much of the period was taken up with the 'Maunder Minimum' when there was a dearth of sunspots. In 1769 Alexander Wilson showed that sunspots were depressions in the solar surface by tracking the way that their appearance changed as they approached the solar limb.

Periodicity in sunspot numbers was found by Schwabe in 1843, establishing the famous eleven year sunspot cycle. In 1851 Lamont found similar cycles in the terrestrial magnetic field. At first the correspondence between the two cycles was not realized, but it was soon established by Sabine, Gautier, and Wolf. In 1859 Carrington accidentally made the first observation of a solar flare and the associated magnetic disturbances. These discoveries laid the groundwork for the modern discipline of Solar-Terrestrial Physics. Having traced these developments the book concludes with a final chapter presenting a summary of the modern understanding of the Sun.

The Enigma of Sunspots is aimed at the layman, or perhaps even at older children. The presentation is non-technical, with no prior knowledge of either physics or the history of astronomy required to follow the discussion. Both pre- and post-Copernican ideas of the structure of the heavens are clearly explained. There are, however, both references and suggestions for further reading. The book is profusely illustrated. There are many reproductions of historical observations, mostly in black and white, or rather in black and tan, giving an attractive appearance similar to a sepia photograph. There are also a number of spectacular, modern, colour photographs showing sunspots and other solar features in great detail. A purist might cavil that these photographs are not directly relevant to the historical narrative, but given the general audience at which the book is aimed they add to its value.

The author was originally from Hungary, but fled that country following the uprising in 1956. She has variously worked as a physics and mathematics teacher, a librarian and a historian of science. She has published several books on aspects of the history of science, and this experience shows in her handling of the material. Potentially obscure topics are explained in a way which is effortless to follow. The book is well produced, with few typographic errors and is very reasonably priced. It is printed on glossy paper, which allows the illustrations to be of a high standard. The book can certainly be recommended for a layman new to the subject; it would make an ideal present for a teenager who is just getting interested in astronomy. Someone already versed in the history of astronomy will find much of the background material familiar, but unless he is an expert in the history of solar observations will doubtless find much of interest too.

Clive Davenhall

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This issue of the Journal of Astronomical History and Heritage has been arranged by Dr Patricia Whitesell to commemorate the sesquicentenary of the University of Michigan Detroit Observatory, Ann Arbor, Michigan