

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 Tuolumne 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.

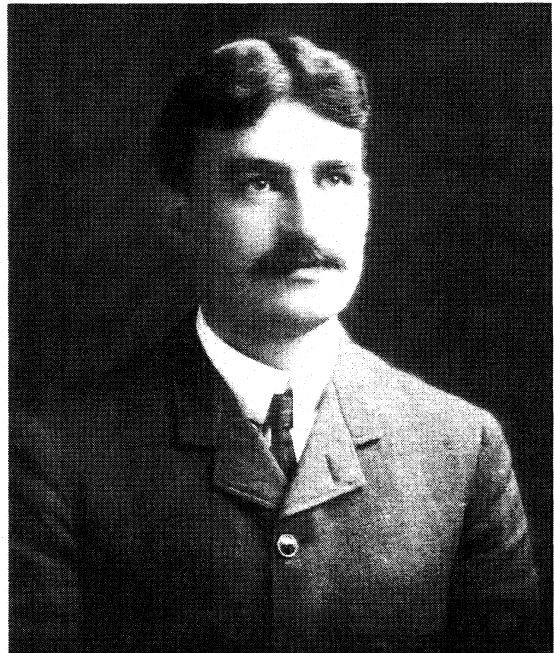


Figure 1. Armin O Leuschner, the young head of the Berkeley Astronomical Department (1903) (Courtesy of the Mary Lea Shane Archives of the Lick Observatory).

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 Leuschner'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).

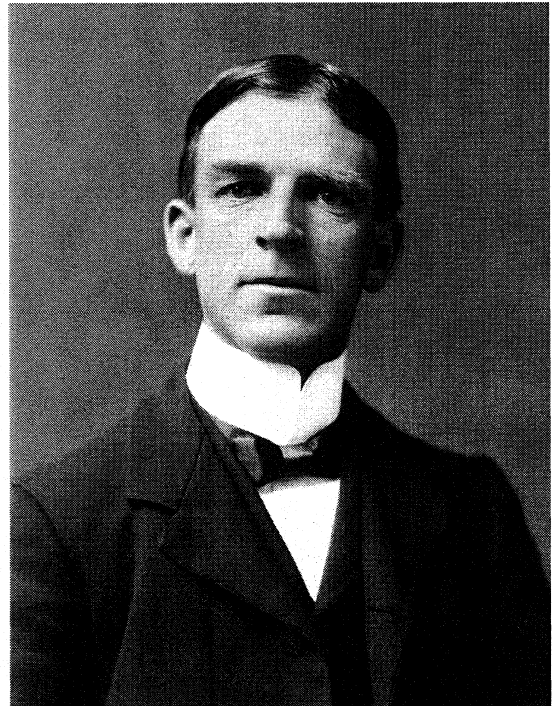


Figure 2. W W Campbell, in his first year as Director of Lick Observatory (1901) (Courtesy of the Mary Lea Shane Archives of the Lick Observatory).

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 Jr 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 noncommittal. 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).

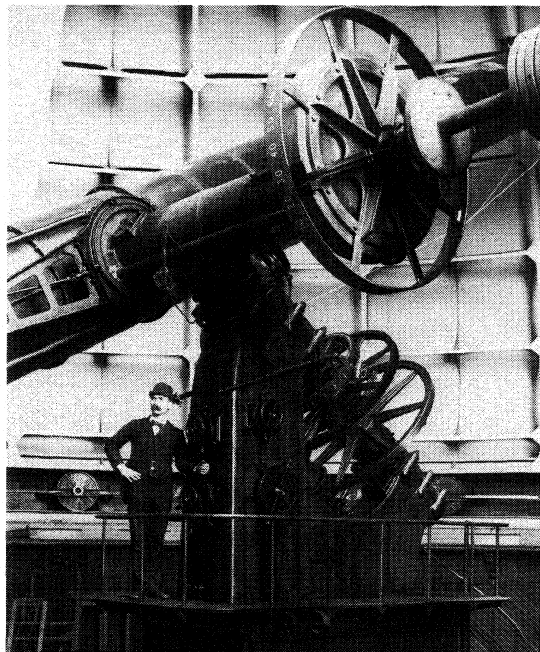


Figure 5. William J Hussey, about when he joined the Lick Observatory staff (c. 1896) (Courtesy of the Mary Lea Shane Archives of the Lick Observatory).

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 piecemeal 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



RALPH CURTISS.

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.

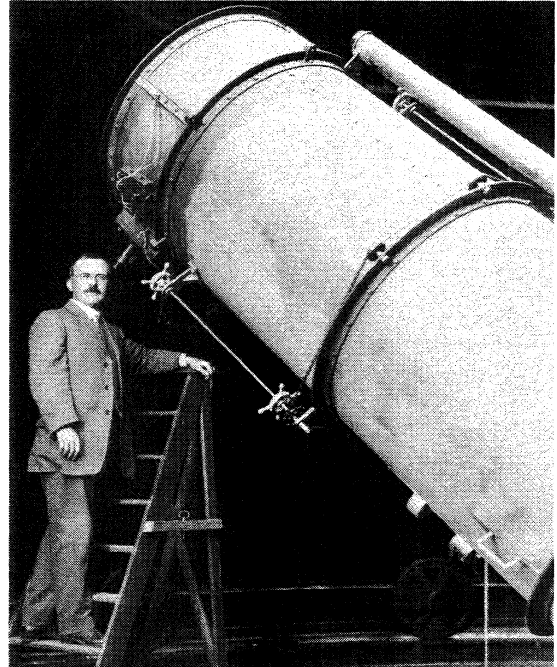


Figure 7. Heber D Curtis at the Newtonian focus of the Crossley reflector, Lick Observatory, c. 1915 (Courtesy of the Mary Lea Shane Archives of the Lick Observatory).

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 'occluding' 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 occluding 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, underfunded 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.

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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

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