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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.

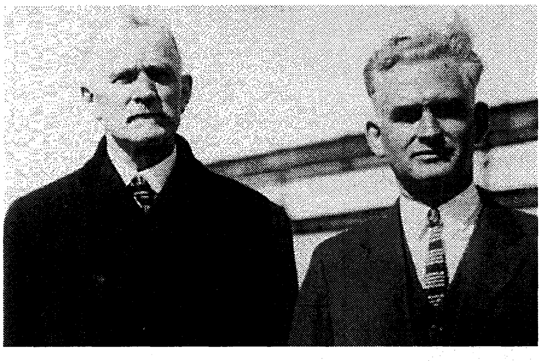

Figure 1. W J Hussey and R A Rossiter *en route* to England in1926 (Courtesy: Michigan Historical Collections, Bentley Library, The University of Michigan).

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.

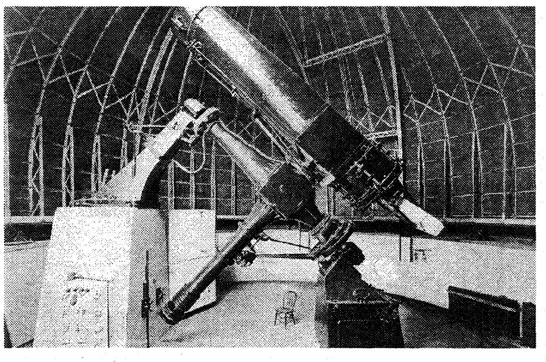

Figure 2. The 'Great Reflector' (Courtesy: Michigan Historical Collections, Bentley Library, The University of Michigan).

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.

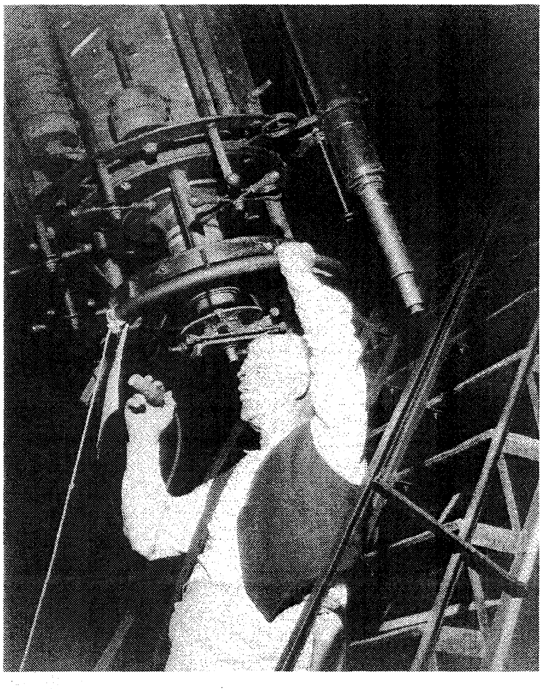

Figure 5. R A Rossiter at the eye end of the Lamont-Hussey refractor (Courtesy: Karl Henize).

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).

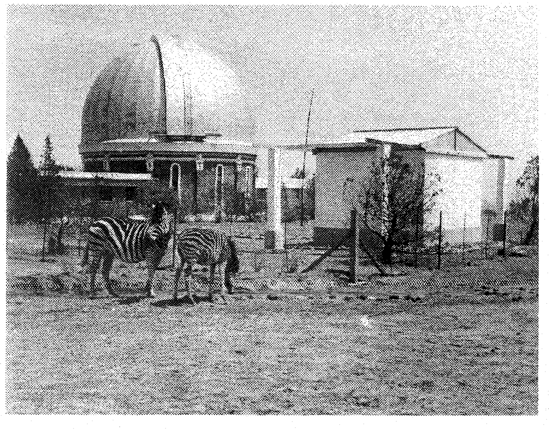

Figure 6. The Lamont-Hussey Observatory, with zebras (Courtesy: Karl Henize).

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.

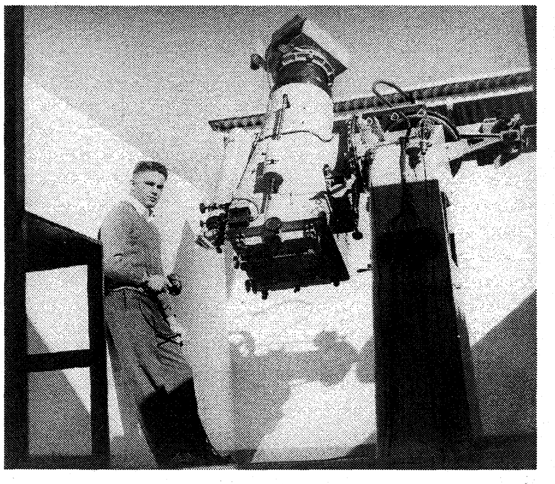

Figure 7. Karl Henize at the Lamont-Hussey Observatory (Courtesy: Karl Henize).

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).

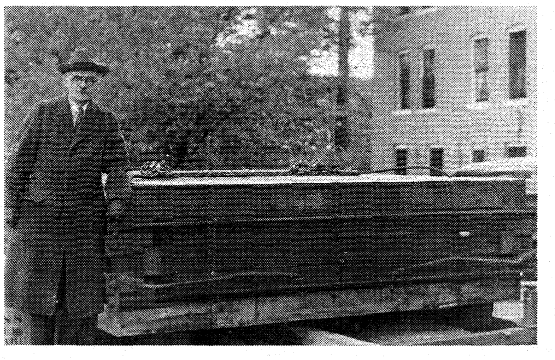

Figure 9. Heber D Curtis with the crate containing the 2.49-m pyrex disc (Courtesy: Michigan Historical Collections, Bentley Library, The University of Michigan).

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)

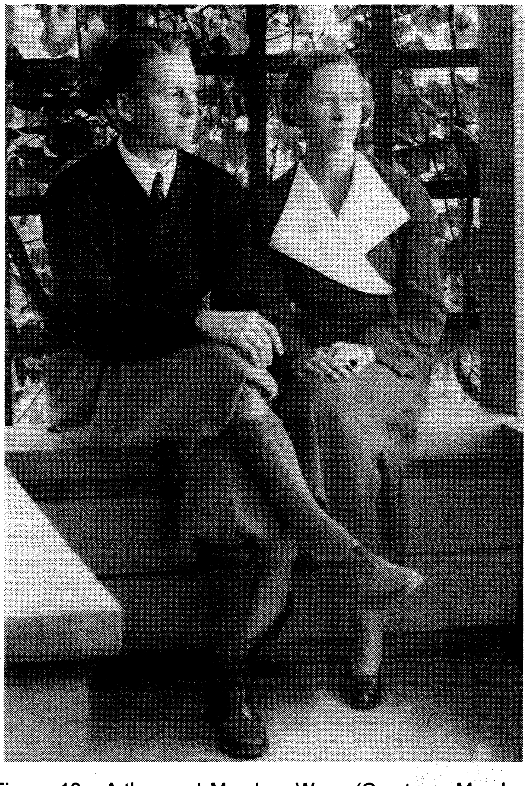

Figure 10. Arthur and MaryLyn Wyse (Courtesy: MaryLyn and Stephanie Wyse).

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).

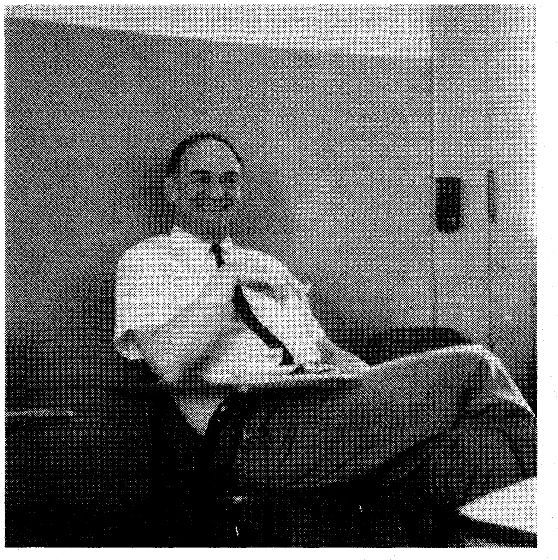

Figure 12. Leo Goldberg at the morning coffee klatsch (Courtesy: Harvard University Archives).

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

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

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