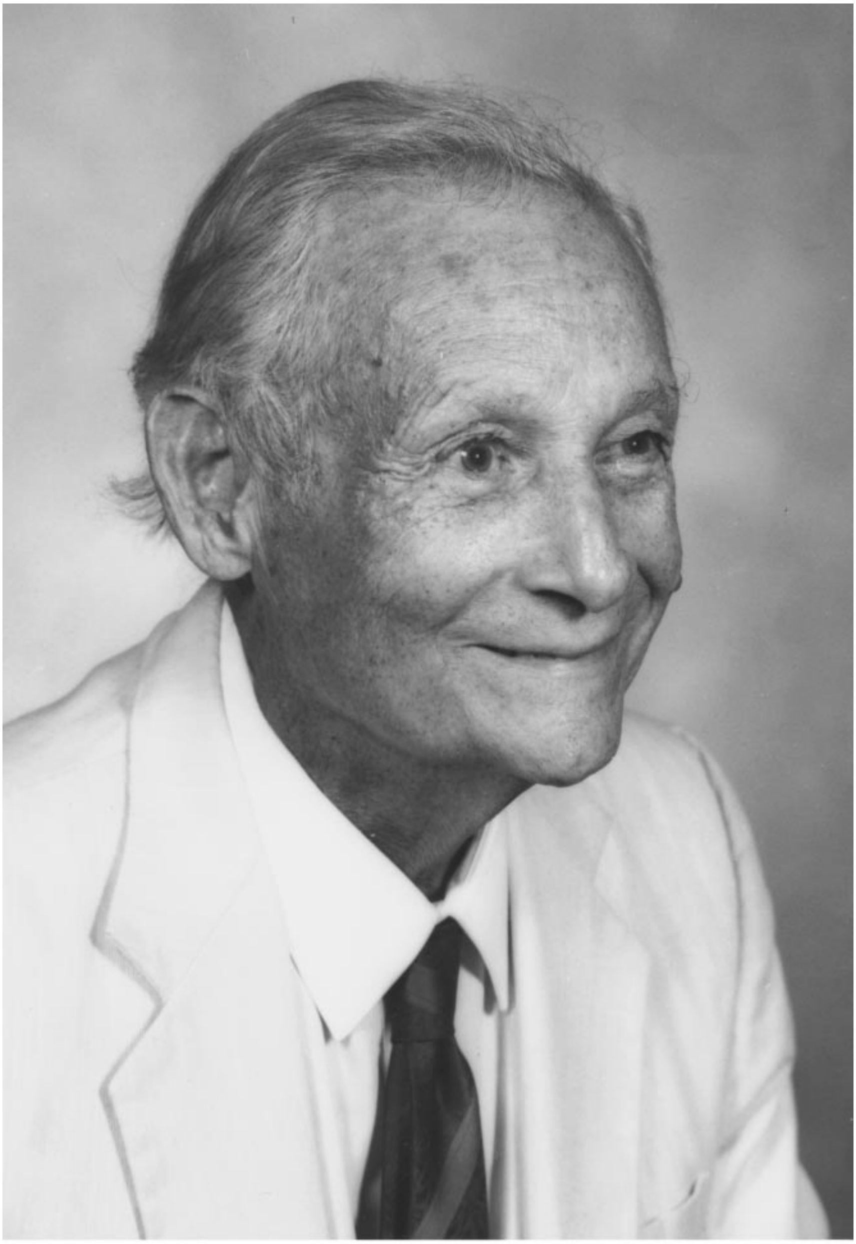

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TELESCOPES, RED STARS, AND CHILEAN SKIES

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PUERTO RICO 1918–1939

I was born and raised in Puerto Rico and was 21 years old before leaving my island home in 1939 to study in the United States. Childhood dreams of becoming an astronomer were not generally considered prudent or realistic on the island if one expected to be assured a reasonable livelihood. This was especially true for children in large families. Out of the twelve children my mother had, nine survived infancy; I was the third youngest of nine. Providing for our needs required cooperative efforts from all siblings to supplement my father's policeman's income; I mainly helped by tending cows Father kept in a mini-farm next to our home. For incidental personal expenses I raised pigs and, indulging in astronomical dreams, gave them such names as Ceres, Vesta, and Ganymede. In junior high school I learned woodworking and became expert enough to hold down a part-time job in furniture making. Ever since then woodworking has been a hobby of mine.

Both my parents were raised during the Spanish colonial administration of Puerto Rico, when educational opportunities were very limited. With his six years of schooling, Father was finding it difficult to make a living as a grocer and baker when in 1898 the US Army occupied the island. Rampant disorder followed the Spanish withdrawal, and the new authorities formed a police force to enforce the law throughout the island. Father was one of the first applicants to be accepted in that force. Through the years Father rose in rank and was eventually appointed chief of the San Juan district, the most important post then available to native policemen. Soon thereafter, however, the US authorities decided to appoint a Puerto Rican as overall chief of the entire island's police force. Father, who had never learned English, lost out in the competition for the appointment, and the winner promptly demoted him to serve in secondary posts far away from San Juan. Mother remained in San Juan in order not to interrupt the schooling of her brood.

I started learning English during my second grammar school year from teachers who were not fluent English speakers. For years, I have struggled futilely to get rid of an accent partly colored by the quaint English of my well-meaning early teachers.

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I was about 17 or 18 when I came down with an infection that threatened to spread into my bloodstream. Septicemia was then fatal, but I was saved by a doctor who knew that a German physician had found that a red dye used in the textile industry was an effective cure for microbial infections. The doctor, a distant relative, was able to procure the dye, known as Prontosil, and tried it on me. This narrow escape started me thinking of a medical career. Throughout grammar school I was an indifferent student, but in high school I was lucky to have excellent teachers of mathematics and physics, who made me aware of the power of formalized reasoning and made me confident that I could successfully undertake university studies. About that time I also became an avid reader of popular science magazines, one of which featured how-to-do-it projects for young readers, including making a reflecting telescope. I obtained the glass blanks, Carborundum, and rouge to make a 6-inch telescope that competed for the space where I raised my astronomically named pigs. The reflector luckily produced excellent images.

Upon graduation from high school, I started premedical training at the local university. Included as an elective was an astronomy course taught by a professor who at that time was a physics graduate student at the University of Chicago. Getting to know how this teacher managed to study what he preferred and a growing lack of interest in medical studies led me to quit the university and start raising the money required for a trial period of astronomical studies at the University of Chicago. Full-time employment in furniture making enabled me to save enough so that when added to what my parents could spare, it was sufficient for me to enroll at the University of Chicago for the trial period I had planned. I arrived in Chicago in time to start as an undergraduate junior-year student during the autumn quarter of 1939. My funds allowed me completion of this one quarter; when it was over I went to see a dean, showed him my grades, and told him how and why I had come to the University. The dean kindly arranged free tuition for me and contacted the student affairs office, which helped me find a job at a local drugstore.

TEXAS AND WAR YEARS 1940–1946

In the fall of 1940, Otto Struve, the head of the University's Astronomy Department, offered me a 6-month position as an observational assistant at the McDonald Observatory in Texas, which was then managed by the University of Chicago. Although this meant interrupting my undergraduate studies, I decided that the experience would be worthwhile and began work at McDonald on New Year's day of 1941. My stay at McDonald ended when in the summer of that year I received a military draft summons. The US Congress responded a year before the Pearl Harbor attack to the worsening political and military situation in Europe. In the 1940s practically all astronomical research was based on photographic recording, and Otto Struve, on learning of my draft summons, gave me a letter testifying to my expertise in photographic matters. The letter got me an assignment to the US Army Signal Corps where my duties, after boot training, consisted of taking identification badge pictures. Soon thereafter I was able to change to a more challenging assignment and was trained in the maintenance of electronic equipment, specializing in the repair and tuning of radar aircraft detectors. Later, after transfer to the Army Air Corps, I was trained in tropical meteorology, specializing in the detection and forecasting of atmospheric refractions that affect the direction of propagation of radar search beams. All this led to service in the active war zones of New Guinea and the Philippines, where in addition to predicting how our own and Japanese radar beams were expected to behave, I had to brief the pilots who were undertaking strategic and tactical missions about the weather they were likely to encounter. Only after the Japanese surrender was I released from soldierly duties, early in 1946.

Returning to the University of Chicago, I was admitted to graduate studies after the University credited my meteorological training as equivalent to the courses I had missed that were required for a Bachelors's degree. Graduate courses in astronomy were at that time offered at the Yerkes Observatory and consisted mostly of reading assignments and occasional interviews with the professors. The only exceptions I recall were the memorable lectures presented by Chandrasekhar. My stay at Yerkes was cut short when Otto Struve, who offered a course in stellar spectroscopy, asked me during a test to describe what was peculiar about the spectra of several stars he named. Shown a spectrum, I was prepared to point out what the spectral lines indicated, but not to describe what was odd about a given star's spectrum. I flunked the test. When I protested to Struve that the test had called for rote learning he lectured me that a good astronomer must be aware of the outstanding features of prototype stars. Perhaps Struve's own training had been rather different from what I was used to. Anyway, I then applied for graduate studies at the University of California at Berkeley, was accepted, and went there in August of 1946.

BERKELEY 1946–1949

At Berkeley at that time the astronomical staff consisted mostly of astronomers who had manned the department while younger staff members were engaged in war services. Traditionally, the department's strength had been in celestial mechanics, a discipline that was still emphasized, but a year later Louis Henyey joined the staff, and he and Robert Trumpler offered advanced courses in other astronomical subjects. Students could also take mathematics and physics courses in other departments. My doctoral work was guided by Robert Trumpler and consisted of a statistical combination of proper motion and radial velocity data to determine the luminosity of main sequence A-type stars.

My first astronomical publication was submitted while I was at Berkeley and was about an effect that Otto Struve had recently investigated, namely that among single-line spectroscopic binaries with available orbital determinations, the distribution of the longitude of periastron showed a pronounced maximum near 45°. By examining available data about these binaries, I found that the longitude of periastron maximum occurred only in stars earlier than type F2 and only if their periods were less than five days. These results supported Struve's conclusion that absorption lines due to gas flowing between the binary components distorted the observed radial velocity curve used in deriving orbital elements. Apparently, this publication restored my standing with Otto Struve, for some time later he assisted me in finding a job. The only publication related to my doctoral dissertation was a short note critical of the method I had used. Possibly the only worthwhile result of that investigation was finding that an unusual concentration of A-type stars near the southern galactic pole was caused by a previously unknown open cluster now known as the Zeta Sculptoris cluster.

As a veteran with close to five years of service, my tuition at the University as well as a modest stipend for living expenses were covered by the US Government as part of the so-called GI Bill of Rights. Having a spouse and two small children, I had to find additional income, and for a while I worked on weekends as a night orderly in a hospital in Oakland; my premedical training came in handy after all. During my last two years in Berkeley I enjoyed first a fellowship granted by the Puerto Rican government and later one from the John Simon Guggenheim Foundation, and I was able to work full time on my thesis project.

PUERTO RICO AND OHIO 1949–1965

In the summer of 1949 I returned to my island, where I had been offered a position teaching physics and elementary astronomy at the University of Puerto Rico. However, a year later I had to look for other employment after I was informed that the University could not afford to retain an astronomer. This released me from an obligation I had incurred by accepting Puerto Rican financial assistance while at Berkeley. With Otto Struve's recommendation, I obtained a position at the Case Institute of Technology in Cleveland, Ohio, now part of Case-Western Reserve University, where Jason Nassau headed the Astronomy Department and the now defunct Warner and Swasey Observatory. Nassau, who had distinguished himself as an inspiring teacher and Cleveland's astronomy popularizer, also founded Cleveland's Astronomical Society, which offered lectures by eminent astronomers and financed, during the immediate post–World War II years, fellowships that allowed young astronomers, principally from Europe, to do research with Case Institute's Burrell Schmidt telescope. One of these fellows was Jurgen Stock, who stayed on as a faculty member at Case Institute and who, years later, had much to do with the initial development of the Cerro Tololo Inter-American Observatory in Chile. Jason Nassau's fund-raising abilities had made possible acquisition of the Schmidt telescope, one of the first large ones made after Bernhard Schmidt's invention, and also, as far as I recall, the first to be equipped with objective prisms. In collaboration with Cleveland Astronomical Society fellows, Nassau had developed near-infrared, low-dispersion spectral classification schemes for M-type stars and carbon stars. After my arrival in Cleveland Jason Nassau and I undertook an extensive survey of the Milky Way for red stars, with financial help from the US Office of Naval Research. The survey covered all galactic equator longitudes observable from Cleveland and was extended by 70° in observations I made in collaboration with Luis Münch at the Tonantzintla Observatory. Early results were that by far a majority of detected M-type stars were giant sequence objects and that we could also recognize M-type supergiants as well as S stars in the near-infrared spectrograms. A remarkable result was that the galactic central bulge was extremely rich in M-type giants and practically devoid of carbon stars, but in the anticenter direction carbon and M-giants were found in roughly equal numbers.

When the UBV photometric system was developed in the 1950s, its use for determining stellar distances required knowledge of the value of the ratio of total to selective interstellar absorption. Early determinations of that value assumed, for simplicity, that the UBV colors were monochromatic. By taking into account bandwidths of the colors, I showed how the ratio depended on a star's spectral intensity distribution and on interstellar extinction. These findings were particularly useful in estimating distances of the red stars found in the Milky Way survey.

In addition to research, astronomers at Case Institute of Technology were required to teach. Besides astrophysics, I was occasionally called upon to teach mathematics. Case Institute of Technology also offered seminars to professional engineers. Soon after the Soviet Union's Sputnik satellite was launched, a seminar was offered to the technical staff employed at the National Aeronautics Civil Authority, NASA's predecessor, which was located in Ohio. When that seminar was held a need became obvious for a textbook stressing celestial mechanics and current knowledge about the solar system. Sidney McCuskey joined me in preparing such a textbook, which was published in 1961 and may now be regarded as a summary of what we thought we knew about the solar system prior to the age of space explorations.

While at the Case Institute of Technology, I supervised the transfer of the Burrell Schmidt telescope from its location within city limits to a more favorable location in northern Ohio. Eventually, the telescope was relocated again and is now at the Kitt Peak National Observatory (KPNO). While still employed at Case, during a leave of absence, I put into operation a Schmidt telescope in Java, Indonesia, at the Bosscha Observatory, which in the past had functioned as part of Leiden University's research facilities. Optics for the telescope were donated by a United Nations agency, but final assembly was postponed until Indonesia gained its independence. On my way to Indonesia I stopped in Leiden, where the makers of the telescope mounting were located, and discussed pending assembly procedures with them. I also talked with Jan Oort, who had contributed to the telescope design and had planned observational programs to be undertaken once the telescope was operational. At Bosscha, valued assistance from the observatory's mechanic and from Pik Sin The, then the Director, made possible completion of the telescope in appreciably less time than projected by UNESCO, the United Nations agency that had hired me. The first photographic plates were taken less than two months after my arrival in Java. A unique problem that had to be solved before normal observations were started was how to prevent tarnishing of the telescope's objective mirror by fumes that now and then reached the observatory from a not too distant semi-dormant volcano. Chemists at the nearby Bandung Institute of Technology helped me solve this problem by recommending a device that provided filtered air to the telescope if it were sealed when not in use. After completion the telescope was named after Bima Sakti, a gigantic hero in the Hindu epic Mahabharata, which is popularized in Javanese Wayang (puppet) plays. Bima Sakti is so tall that when standing he plants his feet on opposite sides of the world, forming across the sky the arch we call the Milky Way. For a telescope that would be used in galactic research, this name seems appropriate. Before I departed from Bosscha UNESCO agreed to convert the remaining funds set aside for my salary into fellowships for Indonesian students. Bambang Hidayat, who later became Bosscha's Director, was one of the students awarded a fellowship.

I worked for Case Institute of Technology until the summer of 1965, when I joined the US Naval Observatory as head of the Astrometry and Astrophysics Division, whose main task was carrying out a parallax determination program with the Kaj Strand 61-inch telescope located near Flagstaff, Arizona. This employment lasted less than 2 years and ended when I resigned to accept the directorship of the Cerro Tololo Inter-American Observatory (CTIO).

CERRO-TOLOLO INTERAMERICAN OBSERVATORY, CHILE 1967

CTIO was created in 1961 after AURA, the Association of Universities for Research in Astronomy, took over a project to establish an observatory in Chile on behalf of the US National Science Foundation (NSF). The project originated when Professor Federico Rutllant from the University of Chile visited the United States in 1958 to explore possible US-Chile collaborations for building and operating an astronomical observatory in Chile. Rutllant tried to interest the recently formed AURA, but it was from Gerald Kuiper and Albert Hiltner at the Yerkes Observatory that he received a favorable response. Later, Kuiper secured support from the US Air Force to acquire a 60-inch reflector for planetary research to be operated jointly by the universities of Chicago, Chile, and Texas. Prior to CTIO's establishment, the total light-gathering power of southern hemisphere telescopes was less than 10% that of northern ones, and no southern observatory was located on a site with frequent clear night skies and exceptional seeing. With NSF support, AURA undertook establishment of an optical astronomical observatory where US and Latin-American astronomers, in preference but not exclusively, could observe the southern skies.

While employed by the Universities of Chicago and Texas, Jurgen Stock started site surveys in Chile with the collaboration of Chilean astronomers. The surveys resulted in the selection of Cerro Tololo, a 2200-m high mountain in the foothills of the Andean cordillera at South latitude $30^\circ 10'$ and some 60 km southeast of the seashore town of La Serena. These site surveys covered an extended section of the southern part of the Atacama desert, one of the world's driest, and showed that superb astronomical observing conditions abound in northern Chile, where atmospheric turbulence is rare because of a pronounced inversion layer caused in part by subsidence of dry air in a semi-permanent high pressure cell and in part by the cold oceanic Humboldt (or Peru) current that flows northward from Antarctica along Chile's coast. Discovery of these excellent conditions would eventually result in the establishment of other US and European observatories in Chile.

The project of establishing the southern observatory that Rutllant had envisioned was taken over by AURA in 1960; in 1962 Cerro Tololo was selected as its site, and Jurgen Stock was appointed its director. Three years later he resigned under circumstances that have never been clear to me, but which, unfortunately, caused seriously strained relations between AURA and astronomers and students at the University of Chile where Stock was appointed a faculty member soon after leaving Cerro Tololo.

Early in 1967 Nicholas Mayall, KPNO's director and the person officially responsible to AURA for CTIO's development, asked me whether I was interested in being appointed CTIO's director. After Stock's departure, work on Tololo was supervised in turns by members of AURA's board of directors or by KPNO astronomers. Arthur Hoag and Albert Hiltner had taken turns at CTIO and were most helpful in acquainting me with ongoing problems. In June 1967 I accepted Mayall's offer. Immediately after arriving at CTIO I had to organize the observatory's dedication ceremonies, which AURA had already scheduled for November of that year. Luckily, CTIO already had a competent administrative staff who took care of organizational details in La Serena, where CTIO's headquarters are located, while I spent most of my time on Tololo mountain, where the principal research instrument, the 60-inch telescope, acquired with US Air Force funds procured by Gerald Kuiper, was still being assembled and where the dormitory–dining room building, where parts of the dedication ceremonies were to take place, was not yet finished. Thanks to the efforts of the provisional directors who preceded me, a mechanical engineer experienced with optical telescopes had been hired, and the building construction program was handled by a competent civil engineer who was a firm and effective supervisor. The 60-inch telescope saw its first starlight shortly before the scheduled dedication and was finally collimated the night before the ceremonies. Besides the 60-inch telescope, CTIO had acquired a 36-inch reflector funded by the NSF, two smaller telescopes that had been used in site surveys, and the 24/36-inch Curtis Schmidt that had been obtained on loan from the University of Michigan. Ironically, this Schmidt telescope carries the name of Heber D Curtis who, when surveying northern Chile very early in the 1900s for possible observatory sites, declared the entire region of the southern Atacama desert unfit for astronomical observations.

On the morning of November 6, 1967, the dedication program was held in La Serena, attended by Chilean educational, political, and religious leaders and delegations from the US Congress, AURA, and the NSF. In the afternoon a group of these attendees went to Cerro Tololo to receive Chile's President Eduardo Frei, who arrived there directly by helicopter from Santiago. A formal dinner was offered at the newly completed dormitory–dining room building, after which President Frei and company were shown a number of carefully selected, impressive astronomical objects through the 60-inch telescope.

I first entered Chile as a tourist, and my stays could be regarded in Chile as illegal because I was gainfully employed there, even though my salary came from the US. Following the advice of AURA's Chilean lawyer, during a trip to the United States I obtained the visa I required from a Chilean consulate. That visa turned out to be rather inconvenient because each time I had to leave Chile, as was frequently the case, I had to obtain clearances from both the police and the tax authorities, clearances that had to be requested well in advance. Obviously, the visa problem had to be solved if we were to attract US scientists and technicians to work at CTIO. Sometime earlier, while paying a courtesy visit to the US ambassador, I found out that Malena Saavedra, the Chilean legal counsel at the embassy, was far more willing to help CTIO than the ambassador or his deputies. Informed of my visa problem, Ms. Saavedra obtained from Chilean authorities a decree whereby CTIO's non-Chilean staff members could freely enter and leave Chile.

When I became better acquainted with my new employment, I found out that the associate director for administration at KPNO had been made jointly responsible with the CTIO director for establishing and implementing CTIO's administrative policies and procedures. This amounted to overlapping responsibilities by two individuals and was not in agreement with Mayall's written statement of my duties. I called Mayall's attention to this circumstance, and he later responded that as CTIO's director I could consult on administrative issues with KPNO's administrator but that establishing and implementing related policies were my responsibility unless specifically disapproved by KPNO's director. I felt it was important to clear up this matter in order to avoid mistakes such as had previously resulted in CTIO acquiring a fleet of electric golf carts for transportation between buildings on or near Tololo's summit. The carts, designed for use in relatively flat terrain, had proved excruciatingly slow when going uphill and dangerously fast when going downhill, and were replaced at my request with reliable transportation.

A problem requiring attention when I joined CTIO was related to the importation into Chile of CTIO's equipment. By a procedure previously approved by local authorities, items for CTIO could be imported duty free under the University of Chile's duty-free franchise, provided that the University handled importations. By 1967 this arrangement was not working well. AURA's lawyer in Chile was reluctant to seek a different importation procedure, and AURA decided to replace him. With Malena Saavedra's assistance, a lawyer was found who agreed to find a new way for CTIO to do its importations. Eventually, the new lawyer managed to obtain a governmental decree allowing CTIO to manage its own duty-free importations.

Possibly one of the reasons CTIO's importations via the University of Chile had not worked well was related to the animosity generated by Jurgen Stock's departure from CTIO. Accordingly, Claudio Anguita, the head of the University's Astronomy Department and director of Chile's National Observatory, a fair minded individual with exemplary integrity, collaborated with me on how to improve

AURA's awkward relationship with the University. In addition, Claudio Anguita and I discussed unsettled issues in the previous agreements between AURA and the University, especially those defining the rights Latin-American astronomers would have to use CTIO facilities. We then drafted an agreement to supercede the previous one. This was accepted by University authorities and by AURA.

In addition to major administrative problems, we also had much easier ones. For example, CTIO's headquarters in La Serena, located next to the University of La Serena, had employed a night watchman who carried a revolver. It did not seem prudent for him to carry a gun with so many students around, especially because the watchman was an older man with no experience in handling a firearm. As I recall, my very first action as CTIO Director was to disarm the watchman.

Acquisition of a 4-m telescope for KPNO was an early consideration in the development of that observatory. Negotiations with the NSF made possible obtaining the reflector now known as the Mayall telescope at a cost of about 10 million dollars. At that early time, a similar telescope for CTIO was also envisioned, but budgetary restrictions interfered until the Ford Foundation informed AURA that it would consider a proposal to cover half the cost of a 4-m telescope for CTIO. The NSF granted AURA additional funds to cover the total cost. In 1967 President Johnson and Chile's President Frei made a joint announcement that the telescope would be acquired and installed on Cerro Tololo. Fabrication of the telescope proceeded rapidly in the United States, under the supervision of KPNO's Larry Randall and David Crawford, and was facilitated by adoption of already available engineering plans for the Mayall telescope. On Tololo construction of a building to house the telescope was initiated with designs provided by a Chicago architectural firm. Chile is prone to earthquakes, and extraordinary precautions were taken in the building's design and in the preparation of the building's site. The columnar make-up of Tololo mountain was consolidated by injections of a cement slurry to prevent differential motions that could endanger the structure. The building's steel framework was prefabricated in the United States and disembarked in the port of Coquimbo, a town near La Serena. One of my tasks was expediting delivery of steel frames at the port and transporting them to Tololo. In this I was fortunate to have the cooperation of the intendente (governor) of the province. I had made the intendente's acquaintance during CTIO's dedication, and he proved to be a friendly authority who helped CTIO in many ways. For example, when a dock workers' strike threatened cancellation of a critical delivery, he managed to persuade the strikers to suspend the strike momentarily while delivery was made onto our trucks.

In 1967 no astronomer besides myself was employed at CTIO; forming a scientific staff was of the highest importance. Efforts to attract some experienced astronomers had no effect and resulted instead in employment of a cadre of enthusiastic and able recent Ph.D. graduates, namely: John Graham, James Hesser, Barry Lasker, Malcolm Smith, William Kunkel, and Patrick Osmer. Everyone in this core group was to distinguish himself either as a competent observational astronomer capable of effectively assisting CTIO observers in the use of our facilities, as a scientific administrator, or both. John Graham, James Hesser, Barry Lasker, and Patrick Osmer remained employed at CTIO for many years and participated in getting the 4-m telescope ready for service to the astronomical community.

John Graham and occasionally James Hesser or Barry Lasker served CTIO as acting directors when I had to be away. James Hesser was also locally responsible for the observatory's library, which originally had been formed by KPNO's Helmut Abt, and Barry Lasker was responsible for computer control of the CTIO telescopes and for developing an analytical computing facility used by visitors and staff. Eventually, Lasker assisted AURA in preparing its proposal to NASA for management of the Space Telescope Science Institute, and he became one of its earliest staff astronomers. Patrick Osmer, the in-house expert in stellar spectroscopy, succeeded me as CTIO director in 1981.

While fabrication of the 4-m telescope and its housing proceeded, scheduled observations by visitors and staff were initiated with CTIO's other telescopes. Availability of these telescopes allowed me to carry out some observational programs. I used the Curtis Schmidt for charting the Magellanic Clouds with sky-limited exposures on fine grain photographic emulsions. The charts were later used in preparing observational programs to be carried out with the 4-m telescope. The galactic bulge region, which transits close to CTIO's zenith, was similarly charted to identify regions similar to Baade's Window that are relatively free of interstellar extinction. With Olav Hanson, I carried out observations with the Curtis telescope that resulted in the identification as carbon or M-type giants numerous objects found in the infrared two-micron survey by Gerry Neugebauer and Robert Leighton. Some of the identifications in this study were made with spectra obtained by attaching to the Curtis Schmidt telescope a special objective prism that I had designed for use with the Burrell telescope at the Case Institute of Technology. The criteria for classifying carbon and M-type stars developed by Jason Nassau and collaborators at the Case Institute were based on spectra obtained with an objective prism designed for other purposes. Suspecting that these stars could be identified if one used an objective prism yielding significantly smaller dispersions, I worked out the features of a so-called thin prism capable of yielding classifiable spectra of fainter red stars than possible in the past. CTIO's thin prism was also used by Malcolm Smith for discovering numerous faint quasars. Follow-up studies by Patrick Osmer investigated the space distribution of the quasars.

The 60-inch telescope with its modified Ritchey-Chrétien wide-field optics proved ideal for discovery of RR Lyrae stars in the Magellanic Clouds, a program undertaken by John Graham, and in several galactic bulge regions, including Baade's Window, a program I undertook with the collaboration of Betty M Blanco. In our search for these variable stars in the galactic bulge, timing of observations was according to a Monte Carlo simulation that favored discovery of these stars. RR Lyrae variables previously found by Walter Baade in Baade's Window suffered a 24-hour bias because from Mt. Wilson, where Baade made his survey, the galactic bulge can be observed only for a few hours a night. Also, we suspected, as proved to be the case, that Baade's search suffered from incompleteness of faint bulge RR Lyrae stars. Discovery of the variables and analysis of the findings were undertaken by Betty M Blanco.

SALVADOR ALLENDE 1970

While observational programs were going on at CTIO, the political situation in Chile changed drastically in September 1970, when Salvador Allende, the presidential candidate of an alliance of several leftist political parties, won an election. Not long after the election, Nicholas Mayall informed me that he, as well as others in AURA and the NSF, were apprehensive about going ahead with plans to locate the 4-m telescope at CTIO if a Marxist government with anti-United States policies came to power in Chile. In order to find out what I could about that possibility, I managed to arrange an interview with the president-elect, with the help of a CTIO employee I knew to have actively campaigned for Allende's election. The interview was granted and I went to Santiago the day before I was supposed to see Allende, but on arriving I was informed that I would not be able to see him. Disappointed, I planned to return to La Serena the next day, but at 4 A.M. I was told by phone that Compañero (Comrade) Allende, as he was referred to by his partisans, would see me that morning at 8 A.M. When I showed up for the interview, a gentleman who identified himself as the designated minister of the interior received me and said that Compañero Allende was too busy after all and had asked him to meet me. I had prepared a pamphlet describing CTIO, and with its help I explained to the future minister what we were doing in Chile. I was then assured that the new government would support CTIO and told that Compañero Allende personally wanted to so emphasize; I was conducted to a room next door where I met Salvador Allende. The president-elect cordially repeated the promise of support and also told me he had already been informed about CTIO's activities by University of Chile personnel. Before I left, he said I should appeal personally to him if CTIO ever had any problems with his government. This memorable occasion was later summarized in the local press with the comment that Compañero Allende had been asked favors by beggars as well as by astronomers! I am not sure whether my report about the interview had any effect, because it was possible that the NSF had corroborating evidence of Allende's support. Regardless, plans for sending the 4-m telescope were not put on hold.

Economic conditions in Chile worsened after 1970 as the new government implemented its programs of agrarian reform and nationalizations, especially of foreign-owned industries and public utilities. There are different explanations for the economic downturn. Possibly it was caused by hastiness in implementation of the government's agenda, by obstruction from the wealthy or conservative sector of the population, or both. In any case, the result was a marked scarcity of food and consumer items and a pronounced inflation. The latter, together with officially regulated Chilean peso–US dollar exchange rates, led to a budgetary crisis at CTIO and resulted in various economies and staff reductions. A flourishing black market sprouted almost overnight. At CTIO we avoided black market transactions in order not to jeopardize the observatory's relationship with the government. Nonetheless, CTIO functioned normally during the time Salvador Allende remained in power and not a single observing night was lost.

On Tololo a busy building program went on aimed at completion of the building to house the 4-m telescope and fabrication of dormitories and laboratories to be occupied or used by the technical crews working in the telescopes' maintenance and operations. These crews had in the past used temporary shacks. In La Serena houses were added for our non-Chilean staff members, a necessity caused by the lack of rental housing in the town. Laboratories and machine and vehicle maintenance shops were built or assembled from imported prefabricated parts, and the headquarters building, originally built to accommodate a small administrative staff, was expanded to include a library and offices for astronomers and engineers. All structures deemed necessary after observations with the 4-m telescope were initiated were completed by the end of 1972. A policy of locating in La Serena all facilities that did not by necessity have to be on Cerro Tololo was one that AURA approved after I requested it with Mayall's endorsement. Originally, following a model inspired by the way Lick Observatory used to be operated, all facilities were to be located on Cerro Tololo with the exception of La Serena's administrative offices.

The 4-m telescope components arrived in the port of Coquimbo in June 1973, and assembly of the telescope was completed late in 1975. Assembly was carried out by a small group of mechanics led by one who had previously worked on the assembly of the Mayall telescope. John Graham acted as scientific advisor while the telescope was being assembled, and he tested the optical quality of the primary mirror, finding a narrow turned-down area on its periphery that had to be masked to avoid deformation of stellar images. I worked out the final adjustments, a process that for large equatorially mounted telescopes, especially if equipped with massive primaries as is CTIO's telescope, was a daunting procedure before lasers and computers came into general use, and one that I did not find described in astronomical publications. The procedure, assuming the polar axis to be properly oriented, called for first finding the central line of the declination axis, then defining a line perpendicular to that one but passing through the centers of the primary, if already centered in its cell, and the center of the secondary mirror, likewise centered in its cell, and finally adjusting the primary and secondary mirrors so that their optical axes conformed to that line. Nowadays with computer controls one may use alt-azimuth telescope mountings and even correct alignment errors. Following fine tuning and trials by CTIO staff members, visiting astronomers started using the 4-m telescope in January 1976.

POST-ALLENDE CHILE 1973

In the meantime, a dramatic change in Chile's government occurred in September 1973 when Chile's armed forces overthrew Salvador Allende. Severe actions were taken against known or suspected Allende partisans or sympathizers who did not manage to leave Chile, and reportedly against some that did, as the military carried out what they called “an internal war.” Most of the severe actions took place in Santiago and other central and southern cities. In La Serena, apart from some executions that took place soon after the overthrow of Allende, relative calm prevailed, although for a while we were affected by a nationwide curfew, travel restrictions, and a prohibition of most private radio broadcasts. Because telephonic communications with the United States were extremely poor, our communications with KPNO were by means of an amateur radio station we operated under license held by the University of Chile. Before our radio communications from La Serena were prohibited on the day of the military takeover, KPNO was alerted to keep its radio receivers permanently on, as we were going to try sending short messages at specific times. This we managed to do by transmitting from Tololo, where the beam of a highly directional antenna was aimed toward Tucson, Arizona. In this manner observers planning to come to CTIO were informed of how they would be met at Santiago’s airport and taken to Cerro Tololo. Only one or two observing nights were lost during the worst moments of the military crisis.

After Salvador Allende’s overthrow, Chile was governed by a junta formed by the heads of the various armed forces, including the national police. The junta was soon replaced by Augusto Pinochet, the commanding general of Chile’s army, who assumed the title of president and who was to govern for close to 17 years. Not long after General Pinochet became president, I accompanied a delegation from KPNO and AURA that met him. As I had done previously when seeing Allende, I prepared a pamphlet explaining our operations and verbally summarized its contents. Unlike Salvador Allende, who promised his support, General Pinochet limited himself to acknowledging the information we provided. No untoward incidents affecting CTIO occurred, but at one time we were told that General Pinochet wanted to visit Cerro Tololo, and I was asked by one of his adjutants to provide a list of our staff members indicating the political affiliations of each person. I replied that we had always adhered strictly to a policy of staying out of Chile’s politics and could not continue to do so were we to inquire about Chilean staff political affiliations. General Pinochet visited Cerro Tololo anyway, and we kept those Chilean staff members we knew to have been pro-Allende well away.

A notable form of assistance extended to CTIO by General Pinochet was to declare us and the other foreign observatories in Chile privileged scientific territories where mining was prohibited unless expressly allowed by Chile’s president. This decree was promoted by Malena Saavedra, the friendly lawyer mentioned earlier, as a parting gift to CTIO before she left Chile to become the new government’s cultural attaché for Chile at the United Nations. The decree saved us having to pay hefty annual fees to prevent mining activities within CTIO’s holdings. In Chile owning land does not prevent someone else from registering mining claims in one’s property, paying the required fees, and starting mining operations.

A few months after the takeover of the government by the armed forces, relative calm prevailed in Chile, the curfew had been lifted, and travel restrictions were eliminated, but popular measures implemented by President Allende such as the nationalization of US-owned copper mines were kept. However, the universities had been put under military control and remained so for years, and press censorship continued. Nevertheless, CTIO functioned normally. The scientific and technical staffs were increased, and the telescopes were much in demand.

In May 1973 Leo Goldberg, who had succeeded Mayall at KPNO, proposed and AURA approved a clarification whereby the status of CTIO, which on paper up to that time had been equivalent to one of KPNO's divisions, was now formally changed to that of a quasi-autonomous entity with a director supervised by the KPNO director. The change recognized what for years had been the case. CTIO prepared its own budget requests, and after approval by the KPNO director, defended them at the NSF, and later controlled how assigned funds were spent. CTIO's director was also responsible for recruiting, hiring, and recommending promotions of all scientific staff members. Not being dependent on community services, CTIO provided its own road and buildings maintenance services, operated its own machine and vehicle maintenance shops, and kept a sizeable inventory of replacement parts to cover emergencies. All this was done without the benefit of conveniently available contractors, suppliers, or sales representatives, and while running a bilingual and bicultural organization and keeping track of and obeying Chilean regulations. Nevertheless, close ties with KPNO are necessary because, after all, both observatories provide the same services to practically the same astronomical community, and development of their equipment in pairs is not only economical but results in facilities familiar to our users. Years later AURA reorganized the statuses of CTIO, KPNO, and AURA's National Solar Observatory by making them components of the National Optical Astronomy Observatories, whose director supervises the individual directors of the component observatories.

MORE TIME FOR OBSERVATIONAL RESEARCH 1980

In late 1980 I resigned as CTIO director and was thus able to spend more time on observational research. In essence, the motivation of most of my investigations was increasing our knowledge of the nature of stars and how they evolve as means towards a better understanding of the makeup of our galaxy and possibly of other ones. I was fortunate in that most of the observational techniques I had learned early in my astronomical career proved useful when used with a large reflector. The 4-m telescope enabled me to initiate studies of galactic and extra-galactic red giant stars by using a grism, or grating-prism combination, that Ira Bowen and Arthur Vaughn had developed for the Hale telescope. Arthur Hoag and the opticians at KPNO had modified the grism design and had made one that at the prime focus of CTIO's 4-m telescope yielded near-infrared spectra with a dispersion similar to that used years earlier in the Milky Way surveys that Jason Nassau and I carried out at the Case Institute of Technology. With the grism, Arthur Hoag, Martin McCarthy, and I used Kodak IV-N hypersensitized photographic plates to survey Baade's Window. Spectra past I-magnitude 18 were recorded, and on the 0.13 degrees squared covered by the grism over 300 giant stars of types M5 or later were found, but only one carbon star. The frequency of M-type stars showed a sharp maximum at I = 12.2, corresponding to the distance at which the line of sight passed closest to the galactic center.

With Martin McCarthy, I also observed the central regions of the Magellanic Clouds, finding in both of these galaxies numerous carbon and giant M stars. The ratio of the number of stars of type M5 or later to that of carbon stars found in the same area was radically different from the ratio of about 300:1 found in Baade's Window. In the Large Magellanic Cloud (LMC) the ratio is about 1:2 and in the Small Magellanic Cloud (SMC) close to 1:20. In both Magellanic Clouds the average absolute magnitudes of carbon and late M stars are similar and show frequency maxima at I = 14.0 in the LMC and 14.6 in the SMC. These results provided the first reliable estimates of the absolute magnitudes of carbon stars and were timely because Icko Iben and collaborators had recently estimated their luminosities from asymptotic giant branch theory. If the ratios of M5 or later giants to carbon stars are ordered in a decreasing sequence, the result is identical to that found for decreasing metallicities in the galactic bulge and the Magellanic Clouds, a result that suggests a relatively easy way of estimating metallicity values in stellar populations. My collaboration with Martin McCarthy also resulted in the identification of thousands of carbon and giant M-type stars in numerous widely spread selected areas of the Magellanic Clouds and enabled us to determine how these stars are distributed over those galaxies. In the LMC the late M giant to carbon star ratio is nearly constant over the extent of the galaxy, but in the SMC the ratio drops appreciably from the center toward the periphery. These findings suggest how metallicity is distributed in those galaxies, and how these galaxies evolved.

Determination of apparent magnitudes in the observing program just described got me working again on problems related to precision photometry. In the 1970s some astronomers were publishing stellar magnitudes estimated with the help of the so-called Pickering-Racine wedge. This is a small glass prism with a slim apex angle that if placed in a telescope's converging or entrance beams produces, with negligible dispersion, secondary stellar images in pairs that differ approximately in magnitude according to the fractional area of the telescope's light beam covered by the wedge. With this device, in photographic plates, stellar magnitude sequences could in theory be calibrated and then extrapolated to faint limits. In a published cautionary note, I called attention to the fact that such extrapolations resulted in appreciable errors because, among other things, the images in a given pair differed in the size of Airy disks and could be affected by a photographic intermittency effect related to atmospheric seeing. As observers well know, with relatively small telescopic apertures seeing produces constantly dancing images, whereas with sufficiently large apertures steady images are produced, each spread over an area similar to the dancing area produced with small apertures. My cautionary note probably helped cause the abandonment of this photometric technique. Fortunately, charge-coupled devices (CCDs) came into wide use soon thereafter.

A survey of the Fornax and Sculptor dwarf galaxies by Jay Frogel, Martin McCarthy, and myself showed carbon stars in Fornax but not in Sculptor. In these two galaxies late M Stars are rare or do not exist. The red giant stars that Martin

McCarthy and I found in an LMC central region had their infrared colors and luminosities determined by Jay Frogel and appeared to belong to two sequences of asymptotic giant branches, indicating two major episodes of star formation subsequent to an older one that resulted in now observable RR Lyrae stars. In another collaboration Jay Frogel determined infrared colors and CO and H_2O indices for giant M stars that I identified along the galactic-center meridian within latitudes -3° to -12°. The results indicate a gradual decrease in [Fe/H] values away from the galactic center. Also, the reddest and most luminous stars are found nearest to the galactic center, are of type M7 or later, are all long period variables, and most had been previously listed as infrared sources.

Donald Terndrup joined me in a study of the distribution of giant M stars along galactic longitudes ranging over 24° on each side of the galactic center. Twenty areas, all at galactic latitudes close to -6° and selected for interstellar clarity, were observed with the 4-m telescope and the grism. Over 2000 giant stars of type M5 or later were found but only 5 carbon stars, thus confirming the extreme rarity of carbon stars in galactic bulge directions. The M stars showed a sharp frequency maximum toward $l = 0^\circ$. These results combined with those previously obtained along a galactic meridian indicate an axial galactic bulge ratio close to 0.7. The observed distribution of M stars along galactic longitude is incompatible with de Vaucouleur's $R^{1/4}$ law, a relation meant to describe how in a spiral galaxy the mass distribution varies with distance from its center, and suggests that, viewed from outside, our galaxy would show a rather compact central bulge region unlike that in the traditional prototype, M31.

Besides participation in surveys of carbon and M stars, I was also interested in how to accurately calculate interstellar extinction color excesses of RR Lyrae variable stars, which are useful standard candles in astronomical distance determinations. Methods for evaluating $E_{B\text{-}V}$ were formerly based on observations of the color index U-B, a procedure I thought not to be satisfactory, because this color index depends partly on interstellar extinction. A study of practically all RR Lyrae stars for which metallicity estimates were available from determination of George Preston's ΔS values, which are spectroscopically rather than photometrically derived, enabled me to estimate $E_{B\text{-}V}$ for type ab RR Lyrae variables. For a given star, the method is based on its ΔS value, its periodicity, and its observed B-V color index near minimum light and is independent of the U-B color index. This study is the last one I completed and got published before my retirement from CTIO in 1993 at age 75.

RETIREMENT FROM CTIO 1993

Prior to the existence of AURA, access to the facilities at major observatories was limited to their own employees or their students and, occasionally, to invited astronomers from other institutions. AURA was a pioneer in providing the astronomical community observing opportunities with major telescopes and advanced observational instrumentation. The number of interested users of AURA's facilities was such that assignment of time at the telescopes had to, by necessity, be based on a determination of merit. Some astronomers have criticized the way such determinations were made, but any review of the astronomical literature of the last four decades shows, by the numerous major contributions made by observers at the AURA observatories, that the telescope assignment procedure worked rather well. While I was at CTIO an astronomer proposing to carry out an observational program was assigned telescope time to personally carry out the observations. The number of assigned nights took into account the astronomer's request and the opinions of referees deemed familiar with the nature of the program. A committee of invited competent observers then recommended how available telescope time was to be parceled. This, often called the "classical" mode of telescope assignments, ignores the fact that some important programs can only be carried out successfully when atmospheric conditions are extremely favorable. This has led to queue telescope assignments that aim at matching a program's requirements to the seeing and extinction prevailing at a given time. The required conditions are not readily predictable, and in queue assignments the observations are usually, if not always, carried out by observatory staff members. This may, however, deny valuable experience to program initiators from the community at large who do not have access to major telescopes and advanced auxiliary equipment, experience that undoubtedly would be useful in the preparation of observing proposals.

During my years at CTIO I received various honors that I much appreciated. These include commendations from Chile's Academy of Sciences, from the US National Science Foundation, and from AURA, which I value because they acknowledged principles I tried to follow as CTIO's director. I believed that if CTIO was truly to be "Inter-American" it had to be formed and operated in a cooperative way where each of the US and Chilean agencies participating in its development made vital contributions to the success of the observatory. Furthermore, the cooperative effort would work best if the friendliest possible relationship existed among all individuals involved with the observatory. In regard to management, I believed that the observatory's staff would perform best as a well-integrated unit where no class distinctions existed. At CTIO this was, in part, promoted by social gatherings where all employees were welcome. Also, our dining facility on Cerro Tololo provided everyone the same meals on a first-come-first-serve basis, and a common dining area was accessible to all. Dealing with administrative problems could be vexing at times, but fortunately observational research was a welcome diversion. Using the telescopes also helped me to better judge how the observatory was functioning and gave me the opportunity to get acquainted with CTIO users.

While I was in Chile, CTIO grew from a partly completed astronomical facility whose potential was untested, into one much in demand as a provider of front-line observational research opportunities. Eventually, CTIO was to become the nucleus of an expanded facility, the AURA Observatories in Chile, that includes the Gemini southern 8-m telescope. To the NSF, AURA's sponsor, to AURA's guidance, to KPNO's support led by Nicholas Mayall and Leo Goldberg during

CTIO's formative years, and to the scientific and technical staff at CTIO, much credit is due for the observatory's success. In particular, CTIO owes much to the Chilean staff that has carried out all the routine and at times difficult tasks required in its operation. Moreover, CTIO would never have existed or evolved into what it is today were it not for the assistance, so freely given, of Chilean professional scientists, especially the astronomers at the University of Chile, one of whom originated the idea of building in Chile an Inter-American Observatory.