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OBSERVATORY REPORT

Kitt Peak National Observatory, Tucson, Arizona, Cerro Tololo Inter-American Observatory, La Serena, Chile (Biennial Report 1 July 1963–30 June 1965)

In the two-year interval 1 July 1963 through 30 June 1965 a number of the original objectives of the Association of Universities for Research in Astronomy (AURA), Inc. were achieved. Among these were the bringing into regular operation for use by visiting scientists and staff members the Kitt Peak National Observatory’s principal research instruments, the 84-in. stellar telescope and the Robert R. McMath Solar Telescope, on Kitt Peak (elevation 6875 ft).

The period under review also was marked by completion of all headquarters buildings of the Cerro Tololo Inter-American Observatory (CTIO) in La Serena, Chile, and by completion of the first two permanent structures at the CTIO site on the summit of Cerro Tololo (elevation 7200 ft). The two Observatories’ progress and activities are discussed separately below.

KITT PEAK NATIONAL OBSERVATORY

General

Observing Conditions. Weather conditions on Kitt Peak were:

<table>
<thead>
<tr>
<th>Period</th>
<th>Rainfall (inches)</th>
<th>Snowfall (inches)</th>
<th>Temperature (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1963–64</td>
<td>17.83 on 55 days</td>
<td>24.8 on 10 days</td>
<td>Highest: 98°F</td>
</tr>
<tr>
<td>1964–65</td>
<td>30.66 on 68 days</td>
<td>25.5 on 8 days</td>
<td>Lowest: 18°F</td>
</tr>
</tbody>
</table>

The worst observing conditions experienced so far on Kitt Peak were recorded in the 1964-65 year. The 84-in. telescope, which went into full-time service 15 September, 1964, was used on 230 nights for 1870 h (61% of possible night hours). Of the total usage, 127 nights were scheduled for visiting scientists.

In the 1963–64 year the 36-in. telescope was used on 247 nights for 1804 h (54% of possible night hours). Work was possible on 160 of the 235 nights scheduled for photometry.

In the 1964–65 year the 36-in. telescope was used on 232 nights for 1657 h (52% of possible night hours). Work was possible on 179 of the 266 nights scheduled for photometry. Of the total usage, 209 nights were scheduled for visiting scientists.

The two 16-in. telescopes were used by visitors on 330 nights during the 1964–65 year.

Public Visitors. A total of 92 246 public visitors were recorded at Kitt Peak during the biennium, 51 130 in the 1963–64 year and 41 116 in the 1964–65 year. Visiting hours are from 10 a.m. to 4 p.m. daily. In October 1964, Jay C. Evans assumed the duties of Kitt Peak guide and has since conducted many tours for interested groups of students from schools in the area.

Computer Facilities. A Control Data Corporation model 160A computer was used in the 1963–64 year for data reduction and analysis. Rapidly expanding use of the equipment indicated that a larger, faster type of computer was needed. Early in 1965 a model 3200 was installed at the Tucson headquarters.

The model 3200 has a greatly expanded core memory, additional auxiliary equipment, and operates 10 times faster than the model 160A. The new computer also has four times the storage capacity and much greater versatility with respect to program input and data processing output. It was selected after extensive staff discussions and after receiving representatives from a number of competing companies.

Library Holdings. A total of 15 500 books presently make up the two Observatories’ library holdings. Of these, 12 300 are in the Tucson headquarters library, 1500 on Kitt Peak, and 1700 in the Chilean libraries in La Serena and on Cerro Tololo. Tucson holdings are divided as follows:

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>General science</td>
<td>13%</td>
</tr>
<tr>
<td>Mathematics</td>
<td>4%</td>
</tr>
<tr>
<td>Astronomy</td>
<td>42%</td>
</tr>
<tr>
<td>Physics</td>
<td>18%</td>
</tr>
<tr>
<td>Engineering</td>
<td>15%</td>
</tr>
<tr>
<td>Geophysics, reference, miscellaneous</td>
<td>8%</td>
</tr>
</tbody>
</table>

These library holdings have been assembled partly through purchases of private libraries and the generous
gifts of friends and astronomers. All books are classified under the Library of Congress system and are available by interlibrary loan.

Journal subscriptions number 202 for Tucson and 24 each for Kitt Peak and Chile.

KPNO Astronomical Museum. The KPNO Astronomical Museum was completed in the 1963–64 year and exhibits were installed in March 1965. The building was opened to the public in April after a preview of exhibits by AURA’s Board of Directors on 21 March.

The museum contains integrated, interpretative displays and exhibits indicating the purposes of astronomy, the ways in which astronomers obtain information about celestial objects, descriptive and graphic material concerning the design and function of telescopes, and the history of the Observatory. By agreement with the Papago Indians, on whose reservation the Observatory is located, examples of their basketry and other handicrafts are displayed and offered for sale at the museum; all profits go to the Papago Tribe. The Observatory’s illustrated descriptive booklet is on sale to the public at the museum.

The tile mosaic mural on the facade of the museum offers visitors an interpretive link between modern astronomy and the first primitive astronomers of the Americas, the Maya Indians of Yucatan and Central America. The museum exhibits and the colorful exterior mural have elicited favorable comment from scientists and the public.

Facilities Construction. Major facilities construction during the 1963–64 year included completion of the Kitt Peak Astronomical Museum building, the Horseshoe Valley earth-fill dam, and expansion of the public picnic area to meet a need introduced by heavy usage of existing facilities by the visiting public.

In the 1964–65 year completions included a worker’s dormitory to house 22 people and an access road to the site of the National Radio Astronomy Observatory’s 36-ft millimeter-wave antenna. Facilities construction projects in progress but not completed on 30 June 1965 include a seven-room addition to the night observers’ dormitory, and the dome and mounting for the NRAO radio telescope on the southwest ridge at Kitt Peak.

At the Tucson headquarters a second-story addition to the Engineering Department and Optical Shop is in progress.

Land Acquisition in Tucson. For some time an ad hoc AURA committee studied the problem of expanding observatory needs for floor space, and on 22 September 1964 the Executive Committee authorized purchase of two plots of land at the corner of Second and Warren Streets in Tucson from Corporate funds.

At present the land is occupied by a duplex, which is to be razed upon expiration of the lease to provide additional headquarters parking, and a unit of five apartments which are being used on an interim basis for certain activities of the Solar Division, Photographic Laboratory, NRAO offices, and CTIO offices. Ultimately all structures will be removed from this land and the entire area will be used for parking after the proposed headquarters addition is completed.

NRAO Radio Telescope. On 22 January, 1965 AURA’s Executive Committee authorized the Officers to enter into necessary agreements of implementation for installation of the National Radio Astronomy Observatory’s 36-ft millimeter-wave radio telescope on the southwest ridge of Kitt Peak. Earlier the Executive Committee and the KPNO staff had received the proposal and expressed enthusiasm and interest in the scientific value of such cooperation between the fields of optical and radio astronomy.

At the end of the biennium an access road to the NRAO antenna site was completed and almost all structural steel for the dome was erected. The main parts of the antenna altazimuth mounting were assembled inside the dome. The antenna is under construction in California.

Meetings, Conferences, Symposia. An informal meeting to discuss image tube work was held at Tucson Headquarters 10 January 1964. The meeting was prompted by three causes: (1) Almost 2½ yr had elapsed since workers in the field had gathered to exchange information; (2) W. L. Wilcock was visiting KPNO, thereby offering opportunity to learn of progress abroad; (3) There was a need to review the optical requirements associated with the different tubes, and to find better solutions to the optical problems of using image tubes. In connection with the latter topic, I. S. Bowen, A. B. Meinel, and D. H. Schulte attended and presented their optical designs.


Observatory personnel attending the meeting considered it helpful and stimulating, and the proceedings are available in condensed report form for interested persons, upon request to W. C. Livingston.

In November 1964 the director and staff of KPNO were honored in welcoming to Tucson the National Science Board and the Astronomy panel of the National Science Foundation. Convening in Tucson for the first time in several years, the Astronomy Panel met at the Observatory’s Tucson Headquarters 13–14 November, 1964. The National Science Board, gathering in Arizona for the first time since March 1960, when it met in Tucson in connection with the dedication of the Kitt Peak National Observatory, convened 19 November on the campus of the University of Arizona. Members of the Board together with members of AURA’s Executive Committee, also meeting in Tucson at that time, visited the Kitt Peak telescope installations on 20 November 1964.

On 28–29 December 1964 KPNO and the University of Arizona were hosts to the 75th anniversary meeting of
the Astronomical Society of the Pacific at which 40 scientific papers were presented.

An important event for the Observatory's 150-in. telescope program was the symposium, "The Construction of Large Telescopes," sponsored by the International Astronomical Union. The symposium opened 5 April 1965 in Tucson where it continued for several days before moving to Pasadena, California, for more discussions. The symposium was concluded with a visit to Lick Observatory.

**Election of New Corporate Officers.** At the annual meeting of AURA's Board of Directors held in Tucson 23 March 1965, Rupert Wildt of Yale University was elected president. G. L. Lee, Jr., controller of the University of Michigan, was elected vice president and W. A. Hiltner, director of Yerkes Observatory, was named chairman of the Scientific Committee.

Robert H. Hardie of Dyer Observatory, Vanderbilt University, was elected to a three-year term as director-at-large, replacing A. P. Linnell of Amherst College.

James H. Corley, vice president-Governmental Relations and Projects, University of California at Berkeley, retired from the university and his place on the AURA Board was assumed by O. W. Campbell, vice chancellor—Business and Finance at Berkeley.

All other board members whose terms expired in 1965 were re-designated by the presidents of their universities to serve three additional years. Annual consultants and non-board-member officers (secretary, treasurer, assistant secretary, and assistant treasurer) were re-elected to serve until the 1966 annual meeting.

**Organizational Changes.** KPNO and CTIO organizational changes were recommended by the Audit and Organization Committees of AURA and approved by the Executive Committee in September 1964. Among major organizational changes were those making the director of Kitt Peak National Observatory responsible for the administration of both observatories and placing the chief engineer in charge of the Telescope Development Group, under the observatory director, to devote his talents primarily to development of the 150-in. telescope.

**Future Observatory Plans.** On 21–22 January 1965 the observatory director presented to the AURA Scientific and Executive Committees a five year long-range plan for both KPNO and CTIO. On 4 February the plan was presented to the staff of the National Science Foundation.

Under the plan, major projects contemplated for KPNO include a feasibility study for a very large telescope, the X-inch, continuation of the Physics of Seeing program at least at its present level, and extension of the program to embrace investigations of other sites possibly in Baja California, Hawaii and Chile, and a second large solar telescope either in the northern or southern hemisphere.

Contemplated for CTIO are a 150-in. stellar telescope, a larger Schmidt telescope than that originally planned, and two 24-in. telescopes.

**Summer Research Assistant Program.** This program was continued for the fifth consecutive year. In the summer of 1964 a total of 13 advanced astronomy students were selected on the basis of replies received from an announcement sent to the leading graduate training centers for astronomers. In the summer 1965 14 graduate students participated in the program.

The program not only provides the research staff with needed assistance, but also gives students valuable experience in observatory work, and keeps the staff in touch with promising trainees in the field.

**Stellar Division**

**Instrumentation**

**150-in. Telescope Project.** At the end of the 1962–63 fiscal year (30 June 1963) D. L. Crawford was appointed 150-in. telescope Project Manager. On the same date AURA's Board of Directors authorized the Westinghouse Electric Corporation of Sunnyvale, California, to begin preliminary design of the telescope mounting. On 14 September, 1963 the 150-in. Telescope Advisory Committee met in Tucson and the following general specifications for the telescope were defined:

1. Large field at prime focus (3/4° to 1°); primary mirror focal ratio of about f/2.8; field correctors should transmit ultraviolet light.
2. A Ritchey-Chrétien optical system for the f/8 Cassegrain focus and a horizontal coudeé spectrograph.
3. Primary and all secondary mirrors to be made of fused quartz.
4. Extensive study to be given to local seeing effects, including the possibility of placing the telescope approximately 150 ft above the ground.
5. As versatile an instrument as possible without compromising efficiency, and at reasonable cost. Provision for rapid interchangeability of secondary mirrors.
6. No extensive engineering studies to be undertaken.

Discussions concerning fabrication of a fused quartz mirror blank were pursued with three industrial organizations: Corning Glass Works, Corning, New York; a partnership of the firms of Heraeus of Hanau, Germany, and the Amersil Quartz Division of Engelhard Industries, Hillside, New Jersey; and General Electric Company's Lamp Glass Division, Cleveland, Ohio. Sample blanks from the three concerns were tested extensively in the Observatory's optical shop. On the basis of these tests and cost and delivery quotations, a contract was signed with General Electric 31 December 1964 for fabrication and delivery in Tucson on or before 1 June 1966 of a 150-in. fused quartz mirror blank.

Grinding, polishing, figuring, and testing will be done in the Observatory's optical shop, which produced the 84-in. Kitt Peak mirror and the 60-in. mirror for use...
on Cerro Tololo. Final testing of the 150-in. mirror will be done in the telescope on stars as one of the last steps before regular observing begins.

On 12 October 1964 the 150-in. Telescope Advisory Committee again met in Tucson to discuss general design of the telescope, dome, auxiliary instrumentation and operational functions. On the basis of this discussion and the preliminary building and dome designs submitted by Skidmore, Owings and Merrill (the Chicago architectural firm selected for the 150-in. project by AURA's Board of Directors in April 1963 because of the firm's outstanding design work on the McMath solar telescope), the following general preliminary specifications were adopted:

The telescope structure and dome will be constructed in such a manner that the declination axis of the instrument will be about 150 ft above the ground. The dome will be 100 ft in diameter. The fixed walls of the building will be of double-shell construction for thermal control, since the air temperature inside the dome must remain during daylight hours within a few degrees of nighttime values.

The rotating dome will be similar to the double-shell arrangement at Palomar and Lick observatories. Air venting in the space between the shells will carry off excess daytime heat absorbed by the outer surface. Although preliminary design calls for placing the declination axis about 150 ft above the ground, additional results from the Physics of Seeing Program may indicate that this height can be reduced.

There will be two elevators in the building, one for staff and light freight, the other for visitors. Heavy freight will be raised by cable hoists ranging in capacity from 5 to 50 tons.

As indicated above, special design efforts have been made to assure that the diurnal temperature range inside the dome shell is kept to a minimum. The possibility of complete air conditioning also has been considered. Temperature and humidity will be controlled in the darkrooms and laboratories. The covered spectrograph room and covered laboratory should operate on an average nighttime temperature. The visitors' gallery will be ventilated but unheated.

The telescope mounting will be supported by a hollow reinforced concrete pier, approximately 37 ft in diameter built up from bedrock and isolated from all vibrations in other parts of the building. This type of pillar support is similar to that in the McMath Solar Telescope.

The concept for the 150-in. telescope mounting was developed by W. W. Baustian, the Observatory's chief engineer in charge of the Telescope Development Group. It is a modification of types investigated originally for the Palomar 200-in. telescope. In many ways it is similar to that instrument's mounting, but the "horseshoe" yoke is located at the declination axis so the tube may swing freely between the tines of the yoke, rather than between the struts running from the yoke to the south bearing. The yoke, approximately 41 ft in diameter, will also act as the north journal of the polar axis, as in the 200-in. design.

The dome will contain an up-and-over shutter similar to that of the 84-in. telescope, but with a prime focus elevator to move up the shutter opening to the top of the telescope tube, thereby providing access to the prime focus cage. There also will be an observing cell at the Cassegrain focus behind the main mirror.

The coude system will include five mirrors at all times so that the center section of the truss-type tube need not be weakened by a slot to pass the light beam, as is necessary in the three-mirror coude arrangements. A folded Cassegrain system will use the first coude flat mirror to bring light to a focus in one arm of the yoke, as with the 200-in. telescope. In one of the preliminary designs, the upper part of the telescope tube would have interchangeable sections, one to carry the observer's cage, the other to hold the Cassegrain secondary.

Both right ascension and declination axes will have high-precision drives of several speeds. The final design of the main sidereal drive has not yet been determined, as noted below. Readout of telescope position will be through encoders and synchros attached to the axes. There will be a main control console, and substations at each observing location.

Present optical design calls for a one-degree field corrector transmitting the ultraviolet at the prime focus, and a Ritchey–Chrétien system at the Cassegrain focus. Focal ratios are f/2.8 at the prime focus and f/8 at the Cassegrain focus.

The Telescope Development Group is proceeding with design studies of various components of the mounting, including both modifications of, and alternatives to, designs proposed in the Westinghouse preliminary design study. The group also is engaged in the design of other components not included in the Westinghouse study. This work produced the revised design of the horseshoe polar axle bearing assembly to permit location of the declination axle on the polar axle center line. Thus the mounting will be symmetrical, a condition requiring more counterweighting in the horsehoe but presenting fewer operating problems.

A search and review is being made of available publications dealing with the theory of mirror support and deflections. Until more definite decisions are reached concerning the type of support system to be used, detailed design studies of the primary mirror support and cell will be held in abeyance. Detailed designs for right ascension and declination drives also are being deferred until results are available from tests of an experimental torque motor drive on the 84-in. telescope.

Preliminary work on design of the base frame and table drive assembly for the 150-in. grinding machine was started in June 1964. Preparation of final dome designs is scheduled to begin in the fall of 1965. A test program has been arranged at the University of Arizona's aerospace laboratory, for their wind tunnel to
test a number of shutter configurations. The principal purpose of these tests is to determine relative coefficients for the rotational torque induced by wind loads.

The construction of a mockup of the prime focus observer's cell is progressing. This will be used to determine observing requirements, both with regard to cell size and chair arrangement. It will also be used to determine the extent of available space for auxiliary instrumentation or "cabinet" storage that will be available in the cell.

**84-in. Telescope.** Before the 84-in. stellar telescope was placed in regular operation 15 September 1964, and after a considerable period of testing, it was necessary to decommission it during the month of May 1964 to replace the babbitted surface of the oil film bearings. Due to improper heat treatment the babbitt did not adhere to the large steel blocks of the bearings.

Another difficulty that arose in operation, and has not yet been corrected, is a periodic error in the main tracking drive. The error was zero after rebabbitting but later increased to an amplitude of nearly 2 sec of arc, with the 2-min. period of the main worm. Tests in progress to determine what corrective action is needed. Although the error does not impair operation of the telescope, it is troublesome for direct photography. The error has little effect on photometry and spectroscopy.

As a result of intensive effort by the Observatory's engineering services department under D. J. Ludden, and with the unstinting participation of Helmut Abt, the large coudé spectrograph was placed in partial operation 1 March 1965. Two of the cameras are in operation and the other four are in various phases of construction, with completions expected during the remaining months of 1965.

The continued testing of the 84-in. optical system had to be suspended during much of the time the coudé spectrograph was being installed, since that activity seriously disturbed temperature conditions within and around the telescope. Thus final adjustment of the mirror support system has not yet been made, and Hartmann and Foucault testing will be continued for some time.

One of the interesting uses of the telescope was observation of the moon at the time of lunar impacts of Rangers 7 and 8. Conditions for the first event were poor but those for the Ranger 8 impact were nearly perfect. An expert observer from the University of Arizona's Lunar and Planetary Laboratory was present on both occasions, but he was unable to observe any evidence of either impact. Ranger 8's position was known within several seconds of arc, and its impact time within 1 sec. The observer reported that if a dust cloud or its shadow had been of the order of half a mile in diameter, the excellent conditions and the telescope's performance would have revealed evidence of the impact.

**No. 1 36-in. Telescope.** In September 1963 a new primary mirror was installed in this telescope. The instrument soon will have a flip-top secondary arrangement to provide two Cassegrain foci, one of f/7.6 for direct photography, the other of f/13.5 for spectroscopy and photometry. The f/7.6 focus is a coma-free Ritchey-Chrétien system.

A leveling device for the observing platform was manufactured and installed to compensate for the unbalanced condition of the platform caused by heavy loading of electronic equipment. Extensive rewiring in the power supply and control circuits was completed and the darkroom was air conditioned during the 1963-64 year.

**No. 2 36-in. Telescope.** A second 36-in. stellar reflector is under construction by Boller & Chivens, Inc., of South Pasadena, California for installation at Kitt Peak. Site preparations have been completed for this instrument, which will be located between the No. 1 36-in. and the 84-in. telescopes.

Construction of the No. 2 36-in. began in June 1964. The telescope is expected to be ready for installation early in 1966. Although very similar to the No. 1 telescope, the No. 2 instrument will provide an f/30 coudé focus for experimental work in addition to the Cassegrain focus. This modification will make possible the use of large, heavy and complex experimental instrumentation that cannot be mounted on the telescope tube.

**No. 3 and No. 4 16-in. Telescopes.** The two original 16-in. telescopes (No. 1 and No. 2) used during the Kitt Peak site survey and now installed on Cerro Tololo, have been replaced by two new instruments made by Boller & Chivens. Both have mountings similar to the site-survey telescopes. The No. 3 telescope, located just southeast of the 84-in. telescope dome, has been in service since 1962. Number 4 was placed in service in November, 1963.

The No. 3 is an f/7.6 Cassegrain reflector; No. 4 is an f/18 Cassegrain. Both instruments include standard photoelectric photometers identical in most details with those used on the No. 1 36-in. (f/13.5) and the 84-in. (f/7.6). Each telescope has an instrument adapter and a slide mirror assembly to permit viewing the field in front of the focal plane diaphragm. The photometer head module contains the diaphragm, and a filter slide assembly with space available for seven 1-in. square filters.

A cold box for a 1P21 photomultiplier attaches to the end of the photometer head assembly. Integrators of the type designed by Weitbrecht (Rev. Sci. Instr. 28, 883, 1957) and modified by Gardiner are used on both telescopes.

A prototype digital readout system has been used with the No. 4 instrument. This system permits either manual or semi-automatic recording of up to four integrators simultaneously.

**Physics of Seeing Program.** C. R. Lynds has completed more than three years of work in this program directed toward the development, construction and operation of.
 impersonal instrumentation for studying the phenomenon of astronomical seeing. Much of this time was spent in development of suitable optical and thermal sensors, which have been placed at various Kitt Peak sites of possible interest as a location for the 150-in. telescope.

Originally it was hoped that data from these instruments would offer a clear-cut indication of the best possible 150-in. site. It now appears, however, that much more data are required before any significant differences can be demonstrated. Program results, nevertheless, show rather clearly that a large telescope should be located not less than 100 ft above the ground, and that the phenomenon of seeing around the summit of Kitt Peak is much more complex than was initially foreseen.

Results to date suggest that the phenomenon is composed of at least two parts: first, a ground-level inversion layer determined by local topography, vegetation cover, and wind direction and, second, at least one higher-level interface between different density air masses above 100 ft of elevation, which may lower or raise at different times under different conditions. These conditions are not very well understood, because the program has not included a parallel project involving the micrometeorology of the local and general area of Kitt Peak. The program is continuing in an effort to learn more about the individual sites under test. The 150-in. telescope location decision will be delayed as long as possible in order to obtain these site-test data. Ultimately, a rather arbitrary decision may be necessary.

**Polaris Image Motion Analyzer (PIMA).** The PIMA program of astronomical seeing measurement by photoelectric means discussed in the last annual report was continued and expanded during the biennium under review. At the end of the 1962–63 year two such PIMA systems were under construction for location atop two wind-screened 35-ft piers on Kitt Peak. At each PIMA location there also is a 100-ft scaffold tower to support the thermal sensors that measure the frequency and amplitude of microthermals. One of these towers was erected between the domes of the No. 1 36-in. and 84-in. telescopes. The other was placed 700 ft down the slope of the ridge west of the No. 1 36-in.

The first PIMA model was installed on Kitt Peak in January 1964. It is made up of a beam-splitting optical system, two photomultiplier tubes with a differential amplifier and feedback circuit, and a vibrating knife edge set on the image of a star. Essentially, the device makes it possible to obtain impersonal measurements of image motion alone. In preliminary tests of the device with Polaris as the source and a Questar telescope the imaging system, the minimum detectable signal corresponded to an image motion of 0.2 sec of arc. Simultaneous recording of the scintillation showed no correlation between image brightness and displacement.

**Grant Profile Measuring Engine Recording System.** A simplified digital recording system, using punched paper tape, was constructed by the Observatory’s Electronics Research Laboratory for the Grant profile measuring engine, thereby permitting computer reduction of radial velocity and Hartmann test plates. A more versatile readout system was later designed to make possible recording of more information, thus making computer reduction more effective.

**Palomar Sky Atlas Blink Machine.** A Palomar Sky Atlas blink and viewing machine, based on the design of the one in use at Lick Observatory, was constructed and is in use at Tucson headquarters. It is used with the Observatory’s glass copies of the Sky Atlas plates.

**Staff Research**

Staff research at the observatory is reflected in an increasing number of reports and publications. Many of these are reprinted from technical journals for the *Kitt Peak National Observatory Contributions* series, totaling more than 90 accepted for publication. *Contributions* through No. 58, plus two indexes, have been distributed on a world-wide exchange basis. Therefore only brief descriptions of staff research are included herein.

1963–64 Year:

Helmut Abt and Laura P. Bautz, a summer research assistant, published the first in a series of papers on the stellar radial velocities in the Perseus Arm. Abt and Michael S. Snowden, also a summer research assistant, have discussed the galactic cluster IC 4665, using Kitt Peak and Trumpler’s Lick material.

D. L. Crawford placed emphasis on firmly establishing the standard star system for the Strömgren four-color (u,b,vy) and for the photoelectric Hβ system (β).

The Hβ system was slightly revised and extended to include A and F type stars.

The faint extinction-star network for the four-color system mentioned in the 1962–63 report was completed. Four-color and Hβ photometry were obtained for a number of clusters. Observations of the Hyades and Coma cluster members were presented in a report at “The H-R Diagram Symposium” in Flagstaff, Arizona. In addition, observations were completed on the Pleiades, Praesepe, and IC 4665.

The photometry on the bright B stars mentioned in the last report was completed. A preliminary report on this work was given at the Stellar Evolution Conference in New York in December 1963.

J. C. Golson of KPNO spent two weeks at CTIO continuing the work begun by Crawford and discussed in the 1962–63 report.

C. R. Lynds pursued his photographic search for, and made photoelectric observations of, quasi-stellar sources with the 84-in. telescope. He also was engaged in high-resolution spectroscopy of the interstellar D lines in early-type stars, with the solar telescope's spectrograph and image tube. In the Physics of Seeing Program, stellar image motion monitors were successfully...
developed for installation on Kitt Peak to monitor Polaris. A high-speed spectrum scanner was developed for use with the solar spectrograph and, in the future, with the 84-in. coudé spectrograph.

1964–65 Year:

During his two-year joint appointment between the Institute for Advanced Study and the Observatory, Charles Perry conducted a four-color photometric program comprising all of the F5-G0 stars in the visual magnitude interval 6.4 to 7.3 and selected from the General Catalogue. The program was 87% complete on 30 June 1965. The data will be used by Bengt Strömgren of the Institute for Advanced Study to determine the interstellar reddening in the solar vicinity. A catalogue of the observations will be published soon.

Crawford used the observed Hyades main sequence as a starting point for absolute magnitude calibrations involving other clusters. To extend the calibration to earlier spectral types, Perry observed the stars in the inner region of h and x Persei on the four-color and Hβ systems. This program was completed; results will be published in the near future.

Perry collaborated with Crawford and his associates in making Hβ observations of all stars in the Strömgren-Perry catalogue. This work will aid a study begun by Strömgren and Crawford of the general properties of nearby field stars.

R. W. Michie and Perry initiated a photometric investigation of selected galactic clusters (M34, M37, M67, NGC 7243 and NGC 7789) employing the Strömgren four-color system. Their aim is a study in conjunction with Michie's theoretical research on clusters, of the behavior of the metallic line index m1 within individual clusters and among the clusters.

A A. Hoag, former director of the U. S. Naval Observatory Station at Flagstaff, Arizona, who joined the KPNO staff 18 January 1965 as associate director, Stellar Division, measured polarizations of stars in open clusters and obtained photoelectric Hβ measures to be used for calibration of absolute magnitudes of early-type stars.

Solar Division

Instrumentation

McMath Solar Telescope. Although the solar telescope has been in regular use by visiting scientists and Observatory staff members during much of the biennium, a number of problems has arisen in connection with its operation. Unfortunately, not all of these have yet been solved.

At the beginning of the 1963–64 year it was necessary to take the heliostat out of service for two months, due to the fact that the original right ascension worm had developed fine cracks. A new worm was installed and the declination motion was reworked in an effort to eliminate backlash and decrease friction. While the instrument was out of service an electric motor was installed to replace the air motor used for slewing.

Despite this reworking, the declination system continued to give trouble. The friction became so high that nine times the design torque had to be applied in order to move the main heliostat mirror.

From 2 February to 10 March 1965 the heliostat was again decommissioned and the declination bearings were removed for inspection. It was found that one was severely damaged, and that the cause of the trouble was excessive preloading by the manufacturer in initial assembly. This bearing was replaced, new clamps were designed and installed, oil seals were modified, and the whole reassembled. Little improvement was noted, however. Additional steps are being taken to correct the continuing problems of irregular motions, backlash, and lack of repeatability.

During the time the telescope was inoperative, completion of the lining of the tunnel in the vicinity of the aluminumizing room was accomplished. This part of the tunnel had been left unlined to permit installation of all the large mirror carriages. Experience indicated that this area often produced poor internal seeing due to convective currents that could occur in the opening.

Another problem, which has since been solved, was that the efficiency of the telescope cooling system was impaired by frequent airlocks. Although these could be located and eliminated, they kept reoccurring. A cooling system consultant was engaged and his thorough study resulted in the installation during the summer of 1964 of equipment for de-aerating the coolant. The circulation was improved substantially, with a recycling time of 30 min and a time of 2 h to reach a prescribed temperature.

It was found necessary to redesign the original version of the double-pass spectrographic system, due to an unexpected beam of scattered light from the grating. The first system employed two mirrors at the focal plane of the single-pass system to return the beam to the camera mirror, grating, collimator and to a mirror near the entrance slit directing light off to the side. A different arrangement of mirrors, in which the light is taken from the single-pass focus across to the entrance side, then sent again through the system in nearly the same path as the first pass, has since worked very well.

Vacuum Spectrograph. The design of auxiliary equipment for the vacuum spectrograph was completed in the 1963–64 year. The basic design is similar to that of the Mount Wilson magnetograph developed by Horace W. Babcock. The Observatory apparatus was designed to facilitate rapid replacement and alignment on the spectrograph.

During the 1964–65 year the vacuum spectrograph was seldom operated in the vacuum mode. There was little need to do so since the tube is vertical and in a deep pit with good temperature stability. The tank, however, breathes at the slit, photographic ports, etc., during gusty wind conditions. The grating drive has been constantly improved, and provision also has been
made for scanning in double-pass by moving the exit slit, and the intermediate slit, the latter with one-half the motion.

*Image Slicers.* Several image slicers, following Bowen's design, were constructed for use with the vacuum spectograph. The smallest divides a 1 mm square into 13 slices and has been used in stellar spectroscopy and for fine-detail studies of the solar magnetic field. The largest cuts a 5 mm square into 12 parts.

*Solar Magnetograph.* The solar magnetograph was fitted to the vacuum spectograph in the 1964–65 year and magnetic observations have been made on an exploratory basis since October 1964. Results of this preliminary work suggest certain modifications of the equipment.

Provision has now been made for the rapid scan of localized areas up to 2×3 min of arc in size with an aperture of 2×2 arc sec. One scan takes 12 sec and many scans are averaged on a computer to produce a map with the desired sensitivity. In common with a photographic “snapshot,” the magnetic information across the map is free from time delay. This technique is expected to be most useful in following the time variation of magnetic fields in active areas.

Another equipment change was addition of a complete second channel so the magnetic fields may be observed in two lines simultaneously. This change is expected to yield information on level effects in the solar atmosphere.

*Computer Facilities.* A new phase in the instrumentation program for the solar telescope began in December 1964 with delivery of an on-line control computer from Scientific Data Systems. The number of tasks proposed for this equipment has since grown rapidly. They now include telescope position control (refraction and declination change compensation, scanning of the solar image in pre-selected patterns); timekeeping (for automatic compensation of corrections depending on zenith angle or hour angle); spectograph control (repetitive wavelength scanning, shutter control), and on-line data handling (scaling, averaging, plotting, etc.).

The nucleus of this control system is an SDS 910 general-purpose computer with 8 μsec cycle time and a memory of 8192 24-bit words. Peripheral equipment includes an input–output typewriter, a 100 card/min card reader, a 300 character/sec paper tape recorder, a 150 character/sec paper tape punch, and X–Y digital plotter and an oscilloscope display. The computer has 16 priority interrupt lines which may be activated externally to execute special routines.

To meet the complex demands of the solar installation, a number of more specialized input–output functions also have been provided. The nerve center of these functions is an interface console designed by D. E. Trumbo of the Observatory’s Electronics Research Laboratory. The console contains special circuitry needed in some cases to translate external signals into a form the computer will accept, and vice versa, and a programming plugboard used for interconnecting the various computer inputs and outputs with the external equipment. Eventually each observing program will have its own prewired plugboard and paper tape program, so that changing from one type of observation to another will be rapid and simple.

**Eclipse Expeditions**

*Expeditions of 20 July 1963.* To optimize chances of successful observational experiments during the total solar eclipse of 20 July 1963, for which rather poor weather conditions were predicted all along the path, three observing locations were selected for use by Solar Division investigators working under A. K. Pierce, associate director in charge of the division. Sites chosen were Lake Tyone and Hogan Hill in Alaska, and Dexter in Maine. Clear weather was experienced only at Lake Tyone during the eclipse, where cirrus prevailed until 15 min before totality. At Hogan Hill moderately heavy cirrus covered the sun 10 min before totality; in Maine heavier clouds prevailed.

Equipment used in Maine followed closely that of Von Klüber, who first observed interference fringes from the green coronal line in the eclipse of 1954. Von Klüber and Jarret were able to photograph fringes to 1.8 solar radii. With greater camera speed, better transmittance filters, and a Fabry-Perot etalon, Observatory staff members hoped to extend this limit to the sky fog.

The instrument consisted of a 5-in. aperture f/5 doublet lens forming a solar image ¾-in. in diameter. The light was then collimated and sent through a narrow-band interference filter isolating 5303 Å, then through the Fabry-Perot etalon. The fringes and coronal image were focused on the photographic film by an f/2 camera lens. The solar image size was thus reduced to 2.5 mm, but the geometrical speed was that of the f/2 camera.

To circumvent problems experienced by previous observers of limb darkening, namely integration of the whole crescent, photographic effects and irregularities on the moon’s limb, the Observatory group proposed photoelectric observation of a small portion of the crescent defined by an oscillating slit. At Lake Tyone, a 10-in. celestat was used to direct sunlight to a fixed horizontal telescope of 6-in. aperture and 13.7 ft focal length. A static inverter synchronized by a tuning fork oscillator provided an accurate frequency power source for the synchronous-drive motor.

At the focus of the photometer a narrow radial slit oscillated back and forth along the thin crescent of sunlight present immediately before and after totality. A cam, shaped to provide a constant scanning rate, moved the slit. An interference filter centered on a region of the spectrum free of Fraunhofer lines (6043 Å) limited the bandpass to 15 Å. The light measuring units consisted of a photomultiplier dc amplifier, and analogue-to-digital converter.

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Also at Lake Tyone an attempt was made to photograph the emission spectrum of the corona to as great a distance from the sun as possible. The attempt failed, probably because of too low dispersion, which did not build up the emission line strongly enough with respect to the background.

At Hogan Hill two spectrographs were used, one with a dispersion of about 200 Å/mm, the other 20 Å/mm. The latter consisted of an Ebert grating spectrograph fed by a 6-in. parabolic mirror of 30-in. focal length pointed directly at the sun. With this instrument the aim was to search for the broadened spectral lines of the electron corona. Although a good spectrum of prominences and the brighter corona was obtained, the integration and obstruction by cirrus clouds prevented recording the desired result.

**Expedition of 30 May 1965.** To obtain measurements of the spectrum and intensity in the outer parts of the solar corona, the Observatory sent an expedition to the eclipse path that crossed the islands of Bellinghausen and Manuae in the South Pacific Ocean. Through its program for the International Year of the Quiet Sun, the National Academy of Sciences asked A. K. Pierce to serve as scientific leader of a combined expedition of all U. S. eclipse-observing parties. At Pierce’s request, J. M. Miller, the Observatory’s associate director for Administration, served as logistics leader of the combined expedition.

The U. S. group, made up of eight parties numbering 33 persons and its scientific equipment was transported to the South Pacific by the ship Goodwill, a sailing schooner owned by Mr. Ralph Larrabee, an industrialist who made the vessel available for the expedition on a no-rent basis. The 12 000 mile two-way voyage of the Goodwill covered a period of 109 days.

The Observatory group operated in two parties, one going to Bellinghausen in the French Polynesian Islands, the other to Manuae in the Cook Islands, which is under New Zealand’s governing mandate. The two islands are separated by approximately 350 miles.

Because weather prospects were unfavorable at each site, with only one chance in ten of clear skies at eclipse time, one of the Observatory’s experiments was duplicated on both islands. It consisted of spectroscopy of the lower corona in the region of the H and K lines. A search was made for those lines in the spectrum resulting from scattering of photospheric radiation by electrons and broadened to a half-width of 150 Å by the high coronal temperature.

Also on Bellinghausen the corona was scanned photoelectrically in violet, yellow-green and red wavelengths. The image of the eclipsed sun and corona was moved mechanically in a spiral pattern, building up a picture totaling 40 000 points. Precision photometry was carried out in an attempt to provide data for discussions of the density, temperature and structure of the corona, and of the problems of energy dissipation and solar wind.

Manuae was completely cloudy at eclipse time. At Bellinghausen light cirrus may have prevented achievement of all objectives.

**Staff Research**

1963–64 Year:

The fine definition of the achromatic image obtained in the McMath Solar Telescope led Pierce to begin a program of recording chromospheric spectra. Approximately 100 photographs were obtained during the year in the 1st through 7th orders from 4000 to 9000 Å. It became apparent that about half the emission lines obtained outside of eclipse with the slit of the spectrograph tangent to the limb are due to rare earths, with the others attributable to Fe ii, Li ii, Sc i, ii, Co i, Cr i, La ii, etc. Approximately 3000 lines were measured for wavelength.

J. H. Waddell’s theoretical work was directed toward answering the questions: How are Fraunhofer lines formed in the solar atmosphere? How important are non-LTE effects in the sun?

These problems hold interest because present theory and knowledge of collisional and radiative cross sections predict strong departures from LTE, whereas, in fact, many solar observations indicate at least a strong mimicry of LTE. An analysis by Pierce and Waddell of White’s and David’s observations of the Balmer lines indicates that these lines may be described by a common temperature.

Because of some inherent conceptual difficulties in the present formulation of the non-LTE problem, Waddell sought a new approach. As a first step, the Kothari-Synge source function (Wildt, Astrophys. J. 123, 107, 1956), was tested to eliminate a long-standing infrared discrepancy between the empirical and theoretical opacity of the sun. This discrepancy was, in fact, eliminated. Furthermore, the degeneracy parameter was sufficiently small that, with such a source function, a mimicry of LTE in line-source functions was clearly reproduced.

Although solar observations indicate no differential non-LTE effects, no unambiguous observations had been made to establish the existence or nonexistence of absolute non-LTE effects. Thus, observational programs were directed toward establishing the existence or nonexistence of absolute non-LTE effects. These included studies of continuum limb darkening in and out of eclipse to establish better the solar boundary temperature, a program of multiplet comparisons extended to provide eventually for inter-element comparisons, and detailed studies of lines of high excitation potential formed in the very outer layers of the sun.

Other solar staff observational programs included a search for certain very weak lines. These include those of boron, D_n, forbidden lines, and isotopes of lithium and carbon.

With the McMath telescope, high dispersion spectra (6.1 mm/Å) were obtained by W. C. Livingston and Lynds of several early-type stars in the Scorpius region.
The English Electric Valve intensifier tube was employed to reduce exposure times to 13 min for β² Sco.

With completion of the improved image slicer, the observation of interstellar lines in early-type stars was continued with the solar telescope. The very high resolving power of the solar spectrophotograph permits detailed study of lines that before were incompletely resolved. The solar telescope has thus proved to be a dual-purpose instrument, for both sun and the stars.

Experiments conducted by Livingston led to better understanding of the limitations and advantages of the imaging photomultiplier. A unique property of this tube is its very high gain, which causes individual photoelectron events to appear on the output phosphor as relatively bright scintillations. The question Livingston sought to answer was: Can these scintillations be recorded and summed to provide an accurate map in two dimensions of the original image photon flux?

A successful system was developed for detecting and summing digitally the scintillations of more than 400 elements. It was found, however, that the photometric accuracy attained does not justify such elaborate techniques, because considerable degradation in the photon flux information occurs within the image tube. It was concluded that, at this stage in the state of the electronic art, no image tube can be objectively considered equivalent to a hypothetical array of photomultiplier tubes. In view of this conclusion, staff research in this area was then directed toward the simpler problem of using image tubes to reduce exposure times for stellar spectroscopy.

1964–65 Year:

As mentioned earlier, Livingston completed the design and construction of a magnetograph with which full-disk magnetograms with a resolution of 10 x 10 sec of arc and a noise level of 0.1 G (rms) were obtained. At this resolution the disk is found to be covered by fields with rms values of about 5 G (avoiding pronounced BM regions and the polar latitudes). This magnetic structure shows no center-to-limb variation. Since at the center the records are of “longitudinal fields,” while at the limb of “transverse fields,” it was concluded that the structure is isotropic. In the fall of 1964 a predominance of S-seeking fields existed at high northern latitudes. Similarly, N-seeking fields were found around the south pole. A series of full-disk magnetograms were obtained around the time of the 30 May 1965 solar eclipse. These may prove useful in interpretation of coronal data.

Over limited regions, high-resolution (2 x 2 arc sec) maps have been obtained with 0.5 G sensitivity. At this resolution, the magnetic structure is very complex, although there appears to be a characteristic size around 5 arc sec diameter. The rms field strength is 3 G, but peak fields of 10 to 15 G are common.

Livingston and Lynds continued their program of investigating image tube techniques. Particularly interesting was the observation of faint stellar sources, with the new EEV-P829 tube mounted on the No. 1 36-in. telescope spectrophotograph modified for use at the 84-in. Cassegrain position. Useful spectra of objects as faint as 18th magnitude have been obtained. Tests of the tube developed by the Carnegie Image Tube Committee (RCA-Cascade) were made at the solar telescope in March 1965 during a visit by M. Tuve, W. K. Ford, and A. Purghofer. This tube, on loan to the Observatory, will be used in the 1965 fall months for several stellar programs with the McMath Solar Telescope.

Pierce continued the chromospheric spectrum mapping program. Acquisition of plates has been slow due to the very high-quality seeing required, but efforts are being made to fill in gaps and to extend the interval over the complete photographic range from 3000–12 000 Å. Seventy-five percent of the available plates have been measured and reduced, which brings the list of lines to about 5000.

Waddell’s research during the year was divided into two aspects: observational and theoretical. Observational work included one program with Charles Slaughter to obtain photoelectric observations in the spectral region where a recent laboratory identification of boron lines was made. A tentative identification and abundance determination of boron in the sun was made. Another observational long-term program is aimed at obtaining center-to-limb observations of a variety of solar lines with respect to excitation potential, atomic weight, line strength, etc.

Waddell’s theoretical work was devoted to the solar non-LTE question as a macroscopic problem. Necessary information for this approach is found in the divergence of photospheric photon number flux. A paper in the July 1965 Astrophysical Journal will report on this work. A later paper has been submitted in which the Kothari or two-parameter source function is derived in a simple fashion. It arises from the final state factor in the usual sense of the word, and perhaps must be considered something akin to a hidden variable.

Space Division

Instrumentation

50-in. Remotely Controlled Telescope. After extensive testing with the digital communication system at Tucson Headquarters, the 50-in. Remotely-Controlled Telescope (RCT) mounting was moved to Kitt Peak for final alignment in July 1964. The mounting was fitted temporarily with a 16-in. optical system and tube from one of the original site-survey telescopes.

The RCT has undergone a comprehensive checkout program of commands for coarse pointing in different directions via a telephone line link from Tucson. The setting accuracy is approximately 2 min of arc. This will be increased to 2 sec of arc when the fine pointing control is installed. Several initial programs of bright-
star photometry are already programmed on paper tape. These will be used as soon as the full-size 50-in. telescope tube structure is installed and a photometer is constructed. A microwave link may be used between Tuscon and Kitt Peak when the RCT is complete.

The tube structure, fabricated wholly of aluminum, was delivered to Kitt Peak in February 1965. The primary f/2 Ritchey-Chrétien aluminum mirror is completed and the secondary mirror is nearly finished. Assembly and full-scale operation is expected during the summer and fall of 1965.

The RCT will have a Cassegrain focal ratio of f/13.5. Eventually instrumentation will include a new photoelectric finder with offset guiding operable up to 7.5 min off-axis. This limited displacement is due to the guider operating within the field of view of the main telescope. The guider will operate on stars down to at least 8th magnitude with an accuracy of ±2 sec of arc for such stars, including offset errors.

The RCT was developed as part of the space program on flight systems, in order to study communication problems with an unmanned telescope. Its automation features, however, make it of great interest to astronomers because its adaptation for some ground-based programs would result in a substantial increase in the rate of data acquisition and reduction. It possesses unique features of particular value for observational programs related directly to space astronomy.

Rocket Flight Program. The space astronomy study through use of sounding rockets, as described in the 1962–63 annual report, was continued and expanded in the biennium under review, a period in which five additional Aerobee rockets were launched. This brings the total number of Observatory-instrumented launchings to seven, which completed the first phase of the program.

Since the attitude control system for the rockets is still in a comparatively low-accuracy state of development, experiments were limited to wide-sky type observations. Several experiments recorded the radiation at various wavelength regions in the dayglow of the earth’s atmosphere, and one of them scanned the zodiacal light. On one of the flights certain radiations from atmospheric molecules and atoms were observed for the first time in the dayglow sky.

The second phase of the rocket flight program will involve more accurate attitude control systems made by outside contractors according to designs by the Space Division’s Systems Engineering Laboratory. The next series of flights will carry payloads for x-ray solar coronal photography and stellar photometry, the latter for the field of bright stars in Orion. The x-ray camera and ultraviolet telescope-spectrometer instrumentation have been designed, and most of it is presently under construction in the Observatory shops.

Astrophysics Laboratory. This activity under D. M. Hunten has involved operation of the Airglow Laboratory on Kitt Peak, and experimental laboratory investigations at Tucson headquarters. At Kitt Peak a spectrometer and memory unit are in use for regular observations of one of the so-called “twilight flashes” that occur after sunset and before sunrise. A very large seasonal and morning-to-evening variation has been discovered.

At Tucson headquarters, development of far-ultraviolet radiation sources for calibration of space experiments has been one of the projects during the 1964–65 year. In addition to providing backup instrumentation for the rocket flight program, assistance was given to A. M. Gehrels, of the University of Arizona’s Lunar and Planetary Laboratory, in calibrating ultraviolet polarizing photometers he plans to fly in high-altitude balloons.

NBS Scanning Photometer. The National Bureau of Standards, Airglow and Aurora Section, Boulder, Colorado, under F. E. Roach, installed and is operating at the Kitt Peak Airglow Laboratory an all-sky automatic, fully digitized scanning photometer. The device records the intensities of the most prominent night-sky and auroral radiations, together with the fainter solar system zodiacal light and the Milky Way’s band of light. The equipment also monitors at the zenith the general background night-sky continuous radiation.

Bolivian Expedition

As a ground-based preliminary to one of the Aerobee rocket flights, an Observatory expedition was sent in the summer of 1964 to observe the zodiacal light from one of the highest observing sites in the world at Chacaltaya, Bolivia, where the elevation is 17 634 ft. Despite very severe observing conditions that incapacitated three of the four expedition members, several hundred scans with digitized and magnetic tape recording equipment were obtained of the zodiacal light.

Measurements were made during seven nights in July and August 1964 with two scanning instruments. Almucantar scans at different altitudes were made with the first instrument, which consisted of six parallel polarimeters. Scans from horizon-to-horizon through the zenith at various azimuths were made with the second instrument, which contained four polarimeters.

More than 100 scans were made with each. These provided the basis for determining isophotes of the brightness and polarization of the zodiacal light in five colors ranging from 3650 to 9550 Å. Reduction of these data is in progress. It is expected that the principal observational data will be in a form suitable for publication within a year.

Staff Research

J. W. Chamberlain, associate director in charge of the Division, has studied the radiation characteristics of the outer atmosphere of Venus. He and D. M. Hunten have reviewed critically previous work done to estimate the total pressure of the Martian atmosphere. The latter
work is of particular interest in connection with the proposed "soft landers" on Mars.

M. J. Belton, who joined the Division in July 1964, has been engaged in a study of the dynamics of comet tails and their interaction with the interplanetary gas.

Continuing studies for a model of the upper atmosphere of Mars, and on helium in the earth's atmosphere have been the principal research activities of M. B. McElroy.

R. M. Goody, visiting professor from Harvard University serving as consulting astronomer, has investigated the circulation of the upper atmosphere of Venus through detailed analysis of the pattern of "isotherms" obtained from far-infrared scans with the 200-in. telescope.

A. L. Broadfoot's investigation of the N₂⁺ emission line in twilight has yielded two interesting by-products: first detection in the earth's atmosphere of the ortho-helium line at 3889 Å, and detection of the resonance-scattered Ca⁺ lines at 3934 Å.

J. C. Brandt has been engaged in investigations of radiative losses in the interplanetary gas and a study of the size of the H II region about the sun.

CERRO TOLOLO INTER-AMERICAN OBSERVATORY

Under the direction of Jurgen Stock, the biennium was marked by starting a number of large-scale construction projects. Several of these were completed during the period.

Construction of a provisional access road to the summit of Cerro Tololo was initiated in the summer of 1963; the road was extended to the summit 10 September 1963. An extensive road-improvement followed. On 14 December the road was officially opened by former AURA president Frank K. Edmondson. The U. S. Ambassador to Chile and local authorities participated in the ceremony.

Leveling of the summit of Cerro Tololo was completed 5 June 1964. The spring at Los Placeres was developed and installation of a pumping system and pipeline to carry water from the spring to the observatory site was completed. A large generator and distribution network to supply electrical power was installed during the 1963-64 year.

In October 1963 a tract of land was purchased at La Serena as the site for the observatory headquarters. The site is located adjacent to the Regional Agricultural College of the University of Chile. Construction on the headquarters site began 1 January 1964 and the four buildings—administration, two residences and a caretaker's house—were completed in March 1965. The headquarters is linked via shortwave radio with Cerro Tololo, and with the Kitt Peak National Observatory in Tucson.

The entire road system on the summit of Cerro Tololo was completed during the 1964-65 year and the improvement program on the mountain road was continued. All construction sites on the summit were leveled and most of the distribution network for electrical power and water on the summit was completed.

Construction of the first permanent building on Cerro Tololo began in December 1964. The two buildings for the 16-in. telescopes were completed and virtually ready for occupancy at the end of June 1965. Excavations were completed for the 36-in. telescope. A road to the Carnegie Southern Observatory site tests on Cerro Morado was completed by the CTIO work crew in January 1965.

Observing Conditions. On 17 March 1963 the volcano Mount Agung on the Isle of Bali exploded and ejected a great amount of fine material into the atmosphere. Photometrically, the effect became noticeable at Cerro Tololo at the end of April 1963. Similar phenomena were observed throughout the southern hemisphere. During most of the 1963-64 year atmospheric extinction remained between 0.2 and 0.3 of a magnitude above normal (in the visual spectrum) on Cerro Tololo. By the end of June 1964 the extinction excess had declined to 0.09 of a magnitude.

The effect of this phenomenon on the climate in the region of Cerro Tololo was very apparent. Winter cloudiness was about 20% above normal and the precipitation effect was marked. Instead of the normal 50 mm, total rainfall at Cerro Tololo during 1963 was about 500 mm and in the single month of June 1964 a total of 53 mm was recorded.

During the 1964-65 year 290 nights were useful for astronomical work and 245 of those were useful for photometric work. The 16-in. telescope was in use on all photometric nights. More than half of the observing time was used by visiting investigators from the United States, Chile, and Argentina.

Instrumentation. The 16-in. telescope was operated throughout the biennium as weather conditions permitted. Construction of the 60-in. and 36-in. telescopes was proceeding well as the report period ended, and it is expected that they will be ready for shipment to Chile near the end of 1965. The second 16-in. telescope was overhauled in the shops of Kitt Peak National Observatory and was ready for shipment to Chile in June 1965.

In September, 1964 a photoelectric spectrum scanner, on loan from the University of Wisconsin, was added to the auxiliary equipment for the 16-inch telescope. Considerable improvement in photometric programs was achieved through purchase of a dry ice machine, which made possible refrigeration of the photocells.

Negotiations are nearing completion with the University of Michigan for the loan of its 24-inch Curtis Schmidt telescope for a period of five years. The loan has been approved by AURA and by the University of Michigan. Pending funding by the National Science Foundation, the telescope will be transferred to Chile during the coming year. The staff of the University of Michigan will use a certain fraction of the telescope.
time; remaining time will be available for visiting investigators and the CTIO staff.

Observing Programs. Observations for the UBV-standards program were continued throughout the 1963–64 year, and it neared completion at the end of the year. Four computers worked on the reductions at the Chilean National Observatory on Cerro Calán in Santiago. New methods of determining and eliminating the atmospheric extinction were developed and applied to the material.

Observations for a new UBV-standard sequence were completed in the 1964–65 year, and the reductions were nearing completion at the end of the year.

European Southern Observatory. In June, 1963 representatives of the European Southern observatory (ESO) met with AURA representatives on the AURA property in Chile and discussed the possibility of establishing the proposed ESO observatory on AURA's land. At that time the ESO representatives were primarily interested in Cerro Morado (elevation 7100 feet), located within the AURA "estancia" called El Totoral. Studies of conditions at several sites on AURA land as well as some outside of it were planned by ESO. Meanwhile, ESO maintained its interest in possible South African sites.

In March 1964 the ESO council decided to establish its future observatory in Chile and ESO test equipment was erected on Cerro Tololo for comparison purposes. The equipment consisted of a 24-m tower with thermal sensors for measurement of microthermal fluctuations at several levels above ground, and a double-beam telescope on loan from AURA.

Results obtained in May and June 1964 indicated that during the test period conditions on Cerro Tololo were superior to any of the South African sites studied by ESO. Determining to continue operation of its thermal sensor tower on Cerro Tololo, ESO began concentrating its efforts on investigation of a new site about 100 km north of Tololo. During the 1964–65 year the ESO group selected this site, the mountain La Silla, for its observatory.

Carnegie Southern Observatory. Horace W. Babcock, associate director of Mount Wilson and Palomar observatories and in charge of the Carnegie Southern Observatory (CARSO), visited Chile in November and December 1963 and again in February 1964 to initiate a site survey for the proposed southern observatory. Initially, CARSO restricted its Chilean site survey to areas located on AURA land.

The first site studied by CARSO was Cerro Pachón (elevation 8900 ft) at the southern border of AURA's land. Meanwhile, CARSO seeing-test equipment was operated on Cerro Tololo for comparative purposes. Meteorological equipment was erected on Cerro Pachón and maintained jointly by CARSO and AURA.

Wind records indicated considerably higher wind velocities on Cerro Pachón than at Cerro Tololo. During a storm in June 1964 the entire 12-m steel mast bearing the Cerro Pachón equipment was blown away. In the same month John B. Irwin took charge of CARSO operations in Chile and soon thereafter initiated investigations on Cerro Morado. Members of the CTIO work crew began construction of a road to this site in September 1964.

CTIO Scale Model. A scale model of Cerro Tololo was exhibited at the Smithsonian Institution in Washington, D. C. during October 1964 in connection with the Chilean and U. S. Scientist Exchange Program sponsored by the National Academy of Sciences and the Embassy of Chile. The model has since been on display in the lobby of the Kitt Peak National Observatory, Tucson Headquarters.

Yale-Columbia Southern Astrograph Station Visit. During a trip to Chile in November and December 1964, a group of AURA board members, a National Science Foundation representative and Kitt Peak National Observatory staff members visited the Yale–Columbia Southern Astrograph Station at El Leoncito, Argentina. The group was welcomed by the station staff, spent a night there, and returned to Chile over the Andes the next day.

Visiting Observers and Graduate Students

AURA's established policy provides approximately 60% of the Observatory's total instrument time for the use of visiting observers. In line with this policy, the major effort of the Stellar Division is devoted to development of research facilities for visiting observers. In addition to the development of telescopes, this includes design and preparation of auxiliary equipment and measuring apparatus, and instruction and assistance in their utilization. The Stellar Division makes available the services of three full-time assistants to aid visiting observers in effective utilization of telescopes and auxiliary equipment.

Since virtually all of the research conducted by visiting astronomers and graduate students is published in the astronomical literature by the respective investigators, only brief identifying references to their scheduled work with Observatory facilities are indicated below.

Stellar Division

1963–64 Year 16- and 36-in. Telescopes:
D. P. Cruikshank and A. B. Binder, University of Arizona, 14 nights, 16 and 36-in. telescopes, observations of Galilean satellites of Jupiter.
Thomas Kelsall, NASA, 16 nights, 16-in. telescope observations of Cepheids.
R. H. Koch, Amherst College, 4 nights, 36-in. telescope, photoelectric observation of the short-period eclipsing binary BH Vir.
A. U. Landolt, Louisiana State University, 16 nights, 16 and 36-in. Telescopes, UBV sequences in two regions of Taurus.
B. T. Lynds, University of Arizona, 1 night, 36-in. telescope, to obtain spectrum of M17.
D. J. McConnell, Warner and Swasey Observatory, 7 nights, 36-in. telescope, to establish a UBV sequence in the region of Cepheus IV.

A. E. Merchant, University of California, Berkeley, 5 nights, 36-in. telescope, spectra of emission regions in M51.

G. S. Mumford, Tufts University, 17 nights, 16 and 36-in. telescopes, additional three-color photoelectric observations of various cataclysmic variables.

M. W. Ovenden, University of Glasgow, Scotland, 25 nights, 16-in. telescope, observations critical with respect to a model of the spectroscopic binary 57 Cyg.

Tobias Owen, IIT Research Institute, 6 nights, 36-in. telescope, planetary spectra and a spectrogram of X Cygni.

V. C. Rubin, Georgetown College Observatory, 13 nights, 36-in. telescope, radial velocities of 28 O6 to B3 stars.

Hyron Spinrad, University of California, Berkeley, and R. L. Newburn, Jet Propulsion Laboratory, 11 nights, 36-in. telescope, spectra for study of excited lines of the 2-0-1 rotation-vibration band of water vapor in about a dozen M-type giants.

Conrad Sturch, Lick Observatory, 20 nights, 36-in. telescope, UBV observations of about 40 RR Lyrae stars.

A. H. Vaughan, Jr., University of Rochester, 17 nights, 16 and 36-in. telescopes, interferometer study of He I emission line in the Orion nebula.

P. A. Wehinger, Warner and Swasey Observatory, 19 nights, 16 and 36-in. telescopes, photoelectric observations of four galactic fields.

H. J. Wood, Indiana University, 32 nights, 16-in. telescope, study of Balmer lines in the spectra of several peculiar A-type stars.

1964–65 Year—84-in. Telescope:

A. and C. Cowley, Yerkes Observatory, 8 nights, abundances of elements in carbon-rich giants and spectroscopic investigations of binary systems with extended envelopes.

James Cuffey, Indiana University, 5 nights, cluster photographic photometry.

A. M. Gehrels, University of Arizona, 5 nights, Trojan light curves.

Graham Hill, University of Texas, 1 night, search for β Cephei stars.

John Irwin, Carnegie Southern Observatory, 1 night, UBV integrated colors of globular clusters.

H. M. Johnson, Lockheed Missiles & Space Corporation, 2 nights optical identification of x-ray sources.

G. P. Kuiper, University of Arizona, 16 nights, Mars infrared spectrometry.

A. U. Landolt, Louisiana State University, 16 nights, additional UBV sequences in Scorpio-Ophiuchus.

F. J. Low, University of Arizona, 3 nights, 7.5 14 μ infrared spectrometry and Ne* emission.

E. E. Mendoza V., Universidad Nacional de Mexico, 5 nights, spectroscopy of M-type subgiant stars.

G. S. Mumford, Tufts University, 2 nights, Hβ observations of EX Hydrae and EM Cygni.

Tobias Owen, IIT Research Institute, 6 nights, infrared spectra of Mars and selected red stars.

Peter Pesch, Warner and Swasey Observatory, 7 nights, radial velocity study of blue stars above the turnover point of M67.

K. D. Rakos, University Observatory, Graz, Austria, 2 nights, photoelectric photometry of Phobos eclipses.

T. P. Roark, Rensselaer Polytechnic Institute, 5 nights, photometric study of reflection nebulae.

Hyron Spinrad and R. L. Newburn, University of California, Berkeley, 8 nights, near-infrared spectroscopy of cool stars.

G. Van Biesbroeck, University of Arizona, 25 nights, visual micrometer measurements of double stars.

P. A. Wehinger, Case Institute of Technology, 6 nights, UBV photoelectric photometry of the Plaut fields.

F. R. West, 2 nights, high-dispersion spectroscopic study of the visual binary ADS 10598.

K. M. Yoss, Mount Holyoke College, 2 nights, calibration of spectroscopic luminosity criteria.

1964–65 Year—36-in. Telescope:

D. P. Cruikshank and A. B. Binder, University of Arizona, 11 1/2 nights, infrared spectrophotometry of Mars.

K. Bracher, Indiana University, 14 nights, investigation of some Wolf-Rayet spectroscopic binaries.

C. C. Dahn, Case Institute of Technology, 9 nights, photometric studies of reflection nebulae.

U. Haug, University of Tübingen, Germany, 9 nights, photometry of stars from the Catalogue of Luminous Stars in the Northern Milky Way.

R. C. Henry, Princeton University Observatory, 29 nights, measuring strength of K line in A0 stars, and four-color photometry.

Graham Hill, University of Texas, 5 nights, search for β Cephei stars.

A. R. Hogg, Mount Stromlo Observatory, Australia, 7 nights, light curve of CW Cassiopeae.

John Irwin, Carnegie Southern Observatory, 5 nights, UBV integrated colors of globular clusters.

G. P. Kuiper, University of Arizona, 2 nights, Mars infrared spectrometry.

A. U. Landolt, Louisiana State University, 16 nights, additional UBV observations of the eclipsing binary V382 Cygni.

A. P. Linnell, Amherst College, 13 nights, photometry of eclipsing binaries.

B. T. Lynds, University of Arizona, 6 nights, monitoring Crab Nebula.

E. E. Mendoza V., Universidad Nacional de Mexico, 5 nights, spectroscopy of M-type subgiant stars.
G. S. Mumford, Tufts University, 17 nights, Hβ observations of EX Hydræa and EM Cygni.
Tobias Owen, IIT Research Institute, 2 nights, infrared spectra of Mars, and selected red stars.
A. G. D. Philip, University of New Mexico, 2 nights, investigation of a bluing effect found in the $B-V$ colors of distant A stars.
T. P. Roark, Rensselaer Polytechnic Institute, 5 nights, photometric study of reflection nebulae.
V. C. Rubin, Georgetown College Observatory, 12 nights, radial velocities and spectral types of early-type stars in NGC 2167.
Susan Simkin, University of Wisconsin, 31 nights, $UBV$ and far-red luminosity distributions in nearby Sb galaxies.
P. A. Wehinger, Case Institute of Technology, 5 nights, $UBV$ photoelectric photometry of the Plaut fields.
B. E. Westerlund, Mount Stromlo Observatory, Australia, 8 nights, multicolor photometry and spectroscopy of northern Wolf-Rayet stars.
H. J. Wood, University of Virginia, 8 nights Hα photometry of HD 215441.

1964–65 Year—16-in. Telescope:

M. F. A'Hearn, University of Wisconsin, 47 nights, Venus polarization measurements.
C. C. Dahn, Case Institute of Technology, 3 nights, photometric studies of reflection nebulae.
U. Haug, University of Tübingen, Germany, 89 nights, photometry of stars from the Catalogue of Luminous Stars in the Northern Milky Way.
R. C. Henry, Princeton University Observatory, 3 nights, measuring strength of $K$ line in A0 stars and four-color photometry.
Graham Hill, University of Texas, 86 nights, a search for $β$ Cephei stars.
Thomas Kelsall, NASA, 32 nights, intermediate-band photoelectric photometry of Cepheid and RR Lyrae type variables.
A. U. Landolt, Louisiana State University, 7 nights, additional observations of the eclipsing binary V382 Cygni.
B. T. Lynds, University of Arizona, 5 nights, monitoring Crab Nebula.
G. S. Mumford, Tufts University, 1 night, Hβ observations of EX Hydræa and EM Cygni.
M. W. Ovendon, University of Glasgow, Scotland, 1 night, photometric observations of 57 Cygni.
A. G. D. Philip, University of New Mexico, 9 nights, investigation of a bluing effect found in the $B-V$ colors of distant A stars.
T. Schmidt-Kaler, University of Bonn, Germany, and U. Haug, University of Tübingen, Germany, 5 nights, luminous stars in Monoceros.
P. A. Wehinger, Case Institute of Technology, 1 night, $UBV$ photoelectric photometry of the Plaut fields.

Solar Division

1963–64 Year—McMath Solar Telescope:

D. C. Schmalberger, University of Rochester, determined by photoelectric scans of blended and unblended Fraunhofer lines the depth dependence of the physical properties of the solar atmosphere.
G. W. Withbroe, University of Michigan, photographic and photoelectric program on the spectrum of the CH molecule in the solar atmosphere.
V. Bumba, Ondrejov Observatory, Czechoslovak Academy of Sciences, obtaining a series of plates for investigation of radial motions in small sunspots and photospheric faculae.
T. Owen, Lunar and Planetary Laboratory, University of Arizona, high-dispersion spectra of Jupiter.
W. L. Wilcock, Imperial College, London, consulting on image tube program.

1964–65 Year—McMath Solar Telescope:

Richard Canfield, University of Colorado, investigation of center-to-limb variation of the profiles of 3o to 40 lines of Ce ii in spectral region 4000—4700 Å.
Mark Daehler, University of Wisconsin, spectrometer observations of solar spectrum in the region of the lithium line 6708 Å.
L. Delbouille and G. Roland, Institute d' Astrophysique, Liège, Belgium, use of a newly developed stabilized laser for study of the instrumental profile of the vacuum spectrograph.
E. Frazier, University of California, study of velocity fields in granulation using lines whose "contribution functions" indicate formation at widely differing elevations in the solar atmosphere.
Lewis Hobbs, University of Wisconsin, attempted use of high-resolution spectrometer for study of fine details in the spectrum of Deneb and Venus.
John Kirk, University of Michigan, study of the spatial power spectra of the local Doppler shifts.
G. F. W. Mulders, National Science Foundation, and C. D. Slaughter, Kitt Peak National Observatory, investigations leading to the conclusion that the temperature of the sun's equatorial limb is identical with that of the polar limb to within the accuracy of the measurements (0.2%).
Gerald Newsom, Harvard College Observatory, search for new autoionization lines other than those of Ca at 6300 Å.
T. Owen and J. Marshall, University of Arizona, spectra of Saturn and Jupiter, and low sun records of the CO$_2$ band 1.02 μ.
Hyron Spinrad, University of California, obtained a series of plates of telluric lines.

S. E. Strom, Harvard University, and David Latham, Smithsonian Astrophysical Observatory, used the solar telescope in an exploratory manner to investigate the possibility of obtaining high dispersion, high resolution spectra of early-type stars.


R. A. Williams, the Ohio State University, experiments with a submillimeter (50 μ to 1000 μ) Michelson interferometer at the east auxiliary beam of the solar telescope.

**STAFF**

**Kitt Peak National Observatory.** The observatory had 217 full-time employees on the payroll as of 30 June 1965. By divisions and departments, these were divided as follows:

Administrative Division 31, Telescope Development Group 2; Operations Department 55, of which 41 work on, or are based at, Kitt Peak; Engineering Department 26; Instrument Shop 16; Optical Shop 8; Electronics Research Laboratory 14; Photographic Laboratory 3; Stellar Division 14; Solar Division 11; Space Division 37.

In addition, there were 58 part-time employees, some of whom are graduate students at the University of Arizona and elsewhere. These part-time employees included 10 regular research assistants, 14 student assistants in the Summer Research Assistant Program, and 20 part-time employees, mainly Papago Indians, on Kitt Peak.

**Cerro Tololo Inter-American Observatory.** CTIO had seven full-time employees on the U. S. payroll as of 30 June 1965. Of these, two are stationed in Tucson and five are located at the La Serena headquaters.

**Changes in Scientific Staff.** In the biennium under review the following scientific appointments were made:

Solar Division: James W. Brault, 16 August 1964.
Space Division: Michael J. S. Belton, 8 July 1964; Stephen P. Maran, 27 July 1964; Michael B. McElroy, 7 October 1963.


**BIBLIOGRAPHY**

Broadfoot, A. L., see also Brandt, J. C.


Hunten, D. M. See also Broadfoot, A. L.

Hunten, D. M. See also Chamberlain, J. W.


Lynds, C. R. See also Livingston, W. C.


McElroy, M. B. See also Brandt, J. C.


Miehe, R. W. See also Brandt, J. C.


Nicholas U. Mavall, Observatory Director