imeter. Both types of pulses have characteristically narrow bandwidths. The nature and origin of the fast pulses remains one of the most obscure points in the study of Jupiter.

The Jupiter activity prediction program has been rewritten by Merritt to reduce computer running time and to present the results diagrammatically. It is noted that predictions occur periodically and drift in time across the diagram. The duration of the prediction varies in length in a periodic manner.

In 1958 and 1959 the only stations observing Jupiter (University of Florida and Yale University) reported very little activity. Running the prediction program in retrospect for these years shows that many of the relevant predictions were of short duration, often only a few minutes, and that the drifts were such as to avoid the observation periods used at these stations on many occasions. Clearly, this is a point that needs to be taken into consideration when assessing, for example, the lack of activity in solar correlation studies.

Editing of records for microfilming for the NASA Space Data Center has continued. A second catalogue of Jupiter activity for the apparitions of 1965–66 and 1966–67 has been prepared and circulated. Observation times and periods of activity are listed by frequency. Histograms of 18 Mc/sec occurrence probability and Io effects are included.

An experiment has been initiated to try to detect decimeter-wave radiation from Saturn using the following instrumentation: (1) Arecibo reflector using two two-element Yagis at 16 and 18 Mc/sec crossed on a common boom mounted on Carriage-House 2. (2) Florida State University 18 Mc/sec phase-switched interferometer, enlarged to 10 whole-wave dipoles in each array. (3) 26 Mc/sec swept-frequency antenna array built at Clark Lake by Rech.

As Saturn moves to a northerly declination a search for decimeter-radiation is an obvious investigation to make. If such radiation exists, however, it must be weaker than the corresponding Jupiter emission by more than the inverse-square law factor otherwise it would already have been detected with existing Jupiter equipment. The observations at Arecibo are being conducted by Barrow in collaboration with Dr. S. Gulkis (Arecibo-Cornell University).

An interesting aspect of this experiment is that it may help indirectly to clarify the Jupiter radiation mechanisms. No matter whether the result is positive or negative a comparison of the known physical properties of Jupiter and Saturn should allow some to be eliminated or retained as possible contributors to the Jupiter radiation process in the light of the eventual Saturn result.

Capone has modified and extended the Kuiper model of the Jovian atmosphere to include the upper atmosphere and ionosphere. The top of the stratosphere has been found to be about 100 km above the tropopause and a first ionospheric layer of electron density about 10^6 cm^-3 is found to occur at about 40 km above the mesopause. Further layers due to H₂ and H will occur above this. The predicted electron densities from solar flux considerations are to be compared with estimates from radio observations. The limit of the exosphere can also be found.

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PUBLICATIONS


COLIN H. BARROW, Director

Kitt Peak National Observatory, Tucson, Arizona and Cerro Tololo Inter-American Observatory, La Serena, Chile

Some highlights of the two observatories’ activities during this report interval (1 July 1966–30 June 1967) are as follows:

Kitt Peak. Use of a computer for control and data acquisition at the McMath telescope has made possible the rapid production of high-resolution solar magnetograms. Dr. W. C. Livingston now has in operation a two-channel magnetograph that permits simultaneous recording of the magnetic vector, the velocity, and the brightness of each of two Fraunhofer lines with a spatial resolution from 1 to 10 sec of arc as desired. A large spectroheliograph designed jointly by Dr. A. K. Pierce and by Dr. R. B. Leighton, California Institute of Technology, Pasadena, has been put into operation by Dr. N. R. Sheeley. It is being used for high-resolution studies of magnetic and velocity fields.

Image-tube spectrograms of Cyg XR-2 obtained by Dr. C. R. Lynds revealed spectroscopic similiar-
ties to Sco XR-1 and to old novae, thus supporting the optical identifications of these x-ray sources. The image-tube spectrograph continues to be an effective instrument for the study of faint sources. Spectrograms of objects as faint as 19.7 mag have been obtained at dispersions of 125 Å/mm and resolutions of 10 Å with the 84-in. telescope.

Rocket Flight Program: Two of three Aerobee flight experiments launched at White Sands, New Mexico, during the report year were successful. Aerobee KP 3.21, flown in June 1967, carried a pair of objective grating instruments for Dr. Donald Morton, Princeton University, Princeton, New Jersey, for spectroscopy of Venus and Jupiter. Spectrograms of both planets were obtained in the ranges 1200–2000 Å and 2000–3000 Å with spectral resolutions of the order of 1 Å.

Cerro Tololo. The 36-in. reflector and the 24/36-in. Curtis Schmidt telescope, on loan from the University of Michigan, Ann Arbor, were put into operation, thereby supplementing the two 16-in. reflectors that have been in use for several years. The 36-in. was initially used for polarimetric and photometric studies of Sco XR-1, under the direction of Dr. W. A. Hiltner. Objective prism surveys were initiated with the Curtis Schmidt; they included a southern extension of the Case Institute's OB star survey by Dr. N. Sanduleak, and a more general survey being directed by Dr. W. P. Bidelman at Ann Arbor.

On 13 April 1967, at Punta del Este, Uruguay, the Presidents of Chile and of the United States announced that a 150-in. telescope would be built at the Cerro Tololo Inter-American Observatory, near La Serena, Chile, by joint funding between the National Science Foundation and The Ford Foundation. On 19 April 1967, Dr. Rupert Wildt, President of AURA, was informed that The Ford Foundation had approved a grant of $5 million as its share toward the construction of this telescope, which will be built as nearly as possible concurrently with the similar one for Kitt Peak, where the construction site is ready.

Plans and specifications are being completed for the mechanical mountings for both these 150-in. telescopes, and a pre-bid conference for the Kitt Peak building and rotating dome was held on 8 June 1967. Another bidders' conference is set for 10 August 1967, and a general contractor for the building and two rotating domes will be chosen after the bids are opened on 13 September 1967. Bids for the two mountings will be requested on 18 September 1967, with opening scheduled for 18 October 1967. Depending on the relationship between bids and budgets, commitments on all major elements of the two 150-in. telescope projects are expected to be made before 1 January 1968.

Further details for these and other programs of resident staff and visitors are given below, separately for the two observatories.

KITT PEAK NATIONAL OBSERVATORY

Congressional Visitors. Led by Congressman George P. Miller, Chairman, the House of Representatives Committee on Science and Astronautics visited the Observatory's Tucson Headquarters and Kitt Peak telescope installations on 24 and 25 February 1967. The five Committee members were accompanied by Arizona's Second District Congressman, Morris K. Udall; Director Leland Haworth and staff members of the National Science Foundation; Chairman Philip Handler and members of the National Science Board; and Congressional staff and Air Force liaison personnel.

Public Visitors. A new record of 6728 persons for the number of public visitors in a single month was set in March 1967. In the 12-month report period, 52,080 persons came to the Observatory grounds, and of those, 13,904 took advantage of the group tours conducted by the Observatory's visitors guide, AF Brig. Gen. (ret.) Jay C. Evans.

Stellar Division

Astronomers-in-Residence. Dr. A. D. Code, Washburn Observatory, University of Wisconsin, Madison, came to Tucson in September 1966, for a year's sabbatical leave at the Observatory. During three observing runs with the 84-in. telescope, he obtained a number of image-tube spectrograms of barred spiral galaxies. Some of this work was reported at the University of Arizona "Symposium on Spiral Structure", March 1967, and at the June Meeting of the American Astronomical Society. In addition, he made a number of spectrophotometric measures with a University of Wisconsin scanner of galaxies, quasi-stellar objects, x-ray sources, and stars. He has collaborated with Dr. Robert H. Hardie, Dyer Observatory, Nashville, Tennessee, in observing stars in the VI Cygni association with the image tube for spectral classification. Dr. Code's investigations included: "Radiative Transfer in a Spherical Compton Scattering Atmosphere," Astrophys. J., August 1967, KPNO Contrib. No. 229; a paper on the Coefficient of Dynamical Friction; a study of large optical telescope arrays as compared to a single large telescope; and studies of three problems in collaboration with Dr. Michael B. McElroy on intensities of the helium triplets in planetary nebulae, the Eddy diffusion coefficient in the earth's atmosphere, and models of x-ray sources.

Dr. Kunihiko Misawa, Assistant Professor, Kagawa University, Takamatsu, Japan, also arrived in Tucson in September 1966, for 10 months' work at the Observatory. Dr. Misawa carried out
photometric studies of a number of eclipsing binaries and peculiar A stars.

Instrumentation—150-inch Telescope. This project has continued to absorb the time and talent of a major part of the staff as well as that of numerous consultants and contractors. This effort is organized on a project basis: Dr. D. L. Crawford is the project manager, and the project staff is headed by W. W. Baustian, chief engineer, who reports directly to the Observatory Director.

Progress on the design of the 150-in. telescope, building, and rotating dome has been rapid during the past year. On 8 May 1967, the 150-in. telescope advisory committee met in Tucson to review the design of the Kitt Peak telescope, and to discuss the one proposed for Cerro Tololo. In order to facilitate construction and to save time and money, bids are being requested for simultaneous construction by the same contractor of both mountings and both rotating domes. The design of the 150-in. telescope mountings has been completed by W. Lydster and associates, San Jose, California. This design has been evaluated by the advisory committee, and in greater detail by Mr. Bruce Rule, California Institute of Technology, a member of the committee, who made a more extensive review of the design on a consulting basis. The construction of the Cerro Tololo building, and assembly of the rotating dome, will be undertaken by AURA in Chile. Mr. S. R. Hurdle, who has served as mountain superintendent on Kitt Peak, will be construction superintendent on Tololo for this project.

The General Electric Company's fused quartz mirror blank for the Kitt Peak telescope is being rough ground at their plant in Cleveland, Ohio, to the approximate final shape. Following extensive strain tests and bubble count evaluation, it will be inspected for acceptance and, if satisfactory, is to be delivered in the fall of 1967. The grinding machine constructed by the L & F Machine Co., Huntington Park, California, has been installed in the Observatory's optical shop. It will first be used for figuring a 100-in.-diameter cast aluminum mirror, required for the Hindle sphere test of the convex secondary mirrors.

A number of other groups are involved in constructing telescopes in the 150-in.-diameter size range. Close communication has been maintained with the European Southern Observatory, Canadian, French, and British-Australian groups.

Dr. C. G. Wynne, Imperial College, University of London, is acting as an optical design consultant on a number of problems in connection with field corrector lenses for the 150-in. telescope. This work forms part of the basis of a paper, "Ritchey Chretién Telescopes in Extended Field Systems," which has been prepared for publication.

84-inch Telescope. The optical parts for the No. 1 (shortest focus) coudé spectrograph camera have been completed. Following installation of this camera, a total of 4 cameras will be available, and they can be used for a spectrography at dispersions of 2.2, 8.9, 13.5, and 24.3 Å/mm in the second-order blue-violet when used with the 600 line/mm grating. The Observatory has acquired a second 8×10 in grating having 1200 lines/mm, for work at higher dispersion. The design of a three-mirror image rotator has been completed, and this accessory for compensation of diurnal field rotation at the slit plate is under construction.

The development of a coudé spectrograph photo-electric exposure meter was completed by Neil Sullivan of the Observatory's electronics research laboratory. This instrument has been in service during most of the report year, and its use has led to increasingly efficient use of the coudé spectrograph. A small pivoting mirror immediately behind the entrance slit of the spectrograph diverts all the light to a photomultiplier at frequent intervals, but only for a small fraction of the time. Pulse-counting techniques are used to eliminate the effect of photomultiplier dark pulses and to control the total exposure. Upon the completion of the declination torque motor drive system, the exposure meter will be used to control the trail rate of the star image on the slit.

A dust control system has been installed in the coudé room. Nucleonic Industries, a Tucson company, has installed a number of dust control elements in the vicinity of the optical components. The dust is ionized by radiation and collected through a potential gradient. It is anticipated that this apparatus will improve the long-term efficiency of the mirror optics.

An f/0.6 camera for the Cassegrain spectrograph is under construction. The thick hemispherical quartz mirror and compound field flattener of this semi-solid Schmidt camera have been completed, and the corrector plate is being figured. The tolerances for this camera are extremely stringent so that the optical performance sought is difficult to achieve. The Cassegrain spectrograph body is also being used for the image-tube work that is done with the 84-in. telescope. In this application the present f/1.2 flat-field Schmidt camera is removed and replaced by an optical bench assembly. The EEV transmission-secondary-emission type tube is currently used in conjunction with an f/1.6 semi-solid Cassegrain Schmidt camera for work on photon-limited problems. This camera, designed by Dr. C. R. Lynds and Mr. Gary L. Villere, is fabricated entirely of quartz components, which permit spectrographic work to the atmospheric cutoff limit at approximately λ 3100 Å.
A special image-tube spectrograph is under construction following a design supervised by Lynds. This spectrograph will contain a step-driven offset mechanism, a photoelectric guider, a photometer, and a plate holder assembly for securing offset plates. Some new image-tube systems are also being evaluated. Dr. J. D. McGee, Imperial College, London, spent the month of March 1967, at the Observatory as a consultant in image-tube technology. He left on loan a number of image tubes at the Observatory, and an associate of his, Dr. J. R. Powell, has been appointed for one year to help in evaluating these systems.

A number of revisions to the 84-in. telescope, building, and dome are planned during August 1967. The declination drive is to be replaced by a torque motor drive similar to the one used on the right ascension drive for over a year. A system for ventilating the tube and primary mirror is being installed, and the interior wall panels of the dome are being insulated. An isolated electronics room is being constructed on the west side of the observing floor; it will contain the drive controls and an automatic data acquisition system, for recording photometric data, that is nearing completion.

36-inch Telescopes. The No. 2 36-in. telescope was put into service in February 1967. The mounting, constructed by the Boller and Chivens Company, South Pasadena, California, is, like the previous 36-in.-telescope mounting, of the asymmetric type and incorporates several new features. The drive worms are pressure loaded against the worm wheels to eliminate backlash, and a balance indicating device is provided. A strain gauge is magnetically attached to the worm wheel, and then the worm is partially released to allow some motion of the telescope. The static moment of the telescope is then indicated on a console meter. A new type of encoder has been provided on both telescope axles for controlling a digital display of telescope position. The precision of this display is such that stars can be set in a 20 sec of arc photometer aperture without reference to auxiliary optical systems. The telescope tube contains a flip-top secondary mirror arrangement for rapid change from an f/13.5 Cassegrain focal position to a coude focal position, but the coude optics have not yet been completed. Instrumentation for the Cassegrain focus presently includes a single or 2-channel photometer that can be used with a simple adaptor or offset guider. A prototype 4-channel spectrophotometer is also used with this instrument. An automatic data acquisition system has been provided for use with the photometers.

Plans for developing the coude system for this telescope are in progress. The primary mirror of the No. 2 36-in. telescope is made from an aluminum casting. This mirror has so far performed quite well, and long-term evaluation of its performance is under way. A dust control system was installed in the tube by Nucleonic Industries. Initial tests of this system over a six-month period, in comparison with the No. 1 36-in. telescope, have demonstrated that this dust control system is quite effective.

A new tube was installed on the No. 1 36-inch telescope in September 1966. The new tube has a flip-top with two secondaries: one for an f/13.5 Cassegrain arrangement, and the other for an f/7.5 Ritchey Chretien arrangement. This versatility will permit the telescope to be used as a wide-field photographic instrument, and as a test telescope for instruments that will later be used on the 84- and 150-in. telescopes.

A new offset guider for use with photoelectric photometers has been provided. The photometer and spectrograph for this telescope are used with the f/13.5 focal arrangement. A double-slide camera has been completed for use with the f/7.5 Ritchey Chretien system. A photoelectric guiding device based on an image dissector tube has been completed by Warren Ball, of the Observatory's electronics research laboratory. Initial tests have demonstrated that this guiding control system is remarkably effective. The camera has been designed so that it can also be used on the 84-in. telescope.

The automatic data acquisition system that is used with the No. 1 36-in. telescope includes a punched paper tape readout of up to 4 channels of photometric information, together with star identification, telescope position, and other data that define the observations. The photomultiplier outputs can be read by integrators and a digital voltmeter, or by pulse counting equipment. A prototype pulse counting exposure meter is in use with the Cassegrain spectrograph.

16-inch Telescope. The drive systems of both 16-in. telescopes have been overhauled to provide for better tracking accuracy and more positive pre-loading. These instruments have been used entirely for photometric work. The No. 3 f/7.5 16-in. reflector is used with programmed integrator amplifiers and a strip chart recorder, while the No. 4 f/18 16-in. telescope is used with an automatic data acquisition system similar to that used with the 36-in. telescopes.

Telescope Usage and Weather

The 84-in. telescope was used for 2596 hours (75%) on 297 nights, and for 15 hours on 3 days, with visiting astronomers and graduate students scheduled for 187 nights. The telescope was in service on all but 4 nights of the report year.

During the same period, the No. 1 36-in. telescope was used for 1818 hours on 239 nights for 53% of
the nighttime hours. Visiting astronomers and graduate students were scheduled for 150 nights.

The No. 2 36-in. was put into operation in February 1967. During the interval March through June, the telescope was used for 364 hours on 61 nights (35%). Visiting astronomers and graduate students were scheduled for 61 nights.

The two 16-in. telescopes were scheduled for 247 nights and 1 day for photometric work by visitors.

A brief summary of weather conditions on Kitt peak is the following: rainfall 21.51 inches in 46 days, highest temperature 89°F, lowest temperature 14°F. More extensive statistics of telescope use and the weather have been compiled for previous years, and they are available upon request from the office of the divisional associate director, Dr. A. A. Hoag.

Visitor Research

Forty-eight visiting astronomers, 31 graduate students, and 3 technical assistants used the stellar telescopes during the year. Of these, 16 and 6, respectively, were from 17 institutions in the East; 10, 9, and 1, respectively, from 8 institutions in the Midwest; 8, 6, and 2, respectively, from 6 institutions in the South; and 9 and 9, respectively, from 7 institutions in the West. In addition, foreign visitors who used the telescopes included one each from Belgium, Canada, Germany, Japan, Mexico, and The Netherlands. In the following listings of visitors and their programs, the figures in parentheses are the hours of actual observing time logged by visitors; the number of nights refers to scheduled time.

84-inch Telescope Programs. Claude Arpigny, Liege, Belgium, 4 nights (35.5 hours): coude spectroscopy of two metal-deficient weak-lined stars, 85 Peg and HD 19445.

Roberto Barbon, California Institute of Technology, 8 nights (42.5 hours): Cassegrain spectrography of compact galaxies and parent galaxies of supernovae at a dispersion of 200 Å/mm. The latter material is being used to provide velocities for increasing the material available for a determination of the Hubble constant, by making use of the absolute magnitudes of the supernovae.

Sidney van den Bergh, David Dunlap Observatory, Toronto, Canada, 5 nights (37.5 hours): UBV plates of the area surrounding the globular cluster NGC 6522. These plates will be reduced in collaboration with A. Terzian to study the stellar population of the nuclear bulge of the galaxy. Multicolor plates were also obtained of the galaxy M101, and of the diffuse nebulae M8 and M20.

G. van Biesbroeck, University of Arizona, Tucson, 7 nights (38.5 hours): 167 micrometric measures of close binary stars were made during 5 nights. Most of the measures were made of pairs in critical parts of their orbits, at separations too close to be measured with instruments of smaller aperture.

Bart J. Bok, University of Arizona, Tucson, 6 nights (63 hours): photometric studies of faint intrinsically blue stars in fields of Cepheus and Monoceros. Photoelectric sequences have been established and measurement of photographs of these fields is in progress.

Guisa Cayrel, Institute for Advanced Study, Princeton, 4 nights (4.5 hours): high dispersion coude spectrographic investigation of F-type stars selected on the basis of Strömgren u to loose photometry, for study of the metal-index to metal-content relationship.

Frederick H. Chaffee, Jr., University of Arizona, Tucson, 3 full nights and half of 1 night (40.5 hours): coude spectrography of A2 to G0 mainsequence stars for the purpose of studying the behavior of microturbulence.

Arthur D. Code, Washburn Observatory, University of Wisconsin, 12 nights (114.5 hours): spectrophotometry of nebulae and galaxies with the Cassegrain spectrograph, a Carnegie image tube and the University of Wisconsin rapid-scan integrating spectrophotometer. Objects of special interest included the Orion nebula and a number of barred spirals.

Arthur D. Code, and Robert Hardie of the Dyer Observatory, Vanderbilt University, Nashville, 4 nights (32.5 hours): image tube spectrography of galaxies and highly reddened early-type stars in the Cygnus VI association, with a Carnegie image tube and the Kitt Peak Cassegrain spectrograph. Recent photometric studies of the Cygnus VI association completed at the Dyer Observatory, together with the MK types derived as a result of the image-tube spectrography, will provide a basis for an evaluation of the ratio of total to selective absorption in this region.

Allan F. Cook and Fred A. Franklin, Harvard College Observatory, Cambridge, halves of 3 nights (13 hours): spectrophotographie study of the Saturn ring system by observations of the satellites Dione and Rhea when behind the edge-on ring. Spectrograms of these satellites and of Tethys when clear of the ring system were used for comparison.

Mart deGroot, University Observatory, Utrecht, The Netherlands, 6 nights (62.5 hours): coude spectrograms of early-type stars in three open clusters were obtained for measures of radial velocity and H{beta} line profiles. The latter measures will be used to provide additional information concerning absolute magnitudes of O stars.

David L. DuPuy, VanVleck Observatory, Middletown, Connecticut, 5 nights (53.7 hours): Casse-
grain spectroscopy of a number of Haro blue galaxies and standard stars at a dispersion of 200 Å/mm.

W. Kent Ford and Vera Rubin, Department of Terrestrial Magnetism, Carnegie Institution of Washington, 5 nights (38$\frac{1}{2}$ hours): image-tube spectrography with the DTM spectrograph of a variety of faint objects including quasi-stellar sources, galaxies and novae. Some of their previous work at Kitt Peak is reported in “Quasi-Stellar Objects with Small Redshifts,” Astrophys. J. 145, 357, 1966, KPNO Contrib. No. 166.

Lawrence W. Frederick and Paul Knappenberger, Leander-McCormick Observatory, University of Virginia, 3 full nights and half of 1 night (27$\frac{1}{2}$ hours): image-tube spectrography in the 1$\mu$m region with a Carnegie image tube and a special camera attached to the Cassegrain spectrograph. They observed phase effects in the 10 830 Å line of He and β Lyra, and also found that red dwarfs of types M0V to M8V appear featureless in the 1.0 to 1.1 $\mu$m region.

Rebecca C. P. Gordon, University of Michigan, 2 full nights and halves of 6 nights (52$\frac{1}{2}$ hours): Cassegrain spectrography in the red and blue spectral regions of a number of carbon stars at approximately 100 Å/mm. These spectrograms, combined with other material already available, form the basis of a paper in preparation for publication.

Arnold Heiser, A. J. Dyer Observatory, Vanderbilt University, Nashville, Tennessee, 12 nights (99$\frac{1}{2}$ hours): photoelectric measures for the establishment of faint UBV sequences in the fields of the open clusters NGC 2244, 6910, 6913, 7063, and 7380. A photometric study of the RR Lyrae star U Comae is also in progress.

Hugh M. Johnson, Lockheed Missile & Space Co., Sunnyvale, California, 3 nights (16$\frac{1}{2}$ hours): spectrographic study of Sco XR-1 including radial velocity measurements. A publication during the year, partly a result of work done at Kitt Peak, was: “A Possible Old Nova Near Sco XR-1,” Astrophys. J. 146, 2, 1966, KPNO Contrib. No. 196.

James B. Kaler, University of Illinois, Urbana, 2 nights (17 hours): coudé and Cassegrain spectrography of NGC 6826, obtained as part of a study of emission line intensities.

Yoji Kondo, Goddard Space Flight Center, Greenbelt, Maryland, 3 nights (26 hours): investigation of possible abundance anomalies in close binary systems by coudé spectrography of A- and F-type systems. Dr. Kondo has been invited to present a paper, “Investigation of Possible Abundance Anomalies in Spectroscopic Binaries of Spectral Types A0–A2 and F5–F6 (IV–V),” at the “Joint Discussion on Close Binaries and Stellar Evolution,” scheduled for the XIII General Assembly of the IAU in Prague, Czechoslovakia.

Arlo U. Landolt and R. L. Stephens, Louisiana State University, Baton Rouge, 5 nights (24$\frac{1}{2}$ hours): image-tube spectrographic observations of a faint blue star were obtained in collaboration with Dr. C. R. Lynds. As a supplement to these observations, Dr. Landolt and Mr. Stephens obtained simultaneous photometric observations of this object with the 36- and 16-in. telescopes. Interpretation of the spectrograms and periodogram analyses of the photometric data are in progress.

Paul D. Lee, University of Illinois, Urbana, 4 nights (47 hours): He obtained a long-exposure spectrogram of NGC 1976 for a study of intensities of high-order Balmer lines. Cassegrain spectrograms of IC 2149 and IC 3568 were obtained for emission line intensity studies.

Pavel Mayer, Yerkes Observatory, University of Chicago, 3 nights (28$\frac{1}{2}$ hours): photoelectric photometry and direct photography of stars in faint open clusters in H II regions.

Eugenio E. Mendoza, V., Observatorio Astronomico Nacional, Mexico, 3 nights (31$\frac{1}{2}$ hours): spectrography of extremely red stars in the near infrared. Tonantzinlo Bulletin No. 28, 1967, CTIO Contrib. No. 11.

Tobias Owen and Jack Greenspan, IIT Research Institute (ASC), Chicago, 4 nights (40 hours) and 3 days (14$\frac{1}{2}$ hours): analysis of high-dispersion spectrograms of Venus in the 8200 Å region; the results are being prepared for publication. Coudé spectrograms taken of Mars are being used for the determination of carbon dioxide abundance from the weak band at 8689 Å. Spectra of the outer planets have verified some previously marginal observations of weak absorptions, and they suggest that the variable ammonia absorption reported in the spectrum of Saturn may be due to methane. Publications resulting from observations obtained at Kitt Peak include: T. Owen, “Comparisons of Laboratory and Planetary Spectra. IV. The Identification of the 7500 Å Bands in the Spectra of Uranus and Neptune,” Icarus 6, 108 (1967), KPNO Contrib. No. 185; “On the Abundance of Ethane in the Atmospheres of Jupiter and Saturn,” Icarus 6 138 (1967), KPNO Contrib. No. 202; “An Identification of the 6800 Å Methane Band in the Spectrum of Uranus and a Determination of Atmospheric Temperature,” Astrophys. J. 146, 611 (1966), KPNO Contrib. No. 203.

Benjamin F. Peery, Jr., Indiana University, Bloomington, 4 nights (46 hours): coudé spectrography of selected stars to be used in a study of relative abundances of heavy elements in stars having differing degrees of S-type characteristics.

A. G. Davis Philip, Dudley Observatory State University of New York, Albany, 4 nights
(36 1/2 hours): Cassegrain spectroscopy of high galactic latitude A stars. (See 36-in. summary for publication.)

Jeffery D. Rosendhal, Yale University, New Haven, Connecticut, halves of 8 nights (39 1/2 hours): coude spectrography of Ia and Iab supergiants in the spectral range B0-A5. This observational material forms the basis of a dissertation entitled, “Evolutionary Effects in the Rotation of Supergiants.” As part of this work, a theoretical paper, “The Effect of Electron Scattering on Curves of Growth,” was presented at the June 1967 meeting of the Astronomical Society of the Pacific.

Maihiro Simoda, Institute for Space Studies, Columbia University, New York, 3 nights (25 1/2 hours): direct photography of the globular clusters M5, 13, and 92 for a search for faint blue stars and investigation of the luminosity functions of these objects.

Alan Stockton, University of Arizona, Tucson, 8 nights (76 1/2 hours): direct photography and image-tube spectrography of compact blue nonstellar objects found in association with elliptical galaxies. The objects examined so far show a wide range of emission-line strengths, some having no lines at all.


Leslie J. Tomley, University of Washington, Seattle, 4 nights (39 hours): He obtained coude spectrograms of the hot subdwarfs HD 127493, 128220, and 113001; the latter two stars are members of the binary systems. This material is being used to determine stellar atmospheric parameters and chemical abundances.

George Wallerstein, University of Washington, Seattle, 12 nights (71 1/2 hours): a search for lithium in F and G stars of luminosity class Ib, and in classical Cepheids, with coude spectrograms, yielded negative results. Coudé spectrograms of the hot silicon star HD 34452 were taken by Wallerstein and L. J. Tomley to study variation of line strengths and other atmospheric parameters with phase, with the purpose ultimately to derive abundances of the elements. Cassegrain spectrograms of T Pyx, RS Oph and Sco XR-1 were obtained. Additional spectrograms of a number of stars near Sco XR-1 were obtained as part of a program to establish its distance by comparison of the interstellar calcium lines with the interstellar lines in nearby stars.


Peter A. Wehinger, University of Michigan, Ann Arbor, 4 full nights and halves of 4 nights (65 1/2 hours): coude spectrograms of M-giant and supergiant stars were obtained for the purposes of determining rotational temperatures, and identification of circumstellar lines for mass-loss studies. (See Solar Division.)

Derek Wills, University of Cambridge, England, and the University of Texas, Austin, 4 nights (14 hours): collaboration with C. R. Lynds in image-tube spectrography of quasi-stellar objects selected primarily from among radio sources.

H. John Wood, Leander-McCormick Observatory, University of Virginia, Charlottesville, halves of 4 nights (18 hours): coude spectroscopy of α² C Vn and ε UMa at 2 Å/mm for observation of short-term variations in line structure. Simultaneous dual-channel photometric measures were made with McCormick Observatory equipment mounted on the No. 4 16-in. telescope. Mr. George Lockwood assisted with the photometric observations, and Mr. Robert Redick with the special photometric equipment.

Kenneth M. Yoss, University of Illinois, Urbana, 5 nights (57 1/2 hours): Cassegrain spectrography of giants in NGC 188, and coude spectrography of late-type giants. The high-dispersion spectrograms are being used in a study of abundances as a function of the CN anomaly in these late-type stars.

36-inch Telescope Programs. John D. Bahng, Northwestern University, Evanston, Illinois, 4 nights (22 1/2 hours): infrared photometry of stars with special Dearborn Observatory equipment. A publication resulting from previous work at Kitt Peak with this instrument was: “Infrared Photometry of Late-Type Stars,” *Proceedings of the IAU Colloquium on Late-Type Stars* (M. Hack, editor; Trieste, Italy) p. 225, 1967, KPNO Contrib. No. 228.

Roberto Barbon, California Institute of Technology, Pasadena, 3 nights (15 1/2 hours): spectrography of compact galaxies and parent galaxies of supernovae. The 36-in. telescope and spectrograph were found to be only marginally suited to this
kind of observing, so additional time with the 84-in telescope was provided at a later time.

L. Binnendijk, University of Pennsylvania, Philadelphia, 9 nights (63.5 hours): UBV observations of eclipsing binaries. Light curves were obtained for TZ Bootis in collaboration with Dr. B. B. Bookmyer and for V 502 Ophiuchi.

Howard E. Bond, University of Michigan, Ann Arbor, 8 nights (52.4 hours): spectrography for radial velocity measures and spectral classification of 52 F- and G-type stars whose spectra appeared weak-lined on objective prism plates obtained with the Curtis-Schmidt telescope. Together with the photometry reported elsewhere, this material will form the basis for a doctoral dissertation.

Beverly B. Bookmyer, Villanova University, Villanova, Pennsylvania, 6 nights (23 hours): BV observations of the short-period eclipsing binaries BV 449, AK Her, and LS Her.

Katherine Bracher, University of Southern California, Los Angeles, 7 nights shared with Howard Cohen (30 hours): spectrographic study of the Wolf-Rayet binary systems HD 193077, 197406, 211853, and 9974. The plates of HD 211853 have been used in a study of an anomalous absorption-line velocity curve. This work was reported at the June, 1967, meetings of the American Astronomical Society. Analysis of the remaining material is in progress.

Howard L. Cohen, Indiana University, Bloomington, 7 nights shared with Katherine Bracher (16 hours): spectrography of V448 Cygni (HD 190967) for radial velocity measurement. An analysis of this material combined with additional spectrograms on loan from the Dominion Astrophysical Observatory, Victoria, Canada, is in progress.

I. Epstein, Columbia University, New York, 8 nights (61 hours): wby measures of the RR Lyrae variables XX And, BK Eri, SV Eri, UZ Eri, AR Per, RR Gem, SS Cnc, TT Cnc, and RW Cnc, referred to comparison stars and standard stars listed in the Strömgren-Perry Catalogue preprint. Additional variables are to be observed before publication of the results.

Tom Gehrels, University of Arizona, Tucson, 1 night (7 hours): attempt to do photometry of asteroids foiled by clouds.

James Gibson, Princeton University, Princeton, New Jersey, 7 nights (31.5 hours): intermediate-band filter photometry of A0 stars, in collaboration with B. Strömgren.

Martha S. Hanner, Rensselaer Polytechnic Institute, Troy, New York, 7 nights (44 hours): color distribution of scattered light in the reflection nebula IC 1287 with a dual-channel photometer.

Graham Hill, Louisiana State University, Baton Rouge, 3 nights (21 hours) and 5 nights for wby photometry in the initial testing stage of the No. 2 36-in. telescope: spectrography for radial velocity measures of β Cephei stars, and 4-color photometer tests with the No. 2 36-in. telescope.

Robert H. Koch, University of New Mexico, Albuquerque, 1 night (3 hours): an attempt was made to observe the rotational disturbance in the radial velocity curve of u Her, but only fragmentary results were obtained because of poor weather.

Arlo U. Landolt, Louisiana State University, Baton Rouge, 9 nights (51.5 hours): continuation of observations of O-Of stars to evaluate a narrow-band filter system selected to provide luminosity sensitive indices at 4637 Å (N11). Approximately one-third of the O stars known have been observed; and HD 188001, 34656, and 10 Lac have been intensively observed to check on short-term variations. Photometric observations of a faint blue variable were made in conjunction with simultaneous image-tube spectrophotometry at the 84-inch telescope. Other work published is: "Photoelectric UBV Sequences in Taurus," Astron. J. October 1967, KPNO Contrib. 258.

Albert P. Linnell, Michigan State University, East Lansing, 2 nights (8 hours): UBV observations of eclipsing binaries.

Thomas E. Lutz, University of Illinois, Urbana, 2 nights (10 hours): spectrography of both components of several binaries for absolute magnitude determinations based on spectroscopic luminosity criteria; their usefulness will be evaluated by comparing the difference in the derived absolute magnitudes with the observed differences in apparent magnitude.

Beverly T. Lynds, University of Arizona, Tucson, 2 nights (6 hours): spectrography of IC 59 and IC 63 to detect possible changes associated with luminosity changes of γ Cas; however, the program was discontinued because γ Cas has not continued to increase in brightness.

Joseph S. Miller, Washburn Observatory, University of Wisconsin, Madison, 14 nights (75 hours): spectrography of emission nebulae. Velocities were obtained for 36 H II regions for a study of the relationship between optical and radio distance estimates of spiral features. The velocities of the nebulae observed in the Sagittarius and Orion spiral arms agree with rotation curves based on studies of 21-cm radiation and young stars. These observations are being reported in a paper, "Radial Velocities and Kinematics of Galactic H II Regions," which has been submitted for publication.

Eugene Milone and Eugene McClurken, Gettysburg College, Gettysburg, Pennsylvania, 3 nights (25 hours): spectrography of the eclipsing binary CG Cygni.

Kunihiro Misawa, Kagawa University, Takamatsu, Japan, 21 nights (43.5 hours): photometry

W. W. Morgan, Yerkes Observatory, University of Chicago; A. B. Meinel and Don Barry, University of Arizona, Tucson, 5 nights (20 hours): a revised program for completion of a low-dispersion grating atlas of standard stellar spectra, in collaboration with H. A. Abt. The purpose of this atlas is to furnish a network of spectral standards of faint stars, for use with low-dispersion spectrometers obtained with large reflecting telescopes. Since only about one-fourth of the necessary number of spectrometers was obtained during this run, the remaining plates are being obtained by H. A. Abt.

George S. Mumford, Tufts University, Medford, Massachusetts, 19 nights (104 hours): continuing photometric studies of nova-like variables and related objects. Colors and magnitudes of the x-ray source, Scorpius XR-1, as well as of Nova Herculis 1963 and Nova GK Persei, were published in \textit{Astrophys. J.} 146, 962, 1966, \textit{KPaNo Contrib.} 207. All observations pertaining to the eclipsing system of EX Hydrae, which have been obtained at Kitt Peak during the past four years, will appear in \textit{Astrophys. J. Suppl. No.} 133, \textit{KPaNo Contrib.} No. 236. Preliminary light curves of T Leonis and CN Orionis are published in \textit{Publ. Astron. Soc. Pacific} 78, 283, 1967, \textit{KPaNo Contrib.} No. 251. A possible period change in Nova T Aurigae is also discussed in this paper. Additional observations have been obtained in U Geminorum, TU Leonis, TT Booits, and Nova Her 1963; it is not yet clear whether the latter is an eclipsing binary.

Brian T. O’Leary, University of California, Berkeley, 20 nights (60 hours): six-color photometric measures of Mars at small phase angles, for investigation of the Martian surface and atmospheric characteristics, by examination of the opposition effect at various wavelengths. These measures were supplemented by \textit{UBV} observations made at Dr. O’Leary’s request by N. Sanduleak and D. J. MacConnell in Chile. Preliminary results are to appear in the September 1967 issue of \textit{Astrophys. J. L.}

A. G. Davis Philip, Dudley Observatory, Albany, New York, 21 nights (146 hours): spectrography and \textit{ubvy} photometry of high galactic latitude A stars. Twenty-two possible horizontal-branch field stars have been found, with results reported in a paper “Possible Horizontal-Branch Stars at High Galactic Latitudes,” \textit{Astrophys. J.} 148, L143, 1967, \textit{KPaNo Contrib.} No. 245.

W. W. Rolland, John Reuning, Randall Cook, King College, Bristol, Tennessee, 1 night (8 hours): photometry of Ap stars.


Gummuluru N. Sastry, Wesleyan University, Middletown, Connecticut, 7 nights (18 hours): photoelectric observations for a color distribution study of supergiant elliptical galaxies. Because of poor weather conditions, results were obtained for only 4 objects. The observations have been used as parts of a thesis for a master’s degree.

Conrad Sturch, University of Rochester, New York, 2 nights (21 hours): \textit{UBV} photometry of RR Lyrae stars with large color excesses (see \textit{KPaNo Contrib.} No. 223.) Among those stars observed, the BK Cas measures did not confirm the published period, UB Mon appears to have a large ultraviolet excess, and BK Eri was found to have a period of 0.056 as compared to the published value of 0.037. The period, ultraviolet excess, and metallicity confirm that BK Eri is a normal RR Lyrae star: “B. K. Erind: A Normal RR Lyrae Star,” \textit{Publ. Astron. Soc. Pacific} 79, 468, \textit{KPaNo Contrib.} No. 239.

John L. Schmitt, University of Michigan, Ann Arbor, 11 nights (85 hours): spectrography of CN stars for classification and a study of the behavior of the NH bands at \(\lambda 3360\) and \(\lambda 3370\) in the spectra of high velocity stars and CN stars.

Gary A. Welch, University of Washington, Seattle, 8 nights, (30 hours): photometric observations of K giant in globular clusters, with a filter system selected to yield a reddening-free metal abundance index.

Kenneth M. Yoss, University of Illinois, Urbana, 2 nights (9 hours): spectrography of late-type stars having known parallaxes, for the purpose of establishing spectroscopic parallax criteria.


Howard E. Bond, University of Michigan, Ann Arbor, 28 full nights and halves of 4 nights (152 hours): \textit{ubvy} photometry of 270 F- and G-type stars selected as weak-lined stars on Curtis–Schmidt objective prism plates. In almost every case these stars were confirmed to be weak-lined in comparison to Hyades stars, the \(\Delta m_1\) index being greater than 0.050 in over half the cases. Objects of this kind have been found in the past mainly on the basis of large proper motions.

Beverly B. Stokmyer, Villanova University, Villanova, Pennsylvania, 14 nights (13 hours): photometry of eclipsing variables (see summary under 36-inch Telescope Programs).

Michel Breger, University of California, Berkeley 11 nights (36 hours): photometry of possible \(\delta\)

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Scuti-type stars, by searching for small-amplitude light variability among stars selected from a region in the HR diagram between the RR Lyrae gap and main sequence F0 stars.

Roger B. Carr, University of Florida, Gainesville, 47 nights (165 2/3 hours): photometry of the eclipsing variables CZ Aquarii and UV Piscium.

Larry Cathy, Vanderbilt University, Nashville, Tennessee, 7 nights (10 1/2 hours): uvby photometry of stars in Orion north of the Belt area.

Tom Gehrels, University of Arizona, Tucson, 1 night (0 hours): attempt to observe asteroids photometrically foiled by clouds.

James Gibson, Princeton University, Princeton, New Jersey, 72 full nights and halves of 4 nights (359 2/3 hours): uvby photometry of A0 stars in collaboration with B. Strömberg. The observations are in preparation for publication.

Graham Hill, Louisiana State University, Baton Rouge, 48 nights (271 hours): intensive photometric observations of 11 β Cep stars selected from among 24 examples of this class that Dr. Hill discovered during earlier work at Kitt Peak. These observations have been reduced and are being analyzed by periodograms in an attempt to detect multiple periodicities in the light curves: "On Beta Cephei Stars. I. A Search for Beta Cephei Stars," and "Some New Variables in Nearby Associations and Galactic Clusters," Astrophys. J. Suppl. No. 130, 1967, KPNO Contrib. No. 246.

Thomas Kelsall, Goddard Space Flight Center, 15 1/2 nights (79 1/2 hours): continuation of work on a program of multicolor photometry of Cepheids and supergiants. A doctoral dissertation based on these observations, and on others previously reported, is completed and publication of results is in preparation.


Charles F. Lillie, Washburn Observatory, University of Wisconsin, Madison, 27 nights (38 hours): photometry of standard stars with a special 3-channel photometer constructed at the University of Wisconsin. Initial reductions reveal that good colors can be obtained during large variations in transparency.

Albert P. Linnell, Michigan State University, East Lansing, 8 nights (52 2/3 hours): observations of eclipsing binaries: "UBV Photometry of RR Lyneis," Astron. J. 71, 6, 1966, KPNO Contrib. No. 170. UBV light curves of VV Ori and RZ Cas have been observed and reports are in progress.

Thomas E. Lutz, University of Illinois, Urbana, 4 nights (23 hours): UBV and Hγ measures of stars selected for calibration of K-line absolute magnitudes.

Ed Mannery, University of Washington, Seattle, 17 nights (65 hours): observations of field K-giant stars with a broad-band filter system selected to yield a reddening-free metal abundance index. A preliminary correlation of this index, and the metallicity of K III stars as measured by the quantity [Fe/H], has been established.

Pavel Mayer, Yerkes Observatory, University of Chicago, Williams Bay, Wisconsin, 11 nights (88 1/2 hours): photometry of OB stars with an intermediate-width bandpass filter selected to provide luminosity criteria.

Eugene Milone and Eugene McClurken, Gettysburg College, Gettysburg, Pennsylvania, 5 nights (37 1/2 hours): UBV photometry of the eclipsing binary CG Cyg for comparison with the light curve observed at Kitt Peak in 1965. Photometry of CI Cyg in connection with a study of this star by D. Hoffleit, and of the open-cluster Cepheid, EV Scuti.

Kunihiko Misawa, Kagawa University, Takamatsu, Japan, 21 nights (7 hours): photometry of Bp and Ap stars for studies of brightness variations.

Brian T. O'Leary, University of California, Berkeley, halves of 3 nights and 1 day (11 1/2 hours): photometry of Mars at small phase angles.

A. G. Davis Philip, Dudley Observatory, State University of New York, Albany, 9 nights (51 1/2 hours): uvby observations of high galactic latitude A stars and UBV sequence observations in high galactic latitude regions.

W. W. Rolland, John Reuning, and Randall Cook, King College, Bristol, Tennessee, 22 nights (96 1/2 hours): photometry of Ap-type spectrum variables from the list of Abt and Golson. Stars having broad spectral lines and brighter than 8 mag were chosen for this study. Reductions were completed as soon as possible following the observations so that confirmed variables could be observed more intensively.


Theodor Schmidt-Kaler, Universitäts-Sternwarte Bonn, Germany, 5 nights (33 3/4 hours): UBV and
Hβ photometry of OB stars in Monoceros, to supplement the work of Haug and Schmidt-Kaler previously done at Kitt Peak.

H. John Wood, George Lockwood, and Robert Redick, Leander-McCormick Observatory, University of Virginia, Charlottesville, 10 nights (58½ hours): approximately 4000 narrow-band observations of ε UMa, α² C Vn, and other spectrum variables were obtained with a special dual-channel photometer and readout built at the University of Virginia. Reductions of K-line and Balmer-line light curves obtained simultaneously with spectrograms taken with the 84-in. telescope are nearly complete. It is hoped that detailed correlations between the simultaneous photometry and spectrography will be possible.

Special Equipment Programs. David Armstrong, University of Hawaii, Honolulu, double-beam telescope observations of seeing: a 3-month series of measurements was made to compare atmospheric image motion on Mauna Kea and Kitt Peak, and to study the relation between seeing measures made with the double-beam telescope and the 84-in. reflector. The double-beam telescope seeing measure is the dispersion from the mean separation of the two-star image trails, produced on moving film, by the two apertures separated by 65 inches. Similar double-beam measures were also made with the 84-in. telescope on several occasions. Evaluation of the double-beam telescope measures is proceeding at the University of Hawaii, under the direction of Dr. John Jeffries.

Charles F. Lillie, University of Wisconsin, Madison, measurement of integrated starlight in visible and infrared wavelengths: special University of Wisconsin equipment consisted of a 3-in. f/6 reflector equipped with multichannel photometers designed for narrow-band measures at 3600, 4300, 5400, 7400, and 9600Å. A three-axis telescope mount was used to permit simulation of Aerobee scans of the sky. The purpose of the experiment was to determine the interstellar radiation density and spectral distribution, but such observations require relatively large corrections for the dominant zodiacal light and night airglow components. One of the reasons for observing at Kitt Peak was the availability of independent airglow monitoring information, regularly recorded at the Space Division's airglow laboratory, under the direction of Dr. D. M. Hunten and Dr. A. L. Broadfoot.

Staff Research

Dr. H. A. Abt and his colleagues have continued spectrographic studies of the kinematics of stars and stellar systems; with Dr. Netra Sanwal by measurements of velocities of components of visual binaries; with Mr. Michael Snowden by investigation of the frequency of binaries among Ap stars; and with summer research assistants, Messrs. F. H. Chaffee and G. Suffolk, determination of the rotational velocities of 70 Ap stars from coudé spectrograms. The latter work was reported at the June, 1967, meeting of the American Astronomical Society. Chaffee, a student of the University of Arizona, Tucson, is studying turbulence in main sequence stars, with Abt acting as his doctoral dissertation adviser. Mr. J. Rosendhal began a study of rotational velocities and turbulence among early-type 1a supergiants while a summer research assistant working under Abt. This work has developed into a Yale research project for Rosendhal, with Abt as his dissertation adviser. As part of this work, Mr. Rosendhal presented a paper, “On the Effect of Electron Scattering on the Curve of Growth,” at the June 1967 meeting of the Astronomical Society of the Pacific. Mr. Tom Bolton, who also worked with Abt as a summer research assistant, began a study of the frequency of spectroscopic binaries among the member stars of the open cluster IC 4651. Abt is continuing his own spectroscopic studies of stellar rotation, with the coudé and Cassegrain spectrographs. A rotational limit of approximately V sin i = 40 km/sec can be reached with the Cassegrain spectrograph. In addition to the rotational velocity programs, a number of galactic structure radial velocity programs are being carried out. Working with Mrs. Eleanor S. Biggs, Abt has prepared a General Index to the Astrophysical Journal for Vols. 136–145, which is in press. He and Mrs. Biggs are also preparing a bibliography of all stellar radial velocities, and 22,000 references are now punched on IBM cards. He continued work at the Mt. Wilson and Palomar Observatories to collect individual velocity determinations. Approximately 30,000 additional individual velocities are obtainable from this source.

Dr. D. L. Crawford and his associates, primarily Mr. J. C. Golson and Mrs. Jeannette V. Barnes, are continuing their extensive program of intermediate- and narrow-band photometry of all G0 and earlier-type stars brighter than magnitude 6.5. These observations are being made in both hemispheres through use of the 16-in. telescopes at Kitt Peak and Cerro Tololo. Initial luminosity calibration of stars in the spectral range A0 to G0 through use of radial velocities, proper motions, and trigonometric parallaxes seen to give results of high internal consistency. The 4-color and Hβ photometric system yields more parameters giving better calibration resolution than the UBV system. Mr. J. W. Glaspey, a summer research assistant, worked with Crawford in assembling similar material for the luminosity calibration of the bright early-type stars in both hemispheres from this 4-color and Hβ photometry. The results of some of this bright
star photometric work were reported jointly with Dr. Bengt Strömgren at the June, 1967, meeting of the American Astronomical Society, in a paper entitled "Intrinsic Colors for Main Sequence A- and F-Type Stars." Increasing use has been made of the Observatory's computer in reducing and analyzing this extensive observational material. Mrs. Jeannette V. Barnes, Mrs. Barbara Weymann, Dr. John Graham, Dr. Netra Sanwal, and Sr. F. J. Lopez-Lopez have collaborated in the necessary programming and data handling. A number of programs involving the observation of fainter stars with the 36- and 84-in. telescopes, with the 4-color and Hβ systems, are in progress. A number of A2 to G0 stars to magnitude 9.0 have been observed in collaboration with Dr. Bengt Strömgren, and stars to fainter limits have been observed in h and χ Persei, the Orion Association, Praesepe, the Upper Scorpian arm, the ζ Perseus group, and the α Persei cluster. Some work on faint stars with the UBV system, is being continued.

Dr. A. A. Hoag is working on the luminosity calibration of a photoelectric Hβ system. He has observed the stars used by R. M. Petrie in the revised calibration of spectroscopic absolute magnitudes of early-type stars. For individual stars, there are significant differences between the photographic and photoelectric systems. This result is presumably brought about by the details of differences between the application of the two techniques.

A preliminary report of this work was presented at the December 1966 meeting of the American Physical Society in Nashville, Tennessee. Final analysis of this material is being done in collaboration with Mrs. Dorothy Orinski. Hoag has obtained a number of spectrograms of OB stars in galactic clusters with the 36-inch telescope at a dispersion of 63 Å/mm, and these spectrograms will be used for the measurement of radial velocities. He has extended to magnitude 18 a UBV photoelectric sequence in the open cluster NGC 6709, and has taken a number of 3-color direct photographs of this cluster and of NGC 457. Mary K. Meacham, while a summer student assistant working with Hoag, attempted a photometric program of drift photometry of reflection nebulae with the 36- and 16-in. telescopes, and she developed a computer reduction program for the data output format obtained by this technique. Because of poor observing conditions, no significant observational results were obtained.

Dr. J. A. Graham has continued his work on intermediate-band photoelectric photometry of high galactic latitude blue stars. In the last year, white dwarf stars have been given special attention, with observations made on the Strömgren ubvy system to determine whether the bluest stars of this type can be distinguished among the hot sub-dwarfs from photometry alone. The ubvy system gives a good leverage on photometric effects among the high latitude stars, as compared to the UBV system that is subject to line-blocking difficulties. Observations can be conveniently made with the 36-in. telescope on this system down to a limit of about 14th mag and, with the same system, approximately 5 to 6 stars per hour to a magnitude limit of 16 can be observed with the 84-in. telescope. The effects of reddening do not seem to be serious in the study of these objects. During a visit to Chile, where he used the 36-in. telescope, Graham observed 47 horizontal branch stars belonging to the globular cluster NGC 6397, with the aim of relating these stars to the field stars of similar intrinsic color among the high latitude blue stars. He also is preparing for publication the results from 5-color photometry on Walraven's system for 450 OB-type stars in Carina; and from Hβ photometry carried out for 11 of these Carina stars, he finds that they appear to form a physical group near the H ii region numbered 54 in Miss Hoffleit's 1953 survey.

Dr. C. R. Lynds has continued his work on the development of image-tube techniques and the application of this equipment to the observation of quasi-stellar sources, x-ray sources, galaxies, and faint emission nebulae at high galactic latitudes. The spectrograms of a number of quasi-stellar sources show complex absorption features at relatively high dispersions. The present maximum dispersion obtainable with this equipment is 16.7 Å/mm, and Lynds notes that the physical nature of these objects is such that the maximum dispersion should be used on the faintest objects. Some of Lynds' observational work was carried out in collaboration with A. Stockton and K. Heere, summer research assistants. Lynds and his collaborators have continued to do direct photographic work with the 84- and 36-in. telescopes, for identifications and the measurements of offsets for use with the image-tube spectrograph. He has also done some experiments involving the use of phenadone developer. This is a "large-scale" developer that is useful in recording a wide range of intensity.

Dr. Netra Sanwal is continuing his study of visual binary systems in collaboration with Abt. The principal aim of the program is to determine mass ratios by study of radial velocities. The program has been formulated by study of approximately 600 pairs of stars with known m₁ + m₂ determined from orbital information. The program has naturally divided into three parts: first, an analytical study of orbital information for determination of ephemerides; secondly, a determination of parallaxes through MK classification and UBV photometry; and, finally, a study of velocities of approximately 100 systems with the 84-in. telescope coudé-spectrograph at a dispersion of...
13 Å/mm. The 36-in. telescope and Cassegrain spectrograph is used for spectral classifications, and the 16-in. telescopes are being used for UBV photometry of these systems. The separations of these systems are, in general, less than 2", and the periods range from approximately 25 to 1000 years. The maximum amplitudes of the radial velocity curves are about 10–15 km/sec. Some are double-lined binaries that can be spectrographically resolved over a limited part of the orbits. A substantial number of measures have been completed and reduced on this program.

Several site and telescope evaluation programs are being carried out by Hoag with a number of collaborators. The PIMA (Polaris Image Motion Analyzer) program initiated by Lynds is being continued in collaboration with Kelly Cook and Gary Villere. Microthermal observations in the vicinity of the slit of the 84-in. telescope dome, obtained by Cook, have been analyzed and published. A number of double-beam observations were made with the 84-in. telescope in collaboration with David Armstrong of the University of Hawaii, Honolulu. Results of Hartmann tests of the 84-in. telescope optics are being prepared for publication in collaboration with D. H. Schulte and Abt.

Other Staff Activities. Dr. Abt was elected president of the Astronomical Society of the Pacific in November 1966; he provided consulting services on spectrographic problems in New Zealand and at the University of Hawaii during January and February 1967; and he lectured at the Summer Institute held in June 1967 at the Stony Brook campus of the State University of New York.

Dr. Crawford also lectured at the same Summer Institute; in his capacity as project manager of the two 150-in. telescopes, he gave a progress report to the National Science Foundation in Washington, D. C. in November 1966; he presented a paper entitled "The Kitt Peak 150-in. Telescope," at the December, 1966, meeting of the American Astronomical Society; and he served as joint chairman of a symposium "Mirror Support Systems for Large Telescopes," held in Tucson, Arizona, in December 1966.

Dr. Lynds participated in the 1967 Texas Symposium on Relativistic Astrophysics, held in New York in January 1967.

Dr. Graham visited the University of Hawaii in November 1966 to confer with Dr. J. T. Jeffries regarding site evaluation programs; and he presented colloquia at the University of Toronto, Canada, Case Institute of Technology, East Cleveland, Ohio, and Northwestern University, Evanston, Illinois, in January 1967.

Dr. Hoag reported on "Polarization Problems and Spiral Structure" at a symposium, "The Spiral Structure of Our Galaxy," held at the Steward Observatory, University of Arizona, Tucson, in March 1967. Dr. Graham was a member of the organizing committee for this symposium planned by Dr. Bart J. Bok, Director of the Steward Observatory.

Solar Division

Instrumentation. An 82-in.-diameter, 10-in.-thick blank of fused silica was received from Corning Glass Works, Corning, New York, in June 1966. Made of four thin disks fused together, it will be, when figured, the replacement for the 63-inch quartz flat now in use for the heliostat. The new flat mirror will more fully illuminate the concave image-forming mirror, give less vignetting, have fewer bubbles on the surface to give less scattering, and, hopefully, have a better figure. An advantage of fused silica is its low coefficient of expansion; however, it is not zero. This mirror when exposed to sunlight bows convex 20 wavelengths for a temperature differential of 10°F between front and back. To alleviate this difficulty, the mirror will be supported by 18 metal bellows that act as pistons around the bottom edge, while a vacuum of 3 lbs/ sq. in. at the back of the mirror will mechanically bend the mirror into a near-plane surface. The radial edge support is a mercury-filled tube, which also serves as the vacuum seal. Cooling coils are provided to bring the mirror temperature to that of the ambient air temperature.

In November 1966, the Boller & Chipens Co., South Pasadena, California, installed a 15-ft focal length spectroheliograph in the pit of the observing room alongside the vacuum spectrograph, and Dr. N. R. Sheeley has been concerned with making this instrument operational. The spectroheliograph follows many of the design features developed by Dr. R. B. Leighton for the Mount Wilson Observatory spectroheliograph. It differs from it in being an all-mirror system, and in having a roof beamsplitter just in front of the focal plane. By this arrangement, light from either side of a spectrum line can be recorded on two 8X10-in. plates, or from two different spectrum lines that lie within range or in overlapping orders.

Visitor Research

Miss Karen L. Angle, Lockheed Solar Observatory, Burbank, California: Magnetograms of active regions were obtained, with the magnetic structure to be correlated with H-alpha filtergrams.

J. E. Beckman and Dale Egan, Jet Propulsion Laboratory, Pasadena, California: although bad weather prevailed during most of their stay, Dr. Beckman and Mr. Egan obtained a few image-tube spectra of Mars, Jupiter, and Venus in the region 8000–1700 Å.
R. W. Boese, NASA, Ames Research Center, Moffett Field, California: Dr. Boese and co-workers observed the Martian CO$_2$ bands in an effort to improve the accuracy in the parameters of this planet’s atmosphere. On their second run, photometric spectral scans of absorption lines of molecular hydrogen, ammonia, and methane in Jupiter were made.

Roger Cayrel, The Institute for Advanced Study, Princeton, New Jersey: photometric scans of, 10–20 Å in length, of Procyon, Arcturus, δ C Ma, and ε Virginis, were obtained by Dr. Cayrel in an attempt to disentangle macroturbulence and rotation.

G. A. Chapman, University of Arizona, Tucson: for his doctoral thesis, Mr. Chapman is working on small-scale magnetic features in the neighborhood of sunspots.

R. F. and R. E. M. Griffin, The Observatories, Cambridge, England: in order to check the calibration of high dispersion spectra of Procyon obtained at the 100-in. at Mount Wilson, Dr. and Mrs. Griffin made double-pass scans of a few strong lines of this star with the vacuum spectograph.

J. W. Harvey, High Altitude Observatory, Boulder, Colorado: Mr. Harvey obtained a portion of material for his Ph.D. thesis on solar force-free magnetic fields. Magnetograph observations yielding the longitudinal component were taken for an active region as it crossed the disk. The reduced magnetic structure will be compared with prominence data obtained at H.A.O.

S. A. Korff, New York University, Bronx, New York: low dispersion spectra of Jupiter and the sun were obtained for intercomparation.

P. J. Léna, Université de Paris, France: because of the great increase of the absorption coefficient of the H$^-$ ion in the far infrared, observations made at these longer wavelengths refer to the highest layers of the photosphere. From limb darkening observations at 17.9, 20.4, 22.6, and 24.2 μ, Dr. Léna has shown that the region of temperature minimum between photosphere and chromosphere is a deep isothermal layer, much thicker than previous theoretical models had predicted.

J. L. Linsky, Smithsonian Astrophysical Observatory, Cambridge, Massachusetts: theoretical calculations by Mr. Linsky suggested that the core of the H line of Ca II, under certain conditions, might be stronger than the K line, although most observational results have indicated the opposite. Scans calibrated against a standard lamp were made for a number of points on the solar disk.

R. K. Long, The Ohio State University, Columbus, Dr. Long’s program involved scans of the solar spectrum at laser wavelengths, at various solar altitudes, to determine the coefficients of atmospheric absorption for laser lines.

Mitsugu Makita, Tokyo Astronomical Observatory, Japan: Dr. Makita used the solar telescope for a small program on sunspot spectra and the effects of scattered light.

Tobias Owen, IIT Research Institute, Chicago, Illinois: the first-order spectrum of the vacuum spectograph was used to obtain spectra of Saturn. An improved value of the hydrogen abundance is 345 km atm. Spectra of the sun and Venus seem to indicate a previous misidentification of lines, and little or no evidence of water vapor on Venus.

D. G. Rea, University of California, Berkeley: a topographical study of Mars was attempted by Dr. Rea looking for variations in the strength of CO$_2$ lines above dark and light areas on the planet.

F. Roddier and G. Ricort, Laboratoire d’Astrophysique, Nice, France: using the magnetic resonance scanning spectrometer, Dr. Roddier, together with his student, M. Ricort, investigated velocity fields and line profiles in and about sunspots.

J. E. Ross, University of California, Los Angeles: as part of his Ph.D. thesis work, Mr. Ross made center-to-limb observations of the profiles of lines from lead, silver and beryllium.

Wes Traub, University of Wisconsin, Madison: as part of his doctoral thesis, Mr. Traub intercompared the performance of the Wisconsin PEP SIOS spectrometer with the Kitt Peak spectrograph as used by J. Braut. A detailed observational study of the lithium lines at 6707 Å in sunspots was made, and the results are being analyzed.

P. A. Wehinger, University of Michigan, Ann Arbor: Dr. Wehinger explored the possibilities of the McMath Solar Telescope for high-dispersion spectra of a few bright stars.

**Staff Research**

At the Hamburg meeting of the IAU, Dr. A. K. Pierce proposed an international cooperative effort on the determination of the central intensities of a number of Fraunhofer lines as solar standards. Preliminary observations in the double-pass optical system of 40 lines have been made by Mr. R. S. Aikens, Dr. James W. Braut and Pierce in the region 3000–7000 Å. The instrumental profile was obtained with a Ne–H laser. Mathematical techniques of smoothing and deconvolution suitable for the Observatory’s CDC 3200 computer have been developed by Braut.

An attempt was made to obtain direct photographs of the structure of the solar atmosphere near the chromosphere-corona interface at the eclipse of 12 November 1966. At a site near Cañaguas, Peru, two photographs, of 5 and 25 sec exposure, were obtained with a 25-ft focal length, 10-in. aperture visual achromat borrowed from the University of Michigan. The photographs were taken in pass-
bands about 800 Å wide centered at 5200 Å. Analysis by Dr. John G. Kirk of these observations is under way.

During periods of excellent seeing at the McMath Solar Telescope, chromospheric emission lines are easily visible when the slit of the spectrograph is placed tangent to the limb of the sun. Over the past three years a collection of plates covering the region 3200–10 000 Å has been obtained. The wavelengths of all emission lines have been measured by Pierce with respect to the absorption spectrum of the limb. From these, a ledger of 11 000 lines has been prepared and the elements identified. Lines of Fe i, Fe ii, Ti i, Ti ii, La ii, Y ii, Zr ii, etc. are particularly strong. A great many of the fainter lines are due to the rare earths, and to CN and C2. Homium ii was recorded for the first time in the solar spectrum, and Tb ii and Th ii were confirmed.

To take advantage of the versatility of the 15-ft focal length spectroheliograph, a number of special techniques have been and still are being developed by Dr. N. R. Sheeley and his students. The methods used by R. B. Leighton and his colleagues at Mount Wilson for obtaining line-of-sight Zeeman and Doppler pictures have been successfully perfected. In addition, for the first time, photographs of the transverse component of strong solar magnetic fields have been obtained, with a technique similar to that developed by Leighton to map the line-of-sight component of fields. A great deal of effort has been made to obtain spectroheliograms in the cores of very narrow Fraunhofer lines, and although it has been very difficult to do this job, it is now possible to define the two-dimensional characters of the magnetic "gaps" shown on spectrograms. Most of this work has been done with the assistance of Mr. G. A. Chapman, University of Arizona, Tucson, and many of the results will be used by him in a Ph.D. dissertation in astronomy.

Magnetograph observations were obtained by Dr. W. C. Livingston as follows: (1) At a time of excellent seeing a slow scan was made across part of the sun with 0.5 sec of arc aperture, in an attempt to detect any field connected with the fine granulation. The predicted field was not found within an accuracy of ±2 gauss rms, despite a clear resolution of the brightness and velocity aspects of the granules. (2) Prominence and disk magnetic maps were made on 12 November 1966, to complement the Peru eclipse observations. Analysis is proceeding jointly with Kirk. (3) Using the magnetograph in the velocity mode, Livingston at Kitt Peak and Dr. R. Howard at Mount Wilson observed simultaneously the exact center of the solar disk. Good correlation to the order of one Hz at both sites was found in the general character of the short period oscillations, but imperfect correlation in detail still leaves open the question of the solar origin of these rapid velocity effects. Mr. Charles Slaughter has continued to make full-disk magnetograms at monthly intervals.

Space Division

Staff Research. Aerobee Rocket Research. A rocket fired from White Sands Missile Range 11 October 1966 carried a number of dayglow experiments, and one to measure atmospheric attenuation of solar X rays. To assist with the baffling against sunlight, one side of the payload was kept toward the sun by a uniaxial pointing control. The axis of the rocket was to have been maintained nearly vertical by a cross-spin control system, which failed to achieve the desired performance. As a result, the absorption experiment failed, and some of the dayglow data were spoiled. Nevertheless, a number of excellent spectra were obtained, showing emissions of O2, N2+, and O1 in the region 7000–10 000 Å. These results are being analyzed by Dr. L. W. Wallace. In addition, two photometers, looking through the side of the rocket, observed the atmospheric and infrared atmospheric bands of O2, both of which are prominent absorption features in the solar spectrum. This experiment was conducted by Dr. D. M. Hunt, with the collaboration of Drs. E. J. Llewellyn and W. F. J. Evans of the University of Saskatchewan, Canada. A large body of excellent data was collected, and its analysis is giving information on primary and secondary processes in the atmosphere.

Another Aerobee was launched on 16 December 1966, carrying a 12-in. aperture telescope with a concave-grating spectrometer for Mr. F. E. Stuart of the Observatory staff. The payload was designed to obtain spectra of stars brighter than 5th magnitude, in the 1050 to 2100 Å range, in a 20°×20° field centered on Orion. The rocket engine suffered a catastrophic failure shortly after ignition, which resulted in the disintegration of the payload at an altitude of about 200 ft.

On 8 June 1967, a rocket was flown successfully for Dr. Donald Morton, Princeton University Observatory, Princeton, New Jersey, for the observation of the ultraviolet spectra of Venus and Jupiter in the range 1200 to 2400 Å at about 1 Å resolution. The payload consisted of two objective grating spectrographs, one for the observation of the 1200 to 2000 Å range, and the other for the 2000 to 3000 Å range. The best spectra are those of Venus in the 2000 to 3000 Å interval. Many sharp features were observed, as well as an unidentified absorption near 2400 Å. The spectra of Jupiter in the same region were not as well exposed as those of Venus, but are of good quality. The films from the short-wavelength camera showed considerable
fogging, and it is not yet clear whether useful data can be obtained from them.

Dr. R. C. Anderson, a visiting astronomer from the University of Florida, Gainesville, is principal scientist for an Aerobee rocket payload for the observation of Venus in December, 1967. The instrument, a 24-cm aperture Cassegrain telescope with a concave-grating spectrometer, is under construction at the Observatory. Anderson has been working closely with the divisional scientists and engineers on the design of the payload since mid-January 1967. Mr. R. M. Fike, a graduate student from the University of Florida, Gainesville, is also in residence at KPNO, working on this program for a master’s degree. The objective of this study is the measurement of the oxygen and ozone concentrations from good photometric spectra of about 10 Å resolution in the 1600–3200 Å region. Two attitude control systems will be used to obtain the required pointing accuracy. The first will be used to point the payload on Venus to an accuracy of a few min of arc; the second will rotate one of the elements in the optical train to obtain a final pointing accuracy of a few sec of arc.

Dr. A. L. Broadfoot published an analysis of the x-ray photographs of the sun that were obtained with a pinhole camera from an Aerobee rocket (KP 3.10) flown on 23 June 1965. Regions of coronal condensation were found to be 2.2±0.3 \times 10^4 \text{km} above the photosphere. Intensity profiles with coarse spectral separation were obtained across one intense x-ray source.

Mariner V. This probe, which was launched toward Venus on 13 June 1967, carried a set of simple ultraviolet photometers to measure the hydrogen and atomic-oxygen emission of Venus. The photometers, designed by Dr. C. A. Barth, University of Colorado, Boulder, and Wallace consisted of three solar-blind photomultipliers with LiF, CaF$_2$, and BaF$_2$ windows, and with baffle systems in front to restrict the fields of view to about 2º. The combination of the signals from the three windows allows the separate measurement of both the Lyman-alpha emission of hydrogen and the resonance line of atomic oxygen. The photometers were turned on shortly after orbital injection, and they will remain turned on through the Venus encounter.

Extensive and excellent quality Lyman-alpha data have been obtained in the near-earth region, but no significant atomic oxygen data have been noted. The Lyman-alpha data show that the hydrogen cloud surrounding the earth extends to at least 10 Earth radii, and that it falls off in density in accord with theoretical predictions. Consequently, these data should yield an excellent determination of the Earth’s exospheric temperature. The prime purpose of the experiment is, of course, the same measurement on Venus, and the good agreement between theory and experiment in the case of the Earth is very encouraging.

In addition to these planetary observations, a number of great circle sweeps will be executed in order to obtain extra-solar-system data on Lyman-alpha emission sources uncontaminated by terrestrial Lyman-alpha. Data from one great circle sweep show what appear to be at least three well-defined sources and several more diffuse sources, but none of these has yet been identified with astronomical objects.

Planetary Atmospheres. Dr. M. J. S. Belton and Hunten have continued their program of high-dispersion planetary spectroscopy, using the solar telescope and spectrometer with photoelectric detection and computer processing of the data. Water vapor absorption in the Venus spectrum was detected by taking the ratio of planetary and solar spectra to reduce the telluric absorption. The resulting line was then studied in conjunction with a number of CO$_2$ bands, in collaboration with Dr. R. M. Goody, Harvard University, Cambridge, Massachusetts. A simplified model of line formation in a hazy atmosphere was used, and computer plots were made of synthetic spectra to fit the observations. An unexpected picture of the atmosphere emerged: the cloud-top pressure is about 0.1 atm, and CO$_2$ is a major constituent, perhaps the dominant one. The scattering mean free path in the clouds is a kilometer or greater; thus, the clouds are better described as “haze.” The mixing ratio of H$_2$O to CO$_2$ was found to be only 15 parts per million. This fraction is far smaller than the value to be expected for water vapor in equilibrium with ice at the observed temperature of the CO$_2$ bands. Thus, the cloud particles are almost certainly not ice or water.

A search was made for CO$_2$ absorption on Mercury, with a negative result. The upper limit is only one-tenth that obtained previously, and corresponds to a CO$_2$ partial pressure of less than 0.35 mbar. As the planet is now known to have a slow rotation with respect to the sun, Belton calculated the diurnal temperature variation of the surface. It has been suggested that this curve might be observably affected by atmospheric heat transport, but analysis showed that the effect is negligible. For a surface like the moon’s, the nighttime temperature would be around 100ºK. Dr. M. B. McElroy analyzed the problem of escape of a possible atmosphere, and concluded that even CO$_2$, with its fast radiative heat transport, would not be retained, and that there is little likelihood of an atmosphere on Mercury whose surface pressure is in excess of 10$^{-4}$ mbar.

Further observations of Mars were made during the 1967 apparition, but few of them are reduced yet. Many recent improvements in the observing
technique have yielded very precise results. The surface pressure on Mars was found to be 5.8 ± 0.8 mbar—a threefold reduction in the uncertainty. An atmospheric temperature of 194° ± 17°K was derived, and definite indications of the temperature gradient in the atmosphere were found. The results refer to an area equal to 1/3 of the planet's disk centered on Elysium. Information will be forthcoming on Doppler-shifted O₂ and H₂O lines, and on possible variations of pressure between light and dark areas. Venus spectra are also being obtained, of much higher quality than those already discussed. For this latest work, Broadfoot has joined the group.

Huten reviewed the topic of the upper atmosphere and ionosphere of Mars. Published interpretations of the Mariner IV observations of its ionospheric layer suggest an analogy with the terrestrial E, F1, and F2 regions, corresponding to atmospheric densities varying over a range of nearly 10⁴. A critical analysis was first made of the observations, with the suggestion that some parameters are not nearly as well determined as has been claimed. It was concluded that the observed layer is most unlikely to be an F₂, or diffusive, region. Of the regions under local chemical control, the E type was favored over the F1. The neutral density at 125 km is, therefore, likely to be fairly large, and the exospheric temperature above 700°K.

McElroy has developed a computer program that treats the energy balance of a planetary atmosphere. It considers the absorption of solar radiation and its subsequent conversion to kinetic energy of atmospheric molecules, and allows for energy transport by radiation and conduction. The theory was tested by application to the Earth's atmosphere, and was subsequently applied to the atmospheres of Mars and Mercury.

McElroy and Dr. R. J. Henry have discussed the role of photoelectrons in planetary atmospheres. They presented a detailed discussion of collision processes involving CO₂, CO, O₂, N₂, O and Ar. They also performed an illustrative calculation of electron temperatures for Mars.

The problem of evaporation of light gases from a planetary atmosphere has been studied by Dr. J. W. Chamberlain and Mr. F. J. Campbell, a graduate student at the University of Arizona, Tucson. With the use of the Observatory's computer and a program based on the so-called "Monte Carlo technique," they tested the accuracy of a well-known formula for the rate of evaporation derived many years ago by the British astronomer, Sir James Jeans, and found it to be surprisingly accurate.

Terrestrial Atmosphere and Airglow. McElroy has studied the physical processes that determine the abundance of N⁺ in the upper atmosphere. He postulated that dissociative photoionization of N₂ provides the most important source of N⁺, and found satisfactory agreement with observation.

McElroy and A. Dalgarno, Queen's University, Belfast, Ireland, have investigated the several excitation mechanisms for emission of N⁺ in twilight. They argued that high rotational temperatures observed by Broadfoot and Hunt for 3914 Å indicate efficient production of N⁺ by a charge-transfer reaction between N₂ and O⁺ (O ions). McElroy, Dalgarno, and Dr. James Walker, NASA, Institute for Space Studies, Columbia University, have calculated temporal variations of electron temperature for the ionosphere. They compared their results with data obtained by the incoherent backscatter technique, and concluded that photoionization provides the dominant heating mechanism for ionospheric electrons.

Huten published a comprehensive review article on spectroscopic studies of the twilight airglow. Broadfoot and Hunt published the results of a two-year observing program on Kitt Peak of the N⁺ scattering in twilight. This investigation established for the first time that the height of the emission is above 200 km. The most striking result was a pronounced winter maximum, which occurs only in the evening. This enhancement correlates well with those times when the magnetic conjugate point is sunlit; it was suggested that fast photoelectrons are crossing the magnetic equator along the field lines to produce the additional ionization observed. Broadfoot published an examination of the intensity distribution among the bands of the N⁺ systems due to resonance scattering of sunlight; the calculations explain the extended vibrational development observed in the twilight spectrum. Detailed analyses of the observations are continuing.

Twilight observations of Ca⁺ were extracted from the N⁺ data and were described in the literature by Broadfoot. The emission was detected at altitudes of 280 km. Although there was evidence that the ions had meteoric origin, no acceptable mechanism was found for injecting them into the atmosphere.

Interplanetary Medium. Chamberlain has studied the polarization that might be expected from resonance radiations scattered by comets. He concludes that, contrary to some earlier work, it is unfortunately not feasible to detect cometary magnetic fields with this simple and inexpensive method.

Belton has continued his study of the dynamics of interplanetary dust particles, with emphasis on the effects of vaporization near the sun, and their interaction with the interplanetary magnetic field. He found that both metallic and dielectric particles in the size range 1 to 10 μ will all eventually be ejected from the solar system on hyperbolic orbits.
providing their initial perihelion distance is greater than a certain minimum distance from the sun. In solar radii ($R_\odot$) this distance, which is quite uncertain, was found to be 2.5 $R_\odot$ for dielectrics and 7 $R_\odot$ for metallic particles. Particles larger than 10 microns are evaporated completely.

The interaction of charged interplanetary dust particles with models of the interplanetary magnetic field was also studied. It was found that a polar component to the interplanetary field (the presence of which is thought to have been indicated by Mariner II, IMP-1 and Mariner IV) would have a very strong effect on the motion of interplanetary dust particles, if its direction is stable over time scales comparable with the period of the solar cycle. The presence of such a field component with the magnitude indicated by space probes, reduces the lifetime of 1-$\mu$ dust particles (thought to be the predominant size in interplanetary space) to only 30 yr, and it puts very strong demands on the source of the particles.

**Stellar and Galactic Astronomy.** Dr. M. J. Price continued work on the computation of complete, physically consistent, non-LTE model atmospheres for early-type stars. A novel numerical method has been developed for dealing with the coupling between the local physical state of the atmosphere and the radiation field, using the constraints of hydrostatic and radiative equilibrium and selected LTE boundary conditions deep in the atmosphere. The local properties of the atmosphere—the electron temperature and density, and the atomic level populations—are computed with a rapidly convergent relaxation technique, with the radiative transfer being handled by a Monte Carlo method. The computational method is completely general and may be readily applied to the study of any type of stellar atmosphere of any chemical composition. To demonstrate the validity and usefulness of the method, a computer program has been written for the CDC 3200 for calculating complete pure hydrogen atmospheres for early-type stars.

Initially a number of early-type atmospheres will be computed for a variety of boundary conditions. The method will then be applied to solar-like pure hydrogen atmospheres. Use of a CDC 6400 or CDC 6600 will then be necessary to deal further with the atmosphere problem. Subsequently, it is planned to repeat the computations for atmospheres composed of a mixture of hydrogen and helium with the solar relative abundance of the two elements.

Mr. Fernando Lopez-Lopez, a graduate student in astronomy at the University of Arizona, Tucson, worked with Price in testing the validity of some recent LTE model atmospheres for A- and F-type stars computed by O. Gingerich (Astrophys. J. 144, 1213, 1966). Theoretical predictions of limb darkening were compared with limb-darkening observations for each component of the eclipsing binary YZ Cas.

Dr. R. W. Michie (who worked for several months as a staff member on the Woods Hole Oceanographic Institution’s 1966 summer program for Geophysical Fluid Dynamics, and visited for a month the Columbia University Astronomy Department) completed two research programs during the year. The first concerns the growth of perturbations in an expanding Friedmann model universe; the solutions bracket those obtained by E. M. Lifshitz (et al.) and W. B. Bonnor. One result is that the oscillations of a perturbation dampen out well before recombination, and while the patch is still quite opaque. This effect is caused by the diffusion of photons past the matter. When these solutions are combined with the requirements of fragmentation after the recombination era, it follows that the first stellar systems to form are in the mass range of the average galaxy and cluster of galaxies. Smaller galaxies, such as dwarf ellipticals, must result from the fragmentation of larger systems.

The second study (with Dr. P. W. Hodge, University of Washington, Seattle) deals with the formation, present structure, and future development of the dwarf galaxies in the Local Group. A relaxation process is presented which, during their formation period, will account for the presently observed well-mixed state. The details of the observed density distributions are also accounted for in terms of an anisotropic stellar velocity distribution and the effect of the tidal force exerted by the Galaxy. The latter force also accounts for the lack of systems closer than 60 kpc. It is shown that the Ursa Minor dwarf galaxy will be broken up if it is now approaching our own giant stellar system.

**Astrophysics Laboratory.** Dr. D. E. Shemansky has set up a system for measuring vacuum ultraviolet absorption of gases. A multiple-pass absorption cell provides pathlengths up to 40 m-atm with a very low impurity level. The first search failed to show any absorption by the Veggard-Kaplan bands in 12 m-atm of N$_2$; thus, the transition probability of this system appears to be below 1 sec$^{-1}$. Absorption by the Lyman-Birge-Hopfield system has been observed, but further work is necessary to define the curve of growth. Computer programs for the computations of theoretical curves of growth are being developed. There are tentative plans for the construction of a 10-meter multiple-pass cell, to be used for the observations of highly forbidden transitions such as the N$_2$ Veggard-Kaplan system.

An electron gun is under construction. It is designed to produce a monoenergetic electron beam with energy between 10 eV and about 500 eV. The apparatus will be used for the measurement of relative and absolute excitation functions of low-
lying electronic states, relative transition probabilities within band systems, lifetimes, and phenomena such as the Thompson-Williams effect of the \( \text{N}_2 \) first positive system.

The Observatory's rocket work on the dayglow of \( \text{O}_2 \) has shown the need for a reliable transition probability for the atmospheric A band. Therefore, Huntten and Belton took spectra in the 68-m path of the solar spectrograph, and the half-kilometer path obtained by autoaligning the solar telescope. These results, analyzed by Huntten and Wallace, have provided satisfactory answers, and show that the accepted values in the literature are wrong by almost a factor of 2.

**Theoretical Atomic Physics.** Cross sections for electron excitation of astrophysically interesting transitions in carbon, nitrogen, and oxygen have been calculated by Henry, in collaboration with Drs. P. G. Burke, AERE, Harwell, England, and K. Smith of Royal Holloway College, England. In addition, Henry has calculated photo-detachment and photoionization cross sections of \( \text{O}^- \) and \( \text{O}_2^- \), respectively. Also, McElroy and Henry have investigated the role of photoelectrons in planetary atmospheres and have calculated electron temperatures for possible models of the Martian ionosphere.

**Orbiting Astronomical Explorer.** The study of the planets in the ultraviolet region has only just begun, but studies of the Earth's spectra indicate the type of information that could be obtained from the spectra of the other planets. The Earth's hydrogen emits radiation in the far ultraviolet, and this glow gives a direct measure of the density of atomic hydrogen and the temperature at the top of the atmosphere. Similarly, atomic oxygen emission and strong absorptions of major molecular constituents also occur in the ultraviolet region, offering the possibility of determining the abundances of these constituents and their variation with altitude.

As with observations of that part of the spectrum accessible from the ground, resolution across a planet's disk will also play an important role in the interpretation of these spectra. At moderate spectral resolution, and particularly at wavelengths less than 2000 Å, the observing times appropriate for spatial resolution of a few seconds of arc will be of the order of 10 h in the case of Venus. An extensive observing program would thus require several weeks. The only existing platform that might be appropriate for such observations is the Orbiting Astronomical Observatory (OAO); it, however, is not designed to provide the offset capabilities required for these studies, while many other features it does provide make it inappropriate for very lengthy observations of a limited number of targets.

For these reasons, the Observatory has had the AVCO Corporation, Lowell, Massachusetts, perform a feasibility and preliminary design study of a satellite system (the Orbiting Astronomical Explorer, or OAE) tailored specifically to provide long observing periods with relatively infrequent target changes. This Scout-launched satellite could house and service a variety of scientific experiments. An experiment weighing 75 pounds can be placed in an orbit with 75° inclination, and one of up to 150 pounds can be placed in a low-inclination orbit with a lifetime of 60 days. These, and other characteristics, make the OAE a very attractive vehicle for the proposed planetary studies and for a number of other astronomical studies. The ultraviolet planetary experiment and OAE will shortly be proposed to NASA.

**Remotely Controlled Telescope.** Dr. S. P. Maran continued in charge of this instrument, which was brought closer to regular operation by two additions to the project staff: Mr. E. Mullen, engineering designer, and Miss Kathy I. Moyer, research assistant. The RCT became useful for staff test programs for bright-star photometry in April 1967, and UBV observations of suspected delta Scuti stars and a magnetic variable commenced. New incremental encoders were installed during the year, to enhance the RCT's precision offset capability, and pulse amplifiers were constructed by observatory personnel. The Mark II star finder, intended to extend the acquisition range of the telescope to at least 13th magnitude, reached an advanced state of construction in the instrument shop. Development of a 10-channel grating photometer and spectrum scanner continued; a full-sized optical prototype was successfully tested in June, 1967. A Freon refrigerator, based on the published design of Broadfoot, was installed to cool photomultipliers associated with RCT instrumentation; a gaseous-nitrogen leak system prevents condensation of atmospheric water vapor on the cooled surfaces.

**Attitude Control System.** The Separable Payload Orientation System, being developed for this Observatory by the Ball Brothers Research Corporation, Boulder, Colorado, is expected to be ready for use on an Aerobee rocket flight scheduled for November 1967. The development is on schedule and the tests run so far have been highly satisfactory. Consequently, there is good reason to expect that the anticipated pointing accuracy of somewhat better than one min of arc will be achieved.

The second and third units of the Observatory's new cross-spin stabilization system, designed to remove the precessional cone of the rocket, have now been flown. The first and second flights gave good results, but on the third, the spin of the rocket was so high that the gyro's, which sense the cross-spin, became too insensitive to provide the neces-
sary error signals. A survey is now in progress to find gyros that will not be subject to this difficulty.

Other Staff Activities. A conference on the atmospheres of Mars and Venus, organized under joint sponsorship of the Observatory's Space Division and Goddard Institute for Space Studies, New York, was held in Tucson, Arizona from 28 February to 2 March 1967. Approximately 86 scientists attended. Proceedings of the meeting, edited by Dr. J. C. Brandt and McElroy, will be published by Gordon and Breach Science Publishers, Inc., in December 1967.

Research Support Work

Computer Laboratory. Usage of the leased CDC 3200 averaged 419 hours per month, with a maximum of 522 hours in January and a minimum of 315 in July 1966. An increasing fraction of jobs was run under closed-shop operation, and an additional improvement was obtained by using a real time operating system.

At the beginning of the report year, a staff study was made of the Observatory's computing needs, current and projected. As a result, a recommendation was made to the AURA Board that the Observatory purchase a CDC 6400. Following Board approval, a detailed proposal for purchase of the larger computer was submitted to the National Science Foundation. Although this proposal received favorable reviews by expert groups within and outside the NSF, inadequate funds have made it necessary to defer acquisition of the larger machine.

Engineering Services. This department was responsible for the completion and installation of the second Kitt Peak and the Cerro Tololo 36-in. telescopes, and for the 24/36-in. Michigan Schmidt telescope, together with supervision of the building construction and assembly of the rotating domes. The Chile 60-in. telescope and building project is nearing completion; and a 78-in. aluminizing chamber was designed, built, and delivered to Cerro Tololo. The design and specifications for the 150-in. mirror grinding machine were completed, and a contract for its construction was awarded to the L & F Machine Company, Huntington Park, California.

An outstanding activity of the engineering services department is its world-wide sharing with other astronomical institutions of drawings which are the result of thousands of man-hours of engineering, designing, and drafting. These drawings are made available at reproduction cost to U. S. groups upon request; for foreign groups, approval of NSF is required. More than 900 Observatory drawings were provided during the fiscal year to fill the many requests received from applicants at home and abroad. Many of the instruments designed and built, or modified, for the Kitt Peak and Cerro Tololo telescope installations are described in the preceding divisional reports, and in previous annual reports. To supplement these drawings, a new series of Technical Reports has been started. The first, "Introduction to the Design of High-Vacuum Metalizing Chambers," was written by Mr. A. S. Brar, assistant engineer. This report and subsequent ones are available upon request to the Office of the Director.

The 117 Observatory engineering and design jobs on the docket as of 30 June 1967, will take approximately 20 months to complete, based on the workforce man-hours presently available. In addition, research and development work planned for the next 6 to 7 years will require 24,000 man-hours. In addition to this paper work, the 83 instrument shop metal-work jobs scheduled will require 22 months to complete, after allowance for the 15% of the shop work that will be done by outside purchase orders or contracts.

Optical Shop. The secondary mirrors for the Chile 60-in. telescope, and new optics for both 36-in. telescopes on Kitt Peak were completed. The second 36-in. telescope mirrors are of aluminum, while those of the first one are of Pyrex figured to an f/7.5 Ritchey-Chretien system and an f/13.5 Cassegrain focus. The mirrors previously in use are installed in the Chile 36-in. telescope.

Work continued on the coude spectrograph optics for the 84-in. telescope, and several Schmidt corrector plates of 20-in. diameter were completed. Some experimental work with different methods of grinding, polishing, and testing was carried out for a variety of materials, including metals, quartz, and CER-VIT.

A 16-in. mirror, figured to the same radius of curvature as the 150-in. primary, was used to investigate the seeing conditions in the vertical testing tower, and the air stability was found to be satisfactory.

Electronics Research Laboratory. A technique for automatic guiding on a star has been developed by Mr. Warren Ball. In this system, the optical image falls upon an image-dissector type of photomultiplier tube, and the photoelectron image of the guide star is electronically scanned past an aperture by deflection coils to develop error signals. The outputs are fed to a pulse-counting preamplifier, and digital techniques are used exclusively to control the correction motions. The system is very sensitive, producing good guiding signals from a 12th magnitude guide star in the 84-in. telescope. This method offers the advantages of a high scanning rate, no moving parts, and high sensitivity. The guider is being adapted for use on a two-
coordinate photographic camera being developed by Dr. A. A. Hoag.

An experimental, thermoelectrically-cooled photometer cold box has been developed and tried on Kitt Peak. It provides an operating temperature adjustable to \(-57^\circ\text{C}\) with a maximum power dissipation of 160 watts. No operational defects were discovered, with the exception of the need to seal properly the insulation against moisture.

An improved and more versatile approach has been taken on the design of the 150-in. telescope control system. Logical design techniques have been used to allow versatile control functions, and to make it easy to connect the 150-in. telescope control computer into the command systems, if desired. Also, a punched-card system of record keeping, using the CDC 3200 computer, has been programmed for the 150-in. telescope, and it is expected that this system will be extended to the other telescopes on Kitt Peak and Cerro Tololo.

The initial electronic equipment required for the Cerro Tololo telescopes was provided by building new electronic modules according to the standard designs developed and checked out for use at Kitt Peak. This work included equipment for photometric observations, telescope drive control, and the spectrograph comparison source power supplies. All this equipment has been installed and is being maintained by Chilean personnel supervised by Sr. Sergio Cathalifaud on Cerro Tololo.

**Construction**

_Tucson Headquarters_. The previously announced new wing for offices and laboratories is well along in construction, with completion scheduled for October 1967. When finished, it will provide 27,000 sq ft on two floors: a full basement mainly for laboratories, and a ground-level floor for offices and a computer room. The footing and load-bearing walls will be strong enough to add up to five floors, in the event of future needs. Much of the new wing will be occupied by Space Division staff, especially the engineering and technician groups for the rocket flight program, who have occupied rental space during the past two years.

_Kitt Peak_. The second polaris image motion analyzer (PIMA) building and tower of the Physics of Seeing Program were moved from the 150-in. telescope site to the southwest ridge, following blasting and removal of materials from the site and bulldozing of an access road. Construction of the building for the second 36-in. telescope required that the anemometer be moved from the top of a 100-ft scaffold and be installed on the top of the first PIMA tower adjacent to the first 36-in. telescope.

Modernization of the restrooms in the public picnic area has been completed, and drinking water has been made available there. The entire 12.2-mile Kitt Peak Road, from State Highway 86 to the Observatory grounds, has received its permanent 2½-inch rolled bituminous cake paving, along with many more guard rails, berms and scalings of slide areas, in order to bring the road to standards acceptable for inclusion in the State highway system.

**AURA Board and Observatory Staff**

_Officers_. At the annual meeting, 14 March 1967, the AURA Board of Directors re-elected Dr. Rupert Wildt, Yale University, and Mr. G. L. Lee, Jr., University of Michigan, president and vice president, respectively. Mr. Lee, now Vice President for Business and Finance of the University of Chicago, replaced Mr. W. B. Harrell, who retired from the Board and who was honored with a resolution, expressing appreciation for his many services since the formation of AURA in October, 1957. Mr. Pierpont replaced Mr. Lee as administrative representative from the University of Michigan. Dr. W. A. Hiltner, Yerkes Observatory, University of Chicago, was named chairman of the Scientific Committee. Dr. John S. Hall, Lowell Observatory, Flagstaff, Arizona, and Prof. Claudio Anguita, Director of the University of Chile's National Observatory on Cerro Calán, Santiago, were elected directors-at-large for 3-year terms; Dr. Hall succeeds Sr. Enrique d'Etigny, Dean of the Faculty of Sciences and Mathematics, University of Chile, who was appointed a consultant to the Board. Staff officers re-elected are: Mr. J. M. Miller and Miss Julie Elliott, secretary and assistant secretary, respectively; Mr. Minton Moore and Mr. Clarence M. Black, Valley National Bank, treasurer and assistant treasurer, respectively.

Other Board members whose terms expired in 1967 were re-named by their respective universities to serve three more years; the present composition of the Board is the following: University of California: Dr. A. E. Whitford and Mr. Earl C. Bolton. Universities of Chicago and Texas: (Joint Membership) Dr. W. A. Hiltner and Mr. G. L. Lee, Jr., Dr. Norman Hackerman (Special Consultant). Harvard University: Dr. Leo Goldberg and Mr. L. G. Wiggins. Indiana University: Dr. F. K. Edmondson and Mr. J. A. Franklin. University of Michigan: Dr. O. C. Mohler and Mr. W. K. Pierpont. Ohio State University: Dr. Arne Slettebak and Dr. G. B. Carson. Princeton University: Dr. Lyman Spitzer and Mr. R. J. Woodrow. University of Wisconsin: Dr. A. D. Code and Mr. Reuben Lorenz. Yale University: Dr. Rupert Wildt and Mr. C. S. Gage.
Directors-at-Large: Lowell Observatory, Flagstaff, Arizona: Dr. John S. Hall. Dyer Observatory, Vanderbilt University: Dr. R. H. Hardie. Mees Observatory, University of Rochester: Dr. S. L. Sharpless. National Observatory, University of Chile: Prof. Claudio Anguita.

Staff. As of 30 June 1967, the Observatory had a personnel roster of 234 full-time employees distributed among three scientific divisions and one administrative division as follows: Stellar, 18; Solar, 12; Space 41; Administration, 163, which included the following groups: Office of the Director and Associate Director-Administration, 4; Accounting, 10; Purchasing, 6; Business Office, 6; Library, 3; Engineering and Instrument Shop, 48; Optical Shop, 9; Electronics Research Laboratory, 16; Photographic Laboratory, 3; Computer Laboratory, 4; Operations Tucson HQ, 19, and Kitt Peak 25. In addition, there were 75 part-time and temporary employees, including 18 Summer Research Assistants from 11 colleges and universities, 10 graduate students from the University of Arizona, and 32 members of the Papago Indian Tribe who worked on Kitt Peak. Only 8 person in the maintenance force of 44 were resident on the mountain.

There was one new appointment to the scientific staff: Dr. R. J. W. Henry, assistant physicist, Space Division, effective 19 September 1966.

CERRO TOLOLO INTER-AMERICAN OBSERVATORY

New Director. On 16 June 1967, the Executive Committee of the AURA Board of Directors approved the appointment of Dr. V. M. Blanco as Director and astronomer, CTIO, to become effective 15 July 1967. Before this appointment, Dr. Blanco was Director of the Astrometry and Astrophysics Division, U. S. Naval Observatory, Washington, D. C., and, previously, was professor of astronomy at Case Institute of Technology, East Cleveland, Ohio. In 1961 he served UNESCO as a consultant in astronomy at the Bosscha Observatory in Indonesia, where he supervised the installation of a new Schmidt-type telescope. Dr. Blanco received his Ph.D. degree from the University of California, Berkeley, in 1949. During 1966 and 1967, and prior to Dr. Blanco's appointment, Drs. F. K. Edmondson, Alex G. Smith, W. A. Hiltner, and O. C. Mohler, of the AURA Board, and Dr. A. A. Hong, of KPNO, served as acting directors at CTIO.

Observing Conditions. There were 257 photometrically useful, 50 spectrographically useful, and 58 useless nights during the 12 months. January and February 1967, had perfect records with 31 and 28 useful nights, respectively. July and August 1966, and May 1967, had the poorest records with 12, 11, and 12 useless nights, respectively.

With 307 useful nights (84%) for observations, and with five telescopes coming into operation, it was necessary to provide support staff for the observers. For this purpose, Srs. C. Bolelli and R. Gonzalez were named night assistants. Also, since the nighttime transparency and seeing have continued to be so superior, it seemed worthwhile to examine the daytime conditions. As the first step in this direction, Dr. John G. Kirk, of KPNO's Solar Division, worked on Cerro Tololo for several weeks in November 1966, with a sky-brightness meter that measured the scattered light close to the sun. These preliminary observations indicated coronographic quality to a degree justifying a more extended program, which should include suitable instrumentation for solar seeing measurements.

Facility Construction. The main warehouse on the mountain was completed in July 1966. The dining-dormitory building, started the same month, is due for completion in the early spring (southern hemisphere) of 1967. In August 1966, construction was started on the vehicle maintenance building. The electronics and instrument shop was completed and occupied in January 1967. Five workers' cottages were completed and occupied during this month and the next. Remodeling of Casa No. 3 in La Serena was completed, and the house was occupied during March 1967. On Cerro Tololo, work began that month on the office building, which at the end of the report period was approximately 35% complete.

Instrumentation and Telescope Construction. Erection of a building to house the Curtis f/3.5 Schmidt-type telescope of the University of Michigan was commenced in October, 1966. The telescope components arrived by February, 1967, and by May this telescope was installed in the new building and put into operation. By agreement between AURA and the University of Michigan, § of the observing time with this telescope is available to CTIO visitors and staff members.

The components of the 36-in. telescope (f/13.5 Cassegrain system) were received in Chile by December, 1966, and were assembled for temporary operation on an outdoor concrete pad in January, 1967, pending erection of the dome on the building. The dome was received and erected the following month. The telescope was later transferred to its own building and was again in operation in April, 1967.

The components of the 60-in. telescope (modified Richey-Crétien) with f/7.5 and f/13.5 secondary mirrors, and the dome for the building to house this telescope, arrived at Cerro Tololo during the interval August 1966, to March 1967. Installation began in May, and by 1 July the dome and telescope mounting had been erected, and awaited installation of the optics and of the electrical sub-
systems. The installation of the various telescopes and domes described so far was supervised by Mr. Dwight J. Ludden, manager of engineering services at KPNO.

In October 1966, a two-prism spectrograph designed by Dr. W. A. Hiltner and used by him at the Yerkes Observatory for MK spectral classification, was received on Cerro Tololo and adapted for operation with the 16-in. telescopes.

Visitor Research. Twenty-two observers, including 4 students, from 5 countries on 3 continents and representing 11 observatories, used the 36-in., the 24/36-in. Michigan–Schmidt, and two 16-in. telescopes as follows:

H. Albers, Vassar College Observatory, Poughkeepsie, New York, 12 nights for a 10th objective prism infrared Milky Way survey.

J. Barnes, Kitt Peak National Observatory, Tucson, Arizona, 13 nights for Hβ and four-color photometry of bright, early-type stars and Sco I Association members.

S. van den Bergh, David Dunlap Observatory, Toronto, Canada, 16 nights for seven-color photometry of galactic globular clusters.


D. L. Crawford, Kitt Peak National Observatory, 5 nights for Hβ and four-color photometry of bright, early-type stars.

A. Feinstein, University of La Plata, Argentina, 17 nights for UBVRI photometry of Am, Ap, and variable stars.

J. C. Golson, Kitt Peak National Observatory, 18 nights for Hβ and four-color photometry of bright, early-type stars.

J. A. Graham, Kitt Peak National Observatory, 11 nights for Hβ and four-color photometry of horizontal branch stars.

E. Hardy, University of Chile, Santiago, 21 nights, scanning of late-type stars.

G. Hill, Louisiana State University, Baton Rouge, 13 nights for UBV, Hβ, and four-color photometry of IC 2391 and IC 2502.

W. A. Hiltner, Yerkes Observatory, University of Chicago, 68 nights for spectroscopic observations of bright B-type stars, and photometry and polarization of Sco XR-1.

A. A. Hoag, Kitt Peak National Observatory, 15 nights for Hγ, Hβ, and four-color photometry of bright stars.

J. B. Irwin, CARSO, 36 nights for spectra and scanning of late-type stars, UBV photometry of SV Cen.

M. Isacson, University of Chile, Santiago, 11 nights for spectral scanning of G-type dwarf stars.

A. U. Landolt, Louisiana State University, Baton Rouge, 18 nights for UBV photometry of eclipsing systems V 346 Cen and W Crv.

D. J. MacConnell, University of Michigan, Ann Arbor, 51 nights for four-color photometry of high-velocity stars, monitoring of the flare star AD Leo, and a 10th objective prism Milky Way survey.

D. Mook, Yerkes Observatory, University of Chicago, 52 nights for photometric monitoring of Sco XR-1.

H. Moreno, University of Chile, Santiago, 29 nights for spectral scanning of early-type stars in the Sco-Cen Association.

C. Perry, Louisiana State University, Baton Rouge, 26 nights for Hβ and four-color photometry of the clusters NGC 6231 and NGC 2602.

T. Schmidt-Kaler, University of Bochum, West Germany, 10 nights for UBV and Hβ photometry of OB stars, and Hα and four-color photometry of globular clusters.

S. Tapia, University of Chile, Santiago, 40 nights for UBV photometry of SX Pho.

C. Torres, University of Chile, Santiago, 21 nights for UBV photometry of W Ser and SX Pho.

Staff Research. Dr. N. Sanduleak, the only resident staff astronomer at CTIO during the report year, initiated a survey of high luminosity stars in the southern Milky Way with the Curtis-Schmidt telescope. This survey is an extension of the Case-Hamburg survey of OB stars, and the plate analysis will be carried out at the Warner and Swasey Observatory, Case Western Reserve University, Cleveland, Ohio.

PUBLICATIONS

Staff members as well as visiting astronomers and graduate students, who are doing research at either Kitt Peak National Observatory or Cerro Tololo Inter-American Observatory, and whose work is subsequently to be published, are included together in the following list:


Barnes, J. V. See Crawford, D. L.


Belton, M. J. S. See also Goody, R. M.


Biggs, E. S. See Abt, H. A.


Breda, I. G. van. See Wolstencroft, R. D.


Burke, P. G. See Smith, K.

Campbell, F. J. See Chamberlain, J. W.

Chaffee, F. R. See Abt, H. A.


Cruikshank, D. P. See Binder, A. B.

Dachs, J. See Haug, U.


Davidson, D. See Lutnes, J. H.


Faure, B. J. See Crawford, D. L.


Ford, W. K. See Rubin, V. C.

Godson, W. L. See Hunten, D. M.

Golson, J. C. See Crawford, D. L.


Goody, R. M. See also Belton, M. J. S.

Graham, D. See Hiltner, W. A.


Henry, R. J. W. See also Smith, K.


Hunten, D. M. See also Belton, M. J. S.


Livingston, W. C., and Orville, R. E. 1967, "Color Through a Raindrop," Natural History 76, No. 5, 44–45.


Ludden, D. J. See also Hiltner, W. A.
Lynds, C. R. See also Burbidge, E. M.
Mcelroy, M. B. See also Belton, M. J. S.
Mcelroy, M. B. See also Dalgarno, A.
Mcelroy, M. B. See also Henry, R. J. W.
Maran, S. P. See Brandt, J. C.
Michie, R. W. See also Hodge, P. W.
Mook, D. E. See also Hiltner, W. A.
Moreno, H. See Gutierrez-Moreno, A.
Perry, C. L. See Crawford, D. L.
Pesch, J. See Haug, U.
Pfleiderer, J. See Haug, U.
Robinson, A. R. See Goody, R. M.
Rose, L. J. See Wolsstencroft, R. D.
Spinrad, H. See Illovaisky, S. A.
Stephenson, C. B. See Johnson, H. M.
Stewart, A. I. See Dalgarno, A.
Stock, J. See Gutierrez-Moreno, A.
Swings, J. P. See Lambert, D. L.
Torres, C. See Gutierrez-Moreno, A.
Trumbo, D. E. See Brandt, J. C.
Walker, J. C. G. See Dalgarno, A.


Wroblewski, H. See Gutierrez-Moreno, A.

N. U. Mayall, *Observatory Director*