Various photographic supplies and equipment have been obtained during the year for processing, storage, and sensitizing plates. In order to obtain spectroscopic plates rapidly and at a reduced cost, a direct dealher has been established with the Eastman Kodak Company. A new Bausch and Lomb grating (600 grooves/mm, first-order blaze at 1 μ) has been installed in the Petit spectrograph yielding a dispersion of 160 Å/mm in the first-order near infrared. Hartmann tests, adjustments, and calibration have been carried out by Wehinger and Smiley.

RESEARCH

Wyckoff and Wehinger obtained minimum-light near-infrared spectra of Mira variables with very long periods (P ≈ 350 to 450 days). These objects range from M8 (RX Boo) to M10 (R Cas). Spectrograms (165 Å/mm) were secured at Kitt Peak National Observatory and at the University of Michigan on ammonia-sensitized I-N plates (1971, Astrophys. J. 164, 383). They also published a study of the near-infrared spectral variations in the long-period variable V Cas (1971, Publ. Astron. Soc. Pacific 83, 89).

Wyckoff obtained a spectrum of the S-type long-period variable, S Lyr, at minimum light (m_v = 14.5) at Kitt Peak. The spectrum exhibits four unidentified red-degraded bands (λ = 8273, 8469, 8610, and 8817) originally found in S-type stellar spectra by Keenan. Among the molecules which may give rise to these bands is molybdenum oxide [see Bull. Amer. Astron. Soc. 3, 242 (1971) and Astrophys. J., in press (1972)].

Wehinger and Wyckoff are carrying out line identifications in the λ 7000-9000 region of a 4.5-Å/mm spectrogram of Mira at maximum light.

Wyckoff is analyzing UBV photometric observations of the short-period eclipsing binary W UMi which were obtained at Kitt Peak. She also observed six more Mira-type long-period variables at minimum light in the near-infrared at Kitt Peak during June 1971.

Gandet has taken spectrograms (44 Å/mm) of four late B-type binaries: VS 05 Sgr, HR 6928, HR 7305, and HR 8861. Provisional orbits were derived for all of these systems except HR 7305. He secured these observations at Kitt Peak with support of a KU Undergraduate Research Grant during August 1970. Publication of these observations is in preparation.

CURRICULUM

The astronomy curriculum has been completely revised and updated. A two-year major's sequence of four courses has been introduced to provide a broad survey of stellar and galactic astronomy (one semester each) as well as an introduction to astrophysics (two semesters). There are currently 22 undergraduate astronomy majors and 150 to 175 students are enrolled in the elementary survey course each semester. A seminar for astronomy majors, "Current Topics in Modern Astronomy", was offered during the spring term. There has been strong interest among the students to expand the general and technical course offerings. At present, all the B.A. and M.A. degrees are offered. Graduate students working toward the Ph.D. in physics can do a thesis in astronomy if they so desire.

REGIONAL ACTIVITIES

In the fall of 1970, several meetings were held with astronomers and physicists of the following state universities: Arkansas, Kansas, Kansas State, Oklahoma, Oklahoma State, and Wichita State to discuss the possibility of establishing a Regional States Observatory with a moderate size (50-60-inch) telescope. Among the astronomers in the group, Dr. John C. Evans, of Kansas State University, has devoted considerable effort over the past several years studying possible sites and feasible facilities for such an observatory. Wehinger drafted a proposal which suggested that the observatory be located on the southwest ridge of Kitt Peak in accordance with the AURA "open-door policy." Others in the group support a closer site, located near Bartlesville, Oklahoma. At present the question of a site remains the major unresolved problem.

MISCELLANEOUS

The observatory public nights, which had been directed by Dr. Storer for many years, were continued with his help and a popular lecture series was initiated. During the year, approximately 1000 persons from the university community attended these lectures.

Visiting astronomers during the report period included James Hesser (Cerro Tololo), John B. Irwin (UCLA), Stirling A. Colgate (New Mexico Tech), and Edward B. Jenkins (Princeton).

Support is gratefully acknowledged from the KU Academic Advisory Committee, the General Research Fund and the Computing Center, and from the Mobil Oil Company. We also want to thank the Kitt Peak National Observatory for providing generous amounts of telescope time.

PETER A. WEHINGER, Director

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

I. OPERATIONAL AND RESEARCH HIGHLIGHTS

Some examples of the activities at the Kitt Peak National Observatory (KPNO) and the Cerro Tololo Inter-American Observatory (CTIO) are as follows for the annual report period (1 July 1970 through 30 June 1971):

Visitor Telescope Usage: Six stellar telescopes of apertures 84, 50, (2) 36, and (2) 16 inches [2.1 m, 1.3 m, (2) 92 cm, and (2) 40 cm], were operated on Kitt Peak.
during the report year in support of 100 visiting astronomers and 46 graduate students who came from 60 astronomical organizations in the United States and from five other countries. Visitors were scheduled for 1230 project-nights of observing time, 56% of the total available time, disregarding down time, unscheduled time, maintenance time, the "monsoon" summer rainy season, or use of the instruments by summer research assistants. On the same basis, the two largest telescopes were assigned to visitors 65% of the time.

The observing facilities of the McMath solar telescope were used by 51 visitors, including seven graduate students and 16 NASA astronauts from Houston who came for training in solar physics for the ATM Skylab mission.

Statistics for CTIO show that during the report year observations were carried out during 295 nights. Approximately 75% of these nights were of photometric quality. During the year, 66 visitors representing 35 institutions carried out observational research programs on Tololo. The telescope observing time was apportioned as follows: 55% to U.S. astronomers (including eight graduate students, but excluding KPNO staff); 11% to Latin American astronomers (plus five Chilean students); and 8% to Canadian and West German observers. The remaining 26% of the time was assigned to KPNO and CTIO staff members.

Research Highlights—Kitt Peak: Dr. T. D. Kinman is completing the analysis of over 2000 photographic observations of variable quasistellar sources and is continuing polarization observations of a number of these objects. Notable results include evidence for marked changes in the polarization of 3C 446 (ranging from a high of 26% in July 1970 to a low of 4% in September 1970), and for the correspondence of rapid variations in the brightness of the source OJ 287 with similar variations at millimeter and centimeter wavelengths observed elsewhere.

Dr. C. R. Lynds has continued his high-resolution, image-tube spectroscopic studies of quasistellar objects. In the case of the source 4C 05.34, his material shows an exceedingly complex absorption-line spectrum. Although the emission-line redshift is \( Z = 2.88 \), analysis of the absorption-line redshifts indicates a number of discrete "cloud" velocities ranging down to \( Z = 2.47 \).

Dr. V. Petrosian and Lynds completed a study of the relative effectiveness in cosmological investigations of source-count and luminosity-volume analyses.

Major activity in infrared programs has continued, primarily with the 1.3-m reflector, with much of the work involving investigation of circumstellar material and other infrared emitters. The observations have been aided by the development of 1- to 20-\( \mu \) photometric equipment by Dr. H. M. Dyck and Dr. G. W. Lockwood. Observers have been: Lockwood and Dyck of the KPNO staff; Dr. S. E. Strom, Mrs. K. M. Strom, and Dr. A. L. Brooke, State University of New York at Stony Brook; Dr. N. J. Woolf and R. D. Gehrz, University of Minnesota; Dr. W. A. Stein and Dr. F. C. Gillett, University of California at San Diego; M. C. Jennings, University of Arizona; S. J. Shawl, University of Texas; M. T. Sandford, Indiana University; J. H. Baumert, Ohio State University; and Dr. J. A. Frogel, California Institute of Technology. Dr. I. J. Danziger and Dr. E. E. Becklin, Harvard University and California Institute of Technology, respectively, have also completed an infrared investigation of galaxy nuclei, with use of their own equipment on the 2.1-m telescope.

Dr. J. R. P. Angel, Columbia University, and Dr. J. D. Landstreet, University of Western Ontario, have continued their studies of circular polarization of the light from selected white dwarfs. Their work has increased the number of objects known to exhibit this phenomenon, and has shown how the circular polarization varies as a function of wavelength and time for some of these stars.

Dr. H. A. Abt has continued his investigations of frequency of binaries, and of determinations of stellar rotation among Ap stars and stars in open clusters.

Dr. D. L. Crawford and collaborators have published a large fraction of their \( u \)-band and \( H \)-band photometry of standards, field stars, and stars in open clusters and associations, which advances the standardization of the system for spectral-classification and absolute-magnitude determinations.

Dr. J. D. Wray, Northwestern University, and Dr. G. J. Corso, Kendall College, have applied a new method for the discovery of faint Wolf-Rayet stars to two fields in M33. They found 25 of these objects in this initial survey to limiting mag 19.

Dr. H. J. Rood, Dr. T. L. Page, and their collaborators at Wesleyan University are completing an extensive radial-velocity study of galaxies in the Coma cluster by means of image-tube spectroscopy.

Dr. M. J. Price, Illinois Institute of Technology, with technical help from a number of KPNO staff members, applied an image tube at the 2-\( \AA \)/mm coude camera of the 2.1-m telescope to the study of \( H_2 \) quadrupole lines in the spectra of Uranus and Neptune. Good results were obtained for Uranus, but a signal-to-noise ratio better than obtained in these initial observations will be required for Neptune. Additional observations that will use techniques developed during this trial are planned for Neptune.

D. E. Trumbo has interfaced a number of telescope observing instruments with a computer system he calls TELCOM 1. The Honeywell 416 computer and specialized interface interact with the instruments through a command unit and a serial transfer communication system that can be operated at any one of four telescopes. Computerized control, data acquisition, and analysis is now possible for the Harvard-designed, Wampler-type spectrophotometric scanner, for an image-dissector scanner, for the Dyck polarimeter, and for the Kinman photometer.

Dr. I. J. Danziger, N. Hazen, and S. Diamond, Harvard College Observatory, spent some time at Kitt Peak in the fall of 1970 testing one of the two two-channel spectrophotometric scanners of the Wampler type built by the Harvard Solar Satellite Project Group for AURA. The second instrument will be used at CTIO. Dr. G. W. Lockwood is in charge of the instrument for KPNO, where further operational tests are scheduled.

The optical and mechanical work has been completed on the large, infrared spectrometer being installed in the McMath solar telescope on Kitt Peak. It now awaits the 14.5- by 18.5-inch grating being ruled by Dr. G. R. Har-
rison at the Massachusetts Institute of Technology.

The 36-inch metal mirror of the east auxiliary system of the solar telescope, which was damaged in an accident, has been replaced with a 42-inch CER-VIT mirror obtained from the core of the CTIO 158-inch primary mirror blank.

Replacement of the original, main set of optics in the McMath solar telescope is underway. Three CER-VIT blanks were purchased, and grinding of the 82-inch heliostat flat is progressing. New mirror cells and support systems are under design.

Dr. J. W. Brault, Dr. A. K. Pierce, and others on the staff have completed and published their observations of the central intensities of 40 Fraunhofer lines between 3200 and 6800 Å. From spectra obtained with high-dispersion photoelectric traces, Brault has found many new lines, and he has analyzed in detail the red system of CN in the Sun.

Dr. D. N. Hall continued his infrared spectroscopy of sunspots during the past year, with equipment developed earlier for the vacuum spectograph.

Dr. J. W. Harvey, in his studies of solar magnetic fields, has carried on several programs, including observations of helium lines, work on the photographic sunspot spectrum atlas, and participation in a world-wide project to uncover systematic errors in magnetograph measurements.

Dr. W. C. Livingston developed (with O. Engvold) a classification system for quiescent prominences, and made high-dispersion studies of prominences. In them he found a trend toward super-rotation of the upper regions of quiescent prominences that has been dubbed the "San Manuel effect".

Dr. R. W. Milkey investigated the line-formation problem for helium by means of a computer code he converted and modified to operate on the Observatory's CDC 6400 computer system. He is continuing reduction of measurements of solar flare x-ray fluxes recorded by instruments aboard Vela satellites, a project that he began at the Los Alamos Scientific Laboratory.

Dr. A. K. Pierce continued his long program of wavelength determination of Fraunhofer lines, obtaining 164 plates this report year. Measurement and reduction of these previous plates progresses steadily.

Dr. N. R. Sheeley, Jr. (with Dr. A. Bhatnagar) obtained high-resolution Doppler spectroheliogram movies of sunspots and their surroundings in order to study the velocity fields. He has also continued his study of bright faculae with the assistance of several students.

Dr. E. J. Weber pursued his theoretical work on the solar wind, with the inclusion of thermal conductivity. With Dr. D. F. Strobel, he studied the properties of the flow equations of a plasma with source terms composed of two ions.

During the report year, two sounding rockets were launched and successfully fulfilled their missions. The first, KP 3.32, was launched on 1 March 1971. Principal investigator was Dr. L. Wallace, KPNO Planetary Sciences Division, with the purpose of observing any radiation of deuterium from Venus. KP 3.37 was launched on 28 May 1971, with Dr. D. C. Morton, Princeton University, as the principal investigator. The Aerobee 150-M1 rocket carried a scientific payload to photograph the ultraviolet spectra of several stars in the constellation of Scorpio.

Ground-based planetary astronomy was carried on with the development of new instrumentation, such as a very-high-resolution Fabry-Perot spectrometer, a Connex-type Michelson interferometer, and a high-resolution 3.34-m spectrometer; the last was used by Dr. T. D. Parkinson, Dr. D. M. Hunten, and I. Gordon at the CTIO 60-inch (1.5-m) telescope for an observational program during the 1971 Mars opposition. The other major subjects for study have been the night airglow and the atmosphere of Venus.

In theoretical research programs focused on planetary atmospheres, Dr. J. W. Chamberlain calculated various characteristics of a light gas escaping from a planetary atmosphere, and Dr. D. F. Strobel studied the production of nitric oxides in the Earth's upper atmosphere and their mixing down into the stratosphere. He and Wallace studied the relevant problem of diurnal variation of atomic hydrogen in the Earth's thermosphere.

Several staff members are actively involved in the science for future NASA spacecraft missions. For the Mariner Venus/Mercury Swingby Mission, Dr. A. L. Broadfoot, Dr. M. J. S. Belton, and Dr. M. B. McElroy have had accepted a proposal to search for the presence of an atmosphere on Mercury by solar occultation, and to identify likely constituents on Mercury and Venus by ultraviolet airglow. As a result, two simple, low-cost, body-fixed extreme ultraviolet spectrometers are being designed.

The imaging science team for this mission, of which Belton is a member, has decided upon the conceptual design for the TV system; it will consist of two identical 1500-mm focal length Cassegrain cameras.

Belton has also been appointed team leader for the imaging experiment in the definition phase of the Grand Tour of the Outer Solar System, another future NASA endeavor.

Research Highlights—Cerro Tololo: During the report year a variety of research programs have been undertaken by staff and visiting astronomers. Dr. M. G. Smith has studied radial velocities in the Magellanic Clouds. Dr. B. M. Lasker and Dr. J. E. Hesser, in a study of periodic variables, concentrated on the white-dwarf star R548. Dr. J. A. Graham continued his search for novae in the Magellanic Clouds and two were discovered during the 1970-71 observing season. A "hot spot" in the center of the peculiar galaxy NGC 5128 was studied by Dr. W. E. Kunkel and his collaborator, Dr. H. Bradt of M.I.T. Dr. P. Osmer has observed known and suspected F-type supergiants in the Magellanic Clouds with narrow-band interference filters to determine the strength of the O I 7774 triplet.

A project to determine the precise geodetic and astronomical positions of Cerro Tololo was begun by Dr. R. Harrington, U.S. Naval Observatory, Washington, D.C., and Dr. and Mrs. V. M. Blanco.

Visitors' research activities have included observations of Eta Carinae, optical observations of x-ray sources in coordination with satellite and radio observations, and studies of galactic structure.

Research on Tololo has been enhanced by new instrumentation during the past year. This includes: (i) an IBM 1130 computer system installed at the La Serena headquarters; (ii) the inter-connection of the 60-
of this instrument, construction lead-time is such that completion is unlikely before the telescope is ready. Therefore, an "intermediate" model is being prepared that will function as a manually operated guiding system pending completion of the fully automatic unit. The intermediate model can later be converted to form the second of the two scheduled automated units.

A subcontract for design, drawings, and working specifications for the basic Schmidt camera of the Cassegrain spectrograph was let, and the work will be reviewed by Dr. I. S. Bowen, who is acting as AURA's consultant for the project. Detailed design work continues on the spectrograph itself.

All these instruments will be built in duplicate, one set for KPNO and the other for CTIO.

(iv) Optics. During the first half of 1971 the KPNO 158-inch primary mirror approached an acceptable state of completion after nearly two years of continuous work in the optical shop.

In recent months, much emphasis was placed on refining test procedures and in correlating results from different tests. In general, Hartmann testing is used to check the over-all figure after a polishing run, while knife-edge test photographs are used as an interim check to determine where to polish locally.

During early stages of grinding and polishing, a refined test method was not essential, but as 1970 drew to a close, more sensitive tests were needed. Until then, an 80-hole Hartmann screen had been used, but the resolution of surface features was inadequate and the correlation with other tests was unsatisfactory. Therefore, a rectangular-grid screen with 440 holes was built in the KPNO shops, with a hole position accuracy of 0.004 to 0.006 inch over the screen. A special feature of the screen is the option to change hole size (and resultant diffraction pattern) from 1.0 inch to 2.75 inches in diameter by popping out special hole covers.

This screen produces test-result accuracy to about 0.2λ, which, in turn, enables contour mapping of surface features with enough resolution to identify them with corresponding features discernible in knife-edge photographs.

The current testing procedure requires the exposure of at least three photographic plates, with a laser on-axis light source to illuminate the mirror through the 440-hole screen. The coordinates for each hole image are then measured on each plate with the Grant profile measuring engine, and this information serves as the raw data for the computer reduction program. Measurement error is approximately 1 μ, which does not significantly affect final results.

Computer calculation of the image position errors, caused by deviations in slope from the theoretical surface at the places where the light pencils fall on the mirror, is followed by an integration program to establish at each such point the apparent height of the mirror surface above or below an arbitrary reference plane. Print-out of the data yields: (i) numerical values for slope and height at each hole position; (ii) tabulation of light-energy concentration versus focal-plane image size; (iii) an rms value for all measured surface deviations; and (iv) a contour map of the mirror surface.
As of 30 June 1971, more than 80% of the reflected light was concentrated within 0.5 arc sec, and the rms surface deviation was less than 20.3λ.

The CER-VIT mirror blank for the CTIO telescope is being stored in Tucson, and optical work on it will not begin until the KPNO mirror is removed from the grinding machine, sometime in the last half of 1971.

[v] Telescope Computer Systems. For compatibility and versatility, it was decided, following extensive study and consultant advice, to revise the computer systems initially proposed for both 150-inch telescopes, as well as those for the other stellar and solar telescopes, and new bids for these systems have been solicited. This decision will lead to compatible computer systems for nearly all AURA telescope facilities. The previously defined system was not entirely compatible, partly due to hardware obsolescence.

The new approach involves building a basic, but incomplete computer system to perform essential functions for the 4-m and other telescopes, while retaining the option of full development later. Such an initial system will include a central processing unit, a teletype, a magnetic tape unit, a paper tape reader, a disk or drum storage, a video display, and a data acquisition/transmission link connecting several elements of the system. At a later time the system could be completed by adding a second central processing unit to provide automatic telescope control and development of more complete software. Such a modular system will allow for future development of elements without making the rest of the system obsolete.

II. KITT PEAK NATIONAL OBSERVATORY

A. Stellar Division

I. Personnel Notes

Staff Changes: During the report year the following staff changes occurred: C. Batishko left the Observatory in January 1971 following a year’s work as an 84-inch telescope operator and research assistant to Dr. T. D. Kimman. He has resumed his graduate studies at the Optical Sciences Center, University of Arizona.

C. T. Mahaffey III began work as a research assistant to Kimman in January 1971.

C. Allen began working for Kimman as a part-time student assistant in February 1971.

T. Gandet worked with Dr. H. A. Abt as a research assistant on spectroscopic studies of binary stars, and as an 84-inch telescope operator from September 1970 through February 1971.

M. Jennings terminated his part-time student research assistantship in December 1970. He worked for Abt on analysis of coude spectrograms, and with Dr. H. M. Dyck on polarimetric problems.

S. Bracker joined the staff in February as a part-time scientific programmer, assisting D. E. Trumbo with the TELCOM 1 computer system. He has accepted a full-time position at CTIO, beginning in August 1971.

R. Kron was hired as a part-time student assistant to Dr. A. A. Hoag in March. He is analyzing material taken to monitor sky brightness from Kitt Peak.

Consulting and Visiting Scientists-in-Residence: Dr. A. D. Code returned to the University of Wisconsin in the summer of 1970, after a one-year stay as astronomer assigned to the Director’s office. He completed a study of large telescope arrays and continued his Orbiting Astronomical Observatory research programs.

Dr. P. Pesch was in residence from September 1970 as a visiting scientist at KPNO during a sabbatical leave from Case Western Reserve University and the Warner and Swasey Observatory. He worked on a variety of spectroscopic and photometric problems involving open clusters and galactic structure. He also acted as consultant to the Observatory in Schmidt telescope planning, particularly with regard to alignment procedures for Schmidt telescopes. He returned to Case in August 1971.

Dr. V. Petrovian, Stanford University, was a consulting astronomer at the Observatory from April through June 1971, during which time he continued his work on cosmological problems. In a survey with Dr. C. R. Lynds of available information concerning quasistellar objects, they completed source-count and luminosity-volume analyses.

Dr. R. H. Miller spent the first quarter of 1971 as a consulting astronomer at the Observatory, continuing his work on stellar interferometry. Upon his departure, he presented an invited review paper on “High Resolution in Optical Astronomy” at the 134th meeting of the AAS in Baton Rouge. During his stay, he worked with Dr. D. L. Crawford, Associate Director, Research Support Division.

Dr. S. E. and Mrs. K. M. Strom returned to the State University of New York at Stony Brook, after working at KPNO during the summer of 1970 on a number of projects originated at both Kitt Peak and the Smithsonian Astrophysical Observatory.

Dr. A. L. Brooke, State University of New York at Stony Brook, spent a year in residence at the Observatory while conducting infrared and spectroscopic observing programs at the Catalina Observing Station of the Steward Observatory, University of Arizona, and at Kitt Peak.

T. Gurski, consultant from the University of Arizona, began part-time work with Dr. Lynds in May on development of digital, image-tube systems. He is presently working on amplifiers and data storage equipment for a 40-channel Digicon.

Summer Research Assistants: During the summer of 1970, four students worked as research assistants to staff members in the Stellar Division:

R. Dufour, Louisiana State University, worked on scanner instrumentation problems with Dr. Hoag, and on a spectroscopic program in collaboration with Dr. Perry and Dr. Lee from L.S.U. He left to pursue graduate work at the University of Wisconsin.
2. Staff Activities

Dr. H. A. Abt was Chairman of Section D (Astronomy), A.A.A.S., in 1970; he assumed the responsibilities of Managing Editor of the Astrophysical Journal in April 1971; and he serves the National Academy of Sciences Astronomy Survey Committee as Chairman of its Optical Facilities Panel. Abt serves as thesis advisor for M. A. Smith (Ph.D., astronomy, University of Arizona, December 1970). He also presented colloquia at the Yerkes Observatory and the Washburn Observatory (January 1971) and at the Santa Cruz and Berkeley campuses of the University of California (May 1971).

Dr. D. L. Crawford is President of Commission 25 (Photometry) of the I.A.U., 1970-1973, and a member of the Board of Directors of the A.S.P.

Dr. A. A. Hoag is a member of the AAS Working Group on Photography; Councillor-at-Large, Section D (Astronomy), A.A.A.S.; and on the Meetings Committee of the A.S.P. He presented a colloquium at the University of Virginia, and an address at the dedication of the Rosemary Hill Observatory, University of Florida, in May 1971.

Dr. T. D. Kinman serves as a consultant to the Joint Policy Committee of the Anglo-Australian Telescope and its committee for instrumentation.

Dr. G. W. Lockwood and Dr. H. M. Dyck organized and hosted a Conference on Late-Type Stars, held in Tucson, October 1970, with 40 invited participants and 28 contributed papers. They have edited the proceedings which have been printed and issued as Kitt Peak National Observatory Contribution, No. 554.

3. Instrumentation

150-inch (4-m) Telescopes: Development has proceeded along the lines indicated in last year's Observatory Report (1971, Bull. Amer. Astron. Soc. 3 (No. 2, Part II), 284-348). The manually operated cameras being constructed for the prime focus by the Robert L. Parker Co., Phoenix, and the Wynne two-element silica correctors being made by the Perkin-Elmer Corp., Costa Mesa, California, are scheduled to be delivered in August 1971. Wynne triplet correctors for wider field coverage are also being constructed. An automatic, prime focus camera with photoelectric guiders has been designed, but construction is being deferred in favor of more pressing instrumentation needs.

For the Ritchey-Chrétien focus, the instrument-adapter-rotator and guiding unit have been partially construc-
ted in KPNO shops, and the remaining work contracted out. The detailed design work for the 6-inch, monochromatic beam spectrometer is essentially complete and components are being acquired. A prototype photometer has been completed, and is being tested on the 2.1-m telescope. Design of the Schroeder echelle spectrograph progresses. A direct photography camera will be provided and a number of recently developed instruments will be available, such as the Harvard-designed, two-channel scanner of the Wampler type, the Dyck-Lockwood infrared photometer, and the Dyck polarimeter.

Parts were acquired for a 3.34-m echelle spectrophotometer designed by Dr. T. D. Parkinson and Dr. D. M. Hunten for use at the coude focus.

84-inch (2.1-m) Telescope: Detailed design of a 92-cm aperture coude' spectrograph feed system was completed, and construction by KPNO shop personnel and subcontractors started. The CER-VIT imaging mirror has been figured to the required off-axis paraboloidal shape. This facility is planned for operation in the spring of 1972. In September 1970, Dr. H. A. Abt accepted a 37- by 31-cm Bausch and Lomb replica of a grating ruled by Dr. G. R. Harrison at M.I.T. Necessary modifications are being designed to accommodate the larger optical beam in the spectrograph. An image-tube adapter for the 2-A/mm coude' camera was completed and used. Provisions have also been made to apply "clean room" techniques in the spectrograph enclosure. A quartz-prism image rotator is being constructed for the coude' slits head following trials of an all-mirror system.

Dr. T. D. Kinman tested a prototype photometer for the 4-m telescope at the 2.1-m reflector. He and D. E. Trumbo have incorporated an intensifier-Vidicon system into this instrument for acquisition and centering on fields and objects, since tests show that this aid will be useful in faint-star work; it also will be interfaced with Trumbo's TELECOM 1 computer system for control and data acquisition. The new object guider for the image-tube spectrograph was completed under the direction of Dr. C. R. Lynds. Designed by A. Petri and constructed by J. Bedo, it contains an image-dissector, automatic guider developed by W. Ball, as well as provisions for direct work with plates or image tubes while the spectrograph is in place.

Some operational testing of the Harvard-designed, Wampler-type spectrophotometric scanner was done with the 2.1-m reflector during the year.

A new darkroom has been constructed in the upper part of the east wing of the 2.1-m telescope building; the original darkroom will be exclusively reserved for the coude' spectrograph users when the new coude' feed is completed.

50-inch (1.3-m) Telescope: A new optical system was placed in this telescope in November 1970. The original aluminum mirror and support system were replaced by a lightweight CER-VIT primary that is supported axially by an air bag system and radially by a mercury tube, all in a lightweight cell. The new primary and cell weigh only 820 pounds. A replacement secondary of CER-VIT was also installed. The moment of inertia of the telescope tube was actually reduced by this change. The telescope is now a Cassegrain with an f/2 primary and an f/13.5 final focal ratio. The changeover has resulted in greatly improved optical performance, thereby making the telescope more suitable for sky-limited photometry, as well as for other work, on a scale similar to that of the 2.1-m telescope. A torque drive system has been constructed for both right-ascension and declination axes, and it will be installed in August 1971.

Dr. H. M. Dyck and Dr. G. W. Lockwood completed installation tests of a 1- to 20-μ photometer-polarimeter that had been in service at the 2.1-m telescope since fall 1970. Concurrently, an infrared equipment laboratory was constructed in the lower part of the telescope building.

36-inch (92-cm) Telescopes: The optical systems of both telescopes were replaced in the summer of 1970. A new CER-VIT system that includes two secondaries was installed in the No. 1 telescope, which can be used either as an f/7.5 Ritchey-Chretien or an f/13.5 Cassegrain telescope. The No. 2 telescope's aluminum mirror system was, in turn, replaced by the former f/13.5 Duran-50 optics of the No. 1 telescope. New axial primary mirror support systems were provided for each telescope. The image quality at the No. 2 telescope has been greatly improved as a result of these actions.

Dr. G. W. Lockwood has refined his pulse-counting photometric equipment and developed suitable photomultiplier cold boxes of conventional and "Oke-hemisphere" types. Mrs. J. V. Barnes is testing two multichannel photometers built in the KPNO shops. Dr. A. A. Hoag and W. E. Schoening, with R. Harrison, have produced additional photographic and sensitometric equipment for these telescopes and have improved the image-dissector photometric and spectrophotometric instrumentation. Lockwood is testing the Harvard-designed, spectrophotometric scanner.

16-inch (40-cm) Telescopes and Schulte-Belton Schmidt Camera: Digital voltmeter and printing equipment was added to the No. 3 40-cm telescope data-acquisition rack. The f/2, 30-cm Schmidt camera has not yet been used on the No. 3 mount, but this camera has essentially been completed for tests.

Special Instrumentation: The Kron electronographic tubes were completely refurbished by W. J. Henson under Dr. T. D. Kinman's direction. A "clean room" was completed in the No. 2 92-cm telescope building for handling this equipment on Kitt Peak, and a special laboratory was completed at Tucson headquarters and equipped with apparatus for producing new photocathodes. Henson made and tested a number of photocathodes in trials of this apparatus.

T. R. Gurski, working as a consultant to Dr. C. R. Lynds, developed equipment for use with a Digicon D-40 tube, on order from the Electronic Vision Corp., San Diego, California.

W. E. Schoening innovated and put into service two automatic visibility monitoring cameras; one is on Kitt Peak and the other on Mount Hopkins. He is also conducting an automatic, photographic survey on Kitt Peak to evaluate sky glow brightness from natural and artificial sources.
An infrared site evaluation telescope was installed on Kitt Peak by Dr. J. Westphal, California Institute of Technology. It is one of a number of similar instruments being used to evaluate infrared observing conditions at various sites. The instrument is operated under the direction of Dr. G. W. Lockwood.

AURA has entered into a contract with the Optical Sciences Center, University of Arizona, for a study of three possible configurations for a large Schmidt telescope.

A 250- by 250-mm two-coordinate measuring machine that will accept plates as large as the glass copies of the Palomar Observatory-National Geographic Society Sky Survey was delivered by the Grant Instrument Co., Berkeley, California, at the end of this report period. It will be used with automatic readout equipment.

4. Staff Research

Dr. H. A. Abt, with M. S. Snowden and S. G. Levy, studied the frequency of occurrence of spectroscopic binaries among 62 Ap stars. This work is based on ten coude spectrograms per star obtained with the 2.1-m telescope. Including previously known cases, they found six binaries in a sample of 15 Hg-Mn stars and nine binaries in a sample of 47 Ap stars of other kinds. Their findings show that binaries are not exceptionally frequent among these stars, and that the low mean rotational velocity for Ap stars is probably not due to tidal coupling.

Abt and Levy found that the open cluster IC 4665 has a surprisingly high frequency of binaries, as determined from 2.1-m telescope spectrograms taken at the Ritchey-Chéruit focus. Among the 17 brightest cluster members, only one star seems to have a constant velocity. Orbital elements have been derived for 13 of the binary systems. Among these, only one has a period that is less than 7 days. Synchronization has not yet been achieved in the remaining 12 binary systems, and thus could account for the fact that cluster stars do not have extremely low rotational velocities.

In contrast, the open cluster NGC 2516 membership has a very low mean stellar rotational velocity, and Abt and Levy have found only a few binaries in this cluster. In fact, spectrograms obtained with the CTIO 92-cm and 1.5-m telescopes have revealed only three binaries among the 16 brightest cluster members. In this case, the low stellar rotational velocities seem to be due to a high frequency of occurrence of Ap stars.

Abt and Mrs. Eleanor S. Biggs have collected an additional 4000 references from astronomical journals and observatory publications to complete a reference list of radial velocities with 44,000 entries collected from 1100 volumes. This list was compiled with the help of J. S. Varga on IBM cards and magnetic tape in preparation for publication.

In addition to his responsibilities as project manager for the two 4-m telescopes, and as Associate Director of the Research Support Division, Dr. D. L. Crawford has maintained a productive research program as a stellar astronomer. Apart from the subjects listed in the Publications section of this report, Crawford and his staff collaborators, who include Mrs. J. V. Barnes, J. C. Golson, and Mrs. B. L. Weymann, had the following titles in press: (i) “Four-Color and Hβ Photometry of Bright B-Type Stars in the Southern Hemisphere”; (ii) “Four-Color and Hβ Photometry for Bright A0-Type Stars”; and (iii) “A Faint UBV Extinction Star Network”. Manuscripts were completed on: “Four-Color and Hβ Photometry of Open Clusters. VII: NGC 6231” (with J. V. Barnes, G. Hill, and C. Perry), and “Four-Color, Hβ, and UBV Photometry for Northern Hemisphere B-Type Stars with m_v < 6.75” (with J. V. Barnes and J. C. Golson). This group has a number of additional observational and analytical projects under way: (i) calibration of the uvby and β systems in terms of absolute magnitude and intrinsic color for B-, A- and F-type stars; (ii) relation of the uvby and β systems to other photometric systems and to the MK system; (iii) photometry of stars in the α Per, Pleiades, IC 4665, M11, and NGC 6611 clusters; (iv) photometry of B8 and B9 stars; and (v) determination of interstellar reddening in the directions of selected globular clusters by observations of foreground A- and F-type stars. During the year, Mrs. J. V. Barnes also collaborated with Dr. Graham Hill, Dominion Astrophysical Observatory, Victoria, B. C., in a study of NGC 7243. She has also been extensively involved in the assembly and testing of beam splitters in the multichannel photometers being developed for use on Kitt Peak and Cerro Tololo.

Dr. H. M. Dyck, in addition to looking after the 1.3-m telescope and the majority of its users, worked on the development and application of polarimetric and infrared equipment. His principal research has concerned the observational properties of circumstellar material associated with cool stars. In collaboration with M. T. Sandford, M. C. Jennings, S. J. Shawl, and Dr. F. F. Forbes, Dyck’s observational and analytical work now indicates that the infrared excess and intrinsic polarization arise from the same circumstellar grains, and that these grains have radii of the order of 0.1 μm, or significantly smaller than the currently accepted radii of interstellar grains. Accordingly, a number of new theoretical models of circumstellar shells, with constituents of different size, are now under study by Shawl and Dyck.

F. J. Vrba worked with Dyck during the summer of 1970 on a further investigation of the luminosity calibration of G, K, and M stars by means of medium-dispersion spectrograms obtained with the 92-cm telescope spectrograph.

With S. Ridgway, State University of New York at Stony Brook, Dyck is currently working on receivers for interferometric spectrophotometry of stars in the infrared.

Dr. A. A. Hoag has supervised the development of 4-m-telescope instrumentation, and has been working with W. E. Schoening and R. Harrison on photographic and site evaluation equipment. Further work with W. F. Ball and D. E. Trumbo has resulted in additional applications of the image dissector in photometry and spectrophotometry.

R. J. Dufour worked with Hoag during the summer of 1970 on a number of image-dissector spectrophotometric problems. As one project, he monitored the equivalent width of Hβ in the spectrum of the magnetic star HR 9080. In another study, he simulated the uvby system using the image-dissector spectrophotometer. He also
tested a new image dissector with an S-25 photocathode suitable for work in the range 3200-8700 Å.

Hoag has maintained his project in collaboration with Dr. D. J. Schroeder, Beloit College, to obtain, with blazed transmission gratings, low-dispersion, slitless spectra of star fields centered on x-ray sources. Dr. T. D. Kinman supervised the work by W. J. Henson on the Kron electronographic tubes. A special laboratory was constructed and apparatus assembled for depositing photocathodes in these tubes. Since the completion of this facility in February 1971, a continuous effort has been made by Henson to obtain more sensitive and uniform cathodes free of blemishes, and with low background emission. Steady progress has been made in this new technique, but a reliable and practical system for regular scheduling remains to be produced.

Kinman is also investigating means of modifying the Joyce-Loebl microphotometer for reduction of direct electronograms. Kitt Peak facilities for handling the Kron tubes at the telescopes were improved, and application tests began in the summer of 1971.

Kinman, working with D. E. Trumbo, specified an image intensifier-SEC Vidicon system that was custom constructed by the Westinghouse Tube Division, Elmsira, N. Y., and delivered in March 1970. This unit includes a "Lithicon" storage tube that permits continuous display of the Vidicon output between integration cycles. The system has been incorporated in a prototype 4-m telescope photometer being tested at the 2.1-m telescope. The guiding box is designed for completely remote control of acquisition and centering of faint stars in a following photometer or polarimeter.

Kinman used the 2.1-m telescope for polarimetric observations of variable quasistellar objects, part of a photographic monitoring program begun at the Lick Observatory. In an extension of the project, some 545 plates were obtained, mostly by K. Cook, with the 92- and 40-cm telescopes, and an additional 100 plates of three galactic anticenter RR Lyrae fields were obtained with the same instruments. Measures and reductions of all of this material are well in hand. Ninety-four percent of the more than 2300 plates of 12 quasistellar sources have been measured with assistance from C. Batishko and C. Allen. About 4000 measures of the 60 RR Lyrae stars are now on IBM cards and about 40 plates remain to be measured. C. Mahaffey adapted an existing period-finding program to the KPNO computer, improving it in the process, and is analyzing the accumulated measures.

Dr. G. W. Lockwood has in progress a number of observational projects in the near infrared and the infrared: (i) He is completing papers on the photometry, photometric spectral types, light ranges, and amplitudes of variation of some 300 Mira-type stars for which observations and reductions are complete. At the end of this report period, a paper (with R. F. Wing) on light curves of 25 Mira variables was in press. (ii) Near-infrared photometry of IRC stars is another project. R. S. McMillan, who worked for Lockwood during the summer of 1970, and T. A. Zinner have located previously unidentified sources listed in the California Institute of Technology Infrared Catalogue (IRC). Subsequent near-infrared observations by Lockwood provided information on variability and spectral types. A number of unique objects were found that: (a) are of very late spectral types, later than M9; (b) are too red for their spectral types; and (c) have excess redness that is variable and therefore not interstellar. (iii) Lockwood has done infrared photometry, in collaboration with Dyck, in the 1.6-10-μ region. Infrared observations are being carried out at 1.6, 2.2, 3.5, 5.0, and 10.0 μ on late-type giants, Mira variables, and IRC stars to (a) define the energy distributions of normal late-type stars and Mira variables, (b) look for unusual infrared properties of the IRC stars and their relation to the near-infrared photometry, and (c) establish the limits of variability of the above objects at long wavelengths.

In addition to supervising the operations of the 92- and 40-cm telescopes, Lockwood has been deeply involved in equipment development and testing, as mentioned previously. He worked with Dyck on the infrared photometer, supervised the development of pulse-counting equipment and associated photomultiplier cold boxes, and he is completing operational tests on the Harvard, Wampler-type scanner.

Dr. C. R. Lynds obtained new, high-resolution observations of the absorption lines in the spectrum of the quasistellar object 4C 05.34 (Z = 2.88). Measures of the lines were analyzed and the results have been published.

Lynds, with D. Wills, University of Texas, analyzed a complete sample of 4C quasistellar objects and found some information on how the space density of quasistellar objects depends on distance or epoch. It was also possible to estimate the radio and optical luminosity function at an intermediate distance corresponding to Z = 1. The same type of analysis was applied to a sample of 3CR quasistellar objects previously discussed by Dr. Maarten Schmidt. The results derived from the two samples agreed remarkably well.

A large part of Lynds' observing time this report year was devoted to obtaining spectrograms of a larger sample of 4C sources and a sample of Parkes sources. Additional observations are being made. Also, observations of a number of peculiar galaxies and absorption-line quasistellar objects have been obtained.

Lynds made additional observations of the radio galaxy 3C 386 that are consistent in indicating that the object consists of a galaxy with a redshift of Z = 0.0177. Some confusion concerning this object has been caused by a superimposed foreground galactic star. When suitable photometric corrections have been made, data for this object fall exactly on Sandage's redshift-magnitude relation for radio galaxies.

Lynds and Dr. V. Petrovskii worked jointly on an evaluation of the relative effectiveness of source-count and luminosity-volume analyses in cosmological investigations during Petrovskii's consulting stay at KPNO.

The image-tube program under Lynds' direction continued. J. DeVeny and R. Townsend completed an RCA three-stage, image-intensifier system and an ITT magnetically focused fiber-optic-output intensifier system. The RCA tube serves as a standby for Lynds' spectroscopic work, and the ITT system is for use in direct photography and coude' spectroscopy. The ITT tube has proven its effectiveness in narrow-band interference filter photography of extragalactic objects and in spectroscopic work at the 2-Å/mm coude' camera of the 2.1-m telescope.
TABLE I. Summary of telescope usage.

| Telescopes (aperture in meters and inches) | 2.1(84) | 1.3(50) | 0.92(36) | 0.92(36) |
| Telescopes use | Total night hours | 3454 | 3454 | 3454 | 3454 |
| Nights used | 334 | 252 | 293 | 265 |
| Hours used | 2732 | 1910 | 2252 | 1956 |
| Down time (nights) | 2 | 3 | 7 |
| % time used | 79 | 55 | 65 | 57 |
| Scheduled visitor use | Number of visitors | 89 | 66 | 34 | 51 |
| Nights scheduled | 237 | 235 | 170 | 180 |
| % nights scheduled | 65 | 71 | 47 | 55 |
| Actual visitor use | Number of nights | 220 | 184 | 148 | 142 |
| Hours logged | 1823 | 1404 | 1172 | 1098 |
| % scheduled hours used by visitors | 79 | 60 | 68 | 64 |

An experiment to determine the photometric properties of the ITT tube has been undertaken.

DeVeny, Townsend, and R. Barnes completed the design of a cooled solenoid magnet capable of accommodating an f/1.25, 7.5-inch focal length camera and image tube on the 2.1-m telescope image-tube spectrograph.

5. Visitor Research

A summary of stellar telescope usage and the weather conditions on Kitt Peak during the report year are shown in Tables I and II below. The statistics in Table I are for the four largest telescopes.

| Temperature | Extreme high | 90 °F |
| Mean high | 64 |
| Extreme low | 8 |
| Mean low | 44 |
| Precipitation | Rain | 19.11 in. on 41 days |
| Snow | 7.25 in. on 4 days |

Of the 100 visiting astronomers and 46 graduate students who used the stellar telescopes, 34 and 15, respectively, came from 20 organizations in the East; 17 and four were from 15 organizations in the Midwest; 15 and nine were from nine organizations in the South; and 31 and 13 were from 16 organizations in the West. In addition, three astronomers and five graduate students visited from five foreign countries: Canada, Argentina, Sweden, Germany, and England.

In the following listing of visitors and their programs, the first number refers to the number of nights scheduled, the number in parentheses is the actual hours of observation, and the last number refers to the telescope by aperture in inches:

M. A'Hearn, University of Maryland: Polariometry of diffuse interstellar features, 6(28)350.
J. Angel, Columbia University, and J. Landstreet, University of Western Ontario: Measurement of circular polarization in optical radiation from white dwarfs and Ap stars, 7(53)350, 2(9)36.
E. Avner, University of Illinois: Radial velocities of G-K stars, 6(58)36.
D. Barry, University of Southern California: Spectroscopic absolute magnitude indicator for late F and early G dwarfs, 5(37)36.
K. Batishko and F. Roach, Battelle Memorial Institute: Photoelectric photometry of diffuse galactic light, 18(82)16.
J. Baumert, Ohio State University: The absolute bolometric magnitudes of carbon stars, 9(78)36, 8(42)16.
L. Bautz, Northwestern University: Redshifts of galaxies in and near the galaxy cluster A2147, 6(28)84.
A. Binder and D. McCarty, Illinois Institute of Technology, Research Office, Tucson: Spectrophotometric observations of Mars and of the outer planets and their satellites, 9(49)50.
L. Binnendijk, University of Pennsylvania: Photoelectric observations of eclipsing variables, 7(35)36, 6(32)16.
B. Brattlund, Stockholm Observatory, Sweden: A study of chemical abundances in late-type stars, 8(24)84.
M. Breger, State University of New York at Stony Brook: Pre-main-sequence contraction and pulsation of stars in NGC 2264, 27(204)36.
A. Brooke, State University of New York at Stony Brook: Pre-main-sequence A-F stars in NGC 2264, 15(122)50.
E. Burke, R. Tate, J. Howard, and D. Cross, King College: Photometry of magnetic and spectrum variables, 2(8)36, 23(115)116.
L. Cathey, University of California at Santa Cruz: UBV photometry of giant and subgiant stars in globular clusters, 15(49)50.
F. Chaffee, Jr., Smithsonian Astrophysical Observatory, Mt. Hopkins: Abundance analyses of stars in open clusters, 4(40)84.
G. Chincarini, NASA Manned Spacecraft Center, Houston, and H. Rood, Wesleyan University: Spectrographic observations of compact galaxies, 7(43)84.
H. Y. Chiu, Goddard Institute for Space Studies, New York, S. Maran, Goddard Space Flight Center, and T. Gurski, University of Arizona: Tests of video pulsar hunter in preparation for observing time at CTIO [84-inch telescope; apportioned some of staff time in collaboration with C. R. Lynd];
F. Chromey, Harvard College Observatory: Standard star calibration of 12-color narrow-band photometric system, 40(162)16; a spectrographic and photometric study of the irregular galaxy NGC 4691, 7(59)84, 5(25)36.
W. Cocke, University of Arizona: NGC 6302 polarization, 3(16)50.
A. Cowley, University of Michigan: Spectroscopic investigation of some peculiar binaries, 4(44)84; high-dispersion spectroscopy of peculiar A stars, 4(32)84.

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P. Crane, Princeton University: An investigation of the luminosity function in rich clusters of galaxies, 10(71)36.
J. Cuffey, New Mexico State University: UBV photometric photometry of standards in open clusters, 5(56)350.
R. Culver, Colorado State University: Spectrography of semi-carbon stars, 4(46)84.
I. J. Danziger, Harvard College Observatory: Image-tube spectroscopy of galaxies, 4(24)84; tests of scanner and spectrophotometry of galaxies, 2(13)84, 17(80)36.
I. J. Danziger and J. Goad, Harvard College Observatory: Scanner observations of galaxy nuclei, 8(41)36.
J. Drilling, Louisiana State University: Four-color photometry of early-type stars, 10(56)50.
I. Epstein, Columbia University: Four-color photometric photometry of RR Lyrae field stars, 6(29)50.
S. Faber, Harvard College Observatory: Photometric observations of multiple galaxies and standard stars, 21(130)36, 11(101)16.
A. Feinstein, Observatorio Astronomico, La Plata, Argentina: Ha, H, and H2 measurements of Be stars and of some metallic-line stars, 6(37)16.
W. K. Ford and V. Rubin, Carnegie Institution of Washington: High-dispersion spectra of the nuclei of galaxies, 5(53)84.
J. Froehlich, California Institute of Technology: Photometry in the two-micron region of CO and H2O features in late-type stars, 10(84)36.
G. Gandet, Jr., University of Kansas: Spectroscopic observations of three suspected late B-type binaries, 10(29)50.
E. Guinan and E. O'Donnell, Villanova University: High-dispersion spectrographic study of V1010 Oph and bright eclipsing binaries, 4(35)84.
A. Heiser, A. J. Dyer Observatory, Vanderbilt University: Photometric investigation of possible subgroups in Monoceros OB1 and OB7; Hβ photometry of late B stars in NGC 2244, 3(250), 5(41)16.
T. Herceg, University of Oklahoma: Photoelectric observations of TX Ursae Majoris, 8(35)16.
W. Hiltner, University of Michigan: Optical monitoring of Sco X-1, 3(15)36.
R. Honeycutt, Indiana University: Spectrophotometry of diffuse interstellar bands, 4(38)84.
R. Humphreys, University of Arizona: Spectral classification and photometry of stars in the Car OB1 Association and the cluster NGC 663, 3(29)36, 8(65)16.
K. Janes, Yale University: Photometry and spectroscopy of strong cyanogen stars, 3(20)84, 14(83)16.
M. Jennings, University of Arizona: Infrared polarimetry of NGC 3034 and related objects, 7(16)50.
R. Koch, University of Pennsylvania: Photographic search for close binaries in NGC 2264, 5(36)36.
A. Landolt, Louisiana State University: Faint standards, 26(159)36, 12(49)16.
P. Lee, Louisiana State University: Spectroscopy of helium-rich stars, 8(48)84; photometry of stars in the open cluster Roslund 5 and photometry of planetary nebulae, 6(53)16.
K. C. Leung, University of Nebraska: Photometric study of YY Gem in the near infrared, 8(53)36.
W. Liller and C.-Y. Shao, Harvard College Observatory: UBV photometry of planetary nuclei, 6(44)36.
J. Lutz, Washington State University: UBV and H7 photometry of early-type stars in the direction of selected planetary nebulae, 8(47)36.
T. Lutz, Washington State University: Spectroscopy and photometry of selected visual binary systems, 15(113)36, 2(17)16.
R. McClure and S. Danford, Yale University: Photometry of K stars at the north galactic pole, 8(79)50, 29(11)16.
T. McCord, C. Chapman, A. Lazarivicz, Massachusetts Institute of Technology: Spectrophotometry of Venus, moon, and satellites and asteroids, 8(72)36.
E. Milone, Gettysburg College: Photometric and spectroscopic studies of selected eclipsing binaries, 6(37)36, 3(11)16.
D. Mook, Dartmouth College: Photometric and polarimetric observations of Sco X-1, 5(40)36.
B. O'Leary, California Institute of Technology: Post-eclipse observations of Io and other Galilean satellites, 3(10)36.
E. Olson, University of Illinois: Spectrophotometry of eclipsing binaries, 5(46)84.
T. Owen, State University of New York at Stony Brook: Spectrography of planets, 4(36)84.
R. Partridge, Princeton University: A search for galaxies at very large redshifts, 6(29)50.
B. Peery, Indiana University: High-resolution spectroscopy of cool heavy-element stars, 3(34)84.
J. Percy, University of Toronto: Photometry of variables, 17(98)16.
M. Perinotto, University of California at Los Angeles: Spectrophotometry of planetary nebulae, 3(23)84.
C. Perry, Louisiana State University: Spectrophotometric observations of Roslund 5, 4(12)36; uvby and Hβ observations for stars in NGC 1039 and NGC 2169, 6(40)36, 7(47)16; photometry of late F-type stars, 10(25)16.
P. Pesch, Warner and Swasey Observatory: Photometry, spectral classification, and radial velocities of luminous stars in the northern Milky Way; image-tube spectroscopy of a sample of faint M stars in the direction of the north galactic pole; photometry of Pleiades, Hyades, and Lowell proper motion stars; and spectrography of stars in NGC 6530, 21(177)84, 9(30)50, 36(199)36.
A. G. D. Philip and L. Relleya, Dudley Observatory: High galactic latitude A stars and horizontal branch stars, 8(53)50, 8(47)36, 12(68)16.
P. Phillips and D. Gillman, Cornell University: Infrared spectroscopy in the 20 μ region, 7(38)36.

S. Plagemann, Institute for Theoretical Astronomy, Cambridge, England: Power spectrum analysis of the variability of certain celestial objects, 7(42)50, 6(19)36, 25(12)016.


P. Rigterink, University of Pennsylvania: A study of the "disturbances" in close binary systems, 30(143)16.

W. Roberts, University of Washington: Violet-green-red photometry of stars of known metal abundance, 13(70)16.

H. Rood, Wesleyan University, and G. Chincarini, NASA Manned Spacecraft Center: Kinematics of the cluster around NGC 541 and the Perseus cluster, 4(44)84.

H. Rood, Wesleyan University: Kinematics and dynamics of the Coma and Abell 1367 clusters, 9(76)84.

J. Rosendhal, University of Wisconsin: Spectroscopic observations of helium-rich stars and microturbulence in G and K supergiants, 4(33)84.

E. Schmidt, University of Arizona: High-dispersion spectrographic studies of classical Cepheids, 13(130)84.

L. Schroeder, K. Oines, Oklahoma State University, and J. Evans, Kansas State University: Atmospheric structure and chemical composition of A and F stars, 3(25)84, 4(23)36.

S. Simkin, Columbia University: Stellar velocity fields in disk galaxies, 4(26)84.

M. Smith, University of Arizona: Line-width study of high-microturbulence Am stars, 2(25)84; four-color photometry of A stars in I Orionis, 1(12)36, 4(28)16.


J. Stephens, Georgetown College Observatory: Photometric photometry of two Delta Scuti stars, 8(45)16.

W. Stoner, Princeton University: He used his own instrumentation, apart from the stellar telescopes on Kitt Peak, during a two-month stay for a study of diffuse background light in the Coma cluster of galaxies.

S. and K. Strom, State University of New York at Stony Brook: Spectrography of stars in globular clusters, 9(23)84; image-tube spectrography of stars in NGC 2264 and the Orion Association, 13(125)84.

S. and K. Strom, and A. Brooke, State University of New York at Stony Brook: Infrared photometry of stars in NGC 2264 and I Orion; study of circumstellar shells, 16(74)50.

C. Sturch, University of Rochester: Spectroscopy of Upgren's unclassified stars in north galactic pole fields, 5(51)36.

S. Tapia, University of Arizona: UBV photometric photometry of the flare star EV Lacertae, 7(11)16; study of color term in the (U-B) extinction coefficient, 3(26)16.

R. Tate, Vanderbilt University: Photometry of long-period eclipsing binaries, 7(46)36, 7(37)16.

C. Tolbert and W. Gutsch, University of Virginia: Hα photometry of stars earlier than type F in McCormick proper motion fields, 6(46)50.

G. Van Biesbroeck, University of Arizona: Micrometer measures of double stars, 7(48)84.

K. Voelcker and W. Hofmann, Heidelberg Observatory, Germany: Infrared photometry of extremely red stars in Cygnus, 39(262)50.

N. Walborn, Yerkes Observatory: Some spectroscopic characteristics of the OB stars, 14(90)36.

G. Wallerstein, University of Washington: High-dispersion spectra of long-period variables and similar stars, 4(33)84.

A. Wawrzkiewicz, Western Kentucky University: Photometry of M supergiants, 21(146)16.

D. Weedman, A. J. Dyer Observatory, Vanderbilt University: Photoelectric observations of galaxy nuclei, 4(19)84, 4(29)50.

E. Weis, University of Illinois: Rotational velocities in close visual binaries, 9(67)84.

M. Wicht, Jr., University of Arizona: Light variations in Seyfert galaxies, 7(41)16.

D. Wills, University of Texas: Spectrographic observations of quasistellar sources, 6(62)84.

J. Winzer, University of Toronto: Photoelectric photometry of Ap stars, 14(58)16.

A. Witt, University of Toledo: Spectrophotometric studies of reflection nebulae, 8(61)84, 6(27)16.

J. Wray, Northwestern University, and G. Corso, Kendall College: Search for Wolf-Rayet stars in M 33, 3(50)84.

S. Wyckoff, University of Kansas: Spectra of late-type, long-period variables at minimum light, 6(43)36.

A. Young, B. Nelson, F. Vaughan, G. Grupsmith, A. Martin, and D. Socke, San Diego State College: uvby photometry of BD +16° 516, 3(27)84, 3(22)50, 5(49)36; faint eclipsing stars, 7(33)84.

D. Zipoy, University of Maryland: Near-infrared photometry of stars in young clusters, 5(15)36.

B. Solar Division

I. Personnel Notes

Staff Changes: Dr. R. W. Milkey joined the scientific staff on 18 January 1971. He most recently worked as a post-doctoral research associate at the Los Alamos Scientific Laboratory.

Consulting and Visiting Scientists-in-Residence: Dr. R. G. Giovanelli, Chief of the Division (Physics), Commonwealth Scientific and Industrial Research Organization (C.S.I.R.O.), Sydney, Australia, served as consultant to the Solar Division from 26 October through 31 December 1970. Dr. Oivind Hauge, Institute of Theoretical Astrophysics, Oslo, Norway, was at KPNO during April, May, and June 1971 as a long-term visitor.

Summer Research Assistants: During the summer of 1970, scientific staff members supervised the research projects of seven students participating in the summer research assistantship program: J. Beck (University of Arizona) – Dr. W. C. Livingston and Dr. J. W. Harvey; B. Gillespie (University of Michigan) – Dr. N. R.
Sheeleý, Jr.; C. Lada (Boston University) – Dr. A. K. Pierce; S.-Y. Liu (University of Maryland) – Sheeleý; R. Rose (University of Arizona) – Pierce; M. Snellen (Colgate University) – Harvey; and P. Szkody (Michigan State University) – Dr. J. W. Brault.

During the summer of 1971 ten students worked as research assistants to the scientific staff: T. R. Ayres (Harvard University) – Dr. D. N. Hall; D. J. Bechis (Harvard University) – Pierce; G. B. Chaplin (Cambridge University, England) – Harvey; J. B. Gurman (Harvard University) – Sheeleý; N. S. Hartunian (Brandeis University) – D. R. W. Milkey; J. N. Heasley (Yale University) – Milkey; G. A. Radford (University College, England) – Dr. E. J. Weber; L. Testerman (Kansas State University) – Pierce; Brault; S. P. Worden (University of Michigan) – Sheeleý; A. C. Zook (Pomona College) – Livingston.

2. Staff Activities

The joint meeting on “Solar Astronomy” held by the Solar Physics Division of the American Astronomical Society and by the American Institute of Aeronautics and Astronautics at Huntsville, Alabama, during 17-19 November 1970 was attended by Dr. J. W. Harvey and Dr. A. K. Pierce. Harvey presented a review paper on “Recent Solar Magnetograph Results”.

Dr. E. J. Weber attended the American Geophysical Union meeting in San Francisco, 7-10 December 1970, and presented a paper, authored jointly with Dr. D. F. Strobel, on “Properties of the Flow Equations of a Multi-Component Plasma with Source Terms”.

Weber, Dr. N. R. Sheeleý, Jr., and Dr. W. C. Livingston attended the Solar Wind Conference at Asilomar, California, 21-26 March 1971. The conference was sponsored by the University of California (Berkeley and Los Angeles) and the NASA-Ames Research Center, Sunnyvale, California. Weber presented a paper on “Comments on Recent Observations of the Angular Momentum Flux in the Solar Wind” and Livingston contributed a paper, “New Evidence from Prominences for Super-Rotation in the Solar Atmosphere”.

Harvey went to the summer scientific meeting of the Astronomical Society of the Pacific, held in Wallau, Kauai, Hawaii, 22-25 June 1971, and gave a paper entitled, “Small-Scale Solar Magnetic Fields”.

Harvey and Dr. D. N. Hall attended the Joint Meeting on Solar Physics of the Sacramento Peak Observatory and the High Altitude Observatory, held in Santa Fe, New Mexico, during 19-21 May 1971. They together presented results on studies of the 10 830-Å helium line; Harvey presented results on polarization measurements at Kitt Peak and Hall led the session on infrared spectroscopy.

Harvey and Livingston presented papers at I.A.U. Colloquium No. 11, “Automation in Optical Astrophysics”, held in Edinburgh, Scotland, 12-14 August 1970. Together with Hall and Pierce, they attended the XIVth General Assembly of the I.A.U. at Brighton, England, later in August. Pierce summarized the results of the Working Group on Central Line Intensities; he moved to dissolve this group, and was appointed chairman of a Working Group on the Spectra of Sunspots. Joined by Sheeleý, they then attended the Paris I.A.U. Symposium No. 43 on “Solar Magnetic Fields” during 31 August - 4 September 1970. Papers were presented by Harvey and Sheeleý. After these meetings, Hall participated in the NATO Advanced Study Institute on the Solar Corona held in Athens, Greece, 7-17 September 1970.

Dr. J. W. Brault attended a meeting of the Group on Atmospheric Transmission Studies sponsored by the Institute for Molecular Physics, College Park, Maryland, 25 May 1971, where he presented his work on H₂O, CN, and O₂.

Livingston was on sabbatical leave from September 1970 through February 1971. During this time he visited the Institute of Theoretical Astrophysics, Oslo, Norway; the Astronomical Institute, Utrecht, The Netherlands; the Uttar Pradesh State Observatory in Nainital, the Tata Institute of Fundamental Research in Bombay, and the Astrophysical Observatory in Kodikanal, India; and C.S.I.R.O. and the University of Sydney, Australia.

3. Instrumentation

The mechanical and optical work on the large infrared spectrometer was completed under the direction of Dr. D. N. Hall. Testing was carried out with a small echelle grating while awaiting the 14.5- by 18.5-inch grating being ruled by F. Denton and Dr. G. R. Harrison on the “C” engine at the Massachusetts Institute of Technology.

Shortly after the 36-inch metal, image-forming mirror of the east auxiliary system of the solar telescope was refigured, it was damaged in an accident. The carriage was rolled along the 32° incline beyond its lowest position, unwrapping all of the cable on its hoist drum. This auxiliary carriage then freely accelerated 125 feet along the incline and struck the main mirror carriage, the impact causing the 63-inch quartz mirror to jump several inches out of its support band. A large glass chip 6 by 6 inches was knocked out of the edge of the main mirror, and the auxiliary metal mirror was thrown completely out of its support system and it fell 30 feet to part of the frame of the main carriage. This 36-inch metal mirror has been replaced with a 42-inch CER-VIT mirror ground from a slice of the core of the CTIO 158-inch blank, and it has been figured as an off-axis paraboloid of 132.4-ft focal length.

Replacement of the original, main optics of the McMath solar telescope has long been recognized as desirable, for the following reason. Despite the low expansion coefficient of fused silica, a simple calculation shows that the flat heliostat mirror will warp seven waves convex for a temperature differential of 15 °C, front to back. Experience has shown that astigmatism often is present in the image, and that it is worse in summer when the angle of incidence is large. Following the receipt of a very favorable price quotation, three CER-VIT blanks were obtained (82 by 10, 63 by 9, and 60 by 9: diameter by thickness, measured in inches). Although the figuring of the heliostat flat has progressed to an over-all deviation of 3/4 λ, it needs to be carried to much closer tolerance. New mirror cells and support systems are in the design stage.
4. Staff Research

As part of a cooperative effort of solar astronomers in many countries, Dr. J. W. Braught and Dr. A. K. Pierce, with the collaboration of C. D. Slaughter and R. S. Aikens, completed their observations of the central intensities of 40 Fraunhofer lines lying between 3200-6800 Å. The detailed results appear in Solar Physics. The average values obtained from the several groups will appear in the Proceedings of the I.A.U. XIV General Assembly, Brighton, 1970.

A carbon arc burning in air reproduces perfectly the red system of CN in the Sun; if the emission spectrum of the arc is inverted and overlapped on the solar spectrum. Braught analyzed in detail this system with spectra obtained from high-dispersion photometric traces and found that many new lines appear.

As part of the Solar Division’s work in mapping the Sun’s spectrum in double pass, a great many tracings were obtained at low and high Sun, and on days of widely varying water vapor content. Braught and Slaughter have demonstrated that it is possible to combine these tracings by a computer program that cancel out either the solar or the water-vapor spectrum, thus leaving a clean tracing of the other, provided, of course, that the lines are not saturated. In this way Braught has observed 25 bands of water vapor in the interval 4400-9000 Å and has assigned identifications to 40% of the lines.

Center-to-limb observations of the sodium D lines have also been obtained and are being reduced and prepared for publication.

Most of the infrared research carried out during the last year by Dr. D. N. Hall utilized equipment developed previously for the vacuum spectrograph.

A joint investigation of the center-to-limb variation of selected lines of the CO first overtone band was carried out by Hall with Dr. R. W. Noyes and T. Ayres, Harvard College Observatory. These data are expected to yield information about the structure of the solar atmosphere just below the temperature minimum. The material is also being used to test whether there is a sufficiently large pole-equator temperature difference in these layers to explain the oblateness observed by Dicke.

Lines due to water vapor in the Sun, as identified in the infrared umbral spectrum of sunspots, are being analyzed by Hall in a joint program with Dr. W. S. Benedict, University of Maryland. Almost 500 lines in the 1.9- and 2.4-μ regions have been attributed to solar steam and energy transitions have been identified for about half of them.

Greatly improved spectra of the He 10 830-Å line in emission in quiescent prominences have permitted a tentative identification of 3He with a 3He/4He ratio of 4 ± 4 X 10^-4. The verification of this identification and improved precision in the abundance determination are important, both as a test for theories of nucleosynthesis and as a reference for 3He/4He ratios measured in the solar wind and in flare particle events.

The infrared spectrograph is now operating and has yielded excellent solar spectra in the 3-5-μ region. Many strong lines of the CO fundamental system are evident, but the number of atomic lines (about 20) is disappointingly small. Terrestrial lines, which dominate the region and appear to have great potential for the study of the Earth’s atmosphere, are being identified with the help of Benedict.

Recent work by Dr. J. W. Harvey at KPNO and by others elsewhere has shown that conventional photoelectric vector magnetographs frequently yield erroneous results for various reasons. A principal reason is that, although it is known that the magnetic field is very inhomogeneous, it was general practice to assume a homogeneous field in order to reduce observations. This situation has also caused errors in interpreting longitudinal magnetograph observations. In order to resolve these problems, Harvey and Livingston modified the vector magnetograph to scan rapidly solar line profiles in all the Stokes parameters while simultaneous measurements of the longitudinal field are made. These data then are reduced in terms of a simple two-component, nine-free-parameter model atmosphere in which one component contains a homogeneous field and the other is field free. Preliminary results give stable, unique values of the nine parameters, provided the observed fields are larger than a few tens of gauss. Collisional damping seems to be smaller in the magnetic elements, while Doppler broadening is considerably larger. They have verified that both temperature and Zeeman broadening play important roles in the production of line “gaps”.

Good progress on the photographic sunspot spectrum atlas has been made. A suitable sunspot was satisfactorily observed at the end of the report year, and plans to reproduce the data in a format suitable for external distribution are under way. This project has led to the finding that there are no discernible molecular lines in the umbral spectrum below about 4060 Å, although low-temperature atomic lines continue to be prominent. A study of various atomic lines strongly supports the anomalous dispersion explanation of the p component splitting in umbral spectrum lines. A system of molecular lines with negative Zeeman splitting was found around 6300 Å. The same observing program was also used to obtain nearly complete photographic spectra of “gap” regions, wiggly lines, and the Evershed effect in a sunspot near the limb.

Observations of helium lines begun last year were continued by Harvey in collaboration with Hall and Dr. R. G. Giovanelli (10 830 Å) and Dr. G. Chapman (5876 Å). Comparison of simultaneous 10 830-Å and He spectroheliograms showed close agreement in the position of various features, but frequently very little agreement between their intensities. Velocity maps (called tachograms) at 10 830 Å revealed occasional, very strongly Doppler-shifted elements in an otherwise fairly quiescent chromosphere. Preliminary reduction of the 5876-Å observations shows a similar appearance in the 10 830-Å spectroheliograms with a distinct mottling near the poles.

The 40-channel magnetograph was used for several projects by Harvey. Observations of active solar regions were made simultaneously with other observatories in preparation for a similar, world-wide effort scheduled for October 1971. The goal of this project is to uncover systematic errors in magnetograph measurements. Some problems with the system at Kitt Peak were detected in the preliminary test, and these led to a new calibration routine. An on-line CRT display capability was added.

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to the magnetograph to help reduce a serious, data-reduction bottleneck. With Mrs. K. Harvey, observations were made of the evolution of magnetic fields in and around active regions with spatial resolution limited by seeing. The birth of an active region was observed, and moving magnetic elements streaming from sunspots were extensively studied. As in previous studies, no changes in the photospheric field were detected in association with solar flares.

J. W. Harvey and Dr. R. Howard collaborated to make simultaneous observations at Kitt Peak and at Mount Wilson in a search for short-period (about 1 sec) oscillations in solar spectrum lines. Also, with the help of Livingston, a joint study of the integrated magnetic field of the Sun was undertaken.

Dr. W. C. Livingston, with Dr. O. Engvold, Institute of Theoretical Astrophysics, University of Oslo, Norway, developed a classification system for quiescent prominences, based primarily on the width, profile, and the presence or absence of weak, diffuse emission ("fuzz") in the Ca II K line. They suggest that this fuzz represents an exchange of matter between the prominence and its surroundings.

High-dispersion studies of prominences continued with the use of an improved technique similar to Deslandres’ "spectro-enregistre des vitesses". The immediate aim is to clarify the observed systematic motions: a trend toward super-rotation of the upper regions of quiescent prominences. The phenomenon has been termed the "San Manuel effect", named after a local copper smelter by analogy with the appearance of smoke emerging from a stack into a wind.

In July 1965, a pair of mirrors was installed above the spectrograph in the telescope tunnel to allow integrated sunlight to be analyzed by the magnetograph. Measurements of the magnetic field of the Sun (viewed as a star) have since been taken several times a year. The observed field strength is, on the average, about 1 gauss, but it ranges between a high of about 3 gauss with a noise level of 0.2 gauss. The data has failed to show the excellent correlation between the sign of the integrated solar field and that of the interplanetary field as found by Severny and Wilcox. Therefore, the observations made on Kitt Peak may be subject to a variable bias of undetermined origin, but so far, efforts to determine the origin of this bias have been unsuccessful.

On another approach to the same subject, with cooperation from Dr. R. Howard (Hale Observatories), Mount Wilson and Kitt Peak full-disk, point-by-point magnetograms were acquired simultaneously at both observatories and the resulting mean fields were computed and compared. Again, the agreement of the integrated field was unsatisfactory. Because this type of observation can provide a unique measure of the evolutionary time scale of solar magnetism, together with the outflow of magnetism into interplanetary space, efforts will continue to find a bias-free, observational technique.

Observations bearing on solar rotation continued during the report year. It has been shown by Spiegel and Ingersoll that the effects produced by a 5% differential rotation with height through the photospheric layers could account for Dicke’s observed oblateness value. By comparing the rotation rates derived from the low-lying Ca i 5380 A line with an iron line of intermediate origin (Fe i 5397 Å), Harvey and co-workers found that an upper limit could be set at 2%, thus ruling out differential rotation as an important contributor.

Dr. R. W. Milkey worked on several theoretical programs during the year. A computer code that uses the Athay-Skumanich flux-divergence technique for non-LTE radiative transfer calculations was converted to operate on the KPNO computer, and a method for calculating bound-free transition rates by flux divergence was added to the code. This code was extensively examined, and is now being used to investigate the line formation problem for helium. This study, undertaken by Milkey in cooperation with Dr. H. A. Beebe, New Mexico State University, concentrates on explaining the observed characteristics of transitions in the visible and infrared, particularly 10 830 Å. In order to proceed with this analysis, it was necessary to study the instabilities resulting from interaction between the resonance line and resonance continuum source functions.

With J. Heasley, a summer research assistant, Milkey used a model hydrogen atom to compare results obtained with the flux-divergence method with those from an Auer-Mihalas complete linearization calculation. The results from the two codes are essentially identical for an isothermal atmosphere; the comparison is being extended to cases where a temperature gradient is present.

Reduction of solar flare x-ray flux measurements made with instruments aboard Vela satellites (continuation of Milkey’s work begun at the Los Alamos Scientific Laboratory) indicates that the region producing thermal x-ray emission cools in two stages. A paper describing these results, written in collaboration with former colleagues at Los Alamos, was accepted (August 1971) for publication in Solar Physics. A search for the possible 5-min periodicity of multiply peaked x-ray events yielded a negative result, and was reported in a letter to Nature. Due to the termination of the Vela satellite program, these projects will probably not be continued beyond the immediate future. Theoretical study of the energy-loss mechanisms operating on the electrons responsible for the nonthermal burst component of flare x-rays has so far confirmed that inelastic collisions and gyromagnetic radiation cannot be the primary energy-loss mechanisms, because of their failure to account for the observed softening of the spectrum.

To interpret observations made by Sheeley and Dr. A. Bhatnagar of the slowly varying component of the velocity field, Milkey made height-of-formation calculations for several lines used in velocity studies. It appears that the present observations are consistent with adiabatic overshoot of convective elements. Further observations of velocity fields higher in the chromosphere are necessary to determine the extent of the overshoot.

Dr. A. K. Pierce continued his long program of wavelength determinations of Fraunhofer lines, and plates with serial numbering 1144 to 1308 were obtained this report year. Measurement and reduction of the plates have progressed steadily, but this part of the program still remains the bottleneck to completion of this basic but routine work. The observed wavelength region now extends from 2900 to 11 000 Å, although the limits are

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as yet poorly observed. At 2900 Å in the second order, an hour exposure is required with a Kodak IIa-O plate. In the red on a 1-Z plate hypersensitized, approximately 1 min exposure is needed to record the spectrum.

Dr. N. R. Sheeley, Jr., and Dr. A. Bhatnagar (Hale Observatories) obtained high-resolution, Doppler spectroheliogram movies of sunspots and their surroundings during several days in August 1970. In addition to clarifying the detailed velocity field in sunspots, the subsequent reduction of these velocity fields into movies of the oscillatory and slowly varying velocity components led to the initially surprising result that, near the disk center, the slowly varying component has an organized, small-scale appearance resembling photospheric granulation. The 16-mm movies suggested that the velocity granules, which rise relative to their intergranular backgrounds, last at least 30 min and perhaps as long as 1 hour. If these velocity features represent the velocities of photospheric granules, then the 30-min to 1-hour lifetimes of the velocity elements are inconsistent with the 7-min lifetime measurements of photospheric granules.

To clarify this situation, J. Mosher, a graduate student in physics, California Institute of Technology, made cross-correlation measurements of a time sequence of spectroheliograms of the slowly varying velocity component. Although the data are limited to spatial resolution of 2 to 3 arc sec and are confused by an inclusion of both quiet and active regions in each of these spectroheliograms, Mosher's initial measurements showed that the cross-correlation function falls to approximately one-half its initial value in 5 min. Although seeing conditions at Kitt Peak during 1971 have not yet been sufficiently good to study this velocity field, it is still hoped to obtain a Doppler movie of a homogeneous quiet region near the center of the solar disk with spatial resolution of 1 arc sec, so that a more reliable measurement of this decay time can be made.

On 24 June 1971, a balloon was launched under the direction of Dr. J. Blamont, Centre Nationale d'Etudes Spatiales, to take high-resolution photographs of the Sun at 1980 Å. As ground support, high-resolution, full-disk CN 3883-Å spectroheliograms and Fe I 5233-Å magnetograms were taken by Sheeley and Livingston at Kitt Peak. The 1980-Å photographs from an earlier flight in October 1970 show features that look remarkably similar to the bright faculae visible on CN spectroheliograms and to the magnetic field elements associated with these faculae.

Sheeley's study of bright faculae visible on high-resolution CN 3883-Å spectroheliograms continued with the participation of C. C. Curtis, a graduate student in physics, University of Arizona; B. Gillespie, a University of Michigan undergraduate in astronomy and former summer research assistant at KPNO; and S.-Y. Liu, a graduate student in astronomy, University of Maryland. With the help of Curtis, Sheeley averaged time sequences of high-resolution CN spectroheliograms to reduce the noise level of the non-facular solar background. This technique enabled very faint faculae to be detected, and the results suggest that the corresponding magnetic fields may be relatively weak even with 1-arc-sec resolution. From a high-resolution CN spectroheliogram taken in July 1970, Gillespie measured the relative brightness of 100 faculae, and he obtained a corresponding brightness distribution of features having intensities ranging from a noise level of 1.3 times the background intensity to an upper limit near 2.4 times the background intensity.

Liu used the CN spectroheliograms as a reference with which to compare time-lapse sequences of Ca II 3934-Å spectroheliograms. As part of a project to study the behavior of various spectral features in the K line as a function of both spatial position and time, simultaneous time-lapse sequences of spectroheliograms were obtained in the bandhead of CN at 3883 Å and in the violet emission peak (K337) of Ca II 3934 Å. Observations were obtained with a spatial resolution approaching 1 arc sec and a time resolution of 10 sec/frame.

Several interesting results were obtained, some of which are: The K337 bright points rapidly appear and disappear in approximately 45 sec, without appreciable proper motion, as had previously been suggested with a time resolution of 20 sec/frame. The intensity of the K337 chromospheric network oscillates significantly with a well-defined 5-min period, while the intensity of the corresponding bright features of the CN photospheric network remains relatively unchanged during this time. A preliminary view is seen as a photospheric network of faculae with relatively stable intensities closely related quantitatively to the corresponding photospheric magnetic field strengths, and an overlying chromospheric network whose intensity fluctuates significantly with a regular 5-min period.

Sheeley and Dr. H. Leinbach (ESSA, Boulder, Colorado) are making a joint effort to obtain and interpret photographic spectrograms of the Mg II b group in magnetic field regions.

Sheeley and R. A. Shine, a graduate student in physics at the University of Colorado, undertook a study of the average profile of the Ca II H, K, and infrared triplet lines in plage regions. In addition to data of high-temporal and spatial resolution obtained with the spectroheliograph, photoelectric tracings of average plage regions also were taken.

Sheeley also has under way a program to determine what mechanisms lead to the formation of the dark plages observed in so many strong lines of metallic ions and in high excitation lines of neutral atoms of high ionization potential. Another program is to obtain a magnetogram with the highest possible spatial resolution and sensitivity by the use of rapid scanning and time-averaging techniques.

Finally, since in some of the above investigations it was necessary to obtain time-lapse sequences of spectroheliograms over a time interval of a few hours, it was necessary to correct for various sources of spectral-line drift. Accordingly, Sheeley had a device built to monitor continuously the position of a spectral line relative to the exit slit. With this monitor it was possible to detect and correct for spectral-line drifts of approximately ±0.01 Å (with dispersion ~ 1 Å/mm).

Dr. E. J. Weber and Dr. D. F. Strobel studied the properties of the flow equations of a plasma with source terms composed of two ions. They found that for a multi-ion plasma the critical points of the solutions are functions of the ion densities and flow velocities, and
they have applied this result to the "polar wind" model of the Earth's ionosphere.

Weber pursued his theoretical work on the solar wind with the inclusion of thermal conductivity, the latter supplying the necessary energy to the solar plasma to produce the solar wind. His work shows that a unique solution of the more general equations can be found from the conditions at the sonic critical line, and from the requirement that the solution be continuous to infinity.

5. Visitor Research

Visiting observers who used the facilities of the McMath solar telescope on Kitt Peak are listed below with a brief description of their research programs.

Dr. Claude Arpigny, Université de Liège, Belgium: Photoelectric scanning of integrated solar spectrum in the violet CN band system.

Dr. Grant Athay and Dr. O. R. White, High Altitude Observatory, Boulder, Colorado: Line profiles of a few multiplets of Fe I and Ca I at three different positions on the solar disk.

Tom Ayres and Dr. Robert Noyes, Harvard College Observatory, Cambridge, Massachusetts: Near-infrared observations of the solar photosphere and sunspots.

Philip Barnes, Otterbein College, Westerville, Ohio: Photoelectric measurements of mean chromospheric heights above the continuum photosphere.

Dr. Arvind Bhatnagar, Hale Observatories, Pasadena, California: Two-dimensional, time-lapse velocity fields in and around sunspots.

Dr. Robert Boese, J. Miller, L. Giver, and R. Albers, NASA-Ames Research Center, Sunnyvale, California: A program to determine spectroscopically the Martian carbon dioxide abundance and surface pressure from the CO₂ band at 0.782 μ.

Dr. Gary Chapman, The Aerospace Corporation, Los Angeles, California: Observations of magnetic fields associated with flares and studies of the force-free magnetic field configuration in the chromosphere.

Dr. Roger Griffin, The University Observatories, Cambridge, England: Spectrophotometry of Arcturus.

Mrs. Karen Harvey, Lockheed Solar Observatory, Burbank, California: Observations with the 40-channel magnetograph of sunspot regions, flares, and transient magnetic features.

Dr. Qvind Hauge, Institute of Theoretical Astrophysics, University of Oslo, Norway: Determination of solar abundances and isotope ratios of chemical elements.

Sou-Yang Liu, University of Maryland, College Park: Studies of the fine structure in the solar Ca II K line.

James Mosher, California Institute of Technology, Pasadena: Transmission profiles of several Œhman-Lyot-type filters.

Dr. Paul Mutschlechner, Indiana University, Bloomington: Observations for the determination of abundances of rare elements in the solar atmosphere.

Stephen Ridgway, State University of New York at Stony Brook: Development and use of a Fourier transform spectrometer to observe K-giant stars in the range 1 to 3 μ.

Dr. Stephen A. Schoolman and Dr. Robert C. Smithson, California Institute of Technology, Pasadena:

A study of small, rapidly changing magnetic features using filters.

Richard Shire, Joint Institute for Laboratory Astrophysics, Boulder, Colorado: Photoelectric spectra of Ca II K, H, and infrared triplet lines in plage and sunspot regions.

Dr. J. P. Swings, Institute d'Astrophysique, Belgium: Observations of forbidden lines in the photospheric spectrum.

Lawrence Testerman, University of Kansas, Manhattan:

Observations and production of synthetic solar spectra.

Dr. Alan Title, Harvard College Observatory, Cambridge, Massachusetts: Test of narrow-bandpass Fabry-Perot filters; observing runs with the spectra-spectroheliograph.

Dr. Pierre Turon, Observatoire de Paris, France: Far-infrared observations of the photospheric brightness field.

Dr. G. Walker, Dr. B. Goldberg, Dr. J. Aumand, Dr. D. Wright, and Dr. B. Isherwood, University of British Columbia, Vancouver, B. C., Canada: Photoelectric detection and measurement of weak stellar magnetic fields.

Dr. Peter Wilson, University of Sydney, Australia: Observations of brightness fields and velocity fields of solar granulation.

Charles Curtis, University of Arizona, Tucson: Continuation of studies of photospheric faculae in CN 3883 Å.

Dr. R. Giovanelli, C.S.I.R.O., Sydney, Australia: Observations of the fine structure of He.

Dr. Frank Orrall and 16 astronauts, NASA, Houston, Texas: Training in solar physics for the ATM mission on Skylab.

C. Planetary Sciences Division

1. Personnel Notes

Staff Changes: Dr. M. B. McElroy, physicist, accepted an appointment to the staff of the Division of Engineering and Applied Physics at Harvard University, and left KPNO on 24 September 1970. Dr. J. C. McConnell, who worked in association with McElroy in the field of theoretical astrophysics, accepted an appointment to the same Division at Harvard so that their joint projects could continue. He left KPNO on 1 October 1970.

Dr. J. W. Chamberlain terminated his appointment as astronomer on 31 May 1971. He had served as Associate Director, first of the Space Division and then, after its renaming, of the Planetary Sciences Division from the date of his appointment in April 1962 to 30 June 1970. During that time he provided the scientific leadership that led to the development of a scientific group which gained wide recognition for its competence in the field of planetary atmosphere studies. Chamberlain left the Observatory to become the Director of the Lunar Science Institute, Houston, Texas.

Consulting and Visiting Scientists-in-Residence: Dr. R. T. Brinkmann, California Institute of Technology, Pasadena, visited KPNO from 1 December 1970 to 1 April 1971 to work with the scientific staff on problems of planetary atmospheres, including atomic hydrogen escape and the interpretation of occultation observations.
Dr. G. E. Hunt, Atlas Computer Laboratory, Chilton, Didcot, Berkshire, England, visited the Observatory as a consulting scientist from 22 February to 5 March 1971 and worked on techniques involving high-speed computing machines for solving radiative transport problems.

Dr. J. E. Hansen, Goddard Institute for Space Studies, New York City, visited the Observatory on 4 May 1971 to present a seminar on "Interpretation of the Polarization of Venus".

Summer Research Assistants: Four students worked in the Planetary Sciences Division as participants in the 1970 Summer Research Assistantship program. P. T. Giguerre, Jr., University of Virginia, worked with supervising scientist Dr. M. J. S. Belton in a research program involving photometry of Venus, and measurement in integrated light of the total absorption of the CO\textsubscript{2} band at 1.05 \(\mu\) m. K. H. Rex, Rensselaer Polytechnic Institute, working in laboratory spectroscopy, performed initial setups on an electron gun experiment, tested components and subsystems, and carried out laboratory experiment routines. Dr. K. A. Dick supervised him in these programs. G. S. Sylvestre, Princeton University, working with Dr. D. F. Strobel, investigated polar wind in planetary ionospheres. L. J. Tepper, University of Illinois, worked under Dr. J. C. McConnell in an investigation of the photochemistry of \(\text{C}_2\text{O}_3\) in the Martian atmosphere.

Strobel, as Chairman of the 1971 KPNO Summer Research Assistantship program, arranged a series of weekly seminars to supplement the research activities of the participants. Three of the 20 students for 1971 worked with staff scientists of the Planetary Sciences Division: L. W. Hartmann (Case Western Reserve University) — Dr. K. A. Dick; Miss L. Ma (Princeton University) — Dr. M. J. S. Belton; and G. S. Sylvestre (Princeton University) — Dr. D. F. Strobel.

2. Staff Activities

Fifth Arizona Conference on Planetary Atmospheres: This conference was sponsored by the Planetary Sciences Division, with Dr. D. F. Strobel as Chairman, and was held at the Hilton Inn in Tucson during 8-10 March 1971. Sixty-six scientists, including physicists, aeronomers, and chemists, attended the meetings, the theme of which was "Aeronomy of CO\textsubscript{2} Atmospheres". The program was comprised of three sessions entitled "CO\textsubscript{2} Upper Atmospheres", "Chemical Kinetics of CO\textsubscript{2} Atmospheres", and "Results from Mariner Experiments", plus a panel discussion on "Turbulent Transport Processes in the Upper Atmosphere", and a conference review. The sessions were chaired by M. Nicoléf (Institute d'Aéronomie Spatiale, Brussels), R. Young (York University, Toronto, Canada), C. Leovy (University of Washington), and D. M. Hunt (KPNO); T. M. Donahue (University of Pittsburgh) gave the conference review.

It was agreed by the scientists attending that the conference fulfilled an important function in bringing together laboratory chemists and atmospheric scientists to discuss problems of mutual interest. The proceedings of the conference were published in the September 1971 issue of the Journal of Atmospheric Sciences.

Summer Advanced Study Institute on Aurora and Airglow: This Institute was held in Kingston, Ontario, Canada, during 3-14 August 1970. Dr. A. L. Broadfoot served as lecturer and Dr. D. M. Hunten served as lecturer and as Chairman of Session II on Atmospheric Emissions.

NAS/Space Science Board Summer Study: This session on "Space Sciences and Applications Priorities" was held at Woods Hole, Massachusetts, 27 July - 15 August 1970. Dr. M. B. McElroy was Chairman of the working group on Planetary Exploration. Dr. J. W. Chamberlain also participated in this summer study.

International Astronomical Union: The XIVth General Assembly of the I.A.U., held in August 1970, was attended by Dr. M. J. S. Belton, who took part in Commissions 16 (The Physical Study of Planets and Satellites) and 17 (The Moon), and by Chamberlain.


Apollo 14: By invitation of NASA, Chamberlain and Hunten witnessed the launch of Apollo 14 on 30 January 1971.


Division for Planetary Sciences, American Astronomical Society: Chamberlain attended this meeting in Tallahassee, Florida, during 1-3 February as Chairman of the Division. Belton was Chairman and organizer of the special session on Stellar Occultation by Planets and also presented an invited paper. Hunten and Dr. T. D. Parkinson also attended.

Fourth Summer Institute for Astronomy and Astrophysics: Hunten and McElroy presented a series of lectures at this Institute, held at the State University of New York at Stony Brook, 1-7 July 1970.

Summer Institute in Planetary Atmospheres: McElroy taught a graduate course in the Department of Astrogeophysics, University of Colorado, Boulder, at this session held from 22 June to 17 July 1970.

Conference on the Upper Atmosphere of Venus: Belton, Broadfoot, Hunten, Parkinson, and Strobel attended this conference, held 5-6 May 1971 at the California Institute of Technology, Pasadena. Co-Chairmen and organizers were Belton and Dr. Bruce Murray (C.I.T.).

3. Staff Research

The research activities of the Planetary Sciences Division may be classified into four categories: atmospheric
investigations carried out by sounding rockets, ground-based planetary astronomy, and theoretical programs, plus science for NASA spacecraft missions.

**Sounding Rocket Program:** KP 3.32 (rocket designation) was launched 1 March 1971, with Dr. L. Wallace (KPNO) as principal investigator. The purpose of this flight was to study the emission of deuterium from Venus. An $^1\text{H}/^2\text{H}$ abundance ratio $\sim 10$ in the upper atmosphere of Venus had been suggested by Donahue, Hunten, and McElroy to account for the low-resolution Mariner 5 Lyman-alpha observations. Resonance scattering of the $\sim 1$-Å-wide solar Lyman-alpha line by both $^2\text{H}$ and $^1\text{H}$ (isotope splitting $= 0.33$ Å at 1216 Å) would produce the two scale heights apparently required by the Mariner data and would also yield the $^2\text{H}/^1\text{H}$ intensity ratio $\sim 2.5$. A 14-inch aperture Cassegrain telescope and high-resolution spectrometer were flown in a payload and high-resolution spectrometer were flown in a payload on 1 March 1971 (an Aerobee 150-M1 rocket) to measure the $^2\text{H}/^1\text{H}$ Lyman-alpha intensity ratio. It was found that the intensity ratio $^2\text{H}/^1\text{H}$ is $\gtrsim 0.5$, in contradiction to the deuterium interpretation. Although the deuterium interpretation was the least objectionable of several proposed, it did place severe constraints on the Venus atmosphere, requiring either a very low eddy mixing coefficient or extensive loss of $^1\text{H}$ by Jeans' escape flux. Since the deuterium is now ruled out by observation, these constraints are not necessary. It also seems that the portion of the Mariner 5 data that appeared to require the deuterium may be spurious.

KP 3.37 was launched on 28 May 1971, with Dr. D. C. Morton (Princeton University) as the principal investigator. An Aerobee 150-M1 rocket carried the scientific payload to photograph the ultraviolet spectra of several stars in the constellation of Scorpio. Two Schmidt-objective spectrographs with lithium fluoride corrector plates were used to obtain spectral resolutions of 0.3 and 1.0 Å above 1100 Å. The principal objective was to search for interstellar absorption lines of carbon, nitrogen, oxygen, silicon, sulphur, and iron to determine the abundances of these elements between the stars. These elements have no resonance lines in the visible region, and hence are not measurable from the ground. Hydrogen abundances would also be obtained from the Lyman-alpha absorption line for comparison with the heavier elements. These interstellar abundances are especially needed for theories of the production mechanisms of the interstellar molecules of $\text{H}_2\text{O}$, OH, CO, and formaldehyde, recently detected by radio telescopes. In addition, they are of interest because of recent Princeton rocket spectra that show oxygen may be 10 times overabundant, relative to hydrogen, in the direction of δ Sco and ξ Oph.

The rocket reached an altitude of 111 miles, all systems operated very well, and the scientific objectives appear to have been realized. The data were being analyzed at the end of the report year.

**Ground-Based Planetary Astronomy:** Dr. A. L. Broadfoot continued development of a very high ($10^4$) resolution Fabry-Pérot spectrometer combination that will be used at the McMath solar telescope for measuring molecular line profiles in spectra of Venus, and preliminary tests of the instrument have been made.

Dr. D. M. Hunten is monitoring the building of a Connes-type Michelson interferometer for planetary and solar work at the Kitt Peak 4-m and solar telescopes. Hunten and Dr. T. D. Parkinson spent much time in 1971 preparing instrumentation for use on Mars. They intend to do further work on the distribution of CO$_2$ on the planet, with an emphasis on deriving a wide-coverage, topographic map of the planet’s surface. Parkinson designed and constructed a special high-resolution (3 × $10^5$) 3.34-m spectrometer to be used with the CTIO 60-inch telescope to measure the intensity of the 1.05-μ CO$_2$ band. Hunten, Parkinson, and I. Gordon began an observational program with this instrument on Cerro Tololo near the end of the report year, in preparation for the favorable August 1971 opposition of Mars.

Dr. K. A. Dick concluded, from an investigation of the emissions arising from electron bombardment of CO$_2$, that the mechanism responsible for observed CO Cameron-band intensities on Mars is unlikely to be population of the CO a state by cascade through CO Asundi, Triplet, and Herman band systems, as was recently suggested by McConnell and McElroy.

Dick also began an investigation of hydroxyl emissions in the night airglow. The sensitivity of the 1-m Ebert-Fastie spectrophotometer allows OH intensity and rotational temperatures to be determined every 13 min. Even with some smoothing, temporal variations are detectable on time scales shorter than previously possible. Preliminary results indicate finer structure to diurnal variations than previously reported, and seasonal effects are evident.

Dr. M. J. S. Belton and Parkinson obtained excellent photoelectric spectra of Venus in a program to detect the amount of H$_2$O in the planet’s atmosphere. More specifically, their far-infrared spectra indicate that very small amounts of H$_2$O are present, while the Venera results suggest rather large amounts, of the order of 1%. The Belton-Parkinson spectra, taken during a relatively dry period, tend to support the far-infrared spectra.

A program of narrow-band ($\sim 10$ Å) filter photometry was started to measure temporal and phase variations in CO$_2$ absorption integrated over the Venus disk. A second program will use the solar telescope’s spectograph to measure center-to-limb variations in CO$_2$ absorptions, from which it is hoped to learn something about the structure, stability, and lateral homogeneity of the Venus clouds. First results show a weakening of CO$_2$ absorption toward the limb and cusps, and an asymmetry between northern and southern hemispheres. An attempt also was made to measure the rotation period of the visible cloud cover on Venus. A device has been constructed for use at the solar telescope that can, in principle, measure rotational velocities of 50 m/sec on Venus. Unfortunately, during the time available, initial attempts were frustrated by bad seeing. An improved image stabilizing system is being designed to try to circumvent this difficulty.

**Theoretical Programs:** In recent Monte Carlo calculations by Dr. J. W. Chamberlain, and by Chamberlain in conjunction with Dr. F. J. Campbell, of a light gas escaping from a planetary atmosphere, the exospheric density gradients were incorrect because of a conceptual error in the analysis. The calculated escape fluxes and the velocity distributions were correct, however, because the
earlier method of computing escape fluxes was equivalent to the more rigorous technique used by Dr. R. T. Brinkmann. The calculations were repeated with Brinkmann's refinements, and the departures of the escape flux from the classical (Jeans') rate were calculated as functions of temperature and of the atomic-mass ratio for escaping gas to background gas. The escape flux approaches Jeans' classical values as the exospheric temperature goes to zero. Finally, the density distribution of the escaping gas is appreciably affected by the loss of the high-energy tail and a consequent increase of the upward diffusive flow. This effect partly offsets the diminution of the Jeans' escape flux.

Strobel studied the production of oxides of nitrogen in the Earth's upper atmosphere and their mixing down into the stratosphere, because in preceding staff studies of dayglow enormous concentrations of metastable molecular oxygen (O$_2$ $^1\Delta$) were observed. For some time it was supposed that this constituent might be the reactive species responsible for the production of nitric oxide in the lower atmosphere. Strobel's work aroused considerable interest among those studying the possible pollution of the stratosphere by the SST. He also applied similar models to the Martian atmosphere and searched for possible observable molecules that may give clues to nitrogen abundances on the planet, a prime factor in the question of the possible existence of life on Mars.

Strobel and Dr. L. Wallace studied the problem of the diurnal variation of atomic hydrogen in the Earth's thermosphere. The problem is of particular relevance in the interpretation of numerous sounding rocket and satellite observations of the 1216 Å emission, which is primarily due to resonance scattering of solar Lyman alpha by the Earth's atomic hydrogen. Because the escape flux of atomic hydrogen from the top of the thermosphere is a sensitive function of the upper thermospheric temperature, which undergoes a significant diurnal variation, diurnal variations in H of as much as a factor of 10 have been suggested. Strobel and Wallace solved the time-dependent diffusion and continuity equations with the Jeans' escape flux as an upper boundary condition, in order to obtain a measure of the magnitude of the density variation. The results show a factor of about 2 variation at most, and are in satisfactory agreement with the best observations.

**Mariner Venus/Mercury Program; Extreme-Ultraviolet Experiment:** Several members of the scientific staff of the Planetary Sciences Division have acted in an advisory capacity to NASA in connection with science on future spacecraft. Later they became more directly involved, since an extreme-ultraviolet (XUV) experiment proposed by them was accepted for inclusion on the Mariner flight to Venus and Mercury in 1973. The team of Broadfoot, Belton, and McElroy submitted "A Proposal to Search for the Presence of an Atmosphere on Mercury by Solar Occultation in the Extreme Ultraviolet and to Identify Likely Constituents on Mercury and Venus by Ultraviolet Airglow". Broadfoot is the principal investigator for this team.

NASA mission planning groups have found several opportunities to fly by two or more planets with a single spacecraft launch. The first such opportunity occurs in late 1973. A spacecraft launched to Venus at an appropriate time will receive an assist from the gravitational pull of Venus that will put the spacecraft on a close flyby course with Mercury. There is a further possibility; if the Mercury flyby can be made with sufficient accuracy, the spacecraft can then make a second pass by Mercury 176 days later. The spacecraft's orbital period about the Sun is 176 days, just twice Mercury's period of 88 days. A third flyby is also possible.

The prime objective of the mission is to detect a Mercurian atmosphere. There is no evidence from ground-based observations that Mercury has an atmosphere; on the other hand, the possibility of an atmosphere with a surface pressure as large as 2 mb cannot be excluded. The abundance of gases such as neon and argon could be as large as this value.

The composition of the atmosphere can also be influenced by the solar wind that provides a source of gases of solar composition, and which can also act as a loss mechanism, picking up planetary photo-ions at the limb. The nature of the interaction with solar wind depends on the density of any atmosphere on the planet.

In preparation for the 1973 Mariner Venus/Mercury Mission payload, two simple, low-cost, body-fixed extreme-ultraviolet spectrometers are being designed: (i) to detect a Mercurian atmosphere with the greatest sensitivity, and (ii) to analyze the composition and structure of Mercury's atmosphere. The two multichannel spectrometers, which have no moving parts, will point in separate directions. The first will observe the occultation of the Sun by Mercury's atmosphere at four wavelengths between 400 and 850 Å and accomplish (i) above, down to a partial pressure of argon equal to 10$^{-14}$ mb; the upper limit for neon is higher, whereas trace amounts (less than 10$^{-14}$ mb) of other gases are easily measured. The occultation experiment will also provide definitive information on (ii). The second spectrometer will observe airglow at the limbs of the planet with high spatial resolution and accomplish (ii) in the resonant radiation of H (1216 Å), He (584 Å), He$^+$ (304 Å), C (1657 Å), O (1304 Å), Ar (870 Å, 1048 Å), and Ne (744 Å).

The airglow spectrometer will be on a scan platform that will allow for the detection of lighter elements on all three of the planets, Earth, Venus, and Mercury, by airglow radiation. It will also monitor and map the diffuse galactic and interplanetary background radiation.

At the end of June 1971, the engineering design work was under way and over-all progress was regarded as satisfactory.

**Imaging Science:** Belton is a member of the Mariner Venus/Mercury Imaging Science Team. The conceptual design for the TV system consists of two identical 1500-mm focal-length Cassegrain cameras that have a field of view of approximately 0.5 deg square. A wide-angle field of about 11 by 9 deg is also provided by feeding the light from short-focal-length optics to the Vidicons through the filter wheel system of the long-focal-length cameras. The group has summarized this strategy for the MVM mission in a paper that was in press (Icarus) at the end of the report year.

**Grand Tour Mission of the Outer Planets:** Belton was appointed Team Leader for the Imaging Experiment in
the "definition phase" of the Grand Tour of the Outer Solar System, and on 15 April 1971 he received a grant from NASA for support of expenses connected with his participation in the Imaging Investigations Study for Outer Planets.

D. Research Support Division

Information and Illustration Requests: One important service this Division offers is worldwide sharing with other astronomical institutions of the engineering information and drawings for telescope buildings, rotating domes, and instrument designs produced by KPNO engineering and technical personnel. During the past report year, 665 drawings were provided to meet requests from 24 institutions.

AURA Engineering Technical Reports: During the report year, the following 11 reports were issued as in-house publications:

No. 22 – Vokac, P. R., "Conceptual Design of a Shaft Encoder Interface"
No. 28 – Barr, L. D., "Analysis of Bullgear Deflections – 150-Inch Stellar Telescope"
No. 29 – Miller, R. H., "A Fringe Detector for Use with Michelson Stellar Interferometers"
No. 30 – Pearson, E. T., "150-Inch Stellar Telescope Optical Studies, Part V: Refocusing"
No. 31 – Miller, R. H., "A Phenomenological Representation for Seeing"
No. 37 – Schroeder, D. J., "Design Considerations for Astronomical Echelle Spectrographs"
No. 38 – Barr, L. D., Brar, A. S., Mortara, L. B., Pearson, E. T., Richardson, J. H., and Simmons, J. E., "Preliminary Considerations for a Proposed Coude Laboratory Telescope"

E. General

Computer Laboratory: At its Annual Meeting on 21 January 1971, the AURA Inc., Board of Directors established a policy regarding the use of the computer laboratory facilities by nonstaff astronomers. In effect, it makes the Control Data Corporation 6400 system available on a basis similar to that for visitor use of the Observatory telescopes.

Observatory Staff: As of 30 June 1971, there were 331 regular, full-time staff positions authorized by the National Science Foundation. In addition, Summer Research Assistantships were awarded to 20 students from more than 100 applicants. The participants for 1971 represent 13 U.S. universities and colleges, two British universities, and one in New Zealand.

Public Visitors: During the report year 1971, visitors to Kitt Peak numbered 52 336 and came from all 50 states, the District of Columbia, and five foreign countries.

Journey Into Light: A nontechnical, documentary film, Journey Into Light, portraying the facilities and the astronomical research at the Kitt Peak National Observatory, was produced by the Observatory for educational and public relations purposes. Since its completion in October 1970, the film has been loaned to more than 100 organizations for viewing and has elicited very favorable reactions.

III. CERRO TOLOLO INTER-AMERICAN OBSERVATORY

A. Personnel Notes

There were no changes in the composition of the scientific staff during the report period. Dr. B. M. Lasker was promoted to Associate Astronomer, effective 1 July 1970.

R. Korp resigned as CTIO's Administrative Manager as of 30 September 1970. J. Palacios, a Chilean civil engineer with extensive administrative experience, was appointed to this position effective 10 June 1971.

F. Golden was appointed technical associate (mechanics) on 27 July 1970. C. Schulz resigned as technical associate (electronics) as of 4 April 1971.

B. Staff Activities

Dr. V. M. Blanco visited the Córdoba Observatory, Argentina, during 31 October through 7 November 1970 to offer a series of lectures at an I.A.U.-sponsored educational program for young Latin-American astronomers and graduate students.

Dr. J. Graham attended the AAS meeting in Tampa, Florida, 6-9 December 1970 and lectured on "The Field RR Lyrae Stars in the Magellanic Clouds". Graham also visited the Córdoba Observatory during 22-25 July 1970 to confer with the staff, and the Yale University Observatory during 1-4 December 1970 and 26-27 April 1971 to collaborate with Dr. E. B. Newell on a research project.

Dr. J. E. Hesser attended the I.A.U. XVth General Assembly at Brighton, England, in August 1970 and also the I.A.U. Symposium No. 42 held at St. Andrews, Scotland, 15-18 August. At the latter he read the papers, "Photoelectric Monitoring of Southern White Dwarf Stars" and "On the Rapid Variability of Degenerate Stars", both of which were co-authored by Dr. B. M. Lasker. Hesser also attended the 134th AAS meeting at Baton Rouge, Louisiana, 29 March - 2 April 1971, where he presented a paper, "Observations of K-line Strengths in A Stars of Population I Galactic Clusters", co-authored with Dr. R. C. Henry. Hesser presented a colloquium at the University of Washington, Seattle, on 30 April 1971 and also visited the University of Victoria, British Columbia, to confer with F. D. A. Hartwick on a joint research project.
Dr. W. E. Kunkel attended the AAS meeting in Tampa and contributed the paper, "A Search for Periodic Phenomena in the Activity of Solar Neighborhood Flare Stars". In addition, he participated in colloquia at the University of Texas on 23 November and at the University of California at Berkeley on 3 December 1970.

Dr. B. M. Lasker attended the I.A.U. XVth General Assembly and the I.A.U. Symposium No. 44 at Uppsala, Sweden, 8-15 August, where he presented a paper, "The Cerro Tololo Data Acquisition System". He also visited the Córdoba Observatory during 13-16 January 1971 to participate in a colloquium. He spent from 1 March to 25 April in the U.S., where he worked at KPNO, offered colloquia at the University of California at Los Angeles and at Santa Cruz, the University of Texas, and the University of Michigan. Lasker also presented a paper at the Baton Rouge AAS meeting, entitled "The Periodically Variable White Dwarf RS 484".

Dr. M. Smith presented a paper, "Some Recent Observations Related to the Kinematics of H II Regions", at the I.A.U. XVth General Assembly. He also participated in the oral examination of a doctoral candidate at the University of Texas on 11 September 1970.

The entire CTIO scientific staff attended a joint staff meeting with the European Southern Observatory (ESO) and the University of Chile Astronomy Department held at the ESO Headquarters in Santiago, Chile, on 2 April 1971. Reports on individual research projects were presented by Blanco, Graham, Kunkel, Lasker, Osmer, and Smith.

C. Instrumentation

An IBM 1130 computer system was installed and put into operation in September 1970 at the La Serena headquarters. The system consists of a central processing unit with an 8K memory, a card reader, card punch, and line printer.

The instruments in the 60-, 36-, and No. 1 16-inch (1.5-m, 92-cm, and 40-cm) telescopes were interconnected by underground cable to the Novo data control system that is installed on the first floor of the 92-cm telescope building.

The coude spectrograph of the 1.5-m telescope was installed and put into operation during September and October 1970. The spectrograph has a 36-inch Schmidt camera that gives a dispersion of 9.1 Å/mm with a 9-inch, 600-grooves/mm grating. Two additional cameras with effective focal lengths of 18 and 72 inches will be acquired later.

The aluminizing chamber and vacuum pumps for the 4-m telescope mirror were received and installed on the first floor of the 4-m telescope building, which is complete except for minor finishing details.

In March 1970, an automatic-recording seismograph station was established on Tololo by the University of Chile Geophysics Department.

D. Staff Research

Interferometric observations by Dr. M. Smith indicated that the most violent relative motions so far measured in 61 H II regions studied in the Large Magellanic Cloud are found in the 30 Doradus Nebula. In other regions of the sky, exceptional motions were also found in the Great Carina Nebula and in M17. The work on the Large Magellanic Cloud has yielded very accurate radial velocities that will be useful in refining the optical rotation curve of that galaxy.

Dr. B. M. Lasker and Dr. J. E. Hesser found that the white dwarf star RS 484 is a periodic variable with a dominant period of 212.861 ± 0.031 sec and a secondary period of 273.0 ± 0.6 sec. The amplitude of the dominant variation is only 0.01 mag and of the secondary even less, between 0.01 and 0.001 mag. Except for DS Her and the pulsars, RS 484 is now the shortest-period variable known with a well-defined light curve.

A survey for novae in the Magellanic Clouds was initiated by Dr. J. Graham, since he found that objective-prism plates of unwinned spectra taken with the Curtis Schmidt telescope are an effective means for discovering novae brighter than photographic magnitude 14. In this program, two novae were discovered during the 1970-71 observing season: Nova Mensae 1970b and Nova Doradus 1971, discovered on 5 November 1970 and 1 February 1971, respectively. Prior to this survey, only four novae were previously known in the Small Magellanic Cloud and seven in the Large Magellanic Cloud.

Dr. W. Kunkel, in collaboration with Dr. H. Bradt, Massachusetts Institute of Technology, studied a "hot spot" for 5.5 arc sec in the center of the peculiar galaxy NGC 5128, also known as the Centaurus A radio source. The feature was previously noticed by other observers, and probably is the nucleus of the galaxy. This conclusion is suggested by the facts that the "hot spot" is within 15 arc sec of the centroid of the elliptical component of NGC 5128, and that its integrated luminosity is 2.5 x 10^41 erg/sec, a typical value for nuclei of galaxies, from radio observations.

Dr. P. Osmer worked on line-strength determinations of the O I 7774 triplet, with narrow-band interference filters, for known and suspected F-type supergiants in the Magellanic Clouds. Since the strength of this spectral feature increases linearly with absolute magnitude between M_V = -4 to M_V = -9, these observations will be useful in the calibration of the method.

A program to determine the precise geodetic and geographic positions of Cerro Tololo was initiated by Dr. R. Harrington, U.S. Naval Observatory, Washington D. C., and Dr. and Mrs. V. M. Blanco, CTIO. Observations of the Geos B satellite, which was flashed especially for this purpose, were made with the Curtis Schmidt telescope. The final reductions made at the Goddard Space Flight Center yield the following geodetic position:

\[ \phi = -30^\circ 10' 8.2', \]
\[ \lambda = W70^\circ 48' 21.1'. \]

The geographic or astronomical position was determined by the method of equal altitudes with data obtained from a series of theodolite observations. The preliminary results are

\[ \phi = -30^\circ 9' 53'' \pm 1', \]
\[ \lambda = W70^\circ 48' 54'' \pm 3'. \]

These figures suggest a deflection of the vertical of approximately 39 arc sec in the west-northwesterly direc-
tion, approximately perpendicular to the orientation of the Andean Cordillera and the deep off-shore Chile-Peru oceanic trench, which are the probable sources of the deflection.

E. Telescope Usage and Weather Conditions

During the interval from 1 July 1970 to 30 June 1971, 66 observers representing 35 institutions worked as visiting scientists on Cerro Tololo. Of these, 47 came from the U.S., including eight graduate students who collected data for doctoral dissertations. The telescope observing time was apportioned as follows: 55% to U.S. astronomers and students, excluding KPNO staff; 11% to Latin-American astronomers; and 8% to astronomers from Canada and West Germany. The remaining 26% of telescope time was assigned to CTIO and KPNO staff. Not included in the totals were three advanced students from the University of La Plata, Argentina, and one from the University of Chile, who continued to receive instructions in observing procedures from their professors. In addition, a University of Chile graduate student visited Cerro Tololo several times to work on a thesis project under Dr. J. A. Graham's supervision.

During the 12 months covered by this report, observations were carried out on 295 nights; 75% of these were of photometric quality. On 21 June 1971, a storm brought more precipitation to La Serena and Tololo than had cumulatively fallen in the four years since July 1967. Snowfall from this storm on Tololo was 56.5 cm, and 20.8 mm of rain fell in La Serena. See Table III for a summary of weather conditions on Tololo.

| Table III. Weather conditions on Cerro Tololo. |
|-------------------------------|-----------------|
| Condition                     | 1 July 1970 - 30 June 1971 |
| Temperature                   | 24.44 °C         |
| Maximum                       | 24.44 °C         |
| Minimum                       | -5.00            |
| Maximum wind speed            | 80 mph           |
| Total precipitation           | Rain 9.4 mm      |
|                               | Snow 65.5 cm     |

F. Visitor Research

A major research trend during the past year at CTIO was the increasing use of infrared detectors covering wavelengths up to 20 μ. Several groups, for example those headed by Dr. G. Neugebauer and Dr. J. Westphal, California Institute of Technology, Pasadena, by Dr. E. Ney, University of Minnesota, Minneapolis, and by Dr. H. Johnson and Dr. F. Forbes, University of Arizona, Tucson, have brought their equipment to Tololo. The peculiar variable Eta Carinae has been the object of much observation. At 20 μ this star is the brightest object observed in the sky, excluding solar system objects. In integrated radiation it is intrinsically the most luminous star known. Observations from Tololo suggest that its total energy output has not changed significantly since December 1967. The infrared observations also suggest considerable polarization in its light, and the presence of a dense circumstellar cloud around the star.

The extensive emission nebula surrounding Eta Carinae has also been observed with the Fabry-Perot interferometer by Dr. T. Bohuski, Washburn Observatory, and Dr. M. Smith, CTIO. The reductions made so far show the [O III] 5007-Å line profile to be double over a widespread area.

Optical observations of x-ray sources, made concurrently with x-ray observations by satellite (UHURU) and by radio observations at NRAO, were carried out by Dr. H. Bradt, M.I.T., in collaboration with Dr. W. Kunkel, but analysis of the material obtained is still incomplete. Extensive work on the optical identification of x-ray sources at positions defined by the UHURU satellite was also undertaken by the investigators. Their results suggest that optical identifications by the criteria of ultraviolet excess, time variations, and Hα emission are inadequate.

Extensive work on galactic structure was carried out by a large number of observers. Special attention was given to the Sagittarius-Scorpius-Norma-Centaurus-Crux-Carina region of the Milky Way, in which photometry and spectroscopy of numerous stars, especially intrinsically luminous ones, were done.

In the following listing of visiting observers and their programs, the first number indicates the number of nights scheduled, the hours of actual observing time logged are within parentheses, and the last figure denotes the telescope used by aperture in inches.

H. A. Abt, KPNO, Tucson, Arizona: Rotational velocities of southern B, A stars and classification of southern A stars, 9(52)60.
L. H. Aller, University of California at Los Angeles, S. Czyzak, Ohio State University, Columbus, and H. Epps, University of California at Los Angeles: Spectrophotometry of selected stars and nebulae in the Magellanic Cloud and η Carinae, 5(33)60, 10(87)36, 3(26)24/36.
T. Bohuski, Washburn Observatory, Madison, Wisconsin, and M. Smith, CTIO: Studies of the internal motions of the Great Carina Nebula, 10(100)36.
B. J. Bok and P. Bok, University of Arizona, Tucson: Photometry in the Carina-Centaurus-Norma sections of the Milky Way, 10(101)60, 12(106)36, 7(62)24/36, 2(19)16.
E. Brandi, Universidad de La Plata, Argentina: Spectroscopy of variable stars, 12(92)60.
E. M. Burbidge, University of California at San Diego: Spectrographic observations of Southern Hemisphere extragalactic objects, 12(108)60.
L. Cathey, Lick Observatory, Santa Cruz, California: UBV photometry of giant and subgiant stars in globular clusters, 4(33)60, 7(15)36, 1(3)24.
H.-Y. Chiu, Goddard Institute for Space Studies, New York City, and S. P. Maran, Goddard Space Flight Center, Greenbelt, Maryland: Search for optical counterparts of southern pulsars, including Vela X, 6(48)60.
J. J. Claría, Universidad Nacional de Córdoba, Argentina: UBV photometry of the I Canis Stellar Association and of galaxies with peculiar nuclei, 2(8)36, 12(81)16.
C. Coutts, David Dunlap Observatory, Richmond Hill, Ontario, Canada: Study of variable stars in southern globular clusters, 12(38)24/36.
J. Dachs, Astronomisches Institut Ruhr-Universität, Bochum, Germany: (a) Photoelectric UBV photometry of the open clusters NGC 2516 and NGC 4755; (b) photoelectric photometry in a 4° by 4° field near the galactic equator in Norma, 5(372)24/36.


S. Demers, Laurentian University, Sudbury, Ontario, Canada: (a) A search for variable stars in Fornax; (b) magnitude and color curves of Population II Cepheids in the Large Magellanic Cloud, 2(17)60, 10(59)24/36.

J. Drilling, Louisiana State University, Baton Rouge: Space distribution of stars at high galactic latitudes, 13(77)36, 5(21)16.

F. Forbes, University of Arizona, Tucson, and A. Feinstein, Universidad Nacional de La Plata, Argentina: Infrared polarization of selected Southern Hemisphere objects; daytime observations, 6(16)60; night observations, 6(53)0, 7(40)36, 6(40)24.

R. Garrison, David Dunlap Observatory, Richmond Hill, Ontario, Canada: (a) Spectral classification of southern OB stars; (b) spectral classification in the Sco-Cen Association; (c) spectral classification of Mira variables, 3(38)60, 24(263)36, 3(16)16.

E. J. Grayzec, University of Maryland, College Park: Investigations of the Sagittarius arm by means of distant Cepheids, 16(103)36, 17(91)16.

G. Hagen, David Dunlap Observatory, Richmond Hill, Ontario, Canada: Evolved stars in open clusters, 19(150)36.


R. M. Humphreys, University of Arizona, Tucson: Radial velocities with spectral types for luminous stars in the Southern Milky Way, 7(58)60, 11(101)26, 13(10)16.

P. D. Jackson, University of Maryland, College Park: Distances and radial velocities of luminous OB stars in Centaurus, 9(90)36, 9(95)16.

P. Keenan, Perkins Observatory, Delaware, Ohio: Classification of spectra of supergiants and carbon stars, 10(60)60.


A. U. Landolt, Louisiana State University, Baton Rouge: (a) Photometry of eclipsing binary V 346 Cen; (b) spectra in celestial equator selected areas; (c) high-dispersion spectroscopy of selected eclipsing binaries; (d) the secondary star of the eclipsing binary CV Car; (e) photoelectric and photometric observations of the globular cluster M4, 7(40)60, 7(33)36, 3(152)24/36, 11(64)16.

O. H. Levato, Universidad Nacional de La Plata, Argentina: Rotation of binary stars, 6(42)36.

L. López, Universidad Nacional de La Plata, Argentina: Photometric observations of γ2 Velorum, 21(189)16.

P. Lucke, University of Washington, Seattle: Photometry of clusters and stellar associations in the Large Magellanic Cloud, 4(28)24/36, 3(24)16.

D. J. MacConnell, University of Michigan, Ann Arbor: Search for x-ray stars among the flare stars, 7(53)24/36.

S. M. Malaroda, Universidad Nacional de La Plata, Argentina: Spectroscopy in the Carina-Centaurus region, 6(42)16.

J. Maza, Universidad de Chile, Santiago: Spectrophotometry of Cepheids, 18(133)16.

E. Mendoza, Universidad Nacional de Mexico, Mexico: Infrared photometry (JHK) of objects in the Large Magellanic Cloud, 12(95)60.

R. W. Mitchell, University of Arizona, Tucson: Multicolor basic photometry for stars brighter than 5.0 magnitude, 25(163)16.

H. Moreno, Universidad de Chile, Santiago: Spectrophotometry of late-type stars, 11(49)36.

E. P. Ney and D. Strecker, University of Minnesota, Minneapolis: Infrared photometry of: (a) Wolf-Rayet stars; (b) H II regions; (c) globular clusters; (d) planetary nebulae, 6(52)60, 6(63)36.

B. O'Leary and D. Ward, Cornell University, Ithaca, New York: Photometry of Venus and Mercury; daytime observations, 26(182)16; night observations, 18(69)16.

D. M. Peterson, State University of New York at Stony Brook: Post-main-sequence evolution of O stars, 7(51)60, 1(8)16.

A. G. D. Philip, Dudley Observatory, Albany, New York: Photometry of blue horizontal-branch stars, 3(266)0, 9(79)36, 6(442)24/36.

R. Rubin, University of Illinois, Urbana, and M. G. Smith, CTIO: (a) Observations of compact H II regions with optical counterparts; (b) helium abundance in southern H II regions, 3(25)60, 6(58)36.

W. Sargent and G. Neugebauer, California Institute of Technology, Pasadena: Infrared photometry of the Magellanic Clouds, of η Carinae, and of selected objects, 4(326)0, 6(55)36.

R. Sisté, Universidad Nacional de Córdoba, Argentina: Photoelectric photometry of eclipsing binaries, 9(73)16.

A. Slettebak, Perkins Observatory, Delaware, Ohio: (a) Bright southern rotational velocity standard stars; (b) early-type stars in the south galactic pole region, 4(32)60.

B. Starischka, Universidad Católica de Chile, Santiago: Photographic and photometric observations of the globular cluster Ruprecht 64, 2(142)24/36.

J. Stock, Universidad de Chile, Santiago: Spectroscopic observations of peculiar high-latitude stars, 5(28)60.


W. Stonaker, University of Arizona, Tucson: Multicolor basic photometry for stars brighter than 5.0 magnitude, 156(574)16.

S. E. Strom and K. M. Strom, State University of New York at Stony Brook: Spectroscopy of stars in the galactic center, 8(80)60.

S. van den Bergh, David Dunlap Observatory, Richmond Hill, Ontario, Canada: Faint-star photometry in the central bulge of the Galaxy, 7(62)60.
N. R. Walborn, Yerkes Observatory, Williams Bay, Wisconsin: Spectroscopic observations of certain concentrations of OB stars along the southern galactic equator, 3(2860), 6(61)36.

G. Wallerstein, University of Washington, Seattle: High-dispersion spectra of long-period variables and similar stars, 7(66)60.

W. B. Weaver, Warner and Swasey Observatory, East Cleveland, Ohio: Flare star investigations, 23(181)24/36.

D. Weedman, Dyer Observatory, Vanderbilt University, Nashville, Tennessee, and M. G. Smith, CTIO: Fabry–Perot interferometry of the 30 Doradus Nebula, 11(95)36.

R. Williamson, University of Florida, Gainesville: Photometry of the variables BV 421 OCT and TW Ceti, 17(7)116.

R. Wing, Ohio State University, Columbus: Infrared narrow-band photometry of late-type stars, 7(68)60, 14(89)36, 13(82)16.


University of Michigan program: 115(480)24/36.


G. General

**Observation Station on Cerro Morado:** A temporary observing station was erected on Cerro Morado, part of AURA’s holdings in Chile, for the photographic recording by NASA, the University of Chile, and the Smithsonian Astrophysical Observatory of the barium ion cloud experiment to be conducted jointly by NASA and the Max-Planck Instittut. The barium ion cloud will be injected via a rocket fired from Wallops Island, Virginia, into the Earth's upper atmosphere during September, 1971, if all goes well with the launching and if observing conditions are simultaneously satisfactory at the several sites in North and South America.

**Public and Noted Visitors:** During the report year, 4377 public visitors were received on Cerro Tololo. Apart from the visiting scientists listed previously, the following astronomers paid brief visits to Tololo: Dr. A. N. Deutsch, Dr. A. Nemiro, Dr. V. Chkhotov, Dr. B. Firago, Dr. L. Medvedeva, and Dr. D. Polontjentsev, Pulkovo Observatory, U.S.S.R.; Dr. Pik Sin The, University of Amsterdam, The Netherlands; Dr. Schmidt-Kaler, Bochum University, West Germany; Dr. R. Fleischer, National Science Foundation, Washington, D.C.; Dr. K. Ford, Carnegie Institution of Washington; Dr. J. Sahade, University of La Plata, Argentina; Dr. R. Harrington, U.S. Naval Observatory, Washington, D.C.; and Dr. D. MacRae, David Dunlap Observatory, Richmond Hill, Ontario, Canada.

**Library Acquisitions:** During the year reported, 16 shipments of library material for La Serena and Cerro Tololo were received from KPNO, consisting of astronomical and astrophysical journals, observatory publications, and books. Over 300 new books were received for the two CTIO libraries; the holdings of the La Serena library now total 3700 volumes, those of the Cerro Tololo library 1500.

**Shipments for Fiscal Year 1971:** Eighteen ocean shipments totalling 185 tons and 39 air shipments totalling 3000 tons were received at CTIO during the report year after being processed for shipment at KPNO headquarters.

**Construction of Facilities:** A dormitory providing rooms for 36 employees on Tololo was finished and occupied during the past year. In La Serena, the headquarters building was enlarged with a new wing that contains six offices for the scientific staff and secretaries, a conference room, a photographic darkroom, and two rooms for analytical instrumentation.

**Observatory Staff:** As of 30 June 1971, the Observatory had approval of the National Science Foundation for 81 regular, full-time staff positions.

V. M. BLANCO,
Director, CTIO

**IV. PUBLICATIONS**

Staff members as well as visiting scientists and graduate students who have done research at either KPNO or CTIO, and whose work was published between 1 July 1970 and 30 June 1971 are included in the following list.


Abt. H. A. – See also Geary, J. C.


Aller, L. H. – See Kaler, J. B.

Anderson, D. E., Jr. – See Wallace, L.


Angel, J. R. P. – See also Kemp, J. C.

Angel, J. R. P. – See also Kestenbaum, H.


Ball, W. F. – See Hoag, A. A.

Barnes, J. V. – See Crawford, D. L.

Barnes, J. V. – See Hill, G.

Barth, C. A. – See Wallace, L.


Chiu, H.-Y. — See also Hudson, K. I.


Conner, J. P. — See Evans, W. D.

Contreras, C. — See Alcaino, G.


Crawford, D. L. — See also Brandt, J. C.

Crawford, D. L. — See also Cowley, A. P.

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Danziger, I. J. — See also Faber, S. M.


Dick, K. A. 1970, “Tentative Identification of Several $N_2^+$ $\Sigma_u^+ \rightarrow \pi^+ \Pi^+$ Bands in Auroras,” J. Geophys. Res. 75, 5609.


Drilling, J. S. — See also Philip, A. G. D.


Dyck, H. M. — See also Jennings, M. C.

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Ellison, R. — See Fontijn, A.


Evans, C. D. — See also Wilson, P. R.


Fastie, W. G. — See Wallace, L.


Frye, R. L. — See also MacConnell, D. J.


Gehrels, T. — See Taylor, R. C.


Gehrz, R. D. — See also Dyck, H. M.

Gertken, R. H. — See Hall, D. S.


Glaspay, J. W. — See Crawford, D. L.

Golson, J. C. — See Abt, H. A.

Gomez, A. — See Miller, F. D.

Grader, R. J. — See Burgin, G. A.


Hagen, G. L. — See Fernie, J. D.

Hagen, J. P., Jr. — See Fernie, J. D.


Hartmann, W. K. — See Lockwood, G. W.


Harvey, J. — See also Livingston, W. C.

Heeringa, R. — See Bergh, S. van den

Helfer, H. L. — See Sturch, C.

Henry, R. C. — See Hesser, J. E.


Hesser, J. E. — See also Fontijn, A.

Hesser, J. E. — See also Hartwick, F. D. A.

Hesser, J. E. — See also Lasker, B. M.


Hill, R. W. — See Burginony, G. A.


Hiltner, W. A. — See also Burginony, G. A.

Hiltner, W. A. — See also Cowley, A. P.

Hiltner, W. A. — See also Evans, W. D.

Hiltner, W. A. — See also Kunkel, W. E.

Hiltner, W. A. — See also Mook, D. E.


Hoag, A. A. — See also Kunkel, W. E.

Hoag, A. A. — See also Schoening, W. E.


Hudson, K. I. — See also Abt, H. A.


Humphreys, R. M. — See also Frye, R. L.


Hunten, D. M. — See also Strobel, D. F.

Hyland, A. R. — See Gillett, F. C.

Iben, I., Jr. — See Strom, S. E.

Jackel, L. — See O'Leary, B.


Jennings, M. C. — See also Abt, H. A.

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Kelly, K. K. — See Wallace, L.


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MacConnell, D. J. — See also Bond, H. E.
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Mannery, E. J. — See Burginyon, G. A.
Maran, S. P. — See Brandt, J. C.
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Maran, S. P. — See Hudson, K. I.
Marraco, H. G. — See Feinstein, A.
McClure, L. — See Fernie, J. D.
McClure, R. D. — See also Janes, K.
McCord, T. B. — See Plicher, C. B.
McElroy, M. B. — See Belton, M. J. S.
McElroy, M. B. — See Hunten, D. M.
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McElroy, M. B. — See Strobel, D. F.
McMillan, R. S. — See Lockwood, G. W.
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Roesler, F. L. — See Traub, W. A.

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10, 147.


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