tinum and autoionization lines of Al I are being similarly studied by Kohl by shock-tube absorption spectroscopy.

Banfield, Huber, and Parkinson measured oscillator strengths of many lines of Fe I, using the hook technique in combination with a furnace or a shock tube. The shock-tube j values have been analyzed and agree within respective error limits with those obtained by Wiese and associates at the National Bureau of Standards. The furnace data cover the region below 3000 Å, where there has been little previous work.

Upper Atmosphere, Planets, and Comets: The role of metastable species in the physics of the ionosphere was studied by Dalgarno. He and his associates used the Mariner ultraviolet data to derive an upper limit to the nitrogen abundance on Mars, and made a detailed interpretation of the observations of the emission bands of ionized carbon dioxide.

In May 1971, Elliot and Liller joined two astronomers from Cornell, Veverka and L. Wasserman, in an expedition to the Boyden Observatory to observe the occultation of β Sco by Jupiter and possibly by Io. The Jupiter event was successfully monitored simultaneously in three wavelength channels; however, Io at no time covered the star, as it did when viewed from more northerly Earth latitudes.

Whipple studied accretion problems of cometary and asteroidal material in a postulated Laplace-type nebula, applying aerodynamic processes. He showed how chondrules could have been selectively accumulated on planetesimals in the asteroid belt, and demonstrated that radial pressure gradients in the primitive nebula could have caused accreting planetesimals to spiral in the radial direction of the pressure gradient field. This latter effect may account for the position and large size of Neptune, the possible absence of a comet belt beyond Neptune, and may have helped to prevent the growth of a sizable planet between Mars and Jupiter. Whipple also established limits on the amount of dust in the asteroid belt and studied research possibilities and problems associated with a space probe to a comet. With Dr. S. E. Hamid of Smithsonian he continued the search for evidence of Encke’s comet in ancient oriental records.

An analysis of rainfall data available for the past century was begun by Dr. B. Bell, looking particularly for widespread synchronous fluctuations to wetter or drier climate regimes, lasting at least a few decades. This is essentially an extension to other geographical areas of work reported by E. B. Kraus in 1954-56 which indicated a shift to a drier regime around 1900 at a number of widely separated stations. She is analyzing also the modern (especially post-1870) and medieval (A.D. 622-1522) records of the Nile River.

DEPARTMENT OF ASTRONOMY
Enrollment in the Department comprised 20 undergraduate concentrators and 39 graduate students. Six students received the A.B. degree in June 1971; three received the A.M. degree in March and four in June. The Ph.D. was awarded in June to John R. Burke, Jonathan E. Grindlay, Jeffrey A. Hoffman, Michael A. Jura, John W. Leibacher, and Elia M. Lebowitz.

MISCELLANEOUS
A symposium on Solar Physics, Theory of Atomic Spectra, and Theory of Gaseous Nebulae, was held by the Observatory on 8-9 April 1971, to honor Menzel’s contributions to these three branches of astrophysics. The speakers included many of his former students.

An award of the Bart J. Bok Prize was made in May to Dr. Stephen E. Strom in recognition of “his original researches on the interpretation of stellar spectra.”

The Harvard College Observatory: The First Four Directorships, 1839-1919, written by Bessie E. Jones and Lyle G. Boyd and supported in part by the NSF and in part by the late Richard S. Perkin, has been published by the Harvard University Press.

A bibliography of Observatory publications for the year 1970-71 is available on request from the Librarian, Harvard College Observatory.

Leo Goldberg, Director

University of Hawaii, Institute for Astronomy, Honolulu, Hawaii

This report covers progress at the Institute for Astronomy during the period July 1970 through June 1971.

I. STAFF

The scientific staff during the report period consisted of Lothar Bandermann, Ann M. Boesgaard, Walter K. Bonsack, Jean E. Burns, Dale P. Gruikshank, Gerard D. Finn, Richard R. Fisher, John T. Jeffries, Director (on sabbatical leave), Nessim Lagnado, Marie K. McCabe, David Morrison, Donald L. Mickey, Frank Q. Orrall (on sabbatical leave), Theodore Simon, William M. Sinton, Alan N. Stockton, Richard J. Wolff, Sidney C. Wolff, Ramon D. Wolstencroft, and Jack B. Zirker (Acting-Director). Howard C. McAllister of the University’s Department of Physics and Astronomy was affiliated with the Institute in connection with the rocket spectroscopy program. Of these, Burns, Lagnado, Mickey, and R. J. Wolff joined the staff during the report year, and Beery, Menon, and Tomley left to take positions elsewhere.

Visiting colleague in residence was James C. Kemp of the Department of Physics, University of Oregon.

Operations at the Haleakala Observatories were supervised by Fisher as Resident Astronomer. At the Mauna Kea Observatory, Murphy served as Resident Astronomer until June 1971 when the responsibility was transferred to R. Wolff. Administrative and engineering services are respectively under the direction of Donald R. Tam, Administrative Officer, and Hans Boesgaard, Chief Engineer.

II. FACILITIES AND INSTRUMENTATION

The sections below describe only changes during the report periods — see the two preceding Annual Reports for a comprehensive description.
A. The Haleakala Observatories

A very sensitive complete Stokes-vector polarimeter, designed and constructed under Orrall's direction (cf. IAU Symposium on Solar Magnetic Fields) was put into operation on the 12-ft spar of the Mees Solar Observatory. Preliminary design on a high-resolution scanning spectrometer for the polarimeter was also completed. Testing and use of the instrument has been carried out by Mickey. A differential photoelectric polarimeter that uses the same photon-counting techniques as in the polarimeter is also to be constructed to study the forbidden lines in the corona and will complement coronal measurements made with the polarimeter.

Substantial progress has been made in the design and fabrication of a digital data acquisition system for the zodiacal light polarimeter. A disk storage unit has been added to the PDP8/I for this purpose and it is planned to complete the system, with software, early in 1972.

B. Mauna Kea Observatory

Stockton completed the design of semi-solid Cassegrain Schmidt optics to allow the use of image intensifiers with the Cassegrain spectrograph. The optics, built by Boller & Chivens, have performed satisfactorily in observations using a single-stage intensifier with fiber-optic faceplates.

Under the supervision of Morrison, a new infrared radiometer began operation on the 224-cm telescope in March. The instrument was built jointly at the Institute and at Los Alamos Scientific Laboratory, where J. G. Beery supervised construction. In this first version, a Low bolometer built by Infrared Laboratories is the detector. The radiometer is used in a sky-chopping configuration with apertures from 2 to 15 arc sec, beam separation of 5 to 20 arc sec, and provided with broadband filters for wavelengths of 5, 10, and 20 microns. Preliminary results indicate that Mauna Kea fulfills expectations as a 20-micron observing site, with acceptable transparency and low sky noise at this wavelength on at least 50% of the nights. On the best nights, the water-vapor content of the atmosphere is below 1 precipitable millimeter, the 20-micron extinction is less than 0.3 mag/air mass, and the system is effectively detector-noise limited. Scientific results using this instrument are reported below.

Under Bonsack's supervision, adjustments were completed on the second camera of the coude spectrograph, of 244-cm (8.0 ft) focal length. Problems involving stray light and peculiar image profiles were corrected by installing baffles and regrinding the slit jaws. Regular observations with the coude spectrograph began in November 1970. Tests of the Cassegrain spectrograph revealed substantial image shifts as the telescope was moved. Subsequent reworking of some components in the Institute shop eliminated most of this problem, and the spectrograph was placed in service in December.

S. Wolff and Bonsack installed the circular polarization analyzer for the coude spectrograph, which permits observation of the stellar Zeeman effect. Calibration of the Babinet compensator, which removes the effects of the telescope on circularly polarized light, was completed in March for blue and ultraviolet wavelengths. Regular Zeeman effect observations have been under way since March.

Attention was given to obtaining the best seeing in the 224-cm telescope and to obtaining the best performance from its optics. Initially, the seeing was found to be greatly inferior to the excellent quality found at the neighboring 61-cm Planetary Patrol telescope (see last year's Report). The normal pattern at the 224-cm telescope showed a progressive improvement through the night from a very poor beginning; on occasion, seeing of about 0.5 arc sec was obtained near sunrise at the coude focus. A very large part of this trouble was removed by the installation of exhaust fans at the "bent" Cassegrain focus positions to eliminate heated air in the tube. Further improvement is anticipated when the floor chillers can be placed in satisfactory operation. The Ritchey-Chrétien optics have been carefully aligned with an autocollimator and no shift of collimation is detectable with telescope orientation. Full computer control of the telescope has not been possible due to electronic difficulties with the drive and the position encoders, as supplied by the manufacturer. The computer has been used regularly, however, for accurate right ascension indication, airmass computation, and data-acquisition programs. Software has been written for a variety of telescope scanning modes, coordinate rotations, guiding, and precision offsetting and is presently being tested.

Design of a route for a paved road up Mauna Kea is well advanced; delays were encountered in meeting objections of various special interest groups outside the University. Funds for design of a mid-elevation complex of buildings to provide dormitory, housing, and maintenance facilities were approved by the State Legislature; design is to start following acquisition by the University of the land on which the facility is to be constructed.

With support from NASA, a program of continuous measurement of sky noise at 10 microns and daily measurement of precipitable water vapor above Mauna Kea began in April 1971. The instrument for determining the sky-noise variations was supplied by the California Institute of Technology and is identical to those being issued to other astronomical sites by NASA. The survey program will be run for one year.

C. University Campus

Design and specifications were completed for a permanent facility on the Manoa campus of the University of Hawaii. The project was approved by the State Legislature for commencement in the fiscal year 1972/73. Two additional temporary buildings were added to the six already occupied by the Manoa staff of the Institute.

III. RESEARCH

A. Solar Physics

Jeffries, Orrall, and Zirker (1971, Solar Phys. 16, 103) completed the detailed measurements of the spectra of the inner corona obtained at the 1965 eclipse. Reduction of spectra from the 1970 eclipse has been completed under Zirker's direction. Detailed observations of forbidden-line intensities at many position angles in the inner corona are now available from the Institute's expeditions to the solar eclipses of 1965, 1966, and 1970, and from observations by others in 1952 and 1961. Jeffries, Orrall, and Zirker (Solar Phys. in press) have ana-
lyzed this data and have given a critical discussion of the additional observations and atomic parameters needed for a full understanding of excitation and ionization processes and of physical conditions in the inner corona.

Graduate student M. Cha completed an observational study of the center-to-limb variation of the 5-min oscillations in the photosphere and chromosphere. Cha and Orrall have completed an observational and theoretical study of amplitude-phase-frequency relationships in the 5-min oscillations. They observed that both phase and the ratio of brightness amplitude to velocity amplitude depend on the frequency. They find that this is to be expected from theory but that the actual form of these variations with frequency depend on parameters of the Sun's atmosphere which are, as yet, uncertain.

Zirker and McCabe have concentrated on acquiring observations necessary for the investigation of coronal processes following flares; they have reviewed some of the existing theory for these processes and have refined some diagnostic tools for the data analysis. The probability is small of observing a flare at the solar limb, especially one which produces extensive coronal and interplanetary effects. Nevertheless, a concentrated observational program was successful in obtaining excellent data on a variety of coronal events.

Observing programs were set up by McCabe at Haleakala Observatory as part of a trail spray-prominence patrol organized by an IAU-Commission-10 Working Group for the period April 1 - June 1971. In this program, which was carried out by McCabe, Zirker, Fisher, Simon, and Burns, limb events were observed in Hα and λ5303 using the dual coronagraphs at Haleakala; simultaneous exposures with the Zeiss filter telescope — at the center of Hα and at λ 5/8 Å — show the base of the active area against the solar disk. At the same time, spectra were obtained covering wavelengths from K to D₃, and with the spectrograph slit stepped in graded heights through the erupting material. The spectra will be used to study the Doppler motions and the physical conditions in the prominence. The 3-month program was fruitful in gathering data on five events where eruptive prominences rose from 0.3 to 0.5 radii above the limb. The west-limb crossing of an extensive action region on 12-15 May was accompanied by a complex sequence of flares, surges, loop prominences, and sporadic coronal activity.

Coronal loops were observed on 13 May following a class 2 limb flare and showed strong yellow-line (λ5694) emission. Strong centimetric and decimetric bursts may be associated with this post-flare loop system. Information on associated x-ray, metric bursts, and particle emission is presently being assembled.

On 16 February 1971, an active region at the east limb produced moderate activity of wide variety. Complete spectroscopic and photographic coverage was acquired. It now seems likely that the 100-fold increase in cosmic-ray protons (0.6 to 13 MeV) recorded by Pioneer VI during the next four days is associated with the passage onto the disk of this active region.

Burns completed a study of the ionization and radiative energy balance in quiescent solar prominences, using the radiative transfer equations for the Lyman lines and continuum and a four-level model hydrogen atom. She showed that prominence material at 6000 K or below is mostly neutral, and radiates energy very slowly; it loses temperature at a rate no higher than 0.2 K/sec.

Simon and Pope observed a limb flare on the west limb of the Sun on 16 August 1970. Spectra (at a limited number of heights above the limb) were obtained during a period of 5 hours preceding a violent explosive phase; strong emission in Ca xv and A xiv was seen throughout the duration of this event. The spectra are presently under study.

Nine coronal lines observed from the coronal enhancement on 17 June 1970 were the basis of further studies by Fisher. The ratios of emission-line intensities in three ionization classes characterized by temperatures of 1.0, 1.5, and 2.3 X 10⁶ K were used to calculate temperature variation and the variation of electron density as a function of ionization for differing path lengths through the enhancement. His results indicate a temperature maximum greater than 2.3 X 10⁶ K and a peak mean electron density of 2.32 X 10¹⁴ cm⁻³. The peak temperature and peak mean electron density do not coincide, indicating an asymmetric model for this coronal enhancement. A hot dense core region and cooler surroundings are suggested by the data.

Fisher has studied spectrograms of the east-limb post-flare loop system of 12 August 1970 in order to determine the distribution of electron density as a function of temperature for three coronal regions. The spectra indicate an increase in density at the tops of the loops with most of the material at a relatively cool temperature: Nₑ ≈ 6.0 X 10¹⁶ cm⁻³ T = 3 X 10⁶ K. For the areas just above and just below the loops, the results indicated a lower electron density and the presence of material at high temperature — Nₑ ≈ 2.0 X 10¹⁴ cm⁻³ and T ≈ 2.6 X 10⁶ K above the loops, but T ≈ 4.4 X 10⁵ K for material below the loops.

B. Rocket Spectroscopy

Under the direction of McAllister and R. Wolff, an echelle spectrograph was flown in an Aerobee rocket launched at White Sands Missile Range on 14 June 1971. The instrument is a Czerny-Turner spectrograph using a 79-line/mm echelle as the primary disperser and a 1200-line/mm grating for cross dispersion. The latter was rotated during flight so as to change the portion of the solar spectrum being photographed. In order to reduce internal scattered light, the collimating mirror was coated by the Perkin-Elmer Corporation so as to have high reflectivity in the 1650 - 1750-Å region and low reflectivity in the visible.

Excellent spectrograms were obtained in the spectral region from 1550 to 1780 Å at a resolution of 0.013 Å and a dispersion of 0.5 Å/mm. The prominent emission features produced by Si II at 1808.0, 1816.94, and 1817.42 Å, Si III at 1892.03 Å, and S I at 1900.27 and 1914.68 Å are well recorded on a sufficient number of exposures to yield accurate line profiles. Profiles of the Si II lines are gaussian with a width at half-intensity of 0.10 Å. The remainder of the emission features are being studied. Determination of the center-to-limb variation in the profile of the Al I autoionization absorption doublet at 1935-1937 Å, and measurement and identification of the spectral lines in the region recorded is in progress. Another instrument, to be flown August 1972, is now
under design. This will contain parabolic mirrors to reduce astigmatism, as well as to replace the chromatic LiF collecting lens. We plan to fly to a higher altitude on an Aerobee 170 rocket and to utilize two grating positions, to obtain spectra in the λ2800 and λ1640 regions.

C. Analysis of Spectral-Line Data

Jefferyes, Orrall, and Zirkel (Solar Physics, in press) have developed a general method for interpreting a set of line intensities observed from an optically thin gas in terms of its temperature and density structure. This has usually been considered a trivial special case of the general problem of radiative transfer, but since many astrophysical sources are thin to most radiations (the corona, the chromosphere-corona transition region, planetary nebulae, the interstellar medium, etc.) it is a very significant one in practice. This method has been applied to spectroscopic data on the solar corona, as obtained in 1965, 1966, and 1970.

Jefferyes completed a paper on the population inversion in cool OH clouds. This order-of-magnitude study was sufficiently encouraging to indicate the need for a more accurate calculation. This has been undertaken and completed by Finn in an investigation into the transfer of radiation of far-infrared rotational lines in cool OH clouds. Finn has also completed a study of the probability that a photon of a spectral line formed at a particular depth in an atmosphere ultimately escapes from the atmosphere with a particular frequency. This has led to a study of associated statistical functions—the mean and mean square number of scatterings undergone by a photon before this escape.

D. Solar System Studies

1. Interplanetary Medium

Wolstencroft has continued several programs with the night-sky polarimeter at Haleakala. These include the measurement of (i) the north-south asymmetry of the zodiacal light and (ii) the solar ecliptic coordinates of the neutral points of polarization in the night sky. One of the principal aims of the latter program is to establish whether the fluctuations in the positions of the neutral points (near the anti-solar direction) are related to structure in the solar wind beyond 1 A.U.

Bandermann continued theoretical work on the physical properties and dynamics of interplanetary dust. At the 12th colloquium of the IAU, "Physical Studies of Minor Planets", he reported on computer studies of the effects of particle collisions on the size distribution of the dust. He has also concluded several studies (Bandermann, Monthly Notices Roy. Astron. Soc. in press; Bandermann, Modern Geology, in press) of orbital motion of dust and its accretion in the solar system and in the Earth-Moon system.

In collaboration with R. D. Wolstencroft, Bandermann continued studies on the change of intensity $P_{O/C}$ of the zodiacal light as these may give a clue to the distribution of interplanetary dust relative to the ecliptic plane. A large annual variation reported earlier was found to be fictitious (systematic observational error). Values of $P_{O/C}$ at various points in the ecliptic plane are now available for a time period of nearly 2 years and are presently being evaluated.

2. Planetary Programs

Sinton continued his photography of the major planets in the methane band (8875 Å). Excellent photographs of Saturn, limited primarily by diffraction, were obtained with the 61-cm reflector.

In January, a program for the spectroscopic measurement of the water-vapor content of the Martian atmosphere was begun. The coude spectrograph was used in a double-pass mode giving a dispersion of 1.2 Å/mm at 8200 Å, and an image scale of 3 arc sec/mm perpendicular to the dispersion. Good spectrograms of Mars, with resolution close to 240 000 were obtained in May and June. These showed that the strongest Martian water-vapor lines had equivalent widths of 5 mA. The program is to be continued after opposition.

In spring 1971, a search was begun by Kemp and Wolstencroft for possible circular polarization of scattered light from planets. A new phenomenon termed the polar scattering effect was discovered on Jupiter, in which light from the separate hemispheres was found to be circularly polarized, with opposite senses for north and south. The interpretation of the effect was verified by measurements through the period of opposition on May 23rd. Measurements were then made of Mars, Venus, Mercury, and the Moon, revealing the same effect but with differing signs, magnitudes, and wavelength dependences. Among other applications, the effect can be used to distinguish between solid and gas surfaces on the planets.

In an attempt to explain quantitatively the measured polarization, Bandermann has studied the polarization of light reflected between smooth surfaces. His particular model of a rough surface consists of spheres distributed in a plane, and the incident unpolarized light is reflected either between spheres or between sphere and plane. The degree of circular polarization is calculated as a function of the geometry and of the two components of the (complex) index of refraction of the surface.

During the report period, Cruikshank completed, with A. B. Thomson of the Lunar and Planetary Laboratory, a study of the possible occurrence of ferrous chloride dihydrate in the clouds of Venus by examining the observational material (spectra in the visible and near infrared) which had been used by Kuiper to conclude that this compound is the major constituent of the clouds. Their findings (Icarus, in press) were that the observations do not support Kuiper's theory.

Together with D. Morrison, Cruikshank obtained photometric observations of Venus near inferior conjunction in a search for the anomalous brightening near phase angle 158° originally reported by O'Leary some years ago. The observations showed the anomaly, but not convincingly; the series of observations is to be repeated in the summer of 1972.

Cruikshank obtained coude spectra of Saturn at the 1970 opposition to search for ammonia gas absorption but failed to find any. Using these data, together with some infrared spectra obtained jointly with Kuiper and Fink at the Lunar and Planetary Laboratory in 1969, he set an upper limit of 20 cm - atm for NH₃ above the mean reflecting layer in the clouds. This information, along with the known infrared reflectivity of ammonia frost surfaces, led him to conclude that the clouds of
Saturn are not composed of ammonia ice particles unless the particle size is less than about 2 microns.

Cruikshank and Murphy jointly obtained coude' spectra of Jupiter to search for anomalous ammonia line inclinations originally reported by Spinrad and Giver. The good quality data are being reduced.

D. Morrison, Cruikshank, and Murphy began a program to study the thermophysics of the Galilean satellites Io, Europe, and Ganymede by measuring changes in their 20-micron emission during eclipses. The new infrared radiometer was first used to measure the brightness temperature of Ganymede throughout the eclipse of 17 March. Analysis of these data (Morrison et al., 1971, Astrophys. J. Letters 167, L107) indicates that the thermal inertia of this satellite is \( (3 \pm 1) \times 10^4 \) erg cm\(^{-2}\) sec\(^{-1.2}\) K\(^{-1}\), implying a surface of high porosity and ruling out an atmosphere with surface pressure greater than 1 mb. Several eclipse disappearances of Io and Europa were subsequently observed during April, to be supplemented by reappearance radiometry of these objects during July and August. Murphy and Cruikshank obtained photometric data in the visual of several favorable eclipse disappearances of Io, Europa, and Ganymede in conjunction with the radiometric measurements and as a part of a continuing study of the eclipse phenomena.

D. Morrison and graduate student R. Carson, have almost completed a study of thermophysical models of the planet Mercury. They find that the microwave spectrum can be matched by a subsurface conductivity that varies as either \( T^6 \) or \( T^8 \). They have also re-examined the reported measurement of a dark-side temperature of \( 111 \pm 3 \) K for this planet by Murdock and Ney and suggest possible alternative interpretations of these data.

In collaboration with E. E. Epstein of The Aerospace Corporation, Morrison made 3-mm radiometric observations of Mars with the NRAO 36-ft telescope at Kitt Peak. A simultaneous attempt to observe the planet at 1 mm was not successful. The new brightness temperature of Mars will be combined with other observations in the infrared and submillimeter regions to help define an improved thermal emission spectrum.

E. Stellar Astronomy

S. Wolff and R. Wolff have completed \( w b y \) measurements of a number of Ap stars for which studies of the spectrum and magnetic variations were already available. The observations suggest that variable absorption by strong rare-earth lines in the ultraviolet region of the spectrum, and the redistribution of this flux into the visible, may be a major cause of light variations in the rare-earth spectrum variables.

The program of \( w b y \) photometry of Ap stars is being continued by graduate student N. Morrison and S. Wolff, and they have determined periods for 108 Aqr, HD 184905, and \( \theta^1 \) Mic. Current observations primarily include objects chosen from Preston’s list of Ap stars with \( \sin i < 10 \) km/sec. These observations will be used to determine the distribution of long periods among Ap stars and to set some boundary conditions on the nature of the deceleration mechanism which has produced the slow rotational velocities.

An analysis of the periodic variations of HD 111133 is being carried out by S. Wolff and R. Wolff. They find that the period of this star is 16.30 days and that the light and magnetic variations are in antiphase. The magnetic and rotation axes in HD 111133 are nearly parallel. The spectrograms were supplied by George Preston.

Using the recently installed Zeeman analyzer, Bonsack and S. Wolff obtained spectrograms of a number of well-studied Ap stars in order to test the performance of the system. Preliminary values obtained for \( \beta \) CrB are in good agreement with results published earlier by Preston. Zeeman spectrograms, centered at A3600, are being used to determine whether the magnetic field of \( \alpha \) CVn varies with atmospheric depth. The two Ap stars that seem to show long-term secular variations in their magnetic amplitudes are \( \beta \) CrB and 73 Dra. Spectrograms of both are being measured in order to determine whether these apparent variations are real. Zeeman spectrograms of 52 Her are being combined with simultaneous photometric observations by N. Morrison in an effort to derive a period for this star.

D. Morrison, Simon, and Cruikshank, in collaboration with A. G. Blair of Los Alamos, have begun a program to measure the 20-micron brightness of a number of bright standard sources and to monitor the 10- to 20-micron variability of long-period and irregular variable stars. The goal is to produce a well-calibrated catalogue with relative 20-micron fluxes determined to within better than 5%. Preliminary observations indicate that this precision can be achieved routinely at Mauna Kea at 20 microns. Simon and D. Morrison observed the remarkable variable star \( \nu \) 1057 Cyg (LK Hs 190) at 5, 10, and 20 microns. The large 20-micron flux measured is indicative of radiation from a very cool envelope.

A polarimeter for sensitive circular polarization detection, based on a photoelastic modulator, was constructed by Kemp for use at the Cassegrain focus on the 224-cm telescope. A survey of white-dwarf stars, mainly of the DC type, was begun by him in November 1970. The first result was a verification of the 0.3% circular polarization of G-195, the second known magnetic white dwarf. A series of null results and upper limits, generally at the 0.2% level, has been accumulated for about 12 other white dwarfs. Upper limits of the order 0.2% were also obtained for a few other types of objects including 3C 273, NGC 1068, and M87.

Bonsack (Astron. and Astrophys., in press) completed an investigation on the application of the Institute's digital microphotometer and computer system to several problems in the analysis of stellar spectrograms. Included were questions of the smoothing of grain noise, the removal of instrumental broadening, the utilization of underexposed spectrograms by digital addition, and the interaction of observing and reduction techniques with respect to the reduction of grain noise.

Bonsack has undertaken a study of the intensity and wavelength variations of the hydrogen lines, and of the 4481-A line of Mg II, in the spectrum of the Ap star 56 Ari. He has used the spectrograms which formed the basis of an earlier study on the variations of Si II and He I lines. Some of these spectrograms were remeasured using the digital microphotometer system, and the results reduced to difference spectra relative to a composite reference spectrum. Equivalent widths and line-blocking coefficients for the \( v \) band of the \( w b y \) photo-

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metric system were obtained by computer techniques. Analysis of the results is still in progress.

Boesgaard (1971, *Astrophys. J.* 167, 511) has completed a study of the lithium content of the two components of the spectroscopic binary α Aurigae = Capella. The work was based on seven spectrograms at 2 Å/mm dispersion and 2 mm width which were obtained at the coude' spectrograph of the 120-inch reflector at Lick Observatory by George H. Herbig. A weak Li I line (22 mÅ) was found in the G5 III star in addition to the Li I line found previously in the hotter star (F8-G0 III) by Wallerstein on lower-dispersion spectra. The Li content of the F giant was found to be only 15 times that of the G giant. Boesgaard concluded that the G star need not have evolved to or past the red-giant tip as was thought previously on the basis of Wallerstein's work. Measurements made to determine the Li isotope ratio indicated that there is little or no Li² in either star.

Boesgaard has used the coude' spectrograph of the 224-cm telescope to search for interstellar lines of Be II in the spectra of 20 distant O and B stars. The resonance lines of Be II occur at 3130 and 3131 Å; the exceptionally high ultraviolet transparency of the 14 000-ft Mauna Kea site assisted in reducing the exposure time on these spectrograms. The dispersion was 3.2 Å/mm. No definite interstellar Be lines have yet been detected although more observations are planned.

Zeeman spectrograms of young main-sequence stars have been obtained by Boesgaard to ascertain the extent of magnetic activity in young stars. Criteria for youthfulness have been strong Ca II emission and/or high Li abundance and/or faster than normal axial rotation.

Murphy has obtained spectra of the peculiar eclipsing binary V700 Tauri in the near infrared and finds no indication of the cold disk-like secondary often proposed to explain the light curve.

N. Morrison (Astron. J., in press) in collaboration with B. Zellner of the University of Arizona, has completed a study of the polarization of nova HR Delphini 1967.

**F. Galactic and Extragalactic Studies**

In a joint investigation (*Astrophys. Space Sci.*, in press) by Nandy of the University of Edinburgh and Wolstencroft, a new spectropolarimeter has been developed and used in a pilot study of the interstellar polarization curve at a resolution of 50 to 100 Å. No features down to the 0.5% polarization level were found in the curves of two stars with polarizations (at 1/λ = 2.0 μ⁻¹) of 1.5% and 3.7% which could be unambiguously attributed to interstellar polarization.

Stockton has continued a program aimed at the discovery of bright N-type galaxies or quasars associated with clusters of galaxies. A technique has been developed for separating quasars from blue stars by means of their differing spectral-energy distributions, using a blazed transmission grating in the telescope beam a short distance in front of an image intensifier. With the 61-cm telescope, spectra of eighteenth-magnitude objects at 3000 Å/mm can be recorded in under 10 minutes.

Attempts to record slit spectra of a faint cluster of galaxies near the quasar 4C 37.43 have not yet been successful but will be continued next year.

**IV. OTHER ACTIVITIES**

Cruikshank and D. Morrison obtained spectra at three different eruptive events at Mauna Ulu and Kiluaea volcanoes on the Island of Hawaii, searching for spectral clues to the combustion processes that lead to the formation of large and spectacular flames from the gases emitted. The spectra are good and will yield considerable information but are presently in a preliminary stage of analysis. They obtained financial support from the National Geographic Society for this project for a one-year period, while the spectrograph was kindly lent by Dr. G. P. Kuiper.

Cruikshank, with C. Wood of the Lunar and Planetary Laboratory, made a study of terrestrial lava tubes on Kiluaea, and lunar sinuous rilles.

Orrall, while on sabbatical leave at the High Altitude Observatory, Boulder, Colorado, gave a course in solar physics for the astronauts who are to operate the ATM solar telescope on the Skylab mission. He also presented an invited paper on "Outstanding Problems in Solar Physics," at the AAS Spring Meeting in Baton Rouge, Louisiana.

Zirker gave a review paper in Athens, Greece, in September 1970, on coronal activity and at Harvard, April 1971, on coronal models.

In November and December 1970, while on sabbatical leave, Jeffries presented a series of lectures at the Collège de France entitled "Analysis of Spectral Line Profiles". Jeffries was awarded a Guggenheim Fellowship for 1970, for studies in theoretical astrophysics. He was appointed President of Commission 10 of the IAU, and Chairman of the Solar Physics Division of the AAS.

D. Morrison continued his participation in the infrared radiometer team for the 1973/74 Mariner Venus/Mercury flyby Experiment. He participated in a National Academy of Sciences review of sterilization requirements for spacecraft designed to land on Mars. He also began a 3-year term in February 1971 as Secretary-Treasurer of the AAS Division for Planetary Sciences: W. Sinton was elected for a 3-year term to the Committee.

As a committee, Bonsack, McCabe, and S. Wolff made local arrangements when the Institute for Astronomy hosted the annual scientific meeting of the Astronomical Society of the Pacific, which was held on the Island of Kauai. Boesgaard was elected to the Board of Directors of the A.S.P. for a 3-year term.

M. Cha and J. Burns earned Ph.D. degrees in the University's Department of Physics and Astronomy with dissertations, supervised by Orrall, in the field of solar physics.

**V. PUBLICATIONS**

Thirty-five papers were published or accepted for publication in the regular scientific literature during the 12-month period. Titles are not given here, however the Institute periodically circulates a list showing available reprints and those wishing their names placed on the mailing list should write to the undersigned.

**JOHN T. JEFFRIES, Director**