I. STAFF


II. FACILITIES

A. Haleakala Observatory

1. Mees Solar Observatory

The Stokes spectropolarimeter has been enhanced by the addition of spectral multiplexing in the detector system. The scanning exit slit in use previously has been replaced by a pair of 128-element linear Reticon arrays. A dedicated microprocessor controlling the array readout accumulates the sum and difference data for each pixel pair in temporary buffers at each modulation state. The accumulated data are then stored by the controlling PDP-11/45 for off-line processing. Overall instrument control and operator interface have been implemented in a separate LSI-11 microcomputer.

New data reduction and analysis software has been developed for use with the updated operating system of the multichannel coronal spectrophotometer apparatus.

2. Lunar Laser Ranging Observatory

The entire year was spent in refurbishing the satellite laser-ranging system. An entirely new computer control system, utilizing LSI-11/23 computers, was installed and tested. Final acceptance testing for laser ranging began as the reporting period ended.

B. Mauna Kea Observatory

1. UH 2.2-m Telescope

The primary improvements to the 88-in. telescope during the past year have been in the area of instrumentation. In addition to development of CCD and intensified Reticon detector systems, which are described elsewhere in this report, we have also used successfully a $1 \times 1000$ multianode microchannel array developed by G. Timothy (Univ. of Colorado).

During the past year, Thompson and Heacox joined the staff as support scientists for the 88-in. telescope.

Major building repairs during the year included repainting of the dome and replacement of the siding on the south wall of the coudé room.

2. Canada-France-Hawaii Telescope (CFHT)

Aside from commissioning the coudé focus and the spectrograph, observations were stopped completely in July for the installation of instrumentation cables at the prime and coudé foci, and cables for the remote control of the coudé mirror turrets. Because of primary mirror deformations and instabilities, the mirror was removed from its cell in September and the problem corrected. The computerized telescope control system, which allows faster and more convenient pointing with astronomical correction, was tested in September and November. The first pointing under computer control took place in March; dome tracking is soon to be automated. The infrared upper end was installed in mid-April, but was found to be too heavy; a lighter fit arrangement is being fabricated and is to be installed in July.

A sustained effort is under way to improve the dome seeing by optimizing the cooling-floor temperature and the general building ventilation. The next few months should see the sky testing of the Cassegrain bonnette, commissioning of the IR upper end, and installation of the new prime-focus central unit.

Sixty-two observing programs were awarded time during the report period with 41 of these using the prime focus. Most of these used the wide-field corrector for direct photography to take advantage of the large field and exceptional quality of the seeing available most of the time. The most dramatic result was obtained by L. Thompson, who reported image sizes of 0.6 arcsec during his observing run at the beginning of November. Observing time on the CFHT Telescope is allocated twice a year to astronomers from Canada, France, and the University of Hawaii.

3. Infrared Telescope Facility (IRTF)

Scientific research carried out at the 3.0-m Infrared Telescope Facility (IRTF) by University scientists and grad-
uate students is discussed in the body of this text. An annual report for the IRTF is contained elsewhere in this issue.

4. United Kingdom Infrared Telescope (UKIRT)

During the report period, investigations have been carried out on the static and dynamic performance of the 3.8-m telescope with a view toward improving the telescope performance. The UKIRT is the world's largest infrared telescope. It has been discovered that the performance of the telescope can be improved; improvements are planned in the telescope's pointing accuracy and in the speed and precision with which small movements of the telescope can be made.

The telescope has been in operation every night of the report period for astronomical observing, except for those nights used for engineering time (about 20%). Observers have included scientists from the UK, the U.S., the Netherlands, and Australia.

Scientific work is concentrated on photometry and spectrophotometry in the 1–5-μ region, where the potential of the telescope and the site is greatest. Users of the facility have obtained exceptionally high-quality data in this spectral region. Good results have been obtained, for example, on planets, their rings and satellites, on galaxies, and on ionized regions in our own Galaxy.

Observing time on the UKIRT is allocated quarterly.

III. INSTRUMENTATION

During the last year, the Perkin-Elmer 3220 computer, purchased with NSF monies, was installed, along with UNIX (trademark of Bell Laboratories) operating system. Currently, five terminals are supported. An image-display system, a model 70/F from International Imaging Systems, will be purchased during the fall. An interactive image-processing language is being developed and will be available to the users in the latter part of 1981.

The photon-counting Reticon system, based directly on the design of S. Schectman (Mount Wilson Obs.) was used at the 2.2-m telescope for the first time in February 1981. The design differs from other such systems only in that, for this "blue"-sensitive system, light amplification is provided by two RCA image tubes. A "red" system utilizing Varo image tubes and a Varo microchannel plate is being assembled for use in the fall of 1981. Also in the initial construction phase is a new set of electronics modeled after the SAO/Steward Observatories' system. As part of the Reticon system, a dual-density magnetic tape and a 10-Mb disk were added to the 2.2-m data-acquisition system.

The Institute for Astronomy is building a CCD camera for use with a 500 × 500 device provided through JPL under the auspices of the Galileo Imaging Team. The camera will be used by team members to gain experience with CCD's prior to receipt of spacecraft data, and by the Institute for general astronomy research. During the past year, a new dewar and support electronics were built, and a DeAnza Visacim system, which will travel with the camera to provide some image-processing capability at the telescope, was acquired. The complete system will be integrated with a blemished 500-square device at JPL in July 1981 with observing at the 2.2-m telescope scheduled for the following month. In late 1981, a "very good" three-phase thinned backside-illuminated TI CCD will replace the blemished device.

IV. RESEARCH

A. Solar Physics

In a collaborative program with the Laboratory for Atmospheric and Space Physics (Univ. of Colorado), Orrall has continued as co-investigator in a program of EUV rocket spectroscopy. A new, stable, high-resolution spectrometer, designed for studies of coronal dynamics, was built at LASP by G. Rottman. This has been flown twice with a third flight scheduled for fall 1981. In each flight, about 800 spectra have been recorded with a linear-array detector in ten repeated scans along a solar diameter. Together with G. Rottman and J. Klimchuck (LASP), two papers on the results have been prepared. A major result is that they confirm a strong Doppler signature corresponding to a relative outflow from low-latitude coronal holes, amounting to as much as 7 km s⁻¹ in the transition line O V (429.629) and 15 km s⁻¹ in the coronal line Mg x 625. The most direct interpretation of this signature is that it represents a real net outflow of mass into interplanetary space from deep in the atmosphere. They show that this interpretation is consistent with the conservation of mass, the observed proton flux at the Earth, and with current empirical models of the transition region and corona. This interpretation is also consistent with the well-known relation between coronal holes, high-speed solar-wind streams, and persistent geomagnetic storms. Other interpretations are, however, possible and are being explored.

Orrall completed the work of editing a volume on Solar Active Regions, being published by the Colorado Associated University Press. This monograph is the result of the third Skylab Solar Workshop of which Orrall was Director. It forms a companion volume to the monographs produced by the two preceding workshops on Coronal Holes and High-Speed Wind Stream, and on Solar Flares, directed by J. B. Zirker and P. A. Sturrock, respectively.

Orrall served as leader of the Science Working Group for the Solar Corona Explorer and assembled its final report. The aim of this proposed NASA mission is to study the structure, dynamics, and evolution of the corona, globally and in the required physical detail, to study the close coupling between the inner corona and the heliosphere.

In collaboration with G. W. Pneuman (HAO), Orrall has prepared a critical, extended review chapter on solar "Atmospheric Structure, Flows and Heating." This is to be included in a volume on the Physics of the Sun, which is being prepared as part of a review of solar physics conducted by the Space Science Board of the U.S. National Academy of Sciences.

Orrall prepared and presented an invited paper on "The
structure of the solar corona” at the 157th Meeting of the AAS in Albuquerque.

Landman, R. Rousset-Dupré, and summer research assistant G. Tanigawa have undertaken a detailed study of the uncertainties associated with Gaussian fits to observational line profiles. Standard deviations for the line center, width, and peak intensity have been derived as functions of the (frequency-dependent) signal-to-noise ratio, the density of points in the line, and the offset of the central measured frequency from line center.

Landman and Pasachoff have reduced and are analyzing the data obtained from two of the observing programs at the February 1980 eclipse in India: (i) a search for short-period (0.3–3.0 s) oscillations in the Fe\(^{13+}\) \(\lambda\) 5303 integrated intensity at selected coronal positions (Landman and Pasachoff) and (ii) prominence and coronal spectra in the range \(\lambda\lambda\) 3300–7000 at points around the limb (Landman, Jefferies, and Orrall).

Continuing his program of computing proton-excitation cross sections and rate constants for fine-structure transitions in coronal and transition-region ions, Landman completed calculations for transitions between the \(2p^3S\) \(3e^+\) Ne isoelectronic sequence ions Na\(^{2+}\)–Ni\(^{11+}\).

Landman, Bernat, and Pasachoff have continued work on the on-going prominence-spectrophotometry program, using both the OMA-25-cm coronagraph/3-m coude spectrograph system for high-dispersion measurements of selected lines, and the improved MCS system for low-dispersion wide-spectral-range observations. The Na D-line, He D\(_1\), and Ca\(^{11+}\) \(\lambda\) 8498 study has been completed (Landman, Astrophys. J., in press), and a variety of projects deriving from that work are now in progress. These include studies of the nature and causes of the He triplet-metal line-intensity branching relation, and magnitude of the macroscopic vertical velocity field, the detailed characteristics of the microturbulent velocity field, and the physics of the Ca excitation-ionization equilibrium.

Bernat and Jefferies have begun a program to study the motion and structure of the sunspot chromosphere using high-resolution observations of the Ca II K line.

Heasley and graduate student C. Beerman have been working on the analysis of Stokes line-profile observations made using the High Altitude Observatory. These data are being used to evaluate a number of methods proposed in the literature for determining the vector magnetic field on the Sun from observations of Stokes line profiles. Their tests have shown that almost all methods which use all four of the Stokes parameters can give erroneous field information when the intensity profiles are contaminated by scattered light. Heasley is now working on a procedure for determining the field strength and direction from the shapes of the linear and circular-polarization line profiles alone. Tests of the new method with synthetic data are promising, although the application to the actual Stokes profiles has met with limited success. The goal of this work is to provide a rapid analytical method for determining maps of the vector magnetic field in active regions from Stokes-profiles measurements with the Haleakala polarimeter.

Graduate student S. Walton has been investigating the application of multicomponent radiative-transfer calculations for the study of the physical condition in solar plages. A computer program for the determination of the emergent intensity from a two-component model atmosphere has been developed. The results of these calculations are being compared with observations of ten Zeeman-insensitive photospheric lines and the Ca II K-line wings. The observations have been obtained recently for a number of plages at varying \(\mu\)-values using the OMA-25-cm coronagraph at Haleakala; they will also be used to quantify plage center-to-limb and plage-to-plage variations.

During the recent Solar Maximum Year (SMY), intensive observing programs were operated at Haleakala in support of the NASA Solar Maximum Mission (SMM) to coordinate with the scientific objectives formulated by SMM-experiment teams and ground-based observatories. McCabe has attended a series of SMY workshops where contributing investigators have examined the data from all sources in order to select periods when successful observations had been obtained with good time resolution and extending from the x-ray through the radio-frequency range of the spectrum. Detailed studies are now in progress by several teams, each directed toward a specific question relating to the understanding of flares and associated phenomena through the solar atmosphere. In a joint study of homologous flares, two regions have been chosen that each produced a large number of flares as they crossed the disk; McCabe has examined H\(_\alpha\) observations to determine the flare locations with respect to the active-region configuration and changes in magnetic-field constituents, and classified possible homologous groups. She is analyzing the Hz aspect of a small flare which produced strong \(\gamma\)-ray and x-ray emission with rapid time variations; the Hz data from Haleakala were obtained with good temporal-spatial resolution. McCabe is continuing with the study of the kinematics of Hz eruptive prominences at the solar limb, particularly those which are related to coronal transients observed by the SMM coronagraph/polarimeter or the P78-1 satellite experiment.

Becklin, Lindsey, Orrall, and Jefferies have collaborated with M. Werner (NASA-Ames) and L. Gatley (UKIRT) during the last year to make solar observations in the 30-, 50-, 100-, and 200-\(\mu\)m continua from the NASA-Ames Kuiper Airborne Observatory. The project necessitated special adaptations to the equipment for solar observing. The program included the successful observation of a total solar eclipse on 31 July 1981. The purpose of the eclipse experiment was to obtain high-resolution profiles of the continuum intensity of the solar limb by observing its occultation by the lunar limb; earlier observations in the program provided data on the gradual radial, intensity profile from center to limb. A preliminary examination of the data indicates four important results:

(i) An unexpected strong radial darkening of the solar limb appears at 200 \(\mu\)m, where minimum brightness temperature occurs at disk center. This suggests that the low chromosphere is heated preferentially—if not exclusively—in the regions recessed in vertical magnetic flux tubes. The heated regions presumably disappear on approaching the
limb, causing the observed darkening. The darkening at 200 μm may be reversed at the extreme limb, giving rise to a spike with a brightness in excess of several hundred K. The latter result is tentative pending an analysis of systematic errors.

(ii) The quiet 200-μm limb lies about 1.5–2 arcsec above the 30-μm limb, which probably lies considerably above the visible limb, although this has not yet been checked. At the point of third contact, where there is evidence of limb activity, the 200-μm limb appears to be even further beyond the 30-μm limb.

(iii) Solar plages, which have a low (1%–2%) contrast in the 10-μm continuum, show a strong increase in contrast (to about 10%) at 100–200 μm. This is a strong indication that the preferentially heated elements, thought to be confined to narrow flux tubes in the low photosphere, diffuse rapidly to a much larger filling factor near the temperature minimum.

(iv) A careful comparison between the infrared brightness profile of the moon at several different phases and of the Sun is now underway. The results will require further detailed analysis, but it is hoped that these data can assist in a confirmation of the determination of the absolute brightness of the Sun in the infrared continuum.

B. Solar Ultraviolet Spectroscopy

R. Roussel-Dupré and graduate student C. Beerman have completed a paper which examines the effects of diffusion and mass flows on C IV and Si IV lines formed in the solar atmosphere. Their primary conclusions are that diffusion acts to deplete the transition region of heavy ions to an extent which depends on the detailed temperature and density structure while directed motions maintain uniform elemental abundances. This can, however, lead to departures from ionization equilibrium and can have strong effects on computed line intensities with large asymmetries introduced into the line shapes, depending upon the magnitude of the flows. Based on their results, Roussel-Dupré and Beerman suggest that redshifts observed in the network in lines of C IV and Si IV could be due to gravitational settling of the ions following their injection, via thermal diffusion, into the corona from spicules.

R. Roussel-Dupré has obtained new helium-ion diffusion and viscosity coefficients from a numerical solution of the first-order Boltzmann-Fokker-Planck equation. Included in his calculations is the effect of a self-consistent electric field, a term heretofore omitted and one which bears strongly on our understanding of the physical processes which dominate thermal diffusion. These diffusion coefficients are important for studying helium abundances in the solar atmosphere, in the envelopes of helium-rich white dwarfs, and in stellar evolution calculations.

M. Roussel-Dupré and summer student Yvette Kirby have completed the absolute calibration of the NRL HRTS-II rocket spectra. Their results indicate that the HRTS-II instrument was more efficient than the HRTS-I throughout the spectral range (1175–1715 Å) of the two instruments. Absolute intensities can be determined to within 50% and will be used in analyzing and interpreting HRTS-II data.

J. Wrathall (Brigham Young Univ., Hawaii) and R. Roussel-Dupré are analyzing HRTS-II spectra of a small (~10 arcsec) bipolar region located near the center of the solar disk. This region is likely to be an EUV magnetic loop which extends above the solar chromosphere into the corona. A total of 15 EUV lines from various ions are included in their analysis, which is aimed at mapping the temperature, density, and velocity structure across the neutral line. A second goal of this project is an evaluation of the importance of kinetic processes in solar magnetic loops.

D. Roussel-Dupré has completed the data reduction and calibration of Skylab Lα line profiles obtained above the solar limb. These observations complement the disk profiles which were reduced last year. Her observations show that the line profile retains its disk value for both the linewidth (0.88 Å FWHM) up to +12 arcsec, where it decreases to 0.51 Å, and the integrated intensity up to +4 arcsec, where it begins a gradual decrease. The central reversal shows a weakening with increased height above the limb and at +8 arcsec and +12 arcsec the line profile may be flat topped.

The possibility of using the Lα line wings above the limb as a density diagnostic is being investigated. From a cursory examination of these data, D. Roussel-Dupré infers the existence of neutral hydrogen at heights greater than 8 arcsec with column densities of 3×10^{17} cm^{-2}, which corroborates the findings of Schmahl and Orrall (1979). A more detailed analysis of the line wings is in progress.

In a related study, D. Roussel-Dupré has made partial coherent-scattering (PCS) calculations of the line wings and compared them to the center-to-limb behavior of the Lα disk observations. The PCS calculations include an improved redistribution function, a new Stark-broadening parameter which accounts for the effects of the energy fine-structure splitting, and the C I 1240-Å continuum in non-LTE. Several new results have been obtained thus far from this study. The magnitude of the noncoherence fraction resulting from the new redistribution function is much smaller than the value used by Val (1981), which was chosen to fit the observations. Also, the Lα wings (Δλ > 2 Å) are strongly influenced by the C I 1240-Å non-LTE continuum, which is an important consideration when using the Lα wings for semiempirical modeling of the solar chromosphere. These results and the above-the-limb observations were reported by D. Roussel-Dupré at the June 1981 meeting of the AAS.

D. Roussel-Dupré has also used the O V λ1218 intensities that were obtained from the Lα data reduction in conjunction with the O V λ760 intensities reported by Vernazza and Reeves (1978) to obtain the line-intensity ratio, which is sensitive to both the electron temperature and the proton-mixing rates. This ratio has been previously estimated to be 0.64, based upon the observations of Burton et al. (1971). Using the ATM data, this ratio is found to be 2.39 in the interior of supergranule cells and 5.17 in the network. These values are much larger than the theoretical values of Dufkin et al. (1978). The discrepancy between the observed and theoretical ratio may indicate a need to reevaluate the proton-mixing rates, which are included in the theoretical calculations.
Heasley and graduate student J. Varsik have been investigating the Si i 2881-Å line as a spectroscopic diagnostic of the thermal structure in the upper photosphere and lower chromosphere. This line is one of the strongest absorption features in the rocket-ultraviolet spectra of the Sun and late-type stars. The line arises from the same level as the Si i 1682-Å photoionization continuum. J. Vernazza, E. Avrett, and R. Loeser (CFA) have modeled the continuous spectrum of silicon in a number of models of the solar atmosphere. They find that to reproduce the observed 1682 continuum in the solar spectrum, the temperature in the quiet solar atmosphere must be about 4200 K at the temperature minimum. Heasley and Varsik have used the identical model atoms and atmospheres used by Vernazza, Avrett, and Loeser to compute non-LTE line profiles for the 2881-Å line. They find that the core of the theoretical profiles is extremely saturated and far too broad when compared with observations of the line made during the 1974 University of Hawaii rocket flight. Using models of the solar atmosphere with hotter temperature minimum does not significantly improve the comparison with the observations. It appears that the overall population of the $3^3 P$ level of neutral silicon in the solar atmosphere must be reduced by some process in order to avoid the severe saturation of the 2881-Å line core. Work is now in progress in an attempt to clarify the dependence of the silicon level populations upon the various atomic parameters used in the non-LTE modeling.

C. Solar System Studies

1. Planets

Tokunaga, S. Beck, E. Serabyn, and C. Townes (Univ. of California, Berkeley), T. Geballe (Mount Wilson and Las Campanas Obs.), and J. Lacy (CIT) have observed Jupiter and Saturn on the IRTF with the Berkeley 10-μm Fabry-Perot spectrometer in a program to detect new minor constituents. The presence of hydrogen cyanide (HCN) on Jupiter was established for the first time, and an HCN-column density of $5 \times 10^{-3}$ cm-1 magat was derived. An upper limit to the HCN-column density was determined for Saturn. These results have been submitted to Icarus. Propylene ($C_3H_6$) was also observed on Saturn and Titan, confirming the Voyager detection of these gases, and in addition, $C_3H_2$ was observed on Jupiter for the first time. Tokunaga and graduate student D. Lindwall are also determining abundances of acetylene ($C_2H_2$) on Saturn and Titan using data acquired last year.

J. Caldwell [SUNY, Stony Brook], G. Orton (JPL), and Tokunaga have obtained narrowband 10- and 20-μm observations of Uranus and Neptune. These observations show a brightness-temperature enhancement at 17.8 μm relative to 19.6 μm of 0.9 ± 0.5 K for Uranus and 1.8 ± 0.6 K for Neptune. Since the pressure-induced molecular hydrogen opacity at 17.8 μm is greater than at 19.6 μm, these observations confirm the existence of a temperature inversion on Uranus and Neptune, although somewhat weaker on both planets than previously reported. In addition, Uranus was detected at 12.5 μm and Neptune at 10.5 μm. These data are being modeled to determine whether hydrocarbon-emission bands or the hydrogen continuum was detected at 10 μm.

Caldwell, Orton, and Tokunaga have also continued their program of monitoring the temporal and spatial variations of the infrared emission of Jupiter and Saturn. The enhanced 8-μm emission from the $ ν_s$ band of CH$_4$ at the magnetic poles of Jupiter was confirmed. They suggest that it originates from collisional excitation of CH$_4$ by charged particles. The variation in the CH$_4$ emission on Jupiter is also interesting at lower latitudes, showing peaks at 18°N and S latitudes. Whether this is caused dynamically or radiatively is not known. More work is planned to distinguish between these possibilities.

M. A’Hearn and E. Sdwek (Univ. of Maryland), and Tokunaga searched for 1.3–2.6-μm ice-absorption bands in the coma of comets Stephan-Oterma and Tuttle. No features were found. In addition, J, H, and K observations were obtained for these comets and for comets Meier and Bowell. All of the comets have $J – H$ and $H – K$ colors similar to those of certain asteroids. It appears either that ice particles are not the dominant material in the coma of these comets or that small-particle scattering has greatly reduced the contrast in the ice bands.

R. Knacke (SUNY, Stony Brook), S. Ridgway (KPNO), and Tokunaga obtained a high-resolution spectrum of Jupiter in the 9–10-μm region using the KPNO FTS at the Mayall 4-m telescope. It is possible to probe down to the 1-bar level at these wavelengths; CH$_4$, CH$_3$D, NH$_3$, and PH$_3$ were observed in absorption. Analysis of the data shows high abundances of these gases, consistent with the enhanced C/H$_2$ ratio found at shorter wavelengths. This spectral region is also interesting since H$_2$S and many hydrocarbons, such as H$_2$CO, have fundamental absorption bands at these wavelengths. However, no new minor constituents were observed.

Howell and Cruikshank, with the assistance of graduate students R. H. Brown, J. S. Morgan, and E. Shayea, continued a study of the photometric variability of Neptune in the near-infrared $J$ and $K$ bands. The diurnal light curve of Neptune in $J – K$ is different from that observed in the previous year (1980), with more irregularities and a displacement of about 1 mag fainter. This change in the overall brightness of the planet suggests a global dissipation in the high-altitude haze believed to account for the diurnal light curve, while the irregularity in the light curve suggests a nonuniform breakup.

2. Magnetospheres

Pilcher has obtained more than a hundred new images of the Jupiter plasma torus in the [S II] $λ$ 6731 line, some of which have led to a substantial improvement in our understanding of the plasma characteristics. In particular, he, Morgan, research associate J. Fertel, and C. Avis (JPL) have assembled 24 images obtained on a single night in March into a movie that reveals a great deal of variation in the structure of the torus with magnetic longitude. The movie...
data show that [S II] emission at longitudes near that of the south magnetic pole ($\lambda_{\mu \mu}(1965) = 20^\circ$) is weak and concentrated inside of Io's orbit about 5.6 $R_J$ from Jupiter. Between longitudes $\sim 150^\circ$ and $\sim 350^\circ$ there is a brightness maximum at (5.6-5.7)$R_J$ that is elongated in the direction of the field lines. Associated with this field-aligned feature (FAF) is [S II] emission extending throughout the hot outer torus to $\sim 7.5R_J$. It appears that the FAF is a manifestation of a region in which plasma is being rapidly formed, and the extensive emission associated with the FAF is from plasma flowing rapidly outward from this region. The maximum near $5R_J$, which is absent at longitudes between $\sim 245^\circ$ and $\sim 325^\circ$, is probably the result of inward diffusion and cooling of the plasma. The range of longitudes over which only the FAF is present may be a region of one-way outward motion of the plasma, suggestive of plasma convection as discussed by Hill et al. (submitted to J. Geophys. Res.).

Pilcher has also obtained more observations of directional features in Io's sodium cloud, but none as pronounced as those obtained during a four-day interval last year. It appears that at that time there was unusually bright sodium emission around the satellite, perhaps accounting for the prominence of the directional features. Pilcher and W. Smyth (Atmospheric and Environmental Research, Inc., Cambridge, Massachusetts) are analyzing these images. They are, in particular, pursuing the possibility that these features are the result of collisional sweeping of the neutral-sodium cloud by the corotating heavy-ion plasma. The first step in their analysis is to determine the actual three-dimensional distribution of the sodium at the time the images were acquired, a task for which Smyth's programs—developed over the past several years—are particularly well suited. Once these three-dimensional distributions have been determined, it should be possible to distinguish between the sweeping mechanism and other possibilities such as directional ejection directly from Io's surface.

Morgan, working with Pilcher, has completed the analysis of 53 "order-overlap" spectra of the plasma torus acquired in 1979 and has begun the analysis of over 300 additional spectra obtained in 1980 and 1981. The order-overlap spectra, in which the first- and second-order spectra produced by the Cassegrain spectograph are measured simultaneously, encompass at least seven plasma emission lines of S II, S III, and O II. Morgan and Pilcher have found that early indications of different electron densities derived from the S II and O II lines were probably due to the use of inaccurate O II collision strengths. When the best available collision strengths are used for both ions, the derived-average electron densities are consistent. A few spectra, however, show electron densities for the [O II]-emitting regions that are significantly lower than those derived from the [S II] lines. These differences may reflect different spatial distributions of these ions.

The early indications, based on order-overlap data, of cold ($T_e < 1 \times 10^4$ K), dense ($n_e \gtrsim 10^9$ cm$^{-3}$) regions in the emitting plasma have been supported by subsequent analysis. In both single- and double-electron temperature models, these conditions are required to account for spectra that show the blue ($\lambda \lambda 4069, 4076$), but not the red ($\lambda \lambda 6716, 6731$) doublet of S II. A paper on the order-overlap spectra is in press at *The Astrophysical Journal*.

Pilcher has co-authored two reviews on the Jovian magnetospheric emissions. One, by Pilcher and D. Strobel (Naval Research Laboratory) is to be published in *The Satellites of Jupiter*, edited by Morrison. The other, by R. Brown (Univ. of Arizona), Pilcher, and Strobel will appear in *The Physics of the Jovian Magnetosphere*, edited by A. Dessler (Rice Univ.). In both papers, the authors sought not only to review, but also to expand and clarify an understanding of, the Io-associated emitting clouds. In the first paper, for example, Pilcher and Strobel show that there is no discrepancy between most of the ground-based measurements of plasma-torus electron density and those derived from *Voyager* data. In the second paper, the authors point out the possible importance of collisional sweeping of neutrals by the corotating heavy-ion plasma, a process that may be responsible for some of Pilcher's observations as noted above. The books containing these papers should both appear in early 1982.

3. Satellites, Asteroids, and Comets

Sinton has continued work on the infrared observation of volcanism on Io. The monitoring program at $K$, $L$, and $M$ bands has been continued mostly with the 2.2-m telescope, but some observations have been made with the UKIRT 3.8-m and IRTF 3-m telescopes. The new data set confirms conclusions drawn from the previous data. Io exhibits a large night-to-night intrinsic scatter at 4.8 $\mu$m, less scatter at 3.8 $\mu$m, and no measurable scatter at 2.2 $\mu$m. Several minor outbursts (50%-100% increases) were found, but no major outbursts (three- to fivefold increases) were observed. A new phenomenon has been observed. Io "flickers" at 4.8 $\mu$m with a time scale of about 30 s. The flickering is intermittent. Sometimes it cannot be detected, while at other times the amplitude is up to 10%. The flickering has been sought at 10 $\mu$m. On the several occasions that observations were made with the 3-m IRTF telescope, a $\sigma$ upper limit of 1% was set. The flickering at 4.8 $\mu$m has been observed with both the 2.2-m and IRTF telescopes on a number of occasions.

Sinton has also observed a number of eclipse reappearances of Io with particular emphasis on obtaining uniform coverage of the spectrum between 3.5 and 30 $\mu$m during the observable half-hour before emergence from the shadow. During this period Io has its lowest background emission as observable from the Earth; the hot-spot emission is therefore best seen during these periods. The total flux from the hot spots in these new observations agrees reasonably well with the value of 1.5 W m$^{-2}$ found by Morrison and Telesc. In connection with this work, Sinton found that on all occasions observations could be made from Mauna Kea through a 0.2-$\mu$m-wide filter centered at 6.295 $\mu$m which coincides with a "window" in the 6-$\mu$m water-vapor band. The observed extinction was $\sim 1.3$ mag airmass.

Sinton has been working on a hypothesis that the observed hot-spot emission is from currently active volcanoes at $\sim 600$ K and a steady-state mixture of cooling flows of old eruptions. The emission from the old flows eventually ceases.
because of resurfacing by deposition of debris. This model could yield flickering at 4.8 μm owing to the current activity, but since in the model most of the 10 μm emission arises from the old flows, flickering is not expected at this wavelength. The model gives a good fit to the spectrum of the hotspots with only three adjustable parameters.

Several eclipse reappearances of Europa have also been observed by Sinton with the UKIRT and IRTF telescopes, partly in collaboration with Tokunaga, and A. Longmore and I. Gatley (UKIRT). They set a tentative upper limit to any hot-spot emission from Europa of 3% of that of Io. It is possible, however, that a yet-lower upper limit or a positive detection may result from a very careful modeling of Europa's natural eclipse flux. This modeling is under way.

Howell and Cruikshank made observations of zonal variations of the strength of the 4.08-μm SO₂ absorption band on Io in a study of the volcanic activity on that satellite. The new data show the band to be weakest near 270° longitude, consistent with the SO₂ distribution reported from IUE ultraviolet spectra. Comparison of the new data with the discovery observations made in 1976 suggests that the absorption has weakened near longitude 270° in the intervening five years.

L. Lebofsky (Univ. of Arizona) and Tokunaga obtained high signal-to-noise 3-μm spectra of Callisto, Europa, the dark side of Iapetus, and Ceres. These observations were made to search for or confirm the presence of water of hydration on these objects. The most interesting result was that water of hydration was confirmed on Ceres, but in addition, evidence for H₂O frost was found for the first time. This was unexpected because of the short lifetime of free H₂O on Ceres.

Graduate student R. Brown and Cruikshank used a 5% CVF to obtain a high-quality spectrum of Hyperion which shows the water-ice absorption bands discovered earlier by Cruikshank. The new data will permit a close comparison with other ice-bearing satellites and with laboratory data presently being obtained by Brown in connection with his Ph.D. thesis. A recomputation of the effective radius of Hyperion from Cruikshank's earlier 20-μm thermal flux measurement is now in good accord with the directly measured dimensions from Voyager.

Cruikshank, with Brown's assistance, obtained an improved infrared spectrum of Triton. Analysis of the spectrum in collaboration with J. Apt (JPL) is in progress. The spectrum confirms the strong absorption band at 2.35 μm with a superficial resemblance to gaseous CH₄, although details in the spectrum differ. Methane in the solid state is a working hypothesis, pending further laboratory work.

New photometric and spectrophotometric data on the dark side of Iapetus have been analyzed by Cruikshank, in collaboration with graduate students J. Bell, Brown, and C. Beerman, and colleagues M. Gaffey and R. Clark (Univ. of Hawaii, HIG), and Howell. The new spectrophotometric data from 0.3 to 2.6 μm show that the dark side is extremely red, similar to a few asteroids and the Moon and Mercury. The dark side's albedo and reflectance spectrum are most closely matched by carbonaceous residue from the Murchison C2 carbonaceous chondritic meteorite. Reflectance data for Phoebe, long thought to be the source of dark material on Iapetus, show that its colors in the region 0.3-2.5 μm are significantly different from those of the dark side of Iapetus, more closely resembling ordinary carbonaceous chondritic meteorites.

In collaboration with Brown, Cruikshank has pursued the reflectance spectroscopy of the four brightest satellites of Uranus using a 5% bandpass circular variable filter. The presence of water ice is confirmed from spectra in the region 1.4-2.6 μm; the spectral coverage includes the 1.8-μm region of terrestrial absorption without interruption. The precision of the spectra permits comparisons with other ice-bearing satellites and laboratory spectra. Differences in the continuum slope and band strength are seen in the spectra. Analysis is in progress by Brown, who will use the results in his Ph.D. dissertation.

Cruikshank and Howell obtained CVF spectra of several asteroids of representative taxonomic types with the UKIRT, working in the 3-μm region. The bound-water band was seen on several objects; details of the band shape are being studied.

Becklin and Wynne-Williams made thermal infrared emission measurements of the Earth-crossing asteroid 1862 Apollo. These measurements have been combined by G. Veefer (JPL) with others taken at Mauna Kea to yield a geometric albedo of 0.21 ± 0.3, and a diameter in the range 1.3-1.5 km for this object.

Morrison, Brown, and Telescope have continued their radiometric studies of asteroids. The project to recalibrate the infrared technique of determining diameters and albedos using the well determined occultation diameters of 2 Pallas and 3 Juno, together with that of 34 Callisto, has been completed and submitted for publication. The new calibration yields diameters about 5% less, and albedos about 10% higher, than those in the standard TRIAD file of asteroid data; for example, the diameter of 1 Ceres now appears to be ~960 km, rather than ~1020 km. New radiometric observations have been made of four Earth-approaching objects, including 1862 Apollo, 2 Trojans, and about 30 previously unobserved main-belt objects; these data are being reduced using the new calibration and will be ready for publication before the end of 1981.

In a continuation of his studies of outer solar system bodies, Cruikshank, in collaboration with J. Degewij (JPL), W. Hartmann [Planetary Science Institute], and Capps, completed a study of the VJHK photometry of the unusual object 2060 Chiron. They found that the V - J and J - K colors of Chiron suggest that its surface is dark and that its reflectance properties may be similar to those of C- and RD-type asteroids. A low albedo for Chiron implies a radius on the order of 150-200 km.

In related work, Cruikshank, Degewij, and Hartmann have observed the near-infrared colors of several comets, with emphasis on P/Schwassmann-Wachmann I during periods of quiescence and activity. Their results suggest that during quiescent periods the comet is undisturbed by significant coma and that the nucleus itself may be visible, permitting studies of its surface composition and dimensions.
D. Stellar Astronomy

S. Wolff, former graduate student (now Professor) S. Edwards, and G. Preston (Mount Wilson and Las Campanas Obs.) have completed a survey of rotational velocities in 306 main-sequence stars of spectral types B0–B5. The measurements show that the distribution of apparent rotational velocities peaks at low values of \( v \sin i \) and decreases monotonically with increasing \( v \sin i \). Comparison with distributions for stars of types mid-B to late A shows that, surprisingly, the fraction of slow rotators \( (v \sin i < 50 \text{ km s}^{-1}) \) decreases with decreasing mass.

Simple statistical arguments suggest that the distribution of rotational velocities should be Maxwellian. Clearly it is not, and this conclusion is true for all spectral classes earlier than F0. In the past, it has generally been assumed that slow rotation is an anomaly, and various mechanisms have been proposed that would serve to reduce initially high rates of rotation to the low values that are observed. Wolff, Edwards, and Preston show that none of the suggested mechanisms, including magnetic braking, tidal interactions in close binaries, and mass exchange in close binaries, is adequate to account for the large number of slowly rotating stars. As an alternative, they suggest that star formation may be favored in regions of low angular momentum and that the interactions of turbulent elements within protocluster clouds. This hypothesis can explain a number of the observed characteristics of stellar rotation, including most notably the random orientation of the axes of rotation (Astrophys. J., January 1982).

During the past decade, there have been dramatic advances in our ability to model the emergent spectra of early-type stars. In particular, extensive grids of self-consistent non-LTE model atmospheres, which allow for departures from LTE in the hydrogen and helium excitation and ionization equilibria, have been calculated by Auer and Mihalas. S. Wolff and Heasley have undertaken a program designed to test rigorously the ability of these models to reproduce the line profiles and energy distributions of main-sequence B-type stars. The first line to be studied intensively was He I \( \lambda 4922 \). Wolff and Heasley obtained observations of this line in 15 stars of spectral types B0–B5. The computed profiles reproduce the core and the red wing of the stellar profiles, but the forbidden component in the blue wing of the line is deeper and broader than theoretical predictions (Astrophys. J. 245, 977). Work on Hz and other helium lines is in progress. The ultimate goal is to derive accurate abundances from B-star spectra.

Boesgaard has completed a study of the velocity structure in the circumstellar shell of \( \beta \) Peg (M2.5II–III) from the profiles of the Fe II emission lines (\( \lambda \lambda 3150–3300 \)) and the Ca II emission reversals. Nine spectrograms at 6.7 \( \text{Å mm}^{-1} \) were used to determine radial velocities and line-profile shapes. The data were compared to line-profile predictions from a model of an expanded, expanding envelope. The best match for the Fe II emission lines shows material expanding from \( 0 \text{ km s}^{-1} \) to a terminal velocity of \( 25 \text{ km s}^{-1} \) at \( 2R \). with a characteristic turbulence of \( 10 \text{ km s}^{-1} \). Measurements of the Ca II circumstellar absorption reversal show it is formed over a similar velocity gradient and that the turbulence beyond \( 2R \) is \( < 4 \text{ km s}^{-1} \). The velocity gradient in the shell is also revealed by differences in line profiles in Ca II K vs Ca II H. The shell structure for this M giant is considerably different from that in the M supergiants, \( \alpha \) Ori and \( \alpha \) Sco, which have been investigated in a similar way.

With collaborators F. Praderie, A. Talavera, P. Felenbok, and J. Czarny (Meudon Obs.), Boesgaard has studied evidence for a chromosphere and a wind in the Herbig Ae star, AB Aur. Spectrograms at 2.4 \( \text{Å mm}^{-1} \) were obtained on two successive nights with the coude' spectrograph of the Canada-France-Hawaii 3.6-m telescope. The Ca II K line shows an asymmetric and variable profile with weak emission in the absorption core at least some of the time. Other evidence for a chromosphere in this Ae star comes from their IUE observations of strong P Cygni-type emission at the Mg II h and k lines and CFHT Reticon observations of He I \( \lambda 5876 \) emission. An apparent outburst occurred as witnessed by a strong blueshifted \( (\sim 170 \text{ km s}^{-1}) \) absorption component in the Balmer lines and the Ca II K line on the night of 26 October 1980. The average velocity of the Balmer lines (H8–H14) and the velocity of Ca II indicate global motions with time variations. The line emission, velocities, breadth, and variability show the presence of an active and variable chromosphere with mass outflow.

Boesgaard and Simon have made observations with the IUE satellite of a selected group of young, solar-type field stars for a comparative study of the chromospheres of young and old F and G stars.

With observations made with the Reticon at the CFHT Telescope with signal-to-noise ratios of several hundred, Boesgaard is looking at possible subtle differences in the chemical composition of the Be-deficient F stars relative to normal stars. Under the hypothesis that these stars represent an extension of the Am-star sequence, she is determining abundances of elements such as Ca, Na, Mg, and Si.

The Hg–Mn stars are known to show overabundances of Be, and Boesgaard, S. Wolff, and Heacox, together with Praderie and J. Borsenberger (Meudon Obs.), have determined Be abundances in 43 Hg–Mn stars and ten normal stars of similar temperatures in both LTE and non-LTE conditions. For the strongest Be lines, the LTE models predict Be abundances of 2–4 times larger than the non-LTE models. Overabundances of Be relative to the Sun of factors of \( 20-2 \times 10^4 \) have been found in 75% of the Hg–Mn stars. The 25% with little or no Be are among the coolest Hg–Mn stars. They suggest that diffusion driven by radiation pressure causes the Be abundances anomalies.

Boesgaard, with E. Avrett (CFA) and S. Edwards (Five College Astronomy Department), are attempting to model H I and Ca II line profiles in T Tauri stars using an expanding high-temperature chromosphere model. The calculations are being compared with coude' observations at 25 \( \text{Å mm}^{-1} \) from Mauna Kea and high-dispersion echelle observations from CTIO of several T Tauri stars.

Bernat has carried out further work on the structure of the circumstellar shells surrounding M supergiants using high-resolution observations of the fundamental vibration-rotation band of CO at 4.6 \( \mu \text{m} \). Nine stars were studied; a
common feature was multiple absorption lines which were identified as due to separate shells. Column densities for each shell are well fit by a single excitation temperature which is identified as the local kinetic temperature. There is no correlation of CO column density with either gas or dust column densities, nor of expansion velocity of the component with its distance from the star. The major conclusion is that mass loss is most likely episodic in nature (Astrophys. J. 246, 184).

Bernat has completed a comprehensive study of the ultraviolet absorption spectrum of α² Sco as a guest investigator with the IUE satellite. These lines arise from matter being lost by the red supergiant primary, α¹ Sco M1.5Iab, which is passing in front of the companion. This is the first study providing abundance determinations for a large number of major elements without the need for ionization corrections. There is a factor-of-30 spread in the hydrogen column densities derived from different elements on the assumption of solar abundance ratios. Possible causes are discussed—observational error, shell chemistry, and interstellar contributions—none appears to provide the answer. An unweighted mean of all observed species gives a mass-loss rate of 6.4 × 10⁻⁶ M☉/yr (Astrophys. J., January 1982).

Bernat, with J. Piccirillo (Teledyne Brown) and H. Johnson (Indiana Univ.), has shown that M-star model atmospheres are now in good agreement with observation. They also find that color temperatures derived from the Wing 8-color narrowband system are systematically affected by TiO absorption (Astrophys. J. 246, 246).

E. Extragalactic Studies

Lonsdale has undertaken the observation of 43 galaxies exhibiting strong optical emission lines with UKIRT and IRTF. The data consist of broadband and CVF photometry between 1.25 and 10 μm. The infrared energy distributions can be interpreted in most cases as having been produced by a massive burst of star formation in the nucleus of the galaxy.

Lonsdale and S. E. Persson (Mount Wilson and Las Campanas Obs.) have detected strong 10-μm emission from several peculiar and interacting galaxies from the catalog of Arp. They attribute this emission to star formation triggered by interaction.

J. Rose has continued to study the physical conditions and kinematics of the ionized gas in the nuclear region of the spiral galaxy M51. Rose and L. Searle (Mount Wilson and Las Campanas Obs.) obtained long-slit spectrophotometry with the Hale 5-m telescope of the central regions of this galaxy and found that the region over which the ionized gas exhibits an anomalous emission-line spectrum is 9 arcsec in radius, centered on the nucleus. The most prominent anomaly is the high ratio of [N ii]/Hα first reported by the Burbidges. Within the 9-arcsec-radius "nuclear region," Rose and Searle found radial gradients in several key emission-line intensity ratios which correspond to a decrease in the degree of ionization of the gas with increasing distance from the nucleus. They conclude that the gas is probably photoionized by a nonstellar ultraviolet continuum which is much flatter than that produced by hot stars. Other mechanisms such as photoionization by hot stars, thermal collisional ionization, or shock heating and ionization fail to account in a natural way for the anomalous emission-line intensity ratios as well as the radial gradients in these ratios. The kinematics of the gas are also interesting in that, within the nuclear region, the FWHM of the emission lines are in the range 200-450 km s⁻¹, with a complex dependence of linewidth on position in the region. The largest linewidths are found ~3 arcsec south of the nucleus. These data imply that the unusual emission-line spectrum and kinematics observed in M51 are the result of nuclear activity that is qualitatively similar to, but milder in form than, that observed in the nuclei of Seyfert galaxies. This work is in press in The Astrophysical Journal.

Rose and graduate student G. Cecil have recently acquired higher-dispersion observations with the UH 2.2-m telescope. The new observations are intended to investigate the line profiles at higher-wavelength resolution, to determine directly the gas temperature, and to detect weak emission lines of several new ionization species. The data are still being analyzed, but the following results are apparent. All emission lines show strongly asymmetric profiles with a broader blue than red wing; the line wings extend to ~1800 km s⁻¹ FWZI. They now have a strong upper limit to the temperature of the [O iii]-emitting gas (via an upper limit to the ratio [O iii]/λλ 4363/5007) which appears to rule out shock ionization as the principal ionization source for the gas. As a result, the case for photoionization by a nonstellar UV continuum has been greatly strengthened. Finally, a determination of the temperature of the gas via the ratio of blue to red [S ii] lines has been achieved allowing a determination of the chemical abundances within the nuclear region.

Rose and K. Hummel (Univ. of New Mexico) are examining the possible relationships between the presence of ionized gas in elliptical galaxies, the presence of nuclear activity in these galaxies as evidenced by a compact nuclear radio source, and the presence of a young stellar population in the nucleus. They are acquiring high-S/N optical spectra of 123 nearby elliptical galaxies which have been examined for the presence of a compact radio source by Hummel, Ekers, and Kotanyi.

Stockton and graduate student J. MacKenty have continued obtaining and reducing spectroscopic and photometric data for galaxies in extensive fields around the low-redshift QSO's PG 0026 +129, LB 9743, and PKS 2135—147; they have also begun similar observations in the fields of 4C 25.01, NAB 0205+024, PG 0953+415, and GQ Comae. MacKenty has developed new reduction software that, coupled with the availability of the Perkin-Elmer 3220 computer, should greatly reduce the required reduction time.

Stockton has completed an investigation into the nature of the compact objects found near the QSO's Markarian 205, 3C 223.1, and PKS 2135—147. All have redshifts within 200 km s⁻¹ of their neighboring QSO's and projected separations of less than 10 kpc. The object near PKS 2135—147,
which is the best studied of the three, appears to have a predominantly nonthermal continuum. These objects can plausibly be interpreted as galaxies that appear compact because they are tidally limited or have enhanced nuclear emission (or both). They have apparently interacted with the galaxies in which the QSO's reside, and it is likely that the QSO activity is a direct consequence of this interaction.

Thompson determined an observational upper limit for the mass of the Type II supernova discovered in the nearby galaxy NGC 6946. On a photograph taken with the CFH Telescope a mere 49 days before the supernova's maximum light, there is no detectable image at the location of the supernova. The stellar progenitor must have been less massive than 18 solar masses to have escaped detection.

In another project related to supernovae, Thompson redetermined galaxy types for all Coma cluster galaxies which have shown supernova explosions. This sample showed an overabundance of the rare I0 class of galaxies. The analysis was published in Publ. Astron. Soc. Pac. 93, 176.

In a continuation of Thompson's collaboration in the study of superclusters, a joint project was undertaken with H. Rood (Institute for Advanced Study, Princeton) and G. Chincarini (Univ. of Oklahoma) to analyze the galaxy distribution between two groups of galaxy clusters. In the intervening region between Hercules and A2197/2199, a bridge of galaxies was discovered, and the bridge appears to connect these two widely separated groups. This work is in press in The Astrophysical Journal Letters.

Thompson also analyzed the distribution of barred versus nonbarred galaxies within the Coma cluster. The analysis indicated that a significantly larger fraction of galaxies belonging to the cluster core shows a central bar structure. This result was interpreted both in terms of the overall cluster structure and in terms of the internal dynamics of the individual galaxies (Astrophys. J. Letters 244, L43, 1981).

Tully has analyzed the distribution of galaxies in the Local Supercluster, primarily using neutral-hydrogen observations of 1787 nearby galaxies by Fisher and Tully. The Local Supercluster comprises a disk component with 60% of the luminous galaxies and a halo component of several discrete clouds with 40% of the luminous galaxies. A few of the clouds are prolate with their major axes pointed towards the Virgo Cluster, indicating tidal stresses exerted by it. The disk of the Supercluster has a ratio of longest-to-shortest axes of 6 to 1. The flattening and low random velocities are evidence that dissipative processes were important in the formation of the Supercluster.

In a separate but related study, Tully has been examining the role that massive neutrinos might have had in causing the large-scale structure to collapse first and then fragment into galaxies.

Becklin, Tokunaga, and Wynn-Williams studied the infrared emission from the unusual elliptical galaxy NGC 1052. They showed that the strong 10–20-μm emission from the nucleus of this galaxy comes from a region smaller than 270 pc in diameter. It is therefore more probably associated with the compact VLBI radio source than the extended clouds of ionized and neutral gas in the central regions of the galaxy. The stellar content of the galaxy appears normal.

Becklin, Telesco, and Wynn-Williams continued their IRTF study of the extended infrared emission from the Seyfert galaxy NGC 1068. They found that about 15% of the 10-μm emission comes from a 3-kpc-diameter visibly bright disk. This disk, which probably contains vast numbers of young stars, is probably responsible for about half of the total infrared luminosity of the galaxy. The causal connection, if any, between the disk and the Seyfert nucleus is unclear.

Becklin and Wynn-Williams have observed the hot-spot galaxy NGC 2903 at 2.2 and 10 μm with the IRTF, and at 6 cm with the VLA. Emission is seen at all wavelengths from approximately the same-sized region, but, so far, no detailed correspondence has been found between visible, radio, and infrared features.

Capps, together with Sitko and Stern (Univ. of Minnesota), used the IRTF to extend the photometry of a sample of optically-selected QSO's to wavelengths between 3.5 and 20 μm. Among low-redshift quasars, they found no differences at these wavelengths between radio-loud and radio-quiet objects, but found a variety of spectral indices, with some objects resembling Seyfert II galaxies, and others resembling strongly nonthermal sources. Some high-redshift radio-quiet quasars exhibit rather flat flux distributions.

A large number of infrared astronomers have been using part of their IRTF time to monitor the 1.2–3.5-μm light curve of supernova 1980k in the galaxy NGC 6946. Between December 1980 and May 1981, the energy distribution changed from a Rayleigh-Jeans law to one with a much cooler (800 K) component, the existence of which might indicate dust grain formation. Monitoring of the object continues.

Rudy (Univ. of California, San Diego) and Tokunaga obtained 3-μm spectra of NGC 1275, NGC 7469, Mrk 335, Mrk 509, and 3C 120 to determine the extent to which dust emission contributes to the strong infrared flux in Seyfert 1 galaxies. The unidentified 3.3-μm feature was observed to be present in only NGC 7469, indicating that dust emission is significant in this galaxy. The spectrum of NGC 1275 and Mrk 335 also appears to have a significant component of dust emission, but in Mrk 509 and 3C 120 it is not possible to distinguish between thermal and nonthermal origins for the infrared flux.

Impey has completed a long-term study of the polarization properties of BL Lacertae objects in the near infrared, in collaboration with Brand (Univ. of Edinburgh), Wolsten-croft (ROE), and Williams (UKIRT). Eighteen objects have been observed in the J, H, and K bands, with monitoring runs of up to five nights on six of these. High and variable polarization is a general property of the sample. Two BL Lacertae objects show wavelength-dependent polarization, with the polarization increasing toward shorter wavelengths, and two objects showed position-angle rotations over a five-day period. The BL Lacertae objects span an enormous range of infrared luminosity; from $L_{IR} > 10^{10}$ erg s$^{-1}$ down to luminosities similar to those of normal elliptical galaxies. This work is in press in Monthly Notices of the Royal Astronomical Society. Simultaneous optical/infrared polari-
metry on the spectacular BL Lacertae object AO 0235 + 164 has been obtained in collaboration with Tapia (LPL). At the peak of its outburst, this object had one of the highest luminosities ever measured in an extragalactic source, and the highest polarization ever measured in a BL Lacertae object (MNRAS, in press). Enough polarimetry has been accumulated in this monitoring program for a statistical comparison with the predictions of the relativistic-jet model of Blandford and König.

Using the UK Schmidt telescope in Siding Spring, Impey has undertaken a search for radio-quiet BL Lacertae objects using a polaroid filter. The search technique was described in MNRAS 194, 275. By analyzing automated microdensitometer measurements of > 33,000 stars, candidates have been selected using combined criteria of polarization and variability. The photometric and polarimetric calibration is discussed in a paper with Brand (MNRAS, submitted).

Impey and Brand have published an infrared study of a sample of flat-spectrum radio sources, using data obtained on the AAT (Nature 292, 814). By observing objects in the infrared without regard to optical morphology, it was shown that the red objects found by Rieke et al. do not appear to form a new population of quasars.

Impey has obtained multiaperture infrared photometry on the 2.2-m of low-redshift BL Lacertae objects and radio galaxies. The data are being used to deconvolve the contributions to the total light from the bright nucleus and the surrounding elliptical galaxy.

As part of a photographic survey of BL Lacertae objects, Impey has taken image-tube plates of 48 objects on the 2.2-m telescope. Two color plates were taken of each field, and they will be analyzed on the PDS machine to search for nebulae and galaxies underlying the compact sources. Many of the BL Lacertae objects are radio sources which have not yet been studied optically with a good plate scale.

Using the IRTF, Impey has obtained energy distributions of BL Lacertae objects from 1 to 10 \(\mu m\) in order to test the applicability of the synchrotron hypothesis for explaining the high-infrared luminosities in these objects. For most of the sample, the spectrum is well represented by a power law, with no signs of a turnover at the longer wavelengths.

F. Interstellar Matter

Becklin and Telesco, in collaboration with Gatley (UKIRT), have mapped the central few parsecs of the Galaxy at wavelengths between 10 and 30 \(\mu m\), in order to look for temperature gradients that could indicate whether the dent in the region is heated by a single luminous object or by a cluster of young stars.

Becklin and Wynn-Williams, together with Downes (IRAM, Grenoble) and Genzel (Univ. of California, Berkeley), have searched for 20-\(\mu m\) emission associated with \(H_2\) masers in molecular clouds. They detected compact infrared sources associated with over 90% of the masers searched, a far higher success rate than expected.

Capps, together with Dinerstein and Werner (NASA-Ames) and Dwek (Univ. of Maryland), used the IRTF at 10 \(\mu m\) to place new limits on the presence of dust in the fast-moving knots in Ori A.

Capps, together with Dinerstein and Werner (NASA-Ames), found polarization in excess of 50% at 3-8 \(\mu m\) from a region in the Orion BN-KL complex. Spatial variation in both the magnitude and direction of the polarization was found, suggesting that scattering of the dust surrounding BN is the cause of this extraordinarily large polarization.

Dyck continued his infrared slow-slit-scanning studies of molecular cloud sources with H. J. Staude (Max-Planck-Institut), and began one-dimensional speckle interferometry with Howell, Zuckerman, and Simon. In four cases (W 33A, Mon R2-IRS 3, W3/IRS 5, and W3 /IRS 9), double sources were found with separations of the order of 10\(^{-5}\) AU and comparable brightness for the two components. S 140/IRS 1 has been found to be a compact source (<0.2 arcsec) surrounded by an infrared reflection nebula from scan measurements at 2.2 and 4.8 \(\mu m\). Measurements of BN at 4.8 \(\mu m\) indicate that its angular diameter is less than 80 milliarcsec, in agreement with previous observations. NGC 7538/IRS 1 and IRS 9 have resolved cores of 0.5 and 0.9 arcsec at 3.8 \(\mu m\).

Simon and Lonsdale, together with S. E. Persson and T. R. Geballe (Mount Wilson and Las Campanas) and F. Baas (Leiden), have used a Fabry-Perot interferometer coupled to the cold-grating spectrometer constructed by Persson and Geballe to measure the line profile of the \(v = 1\rightarrow 0\, S(1)\) line of \(H_2\) at 2.12 \(\mu m\) at 20-km s\(^{-1}\) resolution in the vicinity of the microwave maser and infrared continuum sources north of NGC 2071. The line profile observed near the peak of the extended \(H_2\)-emission region has a full width at zero intensity of \(\sim 100\ km\ s^{-1}\) with a prominent blue wing. The NGC 2071 region thus represents the second detection, after OMC-1, of high-velocity \(H_2\) emission in a region showing signs of recent star formation. The width of the line may result from a supersonic outflow of gas, the source of the outflow being an intense stellar wind from an object embedded in the molecular cloud.

Scoville (Univ. of Massachusetts) spent a sabbatical leave at the Institute for Astronomy during the spring and summer of 1981. During this period he analyzed observations taken at the University of Massachusetts of the 2.6-mm CO line in the spiral galaxies IC 342, NGC 6946, and M51. In all three galaxies the molecular cloud distribution decreases continuously with increasing galactic radius, closely following the exponential fall-off found previously for the optical light. No evidence is seen in any of these galaxies for a void in the molecular gas, star-forming regions at 2-4 kpc like that seen in our galaxy. It appears plausible that the difference be ascribed to the occurrence of the inner Lindblad resonance in our galaxy at \(R\sim 3\) kpc and the lack of a strong resonance in the three other galaxies. These data are also being compared with far-infrared maps, which provide a measure of the luminosity from young stars presently forming in these galaxies.

A second area of research by Scoville while at the University of Hawaii was in near-infrared high-resolution spectroscopy of protostars. Data at \(\lambda = 2-5\ \mu m\) on the Becklin-Neugebauer object in Orion (obtained in collabora-
tion with D. Hall and S. Ridgway (KPNO) and S. Kleinmann (MIT) reveal ionized and high-excitation molecular gas, within 1–25 AU of BN. These data suggest a model for BN in which the central star (perhaps a B0 main-sequence star) is surrounded by a dense molecular-gas disk extending from radii less than 1 AU to about 25 AU. The ionized gas appears to be in a high-velocity wind ($V > 100$ km s$^{-1}$) streaming out the poles of this disk.

G. Other Activities

Boesgaard was awarded an Honorary Doctor of Science Degree from Mount Holyoke College at its spring commencement ceremonies.

Pilcher and Morrison continued their participation in the Galileo project. Cruikshank worked with the IRIS Science Team, and Morrison with the Imaging Science Team on the Voyager project for the two encounters with Saturn.

Morrison served as Chairman of the AAS Division for Planetary Sciences. Morrison was granted a six-month leave of absence to serve a special term in Washington, D.C. as NASA Acting Deputy Associate Administrator for Space Science.

In April, the Institute for Astronomy organized the first Hawaii Neighborhood Astronomers Meeting, which was held at the Institute's Manoa campus facilities. Invitations were extended to all astronomers and graduate students resident in the Islands. Approximately 70 persons attended two days of sessions, which included scientific papers, status reports from the observatories, and discussions of proposed programs and instrumentation. Staff members attended from all of the institutions having permanent facilities on Mauna Kea; in addition, representatives of the Mauna Loa (coronal) Observatory (HAO), the Avco Everett Research Laboratories (operators of a satellite tracking station at Haleakala), the Vienna Observatory, the Bishop Museum Science Center, and the University's Planetary Geosciences group (Hawaii Institute of Geophysics) and Department of Physics and Astronomy contributed to the meeting. The meeting was clearly successful, and it is planned to make it an annual event.

H. Visitors' Highlights

J. Pasachoff (Williams College) observed prominences at Haleakala in collaboration with Landman and Bernat. He also worked on reducing data from the 1980 Indian eclipse expedition, and conducted a search for T Tauri stars embedded in dark clouds using the NASA IRTF.

N. Scoville (Univ. of Massachusetts) analyzed observations of the 2.6-mm CO line in the spiral galaxies IC 342, NGC 6946, and M51.

B. Zuckerman (Univ. of Maryland), in collaboration with Dyck, began a program of 5-, 10-, and 20-μm speckle interferometry of OH sources suspected of containing binaries. He also gave a highly successful public lecture on life in the Universe.

H. Staude (Max-Planck-Institut) used the 2.2-m telescope in collaboration with Dyck for polarimetry of S 106 and was able to determine the center of illumination and modeled the distribution of dust.

J. Caldwell (SUNY, Stony Brook) collaborated with Tokunaga in using the NASA IRTF for mapping Jupiter at 10 and 20 μm, confirmed an enhancement of 8-μm emission at the Jovian magnetic poles, suggesting an infrared-red aura, and confirmed the existence of a temperature inversion of Uranus and Neptune from infrared photometry.

V. INSTRUCTIONAL PROGRAM

Wynn-Williams succeeded Morrison as chairman of the graduate program in astronomy. Rose joined the teaching staff, while visiting positions were held by Jay Pasachoff (Williams College) and John Caldwell (SUNY, Stony Brook). Suzan Edwards completed her Ph.D. on T Tauri stars.

John T. Jefferies

Director

Data Survey

(1) No. of faculty/staff: tenured or tenure-track 17 (M), 3 (F); post-doc 4 (M), 1 (F); res. assoc. 11 (M), 2 (F); other Ph.D.'s 0 (M), 0 (F).

(2) No. of graduate students: first year 2 (M), 2 (F); total 13 (M), 2 (F).

(3) No. of degrees awarded: terminal Master 0 (M), 0 (F); Ph.D. 0 (M), 1 (F).

(4) Employment of those in (3): post-doc 0 (M), 0 (F); res. assoc. 0 (M), 0 (F); tenure-track 0 (M), 1 (F); FFRDC 0 (M), 0 (F); govt. lab 0 (M), 0 (F); industry 0 (M), 0 (F); foreign 0 (M), 0 (F); other 0 (M), 0 (F).