effect of neutrino pressure due to neutral current interactions on supernova. In this line, the properties of a proposed renormalization of general relativity were explored.

Work on the development and application of methods of quantum mechanics to atomic and molecular processes and on the role of atomic and molecular processes in astrophysics continued.

GEORGE B. FIELD
Director

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I. STAFF

The scientific staff during the report period consisted of Lothar W. Bandermann, Ann M. Boesgaard, Walter K. Bonnack, Dale P. Cruikshank, H. Melvin Dyck, Gerard D. Finn, John H. Goebel (appointed effective September 1974), Rainer M. E. Illing, John T. Jefferies (Director), James C. Kemp, Donald A. Landman, Marie K. McCabe, Donald L. Mickey, David Morrison, Frank Q. Orrall, Carl B. Pilcher, John G. Pipes (appointed effective June 1975), Theodore Simon, William M. Sinton, Alan N. Stockton, Richard J. Wolff, Sidney C. Wolff, Ramon D. Wolstencroft (on sabbatical leave for one year), and Jack B. Zirker. Howard C. McAllister of the Department of Physics and Astronomy and Franklin E. Roach were affiliated with the Institute. Visiting colleague in residence was Friedrich Meyer of the Max Planck Institute for Physics and Astrophysics, in Munich, West Germany.

II. FACILITIES

A. Haleakala Observatory

1. Mees Solar Observatory

The polarimeter detector system has been replaced by a multichannel spectrometer, which provides spectral resolving power of $2 \times 10^5$ together with an increased spectral range. The software control system for the polarimeter is in the process of being rewritten to take advantage of this expanded capability. The PDP 11/45 computer system has been upgraded by the addition of core memory, CAMAC modules, and a plotter. Also being installed for this system is a new real-time executive software operating system which has multiprogramming capability. A communications link between the PDP 11/45 and PDP 8I computers has been implemented facilitating both program development and data analysis for the PDP 8I-controlled Stokes polarimeter.

2. Lunar Laser Ranging Observatory

Unexpectedly prolonged delays in completion of the receiver telescope being built at JILA, University of Colorado, and National Bureau of Standards, have resulted in extensive redirection of efforts during the report period. In the meantime, it was decided to attempt ranging using the Lunastat as both transmitter and receiver. A special receive package was built and installed just prior to the September lunation. System checkout stalled when the laser failed to operate acceptably. Extensive testing resulted in the decision to delay any further attempts at ranging until major corrective modifications to the laser were completed in February 1975.

Ranging attempts were begun during the February lunation, and continued during the March and April lunations. Several possible returns were recorded, but the signal-to-noise ratio was not adequate to be conclusive; the 40-cm-diameter Lunastat did not provide the collecting area required for initial acquisition purposes. Arrangements were then made with the Advanced Research Projects Agency (ARPA) Maui Optical Station to use their 120-cm telescope as a receiver, and the receive package was modified and installed in time for the June lunation. Weather conditions were marginal during the June lunation and limited attempts at ranging produced no identifiable returns. (Successful ranging was achieved with this system in August 1975.)

Arrangements have been made to use the ARPA 120-cm telescope on a no-cost, noninterfering basis until the Lureoscope is received—expected during the last quarter of 1975.

B. Mauna Kea Observatory

1. UH 2.24-m Telescope

The 2.24-m telescope was scheduled for use throughout the report period except for three holidays: 24, 25, and 31 December. Weather was suitable for observations 66% of the scheduled nights; instrument and telescope system failure accounted for a few hours lost time, as did failure of the power generating system at the summit. Owing to periods of exceptionally heavy snowfall—the worst since the Observatory was put into operation in 1970—access to the summit was impossible for two periods of a few days each during which operations at the summit were halted.

The No. 5 Coudé camera was put into operation during the report period, bringing to completion the Coudé spectrograph. This camera has correctors for the blue and violet, and has focal length 30.5 cm. Construction of an oscillating Cassegrain secondary mirror system for the 2.24-m telescope has been completed, and testing is underway. An upper-end ring for this secondary has been completed. Interchange of the normal secondary mirror support and this special ring for the oscillating mirror requires about two hours.

The installation of the new telescope control system has been completed and the digital television readout equipment is nearly installed. The upper seven-mile stretch of the Mauna Kea Access Road is presently being realigned to a maximum grade of 15%, and will be surfaced with an oil-base aggregate. Construction is scheduled for completion by January 1976.
2. Canada–France–Hawaii Telescope (CFHT)

Construction resumed on the building for the Canada–France–Hawaii Telescope in the summer of 1975 after being halted during the winter season. The Scientific Advisory Council and its working groups continue to work on detailed specifications of the telescope instrumentation. The $22$ million, 3.6-m telescope is expected to be operational in 1978.

3. Infrared Telescope Facility

In October 1974, the University of Hawaii contracted with NASA for the design of the Infrared Telescope Facility (IRTF) to comprise a 3.0-m equatorially mounted telescope with associated building and control systems to be located on Mauna Kea. The plan calls for the installation to be completed in 1977 in order to support the Mariner Jupiter/Saturn Mission. In May 1975, NASA and the University of Hawaii entered into a second-phase contract for construction of the facility. Under a separate agreement between Kitt Peak National Observatory and the University of Hawaii, the optics are to be completed at Kitt Peak. The building and telescope designs are almost complete. In-house work on design of the control system, chopping secondary, and several smaller items are well advanced. It is anticipated that construction on Mauna Kea can begin before the winter season at the end of 1975.

4. United Kingdom Infrared Telescope (UKIRT)

The UK Science Research Council is proceeding with plans to construct a 3.8-m infrared telescope on Mauna Kea. They hope to begin construction of the building in the spring of 1976, with completion of the entire project scheduled for the end of 1977.

C. University Campus

Construction was completed on the Institute’s Manoa Campus permanent headquarters in April 1975, and Institute staff moved into the new buildings at 2680 Woodlawn Drive, Honolulu 96822, the following month. The facility comprises three two-story buildings placed around a center courtyard, and contains about 66 000 ft² of offices, laboratories, and a machine shop.

III. RESEARCH

A. Solar Physics

Recent years have seen the development of increasingly sophisticated models of the Sun’s chromosphere and the overlying chromosphere–corona transition region. However, the temperature structure of the inner corona itself has remained uncertain both because the intrinsic emission from the corona is faint compared to the transition region, and because the deposition of energy with height in the solar corona is not known. A new approach to constructing models of the inner corona in open field regions has been made by Orrall working with R. A. Kopp of the High Altitude Observatory. Kopp and Orrall represent the unknown heating term in the energy equation by a function in two unknown parameters—one the mechanical flux at the bottom of the corona and the other its characteristic height for dissipation. The complete energy equation (including solar wind convection) is then integrated, subject to hydrostatic equilibrium and lower-boundary conditions provided by existing models of the transition region. The unknown parameters of the heating term are then chosen such that the resulting models fit the observed emissions from the corona and produce the observed solar wind at the Earth. The theory provides models for the corona in both quiet regions and coronal holes.

To date, no observational evidence has been found for the waves that are presumed to heat the corona, although random intensity pulses have been observed in EUV lines that originate in the temperature transition region. Mickey and Zirker searched for intensity fluctuations in a coronal emission line (A5303 of Fe xiv) and in the electron-scattered coronal continuum. The photoelectric polarimeter was used in both attempts to measure the Stokes parameters of the radiation as a function of time and height in the corona. Both sets of observations produced essentially null results. A power spectrum analysis of the data revealed no periodic components with amplitudes greater than 1%, and these intensity variations were probably due to seeing noise. These results further reduce the upper limits of coronal intensity fluctuations attributable to heating waves.

F. Meyer (Max Planck Institute) and Zirker investigated the heating and flow of flare-associated ejections of gas, such as sprays and coronal transients. Their study supports Hirayama’s hypothesis that rapid heating of chromospheric gas near the flare site supplies material that is ejected into the corona. In impulsive flares, the heating of the chromosphere may occur through bombardment by nonthermal electrons and protons. Meyer and Zirker compared estimates from this theory with observations of the 11 January 1973 coronal disturbances and concluded that much of the ejected cloud originated as chromospheric gas.

McCabe has continued the analysis of EUV forbidden-line intensities in quiet coronal regions from rocket observations obtained by an international group during the March 1970 solar eclipse. If uniform temperature and density structure is assumed within a quiet region, it is found that the ratio of the “line intensity ratios” of the same pair of lines for each of two regions is dependent only on the ionization equilibrium values, which are known functions of T_e. Thus, if the temperature of one region is known, that of another region can be determined by a comparison of the intensity ratios of different pairs of lines in both regions. For the eclipse data, she has calculated approximate electron temperatures ranging from $1.1 \times 10^6$ K in a coronal hole to $1.55 \times 10^6$ K in the hottest region considered, using the results of a previous study for the comparison region. She is presently calculating more reliable temperatures by determining a least-squares solution to a system of nonlinear equations for all the observed intensities in terms of temperatures, electron densities, and atomic parameters. Based on the preliminary temperature estimates, the electron densities for each region have been calculated from the $\text{L}\alpha$ and O I v lines; they lie within the range 0.95–3.0 $\times 10^6$ cm$^{-3}$.

Recent theoretical research on the helium and hydrogen emission on quiescent prominences requires for its evaluation more complete observational material than is presently available. The multichannel coronal spectrophotometer system provides an especially powerful instrument for obtaining such data. It offers significant advantages over more conventional photographic instruments for prominence spectrophotometry,
the most important being linearity, wide spectral range, and ease of data processing. We have initiated a program to measure in detail the helium and hydrogen emission in prominences both to test the various assumptions underlying the theory and to provide data for an eventual precision helium-to-hydrogen abundance determination. Illing, Landman, and Mickey have presented the initial results of this work; much remains to be explored in this area and the research is being vigorously pursued.

One of the features of the above prominence work has been the unusual behavior of the relative $\lambda 10$ 830 helium emission. Landman has undertaken a study of this line using the silicon vidicon optical multichannel analyzer mounted as a detector for the 25-cm coronagraph–Coudé spectrograph system. The observations (which have a high signal-to-noise ratio) are being analyzed in terms of theoretical models.

Orrall and Zirker have studied the effect of a beam of energetic (nonthermal) protons impacting on a neutral or partially neutral hydrogen atmosphere. They find that the $\lambda 1$ line profile from such a region of impact will be asymmetric, and that the shape of the profile may contain recoverable information on the flux and energy spectrum of the proton beam. As an illustration of the effect, they have carried out detailed calculations for the Sun’s atmosphere. During the impulsive phase of solar flares, energetic beams of electrons (10–300 keV) are believed to impact on the solar chromosphere to produce observed hard x-ray bursts. Orrall and Zirker find that if similar proton beams exist, they should produce a measurable effect on the $\lambda 1$ line profile. Observations of this profile may thus prove an important diagnostic for studying fast protons near their place of acceleration in the Sun’s atmosphere. (The effect should also be present but be much more difficult to detect in other spectral lines.) With Jeffries and McAllister they have designed a space experiment capable of detecting the effect using existing technology.

Landman has continued studies of the effects of proton collisions in the production of coronal emission-line polarization. Particular emphasis has been placed on understanding the disagreement between Landman’s previous Fe$^{12+}$ ground state configuration results and those of Maxon–Seeuws and McCarroll. The matter has now been resolved in favor of the former’s calculations.

Finn, Illing, and Landman are presently developing a capability for calculating line profiles and equivalent widths, in LTE, of Zeeman-split spectral lines emitted by model cylindrical sunspots, including magnetic field and velocity gradients; they are using published models for the sunspot structure and magnetic fields. They plan to apply these calculations to observations made in the visible region with the new polarimeter–monochromator system at Haleakala.

Illing has made a study of the curious appearance of the CN($\lambda 10$ 950) lines in circularly polarized light in sunspot umbras; viz., the rotational lines of the band show $\sigma_+$ and $\sigma_-$ magnetic components of greatly different intensity. A quantum mechanical analysis of molecular line emission in a magnetic field leads to the interpretation that, for a conservative estimate of the observed intensity ratio of the magnetic components, the lines are formed in a region possessing a magnetic field of the order of 100 kG. Further observations of the lines and surrounding continuum will be performed with the photoelectric polarimeter–monochromator in conjunction with continued theoretical investigation of this problem.

B. Rocket Spectroscopy

McAllister and research assistant Peter Smith completed wavelength measurements and identifications of the solar spectrum from 1969 to 1889 Å. The spectrograms used for their work were those obtained in 1969 with a rocket-borne echelle spectrograph. The results obtained have been published. Similar work continues on spectrograms obtained in a 1971 rocket flight.

Finn has completed a study of the non-LTE transfer of radiation in the UV lines of ionized silicon. He used a model atom consisting of four discrete levels plus a continuum for the silicon ions, and adopted a standard model for the physical structure of the solar chromosphere and photosphere. His results have allowed a broad interpretation of the rocket observations of the Si $\pi$ lines near 1814 Å obtained in the 1971 rocket flight.

McAllister, Smith, and Jeffries have reported preliminary comparisons of the Mg $\pi$ emission lines in a filament, a plage, and in the quiet Sun, using spectrograms obtained in the June 1974 flight of the echelle spectrograph. Jeffries has initiated a study of the wing shape of the Mg $\pi$ lines, and McAllister is measuring and identifying the spectral features in the spectrogram obtained in the 1974 flight.

Work is proceeding on the design of a new spectrograph with a TV acquisition link for observing prominence spectra. Scheduled flight is for June 1976.

C. Solar System Studies

1. Planets

Pilcher and graduate student T. D. Kunkle have used an area-scanning photometer to obtain photometrically calibrated limb-darkening scans of Jupiter at four wavelengths: 6190, 6300, 7250, and 8200 Å. The first and third of these correspond to methane absorptions, and the second and fourth to continuum regions near the 4–0 and 3–0 H$_2$ quadrupole bands, respectively. They calculated single-scattering albedos at all four wavelengths for several areas on the planet assuming a semi-infinite, homogeneous, isotropically scattering atmosphere. The values obtained at the wavelengths of the quadrupole bands range from 0.97 over the NEB to $\geq$ 0.99 over the NTRZ and the bright band in the southern hemisphere. They used these single-scattering albedo values to show that the 5-μ-emitting equatorial regions of the planet may be relatively free of particulate scatters compared to the tropical regions.

Former graduate student T. Z. Martin, with Cruikshank, Pilcher, and Sinton, has continued study of the S$(1)$ line of the 1–0 pressure-induced vibrational band of H$_2$ at 4750 cm$^{-1}$ (2.1 μ) in spectra of Saturn and Jupiter obtained with the Block/Digilab Fourier transform spectrometer (interferometer). They compared the observed line profiles to the predictions of reflecting layer (RLM) and homogeneous scattering (HSM) atmospheric models. For Saturn, the RLM gives better results than the HSM, indicating a base level H$_2$ density of 0.51 +0.07, −0.06 amagat. The corresponding H$_2$ abundance is 26% km amagat for an assumed scale height of 50 km. The Jupiter data are compatible with the RLM and a boundary temperature near 130 K only if there is an unidentified continuum opacity source at 5000 cm$^{-1}$. In the absence of additional opacity the RLM is successful if the boundary
level is at a temperature of about 200 K. For both planets, the apparent H₂ abundances are lower than values previously derived by other investigators from the H₂ quadrupole lines in the 6000–8000-Å region.

Sinton, in collaboration with L. Nolt (Univ. Oregon) and E. Erickson (Ames Research Center), has measured the disk-to-ring ratio of Saturn's thermal radiation with the 2.24-m telescope and with a detector–filter combination whose response extends from 33 to 50 μ with peak response at 37 μ. This response, when combined with the typical Mauna Kea atmospheric water vapor transmission and the thermal emission models as to Saturn, yields a scaling factor of 38 μ. Erickson, as part of the collaborative program, has observed the ratio of Saturn to Jupiter with the same detector–filter combination from the Lear jet. Thus, the aircraft observations are used to gain an absolute calibration of disk plus ring against Jupiter, while the ground-based observations are used to define the ratio of ring to disk. A preliminary reduction of the data yields 38-μ disk and ring temperatures of 96 ± 2 and 88 ± 2 K, respectively.

Together with P. C. Crump (NASA–Lowell Planetary Patrol observer, now retired) and R. M. Kellerman (visiting site-test technician from the United Kingdom), Cruikshank made a study of the rotation periods and morphology of a series of intensely red spots discovered on Jupiter in mid-1974. The spots were generally so small (less than 1-arcsec diameter) as to have probably gone unnoticed by most other observers, but they are visible on the best photographs obtained at the Mauna Kea Observatory 61-cm Planetary Patrol telescope. The spots are not greatly distinguished from other Jovian features on the basis of their rotation or longitudinal drift, their distinct red color being the main point of interest in the light of current ideas as to the origin and nature of the Great Red Spot. Of the four spots studied, three were small, but the other was quite large. The large spot is of considerable interest because it was present during most of the apparition and appeared to be associated with the disturbance which propagated ahead of the nucleus of a plume observed by Pioneer 10.

Morrison continued his activity as a co-investigator on the Mariner 10 infrared radiometer experiment; he discussed the infrared observations of Mercury at the IAU Colloquium on Mercury in June 1975.

Wolstencroft reduced observations of the distribution of circular polarization across the disk of Jupiter and developed a model to explain these observations. The circular polarization was assumed to arise from the secondary scattering by aerosols of partially linearly polarized light produced in the first-order Rayleigh scattering of sunlight. The positions of the three neutral lines, which separate regions of opposite handedness of circular polarization, and of the four hot spots of high polarization are determined mainly by the relative magnitude and scattering angle of the positive and negative terms in the phase term of the aerosol scattering function. Observations at high angular resolution and at several wavelengths should allow the main features of the aerosol phase term to be determined.

2. Satellites and Asteroids

Morrison and graduate student T. J. Jones have continued the program of photometric observations of the Galilean satellites begun in 1973. They observed on a six-color uvby system over a full range in orbital and solar phase during the autumn of 1974. The results generally confirm and extend the earlier work, but in addition they show a remarkable increase in brightness of all four satellites from 1973 to 1974, amounting to 0.02–0.03 mag, as well as an unexpected difference in the ultraviolet rotation curve of Io between the two years.

Cruikshank, Pilcher, and Sinton obtained interferometric spectra in the region 4000–10000 cm⁻¹ of Io, Ganymede, and Callisto at an apodized resolution of 6 cm⁻¹. The Io spectrum has been subjected to a thorough search for atmospheric molecular absorptions; none has been found. Comparison has been made with laboratory data for the molecules CH₄, NH₃, and H₂S on a feature-by-feature basis. These three gases all have blends of strong lines that are evident at 6-cm⁻¹ resolution, but are smeared out at the 20–30-cm⁻¹ resolutions of earlier published spectra. Carefully determined upper limits for the above molecules have not yet been established from the new data.

Cruikshank located Jupiter's very faint satellites J6 and J7 and attempted radiometric measurements of both at 20 μ. In both cases, the satellites were not detected. For objects in thermal equilibrium with the insolation, the corresponding lower limit on the geometric albedo is about 3%. These results suggest that these two satellites are not as dark as the Trojan asteroids, but until the radiometric observations are repeated with higher sensitivity, this cannot be asserted with confidence.

Pilcher is nearing the completion of a study of the stability of water frost on the Galilean satellites. The study involves the examination of all known mechanisms for the loss of water from the satellites and the calculation of probable present-day loss rates. For Io, these processes include thermal escape, photolytic decomposition, and charged-particle collisions. The last category includes interactions between gas phase molecules and all charged particles as well as sputtering from the solid surface. Preliminary results indicate that at present-day loss rates, no more than a few meters of water frost could be lost from the surfaces of any of the Galilean satellites during the age of the solar system. If this result is confirmed by more detailed calculations, it has important implications for the formation process of the recently proposed evaporative salt surface on Io.

Morrison and Jones observed the rings of Saturn in six colors with the Rakos area-scanning photometer at several phase angles during the 1974/1975 apparition. The typical spatial resolution is about 1 arcsec, which—together with the low scattered light in the telescope and atmosphere—permits separate phase curves to be determined for the anse of rings A, B, and C. These observations are still being reduced and analyzed.

As part of a continuing program to measure the long-term radiometric variations of the rings of Saturn, Morrison measured the 11- and 20-μ surface brightnesses of the B-ring anse at several solar phase angles. Preliminary reduction of the data indicates no decrease in ring temperature over that measured two years before. The reduction also provides verification of the difference in 20-μ brightness between the anse as reported previously, and indication of a modest radiometric opposition effect at 20 μ. As suggested by J. B. Pollack of Ames Research Center, such an opposition effect indicates that interparticle shadowing is an important effect in the rings.

Morrison and Jones have reobserved Titan this year employing the same equipment, techniques, and comparison
stars as were used in the 1972/1973 six-color photometry of the satellites of Saturn at Mauna Kea Observatory. They confirm the secular increase in the brightness of this satellite reported by other observers. The brightening in \( V \) magnitude during the two years since the earlier photometry was carried out is about 0.04.

Sinton, Nolt, and Erickson observed Titan in their 38-\( \mu \) band, and Sinton and graduate student R. Ruotsalainen are working on the data reduction. Calibration of the essentially point image of Titan against Saturn’s rings will require precise knowledge of the beam profile. Ruotsalainen has found that the 38-\( \mu \) profile from scans of IRC + 10216 is very well represented by a Gaussian with a full-width at half-height of 5.7 arcsec. This profile has been subjected to further observational tests and has been found to yield satisfactory agreement with observations. The resulting preliminary 38-\( \mu \) temperature is 88 ± 4 K with the error including the uncertainty in the profile correction.

During the past year, C. R. Chapman (Planetary Science Inst., B. Zellner (Univ. Arizona), and Morrison have continued work on synthesizing a variety of new physical observations of asteroids in order to understand the nature and evolution of the asteroid belt and the relationships between asteroids and meteorites. They published an extensive paper on this topic in Icarus this year and also presented an updated report as an invited paper at the 1975 meeting of the AAS Planetaries Sciences Division. They find that nearly all asteroids can be classified into broad carbonaceous (C) or stony-iron (S) classes. The C-type asteroids predominate, particularly in the outer part of the belt, although they have been neglected in past studies because of their low albedo and consequent faintness. The largest C asteroids are Ceres, Pallas, Hygiea, Ida, Cybele, Europa, and Dacida, all of which are more than 250 km in diameter. In contrast, the largest S asteroids (Eunomia and Juno) are only 250 km in diameter. Important and unusual asteroids include: Vesta, which appears to be differentiated with a surface resembling a basaltic achondrite; Dembowska, which looks like an ordinary chondrite; Nysa and Angelina, which may have enstatite surfaces; and Psyche, which may be primarily metallic. These analyses are continuing as new data rapidly become available.

Morrison has continued his radiometric survey of asteroids, both at Mauna Kea and (in collaboration with C. R. Chapman) at Kitt Peak. These observations have yielded diameters and albedos for 39 objects in addition to the first 40 published by Morrison this year. The new results include the discovery of a large number of additional C-class objects, including what is probably the sixth largest asteroid (Cybele), and the discovery of several objects of unusually high albedo including Nysa and Angelina. The survey has now been extended also to a few very faint objects (17′′). In January 1975, the asteroid 433 Eros made a very close passage to the Earth, and Morrison carried out 10- and 20-\( \mu \) observations of it as part of an international program of physical studies. The radiometric albedo is \( p_{\text{R}} = 0.17 \), corresponding to an effective diameter at maximum brightness of 21 km. In addition, Morrison’s data allow a determination of the 10-\( \mu \) surface brightness over a wide range in phase angle. From the phase variation, he concludes that the surface has low (lunar-like) thermal conductivity, a result that appears to exclude the possibility of a major free metallic surface component.

Cruikshank has pursued an analysis of G. P. Kuiper’s published and unpublished visual diskmeter observations of planets, satellites, and asteroids in order to derive the most probable values for the diameters of Pluto and Triton. Many of the objects that Kuiper observed in the subtended size range of 1–0.15 arcsec have had their diameters derived by other techniques in recent years. The point of this study is to deduce the systematic error in Kuiper’s diskmeter observations as calibrated against objects of known size, and then to apply the correction to his measurements of Pluto and Triton. The maximum correction factor to Kuiper’s diameter measurement of Pluto allowable by observations of near-stellar occultation is 1.15, giving a diameter of 6800 ± 350 km (the error bars are those on Kuiper’s measurement). Kuiper’s observation of Triton with the 200-in. telescope gave a subtended diameter of 0.17 arcsec; as corrected, the satellite’s diameter becomes 4500 km, with an estimated uncertainty of 20%. Corresponding densities for Pluto and Triton are 3–3.5 and 2.5–3 g/cm\(^3\), respectively.

Two review papers by staff members will appear in Planetary Satellites, the Proceedings of the IAU Symposium held in Ithaca, New York, in August 1974. These are Satellite Spectrophotometry and Surface Composition by T. V. Johnson of JPL and Pilcher, and an introductory review by Morrison, Cruikshank, and J. A. Burns of Cornell (who is also the volume’s editor). Morrison, in collaboration with Burns, was also asked to give an invited review on the Galilean satellites at the IAU Jupiter Colloquium in Tucson in May 1975. This paper will be published in the book Jupiter, the Giant Planet, edited by T. Gehrels of the University of Arizona.

D. Stellar Astronomy

Graduate student N. D. Morrison completed her dissertation research involving a comparison of the spectra of O- and B-type stars with the predictions of recently published non-LTE model atmospheres. In addition to the results given in the previous annual report, she attempted to obtain equivalent widths of lines in the 1–3-\( \mu \) region of the infrared using a Fourier transform spectrometer. The poor signal-to-noise ratio obtained in these blue stars prevented the measurement of reliable equivalent widths; lines of the Paschen series were detected, and remarkably strong lines of He I were found in the B stars.

S. Wolff and R. Wolff have continued their research into the relationship between the Hg–Mn peculiar stars and the normal stars of type B. The rotational velocity distributions of the peculiar and normal stars were derived by a new method, and it was found that the distributions are not Maxwellian, as previously assumed. It follows that although all Hg–Mn stars are slow rotators, there are also slowly rotating normal stars. The most likely mechanism for producing the surface peculiarities which characterize the Hg–Mn stars remains rotation-driven diffusion in a stable atmosphere, but all of the conditions necessary for the mechanism to work are not yet clear.

The peculiar B star HR 7129 was investigated spectroscopically by R. Wolff and S. Wolff, who found a strong magnetic field which varies through a range of 12 G. A conspicuous crossover effect is also present. At an effective temperature of 20 000 K, this star, together with HD 215441 and possibly α Cen, appear to define the high-temperature limit of the magnetic star phenomenon. S. Wolff has also investigated the magnetic variations of the well-known Ap stars.
technique or it varies on a long-time scale.

Graduate student C. A. Pilachowski has completed her dissertation research involving a detailed analysis of a group of late-type giant stars which were suspected of having enhanced heavy metals on the basis of a discrepancy between the strength of Sr II λ4077 and the strength expected on the basis of the K-line luminosity calibration. Filter photometry was used to obtain effective temperatures, and Coudé spectrograms provided equivalent widths and line profiles. Seven program stars, one Ba II star, and four normal standards were included in the investigation. Model atmospheres published by Carbon and Gingerich were fit to the derived parameters and chemical abundances derived. The heavy-metals/iron ratio showed mild enhancement of the type found in the Ba II stars, in keeping with Keenan's classification of the program stars as Ba O. The Fe/H ratio ranged from solar to a deficiency of about a factor of 2. The strength of Sr II λ4077 was found to be in agreement with that predicted from the abundance based on weak Sr I lines and the adopted model atmospheres.

A. H. Boesgaard and graduate student W. Hagen have continued to make models for the temperature and velocity structure of circumstellar gas shells. For a given run of temperature and density in the shell the computer model determines ionization of several points in the shell, calculates the number of ions in the line of sight, and from this the equivalent widths of the circumstellar component of Ca K and Na D lines. The predicted equivalent widths are compared with the observed equivalent width averages for a given spectral type. Preliminary results indicate that changes in the temperature structure with spectral type cannot explain the observations. The density distribution appears to be more significant; the density seems to fall off more rapidly with distance from the stellar surface in later-type stars. The H$_\alpha$ line is formed within the chromosphere. The ratio of the blueshifted circumstellar component to the stellar equivalent width is interpreted as the fraction of material that is already accelerated outwards in the chromosphere. This fraction is highest for the middle M-type stars and drops for both earlier and later types.

Hagen is studying the circumstellar shells of late-type supergiants. The gas shells will be observed with high-dispersion Coudé spectroscopy, and the dust shells with infrared photometry at wavelengths from 2 to 30 μ. The two types of data will be combined to construct models for the physical conditions in the shells. Observations are approxi-
mately halfway complete and data reduction is beginning.

Simon and Dyck are continuing their program of 33-μ
stellar photometry. Observations of a number of cool stars
indicate the presence of large infrared flux excesses which
may be attributable to emission from circumstellar silicate
dust.

Finn and Simon are studying the transfer of radiation
through nonhomogeneous spherical dust shells surrounding a
cool protostellar object. Assuming radiative equilibrium and
local thermodynamic equilibrium they have devised a new
theoretical method for calculation of the temperature distribu-
tion throughout the dust shell. They have found that the
method is amenable to convenient numerical calculation, and
plan to apply their computer program to spectra, obtained by
Simon and Dyck, of interesting stellar objects.

Stockton, D. Chesley, and graduate student S. Chesley
have completed spectroscopic studies of R Mon and the asso-
ciated nebula NGC 2261. The velocity of the absorption
lines in the reflection spectrum of NGC 2261 is found to be
a function of distance from R Mon, while that of the Fe II
emission lines (which also arise in the vicinity of R Mon and
are reflected by NGC 2261) shows no significant variation.
This observation is interpreted as resulting from velocity var-
iations in the absorbing shell around R Mon and the differ-
ces in total light travel time from R Mon to various points
in NGC 2261 and thence to the observer.

E. Interstellar/Circumstellar Matter

In collaboration with J. W. Campbell (Royal Observa-
tory, Edinburgh), Wolstencroft has built a sensitive spec-
tropolarimeter to be used initially in high-resolution studies of
the interstellar polarization curve. The instrument com-
bines the advantages of the programmable ROE pulse-
counting Czerny–Turner spectrometer with the rapid modula-
tion and very low instrumental polarization of the photo-
electric polarimeter. The instrument has been designed to mea-
sure the degrees of linear (p) and circular (g) polarization,
with passbands typically between 1 and 75 Å, to a precision
of 0.01% polarization in p, and either 0.0005% or 10−5 p
(whichever is larger) in q—limited only by photon noise.
Laboratory tests and a first observing run with the 60-in. re-
flector at Tenerife indicate that these design goals can be
achieved. Measurements of two reddened stars confirmed
the existence of small-amplitude structure in the interstellar
polarization curve p(λ) detected previously with spaced, nar-
row (50 Å) interference filters.

Wolstencroft and Simon have observed that the visible
light from V1057 Cygni is circularly polarized. Because
the polarization is variable, they argue that it is intrinsic to the
star rather than being of interstellar origin. The linear polar-
ization shows no evidence for variability and is thus primarily
interstellar.

F. Extragalactic Studies

During his sabbatical leave at the Royal Observa-
tory, Edinburgh, Wolstencroft has been studying plates taken with
the UK 48-in. Schmidt telescope at Siding Spring, Australia,
during the initial stages of the Southern Sky Survey. The
plates were mostly Kodak III–J, and sky-limited exposures
had limiting magnitudes fainter than B = 23.0. A list of
bright southern peculiar galaxies was compiled using all av-
ailable 48-in. plates, and the right ascension and declination
of the majority of these galaxies have been measured. Faint
filaments, both curved and straight, have been seen in a
number of these objects; for example, NGC 1097 shows two
linear rays extending at least 55 kpc from the center of the
nuclear bulge, and the linearity and radial nature of these
features suggest that they are the result of ejection. It is
hoped that spectrograms can be obtained of the brightest of
several condensations which are situated at the end of one of
these rays, in order to test this idea. A detailed study of one
plate centered at α = 2°40′, δ = −39° was made, and a
catalogue is being prepared giving the positions and short de-
scriptions of the 550 peculiar galaxies found on a sky-limited
exposure of a III–J plate. A count of all galaxies (both
peculiar and normal) is being made on selected parts of the
plate to yield information on the relative frequency of dif-
ferent classes of peculiar galaxies.

Pilcher and graduate student T. Kunkle have used an
area-scanning photometer to measure the UBV brightness dis-
tributions across the spiral arms of M51 and M81. The data
are being analyzed to determine if significant color gradients
are present as predicted from the density-wave theory of
galactic spiral structure.

Stockton collaborated with J. Glasphey and G. A. F.
Walker (Univ. British Columbia) in a study of emission-line
photographs in Seyfert galaxies, using the UBC self-scanned
diode-array camera on the Mauna Kea Observatory Casse-
rain spectrograph. Hα profiles were also obtained of the
galactic source Cyg X–1.

Stockton also collaborated with H. Ables (U.S. Naval Ob-
servatory, Flagstaff), G. Chincarini (Univ. Texas, Austin),
and H. Heckathorn (NASA–Johnson Space Center) in an
exploration of applications of the Kron electrographic camera
to a variety of extragalactic problems at Mauna Kea Obser-
vation.

Nebulosity found by Stockton around the quasistar
source 4C37.43 shows a strong emission-line spectrum very
similar to that of the nebulosity around 3C48 [Wampler et
al. (1975). Astrophys. J. Lett. 198, L49]. The great strength of
the [O III] λλ4959, 5007 lines in comparison with that of
Hβ points to a collisional source of excitation for these lines.
Limits on the electron temperature and density are being de-
ferred from an analysis of the spectrum.

Infrared photometry of NGC 1068 (at 25 and 33 μ) by
Simon and Dyck has corroborated earlier evidence that the
flux distribution of this object peaks near 20 μ and declines
towards longer wavelengths. Additional 33-μ photometry,
obtained since the publication of the initial Mauna Kea ob-
servation, has confirmed the published flux measurement at
this wavelength.

G. Observations of the Night Sky

The program of polarimetric observations of the night sky
was continued with the Haleakala scanning photoelectric
polarimeter. Observations of the antisolar hemisphere at 5300
Å on 72 nights in 1973 and 1974 were analyzed. Nightly
maps of the polarized intensity vector were prepared. All
data of galactic latitudes |b| > 45° were combined to derive
an average zodiacal light. The orientation of the polarization
vectors is generally consistent with positive polarization.
However, significant deviations from that orientation occur
in certain regions of the antisolar hemisphere, indicating that
a significant fraction of the interplanetary dust is nonspheri-
cal and aligned (probably by the interplanetary magnetic

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field). From the data at 5300 Å, the polarization vectors of the Milky Way between $l = 33^\circ$ were calculated. Their orientation is predominantly normal to the galactic plane, as expected for the diffuse galactic light. Typical polarization values are 2%–7%. The results are being prepared for publication in *Memoirs of the Royal Astronomical Society*.

### H. Other Activities

The Astronomical Society of the Pacific, and the University of Hawaii’s Institute for Astronomy and Department of Physics and Astronomy cosponsored a series of public lectures during the spring of 1975. Morrison talked about life in the universe. Orrall discussed the Sun and solar activity, and P. Dobson (Department of Physics and Astronomy) spoke on black holes.

The Institute for Astronomy will host the 149th meeting of the AAS, to be held in Honolulu in January 1977. Bandermann was appointed to Commission 21 of the IAU as a Consulting Member.

Boesgaard was elected Vice President of the Astronomical Society of the Pacific. She continues to serve on the Board of Directors of the ASP and on the council of the American Association for the Advancement of Science.

Cruikshank was appointed Associate Director for Mauna Kea Observatory in December 1974.

Jefferies continued to represent the University of Hawaii on the Canada–France–Hawaii Telescope Corporation’s Board of Directors. He also served on a Review Committee for the High Altitude Observatory.

Morrison was appointed by NASA to membership in the Mariner/Jupiter Orbiter Science Working Group, and is serving as a special editor for a forthcoming issue of *Icarus* to be devoted to recent research on the planet Mercury. He also continued to serve as Chairman of the IAU Task Group for Nomenclature for the Planet Mercury, and as member of the IAU Working Group on Planetary System Nomenclature.

Orrall spent the period from March to September 1974 as a visiting scientist at the High Altitude Observatory of the National Center for Atmospheric Research.

Fitcher and Morrison are serving jointly as local organizers for the 1977 annual meeting of the AAS Division for Planetary Sciences, which is to be held in Honolulu.

Stockton, with Cruikshank, continued as representative on the Scientific Advisory Council for the Canada–France–Hawaii Telescope Corporation.

Wolstencroft was on sabbatical leave during the 1974/1975 academic year. He spent the period September–June as a Visiting Principal Research Fellow at the Royal Observatory, Edinburgh, and during this period gave a short lecture course on galaxies at the Department of Astronomy, University of Edinburgh. During part of July and August, he was a summer visitor at the Institute of Astronomy, University of Cambridge.

Zirker continued to serve on the Astronomy Advisory Panel for the National Science Foundation, and the Solar Spacelab Working Group for the National Aeronautics and Space Administration. He was appointed as Director of the first Solar Skylab Workshop series, a nine-month study of coronal holes.

### IV. VISITORS’ PROGRAM

R. Giovanelli, CSIRO Sydney, visited the Institute for Astronomy for two months beginning in September 1974. He was involved in interpreting results from highly detailed Hα filtergrams and their bearing on the magnetic cycle of the quiet Sun.

The following visitors were granted observing time at Mauna Kea during the report period:

D. K. Aitken, University College, London, used the 2.46-m telescope to carry out 10- and 20-μ spectroscopy of the galactic center and other H II regions.

D. A. Allen, Royal Greenwich Observatory, carried out infrared photometry of extragalactic objects.

J. W. Campbell used both the 61-cm and 2.24-m telescopes for absolute photoelectric spectrophotometry of early-type stars in the 3000–10 000 Å region.

P. E. Clegg, Queen Mary College, London, obtained 350-μ photometric observations of galactic and extragalactic objects.

J. L. Elliot and J. Veeverka, Cornell University, used the 61-cm and 2.24-m telescopes for photometry of selected comets to determine their axial rotation periods.

G. H. Herbig, Lick Observatory, searched for weak interstellar absorption lines of formaldehyde (~3400 Å), HCN (3500), NH (3360), OH (3070) in ζ Oph.

M. Simon and G. Righini, SUNY, Stony Brook, continued galactic and planetary observations in the submillimeter on the 61-cm and 2.24-m telescopes.

H. Richter, University of British Columbia, used the 61-cm telescope to observe white dwarfs and central stars of planetary nebulae having low surface brightness.

G. Neugebauer, E. Becklin, and G. Wynn-Williams, California Institute of Technology, observed H II regions including NGC 6334, and other compact H II areas containing OH maser sources on both the 61-cm and 2.24-m telescopes.

C. H. Townes, P. Dyal, T. Geballe, and L. Greenberg, University of California, Berkeley, used their infrared spectrometer at the 2.24-m Coudé focus to carry out 20-μ spectroscopy of planetary nebulae and molecular clouds.

G. A. F. Walker and J. Glasey, University of British Columbia, carried out spectrophotometry at intermediate and low resolutions of emission lines in the near-infrared spectra of selected galaxies, QSOs, and the Lactertides.

Many of these visitors presented colloquia at the Institute’s Honolulu offices.

**John T. Jefferies**  
*Director*