IV. LICK OBSERVATORY-SANTA CRUZ CAMPUS

A. Personnel

Osterbrock spent the fall quarter on sabbatical leave at the University of Chicago, dividing his time between the Chicago campus and Yerkes Observatory. He worked on the analysis and interpretation of his Seyfert-galaxy data. In his absence, Kraft served as Acting Director of Lick Observatory for the period 1 October 1980–31 December 1981. Faber spent the academic year on sabbatical leave, chiefly on the Santa Cruz campus, devoting her full time to research and planning for the University of California’s Ten-Meter Telescope.

Richard Stover was appointed Postgraduate Research Astronomer effective 1 April 1981. Donald G. York (Princeton), Hubert Reeves (Saclay), Jay A. Frogel (CTIO), R. L. Miller (Naval Observatory), Michael Rosa (Heidelberg), D. McNally (London), Gregory A. Shields (Texas), and G. E. Langer (Colorado Coll.) were at Lick for extended periods of time working on their research with various Lick faculty members. Reeves and Frogel were partially supported by the Alexander F. Morrison Fund.

Staff Activities

Faber and Wampler continued to serve on the Astronomy Survey Committee, chaired by George B. Field (Harvard), working on establishing priorities for ultraviolet, optical, and infrared astronomy in the 1980s. Faber also served on the Astronomy Advisory Panel and the Grants Review Panel of the National Science Foundation. She was elected as a Councillor for the American Astronomical Society and also served on the Warner-Pierce Prize Committee and the U.S. National Committee for the International Astronomical Union. After serving on the KPNO-CTIO Committee of the AURA Board, Kraft was elected a member of its Executive Committee in March 1981. He was elected to the Board of the Astronomical Society of the Pacific for a three-year term. He also served, beginning on 1 June 1981, as the Lick Observatory representative to the Executive Management Committee for the University of California’s Ten-Meter Telescope. Osterbrock continued on the Board of Trustees of Universities Research Association and on the NRC Assembly of Mathematical and Physical Sciences.


B. Instrumentation

1. Shane Telescope

Work has begun on a new high-resolution faint-object coudé echelle spectrograph designed by Vogt. The instrument incorporates a prism-cross-dispersed echelle with a 20.3-cm-diameter collimated beam feeding a CCD detector. With a 1.2-arcsec slit, it will provide over 2000 Å of spectrum in a single exposure at a resolution of 6×10⁴. Using presently available CCD’s it should reach 15th to 16th magnitude at a signal-to-noise of 30 per pixel, and 17th magnitude within the next few years as improvements occur in CCD technology. Detailed ray-tracing optimization of this instrument is being carried out by H. W. Epps (UCLA). The collimator, Schmidt camera, and prism cross dispersers are being made by B. Lizotte in the Lick Optical Shop.

Vogt has finished work on a second Reticon detector for high-dispersion spectroscopy. This device features a single linear array of 1872 pixels on 15-μm centers, with an average readout noise level of 700 electrons. The device is currently in use on both the 40-in. and 80-in. spectrograph cameras, and is soon to become operational on the 20-in. camera as well. It is generally available to all users of the Shane 3-m telescope and/or CAT.

Rank, with F. Witteborn (NASA/Ames), has been developing SiBi detector arrays for use on the NASA C141 airborne observatory and at the Shane 3-m telescope on Mount Hamilton. The detectors are used in a grating spectrograph which operates over the wavelength range of 5-13 μm.

2. 1-m Nickel Telescope

The microprocessor-based telescope controller has been used successfully on the 1-m Nickel telescope for the past year, controlling the dome and telescope. The Commodore "PET" microcomputer that supervises the controller now allows the observer to select most of the functions commonly associated with larger computer systems, such as coordinate corrections, listing of objects to be observed, track rate adjustments, automatic slit changing or offsetting, and dome control. The PDP-8 data acquisition computer can interrogate the telescope controller to obtain object name, coordinates, time of day, and telescope hour angle. The fairly demanding task of keeping the 1.1-m wide dome slit aligned with the 1-m diameter telescope has proven well within the capabilities of the controller. A number of improvements in the controller's software and hardware have been made by Kibbrick and Ricketts to improve reliability and convenience of operation. A major reason for the extensive testing and improving of the controller at the 1-m telescope was to ensure trouble-free operation when an identical controller is installed at the Shane 3-m telescope.

Rank, with H. W. Epps (UCLA), is designing a new optical spectrograph for the 1-m Nickel telescope. The spectrograph will use ITS modules as detectors and should have twice the throughput of the present 40-in. spectrograph.
3. 0.9-m Refractor

The 93-cm telescope lens was refigured by Lizotte in 1979–1980 in order to remove the fine cracks in the surface of the front element that had appeared over the years. The lens is now back in the telescope and undergoing tests to evaluate its performance characteristics.

4. General

Under Robinson’s supervision, three NSF-funded 75-ips 1600-bpi vacuum-column magnetic tape drives have been installed on PDP-8 computers at the Shane 3-m and Nickel 1-m telescopes and at Santa Cruz. They are interfaced using microprocessor-controlled channel drivers that provide features usually found only on much larger computer systems. This equipment makes it convenient to record large amounts of incoming data directly in IBM-compatible form. Fears that vacuum-column drives would cause problems at high altitude have proven groundless, at least for the 1283-m altitude of Lick Observatory.

A VAX 11/780 minicomputer whose purchase was funded by an NSF grant has been delivered to the Observatory. It will be used at the Santa Cruz campus under Robinson’s supervision for interactive data reduction and for astrophysics computations.

An autoguider which can generate telescope-guiding signals from any standard TV image has been developed and tested by Robinson. The microprocessor-based instrument compares the position of a guide star with a marker positioned by the observer. Guide signals are sent to the Commodore “PET” microcomputer, which adjusts for image rotations and sends suitable commands to the telescope controller.

Robinson, Stover, Rank, and Vogt have continued the work of bringing CCD detectors into operation at the Lick telescopes. To make data acquisition possible, video picture display equipment and 75-ips 1600-bpi magnetic tapes have been installed on the PDP-8 computers at the Shane 3-m and Nickel 1-m telescopes and on one identical computer in Santa Cruz. A number of direct CCD images have been taken at both telescopes. Background subtraction and flat fielding of the images have been done by the PDP-8 using interactive software developed by Kibrick and graduate student T. Lauer. The PDP-8 is grossly inadequate for such data reduction but must serve until better equipment can be installed.

The CCD used to date is a Texas Instruments thinned, back-illuminated 500×500-pixel 3-phase detector. Readout noise achieved to date is 20 electrons (rms) per pixel. The CCD has very few bad pixels but its quantum efficiency is only about 30%, with position-dependent sensitivity variations greater than a factor of 2. Because the sensitivity variation is also wavelength dependent and because the interference fringes common to thinned chips are present, flat-field corrections for broadband images are difficult. Work is under way to apply the device in spectroscopic research.

The Lick Automatic Measuring Engine is being extensively modified under the supervision of Jones. Linear Reticon arrays of 1024 elements are being used to read the scale lines, and a Reticon 100×100 array will be used to replace the present spinning scanner. The modifications will lead to a marked improvement in accuracy as well as a tenfold increase in speed.

Jones and D. G. York (Princeton) have begun testing the instruments, described in last year’s report, designed to measure proper motions and parallaxes by the use of a moving Ronchi ruling in the focal plane. The modulated starlight from many stars in the field is detected by an image-tube disector acting as a multichannel high-speed photometer. Initial runs at the telescope have been encouraging. It is expected the instrument will be put into routine operation during the fall of 1981 or the winter of 1982.

5. Site Testing

Walker served as consultant to the Dark Sky Site Survey sponsored by the National Science Foundation and administered through the Kitt Peak National Observatory. The purpose of this survey is to study seeing and other observing conditions at a number of existing and potential dark-sky optical observatory sites in the United States. The first undertaking of the survey is to be a study of the observing conditions on Mauna Kea, comparing seeing and other parameters on the summit cinder cones where the present telescopes are located, and down off the cones on the top of the underlying shield volcano. In July 1980, Walker visited Hawaii, together with D. L. Crawford (KPNO), the project supervisor, to initiate arrangements for the survey. In February–March 1981, Walker visited the KPNO in connection with the organization of the survey, and in May 1981 he again visited Hawaii to oversee its final preparations. In addition, in April 1981, Walker collaborated with W. L. Sanders (New Mexico State University) in the calibration of polar star-trail seeing telescopes to be used in a survey of seeing conditions on various mountain peaks in New Mexico.

6. Ten-Meter Telescope

Faber worked on the University of California’s Ten-Meter Telescope project, primarily on the optical design and alignment tolerances and on the design of spectrographs and reducing cameras for direct imaging. She developed a rigorous criterion based on information theory for optimizing the pixel match between the focal-plane scale and detector pixel sizes. Rough design parameters for cameras and low- and high-resolution echelle spectrographs were worked out, based on this criterion. The results were encouraging and indicated that it will be possible to build optimal spectrographs and cameras for the TMT with currently available gratings and detectors. The results will appear in three TMT technical reports.
C. Scientific Program

1. Astrometric Studies

Work on the northern proper-motion program with respect to galaxies continues with the participation of Jones, Klemola, and Hansson. Assistance at the telescope was provided by Harlan. Second-epoch plates have now been secured for 1060 of the 1248 fields. Measurements have been completed for 650 fields in the declination band extending from -3\degree to +70\degree outside the zone of avoidance. Reductions for proper motion, photometry, and equatorial coordinates are in progress.

List III, containing trigonometric parallaxes for 14 fields, has been published. This list contains red and white dwarfs and the helium star BD + 10°2179. Measurements have been started for List IV, which contains about 15 dwarf novae and related objects. Since the expected parallaxes for this class are small, the study of mean luminosity will make use of the proper motions applied to standard statistical methods. Observations of new parallax fields with the 0.9-m refractor have been halted pending completion of the refocusing of the outer surface of the crown element.

Hanson and T. E. Lutz (Washington State) completed their study of systematic effects in the existing trigonometric parallaxes, in order to help define the system for the new Yale Parallax Catalogue being compiled by W. F. van Altena. The results indicate the need for major changes in the precepts of the present General Catalogue, including:

1. the abandonment of the classical "observatory corrections" and the inherent concept of basing the catalog system on that of a single observatory;
2. the correction of the Allegheny bright star parallaxes for the systematic magnitude error arising from the use of very narrow sectors in the Allegheny observing program;
3. the introduction of a carefully defined system of observatory weights, based on comprehensive external error investigations, for use in combining multiple observations and assessing parallax errors.

R. L. Walker (Naval Observatory) continued his program of astrometric observations of double stars with the 0.9-m refractor for two weeks during August 1980.

2. Stellar Spectroscopy

Kinman (KPNO) and Suntzeff (Washington) joined Kraft in a study of [Fe/H] and [C/Fe] abundances in nine cool giants in the Draco dwarf galaxy, on the basis of scans obtained with the KPNO 4-m telescope. Using Suntzeff's relationship between H- and K-line strength and metallicity, they showed that Draco giants have a 1-dex range in [Fe/H]. Using Carbon's (KPNO) model CH spectra, they also established that [C/Fe] is unusually high (on the average) in the Draco galaxy compared with globular clusters of comparable metallicity. This is of particular interest because of the recent discovery that Draco appears to contain a bona fide carbon star.

Kraft, Stone, and graduate student E. Friel, joined by Ch. Tretzger (Basel), G. E. Langer (Colorado Coll.), D. Carbon (KPNO), and N. Suntzeff (Washington), completed their observational program to study 60 metal-poor halo giants for C and N abundances with the image-tube scanner on the Shane telescope. They found that the distribution functions [C/Fe] and [N/Fe] were strikingly different in these field stars compared with giants in M3, M13, M15, and M92. Interpretation in terms of kinematics and chemical history is now under investigation.

Herbig and Marcy have used the Griffin-type radial velocity device at the 3-m could very successfully in a small pilot program on stars in the Hyades, but found that the choice of λ 4400 as central wavelength was not suitable for work on broad-line late-type stars. From this experience, the apparatus has been modified to work at λ 5200. It is hoped that in this region the absorption-line velocities of T Tauri stars can be measured more accurately and efficiently than by conventional methods.

Graduate student D. Duncan completed his thesis study on the age dependence of Li abundance and Ca ii K-line emission in over 100 F5–G5 dwarfs and subgiants, the former being an ab initio recalibration of old and new data with modern model atmospheres. His new data were obtained with a 3-channel spectrometer of his own design at the 3-m could. The K-line fluxes in the same stars were also measured with that device. A consistent time scale from Li depletion theory was fitted to clusters of known age and to the Sun, and applied to field stars. Briefly, Duncan confirmed that surface Li abundance declines smoothly with time as well as with spectral type between F7 and G5, but that Li deficiencies in some F5–F6 stars must be caused by some mechanism other than the conventional convective one. He found also that the fraction of a star's luminosity in K-line emission is, in the mean, approximately constant from F5 to G5, although its distribution function changes from single-peaked at the start of this interval to doubled-peaked at the end. The correlation between K-line flux and Li abundance is good for some stars, but some Li-rich stars have very weak Ca ii emission. The Li abundances in the youngest main-sequence stars are very similar to those of T Tauri stars but may be slightly less than in Type I carbonaceous chondrites and in the interstellar gas. In collaboration with Harlan, Duncan is now enlarging this data base by determining Li abundances in a large number of fainter F5–G5 stars observed photographically at 11-A mm⁻¹ dispersion.

Graduate student D. Soderblom completed his thesis study of rotational decay in solar-type dwarfs. The v sin i's were measured for 82 stars, down to a level slightly below the solar value (1.8 km s⁻¹) with the couldé echelle scanner. The ages of these stars were estimated from surface Li abundances, calibrated by a procedure very similar to that used by Duncan. Soderblom confirmed earlier conjectures that solar-type stars lose angular momentum on the main sequence: the v sin i's decay very nearly as t⁻¹/₂, although that rule fails for extrapolation to stars younger than the age of the Pleiades, where it predicts rotational velocities too high. He found also that chromospheric Ca ii flux is clearly proportional to rotational velocity, while the dependence of Ca ii emission upon Li abundance (i.e., age) is more compli-
cated. There is no evidence that rapid rotation enhances Li depletion. The rotational velocity of the Sun is found to be somewhat lower, although not significantly so, than the mean for stars of its age and mass, so there is no reason to regard its angular momentum as anomalously low.

Jones and Duncan (the latter now at Mount Wilson and Las Campanas Observatories) measured Li abundances in a number of late G and early K Pleiades and Hyades members, using a variety of telescopes and instrumentation. They found no unambiguous evidence for pre-main-sequence depletion in the Pleiades. The Hyades Li abundances fall increasingly below those of the Pleiades toward lower masses. The dispersion in Li abundance at a given mass increases with decreasing mass in both clusters. It appears that most Li depletion occurs after a star reaches the zero-age main sequence. Assuming that the Li abundance dispersion is due to a spread in time of arrival on the main sequence leads to the conclusion that the oldest Pleiades stars are $5 \times 10^7$ yr old, nearly a factor of 10 older than the nuclear age, although other interpretations are possible.

Vogt is continuing work on obtaining resolved images of spotted stars in collaboration with graduate student D. Penrod and with F. Fekel (NASA/Goddard). Several of the brighter RS CVn stars show distortions in their rotationally broadened spectral line profiles owing to the presence of large dark starspots on their surfaces. These distortions move across the line profiles as the spots are carried across the disk by stellar rotation. The profile of each distortion represents an accurate one-dimensional map of a given spot on the star, and by combining multiple observations at different phases, we expect to derive spatial information in a second dimension as well as to construct actual pictures of the spots. Eventually, this technique should lead to a detailed image of a starspot and should provide accurate information on the movements of the spot on the stellar surface, which should be useful for studies of differential rotation.

Graduate student G. Marcy, under the supervision of Vogt, is continuing his thesis project of detecting and measuring magnetic fields on solar-type and late-type main-sequence stars. The method involves obtaining, for each star, two high-resolution line profiles, one sensitive and the other insensitive to the Zeeman effect in order to detect magnetic splitting. Using the coudé echelle spectrograph, fed by either the coudé auxiliary telescope or the Shane telescope, he has obtained data for about 25 stars, of which roughly half exhibit Zeeman broadening. Furthermore, three sets of nearly simultaneous magnetic-field and soft x-ray measurements have now been obtained for the active star $\xi$ Boo A, which suggest a strong relationship between the photospheric fields and the extent of the corona. Simultaneous IUE and magnetic-field measurements have also been obtained with the aim of determining the dependence of the chromospheric and transition regions on the photospheric fields.

Vogt and Penrod are continuing work on resolving structure in the ring around $\zeta$ Oph using the coudé Reticon detector. Time variations in the rotationally broadened line profiles of this star indicate density inhomogeneities in the circumstellar ring which are carried across the stellar disk by orbital motion in the ring. We have been unable to model satisfactorily the observations with simple spherical knots in the ring, and are now investigating models involving radial spokes in the ring.

Vogt has been collaborating with G. Basri and L. Kuhi (Berkeley) on a project involving detailed observations and modeling of T Tauri atmospheres. They are using the coudé Reticon to obtain high-resolution, high-signal-to-noise spectral-line profiles of the Ca II IR triplet, Hz, H$\alpha$, and the Na D lines. These data are flux calibrated with lower-resolution spectrophotometry obtained simultaneously with the image dissector scanner at the Nickel 1-m telescope. The flux-calibrated line profiles will then be used to constrain empirical models of atmospheres generated by Basri.

Vogt is also using the coudé Reticon in collaboration with T. Matzeh and R. Treffers (Berkeley) to study the short-period behavior of the Hz emission line in the periodic x-ray variable X Per. Our preliminary results indicate that part of the Hz emission line pulses with the same 14-min periodicity as seen in the x-ray luminosity, and is highly suggestive of a degenerate companion orbiting X Per.

Whitford and graduate student M. Rich (now at Caltech) analyzed the line strengths of bulge K giants in Baade's Window on Reticon spectra obtained at Las Campanas Observatory. Spectra of stars having high-dispersion abundance analyses observed in the same way provided the calibration. The metallicity distribution among the bulge giants is bimodal: the dominant group is super metal rich, with a mean $[\text{Fe/H}] = +0.3$ and a range $-0.2$ to $+0.7$. A minor fraction ($<20\%$) is metal poor, with $[\text{Fe/H}] < -1.0$. Infrared colors observed in collaboration with J. A. Frogel at CTIO were used to separate the influence of temperature and abundance on line strengths.

Whitford also collaborated with Frogel in determining bolometric luminosities of the M4--M9 giants identified by V. M. Blanco on 4-m grism plates in Baade's Window. The energy distribution curves of these stars plotted from $BVR\text{HKL}$ magnitudes all show a prominent $R$-band dip, attributed to heavy molecular blanketing in a super-metal-rich atmosphere. Integration shows ($M_{\text{bol}}$) = $-4.5$ for the M7--M9 giants. Because of slower main-sequence evolution, super-metal-rich stars of initial mass $M = 1.0$--1.1 do not become giants until after 12 billion years, and the greater mass relative to metal-poor globular cluster giants of the same age appears sufficient to fuel ascent onto the upper asymptotic giant branch, well above the highest luminosity attained by globular cluster stars. Accumulated information on the numbers, spectral characteristics, and evolution rates of bulge giants should permit a straightforward synthesis of an old galaxy population for comparison with the integrated light of unresolved external systems.

3. Variable Stars

An international cooperative observing program was organized by Walker in December 1980, to secure continuous spectroscopic observations of YY Ori, DR Tau, and RW Aur over a period of several days by means of observations made from different latitudes. Despite limitations imposed
by weather and individual observing schedules, reasonably good coverage was obtained. The purpose of the observations was to study the time variation of the inverse P Cygni absorptions in these objects in order to determine how the infall of material takes place. Significant changes in these absorptions were detected, and the observations obtained at Mount Hamilton indicate that the inverse P Cygni absorptions in VY Ori can appear or disappear on a time scale of about 90-120 min. In addition to Walker, the observers participating in this program included I. Appenzeller (Heidelberg), S. Isoye (Tokyo), and B. Wolf (La Silla).

Kraft, Butler (Yale), Suntzeff (Washington), and graduate student E. Kemper completed their study of metal abundances of 26 RR Lyrae stars discovered by Kinman in several low-latitude anticenter fields, based on Lick 3-m and KPNO 2.1-m scanner spectroscopy. The mean metallicity and metallicity spread of these stars are essentially the same as those derived earlier for RR Lyraes in the north galactic pole. There is no evidence for a metallicity gradient. Work continues on the stars in the Ophiuchus field MWF 361A.

Kemper completed his Ph.D. thesis on c-type RR Lyraes under Kraft's supervision. He established a metal-abundance system based on the K line and hydrogen lines that is analogous to the Preston $\delta s$ for Bailey $a's$. Accurate $T_{\text{eff}}$'s and metallicities were established for field Bailey $c's$ over a wide range in [Fe/H]. Data on the temperature boundaries of the instability strip provide no convincing evidence for helium abundance differences among field RR Lyrae stars with differing metal abundances.

4. Star Clusters and Associations

Spectroscopic observations of faint, gravitationally contracting stars in the Orion nebula were continued by Walker, using the Spectracon and Bowen f/1 camera of the 3-m coudé. Major emphasis was placed on obtaining repeat spectra of stars showing discordant radial velocities in the first observations made earlier. The new observations confirm the reality of the large velocities and indicate that for the most part they are systemic in nature, although some variation in radial velocity appears to exist in a few cases.

Jones is continuing his program of proper-motion membership determination in nearby and young clusters. In addition to the Pleiades, the results for Praesepe, obtained in collaboration with K. M. Cudworth (Yorkes), are now complete. The membership segregation is exceptionally good. J. Stauffer (Berkeley) has observed many of the new members to $V = 16$ in $BVRI$. Jones and Herbig have postponed their proper-motion search for post-T Tauri stars in the Taurus-Auriga dark clouds until after the modifications to the AME are complete. The upgraded machine will be able to measure the small, hard Schmidt images far more accurately than with the present system and thus will give a marked improvement in segregation. It is planned to measure tens of thousands of stars in the region. Plates have been obtained of the $\alpha$ Per and Orion region with the 48-in. Palomar Schmidt. For Orion, Shane and Crossley plate material will also be used. NGC 2264 has also been added to the program, in collaboration with W. F. van Altena (Yale).

Klemola has begun a program for the measurement of absolute proper motions in the field of the open cluster NGC 188 on the basis of plates taken with the 51-cm astrophograph and the 3-m Shane reflector. These plates show faint galaxies which are suitable for defining a fixed reference frame for the motions. In another project, Klemola has started the measurement of absolute proper motions in the sparse open cluster Blanco 1, which is located at a distance of about 150 pc near the direction of the south galactic pole. Klemola is exploring the feasibility of measuring the absolute proper motions for several globular clusters (M3, M13, and NGC 4147), around which faint galaxies have been identified. The study of the resulting galactocentric motions is being conducted in cooperation with D. Lin.

In November 1980, Walker, in collaboration with J. Anderson (Copenhagen), carried out two-color direct electronographic observations of star clusters in the Magellanic Clouds. These observations were made using the 80-cm McMullan electronographic camera on the Danish 1.5-m reflector at the European Southern Observatory, La Silla. The purpose of the observations is to derive color-magnitude diagrams for star clusters in the Magellanic Clouds to $V = 22$ or 23, continuing the work begun earlier by Walker using a Spectracon image converter on the 1.5-m Tololo reflector. Observations in $B$ and $V$ were obtained of four clusters in the SMC ($L$ 1, $K$ 3, $L$ 11, and $L$ 113) and four clusters in the LMC (N 1841, N 2210, T 2146, and H 11) with exposures of up to 180 min on Ilford L4 nuclear research emulsion. Owing to the high optical quality of the Danish reflector and to the extreme precautions that have been taken to minimize dome seeing for this telescope, external-seeing-limited exposures were obtained with image sizes of FWHM = 1'0 to 1'7. Consequently, the limiting magnitude attainable on these exposures should be somewhat better than was obtained from the Tololo observations.

5. Gaseous Nebulae and Interstellar Matter

Jones and Herbig have continued work on the proper motions of Herbig-Haro Objects, using Shane, Crossley, Mount Wilson 100-in., and Palomar 200-in. plate material. Preliminary results show that some of the knots of HH-39, associated with R Mon and NGC 2261, are moving along the axis of NGC 2261 and away from R Mon at velocities of up to 400 km s$^{-1}$. The objects HH-7 to HH-12 near NGC 1333 lie in a complicated region. The motions of some of the objects are large. Other objects in the program include HH-31, HH-43, and HH-32. The results to date indicate that many HH objects have large motions away from their probable sources of excitation (HH-1, HH-2, HH-28, HH-29, and HH-39). The most detailed information now available is for HH-1 and HH-2, whose motions are oppositely directed at velocities up to 400 km s$^{-1}$ away from a heavily obscured T Tauri star. Beaming of a strong stellar wind is indicated.

Herbig and Soderblom have completed observations of several diffuse interstellar bands with the 3-m coudé echelle scanner, at a resolution of about 3 km s$^{-1}$. No indication
was found that the lines can be broken down into densely packed fine structure, but coarse structure and asymmetry do exist in the $\lambda$ 6613 band. The narrowest feature known is $\lambda$ 6195, with a total width at half-depth of about 0.35 Å, which is small enough to permit a clear resolution of the band into two components in HD 183143, at wavelengths and a splitting that correspond to those found from the double interstellar K I lines in the same star. Similar duplicity can be discerned in $\lambda$ 6613, although less obviously because that band is much wider. Two new diffuse bands have been found at $\lambda$ 6992 and $\lambda$ 7223, which had been missed in earlier surveys because of interference by atmospheric H$_2$O lines. The asymmetries that have now been found in some diffuse band profiles are opposite in sense to those predicted by the Purcell-Shapiro theory of grain impurities.

It had been hoped by Herbig that some clue as to the carrier of the diffuse band spectrum might be provided by the discovery by Schmidt, Cohen, and Margon of a group of emission lines, apparently excited by fluorescence, in the reflection nebulosity (the "Red Rectangle") at HD 44179. The strongest group of these lines lies between $\lambda \lambda$ 5800 and $\lambda$ 5940, which is not far from a set of interstellar diffuse features $\lambda \lambda$ 5778–5850. Similar interesting near-matches are in the $\lambda$ 6370 region and near $\lambda$ 6614. On coudé spectrograms of resolution about 1 Å (as compared to the discoverers' of about 7 Å), the Red Rectangle emission features are clearly seen not to be sharp, and in some cases are asymmetric, with wings extending to longer wavelengths. The wavelengths measured by Schmidt et al. are found, however, to be quite accurate: the mismatch with the interstellar band wavelengths is real. There is some correspondence with a singlet-triplet electronic system of the C$_2$ molecule observed in the laboratory, a possibility which may deserve further exploration.

McNally used the coudé spectrograph of the coudé auxiliary telescope in his search for anomalous behavior of the diffuse interstellar lines $\lambda \lambda$ 5780, 5797. They are relatively sharp; the same spectrograms also recorded the Na I D lines and in some cases the broader diffuse feature at $\lambda$ 5778. In most cases an additional plate was taken to record $\lambda$ 6284. To date eight stars with anomalously weak $\lambda \lambda$ 5780, 5797 lines have been analyzed and compared with a sample of similar stars with "normal" diffuse interstellar features. The stars with anomalously weak features are HD 23512, HD 24534, HD 37022, HD 37020, HD 37061, HD 36629, HD 37903, and HD 23512, all of which, except the last, are of spectral type B2 or earlier.

Duncan, Harlan, and Herbig have completed their photometric study of a series of Crossley direct plates of the nebulosity at V1057 Cyg, taken between 1971 and 1979. This complex nebula was discovered shortly after the star flared up in 1969–1970. The photometry shows that in the red, the nebular surface brightness has since fallen in precise proportion to the decline in the K magnitude of the star. All but the brightest area in this reflection nebula should disappear below the threshold of these plates in about 1985, given the present rate of decline of V1057 Cyg. It appears that the nebula is a pre-existing dust structure, temporarily illuminated by the flare-up of the star. Its shape suggests that it has been affected by material ejected by V1057 Cyg at earlier outbursts.

Herbig took advantage of the fact that the symbiotic long-period variable R Aqr was near minimum light in October 1980, to repeat a series of direct plates that he had taken at the 3-m prime focus in 1960 and 1970. The complex emission nebulosity very near the star shows striking changes since 1970. In particular, a "jet" that extends from the star for about 10" in p.a. 22° has appeared. This feature is so bright that it is strikingly apparent to the eye at the telescope as a spike protruding radially from the star image. Radial velocities of this and other features in the inner nebulosity were measured with the coudé spectrograph. The direct plates show outward movement in the inner nebulosity over the 20-yr time interval, and confirm as well the slow expansion of the faint outer nebular arcs announced by Baade in 1944. Results from preliminary measurements of these plates are reported in IAU Circular No. 3535.

Shields completed a study of the planetary nebulae NGC 2440 with L. H. Aller (UCLA), C. D. Keyes (UCLA), and S. J. Czyzak (Ohio State). Optical and ultraviolet emission lines indicate N(C)/N(O) = 0.4 and N(N)/N(O) > 1, consistent with strong enrichment of the progenitor with 3α carbon followed by efficient conversion to nitrogen. M. McCall, P. Rybiski (McDonald Observatory), and Shields discovered that the H II regions in the Sbc galaxy NGC 3344 have [O III] intensities much stronger than seen in other early-type spirals. This may indicate that this galaxy has low metal abundances and a strong radial gradient similar to what has heretofore been found only in late-type spirals.

6. Normal Galaxies

Faber continued her survey of velocity dispersions and metallicities in all nearby bright elliptical galaxies in collaboration with D. Burstein, R. Davies, R. Terlevich, and A. Dressler. D. Lynden-Bell, A. Wegner, and R. Stone joined the group to obtain photoelectric photometry and apparent magnitudes. The survey is intended to explore the correlation, found earlier by the group, between velocity dispersion, metallicity, luminosity, and axial ratio, and to map local deviations from a uniform Hubble expansion using the L-σ relation. Observations are progressing well in both northern and southern hemispheres, with the spectroscopic work nearing completion. Observational efforts are now shifting toward obtaining the necessary photometry.

Faber, J. Gallagher (Illinois), and G. Knapp (Princeton) completed a study of integrated H I profiles in compact groups of galaxies. The H I motions in several of these groups are peculiar, showing evidence of noncircular motions arising, presumably, from dynamical interactions among group members. Single-dish surveys can often pick out such peculiarities and are thus a promising tool for selecting objects to be mapped with H I interferometers.

Faber and graduate student E. Friel began a study of line-strength variations in the spectra of K giant stars at low-to-intermediate spectral resolution. They are concentrating on
strong features which can also be measured in early-type galaxy spectra. They plan to calibrate the changes in feature strengths for K giants of known composition and then compare these results to the variations exhibited by the galaxy spectra. In this way, they hope to test whether the abundances of all elements in galaxies vary in lockstep or whether some elements, such as nitrogen or magnesium, are overabundant.

Miller, working in collaboration with former graduate student H. French, completed a study of two seemingly unrelated objects, the QSO B 234 and the irregular galaxy NGC 4861. They found that both these objects could be assigned to the class of isolated extragalactic H II regions. These objects have spectra dominated by very strong, sharp emission lines characteristic of a low-density gas. For B 234 and NGC 4861, abundances of He, O, Ne, and N are quite low. The abundance of He that they derived for B 234 is near the lower limit for such objects found by French in his thesis investigation of the class. Miller and French conclude that H II regions of this type can have a wide range of luminosity, with B 234 being the most luminous one known.

Graduate student W. Keel pursued his thesis research, an investigation of low-ionization emission in the nuclei of spirals. A complete sample of spirals is being observed with the 1-m Nickel and the 1.5-m Mount Lemmon telescopes and IDS systems. The results to date indicate that every spiral has either a low-ionization emission region or an H II region at its nucleus. Higher-quality spectra of a number of nuclei are being analyzed to determine the contribution of stellar continuum features to emission-line flux measurements. This is accomplished with the aid of a library of stellar standards observed with the same spectroscopic setup. Some information has been obtained on the spatial extent and structure of the emission, a major goal of this study.

Keel has amassed spectrophotometry with the 1-m, 1.5-m, and 3-m reflectors of nuclei of spirals containing radio sources. These spectra will be similarly analyzed for stellar contributions, yielding more accurate line fluxes and ratios than otherwise obtainable. Preliminary inspection suggests that irregular and multiple radio sources are associated with H II regions and recent bursts of star formation, while small, single sources are associated with low-ionization emission. The optical spectral properties are not good predictors of radio properties. New plates have been obtained in support of this work; they are being used for both morphological and astrometric studies.

Klemola has begun a program for the measurement of absolute proper motions for stars in a 1°×1° field centered on the outlying Small Magellanic Cloud cluster NGC 121. Measured stars should include members of NGC 121, 47 Tuc, the halo of the SMC, and galactic stars in the line of sight to the field. The first-epoch plate material consists of the extensive series taken in 1969-1970 with the CTIO 1.5-m reflector by Graham (CTIO) for his RR Lyrae star survey. These plates contain a number of suitable galaxies for defining a fixed reference frame for the motions. The analysis of the resulting galactocentric motions is being carried out in cooperation with D. Lin.

7. Active Galaxies and QSO's

Osterbrock completed his spectrophotometric study of the Seyfert 1 galaxy III Zw 77. Many faint emission lines were identified, including [Fe II], [Fe VI], several lines of [Fe VII], and one line each of [Fe X], [Fe XII], and [Fe XIV], as well as several of the O III Bowen resonance-fluorescence lines. The [Fe XIV] λ 5303 green coronal line is blended with [Ca V] λ 5390 but is definitely present. Emission in [Fe II] and [Fe II] is very weak if present at all. The H I emission lines have composite profiles of the Seyfert 1.2 type and cannot be separated unambiguously into broad and narrow components. [Fe II] λ 4686 appears to have a weak, broad component blueshifted by ΔZ ≈ −0.0025. Among the narrow emission lines there is a systematic increase of width with degree of ionization from FWHM 150 km s⁻¹ for [O I] and [S II] to about 400 or 450 km s⁻¹ for [Fe X] and [Fe XIV]. The continuous spectrum fits a featureless power law ν⁻¹.5, making up about 85% of the continuum flux near Hβ, and a normal-galaxy spectrum making up the remaining 15%. The interpretation of the emission-line measurements cannot be made with high precision because the reddening is uncertain. However, with either no reddening assumed, or an estimated reddening by analogy with NGC 4151, the [O III], [Fe VI], [Fe VII] line ratios all seem to indicate photoionization as the energy-input mechanism to the narrow-line region.

Osterbrock also discussed his spectrophotometric measurements of five galaxies with fairly strong narrow emission lines combined with weak broad Hα and, in some cases, Hβ emission components. These objects have line and continuum spectral properties intermediate between those of Seyfert 1 and Seyfert 2 galaxies, but much closer to the latter, and are therefore called Seyfert 1.8 and Seyfert 1.9 galaxies. The physical properties of these objects were described and discussed. In all of them, the observed intensity ratios of the broad Hα/Hβ emission lines are unusually large compared with those of typical Seyfert 1 galaxies, suggesting that dust may be particularly important in the broad-line regions of these objects. The narrow-line spectra of the Seyfert 1.8 and 1.9 galaxies, although definitely Seyfert 2 in character, tend to have relatively low ionization, implying that relatively few high-energy photons reach the narrow-line region in these objects. There is a tight correlation between a strong featureless continuum and broad H I emission lines in Seyfert and radio galaxies. Such objects may normally be close to the critical Eddington luminosity, and the high-velocity gas may be produced when they go above the limit at times.

Shuder and Osterbrock measured a large selection of emission-line galaxies spectrophotometrically. Combined with previous Lick Observatory measurements, these data provided criteria that allow Seyfert 2 galaxies to be quantitatively isolated from the narrow-emission-line galaxies. The criteria are based on the result that galaxies with [O III] λ 5007/Hβ < 3 have emission linewidths that are usually considerably smaller than the widths in galaxies with [O III] λ 5007/Hβ > 3. In addition, large He II λ 4686/Hβ ratios are consistent with [O III] λ 5007/Hβ > 3. Shuder and Osterbrock also compared the physical conditions in the narrow-
line regions of Seyfert 1 galaxies with those in Seyfert 2 galaxies. Significant differences were found for the temperature-sensitive [O III] ratio and for the luminosity of [Fe xIII] \( \lambda 6087 \) relative to the luminosity of the low-ionization forbidden lines.

Shuder has also begun work with Osterbrock on an atlas of Seyfert 1 emission-line profiles. This atlas will present symmetric and asymmetric Balmer-line profiles for about 20 Seyfert 1 galaxies. The range in FWHM to be presented is from 4000 to 30,000 km s\(^{-1}\). In addition to this project, Shuder has investigated the Seyfert 1 galaxy Mrk 335. This galaxy was found to vary not only in its continuum and emission-line luminosities, but also in the strength of the \( \lambda 3000 \) bump. This observation may help to determine the nature of the excess emission near \( \lambda 3000 \).

Baldwin (CTIO), graduate student M. Gaskell, and Wampler have completed optical observations of a complete sample of flat-radio-spectra QSO's. The data will be used to investigate the correlation between C IV line strengths and continuum luminosity for these objects. C IV can be observed from the ground for objects with \( z > 1.1 \). Several lower-redshift quasars are now being studied with the IUE satellite. The observations confirm the preliminary results found and published previously, but the total number of objects observed has been nearly doubled, including a number of intrinsically faint sources. Because the observations of C IV line strengths can be used to estimate the continuum luminosity of quasars, quasar observations can be used to estimate the deceleration parameter \( q_0 \). With the IUE satellite results in hand, a formal value for \( q_0 \) can be determined with rather low observational error.

Wampler used the dissector scanner attached to the Mount Lemmon 1.5-m telescope to observe the Mg II \( \lambda 2800 \) line in four quasars that show broad deep absorption at C IV, S IV, and N V. As with PHL 5200 and RS-23, none of these new sources show evidence for absorption in Mg II. Thus, the Mg II emission clearly comes from a region with a rather different physical configuration from the region that produces radiation from the more highly ionized species.

Wampler used the CTIO 1-m and 1.5-m telescopes to obtain spectra of the stellar component of Cen A=NGC 5128 as a function of radius from the nuclear dust lanes. Good optical spectra were obtained at distances as much as 5 arcmin from the nucleus. These are now being analyzed for metal line strength and stellar composition. Several IUE spectra obtained in the nuclear region of Cen A show a turnover in the UV owing to a population of blue stars. The IUE data will be used together with the ground-based observations to estimate the relative contribution of young stars to the stellar population of this interesting galaxy.

Using the image-dissector scanner on the Shane 3-m telescope, Wampler has obtained spectra of some of the nuclear patches near the galaxy NGC 3077. The patches show strong low-ionization emission at the redshift of NGC 3077. The relative strengths of the emission lines are very similar to the strengths of the lines near the nucleus of NGC 3077. Thus there is at the most only a slight depletion of metals in these outlying clouds.

Miller, working with graduate students W. Keel and R. Antonucci, carried out a study of the variability of the double QSO 0957 + 561A, B. Keel had discovered variability of the pair on Crossley telescope plates he had taken during the first half of 1980, and the group obtained spectrophotometry of the pair in order to investigate the nature of the variations. They used the image-tube scanner on the 3-m Shane reflector and found that the light variations were accompanied by spectral changes. The southern image, \( \beta \), evidently brightened as a result of an increase in continuum flux while the emission lines remained constant. They concluded that the most likely cause of these variations was that the QSO itself is an intrinsic variable, finding it unlikely that changes in the gravitational lens could have produced the observed variations. Keel has continued his study of the variability of the pair using Lick Observatory archival plates as well as new ones. His results indicate that the behavior of the QSO is indeed best interpreted as resulting from intrinsic variability. So far he has been unable to establish a value for the time delay between the light paths that form the two images, but it appears to be greater than two years.

Miller, working with graduate student R. Antonucci, has continued his investigation of quasi-stellar objects and active galactic nuclei using the spectropolarimeter modification of the image-tube scanner. The instrument has been described in a paper by Miller, Robinson, and Schmidt. A detailed study of NGC 4151 by Schmidt and Miller is being followed by similar studies of other Seyfert galaxies. So far, two primary types have been found: those of the NGC 1068 kind, where the polarization is produced by scattering, and those of the NGC 4151 kind, where the polarization is produced by the continuum emission process. In addition, a detailed spectrophotometric study of NGC 1068 shows that the situation there is very complex, with many polarization variations across lines and from line to line being evident. These results are currently being analyzed.

Miller and Antonucci are also studying QSO's of low polarization for which the position angle of polarization is aligned with the double radio structure. This is a relatively long-term project because the objects are sufficiently faint so that long integrations are required in order to measure the wavelength dependence of the polarization and thereby determine its origin. Preliminary results suggest that, at least for some of the objects, the polarization is present in both the lines and the continuum, indicating scattering as the origin. This suggests that a flattened or disk-like structure is present, the perpendicular to which points at the extended radio source structure.

Antonucci is carrying out a thesis investigation of the polarization properties of radio galaxies. Using the 1-m Nickel telescope, a search for polarized objects in nearly 100 galaxies is being conducted, and spectropolarimetry is being obtained for a sample of these objects to investigate the origin of polarization. As a further component of the study, Antonucci has obtained radio observations with the VLA to allow a search for correlations between optical characteristics and radio morphology.

Miller has completed a long-term study of the galaxy components of BL Lacertae objects, N systems, and QSO's.