IV. LICK OBSERVATORY—SANTA CRUZ CAMPUS

A. Personnel

Carl A. Wirtanen retired on 30 June 1978, after 37 years of loyal service to Lick Observatory, in which he made many important research contributions, particularly in the astrometric program and the counts of galaxies.

Osterbrock spent the fall and winter quarters on sabbatical leave, doing research on radio and Seyfert galaxies at the University of Minnesota, and Kraft was Acting Director during this period. G.K. Miley, on sabbatical leave from Leiden, worked at Lick September 1977–June 1978, and D.J. Schroeder, on sabbatical leave from Beloit College, worked at Lick September–December 1977. Both were Martin Kellogg Fellows. L. Biermann (Max-Planck Institut für Astrophysik) spent a month at Lick in the spring of 1978 as a Visiting Astronomer. C. Treffzger (Astronomy Inst., Univ. Basel) spent the year at Lick as a Post-doc working with Kraft on problems of element abundances in late-type stars. G.E. Langer (Colorado College) returned in June 1978 to continue work with Kraft on abundances of giants in M 92 and M 15. J. Fried (Max-Planck Institut für Astronomie, Heidelberg) spent the year at Lick working with Herbig on stellar spectroscopy and variable stars.

Guest observers at the 36-in. refractor included R.L. Walker (U.S. Naval Obs.) and F. Holden for visual double-star measurements.

Staff Activities

Osterbrock gave invited review lectures on his research on active nuclei of galaxies at the NATO Advanced Study Institute on Quasars held at Cambridge in July–August 1977, at the Midwest Astronomers' Meeting, Madison, in October 1977, at the Symposium on Important Advances in Twentieth Century Astronomy, Copenhagen, May 1978, and at the American Astronomical Society Meeting: Madison, June 1978. Kraft was an invited speaker at the Bamberg Variable Star Colloquium in September 1977, at the IAU Symposium on the HR Diagram in Washington, D.C., in November 1977, and at the IAU Symposium on the Large Scale Structure of the Galaxy at Maryland in June 1978. Walker also attended the Bamberg Variable Star Colloquium, as well as the IAU Colloquium on Protostars and Planets in Tucson in January 1978. Miller presented a review paper on Recent Advances in Optical Studies of Planetary Nebulae at the IAU Symposium on Planetary Nebulae held at Cornell in June 1977. Miller also attended the NATO Advanced Study Institute and presented a paper on his recent observations of BL Lacertae. Miller was a member of the Organizing Committee and participated in a conference on BL Lacertae objects held at Pittsburgh in April 1978. He presented a review paper on the optical spectra of BL Lac objects and a paper on the QSO 3C 446. Miller was a member of the Organizing Committee of a Workshop on Supernovae held at UCSC in July 1977. Miller attended the Conference on Supernova Remnants held at the Dominion Astrophysical Observatory in May 1978, and presented a review paper on abundances in these objects. Kraft served as Chairman of the Fachbeirat of the Max-Planck Institut für Physik und Astrophysik, Munich, and also served on the visiting committee for the Institute of Astronom-
late-type giants. The spectrograph design and construction was a collaborative effort involving Hartog, Herbig, Robinson, Soderblom, Wampler, and the Lick technical groups. The construction was supported by the University of California and by the National Science Foundation.

An integrating TV system is about to go into operation at the 120-in. coude. It is intended principally for finding and guiding on very faint stars, but will probably be used on brighter stars in the autoguiding mode as well. The primary incentive for its installation is to make possible a comprehensive radial velocity study of Herbig–Haro Objects, most of which are too faint to be seen directly on the slit even with an image intensifier. Several H–O Objects already have been found to have high radial velocities. During the past year, for example, Herbig found multiple line structure in H–O 32, with components lying between the dark cloud velocity and about +270 km s⁻¹. K. Cudworth (Yerkes) and Herbig have recently restudied the high proper-motion H–O Objects H–O 28 and 29, whose large motions were originally discovered by Luyten. The two appear about 6' apart on the sky; their cross motions of about 145 km s⁻¹ are confirmed and appear to be nearly parallel.

A number of PDP 8/I computers are in operation at Lick Observatory; two for interactive data reduction and software development at Santa Cruz, one at the electronics shop for instrument testing and development, two at the Shane telescope for data-taking at the Cassegrain and Coude foci respectively, and one for data-taking at the 24-in. telescope. All these machines have essentially identical configurations with magnetic tapes, memory CRT, calcomp plotter interface, and fast arithmetic hardware. All can run identical software. The addition of 32K memories, floppy disks, and improved interactive software has allowed these small machines to keep up with increasing amounts of data.

It has been found that the high light-amplification of “gain” of image tubes will allow a large increase in the number of image elements scanned by the image-dissector scanner, so that direct imaging and simultaneous recording of multiple spectra is feasible. To this end, Ricketts and Robinson have made a 32K 24-bit data-taking memory that scans at 8 MHz to replace the 4K 24-bit, 1-MHz memory. Faber has used the new IDS to record eight simultaneous 2048-channel spectra of extended objects. Robinson and Wampler have made preliminary tests of the equipment for direct imaging at the 24-in. telescope, with a view to using the IDS for photometry of faint objects.

Robinson has measured the pulse height distribution of a high-gain proximity-focused microchannel plate image intensifier. Results indicate that the distribution is peaked enough to allow use of the tube in the IDS for much higher gain with lower applied voltage, although there may be some degradation in resolution.

Tests of a Fairchild 100 × 100 CCD have been carried out by Robinson and visiting graduate student S. Nelson (UCSB). McKenna developed circuitry that allows automatic guiding of the Shane telescope using the image produced by the TV acquisition and guide camera.

Schroeder studied possible echelle spectrograph configurations for either the Cassegrain or Coude Focus of the Shane telescope, and prepared optical designs for each location. Each design provides a plate factor of about 5 Å/mm in the blue. A second instrumentation study by Schroeder looked into the possibility of providing cross dispersion with the image-tube scanner of the Shane telescope. A practical design with a prism between the main grating and camera was prepared.

2. 1-m. Reflector

Rank is supervising the construction of a new 1-m reflecting telescope for Lick Observatory. This new telescope will have a conventional yoke mount with an f/17 Cassegrain focus. The mirrors were ground and figured by H. Cowan in the Lick Observatory shop. Initial instrumentation for the telescope will include a TV guider, image-dissector scanner with computer control and data reduction. Current plans indicate that the new instrument will be operational in the former 12-m dome of the Main Building by the beginning of the summer of 1979.

3. Large Telescope

Studies were begun of possible designs of a large telescope, with diameter of order 10 m, to be built by the University of California. The initial study, funded so far from UC funds, is aimed at producing a preliminary design and a proposal to be used in raising funds for the entire project. A Large Telescope Committee, with members from Lick, Berkeley, Los Angeles, and San Diego has been set up under the chairmanship of Osterbrock, and a Technical Subcommittee consisting of Nelson (LBL), Chairman, Wampler, Welch (Berkeley), Eggs (Los Angeles), and Rank is actively working on this project. Possible monolith and segmented-mosaic designs are being considered by the Technical Subcommittee. Schroeder, in collaboration with Wampler, investigated the optical characteristics of large telescopes as part of the effort on this project. In particular, the study evaluated the possibilities and limitations of prime focus correctors in primary beams faster than f/2.

C. Scientific Program

1. Astrometric Studies

Work on the proper-motion program with respect to galaxies is continuing with the participation of Jones, Klemola, and Wirtanen. Second-epoch plates have now been secured for about 850 of the 1246 fields, while measurements are now on hand for over 400 fields in the declination band extending from −3° to +43° lying outside the zone of avoidance.

Jones is continuing in his study of the motions of the T Tau and other stars in the Taurus dark cloud. Jones and Klemola have completed a study of the motions of a color-selected sample of faint blue stars in a field at 8°48′, +18° provided by A. Sandage.

Klemola is engaged in a project with the Jet Propulsion Laboratory for the measurement of reference-star positions for an extended field against which TV camera observations will be made by the Voyager spacecrafts in their passage by Jupiter in 1979.

Klemola, together with B. Marsden (SAO and Harvard), W. Liller (SAO and Harvard), and J. Elliot (Cornell), has participated in the prediction of stellar occultations by and pulses to Uranus (12 during 1977–1980) and Neptune (26 during 1978–1980). These events will be used to study the ring structure for Uranus and to extend the search to Neptune.

Attempts by Klemola to identify stellar candidates for radio sources reported by H. Johnson (Lockheed) and others in the
fields of several globular clusters have led to reasonable identifications on the basis of position coincidences. These clusters include NGC 6205, NGC 6440, NGC 6864, and NGC 7078. A negative result was found for NGC 5024, while a possible coincidence was noted for NGC 5272.

Vasilevskis completed preparation of and published the second catalog of photographic double-star measurements made under the direction of Jeffers, and in collaboration with Hertzsprung, in the period 1948–1960. A total of 302 stars is listed.

R.L. Walker of the U.S. Naval Observatory continued his program of observations of close double stars with the 36-in. refractor during July 1977. A total of 230 visual measurements of 87 binaries was obtained in the 14-night period.

2. Stellar Spectroscopy

Hartoo has completed a search for new peculiar B stars which have He in their spectra. Eight new definite or probable He stars have been found. These include α ScI, HR 1951, HR 2306, HR 7129, HD 191890, 33 Gem, 40 Gem, and HR 5998. The previously reported He stars 3 Cen A, 1 Ori B, and HR 7467 were also confirmed. Six He-weak stars were found which had shown no evidence of He. The He-stars occupy a narrow strip in the HR diagram between the He-strong B-stars and the He-weak B-stars without He. Among the He stars the fractional He content tends to increase with increasing effective temperature. These results greatly strengthen the link between the He-weak and He-strong stars and the diffusion hypothesis as an explanation of both.

Kraft, A. Young (San Diego State), and Harlan continued their program to improve M-dwarf radial velocities from Vario-tube plates obtained with the coude spectrograph using both the CAT and the Shane telescope. Several DMe stars have been found to have unusually wide lines that may indicate either rotation or incipient doubling.

Stone is compiling a catalog of spectra observed with the ITS spectrograph at the 24-in. telescope. The primary purpose is to attempt to establish an MK classification system with this equipment. Preliminary results are that spectral types are generally straightforward to determine but luminosity classes present serious difficulties using classical criteria, due to the limited effective resolution of the spectra. For this reason, observations are being extended well beyond the traditional photographic classification region; total coverage will be approximately from 3500 to 9000 Å. In addition, most of the spectra are being individually flux-calibrated by prime-focus spectrophotometry with the Wampler scanner at the Crossley telescope. The result will be a large body of homogeneous spectra which are photometrically accurate and of fair resolution. These should find a variety of applications beyond classification, including population synthesis. A number of unusual objects will be included in the atlas.

3. Variable Stars

Herbig took advantage of several nights of very good seeing at the 120-in. coude to observe, with the aid of the moonlight eliminator and a narrow slit, the spectra of about ten of the faint red variables very near the Orion Trapezium. These spectra had not been obtained before on account of the very brilliant nebular background. Although the stellar Hz is generally masked by the nebular line, at least seven of these stars are of late type and show the Li I λ6707 line strongly in absorption, as expected for very young stars. Measurement of their radial velocities is under way.

Herbig has continued his search for post-T Tauri stars both in the general field and in young associations. Radial velocity work has concentrated on a few candidates for variable radial velocity objects among conventional T Tauri stars; one of these is almost certainly a single-line binary.

Herbig is working on a series of coude spectrograms of the expanding shell around Nova DQ Her 1934, taken with the slit in a variety of position angles. As the coude scale and at 32 Å mm⁻¹, the Hz line appears as a broken, nearly circular loop. Its dimensions and structure vary with position angle. The interpretation in terms of the circumstances of ejection in 1934 is under way.

Kraft continued his inquiry into the origin of the metal-rich RR Lyraes of the old galactic disk; they have somewhat lower luminosities than halo and globular cluster RR Lyraes, and periods also considerably shorter. Kraft showed that these anomalies are compatible with the view that metal-rich RR Lyraes of the ancient galactic disk have a helium abundance Y about 0.07 ± 0.03 smaller than those of globular clusters. This "inversion" of the normal theoretical expectation of the relationship of Y and Z supports earlier results by Goss (1973) and Demarque and McClure (1977); it suggests that material accumulated in globular clusters early in the formation of the galaxy underwent a radically different nucleosynthetic enrichment history than material destined to form the galactic disk.

Walker completed the analysis of a series of simultaneous photoelectric and spectroscopic observations of YY Ori, the prototype star of the group of extremely young stars previously discovered by Walker, to show inverse P Cyg absorptions resulting from the infall of the remnants of the prestellar material into the star. The spectroscopic observations were made using a Spectracon image tube at the focus of the Bowen 1/1 camera of the 120-in. coude spectrograph, and the photoelectric measurements of brightness were made with the 24-in. reflector. These observations indicate that the behavior of the system is very complex. The light variations occur over characteristic intervals of a few days and appear to result primarily from variable obscuration by remnants of the prestellar material. The infalling gas which produces the inverse P Cyg absorptions arises in a different region and varies independently from and more rapidly than the dust producing the light variations, appearing or disappearing within one day. The region in which the emission lines originate is separate from both the dust and infalling gas regions, and is complex. The H lines show variable structure, and neither this structure nor their intensities are correlated with the light variations or the inverse P Cyg absorptions. The intensities of the H lines are not strongly correlated with the Ca ii emission intensity, while the intensity of the He i is more nearly constant and often varies differently from H or Ca ii. The ultraviolet excess and blue continuum are probably the result of Balmer and Paschen continuum emission, although discrepancies with theory exist and the possibility that some portion of the continuum results from another source cannot be entirely ruled out.

Fried is engaged in a study of the symbiotic variable TX CVn, using both old and new spectrograms obtained by Herbig at the 120-in. coude. Fried is also working on the emission-line spectrum of the old nova RT Ser.

4. Star Clusters and Associations

Reductions of the direct electrophotographs of Magellanic Cloud
clusters obtained by Walker in 1968–1969 using a Spectracon image tube on the Tololo 1.5-m reflector have been continued. Reductions of the clusters NGC 458, NGC 2094, and NGC 2231 were partly completed this year. Preliminary analysis indicates that the color–magnitude diagram of NGC 2231 is very similar to that of NGC 2209, showing an evolved main sequence, but with a much smaller Hertzsprung gap than is observed in similar clusters, such as the Hyades, in our galaxy.

Young completed a study of spectral types for 69 stars in the very young cluster NGC 2264, based in part on plates obtained by Kraft at the Shane-telescope coude. The material leads to the conclusion that about 23% of the stars are rather heavily reddened by intraccluster dust.

Treffiger, working from IDS scans of M 92 giants and using the theoretical colors of Bell and Gustafsson as a guide, discovered an ultraviolet gravity-sensitive pseudo-color index that measures the relative surface gravity of subgiant and symptotic giant branch stars. He also took up a study of C and N abundances in M 15 giants, using scans obtained by Kraft.

Under Kraft’s general direction, graduate student N. Suntzeff began a study of the relative abundances of C and N in M 13 and M 3, clusters having very nearly the same Fe-abundance.

5. Gaseous Nebulae and Interstellar Matter

Rank (with graduate students D. Lester and D. Dinerstein) is studying near- and far-infrared emission lines from compact H II regions. These measurements are leading to a better understanding of the type of stellar sources which excite these objects. It has also been possible to observe a number of lines from the same ionic species at wide wavelength intervals across the visible to far-IR spectrum, thus determining the reddening produced by dust in these objects. For example, the AR 111 lines at 7000 Å and 9 μ have yielded the first direct measurement of the optical depth in the IR “silicate” feature.

Rank (with Lester and Dinerstein) used the NASA–JPL CCD camera on the Crossley reflector to obtain near infrared pictures of a number of obscured far IR sources. The deep-red response and speed of the new CCD allowed previously unphotographed objects to be observed. For example, S 140 was resolved into a cluster of four nebulous objects with an extent of about 20".

Miller and graduate student S. Hawley completed a spectrophotometric investigation of the Dumbbell Nebula using the Cassegrain image-tube scanner attached to the Shane telescope. They observed six positions covering a wide range of ionization. They found the consistent abundances for helium, oxygen, nitrogen, and sulfur could be obtained by using simple formulae to correct for unobserved states of ionization. However, they found that the neon ionization structure deviated from that described by the formula, with an apparent excess of Ne II in the outer regions where Ne I would be expected to dominate.

Hawley completed his thesis study of abundances in galactic and extragalactic H II regions. He found definite gradients in the abundances of oxygen and nitrogen in our galaxy and that the magnitude of these gradients agreed with those observed in external galaxies.

Grandi and Hawley calculated grids of model H II regions to test the agreement of the standard ionization formulae. They concluded that given the errors in the observational data, these correction formulae give adequate values of elemental abundances. However, observed anomalies in the Ne and S abundances in gaseous nebulae cannot be explained by their models.

6. Galactic Structures and Populations

Kraft, Treffiger, and Suntzeff, with the cooperation of D. Butler (Yale) and T. Kinman (KPNO), have nearly completed a study of the abundance gradient in the galactic halo, based on RR Lyrae discovered by Kinman in the Lick astrographic survey. They find little evidence for a change in [Fe/H] at distances above the galactic plane from 5000 to 25 000 pc. They note also that methods for determining metal abundances of late-type stars from UV blanketing tend to discriminate against the discovery of stars with very low metal abundances ([Fe/H] < −2.0); this could have an effect (probably minor) on the problem of determining the abundance gradient in the halo.

Whitford used scanner measurements to make a quantitative spectrophotometric comparison of the integrated light of sample patches of the nuclear bulge of the Galaxy with that of nine other galaxies and two halo globular clusters. The sample patches, observed from Cerro Tololo, were in the Baade window near NGC 6522. After corrections for reddening and the foreground stellar population had been applied, the energy curve of the net bulge light and the strengths of the spectral features were found to be very close to those observed in comparable regions of other galaxies. This result suggests that a detailed statistical study of the resolved bulge stars could supply essential information regarding the luminosity function of old stellar populations.

Stone and H. Spinrad (Berkeley) have attempted to verify the measurement of the extragalactic background light (EBL) made by K. Matilla. Using the prime-focus scanner on the Crossley reflector and following Matilla’s example, the dark cloud L 134 was used as a reference to calibrate out various foreground effects, and was compared to nearby clear areas of sky. Their 10 upper limit was 2.6 S_n units (1 S_n unit equals 1/10 mag star/sq deg) which does not verify Matilla’s value of 10 S_n units, but is more nearly in agreement with the values obtained by other workers using different techniques.

Treffiger continued his photoelectric calibration of UV-excesses on the Basel RGU system, using the Lick 24-in. photometer. The goal is that of obtaining abundances for G-type stars at large distances from the galactic plane, in the various Basel halo fields.

7. Normal Galaxies

In collaboration with C.C. Wu (Goddard), J. Gallagher (Illinois), and B. Tinsley (Yale), Faber has been studying the stellar content of early-type galaxies based on ultraviolet fluxes from the ANS satellite. For the central 2.5 arcmin of M 31, the data confirm the UV excess found by OAO over the fluxes predicted by stellar population models containing only the main-sequence, subgiant, and giant branches. Hotter stars are therefore necessary. The evidence suggests that the UV excess is due to naturally occurring hot stars in an old stellar population rather than to young stars. If so, the K corrections for ellipticals at large z could be significantly different from the conventional values, which are based on model populations containing no hot stars.

The same group, plus K. Freeman (Mt. Stromlo), has also studied the peculiar galaxy NGC 5102. This gas-rich S0 bears a striking resemblance to NGC 205, one of the companions of
M 31. In both objects, a large burst of star formation centered on the nucleus occurred a few hundred million years ago. Some residual star formation continues to the present at a much lower rate.

A method has been developed for distinguishing galaxies with young stars like NGC 5102 and NGC 205 from those that are simply metal-poor. Using this method, abnormal bursts of star formation have been discovered in a large number of low-luminosity Es and S0s. The phenomenon seems to be rather widespread in galaxies in this luminosity range ($-15 < M_B < -17$).

Faber has studied the cool stellar populations in the nuclei of M 31 and M 32 based on spectra of 10 Å resolution between 6700 Å and 8700 Å. The mean [Fe/H] of M 32 is $-0.1 \pm 0.1$ dex relative to the sun. M 32 is fitted very well by a population synthesis based on typical old-disk stars in the solar neighborhood, and it is found that significant numbers of very cool M 7 and M 8 giants are required. A firm upper limit can be placed on the number of M dwarfs, which corresponds to an exponent $<1.5$, if the main-sequence mass function is modeled as a power law. This upper limit is considerably more stringent than previous estimates.

These results on M 32 are generally in agreement with Tinsley's models for old stellar populations, based on the local old-disk luminosity function constructed by Tinsley. They are in considerable disagreement with models that are based solely on giants hotter than the helium flash point (spectra) type M 3 III. Cooler M giants are clearly required and must be added to the model on an empirical basis.

The interpretation of the M 31 spectrum is still continuing. However, it is clear that the contribution of late M giants to the flux is only slightly greater than in M 32. This result is unexpected on the simplest grounds because the generally higher metal abundance in M 31 ought to shift the giant branch to cooler temperatures, producing a significantly larger contribution from cool stars. The observed effect, however, is not nearly as large as expected.

In collaboration with Gallagher, Faber has measured $B - V$ colors in the outer halos of three normal giant elliptical galaxies down to a surface brightness of 26.5 B mag (arcsec)$^{-2}$. The colors indicate approximately solar metal abundance in all cases. This value is consistent with abundance gradients measured in the central regions of the galaxies when extrapolated to these larger radii of $>100$ kpc. One of the objects studied (NGC 6166) is a cD galaxy. The data on $B - V$, together with line-strength measurements on two other cDs, indicate that abundance gradients in cD galaxies basically resemble those in less luminous giant ellipticals.

In collaboration with G. Knapp (Caltech) and Gallagher, Faber and Krumm continued their long-term study of hydrogen in early-type galaxies. Observations of several objects rich in H I, including the elliptical NGC 4278, were obtained with the Westerbork array. Image-tube photographs of a large number of SOs were taken with the Steward 90-in. telescope to study possible correlations between gas content and optical morphology.

Under Faber's direction, graduate student D. Burstein completed a thesis on the luminosity distributions of SO galaxies. In addition to the results summarized in last year's report, Burstein finds that the bulge-to-disk ratio in SOs is significantly higher than in normal nearby spirals, suggesting that SOs are not spirals stripped of gas at a late stage of their evolution. Other processes differentiating the two classes must play a role.

Stone worked with Spinrad, Chiu, A. Bruzual (Berkeley), and J. Ostriker (Princeton) on the detection and measurement of halos of the spiral galaxies NGC 4594 (Sa), NGC 4565 (Sb), and NGC 253 (Sc). Each has an extensive faint spheroidal component whose integrated luminosity contributes a large fraction of the total light of the galaxy. In all three cases, the luminosity becomes less elliptical with increasing radius, and falls off more steeply than the Hubble law would predict. When the data for NGC 4594 and 4565 are combined with rotation curves, it is found that the mass-to-light ratios increase from very low values in the central regions to as much as 1000 at 50 kpc for NGC 4565.

Stone has nearly completed analysis of the radial CN gradient in the southern E0 galaxy NGC 1399, using data obtained with the CTIO 1.5-m telescope. From the nuclear value of 0.14, the DDO CN index (C1) declines to 0.11 in less than 1 kpc. Thereafter, the observed values suggest the index flattens out at about 0.10 out to the limit of the measurements (20 kpc), thus confirming and extending the result reported by Spinrad and Stone in 1974.

Krumm has been pursuing studies of 21-cm neutral hydrogen emission from galaxies. A survey of 84 elliptical, SO, and Sa galaxies in the region of the Virgo cluster with E. Salpeter (Cornell) at Arecibo has demonstrated that the gas properties of these early-type systems are very diverse. The neutral interstellar medium comprises at most 1% of the total mass, compared with 10%–20% for the later-type spirals. Rotation curves indicate a higher central condensation of mass than for spirals. Galaxies close to the cluster center are systematically gas-deficient compared to those on the periphery, suggesting that the denser cluster environment strips the interstellar medium from these galaxies.

With P. Silverglate (Cornell), Krumm obtained 21-cm spectra at Arecibo of seven very distant "ring" galaxies. Four more were undetected. The profiles are similar to those from normal spirals, though apparently somewhat narrower. Such a finding is consistent with their being formed by collisions with intergalactic gas clouds, a model which predicts low angular momentum for the resulting gas distribution.

With G. Helou and Salpeter, Krumm studied the neutral hydrogen profiles of 11 low- and high-velocity spirals in the direction of the Virgo cluster. Analysis of the line widths demonstrates convincingly that these galaxies are in fact members of the cluster, on the tails of the velocity distribution. As a result, there is no difference in the mean redshift velocity of ellipticals and spirals in the Virgo cluster, but the spirals have a much larger dispersion in velocities.

Krumm obtained 21-cm spectra at Arecibo in March 1978 of more than 100 spiral galaxies in a project with Salpeter. The narrow beamwidth allowed partial resolution of the neutral hydrogen extent. The data should yield accurate redshift and rotation velocities, as well as a crude indication of the hydrogen distribution, in a large sample of spirals of all types.

Krumm is presently finishing a project with F. Briggs (Pittsburgh) and Salpeter in which the hydrogen radii and rotation curves of 14 nearby, edge-on spiral galaxies are determined. Systematic errors caused by "slideobs" in the Arecibo beam have considerably complicated the data analysis, but a reliable means of correcting for them has finally been arrived at. The results show a wide scatter in the ratio of hydrogen-to-optical radii. However, there is no systematic variation of this ratio from early- to late-type spirals, although the total hydrogen content changes by an order of magnitude. Flat rotation
curves are found out to at least the edge of the optical image of all later spirals.

Wampler and graduate student M. Gaskell collaborated with J. Baldwin (Cambridge) in a continuing investigation of the correlation between C IV line strengths and the continuum luminosity of QSOs. Baldwin earlier showed that for an arbitrarily selected sample of objects at different redshift, the equivalent widths of C IV \( \lambda 1549 \) and \( \text{L} \text{O} \) are strongly correlated with the measured continuum magnitude. To reduce the possibility that this correlation could be attributed to selection effects or to the choice of cosmological models, a new program was directed towards the observations of QSOs in complete samples of flat-spectrum radio sources. These observations confirmed the strong correlation between the equivalent width of C IV \( \lambda 1549 \) and continuum luminosity. Since the correlation also is present in a subset of these sources which has a comparatively narrow range in \( z \), the possibility that the choice of cosmological models is biasing the results can be excluded.

By using the observed correlation, it is possible to reduce the scatter of observationally determined points in a QSO Hubble diagram sufficiently to allow QSOs to be used to discriminate between various cosmological expansion models. In a preliminary summary of their results, Baldwin, Burke, Gaskell, and Wampler found that \( q_0 \approx 2 \).

The observations, which were obtained at Lick Observatory, have raised at least as many questions as they have answered to date. As yet, there is no good theoretical explanation for the correlation; it was totally unexpected. Both \( \text{L} \text{O} \) and C IV \( \lambda 1549 \) seem to be good luminosity indicators, and while preliminary data indicated that \( \text{Mg II} \) might also serve as a luminosity indicator for low-redshift QSOs, more data show that the intrinsic scatter in the \( W(\text{Mg II}) \) vs continuum magnitude diagram is much larger than in comparable diagrams using either \( \text{L} \text{O} \) or C IV \( \lambda 1549 \).

Osterbrock combined measurements made by himself and Koski on Lick spectral scans to find the equivalent widths of the total \( \text{H} \text{H} \) (broad + narrow component) and [O III] \( \lambda 5007 \) (which has a narrow component alone) emission lines, expressed in terms of the featureless continuum, for a large number of Seyfert galaxies.

He found that the \( \text{H} \text{g} \) equivalent widths of the Seyfert 1, Seyfert 2, and intermediate type (Seyfert 1.5) galaxies all have approximately the same distribution functions. On the other hand, the [O III] equivalent widths of these three types of Seyfert galaxies have different distributions, the Seyfert 2 galaxies having on the average the largest equivalent widths and the Seyfert 1 galaxies the smallest. Since the excitation mechanism for the narrow emission-line components is well established as photoionization by the featureless continuum, these frequency distributions imply that photoionization is less effective on the narrow-line gas in Seyfert 1 galaxies than in Seyfert 2 galaxies. This result, coupled with the fact that the \( \text{H} \text{g} \) distribution functions are more nearly the same, strongly suggests that the broad-line gas is also excited by photoionization by the featureless continuum, and that in being photoionized it absorbs photons that would otherwise photoionize the narrow-line gas. Osterbrock proposed a geometrical model in which the dense, broad-line gas is concentrated in a rotating, turbulent disk, on the basis of these observational results.

Osterbrock continued obtaining IDS spectral scans of Seyfert and radio galaxies. Most of these spectra were taken to investigate reported possible Seyfert galaxies and to get spectrophotometric measurements of them. Among the most interesting objects observed were Mrk 830, which turned out to be a Seyfert 1 galaxy with a relatively large redshift, \( z = 0.210 \), Mrk 854, another Seyfert 1 with \( z = 0.156 \) and relatively strong Fe II emission, and Mrk 493, a Seyfert 1 with unusually strong, narrow Fe II. A detailed study is being made of this object, to compare its spectrum with J ZW 1, Mrk 478, and the predictions of Phillips’s theoretical calculations. Several Arakelian galaxies were observed, and also several radio-quiet N galaxies, to see if they have the same optical spectra as N radio galaxies. To date, two of these latter objects, S 10721 and X Comae, have been found to have emission-line spectra spectrophotometrically similar to broad-line radio galaxies, while two others S 1102 Cyg and V 395 Her have only absorption-line spectra.

Miller, in collaboration with graduate students H. French and S. Hawley, completed a study of the galaxy component of BL Lac. They used annular and circular apertures with the image-dissector scanner and Shane telescope to obtain good spectra of the stellar system associated with this active object. Their results confirmed their earlier redshift of 0.07 based on observations of the nucleus. They found the line and continuum spectrum of the stellar component entirely normal for a luminous giant elliptical galaxy, and the derived brightness for the associated galaxy was about one magnitude fainter than that of a first-ranked giant elliptical. They concluded that if the severe physical difficulties associated with interpreting the phenomena observed in BL Lac are avoided by postulating noncosmological redshifts, then such deviant redshifts must apply to an entire galaxy of stars, not just to the nucleus region of an active system.

Miller, again in collaboration with French and Hawley, completed a spectroscopic survey of BL Lac objects and reported their results at the Pittsburgh Conference on BL Lac Objects. They obtained redshifts for about 12 objects and presented data on the nonthermally and stellar components of these systems. They found that the optical luminosities of the nonthermal continuum varied by over a factor of 1000 among the objects, with the most luminous, B2 1308 + 328, one of most luminous objects known in the universe. It was possible to detect galaxy components in all of the low-redshift objects, and the magnitudes and spectra of these components are consistent with those expected for luminous giant ellipticals. They concluded that the data are consistent with all BL Lac objects being located in elliptical galaxies. They also found that 75% of the BL Lac objects showed weak emission lines.

Miller and French continued a spectrophotometric study of optically violently variable (OVV) QSOs. They observed 3C 446 during an outburst in late 1977 and found its observational properties—high and variable polarization, rapid light variations, power-law continuum—closely resembled those of BL Lac objects. They discovered Mg II and Fe II absorption lines at \( z = 0.85 \) \( q_{\text{mm}} = 1.4 \). A second OVV QSO, PKS 0420-01, also had similar optical characteristics, and Mg II in absorption at a lower \( z \). Comparison with data obtained ten years earlier by Wampler indicated that the strengths of C IV and C III emission lines in 3C 446 had not changed significantly.

Miley, together with A. Tielen (Leiden) and A. Willis (Leiden and Brandeis), completed a study of 35 4C radio sources with steep spectra (\( \alpha < -1 \)) using the Westerbork Radiotelescope. Comparison with a similar sample of 4C sources with normal radio spectra (\( \alpha > -0.7 \)) shows that the steep spectrum sources are systematically further away. H. Butcher (KPNO), Miley, Willis, and D. Harris (Penticton) are using the KPNO ISIT television system and 4-m telescope to