of the emission from high-temperature plasmas and is needed in the interpretation of models of thermal x-ray sources. A. Marscher has been making an effort to link the physical processes which cause the observed emission in QSOs at radio, optical, and x-ray frequencies. Using the HEAO-1 A2 all-sky survey, he and his collaborators at NASA Goddard have searched for Compton x-ray emission from sources which were bursting at radio wavelengths. Out of 28 such objects, two were detected in the x-ray. The otherwise absence of x-ray emission despite the small sizes of the radio sources implied by their rapid variability, can be explained in terms of special relativistic effects. Along these lines, Marscher has devised a relativistic jet model which attempts to explain the origin of the nonthermal emission at all frequencies. The model is also capable of reproducing the observed supraluminal motions of the radio components of QSOs if knots of enhanced emission are present. The creation of such knots can occur through radiatively driven thermal instabilities in the jet.

A.M. Wolfe, with Allan D. Tubbs at U. Pittsburgh, continued his study of the large-scale uniformity of physical constants, using the coincidence of redshifts obtained from 21-cm and optical absorptions in the QSOs AO 0235 + 16, PKS 1229-02, 3C286, and MCG 1331 + 17.

IV. LICK OBSERVATORY—SANTA CRUZ CAMPUS

A. Personnel

Lloyd B. Robinson was promoted from Research Physicist to Astronomer on the Lick Observatory faculty effective July 1, 1978. Steven S. Vogt was appointed Assistant Astronomer/Assistant Professor effective October 1, 1978. Mark R. Hartoog resigned his appointment as Assistant Research Astronomer/Lecturer effective May 18, 1979. Gary D. Schmidt and James M. Shuder were appointed Postgraduate Research Astronomers at Lick Observatory effective September 1, 1978 and January 1, 1979, respectively. Barry M. Lasker, CTIO, was on sabbatical leave at Lick July–December 1978, doing research on supernova remnants and gaseous nebulae. Michael Oppenheimer, Smithsonian Astrophysical Observatory, spent the academic year 1978–1979 at Lick Observatory doing research on spectra of bright comets, supported by a Guggenheim Fellowship and by the Alexander F. Morrison fund. Roger Davies arrived in February 1979 and is visiting Lick from the Institute of Astronomy, Cambridge, on a Lindemann postdoctoral fellowship for one year to work on the stellar dynamics of elliptical galaxies. J. Kormendy, KPNO, D.C.B. Whitet, University of London Observatory, B. Taylor, NASA-Ames, R.L. Walker, U.S. Naval Observatory, and F. Holden were guest observers at Lick Observatory.

Schmidt received the Robert J. Trumpler Award of the Astronomical Society of the Pacific, and presented an invited paper on his research at the Society meeting at Sonoma State University in June 1978.

Staff Activities

Osterbrook gave an invited review paper on optical spectra of radio galaxies, Seyfert galaxies and quasars at the 9th Texas Symposium on Relativistic Astrophysics held in Munich in December 1978. Osterbork also gave an invited paper on the future of ground-based optical astronomy at the Symposium held at the dedication of the MMT in Tucson in May 1979. Kraft attended an informal workshop on abundances in late-type stars at the University of Washington in March 1979. In addition he was an invited speaker at the Hans Bethe Conference on “Forty Years of Stellar Energy,” held at SUNY-Stony Brook in May 1979. Walker attended the Seventh Symposium on Photo-Electronic Image Devices at Imperial College, London, in September 1978. Walker attended meetings of the NASA Workshop on Ground-based Techniques for Detecting Other Planetary Systems at Asilomar in October 1978 and at the University of Maryland in January 1979. Faber was an invited participant at a conference sponsored by Battelle Laboratory in May 1979 on the impact of the proposed Satellite Power System on astronomical observations. In collaboration with J.S. Gallagher, Illinois, Faber submitted a paper calculating the deleterious effects of SPS on optical astronomy. Klei- mola participated in the IAU Colloquium No. 48 (Modern Astronomometry), held in September 1978, in Vienna.

Wampler accepted the chairmanship of the Ultraviolet, Optical and Infrared (UVOIR) panel of the Astronomy Survey Committee chaired by G. Field, Harvard. It is the task of the UVOIR panel to survey the U.S. facilities and needs in the 1980s. Faber is also serving on the Astronomy Survey Committee and is chairing its Extragalactic Working Group. Rank served as chairman of the Scientific Advisory Committee for NASA's cryogenic telescope SIRTF. He also served as a member of the NASA Committee on Space Astronomy and Astrophysics. Osterbrock was appointed to the NASA Management and Operations Group for Airborne Astronomy. Osterbrock (Chairman), Wampler, and Miller served on the Organizing Committee for the Workshop on Quasars and Active Galaxies held at UCSC in July 1978. Faber was appointed to the National Science Foundation Advisory Panel on Astronomy and to the Panel's subcommittee on optical and infrared astronomy. Wampler served on the review committee for the Department of Astronomy and Astrophysics at Michigan State University.

Faber is continuing to represent Lick Observatory in negotiations with the City of San Jose concerning the installation of new street lights. A trial installation of 1000 low-pressure and 1000 high-pressure sodium luminaires has just been completed. The reaction of the public and the police and fire departments is being sampled by questionnaire. Low-pressure sodium (LPS) proved 25% less costly to install than high-pressure in residential areas. On arterial streets, installation costs were comparable, but low-pressure will cost less for electricity. The trial installations thus bear out the Observatory's contention that LPS would save the city of San Jose a significant amount of money. LPS would simultaneously benefit research on Mount Hamilton because its monochromatic emission contaminates only a narrow spectral region.

B. Instrumentation

1. Shane Telescope

Miller, working in collaboration with Schmidt, supervised the construction of a new spectropolarimeter for the 3-m Shane telescope. The device uses a Pockels cell as the polarization modulator and is incorporated into the cassegrain imager-tube scanner with its new area scanning capabilities. Using a Fresnel rhomb as a circular-to-linear polarization converter and a calcite block to split the light into separate, orthogonally polarized beams, the device and spectrograph ultimately produce four spectra at the focus of the spectrograph camera, two of perpendicular polarization sense from each of the two entrance apertures. The modulator of the Pockels cell, typically at a rate of 0.5 Hz, is synchronized with the area scanner memory so that the spectra obtained from the two stages of the cell

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are stored in separate portions of memory. The device ultimately provides a measurement of the polarization in each channel of the spectrum along with simultaneously permitting spectrophotometry in the usual sense. Since the only light losses are the small reflection and absorption losses of the various polarization optics, the device is almost as efficient as in the instrument in the pure spectrophotometric mode. Since sky and object are measured simultaneously, it is possible to observe very faint objects efficiently. The spectropolarimeter is being used by Miller and Schmidt to study quasistellar objects, active galactic nuclei, and various galactic nebulae.

The two-dimensional image-tube scanner with 32K channel memory developed by Robinson has continued to be used mostly for simultaneous recording of several spectra along the slit of the spectrograph. This capability has proven particularly valuable in the case of the Miller–Schmidt spectropolarimeter where, as described above, eight separate spectra are recorded as the polarization analyzer is rapidly switched between two opposite states. Modifications have been made to the PDP-8 data multiplexers with Robinson’s supervision so that two or more computers can share the sidereal and standard-time clocks and read the telescope positions. The multiplexer allows any computer or microprocessor attached to the multiplexer bus line to communicate with any instrument attached to any of seven multiplexer crates at various locations within the telescope dome. The long-standing problem with “wings” on the spectrum lines produced by the Lick image-tube scanner appears to have been solved. A new 25-mm dissector tube obtained from ITT shows no wings and gives better resolution than has previously been obtained.

An intensified Reticon CP1001 self-scanned silicon photodiode array detector system is under construction by Vogt for use in high-dispersion spectroscopy with the 40-in. camera in the coude spectrograph of the Shane telescope. This dissector features two parallel linear arrays of 936 silicon photodiodes each. The arrays are separated by 0.375 mm center-to-center in the direction perpendicular to dispersion and the sensing area of each diode is 0.03 by 0.375 mm, with effectively no deadspace between adjacent diodes. New electronic signal processing techniques will be employed, which are expected to achieve an overall readout noise level of 200–300 electrons (rms). Dispersions available will range from 3.4 Å/mm in the blue to 10.3 Å/mm in the near-infrared. This system will become generally available to all users of the Shane telescope. Initially, Vogt intends to use it in conjunction with existing Zeeman analyzer optics for magnetic studies of cluster-member Ap stars and T Tauri stars.

2. 1-m Reflector

A new 1-m telescope is to be installed on Mount Hamilton. The telescope was designed and fabricated in the Lick Observatory shops under the supervision of Rank and Osborne, with funds provided by a bequest from Anna B. Nickel. Present plans call for the telescope to be operational by October 1979 with an ITS scanner for spectroscopic observations.

The main thrust of development work by the electronics group under Robinson’s supervision has been to develop the capability to use microprocessors for Observatory instrumentation. Hardware and software diagnostic equipment and techniques have been acquired or developed so that future control and data-taking hardware can readily be assembled from well-understood modules. The first major application of this technology is in the controller for the 1-m telescope, which uses an 8-bit microprocessor to provide all clocks and drive rates for the telescope, control the dome, calculate pointing corrections, control limits of travel, and accept commands from a keyboard or data-taking computer for moving or offsetting the telescope. The relative simplicity of the hardware will allow easy maintenance by replacement of parts or of the whole unit.

A second application of this technology is a small stand-alone system that accepts data from a dual channel photometer and records it on a floppy disk. This should be of value for observations at the smaller telescopes. A second two-dimensional scanner memory has been built for use at the 40-in. telescope. It will also provide backup for the unit at the Shane 120-in. telescope, and be useful as a computer video display to aid in reduction of CCD pictures.

3. Large Telescope

Osterbrock continued as chairman of the systemwide Large Telescope Committee, which is working on a preliminary design and proposal for a University of California 10-m telescope at a dark-sky site. J. Nelson, LBL, Berkeley, is chairman of its Technical Subcommittee, R. F. Kraft of its Site Subcommittee, and S. M. Faber of its Science Subcommittee. M. F. Walker and D. M. Rank of the Lick faculty are also members of the Large Telescope Committee.

In December Wampler and Rank organized a meeting of expert opticians and telescope engineers to discuss the feasibility of constructing a 10-m telescope with a thin monolithic mirror. The conclusion of that meeting was that, with modest and reasonable extrapolation of present-day technology, such an instrument could be built. A. and M. Meinel, University of Arizona, worked with Wampler and Rank in developing a possible scheme for the construction of the 10-m telescope. Problem areas were identified and some attempt was made to estimate the difficulty of those areas requiring “new technology.” The result of this study was that it would be possible to build the instrument at a cost substantially below the estimate that would be predicted using conventional cost-scaling laws. Such savings are necessary if the funding of such a large instrument is to be successful.

4. Site Testing

Walker continued to collaborate with the Astronomical Observatory Unit of the Ministry of Higher Education and Scientific Research in Iraq. Walker continued to evaluate seeing data from Polaris trail telescopes mounted at potential sites for the proposed National Astronomical Observatory and, in March 1979, visited Iraq to confer on problems relating to the layout of facilities and the instrumentation of the Observatory. Walker also continued to work with J. Welch and D. Cuda of the White Mountain High Altitude Research Station, evaluating seeing observations made with Polaris trail telescopes at two sites near Barcroft Peak.

5. Mount Lemmon

An additional copy of the Lick image-tube scanner is under construction in the Lick shops for installation at the 1.5-m telescope on Mt. Lemmon. It will be an exact copy of scanners already installed at several telescopes on Mount Hamilton and at the Anglo-Australian Telescope. Construction is being supervised by Robinson and Wampler. S. Nelson, UCSD, who will be responsible for installation and maintenance of the scanner is assisting with the construction and commissioning of the equipment.
C. Scientific Program
1. Astrometric Studies

Work on the proper motion program with respect to galaxies continues with the participation of Jones and Klemola. Assistance was also provided by E. Harlan and graduate students R. Wallace, R. Stoughton, and J. Helsper. Second-epoch plates have now been secured for about 920 of the 1246 fields, while measurements are on hand for 520 fields in the declination band extending from $-3^\circ$ to $+53^\circ$ lying outside the zone of avoidance.

Jones and Herbig have completed a study of the motions for about 75 T Tauri stars, emission-Hz stars, flash variables, objects suspected to be of these types, and 250 anonymous stars in the Tau-Aur dark clouds. An important conclusion is that different segments of the clouds probably are not gravitationally bound to the complex. On the basis of the small observed velocity dispersions (1-2 km s$^{-1}$ in one coordinate), it appears unlikely that many stars have the velocities required to escape from their own subclouds. The observation that very few non-emission stars were found to share the motion of the emission-line cloud members shows that there are very few post-T Tauri stars in the clouds.

Klemola, in a project with the Jet Propulsion Laboratory, has completed a catalogue of reference star positions (5000 stars), used for camera alignment on the Voyager spacecrafts in their passages by Saturn.

R.L. Walker of the U.S. Naval Observatory continued his program of astrometric observations of close double stars with the 36-in. refractor for two weeks during July 1978. F. Holden completed his series of double-star measurements with the 36-in. refractor in April 1979. He plans to retire in England.

2. Stellar Spectroscopy

With D. Butler, Yale, and T.D. Kinman, Kitt Peak, Kraft completed a study of metal abundances for nearly 40 RR Lyraes in the North Galactic Pole. The most distant stars lie at a height $z$ above the galactic plane of 20-25 kpc. The data give no evidence for composition gradients in the RR Lyraes apart from composition differences between variables in the halo ($\langle \Delta z \rangle = 7.7$, $\langle [\text{Fe}/\text{H}] \rangle = 1.5$) and the disk ($\langle \Delta z \rangle = 5.0$, $\langle [\text{Fe}/\text{H}] \rangle = -1.0$). They showed from a statistical argument that the sample of stars is too small to detect an abundance gradient over the 20 kpc interval in $z$ unless the space density of RR Lyraes in Oosterhoff Group I falls off about 4 times faster than the RR Lyraes of Group II. The material at hand gives little evidence for the existence of RR Lyraes with $[\text{Fe}/\text{H}] < -2.2$. Whether this is true for the common subdwarfs depends on the number ratio of RR Lyraes to subdwarfs, a ratio having a dependence on $[\text{Fe}/\text{H}]$ that is imperfectly understood. Thus it is not clear whether the paucity of extremely metal-poor RR Lyraes is related to a corresponding lack of extremely metal-poor subdwarfs or is due to an effect of stellar evolution.

A similar study of RR Lyraes found by Kinman in three low-latitude anticenter fields has been nearly completed by Butler and Kraft. These stars lie on the average some 18 kpc from the galactic center and 4.5 kpc above the galactic plane. In rough accord with some of Larson's galactic collapse models, they have metal abundances nearly identical, on the average, with the stars in the north polar cap.

A study of RR Lyraes in Ophiuchus has been initiated by Butler, Kinman, and Kraft, using Lick and Kitt Peak telescopes. It is hoped that metal abundance determinations for these stars, some of which lie as close as 4 kpc to the galactic nucleus, will clarify current controversies over the shape of the abundance gradient in the outer regions of the galactic nuclear bulge.

Herbig has continued his work directed to a comprehensive rediscussion of MWC 349A, the peculiar high-luminosity member of the Cyg OB2 association that is also a heavily obscured infrared and radio continuum source. Spectroscopically the object is very complex, with a rich emission-line spectrum that exhibits a wide range in electron density. At high dispersion the forbidden lines are found to be either broad or distinctly split into two components, reminiscent of the line splitting in planetary nebulae. The results to date can be explained without recourse to a disk model.

Graduate student D. Soderblom attended the 4th Astrophysical Colloquium at Trieste in July 1978, and reported on the design and performance of the coudé echelle scanner. He has been using this instrument in a study of rotational velocities in solar-type (F8-G2 V) dwarfs in the field. Preliminary results show that the sun is an exceptionally slow rotator, and that there is a slow decline in rotational velocity with age (as inferred from Li abundance), but that the major part of the angular momentum of these stars is lost earlier. Observations of a few stars in the U Ma stream have been obtained as an age calibration. Soderblom has also observed with the echelle a number of the beryllium-deficient F stars detected by Boesgaard. No explanation for that phenomenon is as yet apparent, although Soderblom has discovered that one of these objects, HR 7955, is a previously-undetected double-line spectroscopic binary.

Graduate student D. Duncan has completed the construction and checkout of a three-channel spectrometer system that operates in the focal plane of the 160-in. camera of the coudé spectograph. Each photomultiplier observes a line or a control slice of the continuum; (a representative slit width is 1 A) while the spectrum is rapidly swept to and fro across the receivers at a rate of about 2 Hz by a rocking silicone plate behind the spectrograph slit. Duncan is using this system to determine the strengths of Li I $\lambda 6707$, Ca I $\lambda 6717$ and hence the Li/Ca ratio in a large sample of late F and early G dwarfs in order to provide a definitive calibration of lithium decay with stellar age. He is also observing a strength of the emission core in the Ca II K line in these stars, with the same spectrometer.

At Herbig's suggestion, Duncan observed the Hz absorption line and the Ca II $\lambda 3933$ emission core in the highly eccentric ($e = 0.83$) spectroscopic binary 26 Aquilae (type G8 II-IV) as that star passed through periastron in July 1979. No obvious change was detected in either feature as the result of the passage of the two stars at a distance of perhaps as little as 40 solar radii from one another.

Stone observed the strange emission-line object SS 433 on eight of nine successive nights in late October 1978. The IRT spectra, approximately centered on Hz, were the first (so far as we know) to suggest the correct interpretation of the emission lines at unfamiliar wavelengths on either side of Hz (and by extension many remaining features of the spectrum); that is, that they are red and blue-shifted Hz at very high and constantly changing apparent velocities. Also, the same spectra reveal a faint velocity reversal and return to normal which was observed to occur in both the red and blue moving lines at the same time (but in opposite senses), indicating that the emitting region for both line systems could be affected simultaneously, presumably by an event in the central source. This
work has been reported in collaboration with Margon and associates, UCLA, and Klemola. Stone has continued to observe SS 433 whenever possible, and, working with Margon, Ford and Grandi, UCLA, has helped to establish the 164-day periodicity in the moving line systems.

3. Variable Stars

Herbig has nearly completed his radial velocity study of RY Tauri, the first spectroscopic binary to be found among the T Tauri stars. Unfortunately the spectrum of the fainter star has not been detected to date. Preliminary orbital elements show that there is little chance of eclipses occurring. Herbig and Soderblom have almost finished their study of the H, K and infrared triplet emission lines of Ca II in T Tauri stars. The relative intensity pattern in these objects is clearly different from that observed in optically thin sources, such as solar prominences.

Herbig and Duncan, working on Crossley direct plates obtained several times each year by Harlan, have made a photometric study of the fading of the complex nebulous of V1057 Cygni as that star declined from maximum light in 1971. At an effective wavelength of 6500 Å, the surface brightness of the nebula has faithfully followed the R brightness of the star. There is no doubt that this is a pure reflection nebula, possibly with its response very slightly delayed by light-time effect.

Walker and M. Bell carried out a spectroscopic and photometric study of the peculiar variable V751 Cyg. The spectrum of this star resembles that of UX U Ma, and the object is known from previous observations to display the rapid, irregular variations in light characteristic of the cataclysmic variables. The Spectracon and Bowen f/1 camera system of the Shane Telescope could spectrograph was used to obtain single-trial time-resolved spectra at a dispersion at 115 Å/mm. The spectrum was nearly continuous, with only faint, broad emission features at Hβ and Hγ. The intensities of these lines are variable on a time scale of a few hours, becoming, at times, too faint to be detected. Measurement of these lines indicates that the velocity of the system is variable with an amplitude of 2K = 150 km s⁻¹ in a period of about 6 h. In addition, rather rapid variations in velocity occur occasionally with amplitudes of about 200 km s⁻¹ over intervals of about three hours. V751 Cyg thus appears to be a short period binary system similar to UX U Ma and the old nova with superimposed rapid emission activity reminiscent of certain types of flares observed in AE Aqr. However, more observations are needed to derive definitive elements for the system.

Spectroscopic observations of the RW Aur star BM And were obtained by Walker using the Spectracon and Bowen f/1 camera of the coude spectrograph. Simultaneous photometric observations were obtained by Stone using the 0.4-m reflector. Spectra obtained at light levels covering a range of about one magnitude in B indicate that no change in spectral type or appearance occurred during the light variability. BM And thus appears to be a system in which the light variations result from variable opacity, most probably from remnants of the protostellar material orbiting the star. There is almost no variation in B-V color index with brightness, indicating that the occulting material consists of particles considerably larger than those found in ordinary interstellar material.

Spectroscopic observations of the recurrent nova WZ Sge were obtained by Walker during the December 1978 outburst of this system, using the Spectracon and Bowen f/1 camera. These observations reveal the occurrence during the outburst of a velocity variation with an amplitude of K₁ = 160 km s⁻¹ in the (pre-outburst) photometric period. Analysis of the observations by Walker and Bell indicates that this velocity variation results from the orbital motion of the nova component. This analysis further indicates the following:
(1) The dwarf nova, or material immediately surrounding it, was the source of the outburst.
(2) No outward expansion of the luminous material occurred during the outburst.
(3) The mass function of the system is f(M) = 0.024 M☉.

Various observational and theoretical constraints limit the range of possible masses of the dwarf nova to 0.004 < M < 0.48 M☉, the masses of the secondary star to 0.06 < M < 0.25 M☉, and the orbital inclination to 30° < i < 70°. With less certainty, these ranges are further limited to 0.19 < M < 0.48 M☉ and 0.15 < M < 0.25 M☉, if i = 70°, and to 0.004 < M < 0.03 M☉, 0.06 < M < 0.07 M☉ if 50° < i < 60°. The observations suggest that the nova component is a white dwarf, while the secondary may be a late-type M dwarf that might be detectable spectroscopically at minimum light. The outburst of WZ Sge more nearly resembles the outbursts of SS Cyg than it does the explosions occurring in other novae and recurrent novae, and it appears possible that the masses of the component stars in these two systems are also rather similar.

Graduate student G. Marcy has completed two software packages designed to measure radial velocities from image-intensifier spectrograms, which are scanned in two coordinates with the Lick–Gaertner microphotometer. The first automatically sets on individual lines, and corrects for distortion and other instrumental effects, with minimal operator intervention. The second performs a cross-correlation of the spectrum against that of a standard star, as in the Hartmann spectrocomparator technique. With the first procedure, R. Cohen and Marcy have obtained radial velocities from a series of spectrograms of FG Sge taken by Harlan. Some 30 plates obtained between April and November 1978 show no velocity variation greater than about 10 km s⁻¹, which casts doubt on previous suggestions that FG Sge is a short-period spectroscopic binary.

Marcy has carried out a new slitless spectroscopic search for emission-Hα stars in NGC 2264 and NGC 7000/IC 5070, employing the same telescope and equipment used by Herbig about 25 yr ago. Some 18 new emission stars were found, but no new FU Ori-like events were detected (except that of V1057 Cyg). There was no major turnover in the T Tauri-star population of these associations. A study of incompleteness and other factors involved in such surveys will make possible an estimate of the size of the pool of stars from which the emission-line population at any one epoch is drawn, and of the star density.

Klemola reports that, as a by-product of the proper motion program with respect to galaxies, a total of about 60 new variable stars of undetermined types have been found on the 51-cm astrograph plates.

4. Star Clusters and Associations

During 1978–79, reduction of the direct electrographs of Magellanic Cloud clusters obtained by Walker in 1968–69 using a Spectracon image tube on the Tololo 1.5-m reflector were continued. Measurements are now complete for the clusters NGC 339, 458, and 2004, and partly complete for NGC 1783. Preliminary analysis suggests that the color–magnitude diagram of NGC 339 in the Small Magellanic Cloud is similar to that of Kron 3, and is thus a "metal-rich globular" cluster.
Owing to bad weather, Kraft made little progress on the determination of C and N abundances in giants in either M15 or Draco. Graduate student N. Suntzeff, under Kraft's general direction, completed obtaining observations of CH and NH features in about 30 giants each in M3 and M13. The Shane reflector and the KPNO 2.1-m telescopes were used to obtain spectra. These are to be compared with synthetic spectra, computed from D. Carbon's computer program, to obtain C and N abundances. Suntzeff will examine whether there exists an anticorrelation between C and N in these clusters (as opposed to situation in M92), and whether C and N differences between M3 and M13 (which have nearly the same [Fe/H]) might explain the so-called "second parameter" problem.

5. Gaseous Nebulae and Interstellar Matter

Rank, with graduate students H. Dinerstein and D. Lester, has been studying the chemical abundance of S in planetary nebulae. Visible near-IR and medium-IR spectral lines have been used to accurately determine the elemental abundances. They have found that standard ionization correction factors can be considerably in error. The present abundances are remarkably "solar" with no definitive gradient in galactic position. Rank, with Lester and Dinerstein, has also been studying the infrared properties of compact H II regions. This work has led to a calibration of extinction vs CO-column density and established a statistical trend in the relationship of luminosity, excitation, and size of the regions.

With the coudé echelle spectrograph, Herbig and Soderblom have studied the profiles of several of the narrower diffuse interstellar lines (particularly λλ 6196, 6379, 6613) in heavily reddened early-type stars. At this resolution (2 or 5 km s\(^{-1}\)), no evidence of any breakdown into fine structure has been detected. Some of these features do show persistent asymmetries and inflections, and observations of the interstellar K λ 7698 line in the same stars have been made to evaluate the possible effect on this structure by overlapping clouds. Extensive data have been collected on two new diffuse bands at 6992 and 7223 Å. These were originally discovered by Herbig on conventional Lick plates, but since they are heavily confused by terrestrial H\(_2\)O lines, they were not confirmed until spectograms under very low humidity were obtained at Mauna Kea. Removal of the H\(_2\)O lines is relatively simple on the high-resolution echelle scans and both interstellar features are shown very well.

Working with the Coudé Auxiliary Telescope, Whittet obtained 125 spectral plates at a dispersion of 1 Å per mm in his program of the study of the diffuse interstellar bands in lines of sight where anomalies in the band strengths are reaching a maximum may be expected. These include stars in dark clouds, emission and reflection nebulosity, and stars with reported anomalies in the λ 2200 ultraviolet interstellar absorption features.

Lasker wrote up for publication the results of three long-standing research problems on which he has been working. These were a search for [O I] λ 6300 emission from the hypothetical warm neutral medium of the nearby galaxy NGC 4594, a comparative study of shell-shaped and other filamentary nebulae in the Magellanic Clouds in the light of H\(_\alpha\), [O II] and [S II], and the results of a kinematical study of N 132D, a supernova remnant in the Large Magellanic Cloud similar to Cas A. The first two papers have by now already appeared, while the third is in press.

Stone has completed a brief study of the decline in effective temperature of the peculiar planetary nebula FG Sge during the ten-year period 1968–1977. The temperature was estimated from spectrophotometric continuum scans which were compared with a grid of standard star continuum observations. Though the data show significant scatter, as one would expect from this variable object, a mean and roughly linear cooling rate of 310 K/yr is indicated.

6. Normal Galaxies

Faber and graduate student H. French completed their study of the infrared spectra of M31 and M32. Their major new conclusion was that the semistellar nucleus of M31 is enriched in M dwarfs relative to the surrounding bulge. The mass-to-light ratios of their stellar population models were in good agreement with dynamical determinations. For M31, both methods indicate that M/L\(_B\) for the nucleus is 3 to 4 times larger than in the bulge.

Faber, graduate student M. Gaskell, and D. Burstein, DTM, began a study of the spectra of globular clusters in M31. From a sample of 6 clusters in M31 and 16 in the Galaxy, they found the H\(_\beta\) in the M31 clusters is systematically stronger by 30%, independent of metal abundance. This H\(_\beta\) enhancement is identical to that in low-luminosity ellipticals like M32. The interpretation is presently uncertain but may relate to differences in age, He content, CNO content, or stellar rotational velocities. The effect is clearly important to interpretations of broadband blue color indices of red-shifted galaxies.

In collaboration with J.S. Gallagher, Illinois, Faber completed a study of halo color gradients in elliptical and cD galaxies. The B–V gradient in the cD NGC 6166 is steeper than in either NGC 4472 or NGC 5846, two normal luminous ellipticals. These data seem consistent with formation theories in which the cD halo is formed from material stripped away from the metal-poor outer regions of smaller galaxies. Scenarios based on the merger of just a few very large galaxies would predict a smaller gradient.

Faber and Gallagher also wrote a review on masses of galaxies for the Annual Review of Astronomy and Astrophysics. After putting all determinations of M/L from rotation curves, velocity dispersions, binary galaxies, small groups, and great clusters on a common system, they concluded that the evidence for unseen material in the universe is very strong.

Under Faber's direction, undergraduate student J. Baker wrote a thesis on selection effects on samples of binary galaxies. Baker found that relatively isolated binaries have lower mass-to-light ratios than binaries with nearby companions. Two interpretations are possible: (1) Nonisolated binaries are really cluster members, and velocity differences represent group velocity dispersions rather than orbital motions. If so, values of M/L are Artificially inflated for the nonisolated sample. Corrections for this effect would reduce the mean M/L for all binaries to < 10, a value compatible with rotation curve results. (2) Massive binaries more efficiently accrete third bodies during gravitational clustering. If true, the effect produces a strong bias in M/L with binary separation since wide binaries are required to have distant nearest neighbors and hence cannot be massive. Inspection of binaries on the Sky Survey suggests that both effects (1) and (2) play a role. This result is important because it indicates that binary galaxies cannot be analyzed as isolated, two-body systems whose parameters are independent of the surrounding environment.

Krumm has been working as a postdoc under Faber on several observational projects related to the formation and structure of galaxies. With E.E. Salpeter, Cornell, he has prepared a
paper on the velocities and neutral hydrogen distributions of
14 edge-on spiral galaxies. They find flat rotation curves as a
general rule, but disturbed velocity fields when companions
are present. With D. Burstein, DTM, he obtained a 21-cm map
of the face-on S0 galaxy NGC 4203 at Arecibo Observatory.
This remarkable galaxy has an enormously extended H I dis-
tribution and a flat rotation curve, implying a mass-to-light
ratio as high as 1000 in its outer regions. With R. Hohlfeld
he took photometric scans in the J and K bands with the Kitt
Peak 1.3-m telescope of four disk galaxies. The lack of excess
infrared light in their outer regions appears to rule out M-
dwarf stars as primary contributors to the "unseen" mass in
such galaxies. With Faber he obtained emission-like spectra of
the spiral galaxy NGC 4559, using the new 8-slit option of the
IDS on the Shane telescope. From these spectra, the rotation
curve near the center of this galaxy will be measured, and
matched to the velocities in the outer regions, determined
from 21-cm observations. With R. Sramek, NRAO, has obtained
continuum maps at 6-cm of 10 S0 galaxies at the VLA. They are investigating the correlation of radio sources
with neutral hydrogen in early-type galaxies.

Davies is working with Faber on a search for massive halos
around cD galaxies; spectra of NGC 6166 were obtained on
the Shane telescope for this purpose. Davies and Faber have
worked on the core properties of elliptical galaxies; they have
discovered a tight correlation between metallicity and velocity
dispersion for their cores. The correction of velocity disper-
sions to a common metallicity resolves the problem of the ap-
parently disparate velocity dispersion scales found by authors
who have measured line widths in different galaxies.

In the spring, Davies used the 36-in. refractor with D.
Carter, Oxford, to take plates of bright elliptical galaxies.
A study of their isophotal shapes and core profiles is underway.
Davies is also collaborating with the Einstein X-ray observ-
atory in monitoring the emission-line strengths in four Type I
Seyfert galaxies in an attempt to find correlated variability.

Under the supervision of Wampler, undergraduate student
G. Perez observed Shakhbazian galaxy clusters for her under-
graduate thesis project. Using the image-tube camera on the
36-in. refractor, he found that on nights of good seeing it was
possible to distinguish compact galaxy images from those of
stars. She found that many of the Shakhbazian groups were
chance superpositions of red stars and galaxies but that a few
of the observed groups appeared as rich as the prototype
group, Shakhbazian I.

7. Active Galaxies and QSOs

Osterbrock continued studies of the emission-line spectra of
radio galaxies and Seyfert galaxies. The following Markarian
galaxies were confirmed as having Seyfert 1 spectra: Mrk 423,
464, 493, 543, 584, 595, 783, 849, 975, 1040, and 1044, while
Mrk 533, 612, and 622 have Seyfert 2 spectra. Among the
Michigan Cerro Tololo objects, CTIO-M-163 is confirmed as
an object with a Seyfert 1 spectrum, and 16 as a Seyfert 2. Mrk
464 has composite broad plus narrow H I line profiles and
could be described as a Seyfert 1.5 object. Mrk 423 has, in
addition to strong narrow lines, a relatively strong broad com-
ponent of Hα, but broad Hβ is weak and almost undetectable.
This object could be classified as a Seyfert 1.8 object. Mrk 516
has weak, broad Hα, with superimposed strong, narrow Hα and
[N II] emission lines; in addition the Lick scans show very
weak, broad Hβ emission. Mrk 1018 has a similar emission-
line spectrum; these objects, like Mrk 609, might be classified
as Seyfert 1.9 galaxies. Thus there is clear observational evi-
dence for a continuous sequence in the relative amounts of
dense, broad-line emitting gas and low-density, narrow-line
emitting gas in active galactic nuclei. The relative amount of
broad-line gas seems strongly correlated with the relative
strength of the featureless ("nonthermal" or "power-law")
continuum. Further quantitative study of the objects with rel-
atively small, but nonzero amounts of dense, broad-line emit-
ting gas is continuing.

Both Mrk 975 and Mrk 1040 were found to have strong [Fe
vi] and [Fe xi] emission; in addition Mrk 1040 has strong [Fe
xi], which may also be present in Mrk 975. Mrk 783 has rela-
tively narrow lines for a Seyfert 1, and Mrk 595 has strongly
asymmetrical line profiles. It, like all Seyfert 1 galaxies with
asymmetric H I profiles, has a wing extending much further to
the red than to the blue side of the peak. Among the Seyfert 1
galaxies with the strongest asymmetries of this type are Mrk
279, 304, 374, 376, 817, 871, 1040, Akn 120, 374, and III Zw.
These profiles cannot be understood on the basis of largely
rotational and turbulent velocities in the broad-line gas, but
can be qualitatively understood to result from expansion of the
dense gas away from the nucleus together with extinction by
dust or line self-absorption, as suggested by Capriotti, Foltz,
and Byard, Ohio State, and by Ferland, Netzer, and Shields.

Wampler and Gaskell, in collaboration with J. Baldwin,
CTIO, are continuing their work on the luminosity calibration
of quasars. In the next observing season they expect to finish
the observational work on the selected flat spectrum complete
samples. They have found that in addition to Lz and C IV λ
1500, Mg II λ 2800 can also be used as a continuum luminos-
ity indicator, but the intrinsic scatter is greater and the slope of
the correlation between the strength of Mg II λ 2800 and the
continuum luminosity is steeper than for C IV λ 1500 or Lz.
Gaskell is using material collected in this survey in his thesis
on the nature of the optical continuum of quasars with particu-
lar attention to the broad "lump" near λ 2800.

Individually interesting objects have been identified from
the observations of the flat spectrum samples. Gaskell reported
on PKS 0215 +015 in the January 1979 AAS meeting. This
highly polarized, variable, red object displays a well-defined,
low-ionization absorption line system. At the time of the ob-
serve z = 1.345 ± 0.005. In addition there are two unidentified
moderately broad absorption features in the blue. The optical vis-
ual magnitude is about V = 16 so if PKS 0125 +015 is at the
distance indicated by its absorption redshift, it is one of the
brightest objects known.

French, working under the supervision of Miller, completed
his thesis on the so-called "isolated extragalactic H II region"
class of objects. Using spectrophotometric data obtained with
image-tube scanners on the 3-m Shane and 0.6-m reflectors, he
derived line fluxes and abundances for 14 of these galaxies. He
found that the abundances of He, O, N, S, and Ne to be consid-
erably smaller than those found in H II regions of our galaxy.
He abundance data suggest that the primordial abundance
was N(He)/N(H) = 0.069 (Y = 0.216) and ΔY/ΔZ = 3.2.

The nature of the objects is not entirely clear from the study,
but it appears that the gas is photoionized by hot stars and the
mass of ionized gas is small compared to a reservoir of neutral
gas which could provide a continual input of unprocessed ma-
terial, thereby maintaining a continual "youthful" appearance
of the objects; in addition the Lick system at a redshift of

Miller continued his program on optically violently variable
QSOs. He is obtaining spectrophotometric and spectropolarici-
metric measurements of objects in this class as a function of
time. The goal is to investigate the optical activity in terms of continuum behavior and variations in line flux. Preliminary results to date indicate the line fluxes remain constant over long periods, while the continuum levels change dramatically. Miller completed an investigation of QSOs and N systems search for spectroscopic evidence for underlying galaxies. By obtaining high signal-to-noise spectra, he was able to detect galaxies in seven of the nineteen N systems investigated, but in none of the QSOs. The N system galaxies detected were fainter than previous photometric studies indicated, while the data on the QSOs indicate that they are not located in giant E galaxies that are within 2 magnitudes of being the luminosities' first-ranked giant Es.

Osterbrock and Shuder obtained spectral scans of narrow-emission-line galaxies that have been identified as x-ray sources at both 5- and 10-Å resolution. Shuder has measured these spectra and has searched for possible correlations between the x-ray emission and the optical spectra. Preliminary results show these galaxies to be similar in appearance to other narrow-emission-line galaxies and Type 2 Seyferts. However, a faint broad-line component has been detected in four out of six x-ray galaxies surveyed so far, at least at Hz. Shuder plans to observe and measure other galaxies to confirm the apparent correlation between a broad-line component and x-ray emission, which is also seen in broad-line radio galaxies and Type 1 Seyferts.

Shuder has also started an investigation into intermediate redshift QSOs. Observations at 10-Å resolution were taken of several objects with 1.1 < z < 1.55, so that the He II lines at λ 1640 and λ 3204 could be measured with the aim of possibly detecting a line-intensity ratio different from that suggested by recombination theory. This result could give clues to the mechanism(s) responsible for the low ultraviolet to optical line ratios observed in QSOs and Seyfert galaxies.

Osterbrock and Cohen studied the spectrum of the radio source 0Q 208 = Mrk 668, a compact galaxy. It has strong broad H I emission lines and narrow forbidden lines with a large difference in redshift between them, Δz = z(broad) - z-(narrow) = -0.0094 = 2800 km/s. The broad He II and Hβ emission-line profiles are significantly different from one another. In addition, the optical spectrum varied between August 1978 and June 1979, the continuum and broad lines becoming about 0.25 magnitude fainter while the narrow lines remained approximately unchanged. Probably the physical situation in Mrk 668 is related to the situation in the Seyfert 1 galaxies with asymmetric line profiles, which have smaller redshift differences Δz than Mrk 668. It seems likely that Mrk 668 differs chiefly in having a larger outward velocity of the dense gas, and that possibly some of the gas is very close to the active nucleus.

8. Solar system

Rank, in collaboration with Lester and Dinerstein, has been studying the IR ethane inversion spectrum of Jupiter, Titan, Saturn, and Neptune. This work has led to the positive confirmation of ethane in Neptune's atmosphere.

Kemola and Harlan have secured direct photographs with the 51-cm astrophotograph for a continuation of the search for candidate stars for occultations by Uranus and Neptune for the period 1981–1985. Also in cooperation with the activities of the Working Group on Predictions of Occultations by Satellites and Minor Planets of IAU Commission 20, accurate positions of selected stars have been provided from measurements made on Lick astrograph plates.

Oppenheimer worked on determining the source of cometary Na, using Lick Observatory high-dispersion spectra of comets. The method involved the analysis of the brightness profiles of Na D emission in comets Ikeda-Seki, West, Bennett, and Kohoutek. The cometary source of Na was inferred from the morphology of these profiles. The results of this research are still evolving. Preliminary analysis suggests that the source of the Na is a tiny grain or molecule. Attempts are being made to understand this result in terms of the nature of the interstellar grains and the amount of the interstellar Na depletion. A firm connection between cometary and interstellar material would elucidate the relationship between nebular and interstellar material and the nature of the low-mass star formation.

DONALD E. OSTERBROCK
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V. BOARD OF STUDIES IN ASTRONOMY AND ASTROPHYSICS,
SANTA CRUZ CAMPUS

A. Personnel and Faculty Activities

From July 15 through August 3, the Board of Studies hosted a workshop on "Star and Planetary System Formation." The third in an annual series, the workshop was attended by over 110 distinguished faculty, students, and research scientists from more than 10 countries and was sponsored jointly by UCSC, the National Science Foundation, the NASA Ames Research Center, and the Lawrence Livermore Laboratory. It provided a focal point for the discussion and integration of new observational and theoretical results. Locally the workshop was organized by P. Bodenheimer and S.E. Woosley. Other members of the organizing committee included I. Appenzeller (Landessternwarte), D. Black, (NASA/Ames), C. Hayashi (Kyoto), W. Herbst (Wesleyan), G. Knapp (Caltech), L. Mestel (Sussex), M. Walker (Lick), and G. Wasserburg (Caltech).

A wide variety of topics was extensively discussed and progress was reported in many areas. The morning sessions of the first week concentrated on the large-scale aspects of star formation—galactic structure, properties of molecular clouds, and the physics of the interstellar medium. Notable progress was recorded on the detailed structure of molecular clouds, on analytic and numerical calculations of the effects of magnetic fields on cloud evolution, and on the influence of H II regions on the evolution of molecular clouds and on star formation. The second week was primarily concerned with the origin of the solar system and its relationship to star formation. The clues provided by the meteorites regarding the physical conditions in the solar nebula were extensively discussed. Existing models of the solar nebula were compared and the process of collapse from an interstellar cloud to the solar nebula stage was discussed. The two main processes for planet formation—accretion of small particles and gravitational contraction of masses of gas—were discussed and their time scales compared. The third week was devoted to the observations of young stellar objects and protostars. Optical, radio, near and far infrared, and ultraviolet and x-ray observations of these objects were extensively reviewed. Theories of the evolution of spherical protostars and of T Tauri and FU Orionis objects were discussed, as was the theory of fragmentation based on two- and three-dimensional hydrodynamical calculations.

Next summer, the fourth UCSC workshop should again