P. R. Wilson, "Temperature Fluctuations in the Solor Photosphere II. The Mean Limb-Darkening and the Second Maximum," *Solar Phys.* **9**, 303 (1969).

P. R. Wilson, "On Granulation Models," *Solar Phys.* **8**, 20 (1969).

P. R. Wilson (and P. S. McIntosh), "Structure of a Sunspot V. What is the Wilson Effect?," *Solar Phys.* **10**, 370 (1969).

J. P. Cox

Lindheimer Astronomical Research Center and Dearborn Observatory, *Evanston, Illinois;* Corralitos Observatory, *Las Cruces, New Mexico*

I. STAFF

Professors William Buscombe, Karl G. Henize (on leave, scientist–astronaut, Manned Spacecraft Center), Su-Shu Huang, J. Allen Hynek (Chairman), Marvin B. Lewis, David Mintzer (became Associate Dean of the Northwestern Technological Institute but will retain his Professorship in the Department of Astronomy); Associate Professors John D. Bahng, Jay Burns; Assistant Professors Laura P. Bautz, James D. Wray; Joseph M. Chamberlain, Director and Eric Carlson, senior astronomer at Adler Planetarium, hold concurrent appointments as Professor and Assistant Professor, respectively; Administrative Assistant, Diane Congoran; Staff Astronomer, Lloyd R. Wackerling; Engineers and Technologists: Jeff Mack, Fredrick G. O'Callaghan, Jr., Norman Page, Edward J. Pekol, William T. Powers; Staff Photographer, Raymond B. Lazenby; Instrument Shop Head, Bert C. McKenna; Machinist, George C. Walther; Research Assistant, Necia Apfel; Librarian, Jane Rectenwald; Secretaries: Ann Larson, Mary Del Onley, Cindi Trossman. Corralitos Observatory: Resident Director, Justus R. Dunlap; Observers, James R. Gallivan, Roger Hurt, Glenn Jolly, and John Winston.

II. FACILITIES

Evanston, Illinois: A 40-inch Boller and Chivens Cassegrain and coudé telescope, a 16-inch Boller and Chivens Cassegrain, and the 18½-inch Alvan Clark refractor are in operation. The 40-inch is equipped with a Cassegrain spectrograph, a rapid-scanning spectrometer, a photographic camera, and image tubes used in conjunction with the spectrograph. The 16-inch Cassegrain is equipped with a standard *UBV* photometer and the 18½-inch with camera and filar micrometer.

Las Cruces, New Mexico: Both the 24-inch and the 16-inch Cassegrain telescopes are equipped with image orthicon chains, remote readouts, and storage tubes. The 24-inch can be operated in the automatic mode and can be computer programmed. A 12-inch Cassegrain for photometric work, and the 6-inch Chrysler all-reflecting Schmidt telescope are also in operation.

III. GROUND-BASED RESEARCH

Theoretical: Su-Shu Huang has continued his investigation of the light curves of eclipsing stars with scattering envelopes and has applied these calculations to the V444 Cygni binary system. The formulas for the light curves which result from a star which has an absorbing envelope of any given opacity distribution with a spherical symmetry and which is eclipsing another star have been derived, although only the case of uniform opacity has been actually computed. When applied to the observed light curve of V444 Cygni with a suitable choice of parameters, the observed points during secondary eclipse match the computed curve very well, and show that the envelope around the O component may indeed have a uniform opacity. However, no single curve can account for the observed data taken during the primary eclipse, indicating that the envelope around the W star has a density gradient increasing inwards. These results will be published in the *Astrophysical Journal.* Huang is undertaking further investigations along these lines to examine the effects of the variations of opacity as well as the effect of emission of the envelope. Huang is also investigating the surface brightness distribution over the stellar disk of a star with an extended scattering envelope. The emergent intensity, and consequently the surface brightness distribution of a star with an extensive scattering envelope, has been calculated for the purpose of examining the effect of emission of the envelope on the light curve. This material will be included in the second paper on the subject, "Light Curves for Eclipsing Stars with Scattering Envelopes." Huang continues his study of the transfer of radiation in circumstellar dust envelopes, already dealt with in two papers (*Astrophys. J.* **157**, 835 and 843). His present study differs from the previous ones in the assumption that the envelope is at some distance from the star. Under this condition, the optical radiation field is more involved than in the previous cases because the directional flow as well as the diffused flow of optical radiation in the envelope must be considered.

Accepting that the gegenschein is the result of backward scattering of matter with heliocentric symmetry, Huang has spent some time calculating the isophotes of the gegenschein under different laws of scattering.

Lewis has developed and solved an equation for

the density fluctuations of electrons in an equilibrium plasma. The equation includes electron–electron and electron–ion collisions. The results show a broadening and shift in the collisionless spectrum. A set of hydrodynamic equations that describe the fluctuations in the density, velocity, and energy have been developed. The fluctuations are "driven" by stochastic terms in the heat flux vector and the pressure tensor. The problem of energy transfer in a plasma is being studied from the point of view of nonequilibrium statistical mechanics. Both macroscopic and microscopic waves are being considered.

Mintzer continued his work in general plasma physics, but is directing it now into the radio astronomy area [radio wave scintillations and low frequency (1 MHz) solar radio bursts].

Laboratory: Burns has continued his work on photo-emission and his experimental work on image tubes. He published the following articles during the past year:

Burns, J., and Powers, W. T., "Detailed Photocathode Stability in Image Orthicons," *Appl. Opt.* **9**, 1719 (1970).

Powers, W. T., and Burns, J., "Experimental Evaluation of Geometric Accuracy and Stability of the Image Orthicon for Astronomical Applications," *Appl. Opt.* **9**, 2172 (1970).

Burns, J., "An Electrical Readout Tube for Astronomical Spectroscopy," invited paper presented at Princeton Symposium on TV Systems for Astronomy, May 1970, to be published as NASA Special Publication.

Observational: Bahng completed the rapid-scanning spectrophotometer for the 40-inch reflector and placed it in operation. Spectra can be scanned with a resolution of about 15 Å. The use of a PDP8/S computer in this system makes it extremely flexible. The results so far show that the rapid-scan technique is very well suited for obtaining good quality observation even under adverse observing conditions. A study of the variations of emission features in the spectra of early-type stars is underway. Bahng summarized some of his work on carbon stars in the publication "Infra-red Color Indices of Carbon Stars," *Publ. Astron. Soc. Pacific* **81**, 863–866. Bahng also guided James Caplan's PH.D. research on H-alpha lines in late-type stars done with a Fabry–Perot spectrometer attached to the 40-inch telescope. It was found that the equivalent width of H-alpha in conjunction with the $R-I$ color index provides rather good separation of luminosity classes.

Buscombe continued with the reduction of observational material obtained at other observatories and has published the following two papers:

"Line Strengths in the Spectra of Southern OB Stars" (Parts I and II), *Monthly Notices Roy. Astron. Soc.* **144**, 1 and 31 (1969); (Part III) "Balmer Profiles for Slow Rotators," *Monthly Notices Roy. Astron. Soc.* **148**, 75 (1970); (Part IV) "Emission-Line Profiles," *Monthly Notices Roy. Astron. Soc.* **148**, 79.

"MK Types for Southern Supergiants" (with G. F. Benedict), *Inform. Bull. S. Hemisphere*, No. 15, 39 (1969).

He has prepared for publication,

"The Spiral Structure of the Large Magellanic Cloud" (with G. Corso), in which it is shown that the spiral structure is demonstrated from the distribution of Wolf–Rayet stars and long-period Cepheids. Buscombe also has in preparation for publication the following completed research items:

"Interstellar CH II Absorption in the Spectra of Bright Southern Stars from Observations with High Dispersion";

"The Composite Spectrum of Gamma Circini" (with B. R. Barskstrom), in which it is shown to represent a nearby main-sequence star slightly hotter than the sun, with a background optical companion of class B5;

"Spectral Variation of HD 92207" (with J. D. Rosendhal and A. D. Thackeray) describing a southern supergiant A star with an unstable chromosphere in which the line strengths indicate variations of turbulence, based on high-dispersion spectrograms from Australia and South Africa.

Bautz, working in collaboration with W. W. Morgan, established a classification system for rich clusters of galaxies. One-hundred and fifty clusters on the National Geographic Society–Palomar Observatory Sky Survey prints were classified into three major groups. The classification criteria were the relative luminosities of the few brightest members. Categories were: I, clusters dominated by cD galaxies; II, clusters dominated by Coma-type ellipticals; III, Clusters having no outstanding galaxies but with bright members of types E or D. The classification was described in a paper at the AAS meeting, Boulder, Colorado, on 10 June 1970. The paper by Bautz and Morgan ["On the classification of the Forms of Clusters of Galaxies," *Astrophys. J. Letters* (in press)] describes the classification in detail and provides types for 76 clusters. Bautz also calculated models for σ Orionis E, a helium-rich member of a quintuple system in the Orion aggregate. Model atmosphere analysis

(Hunger, Klinglesmith, Bless, and Millis) of this star given the parameters $M=9.8\ M_{\odot}$, $R=4.6$, $T=23\,500$ °K, and $X=0.282$. Bautz and Lloyd Wackerling used Paczynski's code to make model interiors with $X=0.282$ and $M=9.8\ M_{\odot}$. The model was more luminous than σ Ori E is thought to be and had a surface temperature of about 39 000 °K. This is far outside the range of error of the atmosphere so they tried values for lower mass and higher hydrogen content, but were not able to produce satisfactory agreement with the model atmosphere analysis. This result is being written up as a note to the *Astrophysical Journal*.

Wray has completed the preparation of an atlas of the southern Milky Way, an effort which provides coverage of the southern Milky Way to $m_V=+16.0$ with finding chart overlays for Be and carbon stars. A follow-on set of overlays will contain OB stars. The plates were taken by Bengt Westerlund with the Uppsala Schmidt telescope. All subsequent photographic work was done by Wray and Lazenby at Lindheimer.

With the 40-inch telescope, Wray has obtained a number of spectra of galaxies in the red region of the spectrum, primarily for the purpose of obtaining radial velocities and when possible, rotation curves. Although these galaxies are relatively nearby, most had not been observed previously for radial-velocity determinations. Wray undertook this program as a result of the point made by Sandage that more complete information is needed on the radial velocities of nearby galaxies in order to improve the calibration of the "zero point" of the red-shift–distance relation, which is apparently affected by systematic dynamical motions of relatively nearby galaxies. Wray is continuing with his program.

Working with J. Mack, Wray has continued the reduction and analysis of plates of the Virgo cluster of galaxies obtained by him last year at Palomar Observatory with the 48-inch Schmidt telescope. This work, which consists of a detailed analysis of the distribution of color within some 40 galaxies in that cluster, is nearing completion. Wray and Heckathorn have continued their study of the velocity field in the emission halo of the peculiar galaxy M82. Fourteen additional spectra have been obtained with the 40-inch telescope using the Meinel spectrograph equipped with a two-stage Varo image intensifier. On the basis of measurements made on 20 spectra, a detailed contour map of the velocity field as defined by the emission lines has been constructed of the halo region of M82. Their results are in agreement with the expansion of the ionized gas observed by Lynds and Sandage but suggest, in addition, the rotation of this gas about an axis coincident with the axis of rotation of the main body of the galaxy.

George F. Benedict, under the direction of Professor Wray, has undertaken an analysis and study of the surface color distribution in D-type galaxies in the Virgo clusters based on 48-inch Hale Observatory Schmidt plates taken by Wray.

Rybski, a graduate student, under the direction of Buscombe and Henize, has examined the carbon star spectra on Henize's southern H-alpha objective-prism survey plates to determine tentatively their Keenan spectral types. Observations in the red of northern carbon stars have been secured at Lindheimer Astronomical Research Center (LARC) by Rybski to determine which features at 350 Å/mm best reflect the run of Keenan types. To date, correlations have been found in this northern sample which make possible assignment of approximately one-third (approximately 100) of the objective-prism spectra to categories C0–C3, C4, C5, C6, C7, and C8–C9.

Wackerling continued his patrol of bright northern Be stars with the LARC 40-inch reflector. His "A Catalogue of Early-type Stars whose Spectra have shown Emission Lines" appeared during the year (*Mem. Roy. Astron. Soc.* **73**, 153). The catalogue contains collated designations, positions, and data-availability codes for 5326 stars of spectral class, W, O, B, A, and F. A two-part note "On the Inferred Presence of Balmer Emission Features in the Spectra of Early-type Stars" is to appear shortly (*Publ. Astron. Soc. Pacific* **82**, No. 490, in press).

Hynek continues as the principal investigator on the NSF supported real-time supernova search at Corralitos. Some 1300 galaxies are regularly surveyed, several times a month as available, using 4-sec read-outs from the image orthicon in conjunction with a storage tube. Direct comparison of the immediate galaxy presentation with the standard photograph makes possible the detection of the supernovae in real time. During the past year, 24 000 pairs of photographs were taken of 1300 galaxies; a supernova was detected in NGC 1058, mag 13.2, on 2 December 1969, and was observed for six months.

Hynek is also principal investigator on a NASA supported project for the constant surveillance of the lunar surface for possible lunar transient phenomona. Despite frequent reports, during the several years this program has been in progress, of visual observations of color and brightness changes on the lunar surface, the Corralitos observations have failed to confirm these even when simultaneous observations were made. During the report period, some 18 000 routine photographic record checks were made during the 1300 hours during which the lunar surface was under surveillance. Hynek published, with W. T. Powers, "Astronomical Instruments on the Moon," a chapter in *Applied Science*

and Research and Utilization of Lunar Resources," edited by F. J. Malina, Proceedings, Fourth Lunar International Laboratory Symposium, New York (1968).

Hynek arranged with Stanford University computation center (Dr. Jacques Vallee, Head, Information Systems, Stanford Computing Center) a feasibility study for an astronomical retrieval network. A terminal at Dearborn Observatory was connected by land line to the computer at Palo Alto and it was successfully demonstrated that an astronomer, located 2000 miles away from the computer data bank, and knowing little or nothing about programming, could intelligently interact with the computer not only to query the data bank, but to update material and to create new data files. The technical feasibility of a continental information network for astronomy was demonstrated in this two-month experiment conducted jointly by Dearborn Observatory and the Stanford University computation center. The experiment simulated a scientific information network based on a high-level retrieval language of the nonprocedural type named DIRAC. A data base of astronomical catalogues was maintained in Palo Alto and was queried remotely by Wackerling and several others. The relevant parameters of approximately 100 time-sharing sessions were recorded and an analysis of these experiments in terms of operating system efficiency, user interface, and cost effectiveness supports the idea that the network concept is basic to meaningful scientific documentation systems. It also indicated that generalized software is the key to cost-effective information retrieval in the environment considered.

IV. SPACE-BASED RESEARCH

Henize remains on leave in order to continue his work as scientist–astronaut at the NASA Manned Spacecraft Center. He continues as principal investigator in the ultraviolet stellar astronomy experiment (NASA experiment SO 19) which is scheduled for flight on the Sky-lab mission (formerly the AAP orbiting workshop.) Wray now acts as deputy-principal investigator of this program and O'Callaghan and Kotila (of the Manned Spacecraft Center) have been named as co-investigators. Design of the modifications to the UV Spectrograph and of the articulated mirror systems has been completed and a subcontract has been let to Perkin-Elmer Inc., Boller & Chivens Division for the construction of flight units.

Henize continues his work on his list of southern emission-line stars and has published "The Role of Surveys in Space Astronomy" (*NASA SP-233*) *Optical Telescope Technology*, pp. 19–24 (1970). Henize's primary assignment with NASA is as a member of the support crew for Apollo 15.

V. INSTRUCTION

Two Ph.D.'s were granted, one to James Caplan whose dissertation was "Photoelectric Observations of H alpha in Late-type Stars," and the other to Jeffrey Mallow whose dissertation was "Experimental and Theoretical Investigation of Ultra-Violet Transition Lifetimes in Carbon, Nitrogen, and Oxygen Ions."

There are currently 12 graduate students and 30 undergraduate majors. The entire faculty participated in the instructional program: Bahng taught a year-long course, "Introductory Astrophysics"; Bautz taught a year's course of General Astronomy; Burns taught a year's course, "Astronomical Optics"; Buscombe conducted a one-quarter seminar on the "Interstellar Medium" and the following quarter gave a course on "Galactic Structure"; Haung conducted a two-quarter seminar on "Stellar Atmospheres"; Hynek taught "Practical Astronomy," "History of Astronomy," and "Highlights of Astronomy"; Lewis gave a course in "Plasma Physics" and Mintzer conducted two graduate-level courses, "Electromagnetic Theory" and "Radio Astronomy"; Wray taught one quarter of "Practical Astronomy" and gave a seminar on "Galaxies."

Several of the faculty participated in the Astroscience Workshop, the NSF supported year-long project for carefully selected high school students, a cooperative venture with the astronomy departments of the Universities of Chicago, Illinois, Michigan, Iowa, Wisconsin, Indiana, Ohio State, and Northwestern University. The regular Saturday lectures and laboratories are held at the Adler Planetarium. The Adler Planetarium and the Department of Astronomy at Northwestern interact in many ways. Several graduate students find support on the staff of the Planetarium; during the past year, Lee Simon was appointed astronomer, in charge of sky shows and exhibits; James Caplan and Ann Dinger were instructors in Observational Astronomy; Rybski acted as Librarian and Lee Shapiro as lecturer. Harry Heckathorn has been Laboratory Director in the Astroscience Workshop.

VI. REGULAR COLLOQUIA

During the academic year 1969–70, Colloquia speakers from other institutions included Frank J. Kerr, Maryland, "Line Spectra in Radio Astronomy"; George W. Preston, Mount Wilson and Palomar, "Magnetic and Variable Stars"; Icko Iben, Massachusetts Institute of Technology, "Evolution of Stars in Globular Clusters"; Freeman D. Miller, University of Michigan, "Ancient Eclipses"; Stephen Strom, Stony Brook, "Abundances in Stellar Atmospheres"; Kenneth Yoss, University of Illinois, "A Digitized Microphotom-