I. INTRODUCTION

This report covers the period 1 October 1984 - 30 June 1986. The National Optical Astronomy Observatories (NOAO) comprises four divisions—Kitt Peak National Observatory (KPNO), Cerro Tololo Inter-American Observatory (CTIO), National Solar Observatory (NSO), and the Advanced Development Program (ADP)—and six central offices (units)—Director's Office, Public Information Office (PIO), Engineering and Technical Services (ETS), Central Computer Services (CCS), Central Administrative Services (CAS), and Central Facilities Operations (CFO). The administrator of each of these divisions/units reports directly to the NOAO Director—John Jeffries.

II. AURA BOARD

The Association of Universities for Research in Astronomy, Inc. (AURA), which operates the National Optical Astronomy Observatories under contract with the National Science Foundation (NSF), and the Space Telescope Science Institute (STScI) under contract with the National Aeronautics and Space Administration (NASA), currently consists of 20 member institutions. One individual is appointed by each member university to serve on the AURA Board. In addition, the AURA Board currently includes ten Directors-at-Large and the President of the Corporation.

III. KITT PEAK NATIONAL OBSERVATORY

The fifth annual winter workshop was held in Tucson 7 - 11 January 1985. The topic of this workshop, organized by C. Pilachowski and D. De Young, was "Stellar Remnants". Approximately forty participants were invited from the U.S. and five foreign countries. The topics discussed at the workshop included: Taxonomy, Planetary Nebulae, The Physics of Remnant Stellar Atmospheres, Interior Evolution, Pulsations, The Stellar Evolution of Binaries, The Dynamical Evolution of Binaries, and The Post RG/AGB Evolutionary Scenarios.

The sixth workshop in this series was held from 13 - 17 January 1986, and the topic was "The Initial Mass Function (IMF)". This workshop was organized by P. Massey and C. Pilachowski and again involved about forty participants from the U.S. and four foreign countries. The principal topics included at the workshop were Nearby Stars, Star Clusters, Theories of the IMF, the IMF in Nearby Galaxies, Unresolved Galaxies, and Pre-Main Sequence Stars.

The purpose of these workshops is to provide an informal and highly interactive forum for exploring the fundamental problems associated with a given topic. The most recent observations are presented to confront current theoretical ideas, and an effort is made to isolate the basic astrophysics, expose dogmas, and identify areas in need of more observations and theoretical effort. Discussions in the Stellar Remnants workshop centered on single stellar remnants and remnants associated with binary systems. The major issues for single stars involved rotational properties, period changes, temperature determinations, element abundances, and the masses of the remnants. Some critical but unresolved questions that emerged from the discussions were a need to explain the variety of planetary nebula shapes, the slow rotation rate of white dwarfs, the persistent problem of the remnant mass as a function of the mass of the parent star, and the mysterious absence of the very cool white dwarfs. Some questions concerning binary systems involved the role of disks in explaining oscillations and outbursts via disk instabilities, the frequency of binary planetary nuclei, and especially the frequency of long period binary planetary nebulae.

The workshop on the initial mass function also divided along two general topics, namely the mass function at the low mass, and at the high mass limits. This is perhaps not surprising since it is in these regions that the mass function is most poorly known and the controversies most visible. One of the problems that emerged from the discussions was our poor knowledge of the initial mass function in star clusters. This arises due to a lack of completeness, which in turn can be attributed to small sample sizes and a lack of depth in color magnitude diagrams for these clusters. A major issue for some years has been the variation, or lack thereof, of the mass function in different environments. Although some controversy yet persists, a general conclusion from the workshop appears to be that these variations are real. If so, this poses a major problem for theories of star formation, since in general such theories assume star formation to depend on local, rather than global, conditions. Another area discussed at some length was the low mass end of the IMF; does it turn over, and where? This topic was particularly timely in light of the recent observations of brown dwarf stars.

The above paragraphs describe only a
selected few of the many problems discussed at the workshops. The participants' positive comments about the workshops seem to indicate that the informal, interactive atmosphere is producing the desired effect: a workshop that stimulates new scientific investigation.

In addition to the annual winter workshops at KPNO, a workshop on "The Continuum Emission in Active Galactic Nuclei" was held on 11-14 January 1986. Organized by M. Saito, this workshop also encouraged informality among a rather small number (28) of participants. The emphasis was on the observational characteristics of these objects rather than upon theoretical models, and an effort was made to include observational data at all wavelengths, from the X-ray to the radio regimes. One clear, but not incisive impression gained from the workshop is that these objects are extremely complex. For example, one of the principal conclusions reached is that many of the non-variable, radio quiet compact objects manage to emit equal energy per frequency decade over many decades, from X-rays to far infrared. Under the assumption that this radiation is a degraded form of higher energy input, say from pair production, it is not clear just what mechanisms can accomplish this. Many of the suggested processes do not provide a unique signature which will allow discrimination. Another long standing problem with these objects is that of luminosity variations. Data are now plentiful enough that long time baselines are available at many frequencies. It now seems that almost any variation pattern of variations can be found, which again provides a poor discriminant for theoretical models. The idea that different timescales of variation serve to define differing sizes of emitting regions may have to be abandoned. While no single picture of these active objects was developed in the course of the workshop, valuable new insights were gained by the dissemination of new data and through intense discussions among the participants.

In the period 1 October 1984 through 30 June 1986 a total of 291 visiting scientists used the KPNO data reduction facilities as follows: 7 - Grant Comparator (1 axis), 184 - Grant Comparator (2 axis), 100 - PDS Microdensitometer. A total of 521 publications were written by visitors and staff during this period as a result of the use of NOAA facilities. The number of public visitors to Kitt Peak in this same period totalled 171,602.

A. Personnel

1. Staff Changes

Dr. John S. Gallagher, Astronomer, left to accept the Directorship at Lowell Observatory.
Dr. Abhijit Saha, Postdoctoral Research Associate, left to accept a position at Mt. Wilson and Las Campanas Observatory.
Dr. Michael Sitko, Postdoctoral Research Associate, left to accept a teaching position at the University of Cincinnati.
Dr. Dana Backman from the Institute for Astronomy was appointed Postdoctoral Research Associate.
Dr. Elaine Sadler from the European Southern Observatory, Garching bei Munchen was appointed Postdoctoral Research Associate.
Dr. Garth Illingworth, Astronomer, left to accept the Deputy Directorship at Space Telescope Science Institute.
Dr. Vesa Junkkarinen, Assistant Support Scientist, left to accept a position at the University of California, San Diego.
Dr. Larry Govoni, Associate Support Scientist, transferred to NOAO/ADF.
Dr. Nigel Sharp, Postdoctoral Research Associate, transferred to NOAO/CCS as Assistant Support Scientist.
Dr. Sam Barden, Postdoctoral Research Associate, accepted a position as Assistant Scientist.
Dr. Jay Frogel, Astronomer, transferred from NOAO/CTIO.
Dr. Pat Oemler, Astronomer, transferred from NOAO/CTIO.
Dr. William Keel, Postdoctoral Research Associate, left to accept a position at Sterrewacht Leiden.

2. Long-term Visitors

Long-term visiting scientists (defined as staying for three months or more) included the following:
Prof. B. Hauck, Universite de Lausanne, Lausanne, Switzerland
Geoffrey Burke, University of Chicago, Chicago, Illinois

B. Research Highlights

1. Introduction

This report refers to astronomical research performed by visiting and staff astronomers with the Kitt Peak National Observatory (KPNO) telescopes on Kitt Peak; it also includes research done by NOAA/KPNO staff at other facilities. The total number of visiting astronomers who used the NOAA telescopes on Kitt Peak from 1 October 1984 to 30 June 1986 was 1,030. The number of NOAA/KPNO staff visits to Kitt Peak during this report period was 419. A comparison with the numbers given in earlier reports is not possible in the present case because the length of the period covered differs from those covered in earlier reports. Tables that describe the research activity at NOAA/KPNO in statistical form may be found in the NOAA Newsletter.

2. Planetary System Astronomy

M. Belton and E. Alvarez (NOAO) reduced the observations of P/Halley made with the CCD at the KPNO #1-0.9-m telescope by visiting and staff astronomers. Their objective was to provide high-quality astrometric positions of the comet. In all, 22 reduced positions on 19 different nights were obtained and after reduction these were sent to the International Halley Watch. The rms errors in these positions relative to
Yeoman's best orbit were ±0.84 arc-sec in right ascension and ±0.78 arc-sec in declination. Spectroscopic observations of P/Halley were made using the Cryocam at the KPNO 4-m telescope by P. Wehinger and S. Wyckoff (Arizona State U.), M. Belton (NOAO), B. Peterson (Mt. Stromlo and Siding Springs Observ.), H. Spinrad (U. of California, Berkeley) and D. Yeomans (Jet Propulsion Lab.). These covered a range of heliocentric distance of 5.8 A.U. (Oct 1984) when the comet's integrated magnitude was 21.5 to 0.9 A.U. (Jan 1986) when the magnitude was 4.5. The [O I] 6300 line was first seen at a distance of 8.8 A.U.; this was the first detection of the gas coma and quantitatively supported the idea that it is water-ice that is controlling the sublimation rate. The [O I] and CN emission band strengths were used to determine the rate of water production in P/Halley. It was also found that the pre-perihelion spectra of P/Halley show significant differences in chemical composition from those deduced from post-perihelion spectra obtained at CTIO. These observers also used the KPNO 4-m telescope to get comparative spectroscopic data of other comets including P/Arend-Rigaux, P/Kopff, P/WTld 2, C/Boethin, C/Hartley-Good, C/Leyva-Rudenko, C/Shoemaker and C/Thiele. They also determined gas and dust production rates and the CO/H2O abundance ratio for P/Giacobini-Zinner at the time of its encounter with the NASA International Cometary Explorer (ICE) on 11 September 1985.

H. Campins (Planetary Sci. Inst.) contributed to the International Halley Watch by observing the infrared brightness of P/Halley throughout its apparition; J. H and K broadband observations were obtained on four nights with the KPNO 1.3-m telescope. Campins also made broadband infrared observations of P/Giacobini-Zinner before its NASA ICE encounter.

E. Joyce (NOAO) with R. Knacke and T. Brooke (State U. of New York, Stony Brook) carried out a comprehensive infrared polarimetry program of P/Halley using the KPNO 1.3-m and 2.1-m as well as telescopes at CTIO and Infrared Telescope Facility. The near-infrared (1.5 μm) polarization was measured through a range of heliocentric distances and scattering angles. During the current apparition, the scattering angle ranged from 112° to 178°. Near 112°, the 2.2 μm polarization was about 24% but decreased to zero when the scattering angle was 160°. When this angle was between 160° and 180°, a small negative polarization was observed. These data are being compared with model predictions that are based on theoretical work on the scattering of rough particles (Wolf, Muki, Perrin and Lam). K. Meech and D. Jewitt (Massachusetts Inst. of Technology) used the Intensified Image-Dissector Scanning Spectrometer (IDS) on the KPNO 2.1-m telescope to measure the wavelength-dependence of the scattering efficiency of comet grains at optical wavelengths; all of about a dozen comets that have been studied so far showed reddened optical continua. The amount of this reddening decreases with the wavelength of observation—this is only consistent with scattering from micron-sized or larger grains. The smaller grains (common in the interstellar medium) are absent. This situation may have been caused by the agglomeration of interstellar grains during the free fall collapse of the cloud from which the solar system formed. These astronomers also have used time-resolved CCD photometry at the KPNO 4-m telescope to study cometary nuclei. At large heliocentric distances, the comae are absent and it becomes possible to determine a light-curve for the nucleus from which the nuclear optical cross-section, rotation, and shape can be constrained. The nuclei of P/Arend-Rigaux, P/Neujmin 1, P/Halley and P/Kosack have been observed; all show large-amplitude light curves that indicate that the nuclei are very aspherical. The various nuclei have cross-sections that differ by an order of magnitude but which have a typical value of about 1 km². Meech and Jewitt have also been studying the plasma tail of P/Halley—a complex structure that extends in a roughly anti-solar direction and which is thought to be produced by an interaction of the comet's ionosphere with the magnetic field carried by the solar wind. They used both the KPNO and CTIO Schmidt telescopes to get plates of P/Halley. An analysis of 50 of these plates showed that changes were occurring on time-scales as short as 30 minutes as well as daily. The faint, transient plasma tail was first observed in November 1985 at a heliocentric distance of 1.9 A.U. and by early December (1.4 A.U.) a well-developed tail was formed with all classical morphologies. Features were seen to travel down this tail at velocities of 40–50 km/s in December 1985. A spectacular tail-disconnection event was seen in March 1986 (1.0 A.U.); the tail disconnected within 24 hours and during several days the growth of a new tail was monitored. A prominent dust tail was also seen that month. They hope to determine the velocities down the tail as a function of heliocentric distance and to compare these velocities with those obtained from Doppler displacements of the CO ion in the tail and solar wind velocity measurements.

U. Cartesio (Arizona State U.) used the 10° prism with the KPNO Burrell Schmidt to get objective prism spectra of P/Giacobini and P/Halley. While the former showed only reflected sunlight, the latter at 0.835 A.U. from the Sun showed the standard emission features. The data will be used for a study of the molecular photo-dissociation (scalegen) in the outer parts of the comet's coma. In particular, comparison will be made with a previous analysis based on Lowell plates of the 1910 apparition of this comet.

A novel method of probing the extended atmosphere of Jupiter's moon Io has been carried out at the KPNO 2.1-m by N. M. Schneider, D. Huntten, R. Tucker, and W. Wells (U. of Arizona) and R. Brown (Marshall Space Flight Ctr.). They observed the sodium D-line (because as a result of the sunscattered sunlight very strongly) at distances of more than five to ten times the radius of Io.
They avoided the light scattered from the surface of Io by making use of a mutual eclipse of Io and another satellite Europa and observing the sodium line in absorption in the spectrum of Europa. These observations will allow the density profile of Io's atmosphere to be derived and this would help decide what processes continuously lift atoms and molecules off Io and eventually ionize them.

In a cooperative program, J. Africano, B. Binkert and L. Craven (NOAO) used the KPNO #2-0.9-m telescope and photoelectric photometer to get accurately timed light curves for mutual events (mutual occultations and/or eclipses) involving the Galilean satellites of Jupiter. These data are being processed by F. Franklin (Ctr. for Astrophysics) and K. Aksnes (Norwegian Defense Res. Establishment) as part of a program to determine improved ephemerides of these satellites and an evaluation of tidally-induced changes in the orbit of Io.

E. Tesesco and R. Nelson (Jet Propulsion Lab.) used the photoelectric photometer at the KPNO 1.3-m telescope on selected nights to observe eclipses of Pluto by Charon. Modelling of two of these events in 1986 together with three events observed earlier showed that (neglecting limb-darkening or albedo-variation) Charon has a radius of 0.65 Pluto radii, an orbital radius of 16.5 Pluto radii and an albedo of 0.55 times that of Pluto. The density of the system under these conditions is 1.6 g/cm³. If these results are combined with the astrometrically determined radius of the orbit, diameters of 2300 and 1500 km are found for Pluto and Charon respectively.

C. Chapman and collaborators (Planetary Sci. Inst.) concluded their long-term program of determining light-curves of main-belt asteroids using the photometer at the KPNO #2-0.9-m telescope. The program, started in 1982, has resulted in 181 full light-curves and 131 partial light-curves. These data, when combined with what is already published, should allow a major advance in our understanding of the spin properties and, by inference, the gross body geophysics of some of the most interesting asteroids in the main belt. The problems of whether double asteroids exist has been addressed by H. McAllister (Georgia State U.) and his colleagues using the GSU speckle interferometer at the KPNO 4-m telescope. So far, the observation at several dozen asteroids at multiple epochs has led to the conclusion that there are no established cases of asteroid duplicity.

3. Galactic and Stellar Astronomy

Nearby Stars—Diameters and Other Properties: S. Ridgway, J. Africano, G. Jacoby, and R. Joyce (NOAO) and P. Schmidtke (Arizona State U.) extended their occultation study of late type giants to determine the variation of angular diameters with wavelength. An initial study with twelve stars showed that for M0-M5 giants, the diameters are systematically smaller at 1.6 μm than at 2.2 μm. This effect, which may be connected with the H⁺ opacity minimum at 1.6 μm, suggests a greater atmospheric extension than would be expected from radiative models. S. Ridgway and J. Mariotti (U. of Lyon) have evaluated a new interferometric technique called Double Fourier Spatio-Spectral Interferometry for simultaneously determining diameters at different wavelengths. The method involved modifying the Fourier Transform Spectrometer (FTS) to operate as a scanning path difference Michelson two-aperture spatial interferometer. Spatial and spectral information is recorded simultaneously and it is particularly good for determining differential spatial measurements over a short spectral interval.

High precision JHKL photometry of 81 main sequence stars, all located within 22 parsecs of the Sun and all of which had been detected by IRAS at 12 and 25 μm, has been obtained by H. Aumann (Jet Propulsion Lab.) and R. Probst (NOAO) using the infrared photometer of the KPNO 1.3-m telescope. Eight of these stars had a 12 μm excess. That is, the 12 μm flux predicted by the K magnitude and the spectral type were significantly less than that measured by IRAS. This excess may be caused by protoplanetary material similar to that discovered around Vega; further observations in the N and Q passbands are planned for these stars.

Binary and Multiple Stars: The detection and analysis of close binary stars is of fundamental importance for the determination of stellar masses and luminosities. The study of the closer binaries demands the use of speckle interferometry and the Kitt Peak supported use of the Georgia State U. (GSU) speckle interferometer is by far the most productive program of its kind in the world. The GSU system (H. McAllister, W. Hartkopf, D. Hutter and H. Miller (GSU), O. Franz (Lowell Observ.) and P. Schmidtke (Arizona State U.)) uses a microchannel plate intensified CCD as detector and is sensitive to single photon events. It is used at the KPO 4-m Mayall telescope where a complete observing cycle takes only three minutes so that upwards of 200 objects can be observed per night; some 2800 series of observational data were obtained during three observing runs in 1985. Starting with the second of these runs, a hardwired autocorrelator was built into the GSU camera system. The post-observing autocorrelating and bad effects of video tape noise and dynamic range suppression are now avoided. The video data is still recorded on tape for archiving but the integrated auto-correlograms are now available immediately after observing. Some 650 measurements of binaries made during 1985 have been made ready for publication. All ICCD speckle data from Kitt Peak have been analyzed; these observations have yielded 2,753 measures of binary systems of which 966 or 35% have angular separations of less than 0.20 arc-sec. Some 65 binaries, many of which are spectroscopic systems, were directly resolved for the first time. Combining these data with that obtained with
the old KPNO photographic speckle camera. McAlister and collaborators have obtained altogether 5,662 measures representing 83% of all speckle results for binary stars.

The GSU speckle camera has also been used at the KPNO 4-m telescope to search for binary stars in high velocity stars. The idea that the binary fraction is small among older stars has been increasingly questioned in recent years. This investigation by P. Demarque and W. van Altena (Yale U.), P. Lu (Western Connecticut State U.), and H. McAlister and W. Hartkopf (Georgia State U.) aims to determine the binary frequency among halo dwarfs and give new insight into the formation of halo stars. It is hoped to monitor halo binaries with periods of about ten years or less both with this speckle camera and the Center for Astrophysics (CfA) radial velocity spectrometer. The long term goal is to get the mass-luminosity relation for halo dwarfs and hence their helium abundance. This latter is of great importance for constraining models of galactic chemical evolution and theories of cosmology.

The problem of halo binaries is also being attacked in another way by B. Carney (U. N. Carolina) who used the KPNO 1.3-m telescope to obtain UBV and/or JHK photometry of about 250 stars selected from some 1,000 proper motion stars whose UBV colors and radial velocities have recently been surveyed by him and D. Latham (CfA). The earlier survey shows up binaries by their radial velocity variations; the new survey discovers binaries through a comparison of their (b-y) and (y-k) colors. The colors also give improved photometric parallaxes.

D. McCarthy and F. Low (U. of Arizona) have been using the KPNO 4-m telescope and infrared speckle interferometry to search for low mass companions of nearby stars; the technique is capable of detecting companions as close as 0.1 arc-sec with as much as a 4.5 magnitude difference in the near infrared. So far 20 companions have been confirmed that provide masses and luminosities for the empirical definition of the lower main sequence. While several objects appear to be at the theoretical end of the hydrogen-burning main sequence, only VB 8B appears to be definitely substellar. Measurements of VB 8B in 1985 indicate that its period is of the order of 20 to 30 years. McCarthy is also searching the nearest stars to find previously unknown companions. So far two have been found. One, Gl 866 is a nearly equal double with a separation of 0.4 arc-sec; it was not detected by astrometry because its photocenter and mass center nearly coincide.

Trapezium systems of multiple stars have separations that differ by factors of less than three; they are dynamically unstable and therefore would be expected to consist of young stars. A recent catalog of 968 Trapezium stars by Poveda, Allen et al. shows, however, that the most frequent primary spectral type is F which implies an age that is shorter than that of the Hyades. H. Abt (NOAO) has investigated this by classifying 120 stars in 31 Trapezium systems. He found that chance foreground or background stars caused 17 stable hierarchical stable systems to appear to be Trapezium systems and that three more had no physical companions. The remaining 11 Trapezium systems indeed had ages less than that of the Hyades. Abt also found that the maximum dimension of the Trapezium and hierarchical systems decreases rapidly with the age of the system—by a factor of two for every factor of ten in age. According to this rule, a system of the age of the Sun should have a maximum separation of 5,000 A.U.; the existence of Nemesis (a companion to the Sun at a distance of 92,000 A.U.) would be at variance with Abt’s findings.

S. Barden (NOAO) observed several RS CVn binaries (P < 0.5 days) at the KPNO 2.1-m telescope. It is hoped that these will show whether the depressed levels of activity of the secondary components of contact U UMa systems are caused by their contact nature or are a suppression of the magnetic dynamo through tidal interactions with their primary. Observations of XY Leo led to the discovery of a BY Dra-type companion. This binary companion accounts for the previously observed period changes in XY Leo; most of the H and K and Ha emission comes from the companion and not the contact binary; analysis shows that all three orbits are non-coplanar. This supports the idea that close binary pairs are a result of an unstable Trapezium-type system which evolves into the present stable hierarchical configuration. Simultaneously Barden obtained spectra of XY Leo at the 2.1-m telescope and J. Neff (U. of Colorado) obtained a light curve with the CCD at the KPNO #1-0.9-m telescope while X-ray observations (CXOSAT) and radio observations (VLA) were obtained by O. Vilhu and J.-P. Caillault (U. of Colorado) and J. Heise (Utrecht). These multi-frequency observations will be used to model the hot (10^7 K) corona of XY Leo.

P. Schmidtke (Arizona State U.), J. Africano (NOAO), and R. Quigley (West Washington U.) continued their own luminous occultation program at the KPNO #2-0.9-m telescope of known or suspected close double stars. HR 2111 was resolved twice, a previously unknown companion of HD 56176 was discovered and a close visual companion to 6 Sco was also resolved.

D. Backman (NOAO) has been using the FTS at the KPNO 4-m telescope to monitor the hydrogen Brackett emission of the eclipsing binary ε Aurigae. This emission was discovered by Backman in the 1982–1984 eclipse and he is trying to deduce the location of the emitting material from its velocity curve. Estimates of the primary mass of ε Aurigae are quite uncertain and it is hoped that location of the site of the emission will help determine the evolutionary status of this interesting system.

R. Green (NOAO) with R. Wade and J. Liebert (U. of Arizona) is trying to expand our knowledge of contact binary systems that have white dwarf primaries and type K-M secondaries; only after the five systems are known so far where white dwarf masses have been derived from radial velocity curves. Their
technique, using the KPNO 4-m telescope, is to observe at 35 Å resolution at Hα and simultaneously record the Hα absorption line from the white dwarf and the chromospheric emission line from the secondary. It was found that the velocity line profiles for PG 1026+00 is about 365 km/s and its period between 11 and 13 hours; an accurate mass determination will require further observations.

J. McClintock and R. Remillard (Massachusetts Inst. of Technology) made a radial velocity study of the X-ray binary A0620–00 with the IUE spectrometer at the KPNO 4-m telescope. They showed that the compact X-ray source is an excellent candidate for a black hole; its mass exceeds the maximum stable mass for a neutron star. This is the third X-ray binary for which there is now firm dynamical evidence for a massive compact object. It is the first such system which has a late-type (low mass) secondary.

Early Type Stars and H II Region: A. Torres and C. Garsany (U. of Colorado) have been investigating the continuum energy distributions of O-type stars using the Intensified Reticon Scanning Spectrometer (IRS) on the KPNO #2–0.9-m telescope. When combined with IUE data, their wavelength coverage is 1200–8200 Å. The “pair” method is being used: the continua of stars with small reddening (E(B−V) < 0.35) are dereddened with a standard extinction curve. Then the dereddened continua of these stars are used to derive the extinctions for the most reddened stars of the same spectral class. The dereddened continua are then compared with those obtained from model atmospheres. J. Percy (U. of Toronto) used the photometer on the KPNO 0.4-m telescope to study short-term variability (believed to be produced by non-radial pulsation) in early type stars. About half these observations were of C Persei in conjunction with spectroscopic observations by M. Smith (NOAO) and IUE observations by M. Giampapa (NOAO). The other half were follow-up observations of five Be stars that had been studied intensively in an international “campaign” in 1983; long-term changes were found in some but not all of these stars. D. Pyper-Smith (U. of Nevada) also has used the KPNO 0.4-m telescope to continue his long-term study of 4-color/Hβ photometric variations in chemically peculiar upper main sequence stars.

A. Slettebak (Ohio State and Ohio Wesleyan U.) obtained line-profiles of Hα and the near infrared lines of O I and Ca II in the spectra of a number of bright Be stars (of late-type) and also some A-F shell stars. A CCD detector on the coude feed telescope was used. The lines in the shell stars show sharp absorption cores (as expected) and there is a smooth transition between the late-type Be stars and the A-type shell stars; the Hα line, however, changes abruptly from emission to absorption in going from the late AO and FO stars to the early Am stars.

B. Bohannan, D. Abbot, S. Voels, and D. Hummer (U. of Colorado) are trying to derive the basic stellar parameters (including the helium abundance) for a variety of 0 and early B-type stars using high signal-to-noise (S/N) line profiles obtained with an RCA CCD at the KPNO coude feed telescope. Comparison of a wind-blanketed model for the observed mass loss rate of 5 × 10^{-9} M_☉ yr^{-1} gave the following parameters for zeta Puppis: Teff = 42,000 K gravity = 3.5 and helium abundance (by number) Y = 0.17 + 0.03. The effect of wind-blanking on this star is to produce helium lines of the same strength as in an unblanketed model that is 4,500 K hotter. Another program to obtain atmospheric parameters in early-type stars with the same equipment is being made by J. Grigsby and N. Morrison (U. of Toledo). They are using a model-atmosphere analysis (non-LTE and line-blanketed) based on a new code by Anderson.

R. Mathieu (Smithsonian Astrophysical Observ.) and J. Horne (Harvard U.) began a high-precision radial-velocity study of the internal kinematics of the early-type stars in several OB associations. They used the CCD at the coude spectrograph of the KPNO 2.1-m telescope to get high S/N spectra centered on Hβ that have a resolution of 25 km/s. A night-to-night repeatability of better than 2 km/s was achieved by cross-correlation techniques; this was largely independent of the star's v sin i. Preliminary results show that the internal motions in the II Per association are small—similar to those found by Mathieu and collaborators for low-mass stars in associations.

S. Barden and J. Gallagher (NOAO) tested an array of fibers at the KPNO coude feed telescope on various regions in the Orion nebula and in different spectral regions. The system works as if it is a two-dimensional long slit. Software is being developed so that parameters such as line intensity and radial velocity can be conveniently mapped with this device.

Very high resolution spectra of the Orion nebula have also been obtained at the coude feed telescope by C. O'Dell and H. Castaneda (Rice U.). Three velocity systems were found in the [O III] line; detailed line fitting of the spectra show general agreement with the Kolmogoroff theory of turbulence but each system has its own set of characteristics. This study extends the study of turbulence to the smallest scale-lengths yet achieved. O'Dell and Castaneda have also mapped the velocity fields of the bright adjacent H II regions NCG 6514 and 6523 with the highest resolution yet used. The former has one mass flow system and the latter two; all three systems generally agree with Kolmogoroff theory but with different geometries and energy input. NCG 6514 and 6523 bridge the size gap between the fine-scale study of M42 and previous investigations of NCG 1499, 7000, and 5142. D. Hunter (Carnegie Inst. of Washington) is interested in galactic H II regions that contain only a few early-type stars since these may correspond to star-forming regions in photoelectric data.

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which will give point by point values of the reddening, density, and excitation, while the CCD at the #1-0.9-m telescope is being used to get images in the wavelengths of the emission lines (primarily Hα and [N II]) which will be used to explore the morphology of the gas, locate ionization fronts, and image stars through intermediate band filters are being used for a second program (with P. Massey, NOAO) in which the stellar content of these regions is being studied. The question of whether their stellar content is like that of giant H II regions is being studied with the IIDS spectrometer at the KPNO 2.1-m telescope by Hunter and Massey. The work is being supplemented by UVB CCD photometry that has been obtained by Massey and S. Wolff (NOAO). These data allow for the first time an exact correction of the photometry of the underlying stars for nebular contamination and will allow 8 stars to be selected in the galactic anticenter which can be used for abundance determinations.

Interstellar Matter, Circumstellar Shells, YSOs, Molecular Clouds and Late-Type Dwarf: D. York and P. Frisch (U. of Chicago) have been investigating the local interstellar material with the KPNO 4-m telescope; the interstellar density near the Sun is quite low so that the lines produced by the individual clouds are relatively unblended. Once isolated, it is hoped that the properties of these nearby clouds (e.g., temperature, density, fractional ionization, core-halo structure, and kinematics) can be determined with much greater accuracy than is possible for more distant clouds. So far, the interstellar Na I and/or Ca II lines in front of some 100 nearby type A-G stars have been observed; when combined with data obtained with other telescopes, many interstellar components near the Sun have been identified.

K. Josafatsson and T. Snow (U. of Colorado) used the coude spectrograph at the KPNO 2.1-m telescope to measure the strengths of the diffuse interstellar bands (λλ 5700–5870) in the spectra of 96 stars of reflection nebulae; 23 other stars were also observed in the same way. Correlations among the bands will be calculated and compared with uv extinction curves, IR emission and elemental depletions in the same sight lines. The purpose of the program is to search for evidence of very tiny grains (radial length of 50 Å) or complex molecules (~50 atoms) which, it is believed, take part in some of the extinction and emission processes in the interstellar medium.

A. Witt (U. of Toledo) used the IRS at the KPNO #2-0.9-m telescope to observe the extended red excess emission in reflection nebulae. Spectra covering 6300 to 8300 Å were obtained at several nebulae in NGC 2023 and NGC 7023 and also of the corresponding illuminating stars. The nebular spectra show a broad emission band centered on 6720 Å with a full width half maximum (FWHM) of 900 Å, followed by a pronounced minimum near 8100 Å and a rise at longer wavelengths that suggests the presence of other emission bands. The spectrum of the excess red emission closely resembles that seen in laboratory spectra of fluorescence by hydrogenated amorphous carbon after it has been excited by short-wave photons. This discovery should have important consequences for our understanding of the composition and structure of interstellar dust grains.

R. Dickman (University of Massachusetts) and W. Herbst (Wesleyan U.) are attempting to map the visual extinction up to very high levels (A_V = 15 magnitudes) in the neighborhood of the Taurus Molecular Cloud I. This extinction is determined from deep plates of the cloud (with J, F, and N emissions) that have been taken at the KPNO 4-m prime focus and which are calibrated with a BVRI sequence that was obtained with the Mk II photometer at the 1.3-m telescope. A comparison of this visual extinction with the 12CO column density will provide a definitive test of the most commonly employed indirect mass tracer at levels of obscuration where its validity has been questioned.

J. Pipher, A. Moneti, W. Forrest, and C. Woodward (U. of Rochester) continued a program to search for young stars in the Taurus dark cloud in the J, H, K, L', and M' passbands using the Rochester Infrared Array camera attached to the KPNO 1.3-m telescope. Images of LkH 101, HL τ, XZ τ, and the L1551-IR5 regions were obtained in marginal weather. The bipolar object L1551-IR5 showed an extension in the direction perpendicular to its bipolar flow which is interpreted as a flattened circumstellar shell of moderate optical depth seen close to its equatorial plane. Pipher and Woodward also used the KPNO 2.1–m telescope to map the H II regions S156 and S159 at the wavelengths of the 11.3 μm dust emission feature and the 12.8 μm [Ne II] line for comparison with a previous map of the 3.28 μm dust feature. Attempts to detect the 11.3 μm feature in S235A and the reflection nebula NGC 2316 were unsuccessful.

J. Bally (AT&T Bell Lab.) and A. Lane (Boston U.) used the KPNO 2.1-m telescope to observe the 2.2 μm S(1) line of molecular hydrogen and map the distribution of the shock excited H_2 in a number of star-forming regions which show bipolar molecular outflow. The source Cep-A showed two well separated lobes of S(1) emission located on opposite sides of the bright infrared source that is thought to produce the outflow. The western of these lobes coincides with a cluster of highly blue-shifted Herbig-Haro (H-H) objects (known as GGD 37); the strongest molecular hydrogen in CepA is found here. A detailed S(1) line map of the H-H 1-2 region in Orion shows that there is a close association between the molecular hydrogen emission and the H-H objects. The molecular hydrogen may extend beyond the optical emission region of several of these objects, and may be excited in a shock-precursor downwind from the optical emission region. A comparison of the H_2 S(1) emission with published mm-wavelength CO data for NGC 2071 and H-H 12 has been used to determine the mass loss rate and wind velocity in these objects.

J. Fischer, H. Smith, and P. Schwartz (Naval Research Lab.) and T. Geballe (United
Kingdom Infrared Telescope) used the FTS at the KPNO 4-m telescope to search for line emission from the low luminosity outflow sources: Barnard 5/IRS, Lynds 1262, Lynds 1489, Lynds 1536, and Lynds 1582.

Anomalously strong Brackett-α was detected in Lynds 1536 which, when compared with the measured upper limit of Brackett-α in this object and a model of recombination emission from ionized winds, suggests that either Lynds 1536 has an extremely compact emitting region with high mass loss or has a rapidly decelerating flow; this would be the first reported case of such a peculiar outflow. No line emission was found for the other sources and this is consistent with mass loss rates of $10^{-9}$ M$_{\odot}$/yr or less.

Optical spectroscopy with the ICCD at the KPNO 2.1-m telescope has been used by S. Strom and E. Strom (U. of Massachusetts) and J. Stocke (U. of Arizona) to investigate the young stellar object (YSO) Lynds 1551 IRS 5. They obtained a spectrum of the object from a four-hour exposure of the bright rim NNW of IRS 5 which polarimetric results show is illuminated by the YSO. The source itself is very highly obscured so that it cannot be observed directly. The spectrum shows Hα with a P-Cygni profile that has a strong violet-displaced absorption feature (λv ~300 km/s) with a relatively weak emission component; this suggests that this YSO belongs to the extreme class known as FU Ori stars. There is some evidence that the well collimated outflows that are observed from YSOs are parallel to the magnetic fields that thread the host molecular clouds in which these objects are found. The Stroms together with M. Hemeon-Heyer (U. of Massachusetts) and F. Vrba (U.S. Naval Observ.) are attempting to confirm this by (a) a CCD imaging program at the KPNO 3.0-0.9-m telescope that maps the YSO outflows and (b) polarization measurements of stars around these complexes which will show the orientation of the magnetic field in this region. A study of Barnard 335 and Lynds 723 show that the magnetic fields have position angles of 111° ± 4° and 90° ± 8° respectively which are approximately parallel to the direction of the bipolar molecular outflows in these sources.

In many of these YSO, dense neutral regions exist near the central object. P. Hamann and M. Simon (State U. of New York, Stony Brook) have been investigating MWC 349A (which is similar to a YSO in its radio continuum and spectral line emission) with the FTS at the KPNO 4-m telescope. They found double peaked emission profiles in both neutral and ionized species which they attribute to rotation. They suggest that the evaporation of a cool neutral disk is providing the extended outflow from this source.

K. Merrill, F. Gillett, R. Joyce, and K. Gillies (NOAO) continued their long-range program of the systematic monitoring between 1 and 20 μm of a sample of young and evolved stars that are embedded in dense circumstellar envelopes. The sample was taken from the AFGL Infrared Sky Survey. Most of the C-type stars studied show fairly regular light curves and periods in the 400 - 700-day range; two objects whose shells are optically very thick (GL 190 and GL 3068), however, have longer periods - 800 to 1,000 days. The N-type stars show a much wider range of behavior from lightly obscured Miras (periods ~400 days) to highly obscured, highly variable (4 - 5 magnitudes at K) stars with periods ~1,700 days. These latter stars must be highly luminous (10^3 L_\odot) - from their OH kinematic distances and are estimated to be losing mass at the rate of more than 10^{-5} M_\odot/yr. An interesting case of a secular change is shown by the well studied C-star IRC +10216 which has shown, in addition to its 640-day period, a steady decrease in brightness by a magnitude at K between 1968 and 1983. The trend has now stopped and may be reversing - indicating perhaps the existence of a longer cycle.

R. Schwartz (U. of Missouri) used the CCD at the KPNO 2.1-m telescope to obtain direct images of H-H objects (Nos. 2, 11, and 39) through Hα, [O III] and [S II] filters in order to study the ionization and excitation structure of these objects. There was a significant difference between the Hα and [O III] images of the diffuse components in H-H 39, but no difference between the corresponding images of their semi-stellar knots at a level of > 0.6 arc-sec. It is thought that these knots, if caused by bow shock structure, must have a scale size of < 300 A.U. along the flow direction.

S. Edwards (Smith Col.) with S. Strom and K. Strom (U. of Massachusetts) observed the line profiles of [O I], [S II] and Hα with the echelle spectrograph of the KPNO 4-m telescope in a search for winds from T Tauri stars. They found that the forbidden-line emission regions ground these stars had densities ~10^6/cm^3 and sizes of the order of tens to hundreds of A.U. The T Tauri winds also appeared to be anisotropic with the far side obscured by opaque circumstellar material with dust masses of the order of 10^2 g.

E. Weis (Westleyan U.) used the photometer at the KPNO 2.1-0.9-m telescope to continue his photometric survey of selected red stars in Luyten's NLTT catalog for which no trigonometric parallaxes have been measured. The survey has so far been completed from the equator up to declination +65°. Within this zone, trigonometric parallaxes have been obtained for 1,439 stars; of these 232 appear to lie within 25 parsecs, but only ten are closer than ten parsecs. Weis has also identified a number of apparently subluminous stars.

JHK photometry for a sample of M dwarfs from the Gliese Catalogue was obtained by J. Stauffer (Dominion Astrophysical Observ.) at the KPNO 1.3-m telescope; these data were used to derive metallicities for these stars by means of their J-H and J-K colors. Additional data for about 200 of these stars (including BVRI photometry, radial velocities, rotational velocities, and Hα equivalent widths) were compiled and used to study their chromospheric activity, kinematics and metallicities. The Hα absorption feature seen in most M dwarfs
originates almost entirely in the chromosphere, and the most metal weak of these stars (presumably the oldest) has the weakest Hα in absorption. The dwarfs with the reddest J − H colors appear to have metallicities that are comparable with those of the Hyades stars.

J.-P. Caillault (Joint Inst. for Lab. Astrophysics) and J. Patterson (Columbia U.) obtained JHK magnitudes for 30 extremely late-type (M5) dwarf stars with the KPNO 1.3-m telescope. These data will help establish an effective temperature and bolometric magnitude scale and hence an empirical carbon abundance relation for the low mass stars. They also made repeated UBVRI photometric observations of a large sample of X-ray emitting M dwarfs at the KPNO #2-0.9-m telescope.

As part of a program to survey for and study the magnetic properties and dynamo characteristics of late-type dwarfs, S. Saar and J. Linsky (U. of Colorado) used the FTS at the KPNO 4-m telescope to measure the Zeeman splitting in the spectra of K and M dwarfs. The application of improved analysis (such as taking into account radiative transfer effects and using the full Zeeman patterns) to several Ti I lines (near 2.2 μm) in March showed that some 73% of the surface of the M3.5e flare star AD Leo was covered by bright plage-like regions that contained a mean magnetic field of 3800 gauss. This was the first detection of a magnetic field on an M dwarf. A preliminary analysis of other data shows that the M dwarfs have considerably more magnetic flux than their non-emission counterparts—the M stars. The filling factors of the magnetic fields appear to increase with activity levels; this follows the results from G and K stars and the predictions of dynamo theories. Simultaneous measurements of the ultraviolet emission lines from spectra obtained with the IUE in collaboration with M. Giampapa at NOAO for some of the M and K stars has shown that there is a correlation between the magnetic flux and the chromospheric emission.

G. Wallerstein and W. Speirsman (U. of Washington) used the coudé feed with a CCD to observe the strong Fe I line λ 5328 Å in the spectra of K dwarfs. The cores of this very strong line is formed by absorption near the temperature minimum in the stellar atmosphere and an excellent correlation was found between its central intensity and the activity indicated by the Ca II and/or the X-ray emission. It appears that this temperature minimum near the photospheric boundary is raised in active stars and the consequent change in the temperature gradient should be taken into account in an analysis for chemical composition.

A. Young (San Diego State U.) and A. Skumanich (High Altitude Observ.) completed their coudé observations at the KPNO 2.1-m telescope of the Hα fluxes of all dMe stars for which X-ray fluxes are published but no Hα fluxes have been measured. Observations were also completed for all dM stars which were suspected of having a "diluted" Hα profile; two new cases were discovered in sixteen candidates. Extreme Hα "dilution" is still rare but not forbidden as once thought. Young and Skumanich also began a program to search for modulation of the Hα strength in selected dMe stars. Modulation was observed by them in all four of the binary systems and in more than half of the single dMe stars in their sample.

Galactic Structure: P. Schechter (Mt. Wilson and Las Campanas Observ.), M. Aaronson and K. Cook (U. of Arizona) and V. Blanco (NOAO) have searched for carbon stars in the more transparent regions of the galactic plane using objective prism plates taken with the Burrell Schmidt. The carbon stars will be used as tracers of the rotation of the Galaxy at large galactocentric distances and will complement data already obtained in the southern hemisphere. A major goal is to determine the degree to which the potential of the Galaxy deviates from axisymmetry. Six plate pairs were obtained and scanned by Blanco; roughly 450 carbon stars were identified—some 75% being new. To the surprise of the investigators, the yield on the Burrell Schmidt plates was as high or higher than was found on the Curtis Schmidt plates. This indicates that beyond the immediate solar neighborhood, the Galaxy is no more transparent in the north than in the south.

R. Green (NOAO) and J. Liebert (U. of Arizona) are making a survey for cool degenerate stars, low-metallicity halo M-subdwarfs on B, R and I plates taken with the Palomar 48-inch Schmidt telescope; some 400 square degrees at high galactic latitudes are being searched. These rare objects are separated from the more common main sequence M dwarfs by small differences in their location in the color-color diagram so that accurate absolute photometric calibration is essential. This is being obtained by setting up faint stellar photometric sequences within the survey areas using the KPNO 2.1-m telescope.

D. MacConnell (Michigan State U.) used the Burrell Schmidt to take low dispersion infrared objective prism plates to search for M supergiants in the galactic anticenter direction. The plates have also been used to classify several hundred point sources in the IRAS catalog. C. Neese and K. Yoss (U. of Illinois) completed their observations of late-type giants in the anticenter with the IDS spectrometer at the KPNO 2.1-m telescope. The purpose is to determine radial kinematic and abundance gradients by observing velocity dispersions and abundances for these stars in both the anticenter and center directions. The galactic center part of the program is being carried out at CTIO. Yoss and Neese are also working with Hartkopf (Georgia State U.) and Detweiler (Illinois Wesleyan) on a similar survey at the North Galactic Pole, in which the stars, selected in an unbiased manner, will be used to determine how the velocity dispersion and chemical composition vary with height above the galactic plane. This study is extending to 10 kpc and beyond. Red giant stars in the galactic disk are also being studied by J. Lewis and K. Freeman (Mt. Stromlo and Siding
Casertano. A program to determine the abundances of the RR Lyrae stars in fields RR VIII and RR IX using the IIDS spectrometer at the KPNO 2.1-m telescope was started by Kinman together with R. Kraft (U. of California, Santa Cruz) and N. Suntzeff (NOAO). So far spectra have been obtained for 29 of these variables. The aim is to delineate more exactly the change in abundance distributions which is known to occur in the spheroid for Rg between 5 and 10 kpc.

J. Pier (U.S. Naval Observ.) completed his radial velocity measurements of distant RR Lyrae stars. Using the IIDS spectrometer at both the KPNO 2.1-m and 4-m telescopes, he has obtained over 400 stellar spectra including 240 spectra of 136 faint RR Lyrae stars. Velocities were obtained by cross-correlating the spectra with the spectra of radial velocity standards and then applying a phase correction for the atmospheric pulsational velocity of the variables. Multiple observations of program stars show that the mean error of a single observation was less than 15 km/s. Perhaps not surprisingly, the kinematics of the sample are quintessentially those of halo Population II. The sample has a line-of-sight velocity dispersion of $123 \pm 7$ km/s. The solar motion of the sample is $230 \pm 25$ km/s which implies that the halo RR Lyrae stars have essentially no mean systematic rotation about the galactic center. The velocity ellipsoid (in spherical polar coordinates) shows no significant difference between the radial and polar directions (i.e., there is no evidence for anisotropy). The velocity dispersion towards the north galactic pole remains constant (or may increase slightly) to the limits of the sample at about 22 kpc. Ninety of these RR Lyrae stars have previously determined abundances (Preston & index) and a strong correlation is found in the sense that the most metal-poor stars have the highest velocity dispersion.

R. Peterson (Lockheed Palo Alto Res. Lab.) has been using the KPNO 4-m telescope to obtain radial velocities of distant galactic globular clusters. The use of an aperture plate enables her to get spectra of from four to eight individual stars simultaneously in four by two arc-min fields. Radial velocities were obtained to an accuracy of $\pm 25$ km/s for five clusters. From these she found that the velocity dispersion of the cluster system at $R > 70$ kpc is large enough to suggest that there is a substantial amount of dark material at these galactocentric distances. This is in keeping with the deductions made from the rotation curves of other spiral galaxies.

R. Kron and S. Majewski (U. of Chicago) are using plates taken at the prime focus of the KPNO 4-m telescope to study the kinematic properties of a complete sample of Galactic halo field stars brighter than B-22. Roughly 10,000 stars, half of which are expected to be halo stars, will have their proper motions measured on a collection of plates with more than a ten-year baseline. The plates were taken in four fields (The North Galactic Pole, the
anticenter and two fields at $1 = 90^\circ$) and are
in four wavebands. This means that each star
will have three colors so that its population
can be identified and its distance
measured. The colors should allow several
dozen quasars to be identified in each field;
these will provide an excellent astrometric
reference frame. A computer program has been
written which allows specific characteristics
of the halo (velocity ellipsoid, halo
rotational velocity, stellar density
function, etc.) to be compared directly with
the observed data.

Field Giant Stars: V. Smith and D.
Lambert (U. of Texas) are determining the
chemical composition of N, MS, and S stars in
order to define the dredge-up of He-burning
products in asymptotic giant branch (AGB)
stars. Their high-resolution infrared (1.5 -
4.0 $\mu$m) spectra are obtained with the FTS at
the KPNO 4-m telescope and analyzed using
line-blanketed models of H. Johnson (U. of
Indiana). These spectra provide CNO
abundances from CO, OH, NH, and molecular
lines. High-resolution spectra (obtained at
McDonald Observatory) were used to determine
abundances of iron group and s-process
elements. The CNO abundances clearly show
the effects of the first dredge-up that
occurs during the ascent of the first giant
branch and match well those obtained
previously from C and K giants; they also
agree with theoretical predictions. For S
stars (and to a lesser extent, the MS stars),
the carbon is enhanced as expected. This
enhancement of $^{12}$C correlates well with that
of the s-process elements and the integrated
neutral exposure; the MS stars generally show
a lower integrated neutron exposure than the
S stars. The compositions of the M, MS, and
S stars are generally consistent with the
idea that the MS and S stars are thermally-
pulsing low-mass ($M \sim 2 M_{\odot}$) stars in which
the He-burning products have been dredged
into the outer convective envelope. M.
Harris (U. of Texas) and Lambert and Smith
have analyzed CO vibration rotation lines at
1.6 and 2.3 $\mu$m in FTS spectra of MS, S, and
barium stars in order to get the oxygen
isotope abundance ratios. The $^{16}$O/$^{17}$O and
$^{16}$O/$^{18}$O ratios in both MS and S stars were
found to be much larger than expected from
models of the dredge-up following thermal
drives in AGB stars but correlate well with the
$^{12}$C abundance and the degree of neutron
exposure needed to explain the s-process
elements. These major discrepancies cannot be
explained by current models of AGB stars or
simple modifications of them. The CO
lines in the classical Ba II stars are also
puzzling. These stars are thought to be
spectroscopic binaries and their abundance
peculiarities may be caused by the transfer of
material from the companion star when it was
a MS or K type star and now an AGB. In
this case the oxygen isotope ratios of the
most s-process enriched barium stars should
approach those found in the AGB stars. The
values of these ratios that are found for the
barium stars are close to those predicted for
AGB stars but are far lower than those
actually found by Harris, Lambert, and Smith;
they are continuing to investigate this
problem with new FTS spectra. Smith and K.
Gillies (NOAO) used the KPNO 1.3-m telescope
to obtain 1.9 - 4.0 $\mu$m spectrophotometry of
twelve barium stars in order to investigate the
IR-excesses that had been reported for
these stars by Catchpole and Feast using
broadband photometry. Flux distributions
were compared with those of a comparison
sample of G and K giants. No excess IR flux
(such as might have been caused by
circumstellar material) was found relative to
the comparison sample. Smith and Gillies are
also synthesizing the IR flux distributions of
twelve barium stars to see if the increase in
$^{12}$C abundance in these stars.

J. Dominy (U. of Washington) and D. Lambert (U. of
Texas) completed a program of broad band
infrared photometry of warm carbon stars
(spectral type C0 to C4) using the KPNO
1.3-m telescope. They found that most of
these stars have a mild color excess
($\sim 0.1$ mag in K-L) which can be completely
attributed to additional intrinsic
scattering in the spectra of carbon stars; it is not the
result of circumstellar dust emission.

G. Smith (Dominion Astrophysical
Observatory) has obtained JHK and CO photometry of
a sample of Population I giants that show
strong 4A 215 CN bands; the photometry was
done at the KPNO 1.3-m telescope. Some of
these giant stars have CN-excesses that are
comparable with those found in super-metal-
rich giants. On average, the CN-richest
giants have redder H-K colors than those with
normal CN abundance and similar J-H color.
A similar trend among giants in the galactic
bulge was found by Frogel et al. and
the field giants with the strongest CN do have
similar J-H, H-K colors to many of the metal-
rich bulge giants that were identified by
Whitford and Rich. No separation according
to CN-strength was seen in the CO, J-K
diagram where the scatter in CO among giants
of similar J-K is comparable to the
observational uncertainties. Smith has also
used the photometer on the KPNO 0.4-m
telescope to obtain Washington CMT, T$_2$
photometry for a sample of field red
giants. The line blanketing indices $\Delta$(M-T)
and $\Delta$(C-M) correlate very well and also with the $\delta_{MC}$ index of the DDO system. This
suggests that these Washington indices can be
used to derive photometric metal
abundances. Any nitrogen/metals or
carbon/metals variations which may exist
among Smith's sample of old disk giants do
not appear to affect the $\Delta$(C-M) index
significantly.

R. Luck (Louisiana State U.) has been
using the coudé feed telescope to survey CNO
abundances in F and G luminosity class II
stars in order to see whether the CNO content
changes smoothly with mass in going from
giants (class III) to supergiants (class I). Preliminary analyses of 12 stars show
that there is a wide range of CNO behavior
among class II stars; this could imply that
surface CNO strength in evolved stars depends
critically on the mass. The coudé feed was
also used by C. Pilachowski (NOAO) and C.
Snedden (U. of Texas) to monitor some 30
metal-poor giants for variable Ba which may
indicate either mass loss or chromospheric activity. This emission, which is known to occur in the most luminous metal-poor giants, was seen in most of the program stars; small variations in the strength of this emission were detected in some of them.

A novel cryogenic postdisperser (the Goddard postdisperser) has been used with the FTS at the KPNO 4-m telescope by D. Jennings, D. Deming, G. Wiedemann (Goddard Space Flight Ctr.) and J. Keedy (Los Alamos) to search for the 12.32 μm Mg I line in several bright stars. This line, which is known in the Sun, was found in α Ori and α Tau. This absorption line may allow magnetic fields to be measured in these late-type giants; the 12 μm pure rotation transitions of OH were also detected in these spectra. T. Ayres and S. Saar (U. of Colorado) with Jennings and Wiedemann used the same equipment to obtain high S/N and high resolution spectra of the 4.7 μm fundamental vibration-rotation bands of CO in late type stars. A time-sequence of interferograms of Arcturus showed significant variability in the CO bands; work is in progress to determine whether these variations are intrinsic to the star (e.g., P-mode oscillations in the photosphere/chromosphere) or have an instrumental origin.

Stars in Clusters and Nearby Dwarf Spheroidal Systems: J. Stauffer (Dominion Astrophysical Observ.) and J. Africano (NOAO) used the photometers at the KPNO #2-0.9-m and 1.3-m telescopes to get light curves and photometric periods for several spotted, rapidly rotating late-type dwarfs in the Pleiades and α Persei clusters. The light curve of H II 1883 (the most rapidly rotating K dwarf in the Pleiades with P = 5.65 hours and v sin i = 140 km/s) changed considerably during 1985 and early 1986. The light curve was sinusoidal with a V amplitude of 0.2 mag in October 1984. The variability had disappeared by November 1985, but two months later an odd-shaped light curve with 0.09 mag amplitude was present. Photometric periods were also derived for H II 324 (P = 9.9 hours), H II 335 (P = 8.6 hours), H II 244 (P = 13.7 hours), H II 2927 (P = 6.3 hours), and AP 86 (P = 5.0 hours); the last star is in the α Persei cluster.

D. Goisler (NOAO) is examining heavy element and CH + CN abundances in a number of giants in the galactic anticenter open clusters Berkeley 21, King 8, and NGC 2506; he used Washington filter photometry at the KPNO 1.3-m telescope. He also used the CCD at the KPNO #1-0.9-m telescope to obtain improved color magnitudes of these clusters from which improved estimates of their reddening, ages, and distances will be obtained. R. Luck (Case Western Reserve U.) used the echelle-CCD at the KPNO 4-m telescope to observe 25 stars in the χ Persei and Praesepe clusters; he also used the echelle spectra at the KPNO 4-m telescope of seven blue stragglers in the old galactic cluster NGC 7789. It is hoped to use these and TUE spectra to determine CNO compositions for both evolved and unevolved stars in open clusters. J. Sowell (U. of Michigan) has been observing Hα in yellow supergiants in open clusters. These observations at the coude feed are to detect Hα emission as an indicator of mass-loss; none was found. Radial velocities were obtained for 12 supergiants as a test of cluster membership. The KPNO #2-0.9-m was used by Sowell to check 18 of these stars for optical variability; none of these stars proved to be a cepheid. C. Pilachowski (NOAO) used the KPNO 4-m telescope to obtain spectra of many giants and four stars at the turn-off point in the 1.7 Gyr open cluster NGC 7789; she used spectrum synthesis techniques to obtain lithium abundances. The observations suggest that lithium destruction continues in giant stars up to the tip of the red giant branch. With the same telescope, L. Hobbs (U. of Chicago) and Pilachowski began a program to map empirically the evolution of the lithium abundance in the Galaxy. So far excellent spectra have been obtained of 19 main sequence members of NGC 752 (age: 1.7 Gyr) and nine main sequence members of M67 (age: 3.2 Gyr). Acceptable but poorer spectra were obtained for two members near the turn-off in NGC 188 (age: 5.5 Gyr). Pilachowski with A. Saha (NOAO) also used the coude feed telescope to obtain spectra of the lithium line λ 6707 in both NGC 752 and M67; the lithium line was detected in some giants in both clusters. K. Janes (Boston U.) has also been looking for abundance peculiarities in the giant stars of old galactic clusters. Using the IIDS spectrometer on the KPNO 2.1-m telescope, he confirmed that a giant in M67 has anomalously strong CN bands and that a star in the distant anticenter cluster NGC 2158 has λ 4150 CN bands that are as strong as or stronger than any yet seen.

J. Kaluzny (Space Telescope Sci. Inst.) has been making a survey for short period variables, particularly W UMa-type binaries, in the old galactic clusters NGC 188, NGC 2420, and NGC 2360. Six new variables have been discovered; up to now very few W UMa-type variables were known in these clusters and this discovery may be of particular interest in understanding cluster evolution. Blue stragglers in clusters are those that remain on the main sequence when older stars have evolved off the sequence. H. Abt (NOAO) has classified 16 blue stragglers in intermediate age clusters and found that 62% of them were Ap stars—mostly with Si or Sr, Cr, and Eu overabundances. Such stars invariably have strong magnetic fields, so that it is suggested that these intermediate-age blue stragglers it is an internal magnetic field that is causing sufficient internal mixing for the main-sequence lifetime to be extended significantly. S. Hubert (Case Western Reserve U.) is using the coude feed to obtain CNO abundances of blue stragglers in young clusters; it is hoped that these observations will provide evidence as to the evolutionary history of these stars. J. Drilling (Louisiana State U.) with K. Hunger and D. Schoenberge (U. of Florida) have obtained echelle spectra at the KPNO 4-m telescope of seven blue stragglers in the old galactic cluster NGC 7789. It is hoped to use these and TUE spectra to determine gravities, H/He ratios and effective temperatures; this should tell us if these are indeed mixed stars or are the result of mass exchange in close binaries.
M. Mateo and P. Hodge (U. of Washington) continued their program of Washington photometry at the KPNO #1-0.9-m telescope of stars in intermediate-age Galactic clusters and Galactic globular clusters. The aim of the program is to calibrate the surface gravity index and investigate the presence of chemical anomalies in the old clusters. Six open clusters were observed with a single channel photometer and four open and four globular clusters were observed with a CCD. V. Smith (U. of Texas), N. Sunzef (NOAO), and G. Wallerstein (U. of Washington) used the FTS at the KPNO 4-m telescope to observe the $^{12}$C/$^{13}$C and $^{13}$C/$^{12}$C ratios in seven stars in M4 and five stars in M22. Initial analysis of the stars in the globular cluster M22 confirm the large range in CO strengths in stars of similar colors and magnitudes that was reported by Frogel et al. The dredge-up of the carbon cycle material should show a decrease of $^{12}$C with an increase in the $^{14}$N abundance and a lowering of the $^{12}$C/$^{13}$C ratio. The giants in M22 do not show this; the stars with lower $^{12}$C do not show a decrease in the $^{12}$C/$^{13}$C ratio relative to the $^{12}$C-rich giants and in some cases their ratio is larger. This effect is most easily explained as being caused by initial differences in the carbon abundances in these stars and, presumably, in the CNO groups as a whole. R. O'Connell, D. Crockner, and J. Rood (U. of Virginia) have used the KPNO 2.1-m telescope to study the gaps in the horizontal branches of the globular clusters M3, M5, M15, and M92. They are also investigating Sandage's claim that the more metal-rich clusters must have a lower helium abundance.

D. Martins (U. of Alaska) began a program of UBVRI photometry of the distant globular clusters NGC 2619. With the CCD at the KPNO 2.1-m telescope, it should be possible to reach $V = 20$ in good seeing. B. Carney (U. of Utah) and P. Seitzer (NOAO) obtained deep BV photometry of both the Draco dwarf spheroidal and the outer halo globular cluster Pal 15; they used the CCD at the prime focus of the KPNO 4-m telescope. Draco showed a wide lower giant branch ($+1.0 < M_V < +2.5$) which indicates an internal spread in [Fe/H] of about 0.8 dex. Many blue stragglers were also found with numbers that appeared consistent with the known numbers of massive "anomalous cepheids". An extended main sequence is present which suggests that the star formation was prolonged or episodic; this partly explains why the horizontal branch stars are mostly red in spite of the low metallicity of the galaxy. Palomar 15 has proved to be a more difficult object. It is over 80 kpc from the Sun and unlike most other outer halo systems, contains a very thin horizontal branch.

H. G. Grundlay and C. Baifin (Harvard U.) completed the UBVR CCD photometric survey of the northern globular clusters using the KPNO #1-0.9-m telescope. They have data on 23 compact core clusters in the north. Cluster surface brightness profiles are being fitted with seeing-convolved power laws in order to test the prediction that 25% of all Galactic globular clusters have already experienced core collapse and have central surface brightness cusps.

**Intrinsic Variables:** The absolute magnitude of pulsating variables can be determined from a comparison of their light and radial velocity curves in the Baade-Wesselink method. E. Milone (U. of Calgary) used the KPNO 1.3-m telescope to obtain infrared JHKL light curves for a number of bright A1 Velorum and RR Lyrae stars for this purpose. He is also interested in using the color-index of these stars to check whether they are binaries. B. Carney (U. of Notre Dame) also used the KPNO 1.3-m telescope to get JHKL magnitudes for the two RR Lyrae stars SW Dra and X Ari whose radial velocities were obtained by Latham. Together with R. Jones (U. of Notre Dame) and D. Latham and R. Kurucz (CfA, Astrophysics) they used the Baade-Wesselink method to derive absolute magnitudes ($M_0$) of $+0.88$ and $+0.49$ for X Ari and SW Dra respectively. These two variables have $[Fe/H] = -2.2$ and $-0.7$ and the difference in absolute magnitude of 0.06 ± 0.10 is far smaller than has been predicted for globular cluster variables of similar age and these metallicities. Carney suggests that the faint absolute magnitude of X Ari shows that the metal-poor clusters have ages that exceed 18 Gyr. D. McNamara (Bingham Young U.) is investigating surface gravities and chemical compositions of BL Her variables from 4-color photometry at the KPNO 1.3-m telescope. Preliminary results indicate a remarkable range in surface gravity ($\log g = 2.0$ to 3.0); some of these BL Her variables (one with two-day periods) appear to have surface gravities like RR Lyrae stars with periods of 0.44 days. L. Connolly (Southeast Missouri State U.), R. Guigley (West Washington U.), J. Wilson (Georgia State U.), and B. Goodrich (NOAO) are conducting a program of high time resolution photometry of BL Her stars using the KPNO #1-0.9-m telescope. Besides obtaining information on effective temperatures, surface gravities, and metallicities, the pulsational characteristics will be determined by a Fourier analysis of the light curves.

K. Hinkle (NOAO) and W. Scharbach (NRAO) continued their comprehensive survey of the kinematics and atmospheric structure of long period variables (LPVs). They have observed prototype LPVs monthly since 1984, using the FTS at the KPNO 4-m telescope to get high resolution 1.1 to 2.5 μm spectra; these allow Paschen β (in emission) and the CO $Δv = 2$ and $Δv = 3$ bands to be monitored. The hydrogen emission lines are formed by recombination in a thin zone behind the shock, while the CO band provides information on the photospheric temperature and velocity. Analysis of these spectra is giving the velocity of the shock and the distance that it travels as a function of the phase. The same data are being used by Hinkle and H. Olofsson (Onsala Space Obs.) to compare the velocities derived from SiO masers with those obtained simultaneously from the photospheric and circumstellar CO
It is hoped that the known correlation of velocity with height that has been found from the CO lines can be used to determine the height in the atmosphere where the SiO maser lines originate. Hinkle and R. Wing (State U.) have been using the FTS to monitor the Mira variable Z Oph. Keenan found that Z Oph did not appear to fit the period–spectral class relation and it has been speculated that it might be pulsating in the next lower radial mode to that of "normal" Miras. The new observations show that the velocity curve is similar to that of other Miras so that it must be pulsating in the same way; the infrared and CO lines of Z Oph, however, do show that it has a large metal deficiency.

Planetary Nebulae: B. Balick and R. Owen (U. of Washington), R. Hjellming (NRAO) and P. Atherton (U. of Groningen) have completed a CCD survey at the KPNO 2.1-m telescope of some fifty northern planetary nebulae. The images were in the lines of Hα [O III] λ 5007, [N II] λ 6584 and, whenever feasible, [O I] λ 6300, [S II] λ 6716, and Hβ; the seeing was typically one arc-sec. Morphological classification by shape and physical size suggests that the planetary nebulae are shaped by continuous fast winds from the central star which blow from the inside into the asymmetrically ejected envelopes of the progenitor red giant stars. Eventually, these red giant envelopes are penetrated (first along opposite poles) and a new phase of interaction with the interstellar medium starts. Figure preparation is well advanced for the publication of these data as a Planetary Nebula Atlas. T. Barker (Wheaton Col.) used the IIDS spectrometer at the KPNO 2.1-m telescope to continue his spectrophotometric survey of approximately 500 galactic planetary nebulae. So far the survey is about 40% complete and about 70% of these objects were bright enough for their electron temperatures to be measured; of these some 15% have abnormal abundances and 15% are misclassified objects. J. Kaler, R. Shaw (U. of Illinois), and K. Kwit (Williams Col.) also used the IIDS at the KPNO 2.1-m telescope to get spectra of 36 planetary nebulae; they concentrated on those with expected massive nuclei and got complete spectral coverage for 22 of these objects. A further 20 planetary nebulae were observed by them in the summer Milky Way. The purpose of their survey is to derive statistical data on chemical composition and evolution of the planetary nuclei. Kwit, with T. Lydon (Williams Col.) and G. Jacoby (NOAO), has been searching for the central stars in a sample of extended planetary nebulae where the central object is not known. They obtained UBV images with the CCD at the KPNO 2.1-m telescope and picked out the bluest object in each field. On the evolution of planetary nebulae where the reddening was not known, this was estimated from the appropriate emission-line images taken with a CCD at the KPNO 1-0.9-m telescope. So far, some 25 nebulae have been observed and ten probable or definite central star identifications have been made.

Y.-H. Chu (U. of Illinois), G. Jacoby (NOAO), and R. Arendt (U. of Illinois) have studied the frequency of occurrence, morphologies, and internal motions of multiple-shell planetary nebulae (MSPNe). They obtained Ha images of 26 MSPNe with the CCD at the KPNO 1-0.9-m telescope and echelle/CCD data for 16 MSPNe at the KPNO 4-m telescope. Some 126 PNe in the NGC and IC have been examined in the Palomar Sky Survey, the ESO/SRC Southern Sky Survey and with new CCD images in a search for MSPNe; only optically-thin planetary nebulae within three kpc are used in this program. It appears that > 45% of PNe go through the MSPNe phase. The two main kinds of morphologies are: some 30% are type I with faint, filamentary and detached outer shells, and 60% are type II with bright, amorphous attached outer shells. In general, the type I have static outer shells and supersonically expanding inner shells, while the type II have outer shells that co-expand supersonically with the inner shells. It is presumed that both types correspond to different mass loss processes.

A. Grauer (U. of Arkansas) and H. Bond (Space Telescope Sci. Inst.) continued their photometric program at the KPNO 1-0.9-m telescope to search for close binary nuclei in planetary nebulae. They note that IC 2149 probably contains a binary central star but that more data are needed to find out the exact nature of this object. Grauer and Bond observed the central star of the planetary K-16 very extensively. The object has bands of periods near 2200s, 1700s and 1500s that come and go in the light curves. More data will be needed to determine whether this behavior is caused by the beating of close frequencies or physical mode-switching in the star; theoretically this object should be evolving fast enough for changes to be measurable in the course of a few years.

SNR, Cataclysmic Variables, White Dwarfs, Hot Subdwarfs and Gamma-Ray Bursters: The kinematics of the Crab and Tycho supernova remnants (SNR) have been studied by R. Oliversen and T. Gil (Goddard Space Flight Ctr.), T. Williams (Rutgers U.) and R. Pesen (U. of Colorado). Using the Rutgers Imaging Fabry-Perot Spectrometer on the KPNO 2.1-m telescope, they observed the low-velocity kinematic structure of the Crab jet and adjacent filaments from a series of velocity-resolved [O III] images of the northern half of the Crab; the velocity spacing was every 100 km/s from -400 to +700 km/s with a resolution of 120 km/s. The whole radial velocity field of the jet was mapped—both the front and back sides of the jet being detected. It is hoped that this map will show any connection between the jet and the filaments and whether there is any corridor between the jet and the interior of the nebula; in addition, the physical conditions in the jet and its interaction with any "halo" around the nebula will be studied. Velocity resolved images of the S.E. quadrant of the Tycho SNR in Hα were also obtained; they covered 3000 km/s at a resolution of 500 km/s. J. Raymond (Ctr. for Astrophysics), J. Hester (Rice U.) and T. Gill and B. Woodgate (Goddard Space Flight

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Ct.) have been investigating the velocity structure of the Cygnus Loop from echelle observations made at the KPNO 4-m telescope. The velocity structures observed in [O III], [N II] and Ha confirm that the filaments are tangencies with the sight-line of a large, thin, wavy sheet of emitting gas. The velocity splitting observed near the feature XA confirms that this feature is a bow-shock and will enable the shock velocity and orientation of the feature to be determined. P. Winkler (Middlebury Col.) and R. Kirshner (Ct. for Astrophysics) have used the KPNO 4-m telescope for long-slit spectrophotometry of the Cas A SNR; this is part of their program to investigate the chemistry and kinematics of all SNR where undiluted heavy-element ejecta are seen. Preliminary analysis shows for the first time that C, Cl, and Fe are present in the fast-moving knots; it was already known that O and S were abundant there. The measurement of the chemical abundances in this unlabeled, processed matter should provide tests of the predicted yields from nucleosynthesis in massive stars. Observations of carbon abundances are particularly important in constraining the relative yields of C and O during He-burning.

Studies by J. Cowan, R. Henry, and D. Branch (U. of Oklahoma) show that supernovae in external galaxies continue to radiate in the radio for decades after their optical maximum. Recent searches with the VLA have identified a number of sources that are either very compact H II regions or very young SNR. Cowan, Henry, and Branch are investigating these objects optically with the CCD at the KPNO 2.1-m telescope using various narrow-band filters. It is hoped that these and subsequent observations will show how supernovae evolve into SNR, the extent of the mass loss from supernovae progenitors, and the nature of any optical emission that is radiated from very young SNR.

R. Honeycutt and E. Schlegel (Indiana U.) used the IDS spectrometer on the KPNO 2.1-m telescope to get time-resolved spectroscopy of the accretion-disks of selected interacting binaries. The Algol types showed little evidence of the characteristic emission from an accretion ring during eclipse. Among the cataclysmic types, v363 Aur was found to be double-lined and masses for the two components were found. The dwarf nova IP Peg showed Doppler-separated disk components but the "S"-wave (the stream impact radiation) was weak or not present. The object v794 Aql is a dwarf nova which normally is in the magnitude range 15 to 17. In 1984, Honeycutt and Schlegel found that it was fainter than 20th magnitude; its spectra in this state were consistent with the temporary cessation of mass transfer in the system and the collapse of the accretion disk—which is the main source of radiation in cataclysmic systems. P. Szkody and D. Brown (U. of Washington) used the Landstreet polarimeter on the KPNO 2.1-m telescope to obtain time-resolved polarization measurements of eight dwarf novae, two novae and one DQ Her system. The observations covered complete orbits for four of the novae and two complete orbits for the DQ Her system 3A0729 + 103. R. Wade (U. of Arizona) has been trying to get accurate distances to the nova-like class of variables called UX UMa stars. He observes the interstellar D-lines in spectra obtained at the coudé feed of a telescope located on the summit of a nearby mountain. He then uses the abundance determinations of the field stars to estimate the distance to the nova. His work is progressing but the observations are difficult because of the faintness of the nova in the spectra. The major difficulty with this method seems to lie in the detection of enough suitable field stars to bracket the distance of the UX UMa star.

J. Liebert and G. Schmidt (U. of Arizona) and R. Green (NOAO) continued their study of isolated magnetic white dwarfs through the accurate time-resolved spectroscopy of several high-field degenerates using the Cryogenic Camera and the KPNO 4-m telescope. These observations were made to supplement existing UV spectra and optical polarimetry in order to deduce the magnetic field strengths and structures as accurately as possible. The field structure of one of these stars, also a high-field degenerate with a 3.4-hour rotation period, is being analyzed with the help of a program that synthesizes a magnetic photosphere. C. Pilachowski (NOAO) and R. Milkey (Space Telescope Sci. Inst.) obtained echelle spectra at the KPNO 4-m telescope for their study of the rotation of white dwarfs. Their technique is to calculate NLTE profiles for the core of Ha and determine the amount of rotational broadening that is needed to reproduce the observed profile of this line.

G. Fontaine and F. Wesemael (U. of Montreal) and R. Green (NOAO) continued their long range program at the KPNO 1.3-m telescope to obtain Strong-line photometry for all the hot B subdwarfs in the Palomar-Green Survey. Some 285 objects have been observed so far and these sdB stars are seen to form a continuous sequence on the two-color diagram—corresponding to a range of effective temperatures from 20,000 - 50,000K. A real scatter in this diagram is interpreted as being caused by the frequent presence of late type companions to the sdB stars; a study of the frequency of these companions is in progress. The photometric data as well as spectroscopic data from the KPNO 2.1-m telescope and IUE and Voyager data have been combined for some of the brighter of these stars and compared with the predictions of model atmosphere calculations. This has shown up a number of unusual abundances for these objects. A new pulsating DA white dwarf (G238-53), the 19th of its kind, was also discovered. K. Kwitter (Williams Col.) and P. Massey (NOAO) have used the KPNO 2.0-0.9-m telescope to search for faint nebulosities—remnant planetary nebulae—around subdwarf O stars. Some 50 long-slit (nine arc-min) photographic spectra of regions surrounding 37 hot sdO stars were...
obtained. Five of these objects showed extended emission in the Balmer lines and/or [O II] \( \lambda 3727 \). Direct CCD images have been taken to confirm these extended emissions but so far these have proved inconclusive; deeper imaging with wider fields is planned.

R. Remillard (Massachusetts Inst. of Technology) and W. Roberts (Ctr. for Astrophysics) have been taking part in a program to combine X-ray data analysis with a systematic optical identification of some of the fainter sources (1.0 - 3.0 \( \mu \)Jy at 5.2 keV) of the HEAO-1 Survey. They have used the Burrell Schmidt several times to search for uncatalogue UV-bright objects in the positions of the X-ray sources. Some 170 double-exposure (U and B wavebands) that reach to \( B = 17.5 \) have been obtained. So far, follow-up spectroscopic observations at the telescopes of their home institutions have resulted in the identification of 31 previously unknown AGN (galaxies with active nuclei), BL Lac objects, cataclysmic variables and Be star X-ray binaries. Further Schmidt telescope observations are in progress. B. Schaefer and T. Cline (Goddard Space Flight Ctr.) have used the KPNO 1.3-m telescope on three nights to search for an infrared counterpart to three gamma-ray bursters. Their idea was that infrared emission might be visible from a very low mass companion star in the burster system; no such objects were detected.

Calibration and Standardization: R. O'Connell and M. Fanelli (U. of Virginia), D. Ketelsen (U. of Arizona) and M. Roberts (NRAO) have used the KPNO \#3-0.4-m telescope to produce an Atlas of image-tube photographs in support of UIT (Ultraviolet Imaging Telescope). The field of view and scale of the Atlas are close to those of the UIT; each field of the Atlas has four exposures with \( U \) and \( R \) filters under photometric conditions. By the end of 1985, some 611 plates had been obtained and about half of these were usable for the Atlas. Nearly full coverage had then been obtained for the 15 - 0-hr region and it is expected that the survey will be completed in 1986. Preliminary imaging processing at the Goddard Space Flight Ctr. is in progress.

A. Landolt and A. Uomoto (Louisiana State U.) have about half completed their program of observing standard stars on the UBVRI Johnson-Kron-Cousins system at the KPNO 1.3-m telescope. These stars will be used as spectrophotometric standards for the Hubble Space Telescope. Landolt has also completed UBV photometric measurements at the KPNO \#2-0.9-m telescope on several sets of stars that are equally spaced around the sky in right ascension and which cover a range of declination from +80° to -30°. The aim of the program is to provide sets of stars that have internally consistent magnitudes and which will be useful for checking orientation effects in photometric equipment.

P. Massey, J. Barnes and E. Anderson (NOAO) have been using both the KPNO \#2-0.9-m and 2.1-m telescopes to set up spectrophotometric standards that are faint enough to use on photon-counting systems on 4-m telescopes. The hottest subdwarf O and DA white dwarfs have been selected from the Palomar-Green Survey so that the standards have no Balmer jump and few lines. The brighter stars are being observed with the IRS at the KPNO \#2-0.9-m telescope with a large aperture so that accurate (1%) fluxes can be obtained. The fainter stars are being observed with the IIDS with less accuracy.

L. Davis, J. Barnes, E. Anderson and G. Jacoby (NOAO) continued their program to produce accurate faint UBVRI sequences for use with imaging devices. The aim is to get accurate (0.01 mag) photometry of stars in the 13 - 18 magnitude range in selected star clusters. Eight out of the fifteen nights awarded to this project were photometric and good quality CCD frames were obtained for the clusters NGC 2264, NGC 2419 and NGC 4147. The preliminary M92 data is already in use as a calibration field and that for NGC 4147 is nearly ready. The sequences in NGC 2264, NGC 2419 and NGC 4147 are expected to be completed soon.

D. Hayes, R. Joyce, S. Ridgway (NOAO) and R. Wing (Ohio State U.) are setting up absolute calibration standards in the infrared at 14 wavelengths between 1.06 and 4.0 \( \mu \)m. The cooled-grating spectrometer AUDREY was used on the KPNO 1.3-m telescope and a blackbody (placed on the catwalk of the 4-m telescope) was the standard source. Some 46 stars were observed using passbands between 30 and 90 \( \AA \) so as to produce a system of nearly monochromatic absolute spectrophotometry in the infrared. Unfortunately, the existing data (with AUDREY) shows a discrepancy which is not present in observations made later with the dewar-detector OTTO. Laboratory tests have not yet revealed the cause of this discrepancy and further work is in progress.

T. Boroson (U. of Michigan), R. Davies (NOAO), and I. Thompson (Mount Wilson and Las Campanas Observ.) are observing galaxies which are for use as standards for surface photometry by astronomers using CCDs. The standards are small enough to be observed with present CCDs, fairly round and with smooth light distributions; the aim is to observe them with three different telescopes and CCD cameras so as to minimize errors. NGC 2672, NGC 4760, and NGC 5638 were observed with the RCA CCD at the KPNO \#1-0.9-m telescope and some aperture photoelectric calibration of these galaxies was obtained at the KPNO 1.3-m telescope. The other observations are being obtained on the Palomar 1.5-m telescope and the McCormick 1.3-m telescope.

T. Robertson and T. Jordan (Ball State U.) have used the 4° prism on the Burrell Schmidt to find red stars in equatorial Selected Areas (92-115). The aim is to improve the red end of the photometric sequences in these fields. M stars with \( 10 < V < 16.5 \) have already been selected in one and four square degree fields centered on these Selected Areas. Luminosity classes for these stars are being obtained from new widened spectra taken with the 4° + 2° prism combination at the Burrell Schmidt. Robertson has also been studying the nature of the errors in the assignment of spectral types that are caused by exposure variations.
when using objective prism plates. About 350 spectra have so far been traced by him on the NOAO PDS microdensitometer.

4. Extragalactic Studies

K. Cook and M. Aaronson (U. of Arizona) have been studying the red stellar content of nearby galaxies. They use a photometric technique (with intermediate band filters at 7750 A (in a T10 band) and at 8100 A) with which they have identified both carbon stars and late M giants in M31, M33, IC 1613, NGC 6822, the WLM system and the Sagittarius Dwarf Irregular. To calibrate these results in terms of metallicity, Cook and Aaronson have observed about twenty globular clusters and a few open clusters through these filters using a CCD at the KPNO #1-0.9-m telescope; in addition photometric observations of a few bright field giants were made at the KPNO #4-0.4-m telescope. These data should yield both a metallicity calibration and definition of the intermediate band filter systems.

A. Crotts and R. Kron (U. of Chicago) have been using the "count-brightness ratio" method for defining the population in the halo of M31. This technique uses both the color-magnitude of the resolved stars and the color and brightness of the unresolved background light. Using a CCD at the prime focus of the KPNO 4-m telescope, Crotts and Kron obtained multicolor photometry of several patches around M31 that allowed them to get color-magnitude diagrams for stars in these regions that are brighter than about V = 24. These patches were chosen to contain very different proportions of disk and halo stars and in this way the disk and halo color-magnitude diagram, the disk count-brightness ratio, and limits to the halo count-brightness ratio could all be derived from these data. Crotts and Kron showed from these results that the halo of M31 is an old (>10 Gyr) metal-poor ([Fe/H] ~ -2.0) population and that its disk is a younger population that has had less recent star formation than the solar neighborhood.

J. Mould (California Inst. of Technology), T. Kinman (NOAO), and P. Wood (Mt. Stromlo and Siding Springs Observ.) have identified and classified some 400 variable stars in M33 from red plates taken over a period of some three years at the prime focus of the KPNO 4-m telescope. A few of these stars were previously identified as variables by van den Bergh, Herbst, and Kowal. Mould et al. have obtained periods for these and many more of these long period variables; infrared photometry has also been obtained for them at Palomar Observatory. This subset consists of luminous core-burning long period variables; they populate a similar period-luminosity relation to that seen in the Magellanic Cloud but are six magnitudes fainter. When the photometric calibration of this survey is complete, it is intended to publish a catalog of the 40,000 brightest stars in M33, with their colors and with positions accurate to one arc-sec. The survey plates are now available for other workers in the KPNO archives, and work is continuing on similar surveys of NGC 6822 and IC 1613.

H. Ford, R. Giardullo, G. Testa, and D. Neill (Space Telescope Sci. Inst.) and G. Jacoby (NOAO) are interested in the use of novae as standard candles and have been investigating the dependence of the nova rate on the parent populations in M31 and NGC 5128 (Cen A). The novae have been detected by their Hα emission using the CCD at the KPNO #1-0.9-m telescope. In four observing seasons, 28 novae have been found in the bulge of M31 with a distribution that is the same as the light distribution. This shows that the deficiency of novae towards the center of M31 that was found by previous observers was caused by observational selection. R. Humphreys and R. Pennington (Tice U.) have been searching for bright supergiant stars in M31 using the KPNO 2.1-m telescope. They have confirmed the membership of six early-type supergiants; the brightest of those that have been found by them so far are significantly less luminous than those found in other spirals and irregular galaxies. P. Massey (NOAO) and T. Armandroff (Yale U.) are concerned with the hottest and brightest stars in nearby galaxies. They identified Wolf-Rayet stars by their strong emission-lines in nine of the OB associations in M31 using a CCD and interference filters at the KPNO 4-m telescope. CCD frames to get UBV photometry were also obtained. So far, Massey et al. have found 30 WR candidates and several have been confirmed spectroscopically at the Multiple Mirror Telescope (MMT). They think that star-formation may be more common in M31 than has been thought. Thus NGC 206 (a rich association in the SW quadrant of M31 that is not very prominent in Hα emission) has more massive stars than any region in M33. Similarly, the association OB48 has many UV-bright stars (including nearly a dozen WR stars and stars with spectral types as early as O6). J. Gallagher and R. Joyce (NOAO) and D. Hunter (Dept. Terrestrial Magnetism) used the CCD on the KPNO 2.1-m telescope to get RI photometry of NGC 206 and several H II regions in M33; they found only small populations of red stars in these regions.

P. Hodge and M. Mateo (U. of Washington) used the CCD at the KPNO 4-m telescope to get UBV photometry of five regions in the disk of M31. Their aim is to study the characteristics of the disk clusters at different galactocentric distances and to compare them with the nearby stellar population. They found that the integrated colors of these clusters show ages that range from ten million to nearly one billion years. The color magnitude diagrams of the M31 disk stars also differ with galactocentric radius—primarily in the percentage of very young stars that they contain. Hodge with R. Kennicutt (U. of Minnesota) and J. van der Hulst (Netherlands Fndtn. for Radio Astronomy) used the CCD at the KPNO #1-0.9-m telescope to observe the detailed structure of a representative sample of H II regions in M31 and M33. They also obtained, for comparison, data on the H II regions in NGC 2403, NGC 2841, M81, NGC 628, and NGC 2903. Kennicutt and van der Hulst with R. Walterbos (Leiden U.) used the IRS
profiles show very high velocity wings (compared with a gaussian profile) at low intensity levels. Possibly both stellar winds and SNe are contributing to the acceleration of this high velocity gas. Four spatially unresolved large-velocity-width-sources (LVWS) are present in the giant H II regions of NGC 5471 and NGC 5461. Two of the LVWS in NGC 5471 are coincident with non-thermal radio sources and are probably SN. The other two LVWS could be bubbles blown by stellar winds, SNR or combinations of these. The brightest LVWS in NGC 5471B is a remarkable object. Its non-thermal radio-luminosity is about three times that of Cas A, its mass is $6500 \pm 300 M_\odot$ and its kinetic energy some $2.5 \times 10^{50}$ ergs. If this is a single SNR, it is about $4 \times 10^8$ years old and the initial supernova energy was about $10^{52}$ ergs; its peculiar properties presumably result from a high-mass supernova progenitor exploding in a region of high interstellar gas density.

D. Hunter (Dept. Terrestrial Magnetism), J. Gallagher (NOAO), and J. Mathis (U. of Wisconsin) used both the RC spectrograph and the echelle spectrograph to explore Hα filaments and diffuse emission in irregular galaxies. The nature of these features is still not completely understood; they may be associated with ionized gas or with the diffuse interstellar medium. The Hα emission is due to the collision of high-speed gas with the surrounding interstellar medium. The echelle spectra of some of these galaxies show absorption lines of oxygen, carbon, and nitrogen, which are characteristic of stars that have already evolved from the main sequence. These stars are known as post-AGB stars and are thought to be the result of mass loss from the parent star. The presence of these absorption lines suggests that these galaxies are undergoing active star formation.

Normal Galaxies: K. Cook and M. Aaronson (U. of Arizona) and G. Illingworth (Space Telescope Sci. Inst.) continued their search for cepheid variables in four fields that cover 64 square arc-min of the galaxy M101. The observations were made in the R band with the CCD at the prime focus of the KPNO 4-m telescope; those made in 1984 and 1985 covered ten epochs. This was sufficient to derive periods for two cepheid variables found in the two fields analyzed; about a dozen more variables with cepheid colors and a number of very red variables were also found in these two fields. These latter stars will need better phase coverage if their light curves are to be determined. The main purpose of this research is to measure a distance to M101 (the nearest Sc I galaxy) using a primary distance indicator. This distance can then be used to calibrate a number of the secondary distance indicators—e.g., the brightest M supergiants. Previous estimates of the modulus of M101 have differed by nearly a magnitude; the preliminary values given by this study suggest that the larger estimates of the distance may be more nearly correct.

Y.-H. Chu (U. of Illinois) and R. Kennicutt (U. of Minnesota) have surveyed the internal motions of about 40 of the giant H II regions in M101. They find that the line

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the IIDS. They used five H\alpha emission lines to derive $Y = 0.235$ with a 3\sigma error of ±0.013. Peimbert and Torres-Peimbert are currently reducing additional observations of H II regions in NGC 2403, in M 101 and in about 15 blue dwarf compact galaxies. T. Kimman (NOAO) used the KPNO 1.3-m telescope to obtain BV multi-aperture photometry of 36 emission-line galaxies that he discovered in his survey for emission-line galaxies at the Burrell Schmidt telescope. The nature of these galaxies has been confirmed with both red and blue scans at the KPNO 2.1-m telescope. Multi-aperture BV photometry was also obtained for a number of dwarf galaxies that are currently being observed for H I at Jodrell Bank by R. Davies (U. of Manchester); these include nine dwarf companions of the SO galaxy NGC 2859. A preliminary reduction of the data suggests that there are significant systematic errors in the UGK magnitudes of these low surface brightness systems.

W. Waller (U. of Massachusetts) has been imaging nearby spiral and irregular galaxies through H\alpha and broad-band R and I filters with the CCD at the KPNO #1-0.9-m telescope. His aim is to determine the relative birth-rates of high and intermediate-mass stars that are present in the H II regions in these galaxies. H\alpha fluxes and line-to-continuum flux ratios are being determined, and the data will be compared with lower resolution observations of CO and H I emission in order to investigate the possible relation between gas content and star formation in late-type galaxies. C. King and G. Da Costa (Yale U.) have been investigating whether there are differences between the populations of the bulges of spiral galaxies and the stars in elliptical galaxies. They use a spectral synthesis approach that aims to avoid the age-metallicity ambiguity. Spectrophotometric data were obtained with the IIDS spectrometer at the KPNO 2.1-m telescope of both a sequence of elliptical galaxies (covering a range of luminosities) and a sample of nearly face-on spiral galaxies. The sequence of ellipticals is shown to form a one-parameter family where the parameter is luminosity or metallicity. This sequence was thus parameterized by its principal component and was used in the analysis as an old population of varying metallicity. The results of a differential synthesis show that the bulges of spiral galaxies contain 2 or 30% of an intermediate age (5 Gyr) population that is not present in elliptical galaxies; this suggests that there are significant differences in their formation and evolution between the bulges of spirals and elliptical galaxies.

G. Illingworth (Space Telescope Sci. Inst.), M. Franx (Leiden U.) and T. Heckman (Johns Hopkins U.) have started a program to establish the shapes of elliptical galaxies from a kinematical survey. Their sample consists of elliptical galaxies that have been selected by absolute magnitude, ellipticity, and distance. The KPNO 4-m telescope is being used to measure the ratio of the minor-to-major axis rotational velocities in this sample. This ratio can be non-zero for triaxial galaxies that are rotating about their intrinsic short axis. For oblate galaxies that rotate about their symmetry axis, this ratio is always zero. When a large enough sample has been observed, it should be possible to estimate the distribution of the forms of the elliptical galaxies from the distribution of their minor-to-major axis rotational velocities. R. Davies (NOAO), G. Illingworth and R. Peletier (Leiden U.) continued their program for the photometry of elliptical galaxies using the CCD at the KPNO 2.1-m telescope. Observations of five low luminosity (and therefore small) ellipticals, eight normal galaxies (cDs) were obtained in the U, B, and R passbands. With observations previously obtained at the KPNO #1-0.9-m telescope, complete data were available for thirty-four galaxies; all of these have now been analyzed with the GASP surface-photometry package. Preliminary results are that stellar disks are not found preferentially in the low-luminosity systems—as had been suggested to account for their relatively high rotational velocities. The color gradients are steepest in the low luminosity systems and flattest in the cDs; the U-R gradient is always substantially greater than that in B-R. It is also found that the lower luminosity systems show less isophote twisting (and it occurs at larger radii) than in more luminous galaxies. This is consistent with the lower luminosity ellipticals having oblate figures with isotropic velocity residuals.

F. Schweizer and W. Ford (Dept. Terrestrial Magnetism) and P. Seitzer (NOAO) have made a survey for faint structures (ripples, shells, luminous plumes, and dust lanes) in a sample of northern E and SO galaxies. Using the RCA CCD on the KPNO #1-0.9-m telescope, they obtained images for 29 galaxies in excellent seeing and a further five in relatively poor seeing. The total exposure, which was typically 50 minutes in the R passband, was broken into between three and fifteen individual exposures so as to avoid saturation in the bright nuclei. About half the images have been fully processed by both an unsharp masking technique and by a model subtraction technique; the other half have been given a preliminary inspection. About one third of these galaxies, including four S0s, show ripples and shells. Three of the E galaxies have unusual box-like isophotes, and one or two others appear to show faint outer spiral structure. It seems that the ripple appearance is more common in SO galaxies as in ellipticals. It is also noted that the E galaxies with the most box-like isophotes also show ripples and luminous plumes. It seems that these unusual isophotes are caused by extra matter that has been accreted from a disk galaxy and stored for prolonged periods in box orbits.

M. Simon (Space Telescope Sci. Inst.), J. Paresce (Newark, Stony Brook) and J. Fischer (Naval Res. Lab.) have been carrying out a spectrophotometric survey of galaxies that are bright in the IRAS survey. Most of the observations have been obtained with the IIDS spectrometer at the KPNO 2.1-m telescope in the wavelength range $\lambda$ 4000 - 7000 Å with between 7 and 11 Å bands.
resolution. The initial survey includes 58 galaxies reported in IRAS circulars 2 - 13 and about half of them are cataloged galaxies; all appear to be spirals and the faintest has $V = 17.8$. All but seven of those observed show at least Hα emission. Their radial velocities are in the range 1000 to 12,300 km/s. Assuming a Hubble constant of 50 km/s/Mpc, the optical luminosities are in the range $log (L/L_{b}) = 9.0$ to 11.3 and the far infrared luminosities are in the range $log (L/L_{b}) = 9.5$ to 11.6. The ratio of the far infrared to optical luminosity exceeds ten for about one third of the sample and its highest value is about fifty.

Galaxies in Clusters and Interacting Galaxies: V. Rubin and D. Hunter (Dept. Terrestrial Magnetism) used the KPNO 1.0-m telescope with the TI CCD to obtain narrow band and red images of galaxies in Hickson's compact groups. This program complements another by Rubin in which the rotation curves of the individual galaxies are being obtained. The aim is to study the environmental influences of a high space density on both spiral and elliptical galaxies. It is hoped also to find evidence for tidal disturbances and for infall by comparing the outer parts of the distribution of the interstellar gas. In a few of the spirals the H I is known to extend to distances that are several times the optical radius. Deep Hα images were obtained for these and in one, NGC 3198, several H II regions were found almost to the limits of the 21-cm observations. C. Moss (Vatican Observ.) and M. Whittle (U. of Arizona and U. of Cambridge) have completed an Hα objective prism survey of nearby Abell clusters of galaxies. The purpose of this survey on the Burrell Schmidt is to investigate the effect of the environment on star formation in spiral galaxies. Plates, in good seeing, have been obtained for 19 Abell clusters with cz $\leq 10,000$ km/s; the limiting magnitude is roughly 16.5. The data have been reduced for two clusters (Abell 347 and Abell 1367); 20% of the detected galaxies are fainter than the limit of this catalog. Measurements of the global Hα equivalent widths and fluxes for the detected galaxies have been made from the objective-prism plates; they are in good agreement with previous results from wide-aperture photometry. The detection limit for Hα emission in the survey corresponds to an equivalent width $\geq 20$ A and a flux $\geq 10^{-13}$ ergs/sec/cm$^2$. Redshifts (correct to 400 km/s) have been measured for the brighter galaxies on the objective-prism plates. There is some evidence that the spirals with strong Hα emission are found more frequently in the central regions (within 0.5 Abell radii) than in the outer regions of these clusters.

S. Boughn and J. Uson (Princeton U.) measured the integrated luminosities and colors of the cores of several rich Abell clusters using the photometer at the KPNO 1.3-m telescopes. The KPNO #1-0.9-m telescope and the RCA CCD were also used to get BVRI photometry of the same clusters. It appears that the integrated luminosities and colors of these clusters are consistent with the light coming from individual galaxies. A preliminary analysis shows that less than 30% of the "dark" matter in these clusters can consist of even the faintest hydrogen-burning stars. X-ray observations have shown that some clusters of galaxies have accretion flows and if this gas is turning into stars with a "normal" initial mass function, then these new stars may be detectable from color measurements. W. Romanishin (Arizona State U.) has been trying to detect this effect in the central galaxies of clusters that are known to have accretion flows. The combined V magnitudes obtained from CCD observations at the KPNO #1-0.9-m telescope with infrared K magnitudes obtained at the 2.1-m telescope to get V-K colors. Only in NGC 1275 (the central galaxy of the cluster Abell 426) was the already known star formation detected; the V-K colors showed no sign of star formation in other clusters whose accretion rates are comparable to that found in Abell 426.

G. Chincarini and R. Henry (U. of Oklahoma) are investigating the structure of part of the Perseus-Pisces Supercluster. They used the KPNO 1.3-m telescope to get infrared H magnitudes for galaxies for which 21-cm H I observations have already been made at Arecibo. Application of the infrared Fisher-Tully relation allows distances to be calculated and hence the structure of the Supercluster. R. Davies (U. of Manchester) and T. Kinman (NOAO) used the IIDS spectrometer to get spectrophotometric observations of galaxies in three nearby groups. Mass-to-luminosity ratios for these groups were found to be in the range of 20 to 100.

J. Gallagher (NOAO) and D. Hunter (Dept. Terrestrial Magnetism) have been studying dwarf irregular galaxies and related classes of galaxies in the Virgo cluster. Working at the KPNO 2.1-m telescope, they obtained CCD images in Hα and B for a representative sample of Virgo irregular galaxies for comparison with similar measurements of field irregular galaxies. A qualitative inspection of the data suggests that the Virgo irregulars cover a wider range of star forming properties than their counterparts in the field; further, the star formation in the cluster irregulars seems to be more centrally concentrated than in the field galaxies.

R. Kennicutt (U. of Minnesota), W. Keel (NOAO), E. Hummel (Max-Planck-Inst. for Radioastronomy, Bonn) and J. van der Hulst (Netherlands Fndtn. for Radioastronomy) have completed a study of the induced activity in the nuclei and star formation which are found in interacting galaxies. The infrared magnitudes and Hα fluxes (measured with the CCD at the KPNO 2.1-m telescope) were used to determine the star formation rates in these galaxies. It was found that although the response of individual galaxies does vary enormously, spirals that are in close pairs show (on average) twice the rate of disk star formation as is found in isolated spirals. Thus although a large fraction of the interacting spirals exhibit normal star formation rates, others do show massive
bursts of star formation on a scale that is almost never seen in isolated systems. This seems to show that the response of a galaxy to a tidal encounter is very sensitive to the physical conditions in the galaxy and to the orbital properties of the interaction. H. Bushouse (NOAO and U. of Illinois) has also used the CCD at the KPNO 2.1-m telescope to measure Hα and R fluxes for strongly interacting galaxies. He also finds a wide level of star formation activity but concludes that the disk regions are not profoundly affected by collisions. When enhanced activity occurs, he finds that it is primarily concentrated near the nuclear regions. Bushouse also used the KPNO 1.3-m telescope to obtain JHK infrared magnitudes for approximately 30 interacting galaxy systems. He did not find any outstanding anomalies in these near infrared colors compared with what is found for isolated spiral and irregular galaxies. N. Sharp (NOAO) has also been making CCD observations at the KPNO 8-1.0-5-m telescope to determine star formation rates in interacting pairs of galaxies that have been cataloged by Karachentsev. Also, with J. Sulentic (U. of Alabama) he has been using the same equipment for the identification and photometry of elliptical-spiral galaxy pairs.

F. Schweizer (Dept. Terrestrial Magnetism) has used the RC spectrograph at the KPNO 4-m telescope to study the kinematics of gas in colliding and merging galaxies by recording the spectra near Hα with the slit in different position angles. One object studied is the IRAS-bright source IC 4553 (= Arp 220) where the velocity field is highly chaotic. It is hoped that the observations will give kinematic evidence as to whether or not two gas-rich galaxies collided, merged, and produced the super starburst phenomenon that is currently seen in this object.

QSOs, BL Lac Objects, and Active Galaxies: D. Koo (Space Telescope Sci. Inst.), R. Kron (York Observ.) and A. Szalay (Sofotev U.) have continued their redshift program for QSOs and galaxies in SA 57. Using the cryogenic camera at the KPNO 4-m telescope, they are surveying UBV selected quasars to B = 23 and galaxies to V = 20. An analysis of the data obtained so far shows that the volume density of the quasars is like that of the local AGN, but with the typical luminosity nearly 100 times brighter. By redshifts of 2, however, the number of quasars may be declining; this is consistent with the finding that most of the very faint quasars are still bright in the ultraviolet. Only three QSOs have been found in this survey with redshifts over 2.8 although the best published models predict far more. The galaxies are being used to explore large scale structures in the redshift range 0.1 to 0.3 where several large volumes of low density (comparable to the Bootes void) have been found. A preliminary analysis in this and other fields shows significant correlations on scales of over 150 Mpc (Hubble constant 100 km/s/Mpc). Koo and Kron are also studying the galactic halo on 4-m plates. This program should allow a number of faint QSOs to be identified by their colors, lack of proper motion, and variability. The suggestion that faint QSOs could be picked up in asurvey by their variability is of interest in connection with the program by P. Allan and W. Keel (NOAO). They started a program in 1985 at the KPNO 1.3-m telescope to monitor the variability of the quasars discovered in the Palomar-Green (P.-G.) survey. This monitoring program is now being continued at La Palma. The indications so far are that most of the P.-G. quasars do not vary by more than a few percent. E. Borra and M. Beauchemin (U. of Laval) used the CCD at the KPNO 3.1-0.9-m telescope to set up faint photoelectric sequences (B = 21) in several fields that are being observed at the CFH telescope. These sequences will calibrate the photographic slitless plates for surveys of quasars and galaxies. N. Marshall (Space Telescope Sci. Inst.) used the same equipment to obtain confirming BVI photometry for a quasar search field at 13° + 36°.

M. Saito (NOAO) has been monitoring the continuum and emission-line flux variability in the radio-quiet quasar 3C 273 in the optical and infrared range at Kitt Peak and simultaneous spectroscopy with the IUE satellite. The rapidity with which the emission lines respond should depend on the distance of the line-emitting clouds from the ionizing source. The continuum may be produced by the interaction of the optical-uv continuum with some extended medium—perhaps dust—and its variability may indicate the distance of this medium from the source. Saito is currently monitoring another optical-uv variations with standard accretion disk models. With V. Junkkarinen (NOAO), he took advantage of a minimum in the continuum flux of 3C 287 to discover three emission-lines in this BL Lac object. Besides determining a good redshift, they showed that the total luminosity of the emission lines of 3C 287 is similar to that of normal QSOs.

F. Hintzen (Goodard Space Flight Ctr.) used the cryogenic camera at the KPNO 4-m telescope to get a long-slit spectrum of 3C 273.1. This is a distorted radio QSO that lies in a large nebula at the center of a rich cluster of galaxies. He showed that the nebula has a "solid body" rotation out to a distance of 40 kpc. This is very different from the rotation curve of a spiral galaxy and the nebula is tentatively considered to be gas that is falling in from the surrounding cluster of galaxies. R. Green (NOAO), J. Bechtold (Mt. Wilson and Las Campanas Obs.), and D. York (U. of Chicago) continued their long-term program to derive physical conditions in distant galactic halos which are seen by their absorption lines in the continua of more distant QSOs. It has been found that an eight hour exposure of a 16th magnitude QSO with the ICCD on the echelle spectrograph at the KPNO 4-m telescope gives sufficient S/N for useful limiting equivalent widths. The velocity resolution is about 15 km/s. The aim is to disentangle the complex velocity profiles.
typically found in metal-line absorption systems; to derive thermal velocity widths of the lines, and to distinguish between photoionization and shock heating. Ultimately, it is hoped to derive abundances and depletions of the common elements together with the sizes and densities of the individual clouds and the ambient density of the ionizing photons.

V. Junkkarinen (U. of California, San Diego) has been using the cryogenic camera at the KPNO 4-m telescope to take spectra of QSOs in which the absorption redshift exceeds that given by the emission-lines. The emission-line redshifts have previously been based on all emission lines including some (such as CIV 1549) which are asymmetric. The narrow forbidden lines and Mg II are better indicators of the QSO redshift and when these lines are used, the velocity dispersion associated with the absorption systems in 14 QSOs is reduced to only $400 \pm 100$ km/s. This implies that these QSOs do not have to be associated with rich clusters of galaxies because the lower velocity dispersion is what one would expect in galaxy clusters of Abell richness class 0 or even weaker at the current epoch. Low redshift QSOs are often associated with such weak clusters and so the environments of these higher redshift quasars could be similar. One QSO in this sample (4C 17.46 with a redshift of 1.456), shows spatially extended emission in the [O II] $\lambda 3727$ line. The spatial extent and flux of this [O II] is similar to that found in radio galaxies. 4C 17.46 is a steep spectrum radio source with two radio lobes similar to those in double-lobed radio galaxies. Junkkarinen is continuing his study of the asymmetries of QSO emission lines in spectra obtained with the IDS at the KPNO 2.1-m telescope in the blue (CIV $\lambda 1549$) and with the Cryocamera at the KPNO 4-m telescope in the red (Mg II $\lambda 2798$ and [O II] $\lambda 3727$). The [O II] line is used as a reference since it is formed far out in regions of low density. The observed asymmetries in the broad emission lines can be used to constrain the configurations of the regions these lines arise from. It seems that one can reject the hypothesis that these broad-line clouds are ejected in a single direction; partial obscuration of the broad emission-line region by an accretion disk or a mildly anisotropic emission from these clouds can best explain the observed asymmetries and redshift differences.

E. Turner (Princeton U.), J. Hewitt, and R. Burke (Massachusetts Inst. of Technology) used the KPNO 4-m telescope to identify gravitational lens systems from suspected multiple unresolved sources that have been found in a large survey with the VLA. A search is made for multiple optical components on red CCD images that are obtained at the prime focus of the KPNO 4-m telescope. Spectra of suitable candidates are then obtained at moderate resolution with the cryogenic camera the presence of nearby images with identical redshifts is a strong indication of a gravitational lens. Direct images of 53 VLA candidates were obtained; four of these were strong candidates and six were possible candidates for lenses on the basis of their optical morphology. Subsequent spectroscopic observations so far support three of these cases being gravitational lenses but additional confirming spectra are needed. In one case, the maximum separation of the images is only 1.5 arc-sec which would be the smallest yet identified. In addition, further observations were carried out on two confirmed lens systems (0203 + 171 and 2016 + 112).

W. Keel (NOAO and Leiden U.) has been obtaining CCD images at the KPNO 2.1-m telescope of galaxies where both active nuclei and star forming regions are suspected of being present. The images, in various continuum wavebands and Hα were observed in one arc-sec seeing and were well enough sampled for image reconstruction. In several cases, a Seyfert or LINER nucleus is surrounded by a ring of giant H II regions. It is conjectured that these rings represent a "pile-up" of the gas flow which increases the gas density and so enhances the rate of star formation. Spectra of several of these nuclei were obtained by Keel at the KPNO 4-m telescope and a clear separation of the active nuclei and star forming regions was achieved. It seems possible that the H II regions in these environments have unusually high velocity dispersions. Estimates for the ages for these starbursts (based in part on spectra obtained at La Palma with the Isaac Newton telescope) range from 10$^7$ years for NGC 7469 and 10$^8$ years for NGC 1068; Keel points out that these are consistent with the time-scales derived from the radio structures. A high resolution spectrum of the Sy2 galaxy NGC 5292 shows that its double-peaked emission lines arise in two spatially and kinematically distinct narrow-line regions. These are symmetrically placed about the dynamical center which seems to contain a weak broad-line region. This is interpreted as an active nucleus of low optical luminosity that is interacting with distant regions of gas either by particles or radiation. J. Goad and J. Gallagher (NOAO) have been taking espectral spectra of spiral galaxies at the KPNO 4-m telescope. They believe that there is a clear progression of activity in spiral nuclei from normal galaxies through intermediate cases like M51 on up to Seyfert galaxies. At high spectral resolution, they observe broad-line features that are well separated from the nuclear continuum. Thus, in M51, regions a few arcsec both to the north and south of the nucleus show broad emission lines and anomalous line ratios. Goad and Gallagher suggest that collimated gas flows are the common factor in these different cases. They also obtained CCD frames at the KPNO #1-0.9-m telescope to map out the regions of activity in these nuclei.

T. Heckman and A. Wilson (U. of Maryland) and G. Illingworth (Space Telescope Sci. Inst.) have been investigating the dynamics of stars in and near Seyfert nuclei. They aim to relate this stellar dynamics to the easily observed but poorly understood kinematics of the ionized gas on similar spatial scales (0.1 to 1 kpc).
Models in which the gas clouds fall radially inward under gravity seem to be consistent with the properties of the ionized gas. If correct, such flows would be of interest for the maintenance of the active nuclei. Infall models (unlike outflow models) predict a good correlation between the emission-line velocities and the stellar velocity dispersions; the Kitt Peak data suggest that such a correlation is present. T. Heckman and S. Baum (U. of Maryland) and G. Miley (Space Telescope Sci. Inst.) have used the prime focus CCD at the KPNO 4-m telescope to get broad-band (continuum) and narrow-band (red-shifted emission-line) maps of strong extragalactic radio sources that have been observed at the VLA at several frequencies. The first aim of the program is to study the incidence rate, morphology, and excitation of the emission-line gas around the radio sources. The second is to relate the properties of the emission-line gas to the properties both of the radio source and of the parent galaxy.

J. Kielkopf (U. of Louisville) has been studying the narrow-line regions in bright Seyfert galaxies at the coude feed. The nuclei of NGC 1068, 3031, 4051, and 4151 have been observed in the spectral region that includes both Ha and Hb. The data have a resolution of 0.4 A and will allow analyses that yield cloud velocities, emission-line strengths for different lines, and extinctions for distinct clouds. The spectra confirm spatially resolved observations of NGC 4151 and give improved velocities. C. Brungardt (Pennsylvania State U.) has obtained broadband CCD images of both Seyfert and starburst galaxies at the KPNO 1.5m-telescope. His aim is to obtain separate luminosities for the nuclei and the host galaxies. The data will be combined with high resolution spectra of these nuclear regions. W. Keel (NOAO and Leiden U.) has been studying radio galaxies which contain either jets or suspected jets. CCD images were obtained in excellent seeing at the KPNO 2.1-m telescope. Preliminary results suggest that the spectral shapes of jets and hot spots differ in the BVRI range. These measures suggest a remarkable uniformity in the electron spectrum all along several jets; the energy cut-off is quite narrow—less than a factor of two in energy in the case of the jet of Mr7.

R. Davies (NOAO) and M. Birkinshaw (Harvard U.) have been using the KPNO 4-m prime focus CCD camera to get images of two samples of elliptical galaxies from the CfA redshift survey. One set contains radio galaxies and the other normal quiescent ellipticals. Davies and Birkinshaw want to know whether the radio sample has suffered more frequent or more vigorous interaction events than the quiescent sample. Earlier work showed that there was no kinematic difference between the radio and quiescent types. F. Owen (NRAO) and R. Laing (Royal Greenwich Observ.) have been observing bright radio galaxies with the CCD at the KPNO 1.5-m telescope. They find a strong correlation between the radio structure and the shape of the outer optical isophotes of the parent galaxies. Owen and W. Cotton (NRAO) have used the same equipment to search for the optical counterparts of compact, steep-spectrum radio sources. Six identifications were made with weak optical sources. This suggests that either the emission is not from a synchrotron source or that bulk relativistic motion is occurring along the line of sight. T. Thuan (U. of Virginia), J. Condon (NRAO), and K. Mitchell (Virginia Polytechnic Inst.) have been getting deep B and R CCD images of the field at 13h 00m, +30° 36’ that was surveyed by Mitchell and Condon at the VLA at the ujy level. This deep optical material from the KPNO 4-m telescope has allowed about 67% of the radio sources to be identified optically. Colors and morphological classifications will be obtained for these identified sources. These data should be of help in deciding whether or not there is an increase in the number of blue galaxies or in star forming activity as a function of redshift.

H. Spinrad and S. Djorgovski (U. of California, Berkeley) have continued their spectroscopic investigations of faint radio galaxies at the KPNO 4-m telescope using both ICCD and the cryogenic camera. A good slit spectrum of 3C 256 (z = 1.82) showed that the C III] 1909 emission line had the same spatial extent as the local galaxy continuum. This is quite different, for example, from the distribution of [O III] in Cynus A. Spinrad and Djorgovski conclude that the ionization in 3C 256 is produced by stars that are distributed over the face of this large galaxy; it does not come from some central source. They also find that the equivalent width of the [O II] and Lyman alpha emission lines of radio galaxies show a large evolutionary change with cosmic epoch. They select only the most radio-luminous 3CR galaxies into three redshift ranges (z > 1.0, z ~ 0.5 and z < 0.1) and find strong increases in both the equivalent widths and emission line fluxes with increasing redshift. The [O II] flux increases by a factor of 100 in going from the z > 1.0 to the z > 1.0 group (assuming a Hubble constant of 50 km/s/Mpc and q0 = 0). The implication is that these galaxies were much more active ~7 — 12 Gyrs ago.

R. Windhorst (Mt. Wilson and Las Campanas Observ.), D. Koo (Space Telescope Sci. Inst.) and H. Spinrad have a program to find the earliest possible epoch of formation for the giant elliptical galaxies. They identify these very old galaxies with very red, high redshift galaxies whose spectra consist only of starlight. These galaxies are found from optical identifications of very deep radio surveys. The galaxies are known to be very red because they only showed on IIIa-P and IV-M (but not IIIb-J) plates taken at the prime focus of the KPNO 4-m telescope; they were also classical double-lobe radio sources with very steep spectra. Brighter galaxies with these radio characteristics are known to be intrinsically luminous giant ellipticals with a narrow range of absolute luminosities. Spectra of some of these faint objects were obtained.
with the cryogenic camera at the KPNO 4-m telescope and six candidates were discovered with \( 21 < F < 22 \) for their red magnitudes, \( J > 23.7 \) for their blue magnitudes and redshifts of \( 0.60 < z < 0.85 \). The galaxy with \( z = 0.85 \) has one of the highest redshifts known for a galaxy with an absorption spectrum. The data were analyzed using the J-F color versus redshift diagram in comparison with the spectral evolution models by Bruzual. The few very red (J-F \( \sim 2.4 \)) radio galaxies require ages of 14-15 Gyr. Windhorst et al. point out that these ages favor smaller values of the Hubble constant and also argue against very old ages for the globular clusters.

IV. CERRO TOLTO INTER-AMERICAN OBSERVATORY

Cerro Tololo Inter-American Observatory is the U.S. national center for optical astronomy in the Southern Hemisphere. It remains an excellent photometric site, and serves a wide community of astronomers from the U.S., South America, and the rest of the world. Its southerly latitude places it in an ideal locale for the study of the Magellanic Clouds and the center of the Galaxy. The dark sky has also led to an emphasis on the study of faint objects and low surface brightness features. During the period October 1984 - June 1986, 232 separate investigations involving 380 scientists were carried out at CTIO. In the same time period, 240 papers were published based on the use of Cerro Tololo facilities.

A. Personnel

1. Staff Changes

On December 31, 1985 Dr. Patrick Osmer retired as Director, Cerro Tololo Inter-American Observatory/Associate Director, NOAO and assumed the position of Astronomer until he transferred to NOAO/KPNO.

Dr. Robert Williams, formerly of the Steward Observatory, University of Arizona was appointed Astronomer, and on 1 January 1986, assumed the position of Director, Cerro Tololo Inter-American Observatory/Associate Director, NOAO.

Dr. Stephen Heathcote from the Royal Observatory Edinburgh, began his appointment as Assistant Astronomer.

Dr. Donald Hamilton from The University of Chicago was appointed Research Associate.

Dr. Nicholas Suntzeff from Mount Wilson & Las Campanas Observatories was appointed Assistant Astronomer.

Dr. Nelson Caldwell, Assistant Astronomer, left to join the Whipple Observatory, SAO.

Dr. Jay Frogel, Astronomer, transferred to NOAO/KPNO.

Dr. John Graham, Astronomer, left to join the Department of Terrestrial Magnetism, Carnegie Institution of Washington.

Dr. Brian Jarvis, Research Associate, left to take a position at the Observatoire de Geneve.

2. Long-Term Visitors

Long-term visiting scientists (defined as staying for periods of three months or more) under the CTIO Visiting Resident Scientist Program included:

- Dr. Martin McCarthy, S.J., Vatican Observatory Research Group
- Dr. Robert Schommer, Rutgers University, Piscataway, New Jersey

B. Research Highlights

1. Extragalactic Astronomy

Magellanic Clouds: B. Bohannan (U. of Colorado) has completed spectral classification of a sample of 82 H-a emission-line stars in the Large Magellanic Cloud (LMC). Four distinct groups of similar spectroscopic appearance are identified: O, B and A supergiants with to varying degrees relatively normal spectroscopic appearance (51% of the sample); O and B stars with strong emission features (20%) ranging from stars with P Cygni–like H Balmer lines, but otherwise normal absorption features present in the blue; S Doradus-like stars with Fe II and [Fe II] emission (12%); Wolf-Rayet stars (17%). A clear separation of spectroscopic groups into different regions of the H-R diagram is evident. Indeed, in any small range of luminosity and temperature, there are examples of several different spectroscopic groups.

N. Suntzeff (Mt. Wilson and Las Campanas Observ.), E. Friel, A. Kliman and R. Kraft (U. of California, Santa Cruz), and J. Graham (NOAO) have investigated the stellar population of the Small Magellanic Cloud (SMC) near the cluster NGC 121. Estimates of [Fe/H] are obtained from indices measuring the strengths of H and K, the G-band and the Mg-b-λ4471 blend in a sample of giant stars of the SMC halo near NGC 121. Spectra of 13 stars were obtained out of a sample of 31 red stars judged to be members of the SMC from considerations of proper motion—all 13 objects proved to be metal–deficient giants and had radial velocities consistent with SMC membership. One H-type and one C-type giant were found, and one giant in NGC 121 was observed. Calibration of the metallicity indices was based on scans of giants in Galactic globular clusters of known metallicity. Then stars having well-determined indices yielded \( \langle [Fe/H] \rangle = -1.63 \pm 0.031 \), where the standard deviation corresponds to that of a single observation. This compares well with an earlier estimate of \( \langle [Fe/H] \rangle = -1.8 \pm 0.2 \) based on seven RR Lyrae found in this field. Photometrically-calibrated photographic (B-V, V) colors and magnitudes were obtained for 69 red stars identified by Graham in a 20' x 20' field north of NGC 121; the 31 proper motion candidates are a subset of these red stars. CCD photometry was also obtained for small subregions of the Graham field, and all colors and magnitudes were transformed to the CCD-based system.
Estimates of metallicity were obtained for all 31 candidates by fitting the Sandage-Roques composite cluster CMD diagrams to the c-g array using the so-called "short" modulus, viz., \((m-M)^* = 18.85\). These metallicities are shown to correlate well with the metallicities of the subset of stars for which index measurements were obtained. From 30 of the 31 candidate stars (the C-star being omitted), we find \(<[Fe/H]> = -1.56 \pm 0.32\) (a.d. single observation); the spread appears to be real.

N. Walborn (Space Telescope Sci. Inst.) obtained spectroscopic observations of forty members of the 30 Doradus cluster surrounding the object R136, at 1.5 A resolution with the CTIO 4-m SIT vidicon system. The most spectacular known grouping of massive hot stars has been revealed, including 15 members definitely or possibly of type 03, five of which are of the new intermediate 03 Fe*/WN-A class. Sophisticated new direct imagery of R136 itself by A. Walker and by G. Weigelt has resolved it into 28 components, which span a magnitude range identical to that found in the surrounding cluster. In combination these results definitively exclude a supermassive object in 30 Doradus, but identify 15 - 20 members of its central cluster as probably 100 - 200 M\(_\odot\) stars. From the same observing run, the star Sanduleak -66\(^{+40}_\circ\) was identified as a seventh member of the unique Ofpe/WN9 category in the LMC.

J. Frogel (NOAO) in collaboration with J. Elias (California Inst. of Technology) has begun an investigation of IRAS sources in the Magellanic Clouds. The first season's work was based on the so-called Additional Observations made by IRAS of the Clouds. These data generally go to considerably fainter flux levels than the sources contained in the recently released IRAS Point Source Catalogue.

A. Klemola, B. Jones, and D. Lin, (U. of California, Santa Cruz) and J. Graham (NOAO) continued a photometric and astrometric study of the SMC halo field around NGC 121, based on photographs taken with the CTIO 1.5-m reflector. A two-color photometric survey (Klemola) of 8800 stars \((V = 15 - 20)\), based on blue and yellow photographs for the 1.0 x 1.3 degree field, resulted in the identification of more than 1400 red stars as SMC halo red giant candidates. Successful removal of projected galactic field stars from a subset of 69 red stars \((V = 15.5 - 18.5)\) through measurement of relative proper motions, followed by spectrophotometric observations for 13 stars by Kraft and Graham, demonstrates the value of the technique. A different subset of 150 red stars, as possible SMC halo giants, forms the astrometric reference frame for current reductions for absolute proper motion of the SMC with respect to faint galaxies in this field (Klemola, Jones, Lin and Graham).

J. Mould (California Inst. of Technology) and D. Costa (University of Washington) have continued their program of main sequence photometry of the red globular clusters in the Magellanic Clouds. For clusters outside the central very crowded regions in these dwarf galaxies, CCD photometry with the CTIO 4-m prime focus camera yields an unequivocal detection of the main sequence turnoff. Cluster ages have been determined by fitting isochrones computed at Yale with the following results: NGC 121 (12 \pm 2 Gyr); Lindsay 113 (5 grys); Kron 3 (8 grys); NGC 1651 (2.5 \pm 0.4 grys); NGC 2213 (1.6 \pm 0.6 grys).

The quoted ages assume a distance modulus of 18.2 for the LMC and 18.8 for the SMC. Until recently, it would have been maintained that these moduli were 0.5 mag too small. If the longer, pre-1983 moduli were in fact correct, the quoted ages should be reduced by a factor of approximately 1.5. Uncertainty in the distance moduli of the Clouds is the dominant uncertainty in the cluster ages. The second largest uncertainty in the ages of the two LMC clusters, whose turnoff stars have convective cores, is the possible prolongation of the main sequence lifetimes of these stars by convective overshooting. In the course of this program it has also been possible to gain an impression of the age of the population of the field in which each cluster finds itself. For these outer clusters a significant component of this population is old, at least 7 Gyr. Although recent work has suggested that the preponderant age of star formation close to the Bar of the LMC is 1 to 3 Gyr, a few kpc from the Bar we encounter an older dominant population. These results are still consistent with the absence of blue horizontal branch stars in the outer halo of the LMC, as BHB stars are probably confined to populations of the age of Galactic globular clusters. This radial trend in the predominant ages of field samples suggests a slow dissipative collapse of the LMC to its present H I configuration.

P. Hodge and M. Mateo (U. of Washington) completed color-magnitude diagrams for several intermediate age globular clusters in the LMC. Surveys of first open clusters in the SMC are complete, and an analysis of the SMC cluster formation function and the cluster lifetime problem are derived from these new data.

The stellar population of the Magellanic Clouds was reviewed by J. Frogel (NOAO) for the Publications of the Astronomical Society of the Pacific. He showed that there are three easily distinguishable components to their stellar population: (i) an old (>10 Gyr) population whose membership includes field RR Lyrae and clusters which are the counterpart of Galactic globular clusters; (ii) an intermediate age population whose members include luminous field asymptotic giant branch (AGB) stars, both O and N, and the luminous red clusters which also contain large numbers of AGB stars; and (iii) a young (<100 Myr) population which includes the blue and red supergiants. The old, metal poor population comprises about 6% of the total mass of each Cloud.

D. Geisler (NOAO) has embarked on a program to determine abundances of intermediate- to old-age clusters in the Magellanic Clouds using Washington CCD photometry. The long range goal is to determine very accurate abundances for a
large sample of clusters. Recent observations of such clusters suggest that the distances to the Magellanic Clouds may be significantly less than traditional values. One key parameter essential to main sequence fitting and thus distance determination is the metal abundance. Abundances in these distant clusters, however, are only poorly known. The very high Fe abundance sensitivity of the Washington system, combined with simultaneous observations of a large number of giants, should allow an accuracy as small as 0.1 in the mean metallicity to be obtained. Preliminary data yield Fe abundance of 0.32 ± 0.15 for the intermediate age LMC cluster NGC 2213, which, when combined with the color-magnitude diagram study by Da Costa, Mould, and Crawford, gives a distance modulus of 18.7 ± 0.1.

C. Garmany and P. Conti (U. of Colorado) and P. Massey (NOAO) have a very close to complete inventory of O-stars in the SMC—the numbers are very small, in agreement with the previously known small number of Wolf-Rayet stars which are evolved descendents of massive O-stars. Studies of H II emission in the SMC (Ha work) suggest for more O-stars: from their work this does not seem possible. The O-stars might be hotter than Galactic counterparts because of their different metallicity.

Other Extra-Galactic: J. Baldwin (NOAO) and G. Hartig (Space Telescope Sci. Inst.) completed their analysis of the emission-line spectra of a sample of sixteen quasars which have broad absorption lines (BALs). It is of considerable interest to compare those properties of BAL quasars to those of normal quasars, because the combination of the fraction of quasars seen to have BALs and the covering factor deduced for the BAL gas suggests that all quasars might produce BALs when seen from the correct aspect angle. It is found that the spectra of the BAL quasars show a correlation between their emission-line and absorption-line properties. In about half of these quasars the BALs are significantly "detached" from the corresponding emission lines. When compared to samples of non-BAL quasars, the detached-BAL quasars have large [A III] λ 1862/C III] λ 1909 intensity ratios, strong Fe II emission, and unusually weak C IV emission lines whose profiles do not agree with those of the lower-ionization emission lines. In contrast, those quasars having BALs that cut sharply into the emission lines (e.g. "P-Cygni"-like profiles) appear to have emission line properties which, except for the intervention of the BALs, are like those of non-BAL quasars. This leads to the conclusion that either the non-BAL analogs to the detached-BAL quasars have been overlooked in published quasar surveys, or that either the discovery rate or the covering factors are wrong.

A possibly important sidelight of this BAL study is the result that one of the quasars in the BAL sample has very narrow (~1000 km/sec) lines which removes many of the line-blending problems encountered in the interpretation of most quasar spectra. In this particular object, the emission line near 1909 Å, normally interpreted to be C II λ 1909, breaks down into A III λ 1854.7, 1862.8 and Fe II λ 1895.5, 1914.1, 1926.3. Since the apparent presence of the A III lines is the only constraint on the maximum electron density in standard quasar emission-line models, the possibility of it actually being due to some other ion in the spectra of typical quasars would change the standard picture of physical conditions in these line-emitting regions. In fact, there is one other narrow-lined, high-redshift quasar in which the corresponding line definitely is C III, and further UV data are needed before we can know if the present narrow-lined quasar is in fact at all like normal quasars in its ionization properties. The significance of this object is therefore not yet clear.

J. Baldwin and T. Kinman (NOAO) have completed their observations to measure the velocity dispersion of the galaxy cluster around the BL Lac object PKS 0521-36. The goal is to estimate the total mass of the cluster and look for evidence of interaction between the BL Lac object and other members of the cluster. In the two previous cases studied, one BL Lac object was in the center of a compact group of galaxies having the velocity dispersion of a fairly rich cluster (800 km/s), while in the second case the velocity dispersion was much lower. Preliminary analysis of the data for the PKS 0521-36 cluster suggests that there again a relatively modest velocity dispersion is encountered.

B. Whitmore and D. McElroy (Space Telescope Sci. Inst.) observed several SO galaxies with polar rings. Observations of the circular velocities in both the SO disk and the polar ring allow the direct measurement of the shape of the gravitational potential in these galaxies. The three best cases indicate that these galaxies have spheroidal halos whose V/C is 0.97 ± 0.08. One of the candidate galaxies was found to have an elliptical galaxy as the central component with V/C = 0.4. CCD images in B and V reveal distorted structure in the outer regions of some of these systems with tidal tails and possible shell structure.

N. Caldwell and M. Phillips (NOAO), in collaboration with H. Schommer and T. Williams (Rutgers U.), have been using an imaging Fabry-Perot instrument for several projects. This device is capable of taking 2.5 or 0.5 Å images at a specified wavelength; thus a small spectrum (~50 Å long) can be obtained for the entire image. Images at Hα and the longer [N II] emission line were obtained of the Sombrero galaxy (NGC 4594) in hopes of resolving the long standing question about the blue knots in the disk of this early-type spiral galaxy. From a low dispersion spectrum, van den Bergh detected no Hα emission from these knots and concluded they are not H II regions, hence there must be no very early type stars.

Schweitzer, in his study, obtained a much higher dispersion spectrum and successfully detected emission lines in two of the blue knots that were characteristic of H II.
regions. With an efficiency of nearly 15%,
the Fabry-Perot detector can go deeper than
Schweizer was able to do and Hα emission was
detected in about 20 blue knots on the
eastern side of the disk, and very weak [N
II] emission was found from HII
regions. Thus, it now appears that the blue
knots in the Sombrero disk are clumps of hot,
massive stars and that there is no evidence for a
steep initial mass function in this
galaxy.

Another Fabry-Perot project by Caldwell
et al. concerned the emission line region in
the nucleus of the Seyfert 2 barred spiral
galaxy, NGC 5278. Prompted by the peculiar
velocities reported from long slit spectra by
Rubin, they obtained two-dimensional data
with high spatial resolution at Hα and
obtained a velocity map for the nucleus as
well as most of the disk. In confirmation of
theories of gas flow in a tumbling bar
potential, we find skewed velocity contours
around the nucleus. However, the region
within a few hundred parsecs of the nucleus
shows double-peaked emission, indicative of
two separate emission-line regions along the
line-of-sight. Also the general motion of the
gas is perpendicular to the major axis of the
bar, somewhat like a small polar ring.
With R. Schommer (Rutgers U.), J. Graham
(Carnegie Inst.) and J. Hoessel (U. of
Wisconsin), Caldwell has also undertaken a
search for Cepheid variables in several local
group dwarf irregular galaxies as well as the
large spiral M83. Variables have been
identified in the latter galaxy with CTIO 4-m
PfCCD frames, but more observations will be
required before periods and thus distances
can be determined.

S. Kent, S. Tremaine, and M. Weinberg
(Ctr. for Astrophysics) are working on a
program to study the dynamics of barred
galaxies, and in particular, to measure the
pattern speed of the bars using a novel
method. Theoretical modelling of bars
requires a knowledge of the bar pattern speed and
the location of the corotation radius
(where the pattern speed of the bar equals
the local circular velocity) relative to the
length of the bar. Strategically placed
long-slit spectra of NGC 936, 1440, and 7743
were obtained using the CTIO 4-m telescope
and RC spectrograph to measure the velocity
fields in these barred galaxies. An analysis of
the data for NGC 936 shows that the bar in
this galaxy rotates between one-half and one
times the rate needed for corotation to occur
at the end of the bar. Analysis of the
remaining data is in process.

D. Hamilton (NOAO) and collaborator W.
Keel (NOAO) have been preparing the final
results of a program that measured the
optical variability of a sample of Seyfert
galaxies. The major surprise determined from
this survey was that the most unusual Seyfert
galaxy, MARK 231, is the most variable galaxy
found to date. The amplitude of the B-mag of
this galaxy has varied as much as 1.0 mag
over one night. Hamilton and Keel have been
analyzing cryogenic camera long-slit
spectroscopy of MARK 231 to determine the
nature of and physical conditions in the
underlying galaxy. It is clear from the
spectrophotometry of the non-nuclear regions
that the spectrum rises strongly into the
blue indicating an O-B type spectrum.

B. Atwood and J. Baldwin (NOAO) and R.
Carswell (Cambridge, England) have extended
their study of the Lyman absorption lines in
high redshift quasars by obtaining echelle
spectra of the redshift z = 3.78 QSO PKS
2000-330. The aims of this study were to
search for redshift evolution in the
properties of these systems, and particularly
to see if there are any effects due to lower
ionization from the smaller number of
background quasars at very high redshifts.
Preliminary analysis reveals that, while the
number density of such systems is higher than
in lower redshift objects, the statistical
properties of the systems themselves at
redshifts up to z = 3.7 are similar to those
found earlier in the redshift range z = 2 to
z = 3.

S. Mitra (U. of Texas) has been studying the
structure and kinematics of the Southern
Supergalaxy. This is the nearest
supercluster from the Local Supercluster at a
distance of ~20 Mpc. Tertiary distance
indicators can be used to obtain distances to
member galaxies. The aim of the project has
been to obtain radial velocities and redshift
independent distances to determine the
structure and velocity field in the Southern
Supergalaxy. Multi-aperture photometric
observations in UBV of 30 galaxies were made
using the CTIO 0.9-m telescope. He also
obtained spectra for 15 galaxies using the
Image Tube Spectrograph at the CTIO 1.0-m
telescope.

R. Humphreys (U. of Minnesota) and J.
Graham (NOAO) have completed a study of the
brightest M supergiants in the nearby spiral
NGC 300. They obtained near-infrared spectra
of the candidate red supergiants and used the
Ca II triplet, a strong luminosity
discriminant, to separate the supergiants and
dwarfs.

Infrared (JHK) photometry was also
measured to determine the extinction and
bolometric corrections for the confirmed
supergiants. The visual, infrared and
bolometric luminosities of the brightest M
supergiants in NGC 300 confirm the
calibration of these luminous red stars found
for other spiral and irregular galaxies and their
importance as extragalactic distance
indicators.

M. Phillips (NOAO), C. Jenkins (Royal
Greenwich Observ.), M. Dopita (Mt. Stromlo
and Siding Spring Observ.), E. Sadler and L.
Binette (European Southern Observ.) reported
the results of a spectroscopic survey of 203
southern E and S0 galaxies for ionized gas.
The [N II] λ 6584 emission-line was found to
be present in the nuclei of roughly half of
all the galaxies observed, independent of
morphology. Taking into account factors that
work against detections at small equivalent
widths, this translates into approximately
55 - 60% of all early-type galaxies having
λ 6584 emission down to an equivalent width
of 0.5 Å. The amount of detectable ionized
gas is generally small; [N II] < 10^20 M☉.
The presence of emission lines seems to be
unrelated to galaxy color, axial ratio, or
the presence of outer "shells", but may be strongly correlated with X-ray emission. Through the aid of luminosity functions, Phillips et al. find convincing evidence that emission-line luminosity is correlated with absolute magnitude, and that luminous elliptical and 50 galaxies are likely to have emission lines than smaller galaxies. With somewhat less confidence, they conclude that "radio-loud" early type galaxies are more likely to have detectable ionized gas than "radio-quiet" ones.

A 15 square minute or arc field in NGC 300 was observed by N. Rich (British Columbia), C. Pritzker (U. of Victoria) and D. Crabtree (Canada-France-Hawaii Telescope), using four filters with the CTIO 4-m prime focus CCD. Two of the filters were broadband V and I and the other two isolated T10 (7800 Å) and CN (8100 Å). The red giants in the galaxy were fully resolved into stars through all filters. With this filter set it is possible to unambiguously distinguish late-type carbon stars from M stars. In order to calibrate the photometric system, several LMC fields containing known C and M stars were also observed. A very well defined relation between narrow and broadband colors was obtained for stars of known spectral type ranging from AO through M6.5 and including carbon stars. Sixteen late type C stars and 25 cool M stars were discovered in the NGC 300 field. Of these latter stars, we estimate that two should lie in the foreground. The ratio of C to M stars indicates a modestly metal deficient system ([Fe/H] = -0.5)—in excellent agreement with abundance estimates from supernovae shells in this galaxy. A new distance modulus to NGC 300 is derived using carbon stars and the value, (m-M) = 25.87, is significantly smaller than most currently in the literature, but does find support from the recent Cepheid observations of Graham. The full AGB luminosity function of the field observed is obtained and compared with that for the LMC. The deficiency of luminous AGB stars known to exist in the LMC does not appear to exist in our NGC 300 field.

K. Kawara (NOAO), in conjunction with A. Hyland (Mt. Stromlo and Siding Springs Obs.), found Brγ, He I(2P - 2S) and Hα - 0 S(1) lines in the starburst galaxy Hé2 - 10, which is known to have a large number of Wolf-Rayet stars. The He I line at 2.058 μm could come from H II regions or WC stars. The Hα line indicates 4 x 10^5 M☉ for hot He II if the Hα emission is powered by shock. The Brγ implies that 10^4 - 5 O stars are required to produce the rate of ionization. The upper limit on the mass of old red stars calculated from K magnitude is only 10 - 50 times larger than the suggested mass of young stars born within 10^7 years. Their observations, combined with the bolometric luminosity measured by IRAS suggest that the burst of star formation in He2 - 10 is characterized by the initial mass function which is weighted towards very heavy stars.

A. Wilson (U. of Maryland) and J. Baldwin (NOAO) have continued their program of mapping the kinematics and ionization of extended ionized gas in active galaxies. High and low dispersion long-slit spectroscopy have been employed in conjunction with direct imaging in continuum and emission lines. The results have shown a variety of morphological and kinematic behaviors. In NGC 2110, the extended gas is rotating about the stellar minor axis, with a normal rotation curve, but the kinematic center is displaced from the peak of continuum and emission-line light (nucleus). The locations of the broadest [O III] and probably Hβ emission lines are also displaced from the light peak and the data are consistent with their location at the kinematic center. These effects may be related to obscuration, acceleration of off-nuclear gas by radio jets, dominance of the galaxy potential by unseen matter, or displacement of the black hole from the dynamical center of the galaxy. Several other galaxies are found to have their broad emission lines displaced from the nucleus. This is unlikely to be an obscuration effect in view of the excellent correspondence between the optical and radio nuclear positions. Full kinematic mapping of the galaxy NGC 5506 reveals double emission lines above and below the plane of the galaxy, which have been interpreted in terms of expansion or contraction in a conically shaped region with axis roughly perpendicular to the galaxy disk.

The first complete map of the kinematics of the Hα and [O III] emission lines over the inner region of NGC 1068 has been prepared. The distribution of line profiles is being modelled in terms of directed ejecta which drive radiative shock waves into the interstellar gas of the galaxy. In some galaxies a low ionization rotating disk of H II region ("starburst") is found in addition to the expanding or contracting high ionization gas. Particularly large differences in the velocity fields of these two components are found in NGC 7469, a Type 1 Seyfert with a luminous circumnuclear starburst.

J. Frogel (NOAO) observed 19 late-type spirals in the optical and infrared. Their UBVRJK colors and CO and H 0 indices were measured through an aperture of diameter 6.6 arc-sec. The overall result of the investigation is that there must be at least a highly composite stellar population present in the nuclei of the 19 galaxies. The optical light has a significant contribution from young stars with ages less than a few hundred Myr, while the infrared light is dominated by a much older population. These old stars appear to be similar to those in elliptical galaxies although there may be a sizeable contribution from luminous M stars such as those found in Magellanic Cloud clusters with ages of a few Gyr. A principal component analysis of the data showed the surprising result that there is no correlation between the UVB colors and the JHK ones. Also, the correlation of any color with absolute blue magnitude was weak. The star formation rate, averaged over the past 100 Myr, will be estimated from determining the UBVR colors. This rate, then, must vary considerably from galaxy to galaxy.
furthermore, it must be largely uncorrelated with the underlying old stellar population. This old population appears to be similar in all of the galaxies observed. The photometric data do not permit a significant contribution from old, metal-poor stars at any wavelength or for significant contribution to the infrared light from luminous carbon stars. There is evidence for considerable extinction—more than 1.5 mags in $A_V$ due to material in the immediate vicinity of the SCl nuclei. In many cases this extinction is greater than that which would be inferred from the inclination angle of the galaxy to the line of sight alone. The U-V and V-K colors of the nuclei of the SCl are much redder than those of regions somewhat further out. These color gradients are several times steeper than they are for early type galaxies.

B. Jarrett (NOAO) has completed a survey of box and peanut-shaped bulges from the SRF J and ESO B surveys south of declination $-18^\circ$. This study was prompted by recent theoretical interest in constructing self-consistent models for these types of bulges.

An observational program aimed at a detailed kinematical investigation of one of these galaxies, NGC 128, using long slit spectroscopy, is almost complete. Jarrett has also completed observations necessary for a quantitative comparison between the velocity dispersion determination for galaxies obtained from the infrared Ca triplet in the red and the more commonly used Mg b lines, Ca H and K, and G band, etc. in the blue. Analysis of the data is in progress.

2. Galactic Astronomy

Galactic Stars and Clusters: Continuing her research of southern galactic WR stars, V. Niemela (IAFE, Argentina) has also completed the study of the two WR + O binary systems. HD 63095 (jointly with P. Massey (NOAO) and P. Conti (U. of Colorado)—the only WC5 + O system known in our galaxy—turned out to be quite similar to WC5 + O binaries in the LMC. HD 94546 (jointly with C. Mandrini and R. Mendez (IAFE, Argentina)—a WN4 + O8 binary—was found to have low minimum masses for both components, probably due to a low orbital inclination.

280 cataloged visual binaries were observed and 30 more have been found by W. Heintz (Swarthmore). Emphasis is given to pairs in critical phases of their orbits, and to objects which have been unobserved for over 40 years.

V. Blanco (NOAO) continued his collaboration with H. Aaronson, K. Cook (U. of Arizona) and P. Schechter (Mt. Wilson and Las Campanas Observatory) for determining galactic kinematic properties by measuring radial velocities of distant carbon stars in selected galactic equatorial regions. A preliminary value of the product $2\sigma_{\theta}$, found from this study, where $A$ is Oort's constant of differential galactic rotation and $R_0$ is the distance to the galactic center, is $210 \pm 10$ km/s for stars at a distance of 1.5 kpc outside of galactocentric line-of-sight. With the collaboration of B. Blanco (NOAO), V. Blanco has initiated a search for RR Lyraes in two galactic bulge windows found respectively at $l = 0^\circ$ and $l = 359^\circ$; $b = -51^\circ$ and $b = -62^\circ$. V. Blanco also continued his survey of late M giants in various directions within the galactic bulge. The decrease in the total number of such stars with increasing angular distance from the galactic center fails to agree with de Vaucouleurs' $r^{1/4}$ law and suggests that a metallicity gradient within the galactic bulge is affecting the spectral classification of M giants. This gradient is in the sense of increasing metallicity as the galactic center is approached. In turn this causes the bulge giants to show later spectral types toward the galactic center.

G. da Costa (Yale U.), J. Norris (Mt. Stromlo and Siding Springs Observatory) and J. Villumsen (Princeton U.) have obtained spectra of six candidate blue stragglers in the globular cluster $\omega$ Centauri using the "2D-Flotti" photometric counting system on the CTIO 4-m telescope. The spectra cover the wavelength interval 3500–5000 and do not show any unusual characteristics. Radial velocities with a precision of better than 20 km/sec have been derived from these spectra and they indicate that all the blue stragglers are cluster members. Thus $\omega$ Cen joins $M3$ as the second globular cluster containing a confirmed blue straggler population. Particular attention was drawn to the blue straggler E39 which is also an ultrashort period Cepheid. Further observations of this star, and of the other two cluster candidates, should allow the intriguing possibility of determining the masses of these stars relative to that of the cluster RR Lyrae variables. Two faint ($M_v = +3$) blue horizontal branch stars were also confirmed as cluster members. This suggests that $\omega$ Cen is similar to such clusters as NGC 6752 and NGC 288 in having a discontinuous distribution of stars on the blue horizontal branch.

Based on the morphology of its giant branch, an [Fe/H] of $-0.9$ was determined for NGC 6712 by J. Frogel (NOAO). It is the most metal poor cluster found to date with a long period variable star that is more luminous than the top of the first ascent giant branch. Also it has two variables with colors that are significantly bluer for their luminosity than the rest of the giant branch. These are believed to be asymptotic giant branch stars in a rather transitory evolutionary state.

O. Ferrer, N. Morrell (La Plata, Argentina), and J. Sahade, (IAR), have completed a study of the close binary system V379 Centauri. The spectral type of the primary component turned out to be B4 V and not the published spectral type B9, which is the spectral type of the secondary component. Ferrer and Sahade have also detected in Ca II-K the secondary component to the close binary RS Sagittarii, on the basis of material secured with the CTIO 1.5-m coudé. Incipient emission at Hα has also been detected. In addition, Sahade and Ferrer find from spectroscopy on the close binary AU Monocerotis taken with the 1.5-m coudé...
that the behaviour of Hα confirms their previous findings. On the new material, emission intensity variations between February and December, 1984 have been detected. The analysis of the 1984 spectra of AU Mon is near completion.

D. Geisler (NOAO), using the CTIO 4-m echelle with the SIT Vifid, obtained high resolution (0.25 Å) red spectra of bright red giants in the metal-rich globular cluster 47 Tuc in order to examine detailed abundances in this prototypical and controversial cluster. The stars chosen were those already investigated with the echelle photographically several years earlier by Pilachowski, Cuntam, and Wallerstein and Costa, who derived [Fe/H] ≲ 1.0. Their low Fe abundances initiated the current controversy concerning absolute abundances in the metal-rich globular cluster population. The new spectra show that all of the giants have TiO absorption present in the same wavelength region as the previous studies, particularly the two very cool giants in the Pilachowski et al. sample. The TiO bands were not recognizable in the photographic spectra because they extend over several orders while each order had to be analyzed independently. Digital spectra, and the avoidance of the Singer camera, allow one to add all of the orders together and make visible large-scale features such as TiO bands. The presentation of TiO absorption in the spectra indicate that previous Fe abundance derivations are underestimated. Echelle CCD spectra have also been obtained by Geisler for warm giants in three other metal-rich globulars: NGC 6352, 6624, and 6637. These lie within only a few Kpc of the galactic center and are among the most metal-rich globulars known. A detailed abundance study will illuminate enrichment processes in the early inner disk of the Galaxy, and a comparison to coeval halo clusters should prove interesting. Geisler is also conducting an extensive photometric and spectroscopic investigation of old open clusters in the antecenter of the Galaxy. Washington photometry of giants in many of these clusters has been obtained to examine their metal content and to search for any CN or CH variations, which have been found in the metal-rich globular clusters they approximate. Low dispersion spectra, to measure radial velocities and further examine CN and CH properties in the giants, and high dispersion echelle spectra, to explore in detail chemical abundance patterns, have also been obtained.

Geisler, with H. Harris (Lowell Observ.) and R. Schommer (Rutgers U.) has employed the Washington photometric system to measure Fe and CN abundances in over 100 giants in 18 old open clusters in the Galaxy with approximately solar metal abundances. They have also improved the abundance calibrations of the M-T and C-M indices of the Washington system in the region -1.0 ≲ [Fe/H] ≲ 0.5. The M-T calibration is only slightly shifted from previous calibrations; while the C-M abundance calibration is revised downward by up to 0.25 dex for giants with solar and greater abundance.

D. Geisler has observed a number of late-type giants with Fe abundances in the range -4.5 ≲ [Fe/H] ≲ -0.5 in the Washington system. The new data permit a much-improved reexamination of the sensitivity of the Washington system to Fe and CN/CH abundances. The δ(C-M) index is shown to be very sensitive to Fe abundance throughout the entire abundance range. Indeed, its Fe sensitivity is comparable to or exceeds that of all other photometric or low resolution spectroscopic abundance indices at all metallicities. In view of the very broad bands employed, the δ(C-M) index offers, for many purposes, the best choice for an efficient, accurate and sensitive abundance index for normal late-type giants. The system can also differentiate CN- or CH-strong giants from normal giants, but not consistently. The new empirical calibrations yield [A/H] = -0.85 ± 0.15 for 47 Tuc, in good agreement with recent determinations.

Geisler has obtained Washington photometry for 88 stars in a sample of metal-rich globular clusters in the Galaxy. Temperatures, abundances, and membership criteria are determined. CN variations are confirmed in NGC 362, 54 and 671, and a possible CN-strong giant in M69 is identified. The derived cluster abundances are [A/H] = -0.9 for NGC 362, -1.45 for 54, and -0.6 for NGC 6352 and 669, -1.15 for NGC 6723, and -0.7 for M71, with an uncertainty of 0.1–0.15 dex. With the exception of NGC 362, these abundances are in very good agreement with Zinn's latest compilation based on low resolution spectroscopy and photometry.

D. McNamara (Brigham Young U.) secured observational data on BL Her variables that indicates a significant range in such physical parameters as surface gravity and element abundance. The variation in abundances comes as no surprise, but the variation in surface gravity is totally unexpected. Some stars with periods ≲13 have logg values similar to O9.5 RR Lyrae stars (i.e. logg 2.9); other stars for example 716 Oph with a period of 13 has a logg ~1.5. These data suggest strongly that the BL Her variables are not a homogeneous group of stars as was thought previously.

R. Williams, M. Phillips, and S. Heathcote (NOAO) have obtained spectrophotometric of cataclysmic variables (CVs) and low mass X-ray binaries (LMXRBs), and have determined the abundances of the accretion disks from the emission lines. They have found the LMXRBs and some recurrent novae to have consistently low hydrogen in the accreted material. They interpret this situation to be due to the growth of the white dwarf mass in close binaries when H becomes depleted in the secondary star, because nova outbursts cannot occur without H-burning. Since nova outbursts cause the ejection of accreted gas, the absence of outbursts leads to a mass increase of the WD, eventually requiring collapse into a neutron star, when M WD > 1.4M O. They have concluded that H-depletion in old novae eventually must lead to the formation of LMXRBs from CVs, through collapse of the white dwarf.
Williams and D. Lin (Lick Observ.) are considering the formation of emission lines in accretion disks in CVs, incorporating the Stark effect into their calculations. The observed line profiles of many eclipsing systems do not show the double-peak structure that should be caused by Keplerian motion of the accretion disk, and they believe that it may be washed out by intrinsic Stark broadening. Line profiles have been computed from time-dependent disk models of cataclysmics, and the relative line intensities and profiles show good agreement with observations. The relatively high disk densities that must pertain in order for the Stark effect to be important are a natural consequence of the low viscosity in the disks of dwarf novae between outbursts.

V. Blanco (NOAO) continued his survey of red giant stars in the Milky Way and nearby galaxies. In collaboration with M. McCarthy (Vatican Observ.) Blanco is preparing an atlas identifying carbon and M giants found in the Magellanic Clouds, with P. Schechter (Mt. Wilson and Las Campanas Observ.) and M. Aaronson (U. of Arizona), he has surveyed carbon stars in 13 relatively clear windows along the galactic equator. For some 600 such stars in the survey, radial velocities are being obtained in order to determine the galactic rotation curve beyond the solar circle. In addition, Blanco in collaboration with B. Blanco (NOAO) is surveying RR Lyrae variable stars in three galactic bulge windows. Besides playing a fundamental role in the accurate determination of the distance to the galactic center, these stars represent samples of the oldest stellar population that can be identified in the bulge.

J. Sahade (IAR), and A. Riguielet and Rotstein (La Plata, Argentina) are studying material obtained, at the CTIO 1.5-m coudé in December 1984, of the shell star HD 50845 and found changes in the appearance of Ha and in the intensity of some of the shell lines, relative to February 1984. Also Sahade, Bouvier, Riguielet, and Kondo have investigated the Be star Lambda Pavonis, on the basis of spectrograms secured at Bosque Alegre (1951-1953, 1962), Cerro Tololo (1981), and La Silla (1982) together with IUE images secured at the same time as the La Silla material. Regarding the ground-based spectra, we could point out that from 1962 on, the H double central emission reported previously has disappeared, and the absorption profiles of the H lines appear composite—a stellar component and a shell component superimposed.

O. Eggen (NOAO) completed a seven-year observing program of Cepheid variables and nonvariable supergiants and the resulting reports of this work constituted his Henry Norris Russell Lecture to the AAS in June 1985.

D. MacConnell (Michigan State U.), R. Wing (Ohio State U.), and E. Costa (U. de Chile) began a program of three-color, near-infrared photometry and CCD spectroscopy of several hundred galactic M supergiant candidate stars being found on near-IR objective-prism plates of low dispersion taken with the Curtis Schmidt telescope. Photometry of over 100 stars has been obtained on two nights using the CTIO 0.9-m and 1.5-m telescopes, and CCD spectra of 57 of these stars have also been taken with the CTIO 1-m telescope. Reductions of the bulk of this material are underway, but preliminary indications are that at least two dozen new M supergiants have been found, some of which are very heavily reddened. A few new S stars have also been discovered.

M. Aaronson, K. Cook (U. of Arizona), V. Blanco (NOAO), and P. Schechter (Mt. Wilson and Las Campanas Observ.) obtained Curtis Schmidt objective-prism plates for two new low latitude fields and CTIO 0.4-m JHK photometry for nearly 300 carbon stars. Velocities were obtained at Las Campanas for 100 of these, for a three-year total of nearly 200. A preliminary analysis of 87 of these yields a value for the product $2\Omega R_0$ of $210 \pm 10$ km/s for stars ranging in galactocentric distance from $R_0$ to 2.5 $R_0$. An apparent magnitude at K for the "typical" carbon star at a distance $R_0$ from the Sun, uncorrected for reddening, of $6.20 \pm 0.15$ was also obtained. A more thorough analysis is underway, which will allow for derivation from the linear rotation curve assumed in the preliminary analysis and which will account for small systematic errors introduced by the dispersions both in absolute magnitude and in radial velocity.

L. Celis (U. Catolica, Chile) has made extensive photometric observations in the near IR with the CTIO 0.6-m telescope of some 100 red stars, mostly giants.

B. Jarvis (NOAO) has completed a study of the dynamics of the galactic globular cluster Omega Cen using accurate radial velocity data for about 300 member stars. The results showed that the observed kinematics are consistent with Omega Cen being an oblate spheroid flattened by rotation and without significant velocity anisotropies.

R. Wing (Ohio State U.) has obtained eight-color classification photometry for 180 M giants in the direction of the South Galactic Pole. In addition to providing accurate spectral types, near-infrared bandpasses, and color temperatures, the data will show whether the oxygen/carbon ratio (for measures of T$_E$, T$_{10}$ strength, and CN strength) varies with distance below the galactic plane. This may indicate different degrees of mixing of processed material in stars of different populations (i.e., different masses).

J. Clarin and E. Lapasset (U. Cordoba, Argentina) completed a photometric UBV-DDO-CMT study of the giant branch of the open cluster NGC 2539. Their main conclusions are: (i) only seven red stars were found to have a high probability of being cluster giants; (ii) a reddening E(B-V) = 0.08 \pm 0.02; a distance modulus $V - M_V = 9.8 \pm 0.5$ mag, and an age of $(6.4 \pm 0.8) \times 10^8$ yr have been derived; (iii) a comparison among the different abundance indicators suggests the cluster giants to be slightly enriched in elements of the CNO-group; (iv) the cluster giants could have suffered mass loss during their red giant phase of evolution.
T. Kreidl (Lowell Observ.) carried out two projects with the CTIO 0.9-m reflector. The first involved monitoring HD 3326 and HD 4849 (both classified as, but probably not Ap stars) for metallicity variability. Both stars were found to be variable with periods very near to those previously reported. The second project concerned obtaining high-speed, time-series photometry of the rapidly oscillating Ap star HD 6532, which was recently discovered by D. Kurtz (U. of Cape Town). Kurtz and Kreidl have combined their data, totaling 44 hours, and derived a rotation period (P = 157858), as well as identified a frequency triplet with periods near 6.94 min, and a possible 14.28-min oscillation. H. Smith (Michigan State U.) and A. Wehau (U. of Western Ontario) used the CTIO 1.5-m telescope and SIT-vidicon detector to obtain spectra of red giant stars and RR Lyrae stars in the globular cluster M28. M28 was found to have a metal abundance of [Fe/H] = -1.1 ± 0.2 relative to the Sun, making it one of the most metal-rich globular clusters known to contain Cepheid variable stars. The red giant stars did not appear to have unusual CN or CH band strengths compared to those seen in other clusters of equal [Fe/H].

H. Smith (Michigan State U.) and L. Stryker (Dept. Terrestrial Magnetism) obtained low resolution SIT-vidicon spectra of three so-called "anomalous" Cepheids in the Sculptor dwarf galaxy. These spectra, obtained with the CTIO 4-m telescope, were used to estimate the metal abundances of these variables. The stars were found to be metal-poor, with [Fe/H] near -1.9. This low metal abundance agrees with that expected from the color of the Sculptor giant branch. Thus, in Sculptor—and perhaps unlike the case in Draco—giant branch color is a good predictor of metallicity.

S. Yorka and P. Keenan (Perkins Observ.) used the Cassegrain spectrograph on the CTIO 1.5-m telescope to extend the list of southern stars with accurate MK spectral types. Emphasis was placed on metal-rich giants of types G and K, which are to be included in a catalog that is now in preparation.

J. Tyson (Bell Labs.), P. Boeshar (Rider Coll.), and P. Seitzer (NOAO), have surveyed our galaxy in many directions using a CCD imager on the CTIO 4-m telescope. The technique can detect the intrinsically faintest stars out to a distance of 1200 light years. No such stars were seen. However, one would have expected to discover at least four-eight of these stars if they were the objects that accounted for predictions for the unseen or so-called "dark matter" comprising a large portion of the mass of the disk of our galaxy.

P. Charles and R. Corbet (Oxford U., England) and J. Thorstensen (Dartmouth U.) were able to find a definitive binary period for one of the most famous of the Galactic X-ray stars, 4U1753-44, which was the first X-ray burster to be observed bursting in the optical. They found a clear photometric modulation with a period of 4.6 Galactic Nebular and Interstellar

Material: G. Wallerstein (U. of Washington) obtained CTIO 4-m echelle spectra of heavily reddened stars near the center of the rho Ophiuchus molecular cloud. The data include molecular lines of CN, CH, and CNH, as well as atomic lines of Fe I and Fe II. The line intensities were analyzed by J. Cardelli (U. of Washington). For HD 147889 and HD 147701, it is necessary to fit the CN lines with a smaller turbulent velocity than the CH lines if we require that the population of the two CN levels be controlled by the microwave (Texc = 2.8 K) background. However, if the CN lines are fit to the CH curve of growth, we find Texc = 3.2 K, indicating an additional excitation source. The CH data for all four lines of sight are found to follow the relation N(CH) ∝ N(H2)3/2 shown by Pederman (1982) and Danks et al. (1984). For the lines of sight to HD 147701 and HD 147343, the relation N(CN) ∝ N(H2)3/2 as shown by Pederman et al. (1984) is extended to reddened stars, HD 147889 and HD 147648 (log N(H2) > 21), N(CN) is found to be "underabundant" by at least a factor ten. This also appears to be true for the highly reddened Taurus dark cloud star HD 29647 (Crutcher 1985), indicating that the chemistry of CN formation for high reddening (densities) is somewhat different. From the atomic data, ionization equilibrium considerations indicate that use of the attenuated diffuse radiation results in n_e = 0.4 cm^-3 from Ca II/Ca I, which is a factor five to ten larger than from Fe II/Fe I. Although this may in part be due to different line of sight distributions, we find that, due to the anomalously low extinction of Ophiuchus dust at λ 1600 Å (the location of the ionization edge of Fe), the diffuse radiation field underestimates the amount of ionizing flux penetrating the cloud by perhaps a factor of three or more. An examination of the depletion of Ca and Fe for these four lines of sight as well as for ρ Oph, χ Oph, and σ Sco seems to indicate a definite trend of increasing depletion with density. Wallerstein's measurements of the radial velocities of the interstellar lines show small differences among the species such as difference of only 1.0 km/s between CH and CH2.

S. Heathcote's (NOAO) primary research activity has involved combined observational and theoretical studies of the dynamics of the interstellar gas under a variety of circumstances. In one study a theoretical model has been constructed of the gas dynamics in the collimated bipolar outflow driven by a protostellar object. High dispersion echelle spectroscopy, low-dispersion spectrophotometry, and narrow-band images of several H-H objects believed to be associated with such outflows have also been obtained. In combination, this observational material permits a determination of the physical and kinematic conditions within the H-H shocks. Comparison with the predictions of the model should then provide insights into the nature of bipolar outflows and their driving sources. Heathcote has also
initiated a theoretical study of the effects of violent star formation observed in giant extragalactic H II regions and "star-burst" galactic nuclei. This work focusses on the interaction between such star bursts with the interstellar gas and consequent feed-back mechanisms which may control the formation of stars in subsequent generations. Future observations are planned to follow up on this theoretical initiative.

R. Taske (U. of Michigan) obtained photometrically calibrated CCD images of the eastern rim of the Puppis A supernova remnant coronal iron lines [Fe X] 6374 and [Fe XIV] 5303. The final frames are sums of 12 one-hr exposures, and have been calibrated, sky-subtracted, dereddened (with a column density of 4 x 10 cm) and Wiener filtered. The FWHM of faint star images is 2.5". Small-scale structure in the million-degree gas is seen down to scales of 5" (1.5 x 10 cm) in the Fe line pictures, and significant detail is seen at intensity levels below 30% of the night sky. The shock front in the intercloud medium is seen in the green 5303 line, but cannot be certainly seen in the red line, implying a shock speed V > 400 km/s. Evaporation of the "Eastern Knot" (Petre et al., 1982) has been tested by modelling the evaporative flow for a cloud like that seen in the pictures, predicting the surface brightness distributions of the coronal lines, and comparing the observed data. While the line intensity at cloud center and total brightnesses of the lines can be matched, the detailed intensity distributions cannot. Some aspects of the morphology of structures seen in the region in the Fe line pictures appear to be consistent with Heathcote and Brand's schematic model (1983) of interaction of a shock front with a spherical cloudlet.

J. Black (U. of Arizona), and E. van Dishoeck (Harvard U.) have used the CTIO 4-m telescope, echelle spectrograph, and a CCD detector to extend their survey of interstellar absorption lines of C2 and CN in the wavelength range 8750 - 9140 Å. During two clear nights in April 1985, spectra were obtained for 15 reddened stars at a resolving power of approximately 40000. Lines of interstellar C2 with equivalent widths as small as 2 m Å can be seen in the better of these spectra. Interstellar C2 shows detectable absorption arising in several excited rotational levels of the ground state toward many reddened stars, and the relative populations of these levels can be used as a diagnostic of temperature and density. Measurements of the column densities of C2 and CN and of their variation with extinction of interstellar clouds provide important tests of theories of interstellar molecule formation.

3. Solar System

J. Elliot, L. French and J. Kangas (Massachusetts Inst. of Technology), and J. Frogel (NOAO) observed two stellar occultations at 2.2 μm with the CTIO 4-m telescope last Spring. A first result of this work is a clear definition, for the first time, of the companion to the delta ring. It is located adjacent to the inner edge of the delta ring, has a peak optical depth of only 0.04, and is 10 km wide. Further analyses of the occultation data will be used to improve the orbits of the nine presently known rings.

F. Vilas (U. of Arizona) and L. Elowe (NOAO) observed a Neptune stellar occultation on the CTIO 0.9-m telescope. Although there was no occultation by the planet, the close approach of the star SAO 186001 to Neptune was photoelectrically observed on 22 July 1984 with the three-channel high speed photometer. Simultaneous observations of the appulse were carried out on two telescopes at ESO 100 kms to the north. All three experiments recorded a wedge-shaped signal drop at 5:40:09 UTC, for a total duration of about 1.2 sec. The Cerro Tololo occultation occurred 0.13 sec later than the ESO occultations, and the three-channel data confirm that it was a real celestial event, with the star signal declining while Neptune's signal remained constant.

M. A'Hearn, H. Campins and L. McFadden (U. of Maryland) studied Comet Neujmin I intensively. They were unable to detect any extended dust although gaseous emission was readily detected. Because of the unusual lack of dust, it was possible to observe the nucleus simultaneously in the optical and infrared. Significant brightness variations, probably periodic, are thought to be due to rotation of an elongated nucleus. At maximum light, the effective radius is a surprisingly large nine km and the geometric albedo py is a surprisingly low 0.2. The various observed properties are not consistent with those of any single asteroid.

F. Vilas (U. of Arizona and NASA) observed the narrow-band relative reflectance spectra of 17 outer-belt and main-belt (primarily D- and P-class) asteroids, and seven near-Earth and 3:1 Kirkwood gap asteroids using the CTIO 1.5-m telescope with a CCD spectrograph covering an approximate spectral range of 0.5 - 1.0 μm. The spectra of the outer-belt asteroids contributed to a study showing that these asteroids, whose orbits are locked into resonances or Lagrangian points by Jupiter's gravitational interaction, can be divided into four groups based upon distinct changes in slope. The slope changes increases with increasing heliocentric distance, and the spectra resemble laboratory spectra of organic polymer materials. Thus, these asteroids may be remnants of primitive solar system material. With L. McFadden (U. of Maryland), the surface mineralogical composition of the near-Earth asteroids and asteroids located near the 3:1 Kirkwood gap is being investigated for possible genetic links. Vilas also observed the reflectance spectrum of a portion of Mercury containing both smooth plains and intercrater plains using the CTIO 1.0-m telescope and a CCD spectrograph in the 0.53 - 1.02 μm spectral range. No mineralogical absorption features were observed, suggesting the absence of iron in crystalline form in the surface material. A reddened slope suggests that the surface primarily consists of agglutinates.
due to heavy micrometeoroid bombardment.
P. Wehinger and S. Wyckoff (Arizona State U.) and H. Spinrad (U. of California, Berkeley) succeeded in obtaining excellent long slit (4 arc-min) spectra of comet Halley. In the 4 Å resolution spectra, covering 3950 – 7050 Å, they detected important molecular ions in the plasma tail (CO+, H2O+). The measured molecular band strengths and related production rates (numbers of molecules/sec) will provide excellent constraints for determining the dominant ionization mechanism in the comet's atmosphere. The difficult search for H2O (neutral water) emission bands has resulted in several likely candidates in 6800 – 7300 Å region. However, further reductions of the data are needed before any definite identifications can be made. H2O is a parent molecule and these observations of it would be the first to map its spatial extent as it sublimates off the icy nucleus. Higher resolution spectra were obtained of the comet's tail and coma in the red (6800 – 7600 Å, λ = 1.0 Å) and in the blue (4200 – 4600 Å, λ = 0.5 Å) enabling them to measure band strengths and the spatial extent of H2O+, CO+, CH+, CH2+, NH3, and [O I].

CTIO observations of comet Halley in 1986 provided significant new information about the chemical composition and physical processes in comets, as well as insights into the formation and chemical evolution of the solar system. Moreover, the southern hemisphere post-perihelion spectroscopy of Halley provided a unique probe of the primordial abundances in the proto-solar nebula.

Tololo observations of comet Halley obtained after perihelion showed a remarkable increase in the amount of carbon monoxide, probably attributable to the exposure of pristine layers of the comet nucleus. At perihelion passage in February 1986 the measured sublimation rate of water ice from the nucleus, 4000 Kg/s, indicated a total erosion of several meters depth of the surface layers. Thus the high abundance of carbon monoxide in the CTIO data can probably be explained by the initial diffusion outward of the volatile ice, carbon monoxide, while the nucleus was slowly heated by the sun during the comet's inbound journey in 1984 – 1985. This means that only the post-perihelion observations (southern hemisphere) of Halley provide direct information on the primordial chemical composition of the nucleus.

Unique observations of comet Halley were also provided by Tololo observations during the time of the spacecraft encounters (Vega and Giotto) in March 1986. Nearly simultaneous ground-based spectrophotometric observations possible only from the southern hemisphere, were obtained with the CTIO 4-m. The data provide information on the global properties of the comet atmosphere, while the spacecraft data provide complementary "snapshot" information.

New chemical compounds in the comet atmosphere were detected in the Tololo data. The long slit spectroscopy revealed for the first time in the 4000 – 7000 Å region, the probable presence of CO2+ and the possible detection of H2O. These molecules represent more than 95% the volatile mass of the nucleus, and are thus important probes of the nucleus composition. Moreover, the H2O observations, if real, provide information for the first time on the spatial distribution of H2O as it sublimes from the nucleus.

During its closest approach to the earth 0.42 AU in April 1986, Comet Halley was observable only from the southern hemisphere (declination = -47°). Long-slit spectroscopy of the comet obtained in April was used to map the distribution of various molecular compounds at the highest possible spatial resolution (1'' = 290/km). The excellent seeing conditions at Tololo permitted full advantage to be taken of the comet's near-earth approach during the 1986 apparition.

The CTIO observers of comet Halley in March and April 1986 provided unique information on the abundances of H2O, CO, CO2 and CH4, all of which will provide vital constraints on models of the formation and evolution of the solar system.

V. NATIONAL SOLAR OBSERVATORY

A. Personnel

1. Staff Changes

Dr. Bernard Durney's status was changed from Associate Astronomer to Senior Scientist.
Dr. Alfred Healy's status was changed from Assistant Support Scientist to Senior Engineering Physicist.
Dr. John Leibacher's status was changed from Associate Astronomer to Astronomer with Tenure.

2. Long Term Visitors

Long-term visiting scientists (defined as staying for three months or more) included the following:
Chen Fang, Nanjing University, China
Karen Harvey, Solar Physics Research Corporation
You-ran Huang, Nanjing University, China
William Jeffrey, Harvard-Smithsonian Center for Astrophysics
Zhihuang Liu, Yunnan Observatory, Academia Sinica, China
Ciro Marmolino, Universita' di Napoli, Italy
Harry Ramsey, Lockheed Palo Alto Research Laboratory
Frank Recely, NOAA/Environmental Research Laboratory
Elizabeth Ribes, Observatoire de Meudon, France
Jagdev Singh, Indian Institute of Astrophysics
Kim Strander, High Altitude Observatory/NCAR
Zhenda Zhang, Nanjing University, China
Gisar von der Lubbe, Heidenheuer Institut für Sonnenphysik, Germany

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B. Research Highlights

1. Introduction

During the reporting period (1 October 1984 - 30 June 1986) a total of 191 observing programs were carried out at the National Solar Observatory; of these, 125 proposals (65%) were submitted by visiting astronomers, the balance of 66 proposals (35%) were submitted by observatory staff.

2. High Spectral Resolution Solar Studies

Solar granulation introduces wavelength shifts, the effect of which can be reduced by observing tangentially to the Sun's surface. J. LoPresto (Edinboro U.) and A. Pierce (NOAO) have observed the center to limb wavelengths of a number of strong lines on an absolute wavelength scale: Na 5896, Ca 4227, Fe 3969 Å are lines whose cores originate in high layers of the photosphere, presumably above the convection layers producing the 5-min oscillation. The predicted Einstein shift is 636 meters/sec. These lines show a small variation in wavelength center-to-limb. The limb value from a least square fit gives: Na 1.03 ± 0.03, Ca 1.03 ± 0.02 and Fe 1.03 ± 0.03 times the Einstein value.

M. Giampapa (NOAO), W-H Sun (U. of California, Los Angeles), and S. Worden (USAF) applied the "Robinson method" to solar disk magnetic features. Even under conditions of good seeing the observed magnetic field strength in plage and other non-spot regions is no more than about 100 gauss as deduced from Zeeman-splitting in visible light. However, we know from line-ratio techniques and from IR line-splitting that these fields are probably nearer 1,000 gauss and that the problem is inadequate spatial resolution; the magnetic features really occupy only a small fraction of the observed area. The Robinson method involves the detection of line broadening by Fourier analysis, as a function of the Zeeman Lande g factor and is particularly useful for stellar work where a large number of lines can contribute to improve detection sensitivity. Giampapa et al. have made FTS observation of solar disk features and then use Fourier analysis to deduce field strengths. Values of 1200 ± 270, 1020 ± 150, and 570 ± 100 gauss were found for sample plages. Small irregularities found in the reduction process indicated the existence of a possible strong field component at a level of 2.5 - 3 kilogauss. This work substantiates earlier findings of kilogauss fields for solar plage and provides a new method for the determination of filling factors for similar stellar surfaces.

J. Stenflo, S. Solanki (Institut für Astronomie) and J. Harvey (NOAO) have analyzed Stokes spectra of spatially-unresolved flux tubes. In May 1984 they observed ten solar regions, distributed across the solar disk, with the McMath Fourier Transform Spectrometer (FTS) over the spectrum range 4880 - 6000 Å. They analyzed a small subset of these data to explore their utility for studying magnetic flux tubes. A number of interesting conclusions regarding the structure of flux tubes has emerged. The center-to-limb variations of different Stokes line-ratio parameters, and the asymmetry between different components of a linearly-polarized spectrum line, suggest plausible decrease of flux tube field strength with height above the photosphere. Moreover, the temperature difference between the interior and exterior of the flux tubes, at the same optical depth, decreases with height. However, the correspondence between height (above the photosphere) and center-to-limb variation of the line profiles must be derived from future radiative transfer calculations. Stenflo et al. found that mass motions within flux tubes affect the amplitude and area asymmetry, as well as the Doppler shift of the Stokes "V" profile. The absence of a Doppler shift suggests that these mass motions are not stationary.

3. High Spatial Resolution Studies

In August, 1985, the Lockheed tuneable filter experiment (SOUP) aboard Spacelab 2 obtained several superb short sequences of granulation evolution throughout the seven-day flight. NOAO scientists observed the same solar regions with the solar telescopes at Kitt Peak and Sacramento Peak. Time series of magnetograms, spectra, and narrow-band filtergrams were taken. After the flight, G. Simon (USAF) and L. November (NOAO) analyzed granular flows in and near a sunspot, using a 27-min sequence of digital images acquired by the Spacelab instrument. Individual granulation images in this sequence show sub-arcsec white-light structures embedded between normal (e.g., 2-arcsec) granules. Previous ground-based observations in polarized light suggest these smaller structures are the foot-points of strong magnetic fields. November developed a computer technique for producing maps of the transverse motions of granules by cross-correlating succeeding images. Applying this technique, Simon and November found systematic outflows of granules from the vicinity of the observed sunspot. These flows carry the sub-arcsec structures (tentatively identified as magnetic fields) away from the spot, and result in the gradual shredding of the sunspot field. Similar motions have been observed previously, but never with the clarity of the Spacelab observations, which are entirely free of atmospheric "seeing." Granule speeds are typically 300 m/s in the annular region surrounding the penumbra, with one feature sooner 3000 m/s over 60s. Regions of apparent granule convergence have also been identified. Granules flow both inward and outward through the penumbra. The outward flow through the penumbra is also non-uniform, being distinctly faster at some positions on the perimeter.

K. Topka, R. Shine (Lockheed Res. Lab.), and J. Harvey (NOAO) studied a small, mature active region observed by the SOUP experiment. The digital data were processed through a filter designed to isolate small, bright features (facular points), which have angular dimensions at the resolution limit of the SOUP (~4 arc-sec). A comparison was made...
with the simultaneous NSO magnetogram from Kitt Peak which is seeing limited to several arc-sec. The result was, as might be expected from earlier work, a fairly good, but not outstanding, correlation between magnetic field strength in the photosphere and the areal density of facular points. The following results were obtained: (a) the areal density of facular points is about ten times greater inside the active region than outside; (b) the number of facular points for 5 x 5 arc-sec area ranges up to 26; (c) the areal density of facular points peaks at moderate magnetic field strength and then declines at stronger fields; (d) the average magnetic flux per facular point is \(8 \times 10^{17}\) maxwells, if all flux outside sunspots lies in points.

R. Falciani and L. Smaldone (Osservatorio Astrofisico di Arcetri-Firenze and Naples U.), used the Vacuum Tower at Sac Peak to study the fine structure of highly concentrated magnetic fields in the photosphere. They used the UBF to get monochromatic images in Hα, Hβ, N\_I – D2 and Mg-b1. Four days of data were obtained, and these data are now being analyzed. Photometric observations of magnetic faculae were carried out by P. Foukal (CRI) and T. Duvall (NASA) to study the temperature structure in slender magnetic flux tubes. Simultaneous observations in two narrow continuum passbands were used to measure a 20% lower temperature gradient in the facular atmosphere relative to the non-magnetic photosphere. This lower temperature gradient is consistent with the simplest explanation of excess facular brightness in terms of radiative heating. Extension of this technique to the IR is planned to provide a better test against non-thermal heating processes such as waves.

The decay of the small solar active region NOAA 4588 was observed with the simultaneous use of the Universal Birefringent Filter (UBF) and the Ca II K line filter on the Vacuum Tower Telescope by J. Garcia de la Rosa, M. Collados and M. Vazquez (Instituto de Astrofísica de Canarias). The UBF was tuned to the magnetic line 6102 producing a pair of oppositely polarized pictures recorded on photographic film. The subtraction of the two pictures allows us to obtain a high resolution magnetogram of the observed region. The reduction process is however very tedious and although preliminarily started at the NSO microphotometer it is presently being carried out at the PDS microdensitometer at the Instituto de Astrofísica de Canarias.

S. Keil (USAF) is producing a catalog of the effects of magnetic field on convective energy transport. Keil is trying to quantitatively classify the changes in convection as a function of field strength. The main tool for diagnosing convective changes is the change in line asymmetries in lines emerging from regions of differing field strength. This work complements attempts to measure changes in line asymmetry over a solar cycle and attempts to measure properties of convection in the solar atmosphere. Data was obtained from 9 – 13 November 1984, using the Sac Peak Tower and echelle spectrograph with film as a detector. The film has subsequently been digitized using the Sac Peak Fast Microphotometer. Two summer students, T. Roudie and E. Cambell, have helped to reduce the data. A third student, B. Kou, has helped analyze the data. The observations show that without very careful removal of the 5-min oscillations the difference in bisectors between magnetic and non-magnetic regions can be very misleading. Analysis of the observations indicate that less vigorous (small \(v\Delta t\)) corrective penetration occurs in the magnetic regions. However, the horizontal fluctuations in temperature and velocity persist to higher atmospheric levels in the magnetic regions. The program to study changes in line asymmetry between quiet and active regions was changed from using film for a detector to using two MDA arrays. This permitted Keil and C. Marmolino (Inst. of Experimental Physics) to scan a large area on the Sun and simultaneously obtain a magnetogram and line asymmetry map. During this period several active regions were identified and observed several times over a seven-day period. From the observation they plan to derive how the line asymmetries change with position in the disk, age of the active region as well as local field strength. Reduction of the data has just begun by Marmolino. The K I 7699 Å resonance line was added to the asymmetry study. One run (7 November 1985) was made of its center-to-limb behavior. Changes in the asymmetry of this line due to fields and convection are important to understand because this line is often used for studies of solar oscillations. Previous observers have reported an inverted c-shape for this line and a reverse behavior to other photospheric lines in going from quiet to active regions. Their observations do not confirm this picture.

K. Sivaraman (Indian Inst. of Astrophysics), and L. November (NOAO) have obtained several filtergrams of high quality in the Mg-b, line at the core as well as at four \(\Delta A\) positions within the line and in the continuum 2 Å away using the Image of the Sac Peak Vacuum Tower telescope and the universal birefringent filter. Along with these they have filtergrams in the Ca II K line and also on either wing of the magnetically sensitive line Fe I 6302.5. Their aim is to establish where the foot points of the sub-arc-sec intense magnetic structures within the supergranular network are located with reference to the photospheric granulation. November derived the magnetic pictures from the Fe I 6302.5 Å data which show the sub-arc-sec magnetic structures well. They propose to use these along with the Mg-b1 filtergrams and connect up the magnetic structures with the photospheric granulation. Sivaraman, and Karthyappa (Indian Inst. of Astrophysics), and W. Livingston and G. Ladd (NOAO) have obtained line profiles of several absorption lines in the range 3000 Å to 7000 Å with the McMath FTS during the Fall of 1983. These spectra have been obtained at different
positions along the equatorial and polar diameters ($\mu = 1.0; 0.5; 0.25; 0.125; 0.0635$; and 0.0313). The line asymmetries are caused by the blue shifted photons from the hot rising material of the solar granulation. They have very little polar line asymmetries and center-limb variation of 17 Fe I lines chosen from the large number of line profiles from the FTS spectra. They find a red shift in the differences between the polar and equatorial line shifts and interpret this residual red shift in the polar direction as a manifestation of a poleward meridional motion. Their main finding is that lines with central depths 70% - 90% show a weak meridional flow polewards around $\mu = 0.5$ which increases to larger values (40 m/sec) beyond $\mu = 0.3$. Out of the 17 lines, some are Zeeman sensitive and a few are non-Zeeman lines with Lande factor $g = 0$. They find that the poleward flow does not depend on the Lande factor of the lines.

J. Thomas (U. of Rochester) and B. Lites (High Altitude Observ.) measured umbral oscillations in sunspots in photospheric and chromospheric spectral lines with the Vacuum Tower telescope, echelle spectrograph, and multi-diode array. These measurements were made simultaneously with measurements of umbral oscillation in the transition region with the University of Victoria Space Instruments (UVSI) telescope aboard the Solar Maximum Mission (SMM) satellite, in collaboration with J. Gurman (NASA). These measurements show, for the first time, the structure of umbral oscillation from the photosphere up into the transition region and, as such, offer a new method of probing the temperature structure of the sunspot atmosphere. Thomas, Lites, and T. Abdelatif (U. of Rochester) completed the analysis of their observations of the interaction of solar $p$-modes in a sunspot, made at the tower telescope. The results show that a sunspot acts as a selective filter in admitting power from the $p$-modes at certain frequencies and wavelengths. There is also a shift of power to longer horizontal wavelengths in the sunspot.

The study of flux changes in small scale magnetic features was continued by P. Wilson (U. of Sydney) and G. Simon (USAF). Results are at present being analyzed in Sydney. Wilson has prepared a paper providing a theoretical model to account for these changes of the data and comparison with other lines such as He I 10830 Å, Ly alpha, and Mn 5394 Å is underway. Preliminary results show a strong correlation between the strength of 10830 Å and the K line while the weak photospheric lines formed deep in the atmosphere show no variation with chromospheric activity.

C. Zwaan and C. Schrijver (Sonnenborgh Observ. and Lab. for Space Res.) used the Mmacth telescope, its main spectrograph and the magnetograph for simultaneous measurement of the Ca II K line-core intensity, the intensity in the Ca II K line wings and the magnetic flux density across solar active regions. The purpose of this work is to calibrate the Ca II K line-core flux index as a diagnostic for stellar magnetic activity in terms of magnetic parameters, and, second, to derive a constraint of the theory of chromospheric heating.

At the Sac Peak Vacuum tower the routine program of measurements of the Fried seeing parameter $r_0$ was continued by P. Brandt (Kiepenheuer Institut für Sonnenphysik) and R. Smartt (NOAO). An analysis of 1276 measurements taken in the period June 1984 to January 1986 yields an average of $r_0 = 10.5$ cm, with 10% of the values exceeding an $r_0$ of 20 cm.

CCD observations of the short term fluctuations of the K1 T99 region were carried out by M. Vazquez (Instituto de Astrofísica de Canarias) in five positions on the solar disk. In order to estimate the spatial coherence of the correlation between the photospheric oscillations and the line asymmetries due to the high-spatial resolution of the data, we will try to study the height dependence of the granulation.

4. Solar Activity

During the six-day observational period of 28 June through 3 July 1985, C. Fang (U. of Nanjing) and W. Livingston (NOAO) made a series of photoelectric observations of the spectra of faculae and the quiet Sun, as well as some plages. The observations cover the line profiles of Hα, Hβ, Ca II K, H and the triplet lines at $\lambda$ 8490, $\lambda$ 8542 and $\lambda$ 8662. Four sets of center-limb variations in different lines, three sets of facula spectra and two sets of plage spectra were obtained in the condition of good seeing. Fortunately, there was a flare on 2 July 1985; a successful observation of the flare spectra in seven lines during the flare development was made.

In a recent study of small scale magnetic fields, the principal objective was to record changes in the structure of a decaying active region in the 10830 Å line with the Vacuum telescope at Kitt Peak and to concurrently observe cancelling features in the decaying active region with the video spectropolarimeter at Big Bear Solar Observatory. S. Livio (California Inst. of Technology) observed at Kitt Peak while co-investigator, S. Martin (California Inst. of Technology) observed at the Big Bear Solar Observ. from 10 - 13 February 1985. During the observing interval, Martin and observers, W. Marguette and R. Fear (Big Bear Solar Observ.) noted the formation of a group of sunspots in the network fields of the decaying active region. The sunspots were not associated with emergence of new magnetic flux as would be characterized by the growth of a new bipolar field in the magnetograms and arch filaments in Hα. It was tentatively concluded that the sunspots formed from the coalescence of the magnetic flux of the network.

During the period from 27 April 1985 to 1 May 1985, T. Metcalf (U. of California, San Diego) observed three flares with his Hα extreme wing observation setup which uses the Echelle spectrograph on the Sac Peak Vacuum telescope. The first flare occurred on 27 April and consisted of a very long
duration event with soft X-ray emission lasting for many hours. He obtained simultaneous observations with the SMM satellite around the peak of this event. The second flare occurred on 28 April and was an impulsive flare with a C2 soft X-ray classification. Unfortunately, due to intermittent clouds at Sac Peak, the Ha observations do not include the impulsive phase of this event. The final flare, with a C2 soft X-ray classification, occurred on 30 April. Excellent observations of this event were obtained at Sac Peak, and, as the SMM satellite also obtained good observations, it is expected that this flare will be particularly well in Metcalf's analysis. In addition to the flares, observations of the non-flaring active region were also obtained, also in conjunction with the SMM satellite. These active region observations were obtained for about one hour each on 28 April, 29 April, and 1 May. The observations on 1 May were particularly good as Sac Peak did not experience any interference by clouds on that date. R. Canfield (U. of California, San Diego), and Metcalf will correlate the observations of red shifts in the flaring Ha spectral profiles to blue shifted components in coronal lines detected by the X-ray Polychromator instrument aboard the SMM satellite. They will then use these correlations to test theoretical models of chromospheric evaporation whereby chromospheric material is heated to produce hot coronal plasma.

The Universal Spectrograph (USG) program, a monitoring program handled by L. Gilliam (NOAO), is run primarily on solar flares. Spectra from 3550 Å to 9000 Å and the corresponding Ha slit jaw images are obtained in this program. This was one of the Big Dome's most successful programs during the last solar cycle as spectra of several white light flares were obtained. The program has been run on only one or two occasions during the last two years as solar activity is very low. The Solar Flare Patrol (FLP) is operated daily from sunrise to approximately 2400 UT, weather permitting. During periods of high solar activity the FLP is operated to sunset. The picture rate ranges from one per minute during periods of low activity to twelve per minute during flares. Image size is 16 mm, and the filter bandpass is 0.5 Å centered on the Ha line. Prints for each day are sent to NOAA and HAO, and shortened image sections of the original negative film are sent to HAO and Klepenheuer-Institut. In addition the images are widely used as reference material by NOAA, AFGL, and visiting scientists. Another monitoring program, the White Light Patrol (WLP), is operated daily from sunrise to 2400 UT, weather permitting. During periods of high solar activity the WLP is operated to sunset. The picture rate ranges from one per ten minutes during periods of low solar activity to six per minute during solar flares. The solar image size is 14 mm, and the filter bandpass is approximately 200 Å centered at about 5600 Å. The White Light sunspot drawings are drawn by the observers each day, weather permitting. The image size is 20 cm. Sunspot groups are classified and the number of spots in each group is recorded. A NOAA numbering system is maintained and copies of the drawings are sent to numerous organizations. The NOAA Community Monitoring Program is run daily, weather permitting. Images in H, D3, and C4K are produced on the spectroheliograph using either the coronagraph or coelostat telescopes. The data derived from this program are sent daily to the World Data Ctr. at NOAA and to the Goddard Space Flight Ctr. where they are used for SMM program planning. The data, especially the CaK images, are widely used by NOAA, AFGL, and visiting scientists.

K. Harvey (Solar Physics Res. Corp.) using daily full-disk magnetograms and He I 10830 spectroheliograms from the Kitt Peak Vacuum telescope to study the count and distribution of ephemeral regions over the solar cycle, found that "dark points" seen in 10830 (thought to correspond to X-Ray bright points) were more often associated with magnetic bipoles that appeared to result from a "chance" encounter of existing opposite polarity magnetic flux than with emerging magnetic bipoles. Such encounters are more likely to occur in areas of mixed polarity; the fraction of the area of the Sun covered by mixed polarity fields varies anti-correlated with the solar cycle leading to a possible explanation for a similar solar cycle variation of X-ray bright points. To establish the validity of this supposition, a detailed study of time-sequence observations of selected areas of the quiet Sun was initiated about two years ago. Several observatories participated in the six observing efforts to obtain a wide range of data at various wavelengths. These include: National Solar Observatory - He I 10830 spectroheliograms (K. Harvey); Big Bear Solar Observatory - Magnetograms/longitudinal, Ha filtergrams/center line (F. Tang); Ottawa River Solar Observatory - Ha filtergrams through line (V. Giaubin); Marshall Space Flight Center - Magnetograms/longitudinal, Magnetograms/transverse (M. Haygard); Solar Maximum Mission, UVSP - C IV, Si II line profiles, He II intensity (A. Poland); Solar Maximum Mission, FCS - O VIII intensity (J. Saba, K. Strong); Swarthmore College - Ca II line profiles (R. Holt); Very Large Array (VLA) - 20 and 6 cm Ha images (S. Habbal). Spatial resolution of these data was one arc-sec (instrumental) for the He I 10830 data, one to three arc-sec for the Ha filtergrams and magnetograms, and ten arc-sec for the SMM UVSP and FCS and the VLA data. Temporal resolution was three minutes for the He I 10830, VLA cm λ and some Ha data and 5 - 25 min for the magnetograms and SMM data. Selected areas of the quiet Sun were observed for periods of four to ten hours each day. Data were obtained during the following observing periods: (1) 10 - 12 October 1983; (2) 28 November 1984; (3) 9 December 1984; (4) 25 - 28 May 1985; (5) 25 - 27 June 1985; (6) 8 - 9 September 1985; (7) 10 October 1985. One observing run was made by B. Lites and T. Brown (High Altitude Observ.) with the
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McMath Main and the FTS during March 1985. Scans of an active region near the limb (and at constant distance from the limb) were made of the spectral region 6000 - 7000 Å. The intent of these observations is to understand the behavior of temporal average line shifts and asymmetries in the presence of varying degrees of activity. It is hoped both to gain insight into the convective and steady flow processes which lead to the line shifts in the photosphere, and to find combinations of a few spectral lines which allow the systematic atmospheric effects of activity to be "calibrated" in future measurements made with the Fourier Tachometer. They are now in the process of analysis of these data, and have developed stable and accurate means for determining line bisectors for over 60 selected lines within this wavelength region; they are also able to simulate the Fourier Tachometer response for these lines and are beginning to look for systematic correlations of the line shifts. Since only one active region was observed near the limb, a second observing run will be carried out later to obtain additional data for other disk positions.

R. Altrock (USAF) observed coronal transients in Fe XIV with the Big Dome Three-Line Coronal Photometer. These observations occurred in collaboration with the SMM/CP CME (coronal mass ejection) Program at times determined by them and when coronal active regions were on the limb. The purpose is to analyze transient activity to yield information on causes, frequency, and relationship to CMEs.

5. Large-Scale Solar Phenomena

Several solar oscillation study programs were undertaken by staff and visitors at both Sacramento Peak and Kitt Peak by T. Brown (High Altitude Observ.), F. Hill (NOAO), T. Duvall (NASA/J), J. Harvey (NOAO), W. Jeffrey (Ctr. for Astrophysics), L. November (NOAO) and D. Rush (Johns Hopkins U.).

The coronograph monitoring program represented time spent with the coronagraph waiting for solar activity such as flares, loops and prominences. This is a lead-in program for the Big Dome standby and flare programs which have been highly successful in producing solar activity data. During these observing periods, the coronograph and its accessory equipment are in a constant state of readiness.

For the period 1 October 1984 to 30 September 1985, a total of 259 full disk magnetograms and 236 full disk 10830 Å spectroheliograms were recorded as part of the Kitt Peak Vacuum telescope synoptic program. A highlight of special observations made in addition to the regular full disk measurements was the acquisition of several hundred magnetic and Doppler measurements in support of the flight of Spacelab 2. The bibliography of papers using synoptic data stands at 26 and 34 papers respectively for 1984 and 1985 publication dates. More than 43 requests for data were answered during October 1984 - September 1985. In addition, regular observations were published in Solar Geophysical Data.

The Goddard laser heterodyne spectroscopy group—(D. Deming, F. Espenak, J. Goldstein, J. Hillman, T. Kostiuk and M. Mumma (GSFC), H. Kaufi (NAS/NRC), and D. Gleen (Colgate)—continued their laser heterodyne spectroscopy of the Sun and other objects. Stratospheric trace constituents were also studied by observing the Sun at large air mass. In June 1985 solar oscillations were measured using the laser heterodyne spectrometer to view a two arc-sec portion of the quiet Sun at disk center. Measurements were made of an 11.065 μm pure rotational line of OH, on two consecutive days. A power spectrum of the line velocity shows the well known 3 mHz oscillations very prominently, as well as a secondary oscillation at 4.3 mHz. A power spectrum of the line intensity shows only the 4.3 mHz feature, which is identified as the n=1 p-mode resonance of the solar chromosphere. Its prominence in the line intensity power spectrum is consistent with a nearly adiabatic response of the upper solar atmosphere, in contrast to the oscillations in the subphotospheric cavity, which propagate nearly isothermally. The frequency of the chromospheric mode is observed to be in essentially exact agreement with the locus of eigen-frequencies predicted by Ando and Otsuki for radial order n = 1. Since the mode frequency is directly related to the sound travel time across the chromosphere, this detection represents an important new constraint on chromospheric models. In December 1985 the laser heterodyne spectrometer was used to search for CO₂ emission from Comet Halley. No emission was detected, and this should allow the derivation of improved upper limits on the CO₂ content of the cometary nucleus. Also in December 1985, the trace constituent H₂O, was tentatively identified in large air mass solar spectra taken using the heterodyne technique. Analysis of infrared heterodyne measurements of C₂H₆ on Jupiter made by the McMath in 1982 and 1983 has been completed. Spatial variability of C₂H₆ mole fractions in the Jovian stratosphere has been determined. Significant variations of C₂H₆ have been observed in the north auroral region. Effects of vertical temperature and density profiles on the retrieved data were investigated.

The 40-cm coronagraph and universal spectrograph at Sacramento Peak were used by P. Foukal, C. Hoyt (CRL) and L. Gilliam (NOAO) to study electric fields and plasma structure in coronal loops and active prominences. It was found that the true local plasma densities measured in five loops and three active prominences by Balmer line Stark effect and by several line intensity ratios agreed quite well over the full density range 10⁸ < nₑ < 10¹². This agreement implies that macroscopic electric fields are not required to explain the Stark effect in these structures. However, a new technique of analyzing the Stark effect using polarization information obtained in recent USG spectra indicates the presence of a large-scale macroscopic electric field of intensity 10⁷ Volt/cm oriented transverse to

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the magnetic field in the loop. Such a field might be understood in terms of reconnection in the loop.

Foukal (CRI), L. Petro (AER) and W. Rosen (Vassar Col.) have carried out a regular program of limb-darkening observations at the McMath Main spectrograph since 1980. Their objective is to investigate possible slow changes in photospheric effective temperature over the solar cycle. Their data indicate that any real global 11m-darkening variations must be below their rms noise level of about 0.1%. Their study of the sensitivity of continuum limb-darkening to various temperature perturbations indicates that this corresponds to a constraint of about 3 K in ΔTeff or 0.007 for the local mixing length near the photosphere.

W. Livingston, J. Leibacher, L. Wallace, B. Gravena (NOAO), J. Singh (Indian Inst. for Astrophysics), O. White (Lazy FM Ranch) and Z. Liu (Yunnan Observv.), continued their monthly observations to define the spectrum variability of the Sun as a star. Although solar activity fell to a record low for the past eight years, with Ca K responding as expected, photospheric C5830 remained constant in depth and equivalent width. A tentative conclusion is that the temperature of the photospheric layers does not perceptibly respond to activity cycle conditions. However, photospheric Mn 5394 mimics Ca K, creating an unsolved puzzle.

J. LoPresto (Edinboro U.) and A. Pierce (NOAO) continued to obtain center-to-limb scans for the oxygen triplet at 7774 Å, Ha and Hb, using a hollow cathode and iodine comparison. They also obtained some limb scans in emission for the oxygen lines at times of good seeing. It is their intention to publish the center-to-limb behavior of the shifts for these lines, having already done so for a number of other fraunhofer lines. A high sensitivity differential photometer system, capable of recording spatial intensity variations on the solar disc of ~ 0.05% per arc-sec, has been used to form two dimensional differential images of the Sun. The resultant differential photohelograms cover a spatial area of 562.5 x 422 arc-sec on the solar disc and were produced by a slow (1 hr/picture) faster scan motion of the differential photometer detector. B. Seykora (East Carolina U.) recorded 30 such images with the coelostat at the Big Dome between 3 August and 16 August 1985. Each of the images (155 x 200 pixels) shows a high degree of structure, distributed uniformly over the solar disc, at a spatial scale of ~ 30,000 km. Previous measurements, one-dimensional vs. time, have shown this structure to have components which have life times > 10 hours. Investigation of the correlation between the two-dimensional differential photospheric images and the velocity fields as recorded from K-line spectrohelograms are in progress.

Observations of chromospheric emission from the full solar disk continued by O. White (Lazy FM Ranch), W. Livingston (NOAO), and Z. Liu (Yunnan Observv.) on a monthly basis, and the level of emission has dropped to values very close to those for solar minimum in 1976. The Ca II archive now contains spectra characteristic of a complete solar cycle. It is too early to declare Solar Cycle 21 finished, but solar activity is now at very low levels. The K-line data showed a sharp decline to minimum values in May 1984. This objective of low chromospheric emission continued for approximately six months before solar activity increased the flux levels again. With the Ca II archive being substantially complete, analysis of the data and comparison with other lines such as He I 10830 Å, Lya, and Mn 394 Å is underway. Preliminary results show a strong correlation between the strength of 10830 Å and the K-line while the weak photospheric lines formed deep in the atmosphere show no variation with chromospheric activity.

R. Altrock (USAF) and L. Gilliam (NOAO) observed the corona daily with the three-line coronal photometer at the Big Dome and reduced and archived the data. Recent data was used to produce daily coronal maps, which were telecopied or electronically transmitted to space forecasting centers. The archived data, extending back to 1974, are used to examine the solar cycle behavior at the corona.

R. Altrock (USAF) and L. Gilliam (NOAO) observed coronal line profiles, in Fe X, Fe XIV and Ca XV, in order to improve the knowledge of the widths and location of these lines. This will assist us in the set-up of the three-line coronal photometer.

W. Chiang and P. Foukal (AER) with the help of T. Duvall (NASA) and P. Recely (NOAA), obtained digital images using the Kitt Peak Vacuum Telescope. For these observations a 512-diode Reticon (TM) detector in the spectrometer focal plane sampled the λ 525.6 nm intensity of the solar surface along a segment which is approximately 1/4 of the solar diameter in length. Scans of 2048 X 512 samples were obtained covering an area extending slightly beyond the east and west limb and from the equator to 1/2 solar radius either north or south. Four scans were obtained north of the equator and four south of the equator during a two-hour interval on each of the 15 days of observations between 1 and 28 May 1985. Weather or instrumental malfunction prevented observations from being obtained on the remaining 13 days during this interval.

A second program at the Vacuum telescope was carried out by W. Chiang and L. Petro (AER), P. Foukal (CRI) and T. Duvall (NASA) on a photometric search for large-scale convection cells at the photosphere. It was found that any temperature variations due to solar convective scales between 8 x 10^5 km and 2.5 x 10^6 km are at a level below 0.25K rms. This temperature variation is consistent with (uncertain) models of temperature amplitudes in such convection, and imply a contribution of such convective scales to solar irradiance variation at a level below 3 x 10^-5.

D. Deming, D. Jennings and F. Espenak (NASA) and J. Brault (NOAO) continued their monitoring of the apparent velocity of integrated sunlight, using the McMath FTS.
These observations will reveal solar-cycle related changes in the solar convective blue shift. Observations were made of the $\Delta V = 2 \lambda$ CO features in the near infrared (2.3 μm), using a low pressure absorption cell of N$_2$O for wavenumber calibration. During the three-year period from 1983 through 1985 an approximately 30 meter/sec change has been observed in the convective blue shift, in the sense of a greater blue shift near solar minimum. If this effect is periodic with the solar cycle, it will mimic the Doppler reflex produced by an approximately 2-Jupiter-mass planetary companion. Understanding this effect is of importance for spectroscopic efforts to detect planetary companions to solar-type stars. The Goddard laser heterodyne spectroscopy group (M. Mumma, T. Kostiuk, J. Hillman, J. Goldstein, F. Espenak and D. Deming) started making similar measurements in June 1985, using the GSFC laser heterodyne instrument.

6. Solar-Stellar Studies

Mounting evidence suggests that magnetic fields are the primary cause of chromospheric and coronal activity seen in late-type stars. Direct measurements of field strengths and the fraction of the stellar surface they occupy (filling factors), however, are needed to understand the physical mechanisms behind the observed activity. S. Saar and J. Linsky (U. of Colorado) have been using the McMath echelle/Reticon system in two programs to study the magnetic parameters of G and K dwarfs. Some 50 stars have been observed at resolutions of 80,000 and S/N ~ 100 for the survey program, and are being analyzed for magnetic fields using improved line modeling techniques developed by Saar. Preliminary results indicate that the stellar filling factor is an increasing function of angular velocity and the magnetic field strength is a decreasing function of effective temperature. It is hoped that direct tests of stellar dynamo, rotational evolution, and atmospheric heating theories can be made using the results of this study. In the second program, time series of the magnetic fields and filling factors of a number of active dwarfs have been made in collaboration with M. Giampapa (NOAO). Simultaneous observations by D. Duncan (Mt. Wilson and Las Campanas Observ. and Space Telescope Sci. Inst.) of Ca II H and K fluxes were also taken. These data are being examined to look for rotational modulation and time variability of the active regions on these stars, and to study the detailed connection between chromospheric Ca II emission and the magnetic parameters. Preliminary results for the active K2 dwarf Epsilon Eridani shows that over a two month span in the Fall of 1984, the magnetic region field strength was roughly constant, while the filling factor varied by a factor of two, very roughly in phase with the Ca II flux.

Many synoptic observations of ζ Eri have resulted in four new types of transient events in this star. Many of these transients produce temporary bumps in the line profile (He I λ 6678) which obscure the bumps from the nonradial $\ell = 8$ mode in this star. Similarly, another type of transient mars the shape of the line profile, confusing the phasing and ephemeris of the dominant $\ell = 2$ mode. M. Smith (NOAO), G. Penrod (Lick Observ.), and A. Polidan (Ctr. for Space Sciences) believe these features are common in other Be and O stars, and their presence may explain the lack of firm detections of nonradial modes in stars hotter than spectral type OB.

M. Smith (NOAO) observed σ Scorpii on three observing runs and determined the active nonradial modes active on each occasion by detailed modeling of its line profiles.

J. Sowell (U. of Michigan) has analyzed Hα scans of yellow supergiants in open clusters taken with the stellar spectrograph and reticon detector. Two objectives were to measure radial velocities to test for cluster membership and to detect Hα emission, which would indicate the possibility of mass loss. Radial velocities for ten stars were determined via a cross-correlation code that compared the spectral scans of the program stars against those of IAU standards. A noteworthy Hα observation was of R Puppis (G2 Iab), for it showed an emission feature (rising above the continuum) between deep absorption lines.

S. Vogt, G. Penrod, and A. Hatzes (Lick Observ.) are in the process of deriving images of the spotted RS CVn star HR 1099 using their Doppler Imaging technique. Basically, high resolution high S/N spectral line profiles from a rapidly rotating star are mathematically inverted to derive the surface brightness distribution on the star, thus yielding an image of the spotted star. The bulk of the necessary spectroscopic data is being obtained with the Lick Observatory Shane 3-m telescope. However, restrictions on available observing time, and bad weather in the Fall/Winter of 1985 have impeded phase coverage for HR 1099 difficult to achieve. Without good phase coverage, the quality of the image suffers dramatically. In an effort to overcome phase coverage problems, Vogt and collaborators are supplementing the Lick data with McMath spectral data obtained contemporaneously. During the 1984 Fall/Winter quarter, a total of 15 spectra of HR 1099 were obtained on the McMath, with a largest phase gap of 0.1. For the 1985 Fall/Winter quarter, 18 spectra were obtained with a largest phase gap of 0.2. Though the McMath data are of somewhat lower resolution and S/N than the Lick 3-m data, they will help to fill in missing phases, and will provide consistency checks at other phases. Vogt and collaborators hope to obtain one image of HR 1099 every year to follow the appearance and migration of dark spots across the stellar surface for clues on cyclic dynamo processes at work in this star.

An experimental program was implemented by M. Giampapa (NOAO) to explore the feasibility of obtaining observations of the chromospheric Hα absorption line in a selected dMe (i.e., non-dMe) stars with the McMath Reticon system. The results indicated that
Ha observations of acceptable quality could be obtained with the 105-mm lens configuration. Glimpse has subsequently applied for time to acquire synoptic observations of the Ha line in a small sample of the Dm stars. This program was stimulated by a related paper by Giampaola with which he showed that the strength of the Ha absorption line in early-type stars is an indicator of the fractional area coverage of magnetic fields on these stars. If this is true then rotational modulation of the strength of this line should be seen as magnetic activity regions are carried by the rotation of the star in and out of our field of view.

In a recent paper published in the Astrophysical Journal, M. Giampaola (NOAO) suggested that the strength of the He I D line at 5876 Å should be indicative of the area coverage of magnetic plage-like regions on the surfaces of stars like the Sun. Therefore, a synoptic program was implemented at the McMath Reticon to detect the implied rotational modulation of this feature in a small sample of solar-type stars.

D. Martin (NOAO) obtained several high-resolution spectra of the Ca II H and K lines of AR Lacertae using the McMath Reticon system. These spectra were analyzed by J. Neff (U. of Colorado) in order to evaluate the potential the Ca II lines to construct Doppler images of the chromospheres of active RS CVn binaries. The spectra were inferior to those obtained with the coude feed and RCA CCD.

Observations of He I λ 5876 by the McMath have been used to define the onset of stellar activity. In a survey of early F-type stars, T. Simon (U. of Hawaii) find that He I λ 5876 is present in virtually all main sequence stars with colors in the range 0.28 - 0.30 < B - V < 0.42. The line strength is independent of age and rotation. This line is absent in hotter stars, and in cooler stars its strength shows the dependence on rotation and Rossby number that is characteristic of stellar dynamos. The ubiquity of activity in early F-type stars which have very shallow convection zones is surprising. Observations of X-ray and C IV emission support these conclusions about the systematic trends in stellar activity as a function of temperature.

The synoptic observations for a study of chromospheric activity and Li I resonance have been observed with the McMath Reticon. A preliminary analysis by M. Giampaola (NOAO) revealed no variability in the strength of the spot sensitive Li I resonance line at 6707 Å at the detection limit of about 5%. According to Giampaola, this roughly indicates that the area coverage of Sun-like spots on the solar-type stars observed during this program must be less than about 15%. Giampaola has applied for an expansion of this program to RS Canum Venaticorum stars. These active binary systems are believed to have large spots (30% area coverage) on their surfaces.

Recently, M. Giampaola (NOAO) has shown how high quality, unpolarized infrared data acquired with the McMath FTS can be used to measure solar magnetic field strengths. The present program is an extension of this work performed by Giampaola in collaboration with W.-H. Sun (U. of California, Los Angeles) and S. Worden (USAF). In particular, the methods described in this paper will be applied to determine the empirical correlation between magnetic field strengths and chromospheric Ca II emission in magnetic active regions of the Sun. The results will have significant impact for the understanding of the relationship between stellar chromospheric emissions and stellar magnetic fields.

J. Caustad (Swarthmore Col.) obtained spectra of 35 K and M Giants in the 5600 Å region in order to determine how the B (0,0) band of TiO changes with temperature. Using these observations to calibrate similar spectra of 4 Orionis taken at Swarthmore Col. over the past two years, he has shown that the surface temperature of Betelgeuse changes in step with its brightness changes.

L. Goldberg, M. Smith and D. Martin (NOAO) have been getting a great deal of radial velocity (RV) data for some red supergiants during the past year. A portion has been reduced to date and a computer program has been written that will eventually be used to compute RVs relative to the program stars.

In order to test model predictions of a chromospheric activity (rather than subphotospheric) p-mode with a period of approximately two hours, J. Gurman (NASA) and J. Leibacher (NOAO) obtained time series of the Ca II H and K line profiles from the late G giant β Ceti (HD 4128) with the stellar spectrograph and McMath telescope. In a trial run in December 1984, time series of approximately five hours duration were obtained on two nights. The Ca II emission core intensities normalized to the total intensity in the ~150 Å reticon bandpass to remove seeing and transparency variations, show indications of oscillatory changes on time scales of ~ two hours. Longer time series are needed, however, to determine whether the apparent variation is both real and periodic.

Bing the largest telescope in the world without central obstruction, the McMath telescope is highly suited to high angular resolution observations with pupil-plane interferometers. Although the telescope is not large enough to resolve stellar disks, it is large enough to resolve close circumstellar dust shells which have been shown to scatter an appreciable amount of light around cool supergiants. Such observations were carried out in 1982 by C. Roddier and F. Roddier (NOAO), P. Nisenson, R. Stachnick, M. Karavkova (Cr. for Astrophysics) and J. Roland (U. of Arizona), on Orionis showing clearly a time evolution of the dust envelope. They also led to the discovery of a faint stellar companion about 0.5-inches apart from the main star. These observations suggested that a second closer companion might also be present and explain both past observations of bright structures previously thought to be on the disk, and polarization effects. Existence of both companions was recently confirmed from speckle data at Harvard.
Three nights were allocated in February 1985 among which two were totally cloudy. A new system using an intensified CCD camera was operated for the first time and good engineering data were obtained on the only remaining night. This was not sufficient to yield any significant new astronomical results.

7. Laboratory Spectroscopy

High quality infrared spectra for H$_2$CO, HCN and PH$_3$ were obtained by S. Kukolich, J. Choe, T. Tipton, and R. Bumgarner (U. of Arizona) using the 6-m multipass White cell and the McMath FTS. All of these molecules are of astrophysical interest. The high sensitivity of this system allowed measurements on isotope bands in natural abundance and new high resolution work on some hot bands. In the 3300 cm$^{-1}$ region, six bands of HCN, four bands of H$_3^1$CN and two bands of H$_3^2$N were analyzed to obtain band origins, rotational constants and $z$-doubling constants. Hot bands with one and two quanta of excitation in $v_3$ were measured and analyzed at high resolution for the first time. FT spectra for H$_2$CO were obtained for the 1500 to 5400 cm$^{-1}$ range. New high resolution spectra for 3 $v_3$ (1577.761 cm$^{-1}$), 2 $v_3 + v_2$ (4734.193 cm$^{-1}$) and $v_2 + v_5$ (4555.102 cm$^{-1}$) bands were recorded and analyzed. Very precise rotational and distortion constants were obtained for excited states. The 2 $v_3$ overtone, and $v_2 + v_5$ combination bands of PH$_3$ were investigated at high resolution for the first time, 400 transitions were fit with a standard deviation of 0.05 cm$^{-1}$ to obtain excited state rotational parameters and vibration frequencies. Accurate ground state data had been available previously, but now we have excited state rotational constants accurate to 0.0001 cm$^{-1}$ and many more distortion and $z$-doubling constants. This work was also intended as an aid to astronomers who have obtained PH$_3$ data in the 1900 - 2200 cm$^{-1}$ frequency range.

Two new sets of experiments were carried out by S. Kukolich, J. Choe, D. Ogley, R. Bumgarner, and S. Harvey (U. of Arizona). A molecular beam absorption cell was constructed and tested with simple molecules. Spectra were successfully observed for OCS, and N$_2$O, but not for NH$_3$. The purpose of this experiment was to demonstrate cooling of the beam so that complexes may be produced for study and the spectra of larger, individual molecules can be simplified considerably. In the second set of experiments, a gas discharge tube was used to obtain spectra of radicals and molecules in various excited states. Emission spectra were obtained by analyzing. We have observed spectra for NF$_3$, NF$_2$, CO electronic transitions and other molecules.

J. Lawler and co-workers (U. of Wisconsin) are developing and applying techniques for measuring accurate (5%) transition probabilities for the elements in low stages of ionization. This basic spectroscopic work supports ongoing solar and stellar abundance studies. Radiative lifetimes are measured using time-resolved laser-induced fluorescence on atom and ion beams. Such lifetime measurements are free from systematic errors which have traditionally plagued lifetime measurements. Branching ratios are measured by recording emission spectra using the 1.0-m FTS. The FTS is the best instrument in the world for spectrophotometry on complex atoms and ions. Extensive emission spectra of Rh, Nb, Hf, Ta, W and Re have been recorded in recent observing runs. The Rh spectra were analyzed first and branching ratios were determined. The branching ratios have been combined with earlier lifetime measurements to produce reliable absolute transition probabilities. The analysis of the Hf and Rh data is also complete. Infrared branches are important from some Hf levels. A laser technique for testing the completeness of emission branching was developed.

V. Malathy Devi (Col. of William and Mary), C. Rinsland, M. Smith and C. Solomon (NASA) in collaboration with J.-M. Fland and C. Camy-Peyret (LAb. de Physique Moleculaire) have recorded several high-resolution spectra of methane, ozone and its various isotopic species in the 600 - 6000 cm$^{-1}$ spectral region using the high-resolution McMath FTS. These spectra were recorded in order to obtain various molecular parameters useful for the analysis of high-resolution solar absorption spectra and in the application of infrared remote sensing experiments.

A total of 28 spectra covering the $v_4$ and $v_5$ bands of methane (CH$_4$) were recorded by C. Rinsland and M. Smith (NASA) and V. Malathy Devi (Col. of William and Mary) using dilute (1 - 2.5%) mixtures of CH$_4$ in dry air and CH$_4$ in N$_2$. These spectra are being analyzed to determine N$_2$- and air-broadened halfwidths and pressure-induced shifts for individual transitions in both bands.

The intent of the study performed by K. Roth and L. Brow (Jet Propulsion Lab.) was to obtain laboratory spectra of the HDO and OCS molecules using the FTS, however, the molecules observed during this observation period were of CO$_2$ and N$_2$O. The data covered the 2200 to 9355 cm$^{-1}$ region for N$_2$O and 1650 to 5690 for CO$_2$. These spectra will be analyzed at the Jet Propulsion Laboratory and results from this study will aid in the analysis of atmospheric spectra in the above noted spectral regions.

W. Whaling (California Inst. of Technology) has been measuring oscillator strengths in Vanadium I and II to see if the solar models predict the correct ratio in the photospheric V I/ V II. The V I work is complete. For V II, oscillator strengths have been measured for emission lines from the $z^2$G and $z^2$F levels, and work on the $z^2$P, $z^2$G, $z^2$D levels is in progress.

In support of a study by J. Brault (NOAO) of the inductively coupled plasma as a spectroscopic light source, Whaling and J. Lawler (Wisconsin) have measured 135 oscillator strengths in Molybdenum. This work is currently being extended to cover many hundred additional lines in Mo I. Whaling is
using the ICP source to measure oscillator strengths in Fe II.

G. Bell (Harvey Mudd Col.) has been exploiting the high resolution of the FTS to study line profiles from the hollow-cathode spectral source. The goal of this work is to measure relative oscillator strengths in absorption, by comparing the self-absorption of two emission lines that go to the same lower level. Preliminary results in Fe II are quite encouraging.

P. Bernath, C. Brazier, R. Ram (U. of Arizona) and J. Brault (NOAO) observed the high-resolution laboratory spectra of a number of free radicals of astrophysical interest. The molecules observed include CP, PH, C2H, and CH2N.

The McMath FTS was used to record laboratory absorption spectra of molecules thought to appear in planetary atmospheres; participating in this investigation were L. Brown and R. Toth (Jet Propulsion Lab.). A total of 16 molecules were used and included CO2, H2O, HOBr, CH2, CCP, CP2, CC2, C2H2, CH2, CH2, N2O, CN, OCS, and CO2. Most of these were scanned in the 16 to 5 μm region of the infrared. These data were used as reference spectra for the analysis of remote-sensing data recorded by the ATMOS (Atmospheric Trace Molecule Spectroscopy) project from onboard the space shuttle. Molecular line parameters of the freons and CO2, obtained from these lab data, were particularly important in the interpretation of the ATMOS data. Additional detailed studies were undertaken to improve the molecular database for CO2 and HOBr near 10 μm. The latter species was included to support ongoing research to understand the role of bromine in the ozone depletion in the earth's atmosphere.

Observations of the rotational states of several vibrational-electronic bands of the methylidene (CH2) radical were obtained by P. Carrick (Mississippi State U.), P. Engeling (U. of Oregon), P. Bernath, R. Ram, and C. Brazier (U. of Arizona) using the FTS. A corona excited supersonic expansion source was employed to produce CH2 in rotationally cooled, vibrationally hot states. Emission of the 3P - 2P3/2 electronic transition was then detected with the FTS.

Observations of absorption spectra of the violet and red systems of CN, using the Sun's radiation as a background were performed by S. Davis, D. Shortenhour (U. of California, Berkeley) and R. Engleman (Los Alamos National Lab.).

C. De Bergh (Observatoire de Meudon) and J. Brault and R. Hubbard (NOAO) recorded in March 1985 a few spectra of methane near 6200 Å and 6825 Å with the FTS. The spectra were recorded at high spectral resolution (0.02 cm⁻¹), for a long path in the gas (434-m) and as low as possible (between 10 and 40 Torr). By combining these data with spectra recorded during previous runs at Kitt Peak and with spectra recorded at low temperature in other laboratories and with different techniques, it has been possible to assign rotationally several dozens of lines of methane, especially in the 6200 Å spectral range. These assignments are presently used to improve the interpretation of spectra of the giant planets and titan in the visible.

As part of a thorough investigation on the laboratory emission spectrum of neutral titanium, Ti I, recordings were made by P. Forsberg and S. Johansson (U. of Lund) on the McMath FTS in the region 1 - 2 μm. Together with earlier recordings on the same facility the FTS data extends from 0.3 μm up to 5.5 μm. Below 0.3 μm, spectra have been obtained with the 10.7-m Eagle spectrophotograph at National Bureau of Standards, Washington D. C. So far the analysis has resulted in some 50 new energy levels, mainly in the 4d and 5p configurations. Re-identification of transitions has forced a revision of certain tabulated energy levels, leading to changes by up to 2000 cm⁻¹. Finally, the high precision and resolution of the FTS instrument has resulted in corrections of tabulated levels by, in some cases, up to 0.3 cm⁻¹. Currently the line list comprises some 3000 identified transitions. In connection with this major investigation, some work has been done on the absorption spectrum in the region 1900 Å - 2315 Å. The energy levels for the lines found in that investigation have been determined to a high precision with the aid of transitions in the infrared, measured with the FTS instrument.

W. Huber, U. Paulus (ETH Zurich) and N. Grevesse (Institute d'Astrophysique) have used the McMath FTS for laboratory studies of the Fe II spectrum. The aim was to measure branching ratios of a few very weak Fe II transitions (with probabilities, A < 10⁴ s⁻¹).

The interpretation of the respective solar absorption lines will result in an accurate iron-abundance that is independent of line-profile parameters and insensitive to both, uncertainties in the ionization equilibrium and deviations from local thermal equilibrium. The measurements took advantage of the high throughput of the FTS and employed about 2-mm wide filters to enhance the S/N ratio in the spectrum. Additional data for the radiometric calibrations of the FTS at wavelengths below 300 nm were also obtained. The method used is an extension of the frequently-employed FTS calibration which makes use of "families" of rare-gas lines with common upper levels and known branching ratios. The existing AR data were extended towards shorter wavelengths by the use of Kr, which has many suitable lines below 300 nm, as carrier gas in the discharge under investigation. Complementary laboratory studies on both, the Fe II and the Kr spectra are currently in progress with the radiometrically calibrated 3-m grating spectrometer at ETH Zurich.

J. Hillman and D. Jenkins (NASA) recorded infrared spectra of several planetary gases at reduced temperatures using the McMath FTS. They used an absorption cell operated on a closed-cycle refrigerator to achieve sample temperatures of 140 to 180. Low temperature spectra of ethane, propane, and ethylene were obtained, along with ethane broadened by H2.
D. Jennings (NASA), A. Weber (NBS), and J. Brault (NOAO) used the FTS to record Raman spectra of H₂ and D₂ mixtures. The high rotational temperature produced in the flame made possible the detection of several new pure rotational lines in the two species. This is the only FTS in the world which has been used successfully in Raman spectroscopy.

T. Kostiuk, H. Humma, and J. Paris (NASA) used the McMath FTS in the double pass configuration to measure the ortho/para ratio of H₂ from 600 to 1400 cm⁻¹ at 0.0025 cm⁻¹ resolution in a laboratory gas cell. Intensities and frequencies of lines in the 1-0 band of ³⁵ClO and ³⁷ClO near 850 cm⁻¹ are being extracted from the data. A search for spectra of vibrationally excited species is also being conducted. These results can have significant impact on remote infrared investigations of the chlorine cycle for the destruction of stratospheric ozone.

8. Solar System Studies

F. Roessler, F. Scherb, K. Magee, R. Reynolds and J. Harlander (U. of Wisconsin) conducted observations of Comet Halley using the McMath west auxiliary. There were four main objectives of this program. (1) To study the interaction of the solar wind with the comet's plasma. The method employed uses a Fabry-Perot spectrometer to obtain high spectral resolution observations of comet H₂O⁺ emissions in the coma and along the ion tail during each night of observing. Information about the density distributions, and velocities of the comet's ions is obtained from the intensities, profiles, and Doppler shifts of the H₂O⁺ emission lines. For example, tailward accelerations of the comet's ions can be obtained from the variation of Doppler shift of the ion emissions along the tail. (2) To measure the production rate of atomic hydrogen over such a range of heliocentric distances as possible, both pre-perihelion and post-perihelion, from observations of Balmer α (Hα) emissions from the hydrogen cloud surrounding the comet. The hydrogen production rate can be used to determine the comet production rate of gaseous water (H₂O). The heliocentric variation of H₂O production rate is an important aspect of the evolution of the comet during its passage through the inner solar system. (3) To measure the production rate on metastable (¹D) oxygen atoms over a large range of heliocentric distances, both pre-perihelion and post-perihelion, from observations of comet O I 6300 Å emissions. The O(¹D) production rate can be compared with the H₂O production rate (obtained from our Hα observations) to see if the ratio of these rates varies with heliocentric distance. Previous studies have suggested that the ratio seems to be constant in a sample of several comets observed before the present apparition of Comet Halley. (4) To compare our values of the comet O I 6300 Å production rate obtained from our Hα observations with the corresponding rates inferred from satellite UV and ground-based observations of the OH molecule. It will be important to investigate discrepancies that arise among these different techniques for measuring the H₂O production rate. Approximately five hundred Fabry-Perot scans of H₂O⁺, H₂, and [O I] emissions from comet Halley, Hartley-Good, and Theile have been obtained at Kitt Peak in November, December and January. The analysis of the data is in a very early stage, but preliminary results have been obtained on the production rate Q(H) of hydrogen, Q(¹D) of metastable oxygen, and Q(H₂O) of water. The rate Q(H) varied with heliocentric distance, R as R to the power -3.5 ± 0.5. The rate Q(¹D) varied as R to the power -4.8 ± 0.1. The ratio of Q(H₂O) to Q(¹D) was 15 ± 5.

A. Potter (NASA) and T. Morgan (Southwestern U.) measured resonance emission lines of sodium vapor in the atmosphere of Mercury, using the vacuum spectrometer of the McMath solar telescope. A 244 x 248 CID silicon diode array was used to obtain image data in which the vertical dimension was distance along the spectrograph slit, and the horizontal dimension was the spectrum at each point along the slit. Measurements were made with the slit aligned north-south and east-west on the planet to determine the distribution of sodium emission over the planet along these directions. The average abundance of sodium on Mercury was found to be about 1 x 10¹¹ atoms cm⁻² column. The detailed spatial distribution of sodium is still being analyzed. In addition to sodium measurements, a search was done for emissions from ionized calcium and neutral potassium. Results for ionized calcium were inconclusive, but potassium was detected. The abundance of potassium was found to be about 1% of the abundance of sodium. This ratio of potassium to sodium is significantly less than the cosmic abundance ratio, and may reflect a greater loss rate of potassium relative to sodium from the planet.

VI. ADVANCED DEVELOPMENT PROGRAM

The Advanced Development Program (ADP) is responsible for development of the National New Technology Telescope (NNTT) and the optics and instrumentation that will advance the technology of telescopes in general. Toward these ends, the scientific and engineering staffs have continued to work together closely. The planning of telescope technology is an iterative process in which the astronomical goals and the engineering realities are both vital. For example, the scientific priorities for the NNTT have given rise to an initial list of high-priority instruments, whose specifications in turn have played an important role in the design of the telescope itself. At the same time, it has become apparent that adaptive optics will be important to achieving the full potential of large telescopes. The best possible imaging also demands optical components that are accurately figured, properly supported, and uniform in temperature. The technological requirements tend to be interrelated.
Many of the technology developments will see early application on existing telescopes: adaptive optics, optical testing techniques, mirror development, fiber optics, site testing methods, and atmospheric phase have broad applicability in astronomy. While the NTT is the most obvious goal of the ADP, many other projects are being accomplished as prerequisites.

A. Personnel

1. Staff Changes

Dr. Peter Eisenhardt was hired as a Research Associate upon completion of his doctoral degree at the University of Arizona.

Dr. Larry Goad transferred from NOAO/KPNO to NOAA/ADP as an Associate Support Scientist.

Dr. Claude Roodier, who had been a long-term visiting scientist, was appointed as a Scientist.

2. Long-Term Visiting Scientists (defined as staying for three months or more) include the following:


B. Research Highlights

K. Merrill (NOAO), in collaboration with R. Joyce, K. Gillies and F. Gillett (NOAO), continued synoptic infrared photometry as a part of a long-term program to systematically monitor the infrared (1 - 20 \mu m) light curves of a sample of compact infrared sources known to be embedded in dense circumstellar envelopes. The goal is to ascertain the scale, amplitude, and nature of their variability. Included in the study group are OH/IR M-type stars, C-type stars, proto-planetary nebulae, and well-known protostellar objects. Several luminous objects undergoing extreme mass loss (e.g., GL230, GL2205, GL2885) appear to have periods on the order of 1600 days, well outside the classical Mira range. The well-studied carbon star IRAS10216, in addition to its 640-day period, has shown a gradual systematic decrease in brightness at shorter wavelengths, indicative of either a long-term secular decline or an underlying very long period oscillation. The magnitude of this apparent secular decline decreases with wavelength, from a factor of two at 2.2 \mu m to little or no apparent variation at 10 \mu m. When combined with observations in the literature, the resultant database should be a valuable asset in the study of stellar evolution and mass loss in luminous stars. The number of known objects belonging to the categories studied here should be substantially increased as a result of the IRAS sky map, and stars with even colder circumstellar shells than those found in prior IR surveys are now known.

Because of their old stellar population and freedom from dust, gas, and interactions, isolated ellipticals are potentially the simplest type of galaxy to understand. As part of a program to obtain basic observational data on these objects, P. Eisenhardt and J. Frogel (NOAO) have been studying the color-luminosity relation in elliptical galaxies as a function of environment. They used the KPNO 1.3-m telescope to obtain JHK photometry of isolated ellipticals from the Karachentseva (1973) catalog. Eisenhardt has also collaborated with R. Cutri (U. of Arizona) to obtain ten-micron photometry at the IRTF, and with M. Rieke and R. Leach to obtain optical and IR images of isolated ellipticals. These data will be combined to generate optical-IR colors and maps for comparison with similar data for ellipticals in rich clusters such as Coma.

Eisenhardt and R. Davies (NOAO) are investigating the nature and reality of the very red (I-H) (0.8 - 1.6 \mu m) colors reported in Eisenhardt's (1984) thesis for low and moderate redshift giant elliptical galaxies. They have recently obtained red spectrophotometry of 10 such galaxies, and many fainter galaxies in the associated clusters, using multi-aperture plates with the cryogenic camera on the KPNO 4-m. When reduced, these spectra will show whether the I region is in fact fainter than previously thought, and whether the apparent variation in this region from one galaxy to the next can be attributed to, for example, differing carbon star populations.

In collaboration with R. Schild (Ctr. for Astrophysics) and M. Rieke, Eisenhardt is investigating the spatial distribution of excess blue light observed in first-ranked cluster and radio galaxies with z > 0.4. Using a CCD on the MMT, they observed four such galaxies in (photographic) J and K, and in a narrow filter centered on redshifted [0 II] 3727. This was the first use of the MMT to obtain optical images with autoguiding and autostacking, and stellar images less than one arc-sec FWHM were obtained in 20-min exposures. One of the galaxies, 3C368, shows very prominent extended 3727 emission, and bears little resemblance to an elliptical galaxy.

J. Goad (NOAO) has been studying the characteristics of the nuclei of spiral galaxies covering the range from normal to Seyfert, in collaboration with J. Gallagher (NOAO and Lowell Observ.). Long-slit echelle spectrograms for two normal nuclei—NGC 2903 and NGC 4321—show nuclear kinematics consistent with a predominant rotation with some radial motions superposed. The velocity dispersions in the gas are consistent with the stellar velocity dispersions. However, even in these normal galaxies it is apparent that the nucleus is physically different from its immediate surroundings, since the emission line ratios change markedly between the nucleus and the H II regions just 250 ly away.

J. Goad and Gallagher also used a CCD on the KPNO #1-0.9-m telescope camera for direct imaging of these two galaxies and several other quiescent spirals. The V, R, I and Hα images show the locations of star formation and dust absorption and the underlying distribution of stars, to complement the kinematic and line-ratio data from the echellograms.
Earlier EPMN 4-m echelle observations of a transition case, M51, showed that without a doubt there is an overlap between the properties of non-Seyfert and Seyfert 2 nuclei. Further echellograms were obtained of ten Seyfert galaxies (Types 1 and 2) and four other peculiar spirals. Among the Seyferts observed, about half show some extension of emission outside the nucleus. One of these, NGC 3516, displays very peculiar but regular kinematics. Goad and Gallagher are working out a model which could explain the kinematics as a signature of a bidirectional outflow, out of the plane of the galaxy.

The research program being carried out by F. Roddier, G. Roddier, S. Shaklan, J. Freeman and N. Strobel (NOAO) is dedicated to the improvement of angular resolution in optical astronomy. It includes research on seeing, adaptive optics and interferometry with direct application to astronomical observations. (a) Seeing: C. Roddier and F. Roddier made seeing measurements with their rotation-shearing interferometer in May 1985 for three nights at the Steward 2.25-m telescope. They have compared their results with speckle observations made by Christou and Hegel. Interferometric measurements of seeing were also done during 16 nights at the McDonald 30-inch telescope in November 1985 and during ten nights at the ESO 50-cm telescope (La Silla, Chile) in February 1986. A total of 1600 interferograms were recorded on films and are currently being analyzed with a PDS microdensitometer. Extensive software has been written for fast interactive processing of the data. The results are compared with data from tower-based microthermal sensors, acoustic soundings, stellar scintillation monitoring and meteorological data. (b) Adaptive Optics: Analytic formulae have been derived to compute the modulation transfer function of a perfect adaptive optics system limited only by wavefront errors such as produced by stellar scintillation, chromatic effects and departures from statistical independence. In an infrared adaptive optics system, the adaptive mirror will modulate the telescope thermal background, introducing spurious noise. This effect has been studied theoretically and the amount of noise has been estimated for various telescope configurations. (c) Interferometry: G. Roddier has computed theoretical speckle interferograms using log-normal statistics and taking the telescope central obstruction into account. This was done in order to study the effect of calibration errors in speckle interferometry, in cooperation with Christou, Cheng and K. Hegel (U. of Arizona). F. Roddier has looked at the application of interferometric techniques to diffraction-limited imaging in space with a 10-m telescope proposed by P. Bely. A detailed comparison was made between pupil-plane and image-plane beam recombination in a long-baseline optical interferometer. In both cases analytic expressions were derived for the S/N ratios of the fringe visibility, assuming pure image motion. Pupil-plane recombination was shown to provide the best results at all light levels. Triple correlation analysis of speckle interferograms was shown to be related to phase closure techniques. It has been successfully applied to image reconstruction from one-dimensional IR speckle interferograms by J. Freeman in cooperation with D. McCarthy (U. of Arizona). Performance is now being compared with that of standard Knox-Thompson techniques. S. Shaklan has investigated the possibility of using single-mode fibers in long-baseline interferometry. The results of a proposal for a fiber-coupled telescope array will be made. Methods developed by C. Roddier to reconstruct images from pupil-plane interferograms are now being applied with success to the reconstruction of mirror figures from interferometric tests. (d) Astronomical results: F. Roddier and C. Roddier have published their reconstructed image of the star Alpha Orionis. Features observed close to the stellar disk have been interpreted as evidence for dust condensation. Comparisons between interferometric observations made at different dates show evidence for time variations, which may explain part of the stellar variability.

C. NNTT

1. Honeycomb Mirror Fabrication and Testing

A central goal of the NNTT project is to develop the technology needed to produce 1/4 arc-sec images with 7.5-m mirrors. The type of blank under the most intense consideration is the honeycomb style, cast from borosilicate glass. A major portion of the NNTT funding has gone to a subcontract with the group at the U. of Arizona that is working out the casting technology, under the direction of Dr. R. Angel. In the period from 1 October 1984 to 30 June 1986, the U. of Arizona group has taken several important steps toward large paraboloidal casting capability. (i) In 1984 a 1.8-m honeycomb blank (not spin-cast) was polished to a sphere and delivered to NOAO for extensive optical, thermal, and mechanical testing. (ii) In March of 1985 a 1.8-m blank was cast in a rotating 2-m furnace. At 15.6 RPM, the solidifying glass assumed a roughly paraboloidal f/1 surface. (iii) A new laboratory under a wing of the U. of Arizona stadium was completed in the summer of 1985. This is the home of the large rotating furnace that will ultimately be used to cast 7.5-m blanks. (iv) Construction of the full-size turntable was nearly complete by the summer of 1986. Work has also proceeded on the furnace for the first 3.5-m spin-casting, to be made in early 1987. A second 3.5-m blank will be cast in 1987, for thermal and optical testing at NOAO.

The 1.8-m prototype mirror has been tested at NOAO on a 19-point counterweighted support system. Half of the honeycomb cavities were ventilated by exhaust fans capable of circulating up to three mirror
masses of air per hour through the back of the mirror. As it was subjected to various thermal conditions (warm, cool or ambient) and gravitational orientations (horizon- or zenith-pointing), the mirror was tested optically with three different tests (knife-edge, Hartmann, and scatterplate interferometry). Thermistors were installed in and around the mirror, to monitor the temperature distribution at the same time the optical tests were done.

As a result of all this, the NOAO group found that ventilation is helpful but not sufficient to stabilize a large mirror to the surface accuracy required for 1/4 arc-sec imaging. According to the scaling law developed for this case, the temperature variations across each of the NNTT primaries would have to be limited to no more than about \pm 0.05 °C. Active thermal and mechanical control will probably be required. To test the effectiveness of active mechanical control, the mirror has now been set up with 6 force actuators that can substantially correct the low-order surface aberrations. The testing sequence that has been devised will be to: (i) predict, through computer modeling, how the mirror’s surface will distort as a result of the measured thermal distribution; (ii) compute the changes in support forces needed to produce an offsetting mechanically-induced faceplate distortion; (iii) apply the necessary forces; (iv) measure the optical results with real-time analysis of Hartmann exposures on a CCD camera. The sequence from (i) to (iii) will take approximately 45 seconds.

2. Instrumentation Planning

At the end of 1984, several “Instrument Working Groups” began laying out the requirements for the first complement of NNTT instruments: (i) High Resolution Optical Spectrograph (chaired by C. Pilachowski); (ii) High Resolution IR Spectrograph (chaired by S. Ridgway); (iii) IR Imager and Photometer (chaired by R. Gehrz); (iv) Multiple-Object Spectrograph (chaired by R. Weymann); (v) Direct Imaging Cameras (P. Seltzer and E. Kibblewhite). The first two instruments will each be located at a Nasmyth focus, the third will be at the central combined focus, and the last two will be at each of the four individual Cassegrain foci. The high-resolution spectrographs and the IR imager will each comprise three arms, optimized to cover three different wavelength regions. As the optical and emissivity requirements have been specified, the telescope concept has also evolved to satisfy the instrumental needs.

3. Telescope Structure and Building

To accommodate rapid changeovers between secondaries while maintaining a stiff telescope structure, the NNTT group devised a plan to mount the secondaries and terrestrials in square modules that slide in and out of the top end. When not in use they will be stored on elevators attached to the inside of the building. This concept is shown in a 1/60 scale model of the NNTT that was unveiled at the AAS meeting in Houston in January of 1986.

The building concept has not yet been chosen, but one option is a “carousel” enclosure similar to the one recently built on Mauna Kea for the 15-m UKNL millimeter telescope. The architectural firm that designed the UKNL building has completed a feasibility study for a similar NNTT enclosure.

Meanwhile, physical tolerances have been worked out for the optical support structure itself. A finite-element analysis was used to calculate the deflections of the OSS as a result of thermal gradients and gravity. The process of optimization has now begun, to reduce the moving weight and minimize the deflections of the OSS.

4. Coalignment/Co-phasing System

J. Beckers (NOAO) designed an internal optical metering system for coaligning and co-phasing the four telescopes in the NNTT. It uses a white-light reference point source at the NNTT combined focus which will be projected outward through the four telescopes. The edge rays of adjacent telescope pairs are intercepted by means of a co-alignment/co-phasing bridge and brought to a common focus. The precise alignment of the two images and their white light interference fringes are then used to co-align/co-phase the two telescopes. The same is done between each of the four pairs, resulting also in some redundancy. A laboratory mockup of this C2S (co-alignment/co-phasing system) was successfully built to prove the concept.

5. NNTT Site Evaluation

In the Site Evaluation Project, directly comparable data were collected atop Mauna Kea (Hawaii) and Mt. Graham (Arizona). Identical equipment was used at both sites to monitor seeing, IR sky radiance, microthermal activity, wind, and temperature. Testing continued through December 1985 at Mauna Kea and March 1986 at Mt. Graham. Since the end of the data-collection phase, the reduction and analysis phase has been nearly completed. A summary of the results will be submitted to an outside review committee, to be chaired by A. Hoag, and the report is expected by the end of 1986.

During the spring of 1986, J. Beckers, J. Gallagher, and D. Crawford (NOAO) gave colloquia at nine observatories or universities, on the subject of the NNTT program. More “NNTT Colloquia” are planned for the Fall of 1986.

D. Polychromatic Adaptive Optics

The effectiveness of large astronomical telescopes can be improved dramatically by the use of adaptive optics. This is especially the case at infrared wavelengths (> 2 μm) where one might expect close to full-sky coverage and where the increase of the contrast of the object against the bright
thermal background of the sky leads to a large increase in sensitivity. The ADP Polychromatic Adaptive Optics program, with L. Good (NOAO) as Project Scientist, aims at correcting for atmospheric seeing at IR wavelengths by using a 55-actuator adaptive mirror coupled to a 37- to 61-element wavefront tilt sensor working at visible wavelengths.

In the period covered by this report we took delivery of the adaptive mirror built by the Itek Corporation. It was subjected to an extensive calibration and check-out procedure so that we are now well familiar with its mechanical, electrical and environmental behavior. The wavefront tilt sensor is based on the Hartmann–Shack principle for wavefront sensing. It is being built by Adaptive Optics Associates and will be delivered in October/November 1986. Systems integration using all reflective optics will take place in 1987, with first use at the NSO McMath telescope expected in mid-1987. After the integration has been successful there, it will be used next at the KPNO 4-m coude focus and Cassegrain focus.

The present breadboard adaptive optics system is built as a fully post-focus package. Doing this involves the incorporation of a relatively large number of optical surfaces, each of which increases IR emissivity and light losses. To avoid this we are experimenting with ways to make curved adaptive secondary mirrors for telescopes, using bimorph mirrors. F. Roddier is Project Scientist for this portion of the program.

VII. DIRECTOR’S OFFICE

The current management structure for NOAO consists of: John Jefferies, NOAO Director; Sidney Wolff, KPNO Director/NOAO Associate Director; Robert Williams, CTIO Director/NOAO Associate Director; Robert Howard, NSO Director/NOAO Associate Director; Jacques Beckers, ADP Director/NOAO Associate Director; Carl Posey, Public Information Officer; Larry Barr, Acting Manager, Engineering and Technical Services; Steven Ridgway, Manager, Central Computer Services; Glen Blevins, Controller/Manager, Central Administrative Services; Dee Graham, Head, Central Facilities Operations; and Phyllis Williams, Assistant to the Director, NOAO.

The Director and his staff are responsible for the overall operation of the NOAO. The Director is responsible for providing scientific leadership for NOAO, determining priorities, allocating resources, budgeting, and planning. The Director represents NOAO, and in particular, the four scientific divisions (ADP, CTIO, GONG, and NSO) to AURA, the National Science Foundation, and to the scientific community.

VIII. CENTRAL COMPUTER SERVICES

In the period 1 October 1984 through 30 June 1986 a total of 461 visiting scientists used the NOAO Tucson computing facilities for data reduction as follows: CDC Cyber 170 Computer: 172; VAX Computer Systems: 469. During the reporting period developments in NOAO computing have been in the distribution of IRAF, the initiation of the workstation project, and the supercomputer link.

A. IRAF Distribution

The Interactive Reduction and Analysis Facility (IRAF)—currently under development in NOAO—was offered for a limited release in February 1986. A second limited release was offered in July to provide the environment for the first Science Data Analysis System (SDAS) release by the Space Telescope Science Institute. As a result of widespread interest in the limited release, IRAF is now available at over 70 sites around the world. Work is continuing toward the first general release of IRAF during FY 1987.

B. Workstation Implementation

A major project was initiated in FY 1986 to install high performance image analysis workstations at a number of NOAO telescopes. The objectives are to provide data reduction/compression at the telescopes, particularly for the growing data volume from large format imaging systems, and to meet part of the growing need for computer cycles available from several vendors. During FY 1986, workstations were installed at three NOAO telescopes.

C. Supercomputer Link

In July 1986, the satellite link to the San Diego Supercomputer Consortium (SDSC) was activated. Via this link, the scientist can work interactively with the Cray at SDSC. For most typical supercomputer projects, this arrangement is as convenient as if the machine were in the next room.

IX. ENGINEERING AND TECHNICAL SERVICES

In April 1986, the Tucson-based Engineering and Technical Services (ETS) unit was reorganized to enable scientific staff members to become more actively involved with direction of the technical activities, especially the instrumentation projects. The majority of the ETS staff was formed into multi-skill project-style groups—Kitt Peak Support Services, Infrared Development, Optical and UV (Instrumentation) Development, NTT, GONG, Adaptive Optics, and Gratings Laboratory. Each group is directed by a Program Scientist, assisted by a Steering Committee of interested scientists and a Program Engineer. A minority of ETS staff continues to operate the basic facilities needed for doing the work: The Instrument Shop, Electronics Laboratories, Optical Shop, and Drafting. This latter category is known as General Services and also provides limited technical services to all on a "first-come, first-serve" basis.

The CTIO and Sacramento Peak ETS units were not affected by these changes.
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John T. Jefferies
Director