

**Clyde W. Tombaugh Observatory**  
**University of Kansas**  
**Lawrence, Kansas 66045**

## I. PERSONNEL

This report covered the two-year period from mid-August 1981 to 1983. Drs. Barbara Anthony-Twarog and Bruce A. Twarog have joined us as assistant professors. Dr. Donald J. Bord (Benedictine College) continues as Adjunct Assistant Professor. Dr. Robert B. Phillips resigned to accept a position at Haystack Radio Astronomy Observatory.

## II. RESEARCH

### A. Solar System Studies

Armstrong's group continues analyses of Voyager data. The data analysis and interpretation of the Jupiter and Saturn encounters have evolved towards a detailed modeling stage. Earlier work on the Low Energy Charged Particle experiment data has established the salient features of the trapped planetary plasmas and energetic particle populations. Dr. Mark Paonessa (Applied Physics Laboratory) has developed an elegant analysis of the observations in terms of phase space densities which leads towards a quantitative evaluation of the particle sources, losses, and transport. Mr. Ed V. Bell, II has written a computer program to simulate charged particle motion in the vicinity of the natural planetary satellites and to estimate the lifetimes of such particles against impact on the satellite surfaces. Some of the complicating features included in the model are the effects of orbital eccentricity, inclination of the planetary magnetic axis to the satellite orbital plane, and finite gyroradius compared to the satellite radius. Mr. John Lowry has worked along with Paonessa to include the higher-order terms of the planetary internal magnetic field, distributed ring current, and magnetopause contributions in the derivation of phase space densities from the Voyager encounter observations.

Mr. Gul Tariq has developed a computer simulation model of the interaction of the corotating Jovian plasma interaction with Ganymede, with the goal of explaining the large fluctuations in the energetic ion spectra which Voyager 2 observed as it passed near the downstream corotation wake. Both magnetic and electrostatic processes have been modeled and several mechanisms of charged particle energization have been characterized.

Armstrong's group is also involved in long-term studies of solar energetic particle composition. Mr. James Meyer, Mr. Chris Brungardt, Mr. Joe Shields, and Mr. Steve Eckes have assembled a nearly complete time series of solar energetic proton intensities measured from Earth satellites from 1963 to the present. This term series is the longest homogeneous record of its kind and has been made available at the National Space Science Data Center for use in correlative studies with other solar-terrestrial time series. Studies of histograms of composition suggest that there are at least three contributing processes to the interplanetary energetic particle population—solar flares, galactic cosmic rays, and particles accelerated in the interplanetary medium.

Beard, along with Mr. Terrence Whelan, has examined the motion of cometary gases leaving the nucleus and has calculated isophotes of the apparent surface brightness of the atmosphere, including the effect of solar pressure and molecular decay on the atmosphere. When compared with observations, they were able to infer scale lengths for the effect of solar pressure between  $6 \times 10^4$  and  $2 \times 10^5$  km for observations of  $C_2$  in Comet Bennett.

Other cometary work involves an examination of the evolution of gas from a dust-enshrouded nucleus and the predicted brightening of comets as a function of heliocentric distance. They obtain a brightening dependence between  $r^{-2}$  and  $r^{-10}$  or so, depending on heliocentric distance  $r$ . The comet work has been supported by NASA through the Solar Terrestrial Programs.

Beard has been collaborating with Mike Selbey of Imperial College and Carlos Sanchez Magro of the Institute of Astrophysics at Laguna, Tenerife, in an infrared study of coronal polarization. He has deduced the infrared polarization dependence on elongation for a variety of interplanetary dust particle sizes and infrared wavelengths, assuming only electrons polarize the light.

Beard and his students (Keith Propp, Dean Hirschi, Terrence Whelan, and Dian Curran) continue their work on magnetic fields surrounding Mercury, Earth, Jupiter, and Saturn. This work, to infer causative currents from spacecraft observations, is supported by NASA's Planetary Atmospheres and Solar Terrestrial Programs.

### B. Stellar and Galactic Studies

B. Anthony-Twarog has completed a survey of *UBV* photographic material from the KPNO 4-m telescope for white dwarfs in the field of the Praesepe open cluster. Several photographic candidates were found in a subfield of the cluster, including a new candidate, LB 1876. When combined with the results of earlier surveys, as well as Jones and Cudworth's recent study of the structure and membership of Praesepe, an upper mass limit for white dwarf precursors of at least 2.5 solar masses is indicated.

In conjunction with B. Twarog and J. Frogel of CTIO, Anthony-Twarog is completing analysis of Kitt Peak Video Camera photometry in two old clusters, NGC 6535 and 6791, as part of a larger program of *BV* photometry in old open and globular clusters. Preliminary results from *B* and *V* frames in NGC 6791 have indicated a rich and old open cluster strikingly similar to NGC 188. Further photometric and membership studies are planned, including larger field studies using the Griboval electrographic camera at McDonald Observatory.

Anthony-Twarog has completed, at the University of Nebraska's Behlen Observatory and at McDonald Observatory, a *uvby* photoelectric study in the open clusters M39 and  $\delta$  Lyrae. Analysis of the photometric data for both clusters has employed the new luminosity calibration for B9–A3 stars of Hilditch, Hill, and Barnes. Examination of derived distances, luminosity indicators, and rotational velocity data for M39 members suggests that the presently used evolutionary corrections for A stars are in part sensitive to rotational velocity and are too steep a function of  $\delta c_0$ , a result similar to one found in the somewhat older cluster IC 4756 by Schmidt and Forbes.

A spectroscopic survey for lithium in G and K giants using the Cassegrain reticon spectrograph at the McDonald Observatory 1.3-m telescope was initiated by C. Sneden and J. Brown (University of Texas) with B. Anthony-Twarog. The survey will be continued by McDonald observers, and extended to larger samples by increased usage of CCD spectroscopic detectors.

Anthony-Twarog and Schmidt (University of Nebraska) are conducting photoelectric observations at Behlen Observatory to test the possible integration into the *uvby* photometric system of a filter designed by Carney. The filter is centered at the H and K

lines of ionized calcium, and may serve as a metallicity indicator which is detectable even in low-metallicity stars and which is relatively independent of CNO abundances.

Bord and Davidson, with the assistance of graduate student Richard Desko, are pursuing their studies of the ultraviolet spectra of chemically peculiar stars by the method of wavelength coincidence statistics. Global searches for elements with  $1 < Z < 103$  are all but complete for both the long- and short-wavelength IUE spectra of  $\kappa$  Cancri and  $\iota$  Coronae Borealis. Preliminary results confirm many of the spectral characteristics of these stars already well known from optical studies, but suggest several new element identifications not previously found at visual wavelengths; in particular, the statistics support the existence of hafnium in the spectrum of  $\kappa$  Cnc at the 99.999% confidence level, as well as the marginal identification of molybdenum in  $\iota$  CrB. A detailed examination of the spectra of these stars by more traditional line identification techniques is currently being made in an attempt to confirm these results.

These analyses were carried out using the National Bureau of Standards wavelength tables as given in the 61st edition of the *Handbook of Chemistry and Physics*, and were greatly facilitated by recently developed VAX 11/750-compatible software routines which permit the user to display all or part of an IUE echelle order on a Tektronics 2040A color graphics terminal and to select and store for future analysis the wavelength of features through the use of a movable cursor. It is estimated that it now requires only 1/4 as much time to assemble a set of stellar wavelengths from a typical IUE spectrum consisting of approximately 40 usable orders as it did during the early stages of this work when up to approximately 40 man-hours were needed to record the wavelengths as read from Calcomp plots of the spectra. Dramatic as this reduction in the time necessary to produce the stellar line lists is, a further diminution is being sought through the use of a program which locates and records the wavelengths of all minima in a set of spectral data. Although only in its earliest phases of development, the program, which is patterned after the one written by John Rice for the Dominion Astrophysical Observatory, returns approximately 90% of the features accumulated manually using the cursor, the wavelengths of corresponding lines agreeing to within about 15 mÅ. Efforts to improve the program now center on the establishment of subroutines to handle line profiles with saturated cores (and hence, nearly flat bottoms) and shoulders due to blending. This entire set of analysis routines has been successfully devised and implemented in less than a year largely as a result of the tireless efforts of Mr. Desko.

Bord and Phillips have begun a study of the morphological structure of broad continuum flux depressions near  $\lambda$  4200 and  $\lambda$  5200 as a function of temperature and (abundance) peculiarity index in a selected set of nonvariable Hg-Mn stars having low rotational velocities ( $v \sin i < 20$  km/s). High-dispersion ( $< 2$  Å/mm) observations of 23 such stars were obtained using the Mark II spectrograph at the McGraw-Hill Observatory in December 1981, and the analysis of these data will soon be undertaken using reduction programs developed at Dartmouth College. The aim of this investigation is to identify, insofar as possible, any systematic variations in the shapes of these features with temperature and/or abundance anomaly, and then to compare these findings with recent predictions by Maitzen and Muthsam based on models requiring severe line blanketing in these wavelength regions.

Some years ago, Shawl began working with Dr. Krzysztof Serkowski on an analysis of his extensive set of polarimetric observations of red variables obtained during his years in Australia. Unfortunately, it was not possible to complete the work prior to Dr. Serkowski's death in 1981 after a long illness. Shawl was able to be with him for a few days just prior to his death, at which

time we discussed the observations and their interpretation. An effort is being made to complete the analysis of these data in the not-too-distant future.

As discussed in the last report, great progress has been made by Shawl and Hesser (DAO), thanks to the dedicated work of Mr. James E. Meyer and the continued financial support of the NSF, on their systematic reinvestigation of the radial velocities of the galactic globular clusters. A report of this work was published in 1981. At this time we have completed measurements of all standard stars and all clusters. We have performed detailed analyses of the instrumental system as well as the wavelength system for metal-poor globular clusters. As a part of the determination of the wavelength system, we have classified all our integrated globular cluster spectra. Thus, we have new spectral types for 91 galactic globular clusters. We are currently working on the final Fabry-Perot reductions and hope to have final radial velocities available in 1984.

Shawl and White (Steward Observatory) have progressed in their work on the axial ratios, orientations, and coordinates of galactic globular clusters. At this time, they have 1-arcsec positions for 107 clusters. In addition, final reductions are nearly complete for the axial ratios and orientations for 104 clusters. The final results should be available in 1984. This work has also received continued support by NSF.

Shawl, with the help of undergraduate Jim Meyer, has begun an investigation of images of Mira variables on the SRC Southern Sky Survey for objects with observable nebulosity excited by a hot companion. This is preliminary to a more extended search for duplicity among Miras with the methods used by Herbig in the northern hemisphere. Although the prognosis of success in finding additional binaries is low, finding even one such system would be important in that it may allow additional Mira masses and absolute magnitudes to be determined. At this time some 550 star images have been examined; no nebulosity indicative of excitation by a hot companion has been found. The next stages of the search are now beginning in collaboration with Donald J. Bord. This work has been supported by the University of Kansas General Research Fund.

Shawl, along with R. E. White (Steward Observatory) and G. V. Coyne (Vatican), has measured the linear optical polarization of 39 red giant stars in the globular clusters M3 and M13. Thirteen stars have been found to exhibit polarization at greater than a 3 $\sigma$  level of detection. Such polarization might result from circumstellar material produced by red giant mass loss, or via various photospheric mechanisms. A paper has been submitted for publication.

B. A. Twarog has begun a program to study the collapse history of the Galactic disk using the  $z$  distribution of F and early G stars at the South Galactic Pole. *uvby* photometry of stars earlier than G5 to  $V = 14.5$  is being obtained in selected areas near the pole, leading to a final sample of approximately 300 stars. Accurate photometry ( $\sigma = \pm 0.01$  mag) will allow derivation of reliable distances, metallicities, and ages for dwarfs up to 1.5 kpc above the plane.

Twarog has completed preliminary work on a secondary sequence of standard stars on the *uvby* system. He now has observations of 36 stars between  $V = 8.0$  and 13.5, and spectral class A5 to G5, with an average of seven observations per star. One of the standards turned out to be a misidentified, extreme subdwarf, while a second appears to be a semiregular, low-amplitude, variable giant with a period of about 20–22 days, and  $[\text{Fe}/\text{H}] = -1.5$  based on the photometry of Eggen.

Work continues on a program by B. A. Twarog and P. Hemenway of the University of Texas to obtain precision photometry of stars in the old disk cluster NGC 188. Fifteen 4-m plates (8  $B$ , 7  $V$ ) have now been scanned to  $V = 16.5$  out to 20'

from the cluster center with the KPNO PDS. Reduction of the scans is complete for a partial sample of the plates in the outer region of the cluster. The improved photometry removes much of the scatter among the giants in the color-magnitude diagram found in earlier studies and, while confirming the existence of an extended halo of red giants caused by probable mass segregation, shows no significant difference in the position of the outer halo giants in the color-magnitude diagram compared to those of the inner region. The existence of a cluster red giant clump is also established.

Twarog has completed a *uvby* study of the blue stragglers in the old disk cluster NGC 7789. The photometry indicates that, in agreement with earlier work, the stragglers appear normal for their position in the C-M diagram. However, this position is not along the main sequence, but is systematically shifted by close to one magnitude above the unevolved main sequence along the entire three-magnitude range of the blue stragglers, indicative of a systematically lower surface gravity for blue stragglers compared to normal main-sequence stars. Additionally, though the majority of the over 30 sample stars are A stars, none has photometric characteristics consistent with Am peculiarities, in strong contrast with the typical field stars. Star K1211, one of the brighter stragglers, is found to be a photometric Ap star.

Twarog, with undergraduates Troy Mellon and Ray Murray, has started a survey of the South Galactic Pole for faint carbon stars. Objective prism plates of 20 fields taken with the thin prism on the CTIO Schmidt telescope to  $B = 14.5$  and  $15.5$  for another program are being used. All previously catalogued C stars within the fields have been recovered on the shorter exposures, indicating that the fainter-star survey with the deep exposures should provide reliable statistics on all, if any, C stars at large distances from the plane.

### III. TEACHING AND PUBLIC SERVICE

Graduate degrees in space physics were received by Frank J. Kutcho (Ph.D.) and Edwin V. Bell, II (M.A.).

Bachelor of Arts degrees in Astronomy were earned by John F. Riggs and Elizabeth Simon in 1982, and by Richard L. Dyson, Bret D. Goodrich, James E. Meyer, and Merle D. Reinhart in 1983. Ms. Simon and Mr. Reinhart were teaching assistants for introductory astronomy laboratory classes.

The observatory has been able to continue its Friday night open house program only because of the unselfish work of many volunteers and the Astronomy Associates of Lawrence. Most instrumental have been Merle Reinhart and Richard Dyson. James Meyer has continued to write a monthly newspaper article on the sky for distribution to about 50 Kansas newspapers. These people, along with Paula Reinecke, Vicky Wolters, and Jeff Miller, have presented astronomy programs to various groups for both the Observatory and the University of Kansas Museum of Natural History. These programs could not exist without them!

The Astronomy Camp of the MidWestern Music and Art Camp was held for the sixth and seventh years. This successful camp, run by Davidson with the help of Merle Reinhart and Erich Heim, has attracted numerous students from many states and Mexico.

With our increased staff we have begun a monthly public lecture series which nearly 300 people attended during the first semester.

### IV. MISCELLANEOUS

The University has received an Astromechanics Iris Photometer on loan from Yale University. Visitors are welcome to use this

instrument.

Armstrong was a MASUA (Mid-America States Universities Association) Honor Lecturer in 1981–1982 and presented numerous lectures throughout the region.

B. Anthony-Twarog presented colloquia and seminars at the University of Minnesota, Iowa State University, Emporia State University, and Kitt Peak.

Beard was a MASUA Honor Lecturer for 1982–1983 and presented colloquia at the Universities of Nebraska, Oklahoma, Oklahoma State, and the Universities of Missouri at St. Louis, Columbia, and Rolla.

Shawl participated as a Shapley Lecturer for the AAS and visited Drury College in Springfield, Missouri, and Simpson College in Indianola, Iowa.

B. A. Twarog presented an invited review paper at IAU Symposium No. 106 (The Milky Way Galaxy) titled "The Chemical Evolution of the Galaxy." In addition, he presented colloquia at the Universities of Arkansas, Minnesota, and Michigan State, as well as an informal presentation at Kitt Peak.

The N. Wyman Storer Award for outstanding service to the astronomy program was given to Merle Reinhart. The award is in honor of Professor Storer, who gave of himself unselfishly for 35 years at the University of Kansas.

### V. VISITORS

We were pleased to be visited during the report period by the following astronomers: Barbara Anthony-Twarog (University of Texas), Laura P. Bautz (NSF), Owen Gingerich (Harvard and Smithsonian), James E. Hesser (DAO), Steven Little (Wellesley), Irene Little-Marenin (Wellesley), Caty Pilachowski (Kitt Peak), Edward G. Schmidt (University of Nebraska), Bruce Twarog (University of Texas), Robert Watson (Kansas State University), and Raymond E. White (Steward Observatory).

### VI. PUBLICATIONS

- Anthony-Twarog, B. (1983). "The  $H\beta$  distance scale for B stars: the Orion Association," *Astron. J.* **87**, 1213.
- Beard, D. B., Hirschi, D., and Propp, K. (1982). "The tailward magnetopause field beyond  $10 R_e$ ," *J. Geophys. Res.* **87**, 2533.
- Bord, D. J., and Davidson, J. P. (1982). "An application of the method of wavelength coincidence statistics to the ultraviolet spectrum of  $\kappa$  Cancri," *Astrophys. J.* **258**, 674.
- Brown, J. A., and Twarog, B. A. (1983). "The Hyades CN anomaly?," *Astron. J.* **88**, 678.
- Davidson, J. P., and Bord, D. J. (1981). "A statistical search for medium Z elements in the ultraviolet spectrum of  $\kappa$  Cancri," *Bull. Am. Astron. Soc.* **13**, 827 (A).
- Davidson, J. P., and Bord, D. J. (1982). "A search for medium Z elements in the ultraviolet spectrum of  $\kappa$  Cancri," *Astron. Astrophys.* **111**, 362.
- Davidson, J. P., and Bord, D. J. (1982). "TUE data reduction: wavelength determinations and line identifications using a VAX/750 computer," in *Advances in Ultraviolet Astronomy*, Proceedings of a Symposium held at Goddard Space Flight Center, Greenbelt, Maryland, 30 March–1 April 1982; NASA Conf. Publ. No. 2238, 326.
- Desko, R. D., and Bord, D. J. (1982). "The quantum bouncer, revisited," *Am. J. Phys.* **51**, 82.
- Hutchings, J. B., Crampton, D., Cowley, A. P., and Bord, D. J. (1982). "Spectroscopic orbit of WRA 977 (= x-ray source 1223 – 62)," *Publ. Astron. Soc. Pac.* **94**, 541.
- Martin, P. G., and Shawl, S. J. (1981). "Polarization of scattered light in globular clusters," *Astrophys. J.* **251**, 108.
- Martin, P. G., and Shawl, S. J. (1982). "An optical study of the magnetic field in M31," *Astrophys. J.* **253**, 86.
- Shawl, S. J., Hesser, J. E., and Meyer, J. E. (1981). "Image tube radial velocities of selected globular clusters," in *Astrophysical Parameters for Globular Clusters*, Proceedings of IAU Colloquium No. 68 held at Union College, Schenectady, New York, 7–10 October 1981, edited by

- Philip and Hayes (Davis Press, Schenectady).  
Shaw, S. J., White, R. E., and Sim, M. E. (1981). "The determination of globular cluster axial ratio, orientation, and center," in *Astrophysical Parameters for Globular Clusters*, Proceedings of IAU Colloquium No. 68 held at Union College, Schenectady, New York, 7-10 October 1981, edited by Philip and Hayes (Davis Press, Schenectady).  
Twarog, B. A. (1983). "NGC 752 and main sequence bimodality," *Astrophys. J.* **267**, 207.  
Twarog, B. A., and Wheeler, J. C. (1982). "Primary nucleosynthesis in the galactic disk," *Astrophys. J.* **261**, 636.

### *Data Survey*

- (1) No. of faculty/staff: tenured or tenure-track  $1\frac{1}{2}$  (M),  $\frac{1}{2}$  (F); post-doc 0 (M), 0 (F); res. assoc. 0 (M), 0 (F); other Ph.D.'s 0 (M), 0 (F).
- (2) No. of graduate students: first year 0 (M), 0 (F); total 0 (M), 0 (F).
- (3) No. of degrees awarded: terminal Master 0 (M), 0 (F); Ph.D. 0 (M), 0 (F).