

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

### I. PERSONNEL

This report covers the period from August 1984 to August 1985. Within the Department of Physics and Astronomy, those currently involved in astronomical research are Dr. J.P. Davidson and R. Desko (IUE Data Analysis), Drs. David Beard and Thomas P. Armstrong (Solar System Studies), and Drs. Barbara J. Anthony-Twarog, Stephen J. Shawl, and Bruce A. Twarog (Stellar and Galactic Studies).

### II. INSTRUMENTATION AND DATA REDUCTION

Major improvement in the data reduction capabilities of the department has resulted from the continuing upgrade of the VAX 11/750 under the direction of Dr. T.P. Armstrong and Systems Manager Rick Desko. Of the many changes, the most significant have been the acquisition of an array processor and the purchase of a second VAX 11/750, operated in tandem with the older unit.

Growth of the Mid-American Astronomical Image Processing Lab (MAIPL) at KU has continued under the direction of Dr. Barbara J. Anthony-Twarog. The major change in the system capabilities came through the installation of a Model 75 I<sup>2</sup>S Image Display Processor. The system is open to all qualified users in the Mid-America region, and currently supports stellar photometry reduction routines by P.B. Stetson, DAOPHOT, used in either interactive or batch mode, and R2D2 from the University of Victoria. Plans for the future include the installation of IRAF, a software system under development at N.O.A.O. in Tucson for the analysis of surface photometry and stellar spectroscopy.

For educational and research needs, the department has acquired a Mann two-coordinate Measuring Engine on permanent loan from the University of Texas, joining the iris astrophotometer and Grant spectrum comparator on loan from Yale already in continuous operation as part of undergraduate research programs.

### III. RESEARCH

#### a. Stellar and Galactic Studies

The group involved in data analysis of IUE spectra includes Dr. J.P. Davidson, Dr. Don Bord (University of Michigan, Dearborn), Rick Desko, Systems Manager, and student Elizabeth Armstrong. Chief among the results of the year's research has been the development of an effective and important data reduction set of software to reduce spectra from the International Ultraviolet Explorer (IUE) on the VAX 11/750. The process of obtaining radial velocities from wavelength coincidence statistics (WCS) is detailed in Vol. 143 of *Astronomy and Astrophysics*. Davidson, Bord, and Desko are continuing their work in this area and a complete description of the programs, under the title of VAX Interactive Reduction of IUE

Spectra (VIRIS) is being prepared for publication in 1986. An example of the use of the package was presented in a talk at the meeting of the Kansas Academy of Sciences in March, 1985, where evidence for star spots in the spectroscopic binary,  $\chi$  Lupi, was discussed by Desko and Armstrong.

Bord and Desko have continued investigation of IUE spectra of HD101065, better known as Przybylski's star, taken from LWR6999, the only image which currently exists of the star. Through the use of the VIRIS package, Bord and Desko find the presence of iron in the ultraviolet, as well as other iron peak elements, chromium to manganese to titanium II. This confirms the results of Cowley, Cowley, Aikman, and Crosswhite based upon optical spectra. A very strong indication of the ion CoII is observed which confirms the weaker (S=3.3) observation of CoI by Cowley et al. This work is currently being prepared for publication following its presentation at the AAS meeting in Houston.

Shawl and J.E. Hesser of DAO completed their extensive study of the integrated spectral types of 90 Galactic globular clusters in NGC 121 in the SMC. The results can be summarized as follows: (1) their spectral types are essentially on the same system as Kinman's cluster classification system; (2) there are tight correlations between our spectral types and the photometric indices of Harris and Canterna (Qcmt), Zinn (Q39), and Burstein (Mg2), with a large scatter for (B-V)<sub>0</sub> and the DDO index C(42-45); (3) there is a good correlation between our spectral types and most of the metallicity determinations; (4) ultraviolet CN first becomes noticeable at about F8. Finally, they provide detailed compilations of spectral types and photometric parameters from many sources as well as detailed comments on many clusters. This work was partially supported by NSF through grant AST800001, and by the University of Kansas General Research Fund.

Shawl and Hesser completed their analysis of the CTIO 1-meter telescope spectrograph. This analysis used some 500 spectra of the IAU radial velocity standard stars to determine effective wavelengths for F0 to K4 Pop I stars, and to look for systematic correlations with declination, hour angle, and zenith distance. The results show that the 120Å/mm configuration can yield stable radial velocities to some +/- 10 km/sec for a single spectrum. Also provided is a table of radial velocities and residuals for IAU radial velocity standard stars, in addition to some other bright stars. This work was partially funded by NSF through grant AST800001 and by the University of Kansas General Research Fund.

Globular cluster integrated radial velocities, determined with the CTIO 1m telescope and image-tube spectrograph, have been obtained for 90 Galactic globular clusters, and NGC 121 in the SMC. Although the internal measuring errors are estimated to be 13 km/sec per plate, internal plus external errors are more nearly 20 km/sec per plate. Multiple observations have been obtained for 70% of the clusters. Although detailed discussions must wait for inclusion of the Fabry-

Perot results, some of the current conclusions are: (1) histograms of the F-type clusters are centered on 0 km/sec, while the G-type clusters show a mild preference for negative velocities (presumably in part from the general exclusion of G-type clusters on the far side of the Galactic nuclear bulge as well as from possible differential rotation of the innermost cluster); (2) there is generally excellent agreement with the velocities determined by other researchers; (3) solar motion solutions have detected an error in the right ascension of the apex as published by Kinman (it should be 20H32M rather than 21H27M); (4) of the 22 clusters lacking velocities and noted by Mayall as being important for solar motion studies, 19 have newly determined velocities. This research was partially funded by the NSF through grant AST 800001 and by the General Research Fund of the University of Kansas.

Shawl and Hesser, in collaboration with C. Reed of St. Mary's University, are using the new cluster spectral types and Reed's homogenized colors to determine intrinsic UBVR colors for 90 Galactic globular clusters. Analysis of the results is continuing. This work has been partially supported through NSF grant AST800001 and by the University of Kansas General Research Fund.

Shawl and D. Bord (University of Michigan, Dearborn) have made considerable progress in their search for duplicity among long period variables by determining the current epoch of the light curves for some 65 well chosen stars. Current epochs have been obtained from a combination of new photoelectric photometry at CTIO and visual magnitude estimates from the southern Damon plates of the Harvard College Observatory. Periods and dates of maximum light have been determined for a number of stars for which such data were previously unknown. This work is partially funded by the General Research Fund of the University of Kansas.

Twarog entered the final year of a three year study to analyze the evolutionary transition between the halo and the disk through the study of F and G dwarfs at large distance from the Galactic plane. To date, complete data are available on a sample of some 300 stars down to  $V = 14.5$ , with the final 50 being observed in the coming Fall season. The data include uvby photometry which will allow accurate metallicity and luminosity determination, with the ultimate goal of separating the stars according to age for a look at the spatial distribution of stars with age. This work is partially supported through NSF grant AST8302091.

Twarog and student Joseph Shields have completed a study of the effects of potential blue stragglers on analyses of spatial and velocity structure of the disk perpendicular to the plane and in the neighborhood of the sun. No assumptions were made about the stragglers other than that they were produced in all generations at a rate which was proportional to the red giant production, and had the same velocity characteristics as stars typical of their age. They populated the region brighter than and blueward of the turnoff with a steep mass function. It was found that (1) observation of the variation of scale height with temperature does have the capability of placing significant constraints on the scale height history of the disk if a direct temperature index is used instead of spectral type as the bin

determinant, and (2) the blue stragglers play a significant role in distorting the apparent velocity and spatial distribution of stars in the solar neighborhood. Plausible estimates for the percentage of early type stars which are actually old disk blue stragglers go as high as 50% for A stars. More detailed calculations are continuing.

Twarog and students, Murray and Mellon, have completed a survey of short exposure objective prism plates for carbon stars down to  $V=14$ . Coordinate determinations for a followup photometric survey are underway.

Anthony-Twarog, Twarog, Laird (University of North Carolina) and Schmidt (University of Nebraska) have begun a three year program to extend the uvby photometric system to cool dwarfs, adding a Ca filter to the system as a metallicity index, with special emphasis on the very metal-poor stars. To date, observations have been obtained for about 200 stars. Preliminary reductions indicate that an index, replacing  $v$  in the  $m_1$  index with the Ca filter, is two to three times more sensitive to metallicity changes than  $m_1$ , and remains approximately linear to  $[Fe/H] = -3.5$ . The first year of the program includes the observation of stars in the Bright Star Catalog for use as primary standards and checks of secondary effects of luminosity, rotation, etc. This research has been partially supported by the University of Kansas General Research Fund.

Twarog has completed his photometric study of the old disk cluster M67 and finds the following: the cluster metallicity is solar, or slightly higher; the blue stragglers redward of the TAMS are either non-members or composite systems; the intrinsic width of the main sequence is about 0.015 mag, significantly less than for NGC 752, despite the lower internal accuracy of the M67 photometry; and, finally, the main sequence turn-off shows a significant blueward hook, unnoticed in earlier work because of serious contamination of the turnoff region by binary systems which distorted the shape of the  $cm$  diagram. Current plans are to merge the data with that of Poul Nissen to improve the statistical accuracy of the analysis.

Anthony-Twarog, Caldwell (CTIO), and Twarog have continued their program to study disk clusters of intermediate age using a combination of photographic and CCD photometry. Photographic plates of a variety of clusters are being measured by students on the departmental iris photometer. These include plates of NGC 6259 (student Don Payne) - all 11 plates are completely done; IC4651 (student Krishna Mukherjee - 12 of 16 plates completed; and NGC 2354 (student David Bishir - 13 of 21 plates completed.) CCD frames in B and V for the clusters NGC 2354 and IC4651 have been reduced and are awaiting use for calibration of the photographic surveys. Work on NGC 3114 and NGC 3680 is expected to begin later this year. This work has been largely supported by NSF grant AST8420209.

Anthony-Twarog has successfully completed observations at CTIO designed to apply CCD photometers with Stromgren uvby filters to population studies in open and globular clusters. The 4m PFCCD has proven suitable for uvby observations to approximately  $V=18$ ; fully calibrated indices have been obtained for stars down to  $V=16$  from frames with exposure times totalling only 15 minutes. Calibration of the indices appears to be largely limited by the precision of the faint

star photoelectric photometry. Analysis of results of observations in IC 4651 and NGC 6397 are underway. (AST8420209)

Anthony-Twarog and Cudworth (Yerkes Observatory) are completing a joint photometric and proper motion analysis of the very old open cluster NGC 6791, using recent KPNO 4m prime focus plates, as well as original plate material used by Kinman in his 1965 photographic study.

#### b. Solar System and Space Physics

D.B. Beard, with students T.A. Whelan and M.A. Gast, has worked out the expansion neutral cometary molecules under solar radiation pressure and molecular decay. They have analyzed observations of  $C_2$  and CN and have shown that both molecules have a Maxwell-Boltzmann velocity distribution and that solar radiation pressure is a much larger effect than molecular decay. This work has been published in the Aug. 15 issue of the *Astrophysical Journal*, and was supported by the Atmospheric Sciences and Solar-Terrestrial branches of NASA.

Beard has developed more details of the generation of ionized gas tails in comets--the production rate of ions strong shock generation, and, in particular, the observed anisotropic velocity distribution of ions because of ambipolar diffusion in the rays. This work is being prepared for publication.

Beard and student Gast are working on non-gravitational orbit perturbations in nearly parabolic comets. From an analysis of this, they anticipate obtaining the fractional mass lost per apparition, the mass and radius of the comet nuclei, and other physical characteristics. In a preliminary analysis of Comet Ikeya-Seki, for example, it has been determined that the comet should have lost nearly all its mass on the first half of its apparition. This is consistent with observation since the comet broke up and essentially disappeared at perihelion.

Beard and student D.C. Hirschi have analyzed the spectral line distortion, line displacement, and line broadening brought about by zodiacal light because of the Doppler shift in the scattered light. Effects of dust orbit eccentricity, radiation pressure, and radially directed particles have been examined. Line broadening is more noticeable than line shifting in distinguishing between eccentric and circular orbits. This work was initiated at Imperial College at London under an SRC grant.

Beard has analyzed magnetic observations of Saturn made during Voyager flybys. In collaboration with students S. Ross, T. Whelan, D. Hirschi, J. Norcross, and M. Gast, the contribution of the magnetopause currents has been included directly rather than fitting to spherical harmonics which have been of the wrong sign. This work is supported by the Solar Terrestrial Branch of NASA.

Beard and S.W.H. Cowley (Imperial College, London) have added a cross-tail electric field to the magnetic magnetotail field used by K. Propp and Beard in generalizing plasma motion in the Earth's tail. This work will be published in *Planetary and Space Science* this fall and was supported by the Solar-Terrestrial Branch of NASA.

#### IV. TEACHING AND PUBLIC SERVICE

The Clyde Tombaugh Observatory has continued its regular Friday night open house with the support of the Astronomy Associates of Lawrence under the leadership of Mike Holmes, and drew over 500 visitors during the year. The members of the Astronomy Associates have continued to provide valuable service in the form of lectures and demonstrations at schools, community organizations, and the Museum of Natural History. Their help has led to the continued success of the "Eyes on the Universe" lecture series which drew over 300 people to five talks during the year. Speakers included Dr. Dave Alexander of Wichita State, Dr. A.G.D. Philips of Schenectady, New York.

The Astronomy Camp of the University of Kansas was held for the ninth year, drawing over 25 students to two sessions run by Dr. J.P. Davidson with the help of students Erich Heim and Mara Whitacre.

Shawl continued his participation in the Shapley Lecture series of the American Astronomical Society, while Anthony-Twarog and Twarog presented public lectures at the Astronomical Society of Topeka and the Astronomical Society of Kansas City, respectively. Twarog also presented public talks at the Regional Junior Science and Humanities Symposium and Haskell Junior College. Anthony-Twarog presented a public talk at the meeting of the KU Research Club.

#### V. MISCELLANEOUS

Dr. Stephen Shawl was promoted to Full Professor of Physics and Astronomy at the University of Kansas.

B.S. degrees in both Astronomy and Physics were granted to undergraduate Joseph Shields. Shields received the awards from the Department of Physics and Astronomy as both the outstanding senior in Physics, and the Storer Award for unusual contribution to the astronomy program at the University. Shields has also received a NSF graduate fellowship, and, after spending the summer as a research assistant at the Space Telescope Science Institute under Dr. Koo, will join the graduate program in astronomy and astrophysics at Berkeley.

Anthony-Twarog, Shawl, Twarog, and undergraduate Shields all presented talks at the Mid-America Regional Astronomy Conference in Kansas City, Missouri. Talks were also given by Beard, Gast, and Whelan on molecular decay in comets, while Hirschi discussed line profiles in zodiacal light.

Shawl and Davidson attended the winter meeting of the AAS where Shawl detailed results of his globular cluster studies with J. Hesser (DAO). Shawl later attended the Space Science Institute Workshop in Tucson. Shawl has given colloquia during the year at the University of Michigan, San Diego St. University, and presented a seminar at the Dominion Astrophysical Observatory.

Beard presented a paper on cometary atmospheres at a workshop on Plasma and Neutral Gas Environments of Comets at Ann Arbor, a paper on magnetotail ion drift at the Fall meeting of the American Geophysical Union, and a paper on the effect of the solar wind on magnetic fields at the AGU Chapman Conference on Solar Wind-Magneto-

sphere Coupling. He also gave a colloquium on comets at Victoria University of Wellington in New Zealand.

Armstrong and undergraduate Sue Tholen presented a paper on magnetospheric particle bursts at the AGU Conference on Solar Wind-Magnetosphere Coupling.

Anthony-Twarog and Twarog both attended the meeting of the AAS in Charlottesville where they presented poster displays of their research on open and globular clusters.

Shawl completed the second edition of the instructor's manual which accompanies T.P. Snow's introductory astronomy text, "The Dynamic Universe."

## VI. VISITORS

We were pleased to be visited during the time covered by this report by the following researchers in astronomy and space physics for discussions of their research: Dr. Rebecca Chaky (TRW), Dr. Curt Struck-Marcell (Iowa State University), Dr. Robert Phillips (Haystack Observatory), Dr. Larry Thomassen (University of Arizona), Dr. Willet Beavers (Iowa State University), Dr. Adolfo Nemirovsky (University of Chicago), Dr. Richard Henry (University of Oklahoma), and Dr. Olin Eggen (CTIO).

## VII. PUBLICATIONS

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