Clyde W. Tombaugh Observatory
University of Kansas
Lawrence, Kansas 66045-2151

I. PERSONNEL

This report covers the period from August 1987 to August 1988. Within the Department of Physics and Astronomy, those currently involved in astronomical research are Dr. J.P. Davidson (IUE Data Analysis), Dr. Adrian Melott (Cosmology and Theoretical Astrophysics), Dr. Thomas P. Armstrong and Dr. Thomas E. Cravens (Solar System Studies), Drs. Barbara J. Anthony-Twarog, Stephen J. Shawl, Bruce A. Twarog and adjunct colleague Dr. Scott Baird of Benedictine College (Stellar and Galactic Studies). Dr. Cravens joined the department in August 1988.

II. INSTRUMENTATION AND DATA ANALYSIS

The Mid-American Astronomical Image Processing Laboratory (MAIPL) continues to provide image-processing software and display hardware to astronomers at the University of Kansas as well as surrounding institutions with hardware consisting of an International Imaging Systems Model 75 image processor display with three independent picture memory channels. Programs to reduce two-dimensional photometric data and one-dimensional spectra are available for general use and include DAOPHOT for stellar CCD photometry, R2D2 for image operations, and RETICENT for spectrum analysis. In addition, the plotting package MONGO is available on the Department of Physics and Astronomy VAX 11/750 with laser graphics output. Interested users are urged to inquire. A Microvax II (KUSMOS) has been purchased and is dedicated to numerical cosmology. With a 17 Megabyte memory, it will be a powerful new tool for large-scale computing.

III. RESEARCH

a. Stellar and Galactic Studies

Continuing a series of photographic investigations of intermediate-age clusters, Twarog, Anthony-Twarog, and student Don Payne have completed a *BV* survey of NGC 6259. Selected for further study because of its similarity to M11 and its wide upper main sequence, NGC 6259 has been confirmed as having a main sequence significantly wider than can be accounted for by measurement errors, and which is probably not due to variable reddening. Both M11 and NGC 6259 are found to have similar distances, cmd morphology, and ages probably younger than described by Mermilliod (1981).

Twarog, student Scott Daniel and collaborators D. Latham (CfA) and R. Mathieu (U. Wisconsin) have undertaken a photometric and radial velocity survey of the old open cluster NGC 752 to identify cluster members and binary candidates and to better delineate the cm diagram for the faint main sequence. From 13 plates, all previously-known variables have been identified as well as one newly identified variable. The radial velocity results indicate that 3 of the probable members based on proper motions, are non-members; 5 more stars have variable V_r, 4 are possibly variable and 14 are apparently single systems. These results confirm the reliability of the *uvby* system for isolating binary candidate, as evidenced by prior work in M67. Estimates of the cluster age remain at 2×10^9 years on the system of VandenBerg (1985). Twarog and collaborators plan a survey of NGC 6819.

Twarog and Anthony-Twarog, with student Ray Murray, have also completed a photographic *BV* survey of the old open cluster NGC 2360. Like several other clusters of similar age and morphology, NGC 2360 exhibits a color spread at the turnoff significantly larger than can be explained by measurement errors; the lack of a comparable spread on the giant branch reinforces an earlier conclusion that variable reddening is not the cause. For a reddening value of $E(B-V) = 0.09$, the derived age is 1.2×10^9 years on VandenBerg's system, with an apparent distance modulus of 10.5 ± 0.2 derived by comparison of the giants to the Hyades giants.

Work by Anthony-Twarog and student Sheela Shodhan continues on selection and calibration of standard fields for CCD-*uvby* photometry. 30 fields within 20° of the celestial equator have been selected with 2 to 5 stars, and V magnitudes ranging from 8.0 to 13.0. Photoelectric observations of at least one star in each field are being obtained as well as multiple CCD observations.

Following the successful application of CCD photometry on the Strömgren system to the globular cluster NGC 6397, Anthony-Twarog, Twarog and W. Schuster (U.N.A., Mexico) are pursuing further observations of fields in this nearby cluster to identify photometric binary candidates. Candidate identification was possible in the initial survey because the added information from m_1 indices permitted exclusion of foreground stars.

Student Tamara Whitacre Payne completed work on additional software for CCD data processing as part of her investigations into the star forming history of NGC 3293 in the Carina complex. Like several other young clusters, NGC 3293 exhibits a sequence of forming stars with inferred ages older than the age attributed to the turnoff stars. With seven fields distributed widely around the cluster and *UBVRI* frames, Payne, Twarog, and Anthony-Twarog hope to be able to isolate and study the faint members of this interesting cluster.

Student K. Mukherjee, along with Anthony-Twarog and Twarog, have completed a study of the globular cluster Omega Centauri. *uvby* CCD photometry was obtained at Cerro Tololo Inter-American Observatory with the 4m PFCCD camera and reduced at the University of Kansas, Mid-American Astronomical Image Processing Laboratory. From eight frames in each of the four colors, we have derived indices to $V \sim 18.3$, about 2 mag below the turnoff. The cm diagram revealed a significant observed width of 0.08 in $b-y$ with errors of 0.016 in $b-y$ at $V = 18.5$. A major motivation for using Strömgren photometry was to discern the separate contributions of age and metallicity spread in the main sequence color width. We found an intrinsic dispersion in $b-y$ of 0.016, which implies either a spread in age of ± 2 billion years assuming the mean metallicity of the cluster to be -1.7, or a dispersion of ± 0.5 dex in metallicity if there is no age spread. However, the intrinsic dispersion in m_1 of 0.018 implies a dispersion in metallicity of ±0.6 dex, which presumably rules out any contribution to the color spread due to age differences among the stars.

B.A. Twarog, in collaboration with W. Schuster (U.N.A. Mexico), has undertaken a *BV* CCD survey of the intermediate age open cluster, NGC 7789, using the CCD camera on the U. Nebraska 30-inch telescope at Behlen Observatory. The cluster within 10′ of its center will be surveyed to $V = 16.5$ producing photometry accurate to ±0.01 mag. The cm diagram will then be constructed and analyzed to determine if it exhibits the same bimodality as NGC 752, a slightly older open cluster. The richness of the stellar population of the cluster should allow a firmer handle on the reality of the feature, if it exists. Plans are also underway to study the older open cluster, NGC 6819.

B.A. Twarog and B.J. Anthony-Twarog have re-analyzed the color-magnitude diagrams of the old open clusters, NGC 188 and M67. By lowering the reddening of M67 and raising the reddening for NGC 188, it is found that NGC 188 must be only 1.5×10^9 years older than M67, and has an ap-

parent modulus 1.8 mag larger than M67. The younger age removes two anomalies associated with NGC 188, the color of its giant branch and its high Li abundance, while producing no obvious inconsistencies with standard stellar or Galactic evolution.

B.J. Anthony–Twarog, undergraduate Jeff Robertson, and B.A. Twarog have begun an analysis of the color distribution in the m_1, $(b-y)$ plane of the sample of 711 high–velocity stars observed by Schuster and Nissen (1988). The distribution in color exhibits a clear blue edge which varies as a function of metallicity. If the blue edge is due to a lower age limit at each metallicity, the size of the variation with metallicity would place important constraints on the chemical history of the halo.

B.J. Anthony–Twarog, B.A. Twarog, and M. Mateo (MWLCO) have begun a recalibration of the Morphological Age Ratio using the newer isocrones of VandenBerg (1985). The revised data will be used to discuss the chemical histories of both the Galaxy and the Magellanic Clouds.

B.J. Anthony–Twarog, J.B. Laird (Bowling Green State Univ.) and B.A. Twarog have continued their long term calibration of a fifth filter for the *uvby* system based upon the Ca II H and K lines. The first phase, standard stars and a catalog of Bright Star observations, has been completed and phase II, the observataion of a sample of stars with a range in metallicity, has begun. A preliminary calibration indicates that the metallicity of CD–28 345 cannot be as low as [Fe/H] = -4.5. Instead, [Ca/H] = -3.5 appears more realistic.

Shawl and Donald Bord (University of Michigan at Dearborn) have continued the preliminary work required for their search for companions to long-period variable stars. Light curves, periods, and times of maximum light have been derived for 15 southern long-period variable stars on the basis of both archival photographic materials, and new photoelectric data. While in 7 cases the periods agree with values given in *The General Catalog of Variable Stars*, significantly different values are derived for RZ CrA, SV Lib, EE Lib, BM Sgr, and BK Tel. Periods have been determined for 3 stars now having values in the *GCVS*: EN Lib, FF Lup and FL Lup. Finding charts are have been made for many stars whose charts were found to be unsatisfactory. They confirm that times of maximum light for long-period variable stars derived from older ephemerides are unreliable.

Investigations by Davidson continue on the unusual abundances of very heavy elements (tungsten, Z = 74, through mercury, Z = 80) in hot, early-type stars, B5 – A5, using International Ultraviolet Explorer (IUE) images. The software has been mainly developed for this project and currently is in use on our in-house DEC VAX 11/750 computers. We are also interested in the very unusual (*i.e.* vastly different from "cosmic") isotopic distributions found in certain of these stars. In particular the elements Pt and Hg show these ususual isotopic variations. Doctoral candidate S. Ro is presently involved with this program.

b. Cosmology and Theoretical Astrophysics

Melott, McKay, and Ralston are working on the possibility that a strong extragalatic UV background is caused by radiative decay of dark matter.

Melott (with R.J. Sherrer, of Ohio State and E. Bertschinger of MIT) is studying the evolution of universes in which cosmic strings provide the initial conditions for galaxy formation, using numerical simulations.

Melott (with J.R. Gott and D.H. Weinberg of Princeton University and several other collaborators) is studying the topology of the universe using a variety of observational data sets, as well as examining topological implications of various theories. In work with students Alex Cohen and John Beacom, the topology of two–dimensional "slice" redshift surveys is being examined.

A further collaboration with Barbara Ryden of Harvard–Smithsonian Center for Astrophysics is examining the use of very deep one–dimensional information to study large–scale structure. Deep "core" surveys of galaxy redshifts are being examined. The idea of using QSO absorption spectra acquired with the Space Telescope has been proposed as a part of a Key Project for that telescope in collaboration with a group led by D.G. York of the University of Chicago.

The idea that the Local Group of Galaxies began by accretion of matter around two "seed masses" which then fell toward each other is being studied numerically in a collaboration including graduate student L.R. Jiang, postdoctoral researcher M.R. Holmes, and P.J.E. Peebles of Princeton University.

Melott and undergraduate student Beacom are analyzing the extremely deep redshift survey of Koo and Kron in SA57. They are using a technique published by Ryden in order to determine what this survey indicates about the large-scale structure of the universe. Ryden's technique, which is particularly suited for nearly one-dimensional surveys, is based on counting the number of contour crossings per unit length for a straight line drawn through the field at a given isodensity contour. The surface area per unit volume at a given isodensity contour is directly proportional to the number of contour crossings per unit length. This technique is applied to data that have been normalized by division by the number of expected galaxies, as determined by the Schecter form of the luminosity function.

Undergraduate student Beacom has begun a project with S. F. Shandarin (Institute of Physical Problems, USSR) to study the positions of the zeroes of the 3-dimensional genus statistic (Gott, Melott, and Weinberg) as a function of smoothing length, where the smoothing length directly determines the degree of smoothing applied to the Fourier components of a given density field. This smoothing makes the field continuous, in order that the underlying structure can be studied. This problem is related to the scale on which a given density distribution becomes Gaussian (random phases in the Fourier components of the density), and whether all fields become Gaussian on large enough scales (Random Phase Hypothesis).

c. Space Physics and Solar System Studies

Cravens is leading a number of theoretical investigations which seek to improve our understanding of the nature of the interaction of the solar wind with the upper atmospheres and ionospheres of non–magnetic bodies in the solar system, such as Venus, Mars, and comets. The solar wind is an outflow from the sun into the interplanetary medium of protons, electrons, and other charged particles. The ionosphere of non–magnetic bodies act as obstacles to the solar wind, which is thus deflected around them. One tool which we have developed to study the effects of the solar wind interaction with planetary ionospheres is a magnetohydrodynamics model which includes a variety of ion–neutral interaction processes such as chemistry and ion–neutral frictional drag. This model has been used to explain the existence of a magnetic field–free cavity surrounding the nucleus of comet Halley, as was observed by the magnetometer on the Giotto spacecraft during its encounter with that comet. Another theoretical tool which we are using to study the interaction of the solar wind with comets is a test particle computer code which follows thousands of cometary ion trajectories in the solar wind, after they have been created by the ionization of neutrals by solar ultraviolet radiation. We are learning that an important part of the assimilation of cometary particles into the solar wind is the scattering of these particles by magnetic irregularities and waves.

Cravens is also conducting several theoretical investigations, in collaboration with scientists at other universities and at NASA, into the physics and chemistry of the upper atmospheres and ionospheres of the outer planets, Jupiter, Saturn, and Uranus. Evidence for auroral particle precipitation into the upper atmosphere of Jupiter was provided by the ultraviolet spectrometers on board the Voyager 1 and 2 spacecraft, and by the International Ultraviolet Explorer satellite. Magnetospheric measurements made by particle detection instruments on the Voyager spacecraft have indi-

cated the energetic sulfur and oxygen ions are precipitating from the magnetosphere near the Jovian satellite Io, into the atmosphere of Jupiter. We have constructed a theoretical model of the Jovian aurora, which describes the interaction of the precipitating ions with the Jovian atmosphere. The auroral power is dissipated in the atmosphere by ionization, excitation, dissociation, and heating of the atmospheric gas. Another model which is now being developed determines the abundance of vibrationally excited molecular hydrogen in the upper atmospheres of the outer planets. Molecular hydrogen is the major constituent of the outer planets and vibrationally excited molecules are generated by collisions with energetic auroral particles. These excited molecules have a profound effect on both ion and neutral chemistry in the upper atmospheres of the outer planets.

IV. MISCELLANEOUS

Bachelor of Science degrees in Astronomy were awarded to Daniel Henry and Michael Luhman, with a Bachelor of Arts degree to Henry Driskell. Henry is commissioned in the United States Navy, which Driskell is pursuing graduate studies in Computer Science at the University of Utah. Tamara Whitacre Payne completed work for her Master of Science degree in Computational Astronomy in August 1988, with a defense of her work "Matching Algorithms For CCD Images: An Application to *UBVRI* Photometry."

Students Payne, Luhman and Scott Daniel are beginning doctoral studies in Astronomy at the Universities of New Mexico State, Texas and Maryland.

Cravens attended a meeting of the Committee on Space and Atmospheric Research in July of 1988, presenting two invited papers "Cometary Plasma Boundaries" and "Energetics of the Venue Ionosphere". Anthony-Twarog attended the January and June 1988 meetings of the A.A.S., and gave a seminar at Cerro Tololo in September 1987 entitled "Recent Results in CCD-*uvby* Photometry Programs"; she is also serving on the Time Assignment Committee for Cerro Tololo InterAmerican Observatory.

Undergraduate John Beacom has been named a Summerfield scholar of the University of Kansas, and attended the von Neumann National Supercomputer Center's Summer Institute and a cosmology seminar at Princeton University.

Shawl attended the Austin and Kansas City AAS meetings, and both the General Assembly of the I.A.U. and Colloquium No. 106 on the Evolution of Peculiar Red Giants at Indiana University. He also presented AAS Harlow Shapley lectures at Barton Co. Community College in Great Bend, Kansas, and at Western Missouri State College in St. Joseph. He will continue to serve on the AAS Education Advisory Committee.

Shawl initiated a summer workshop for secondary school teachers. The purpose of the workshop was to present teachers with fundamental astronomical ideas using a self-paced, discovery approach. The emphasis of the course was on astronomical measurement and uncertainty. The ten teachers who completed the 3 week course (which met 3 hours daily) found it to be an excellent learning opportunity and one which would have an immediate impact on their teaching. The course will be offered again 1989.

Melott attended the Moriond Astrophysics meeting on Dark Matter, presenting an invited talk entitled "Glowing Dark Matter With or Without Strings Attached". He also presented invited talks at the Aspen Institute Workshop on Large Scale Structures in the Universe and a NATO Advanced Research Institute on the Epoch of Galaxy Formation held in Durham, England. Melott additionally attended a workshop on galaxy formation at Los Alamos Natl. Laboratory, visited the Astrophysics Dept. at Oxford University and presented a colloquium at the University of North Carolina.

Melott is serving on the organizing committee of the proposal IAU Symposium on the evolution of structure in the Universe, to be held in 1990 in the Soviet Union.

Melott hosted and conducted a workshop on the Topology of the Large Scale Structure of the Universe held in Lawrence April 26–29. 25 participants from five countries attended; the conference proceeding will appear in the November 1988 *PASP*. Participant J.R. Gott presented a public lecture in the "Eyes on the Universe" series, entitled "Is the Universe Spongy?"

Twarog presented an invited talk entitled "The Structure of the Galaxy at Large Z" at a workshop on Galactic Structure held at the University of North Carolina in January, 1988.

With Shawl as Chair of the Local Organizing Committee, the University of Kansas joined the Universities of Nebraska and Missouri (Columbia and St. Louis), as well as South West Missouri State University, Benedictine College and Kansas City, Kansas Community College in hosting the 172nd meeting of the American Astronomical Society in Kansas City, attended by approximately 500 participants.

Sergei Shandarin of the Institute of Physical Problems in Moscow visited the department in June and July of 1988. He and Melott are collaborating on investigations into nonlinear evolution of density perturbations in the expanding universe, along with Lev Kofman of the Inst. of Astrophysics in Estonia.

V. PUBLICATIONS

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