

Wesleyan University
Astrometric-Photometric Group
Middletown, Connecticut 06459

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The following report covers the activities of the Astrometric-Photometric Group for the year ending 31 August 1997.

The Astrometric-Photometric Group (APG) came into being last year as a group of astronomers actively pursuing stellar research in a number of closely related fields. Its office is located at 349 Science Center, Wesleyan University, Middletown, CT 06459, email: apg@mail.wesleyan.edu, phone: (860) 685-3678, fax: (860) 685-3992.

1. PERSONNEL AND TEACHING

The APG staff includes Arthur Upgren, John M. Van Vleck Professor of Astronomy; Research Fellows Paul D. Hemenway, A.G. Davis Philip, and Jurgen Stock; Research Associates John T. Lee and Edward Weis; and Research Assistant, John Griese. Lee holds a similar position at Yale University. Some of the others have positions elsewhere, but combine for the purpose of furthering their research on overlapping projects of common interest, and as legitimate members of the Wesleyan community. None remain on the staff of the Department of Astronomy or Van Vleck Observatory; they are now free of restrictions imposed on their instruction and research. The group members and a number of colleagues seek to combine elements of closely related and sometimes funded research programs, with a mutual goal of calibrating and deriving the best possible stellar distances, distributions, and physical properties. They employ data from the Hipparcos and Tycho Catalogues, as well as recent ground-based observations for magnitudes, colors, and stellar radial or line-of-sight velocities for a number of projects, briefly described below.

Upgren was appointed Senior Research Scientist at Yale University, Department of Astronomy in 1997. He has relocated his long-standing astrometry program and its federal funding from Wesleyan to Yale. This is in part a response to the shift in the emphasis in the program from observations to measuring and reduction using the Yale PDS Microdensitometer. He was also elected to the Board of Directors of the International Dark-Sky Association (IDA) at its annual meeting in Tucson in April, and continues to write and advise on a number of outdoor lighting issues as Connecticut State Chair of the New England Light Pollution Advisory Group (NELPAG). He is vice president and trustee of the Fund for Astrophysical Research, Inc. and chair of its Theodore Dunham Jr. Grant Program Committee. He is a member of the Advisory Committee of the Shapley lectureship program of the AAS, and Associate Editor of the ISO Contribution Series (formerly the Contributions of the Van Vleck Observatory). In 1997, he served as Scientific Editor in the completion of the Secrets of Space Series, a group of seven books for young readers, a project of Blackbirch Press, Inc.

Hemenway is Adjunct Professor of Astronomy at the University of Rhode Island, and is a member of the NASA Space Interferometry Mission Science Working Group

(SIMSWG). He serves as an advisor on the staff of the Hipparcos Astrometric Project and is the principal investigator of one of its research proposals. He continues as a member of the Hubble Space Telescope Astrometry Science Team, and the Hipparcos Project Working Group for the Extragalactic Frame Tie.

After thirteen years as an adjunct professor, Philip returns to Wesleyan to continue his joint work with Upgren's funded research. Philip is also a Research Professor at Union College, Director of the Harlow Shapley Lectureship Program of the AAS, a member of the editorial board of *Baltic Astronomy*, and a trustee of the Fund for Astrophysical Research, Inc. serving on its Theodore Dunham Jr. Grant Program Committee. He remains secretary and treasurer of the New York Astronomical Corp., and president of the Institute for Space Observations.

Stock also returns to Wesleyan, where he had been an adjunct professor for three years. He is also Invited Professor at the University of Lisbon, Portugal, through November 1997, and vice president and astronomer at CIDA, the Venezuelan National Observatory at Merida, which he established and directed for a number of years. He is active in the program to install CCD frames onto the 1.5m CIDA Schmidt telescope for drift scan projects described below.

In the autumn of 1996, Upgren became a Fellow at the Wesleyan Center for the Humanities, and taught a course as a part of its program of instruction. The course was named "Light Pollution: From Confrontation to Cooperation," and was the first course taught on the subject of light pollution and night sky brightness for college credit. The information sheets of the International Dark-Sky Association formed the most useful textual material of any source. Each of the students completed a term project overlapping with the central theme. Considerable ingenuity was shown in their selection; they ranged from a discussion of new sulfur lamps to outdoor lighting in movies from the film noir period to the present, to new therapeutic approaches to seasonal affective disorder (SAD). Others dealt with a study of street lighting and fall foliage, and light and darkness in the poetry of Emily Dickinson. Most of these papers will appear in an upcoming article on the course.

Nine guest speakers participated in the course. These included the Mayor of Middletown and local members of the Connecticut State Legislature. Representatives from Northeast Utilities, the Middletown Planning and Zoning Committee, and Wesleyan Public Safety also lectured and led discussions. Although the accommodation to the visitors' schedules interfered somewhat with an orderly progression of topics, their participation was a decided benefit to the students. A second beneficial effect was the acquaintance with and positive reaction to the virtues of full-cut-off shielded lighting; the P&Z Committee now recommends shields for all new outdoor lights, and the city may soon do the same.

Uppgren again taught an introductory course on topics in the history of astronomy. Griese taught an introductory astronomy course at Middlesex Community College in Middletown. Griese was also a teaching aide in Uppgren's course for the Wesleyan Graduate Liberal Studies Program taught in the summer of 1997, and managed visitor's nights at the Stamford Observatory where he is assistant director.

Stock was advisor for Carlos Abad, who finished his doctoral thesis at the University of Zaragoza and obtained the Ph.D. in December 1996. He also advised Ramon Molina at the University of the Andes, Merida, Venezuela, in a Master's thesis. Molina has been working on a method of an automatized and quantitative spectral classification of stellar spectra, based on the material described below.

Uppgren's courses form the bases for his book entitled *Night has a Thousand Eyes: A Naked-Eye Guide to the Sky, its Science, and Lore*. It is published by Plenum Publishing Corp. and will appear in the spring of 1998 in the United States and Great Britain. It is intended for the lay reader, with a foreword by David Levy. Uppgren is working with Stock on a second book, also to be published by Plenum, on climate and weather and featuring El Nino and global warming.

During the year, Philip participated in the XXIII General Assembly of the IAU in Kyoto, Japan in August, and Stock attended conferences on "Stars in Motion" in Lisbon, and of the National Portuguese Astronomy in Porto, Portugal. Hemenway, Uppgren, and Weis participated and presented papers at a symposium held in Venice in May and sponsored by the European Space Agency, at which the Hipparcos and Tycho Catalogues and the first astrophysical results of the Hipparcos space astrometry mission were presented. Philip and Uppgren attended a meeting of the Royal Astronomical Society in London in May. Griese attended the spring meeting of the A. A. V. S. O. in St-Luc, Switzerland.

The Third Conference on Faint Blue Stars was held at Union College in October and is being edited by Philip, J. Liebert of the University of Arizona and R. Saffer of the Space Telescope Institute in Baltimore, for publication by the L. Davis Press. In March a meeting was held at Yale University in honor of the 90th birthday of Dorrit Hoffleit. The proceedings of this meeting are being edited by Philip, W. van Altena of Yale, and Uppgren, and will also be published by the L. Davis Press. P. Boyce of the AAS and Philip are editing the proceedings of the Joint Discussion, "Electronic Publishing: Now and the Future" held at the Kyoto General Assembly, to be published in the Transactions of the IAU and electronically on the WEB.

2. RESEARCH

The parallax program, formerly of the Van Vleck Observatory, and now centered at Yale University, continues to use the 0.5m Van Vleck astrometric refractor and the Yale PDS microdensitometer to derive parallaxes of nearby stars. Currently its primary effort is directed toward stars of intermediate metallicity, some of which were not recognized as such until after the creation of the Hipparcos Input Catalogue. Radial velocity determinations of high precision for

these stars are being continued at the David Dunlap Observatory, and should shortly begin at the Moletai Observatory near Vilnius, Lithuania.

During the year covered by this report, Weis supervised the taking of 256 astrometric plates with the refractor. Observations were completed for 17 additional parallax fields and a twentieth list of parallaxes and proper motions is being published by Weis, Uppgren, Griese, Lee, and others. It includes five resolved binary or triple stars and four white dwarf members of the Hyades cluster. At magnitudes of about 14, the white dwarfs are the faintest stars ever observed for parallax with this refractor. Preliminary results for them have been reported by Lee, Uppgren, and A.H. Lee (*Baltic Astronomy* 6, 19, 1997). Measures were made by Lee, Griese, J. Vincent, and A.H. Lee, and reductions of the newly completed fields have revealed several stars with significant parallaxes or proper motions among those measured for the reference frames.

The three nearby open clusters (the Pleiades, Praesepe, and IC 4756) recommended by IAU Commission 24 for parallax observations (*IAU Transactions Vol. XVIII B*, p. 127, 1982) now have extensive series' of parallax observations taken with the Van Vleck refractor since 1980 on both D and the finer-grain F emulsions. Measures of IC 4756 are being started by Lee on the Yale PDS Machine. Lee has completed a pilot study of the kinematics of this cluster, from his measures of Van Vleck plates taken for proper motion in 1963 and 1997 and found the proper motion differences of the stars from different plate pairs are about 0.2 mas/yr. Thus the epoch difference of 34 years is an adequate base line for the proper motion study of this cluster. The motion is +5 mas/yr and -1 mas/yr in right ascension and declination, respectively, for member stars brighter than magnitude 15. The cluster distance of about 440 parsecs is well within the PDS capability of producing realistic linear motions. Astrometric observations made at the McCormick and the U.S. Naval Observatories may add plate material for this project.

Weis has reduced four-color photoelectric observations that he obtained at Cerro Tololo, of the contact (or near contact) eclipsing binary UZ Puppis. The light curve shows a photometric distortion (extra light) over the phase range 0 - 0.5. In this respect it appears similar to those obtained by R.H. Bloomer (Thesis, University of Florida, 1973) and B.B. Bookmyer (*PASP* 97, 349, 1985) so that the photometric distortion is fairly stable over a period of at least a dozen years. The displacement of secondary eclipse, if real, is too slight and the available times of minimum light too few, to be sufficient to explain with confidence this photometric distortion as a genuine periastron effect.

Griese continued visual observations of a number of cataclysmic variable stars, in collaboration with the A.A.V.S.O.

During the past year J. Rose at the University of North Carolina and R. Agostinho at the University of Lisbon have worked with Stock on a major project of investigation of the structure and kinematics of the Milky Way Galaxy. The observational material consists of objective prism plates taken with the Schmidt telescope on Cerro Tololo and the plates have been digitized with the PDS plate scanner at Yale. From these data astrometric positions, radial velocities, mag-

nitudes, and spectral indices are derived. The necessary computer programs have been developed at Lisbon. So far six southern fields, most of them near the South Galactic Pole, have been fully analyzed. Each field was covered with six plates, divided into two groups of opposite direction of the dispersion. The plates reach a limiting magnitude of 12.5. On average each field has about 1000 stars. With an interference filter the spectral range covered is restricted to about 180 Å, centered on H- δ . The dispersion, obtained with a ten-degree prism, is 82 Å/mm and a scan of a single plate with the Yale PDS scanner takes about 14 hours.

The method to be applied for the determination of positions and radial velocities is explained by Stock (Revista Mexicana 9, 77, 1984) while the spectral indices are explained by Agostinho and Rose (Astronomical Journal 101, 937 and 101, 950, 1991). The Schmidt telescope has now been equipped with a CCD which covers a field of 1.3 x 1.3 degrees. Test observations have already been made by Agostinho and Stock, applying the same observing procedure as before, and involving exposures with the reversed prism technique. The results are expected to show whether the project can be continued without significant loss in the accuracy of radial velocities and positions.

Stock and Jeanette Stock of the Libre Universidad del Zulia, Venezuela, completed and are publishing an investigation of the positions and proper motions in the field of the open cluster NGC 129. The data are of high precision with uncertainties of only one to two milliarcseconds. Four of the stars are included in the Hipparcos Catalogue, and a close agreement is found between the data from the two sources.

Stock presented a paper on "A Test of an Image Centering Algorithm" at the meeting held at New Haven in honor of Hoffleit, mentioned above. The algorithm offers a promising reduction in measuring errors of stellar images, both photographic and acquired using a CCD.

It has become clear that the Hipparcos and Tycho missions have achieved a singular success. Since the public release of the catalogs containing the astrometric and photometric data, astronomers have found many applications for their use. Among these are the identification of the best system or systems for the determination of the basic physical properties of stars. The comparison of parallaxes from Hipparcos and Tycho with those of the Yale Parallax Catalogue should reveal how all of these data can be best combined into a more complete system. Stock, Uggren, and Lee are looking into whether the Tycho Catalogue can fully replace the PPM, the widely-used Position and Proper Motion Star Catalogue by S. Roser and U. Bastian (PPM Star Catalogue, Publ. Astron. Rechen-Institut, Heidelberg, 1991), and the position and motion system it defines. If this is not the case, a combination of the two can be made. They have combined output from the PPM and Tycho Catalogues to find and identify which among the 400,000 stars in the PPM are not among the million stars of Tycho. Any significant gaps in the Tycho catalogue may call for supplementing it with PPM data in order to establish a more complete system suitable for widespread use. Initial results show many PPM stars in both celestial hemispheres are not covered by the Tycho Catalogue, especially for magnitudes between 8 and 12. The PPM Cata-

logue and system will remain very useful in defining astrometric data.

Hemenway participated with a number of colleagues in a program to link the Hipparcos reference frame to an extragalactic reference system using the fine guidance sensors of the Hubble Space Telescope. This definitive paper on the use of the Hubble Space Telescope to tie the Hipparcos Reference Frame to the VLBI reference system at the milliarcsecond level of accuracy has been accepted for publication in the December 1997 issue of the Astronomical Journal. The paper culminates 18 years of work by members of the Hubble Space Telescope Astrometry Science Team and many others involved in the Hipparcos project. Hemenway is the leader of the HST-Hipparcos Link work. The final results, used in the Hipparcos coordinate system, as combined with other techniques, are presented in the paper. Discussions and reports of this work have been presented and published in the proceedings of several meetings.

Hemenway, Lee, Philip, Stock, and Uggren are investigating the calibration of photometric systems designed to determine physical stellar characteristics using data from Hipparcos in their proposals for that satellite. These systems will be used to observe open and globular clusters as well as field stars in the galaxy. The research is in the form of several related investigations.

With V. Straizys (ITPA, Lithuania) and R. Boyle (Vatican Observatory Group) Philip is establishing standards for the Stromvil System (a combination of the Stromgren and Vilnius photometric systems), using the Vatican Advanced Technology Telescope on Mount Graham in Arizona. Stars in open and globular clusters are also being measured (the former to set up standards and the latter to study globular cluster characteristics).

The space distributions and ages of A and F stars are being derived from Hipparcos data by Uggren and Hemenway, who included a preliminary report in the proceedings of the Third Conference on Faint Blue Stars, now in press. These data are superior to previous ground based parallaxes and may be used to recalibrate photometric systems including the Stromgren four-color system.

Hemenway, Lee, and Uggren concluded a study of the stars forming the tightest concentration in the giant branch, as shown in the HR Diagram of almost 9000 stars with $s.e./n < 0.1$ published by M. Perryman and collaborators from Hipparcos data (Astron. Astrophys. 304, 69, 1995). They found that the sequence along this sharply defined region, which appears to slope towards fainter luminosity with decreasing surface temperature (contrary to previous results) is not one of increasing spectral class. This study was reported at the meeting honoring Dorrit Hoffleit.

A long-term program studying the structure of the Milky Way is underway by Stock in collaboration with astronomers at the Universities of North Carolina, Lisbon, and Yale, CIDA, and Libre Universidad del Zulia. It seeks to examine the reality and stellar content of the thick disk and other components of the galaxy, from drift scans and objective prism observations. Objective-prism radial velocities are regularly determined for all stars in a field simultaneously, to a standard error of +7 km/sec. In connection with this sur-

vey, a recalibration is sought of basic physical parameters of stars (e.g. absolute magnitude, surface gravity, metal content) from equivalent widths of spectral lines, possibly supplemented with the best of multicolor photometry.

Research is being made of the populations of the K and M dwarf stars taken from the lists of Vyssotsky and the CNS3 (Catalogue of Nearby Stars, Third Edition: W. Gliese and H. Jahreiss 1997, in preparation) and elsewhere, by Weis and Uppgren. These are very well defined representative groups of stars of the Milky Way, and include both magnitude and distance limited samples. In collaboration with astronomers at the Astronomische Rechen-Institut in Heidelberg, data is being extended to all dwarf stars in these lists. Research on them is continued using the maximum likelihood method of Bahcall, Casertano, and Ratnatunga to analyse the kinematics of dwarf K and M stars. K. Ratnatunga (Carnegie Mellon University) and Uppgren are able to rigorously handle errors of observation and incompleteness in the data, and found clear evidence for young and old disk components among the stars in the solar neighborhood (Astrophys. J. 476, 811, 1997).

Drift Scans using the 1.0-1.5m Schmidt Telescope of CIDA near Merida, Venezuela, are made in collaboration with scientists in the Physics and Astronomy Departments of Yale and Indiana Universities, CIDA, and the Universidad de los Andes in Venezuela. Stock participates in the program with C. Baltay and S. Sofia of Yale, and others. The program is named QUEST (Quasar Equatorial Survey Team) and combines an array of CCD's to cover the wide field of that telescope. Observations in direct and objective prism modes identify and measure great numbers of many kinds of stars, galaxies, and quasars, and other objects of astrophysical interest down to very faint magnitudes. The project is fully described by C. Baltay *et al.* in An Experiment to Search for Dark Matter via Gravitational Lensing of Quasars, Yale University, 1995.

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