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This report covers the interval October 1, 1999, through September 30, 2000.

The astrophysics program in the Center of Excellence at TSU continues to concentrate on understanding magnetic activity in cool stars, building and managing robotic telescopes, and applying automation to astronomy. Astronomy staff in 1999-2000 were Geoffrey S. Burks, Michael R. Busby, Joel A. Eaton, Francis C. Fekel, and Gregory W. Henry. Andre Hedrick served as a technical consultant for computer programming and systems analysis before moving to California in December, and Michael Williamson joined the group as a part-time employee working on telescope control systems. Marino Alvarez (Coll. of Education), Sallie L. Baliunas (CfA), and Douglas S. Hall (Vanderbilt University) continued as adjunct staff. Henry received the Academic Excellence and Quality Award from the Tennessee Board of Regents and a Special Presidential Citation for confirming the existence of planets outside the solar system. Keinon Brooks, Stephen Henry, Allen Keel, and Kenneth McDavis served as student assistants in the astrophysics program.

1 OBSERVING FACILITIES

During the past year the astrophysics group at TSU made great strides in achieving their dream of building and operating a completely automatic observatory affording world-class facilities for precise photometry, imaging, and high-dispersion spectroscopy. This facility is taking shape at Fairborn Observatory in southern Arizona and will consist of nine telescopes managed by TSU. The Center of Excellence has long been operating four Automatic Photometric Telescopes (APTs) at the site, including the Fairborn 0.25 m, the Vanderbilt/Tennessee State 0.40 m, which is run in collaboration with D. Hall, and the SAO/TSU 0.75 m and TSU/SAO 0.80 m telescopes, in collaboration with S. Baliunas. Further information about the APTs and their observing programs can be found on the Web at <http://schwab.tsuniv.edu>. New telescopes now coming into operation include three meter-class APT's, a 0.6 m automatic imaging telescope (AIT), and a 2 m automatic spectroscopic telescope (AST).

Fairborn Observatory recently completed construction of our three new 0.80 m APTs, and we have begun initial operation of them. We expect to use the first six months of observations on them to shake out the inevitable bugs before they begin routine observing. These telescopes will be dedicated to finding evidence for planets around other stars (through observation of transits and starlight reflected off the planets) and extending our very precise observations of Sun-like stars designed to characterize the photometric changes of magnetic activity cycles. Fairborn also continues work on our 0.60 m automatic imaging telescope, for which all the physical parts are in hand, and we expect Fairborn to finish the telescope by our next report. The primary challenge re-

maining in the design and construction of this instrument is building an offset guider for long exposures. This telescope will be used initially to measure the optical light variations of gamma-ray burst sources and to characterize photometric changes with magnetic activity of cool stars in clusters of various ages.

We have also made great progress on constructing the TSU 2 m automatic spectroscopic telescope. Our web site (<http://coe.tsuniv.edu/eaton/homepage.html>) has more details about its development. The telescope is now in its building in Arizona, and we have achieved first light with the primary mirror. The telescope has found stars all over the sky from 5 to 85 degrees zenith distance and tracked them with its developing control system; it should point to within at least 15 arcsec with a mount model. The primary mirror, which was a surplus f/1.5 paraboloid, gives at least 2-arcsec images, although we have not made critical observations of the image quality yet, and the supports for the primary mirror seem to be working properly. Williamson has taken over writing the telescope control system and has integrated code for the acquisition/guiding camera into it. This telescope development began as a NASA-supported project five years ago, but an oversight committee at NASA Headquarters Code S cancelled it as such in May after we were unable to provide impossible certifications of the image quality and the ability of the telescope to find and track stars before shipping it to Arizona. Work on the bench-mounted spectrograph for the 2 m telescope proceeds apace, mostly under the management of Harland Epps, whom we have retained as a consultant for designing a camera for the spectrograph. We have taken delivery of the stands for most of the optical parts from our machinists, M. Wells and M. E. Krebs, and are integrating them mechanically in our lab in Nashville. The enclosures for the spectrograph and for the computers for controlling the spectrograph are finished. Students working on telescope development/instrumentation over the past year were McDavis (telescope assembly) and Keel (calculation of expectation of guide stars). The AST will be used to map the orbits of cool giants in long-period binary systems, to form Doppler images of cool spotted and distorted stars, and to study chromospheres and winds of cool giants physically.

During the past year (4Q99-3Q00), the Fairborn 0.25 m (T2) APT collected 7,892 new group observations during 252 nights, mostly of semi-regular variable stars. In its 14 years of operation, the 0.25 m APT has collected a total of 89,033 Johnson *VRI* group observations. The Vanderbilt/Tennessee State 0.40 m (T3) APT collected 20,493 group observations mostly of chromospherically active single and binary stars and early-F variables on 264 nights. In its 13 years of operation, it has collected 170,698 Johnson *BV* group observations. The SAO/TSU 0.75 m (T4) APT acquired 7,335 group observations of lower-main-sequence stars on 253 nights. It has collected a total of 43,657

Strömgren *by* group observations in 8 years of operation. Finally, the TSU/SAO 0.80 m (T8) APT made 7,165 group observations of solar analogs on 251 nights. In 5 years of operation, it has collected a total of 27,621 Strömgren *by* group observations.

2 RESEARCH

Fekel, in collaboration with C. Scarfe (Univ. of Victoria) and others, is continuing spectroscopic observation of about 25 close multiple systems and a half dozen speckle binaries to obtain fundamental parameters. For most of the systems speckle observations have been obtained by the CHARA group (Georgia State Univ.). Combined spectroscopic and visual orbits usually produce orbital parallaxes more accurate than the trigonometric parallaxes obtained by the *Hipparcos* satellite, providing an important independent check on the *Hipparcos* results. Analysis of the quadruple system μ Ori is in progress. One visual component of this system consists of an Am primary and an unseen secondary, while the other visual component is a pair of mid-F stars.

For over a decade Fekel has monitored the radial velocities of about 30 slowly rotating B and A stars, which are candidates for early-type velocity standards. A bootstrap procedure has been used to tie the velocities of the early-type stars to the IAU late-type velocity system. Most of the early- and mid-B type stars have variable velocities. However, about two-thirds of the slowly rotating late-B and A-type stars appear to have constant velocities.

Fekel, in collaboration with K. Hinkle and R. Joyce (NOAO), has obtained infrared spectra of the $1.6\mu\text{m}$ region of over two dozen D- and S-type symbiotic stars. Infrared radial velocities have been used to improve orbital elements for the cool component of 5 symbiotic binaries, Z And, AG Dra, V443 Her, AX Per, and FG Ser. Each of the orbital periods has been determined solely from radial-velocity data. The infrared velocities of AG Dra do not show the large orbital velocity residuals found for its optical radial velocities. With this second paper, the orbits of the cool components in 11 of the S-type symbiotics now have been reanalyzed.

Fekel and Henry in collaboration with S. Balachandran (Univ. of Maryland) have reanalyzed the lithium abundances of HDE 233517 and HD 9746. Both chromospherically active post-main-sequence giants have *super-meteoritic* lithium abundances as measured from both the 6708 Å and 6103 Å lines. By the inclusion and exclusion of ^6Li in the spectral syntheses, it is shown that consistent ^7Li abundances are obtained only when ^6Li is absent in the fit. This provides evidence for fresh ^7Li production and excludes both preservation of primordial lithium and planetary accretion as viable scenarios for the formation of Li-rich giants.

Fekel and Henry have obtained spectroscopic and photometric observations to sort out the variability of HD 95559 and Gliese 410 = DS Leo. HD 95559 consists of a pair of essentially identical K1 V stars with an orbital period of 1.526 days. A nearly identical photometric period indicates that the stars are synchronously rotating. Despite large minimum masses for each component, a search for eclipses proved negative. DS Leo is also photometrically variable,

but with periods of 13.99 and 15.71 days for the first and second seasons of observation, respectively. These periods are much longer than the value originally ascribed to DS Leo. HD 95559 and DS Leo are both BY Draconis variables, with variability resulting from the rotational modulation of star spots.

Henry continues to study photometric variations in a sample of over 160 Sun-like stars observed with the T4 0.75 m and T8 0.80 m APTs. He and S. Henry performed a preliminary analysis of the first several years of available data and presented their results at a NASA workshop on the Sun-Climate Connection held in Tucson, AZ in March. They find that short-term (day-to-day) variations in solar duplicate stars do not exceed the range of short-term variations observed in the Sun over the course of the 11-year sunspot cycle. However, long-term (year-to-year) variations in these same stars *can* exceed solar long-term variations but by much smaller amounts than previous studies have suggested. The long-term stellar variations might possibly be understood as a result of random inclinations of the rotation axes of the stellar sample. A detailed analysis is underway in collaboration with Fekel, Baliunas, and R. Donahue (CfA).

In the IAU Circulars in November, Henry made the first announcement of the discovery of planetary transits of an extrasolar planet. He found that the star HD 209458 dimmed by 1.58% at exactly the time predicted by orbital elements of a planet detected by the Keck precision radial-velocity program. Henry, G. Marcy (UC Berkeley), P. Butler (Carnegie Institution of Washington), and S. Vogt (Lick Observatory) published their findings in the *Astrophysical Journal*, computing for the first time the radius and mean density of an extrasolar planet. This discovery put to rest any remaining doubts about the reality of the extrasolar planets detected by radial-velocity techniques.

Henry continues to use the APTs in search of additional planetary transits and to make other photometric observations to confirm or refute new planetary detections. A paper finding a very low limit of possible photometric variability in HD 46375, thus supporting the existence of its newly discovered planetary companion, but no transits was published in the *Astrophysical Journal*. Similar papers on BD -10 3166, HD 179949, HD 195019, HD 217107, and HD 187123 are in press or in preparation with various collaborators. A paper in collaboration with D. Queloz (Geneva Observatory) refuting the existence of a planetary companion to HD 166435 is nearly completed.

Henry and Brooks are collaborating with T. Kaye (Los Alamos National Laboratory) in the analysis of about a dozen low-amplitude, early-F variable stars. These variables were identified by G. Handler (South African Astronomical Observatory) as possible new γ Doradus stars from *Hipparcos* results or by Henry as variable comparison stars in our Sun-like stars program. Intensive follow-up observations were made with the 0.4 m APT and the observations are being analyzed to determine whether the stars exhibit δ Scuti or γ Doradus variability. Only a dozen or so confirmed γ Doradus stars are known, so this project will provide the first detailed mapping of the location of the γ Doradus phenomena in the H-R diagram. Kaye is pursuing theoretical models

to identify the pulsation mechanism in these stars. Henry and S. Henry published two short papers in the IBVS on the discovery of two additional early-F variables.

Henry has begun a new collaboration with L. Jetsu (University of Helsinki) to apply Jetsu's new time series analysis techniques to our long-term photometric light curves of chromospherically active stars observed with the 0.40 m APT. A paper on V815 Herculis has been accepted for *Astronomy and Astrophysics* and a second paper on V511 Lyrae has been submitted. For V815 Her, period changes of several percent due to differential rotation were observed. While significant changes in mean light level were also seen in the 15-year time series, no regular periodicity analogous to the Sun's 11-year cycle was found.

An analysis of 13 years of photometry of the luminous blue variable P Cygni taken by the 0.25 m APT and by the AAVSO photoelectric photometry program has been completed by J. Percy and T. Evans (University of Toronto), Henry, and J. Mattei (AAVSO). The light curve shows variations up to 0.1 mag on time scales of years, months, weeks, and as short as 10 days. While the variations are not strictly periodic, characteristic time scales of 50–200 days and around 400 days are observed. A paper has been submitted to the proceedings of the P Cygni 2000 Workshop held in Armagh, Northern Ireland in August.

Burks' main research interests center on studying the use of an interactive electronic network for improving astronomy education. He is collaborating with Alvarez in developing and extending the Explorers of the Universe Project. He is developing an Astronomy minor for TSU and is working with students on senior projects that include computer modeling with different methods for microvariability detection. He is also working on Galactic halo studies. Burks made a presentation about the Explorers project at the January AAS meeting in the session Astronomy 101 – A Continuing Dialog.

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