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This report covers the interval October 1, 2001, through September 30, 2002.

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 2001-02 were Geoffrey S. Burks, Michael R. Busby, Joel A. Eaton, Francis C. Fekel, and Gregory W. Henry. Michael Williamson continued working part-time on telescope control systems and CCD controllers. Marino Alvarez (Coll. of Education), Sallie L. Baliunas (CfA), and Douglas S. Hall (Vanderbilt University) continued as adjunct staff. Mark S. Whorton (Marshall Space Flight Center) began a second sabbatical year at the Center of Excellence through the NASA Administrator's Fellowship Program. Lauren Brown, Allison Cutts, Stephen Henry, Ceteka Lewis, Melvin Poplar, and Shawn Vaughns served as student research assistants in the astrophysics program. Allison Cutts and Ceteka Lewis received first and third place awards, respectively, for their student research projects presented at the 24th Annual University-Wide Research Symposium in the spring. Melvin Poplar and Shawn Vaughn collaborated to win a second place award at the Symposium.

1. OBSERVING FACILITIES

The astrophysics group continues to operate its automatic telescopes at Fairborn Observatory in southern Arizona. Fairborn is a non-profit Educational Corporation directed by Lou Boyd and dedicated to the advancement of automated astronomy. The telescopes include the T2 0.25 m automatic photoelectric telescope (APT) for Johnson *VRI* photometry, the T3 0.40 m APT for Johnson *BV* photometry, the T4 0.75 m and T8 0.80 m APTs for Strömgren *by* photometry, and the relatively new T10, T11, and T12 0.80 m APTs, also for Strömgren *by* photometry.

During the past year (4Q01-3Q02), the T2 0.25 m APT has been out of operation while its old OS9 operating system was upgraded to a new Linux-based system. The photometer is also being upgraded with a CCD acquisition camera and the inclusion of temperature stabilization. In its previous 15 years of operation, the T2 APT has collected a total of 94,728 group observations. The T3 0.40 m APT collected 13,504 group observations, primarily of chromospherically active single and binary stars, on 235 nights. In its 15 years of operation, it has collected 198,824 group observations. The T4 0.75 m APT acquired 6,766 group observations of solar-type stars on 233 nights. It has collected a total of 56,363 group observtions in 10 years of operation. The T8 0.80 m APT made 9,251 group observations of solar-type stars on 254 nights. In 7 years of operation, it has collected a total of 43,044 group observations. The T10 0.80 m APT made a total of 10,828 group observations of solar-type stars on 250 nights. In two years of operation, it has collected a total of 17,825 group observations. The T11 0.80 m APT made a total of 10,537 group observations of solar-type stars on 250 nights. In two years of operation, it has collected a total of 15,708 group observations. Finally, the T12 0.80 m APT made a total of 8,887 group observations of γ Doradus candidate stars and planetary-candidate stars on 172 nights. In two years of operation, it has collected a total of 13,863 group observations. Further information about the APTs and their observing programs can be found on the Web at http://schwab.tsuniv.edu/.

Fairborn is continuing work on our 0.60 m automatic imaging telescope (AIT), for which all the physical parts are in hand, and we expect Fairborn to finish the telescope by our next report. The primary challenge remaining 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 made great progress toward finishing the TSU 2-m automatic spectroscopic telescope (AST) during the past year. See our web site (http://astro.tsuniv.edu) for more details about its development. This instrument is a 2-m altazimuth Cassegrain telescope, fiber-coupled to a benchmounted echelle spectrograph with three modes (R=30,000, 80,000, and 2500), designed for taking spectra primarily in the red (6000-7200A) and near ultraviolet (3700-4100A). The AST has now been at its site in Arizona for about two years; during this time, Williamson has perfected the telescope's control system to the point of automatic observation of stars. Operating automatically, the AST has acquired stars from a list of objects to observe, centered them on a fiber feed, and tracked them steadily for times up to 20 minutes. It ran in this mode for roughly 175 nights over the past year, opening and shutting automatically as the weather permitted. Eaton and Poplar wrote and perfected a computer program to parse the log files from the telescope to assess the quality of the night and mechanical operation of the telescope. Vaughns maintained and improved the simulator for predicting telescope operations, and he and Eaton wrote an algorithm for observing a particular star at a specified time.

Work on the bench-mounted spectrograph for the 2-m telescope proceeds apace. During the past year Harland Epps calculated the final optical prescription for the spectrograph camera, Tucson Optical Research Corp. finished polishing the lenses for it, Spectrum Thin Films coated them, and Alan Schier designed and had manufactured the mechanical mount for these lenses. The camera was being assembled in California as of 1 October, and we were assembling the spectrograph in Nashville. Williamson converted control programs for the spectrograph CCD from an interactive system to a reliable automatic control daemon running under Linux.

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.) and the USNO.

Fekel and J. Tomkin (Univ. of Texas) are obtaining spectra of known spectroscopic binaries with orbital periods greater than 5 days. Such stars are likely targets of various optical interferometers that are now in operation. For some binaries the secondary star may be detected for the first time while for other systems new radial velocities will be used to update the orbits. In both cases the improved results can eventually be included in three-dimensional orbital solutions.

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. In addition, Fekel has obtained rotational velocities of the stars in the sample as well as several dozen additional A-type stars and compared the v sin i values to results in the literature.

Fekel, P. Warner (NOAO), and A. Kaye (Los Alamos National Laboratory) have recently completed a spectroscopic survey of 34 γ Doradus candidates. Basic properties of the variable stars were determined. The spectra of seven stars show metallic lines that have composite profiles consisting of a narrow component near the center of a broad line, indicating that the variables are late-A or early-F shell stars. Two stars are identified as ellipsoidal variables and are not γ Doradus stars.

Fekel and Henry have obtained spectroscopic and photometric observations of the γ Doradus variable, HR 6844. This star is a spectroscopic binary with a period of 4.485 days and a circular orbit. Velocity residuals to the circular-orbit fit have a period of 1.307 days, which is identical to the strongest period found photometrically. Additional periods of 1.435 and 0.623 days have been detected in the photometry.

Fekel, in collaboration with K. Hinkle and R. Joyce (NOAO) and P. Wood (Australian National Univ.), continued a program of high-resolution infrared spectroscopy at Mt. Stromlo Observatory to obtain orbital elements of over 50 southern symbiotic binaries. This survey will greatly supplement their recent results for 15 northern hemisphere systems. Since currently there are less than 24 symbiotic systems with well-determined orbital elements, the results from this observing program will provide statistics on a greatly expanded sample of symbiotic binaries. To date, the observations indicate that the vast majority of southern symbiotics have orbital periods of at least 500 days.

Henry is continuing to study photometric variations in a sample of 354 solar-type stars being observed with the T3, T4, T8, T10, and T11 APTs. The T3, T4 and T8 sub-samples have been observed for 5 to 10 years now, while the T10 and T11 stars have been added to the observing program only in the past year or two. Henry and S. Henry have completed an analysis of short- and long-term variations in these stars, while Fekel has obtained at least one high-resolution spectrum of each star in the sample and is determining spectral types, $v \sin i$ values, and radial velocities. These data sets will be analyzed, along with Ca II H & K observations from the Mount Wilson HK Project in collaboration with Baliunas and R. Donahue (CfA), to place solar luminosity variability in the context of stellar variability. Henry is also collaborating with W. Lockwood (Lowell Observatory) and R. Radick (Air Force Research Laboratory) to merge the APT data sets with the photometric data on some stars collected in the Lowell solar-type star project.

Henry is obtaining photometry of the host stars of extrasolar planetary systems to search for planetary transits and to confirm new planetary candidates, primarily in collaboration with the University of California, Berkeley planet-search group led by G. Marcy. An Astrophysical Journal paper by Marcy *et al.* is in press describing the radial-velocity detection of a planet at 5 AU around the star 55 Cancri with a minimum mass of $4.0 M_{\rm Jup}$. This is the first extrasolar planet found to orbit near or beyond Jupiter's distance from the Sun, and it has a modest eccentricity of 0.16, rather than a larger eccentricity ususally associated with extrasolar planets orbiting beyond 1 AU from their stars. The radial velocities also imply a third planet in the system at 0.24 AU, intermediate between the outer planet and the previously known planet at 0.11 AU. Precise photometry shows that the radial velocities are unlikely to arise from chromospheric activity in the star; it is magnetically inactive and photometrically quiet. This planetary system is also notable in that a hypothetical terrestrial planet could orbit stably at 1 AU.

Another Astrophysical Journal paper by P. Butler (Carnegie Institution) et al. is in press detailing the discovery by the California group of new planets around 7 nearby G and K dwarfs. The planet around HD 49674 orbits the star in only 4.948 days, has the smallest mass yet found for any extrasolar planet, $M \sin i = 0.12 M_{\rm Jup}$, and has a velocity semi-amplitude of only 14 $m s^{-1}$. Precise Strömgren photometry with the T12 APT demonstrated that the star has no intrinsic variability on the 4.9-day period to a limit of 0.0001 mag, thus eliminating surface activity as the source of the radial velocity variability and supporting the existence of the planet. A search for transits of this new ‘‘Hot Jupiter’’ with the T12 APT rules out transits by planets larger than about four Earth radii.

A third paper has been submitted by D. Fischer (University of California) et al. that announces the detection of the first planet around HD 40979 and a second companion to both HD 12661 and HD 38529. The orbital period and minimum mass for the companion to HD 40979 are 263 days and $3.28 M_{\rm Jup}$, respectively. Moderate chromospheric activity predicts a stellar rotation period of 8.9 days, but the observed lack of coherent photometric variability suggests the observed radial velocity variations arise from planetary reflex motion and not stellar surface activity. HD 38529 was previously known to have a companion with a minimum mass of $0.78 M_{\rm Jup}$ and a period of 14.3 days. The radial velocities now suggest a second planet with a minimum mass of $12.7 M_{\rm Jup}$ and a period of 2174 days. The star's low chromospheric activity predicts a rotation period of 34.5 days. Subtle photometric variations detected with the T11 APT reveal the rotation period to be 35.7 days, very close to the predicted period. The photometric results suggest that neither the 14-day nor the 2174-day planets could be artifacts of surface activity and thus support both planets' existence.

Henry, in collaboration with Baliunas and Donahue, found photometric variations with a period of 24 days in the nearby K2 dwarf HD 192263. Both the California and Geneva planet-search groups announced in 2000 that this moderately active star had a $0.75 M_{\rm Jup}$ planet with an orbital period of 24 days. Thus the new photometric results cast doubt on the existence of this planet and suggest the radial velocity variations are due, at least in part, to starspots. Simultaneous photometric and radial velocity observations are being conducted by the Geneva group to resolve the issue. Henry's photometric observations were published in the 2002 October 1 issue of ApJ Letters.

Henry is collaborating with D. Paulson and W. Cochran (Univ. of Texas) to conduct photometric observations of 4 Hyades G dwarfs suspected from radial velocity observations with the 10 m Hobby-Eberly Telescope (HET) to possess short-period planetary companions. Photometric observations with the T12 APT showed all four to have photometric variations whose periods matched the radial velocity periods. A paper demonstrating that the radial velocity variations are due to photospheric spots is in preparation.

Henry is also collaborating with Butler on a similar project for the star HD 19632. Radial velocity observations with the 3.9 m Anglo-Australian Telescope (AAT) suggest a planet with a minimum mass of only $0.3 M_{\rm Jup}$ in a 12 day orbit. Photometric observations, however, reveal a stellar rotation period of 12 days, thus pointing to stellar activity rather than reflex motions.

S. Henry has written and tested software to search for planetary transits in the extensive APT archives. The software is based on a method by G. Laughlin (NASA Ames) using a chi-squared statistic to search for periodic small drops in the brightness of a star. To test the program's capability, simulated transits were added to actual APT data sets, which were then searched by the new software. Due to the high precision of our typical APT data sets (0.001–0.002 mag), transits of a $0.5 R_{\rm Jup}$ planet across a $1.0 R_{\odot}$ star (resulting in a transit depth of only 0.0027 mag) were recovered in 80% of the trials for periods between 3 and 10 days. In the coming year, the new software will be used to scan the APT data sets for undetected transits.

Henry and Fekel are continuing their photometric and spectroscopic search for new Gamma Doradus variables. Two papers were published this year in the AJ and PASP, bringing the total number of confirmed variable stars in this new class to 30. The analysis of another 13 candidates observed intensively this year with the T3 APT is underway; preliminary results indicate that 12 of these are γ Doradus variables. One of these, HD 207651, exhibits simultaneous δ Scuti and γ Doradus variability, as suspected by G. Handler (Univ. of Vienna) and R. Shobbrook (Australian National Univ.). Henry has also completed a large photometric survey with the T12 APT of a sample of 275 γ Doradus candidates to establish the relative frequency of these variables and to add more stars to this class of variables. The observations will be analyzed in the coming year.

Burks is implementing the recently approved Astronomy Minor. A full range of upper level undergraduate courses is being taught. Burks is also working on one of the first streaming video astronomy courses to be delivered, under a NASA NRTS grant. It is aimed primarily toward students at colleges without an astronomy course. Filming and post production on the course are ongoing. He and Whorton are also working on an automated telescope for education to be placed at Dyer Observatory.

Whorton is the principal investigator for an active microgravity vibration isolation system designed for the International Space Station (ISS). The flight system, called g-LIMIT, is scheduled for delivery to the Kennedy Space Center where it will be launched to the ISS and begin operation on-orbit during spring or summer of 2003. While at TSU, Whorton has continued his research in robust control systems for vibration isolation systems with parametric uncertainties. Whorton has involved student teams in control system design, data analysis software development, and design of a passive payload isolation system.

TSU has developed a collaborative relationship with the New Initiative Office (NIO) of the Association of Universities for Research in Astronomy (AURA) on the NSF funded Giant Segmented Mirror Telescope (GSMT) project. Whorton is working on active structural control for future giant telescopes, and the work was presented in two papers at the 2002 SPIE Astronomical Telescopes and Instrumentation Conference, in Waikoloa, Hawaii.

Whorton, Guanpeng Xu (TSU post-doc fellow), and Yong Xin Tao (TSU Adjunct Professor) are co-investigators on a research project entitled ‘‘Dynamic Modeling of Turbulent Shedding Effect on the 30-meter Primary Mirror of GSMT.’’ This project involves Computational Fluid Dynamics (CFD) research in telescope mirror aerodynamics and was presented at the SPIE Astronomical Telescopes and Instrumentation Conference as well. The research focuses on (a) the development of efficient computational techniques to model the unsteady, turbulent flow field around the primary mirror, and (b) understanding the flow mechanisms that affect the dynamic wind loading on the primary mirror of a 30-meter aperture giant segmented mirror telescope.

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