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This report covers the interval October 1, 2002, through September 30, 2003.

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 2002-03 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) and Sallie L. Baliunas (CfA) continued as adjunct staff. Douglas S. Hall (Vanderbilt Univ.) retired from Vanderbilt and completed his long association as an adjunct researcher at the Center of Excellence. Mark S. Whorton (Marshall Space Flight Center) completed his second sabbatical year at the Center of Excellence through the NASA Administrator's Fellowship Program and returned to MSFC in June. Frank Alston, Stephen Henry, and Brent Wright served as student research assistants in the astrophysics program.

1. OBSERVING FACILITIES

Center of Excellence astronomers operate several automatic telescopes at Fairborn Observatory in the Patagonia mountains of southern Arizona. Fairborn is a non-profit Educational Corporation directed by Lou Boyd and dedicated to the advancement of automated astronomy. Operational 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 APT for Strömgren *by* photometry, and the T8, T10, T11, and T12 0.80 m APTs, also for Strömgren *by* photometry. In addition, the T13 2.0 m automatic spectroscopic telescope (AST) began successfully acquiring high-resolution echelle spectra in the spring of 2003 and began routine operation in September (http://astro.tsuniv.edu).

The T2 0.25 m APT has been out of operation for the past two years awaiting completion of an upgrade of its obsolete OS9 operating system to a new Linux-based system. The telescope began operating again in September. The photometer has also been upgraded with a CCD acquisition camera, an active temperature-control system, and a new 1 mm (80 arcsec) photodiode detector from Optec. With the new system, the time required to find and center a target star has been halved to about 8 seconds. The overall observing efficiency (fraction of a night spent integrating on targets) has improved from 45% to 65%, while the internal precision of the observations has improved from about 0.006 mag to 0.003 mag. Initially, the upgraded telescope is being used to make extensive observations of the unusual Be variable γ Cas. The T2 APT has collected 94,728 group observations, primarily of semi-regular variables, in its previous 15 years of operation.

During the past observing year (2002 September – 2003 July), the T3 0.40 m APT collected 15,841 group observations, primarily of chromospherically active single and binary stars, on 242 nights. In its 16 years of operation, it has collected 214,665 group observations. The T4 0.75 m APT acquired 7,310 group observations of solar-type stars on 247 nights. It has collected a total of 63,673 group observations in 11 years of operation. The T8 0.80 m APT made 8,850 group observations of solar-type stars on 241 nights. In 8 years of operation, it has collected a total of 51,894 group observations. The T10 0.80 m APT made a total of 9,486 group observations of solar-type stars on 238 nights. In 3 years of operation, it has collected a total of 27,311 group observations. The T11 0.80 m APT made a total of 9,427 group observations of solar-type stars on 242 nights. In 3 years of operation, it has collected a total of 25,135 group observations. Finally, the T12 0.80 m APT made a total of 11,153 group observations of planetary-candidate stars on 245 nights. In 3 years of operation, it has collected a total of 25,016 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). 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.

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, Scarfe and D. Barlow (Univ. of Victoria) have observed the recent periastron passage of the single-lined triple system HD 166181 = V815 Her in its long-period orbit and determined orbital periods of 1.810 days and 6.3 years. While the short-period orbit is circular, the long-period orbit has an eccentricity of 0.75. The primary star is a chromospherically active G5 dwarf.

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 and 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 several systems, lines of the secondary star have been detected for the first time, turning single-lined systems into the more useful double-lined variety. For other systems new radial velocities will be used to improve the orbital elements so that good three-dimensional orbital solutions can eventually be determined.

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 systems observed from the northern hemisphere. Since currently there are fewer 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, our observations indicate that the vast majority of southern symbiotics have orbital periods of at least 500 days. Unfortunately, on 2003 January 18 a firestorm swept through part of Canberra and largely destroyed Mt. Stromlo Observatory. Both the 1.88 m telescope and our unique infrared detector used for the symbiotic binary project were destroyed. In June at Siding Spring Observatory, we obtained spectroscopic observations with the 2.3 m telescope and an echelle spectrograph. Analysis of the data is underway to determine if the velocity precision of the new observations is high enough to continue the project with that telescope and instrument.

Fekel with Hinkle, Joyce, and Wood have finished observing V2116 Oph. This star is a unique symbiotic, consisting of an M giant and a neutron star. The previously suggested orbital period of 304 days is wrong; the correct period is much longer, about 1160 days. The orbit is not circular but has a modest eccentricity.

Henry, Fekel, and S. Henry are conducting a long-term study of photometric variations in a sample of approximately 350 solar-type stars being observed with the T3, T4, T8, T10, and T11 APTs. The T3, T4 and T8 sub-samples have now been observed for 6 to 11 years, while the T10 and T11 stars were added to the observing program only in the past two or three years. Analysis of the short- and long-term variations in these stars suggests that the Sun's brightness variability, as measured by space-based radiometers, is comparable to the brightness variations in the solar-type star sample, as observed with the APTs. Fekel has acquired spectroscopic observations of nearly all the stars in the sample. Spectral classifications have been made and metallicities estimated. Several stars turned out to be spectroscopic binaries and have been eliminated from the study. Projected rotational velocities have been determined. Solar-type stars that rotate more rapidly than the Sun but have Ca II H and K emission fluxes that are similar to or weaker than the Sun are Maunder minimum candidates. These data sets are being 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 30 stars collected in the earlier Lowell solar-type star project. Fekel and Radick presented details on these two projects at IAU Symposium 219 in Sydney, Australia in July.

Henry is also collaborating with Lockwood and J. Hall at Lowell on a multi-year study of the G2 V star 18 Sco. At present, this star appears to be the one most similar to the Sun in all of its properties and has been labeled a ''solar twin.'' However, while the Lowell Ca II H & K observations show significant magnetic activity variability over seven years, the APT observations show 18 Sco to be constant over the long-term to a limit of 0.0001 mag or so, a result unexpected from solar analogy.

Henry is continuing to obtain 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 Fischer (Univ. of California) *et al.* has recently been published announcing the detection of a planet with an orbital period of 62 days and a minimum mass of only $0.20 M_{\rm Jup}$ in orbit around the K0 V star HD 3651. The star is chromospherically inactive, and 10 years of observations with the T4 0.75 m APT demonstrated it to be photometrically constant to better than 0.001 mag. In particular, no photometric variability was found on the 62 day radial velocity period to a limit of 0.0002 mag, strongly supporting the planetary interpretation of the radial velocity variations. Photometric transits of the planetary companion across the face of the star were ruled out with a probability of 87%.

Henry is using the T12 0.80 m APT to conduct a photometric survey of 93 young solar-type stars (ages 3 Myr to 3 Gyr) that are part of the SIRTF Legacy Science Project ''The Formation and Evolution of Planetary Systems: Placing Our Solar System in Context.'' SIRTF will study the evolution of planetary systems around these stars by observing their dust disks. Marcy is using the 10 m Keck telescope to make precise radial velocity observations of these 93 stars to search for young planetary systems. The APT observations complement the SIRTF and Keck observations by measuring the level of starspot activity in these stars and, in many cases, determining their rotation periods directly. This will allow the radial velocity variations induced by planetary companions in these young systems to be disentangled from the confusing effects of stellar activity and increase the confidence in any detected planetary systems. Henry and TSU undergraduate student F. Alston are analyzing the first year of observations and finding many new rotation periods.

Henry and Fekel are conducting photometric and spectroscopic observations in search of new γ Doradus variables. An analysis was completed of their photometry from the T3 0.40 m APT and spectroscopy from KPNO of 12 γ Doradus candidates, mostly from the lists of G. Handler (Univ. of Vienna). All 12 of these candidates were confirmed as new γ Doradus variables. A paper describing the results has been accepted for the Astronomical Journal, bringing the total number of confirmed γ Doradus stars to 42. A comparison of the location of these 42 stars in the H-R diagram with a

recently published theoretical γ Doradus instability strip showed good agreement. A new sample of 12 additional γ Doradus candidates, selected from Handler and also from our own lists of photometric comparison stars discovered to be variable, was observed with the T3 APT and at KPNO during the 2002-03 observing season; preliminary results indicate that most of these stars are γ Doradus stars as well. A further sample of 12 candidates is also being observed for 2003-04 observing season.

The γ Doradus candidate HD 207651 has been shown to be a triple system. Its 0.7354-day photometric variations are due to the ellipticity effect and not pulsations. Two additional periods of 0.0648 and 0.0634 days result from δ Scuti pulsations in this star. Henry, Fekel, and S. Henry are completing a separate paper on HD 207651 for the Astronomical Journal.

Henry has completed a preliminary photometric analysis of a one year survey conducted in 2001-02 with the T12 APT of 275 γ Doradus candidates chosen from the Hipparcos catalog. A subset of 114 of these stars constitutes a volume-limited sample of stars lying in the γ Doradus region of the H-R diagram. This survey was conducted to establish the relative frequency of γ Doradus stars and to add more stars to this class of variables. A total of 27% of these stars were found to be photometrically variable. However, in most cases, the period analyses were not able to distinguish between short-period δ Scuti and longer-period γ Doradus variability due to severe aliasing resulting from the observing cadence of one observation per night. The variables will each be observed more intensively for a few nights with the T12 APT over the next year or so to enable the photometric periods to be resolved and the variability class to be established.

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. Testing will begin soon. An automated telescope for education to be placed at Dyer Observatory is currently being procurred.

Whorton continued as the principal investigator for an active microgravity vibration isolation system designed for the International Space Station (ISS). The flight system, called g-LIMIT, was delivered to the Kennedy Space Center in December, but its flight to the ISS has been delayed by the loss of the orbiter Columbia in February. It is currently manifested for the next shuttle trip to the ISS, which will occur no earlier than 2004 September.

Whorton has involved TSU students in his research on robust control systems for vibration isolation systems. A team of TSU undergraduates submitted a proposal and were selected as part of the NASA Reduced Gravity Aircraft Student Flight Opportunities program. The students flew their experiment, a test of a passive vibration isolation system for reduced gravity experiments, on NASA's KC-135 aircraft in July. They are currently analyzing their flight data.

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 continued his collaboration with Guanpeng Xu (TSU post-doc fellow in automated controls) to model the turbulent air flow field around the 30 m primary mirror and the resulting wind loading of the mirror. Whorton chaired an invited session on NASA applications of active optics at the 2003 International Federation of Automatic Control Workshop on Control of Optical Systems in Breckenridge, CO in February.

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