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This report covers the interval October 1, 1995, through September 30, 1996. The astrophysics program in the Center of Excellence at TSU continues to concentrate on understanding magnetic activity in cool stars, managing robotic telescopes, and applying automation to astronomy. Astronomy staff in 1995-96 were Michael R. Busby, Joel A. Eaton, Francis C. Fekel, and Gregory W. Henry, Fekel having joined the Center permanently in January, 1996. Sallie L. Baliunas (CfA) and Douglas S. Hall (Vanderbilt University) continued as adjunct staff. Cynthia R. Borrum, Paul Finley, Mark Newsom, and Tamara Williams served as student assistants in the astrophysics program.

1. OBSERVING FACILITIES

During this year the Center for Automated Space Science within the Center of Excellence in Information Systems began developing two new automatic telescopes, a 24-inch Automatic Imaging Telescope (AIT) and a 2-meter Automatic Spectroscopic Telescope (AST), to add to the complement of four Automatic Photometric Telescopes (APTs) previously managed, and collaborated with Fairborn Observatory to select a new site for all six of these robotic telescopes. The four existing APTs include the Fairborn 10-inch, run in collaboration with S. Baliunas, the Vanderbilt/Tennessee State 16-inch in collaboration with D. Hall, the SAO/TSU 30-inch in collaboration with Baliunas, and the TSU/SAO 32-inch.

TSU has contracted with Fairborn Observatory to construct a 24-inch automatic imaging telescope for general imaging in 12 passbands. The telescope will have a Ritchey-Cretien optical system from Star Instruments of Flagstaff, Arizona, and a yoke-type equatorial mount designed by L.J. Boyd. The detector will be a CCD camera with roughly 0.8-arcsec pixels and a 12-arcmin field of view. Control of the telescope will be through ATIS93 commands interpreted by a control system written by D. Epand and based on earlier control systems for APT's written by Boyd and himself. The camera will have a permanent complement of a dozen filters designed for general imaging and for narrow-band imaging of nebulae. Initial observing projects for the telescope are studies of optical flares in chromospherically active stars, photometry of chromospherically active stars in young clusters, variability of active galactic nuclei, and structure of gaseous nebulae.

Receiving no acceptable bids for a complete telescope, TSU has decided to design and build the 2-m automatic spectroscopic telescope as a project within the CASS center with Eaton as project manager. During the first year of this project, TSU contracted with Torus Optics of Iowa City, Iowa, to provide an f/8 Cassegrain optics set based on a surplus 81-inch, f/1.5 Cervit primary mirror. The mount for it will be an alt-azimuth design with the 3200-pound primary mirror centered on both axes. Moving weight will be 12,000-14,000 pounds. The telescope is designed for completely unattended operation. Its focus will be between the mirrors, 18 inches above the vertex of the primary mirror, which reduces the size of the secondary mirror and allows a dramatically lightened secondary support structure of the type used on existing APTs. This feature also reduces the liklihood of interference with the building housing the telescope, which will be a minimal structure (roughly $16\times25\times15$ ft.) with a roll-off top, which will not clear the telescope except in its stowed position. The mount and drives are being designed at TSU with some consulting help from Tennessee Tech University and with advice about maintenance issues from Fairborn Observatory. Engineers at numerous other observatories have freely given advice to this project. Most of the structural analysis for the telescope mount is now finished, and TSU has called for bids for the azimuth bearing and identified local sources for fabrication and machining of the mount. The instrumentation for this telescope is a dedicated bench-mounted spectrograph to be located in a separate building and fed with a fiber-optic cable.

To provide space for the new TSU telescopes and to secure its future, Fairborn Observatory decided in December, 1995, to move from the site it had occupied on Mt. Hopkins for the past decade. Louis J. Boyd, Director of Fairborn Observatory, and Henry, Fekel, and Eaton of TSU collaborated in January, 1996, to select this new site for the automatic telescopes. It is private land located at 5700 feet in Washington Camp, Arizona, about 20 miles east of Nogales and 5 miles north of Mexico, and consists of two old mining claims in the Patagonia Mountains. Fairborn obtained zoning for its operation and bought the property in late March, 1996, had a road to the site in place in about a month, and has since constructed three buildings with ten-foot square spaces for four telescopes each along with partially buried control buildings. The eight telescopes Fairborn has been running at Mt. Hopkins should be back in operation during November, 1996. Primary clients of Fairborn Observatory are TSU, the University of Vienna, and a four-college consortium of Villanova, The Citadel, College of Charleston, and Nevada Las Vegas.

During the past year (4Q95-3Q96), the final year of APT operation Mt. Hopkins, the Fairborn 10-inch APT collected 7,787 group observations, mostly of semi-regular variables, on 236 nights during its tenth year of operation. The Vanderbilt/Tennessee State 16-inch collected 15,418 group observations of chromospherically active, single and binary stars on 246 nights in its ninth year of operation. The SAO/TSU 30-inch APT made 7,014 group observations of lower-main-sequence stars on 247 nights in its fourth year of operation.

After a rather lengthy period of debugging, the new TSU/SAO 32-inch APT began making routine, high-precision observations of solar-duplicate stars in 1996 April. Between then and the end of the reporting year, the APT made 2,133 group observations on 83 nights.

2. RESEARCH

Henry continued his collaboration with the Computational Sciences Division at NASA Ames Research Center to develop an automated scheduling and management system for robotic telescopes. This system, called the Associate Principal Astronomer (APA), will combine AI-based scheduling of observations designed to maximize the precision and scientific usefulness of robotic-telescope observations with automated quality control, data reduction, and telescope management features that should simplify the operation of these telescopes. For several weeks during the spring of 1996, the 32-inch APT on Mount Hopkins was successfully controlled via the Internet in near real-time by the AI scheduler running on a Sun SparcStation at NASA Ames in California.

Henry is currently analyzing the first four years of observations obtained with the 30-inch APT to determine the level of precision obtained in the seasonal means of solar-type stars. He finds that, with suitable comparison stars, these stars can be measured to a precsion of 0.0001 or 0.0002 mag. This level of precision makes it possible to follow the luminosity cycles of Sun-like stars with total amplitudes of only a milli-magnitude or so.

Henry has analyzed the constancy of roughly 450 comparison stars used for the 150 program stars on the observing menu of the 30-inch and 32-inch APTs. Due the the high precision attainable with these telescopes and the need for extremely constant comparison stars, approximately 100 comparison stars were removed from the menu because of low-amplitude variability. Many of these variables were K giants and early F dwarfs, two classes of stars not generally considered to be variable. Fekel and Henry have begun spectroscopic observations with the coudé-feed telescope at Kitt Peak to determine the variablility mechanism of these stars.

Several of the solar-type stars Henry has been monitoring with the APTs have recently been found to exhibit low-amplitude, radial-velocity variations suggestive of planetary-mass companions. Henry, along with collaborators at CfA, have analyzed the photometric observations from the APTs as well as HK observations from Mt. Wilson for the stars 51 Peg, 47 UMa, 70 Vir, and HD 114762. All four stars were found to be magnetically quiet; that is, they lack the typical Ca II and photometric variability due to rotation and activity cycles expected from surface magnetic activity in solar-type stars. Their analysis confirmed that planetary companions are the likely cause of the radial-velocity variations and also revealed an observational bias that favors the detection of planets around magnetically-quiet stars. A paper on their results will appear in the January 1, 1997 issue of the Astrophysical Journal.

Henry, Fekel, and collaborators at CfA prepared another paper with similar results for ρ^1 Cnc, τ Boo, and υ And, additional stars found to have low-amplitude radial-velocity variations. This paper has been accepted in the Astrophysical Journal Letters.

Henry and Hall collaborated with K. Olah and K. Strassmeier on an analysis of 30 years of photometry on the chromospherically active star HK Lac. Spot activity was found to be concentrated at two widely separated longitudes over the 30-year baseline of the observations. Evidence for long-lived polar spots was also found. Although significant variation in mean brightness was observed, no long-term periodicity emerged from the data. A paper on these results has been submitted to Astronomy & Astrophysics.

Henry and Fekel are working with B. Rodriguez, a high school physics and astronomy teacher at the University School of Nashville, on an analysis of photometric data on the star HD 80492. Students at the school requested that observations of this star be made for them with the Fairborn 10-inch APT. This K0 giant was found by R. Griffin to reside in a single-lined binary system with an orbital period of 24 days; hence, photometric variations were expected at a similar period. Analysis of the Fairborn-10 observations reveals this expected photometric variation, although at very low amplitude. A paper is being prepared for Publications of the Astronomical Society of the Pacific.

Henry and Fekel in collaboration with S. Balachandran (Univ. of Maryland) have obtained optical photometry and additional spectroscopic observations of HDE 233517, a rapidly rotating, chromospherically active, single K giant with a dust disk, evidence of mass loss, and large lithium abundance. Photometric observations show low-amplitude light variability with a period of 47.9 days. This assumed rotation period and our revised $v \sin i$ result in a minimum radius of 17 $R_\odot$, confirming its status as a post-main-sequence star. The very large lithium abundance is likewise confirmed, making this an extremely unusual star in many respects.

Eaton and Williams have investigated further the effects of large numbers of moderately large starspots randomly spread over a differentially rotating star to see how well this hypothesis reproduces the sort of light variation seen in RS CVn binaries.

Eaton gave a comprehensive review of his observational work on chromospheres of cool supergiant stars in ζ Aurigae binaries at the Ninth Cambridge Workshop in Florence Italy.

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.). A joint effort by Fekel and C. Scarfe, D. Barlow (Univ. of Victoria), A. Duquennoy (Observatoire de Geneve), H. McAlister, W. Hartkopf, B. Mason (Georgia State Univ.), and A. Tokovinin (Sternberg Astron. Inst.) has resulted in the simultaneous solution of the spectroscopic and visual orbits of the solar-type triple system HD 202908 = ADS 14839. Eighteen years of spectroscopic and speckle observations were combined with earlier visual data. The solution yields masses for each of the three stars with uncertainties of 2% and a distance with an uncertainty slightly greater than 1%. The system provides three well determined points for the mass-luminosity relation. Fekel, Scarfe, and Barlow (Univ. of Victoria) now have a complete 13-year cycle of high-dispersion spectroscopic observations for HR 2130 and are updating the short- and long-period orbits of this late-B type triple system. New multiple systems added to the observing program include HD 16525, ι Tri B, and HD 106225.

Fekel continues to monitor the radial velocities of about

30 B and A stars as candidates for early-type standards. The following stars are variable or probably variable and have been removed from the candidate list: HD 145570, HD 147394, HD 179761, and HD 196426. Added to the list are HD 48843 and HD 184171.

Fekel is working on the orbits of numerous chromospherically active stars with several collaborators including V. Dadonas (Vilnius Univ.), J. Eitter (Iowa State Univ.), and J. R. de Medeiros (Universidade Federal do Rio Grande do Norte). A reanalysis of the orbits of the double-lined systems ι Tri A and 54 Cam is in progress.

Fekel has collaborated with C. Ambruster and E. Guinan (Villanova Univ.) and B. Hrivnak (Valparaiso Univ.) on an analysis of the extremely active single giant 1E1751+7046. Chromospheric, transition-region, and coronal surface fluxes are near saturation level suggesting a similarity to FK Comae. The rotational velocity and lithium abundance of this star are well above that expected for normal cool giants. Two possible evolutionary scenarios are suggested. Either the star has coalesced from a close-binary progenitor or it has dredged up angular momentum and nuclear processed material from its core.

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