Tennessee State University
Center of Excellence in Information Systems

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This report covers the interval October 1, 1996, through September 30, 1997. 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 1996-97 were Michael R. Busby, Joel A. Eaton, Francis C. Fekel, and Gregory W. Henry. Sallie L. Baliunas (CfA) and Douglas S. Hall (Vanderbilt University) continued as adjunct staff. Ezell Allen, Steve Bosh, Tobi Brown, Stephen Henry, Sterling Langley, Kenneth McDavis, Didar Sohi, Richard Tantaris, and Tamara Williams served as student assistants in the astrophysics program.

1. OBSERVING FACILITIES

The Center of Excellence currently operates four Automatic Photometric Telescopes (APTs) at Fairborn Observatory, including the Fairborn 10-inch, run in collaboration with S. Baliunas, the Vanderbilt/Tennessee State 16-inch in collaboration with D. Hall, and the SAO/TSU 30-inch and TSU/SAO 32-inch telescopes in collaboration with Baliunas. During July through October 1996, these telescopes, along with four additional APTs operated by Fairborn for other institutions, were relocated from Fairborn's site on Mt. Hopkins to a new privately-owned site located at 5700 feet in the Patagonia Mountains near Washington Camp, Arizona. The eight telescopes resumed normal operations in early November 1996 and have now completed their first year of operation at the new site.

As reported last year, the Center has contracted with Fairborn to construct a 24-inch automatic imaging telescope (AIT) for general imaging in 12 passbands. The telescope's f/8 Ritchey-Cretien optical system has been delivered by Star Instruments of Flagstaff, Arizona. Mechanical componets for the horseshoe-type equatorial mount are being fabricated by Arizona Machine and Fabrication of Phoenix from a design by L. Boyd (Fairborn). The CCD camera, guider, and control system are under construction by Boyd and D. Epand (Fairborn). Initial observing projects for the telescope will be studies of optical flares in chromospherically active stars, photometry of chromospherically active stars in open star clusters of various ages, variability of active galactic nuclei, and structure of gaseous nebulae. Funding for the project comes from TSU and NASA through the Center for Automated Space Science within the Center of Excellence.

Construction also began for the TSU 2-m automatic spectroscopic telescope, also described in last year's report. This instrument will have a single-channel fiber-coupled echelle spectrograph with three resolutions (3×10^4, 10^5, and 10^3). It is also being built with NASA funding under the Center for Automated Space Science, with Eaton as Project Manager. TSU finished shop drawings for the mount and contracted with the Manufacturing Technology Center (Y12 plant) at Oak Ridge National Laboratory to build the major parts of the mount. Other local manufacturers, such as Schmiede Corp. in Tullahoma, Hamilton Machine in Nashville, and J.W. McDougal in Nashville are making some of the smaller parts. Foundations for the telescope enclosure were finished during this time, and a basic structural design of the telescope enclosure was done during this period. Students working on the project are Allen, McDavis, and Sohi (weather station), Bosh and Langley (enclosures), Brown and Tantaris (control system).

This year the Center also contracted with Fairborn to build three additional 32-inch APTs with precision two-channel photometers to be placed in operation at Washington Camp. The f/8 optical systems of sitall are being fabricated by Star Instruments. The telescope mounts are being built by Rettig Machine of Redlands, CA from a Boyd design similar to existing APTs. The precision photometers are being built by Boyd. These telescopes will extend the work of the 30- and 32-inch APTs and will be dedicated to the long-term monitoring of solar analogs. Target stars will be taken from the expanding searches for planets around sun-like stars. Therefore, the telescopes will also supply complementary photometric data necessary to interpret the findings of the new planetary-search programs. Construction costs for the new APTs come from NASA, NSF, and TSU.

During this past year (4Q96-3Q97), the Fairborn 10-inch APT collected 6,217 new group observations during 217 nights, mostly of semi-regular variable stars. In its eleven years of operation, the Fairborn-10 has collected a total of 65,024 group observations. This year the Vanderbilt/Tennessee State 16-inch collected 14,331 group observations of chromospherically active single and binary stars on 207 nights. In its ten years of operation, it has collected 114,061 group observations. The SAO/TSU 30-inch APT acquired 5,574 group observations of lower-main-sequence stars on 216 nights. It has collected a total of 22,900 group observtions in its first five years of operation. Finally, the TSU/SAO 32-inch APT made 5,212 group observations of solar analogs on 204 nights. In its first two years of operation, it has collected a total of 7,338 group observations.

2. RESEARCH

Henry continues to collaborate with the Computational Sciences division at NASA Ames Research Center to develop automated scheduling systems for automatic telescopes. This year, a new Linux-based computer was purchased and placed on the local network at the new Fairborn Observatory site. The computer supports the operation of the AI-scheduling system called the Associate Principal Astronomer or APA. This system is now routinely being used to schedule observations on the 32-inch APT and will be able to manage additional APTs when their control systems are upgraded. Richard Tantaris (COE graduate student) is writing his Master's thesis on a new telescope scheduling method he calls the Optimal Scheduling Algorithm (OSA) based on dynamic programming techniques.

Henry has completed a preliminary analysis of short-term photometric variability in the 145 sun-like stars he is observing with the 30-inch and 32-inch APTs. These stars range in age roughly from 100 Myr to 10 Gyr (based on Ca II H & K emission levels) and show day-to-day photometric variability of nearly 0.03 mag for the youngest stars down to the measurement limit of 0.0010 mag for solar-age and older stars. A paper with S. Baliunas, R. Donahue, and W. Soon has been submitted to the proceedings of the Cool Stars 10 workshop.

Henry has also completed an analysis of long-term photometric variations in 56 solar-type stars observed for several years with the 30-inch APT. He is able to meausure seasonal mean brightness of these stars to a precision of 0.0002 mag, which enables him to trace long-term brightness changes in these stars that are similar to brightness changes in the Sun observable only with space-based radiometers. Preliminary results were presented at the Cool Stars 10 workshop. A detailed paper is planned.

Henry has made further observations of all the sun-like stars so far suspected to have planetary companions in short-period orbits: 51 Peg, 70 Vir, HD 114762, ρ^1 Cnc, τ Boo, υ And, and ρ CrB. He finds no evidence of optical variability on the planetary period in any of the stars and also no evidence for photometric transits of any of the companions. A paper on the latest results is in preparation.

Henry and Fekel are completing a study of photometric variability found in roughly 30 K giant stars formerly used as comparison stars for the precision photometry conducted with the 30-inch and 32-inch APTs. The amplitude of variability ranges from 7% to less than 1% and decreases with earlier spectral type. The mechanism of variability remains uncertain. Preliminary results have been submitted to the proceedings of the Cool Stars 10 workshop, and a detailed paper is in preparation.

Henry has identified another sample of two dozen or more early-F dwarf stars with low-amplitude variability, possibly members of the newly-recognized γ Doradus variables. He, along with Fekel, Hall, and A. Kaye (GSU graduate student) are conducting additional photometry and spectroscopy on some of these stars. Results on 9 Aur, HD 152569, and HD 165645 have been submitted to the proceedings of the Cool Stars 10 workshop. More detailed papers are planned and in preparation.

Henry is collaborating with R. Gelderman (Western Kentucky University) and his students on an analysis of a new light curve of 44 i Boo obtained with the 16-inch APT in June. The students have derived new times of eclipse minima, combined them with results from the literature, and are considering physical mechanisms for the observed period changes.

S. Henry is comparing 13 years of Lowell Observatory photometry of solar-type stars with several years of APT photometry of the same stars. Results so far suggest that the two data sets can be combined to a precision of less than half a millimagnitude in most cases.

Eaton continued testing the random-spots model for chromospherically active stars, in which 20-40 large spots (groups?) on a differentially rotating star explain the photometric variations shown by actual stars. Williams and Eaton invested the effect of spot lifetime on the predicted results by calculating two-spot distributions for randomly placed spots having average lifetimes of 2, 5, and 10 years. Theoretical calculations for 2 and 5 years gave significantly more realistic results than 2 years, and imply spot lifetimes of the order of 5 years if the random-spots model actually applies. Williams will give a paper about the results in spring, 1998.

Eaton also began a program of monitoring about 100 G, K, and M stars with luminosity classes I, II, and III at Hα to look for variations in the blueshifted cores of these lines. He previously found such variations in 9 K supergiants, mostly long-period binaries. The variations seem to be ''eruptive'' and are probably not cyclic. In a first perusal of the data from the expanded program, about 40% of the stars may be variable in Hα, almost all supergiants and bright giants. Spectra for this work are being taken at the McMath-Pierce Solar Telescope (National Solar Observatory) by Trudy Tilleman, the resident observer.

Fekel, Eaton, and Henry continue to collect spectra at 6430 Å for classifying stars with known (usually low) levels of photometric variability but unknown basic properties. Fekel is using the coudé feed at KPNO and Eaton the McMath-Pierce at NSO. The program is using several hundred stars of intermediate spectral type to determine what properties really do predict low variability and which high.

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 with C. Scarfe and D. Barlow (Univ. of Victoria) has resulted in the simultaneous solution of the spectroscopic and visual orbits of the solar-type binary 12 Per. The orbital parallax resulting from the combination of the two orbits has an uncertaintly less than half that of the Hipparcos result.

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. HD 214994 = o Peg has been found to be a low-amplitude long-period velocity variable. Added to the candidate list are HD 48843 and HD 184171.

Fekel is working on the orbits of numerous chromospherically active stars. One system, 42 Cap, has been found to be double lined. Its components consist of a solar-type subgiant and solar-type dwarf. With J. Eitter (Iowa State Univ.), and J. R. de Medeiros (Universidade Federal do Rio Grande do Norte) a reanalysis of the orbit of the double-lined system 54 Cam = AE Lyn has been completed. The components are both subgiants but on opposite sides of the Hertzsprung gap. Interestingly, the slightly more massive and evolved star is the *fainter* component. With S. Berdyugina (Crimean Astrophysical Observatory) and I. Tuominen (Univ. of Oulu), a revised orbit and improved stellar parameters have been obtained for the extremely active spotted star II Peg, although its companion was not detected.

Henry and Fekel in collaboration with S. Balachandran (Univ. of Maryland) have continued to observe 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. That HDE 233517 is lithium rich is confirmed by an analysis of both the 6707 Å and 6103 Å lines. The abundance of the 6103Å line, however, is 0.7 dex larger, resulting in a super-meteoritic abundance of $\log\epsilon(\mathrm{Li}) = 4.0$. A similar effect is seen in at least one other lithium rich giant.

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