Peculiar Versus Normal Phenomena in A-Type and Related Stars
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PHOTOMETRY OF CHEMICALLY PECULIAR STARS WITH AUTOMATIC PHOTOELECTRIC TELESCOPES

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ABSTRACT The College of Charleston The Citadel, the University of Nevada, Las Vegas and Villanova University constitute the Four College Automatic Photoelectric Telescope Consortium which has a 0.75-m telescope on Mt. Hopkins, Arizona. It has been in regular operation for two years. Prior to this time we obtained some differential UBV observations with the Phoenix 10" APT of the Fairborn Observatory. We are coordinating observations of CP stars of the upper main sequence. Some initial results include evidence for significant changes in the light curve of 56 Ari, the constancy of the HgMn stars 53 Tau and HR 4072, an improved period for HD 244801, and new observations in the broad minimum of HD 9996.

I. INTRODUCTION

In the autumn of 1990, the 0.75-m Four College Automatic Photoelectric Telescope began regular operations on Mt. Hopkins, AZ. It is operated by the APT Service of Fairborn Observatory for the College of Charleston, The Citadel, Villanova University, and the University of Nevada, Las Vegas. The observers use ATIS (Automatic Telescope Instruction Set) to instruct the telescope what to observe. The telescope has been primarily used to obtain differential photometry of variable stars utilizing comparison and check stars in the Strömgren uvby system. The usual pattern of observing is to obtain the dark count rate and then in each filter the sky-ch-c-v-c-v-c-v-c-ch-sky where sky is a reading of the sky, ch that of the check star, c that of the comparison star, and v that of the variable star.

We are coordinating our observations of the chemically peculiar stars of the upper main sequence. Initially we each selected some two dozen CP stars and are consulting each other about adding new stars to our programs. In this division DMP selected many stars with the best known periods as she already had obtained some uvbyβ photometry of them while SJA chose many with relatively large amplitudes. At present we are systematically reducing and analyzing our photometry of magnetic Ap variables and of a few HgMn stars. The major themes of our program are 1) magnetic braking in long period variables and silicon stars, 2) possible periodic light variations in the nonmagnetic CP stars: the HgMn and Am

stars, 3) variations of Balmer lines, 4) the stability of light curves in magnetic CP stars, and 5) improved period determinations of CP stars.

II. PHOENIX 10" OBSERVATIONS

To gain a better feeling for the quality of data obtained with Automatic Photoelectric Telescopes UBV observations for eight magnetic variables were obtained with the Phoenix 10" telescope while the Four College APT was under construction. With R. J. Dukes, Jr. we analyzed the check-comparison star data and showed that none of our check and comparison stars are variable. Data for this telescope is distributed to users only if the rms deviation of the individual measurements (variable-check and check -comparison) is less than 0.02 mag. By accepting only data for which these values are given for U, B, and V, we found that the quality of the data was similar to that attained by astronomers observing with small telescopes.

We obtained data on 63 And, HD 111133, β CrB, χ Ser, CU Vir, HD 147010, 52 Her, and HD 173650. Besides refining their periods, this study (Adelman, Dukes, and Pyper 1992) reminded us that many published periods were based on rather small numbers of values. This, together, with the large separation between data sets makes it very difficult to combine various sets of observations. After several seasons of APT data we will be better able to derive definitive periods. Such an observing strategy also will permit the derivation of the shape of the light curves and allow one to study possible changes in shape over periods of years.

III. STATUS OF STUDIES

We each obtain of order of 1000 high quality Strömgren uvby observations of relatively bright stars each year; if we also include the β wide and narrow filters the total number of good observations is then about 650. SJA has mostly obtained observations in uvby while DMP has included the narrow and wide β filters. After two years of operation we have a substantial number of observations. Those stars for which we have at least 40 good observations include: SJA: HD 14392 (63 And), HD 19832 (56 Ari), HD 34364 (AR Aur), HD 36485, HD 81009 (KU Hya), HD 90044 (25 Sex), HD 111133 (EP Vir), HD 126515 (FF Vir), HD 133029 (BX Boo), HD 170973 (HR 6958), HD 184905, HD 188041 (HR 7575), and HD 192913 (MW Vul), and DMP: HD 2453 (GR And), HD 9996 (GY And), HD 21699 (V396 Per), HD 36629, HD 36916 (V1045 Ori), HD 37058 (V359 Ori), HD 37321. HD 51418 (NY Aur), HD 71866 (TZ Lyn), HD 98088 (SV Crt), HD 137909 (β CrB) , HD 137949 (33 Lib), HD 184927, HD 220825 (κ Psc), and HD 224801 (CG And). Of course, we have other stars on our observing programs. We are willing to discuss with other photometrists the possibility of jointly publishing our observations and theirs as well as cooperative programs.

IV. THE CITADEL PROGRAM

Comparison of light curves taken at different epochs of rapidly rotating Ap stars such as CU Vir (P = 0.5 days) suggest that there might be changes in the shapes of the curves without period changes, particularly the relative amplitudes and phases of secondary light maximum with respect to primary maximum. Shore and Adelman (1976) hypothesized that the observed aspects of such stars might be changed either by free body or forced precession. High quality light curves in a multi-filter system within a few stellar rotations, repeated in each of several successive years can

check this prediction. It is difficult to obtain the required observing time without an APT. The observations have to be made with the same filters in a well-defined photometric system, using the same comparison and check stars to minimize errors.

UBV photometry of 56 Ari (P = 0.7 days) taken at Braeside Observatory (Adelman and Fried 1991) showed that the U light curve in the fall of 1990 had substantially changed its shape compared with two published curves made several decades ago. This is the first definitive example of an Ap star changing the shape of its light curve. The B and V light curves show definite suggestions of change, but the U values present uncontrovertible evidence. The period appears to be constant. While the amplitude of the primary maximum changed from 0.08 to 0.06 mag. that of the secondary maximum remained constant at 0.08 mag. UBV observations taken during the fall of 1991 and the winter of 1992 confirm this result which is further verified by uvby observations taken at the Four College APT in the 1990-91 and 1991-92 observing seasons (Adelman and Fried 1992). Additional seasons of observations are needed to see if these changes are indeed periodic. A precessional explanation is consistent with our current knowledge of and theories concerning these stars. This work could lead to an improved understanding of the nonuniform distribution of the elemental abundances over the surfaces of these stars as well as of the structure of the stellar envelopes.

Whether or not non-magnetic CP are intrinsically variable is still an open question. Particular concerns about published studies are the small amplitudes, the relative paucity of values, and the lack of information on the stability of the observations which we obtain from check-comparison star measurements. First results for 53 Tau and HR 4072, two HgMn stars which are known to be binaries, are presented.

For 53 Tau, Winzer (1974) used 51 Tau (HR 1331) as the comparison stars, for 14 measurements he found $\Delta U = 0.863 \pm 0.005$ mag, $\Delta B = 0.483 \pm 0.005$ mag, and $\Delta V = 0.156 \pm 0.003$ mag from which he claimed slight variability with a period of 4.4320 days, close to the binary period of Dworetsky (1972) 4.4521 days. The error given is σ_{n-1}. Winzer also performed photometry on HR 4072 with HR 4215 as the comparison star. For nine observations in one of three runs he found $\Delta U = -1.538 \pm 0.003$ mag, $\Delta B = -1.484 \pm 0.003$ mag, and $\Delta V = -1.466 \pm 0.002$ mag. This star he believed to have been constant.

Catalano and Leone (1991) presented photometry of three HgMn stars including 53 Tau and HR 4072 which they claim indicates variability. Their results for eight measurements of 53 Tau - 51 Tau are $\Delta U = 0.863 \pm 0.010$ mag, $\Delta B = 0.483 \pm 0.007$ mag, and $\Delta V = 0.156 \pm 0.006$ mag. The differential magnitudes agree perfectly with Winzer. Combining these observations with those of Winzer, they claim a period of 4.428 days with an amplitude of order 0.01 mag. For HR 4072 they used 32 UMa and HD 93427 as comparison stars and found a period of 7.5586 days and amplitudes of 0.02 mag or less from 27 observations which yield $\Delta U = -1.239 \pm 0.014$ mag, $\Delta B = -1.018 \pm 0.013$ mag, and $\Delta V = -0.827 \pm 0.010$ mag.

Adelman obtained 30 Four College APT observations of 53 Tau using HR1375 as the comparison star and 51 Tau as the check star, $\Delta u = -0.592 \pm 0.016$ mag v-c, -0.298 ± 0.015 mag c-ch; $\Delta v = -0.630 \pm 0.009$ mag v-c, 0.020 ± 0.009 mag c-ch; $\Delta b = -0.575 \pm 0.010$ mag v-c, 0.239 ± 0.010 mag c-ch; and $\Delta y = -0.498 \pm 0.008$ mag v-c, 0.350 ± 0.007 mag which are not indicative of variability. For HR 4072 24 observations were made with 32 UMa as the comparison star and HD 93427 as the check star. $\Delta u = -1.252 \pm 0.007$ mag v-

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c, 2.141±0.007 mag c-ch; Δv = -1.054±0.006 mag v-c, 1.972±0.006 mag c-ch; Δb = -0.908±0.006 mag v-c, 1.818±0.006 mag c-ch; and Δy = -0.809±0.006 mag v-c, 1.724±0.006 mag, again which are not indicative of variability.

An analysis was also made of one color of each set of observations for the data of Catalano and Leone and from the Four College APT using the Scargle periodogram (Scargle 1982, Horne and Baliunas 1986). As no set of data exhibited any frequencies whose power S/N ratio exceeded that needed for 1% significance, it is appropriate to conclude that both 53 Tau and HR 4072 are constant. Observations of 53 Tau and HR 4072 will be continued to obtain at least 50 good measurements of each star. It is also desirable to observe other HgMn stars, such as α And and HD 3322 for which there are claims in the literatures concerning their variability.

V. THE UNIVERSITY OF NEVADA, LAS VEGAS PROGRAM

In conjunction with Adelman's work on 56 Ari, observations of CU Vir are being made but are of a preliminary nature at this point. Period improvements have been made for a number of the CP stars listed above for which we have adequate data. An example is HD 224801 (CG And) for which we have 45 good measurements and whose period has been improved to 3.739833 +/- 0.000013 days (Fig. 1). More than 40 observations have been accumulated for each of 8 stars in clusters and associations and analysis of these data is in progress.

A monitoring program for long period (1 month to 1 year) and very long period CP variables (2 to 70+ years) is also being carried out with the APT. There is a very real question as to whether the variations of especially the very long period stars can be represented by oblique rotator models. The

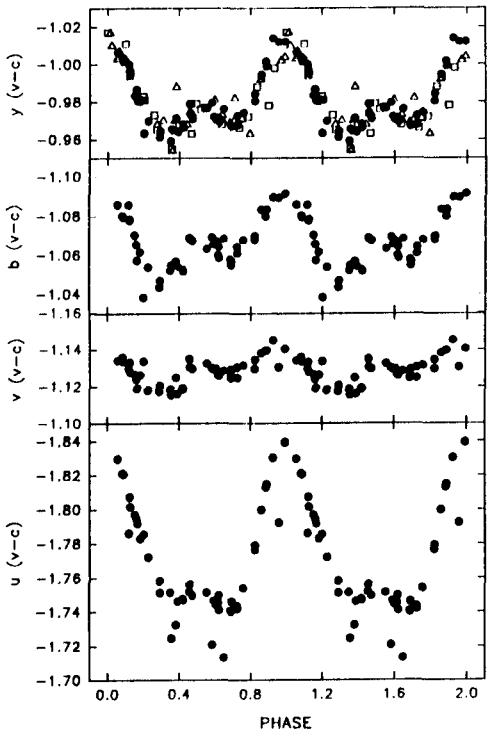

Figure 1. Four-color light curve of HD 224801 (CG And). The filled circles are the APT data; the open squares and triangles are differential V values of Stepien (1968) and Y values of Provin (1953), respectively. Phases are computed with the ephemeris JD = 243 + 3.739833E.

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best example of this group is HD 9996 (GY And) which undergoes spectrum and photometric variations with a period of about 8000 days. Good differential photometry for this star is only available through only one light maximum (V) (Fig. 2). The latest observations are in the broad minimum; they agree with observations in the previous minimum but average to a somewhat fainter magnitude. It is difficult to say whether these discrepancies are real or due to the notorious systematic differences between data from different observatories obtained with different systems. We intend to monitor this star at least through the next light maximum, which, if the 8000 day period is correct, should occur in the year 2005!

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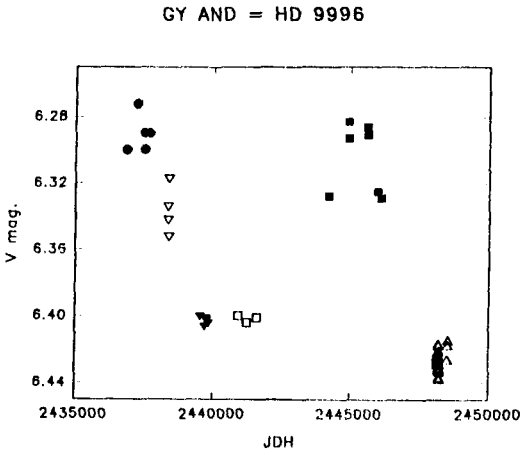

Figure 2. V values of HD 9996 (GY And) vs Heliocentric JD. Filled circles, open inverted triangles, open squares, filled squares and open triangles are values of Abt and Golson 1962, Renson and Fiedler 1963, Stepien 1968, Winzer 1974, Pyper 1979-84, and APT data, respectively (see Pyper 1992 for references).

DISCUSSION (Adelman and Pyper)

DWORETSKY: May I suggest using also the excellent Geneva filter system for automated observations?
ADELMAN: I agree; but most photometers have a limited number of filters. We have Johnson UBV, Strömgren *uvby*, Hα, Hβ, Cousins RI, and neutral density filters.

Let me note that Andy Young (San Diego State University) is designing a five-filter system with overlapping filters. He hopes that such a system will be transformable to a standard system with high precision and accuracy. If this occurs, then much astrophysical information will result. It could well be more useful than many existing systems. Tests are scheduled with one of the 0.75-m Automatic Photoelectric Telescopes on Mt. Hopkins.

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