ASTRONOMY & ASTROPHYSICS
SUPPLEMENT SERIES

JANUARY I **1999**, PAGE 53

Astron. Astrophys. Suppl. Ser. **134**, 53–57 (1999)

uvby photometry of the chemically peculiar stars HD 15980, HR 1094, 33 Gem, and HD 115708⋆

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Received June 19; accepted July 7, 1998

Abstract. Differential Strömgren *uvby* photometry obtained with the Four College Automated Photoelectric Telescope shows that the hot HgMn star 33 Gem is photometrically constant. The Si star HD 15980 is found to be a variable whose period is significantly greater than 2 years. The unusual magnetic chemically peculiar Co star HR 1094 is discovered to be a low amplitude photometric variable with the magnetic field period of Hill & Blake, 2.9761 days. The ephemeris for the magnetic chemically peculiar star HD 115708 of Wade et al. is confirmed with the error in its period of 5.07622 days being greatly reduced. The u, v, b, and y light curves for both HR 1094 and HD 115708 exhibit differences which indicate complex elemental photospheric abundance distributions.

Key words: stars: individual — HD 15890, HR 1094, 33 Gem, HD 115708 — stars: chemically peculiar

Table 1. Photometric groups

HD Number	Star Name	Type	V	Spectral Type
15980		*v*	7.89	Ap Si
16219	HR 760	*c*	6.54	B5 V
16004	HR 746	*ch*	6.36	B9p HgMn
22316	HR 1094	*v*	6.30	B9p
23383	HR 1147	*c*	6.10	B9 Vnn
23594	HR 1161	*ch*	6.46	A0 Vn
21447	HR 1046	*c*	5.09	A1 V
20536		*ch*	6.76	B8 IV
49606	33 Gem	*v*	5.85	B7 III HgMn
48097	26 Gem	*c*	5.21	A2 V
47863	HR 2457	*ch* & *c*	6.28	A1 V
49059	HR 2499	*ch*	6.20	A2 V
115708		*v*	7.83	A2p
116233		*c*	7.07	A9 III
116706	HR 5057	*ch*	5.78	A3 IV

1. Introduction

I examine differential Strömgren *uvby* photometry of four Chemically Peculiar (CP) stars obtained during the two years after Four College Automated Photoelectric Telescope (FCAPT) was moved to Washington Camp, AZ (October 1996-July 1998) and during its last year on nearby Mt Hopkins, AZ (October 1995-July 1996). The telescope obtains the dark count and then measures the sky-*ch*-*c*-*v*-*c*-*v*-*c*-*v*-*c*-*ch*-sky in each filter 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. Table 1 contains group information (Hoffleit 1982; Hoffleit et al. 1983; Schneider 1986) on each variable as well as on the two supposedly non-variable stars, the comparison and check, against which the brightness of the variable is compared. Table 2 summarizes the yearly and ensemble means and standard deviations, *v*-*c* and *ch*-*c* for the four magnitudes for HD 15980 and 33 Gem. Tables 3-6 present the data for all stars. Corrections were not made if neutral density filters were used for one or two of the stars of each group.

FCAPT studies of the magnetic Chemically Peculiar (mCP) stars have both improved periods and better defined the shapes of their light curves (see, e.g. Adelman 1997). From such studies one can relate observations taken at different times, check whether such stars have variable light curves, gain some information on the uniformity of the surface abundances, and study the distribution of periods. But a few such stars have been found to be constant, as have Mercury-Manganese and metallic-line

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⋆ Tables 3-6 are only available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-strasbg.fr/Abstract.html

Table 2. Summary of *uvby* photometry for HD 15980 and 33 Gem

Heliocentric		*u*		*v*		*b*		*y*
Julian Date	*v-c*	*ch-c*	*v-c*	*ch-c*	*v-c*	*ch-c*	*v-c*	*ch-c*
HD 15980								
1995-96								
average	1.945	−0.023	1.471	0.149	1.365	0.170	1.388	0.189
std. dev.	0.007	0.006	0.005	0.003	0.006	0.005	0.007	0.004
1996-97								
average	1.932	−0.027	1.473	0.147	1.363	0.169	1.388	0.187
std. dev.	0.003	0.003	0.003	0.003	0.003	0.002	0.005	0.003
1997-98								
average	1.923	−0.027	1.471	0.147	1.361	0.169	1.388	0.187
std. dev.	0.004	0.005	0.004	0.004	0.002	0.003	0.002	0.002
1995-98								
average	1.929	−0.026	1.472	0.148	1.362	0.169	1.388	0.187
std. dev.	0.009	0.005	0.004	0.004	0.004	0.003	0.004	0.003
33 Gem[1]								
1996-97								
average	−0.260	1.458	0.399	1.510	0.558	1.361	0.637	1.333
std. dev.	0.004	0.006	0.004	0.007	0.003	0.005	0.003	0.005
1997-98								
average	−0.255	1.458	0.400	1.514	0.547	1.385	0.636	1.338
std. dev.	0.005	0.005	0.005	0.005	0.003	0.005	0.004	0.006
1996-98								
average	−0.258	1.458	0.399	1.512	0.553	1.372	0.637	1.335
std. dev.	0.005	0.006	0.004	0.006	0.006	0.013	0.004	0.006
33 Gem[2]								
1997-98								
average	2.174	−1.128	2.852	−1.125	2.960	−1.140	3.042	−1.144
std. dev.	0.004	0.005	0.006	0.006	0.003	0.006	0.003	0.004

Notes: [1] With HD 48097 as the comparison star and HD 47863 as the check star. [2] With HD 47863 as the comparison star and HD 49059 as the check star.

stars. Hipparcos satellite data have been used to confirm such variability studies.

2. HD 15980

Bidelman (1983) discovered HD 15980 to be a magnetic CP star. Intermediate and narrow band photometry by Schneider (1986) indicated that it might be a star with a strong λ5200 broad, continuum feature or depression and thus a star with a potentially strong magnetic field. Adelman et al. (1998) found that Hipparcos photometry indicated that it was possibly variable and that its check star was slightly less variable than its comparison star.

The FCAPT obtained 13 sets of *uvby* observations in the 1995-96 observing season, 34 sets in 1996-97, and 48 sets in 1997-98 (Table 3). HD 15980 is best described as almost constant during an observing season (Tables 2 and 3). The Scargle periodograms (Scargle 1982; Horne & Baliunas 1986) do not yield any significant periods. The mean v and y values are constant for the three seasons, but the mean u value has changed by 0.022 mag and the mean b value 0.004 mag between 1995-96 and 1997-98. The change in u in particular suggests that HD 15980 is a long period variable and hence this star should be quite sharp-lined, a prediction which needs to be checked.

3. HR 1094

Hill & Blake (1996) discovered that the peculiar CP star HR 1094 (= HD 22316) possesses a fairly strong

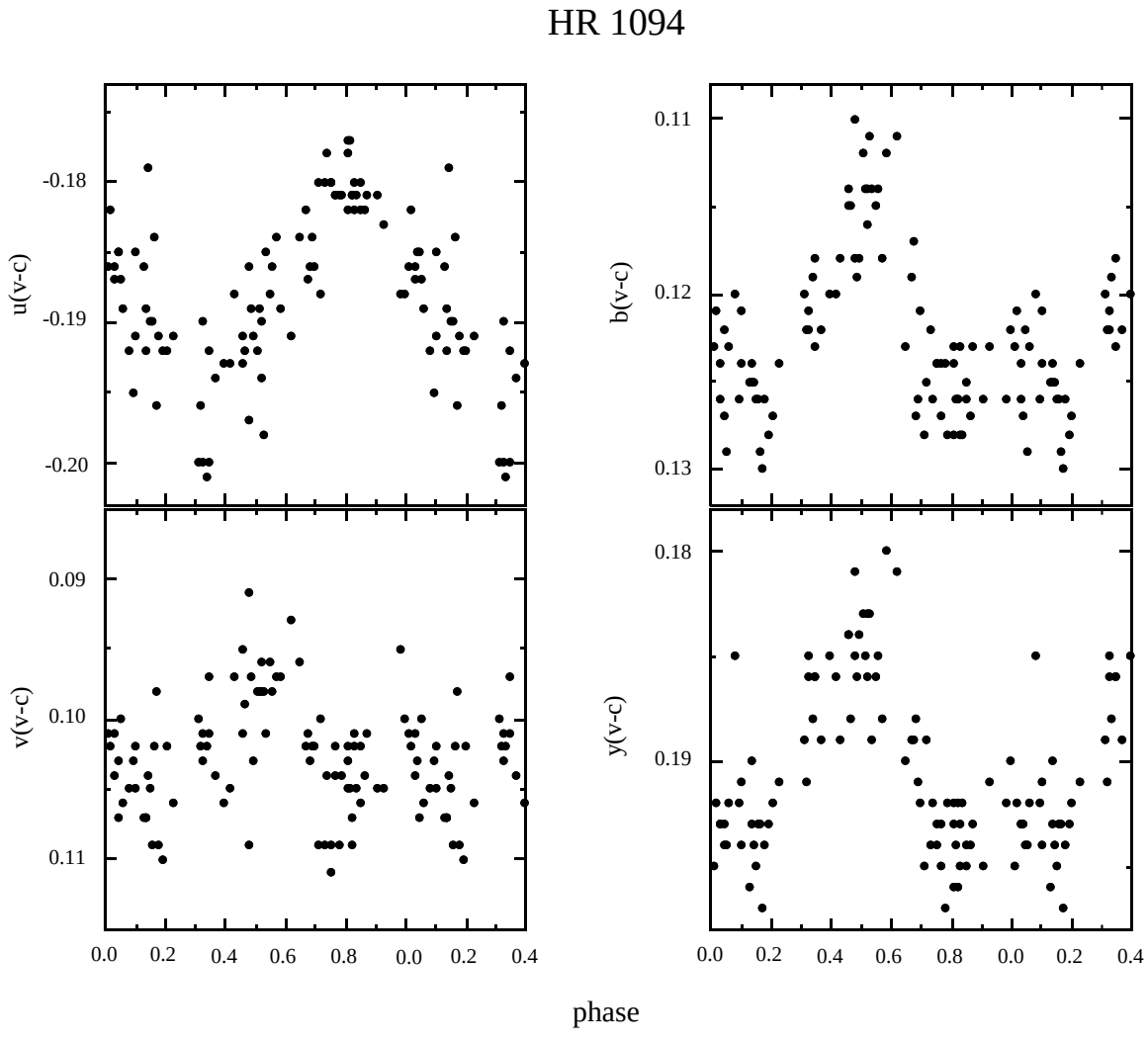

Fig. 1. FCAPT *uvby* photometry of HR 1094 plotted according to the Hill & Blake (1996) ephemeris: HJD (magnetic maximum) = 2449007.589 + 2.9761 E

magnetic field whose effective longitudinal field varies between −2200 and 600 gauss with an ephemeris

HJD (magnetic maximum) = 2449007.589 ± 0.130 + 2.9761 ± 0.0014 E.

This star is one of the few CP stars with Co II lines in its spectrum and is also very Cl overabundant (Sadakane 1992).

Seven, 35, and 46 observations with HD 23383 as the comparison star and HD 23594 as the check star were obtained respectively in the 1995-96, 1996-97, and 1997-98 observing seasons. Another 12 observations were obtained in 1997-98 using HD 21447 as the comparison star and HD 20536 as the check star. Although Hipparcos photometry (Adelman et al. 1998) suggested that the use of the latter stars was preferable to the use of the former, the standard deviations of the means do not confirm this. Scargle periodograms of the larger set of HR 1094 observations suggests several possible periods of which only 2.9749 days is compatible with the magnetic field variations. As the light curves are very similar for this period and that of Hill & Blake, and as the latter period phases the light variations better relative to that of the magnetic field, I have adopted their ephemeris.

Figure 1 shows the photometry as a function of phase. HR 1094 is a low amplitude variable with the amplitudes of u and b being 0.015 mag, v being of order 0.007 mag, and y being 0.01 mag. For comparison the magnetic extrema occur at phases 0.0 and 0.5. The minimum of u is at phase 0.3 and its maximum at 0.8. The light curve for v is almost constant with a weak maximum near phase 0.5. The light curves for b and y are in phase with maxima near phase 0.5. Thus the photometry suggests that HR 1094 may have complex surface abundance patterns.

4. 33 Geminorum

33 Geminorum (HR 2519 = HD 49606) is one of the hottest known Mercury-Manganese stars (Adelman et al.

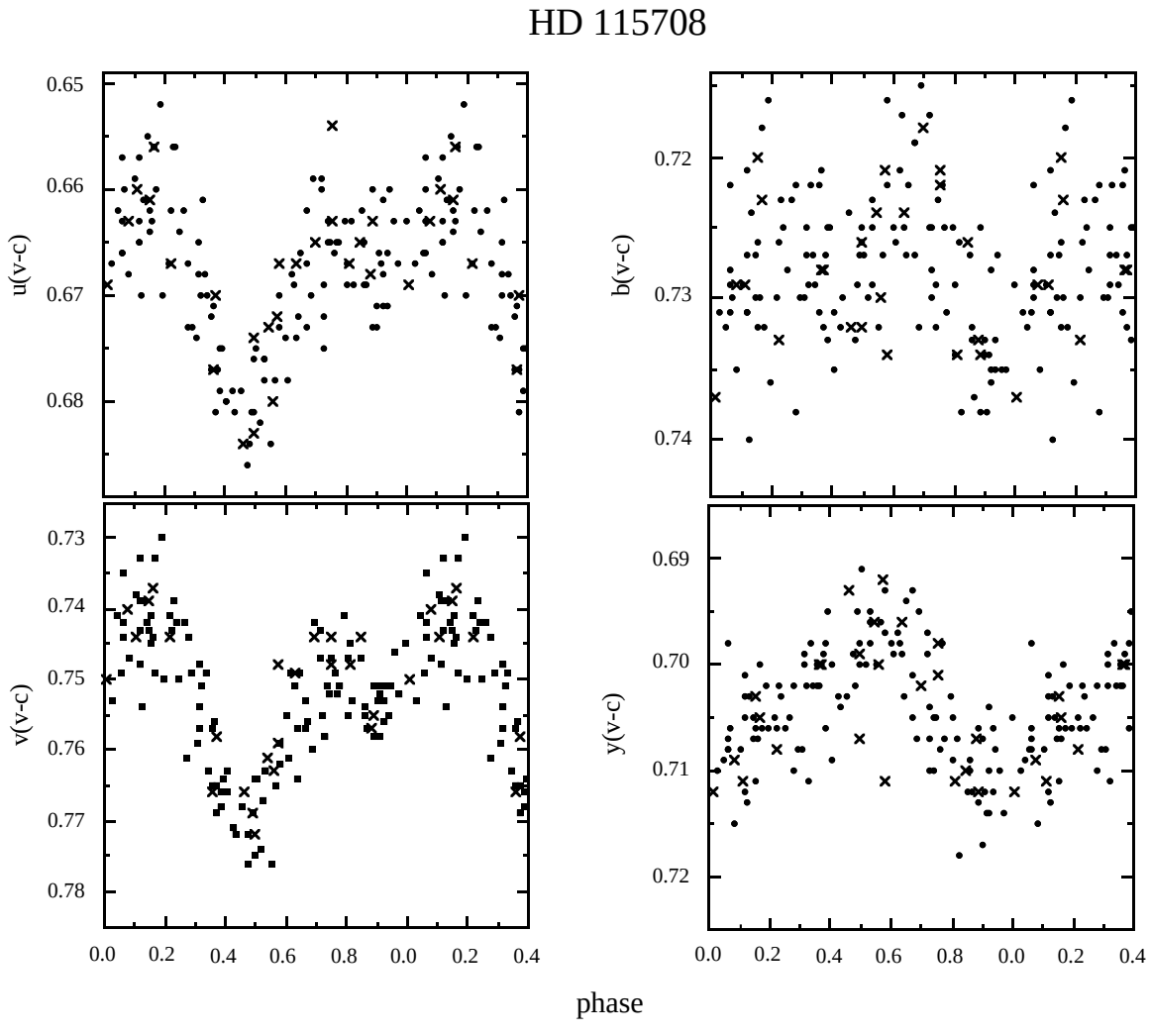

Fig. 2. Photometry of HD 115708 plotted according to the ephemeris of Wade et al. (1996) JD (positive magnetic maximum) = 2435997.50 + 5.07622 E with FCAPT values being given as closed squares and those of Wolff (1975) as plus signs

1996). Bohlender et al. (1993) report that magnetic field measurements yield an average of 440 ± 360 gauss, but do not constitute a definite detection. Glagolevskii et al. (1985) claim a period of 3.3546 day based on light, magnetic field, and spectrum variations. Hipparcos photometry (Adelman et al. 1998) indicates that 33 Gem is not a photometric variable.

Fifty-two and 46 sets of *uvby* observations were obtained with HD 48097 as the comparison star and HD 47863 as the check star and during the 1996-97 and 1997-98 seasons, respectively (Table 5). During 1997-98, 42 sets were also obtained with HD 47863 as the comparison star and HD 49059 as the check star. The stability of 33 Gem is about the same with both data sets although standard errors of Hipparcos data suggests the later data should be slightly more stable. The slight differences in mean v-c values between seasons might be due to the comparison star HD 48097 being marginally variable. The Scargle periodogram applied to the FCAPT data does not indicate any significant periods. Hence 33 Gem does not appear to be variable.

5. HD 115708

Wade et al. (1996) found that the longitudinal component of the magnetic field of the SrEu CP star HD 115708 varies with the ephemeris

JD (positive magnetic maximum) = 2435997.50 + 5.07622 ± 0.0004 E which is consistent with the period found by Leroy (1995) and also takes into account observations taken by Babcock (1958). Photometric variability was found by Wolff (1975) using Strömgren photometry.

The FCAPT obtained 35, 46, and 31 good sets of differential Strömgren values during the 1995-96, 1996-97, and 1997-98 observing seasons, respectively. Their Scargle periodograms suggests a period close to 5.076 days or its alias. When this data and that of Wolff (appropriately rezeroed) are plotted with the ephemeris of Wade et al.

(Fig. 2), they fall on top of one another. Thus the light curves have the same shape for both eras. When one considers of the effects of slight differences in the period, the quoted error in the magnetic period is reduced by a factor of 4.

Minimum light occurs at phase 0.5 for the u and b light curves. A secondary minimum is near phase 0.9. The amplitudes of variation are 0.025 mag in u, 0.035 mag in v, 0.015 mag in b, and 0.02 mag in y. The light curves for u and v are in phase, but out of phase with y and probably b as far as the u and v light minima are concerned, but the b and y light minima coincide with u and v light secondary minima. The phases of the magnetic extrema are 0.43 and 0.93 which are close to those for light variability. This indicates very complex surface abundance distributions. For much of the period there is probably a nearly non-variable wavelength region between the mean wavelengths for the v and b filters.

Acknowledgements. This work was supported in part by NSF grants AST-9115114 and 9528506 and in part by grants from The Citadel Development Foundation. I appreciate the continuing efforts of L.J. Boyd, R.J. Dukes Jr., and G.P. McCook to keep the FCAPT operating properly and the useful comments of the referee G.A. Wade.

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