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uvby photometry of the CP stars HR 149, HD 32966, HD 171782, and HR 7911⋆

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Abstract. Differential Strömgren *uvby* observations from the Four College Automated Photoelectric Telescope (FCAPT) are presented for the CP stars HR 149 and HR 7911 and the mCP stars HD 32966 and HD 171782. The Mercury-Manganese star HR 149 is found to be constant while HR 7911 with a period of 5.9617 days probably has a component which is a magnetic CP star. Improved periods were derived for HD 32966 and HD 171782 of 3.0927 and 4.4674 days, respectively. The former is a rather large amplitude mCP star. Both have at least one light curve different in shape from the others observed.

Key words. stars: chemically peculiar – stars: individual: HR 149 – stars: individual: HD 32966 – stars: individual: HD 171782 – stars: individual: HR 7911

1. Introduction

This paper presents single-channel differential Strömgren *uvby* photometry from the Four College Automated Photoelectric Telescope (FCAPT) at Washington Camp, AZ. Photometry of two supposed Mercury-Manganese (HgMn) stars HR 149 and HR 7911 are examined to help determine whether single class members are variable. The periods and light curves of two magnetic Chemically Peculiar (mCP) stars HD 32966 and HD 171782 stars are improved.

Since the mCP stars are photometric, spectrum, and magnetic variables, their emergent energy distributions, photospheric abundances, and magnetic field strengths depend upon photospheric location. As their magnetic and rotational axes are not usually aligned, a distant observer often sees variability as they rotate. Hydrodynamical processes especially radiative diffusion and gravitational settling in radiative envelopes containing strong magnetic fields are thought to produce their anomalous photospheric abundances which depend on the local magnetic field strength and the time since the star was on the ZAMS (Michaud & Proffitt 1993 and references therein). FCAPT studies have improved their periods and light curves (see, e.g., Adelman et al. 1999). They can be used to better relate observations taken at different times, detect variable light curves, and study the period distribution of the mCP stars. Using spectra, surface maps of abundances for some stars can be derived to serve as tests of mCP star theories.

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⋆ Tables 2, 3, 4 and 5 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/cgi-bin/qcat?J/A+A/390/1023

For each group of variable, check, and comparison stars, the telescope measures the dark count and then observes in each filter sky-ch-c-v-c-v-c-v-c-ch-sky where sky is a reading of the sky, ch of the check star, c of the comparison star, and v of the variable star. Table 1 summarizes group information (Hoffleit 1982; Hoffleit et al. 1993, SIMBAD database). No corrections were made for neutral density filter differences among the stars of each group. The comparison and check stars were chosen from supposedly non-variable stars near the variable on the sky that had similar V magnitudes and $B-V$ colors. Later Adelman et al. (1998) checked their stability using Hipparcos photometry (ESA 1997). The Scargle periodogram (Scargle 1982; Horne & Baliunas 1986) and the clean algorithm (Roberts et al. 1987) were used to help find periods.

2. The presumed HgMn stars HR 149 and HR 7911

For the HgMn stars a question of particular importance is whether single class members are intrinsically variable. Adelman (1998) noted that HR 149 (HD 3322, HIP 2865) and HR 7911 (HD 197018, HIP 101949) were possibly variable on the basis of their Hipparcos photometry. HR 149 is a relatively poorly studied CP star which was classified as B8 IIIp Hg(Mn) by Cowley (1972) and as B8.5 IIIp(HgMn st, Mg wk) by Abt & Morrell (1995) who measured $v \sin i = 15$ km s^{-1}. Aikman (1976) discovered it is a spectroscopic binary while Catalano & Leone (1991) claimed it was a photometric variable star contrary to Winzer (1974) who found it to be constant. They used HD 2924 (HR 133), spectral type A2 IV, and HD 5382 (HR 262), spectral type A5 IV, as comparison stars. Our comparison star was HR 71 and check star HR 78 (see Table 1).

We obtained 103 sets of *uvby* photometry in the course of 3 observing seasons (Table 2). With standard deviations of 0.003 or 0.004 mag for each bandpass, we consider HR 149 to be constant. The amplitudes of Hipparcos photometry (ESA 1997) are 0.03 mag for HR 133 and HR 149 and 0.02 mag for HR 78 and HR 262, and 0.01 mag for HR 71. Thus the variability found by Catalano & Leone (1991) could well be due to one or both of their comparison stars.

HR 7911 was classified by Cowley (1972) as B6 IIIp Mn, but Abt & Cardona (1983) classified combined components AB as B8 III and component C, which is about 2.5 mag fainter in V, as B9.5 V. The Hipparcos/Tycho Celestia 2000 CD (ESA 1998) notes that the magnitudes of components A, B, and C are 6.5, 6.8, and 8.6, respectively, with A and B being separated by 0.85″ and C being 68.9″ from the brighter pair. The Hipparcos parallax is 3.63 mas with a corresponding absolute visual magnitude of −1.13. Paunzen & Maitzen (1998) noted that this star was found to be variable in Hipparcos photometry with a period of 5.960 days. We obtained 26 sets of *uvby* observations in the 1998-99 observing season, 28 in 1999-2000, and 47 in 2000-2001 with the FCAPT (Table 3). Analysis of this data lead to a period of 5.9623 ± 0.001 days. The light curves are plotted, using 2451077.040 as the JD of phase zero, which occurs at light maximum. Figure 1 shows that the u, v, b, and y light curves are in phase with respective amplitudes of 0.032, 0.022, 0.020, and 0.018 mag. These light curves combined with Abt & Cardona's not classifying either component as a HgMn star suggest that one of the components of HR 7911 AB is a magnetic CP star.

Since the four optical region light curves are in phase, we plotted the Hipparcos magnitudes using the same ephemeris. There is a phase shift of 0.05 in the sense that our phase 0.50 corresponds to phase 0.55 in the Hipparcos data. Hence an improved period is 5.9617 ± 0.0005 days.

3. The magnetic CP stars HD 32966 and HD 171782

Manfroid & Renson (1981) found a period of 3.095 ± 0.015 days for HD 32966 (TU Lep, HIP 23755) with amplitudes of variation of 0.174 mag for u, 0.150 mag for v, and 0.131 mag for b, and 0.105 mag for y, which means it is a relatively large amplitude mCP star. Unfortunately, the data was not provided. Bidelman & MacConnell (1973) classified it as a Si star. Celestia 2000 (ESA 1998) indicates that HD 32966 has a period of 3.0928 days and an amplitude of 0.10 mag. For HD 171782 (QV Ser, HIP 91224), Celestia 2000 and Paunzen & Maitzen (1998) provide a period of 4.466 days and an amplitude of 0.045 mag. Renson (1988) notes it is a B9 SiCrEu star in the cluster IC 4756.

There are 10, 31, and 25 sets of *uvby* photometry of HD 32966 obtained during the 1998-99, 1999-2000, and 2000-01 observing seasons, respectively, in Table 4. We derived an ephemeris of

HJD ($u_{\max}$) = 2451078.7464 ± 0.004 + 3.0927 ± 0.0010 E.

The light curves are approximately in phase (see Fig. 2). In fact those for b and y are identical in shape. But they and those for u and for v show small differences with respect to one another which reflect differences in the flux distribution and chemical composition over parts of the surface. These differences are sufficient for us not to use Hipparcos photometry in an attempt to improve the period. The amplitudes for an mCP star are quite large, 0.18 mag, 0.145 mag, 0.12 mag, and 0.105 mag for u, v, b, and y, respectively, and are similar to those found by Manfroid & Renson.

Table 1. Photometric groups.

HD Number	Star Name	Type	V	Spectral Type
3322	HR 149	v	6.50	B8 IIIpHgMn:
1439	HR 71	c	5.87	A0 Vs
1606	HR 78	ch	5.90	B7 V
32966	BD -14° 1045	v	7.08	B9
31726	HR 1595	c	6.15	B1 V
35104	HR 1769	ch	6.56	B8 V
171782	BD +05° 3816	v	7.85	A0p
170200	HR 6928	c	5.73	B8 III-IV
173495	HR 7048	ch	5.83	A1 V + A1 V
197018	HR 7911	v	6.06	B6 IIIp Mn
197392	HR 7926	c	5.67	B8 II-III
195050	40 Cyg	ch	5.62	A3 V

For HD 171782 Table 5 contains 29 sets of *uvy* photometry obtained during the 1999-2000 observing season and 35 sets of *uvby* photometry from the 2000-2001 season. From the u values the following ephemeris was derived

HJD($u_{\min}$ + 0.50) = 2451632.7101 ± 0.004 + 4.4674 ± 0.0010 E.

As the light curves are asymmetric (see Fig. 3), we used the minimum of the u curve to set the ephemeris. The u, b, and y light curves are approximately in phase. But the v light curve has a somewhat different minimum which is somewhat narrower. The u and y light curves appear to have two sub-minima close to phases 0.4 and 0.6 in a broader minimum centered at phase 0.5. The v light curve has only the second sub-minima. For b, there are no values near 0.4 to ascertain if the first sub-minimum is present. These differences in the light curves suggest the first and second sub-minima represent portions of the stellar surface with very different chemical compositions. The amplitudes of variability for u, v, b, and y are 0.09 mag, 0.055 mag, 0.07 mag, and 0.07 mag, respectively. It is clearly desirable to obtain additional b values especially near phase 0.4.

4. Final comments

That HR 149 is constant and that HR 7911 is not a HgMn star make the case that single HgMn stars are constant stars stronger. A few possible variable non-magnetic CP stars noted by Adelman (1998) still need to be observed to strengthen this conclusion.

We derived for each of the light curves of HD 32966, HD 171782, and HR 7911 the Fourier constant and the first two sine and cosine terms as well as the rms error using a least squares technique. This information is given in Table 2. These

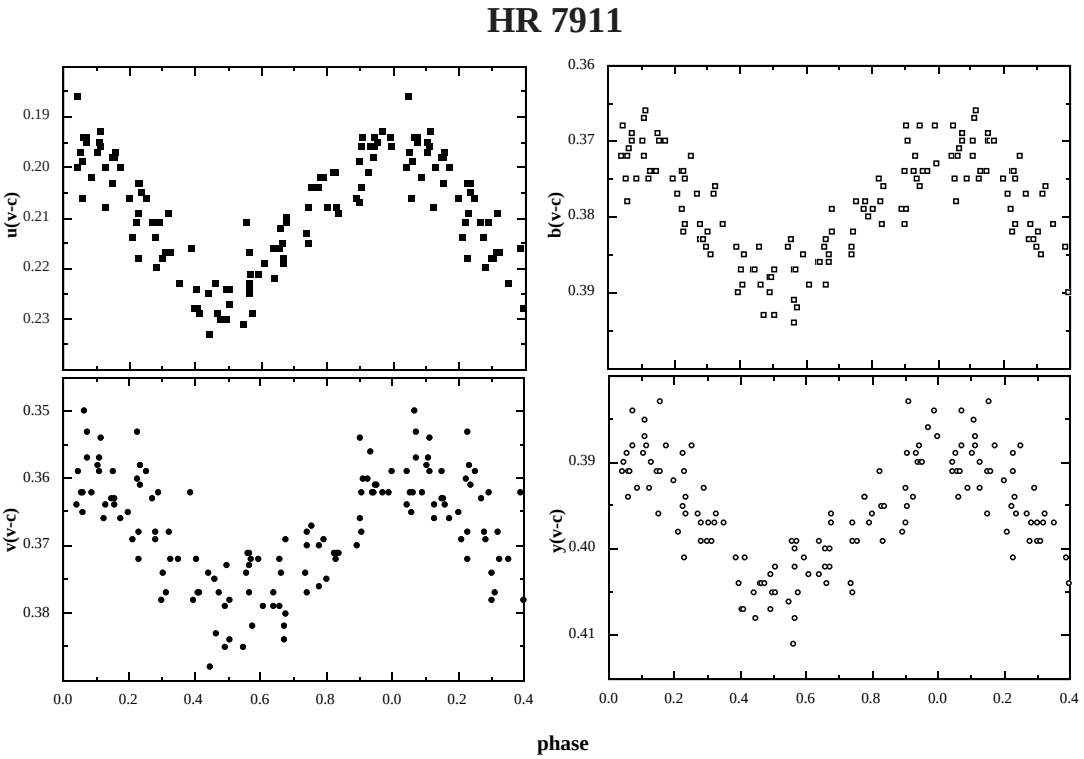

Fig. 1. Differential FCAPT *uvby* photometry of HR 7911 with the ephemeris HJD (light maximum) = 2451077.040 + 5.9623 E.

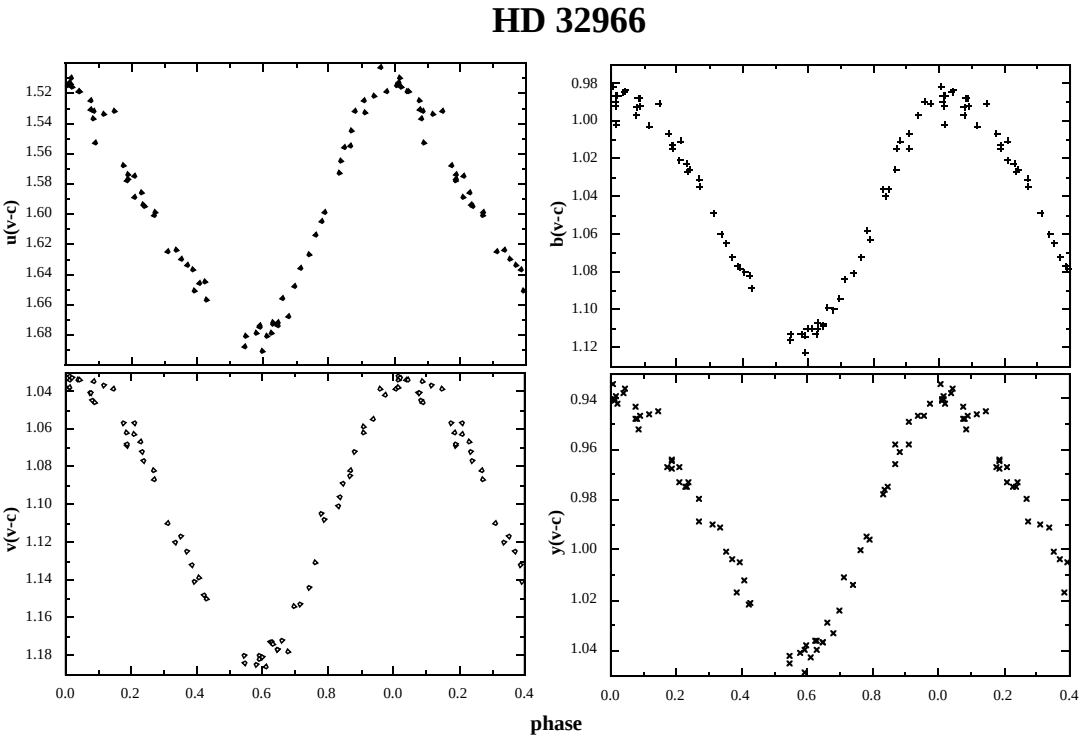

Fig. 2. Differential FCAPT *uvby* photometry of HD 32966 plotted according to HJD (u_{max} = 2451078.7464 + 3.0927 E).

values support the in phase variability of HR 7911 and the small differences seen in the light curves of HD 32966. As HD 32966 is a very large amplitude magnetic CP star, we are probably observing it at a favorable geometry.

For HD 171782 the coefficients were calculated only for the 35 sets of *uvby* data so that all four light curves were sampled identically. Additional observations of HD 171782 especially near minimum light are very desirable.

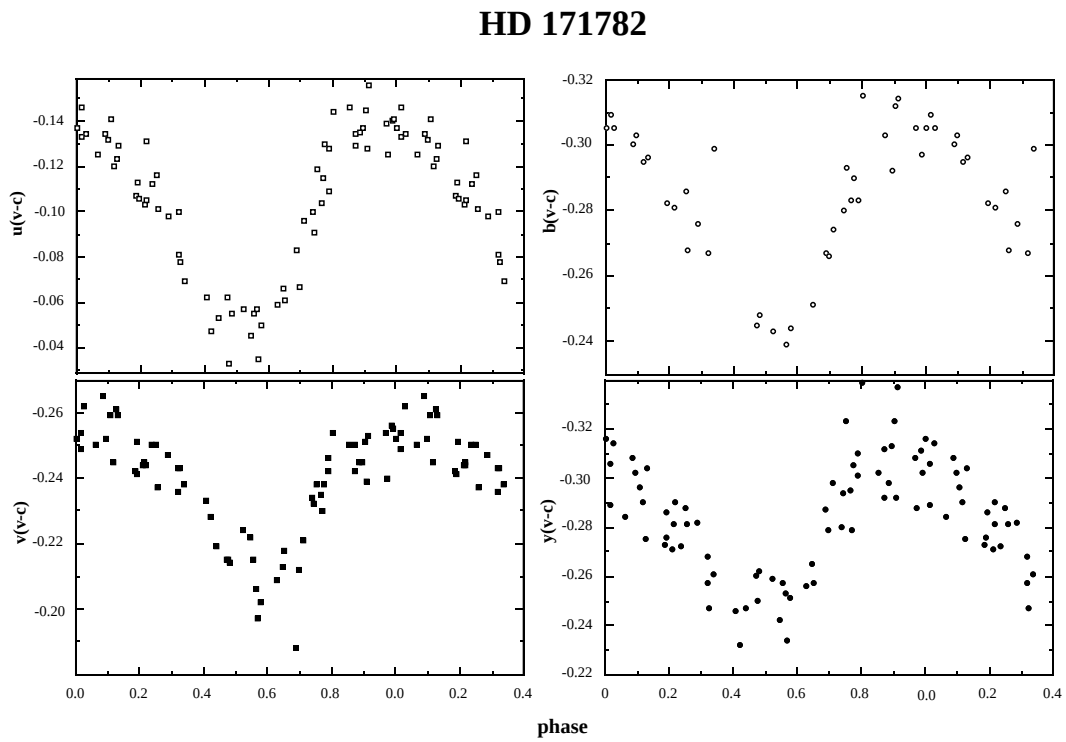

Fig. 3. Differential FCAPT *uvby* photometry of HD 171782 using the ephemeris HJD($u_{\rm min}$ +0.50) = 2451632.7101 + 4.4674 E.

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