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Strömgren *uvby* photometry of the magnetic Chemically Peculiar stars HD 32633, 25 Sextantis, HR 7224, and HD 200311*

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Abstract. Differential Strömgren *uvby* photometric observations from the Four College Automated Photoelectric Telescope refine the rotational periods and define the shapes of the light curves of four magnetic Chemically Peculiar stars. HD 32633 ($P = 6.43000$ d) exhibits an in-phase variability with asymmetrically shaped light curves. 25 Sex ($P = 4.37900$ d) has a complex variability with the v, b, and y light variability crudely in phase, but quite different from that of u. HR 7224 ($P = 1.123095$ d) shows in-phase variability with two nearly equal secondary minima. HD 200311 ($P = 26.0042$ d), which was previous thought to be a long period variable, is found to be a modest photometric variable.

Key words: stars: individual: HD 32633 — stars: individual: 25 Sex — stars: individual: HR 7224 — stars: individual: HD 200311 — stars: chemically peculiar

1. Introduction

I obtained differential photometry of many magnetic Chemically Peculiar (CP) stars in the Strömgren uvby system during the first six years (Sept. 1990 - July 1996) (year 1 is Sept. 1990 - July 1991, year 2 is Sept. 1991-July 1992, etc.) of the 0.75-m Four College Automated Photoelectric Telescope (FCAPT) on Mt. Hopkins, AZ (e.g., Adelman & Boyce 1995) to better determine the periods and the shapes of the light curves so that observations of various types taken at different times can be correctly phased together. The telescope measured the dark count 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. This paper presents results on the magnetic CP stars HD 32633, 25 Sex, HR 7224, and HD 200311. Table 1 gives important information on the variable, comparison, and check stars from Hoffleit (1982) and Hoffleit et al. (1983) supplemented by values from Deutschman et al. (1976) and Oja (1983).

Table 1. Photometric groups

Star	Type	V	$B-V$	Spectral Type
HD 32633	*v*	7.02	−0.06	A2pSiCr
HR 1639	*c*	6.52	+0.16	A5 V
HD 33704	*ch*	6.85	+0.01	A0
25 Sex	*v*	5.97	−0.01	B9pSi(Sr,Cr)
29 Sex	*c*	5.21	−0.06	B9.5 V
HR 4000	*ch*	6.25	+0.01	A2 Vn
HR 7224	*v*	6.52	−0.15	A0pSi
55 Dra	*c*	6.25	0.00	A0 V
π Dra	*ch*	4.59	+0.02	A2 IIIs
HD 200311	*v*	7.70	−0.10	B9p
HD 200030	*c*	6.48	−0.08	B9
HD 199479	*ch*	6.80	−0.05	B9 V

Tables 2-5 present the observations along with their yearly and total means and standard deviations. No corrections have been made for neutral density filter differences among each group of variable, comparison, and check stars. For each star I plotted my data to see if it approximately confirmed the best published period. Then I used the Scargle periodogram (Scargle 1982; Horne & Baliunas 1986) on my data which was for each star, except for 25 Sex, the most extensive data set. I adjusted

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* Tables 2 to 5 only in electronic form at CDS via ftp 130.79.128.5 or http://cdsweb.u-strasbg.fr/Abstract.html

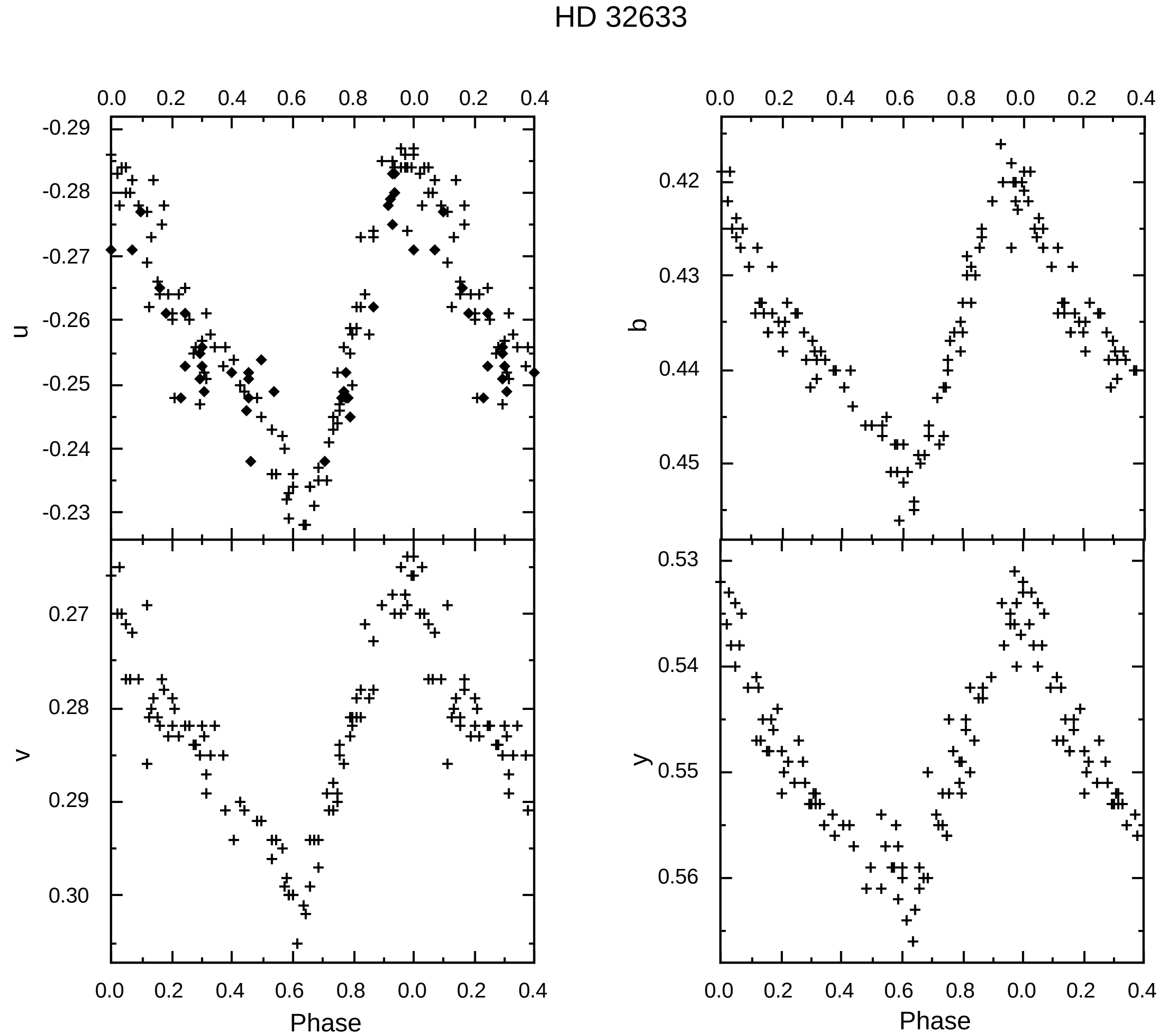

Fig. 1. Differential Strömgren *uvby* photometry of HD 32633 plotted with the ephemeris HJD (u maximum) = 243707.200 + 6.43000 E. Rakosch's (1962) *uv* values transformed to the u scale are plotted as solid diamonds with the FCAPT values indicated by plus signs

the period to make the photometric data coincide as well as possible in phase with published observations.

2. HD 32633 (= HZ Aur)

Jarzebowski (1960) performed the first photoelectric observations of the B9p star HD 32633 in blue light and found what he thought was irregular variability. Rakosch (1962) made *uv*, blue, and yellow observations of this star using HD 32428 and HD 32733 as the primary and secondary comparison stars, respectively. He found a single wave asymmetric variability in 6.429 ± 0.005 days. This period has been confirmed and refined by other studies, e.g. Renson (1984).

Ninety-one *uvby* FCAPT observations were obtained of HD 32633 during years 2, 4, 5, and 6. A periodogram analysis of the u data yielded a period of 6.4309 days. I compared my u photometry to Rakosch's *uv* photometry. His phase of maximum light was satisfactory, but I had to slightly decrease my period to get good agreement:

$$\text{HJD } (u \text{ maximum}) = 243707.200 \pm 0.005 + 6.43000 \pm 0.00002\, E.$$

Figure 1 shows the FCAPT *uvby* photometry (pluses) and the *uv* photometry of Rakosch converted to u (solid diamonds). HD 32633 shows an asymmetric in-phase variability. The amplitudes are 0.055 mag for u, 0.04 mag for v, 0.045 mag for b, and 0.035 mag for y.

3. 25 Sex (= HD 90044 = HR 4082)

The photometric variations of 25 Sex, spectral type B9p Si(Sr,Cr) (Cowley et al. 1969) have been analyzed from observations obtained within the framework of the Long-Term Photometry of Variables project at ESO, most recently by Manfroid & Renson (1994). Their comparison

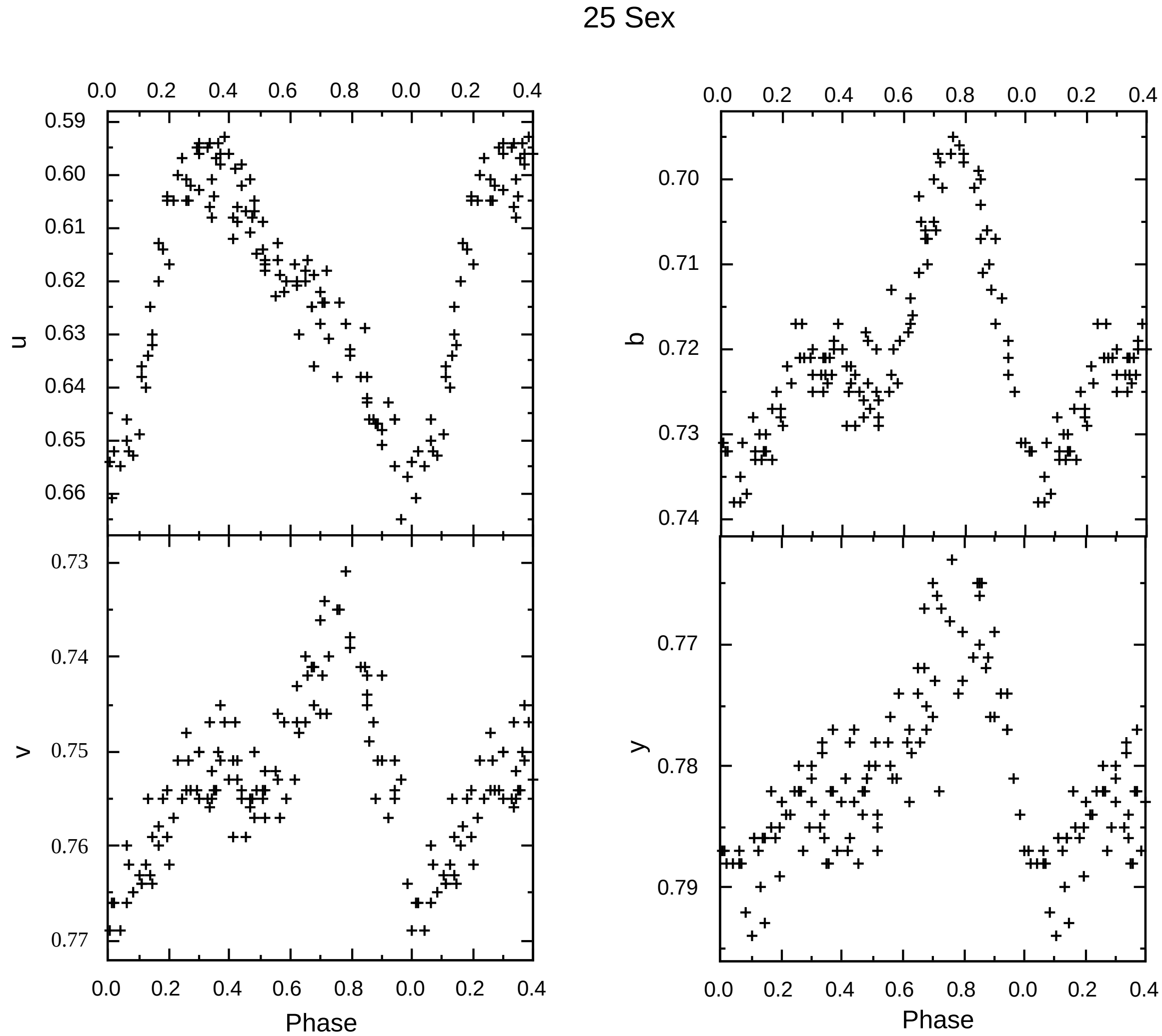

Fig. 2. Differential Strömgren *uvby* FCAPT photometry of 25 Sex plotted with the ephemeris $\mathrm{HJD}(t_0) = 24445659.000 + 4.37900\ E$

star is HD 90882. Their data set consists of 160 *uvby* values obtained over a period of some 4300 days.

Their ephemeris is $\mathrm{HJD}(t_0) = 24445659.000 + 4.37900 \pm 0.00004\ E$.

My FCAPT observations begin just after their data set was completed. There are 123 *uvby* values over an interval of some 1100 days. A periodogram analysis of the u values showed that the most likely period was 4.3790 days in agreement with Manfroid & Renson.

Figure 2 shows the FCAPT data plotted with their ephemeris. This diagram, which is very similar to that of Fig. 5 of Manfroid & Renson, confirms their results. The origin of the ephemeris appears to be minimum light for u. Those for the other three magnitudes appear to be slightly offset. Although the variations for b, v, and y are crudely in phase, they are quite different from that for u. The amplitudes of variations are 0.07 mag for u, 0.03 mag for v, 0.04 mag for b, and 0.025 mag for y. There appear to be two spots with different energy distributions.

4. HR 7224 (= HD 177410 = EE Dra)

Winzer (1974) discovered that the A0p Si star HR 7224 (Cowley et al. 1969) was a light variable with a period of 1.1663 days when he obtained UBV photometry. He used 55 Dra as a comparison star. The largest amplitude was 0.05 mag in U.

One hundred fifty-four FCAPT *uvby* observations were made during years 4 and 5. The periodogram analysis showed that Winzer's period was approximately correct. His V magnitudes were used with the FCAPT y values to adjust the period. The follow ephemeris was adopted

$$\begin{aligned}\text{HJD (light maximum)} = \;& 2441458.8816 \pm 0.0005 \\ & +1.123095 \pm 0.000003\ E.\end{aligned}$$

Figure 3 shows the FCAPT observations (plus signs) and the V values of Winzer (closed squares) transformed to y of HR 7224 plotted according to this ephemeris. The star exhibits in-phase variations in all four magnitudes

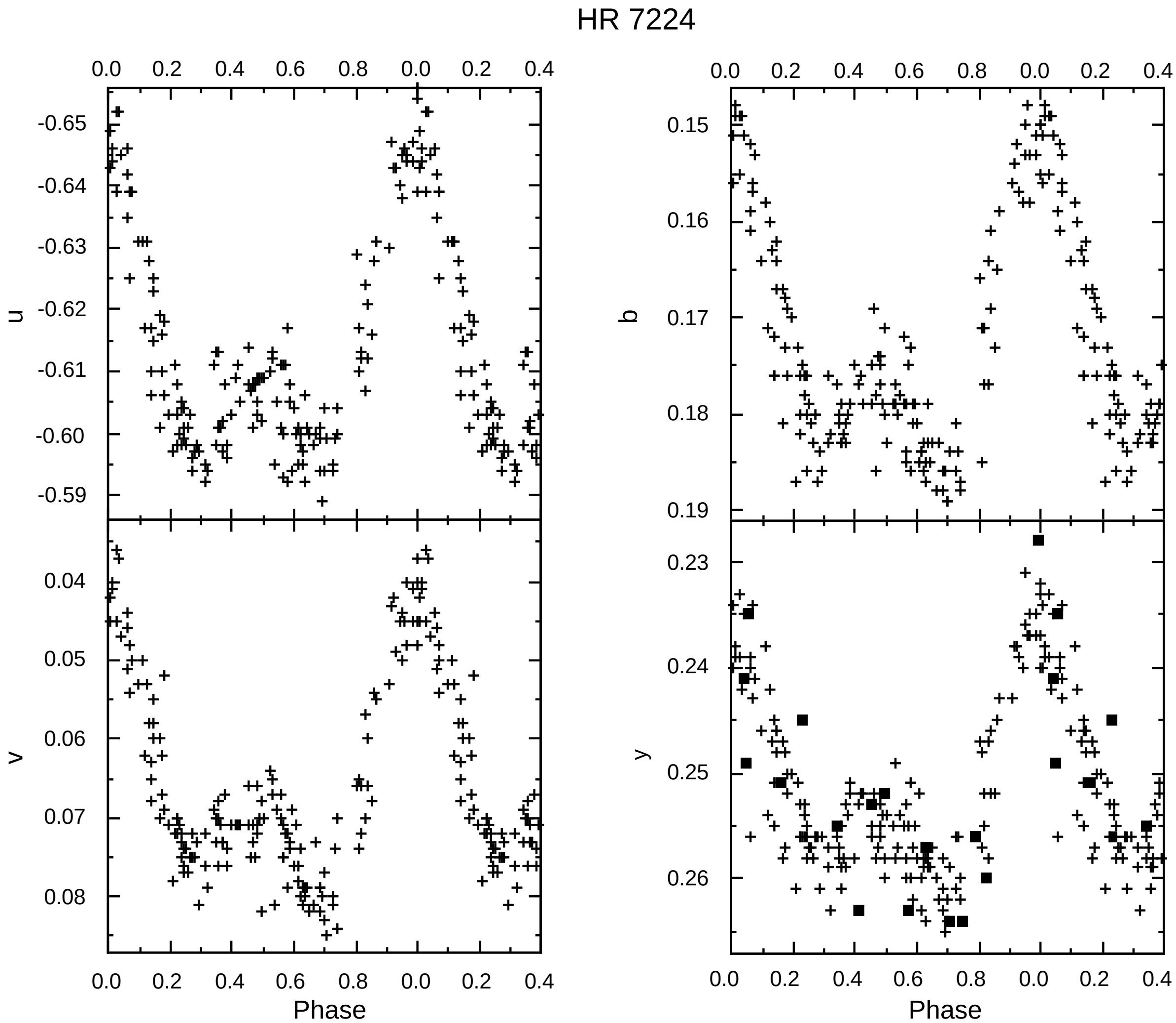

Fig. 3. Differential Strömgren *uvby* photometry of HR 7224 plotted with the ephemeris HJD (light maximum) = 2441458.8816 + 1.123095 E. The FCAPT observations are plus signs while Winzer's V observations are closed squares

with two nearly equal minima, which are about 0.4 of the period apart, separated by a sub-maximum as well as a well-defined maximum. The minimum occurring earlier in phase is always slightly less deep than the second minimum. The amplitudes are 0.06 mag in u, 0.045 mag in v, 0.035 mag in b, and 0.03 mag in y.

5. HD 200311

Preston (1970) included the sharp-lined B9p star HD 200311 ($v \sin i = 9$ km s^{-1}) in a list of CP stars that may have long periods. A high dispersion line identification study (Adelman 1974) and spectrophotometry (Adelman 1980) both show that this is an interesting magnetic star.

During years 2 through 5, 157 *uvby* observations of HD 200311 were made with the FCAPT. The periodogram showed two possible periods 1.037 and 26.0042 days. As on some nights two sets of photometric observations were made and as HD 200311 is a sharp-lined star, I was able to exclude the shorter period. The period is a relatively long one which is consistent with Preston's $v \sin i$ value. The observations are phased according to

$$\begin{aligned}\text{HJD (maximum)} = \; & 2448895.6194 \pm 0.0005 \\ & +26.0042 \pm 0.0007\ E.\end{aligned}$$

Figure 4 shows that with this ephemeris HD 200311 exhibits an in-phase variability of u, v, b, and y with amplitudes, respectively, of 0.035 mag, 0.030 mag, 0.030 mag, and 0.025 mag. There are possibly some slight differences between the light curves, but these require additional observations.

6. Final comments

Each photometric value is an average over the visible surface. Thus complex light curves such as those of 25 Sex imply that over the photosphere there are regions with

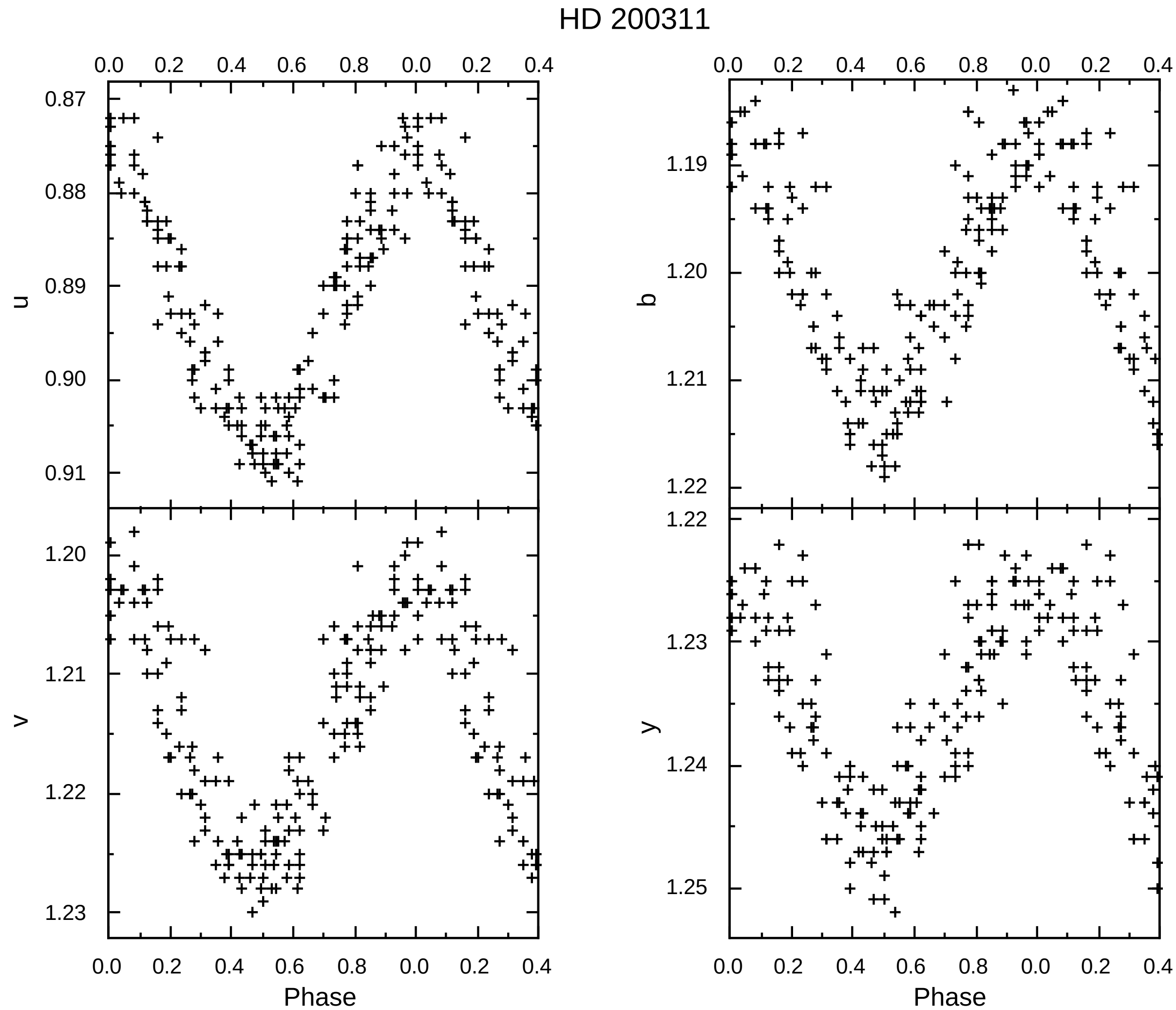

Fig. 4. Differential Strömgren *uvby* FCAPT photometry of HD 200311 plotted with the ephemeris HJD (maximum) = 2448895.6194 + 26.0042 *E*

somewhat different energy distributions. With differences in the stellar opacities due both to abundance and magnetic field differences, the line blanketing and flux redistribution from the ultraviolet change from one location on the surface to another. These need to be modeled with the help of magnetic and spectral data. The photometry is both a constraint and an initial step in this process.

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