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Strömgren and Geneva photometry of the magnetic CP stars 56 Tauri, HD 111133, HD 126515 and HD 215441*,**

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Abstract. — Photometry in the Strömgren and Geneva systems is used to improve the ephemerides of the magnetic CP stars 56 Tau, HD 111133, HD 126515 and HD 215441. The periods we determine are respectively 1.5688840 ± 0.0000047, 16.30720 ± 0.00032, 129.99 ± 0.04 and 9.487574 ± 0.000030 days. We find no evidence for a secular change in the shape of the lightcurves.

Key words: stars: individual: HD 27309, HD 111133, HD 126515, HD 215441 — stars: chemically peculiar — stars: rotation

1. Introduction

Magnetic Ap stars rotate in general more slowly than their normal counterparts, for reasons which are not well understood yet. The abundance anomalies are not distributed uniformly over their surface, so that line blocking and blanketing effects change with the star's orientation with respect to the observer, hence with the rotational phase. As a result, most of these stars are spectrum and photometric variables, with a period identical with the rotational period. Thanks to the stability of the period, its value can be refined to a very large degree as the time span of the observations expands.

There is no convincing evidence for any variation of the rotational period of these objects or for irregular variations. The shape of the lightcurves has, however, been suspected to change on the long term (a decade or so) for the rapidly rotating Ap star 56 Ari (HD 19832), although the evidence is still preliminary (see, e.g. Adelman & Fried 1993). The physical explanation for such a change would be a precession of the rotational axis due to the non-sphericity of the star's envelope, which might be distorted by the magnetic field (Shore & Adelman 1976). Systematic photometric measurements of CP stars are being carried out with the Four College Automated Photoelectric Telescope (FCAPT) to test the long-term stability of their lightcurves' shapes and to refine their periods.

The purpose of this paper is to refine the periods of four classical Ap stars which had been observed long ago in the Geneva photometric system, and more recently with the FCAPT. Precise periods are indeed useful to phase precisely together magnetic and spectroscopic observations, e.g. for Doppler imaging. Another purpose is to give a quantitative description of the shape of the lightcurve by means of Fourier series, following North (1984). Such a description is important for a discussion of the alleged changes in the shape of the lightcurves and has been lacking so far in this context.

2. Observations

The Geneva observations were made at the Jungfraujoch and Gornergrat observatories, with the 76 cm and 1 m Marly telescopes respectively, and at ESO La Silla with the 0.4 m (before April 1980) and the 0.7 m (after April 1980) Swiss telescopes. In the early seventies, the telescope at Gornergrat Observatory was the 0.4 m one which was later used at La Silla. A few early measurements of HD 215441 were made in 1966, 1971 and 1972 with the 1 m Swiss telescope at Observatoire de Haute-Provence (OHP), France, but they have a rather low quality. The photometers used in the northern hemisphere sites were analogic ones, while that used at La Silla after 1976 was the photon-couting, double-beam P7 photometer (Burnet & Rufener 1979). The data used here have been reduced in the standard manner as all-sky measurements, although

*Based on observations collected at Mt. Hopkins, AZ, U.S.A., at the European Southern Observatory, La Silla, Chile and at the Gornergrat and Jungfraujoch Observatories, Switzerland
**The photometric data are available by anonymous ftp 130.79.128.5 at the CDS

one or two comparison stars have been observed in 1979 and 1980 for each variable. But, since the variable and comparisons were observed only once per observation, the precision of the differential magnitudes was not significantly greater than the all-sky, absolute values.

Our Strömgren photometry was obtained with the FCAPT on Mt. Hopkins, Arizona, U.S.A. One observation consisted in a dark current measurement, followed for each of the four *uvby* filters by the sequence sky-ch-*c*-*v*-*c*-*v*-*c*-*v*-*c*-ch-sky, where sky is a reading of a sky patch, ch that of a check star, *c* that of the comparison star and *v* that of the variable star. Corrections have not been made for neutral density filter differences among each group of variable, comparison and check stars. Usually, only one observation was made of a given star per night. Although this would have been a bad policy, had we intended to determine completely unknown periods, it was sufficient here since unambiguous periods were already available in the literature.

3. Results and discussion of individual stars

For each star, we give a table with the least-squares fitted quantities (period, amplitudes and phases of the Fourier terms, generally limited to the first harmonic) as well as their formal uncertainty, and figures showing the lightcurves in the Strömgren and Geneva systems. The photoelectric data themselves are not printed here but are available by anonymous ftp at the Centre de Données de Strasbourg (CDS), according to the instructions given in A&A 280, E1-E2 (1993).

3.1. *56 Tau = HD 27309 = V724 Tau, A0 SiCr*

Winzer's (1974) *UBV* observations showed that this star is a large amplitude variable with a period of 1.5691 days. Nikolov (1974) and other authors also measured this star in *UBV* but adopted the alias period of 2.7098 days, until Musielok et al. (1980) rehabilitated and refined Winzer's period as being 1.56896 ± 0.00003 days. The amplitudes of variability are approximately 0.10, 0.05 and 0.06 mag. peak-to-peak in U, B and V respectively.

It was observed 3 times in Geneva photometry in 1971-1973 (the three measurements routinely done for each star in the Geneva catalogue) at Gornergrat with the 0.4 m telescope. Then it was reobserved at La Silla in 1979, 1980 and 1984, and at Jungfraujoch in 1987. The *uvby* observations took place in 1990, 1991 and 1992 with the FCAPT using 51 Tau (= HD 27176 = HR 1331, F0V) as the comparison star and 72 Tau (= HD 28149 = HR 1399, B7V) as the check star. However, the data of the first year (1990) are of bad quality, so they were finally dropped. The magnitudes we finally use are differential ones, relative to the mean magnitude of the comparison and check stars.

In order to obtain the best possible period, we combined our y magnitudes not only with Geneva's $[V]$ ones (which is justified because the effective wavelengths of both bandpasses are very close), but also with the V data of Musielok et al. (1980) and of Nikolov (1974). Using the Geneva $[V]$ values as a basis, we had to add an offset of 5.592 magnitudes to our y data to make them compatible. This corresponds to the mean of the V magnitudes of the comparison and check stars (5.638 and 5.515 respectively), plus 0.015. The offset applied to the V data of Musielok et al. (1980) is 5.644 which is, within 0.008 mag., the $[V]$ magnitude of the comparison star HD 27176 they used. The "5420 Å" differential magnitudes of Nikolov (1974) were considered equivalent to Johnson's V, Geneva $[V]$ and Strömgren y magnitudes, after application of an offset of 5.647 magnitudes (referring again to the comparison star HD 27176) and elimination of two bad points at JD 2441707.239 and 2441725.225.

Using these combined data, we used a linearized least-squares method to find the period and its rms standard deviation. This method is described by North (1987) and assumes that the lightcurve has the form:

$$\begin{aligned} m(t) \;=\; & A_0 + A_1\cos(\omega t) + B_1\sin(\omega t) + \\ & A_2\cos(2\omega t) + B_2\sin(2\omega t) \end{aligned} \quad (1)$$

where $\omega = 2\pi/P$ and P is the period. As shown by North (1984) and by Mathys & Manfroid (1985), such a sine curve with its first harmonic fits very well the observed data in most cases, and 56 Tau is no exception.

The period we find is given in Table 1, together with its formal uncertainty. Our period is consistent with that of Musielok et al. (1980) within 2.5 σ, taking into account the uncertainty given by these authors. Our uncertainty is 6 times smaller, but it is probably optimistic. Table 1 gives also the coefficients of the Fourier series and their rms standard deviation. The coefficients are not those of Eq. (1) but correspond to the following, equivalent equation:

$$m(t) = a_0 + a_1\cos(\omega t + \phi_1) + a_2\cos(2\omega t + \phi_2) \quad (2)$$

The least-squares fit was applied to Eq. (1) rather than to Eq. (2) because it is linear (for a given period), so the coefficients of Eq. (2) have been computed from the fitted ones through Eqs. (5) of North (1987). Similarly, the whole covariance matrix was propagated using equations such as Eq. (6) of North (1987). The standard deviations (root squares of the diagonal terms of the covariance matrix) and correlation coefficients (non-diagonal terms normalized according to Eq. (7) of North 1987) are also given in Table 1 for every lightcurve. Note that due to a bug just discovered in the printing programme, the correlation coefficients listed in Table II of North (1987) are wrong.

The lightcurves are given in Fig. 1 for the composite V, $[V]$ and y lightcurve and *uvby* lightcurves, and in Fig. 2 for the lightcurves in the Geneva system. In Fig. 2 are presented the curves corresponding to the seven magnitudes $[U]$, $[B]$, $[V]$, $B1$, $B2$, $V1$ and G of the Geneva system, and to the three reddening-free parameters X, Y and Z defined

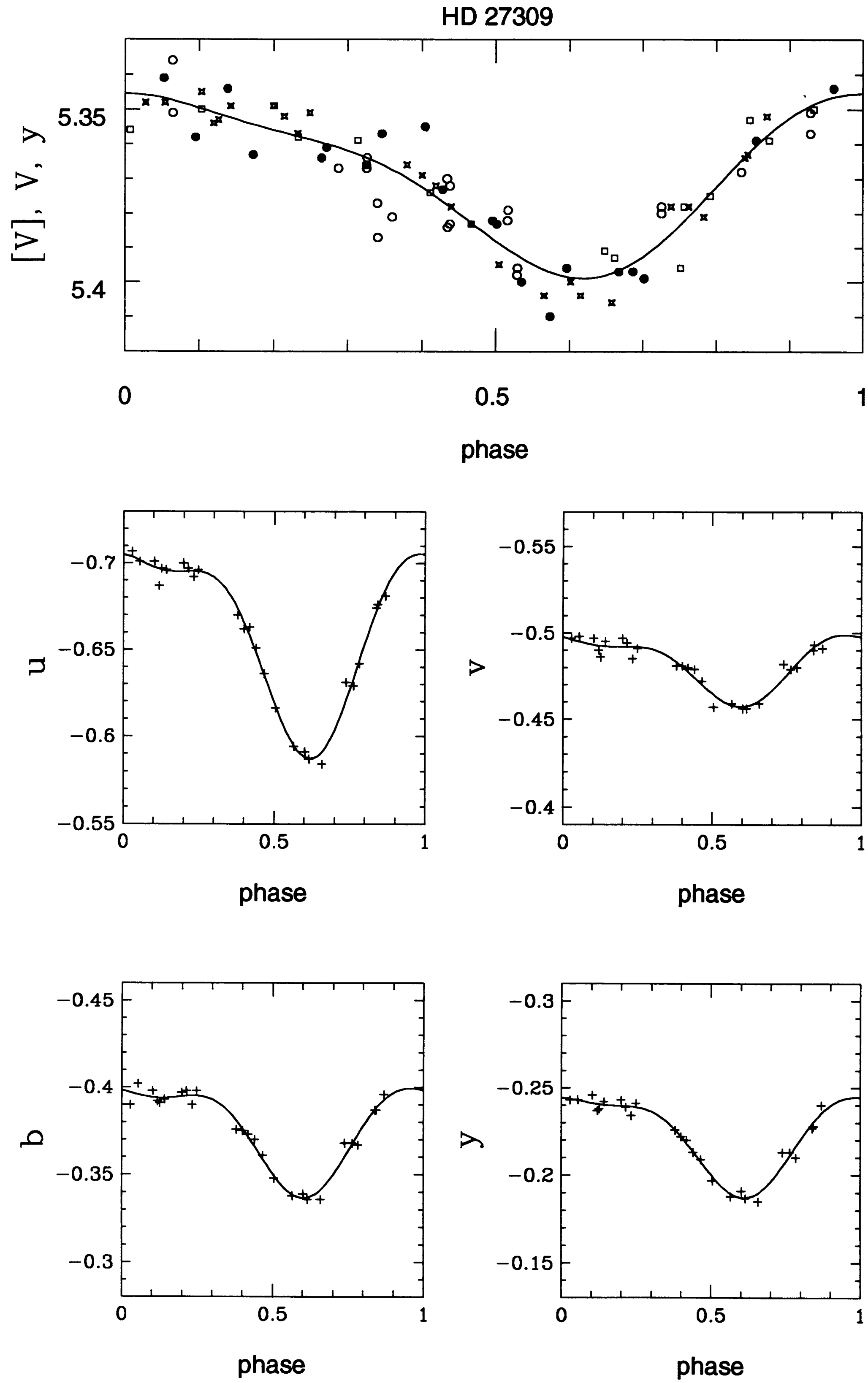

Fig. 1. Composite and *uvby* lightcurves of 56 Tau, according to the ephemeris of Table 1. The fitted curves are sinusoids with their first harmonic. In the top panel, the full dots are Geneva [*V*] magnitudes, the stars are our *y* magnitudes while the open squares and circles are the *V* data from Nikolov (1974) and Musielok et al. (1980) respectively

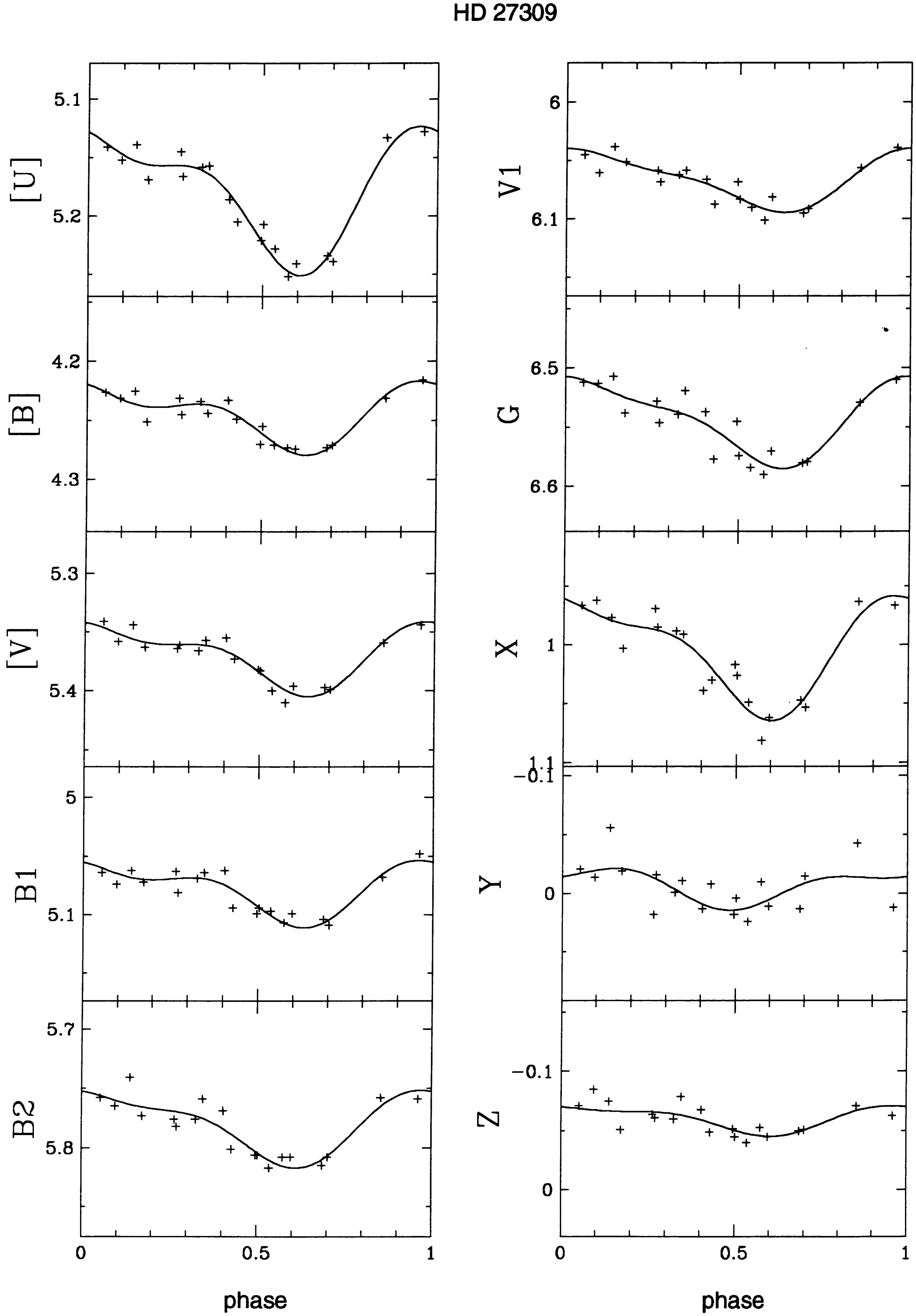

Fig. 2. Geneva lightcurves of 56 Tau, according to the ephemeris of Table 1 (see text for details)

Table 1. Ephemerides of the star 56 Tau and coefficients of the function least-squares fitted to the lightcurves and given by Eq. (2), where $t = \mathrm{HJD} - \mathrm{HJD}_0$. The epoch of zero phase corresponds to maximum light intensity (therefore to minimum magnitude) in the composite $[V]$+V+y lightcurve. For each coefficient of the lightcurves we give the rms uncertainty; only the last digits are given to save place. The phases ϕ_i are given in radians. The non-diagonal terms of the covariance matrix are given under the form of correlation coefficients; the rms residual scatter around the fitted curve and number N of measurements are given too. For Geneva photometry the fit was made on the measurements which have a weight $Q \geq 2$

HD 27309	HJD(min. V mag.) = 2448680.105 + 1.5688840 E ± 0.0000047																					
	lightcurve parameters										correlations											
band	a_0	σ_{a_0}	a_1	σ_{a_1}	ϕ_1	σ_{ϕ_1}	a_2	σ_{a_2}	ϕ_2	σ_{ϕ_2}	a_0a_1	$a_0\phi_1$	a_0a_2	$a_0\phi_2$	$a_1\phi_1$	a_1a_2	$a_1\phi_2$	ϕ_1a_2	$\phi_1\phi_2$	$a_2\phi_2$	σ_{res}	N
[V],V,y	5.3690	7	.0247	11	2.61	4	.0065	11	4.36	17	-0.11	-0.15	0.04	0.07	0.03	0.14	-0.10	0.17	-0.08	-0.02	0.0070	82
u	-0.6615	8	.0549	12	2.47	2	.0198	12	4.67	7	-0.05	-0.14	-0.15	0.12	0.13	0.28	-0.19	0.04	-0.29	-0.07	0.0045	26
v	-0.4825	8	.0183	11	2.69	6	.0074	11	4.90	17	-0.08	-0.13	-0.12	0.14	0.15	0.21	-0.29	-0.08	-0.25	-0.01	0.0041	
b	-0.3768	8	.0288	11	2.56	4	.0114	11	4.93	11	-0.07	-0.13	-0.11	0.15	0.14	0.21	-0.27	-0.06	-0.27	0.00	0.0041	
y	-0.2228	7	.0270	10	2.53	4	.0088	10	4.77	13	-0.06	-0.13	-0.14	0.13	0.14	0.26	-0.23	0.00	-0.28	-0.05	0.0037	
[U]	5.1773	26	.0525	35	2.70	7	.0240	35	4.64	15	-0.13	-0.33	-0.09	-0.04	0.02	0.07	-0.19	0.27	0.11	0.06	0.0108	19
[B]	4.2443	17	.0233	24	2.67	11	.0136	23	4.40	18	-0.12	-0.33	-0.08	-0.06	0.02	0.11	-0.17	0.24	0.16	0.04	0.0072	
[V]	5.3689	16	.0255	23	2.56	9	.0122	22	4.23	19	-0.08	-0.34	-0.05	-0.06	0.00	0.14	-0.19	0.20	0.16	0.01	0.0069	
B1	5.0777	20	.0225	28	2.58	13	.0121	27	4.41	24	-0.09	-0.34	-0.08	-0.06	0.01	0.09	-0.19	0.25	0.14	0.04	0.0085	
B2	5.7799	27	.0287	37	2.68	14	.0101	36	4.53	37	-0.13	-0.33	-0.09	-0.05	0.02	0.09	-0.19	0.26	0.13	0.05	0.0112	
V1	6.0654	21	.0244	28	2.64	12	.0071	27	4.02	41	-0.11	-0.33	-0.05	-0.09	0.01	0.17	-0.13	0.17	0.23	-0.01	0.0086	
G	6.5427	32	.0342	44	2.63	14	.0109	43	4.17	42	-0.11	-0.33	-0.06	-0.08	0.01	0.14	-0.15	0.20	0.20	0.01	0.0134	
X	1.0037	40	.0461	53	2.74	12	.0170	54	4.67	32	-0.15	-0.32	-0.11	-0.05	0.04	0.07	-0.16	0.30	0.11	0.06	0.0163	
Y	-0.0070	49	.0144	68	3.05	50	.0075	66	0.37	91	-0.25	-0.27	0.00	0.12	0.09	-0.17	-0.10	0.03	-0.30	-0.05	0.0202	
Z	-0.0606	22	.0111	30	2.67	30	.0043	30	4.78	70	-0.13	-0.33	-0.12	-0.04	0.02	0.03	-0.17	0.31	0.07	0.06	0.0092	

by Cramer & Maeder (1979). The X and Y parameters are related primarily with $T_{\rm eff}$ and $\log g$ respectively, but they can be affected by the star's peculiarity, especially in Ap stars cooler than 11000 K (North & Cramer 1984). The Z parameter is a very good indicator of the Ap anomaly, especially for stars hotter than about 9000 K (Cramer & Maeder 1980) and is similar to $\Delta(V1-G)$ and Δa as a way of measuring the strength of the λ 5200 Å depression (see e.g. Maitzen & Vogt 1983). As can be seen in Fig. 2, Z does vary through a rotation cycle, though with a small amplitude. The Geneva lightcurves are noisier than the $uvby$ ones, because each point represents one absolute measurement rather than the mean of several, differential measurements.

3.2. *HD 111133 = HR 4854 = EP Vir, A1 SrCrEu*

The light variability of this star was discovered by Stepień (1968), but the right period was published by Wolff & Wolff (1972) who used $uvby$ observations. The peak-to-peak amplitudes are 0.04, 0.05, 0.05 and 0.04 mag. in u, v, b and y respectively. Later Buchholz & Maitzen (1979) obtained Δa photometry which uses 3 filters (among which Strömgren's y one) to measure the strength of the λ 5200 Å broad continuum feature. Adelman et al. (1992) used the y data and the V values from UBV observations obtained with the Fairborn 10inch automated photoelectric telescope on Mt. Hopkins to improve the ephemeris, obtaining

$$\begin{aligned} \mathrm{HJD(light\,max.)} \; = \; & 2440640.20 + 16.3047E \\ & \pm 0.41 \;\; \pm 0.002 \end{aligned} \qquad (3)$$

Their data indicate a variability of 0.04 mag. in U and B and a 0.025 mag. variability in V peak-to-peak. Their comparison star was HD 109860, also used by Wolff & Wolff (1972), while the check star was HD 110951.

We reexamine here UBV data which were already considered by Adelman et al. (1992): we retained only those measurements which internal standard deviation was smaller or equal to 8 mmag in either U, B or V, leaving only 151 of the initial 198 measures. Further, we removed 11 UBV measurements which were clearly far from the mean lightcurve either in V or in B. So we are left with 140 good UBV data, which are relative to the comparison star HD 109860.

Early measurements were made in Geneva photometry at Jungfraujoch in 1969. A few additional measurements were made in 1972 at Gornergrat, while all others have been made at La Silla, essentially in 1979-80.

The $uvby$ observations were made with the FCAPT in 1991, 1992 and 1994, using HD 109860 (= HR 4805, B9.5V) as the comparison star and HD 110951 (= HR 4847, A8m) as the check star. For some unclear reason, the differential magnitudes relative to HD 110951 give much larger residuals around the fitted lightcurve than do those relative to HD 109860, although the latter is 1 mag. fainter, so we did not use HD 110951 when computing the differential values.

The period determination was based on the Geneva $[B]$ magnitudes, combined with Adelman et al.'s B data, with the v and b data of Wolff & Wolff (1972) and with our new v and b data. The choice of the blue range was motivated by the amplitude of the lightcurve, which is greater there than in the yellow. With the $[B]$ magnitudes as a reference, we had to add an offset of 5.347 mag. to the B ones. Rather than use either v or b, we preferred to take an average of both in the hope (fulfilled a posteriori) that the shape and amplitude of the resulting lightcurve would be closer to that of B and $[B]$. The differential v and b magnitudes were obtained from the Wolffs' paper through the relations:

$$\Delta b = \Delta y + \Delta(b - y) \quad (4)$$

$$\Delta v = \Delta m_1 + \Delta b + \Delta(b - y) \quad (5)$$

where Δ means that we are dealing with differential magnitudes. We defined $< vb >$ by

$$< vb >= 0.5(\Delta v + \Delta b) + \text{offset} \quad (6)$$

where the offset is 5.351. We treated our vb data in a similar way, using an offset of 5.350 that was adjusted so as to minimize the residual scatter around the fitted lightcurve. The period and the coefficients of the fitted lightcurves are given in Table 2. Figures 3-5 show the composite B, $[B]$ and $< vb >$ curve and $uvby$ lightcurves, our UBV and the Geneva lightcurves respectively. Offsets of 6.881, 5.347 and 6.321 mag. have been applied to the U, B and V differential magnitudes respectively for an easier comparison with the Geneva data.

Our period is compatible with that of Adelman et al. (1992) but is a few times more precise.

3.3. *HD 126515 = BD +01°2927 = FF Vir, A2 CrSr*

Preston (1970) found a period of 130 days for this star, and this value was confirmed ever since by various authors (Catalano & Leone 1990; Mathys 1991). In Geneva photometry, it was observed once at Jungfroujoch as early as 1971, while all other measurements took place at La Silla between 1976 and 1983. The $uvby$ data were acquired between 1991 and 1994 with the FCAPT using HD 127167 (= HR 5418, A5IV) and HD 125489 (= HR 5368, A7V) as comparison stars. From JD 2448676 on, another set of filters has been used so that the zero point of the differential measurements had to be adjusted.

In order to refine the period, we finally did not use the data published by Catalano & Leone (1990) for two reasons: first, the residual rms scatter of these data around the mean curve is large; second, it is difficult to adjust the offset of these magnitudes (either U, B or V) relative to Geneva ones, because there is a correlation between the offset one choses and the fitted period. Indeed, the V and B data of Catalano & Leone (1990) are distributed in time in such a way that many are on the ascending branch of the lightcurve, so that changing either the offset or the period has the same result. Therefore we used only our Geneva and $uvby$ data, combining $[V]$ and y (adding to the differential y magnitudes an offset of 6.072 mag. before JD 2448676 and of 7.263 after),$[B]$ and v (with offsets on v of 5.335 and 6.532 respectively) and $[B]$ and b (with offsets on b of 5.260 and 6.455). The three period estimates we obtain are about 3 times more scattered than the formal, internal sigma given by the least-squares code, so we adopted a weighted mean of the period (with the inverse of the variance as weights) and an rms standard deviation of 0.04 days, which is an upper limit to the three individual sigmas given by the code.

The value of the period is given in Table 3, while the lightcurves are given in Figs. 6 and 7. In Fig. 6, the composite $[V]$ and y lightcurve is shown, together with the V data of Catalano & Leone (1990), to which we have added an offset of 5.976. These data clearly do not fit ours very well, while the Geneva $[V]$ and y ones are mutually very consistent. The fitted lightcurve is a cosine wave with its first harmonic. For the $uvby$ curves, however, we have fitted a cosine wave with two harmonics, because one harmonic was clearly not enough for a good fit of the u curve. The v, b and y curves were also fitted with 2 harmonics just for homogeneity, although the coefficients a_3 and ϕ_3 are not really significant. The Geneva data, which are a bit less precise, have been fitted using one harmonic only.

Our period is completely consistent with the previous value of 130.0 days.

3.4. *HD 215441 = BD +54°2846 = GL Lac, B9 Si*

Jarzebowski (1960) found the large photometric variability of this star (which has the largest magnetic field among the Ap stars) as well as its period of 9.49 days. Other significant photometry was performed by Cameron (1966), Stepień (1968) and Blanco et al. (1973). Musielok & Madej (1988) performed β photometry and refined the period to 9.4875 days, as did Zverko & Panov (1983).

It was observed in Geneva photometry as early as 1966 (at OHP), but the quality of these old measurements was not satisfactory; it was observed again from Gornergrat between 1978 and 1981. $uvby$ observations were collected in 1991 and 1992 with HD 215501 (= BD +55°2800, A3) and HD 215757 (= BD +54°2856, A0) as comparison and check stars respectively. The differential measurements relative to the comparison star are less scattered around the mean curve than those relative to the check star, so we did not consider the latter any more.

To refine the period, we combined the m_{4200} magnitudes of Jarzebowski (1960), corrected by an offset of +7.987, with the Geneva $[B]$ data, the B magnitudes of Stepień (1968) corrected by an offset of −0.951 and our v data. The latter were corrected by an offset of +7.730. The period found is given in Table 4, together with the coefficients of the fitted lightcurves. Our period is very slightly longer than that of Zverko & Panov (1983), but still compatible with theirs within $3\,\sigma$.

The composite m_{4200}, $[B]$, B and v lightcurves is shown in Fig. 8, together with the $uvby$ lightcurves. Figure 9 shows the Geneva lightcurves. In spite of the large amplitude, one single harmonic was sufficient to fit the observations.

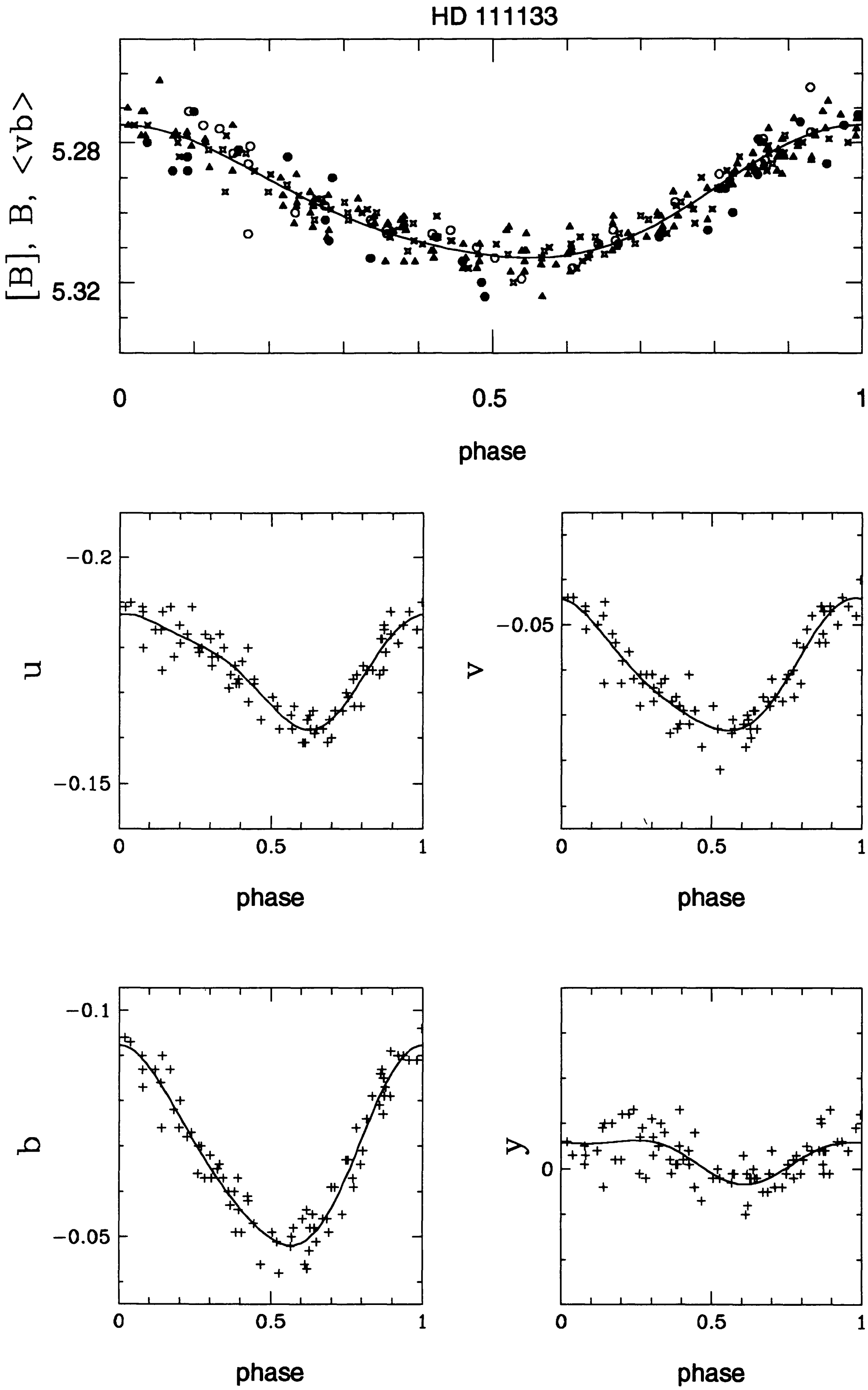

Fig. 3. Composite and *uvby* lightcurves of HD 111133, according to the ephemeris of Table 2. The fitted curves are sinusoids with their first harmonic. In the top panel, the full dots represent the Geneva [*B*] magnitudes, the full triangles our *B* data, the stars our < *vb* > data and the open circles the < *vb* > data of Wolff & Wolff (1972)

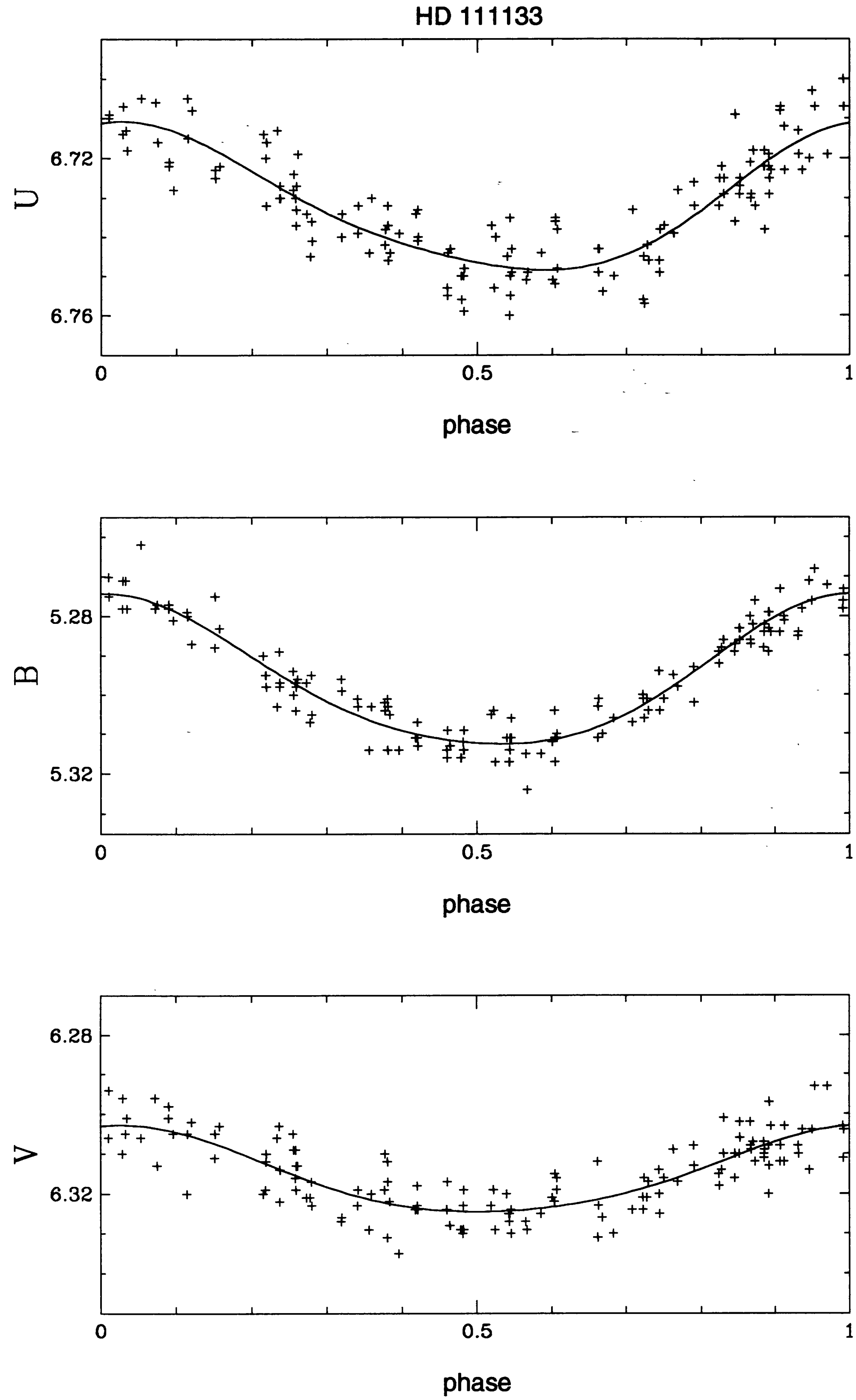

Fig. 4. Our UBV lightcurves of HD 111133

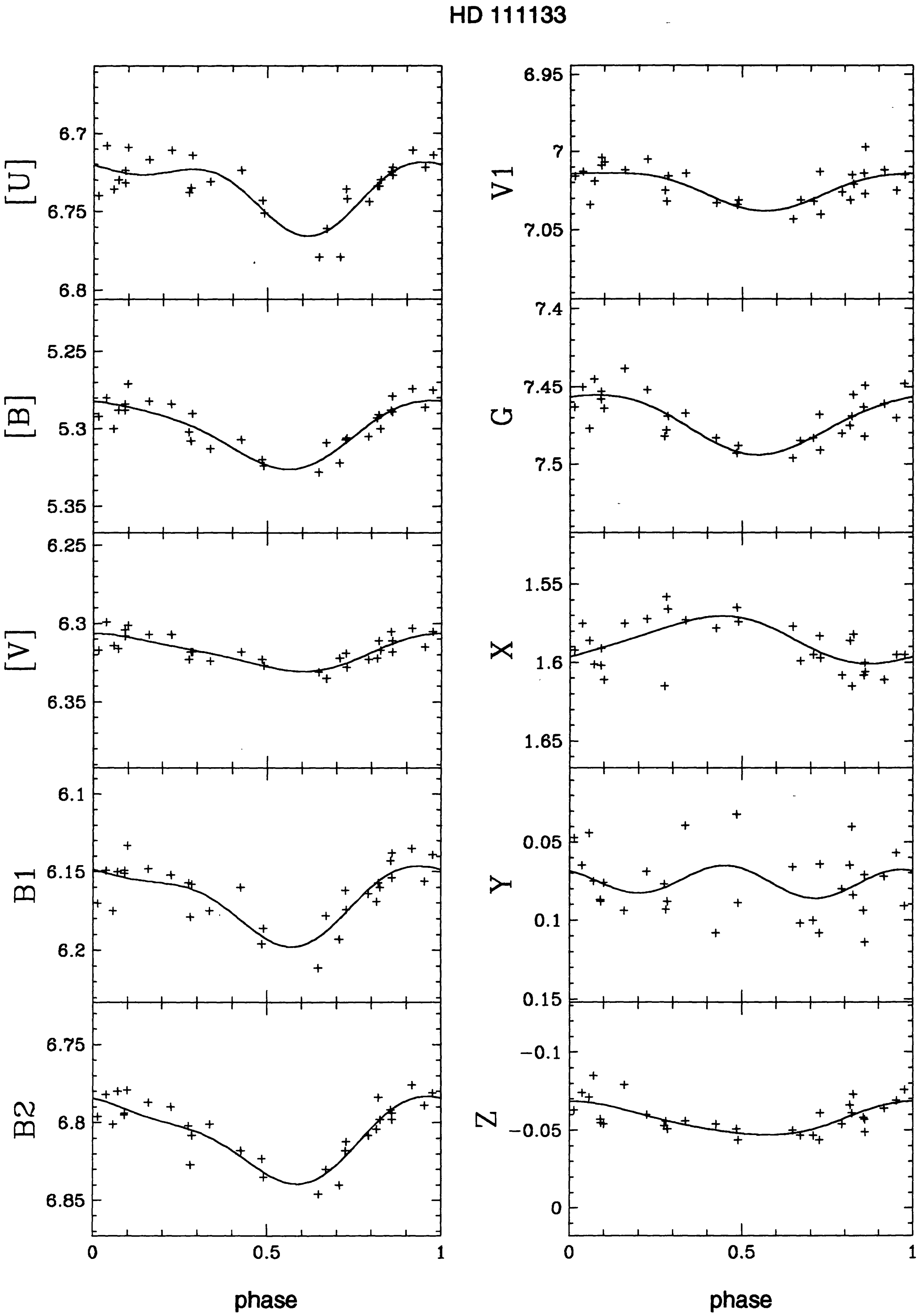

Fig. 5. Geneva lightcurves of HD 111133, according to the ephemeris of Table 2

Table 2. Ephemerides of the star HD 111133 and coefficients of the fitted lightcurves. The epoch of zero phase corresponds to maximum light intensity (therefore to minimum magnitude) in the composite $[B]+B+< vb >$ lightcurve (see text). See Table 1 for other comments

HD 111133 — HJD(min. B mag.) = 2448597.040 + 16.30720 E ± 0.00032

	lightcurve parameters										correlations											
band	a_o	σ_{a_o}	a_1	σ_{a_1}	ϕ_1	σ_{ϕ_1}	a_2	σ_{a_2}	ϕ_2	σ_{ϕ_2}	a_oa_1	$a_o\phi_1$	a_oa_2	$a_o\phi_2$	$a_1\phi_1$	a_1a_2	$a_1\phi_2$	ϕ_1a_2	$\phi_1\phi_2$	$a_2\phi_2$	σ_{res}	N
[B],B,<vb>	5.2958	2	.0188	4	3.04	2	.0024	4	3.54	16	-0.01	0.04	0.00	0.15	-0.09	0.02	-0.08	-0.03	-0.05	-0.03	0.0046	279
U	6.7316	6	.0185	8	2.84	4	.0027	8	3.24	32	-0.03	0.06	0.05	0.19	-0.12	0.06	-0.13	-0.05	-0.09	0.03	0.0070	140
B	5.2956	3	.0191	5	3.06	2	.0023	5	3.26	22	-0.02	0.06	0.05	0.19	-0.13	0.05	-0.15	-0.07	-0.06	0.03	0.0043	
V	6.3149	4	.0109	6	3.03	6	.0012	6	2.67	56	-0.03	0.06	-0.07	0.18	-0.13	0.13	-0.10	-0.02	-0.09	-0.02	0.0056	
u	-0.1759	3	.0120	5	2.57	4	.0028	5	4.19	20	-0.12	0.00	-0.02	0.19	0.07	-0.08	-0.08	0.03	-0.02	-0.13	0.0034	81
v	-0.0400	4	.0142	6	3.10	3	.0022	5	3.96	27	-0.10	0.07	-0.06	0.19	-0.07	-0.03	-0.09	0.06	0.05	-0.16	0.0037	
b	-0.0690	4	.0216	6	2.97	2	.0026	6	3.86	24	-0.11	0.05	-0.08	0.19	-0.03	-0.02	-0.10	0.05	0.04	-0.16	0.0040	
y	-0.0029	4	.0045	6	2.41	14	.0017	6	4.95	40	-0.12	-0.02	0.14	0.15	0.10	-0.12	-0.01	-0.01	-0.04	0.08	0.0041	
[U]	6.7359	21	.0197	32	2.50	14	.0103	29	4.75	28	0.33	0.34	0.04	0.23	0.15	0.17	0.35	-0.17	0.09	-0.11	0.0107	31
[B]	5.3014	15	.0213	24	2.92	9	.0041	20	5.08	54	0.41	0.17	0.12	0.20	0.01	0.20	0.29	-0.27	0.00	-0.08	0.0077	
[V]	6.3182	11	.0113	18	2.79	13	.0023	16	4.16	67	0.38	0.25	-0.11	0.25	0.08	-0.12	0.37	-0.16	-0.15	-0.07	0.0058	
B1	6.1678	24	.0230	37	2.89	13	.0078	31	5.11	43	0.41	0.19	0.13	0.20	0.02	0.22	0.28	-0.26	0.02	-0.08	0.0120	
B2	6.8088	18	.0252	28	2.88	9	.0072	25	4.70	35	0.40	0.19	0.03	0.24	0.03	0.08	0.35	-0.23	-0.07	-0.11	0.0092	
V1	7.0232	19	.0120	29	2.71	20	.0029	24	5.49	97	0.38	0.27	0.20	0.14	0.09	0.35	0.16	-0.16	0.14	0.00	0.0097	
G	7.4728	21	.0193	33	2.79	14	.0021	28	5.97	144	0.39	0.24	0.24	0.04	0.06	0.38	0.01	-0.10	0.20	0.09	0.0107	
X	1.5858	26	.0147	37	0.57	25	.0019	35	2.84	194	-0.42	0.22	-0.22	-0.02	-0.18	0.18	0.14	-0.38	0.13	0.09	0.0133	
Y	0.0755	44	.0022	57	1.15	307	.0089	62	3.67	63	-0.25	0.39	-0.15	0.15	-0.07	0.11	0.20	-0.22	0.31	0.06	0.0219	
Z	-0.0570	16	.0104	25	2.94	20	.0014	23	3.69	152	0.42	0.14	-0.15	0.16	-0.01	-0.23	0.27	-0.06	-0.28	0.06	0.0084	

Table 3. Ephemerides of the star HD 126515 and coefficients of the fitted lightcurves. The epoch of zero phase corresponds to maximum light intensity (therefore to minimum magnitude) in the composite $[V]+y$ lightcurve (see text). Here the lightcurves in u, v, b and y have been fitted using two harmonics instead of one. The correlation coefficients are given under a matrix form. All other lightcurves were fitted using one harmonic

HD 126515 — HJD(min. V mag.) = 2448703.905 + 129.99 E ± 0.04

	lightcurve parameters										correlations											
band	a_o	σ_{a_o}	a_1	σ_{a_1}	ϕ_1	σ_{ϕ_1}	a_2	σ_{a_2}	ϕ_2	σ_{ϕ_2}	a_oa_1	$a_o\phi_1$	a_oa_2	$a_o\phi_2$	$a_1\phi_1$	a_1a_2	$a_1\phi_2$	ϕ_1a_2	$\phi_1\phi_2$	$a_2\phi_2$	σ_{res}	N
[V],y	7.0970	3	.0247	5	2.47	2	.0077	5	4.68	7	0.07	-0.15	-0.09	0.09	0.08	0.08	0.00	0.18	0.08	-0.03	0.0048	157
[U]	7.5414	20	.0145	37	0.19	19	.0104	28	4.24	29	0.33	0.56	-0.44	-0.15	0.43	-0.36	-0.66	-0.39	-0.42	0.11	0.0093	34
[B]	6.1438	13	.0297	15	2.45	8	.0108	19	4.80	16	0.18	-0.48	-0.43	0.10	0.22	0.15	0.24	0.70	0.38	0.12	0.0060	
[V]	7.0978	10	.0239	12	2.30	8	.0058	14	4.38	26	0.29	-0.43	-0.43	-0.07	0.07	-0.09	0.13	0.49	0.61	0.11	0.0049	
B1	7.0380	15	.0276	17	2.37	10	.0058	22	4.94	35	0.24	-0.47	-0.41	0.16	0.14	0.09	0.19	0.73	0.28	0.09	0.0069	
B2	7.6263	17	.0294	19	2.26	11	.0125	24	4.38	20	0.33	-0.45	-0.45	-0.09	0.01	-0.12	0.08	0.51	0.62	0.13	0.0078	
V1	7.8029	23	.0246	27	2.38	18	.0063	32	3.90	58	0.23	-0.47	-0.37	-0.28	0.15	-0.12	0.17	0.17	0.75	0.04	0.0109	
G	8.2535	19	.0338	22	2.37	11	.0121	27	4.29	24	0.25	-0.47	-0.45	-0.13	0.13	-0.04	0.19	0.46	0.65	0.12	0.0089	
X	1.4795	33	.0476	43	5.80	13	.0095	44	3.65	55	0.01	0.55	-0.29	-0.38	0.40	0.14	-0.45	0.01	-0.76	-0.01	0.0150	
Y	-0.0387	36	.0206	57	6.12	29	.0149	48	3.72	38	0.22	0.59	-0.31	-0.37	0.52	0.07	-0.65	-0.07	-0.71	0.01	0.0163	
Z	-0.0536	18	.0083	20	2.11	43	.0088	26	4.57	29	0.47	-0.45	-0.48	-0.04	-0.19	-0.27	-0.06	0.62	0.56	0.16	0.0081	

band	a_o	σ_{a_o}	a_1	σ_{a_1}	ϕ_1	σ_{ϕ_1}	a_2	σ_{a_2}	ϕ_2	σ_{ϕ_2}	a_3	σ_{a_3}	ϕ_3	σ_{ϕ_3}		a_1	ϕ_1	a_2	ϕ_2	a_3	ϕ_3	σ_{res}	N
u	0.7040	3	.0157	5	0.37	3	.0151	5	4.47	3	.0035	5	1.44	15	a_o	0.05	0.06	-0.06	0.04	0.06	-0.03	0.0042	124
															a_1		0.01	-0.08	0.01	0.06	0.02		
															ϕ_1			0.06	-0.01	0.04	0.05		
															a_2				0.02	0.06	0.00		
															ϕ_2					0.09	-0.09		
															a_3						0.08		
v	0.8083	3	.0297	4	2.41	1	.0101	4	5.10	4	.0009	4	1.89	53	a_o	0.03	-0.07	-0.03	0.07	0.03	-0.06	0.0037	
															a_1		0.04	0.06	-0.07	0.03	0.03		
															ϕ_1			0.04	-0.04	-0.08	-0.01		
															a_2				-0.02	0.06	-0.09		
															ϕ_2					0.00	-0.08		
															a_3						0.10		
b	0.8862	4	.0395	6	2.37	1	.0141	6	4.75	4	.0006	6	1.58	110	a_o	0.04	-0.07	-0.05	0.06	0.05	-0.04	0.0054	
															a_1		0.03	0.08	-0.04	0.02	0.04		
															ϕ_1			0.05	-0.02	-0.07	-0.03		
															a_2				0.00	0.08	-0.04		
															ϕ_2					0.05	-0.10		
															a_3						0.10		
y	1.0245	4	.0251	6	2.48	2	.0078	6	4.69	7	.0006	6	5.99	99	a_o	0.03	-0.07	-0.05	0.05	0.02	0.06	0.0049	
															a_1		0.04	0.09	-0.04	-0.03	0.00		
															ϕ_1			0.04	-0.02	0.05	-0.04		
															a_2				0.00	0.01	0.08		
															ϕ_2					0.07	0.09		
															a_3						-0.06		

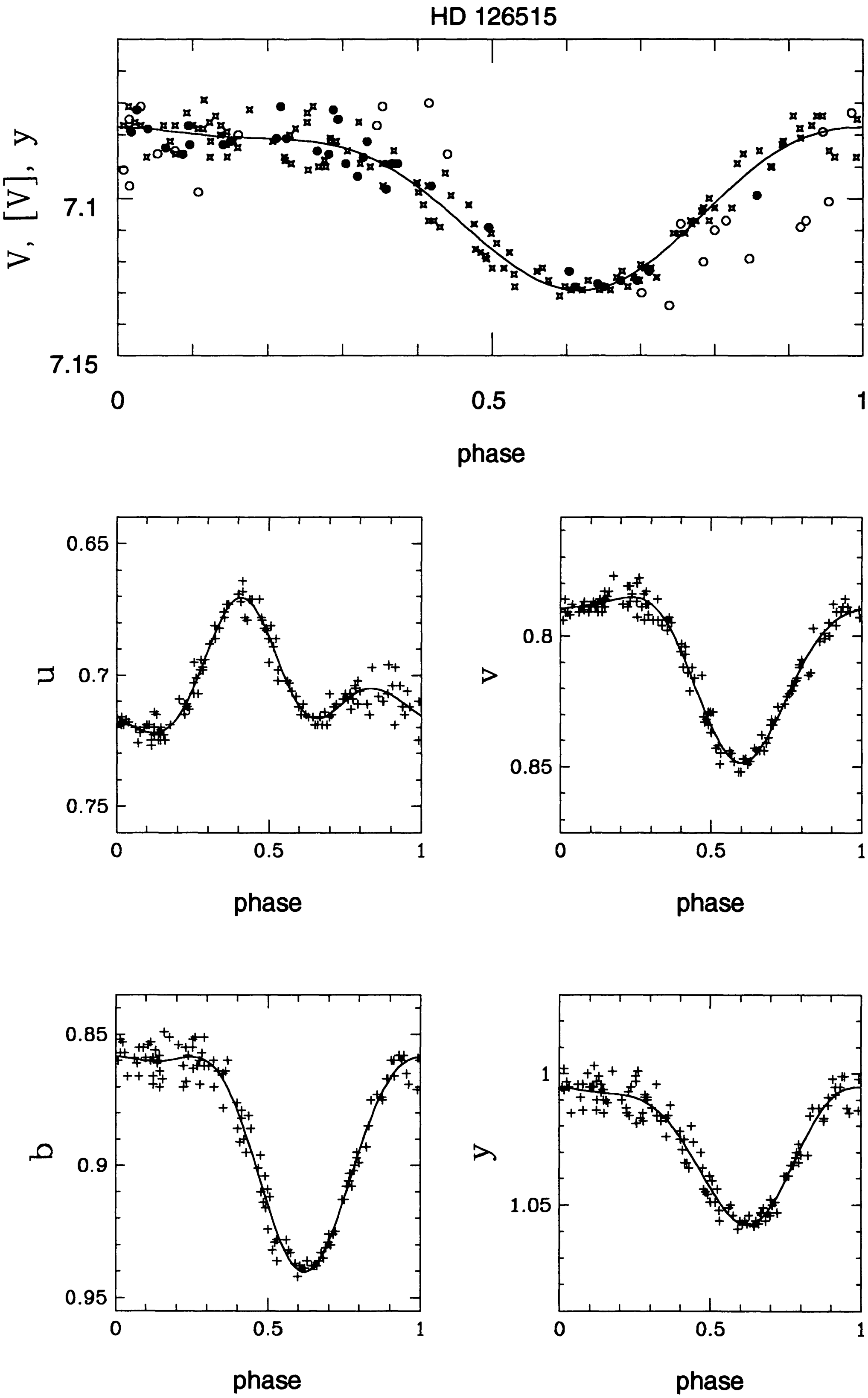

Fig. 6. Composite and *uvby* lightcurves of HD 126515, according to the ephemeris of Table 3. In the top panel, the fitted curve is a sinusoid with its first harmonic and the full dots represent the Geneva $[V]$ magnitudes, the stars our y data and the open circles the V data of Catalano & Leone (1990). The other, *uvby* curves are fitted by a sinusoid with its first two harmonics, which is quite necessary for the u curve (see text)

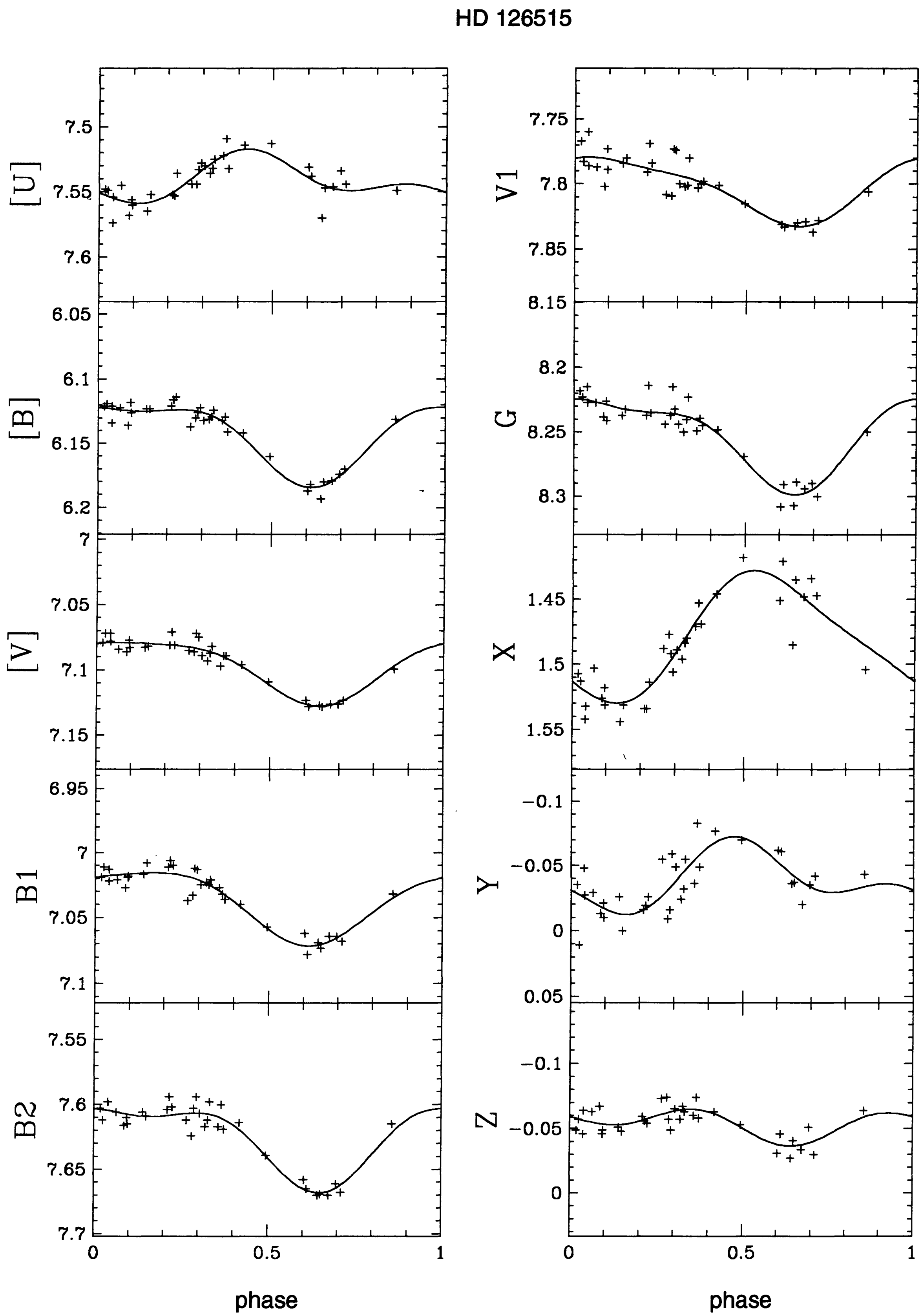

Fig. 7. Geneva lightcurves of HD 126515, according to the ephemeris of Table 3

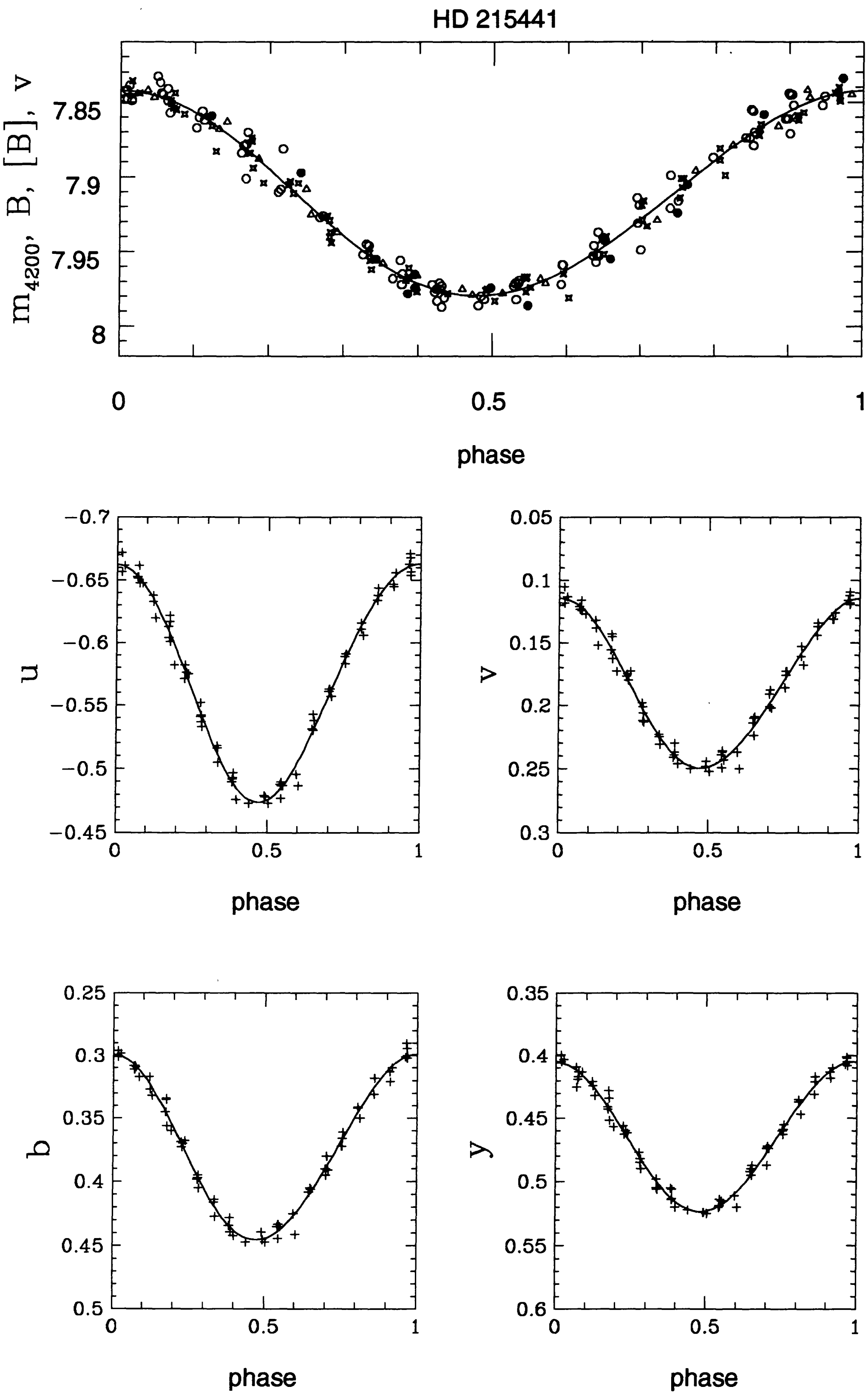

Fig. 8. Composite and *uvby* lightcurves of HD 215441, according to the ephemeris of Table 4. The fitted curves are sinusoids with their first harmonic. In the top panel, the full dots represent the Geneva [*V*] magnitudes, the stars our *y* data, the open circles the m_{4200} data of Jarzebowski (1960) and the open triangles the *B* data of Stepień (1968)

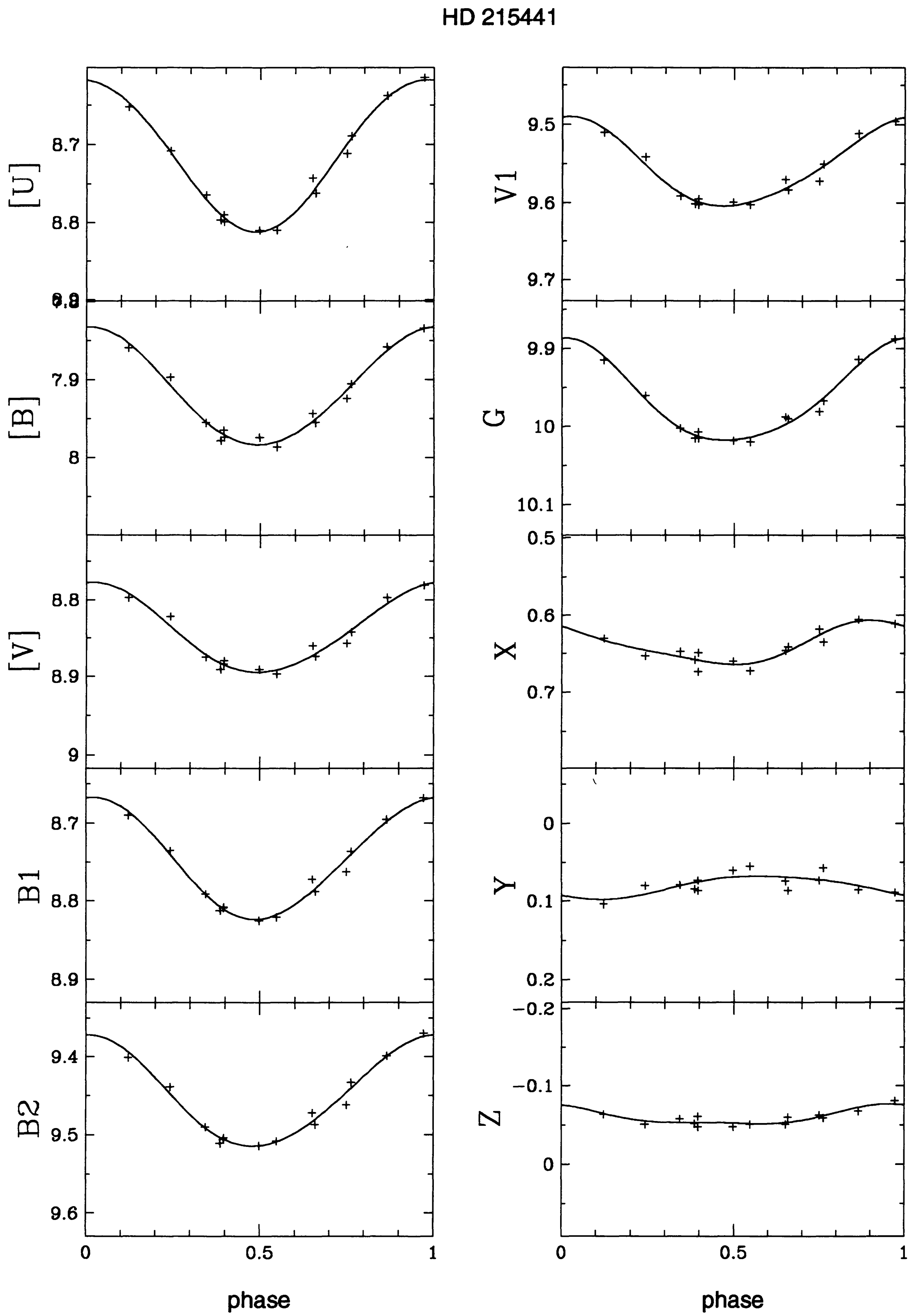

Fig. 9. Geneva lightcurves of HD 215441, according to the ephemeris of Table 4

Table 4. Ephemerides of the star HD 215441 and coefficients of the fitted lightcurves. The epoch of zero phase corresponds to maximum light intensity (therefore to minimum magnitude) in the composite $[B]+m_{4200}+B+v$ lightcurve (see text). See Table 1 for other comments

HD 215441					HJD(min. B mag.) = 2448733.714 + 9.487574 E ± 0.000030																	
	lightcurve parameters										correlations											
band	a_0	σ_{a_0}	a_1	σ_{a_1}	ϕ_1	σ_{ϕ_1}	a_2	σ_{a_2}	ϕ_2	σ_{ϕ_2}	a_0a_1	$a_0\phi_1$	a_0a_2	$a_0\phi_2$	$a_1\phi_1$	a_1a_2	$a_1\phi_2$	ϕ_1a_2	$\phi_1\phi_2$	$a_2\phi_2$	σ_{res}	N
m_{4200},B,[B],v	7.9119	5	.0683	7	3.20	1	.0025	7	2.08	29	0.01	-0.05	0.03	0.07	0.00	-0.05	0.02	0.01	-0.01	0.06	0.0072	192
u	-0.5715	7	.0943	11	3.26	1	.0046	11	1.03	23	0.04	-0.09	0.08	0.00	0.04	-0.01	-0.09	0.04	-0.04	0.03	0.0066	73
v	0.1831	7	.0672	10	3.21	1	.0034	10	2.04	30	0.05	-0.09	0.04	-0.07	0.05	-0.08	-0.04	-0.01	-0.06	-0.02	0.0063	
b	0.3735	6	.0729	9	3.23	1	.0032	9	2.21	28	0.05	-0.09	0.03	-0.08	0.04	-0.09	-0.02	-0.02	-0.06	-0.03	0.0055	
y	0.4646	6	.0592	8	3.23	1	.0010	8	2.11	88	0.05	-0.09	0.04	-0.07	0.04	-0.09	-0.03	-0.01	-0.06	-0.03	0.0052	
[U]	8.7110	26	.0973	36	3.22	3	.0043	37	6.23	78	-0.38	0.16	0.12	-0.20	-0.13	-0.15	-0.06	-0.13	-0.36	0.00	0.0087	14
[B]	7.9099	25	.0755	36	3.13	4	.0029	35	2.41	117	-0.38	0.13	-0.21	0.07	-0.13	0.10	0.11	-0.10	0.37	0.10	0.0085	
[V]	8.8384	25	.0585	36	3.09	6	.0035	34	2.24	101	-0.39	0.13	-0.20	0.06	-0.14	0.08	0.09	-0.16	0.37	0.12	0.0086	
B1	8.7452	23	.0777	34	3.13	4	.0039	31	1.47	87	-0.38	0.13	-0.19	-0.13	-0.13	-0.03	0.14	-0.38	0.13	-0.01	0.0080	
B2	9.4458	24	.0710	35	3.18	4	.0040	34	2.38	85	-0.38	0.15	-0.22	0.06	-0.13	0.09	0.13	-0.12	0.36	0.10	0.0083	
V1	9.5511	24	.0561	35	3.13	6	.0064	33	2.27	53	-0.39	0.13	-0.22	0.04	-0.13	0.09	0.12	-0.15	0.35	0.10	0.0083	
G	9.9600	21	.0652	30	3.14	4	.0085	30	2.79	32	-0.38	0.13	-0.17	0.15	-0.13	0.13	0.07	0.04	0.40	0.06	0.0071	
X	0.6376	27	.0270	37	3.54	14	.0060	36	4.99	63	-0.33	0.25	0.23	0.09	-0.14	0.09	-0.24	0.26	-0.14	0.07	0.0092	
Y	0.0810	33	.0151	49	5.63	28	.0022	43	4.60	217	0.36	0.16	0.18	0.17	0.04	0.17	0.06	-0.33	0.19	0.01	0.0112	
Z	-0.0609	16	.0118	22	3.38	19	.0041	21	3.82	54	-0.36	0.21	0.00	0.24	-0.14	0.21	-0.05	0.28	0.18	-0.09	0.0054	

4. Conclusion

We have analyzed original Geneva and *uvby* photometric data spanning about 20 years to refine the period of four classical Ap stars. Published observations were used as well for this purpose. The shapes of the lightcurves are given in a quantitative way, and we find no evidence of any secular change in their shape. However, the periods of the stars we have examined are rather long compared with the cases for which such a change has been suggested as due to precession, so that the idea of precessing Ap stars is probably not much endangered by this negative result. On the other hand, the stability of the shape of the lightcurves, suggested by the rather small residual scatter, confirms the oblique rotator model and leaves little room for secular phenomena like magnetic cycles.

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