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Long-term monitoring of active stars*,**

X. Photometry collected in 1994

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Abstract. As part of an extensive program focused on the global properties and evolution of active stars, high-precision $UBV(RI)_c$ and UBV photometry of 18 selected stars is presented. $UBV(RI)_c$ observations were collected at the European Southern Observatory over the intervals 21–28 September 1994 and 25 November–05 December 1994. Additional UBV photometry obtained late in 1994 by Catania Astrophysical Observatory Automatic Photoelectric Telescope is also presented. Significant evolution of the light curves, period variations and evidence for long-term variability of the global degree of spottedness are found. Some spectral classifications are revised and photometric parallaxes are compared, whenever possible, with the values measured by the Hipparcos satellite. These observations are finalized to the construction of an extended photometric database, which can give important clues on topics such as the stability of spotted areas, differential stellar rotation, solar-like activity cycles and the correlation between inhomogeneities at different atmospheric levels.

Key words. stars: activity – stars: late-type – stars: pre-main sequence – stars: variables: general – X–ray: stars

1. Introduction

The term *"stellar activity"* is usually referred to the ensemble of phenomena that are observed in the photospheres and outer atmospheres of fast-rotating stars with a sub-photospheric convective envelope. In analogy to the Sun, stellar activity is believed to have a magnetohydrodynamic origin. Photospheric inhomogeneities as cool starspots are one of the most typical features of stellar activity; their visibility on the stellar projected disk is modulated by stellar rotation, and produces periodic or quasi-periodic light variation typically in the 0.1–0.2 mag range (cf. Rodonò 1992 and references therein). In most cases multicolour photometry shows a reddening of the star at luminosity minimum (i.e. the light curve amplitude decreases at longer wavelengths), thus supporting the cool starspot hypothesis. However, anticorrelation of $U-B$ and $B-V$ colour indices compared to the V-band light modulation has been observed for some stars (see Cutispoto et al. 2001 and references therein).

The orbital/photometric periods of active stars span from less than one day to several weeks, and the photometric waves can undergo noticeable changes over time scales as short as few stellar rotations (cf. Figs. 12, 18 and 23 in Cutispoto 1995; Strassmeier et al. 1997). Hence, in order to investigate the physical characteristics and evolution of spotted areas and the time scale of activity cycles, active stars must be systematically observed. Such monitoring program was started at Catania Observatory in the early sixties, and it is now continuing on a selected sample of about 50 stars by using the 0.8-m Automatic Photoelectric Telescope (APT) at our mountain station on Mt. Etna and the 0.25-m "Phoenix" APT of Franklin & Marshall College at Washington Camp (AZ, USA). The 0.5-m and 1.0-m telescopes of the European Southern Observatory (ESO, La Silla, Chile) were also used for this program until December 1996. Our monitoring program aims at acquiring an adequately time-extended database, that is essential in order to investigate fundamental topics such as the evolution of spotted areas and spot lifetimes, photospheric differential rotation, solar-like activity cycles and the time and/or spatial correlation between inhomogeneities at different atmospheric levels (see, among others, Kürster et al. 1997; Catalano et al. 1996; Schmitt et al. 1998; Messina & Guinan 2002; Rodonò et al. 2000). This paper mainly reports on $UBV(RI)_c$ data we obtained by using the 0.5-m ESO telescope. Additional UBV data we obtained with the Catania APT for some of the

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* Based on data collected at the European Southern Observatory, La Silla, Chile.

** Tables 1, 2 and 4 and the complete data set 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/400/659
(Table 3 is also available at the CDS).

program stars are also presented. The paper is organized as follows: equipment details, observations and reduction procedures are given in Sect. 2, the results and the discussion on individual stars are presented in Sect. 3. Previous papers of this series will be quoted according to the order number of the paper (i.e. Cutispoto et al. 2001 will be referred to as PAP IX)

2. The observations

Most of the observations presented in this paper were obtained by using the 0.5-m ESO telescope. Additional data were obtained by the Catania APT. Here we describe the equipment used, the observation and reduction procedures. Details on the quality of data are also given.

2.1. Observations with the 0.5-m ESO telescope

The observations at ESO were carried out from 21 to 28 September 1994 (mean epoch = 1994.73) and from 25 November to 5 December 1994 (mean epoch = 1994.92). The 0.5-m ESO telescope, equipped with a single-channel photon-counting photometer, a thermoelectrically cooled Hamamatzu R-943/02 photomultiplier and standard ESO filters matching the $UBV(RI)_c$ system, was used. In order to attain accurate differential photometry, for each program star (v) a comparison (c) and a check (ck) star were also observed (see Table 1). Each star measurement consisted of 10−15 1−s integrations in each filter. A complete observation cycle consisted of sequential c–v–v–v–v–ck–c measurements. From these data, after sky subtraction, four v−c and one ck−c differential magnitudes were computed; the v−c values were then averaged to obtain one data point in each filter. The observations were corrected for atmospheric extinction and transformed into the standard $UBV(RI)_c$ system. The nightly atmospheric extinction coefficients were determined by observing two standard stars of very different spectral types in the 1−2.5 air mass range; their mean values over the whole periods are listed in Table 2. Comparing these coefficients with those obtained, with the same method and instrumentation, in March 1991 (cf. Table 2 in Cutispoto 1998a – PAP VII), in February 1992 (cf. Table 2 in Cutispoto 1998b – PAP VIII) and early and late in 1993 (cf. Table 2 in PAP IX), it seems that normal mean extinction values were re-established late in 1994. In fact, the strong extinction increase due to the eruption of Mt. Pinatubo observed since 1991 was not detectable anymore. The transformation coefficients were inferred by observing E−region standard stars (Menzies et al. 1989). The typical error of the differential photometry with the 0.5−m ESO telescope is of the order of ±0.005 mag, with somewhat larger values (up to ±0.01 mag) in the U-band due to the lower photon counting level. The standard deviations for the v−c (σ_v) and ck−c (σ_{ck}) mean differential V-band magnitudes obtained over N nights are presented in Table 1. For each program star, the brightest V magnitude and the corresponding colours are listed in Table 3. The V magnitudes and colours of the comparison and check stars were obtained via standard stars (Menzies et al. 1989, 1991) and are given in Table 4. Taking into account the accuracy of the standard stars data and the extinction and transformation errors, the typical accuracy of the absolute photometry in Tables 3 and 4 is of the order of ±0.01 mag, with somewhat larger values (up to ±0.02 mag) for the U−B.

2.2. Observations with the Catania APT

The 0.8-m Catania Observatory APT (APTCT) started operation late in 1992 (Rodonò et al. 2001). It feeds a single-channel charge-integration photometer equipped with an uncooled Hamamatzu R1414 SbCs photomultiplier and standard filters matching the UBV system. Each measurement consisted of 10−15 s integrations in each filter according to the magnitude of the target. A complete observation consisted of sequential ck–c–v–v–v–c–v–v–v–ck measurements. The sky background is measured at a fixed position near each star. From these data, after sky subtraction, six v−c and two ck−c differential magnitudes were computed; the v−c and ck−c values were finally averaged to obtain one data point in each filter. The observations were corrected for atmospheric extinction and transformed into the standard UBV system. The extinction and tranformation coefficients are quarterly determined from our *"standard-star nights"* data. The typical standard deviation for the averaged differential photometry is of the order of ±0.015, ±0.010 and ±0.007 mag for the U, B and V-band data, respectively.

3. Results

The present multicolour photometry has been used to investigate the light curve evolution and to search for photospheric solar-like activity cycles. For several stars we detected the variation of the photometric period compared to literature data. If a new period of photometric variability had to be computed, we performed a Fourier analysis and/or fitted sine waves to the VRI-band data and searched for the minimum χ^2 (see Cutispoto et al. 1995 for further details). We developed a method, hereafter referred to as Active Stars Colours (ASC) method, to infer the spectral classification from the observed colours. The ASC method was implemented taking into account the effects of stellar activity and the luminosity calibration of the HR diagram obtained from Hipparcos data (see Cutispoto et al. 1996; PAP VIII and PAP IX for further details). We used our $UBV(RI)_c$ photometry and, if available, the trigonometric distance (D_T) listed in the Hipparcos satellite output catalogue (Perryman et al. 1997) to infer or further constrain the spectral classification of our targets (see Table 3). For each star studied in this paper the photometric distance (d_{ph}) was computed from the adopted spectral classification and compared, whenever possible, to D_T (see Table 3). Due to the intrinsic dispersion of absolute magnitudes, errors in the photometric distances are of the order of 15−20%, with somewhat larger values for class IV sub-giants and class III giants.

The results for the individual stars are now discussed.

HD 1835 = BE Cet (D_T = $20.4^{+0.4}_{-0.4}$ pc) is a single (Duquennoy & Mayor 1991) bright solar-type star member of the Hyades group (Eggen 1960). It was photometrically and spectroscopically observed by several authors in the past (see the list of

Table 3. Brightest magnitude (V_m) and colours for the program stars measured at the given Epoch (1900.0+), period (P) of variability (days), spectral classification (Spectral Type) inferred by using the ASC method (see text), distance from the Hipparcos satellite database (D_T), photometric distance from the adopted spectral classification (d_{ph}) and V-band brightest magnitude ever observed (V_{max}).

Program Star	Epoch	V_m	$U-B$	$B-V$	$V-R$	$V-I$	P	Spectral Type	D_T	d_{ph}	V_{max}
BE Cet	94.92	6.38	0.22	0.66	0.36	0.69	7.655	G4 V	20.4	20.2	6.35
HD 7172	94.92	9.64	0.05	0.62	0.34	0.68	3.15	G2/3 V	>27	100	9.64
BI Cet	94.92	8.18	0.17	0.71	0.42	0.85	0.520	G6 V/IV + G6 V/IV	66	65	8.08
BC Phe	94.92	8.77	0.31	0.75	0.43	0.83	0.657	G7 V/IV + G3:V	118	118	8.69
BG Psc	94.92	8.68	0.18	0.68	0.38	0.78	7.60	G3 V/IV + G4 V/IV	44:	115	8.63
CC Eri	94.92	8.80	1.09	1.38	0.88	1.84	1.56145	K7 V + M3 V	11.5	11.5	8.70
BY Cet	94.92	9.58	0.29	0.79	0.47	0.94	2.60	G7 V + K5: V	>23	75	9.52
HD 18131	94.92	7.36	0.72	0.98	0.51	0.97		K1 IV + WD	104	96	7.32
ES Eri	94.92	10.65	0.25	0.75	0.44	0.91	4.7	G6: PMS + ?		310:	10.65
YY Men	94.92	8.04	0.70	1.07	0.59	1.16	9.5476	K1 III	292	219	7.93
UX Col	94.92	10.46	0.80	1.06	0.65	1.25	2.29	K3/5 PMS		120:	10.46
AB Dor	94.92	6.82	0.38	0.82	0.48	0.95	0.51423	K0 V	14.9	15	6.75
V1321 Ori	94.92	10.59	0.85	1.29	0.74	1.46	5.7	K3 wTTS		500:	10.50
V1355 Ori	94.92	9.12	0.57	0.95	0.54	1.06	3.82	K2 V/IV + G8:V	43:	100:	8.97
HY CMa	94.92	9.31	0.64	1.01	0.61	1.18	4.977	K3 V/IV + K1 V/IV	>59	176	9.14
V1358 Ori	94.92	7.91	0.06	0.57	0.33	0.64	1.16	F9 V	50	59	7.91
AU Mic	94.73	8.60	1.09	1.43	0.94	2.00	4.865	M1 Ve	9.9	7.6	8.59
FK Aqr	94.73	9.10	1.07	1.50	0.97	2.20	4.39	M1/2 Ve + M1/2 Ve	8.6	8.1	8.98

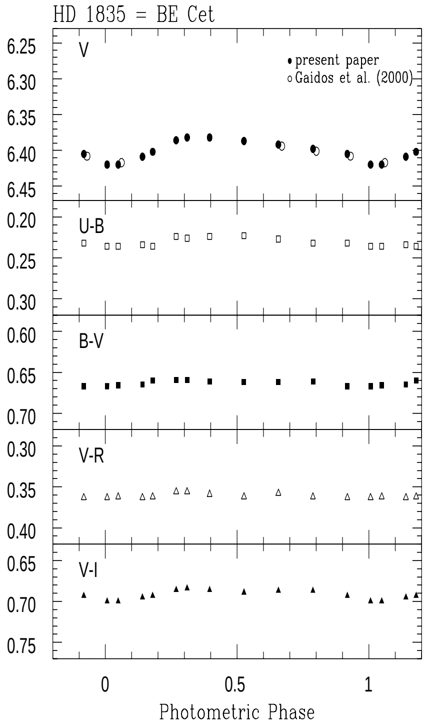

Fig. 1. HD 1835 = BE Cet V-band and colour light curves for the mean epoch 1994.92; phases are reckoned from the photometric ephemeris HJD = 2449681.5 + 7.655 · E.

references in the SIMBAD database). The observations we obtained at mean epoch 1994.92 are shown in Fig. 1; the 7.655 d photometric period (Chugainov 1980) was used for phase computation. Low-amplitude V-band variability is detected. The small colour variations, more evident for the $V-I$ index, are almost in phase with the V-band modulation. Figure 1 also includes Strömgren y-band observations obtained by Gaidos et al. (2000) over the same interval; a shift of 0.005 mag was applied to such data to match our photometric system. The mean colours of HD 1835 fit fairly well those of a G4V star (d_{ph} = 20.2 pc), in good agreement with both the spectroscopic classification by Houk & Smith-Moore (1988) and the trigonometric parallax. The $v \sin i$ value of 6 km s^{-1} reported by Montes et al. (1999) allows us to compute a mimimum radius of about 0.91 $R_\odot$, that implies "i" ~ 90 degrees. A possible chromospheric activity cycle of about 9.1 years with a secondary period longer than 25 years was reported by Baliunas et al. (1995). In a recent study of young solar analogues, Messina & Guinan (2002) have determined a starspot cycle of 6.7 years and no evidence for longer-term trends. Figure 2 shows the collection of all the available photometric data of HD 1835; this plot also includes unpublished photometry kindly provided by Dr. G.W. Lockwood. The amplitude of the V-band light curve has never been larger than 0.06 mag, indicating a relatively low level of activity. Finally, if the optical companion BD-13 60B reported by Gaidos (1998) is physically linked to the primary star, then its spectral type should be M3:V.

HD 7172 = EXO 010919.0-2613.5 (D_T > 27 pc) is a serendipitous X–ray source discovered by EXOSAT. It was studied by Cutispoto et al. (1996), Tagliaferri et al. (1994) and in PAP IX. Our observations, at mean epoch 1994.92, are shown in Fig. 3, where the photometric period of 3.15 d (PAP IX) was used for phase computation. The low-amplitude V-band light curve is at least double-peaked and the small colour variations are almost in phase with the V-band modulation. Significant modifications of the light curve shape compared to previous observations are also evident. Figure 4 shows a collection of the available photometric data of HD 7172. Low amplitude variability, similar to that observed for HD 1835, is present.

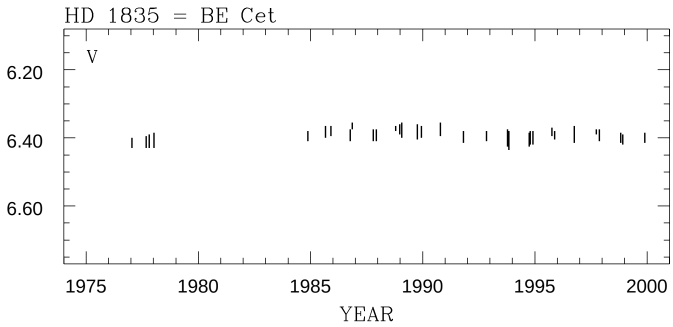

Fig. 2. HD 1835 = BE Cet $V-$band long-term variability; vertical bars indicate the peak-to-peak amplitude of seasonal light curves.

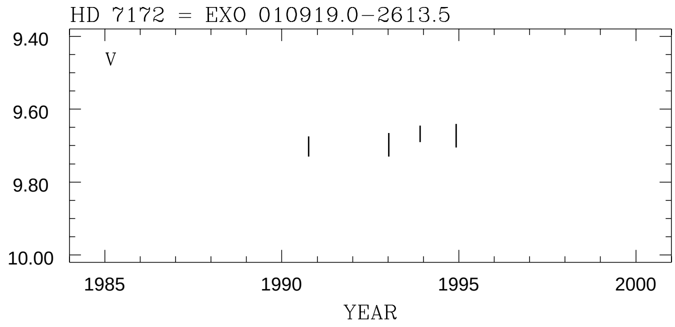

Fig. 4. HD 7172 V-band long-term variability; vertical bars indicate the peak-to-peak amplitude of seasonal light curves.

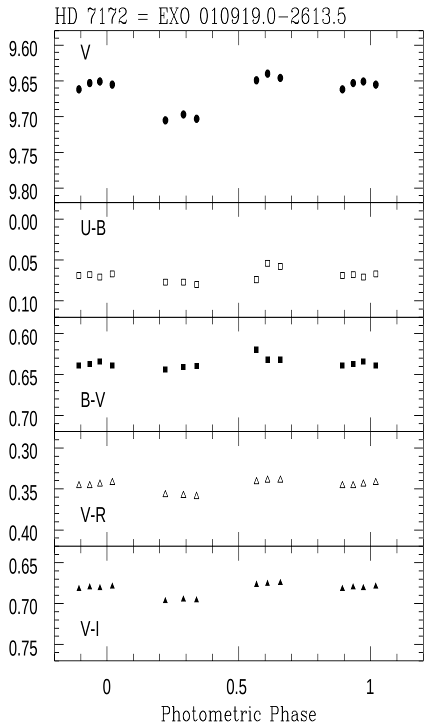

Fig. 3. HD 7172 V-band and colour light curves for the mean epoch 1994.92; phases are reckoned from the photometric ephemeris HJD = 2449681.5 + 3.15 · E.

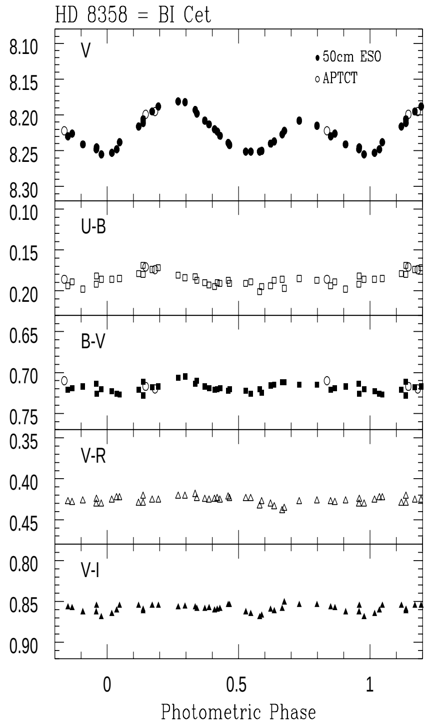

Fig. 5. HD 8358 = BI Cet V-band and colour light curves for the mean epoch 1994.92; phases are reckoned from the photometric ephemeris HJD = 2449577.5 + 0.520 · E.

However, in this case it is not clear if such small variations are due to a low level activity or rather to a small value of the inclination angle "i", which is ∼57° or ∼22° if we assume the G2/3V classification or the alternative G1/2IV classification, respectively (see PAP IX for details).

HD 8358 = BI Cet ($D_{\rm T}$ = 66^{+4}_{-4} pc) is a very active and rather well studied RS CVn-type system (see the list of reference in the SIMBAD database). Our observations, at mean epoch 1994.92, are shown in Fig. 5. The data are folded by using a newly determined 0.520±0.002 d photometric period, which is equal, within the errors, to the value inferred early in 1993 (PAP IX). The light curve is double-peaked, an usual pattern for this star since late 1984 (see PAP IX and references therein). Low amplitude colour variations, in phase with the V-band modulation, are also observed. Figure 5 includes a few data obtained over the same time interval by the APTCT; further observations of BI Cet were obtained by the APTCT late in August at mean epoch 1994.68 (see Table 1). A collection of the available photometry of BI Cet is shown in Fig. 6. The maximum luminosity is getting brighter after the cycle mimimum, late in 1989, and it is close to the value observed late in 1992. We found a zero point error in the APTCT data of late 1993 (Fig. 5 in PAP IX) due to a faint optical companion (IDS 01181+0003 B) of the comparison star HD 8405. Such error has been corrected in Fig. 6.

HD 8435 = BC Phe ($D_{\rm T}$ = 118^{+15}_{-12} pc) is a SB2 system with an orbital period of 0.657 d (Balona 1987). It has been studied by several authors in the past (see the list of reference in the SIMBAD database). Our observations, at mean epoch 1994.92, are shown in Fig. 7. The data are folded by using the 0.657 d orbital period, which is about 0.008 d longer than the photometric periods observed late in 1989 and late in 1990

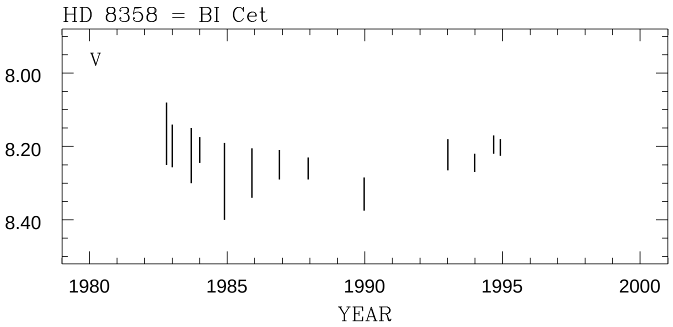

Fig. 6. HD 8358 = BI Cet V-band long-term variability; vertical bars indicate the peak-to-peak amplitude of seasonal light curves.

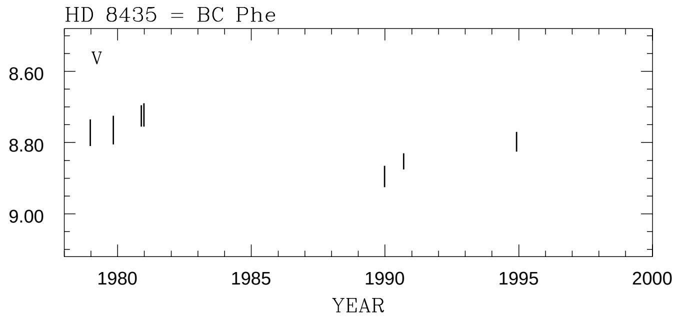

Fig. 8. HD 8435 = BC Phe V-band long-term variability; vertical bars indicate the peak-to-peak amplitude of seasonal light curves.

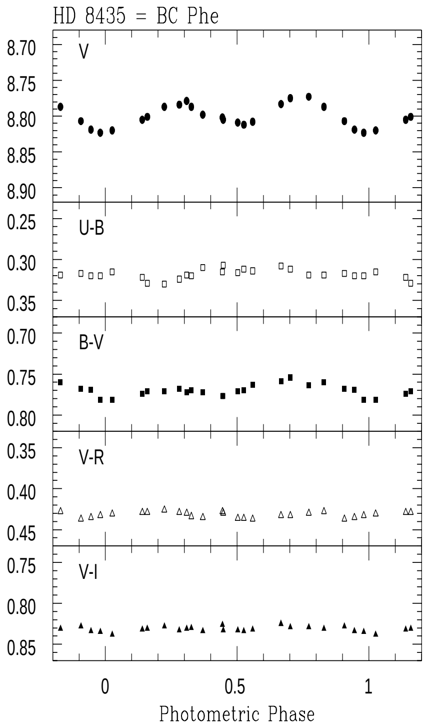

Fig. 7. HD 8435 = BC Phe V-band and colour light curves for the mean epoch 1994.92; phases are reckoned from the photometric ephemeris HJD = 2449681.5 + 0.657 · E.

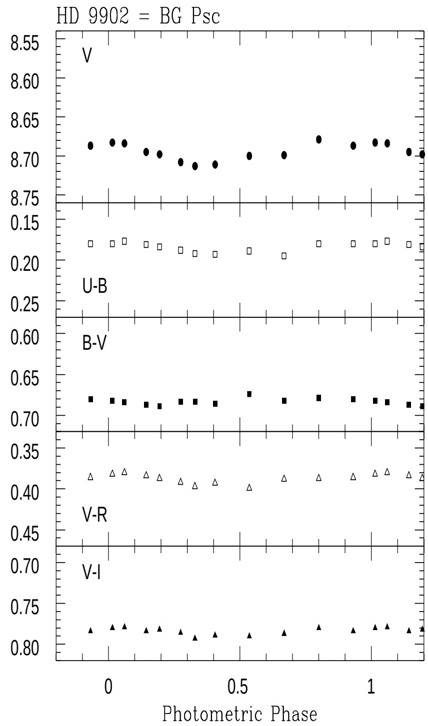

Fig. 9. HD 9902 = BG Psc V-band and colour light curves for the mean epoch 1994.92; phases are reckoned from the photometric ephemeris HJD = 2449681.5 + 7.60 · E.

(Cutispoto 1995 – PAP IV, Cutispoto & Leto 1997 – PAP VI). The light curve is double-peaked, a pattern also observed late in 1990 (PAP VI). Low amplitude colour variations, in phase with the V-band modulation, are observed. A collection of the available photometry of BC Phe is shown in Fig. 8. The data are rather sparse, but a variation of the global degree of spottedness is evident. The spectral classification, already investigated in PAP IV, deserves further discussion. BC Phe is an SB2 system (Balona 1987), although the magnitude difference (ΔV) between the two stars is not known. The Hipparcos parallax rules out luminosity classes III and V for the primary component. The classification proposed in PAP IV implies $\Delta V > 2.5$ mag, which seems unlikely. Assuming ΔV of 2.0, 1.5 and 1.0 mag, the spectral classifications that fit both D_T and the observed colours are G6 V/IV + G8:V ($M_{Va} \simeq 3.5$, $M_{Vb} \simeq 5.5$), G6/7 V/IV + G5/6:V ($M_{Va} \simeq 3.6$, $M_{Vb} \simeq 5.1$) and G7 V/IV + G3:V ($M_{Va} \simeq 3.7$, $M_{Vb} \simeq 4.7$), respectively. We adopt the latest classification, but further high-resolution spectroscopy is needed for a more detailed study of BC Phe.

HD 9902 = BG Psc = EXO 013425+2026.8 ($D_T = 44^{+41}_{-14}$ pc) is an SB2 RS CVn-type system already studied by our group (see Cutispoto et al. 2000 and references therein). Our observations, at mean epoch 1994.92, are shown in Fig. 9. These data are folded by using a 7.60 d photometric period (Cutispoto et al. 2000). The low amplitude light curve is single-peaked. Small colour variations, almost in phase with the V-band modulation, are also observed. A collection of the available photometry of BG Psc is presented in Fig. 10. These data show an evident, though low amplitude, variation of the global degree of spottedness. HD 9902 was also studied by Strassmeier et al. (2000), who inferred a photometric period of 7.41 d (that falls in the range observed by Cutispoto et al. 2000), a strong Li I 6708 Å line (in agreement

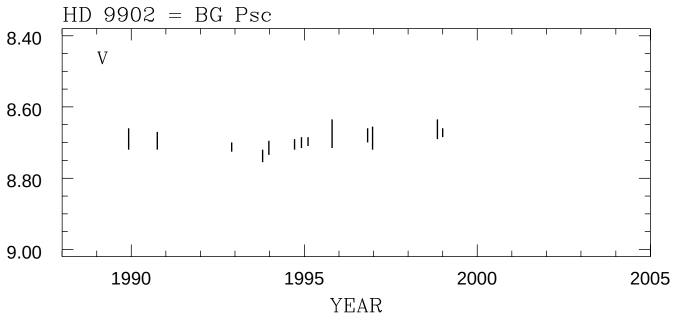

Fig. 10. HD 9902 = BG Psc V-band long-term variability; vertical bars indicate the peak-to-peak amplitude of seasonal light curves.

with the results of Tagliaferri et al. 1994 which, however, were able to separate the two components), and strong Ca II H&K emission lines. However, the spectral classification listed by Strassmeier et al. (2000) does fit neither the observed colours nor the minimum radii that can be computed from the $v \sin i$ of the two components. Hence, we adopt the spectral classification proposed by Cutispoto et al. (2000) and note that the coolest component, which is probably an SB, rotates faster than the hotter component.

HD 16157 = CC Eri ($D_{\rm T} = 11.5^{+0.1}_{-0.1}$ pc) is a BY Dra-type variable that has been studied at different wavelengths by several authors (see the list of references in the SIMBAD database). The data we obtained, at mean epoch 1994.92, are shown in Fig. 11, where phases are reckoned from the 1.56145 d orbital period (Evans 1959). The V-band light curve has a primary maximum at phase ≃0.7 and a secondary less pronounced maximum at phase ≃0.17. The $U-B$ and $B-V$ colour curves are almost flat and weakly correlated with the V-band variations. The $V-R$ and $V-I$ colour indices appear to be correlated, more clearly the $V-I$, with the V-band variations. It is interesting to note that about one year earlier (cf. Fig. 6 in PAP IX) the $U-B$ colour index was clearly anticorrelated with the V-band light curve. Although this kind of variation remains to be explained, different levels of micro-flaring activity could account for the observed behaviour. The collection of the available photometry of CC Eri is presented in Fig. 12. The global degree of spottedness has remained rather stable during the last two years after the maximum luminosity observed early in 1990. The K7 V + M3 V ($d_{\rm ph}$ = 11.5 pc) classification was discussed in PAP VIII.

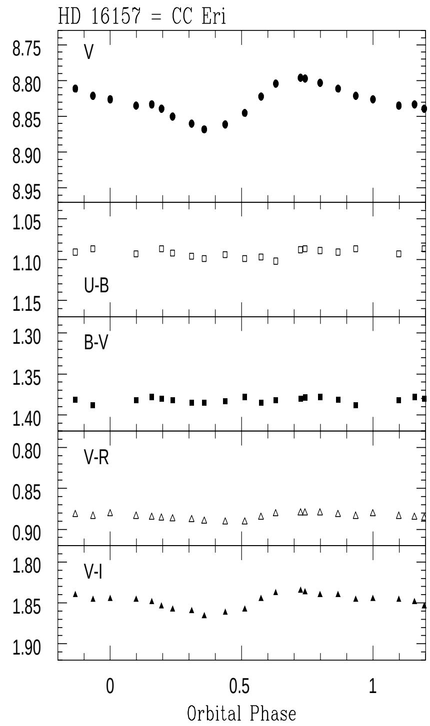

Fig. 11. HD 16157 = CC Eri V-band and colour light curves for the mean epoch 1994.92; phases are reckoned from the spectroscopic ephemeris HJD = 2449681.5 + 1.56145 · E.

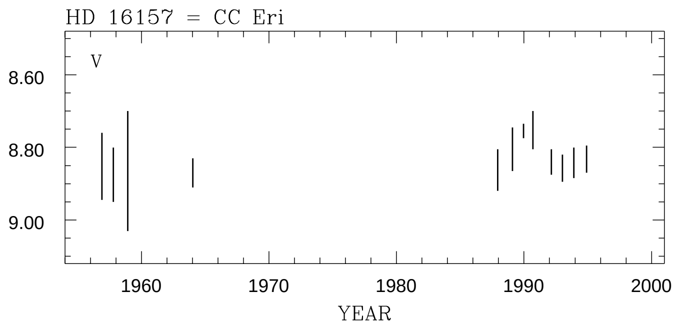

Fig. 12. HD 16157 = CC Eri V-band long-term variability; vertical bars indicate the peak-to-peak amplitude of seasonal light curves.

SAO 130113 = BY Cet = EXO 024453-0024.9 ($D_{\rm T}$ > 23 pc) is an SB2 system detected by the *Einstein* (Fleming et al. 1989) and EXOSAT (Giommi et al. 1991) satellites. Cutispoto et al. (1996) discovered optical variability with a period of 2.62 d; Tagliaferri et al. (1994) determined Li abundance and X–ray luminosity. An orbital period of 2.634 d was found by Duquennoy (private communication) and Baker et al. (1994). Here we present (Fig. 13) the observations carried out at mean epoch 1994.92, which were folded by using the 2.60 d photometric period computed in PAP IX. These data confirm that both the shape and amplitude of the light curve and the luminosity at light maximum are strongly variable. This is even more clear by looking at the collection of the available photometric data of SAO 130113 presented in Fig. 14. The G7 V + K5: V ($d_{\rm ph}$ = 75 pc) spectral classification is from Cutispoto et al. (1996).

HD 18131 ($D_H = 104^{+16}_{-12}$ pc) is a binary system containing a WD and an evolved K-type star (Burleigh et al. 1997; Vennes et al. 1998). The X–ray and EUV emission is most likely to be due to the WD component (see also Osten & Saar 1998), although moderate Ca II H&K emission is present in the spectra collected by Cutispoto et al. (1999) and by Strassmeier et al. (2000). Barstow et al. (2001) were not able to separate the two components and inferred an upper limit of about 19 years for the orbital period. Optical variability with an amplitude of 0.045 mag in the Strömgren y-band and a period longer than 40 d are reported by Strassmeier et al. (2000). A variability of just 0.007 mag results from our V-band observations over a time-scale of six days. However, the mean

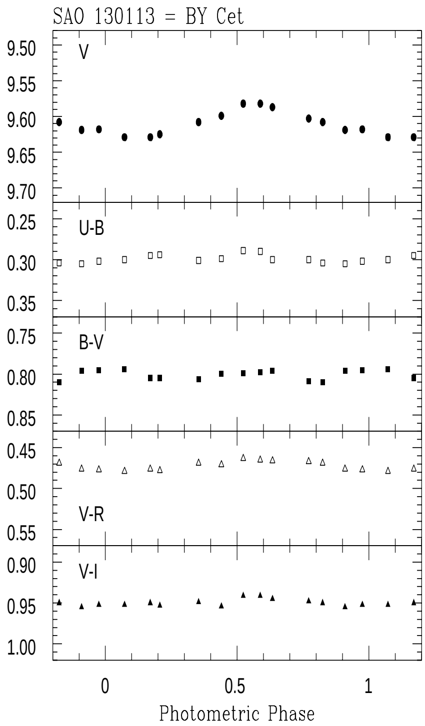

Fig. 13. SAO 130113 = BY Cet V-band and colour light curves for the mean epoch 1994.92; phases are reckoned from the photometric ephemeris HJD = 2449681.5 + 2.60 · E.

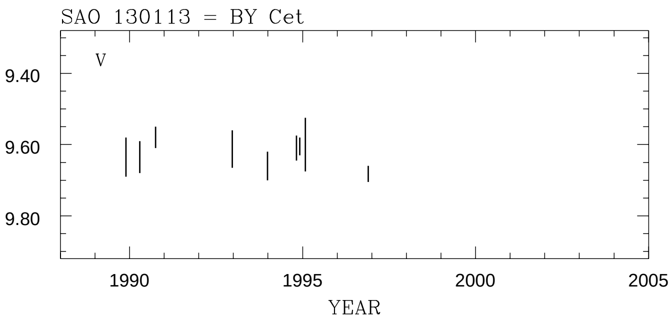

Fig. 14. SAO 130113 = BY Cet V-band long-term variability; vertical bars indicate the peak-to-peak amplitude of seasonal light curves.

V-band luminosity is 0.04 mag fainter than the value observed late in 1993 (Cutispoto et al. 1999), confirming the presence of low-amplitude long-term optical variability. The spectral classification is from Cutispoto et al. (1999).

1E 0315.7-1955 = ES Eri is an X–ray source serendipitously detected by the *Einstein* satellite (Fleming et al. 1989; Stocke et al. 1991). It has been classified as a K5 RS CVn-type candidate by Fleming et al. (1989) and as a PMS binary by Favata et al. (1995) and by Cutispoto & Tagliaferri (1996), who discovered the optical variability. Here we present (Fig. 15) our observations at mean epoch 1994.92, folded by using the 4.7 d photometric period computed by Cutispoto & Tagliaferri (1996). The light curve has a small secondary maximum, which results particularly evident in the $U-B$ colour curve. The other colours show smaller amplitudes variation in phase

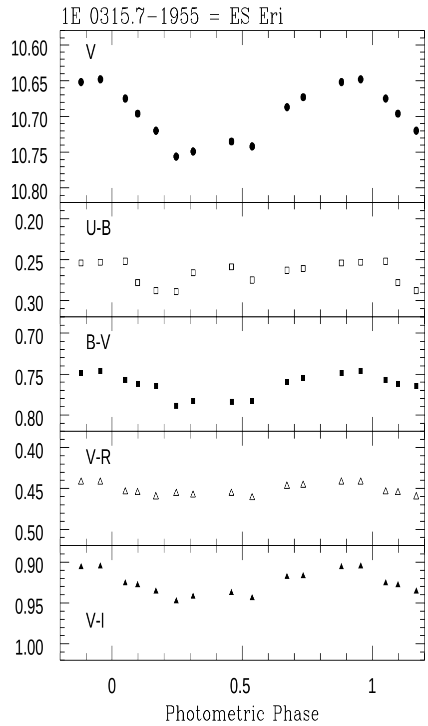

Fig. 15. 1E 0315.7-1955 = ES Eri V-band and colour light curves for the mean epoch 1994.92; phases are reckoned from the photometric ephemeris HJD = 2449681.5 + 4.7 · E.

with the V-band modulation. The mean colours are not consistent with the K5 spectral classification proposed by Stocke et al. (1991) and cannot be fitted with those of any "*normal*" star. However, the best agreement is obtained by considering a middle G-type star. The $v \sin i$ values of 23 km s^{-1} and of 33 km s^{-1} were inferred by Fleming et al. (1989) and by Favata et al. (1995), respectively. From such values an average minimum stellar radius of about 2.6 $R_\odot$ is obtained, which corresponds to the radius of a G5-G7 class IV stars according to Straižys & Kuriliene (1981). Hence, we infer a minimum photometric distance of about 310 pc.

HD 32918 = YY Men (D_H = 292^{+63}_{-45} pc) is an active FK Com-type star. Some flares detected for this star at optical (Cutispoto et al. 1992) and radio (Bunton et al. 1989) wavelengths, are among the most intense and longest duration events ever recorded for any class of active stars. The data we obtained, at mean epoch 1994.92, are shown in Fig. 16, where phases are reckoned from the 9.5476 d photometric period computed by Collier (1982). The strongly asymmetric V-band light curve is single-peaked and colour variations, well-correlated with the V-band modulation, show the star to be redder at light minimum, although a secondary minimum seems to be present. The maximum luminosity is about 0.11 mag fainter than the brightest values observed to date, as can be inferred from Fig. 17, where a collection of the available photometric data of YY Men is presented. It seems that after the maximum attained late in 1990, the luminosity of YY Men is decreasing toward the faintest values observed late in 1978 and late in 1979. From the data presented in Fig. 17 we can roughly

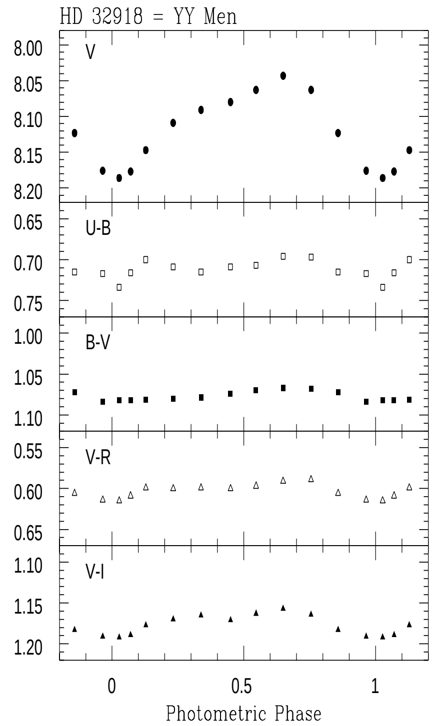

Fig. 16. HD 32918 = YY Men V-band and colour light curves for the mean epoch 1994.92; phases are reckoned from the photometric ephemeris HJD = 2449681.5 + 9.5476 · E.

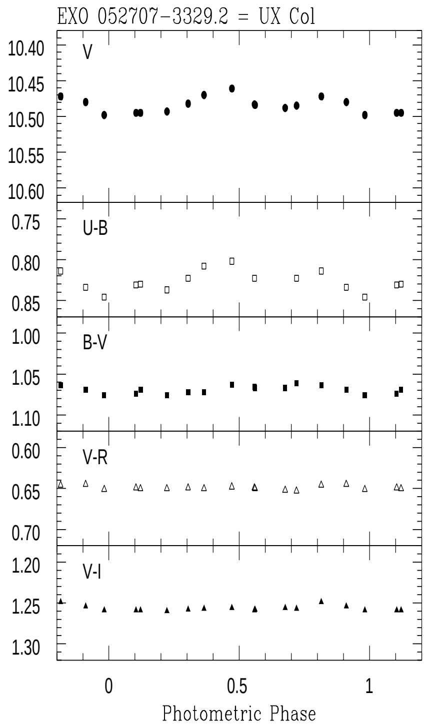

Fig. 18. EXO 052707-3329.2 = UX Col V-band and colour light curves for the mean epoch 1994.92; phases are reckoned from the photometric ephemeris HJD = 2449681.5 + 2.21 · E.

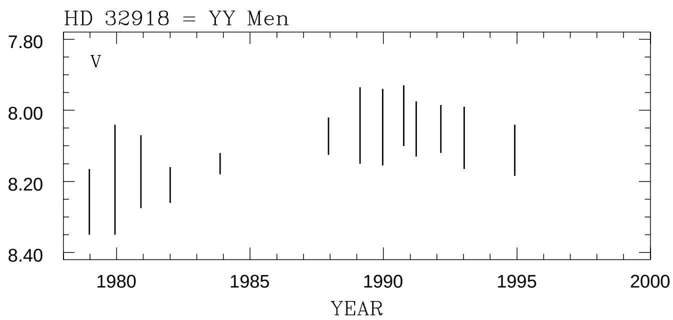

Fig. 17. HD 32918 = YY Men V-band long-term variability; vertical bars indicate the peak-to-peak amplitude of seasonal light curves.

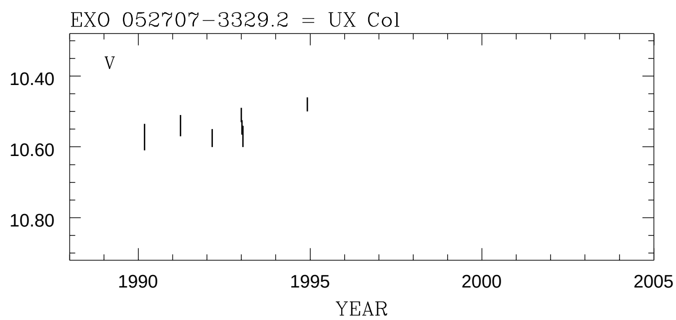

Fig. 19. EXO 052707-3329.2 = UX Col V-band long-term variability; vertical bars indicate the peak-to-peak amplitude of seasonal light curves.

estimate a possible activity cycle of at least 20 years. The K1 III ($d_{\rm ph}$ = 219 pc) classification was discussed in PAP VIII.

EXO 052707-3329.2 = UX Col is a serendipitous X–ray source discovered by EXOSAT and studied by Tagliaferri et al. (1994), who found high Li abundance, and by Cutispoto et al. (1996), who discovered optical variability with a 2.22 d period. Our observations are shown in Fig. 18, where phases are reckoned from the newly determined 2.29 ± 0.04 d photometric period. The low amplitude light curve is double-peaked and colour variations, more clear for the $U-B$ index, appear in phase with the V-band modulation. Apart from the noticeable evolution of the light curve shape (cf. PAP IX and references therein) the present data show the star at the maximum luminosity ever observed, as clearly seen from the collection of the available photometry of UX Col presented in Fig. 19. A K3/5 PMS classification was inferred in PAP VIII. From the $v \sin i$ of 40 km s^{-1} computed by Tagliaferri et al. (1994) and from the photometric periods observed so far, a mimimum radius of the order of 1.8 $R_\odot$ results. This corresponds to a K3/5 PMS star about 2 mag brighter than a MS star with the same colours and leads to compute a mimimum photometric distance of about 120 pc.

HD 36705 = AB Dor (D_H = $14.9^{+.2}_{-.1}$ pc) is one of the most studied active stars, as shown by the large number of papers listed in the SIMBAD database. The observations we obtained, at mean epoch 1994.92, are plotted in Fig. 20, where phases are reckoned from the 0.51423 d photometric period computed by Pakull (1981). The light curve is single-peaked and the low amplitude colours variability results in phase with the V-band modulation. These data contribute to study the long-term brightness evolution of AB Dor (cf. Fig. 19 in PAP IX).

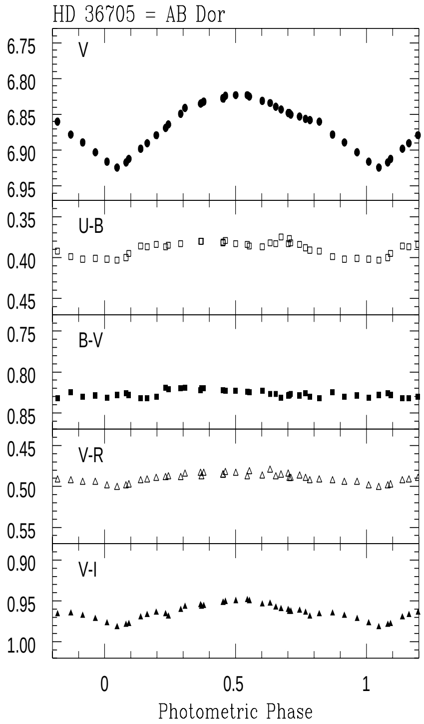

Fig. 20. HD 36705 = AB Dor V-band and colour light curves for the mean epoch 1994.92; phases are reckoned from the photometric ephemeris HJD = 2449681.5 + 0.51423 · E.

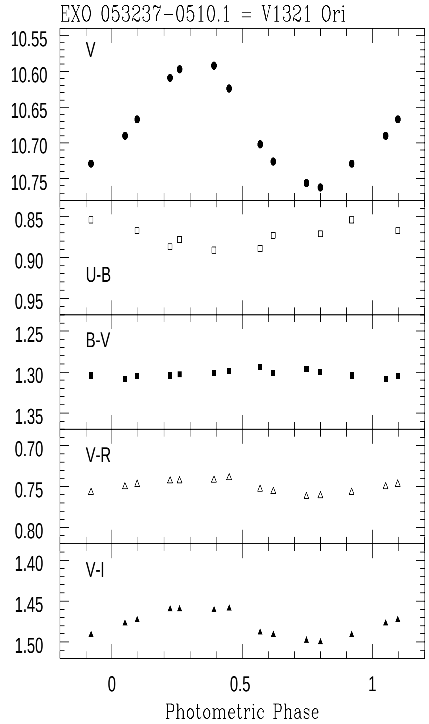

Fig. 21. EXO 053237-0510.1 = V1321 Ori V-band and colour light curves for the mean epoch 1994.92; phases are reckoned from the photometric ephemeris HJD = 2449681.5 + 5.7 · E.

The K0 V (d_{ph} = 15 pc) classification has been discussed in PAP VIII.

EXO 053237-0510.1 = P 1724 = V1321 Ori is a serendipitous X–ray source that has been also studied at optical wavelengths (see the list of references in the SIMBAD database). It has been classified by Preibisch et al. (1995) as a K3 *weak-line* TTS belonging to the Orion complex (see also discussion in PAP VIII). Our observations at mean epoch 1994.92 are presented in Fig. 21, where phases have been computed by using the 5.7 d photometric period given in PAP IX. The V-band light curve is single-peaked and its amplitude is almost equal to the amplitude observed early in 1993 (see Tables 1, 3 and Fig. 20 in PAP IX). Clear colour variations are seen. In particular, the $V-R$ and $V-I$ colours vary in phase with the V-band modulation and present amplitudes and mean values similar to those observed early in 1993. On the other hand, the $B-V$ shows almost no variations and its value is almost equal to the maximum value observed early in 1993. Finally, the $U-B$ curve is clearly anticorrelated with the V-band modulation; it does not show any secondary maximum, as seen early in 1993. The present observations were obtained no more than one year before a strong increase of the global degree of photospheric spottedness occurred, as inferred from the collection of the available photometry presented in Fig. 22.

HD 291095 = V1355 Ori (D_H = 43^{+90}_{-20} pc) is a SB1 system detected during the ROSAT WFC all-sky survey (Pounds et al. 1993) that was lately found to be a variable star by Cutispoto et al. (1995). It was also studied by

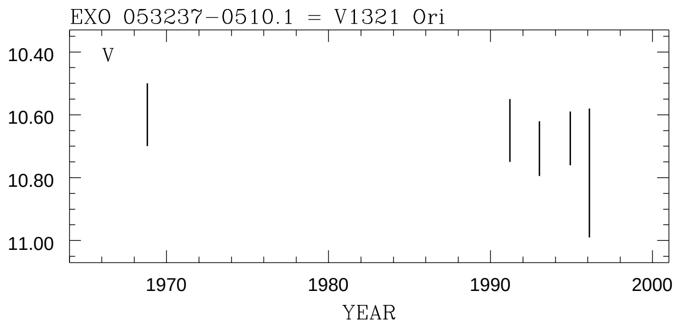

Fig. 22. EXO 053237-0510.1 = V1321 Ori V-band long-term variability; vertical bars indicate the peak-to-peak amplitude of seasonal light curves.

Osten & Saar (1998) and by Strassmeier (2000), the latter computed an orbital period of 3.87192 d and investigated the physical parameters. Our observations at mean epoch 1994.92 are presented in Fig. 23. Phases are reckoned from the 3.82 d photometric period (Cutispoto et al. 1995). The light curve is single-peaked and clear colour variations in phase with the V-band modulation are present. In particular, the $U-B$ and $B-V$ colours show, from phase 0.1 to phase 0.4, an almost flat maximum. As inferred from the collection of the available photometric data presented in Fig. 24. V1355 Ori presents a rather constant global degree of spottedness, while the spot distribution undergoes a rather pronounced variability. Further observations may possibly show evidence of an activity cycle, that from the data in Fig. 24 seems to be of the order of 4 years. The spectral classification has been discussed by Osten & Saar (1998), Cutispoto et al. (1999) and Strassmeier (2000).

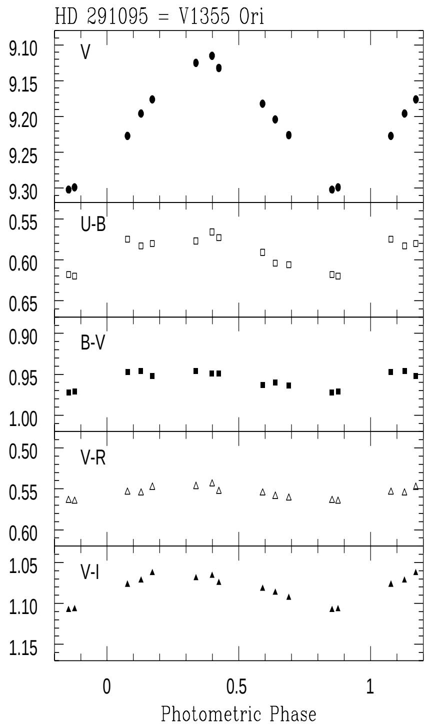

Fig. 23. HD 291095 = V1355 Ori V-band and colour light curves for the mean epoch 1994.92; phases are reckoned from the photometric ephemeris HJD = 2449681.5 + 3.82 · E.

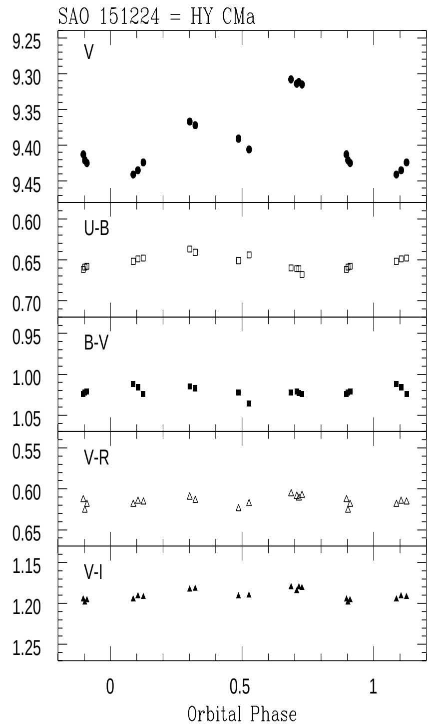

Fig. 25. SAO 151224 = HY CMa V-band and colour light curves for the mean epoch 1994.92; phases are reckoned from the orbital ephemeris HJD = 2449314.93 + 4.977 · E.

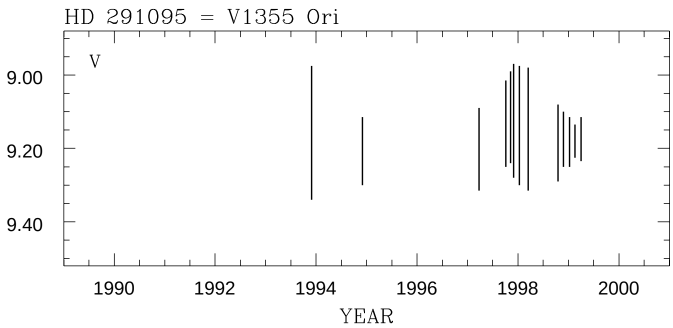

Fig. 24. HD 291095 = V1355 Ori V-band long-term variability; vertical bars indicate the peak-to-peak amplitude of seasonal light curves.

The trigonometric distance measured by Hipparcos is affected by a large error. Cutispoto et al. (1999) inferred a K2 V/IV + G8:V classification that fits such distance, as well as the observed colours and the spectral signatures. A similar classification for the primary component, but with luminosity class IV, and a secondary component in the G-M range has been obtained by Strassmeier (2000).

SAO 151224 = HY CMa (D_H > 59 pc) it a SB2 system detected during the ROSAT WFC all-sky survey (Pounds et al. 1993) that was lately found to be an eclipsing binary by Cutispoto et al. (1995). It has been also studied by Osten & Saar (1998), Cutispoto et al. (1999) and Strassmeier et al. (2000). Our observations are presented in Fig. 25, where phases are reckoned from the 4.977 d orbital period inferred by Cutispoto et al. (1995). No primary eclipses are apparent. It is not clear if the light curve is double-peaked or if its structure around phase 0.5 is due to the secondary eclipse. The colour variations are weak and appear to be in phase with the V-band modulation. The trigonometric distance measured by Hipparcos is affected by a very large error. Cutispoto et al. (1999) inferred a K3 V/IV + K1 V/IV spectral classification that fits both the observed colours and spectral signatures.

HD 43989 = V1358 Ori (D_H = 50^{+2}_{-3} pc) is a solar-type fast rotating single star detected during the ROSAT WFC all-sky survey (Pounds et al. 1993) that was lately found to be a variable star by Cutispoto et al. (1995). It has been also studied by Osten & Saar (1998), Cutispoto et al. (1999) and Strassmeier et al. (2000). Further photometry has been obtained by Strassmeier et al. (1999). According to Montes et al. (2001), V1358 Ori is a member of the Pleiades moving group (age 20-150 Myr). Our observations at mean epoch 1994.92 are presented in Fig. 26. Phases are reckoned from a new 1.16 ± 0.01 d photometric period, which results very close to the period inferred by Cutispoto et al. (1999). The light curve is double-peaked and the weak colour variations are in phase with the V-band modulation.

HD 197481 = AU Mic (D_H = $9.9^{+.2}_{-.1}$ pc) is a nearby flare star, and also a BY Dra-type variable, that has been studied by several authors in recent years (see the list of references in the SIMBAD database). The high level of activity and variability, possibly due to flaring episodes on several time scales, is consistent with highly variable behaviour in the UV (Quin et al. 1993) and X–ray (Pallavicini et al. 1990; Schmitt et al. 1990) spectral domains. Our observations at mean epoch

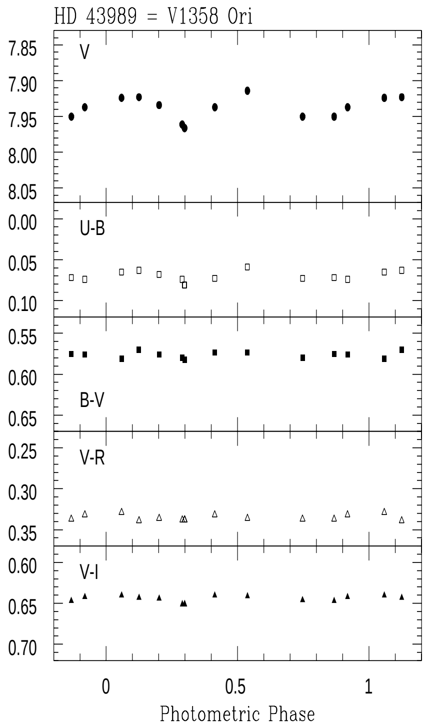

Fig. 26. HD 43989 = V1358 Ori V-band and colour light curves for the mean epoch 1994.92; phases are reckoned from the photometric ephemeris HJD = 2449681.5 + 1.16 · E.

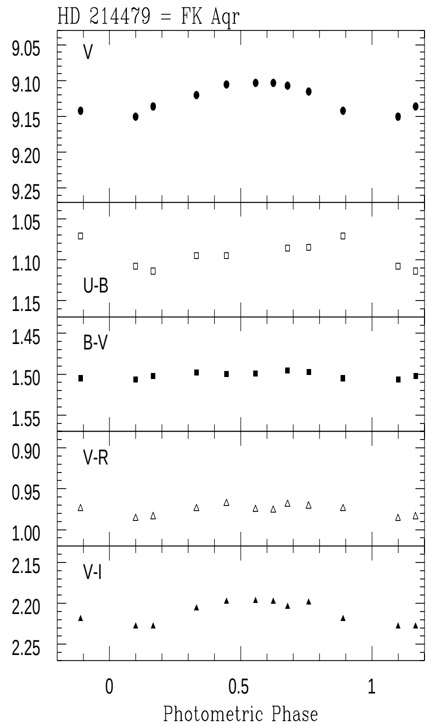

Fig. 28. HD 214479 = FK Aqr V-band and colour light curves for the mean epoch 1994.73; phases are reckoned from the photometric ephemeris HJD = 2447129.529 + 4.39 · E.

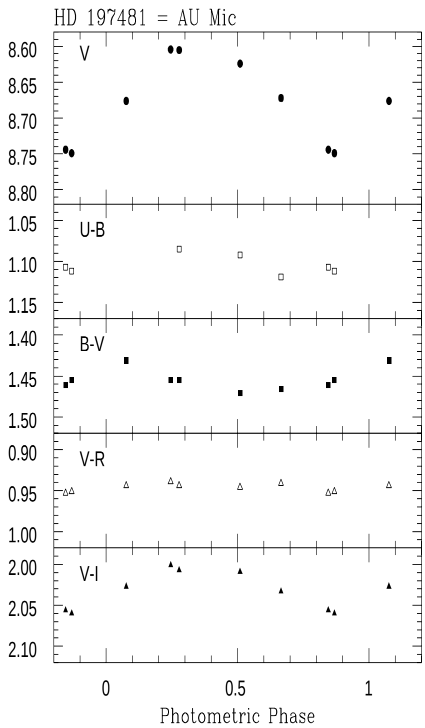

Fig. 27. HD 197481 = AU Mic V-band and colour light curves for the mean epoch 1994.73; phases are reckoned from the photometric ephemeris HJD = 2441054.0 + 4.865 · E.

1994.73 are shown in Fig. 27, where phases are reckoned from the 4.865 d photometric period given by Torres et al. (1972). The large amplitude light curve is single-peaked. The $U-B$ and $B-V$ colour curves are not well-correlated with the V-band modulation, a rather common circumstance for this star (see for instance Fig. 23 in PAP VII and Fig. 37 in PAP IX) that could be due to the presence of micro-flaring activity. The maximum luminosity is close to the brightest value ever observed (cf. Fig. 38 in PAP IX). The spectral classification, and in particular the possibility that AU Mic has not yet arrived on the main sequence, has been discussed by Barrado y Navascues (1998) and in PAP IX.

HD 214479 = FK Aqr ($D_H = 8.6^{+.1}_{-.1}$ pc) is the brightest component of the nearby visual pair ADS 11854 (= GL 867 AB) and is itself a SB2 system with a 4.08322 d orbital period (Herbig & Moorhead 1965). The combined spectral type of FK Aqr is given as dM2e and as M0Ve by Joy & Abt (1974) and by Houk & Smith-Moore (1988), respectively. Our observations are shown in Fig. 28, where phases are computed by using the 4.39 d photometric period given by Byrne et al. (1987). During the observations, particular care was applied to avoid any contribution from the optical companion GL 867 B (= FL Aqr). The light curve is single-peaked and the weak $B-V$, $V-R$ and $V-I$ colour variations are in phase with the V-band modulation. The $U-B$ shows a more complex behaviour, it results almost anticorrelated with the V-band modulation. The presence of strong variation of the photometric period, probably due to the presence of differential rotation (see also PAP VI) is confirmed. The present data show FK Aqr at the faintest luminosity ever attained, as inferred from the collection of the available photometry presented in Fig. 29. Our colours are consistent with a system constituted by two almost equal

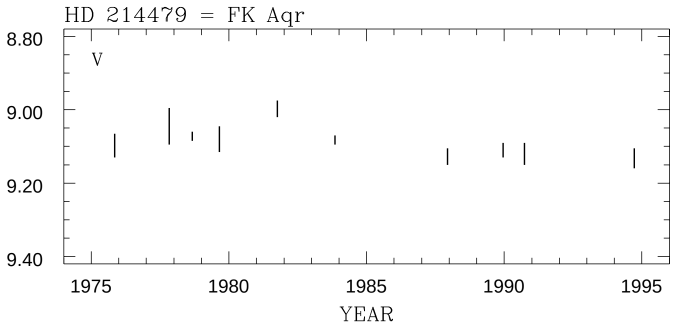

Fig. 29. HD 214479 = FK Aqr *V*-band long-term variability; vertical bars indicate the peak-to-peak amplitude of seasonal light curves.

M1/2 V stars, a classification that fits very well the trigonometric parallax.

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