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BV photometry of UX Ari in the period 1987–2002*

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Abstract. We present 14.3 years of previously unpublished photometric observations of UX Ari. The observations were obtained between 1987.9 and 2002.2 using the T3 0.4-metre Automatic Photoelectric Telescope at Fairborn Observatory and consist of 1228 B band and 1213 V band measurements. The comparison star was 62 Ari. We have analyzed the new data together with previously published photometric observations. The V magnitude shows variations with dominant periods of about 12 and 25 years, where the longest period seems to correspond to an activity cycle. The previously reported anticorrelation between the $B - V$ colour and V magnitude variations is confirmed.

Key words. stars: activity – binaries: spectroscopic – stars: individual: UX Ari – stars: late-type – starspots

1. Introduction

UX Ari (HD 21242) belongs to the group of RS CVn stars, which are synchronously rotating spectroscopic binaries where the cooler primary component is a subgiant or giant exhibiting spot and chromospheric activity (Hall 1976). Carlos & Popper (1971) determined the spectral types of the components to be K0 IV and G5 V.

The oldest photometric observations of UX Ari to be found in the literature are those presented by Hall et al. (1975). They reported a light curve that they suspected to be rotationally modulated, although they had too short a baseline of data to say this conclusively. Their light curve had an amplitude $\Delta V \approx 0.1$ mag and a period of 6.43791 d (determined spectroscopically by Carlos & Popper 1971). Since then, photometric observations have been presented by several authors (Hall 1977; Landis et al. 1978; Weiler et al. 1978; Guinan et al. 1981; Zeilik et al. 1982; Sarma & Prakasa Rao 1983, 1984; Poe & Eaton 1985; Busso et al. 1986; Wacker & Guinan 1987; Mohin & Raveendran 1989; Strassmeier et al. 1989; Nelson & Zeilik 1990; Rodonò & Cutispoto 1992; Elias et al. 1995; Raveendran & Mohin 1995; Ak et al. 1996; Padmakar & Pandey 1996, 1999; ESA 1997; Fabricius & Makarov 2000).

It is well established that the UX Ari light curve is rotationally modulated and displays wave-like behaviour, i.e. the time of minimum light occurs at different orbital phase in different observing seasons. It is also generally accepted that the rotationally modulated brightness variations seen in UX Ari and the other RS CVn stars are caused by extended, cool spots on the surface of the cool primary component.

Applying the Doppler imaging technique to spectroscopic observations provides a detailed analysis of spot evolution and structure. Doppler images of UX Ari exist for the observing season 1986/1987 (three maps, Vogt & Hatzes 1991) and the observing seasons 1995/1996 and 1996/1997 (two maps, Aarum et al. 1999). The maps are few and far apart in time, and they give a baseline of only 10 years for the study of spot evolution and any magnetic cycles. The photometric observations of UX Ari started in 1972 February (Hall et al. 1975) and thus provide a baseline of 30 years. Photometric observations are hence important when studying possible magnetic cycles in UX Ari and other chromospherically active stars.

In this paper we present new B and V photometric observations of UX Ari taken during 1987.87–2002.23. We search for periodic behaviour in the long-term brightness variations and analyze the $B - V$ colour variations as well as the spot properties of UX Ari.

2. New photometric observations

The new photometric observations presented in this paper were acquired between 1987 November and 2002 March with the

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* Tables 2 and 3 are only available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.125.5) or via http://cdsweb.u-strasbg.fr/cgi-bin/qcat?J/A+A/402/1033

T3 0.4 m APT at Fairborn Observatory in southern Arizona[1]. The 0.4 m APT uses a temperature-stabilized EMI 9924B photomultiplier tube to acquire data successively through the Johnson *B* and *V* filters. Each UX Ari observation consists of measurements in the following sequence, termed a group observation: *K*, *S*, *C*, *V*, *C*, *V*, *C*, *V*, *C*, *S*, *K*, in which *K* is the check star (HD 20618 = HR 995 = 59 Ari, $V = 5.91$, $B - V = 0.86$), *C* is the comparison star (HD 20825 = HR 1012 = 62 Ari, $V = 5.55$, $B - V = 1.10$), *V* is UX Ari (HD 21242, $V = 6.47$, $B - V = 0.88$), and *S* is a sky reading. Three $V - C$ and two $K - C$ differential magnitudes are formed from each sequence and averaged together to create group means. Group mean differential magnitudes with internal standard deviations greater than 0.01 mag were rejected to filter the observations taken under non-photometric conditions. The surviving group means were corrected for differential extinction with nightly extinction coefficients, and treated as single observations thereafter. The external precision of our differential magnitudes, defined as the standard deviation of a single differential magnitude from the seasonal mean of the differential magnitudes, is typically around 0.004 mag for this telescope, as determined from observations of pairs of constant stars. Prior to JD 2 449 117 (1993.35), the precision was somewhat worse (~0.007 mag) before the advent of our new precision photometer. The increased scatter, along with slight systematic offsets, can be seen in the $K - C$ differential magnitudes but is not large enough to affect the $V - C$ magnitudes significantly. We have analyzed the $K - C$ differential magnitudes for each observing season and find that the comparison star 62 Ari is constant from night to night at the limit of our precision while its seasonal mean brightness varies no more than ~0.002 mag. Therefore, any possible intrinsic variations in the comparison star will have no significant effect on our analysis of UX Ari. Further information on the operation of the APT can be found in Henry (1995a,b).

Table 1 summarizes the resulting 1228 new *B* and 1213 new *V* observations of UX Ari. Table 2[2] lists the individual $V - C$ and $K - C$ differential magnitudes.

Table 1. A summary of the new *B* and *V* photometric observations obtained during the years 1987–2002. The third and fourth columns give the number of individual *B* and *V* observations.

HJD 2 400 000 +	Equinox	*B*	*V*
47 112.96–47 232.62	1987.87–1988.19	33	35
47 415.90–47 604.61	1988.69–1989.21	140	133
47 789.82–47 969.61	1989.72–1990.21	131	125
48 182.84–48 321.63	1990.79–1991.18	49	45
48 697.61–48 701.61	1992.20–1992.22	3	2
48 874.95–49 066.60	1992.69–1993.21	78	79
49 235.00–49 427.61	1993.68–1994.20	103	101
49 638.87–49 804.62	1994.78–1995.24	68	67
49 982.97–50 169.62	1995.72–1996.24	107	108
50 391.92–50 533.62	1996.84–1997.23	72	78
50 714.86–50 896.63	1997.73–1998.23	97	97
51 085.87–51 262.62	1998.74–1999.23	129	128
51 429.96–51 626.63	1999.69–2000.22	111	111
51 812.95–51 980.66	2000.74–2001.19	65	64
52 176.99–52 358.63	2001.73–2002.23	42	40
47 112.96–52 358.63	1987.87–2002.23	1228	1213

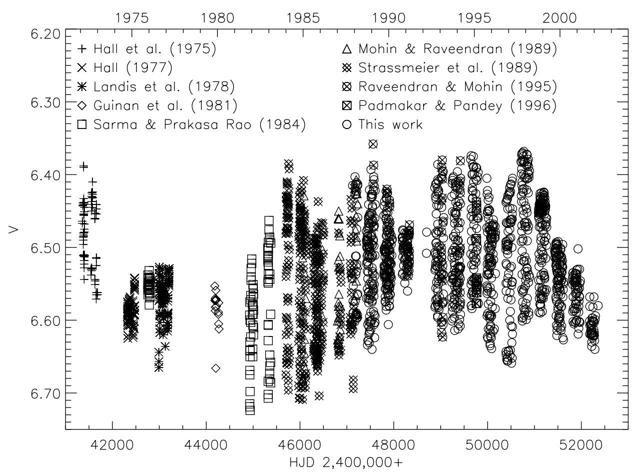

Fig. 1. All the available photometric *V* observations of UX Ari starting in 1972 February. The measurements presented in this paper are plotted as open circles.

3. Photometric analysis

The new *V* band measurements are plotted in Fig. 1 together with the previously published *V* observations. In this and subsequent figures, differential *V* magnitude measurements and differential $B - V$ colour measurements have been converted to apparent magnitudes and absolute colours using $V = 5.55$ and $B - V = 1.10$ for 62 Ari (ESA 1997). Table 3[3] lists the previously published individual $V - C$ observations.

3.1. Period analysis

In the top panels of Fig. 2 we have plotted the long-term variations of the mean *V* magnitude and the peak-to-peak *V* amplitude against time (HJD). The 1991/1992 observing season contains too few individual *V* observations to provide a useful light curve. For each of the other observing seasons we have from 17 to 141 individual *V* observations, the median being 83, spread over all the orbital phases. This implies that we can, within the observational errors, recover the minimum and the maximum of each individual light curve except in the season mentioned above.

The variations of mean *V* magnitude shows a clear minimum around the years 1980–1982 and a maximum around 1993–1995. The mean magnitude varies over a range of ≈0.15 mag, and the peak-to-peak *V* amplitude varies from 0.05 mag to 0.31 mag from season to season. The overall

[1] Further information about Fairborn Observatory can be found at `http://www.fairobs.org/`

[2] Table 2 is only available in electronic form at the CDS.

[3] Table 3 is only available in electronic form at the CDS.

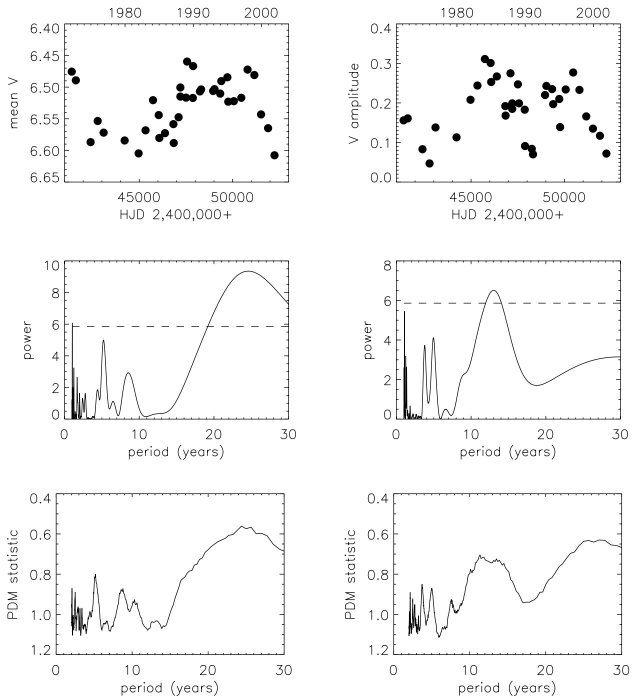

Fig. 2. The mean *V* magnitude and the peak-to-peak *V* amplitude of UX Ari at different observing seasons (top) together with the corresponding periodograms by the method of Horne & Baliunas (1986) (middle) and by PDM (Stellingwerf 1978, bottom). The horizontal dashed lines in the middle plots mark the power level of 90% significance (Horne & Baliunas 1986).

Table 4. The periods found from the period analysis of the mean *V* magnitude and the peak-to-peak *V* amplitude variations between different observing seasons. The periods on the left are those found by the method of Horne & Baliunas (1986), and on the right are the periods found by PDM (Stellingwerf 1978).

HB		PDM	
Mean	Amplitude	Mean	Amplitude
24.6 yr	–	24.4 yr	27.0 yr
–	13.0 yr	–	11.4 yr

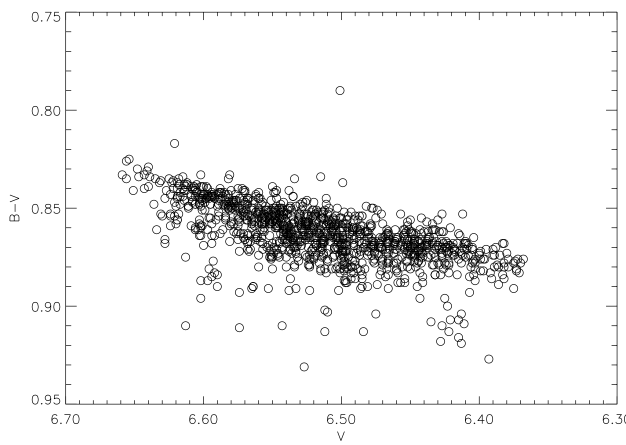

Fig. 3. The $B - V$ colour of the new data plotted against the *V* magnitude.

faintest observation occured in the 1981/1982 observing season (Sarma & Prakasa Rao 1984) and is $V = 6.72$ mag. This should be compared to the overall brightest observation, $V = 6.36$ mag, which occured in the 1988/1989 observing season (Raveendran & Mohin 1995). All these variations indicate a highly variable spot distribution on the surface of the K0 IV primary component.

The temporal behaviour of the *V* magnitude suggests quasi-periodic processes in the spot evolution. Therefore, using a periodogram analysis described by Horne & Baliunas (1986) and the PERIOD phase dispersion minimization (PDM, Stellingwerf 1978) algorithm provided by the Starlink project (`http://www.starlink.rl.ac.uk/`), we performed a period analysis of the mean *V* magnitude and the peak-to-peak *V* amplitude. The resulting periodograms are shown in the middle and bottom panels, respectively, of Fig. 2. Table 4 summarizes all the periods that were found.

The significance levels that can be calculated by the method of Horne & Baliunas (1986) is based on an empirical expression for the number *n* of independent frequencies. The power level of 90% significance has been indicated in Fig. 2. The empirical expression for *n* has turned out to be questionable in some cases (Schwarzenberg-Czerny 1997). Therefore, we have based our significance discussions in the following on the significance calculations made by the PERIOD software package, which in turn are based on the discussions by Linnell Nemec & Nemec (1985).

Two dominant period types were found in the period analysis. The long-term variation with a period of about 25 years was seen in both the mean magnitude and the amplitude and was more than 99% significant in both cases. This period corresponds to the total minimum-to-maximum variation from the early 1980s to the mid 1990s and seems to indicate the change in total spottedness on the stellar surface.

The short-term variation around 12 years was seen in the amplitude only and was more than 99% significant. This period seems to be related to the rearrangement of the spot distribution as indicated by the periods of large and small amplitudes in the *V* light curves (see Fig. 7 and Sect. 3.4) and thus to the differential rotation of the spotted primary component. On the other hand, the 12-year period is roughly half the long period, so we could be looking at a harmonic effect.

3.2. $B - V$ colour

To determine the nature of the spots on UX Ari, we have plotted the $B - V$ colour of the new data against the *V* magnitude. The plot is shown in Fig. 3. The plot shows that the system becomes bluer as it becomes fainter. One would expect that the effect of dark, cold spots would be to make the star redder and fainter (see e.g. Korhonen et al. 2001), not bluer. This so-called anticorrelation between the *V* light curve and the $B - V$ colour index curve has been observed by several investigators (Padmakar & Pandey 1999, and references therein). The cause of the anticorrelation is under debate. Two effects that have

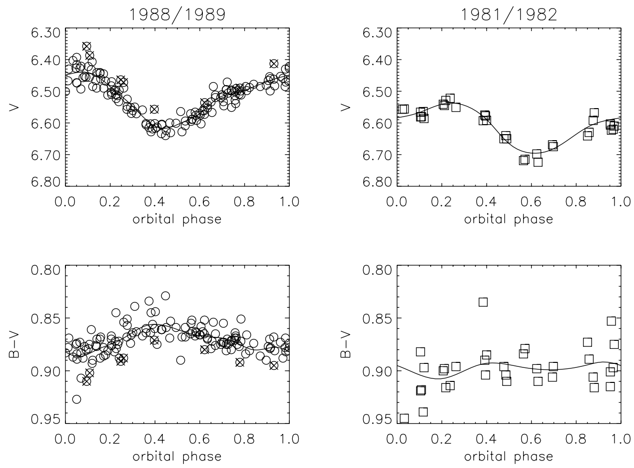

Fig. 4. *Left*: The V light curve and the $B - V$ colour curve for the 1988/1989 observing season (Raveendran & Mohin 1995, and this work) plotted against orbital phase. This season contains the brightest V measurement among the tabulated data, hence being the closest to the unspotted UX Ari primary component surface. *Right*: The V light curve and the $B - V$ colour curve for the 1981/1982 observing season (Sarma & Prakasa Rao 1984) plotted against orbital phase. This season contains the faintest V measurement among the available seasons. The plotting symbols are the same as in Fig. 1 for both seasons, and the solid curves represent cubic spline fits to the observations.

been brought to the table are (1) flares and/or facular areas (Rodonò & Cutispoto 1992), and (2) the fractional contribution of the hotter secondary component to the composite flux in the blue region (Mohin & Raveendran 1989; Raveendran & Mohin 1995). We address this question in a separate paper (Aarum Ulvås & Engvold 2003).

The 1988/1989 observing season of Raveendran & Mohin (1995) contains the brightest single measurement of UX Ari (V = 6.36 mag). The primary component must therefore have been least spotted at that point. We have plotted in the left panels of Fig. 4 the V light curve and the $B - V$ colour curve, together with cubic spline fits to the observations, against orbital phase φ for this season. The plot shows both the data of Raveendran & Mohin (1995) and our new data. The orbital phases were calculated using the ephemeris of Duemmler & Aarum (2001),

$$T_0 = \text{HJD}\ 2\,450\,642.00204 + (6.4372703 \pm 0.0000069)E,$$

where T_0 is the time of maximum radial velocity of the primary component and corresponds to $\varphi = 0$.

Although UX Ari is least spotted in the 1988/1989 observing season, it is not straightforward to deduce the temperature of the unspotted surface of the primary component from the $B - V$ colour curve. UX Ari is a spectroscopic triple system (Duemmler & Aarum 2001, and references therein), so the photometric measurements contain contributions from three stars with quite different temperatures. Without more accurate information on the B and V magnitudes of the two unspotted stars, it is impossible to deduce the unspotted surface temperature of the primary component from the colour curve of the brightest season.

The V observations in the 1981/1982 observing season presented by Sarma & Prakasa Rao (1984) contains the faintest measurements among the available observations (V = 6.72 mag). The V light curve and the $B - V$ colour curve, together with cubic spline fits to the observations, are plotted against orbital phase for this season in the right panels of Fig. 4.

The V amplitude of the cubic spline fit is 0.18 mag in the brighter season and 0.16 mag in the fainter season. The difference in the mean V magnitude between the two seasons is 0.09 mag. Apart from this, the V light curves look reasonably similar in the two seasons. The colour curves, on the other hand, look different. The colour curve of the brighter season shows a distinct maximum near phase 0.4, at the same phase where the V light curve shows a minimum. This illustrates the relation between $B-V$ colour and V magnitude shown in Fig. 3. The colour curve of the fainter season seems virtually flat compared to the brighter season, and it also contains more scatter. The difference between the colour curves can be explained by the quality of the two data sets being different. The brighter season contains a large number of high precision APT measurements, whereas the fainter season consists of relatively few and older measurements.

3.3. Spot evolution

The V band photometric observations were used to investigate the spot evolution on UX Ari in the context of the random-spot model (RSM) introduced by Eaton et al. (1996). The RSM uses 10–40 moderately sized dark spots placed randomly on the surface of a differentially rotating star to reproduce the light curves of chromospherically active stars. The differential rotation continually redistributes the spots over the stellar surface and by doing so can account for much of the changing shape and amplitude of the light curves on rotational timescales. The remaining shape and amplitude changes, as well as the long-term light variations observed in most chromospherically active stars, are reproduced if the spots also appear and decay at random with typical lifetimes of several years. No magnetic cycle is necessary to produce the long-term brightness changes.

Although the UX Ari V light curves are clearly rotationally modulated and show shape and amplitude changes between seasons, the light curves are quite stable within each season, as Fig. 5 shows. A few exceptions are represented by the 1990/1991, 1992/1993, 1994/1995 and 1996/1997 seasons. In the 1992/1993 and 1996/1997 seasons, the light curve amplitude increases slightly. In the 1994/1995 season, the amplitude decreases. In neither of these three seasons does the mean brightness change. This can be explained by a constant level of spottedness that is redistributed (brought closer together in 1992/1993 and 1996/1997, and drifting apart in 1994/1995) by the differential rotation.

The mean magnitude seems to decrease slightly during the 1990/1991 season, while the amplitude remains constant. Such behaviour can be explained by the emergence of spots in circumpolar regions. The orbital inclination of UX Ari is $i = 59°$ (Duemmler & Aarum 2001). If the rotational and orbital axes are aligned, all latitudes above 59° are

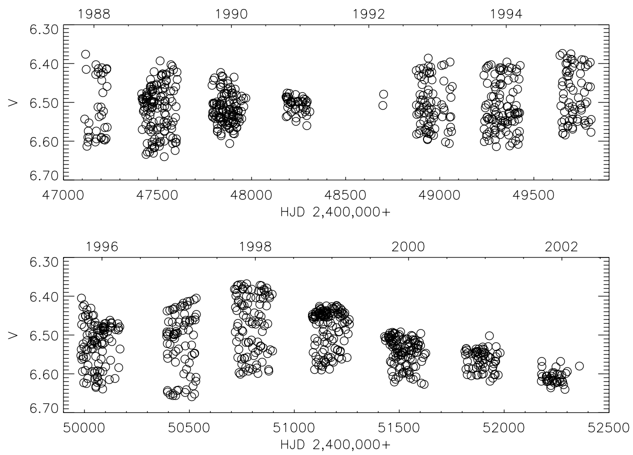

Fig. 5. The photometric *V* observations presented in this paper.

circumpolar. An alternative explanation could be for spots to appear in non-circumpolar regions, but in order to keep the amplitude constant, the spots would have to appear evenly distributed in longitude.

UX Ari also displays long-term variations in its mean brightness, suggesting cyclic behaviour. The RSM can reproduce such behaviour via the random appearance and decay of individual starspots without the need for a driving mechanism, as shown by the sample light curves generated by the RSM in Eaton et al. (1996) and Fekel et al. (2002).

In Fig. 6, the maximum, minimum and mean *V* magnitudes in various observing seasons are plotted against the *V* amplitude. The plot of maximum *V* magnitude against *V* amplitude shows that when the amplitude is small, the brightest areas of the star become darker (or less bright), and when the amplitude is large, the brightest areas become brighter. Similarly, the plot of minimum *V* magnitude against *V* amplitude shows that when the amplitude is small, the darkest areas of the star become brighter (or less dark), and when the amplitude is large, the darkest areas become darker. This can be explained by concentrating the dark spots to a limited area at times when the amplitude is large, and distributing the spots across a larger portion of the stellar surface at times when the amplitude is small. As can be seen in Fig. 6, there is no systematic trend in the mean *V* magnitude with the *V* amplitude. This suggests that the UX Ari light curve amplitude variations are caused to a larger extent by a continual rearrangement across the stellar surface of a more or less constant amount of dark spots, and to a lesser extent by the overall level of spottedness.

We also have spectroscopic observations of UX Ari taken in the observing seasons 1995/1996, 1996/1997, 1998/1999 and 1999/2000. These observations have been used to study the radial velocities of UX Ari (Duemmler & Aarum 2001). They will also be used for Doppler imaging (Aarum Ulvås et al., in prep.) using the photometry presented in the present paper as an additional constraint on the surface maps. The plot of *V* amplitude in Fig. 2 shows a strong amplitude in 1995/1996 and 1996/1997, and a weaker (but not the weakest ever observed) amplitude in 1998/1999 and 1999/2000. We

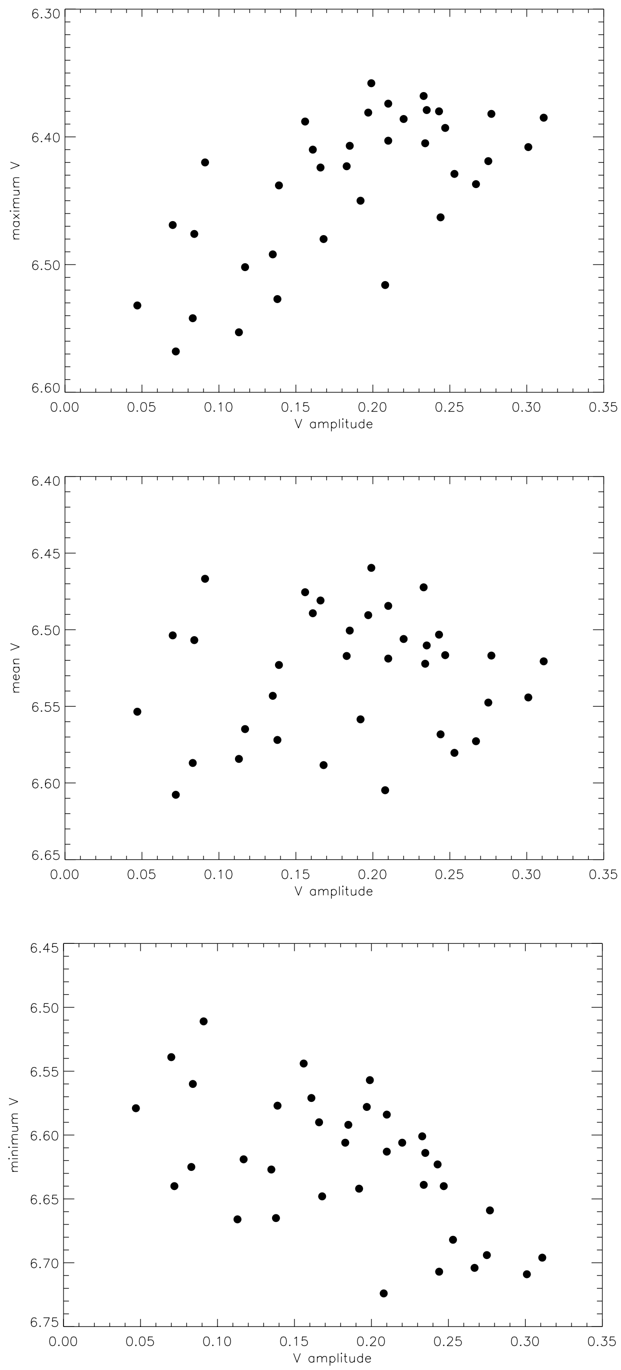

Fig. 6. The maximum (top), mean (middle) and minimum (bottom) UX Ari *V* magnitude at different observing seasons plotted against the *V* amplitude.

should therefore expect our surface maps to show concentrated spots in 1995/1996 and 1996/1997, whereas the spots in the 1998/1999 and 1999/2000 maps should be more widely distributed over the surface.

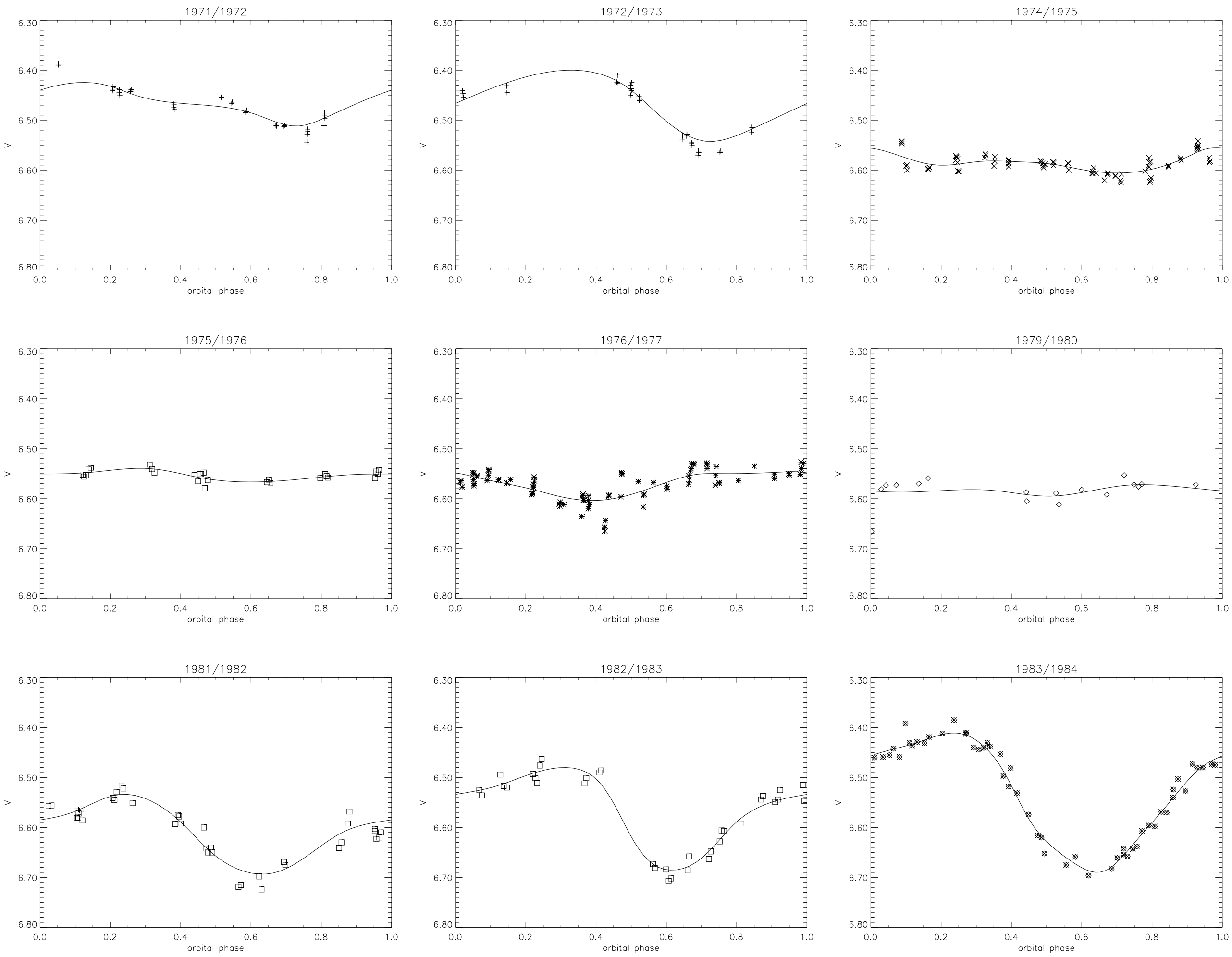

Fig. 7. *V* light curves from 1971/1972 to 2001/2002. Our new data starts in 1987/1988. The 1991/1992 season is missing due to too few measurements to provide a reliable light curve. The plotting symbols are the same as in Fig. 1, and the solid curves represent cubic spline fits to the data.

3.4. *V* light curves from 1971/1972 to 2001/2002

In Fig. 7, we have plotted the *V* magnitudes from each individual season against orbital phase, together with a cubic spline fit to the data.

The 1974/1975 season marks the beginning of about five years of virtually flat *V* light curves. Flat light curves suggest that the spots are rather evenly distributed over the stellar surface, yielding very little brightness contrast as the star rotates. The fact that the mean light level over these five years is considerably fainter than the maximum light level in seasons of high brightness contrast suggests that the star is not unspotted even though the brightness varies little with orbital phase. In the 1981/1982 season the brightness contrast starts to increase. Maximum contrast is reached in 1983/1984 and 1984/1985, after which it starts to decrease. Although the contrast decreases steadily, the light curve is not flat until six years later, in 1990/1991. Two years after this, the contrast is high again, and this time it lasts for five to six years. The last three observing seasons (1999/2000, 2000/2001 and 2001/2002) display low brightness contrast, suggesting that the spots are once again evenly distributed. The contrast variations seem to agree quite well with the 12-year period of the variations in the peak-to-peak *V* amplitude (see Fig. 2 and Table 4).

A very strong UV flare occured on UX Ari on 1995 November 19 (Dupree & Brickhouse 1996). Henry & Hall (1997) reported that this flare was detectable in the *B* and *V* magnitude light curves, using data from the 1995/1996 observing season presented in this paper. Henry & Hall also reported that UX Ari underwent a rather sudden spot redistribution during this season, causing the spread in the *V* magnitude light curve around $\varphi = 0.4$.

3.5. Phase of $V_{\rm min}$

From the cubic spline fits to the *V* light curves in Fig. 7 we have determined the orbital phase of minimum light of those seasons where the *V* amplitude was large enough to allow an accurate determination. We have also determined the difference in orbital phase of minimum light between one season

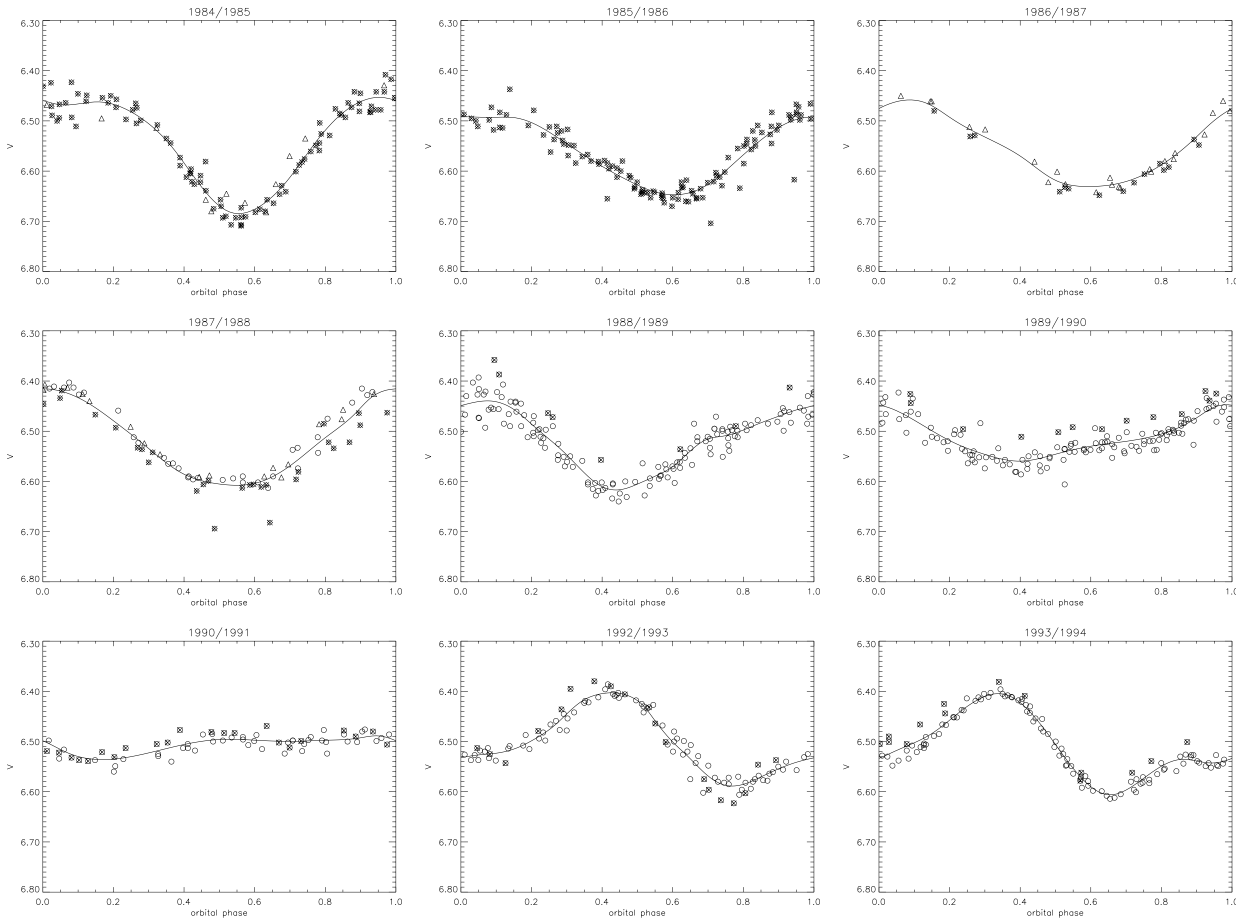

Fig. 7. continued.

and the previous one (i.e. the orbital phase of minimum light of this season minus the orbital phase of minimum light of the previous season). The phase difference was converted into phase drift in units of phase yr^{-1} by dividing by the difference in mean equinox between one season and the previous one. The results are presented in Table 5. Figure 8 shows the orbital phase of minimum light as function of equinox.

Section 3.1 gives evidence of a period ≈25 years in the mean V magnitude, which suggests that UX Ari displays a 25-year activity cycle. Given the 25-year activity cycle, we have defined an activity cycle phase φ_a given in Table 5 along with the mean equinox of each observing season. Fitting a sine curve with period 24.5 years (see Table 4) to the plot of mean V magnitude against equinox (Fig. 2) yields the following ephemeris:

$$T_0 = 1993.42 + 24.5E, \quad (1)$$

where T_0 marks the time (equinox) of maximum V_{mean} and corresponds to $\varphi_a = 0$. Since maximum V_{mean} corresponds to spot minimum, $\varphi_a = 0$ can be said to mark the beginning of a new spot cycle.

We can see no clear correlation between the orbital phase of minimum light and time (Fig. 8). The only exception is in the period 1982–1990, where the orbital phase of V_{min} seems to decrease linearly with time. The phase migration rate of minimum V magnitude in Table 5 varies from $-0.1157\ \mathrm{yr}^{-1}$ (1988/1989) to $+0.2605\ \mathrm{yr}^{-1}$ (1995/1996), but it is mostly negative. We also find no clear correlation between the phase migration rate of V_{min} and time. The migration of photometric minimum in orbital phase is very likely caused by a mixture of effects. Surface differential rotation continually causes spots at different stellar latitudes to clump together for a time and also dissolves existent spot concentrations. The emergence of new spots and the decay of old spots also affect the orbital phase of photometric minimum. In this scenario, the rotation period derived from the phase migration rate may not correspond to the true rotation period at *any* stellar latitude. To obtain more information on UX Ari stellar differential rotation and spot migration, we need to apply the Doppler imaging technique to our spectroscopic observations (Aarum Ulvås et al., in prep.).

4. Conclusions

We have in this paper presented new photometric observations of UX Ari and analyzed them together with previously published observations. Our main results are:

– 2441 new photometric measurements of UX Ari (1228 in the B band and 1213 in the V band) taken in the

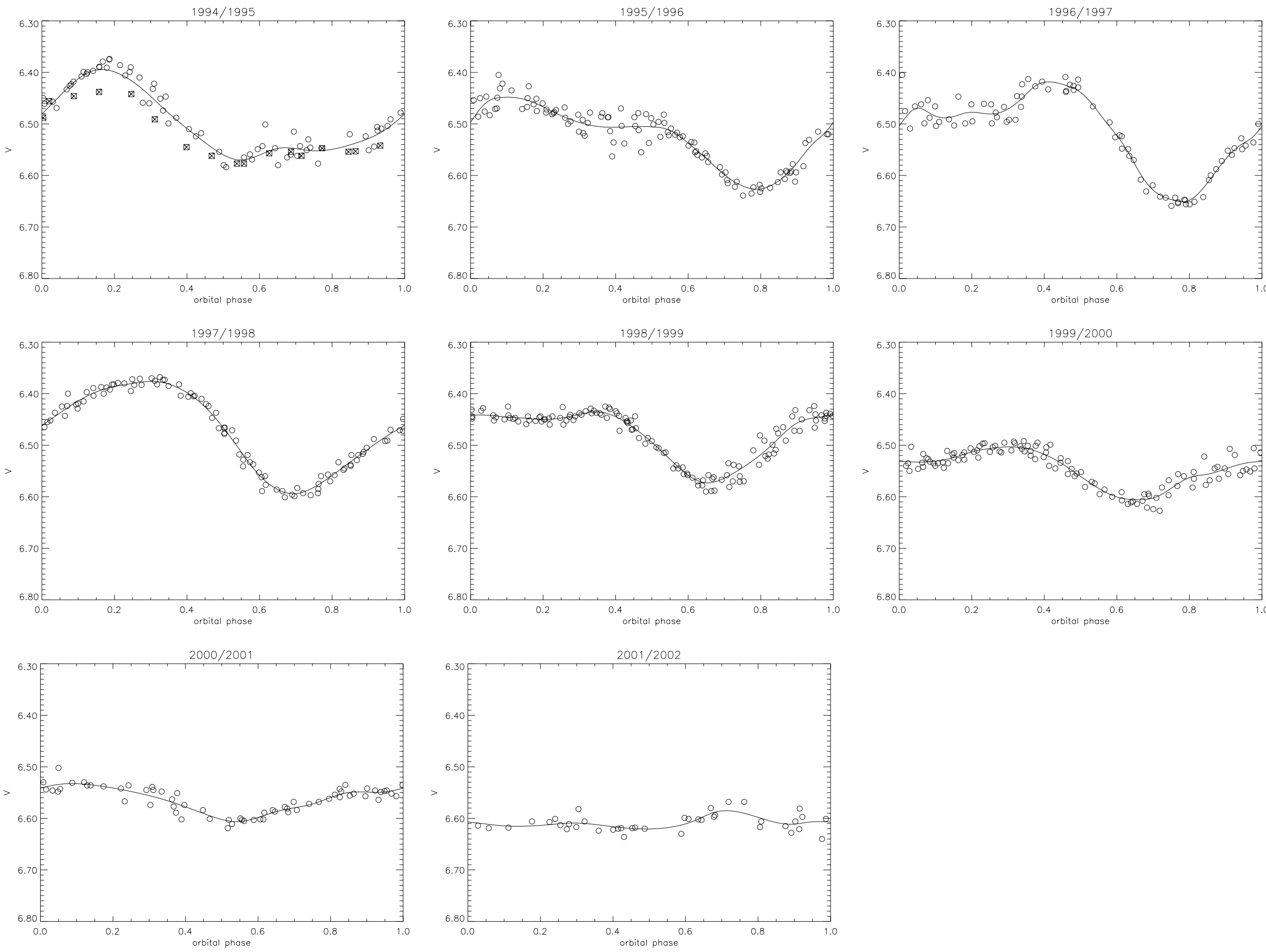

Fig. 7. continued.

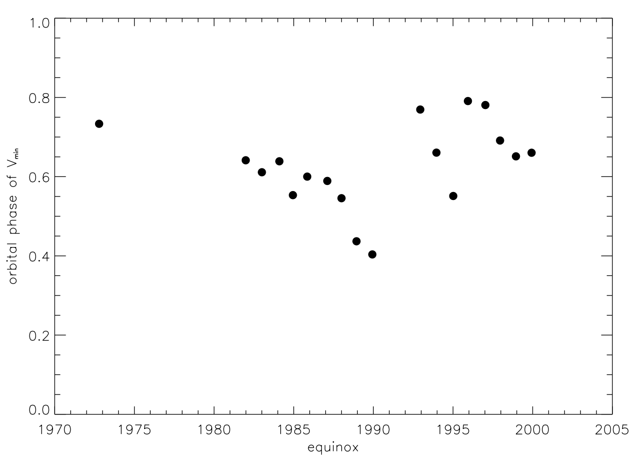

Fig. 8. The orbital phase of minimum light as function of equinox.

period 1987.87–2002.23 have been presented. All the new measurements are available electronically together with all the previously published *V* measurements that have been analyzed.

– The mean *V* magnitude and the peak-to-peak *V* amplitude exhibit a long period of about 25 years and a shorter period of about 12 years. The 25-year period indicates an activity cycle, and the 12-year period seems to be related to the rearrangement of spots and thus the differential rotation of UX Ari.
– The total flux of the UX Ari system becomes bluer as it becomes fainter. The cause of this effect remains unresolved but will be addressed in a separate publication.
– *V* light curves for 7 previously unpublished observing seasons have been presented.

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Table 5. The orbital phase of minimum light for those seasons of the available data where the *V* amplitude was large enough to allow an accurate determination. The first column gives the mean equinox of all the observations in each season. The second column gives the activity cycle phase derived from the ephemeris in Eq. (1). The fourth column gives the orbital phase drift of minimum light from the previous season (this season minus previous season) in units of phase yr^{-1}.

Mean equinox	Activity phase φ_a	Phase of V_{min}	Phase drift (yr^{-1})
1972.19	0.134	–	–
1972.79	0.158	0.7335	–
1974.95	0.246	–	–
1975.99	0.289	–	–
1976.86	0.324	–	–
1979.94	0.450	–	–
1981.99	0.534	0.6414	–
1983.00	0.575	0.6111	−0.0300
1984.10	0.620	0.6388	+0.0252
1984.95	0.654	0.5534	−0.1005
1985.85	0.691	0.6001	+0.0519
1987.11	0.743	0.5892	−0.0087
1988.00	0.779	0.5456	−0.0490
1988.94	0.817	0.4368	−0.1157
1989.94	0.858	0.4036	−0.0332
1991.01	0.902	–	–
1992.94	0.981	0.7694	–
1993.96	0.022	0.6606	−0.1067
1995.01	0.065	0.5511	−0.1043
1995.93	0.103	0.7908	+0.2605
1997.03	0.148	0.7808	−0.0091
1997.95	0.185	0.6912	−0.0974
1998.95	0.226	0.6513	−0.0399
1999.93	0.266	0.6603	+0.0092
2000.95	0.308	–	–
2001.90	0.346	–	–

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