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UX Ari: NEW PHOTOMETRY AND LONGITUDINAL ASYMMETRY IN SPOT ACTIVITY FIXED IN ORBITAL REFERENCE FRAME

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UX Ari (HD 21242) is one of the brightest member of RS CVn binaries, and has been observed photometrically almost every season since the discovery of its light variability in 1972 by Hall et al. (1975). It is a non-eclipsing, double-lined spectroscopic binary with a K0–K1 subgiant as the primary and a G5 dwarf as the secondary in a near-circular orbit (Carlos & Popper, 1971; Duemmler & Aarum, 2001).

We observed UX Ari photometrically in BV bands on 23 nights during January–March 2008 with the 34-cm telescope of Vainu Bappu Observatory, Kavalur. All the measurements were made with respect to the comparison 62 Ari. HR 999 was also observed on several nights along with the variable as the check star. Table 1 lists the results of our photometric observations. Each value given in the table is a mean of 3-4 independent measurements. The typical uncertainty in both the differential V and $(B-V)$ values is $\sim$0.01 mag.

The differential V and $(B-V)$ values given in Table 1 are plotted in Fig. 1 after converting the Julian dates of observation to orbital phases with the ephemeris: JD = 2450646.83 + $6\overset{d}{.}4372703$E. The initial epoch corresponds to the conjunction with the more massive, cool primary in front. The orbital period and the epoch of maximum radial velocity of the active star from which the above time of conjunction is derived are from Duemmler & Aarum (2001). Figure 1 shows that the light variation during January–March 2008 was highly asymmetric with a broad minimum and a narrow maximum. The monotonic decrease in the brightness at light curve minimum observed during 2001–07 (Rosario et al., 2007) seems to be over and the light curve minimum seems to be getting brighter from this season onwards. The trend in $(B-V)$ variation over the photometric cycle is not well-defined; however, there is some indication that the star is bluer at fainter visual magnitudes as reported by several observers earlier.

Aarum Ulvås & Henry (2003), who analysed the individual light curves of UX Ari, have reported that there is no clear correlation between the orbital phase of light minimum and time, except that during 1982–90 the orbital phase seemed to decrease linearly from about $0\overset{p}{.}75$ to $0\overset{p}{.}40$. They also reported that the migration rate of phase of light minimum varied from -0.1157 yr^{-1} to $+0.2605$ yr^{-1}, and most of the time the rate had a negative value.

All the differential V magnitudes of UX Ari with respect to 62 Ari obtained during 1972–2008 (Aarum Ulvås & Henry, 2003; Rosario et al., 2007; Table 1) are plotted in

Table 1: *BV* photometry of UX Ari.

JD 2450000.0+	V	$(B-V)$	JD 2450000.0+	V	$(B-V)$
4475.1170	1.204	—	4476.1592	1.089	−0.203
4477.1181	1.098	−0.225	4478.1951	1.211	−0.239
4480.1072	1.250	−0.257	4481.1188	1.239	−0.240
4485.1243	1.241	−0.253	4486.1181	1.255	−0.241
4487.1100	1.244	−0.262	4491.1278	1.214	—
4502.1311	1.081	−0.232	4514.0905	1.182	−0.255
4515.0924	1.081	−0.211	4516.0944	1.148	−0.217
4517.0917	1.227	−0.230	4522.0912	1.103	−0.224
4525.1090	1.221	−0.244	4528.0953	1.093	−0.254
4529.0993	1.165	−0.248	4530.1026	1.245	—
4531.1078	1.237	—	4532.1035	1.222	−0.235
4534.1023	1.126	−0.211			

Fig. 2 after converting the Julian dates of observation to orbital phases with the above ephemeris. The uncertainty in the orbital period quoted by Duemmler & Aarum (2001) is only $0\overset{d}{.}0000069$ and the accumulated error in orbital phase over 36 years, over which the V band observations of UX Ari span, is only $0\overset{p}{.}002$. Figure 2 shows that the range in the observed differential V magnitudes of UX Ari has a clear orbital modulation, implying that the spot activity in the star has a longitudinal asymmetry that is fixed in the orbital frame of reference. The upper envelope of the ΔV values shows a maximum around $0\overset{p}{.}50$. The lower boundary shows a minimum around the same phase and a maximum around $0\overset{p}{.}0$ where the upper envelope shows a minimum. It is remarkable that the total spread in ΔV magnitudes at $0.^{p}0$ observed so far is only around 0.18 mag while that at $0\overset{p}{.}5$ it is around 0.48 mag.

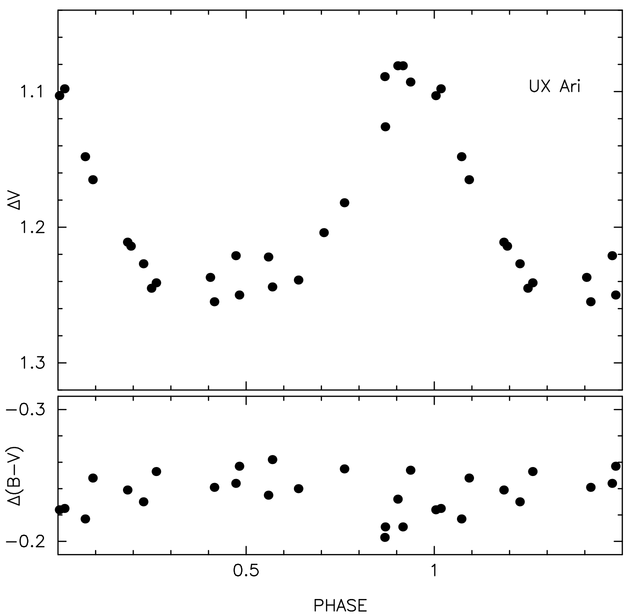

Figure 1. Plot of ΔV and $\Delta(B-V)$ values of UX Ari obtained during January–March 2008 against the corresponding orbital phase computed using the ephemeris JD = 2450646.83 + $6\overset{d}{.}4372703$E.

The fainter secondary component of the binary system also shows a low level of chromospheric activity as indicated by the variation in the Ca II K core emission from it (Aarum Ulvås & Engvold, 2003). UX Ari appears bluer at fainter visual magnitudes, which is unusual for a spotted star. Rosario et al. (2007) have shown that the bluer colour of UX Ari at fainter V magnitudes results because of the increased fractional contribution to the total light in the blue spectral region by the hotter G5 companion as the cooler component becomes fainter. Hence, most of the light variation observed in UX Ari can be attributed to the intrinsic light variability of the cool primary component.

The active stars in RS CVn binaries are presumed to undergo highly enhanced solar-like activity. Starspots, which are analogues to sunspots, distributed asymmetrically across the stellar surface rotationally modulate the observed flux, thereby producing light variability observed in these objects. The variations in light curves are attributed to changes in sizes of spots or spot groups and their distribution on the stellar surface. The phases of light minimum in many of these objects are found to migrate along the orbital phases at different rates. In some of the objects the migration can be traced continuously for several years while in some it can be traced only for a few years. To account for this, in analogy with the sun, Hall (1972, 1991) proposed that there is differential rotation in the active stars and only a particular latitude co-rotates synchronously with the orbital motion, and hence spots present in different latitudes would produce light curves with slightly different periods. The existence of differential rotation in components of close binaries, especially in active stars of RS CVn systems, is not well-established observationally. Almost all information on the differential rotation of spotted stars is based on the migration of the phase of the minimum of light curves of these stars.

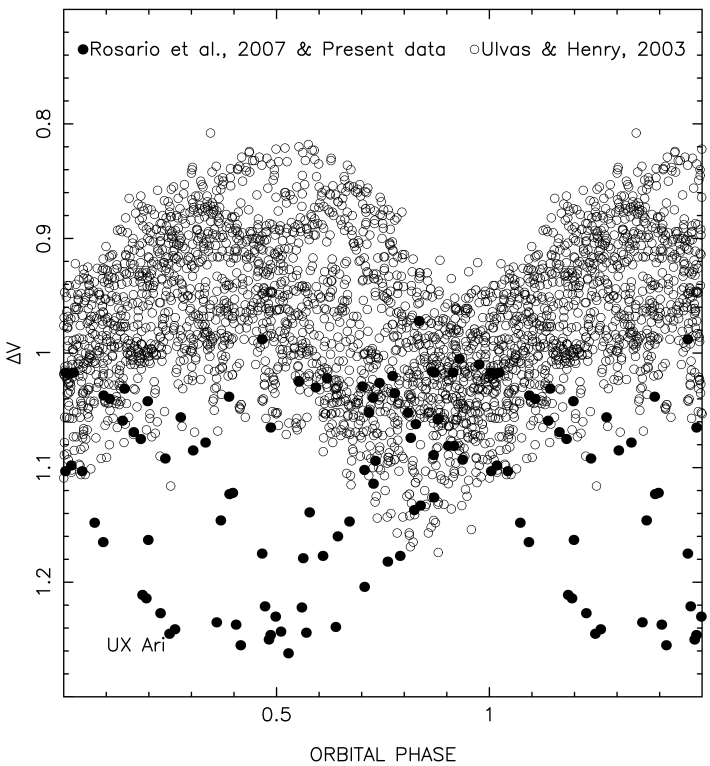

Figure 2. Plot of ΔV values of UX Ari obtained so far against the corresponding orbital phase computed using the ephemeris JD = 2450646.83 + $6^{\mathrm{d}}\!.4372703$E.

Figure 2 clearly shows that there is enhanced spot activity, as indicated by a larger spread in observed magnitudes, in the hemisphere of the active star facing the hotter companion when compared to that away from it. The minimum and maximum of a light curve obtained during a particular epoch may occur over a large range of orbital phases (Aarum Ulvås & Henry, 2003). But the fainter light minima and brighter light maxima among them always occur at orbital phases close to $0\overset{\mathrm{P}}{.}5$. The orbital inclination of UX Ari is around 60° (Duemmler & Aarum, 2001). Hence, the existence of a significant orbital modulation in spot activity implies that the regions of enhanced spot activity are located closer to the equator rather than the poles and that these regions rotate in near-perfect synchronism with the orbit. Any slight difference in the rotational period would completely smear out the modulation when data spread over such a time interval as long as 35 years ($\sim$ 2000 photometric cycles) are combined.

The large spread of about 0.5 mag in V magnitudes close to $0\overset{\mathrm{P}}{.}5$ requires that the regions that produce the enhanced activity have an appreciable latitudinal extent on the surface of the active star. The rotation of a large latitudinal zone in near-perfect synchronism with the orbit would mean that differential rotation in the active star is either absent or really small.

Another implication of the existence of the longitudinal asymmetry in spot activity, which is fixed in the orbital frame of reference, is that the spots do not appear and disappear with equal probability at all longitudes on the surface of the active star in the UX Ari system; the presence of the companion significantly affects the physical processes that produce spots and modulates the surface distribution of spots on the active star.

References:

Aarum Ulvås, V. & Henry, G. W., 2003, *A&A*, **402**, 1033
Aarum Ulvås, V. & Engvold, O., 2003, *A&A*, **402**, 1043
Carlos, R. C. & Popper, D. M., 1971, *PASP*, **83**, 504
Duemmler, R. & Aarum, V., 2001, *A&A*, **370**, 974
Hall, D. S., 1972, *PASP*, **84**, 323
Hall, D. S., Montle, R. E. & Atkins, H. R., 1975, *Acta Astron.*, **25**, 125
Hall, D. S., 1991, *IAU Coll.*, **130**, 353, in: The Sun and Cool Stars: activity, magnetism, dynamos, ed.: I. Tuomien, D. Moss, G. Rudiger, Springer-Verlag
Rosario, M. J., Raveendran, A. V. & Mekkaden, M. V., 2007, *A&A*, **474**, L41