BV PHOTOMETRY OF PROMINENT RS CANUM VENATICORUM STAR UX ARI (HD: 21242)

AJAZ AHMAD, MANZOOR A. MALIK, ABDUL WAHID

University of Kashmir, Srinagar-J&K, India-190006
ICSC, Hawal, Srinagar-J&K, India-190002
Email: ajazorama@gmail.com; mmalik@kashmiruniversity.ac.in; wahidphysics@gmail.com

Abstract. We present the results of BV photoelectric photometry observations of UX Ari RS CVn Star, obtained on 14 nights during the observing run January- February, 2006, using $14''$ telescope and SSP-3 Photometer. Comparison of light curves during the year 1972 by (Hall,1975), 1995-1996, 2001-2002 by Aarum and Henry (Aarum & Henry, 2003), and our observations 2006 clearly shows the amplitude variation of light on different time scales.

Key words: Photometry; RS CV_n; Period; Light Curve.

1. INTRODUCTION

RS Canum Venaticorm (RS CV_n) type stars are chromospherically active binary systems. The most accepted definition of RS CV_n binaries used is based on the classification criteria first formulated by Hall (1972; 1976) with some modifications made by Fakel *et al.*(1986). Apart from the classical RS CV_n binaries, originally defined by Hall (1976), there are several other classes of binaries containing at least one late-type star which can attain similarly high levels of activity (Hall, 1989). These include: short period and long period RS CVn binaries; close binary systems containing a white dwarf or sub-dwarf secondary; semi-detached (Algol) or detached binaries containing a late type subgiant as the secondary star and an early type companion as the primary star; and contact (W UM_a-type) binaries (Padmakar and Pandey, 1999).

RS CV_n stars are bright and interesting and can be observed with a simple photoelectric photometer or CCD camera on a small telescope with ease by astronomers. The term RS CV_n binary is used for a system which show presence of strong Ca II H & K, and H emission in the spectrum. Variable light curves arising primarily due to rotational modulation of the stellar light by large star spots on the surface of the cooler component. The binary usually consists of one hotter component of the spectral type F or G and Luminosity class V or IV. The secondary cooler companion is usually a subgiant or giant massive K-type star. Both stars typically lie well inside their Roche lobe. RS CVn binaries have been further classified into three subgroups

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according to their orbital period:

(i) short period system (P_{orb}≤1 day);

(ii) classical RS CV_n (1 ≤P_{orb} ≤14 days);

(iii) long period system (P_{orb} ≥14 days) (Barwey, 2005).

Discoveries of new RS CVn binaries, apart from enriching the existing samples, are important for understanding the underlying physical parameters like rotation, age, metalicity etc, which are involved in generating and sustaining strong chromospheric and coronal activity in them (Padmakar *et al.*, 1999).

2. UX ARIETIS

UX Ari (HD 21242) is a non-eclipsing type triple-lined system (Duemmler and Aarun, 2001) where the two main components constitute a doubled lined spectroscopic RS CV_n binary system comprising a hot G5V primary and an active cool Ko IV secondary star (Carlos and Popper 1971). UX Ari is located at a distance of 50.2 pc, having Vmax = 6.5 with orbital period of 6.4378553d. The oldest photometric observations of UX Ari to be found in the literature are first presented by Hall *et al.*(1975). Their light curve had an amplitude Δv≈ 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; Zeilik *et al.*, 1982; Mohin and Raveendran, 1989; Strassmeir *et al.*, 1989; Nelson and Zeilik, 1990; Raveendran and Mohin, 1995; Rodono *et al.*, 1992; Padmakar and Pandey, 1996; Fabricius and Markarov, 2000) UX Ari HD 21242 has been assigned the variable star designation UX ARi by Kukarkin *et al.*(1973). After the detection by Hjellming and Blankenship (1973) of radio emission from AR Lacertae, itself an RS CV_n type binary, Hall *et al.*(1975) suggested that UX Ari, is the brightest RS CVn- type binary except for HD 118216.

According to Gibson, Hjellming, and Owen (1975) UX Ari is the second most active radio star (after Algol) in terms of flux density. It is well established that the UX Ari light curve is rotationally modulated and displays wave like behavior, *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 other RS CV_n stars are caused by extended, cool spots on the surface of cool primary component (Aarum and Henry, 2003) previously published photometry of UX Ari reveal an anti-correlation between the V magnitude and B-V color index *i.e.*, the UX Ari system becomes bluer as it become fainter (Zeilik *et al.*, 1982; Wacker *et al.*, 1986; Rodono *et al.*, 1992; Ulvas and Henry, 2003; Padmaker and Panday, 1999; Raveendran and Mohni, 1995). UX Ari also displays strong emission of Ca II H & K lines and phase dependent variable H emission, characteristic of an active chromosphere and corona (Raveendran and Mohin 1995). Strong Ca II H & K emission is supposed to coming from cooler Ko star of the system (Fabricius and Markarov, 2000). The active cool star is also supposed to fill its Roche lobe and probably some mass transfer from the primary Ko star to the secondary G5 star is taking place (Huenemoerder, 1989). UX Ari displays strong radio flares. This star shows an intense coronal emission at x-ray wavelength, and hence it has been extensively studied since its discovery as an x-ray source using various X-ray observatories. Einstein slew survey (Schachter *et al.*, 1996) shows that UX Ari is rather an average x-ray luminous star having plasma temperature of $\simeq$ 107K. Further, chromospheric cycle of about 7 years has been obtained for Ux Ari (Buccino and Mauas, 2009).

3. OBSERVATIONS OF UX ARI USING $14''$ REFLECTOR TELESCOPE

The BV photoelectric photometric observations of UX Ari were carried out during the observing run during the period January-February 2006. Because of rather unfavorable sky conditions we could observe this star for a total of 14 nights only. All the photometric data was obtained using celestron C-14 Schmidt-Cassegrin reflector telescope mounted at Inter University Centre for Astronomy and Astrophysics (IUCAA), Pune, India. The detector used in SSP3 photometer. The response of the B, V filters used closely matches the Johnson standard B, V, R & I response function.

Observations of UX Ari (HD 21242) were carried out by using differential photometry technique which is the magnitude difference between two stars: the chosen variable star and the standard star taken as the comparison star very close to each other in the sky. This technique has capability to measure very small variations in brightness of the star even under adverse sky conditions. To test the non-variability of the comparison star, another star called the check star which also fulfill the selection criteria for comparison star is used. Advantage of having a check star is to determine the accuracy of differential photometry observations for individual nights *i.e.*, standard deviation of differential magnitude and color between comparison and check star gives a measure of uncertainty associated with each observing night. Apart from errors introduced by atmospheric conditions, differential photometry can overcome typical instrumental errors, for example, arising from mismatch of the filter detector combination with standard system (Barwey, 2005; Henden and Kaitchuck, 1990).

In order to obtain accurate differential photometry, we used two nearby stars 62 Ari (G5 III) having visual magnitude: 5.55 as comparison star and Tyc 1796-1308-1 HIP 15548, HD 20644 (K211-111) having visual magnitude: 4.47 as check star. We followed the observing sequence for differential photometry during all observing nights as com S V Ch com S V Ch where com, V, Ch and S represents compari-

Table 1

Observational Data of Uxari Variable star in V- band

JD_V	Ph_V	ΔV	ΔV_c
2453754.087627	0.643276	1.111	1.0288
2453755.097951	0.800159	1.025	1.0543
2453756.177106	0.967915	0.739	1.0234
2453757.078055	0.10786	1.1370	1.0330
2453778.148969	0.27407	1.1841	0.6730
2453759.130370	0.426604	1.283	1.211
2453760.179305	0.589545	0.915	1.060
2453761.184837	0.745652	1.081	1.0235
2453762.133773	0.89306	1.045	0.999
2453763.175173	0.054914	1.127	1.077
2453764.135555	0.204031	1.182	1.0513
2453765.182303	0.366661	1.302	1.0091
2453768.209120	0.836845	1.202	1.0006
2453770.170925	0.141447	1.0870	1.188

son, variable, cheek stars and sky respectively. The observations were corrected for atmospheric extinction also.

The individual differential V observations are listed in table 1. The first column contains the Julian date. The second column contains the phase computed with the ephemeris:

$$JD = 2440133.^{d}76 + 6.^{d}43791E \tag{1}$$

For phase calculation we have taken fractional part of (JD-Epoch)/period. Where Epoch is the time of minimum light or JD at which minima of light curve occurs. Further the period is the variability period in days. From the ephemeris 2440133.76d is initial epoch, 6.43791 is the period and E is the cycle number (Ephemeris from Carlos & Popper, 1971). The third and fourth column contain the differential V magnitudes. Table 2 contains JD in the first column, phase calculation in the second column and last two columns contain the differential B magnitudes.

The graph of magnitude against time as in Fig.1 or against phase gives the light curve of UX Ari. The variability of UX Ari can be seen in Fig.1. Although we have only 14 nights of observation for this star but it is evident from the phase diagram (Fig.1) that the observations cover the entire phase. For comparison, along with our own observations, we plotted the light curve of UX Ari obtained from the data of Hall (1975) and from observations made by Aarum & Henry in year 1995-1996, 2001-2002 (Aarum & Henry, 2003) in Fig.4.

All the observations were corrected for differential atmospheric extinction using extinction coefficients Kb = 0.65 (Fig.2) for B- band and Kv = 0.43 (Fig.3) for V-band, obtained with the help of least square fitting method. Earlier photometry of

Table 2

Observational Data of UX Ari Variable Star in B band

JD_B	Ph_B	ΔB	ΔB_c
2453754.11125	0.6473003	0.713	0.669
2453755.104918	0.801246	0.713	0.665
2453756.192650	0.970245	0.832	0.634
2453757.087523	0.109265	1.0052	0.709
2453758.153148	0.274847	0.920	0.752
2453759.133576	0.427070	1.0007	0.663
2453760.193148	0.591720	0.915	0.658
2453761.193136	0.7475	0.828	0.713
2453762.137777	0.893681	0.768	0.711
2453763.178622	0.05538	0.887	0.611
2453764.138981	0.204496	0.943	1.182
2453765.188425	0.367593	1.0566	0.7143
2453768.212025	0.837311	0.867	0.781
2453770.175914	0.142223	0.9118	0.552

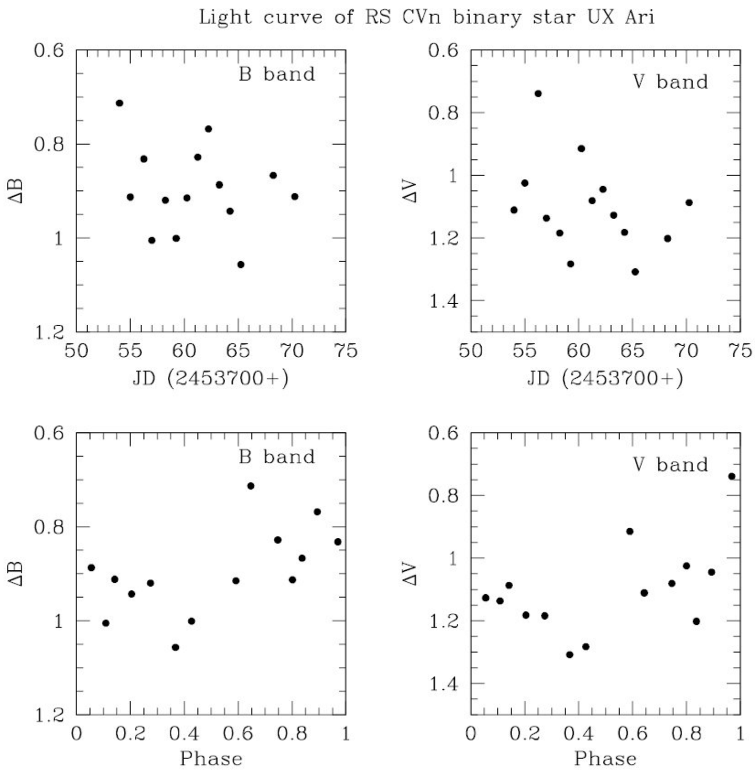

Fig. 1 – V band light curve and B band light curve.

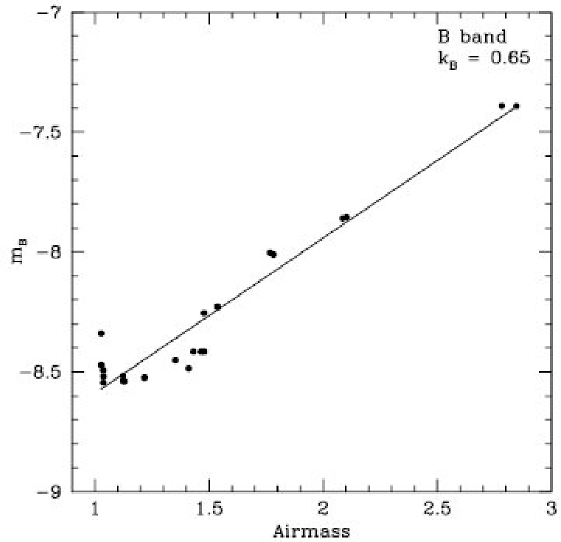

Fig. 2 – B- band extinction coefficient.

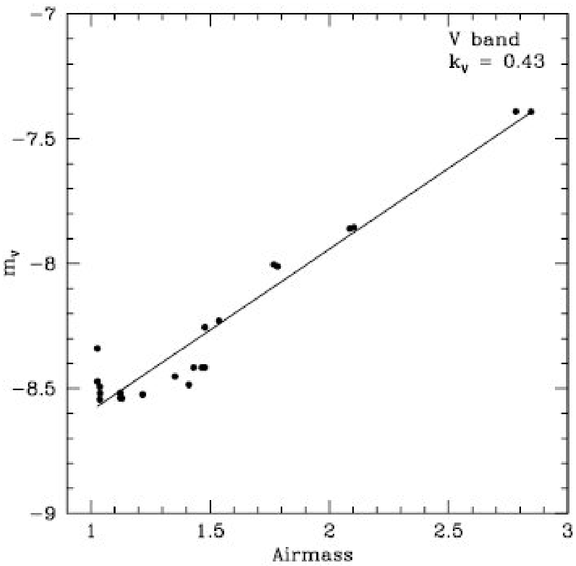

Fig. 3 – V- band extinction coefficient.

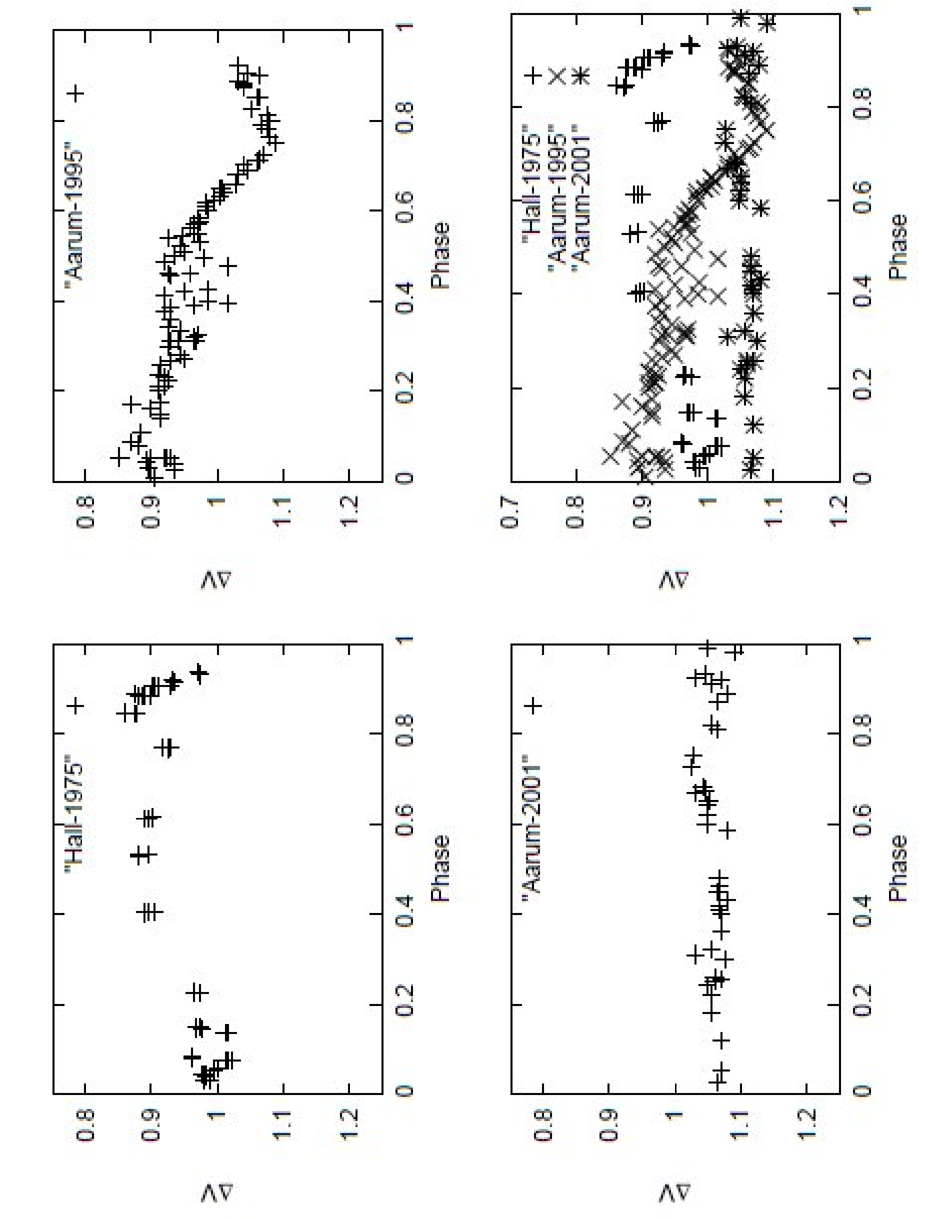

Fig. 4 – In this page, first three figures show light curves of Ux Ari for years 1975, 1995 and 2001. Fourth figure shows the the comparative study of light curves 1975, 1995, 2001.

UX Ari has shown its light to be variable on a variety of time scales (Fig.4)(Hall, 1975). There has been a nearly sinusoidal wave the amplitude of which has varied from year to year even within a year. Comparison of light curves during the year 1975 (Hall, 1975), 1995/1996; 2001/202 (Aarum and Henry 2003) in Fig.4 and our observations Jan-Feb 2006 (Fig.1) clearly shows the amplitude variation of light on different time scales.

4. CONCLUSIONS

In this paper we presented photometric observations and light curves of a prominent RS CVn Star Ux Ari (HD: 21242) and analysed them with published observations and light curves. The light curves obtained were analysed in B and V filters. These light curves are very similar to quasi-sinusoidal photometric curves commonly observed for various RS CVn Stars. Our main results are described below.

Although we observed this star only for 14 nights but it is evident from the phase diagram that observations cover the entire phase. For comparison, along with our observations we plotted the light curves from the published observations of (Hall *et al.*, 1975; Aarum and Henry, 2003).

All the observations were corrected for differential atmospheric extinction using extinction coefficients $K_b = 0.43$ for B-band shown in fig (2) and $K_v = 0.65$ for V-band shown in Fig.3.

Earlier photometry of Ux Ari (HD:21242) has shown its light to be variable on a variety of time scales and this change has been attributed due to the presence of large star spot activity. This variation in light can be clearly seen in Fig.4 obtained from observations of Hall et al.(1975) and observations of Aarum & Henry, 1995, 2001 (Aarum & Henry, 2003). Moreover, there has been a nearly sinusoidal wave amplitude of which has varied from year to year even within a year as can be observed from the light curves during the year 1995/1996, 2001/2002 from Fig.4 (Aarum and Henry, 2003). Our observations January- February 2006 in agreement with above clearly shows amplitude variation at different time scales, which is a good reason to believe that Ux Ari (HD: 21242) is a variable star.

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