

THE RESULTS OF PHOTOMETRIC ANALYSES OF LONG-TERM BV OBSERVATIONS OF UX ARIETIS¹

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Abstract. Including the BV data obtained during 1991-1994 period at the Ankara University Observatory (AUG), a review of long-term light curves analyses of chromospherically active binary system, UX Ari, is presented. The spot distributions for UX Ari were investigated by using Wilson-Devinney (WD) code, and the results are summarized in this study. Large and cool spots located on the primary (K0 IV) component are mainly responsible for the light curve variations but the most convenient results of spot distributions in UX Ari are obtained by adding two other spots on the secondary (G5 V) component of the system. The comparison of achieved results with the previously published results showed that a good fit to the observational light curves could also be achieved without any flares and/or facular areas but with two other spots located on the secondary component of the system.

1. INTRODUCTION

UX Ari is one of the most active non-eclipsing double-lined spectroscopic binary ($P_{orb} = 6^d.43791$) systems, consisting of a G5 V and K0 IV star (Carlos and Popper 1971). The light curve variation of UX Ari was discovered by Montle and Hall (1972). Since then, the photometric variation (as a photometric wave) of the system has been followed by many authors (e.g. Evans and Hall 1974, Guinan et al. 1981, Busso, Scaltriti and Cellino 1986, Mohin and Raveendran 1989, Raveendran and Mohin 1995).

The spot models for UX Ari (see Poe and Eaton 1985, Vogt and Hatzes 1991) predict the existence of quite large and cool spots on the surface of K0 IV component. Furthermore, Aarum and Henry (2003) used the V band photometric observations of UX Ari to investigate the spot evolution on the system in the context of the random-spot model introduced by Eaton et al. (1996). A survey of the IUE spectra of the system by Ekmekçi (2010) showed that the activity of UX Ari arouse not only from K0 IV component but also from G5 V component with the contribution levels of about 80% and 20% for K0 IV and G5 V, respectively. Based on this finding, a review of the photometric analyses of long-term BV observations of UX Ari was performed with spot distributions on both components by using the version of 2004 (Wilson 2005)

¹Tables 1-4 and Figures 2-18 are only available in electronic form at the <http://www.aob.rs/paob/90/pdf/tables> and <http://www.aob.rs/paob/90/pdf/figures>.

of Wilson-Devinney (hereafter WD) programs (Wilson and Devinney 1971, Wilson 1979, Wilson 1990).

2. OBSERVATIONS

Previously published differential B and V data of UX Ari, obtained during 1972-2001 period, as well as the unpublished Johnson BV observations of UX Ari which were carried out between 1991 and 1994 with the 30 cm Maksutov telescope of the Ankara University Observatory (AUG) were used in this study. The telescope is equipped with an SSP-5A photometer containing a side-on R1414 Hamamatsu photomultiplier. The log of AUG observations and nightly standard deviations of differential magnitudes for each filter are given in Table 1. The control of photometer head and data acquisition were carried out with a software prepared by Müyesseroğlu (1992). The data reduction is done by the software prepared by Özeren (1995). HJDs and corresponding differential magnitudes as nightly mean or average of five measurements of BV observations made in the period 1991-1994 are given in Table 2.

3. ANALYSIS OF THE LIGHT CURVES

In the light curve analysis of UX Ari, using the WD code, the photospheric star spot configurations on both components were taken into consideration as a responsible effect for the light variations appeared in the light curves of the system. Since there are no published values for metallicity estimated from spectral analysis of UX Ari, the chemical composition of ABUNIN($[M/H] = 0$ (solar metallicity together with $\log g = 4.27$ for G5 V and $\log g = 3.5$ for K0 IV component) was used in the stellar atmosphere formulation for both components of the system, in the light curve analysis. The code was run for the detached mode (mode 2) in all passbands simultaneously for every year. Since the orbital and dynamical parameters, together with some spectral characteristics of UX Ari were known in a good accuracy from spectral analyses (see Duemmler and Aarum 2001) these parameters were taken as fixed parameters in WD analysis. The convenient limb-darkening coefficients were taken from Van Hamme (1993)'s tables. The rotation axes of the components were taken to be perpendicular to the orbital plane and the synchronized rotation was assumed for the components. Since the albedo for the star that has a convective envelope is 0.5, this value was used in the light curve analysis of UX Ari system. The fixed system parameters used in WD analysis are given in Table 3. The adjustable parameters are the latitudes, longitudes, radii, temperature factors of spots, and the relative monochromatic luminosities (L) of the components in each band. The differential correction program was initiated for the light curves obtained during each observational season, separately, and then a visual inspection of the agreement between synthetic and observational light curves was made. The goodness of the fits, $\Sigma(0 - C)^2$, to the light curves have been checked for every run.

At first, based on the phenomena seen in RS CVn systems, large and cool spots located on primary (K0 IV) component were taken into account in the WD analysis. Then, based on the conclusions of the survey of the IUE spectra of UX Arietis by Ekmekçi (2010), it was tried to test the spot locations not only on the primary but also on the secondary component of the system. The comparison of these two attempts showed that the more convenient results of spot distributions in UX Ari were

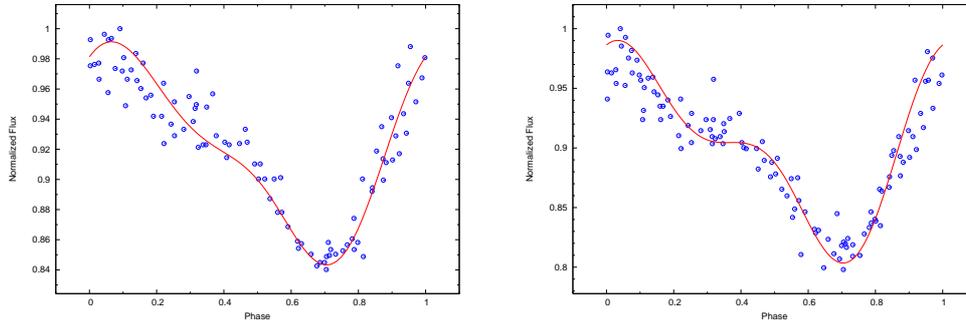


Figure 1: B(left panel) and V(right panel) light curves of UX Ari, obtained during 1992-93 period, together with the theoretical light curves (solid red lines) of spot solution (with 2 spots on G5 V and 4 spots on K0 IV) from WD analysis.

obtained, mostly, by adding two spots onto the secondary component. The results of spot parameters of all light curves are given in Table 3. As an example, the results of the synthetic light curves obtained in 1992-93 observing season are shown in Fig. 1. For the remaining light curves obtained in other observing seasons, the same results are given in Figs. 2 to 18.

4. DISCUSSION AND CONCLUSIONS

The first photometric model involving quite large (with the radius of 25° or 21°) and cool (with the temperature of 3600 K) spots of UX Ari was given by Poe and Eaton (1985). The second spot analysis for UX Ari was done by Vogt and Hatzes (1991) based on Doppler imaging technique applied on CaI 8500 Å lines of the component stars. They found that the spot distribution was characterized by a large polar spot and three low-latitude spots located on primary star (with spot temperatures of 3550 K). Aarum and Henry (2003) presented the random-spot model (RSM) analysis of V band photometric observations, made in the 1987-2002 period, to investigate the spot evolution on UX Ari. Their RSM used 10-40 moderately sized dark spots placed randomly on the surface of differentially rotating star to reproduce the light curves of chromospherically active stars.

This review and extensive spot analyses for UX Ari by means of WD (version of 2004, Wilson 2005) programs together with stellar atmosphere formulation revealed some results which are qualitatively similar to but quantitatively somewhat different from the results of Vogt and Hatzes (1991). The spots located on K0 IV component have temperatures ranging from 3560 to 4740 K, and the spots located on G5 V component have temperatures ranging from 4275 to 5640 K. The spots located on K0 IV were found to be warmer than the spot temperature of 3360 K found by Poe and Eaton (1985), but some of them were found to be in agreement with the temperature value of 3550 K given by Vogt and Hatzes (1991). This WD analyses revealed that two spots are located on G5 V component during 1972, 1974-75, 1975-76, 1981-82, 1982-83, 1984-85, 1985-86, 1989-90, 1992-93, 1993-94, 1996-97, 1997-98, 1998-99 and 1999-2000 observing seasons while there is no spot on G5 V component during 1976-77, 1987-88, 1988-89, 1990-91, 1991, 1994, 1995-96 and 2000-01 observing seasons.

The latitudes of the two large spots on G5 V component are found to be at $\sim 30^\circ$ for all observing seasons while the latitudes of large spots on K0 IV component showed an accumulation near the polar region of this star. The longitudinal distribution of the spots located on the components of UX Ari did not show a uniform variability, but the moving of the phase of minimum light of the light curves (by taking into consideration $\phi_{min} \sim 0.6$ which occurred in 1972, in 1981-82/1982-83, in 1992-93 and in 1999-2000, and which is in close relation with the longitudinal location of the spots) may suggest a periodicity of about 7-10 years. Ekmekçi (2010) have noticed that the variation of the UV emission line fluxes with time may be with the periodicity of 7-9 years. Raveendran and Mohin (1995) have also noticed a cyclic variation in the wave amplitude of UX Ari system with a period of $\sim 10 - 13$ years. However, Padmakar and Pandey (1999) found that the spot activity of UX Ari varies with time scale of nearly 18 years while Aarum and Henry (2003) found that UX Ari displayed a 25-year period that was interpreted as a period of activity cycle. The existence of spots on G5 V component is in agreement with the results of Ekmekçi (2010) on UV activity of the system mentioned in Section 1. Another important point is that it would be better to have a WD analysis with estimated metallicities for the component stars.

It was also seen that if it is taken into consideration the spot distribution not only on the surface of K0 IV but also on the surface of G5 V component of UX Ari could reproduce the light curves of the system with the effect of its activity phenomena. The sizes of the spots of K0 IV component obtained by WD analyses of this study are in agreement with of those given by Vogt and Hatzes (1991) using Doppler image technique, and of that by Elias II et al. (1995) using a WD program.

Based on the analysis of Chandra, ASCA, SUMER and SOHO observational data (see e.g. Testa, Drake and Peres 2004, Elias II et al. 1995, Güdel et al. 1999, Habbal, Scholl and McIntosh 2008), it can be seen that there might be a relationship between the large spots of UX Ari (as active regions) and the coronal structure of active components. In addition, it will be very useful to have more simultaneous and more precise/sensitive UV, X-ray, radio and optical observations (including high resolution spectra and IR band CCD observations) to clarify the characteristics of so large spot distributions on the components of UX Ari.

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