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1985/86 PHOTOMETRY OF THE RS CVn BINARY UX ARIETIS

UX Arietis (HD 21242, BD +28° 0532) is a bright (<V> = +6.55 mag), non-eclipsing RS Canum Venaticorum-type star having a period of 6.438 days. The primary and secondary components of this double-line spectroscopic binary were tentatively classified by Carlos and Popper (1971) as KO IV and G5 V, respectively. It is generally accepted that the light variations of chromospherically active stars (RS CVns, BY Draconis, FK Comae, etc.) are produced by the rotational modulation in brightness of dark starspots. Numerous studies advocating the success of light curve modeling applying the starspot hypothesis have been published (Eaton and Hall 1979; Dorren et al. 1981; Dorren and Guinan 1982; Dorren et al. 1984; Holtzman and Nations 1984; Olåh et.al. 1985; Poe and Eaton 1985). Furthermore, the results of various spectroscopic studies lend increasing support to the existence of cool spotted regions located on rapidly rotating stars (Fekel 1980; Ramsey and Nations 1980; Vogt 1981; Vogt and Penrod 1983; Gondoin 1986).

Multi-color photoelectric observations of UX Ari were obtained at Villanova University Observatory on 20 nights, from 1985 September 14 UT through 1986 January 13 UT. A description of the instrumentation, observing procedure, and data reduction technique, as well as a discussion of the differential color and H-alpha indices, is given elsewhere (Guinan and Wacker 1985). The comparison star was 62 Arietis (HR 1012, BD +27° 0500; G5 III; V = +5.54 mag), which previous photometric studies have demonsrated is constant in light and color (Hall, Montle, and Atkins 1975; Sarma and Prakasa Rao 1984). Nightly mean differential magnitudes were computed, in the sense variable minus comparison, for the intermediate band blue (λ4530), yellow (λ5500), red (λ6600), and narrow band red (λ6568) observations, from which corresponding nightly color and H-alpha indices were calculated. The seasonal mean errors for the nightly $\lambda\lambda$ 4530, 5500, 6600, 6568, $\Delta(b-r)'$, and $\Delta\alpha(v-c)$ data sets are, respectively: 0.009, 0.005, 0.006, 0.017, 0.011, and 0.018 mag.

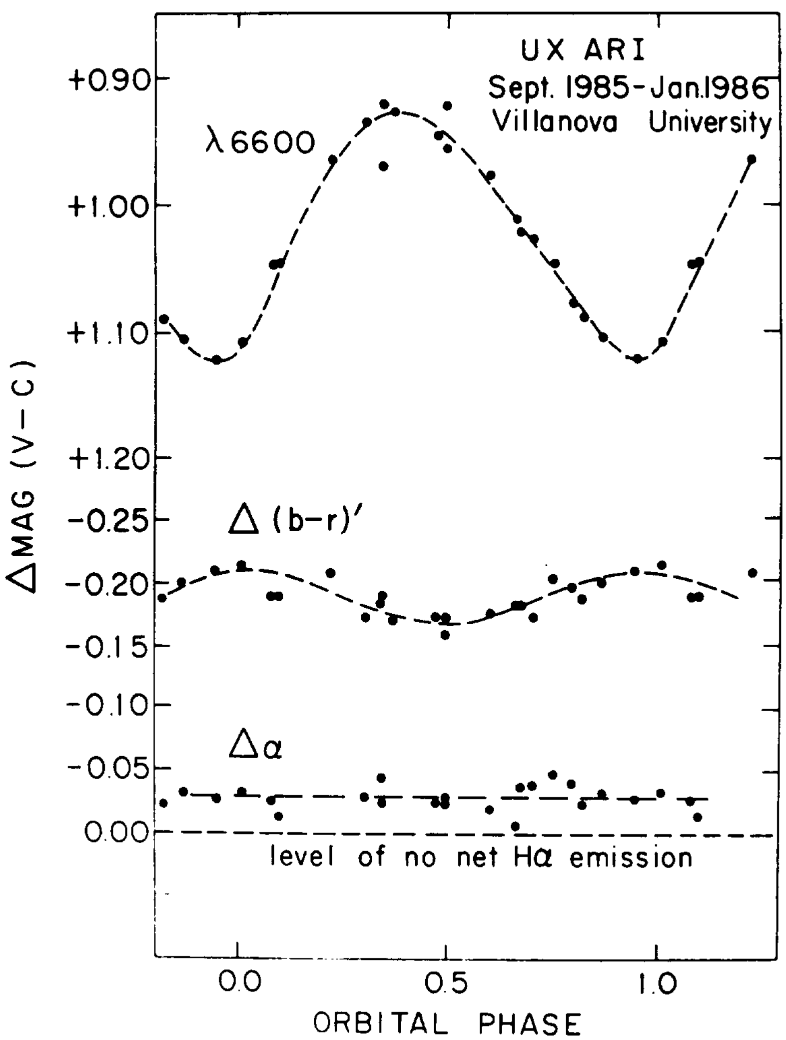

Figure 1

The 1985/86 photoelectric observations of UX Ari, made with respect to the comparison star 62 Ari (G5 III, V = +5.54 mag), are presented. The upper panel is a plot of the nightly mean differential magnitudes formed from the intermediate band red observations. The middle panel is a plot of the differential color index computed from the intermediate band blue and red observations. The lower panel is a plot of the differential H-alpha index, where more negative values indicate greater net H-alpha emission.

The top panel of Figure 1 presents the 1985/86 light curve of UX Ari formed from the intermediate band red observations. The phases were computed according to the ephemeris quoted by Hall, Montle, and Atkins (1975), which is taken from the spectroscopic study of Carlos and Popper (1971). The amplitude of the red light curve is approximately 0.19 mag, with maximum light occurring at about 0.40P and minimum light occurring at 0.94P. Maximum, mean, and minimum light have the following differential values, respectively: +0.93, 1.02, and 1.12 mag. The shapes of the blue and yellow light curves (not shown) are similar to the red light curve. The light variation is wavelength dependent. The blue light amplitude is approximately 0.16 mag, and the yellow light amplitude is about 0.18 mag.

The middle panel of Figure 1 displays the differential color index, $\Delta(b-r)'$, computed from the intermediate band blue and red differential magnitudes. The color curve is phase dependent, with the index reddest when the light curve is brightest. The seasonal mean value of the $\Delta(b-r)'$ data set is -0.186 mag.

The bottom panel of Figure 1 is a plot of the differential H-alpha index, $\Delta\alpha(v-c)$. No apparent phase dependency exists, and the H-alpha emission is present at all phases. Based on the spectral types of the variable and comparison stars, $\Delta\alpha(v-c) = 0.00 \pm 0.01$ mag denotes the level of zero net H-alpha emission. The seasonal mean value for the $\Delta\alpha(v-c)$ data set is -0.027 mag, signifying the presence of weak-to-moderate H-alpha emission during the 1985/1986 observing season.

Wacker et al. (1986) discussed the results of a photometric study of UX Ari conducted at Villanova during Autumn 1981, using instrumentation similar to that of this study. The wavelength dependence of the light variation of UX Ari reported by Wacker et al. is verified by that given here for our 1985/86 observations in which, at visible wavelengths, the light amplitude increases with increasing wavelength. This aspect of the photometric behavior of UX Ari was first documented by Hall, Montle, and Atkins (1975). The Villanova color curves of UX Ari for epochs Autumn 1981 and 1985/86 are both phase dependent with an amplitude of about 0.05 mag, and are reddest at light maximum. It is interesting to note that the Autumn 1981 UBVR light curves of UX Ari obtained by Zeilik et al. (1982) also show a phase dependency of the color index. However, Zeilik et al. state that UX Ari was reddest during light minimum. Most of the chromospherically active stars having color variations that are reddest when the light curve is faintest are single-line spectroscopic binaries, where the spotted visible star is responsible for the photometric distortion wave.

Comparing the seasonal mean values of the Villanova differential color and H-alpha indices of UX Ari for epochs Autumn 1981 and 1985/86 reveals the system was bluer by 0.03 mag, and exhibited slightly greater (by about 0.02 mag) net H-alpha emission in Autumn 1981, with the mean light level of the intermediate band red light curve fainter by approximately 0.07 mag. The differences between the Autumn 1981 and the 1985/86 values of mean light and net H-alpha emission imply a greater degree of starspot activity during Autumn 1981. The fact that UX Ari was bluer at this time is expected on account of the dominance of the hotter (G5) component at visible wavelengths. Thus, in UX Ari, when the spotted regions on the K0 subgiant are most in view, this component (the cooler, redder star) contributes less light, resulting in the systemic color index to be bluest when the light curve is faintest, and reddest when the light curve is brightest (D. M. Popper, 1986, private communication).

The photometric history of UX Ari between 1972 and early 1981 was summarized by Guinan et al. (1981). Subsequent light curves of UX Ari were obtained in 1981/82 and 1982/83 (Sarma and Prakasa Rao 1984), as well as those obtained at Villanova. We compiled all of the published photometric data of UX Ari and, by constructing a smooth curve through each set of observations, tabulated the seasonal values of maximum, mean, and minimum light, phases of the light extrema, and light amplitude. Comparing the phases of minimum light, it is clear that light minimum has remained "anchored" between 0.93P and 0.95P during four of the last six observing seasons (1980/81 - 1985/86). As of January 1987, no observations of UX Ari were available for the 1983/84 season, while the 1984/85 observations acquired by Busso et. al. (1986) have no coverage of minimum light. It is then possible that the phase of light minimum for UX Ari has remained essentially constant for the last six years. In the framework of the starspot model, the phase of minimum light signals the time of maximum visibility of the spotted regions, which is primarily influenced by the longitudinal distribution of the starspots. If the properties of the photometric distortion wave of UX Ari are, in fact, dominated by the presence of spotted regions located on the K0 subgiant, then the constant value of the phase of minimum light demonstrates that the longitudinal distribution of the spots has not undergone significant changes in the last six years. We are not aware of any other non-eclipsing chromospherically active star in which the phase of light minimum has remained constant for four to six years.

In order to gain a satisfactory understanding of the photospheric and atmospheric structure of UX Ari, seasonal photometric and spectroscopic monitoring, preferably coordinated, needs to be established and maintained. A determination of the relative fluxes from the components at visible wavelengths is needed before detailed modeling of the light curves can be undertaken. Obtaining high dispersion, high signal-to-noise spectra of UX Ari would be ideal for this purpose.

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