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OPTICAL DETECTION OF THE INTENSE 1995 NOVEMBER FLARE IN UX ARIETIS

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On 19 Nov. 1995 (UT 10:45) (JD 2450040.9479), Dupree and Brickhouse (1996) detected the brightest RS CVn flare ever observed with the Extreme Ultraviolet Explorer (EUVE) satellite while observing the chromospherically active binary star UX Arietis (HD 21242, G5 V/K0 IV). At that time, the count rate in the Deep Survey (DS) instrument (roughly 70Å to 140Å) was ten times higher than during earlier observations of the star on 7–10 Nov. 1995. The DS instrument detected two additional, weaker flares during the decay phase. By the end of the observing run on 25 Nov. 1995 (UT 11:00) (JD 2450046.9583), UX Ari was still three times above its quiescent level. Dupree and Brickhouse (1996) report that the EUVE spectra of the event are dominated by emission lines of He II and Fe XX, XXIII, and XXIV.

UX Ari was also observed during the period 16–25 Nov. 1995 by Beasley *et al.* (1997) with the National Radio Astronomy Observatory Very Large Array and Very Long Baseline Array. Strong, highly variable microwave emission was detected beginning on 17 Nov. (UT 11:00) (JD 2450038.9583), and multiple flaring events were detected throughout the remainder of the observing run. Further information about these observations can be obtained from tbeasley@aoc.nrao.edu. The first EUVE observation of the flare occurred two days after the start of the enhanced microwave emission.

We have observed UX Ari photometrically every year since 1976, first with manual telescopes and later with automatic photoelectric telescopes (APTs) as part of our program to document long-term changes in chromospherically active stars (see e.g., Henry *et al.* 1995). Since 1987, UX Ari has been observed each night in the Johnson B and V bands with the Vanderbilt/Tennessee State 16-inch APT in Arizona. The observations are made differentially with respect to the comparison star 62 Ari, corrected for differential extinction with nightly extinction coefficients, and transformed to the Johnson system with long-term mean transformation coefficients. Further details of the observing and data reduction procedures can be found in Henry (1995).

Our 16-inch APT observations of UX Ari taken just prior to, during, and just after the 1995 Nov. flare are tabulated in Table 1. Each observation listed is the mean of three consecutive differential magnitudes spanning less than five minutes. The first column gives the Heliocentric Julian Date of the observations. The second column gives the orbital phases computed with the ephemeris

$$JD_{conj} = 2,440,133.75 + 6.43791 \times E \qquad (1)$$

Table 1: 16-inch APT Photometric Observations of UX Ari

Julian Date 2400000+	Phase	ΔB	ΔV
50003.8763	0.1259	0.784	1.041
50004.8801	0.2818	0.674	0.900
50005.8812	0.4373	0.668	0.901
50007.8769	0.7473	0.736	0.987
50008.8776	0.9027	0.760	1.007
50009.8746	0.0576	0.810	1.075
50010.8801	0.2138	0.737	0.965
50011.8767	0.3686	0.659	0.885
50012.8795	0.5243	0.722	0.950
50013.8786	0.6795	0.751	0.988
50015.8735	0.9894	0.800	1.062
50016.8680	0.1439	0.774	1.028
50017.8661	0.2989	0.664	0.897
50018.8655	0.4541	0.681	0.910
50025.7988	0.5311	0.720	0.945
50030.9833	0.3364	0.651	0.881
50031.8096	0.4647	0.692	0.922
50032.9997	0.6496	0.737	0.986
50033.8293	0.7785	0.733	0.975
50033.9791	0.8017	0.732	0.972
50034.9866	0.9582	0.788	1.044
50037.9113	0.4125	0.671	0.900
50038.8219	0.5540	0.735	0.965
50039.8215	**0.7092**	**0.708**	**0.954**
50040.8159	**0.8637**	**0.729**	**0.985**
50043.8107	0.3289	0.661	0.899
50044.8213	0.4858	0.697	0.927
50045.8130	0.6399	0.732	0.964
50046.8368	0.7989	0.729	0.966
50047.7973	0.9481	0.787	1.048

from Carlos and Popper (1971), where zero phase is the conjunction with the G5 V component behind the K0 IV star. Columns 3 and 4 give the differential B and V magnitudes, respectively. Observations acquired during the flare are given in bold font.

The B observations in Table 1 are plotted versus orbital phase in Figure 1. Closed circles represent the observations taken during the four orbital cycles immediately preceding the flare and establish the basic shape of the pre-flare light curve. The circled points represent the observations acquired on four consecutive nights during the orbital cycle in which the flare occurred. The first two circled points, taken at JD 2450037.9113 and 2450038.8219, occur before the start of the flare and are still at the pre-flare brightness level. Note, however, that the second of these two observations was made only 3.3 hours before the start of the microwave flare event observed by Beasley *et al.* (1997). The last two circled points, taken at JD 2450039.8215 and JD 2450040.8159, were acquired during the flare; they show elevations above the pre-flare light level of about 0.03 and 0.015 mag,

respectively. A similar plot of our V data show elevations in V for these two observations of about 0.02 and 0.01 mag, respectively. The open circles in Figure 1 represent the observations taken during the orbital cycle immediately after the flare and show that the light curve has returned to its pre-flare levels. The first of these post-flare observations was not acquired until JD 2450043.8107, three days after the second flare observation. The observed rate of decay implies, however, that the optical enhancement probably became unobservable soon after the second flare observation. Therefore, we estimate the duration of the optical component of the flare to be about two days. It is also likely that the maximum of the optical activity occurred between our observations on JD 2450038 and JD 2450039.

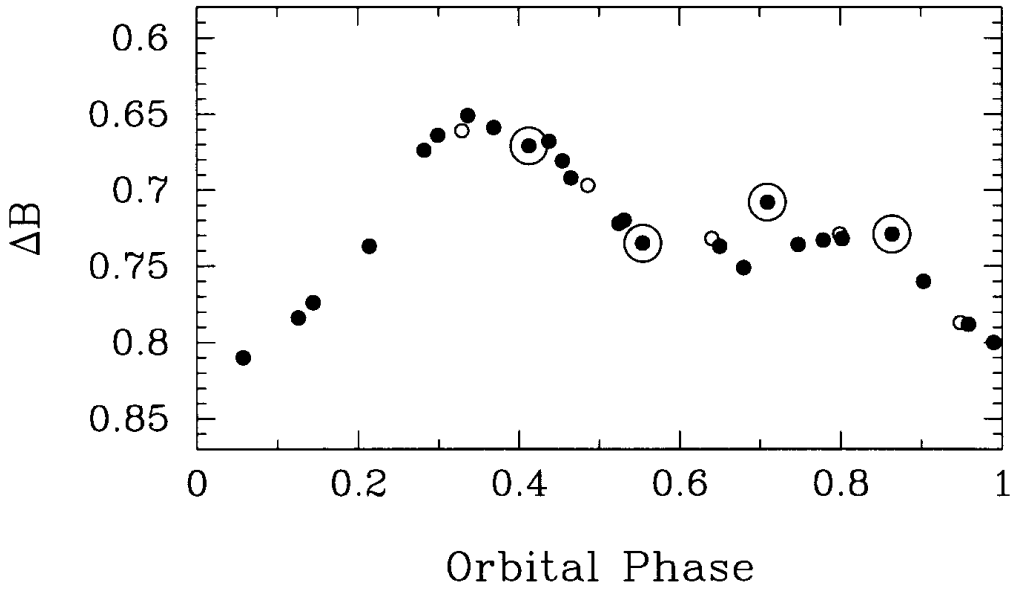

Figure 1. Photometry of UX Ari acquired just before, during, and just after the flare. Symbols are defined in the text.

The light from UX Ari varies continually with an amplitude between about 0.05 and 0.25 mag (Landis *et al.* 1978; Strassmeier *et al.* 1989) due to rotational modulation of star spots. Brightness changes are accompanied by significant (B−V) color changes but in the sense that the star gets redder when it gets brighter due to the light contribution of the G5 V star. The rotation period of UX Ari, as deduced from the brightness variations, is equal to the orbital period. In fact, UX Ari is so well synchronized that the minima of the light curves always occur near orbital phase 0.0, i.e., the most spotted hemisphere of the K0 IV star is always turned away from the G5 V star. (The reflection effect is expected to contribute only about 0.03 mag to the brightness difference between the two hemispheres of the K star.) Amplitude changes over the years are accompanied by relatively little change in mean magnitude of the star, indicating that the amplitude changes are the result primarily of redistribution of a roughly constant total spotted area. UX Ari underwent a rather sudden redistribution of spots during the orbital cycles immediately following those plotted in Figure 1. The light curve brightened by a few percent between phases 0.5 and 0.8, roughly where the flare had occurred, while fading by a similar amount between phases 0.3 and 0.5. The light curve then appeared roughly constant at $\Delta B = 0.7$ between phases 0.3 and 0.8.

Table 2: Optical-Flare Amplitudes in UX Ari

Julian Date 2400000+	Phase	U Amp (mag)	B Amp (mag)	V Amp (mag)	Source
45995.9885	0.5810	0.07	0.02	0.01:	Henry & Newsom (1996)
49686.8136	0.8765		0.11	0.06	this paper
49751.6928	0.9542		0.05	0.03	this paper
50039.8215	0.7092		0.03	0.02	this paper
50040.8159	0.8637		0.015	0.01	this paper

UX Ari is one of a small subset of extremely active RS CVn binaries in which Hα always appears in emission (Nations and Ramsey 1981). It is also one of only three stars from a survey of 69 chromospherically active stars in which Henry and Newsom (1996) found evidence of optical flare activity. In a total of 294 nightly observations from the Phoenix 10-inch APT, spanning 4.0 years between 1984.0 and 1988.0, they detected a single flare, with amplitudes of 0.07, 0.02, and 0.01 mag in U, B, and V, respectively, for a flare-detection rate of 0.0034 flares per nightly observation. We searched our 10-year data set from the 16-inch APT, extending from 1987.9 to 1997.2 and containing 760 nightly BV measurements of UX Ari, for signs of additional flares, following the techniques of Henry and Newsom (1996). We found only two other events, both during the 1994-95 observing season. Therefore, we derive an average flare-detection rate of 0.0039 flares per nightly observation for the 16-inch APT data set. Table 2 summarizes all of the known optical flare events in UX Ari.

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