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PHOTOELECTRIC OBSERVATIONS OF TWO MAJOR FLARES ON UV CETI IN OCTOBER 1983

In 1983 an international program of RS CVn and flare star observations was organized by M. Rodono of the Catania Astrophysical Observatory, Italy (Rodono 1983). This program involved ground-based radio and optical observations carried out in conjunction with IUE satellite observations. One of the stars initially included in this program was UV Ceti (L726-8), and we obtained telescope time at Mount Stromlo Observatory, Australia, for the period 30 September - 7 October. After our observing session was over and we returned to our home cities, we learnt that UV Ceti had been dropped from the international program. Nevertheless, we think there is value in documenting our observations, given the detection of two major flares.

Continuous monitoring of UV Ceti took place on two nights only, 30 September and 1 October, for a total of 4 hours 42 minutes, with a single channel photon-counting EMI Gencom Starlight-1 photometer (see Wolpert 1982) and the 76 cm "Reynolds Reflector". Observations were carried out in the B band of the Johnson UBV system. The photometer was interfaced through UART circuitry to an Hitachi MB-6890 Personal Computer. All machine programs to monitor, store and analyse the photometer output were written in BASIC. A chart output of the photon counter's digital readings provided a real time visual means of flare detection.

Standard stars HD 9228, 10254 and 10824 were selected from Cousins and Stoy (1963) and Cousins, Lake and Stoy (1966), and comparison stars B and C on the finder charts provided by Rodono were used. Continuous monitoring of the program star was undertaken, using a 10 second integration time; the monitoring intervals are indicated in Figure 1.

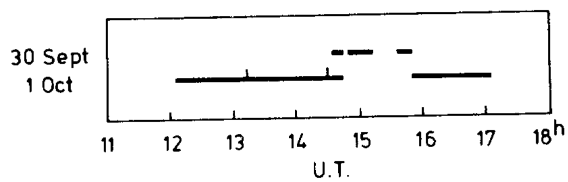

Figure 1

UV Ceti monitoring periods, September-October, 1983.
The two flares detected are indicated by spikes.

Problems associated with flare detection and identification during monitoring runs have been discussed by Kunkel (1973), Moffett (1974) and Gurzadyan (1980), amongst others. The detection criterion we adopted for a flare was the existence of several successive readings above the quiescent level of the star, where the maximum magnitude level exceeded three standard deviations. On this basis, no flares were detected during the short monitoring run on 30 September, but on 1 October two major events were recorded. Details of these are provided in Table I (following the reporting system recommended by Andrews et al. 1969), and light curves are given in

Table I

Characteristics of Observed Flares

Date 1983	Flare Number	U.T. of Max. h.	m.	s.	t_b (sec)	t_a (sec)	Duration (sec)	Δm_B	σ (mag)	Air Mass
Oct. 1	1	13	13	57	18	450	468	2.46	0.06	1.16
Oct. 1	2	(14	30	00)	--	(720)	(>740)	>2.00	0.04	1.06

Figures 2 and 3. The gaps in the light curves indicate breaks in the continuous monitoring to check the centering of the star in the 30 arc second aperture. In Table 1, t_b and t_a give the pre-maximum and post-maximum flare duration, respectively, and "Duration" = $t_b + t_a$. The second last column gives the standard deviation of random noise during the pre-flare quiescent state. It should be noted that because the commencement of Flare No. 2 was missed and its peak intensity may not have been recorded, some values in Table 1 are in parentheses, and the t_b column is blank. Another reason for viewing some of the data in Table I with some degree of caution is the problem of accurately defining the flare start and end points, but particularly the latter (see Kunkel 1973; Oskanian 1968).

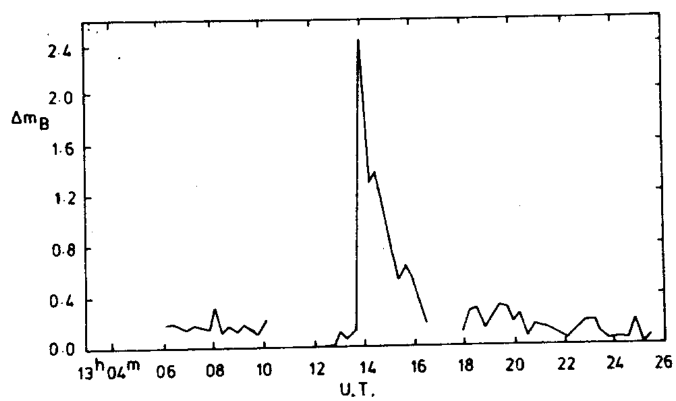

Figure 2

Light Curve of Flare No. 1

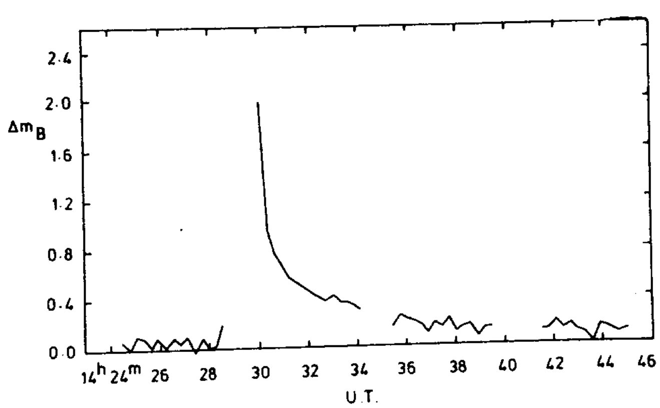

Figure 3

Light Curve of Flare No. 2

Of all known flare stars, UV Ceti is the most active in the visual wavelength band (Bateson 1971), which is to be expected given that there is an inverse relationship between flare frequency ("f", in flares per hour) and absolute magnitude (M_V). For the U band, this is given by the following equation (after Gurzadyan 1980:14):

$$\log f_U = -1.78 + 0.148M_V$$

The absolute magnitude of UV Ceti is 14.78. Flare frequency, meanwhile, is dependent on wavelength of observation:

$$f_U > f_B > f_V$$

We obtained a value of 0.43 for f_B as a result of our observations (but it is important to note that in order to obtain a more statistically reliable value for f_B, a larger number of flares would have to have been observed). Gurzadyan (1980:15) has also shown that flare frequency is not constant, but can exhibit considerable variation on an annual basis. For example, Kunkel (1973) observed that f_U appeared to increase by of the order of 40% over the two years he monitored the star, while Lacy et al. (1978) noted a marked difference in flare frequency between 1976 and 1978. Bateson (1971) has suggested that UV Ceti exhibits a 6-year cycle of flare activity, not in terms of flare frequency per se, but rather the total flare energy output per year. He has proposed 1963 and 1969 as "peak" years, in which case our 1983 observations lie between two maxima (1981 and 1987). Bateson's interesting hypothesis has yet to be subjected to critical examination.

The two flares on 1 October 1983 occurred within 1 hour and 16 minutes of one another, and in this regard our results mimic those of other researchers who report two or more major flares in quick succession, at a rate that differs quite markedly from the flare frequency (e.g., Bateson and Kohler 1968; Higgins et al. 1968; Ichimura et al. 1970; Osawa et al. 1968). This is a feature noted of other flare stars also, and prompted Jarrett and Eksteen (1969:133) to report that flares "...tended to occur within a few hours of one another." In fact, this is not always the case:

Lacy et al. (1976) and Petersen et al. (1984) have clearly demonstrated that the "separation interval" between successive flares is random, and that flare occurrence follows a Poisson distribution.

Both of our flares can be classed as "major flares" (i.e., $\Delta m_B > 1.0$), which are also comparatively common for UV Ceti given that an inverse linear relationship has been established between Δm and M_V. Gurzadyan (1980:19) defined a parameter he terms the "distribution function of flare amplitude", denoted by $F(\Delta m)$, which is given by the equation

$$F(\Delta m) = \frac{n(\Delta m)}{\Sigma n(\Delta m)}$$

where $n(\Delta m)$ is the number of flares with amplitudes between Δm and $\Delta m + 1$, and $\Sigma n(\Delta m)$ is the total number of flares recorded (in any one wavelength band per unit interval of time). Using his own data, derived from 142 UV Ceti flares observed in the B band, Gurzadyan (1980:20) provides the values for $F(\Delta m)$ listed in Table II.

Table II

Distribution function of B band flares, UV Ceti

	Δm				
	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5
$F(\Delta m)$	0.76	0.17	0.04	0.03	0.00

If these figures are indicative of the 1983 situation, we can count ourselves exceedingly lucky in detecting two major flares of such magnitude, given that only 7% of all UV Ceti flares could be expected to display Δm_B values of 2.0 or greater.

Although our light curve for Flare No. 2 is not complete, it would appear that both of the outbursts we detected were discrete flares rather than the more complex "flare events" defined by Moffett (1974). Of the four different types of flare light curves identified by Oskanian (1968), both of our outbursts belong to Type 1, which is characterised by a very rapid rise time, and comparatively rapid decline. Oskanian found this to be the most common type in the case of UV Ceti flares.

In Figure 2 there is a critical short section of light curve missing immediately before the outburst, but the basic pattern suggests that the flare was preceded by a "dip" or "negative flare" of about three minutes duration and $\Delta m_B \sim 0.15$. For many years the existence of such phenomena was in doubt, but their occurrence is now well established, particularly after the remarkable example provided by EQ Pegasi in 1980 (Giampapa et al. 1982). Preflare dips have been noted for UV Ceti by Cristaldi et al. (1980), who produced documentation associating these rare events with 11% of all flares they detected between 1968 and 1976 (where n = 174).

Finally, the post-flare baseline fluctuations that have been reported by Bateson and Kohler (1968) were not apparent during our series of observations.

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References:

Andrews, A.D., Chugainov, P.F., Gershberg, R.E., and Oskanian, V.S., 1969, Inf. Bull. Var. Stars, No. 326.

Bateson, F.M., 1971, Southern Stars 24: 23-33.

Bateson, F.M., and Kohler, D., 1968, Southern Stars 22: 118-127.

Cousins, A.W.J., Lake, R., and Stoy, R.H., 1966, *Photoelectric Magnitudes and Colours of Southern Stars, II.* London, H.M.S.O. (Royal Obs. Bull. 121).

Cousins, A.W.J., and Stoy, R.H., 1963, *Photoelectric Magnitudes and Colours of Southern Stars.* London, H.M.S.O. (Royal Obs. Bull. 64).

Cristaldi, S., Gershberg, R.E., and Rodono, M., 1980, Astron. Astrophys. 89: 123-125.

Giampapa, M.S., Africano, J.L., Klimke, A., Parks, J., Quigley, R.J., Robinson, R.D., and Worden, S.P., 1982, Ap. J. 252: L39-L42.

Gurzadyan, G.A., 1980, *Flare Stars.* Oxford, Pergamon Press.

Higgins, C.S., Solomon, L.H., and Bateson, F.M., 1968, Austr. J. Phys. 21: 725-734.

Ichimura, K., Noguchi, T., and Watanabe, E., 1970, Tokyo Astron. Bull. 198: 2299-2305.

Jarrett, A.H., and Eksteen, J.P., 1969, Mon. Not. Astr. Soc. S. Afr. 28: 131-133.

Kunkel, W.E., 1973, Ap. J. Supp. 25: 1-36.

Lacy, C.H., Evans, D.S., Quigley, R.J., and Sandmann, W.H., 1978, Ap. J. Supp. 37: 313-320.

Lacy, C.H., Moffett, T.J., and Evans, D.S., 1976, Ap. J. Supp. 30: 85-96.

Moffett, T.J., 1974, Ap. J. Supp. 29: 1-42.

Osawa, K., Ichimura, K., Noguchi, T., and Watanabe, E. 1968, Tokyo Astron. Bull. 188: 2205-2211.

Oskanian, V.S., 1968, In Detre, L. (ed.). *Non-Periodic Phenomena in Variable Stars.* Budapest, Academic Press. Pp. 131-136.

Petersen, B.R., Coleman, L.A., and Evans, D.S. 1984, Ap. J. Supp. 54: 375-386.

Rodono, M., 1983, Inf. Bull. Var. Stars, No. 2322.

Wolpert, R.C.; 1982, In Hall, D.S. and Genet, R.M. (eds.). *Photoelectric Photometry of Variable Stars.* I.A.P.P.P. Pp. 4.54-4.57, 5.32-5.34.