STATISTICS OF FLARES OBSERVED FOR UV CETI TYPE STARS YZ CMI, AD LEO, AND EV LAC AT THE OKAYAMA OBSERVATORY

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ABSTRACT.Photoelectric monitoring of flare stars YZ CMi, AD Leo, and EV Lac has been done at the Okayama Observatory since early 1970s. This is a simultaneous UBV observations with a high time resolution. Some statistics of the flares of the UV Ceti type stars are presented.

1. Introduction

A photoelectric patrol observation of several flare stars was started at the Okayama Observatory in 1968 by the request of the "Working group of UV Ceti type stars" of the IAU Commission No. 27 (Osawa et al. 1968). Dr. Chugainov of the Crimean Astrophysical Observatory, the chairman of the working group, kindly supplied necessary information concerning the international cooperative programme.

At Okayama a photometer was designed to observe rapid phenomena like flare-ups of UV Ceti type stars (Shimizu and Norimoto 1972). A three color filter set on a wheel is rotated continuously with a rate of 20 Hz. The light beam collected by the 91 cm reflector is received through the three color filter set by an EMI 6256B photomultiplier and a synchronous detection is made. The time constant of the system is 0.2 second of time. A three-channel strip chart recorder has been used for the observations with the rolling speed of 20 mm per minute on a paper.

This is a simultaneous UBV photoelectric observation of stellar flares with a time resolution higher than one second. The detection threshold of the flare-ups is $\Delta U = 0.2$ mag and depends on the brightness of the quiescent intensity of the stars and sky conditions. It seems to me that it is statistically complete only for those brighter than $\Delta U = 1.0$ mag. Several UV Ceti type stars have been monitored with the photometer since early 1970s by Ichimura et al. (1974, 1978, 1981, 1986), and still on-going at present in 1989. In this brief report, some statistics of the flares observed during 1974 to 1988 in YZ CMi, AD Leo, and EV Lac are presented.

Name	U-B	B-V	V	Mv	Sp.	Period	Remarks
YZ CMi	1.01	1.61	11.20	12.3	M4.5Ve	2.781d	0.12mag var
AD Leo	1.08	1.54	9.43	11.0	M4.5Ve	-	UC? 26.5y
EV Lac AB	0.75	1.37	10.05	11.5	M4.5Ve	4.378d	UC 45y 2au

L. V. Mirzoyan et al. (eds.), Flare Stars in Star Clusters, Associations and the Solar Vicinity, 43–47.

2. Number frequency of flares in YZ CMi, AD Leo, and EV Lac

The total watch time is 147 hours for YZ CMi, 299 hours for AD Leo, and 229 hours for EV Lac, distributing over 15 years from 1974 to 1988. The number of flares recorded is 68 in YZ CMi, 69 in AD Leo, and 46 in EV Lac, which are large enough number to see average number frequency in unit time. The average number frequency of flares in an hour is 0.46 for YZ CMi, 0.23 for AD Leo, and 0.20 for EV Lac. It is interesting to see if there is any time variation of the average number frequency year to year. Dividing the whole period of 15 years into four terms, the average frequencies per an hour appear 0.29, 0.22, 0.25, 0.15 for AD Leo, and 0.17, 0.25, 0.19, 0.20 for EV Lac. For YZ CMi, only the last three terms have large enough length of watching time to see the average number frequencies, which are 0.70, 0.28, and 0.43. Difference of the number frequencies between term to term is noticed for YZ CMi, and barely noticed for AD Leo and EV Lac.

Name	year	t(h)	n	n/t(h)	(U-B)+ rms	(B-V)+ rms	n'
YZ CMi	77-80	49	34	0.70	-1.09±0.22	0.18±0.22	23
	82-84	51	14	0.28	-1.23±0.27	0.22±0.21	10
	85-88	47	20	0.43	-1.16±0.15	0.20±0.20	13
	(77-88	147	68	0.46)			
AD Leo	74-76	65	19	0.29	-1.11±0.19	0.17±0.32	14
	77-80	51	11	0.22	-1.02±0.11	0.16±0.13	4
	81-84	116	29	0.25	-1.19±0.21	0.24±0.35	19
	85-88	67	10	0.15	-0.59±0.58	0.47±0.28	8
	(74-88	299	69	0.23)			
EV Lac	74	29	5	0.17	-1.05±0.23	0.16±0.15	4
	79	32	8	0.25	-1.07±0.12	0.00±0.11	5
	80-84	119	23	0.19	-0.64±0.20	0.38±0.39	17
	85-88	49	10	0.20	-0.78±0.35	0.34±0.21	9
	(74-88	229	46	0.20)			

3. Average color of flares in YZ CMi, AD Leo, and EV Lac

Two colors of (U-B)+ and (B-V)+ of the flares at peak brightness within a few seconds of time from the maximum appeared on the paper chart were read out. The colors of the 126 flares at the peak brightness apparently show similar values in most of the terms, that are (U-B)+ = -0.99±0.21 and (B-V)+ = 0.23±0.23 for the average of three stars in the four terms and standard deviation from the average. The similarity is even more clear if three discrepant values are ignored, that are (U-B)+ = -1.12±0.07 and (B-V)+ = 0.17±0.07 for 92 flares. The present values can be compared with (U-B)+ = -0.88±0.31 (n=153) and (B-V)+ = 0.34±0.44 (n=77) of Moffett (1974) and (U-B)+ = -0.64±0.61 (n=45) and (B-V)+ = -0.02±0.72 (n=12) of Mirzoyan et al. (1983).

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4. Energy release by flare events

The intensity at flare maximum is expressed in terms of the quiescent star's brightness in the U band for stars on which flares were detected, because the U band shows the most prominent flares. Average brightening of 183 flares is $\Delta U = 1.36 \pm 0.28$ mag at flare maximum for the present three UV Ceti type stars in the four terms which covers 1974-1988. The intensity range is large from 0.46 mag to 3.30 mag in average.

The more reliable flare parameter to show the energy released in flare event is the equivalent duration of the flare. The equivalent duration is the energy of flare event expressed in time of the relative intensity of a flare event normalized in unit of the quiescent star intensity in the U band and the relative intensity is a function of time as observed during flare event. The total equivalent durations over the length of the watching time is a rough relative measure of the energy released by flare events. It looks far from a constant value and changes in nearly two orders of magnitude from one term to the other. Cumulative number count of the equivalent durations with frequency of occurrence is expressed by a power law function with an exponent around -0.4 over 3 to 4 orders of energy range of equivalent duration, when summed up for 1974 to 1988. It shows that a few of the biggest flare events are so efficient that one flare event could release more than half or even 95% of the whole amount of energy released by many flare events in a term of a few years.

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Name	year	ΔU rms	n	min ΔU	max ΔU
YZ CMi	77-80	1.55±0.85	34	0.43	3.50
	82-84	1.44±0.54	14	0.55	2.86
	86-88	1.77±0.69	20	0.53	2.97
			(68)		
AD Leo	74-76	1.54±1.12	19	0.34	5.01
	77-80	1.02±0.69	11	0.37	2.30
	81-84	1.17±0.91	29	0.23	>5.17
	85-88	1.12±0.71	10	0.53	>3.14
			(69)		
EV Lac	74	1.45±0.55	5	0.81	2.24
	79	1.80±0.90	8	0.62	3.50
	80-84	1.08±0.60	23	0.24	2.67
	85-86	1.00±0.70	10	0.46	2.90
			(46)		
		1.36±0.28	183	0.46	3.30

Name	year	ΣP/t(h)	No. of Event	P of 1st biggest event (% in ΣP)	P of 2nd biggest event (% in ΣP)
YZ CMi	77-80	1.13	31	>3120min (>94)	86.8min (2)
	82-84	0.020	10	>13 (>22)	12.5 (20)
	86-87	0.14	18	259 (65)	>27.7 (>7)
			(59)		
AD Leo	74-76	0.35	19	>1318 (>95)	39.4 (1)
	77-80	0.072	11	190 (87)	17.8 (8)
	81-84	0.064	27	>350 (>79)	29.9 (6)
	85-88	0.020	10	>65 (>82)	5.2 (6)
			(67)		
EV Lac	74	0.0032	5	2.7 (49)	0.8 (15)
	79	0.038	8	37 (50)	14.0 (19)
	80-84	0.013	19	51 (55)	25.7 (28)
	85-86	0.018	9	46 (86)	>2.6 (>5)
			(41)		

Color band	Filter	λ (A)	Δλ (A)
U	UV-DIC 1mm	3700	430
B	VV-42 + UV39	4300	890
V	VO-51	5500	950

with an EMI 6256B photomultiplier

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PANOV: Did you find any changes of the flare colours during the development of a flare?

ISHIDA: I did not study that problem.

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