A STUDY OF SOME FLARE STARS IN A COMA FIELD

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Although short-lived stellar brightenings had been reported several times prior to 1948, it was Luyten's observations of UV Ceti that started serious study of the stars known as flare stars. Luyten reported a flare of more than 2.5 magnitudes on star L 726-8 (UV Ceti) on 7 December 1948 and calculated a minimum excess energy of 4×10^{31} ergs necessary to produce the outburst. This flare observation was confirmed by another flare observed by Luyten. Searching through the patrol plates in the Harvard collection, Shapley reported brightenings back to 1900. A complete tabulation would today yield over 100 known flares of UV Ceti.

Flare stars are characterized by rare and very short increases in brightness with amplitudes of up to six magnitudes. The sharp rise to maximum brightness takes only a few, or several tens of seconds after the flare has commenced. The total duration of the flare lasts no longer than several tens of minutes and usually much less. All known flare stars are dwarfs of spectral class dK2e or later, and most are class dM3e or later. The H and CaII emission lines are present in these types of stars and sometimes weak HeI lines are also seen. More than 60% of the known flare stars are also members of binary systems, being usually the fainter component. Of the flare stars of known mass, none are above 0.37 solar mass. Their absolute luminosities range from $M_V = +8.0$ down to that of some of the faintest stars known, $M_V = +19.0$. No UV Ceti stars have been found beyond 65 light years distance from the sun. The numbers decrease with increasing distance. The question arises whether the effect is real, i.e. there is an association of these variables around the sun, or is due entirely to the intrinsic faintness of these variables. A high percentage of binaries is a characteristic of stars which form a stellar association, and this lends support to the former conclusion. In addition to flares, these stars appear to exhibit aperiodic variations with amplitudes of several tenths of a magnitude and time scales much longer than those for the flares. Spectral observations indicate that these two types of light variation are caused by different mechanisms. It does not seem that the flares are of thermal origin. Astronomers are continuing to study the possibility of relating the flare outbursts to solar flares.

On the Nantucket plates it is only possible to confirm larger amplitude flares because the long exposure times tend to blend the maxima and minima. Variable 20*, discovered by Pamela Bonnell in 1971, was one flare star I studied. The first step was to measure the variable's magnitude on the plates using comparison stars. The comparison stars were called a, b, c, d, etc. Then I estimated the variable's brightness to lie between two stars to a tenth of an interval. For example, b4 meant that the variable was 4/10 of an interval from b and 6/10 of an interval from c. After measuring

* Provisional designation for as yet unpublished star in the Coma field centered at $\alpha = 12^h\ 25^m$, $\delta = +28°5$ (1900).

the variable on the plates it became apparent that the differences were due only to scatter and that there were only two very bright measurements. I used a flyspanker, a glass plate with several graded series of star images, in order to obtain actual magnitudes for the flares. A scale of this sort can be prepared by photographing a star, or a star field, with exposure in seconds in a geometrical ratio 1, 3, 9, 27, etc. The plate is shifted very slightly between exposures, resulting in a scale of star images in a line with progressively increasing size and density. The interval between successive images corresponds to approximately a stellar magnitude. By placing such a comparison scale on the plate with the unknown stars and examining it with a small eyepiece, one can estimate the brightness of each stellar image to tenths of the unit of the scale. This type of scale has the advantage that account is taken of the general appearance of the images as to side-scatter and blackness. It is advantageous if the scale and the plate to be measured are photographed with the same instrument and are of the same type emulsion. A comparison scale can also be made by photographing stars with different apertures increasing in geometrical ratio, but with equal exposure. By using such a comparison scale I measured a previously determined magnitude sequence and my comparison stars in "flyspeck" units. A calibration curve of flyspeck units versus the known magnitudes from the sequence was then plotted. From the calibration curve I could read the actual magnitudes for my comparison stars and thus determine the magnitudes of the flares. Flare 1 occurred on plate NA4606 on 14-15 June 1968 (JD 40,002.583) with a magnitude of 12.5. Flare 2 occurred on plate NA4989 on 19-20 May 1971 (JD 41,091.682) with a magnitude of 14.7. The average magnitude was 15.8. Thus variable 20 was observed to have an amplitude of 3.3 magnitudes.

Similar work was done on Variable 23*, discovered by D. Hoffleit. This variable was invisible on all plates except the flare-up plates. The flyspanker was again used to obtain magnitudes. The star flared on plate NA4863 on 27-28 May 1970 (JD 40,734.638) with a magnitude of 13.5. It flared again on plate NA5104 on 11-12 May 1972 (JD 41,449.641), and on plate NA5105 taken the same night (JD 41,449.692) with magnitude 13.5. The flare-up thus lasted at least an hour and had an amplitude of not less than 2.5 magnitudes (using the plate limit for the minimum).

A third star, Variable 22*, also discovered by D. Hoffleit, is suspected of being a flare star. I had originally assumed it to be a short period variable and attempted to compute a period for it. On second inspection it seemed possible that it may be a flare with one maximum, possible two others, and a large amount of scatter. One possible maximum occurred on plate NA5105 on 11-12 May (JD 41,449.692) with a magnitude of 15.1. Other possible maxima are on plates NA4376, 22-23 May 1966 (JD 39,268.617) and NA4893, 28-29 June 1970 (JD 40,766.661) with magnitudes of 15.6. The average magnitude is 15.9. Further observations of this star are necessary to determine if it is a true flare star.

* Provisional designations for as yet unpublished stars.

I also checked for flare-ups on the known flare stars CT, CV, and CX Comae. These stars were studied by G. Haro and E. Chavira at Tonanzintla Observatory, Mexico. I found no flares for these stars on our NA plates. However, this was hardly surprising. Their 64 plates with 535 different exposures covered $89^h\ 10^m$ of effective observational time and yielded one flare each for two stars and two flares of the third. Our NA plates cover only approximately 51^h of observing time with individual exposures ranging from 10 to 60 minutes.

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REFERENCES

Glasby, J.S. 1969, Variable Stars (Cambridge, Mass.: Harvard University Press), 229-241.

Haro, G., and Chavira, E., "Flare Stars in Stellar Aggregates." Paper presented at ONR Symposium Flagstaff, Ariz. June, 1964.

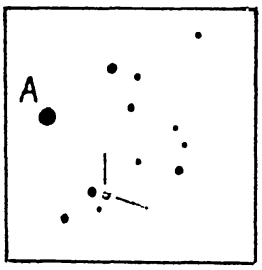
King, E.S. 1930, A Manual of Celestial Photography (Boston, Mass.: Eastern Science Supply Co.) 135-136.

Solomon, Leonard H. 1966, "A Study of Flare Stars," Smithsonian Astrophysical Observatory Research in Space Science Report Number 210, (Cambridge, Mass.: Smithsonian Astrophysical Observatory).

TABLE I

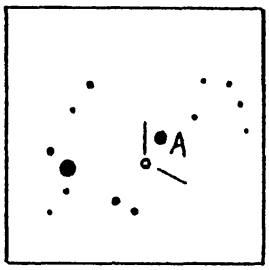
Positions and Magnitude Ranges of Variables in a Coma Field

STAR NAME	R.A. (1900)	DEC. (1900)	m_{pg}	Δm_{pg}	TYPE
CT Comae	$12^h\ 19^m.5$	+24° 38!1	14.9	1.5	M
CV Comae	$12^h\ 20^m.2$	+26° 18!1	16.3	2.5	M
CX Comae	$12^h\ 22^m.7$	+27° 35!1	15.6	1.3	M3-4
Variable 20	$12^h\ 25^m\ 03^s$	+32° 28!4	15.8	3.3	
Variable 23	$12^h\ 25^m\ 52^s$	+29° 32'	plate limit∿16.	>2.5	
Variable 22	$12^h\ 29^m\ 02^s$	+24° 00'	15.9	0.8	



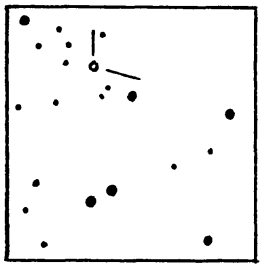
Variable 20

A = BD+32° 2254
approx. 25'x25'



Variable 22

A = BD+24° 2474
approx 15'x15'



Variable 23

approx. 15'x15'

Figure 1. Finder charts for Variables 20, 22 and 23. North up.