FAR-ULTRAVIOLET AND VISIBLE OBSERVATIONS OF FLARES ON dMe STARS

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ABSTRACT

Four large flare events - one on each of the dMe stars UV Cet, AT Mic, EV Lac and EQ Peg - have been witnessed during a total of 17½ hours of far-UV (λλ1150-1950) IUE exposures. Some observational characteristics of these four events are compared. Two showed strong enhancements of chromospheric and transition-region line strengths. The other two did not, even though their visible flares were intense ($\Delta U \sim 2$ mag). The brightest UV flare spectrum (EQ Peg) is contrasted with that of the largest solar flare seen from 'Skylab'.

1. FREQUENCY OF FAR-UV FLARE DETECTIONS

In aggregate, more than 150 hours of IUE exposure time have been devoted to far-ultraviolet spectroscopy of nearby dMe stars. Many "quiescent state" spectra have been recorded (see for example: Hartmann et al 1979, Haisch and Linsky 1980, Butler et al 1981). Detected line fluxes for the prominent C IV λ1550 transition-region emission are in the range from 1 to 5 $.10^{-16}$ Wm^{-2} for a sample of 9 flare stars in the solar neighbourhood. Corresponding stellar surface fluxes (20-150 Wm^{-2}) are similar to, or somewhat higher than, those of solar active regions.

Occasionally, stellar flares have also been detected by IUE, as transient enhancements of line fluxes. We define an event as one showing enhancements of at least 50% (or else at least 3σ) for at least 2 lines, when integrated over the typical time-resolved element of ½ hour, or a measured flare continuum flux exceeding 10^{-17} Wm^{-2} $Å^{-1}$ over more than 100Å. We are aware of only six such positive detections (Butler et al, 1981; Bromage, 1981; and those reported at this Colloquium by Haisch, by Linsky, by Worden for Baliunas and Raymond; and in the present paper). Thus, IUE observers might now expect on average only one such flare per day. This is rather lower frequency than that predicted from U-band statistics and extrapolations below

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3000Å. However, as described below, stellar flares with intense visible flashes but rather insignificant far-UV fluxes may be fairly common.

2. FOUR OBSERVED FLARES

The table summarises some contrasting features of the four strong flare events witnessed by the present authors during four IUE shifts, in 1980 September 17 and 19 and 1981 September 2 and 3. These flares are described and discussed in detail elsewhere (Bromage et al 1983).

	Star	Optical Event		Far UV Event			
	M_V, dist. (mag, pc)	time of max. (UT)	ΔU max. (mag)	IUE exp. time (min)	C IV λ1550Å enhance factor	C IV λ1550Å flare flux*	other lines enhanced
1.	UV Cet (15.8, 2.7)	17.9.80 22.22	2.4	55	<1.5	<1	-
2.	AT Mic (11.1, 7.5)	19.9.80 16.40:?	?	30	5±1	13±3	C II, Si IV
3.	EV Lac (11.7, 5.1)	3.9.81 17.48	$\gtrsim$2#	30	1.5:	2:	-
4.	EQ Peg (13.4, 6.5)	3.9.81 22.55:? (+22.30:?)	? ?	53 (+24)	9±2	18±3	N V, He II, C II, Si II, C III 1176 (Mg II, Fe II)

* units of 10^{-16} Wm^{-2} averaged over 30 minutes
\# estimate based on: observed ΔB of 0.7 mag (Chugainov, private communication)

The flares on AT Mic and EQ Peg were detected by IUE, but had incomplete ground-based optical coverage due to cloud, and no visible flares were seen. Thus, for these events ΔU values are not known, although statistically it is highly unlikely that ΔU exceeded 3 mags. Also, the times of flare maxima can only be estimated to within about 20 minutes.

A strong continuum is present on the AT Mic flare spectrum, amounting to 4.10^{-16} Wm^{-2} $Å^{-1}$ at λ1700-1900Å, smoothed over an assumed effective duration of 100 s. The continuum can be fitted by (inter alia) a black body with T ∿ 13000K.

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The spectrum of the EQ Peg flare has the highest line fluxes so far reported for dMe stars, even though these are averaged over the whole 53 minute exposure. The estimated peak C IV surface flux in the flare is 3000 Wm^{-2}, which is several hundred times that from the Quiet Sun. The far ultraviolet flare spectrum also shows a weak continuum longward of λ1700Å. In addition, just before this spectrum was taken, a mid-ultraviolet (λλ1950-3250Å) spectrum was obtained, and this also shows large line flux enhancements - of Mg II and Fe II multiplet UV1 in this case. From the known position and orientation of the EQ Peg double star in the IUE large aperture at the time of observation, we deduce that the flaring star was component B. It is quite likely that a multiple flare event was witnessed. An effective electron density exceeding 10^{10} cm^{-3} is implied by the presence of C III λ1176 and absence of C III λ1909 and Si III λ1892 lines.

Turning to the UV Cet event, simultaneous UBV and optical spectroscopy were obtained with the SAAO Sutherland 0.5 and 1.9 m telescopes. No detectable far UV line enhancements were seen, even though an IUE exposure was optimally timed. Similarly, only small enhancements were recorded during the EV Lac event. This latter was discovered during simultaneous B monitoring by P F Chugainov (private communication).

3. COMPARISON WITH A SOLAR FLARE SPECTRUM

The far ultraviolet spectrum of an early stage in the largest solar flare observed from Skylab (Cohen et al 1978, Cohen 1981) has been compared with the IUE stellar flare spectra. Extracts from Cohen's Atlas were digitised, calibrated, and then degraded to the IUE low resolution.

During this Colloquium, the many similarities between dMe and solar flares have been repeatedly emphasised. (See also the report by Kahler et al, 1982). It is therefore worth pointing out here some glaring spectral differences, between this particular solar flare spectrum and that of our EQ Peg event. Relative to the C II and C IV fluxes, we note for example that He II λ1640 and N V λ1240 appear to be an order of magnitude stronger in the stellar case. However, the Skylab solar flare spectrum does bear a somewhat closer resemblance to our AT Mic (and the Butler et al (1981) Gl 867A) weaker stellar flare spectra. A more detailed comparison of these stellar and solar spectra will be reported elsewhere (Bromage et al 1983).

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DISCUSSION

Rodonò: Did you attempt any time-trailing during the observations?

Bromage: No. But normally we made two exposures in the large aperture giving 30 minutes time resolution.

Evans: (Question lost).

Bromage: Because of the position angle with respect to the centre of gravity of the aperture.

Evans: You really can resolve them properly.

Bromage: Yes.

Evans: I noticed on your trailed image that you had in fact two things on top of each other. You have a continuum trace which goes right through emission lines and the emission lines on top.

Bromage: It looks like a continuum but it may just be a lot of emission lines.

Mullan: Your plot of intensity against wavelength was of the intensity per unit wavelength. On a plot using intensity per unit frequency interval it would be almost flat. That's the kind of spectrum you would expect from free-free coronal emission and so that is not an argument in favour of a black body.

Bromage: I am not arguing in favour of a black body.

Linsky: I would like to make two comments. The first is that anyone who uses the continuum in IUE data from flares ought to be very careful about scattered light. It is essential to correct for this. If this is not done then the continuum increases both to short and to long wavelengths. The theoreticians would have fun in interpreting such a spectrum. The second remark is that there is a poster paper (by Butler et al) that shows time-trailed spectra of AU Mic that show evidence of flares. So it is possible to use IUE in its time-trailed mode to give reasonably high time resolution.