THE TIMESCALES OF VARIATIONS IN CONTINUUM AND HYDROGEN LINES DURING STELLAR FLARES

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Abstract
Light curves of major stellar flares have been used to study the behavior of U-B, B-V, and V-R. The majority of the flux transmitted through these filters is continuum radiation, but U and B are affected by emission lines. The variability of Hα and Hβ emission lines were monitored through narrow band filters. The timescales of emission line variability are considerably longer than those for the continuum, and the emission line flare peak occurs a few minutes after the continuum flare maximum. No variability in lines at a timescale of seconds is detected in our data.

OBSERVATIONS

High speed photometric observations of the stellar flare phenomenon has been made with the 2.1 m Struve telescope at McDonald Observatory. Narrow band filters (Table 1) centered at the Hα and Hβ emission lines were used to monitor the behavior of these lines, and UBVR filters were used to monitor variations of continuum plus lines during flares. One second integrations were taken in each filter. Including the time needed for filter changes, the actual time resolution is 9 seconds in each filter.

Table 1: Characteristics of the narrow band filters

Designation	λ_{center}(Å)	FWHM(Å)	Transmission(%)
Hα narrow	6566	9.4	69.5
Hα wide	6572	126	52.5
Hβ narrow	4864	33	30.0
Hβ wide	4861	181	67.0

FLARE COLOURS

Figure 1 presents two large U-filter flares on G141-29 (Pettersen 1981) and V577 Mon, together with the time behavior in U-B, B-V, and V-R. It is seen that U-B and B-V remain constant during the flare, except for

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increased noise at low flare amplitudes. Average values of U-B=-1.0 and B-V=0.0 are in accordance with Cristaldi and Longhitano (1979) and Moffett (1974). The upper panels of Fig. 1 show that V-R is not constant during the flare. It peaks at U-filter flare maximum and decays accordingly The noise is considerable at small flare amplitudes, but V-R appears constant during the later part of the flares. The U and B filters are contaminated by emission lines during flares, but the V and R filters are little influenced by this. Hα is at the end of the filter windows, and V-R may be a good approximation to a pure continuum index for flares.

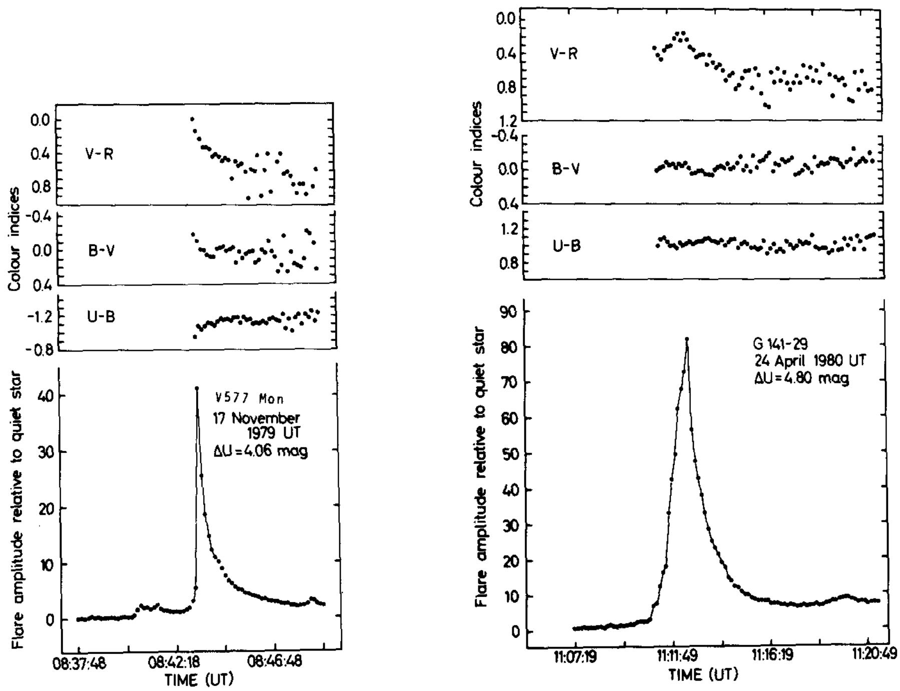

Fig. 1. Flares on V577 Mon and G141-29 with colour behavior of the flare light itself as measured through UBVR filters.

EMISSION LINES

Figure 2 presents variations detected in Hα and Hβ during flares on UV Cet and V577 Mon. The emission line indices are formed by taking the ratio of the fluxes recorded in the narrow and wide filters for each line. This quantity is proportional to the variation of the equivalent width. The timescales involved in emission line variations are longer than those of the flare continuum. This resembles the case for solar flares. Also, there is a time delay between the continuum peak and maximum emission line flux of several minutes.

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DISCUSSION

The presence of Balmer line emission during all phases of a flare indicates a cool flare component ($T_e=10^4$ K) in the chromosphere. The decay timescale for continuum (5-100 seconds) and the values of the flare colours support a hot ($T_e=10^7$ K) coronal flare component (Mullan 1976, 1977).

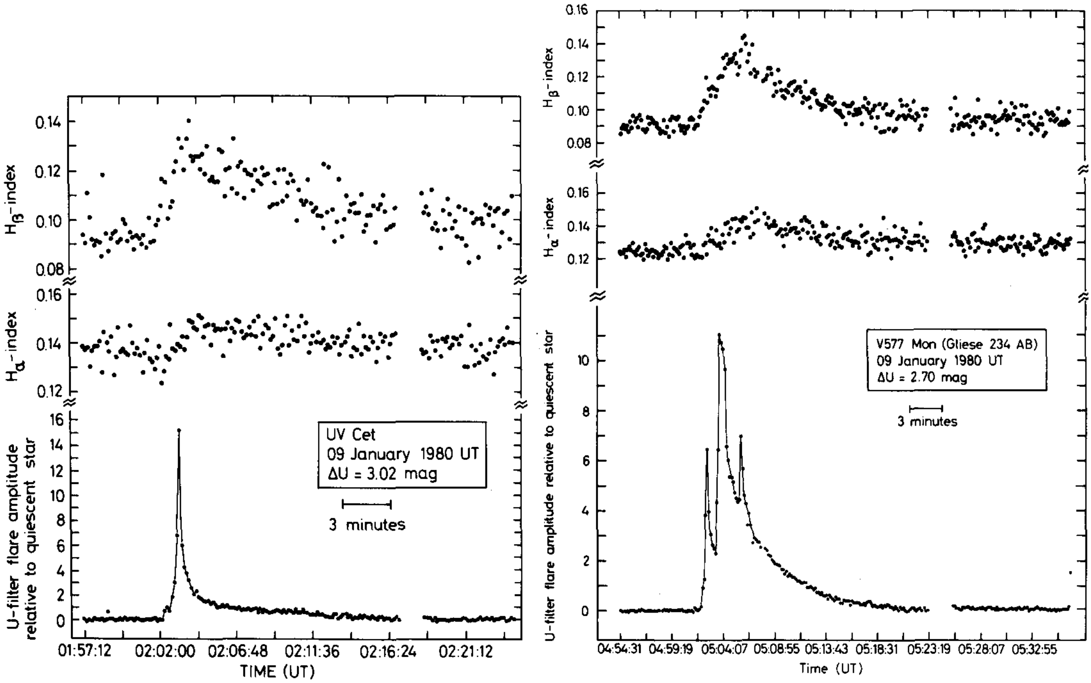

Fig. 2. Flares on UV Cet and V577 Mon with Balmer emission line behavior as measured through narrow band filters.

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DISCUSSION

Linnell: If the flare is the result of increased brightness then I would expect to see a change in (U-B) which is larger than that in (V-R). On your first slide you showed no change in (U-B) at all. Could you explain that please?

Pettersen: I am not sure that I understand your point. This observational conclusion simply says that the flare amplitude in U will be larger than in B, which in turn will be larger than in V and so on. So I don't understand your point as to why (U-B) would not be constant.

Linnell: If the flare is broadband then you expect it to represent a higher surface temperature within the flare region. So you would expect a colour change.

Pettersen: Well, I think that I should say that the (U-B) and (B-V) colours are difficult to interpret because they are influenced but not dominated by emission lines. So what one sees in (U-B) is partly a measure of the continuum and partly of lines. In (V-R) one sees continuum only. There might be some influence from Hα but this is at the edge of the spectral window. My suggestion is that (V-R) is really a continuum index for flares.

Linsky: I think that that is a very important point. Perhaps I make a comment. I would urge people working at wavelengths longer than 3000 A not to use the term ultraviolet. The term ultraviolet nowadays pertaints to the region below 3000 A. It is a question of a nomenclature which can lead to confusion.

Mullan: May I ask you to put up your second to last viewgraph with the spiky flare on it (Fig.2, flare on UV Cet)? It is obvious from this that the Hα and Hβ producing gas is varying much more slowly than the continuum-producing gas. The most direct inference you can draw from this is that the gas producing the continuum has a much smaller inertia than that producing the lines. I believe that this is a strong indication that the continuum arises from the corona i.e. from a region of low density which can respond much more quickly than the Hα and Hβ. This is a very significant result.

Gershberg: It would be desiderable to calibrate your Hα and Hβ indices to equivalent width to compare this result with the previous results by Chugainov and his new spectrographic results. Have you made such a calibration?

Pettersen: I am just in the process of analysing these data. I started with the large flares because I expected to see effects. I have data available which will provide a rough calibration when I compare spectroscopy and photometry. The accuracy of that will be of the order of 1 Å

Gershberg: But is it not a sufficient calibration if you know the filter response?

Pettersen: I know the filter responses very accurately. When I do a calibration from these I get the same results as I do from an empirical calibration. The thing which limits the accuracy of my calibration is the fact that the photometry and spectroscopy were not simultaneous. So average values of the equivalent widths of emission lines were used in the calibration.