The Videometer
An Instrument for Quantitative Measures on Solar Flares

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At optical wavelengths the solar flare is a very complex phenomenon, and one of the major problems in the study of solar flares has been to find a consistent and reliable method of classifying them. A survey of the published data will quickly show that a solution has still to be found. A second problem is to find some parameter which will accurately represent the temporal variation of the flare. The relatively small amount of photometric measures available shows that there is a need for a rapid method of characterizing the flare's intensity and areal fluctuations. In comparison to other astronomical measurements, the techniques used in measuring and classifying flares are primitive and highly subjective. The present system of classification differs only slightly from the pioneering efforts, and little attempt has been made to take advantage of the technological developments to remove the observer's subjectivity—in fact, the latest classification scheme actually increases it!

The main automation in solar observing was the introduction of the birefringent filter which allowed the Sun to be photographed unattended and thus increased the coverage of solar activity. Only a small proportion of the patrol films are measured quantitatively, and in general an observer merely notes the times of flare start, maximum, and end, together with his estimate of the area and a subjective estimate of its brightness.

The measurable characteristics of a solar flare observed through a narrow-band birefringent filter are its projected area and the brightness distribution. Both of these are affected by the transmission properties of the filter; but by carefully aligning a number of filters whose transmission profiles are similar and using them in identical optical systems, it should be possible to obtain uniform quantitative information on the flares observed. The Solar Particle Alert Network (SPAN) set up by the NASA Manned Spacecraft Center (MSC) has seven stations around the world equipped with almost identical telescopes. It is a suitable source for records which can be used for quantitative work. With five of the seven stations in operation we had 85 per cent coverage of solar activity. The problem, then, is to measure the flare areas and brightness as objectively as possible, and to obtain curves which characterize the flare development.

In 1939 Richardson[1] seemed to have the correct approach when he estimated the brightness of the flare emission on a scale of 1 to 5 and then measured the area of each brightness zone. The product gave an integrated intensity for the flare; but the method, in addition to being laborious, again depended on a subjective estimate of brightness. Since the 1950's a number of flare isophotometers have been built, and these removed the subjective element from the brightness estimation. However, most of them had an analogue output which is cumbersome and laborious to analyze. Consequently, only a few outstanding flares have been measured with them, and, as far as we know, none of these instruments is used on a routine basis.

We attempted to measure the flare flux (defined as the product of area and intensity) using a microdensitometer, but even with computer reductions the system was not feasible for routine analysis, although the preliminary measures showed that the flux-curves differed from the more usual line-width or light curves. Independently, Tallant[2] at Sacramento Peak Observatory was developing an instrument which uses video techniques to obtain the required information. He named his instrument a videometer, since it measures video signals, and it is used in conjunction with the video signals from a patrol telescope and operates in a real-time mode.

The Houston videometer differs in some respects from Tallant's prototype and includes several modifications which increase its usefulness and capabilities. The electronic circuits were designed at NASA/MSC by the personnel of the Space and Electronics Systems Division where the instrument was constructed. Unlike the prototype our model was designed primarily for use with film records taken by the patrol telescopes. This eliminated the need for a red sensitive vidicon necessary for real-time operation in Hα. The system as it is now could be connected directly to the telescope if such a vidicon were in the camera. We chose the film analysis method because there are already adequate flare records available which will allow us to make a rapid evaluation of the instrument's capabilities. Since we can measure the same film many times with different threshold levels, we hope to establish the criteria necessary for real-time operation.

The Mark I, now being modified into Mark II, was contained in a console 7 feet high, $2\frac{1}{4}$ feet deep, and $3\frac{1}{2}$ feet wide which contains the three basic systems, namely the projection system, the video display system, and the video analyzing system. The IBM card punch is linked by cable through a coupling unit which adds data giving the flare's coordinates, time, and other identifying information.

A schematic of the Mark I optical system is given in Figure 1. The films are projected through a beam-splitter to produce an enlarged image of the sun on the rear projection screen and an identical sized image on the vidicon target of the RCA TK-22 camera. The projector is positioned to give a 6.5 × linear magnification using a 5-inch, f2.8 lens. In the Mark II we will use a Vanguard Motion Analyzer projector equipped with a zoom lens to ensure a constant projected image size irrespective of the size of the film image. The new projector will give much greater framing accuracy and will be able to handle 1000-foot reels compared to the 100-foot reels of the Mark I.

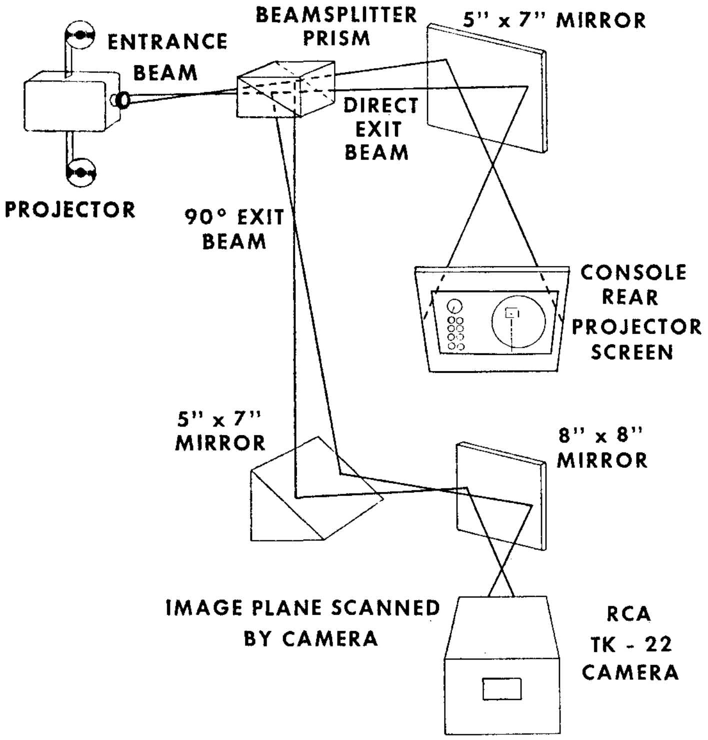

Fig. 1
Schematic Diagram of Projection System

The TK-22 camera can be moved relative to the image by a motor-driven, worm gear operated, two-axes mount. This positioning device allows a movement of ±4 inches horizontally and ±5 inches vertically, which is more than sufficient to cover the image size used. The pointer attached to the top of the camera outlines the section of the image being displayed on the monitor (see Fig. 2).

The video from the camera is fed to two sample-and-hold circuits, each of which is gated by a gating generator. One circuit is called the crosspoint M video sampler and is used to obtain the average video level of a 4.2 square degree sample of the quiet sun intensity. The camera has been modified so that in the *Automatic* mode this average quiet sun sample is compared to a reference and the difference signal amplified to control the target voltage. The target voltage is varied to maintain a constant quiet sun sample, thus compensating for variations in density between film frames. In the *Manual* mode the target voltage is controlled by a potentiometer on the front of the console. This mode is required to measure the film calibrations. The second circuit, the dot-point L video sampler, is used to measure an 0.75 square degree sample of any point in the video field and can be used to obtain conventional light-curve measurements. The positions of both these samples are controlled by joy-sticks on the front of the console, and their positions in the video field are indicated by white markers—the cross-point M by a white rectangular outline and the dot-point L by a white dot.

The threshold level is set by a potentiometer and indicated on the DVM below the monitor. The level is compared to the video signal, and that which is above the threshold is gated to an integrator. The gated video is integrated for one field and updated on each succeeding field. The time constant of the integrator can be selected by a front panel switch so that a full-scale output is obtained for 1/10 white field, $\frac{1}{2}$ white field, or a full white field, where a white field produces a 1.0-volt video level.

The area is measured by gating a 3.0 MHz master counting oscillator and given as counts per field. The maximum number of counts is 999 and corresponds to 21.7 square degrees at this frequency. However, the gated 3.0 MHz frequency is divided by 2, 4, and 8, giving full scale values corresponding to 43.4, 88.8, and 173.6 square degrees respectively, so we are able to cope with greater flares than have been seen to date.

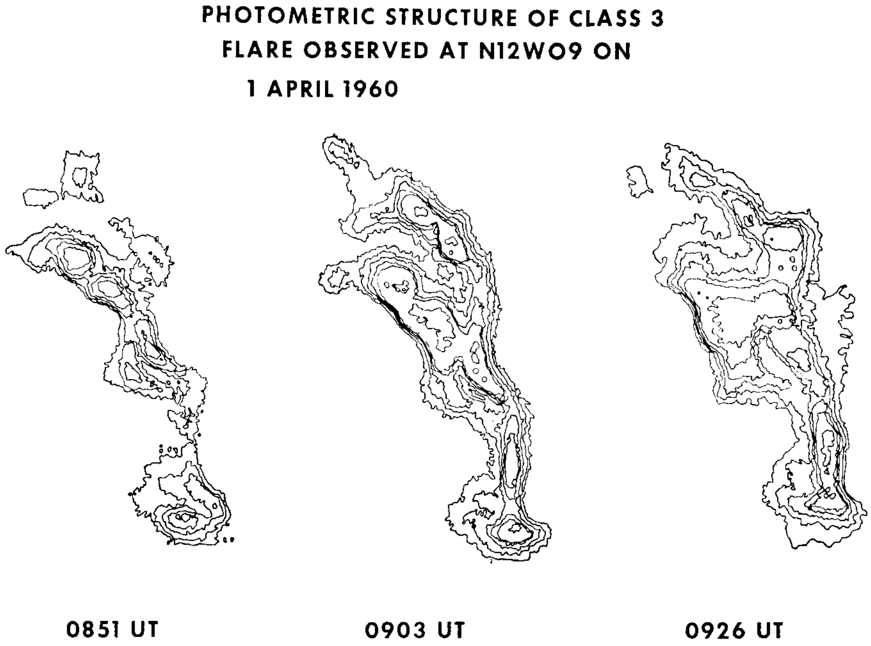

Fig. 4
Isophotal Structures of April 1, 1960 Flares

The area where the video is integrated can be marked on the monitor in two ways. In the first a white marking pulse is fed to the video OR gate during the period the video is being integrated, while in the second the white marking pulse is differentiated and processed to produce a white outline around the area where the video is gated to the integrator (see Fig. 3). By varying the threshold level it is easy to obtain the isophotal structure of the flare (see Fig. 4) and at the same time obtain a measure of the flux and the area.

There is also a peak video detector which detects and marks all video in the prime field which is within 50 mV of the peak value. This appears on the monitor as a dot or dots, showing the locations of the peak intensity or intensities (see Fig. 5).

The dot-point L marker can be connected so that it acts as a marker for the line-extractor. This enables one to view any video line on the oscilloscope, where the intensity variation appears like a microphotometer trace.

In the event that there are more active regions on the monitor than one wishes to measure, the video from the camera can be fed to a blanking generator and the undesired video is blanked using the horizontal and vertical width controls. The position of the unblanked rectangle can be chosen with the joy stick. The video output from the generator is then fed to the processing circuits. The blanking generator can cover from 80 per cent of the field downwards.

Thus, from the instrument we can measure the following parameters:

1. The flare area above the set threshold.
2. The flare flux—the integrated video signal expressed as a fraction of the white field.
3. The peak intensity in the video field being measured.
4. The threshold reference as set.
5. The target voltage on the camera.
6. The cross-point M sample—the quiet sun level reference.
7. The dot-point L sample—at selected positon.

These data are printed out in digital form on printed tape and at the same time punched on a card, together with the flare data added by the coupler unit. The printed tape is used mainly to monitor the operation of the videometer, while the punched cards are fed into the computer for reduction to true intensities. A sample of the curves obtained for different threshold levels is shown in Figure 6.

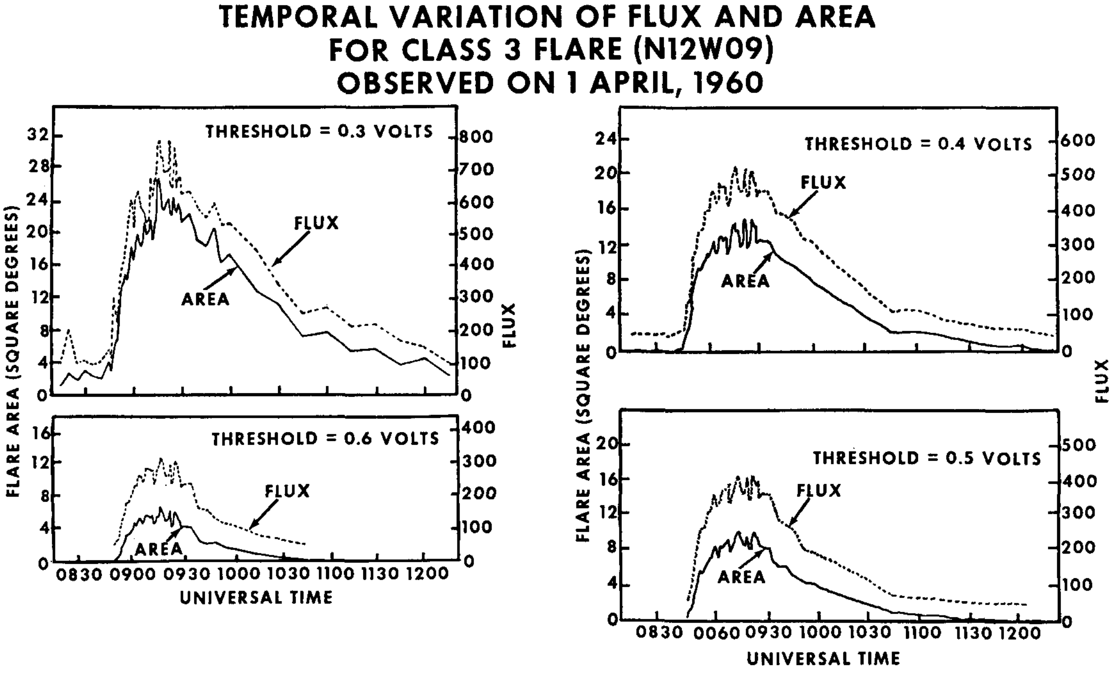

Fig. 6

Area and Flux Curves for Different Threshold Levels

At this time we have not analyzed sufficient material to define the threshold level above which the flare emission should be counted so as to obtain the most significant parameter for comparison with radio ionospheric and particle data. The system will operate with either positive or negative films, though with the latter the signal-to-noise ratio deteriorates as the flare reaches maximum since the light then reaching the vidicon is at a minimum. The Mark I is able to cope with negative films up to a density of 1.7 with the present setting of the quiet Sun reference level.

The system as it currently exists is not restricted to flare measurements, but can be used for sunspots, gaseous nebulae, earth resources, or any phenomena where the area or the flux are of interest. For example, at the recent total solar eclipse in Mexico we obtained over 160 photographs of the corona. It is a slow process to obtain isophotes of this number of photographs, but we recorded all the isophotes on the videometer in two days. It took another four days to make the drawings (see Fig. 7).

For the future, once the necessary threshold criteria have been established, we foresee a totally automatic real-time system. A video system will scan a small scale solar image until it detects a change in intensity at some point. It will then zoom in on this region and change to a videometer mode to record the flare's variation and at the same time record the location of the event on the Sun. Rather than use a red sensitive vidicon we hope to use silicon diode arrays since they have a linear response with a gamma of one. In addition they have ample sensitivity at hydrogen H-alpha and can be exposed to direct sunlight without damage. Such a system should remove the subjectivity from the classification of flares.

ACKNOWLEDGEMENTS

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REFERENCES

1. Richardson, R. S., 1939. *Ap. J.*, **90**, 368.
2. Tallant, P. E., 1970. *Solar Physics*, **11**, 263.

DISCUSSION

M. J. SMYTH: How do you introduce the photographic calibration into the photometry?

J. H. REID: Calibrations are on each frame of the film and have to be measured separately. Since the camera sensitivity is controlled by the quiet-sun density, it is necessary to set the target voltage manually, to the same value as shown by the digital voltmeter for the automatic mode, before measuring the calibrations.

A. BEHR: How do you control the optical bandwidth of the filter, or do you just take this as given?

J. H. REID: The Hα filters are thermostatically controlled, and have bandwidths of 0.5Å or 0.7Å, depending on the telescope. We have a calibration problem, because the calibration exposure is made through a filter with 100Å passband.

F. E. ROACH: What is your unit of area for flares?

J. H. REID: The flare area is measured in units of one square degree (heliographic) at the centre of the disk, and this area has a side of 12 150 km. There is no correction for foreshortening in the output; this correction can be made later.

J. RÖSCH: The width and position of the passband are extremely important when comparing results from different observatories; the effect of changes was very evident in the 15-day flare patrol prepared by H. J. Smith *et al.*

J. H. REID: We are concerned with data from the SPAN system, for which we know the profiles of the filters in use. These are in identical optical systems and should provide uniform results. Films taken with other telescope systems will have different bandwidths and would have to be calibrated separately.