SOLAR RESEARCH MEMORANDUM

19 January 1953

SUBJECT: Flare Activity Index

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I. Need for an Index

Since so many terrestrial phenomena are closely associated with solar flares, a single parameter for expressing the daily level of flare activity may possibly be useful in research. In the past, the parameters generally used in flare correlation studies have been: (a) the number of flares per day; (b) the product of the area x brightness (Richardson); (c) the line width at maximum; (d) the maximum brightness, or still other parameters. However, we do not know of any published index that measures the average rate of generation of energy in flares, and it is this quantity, in our minds, that should be most significant. (This quantity can be estimated from published tables like those of the IAU Quarterly Bulletin, if the total number of observing hours for the flare-observing apparatus involved is known. This latter information, however, is usually not easily available.)

A valuable flare-activity index would be the time-integral of the sum of the integrated intensities of the flares each day, divided by the time during which the flare-detector was operated (e.g., the average ergs/sec. from all flares of the sun for the whole day); or, for greater flexibility in analysis, perhaps such a parameter for each active region. For us to determine the integrated intensity for the computation would require photometric techniques that we are not at present equipped to carry out on a routine basis.

Consequently, we are tentatively adopting a method of computing a new flare activity index based on less complete data, as now reported: (1) maximum flare brightness in an arbitrary scale; (2) percentage of area of the flare at the maximum brightness; (3) duration of the flare, and (4) time during which the flare patrol operated.

We should point out that all measures referred to in this memo are made in Hα alone and in a 1/2 A band-width only. Comparison between flare indices derived from different flare patrol programs cannot be intercompared without further photometric study to express the total flare energy in Hα in absolute units, taking into account such factors as the scattering in the instrument, the actual line-width of the luminous flare, etc. However, for the Sacramento Peak flare patrol alone, everything remains reasonably constant from day to day, and the index of activity so derived, thus, has considerable significance.

II. Method of Computing Index.

In a recent flare-analysis effort with the High Altitude Observatory contour densitometer, Billings and Roberts have found (to be reported in Ap. J.) that the curve of brightness vs. area in a typical large flare intensively investigated was in the form: Figure 1

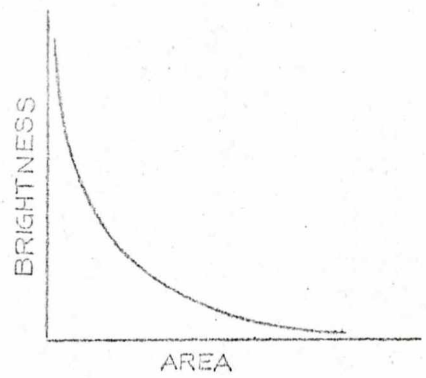


FIGURE 1

This form is apparently very different from that usually visualized by the observers who measure the flares at Sacramento Peak. The latter often report as much as 80% of the area of the flare as being at the level of maximum brightness. Such reports imply a concept of the brightness-area curves of the form: Figure 2

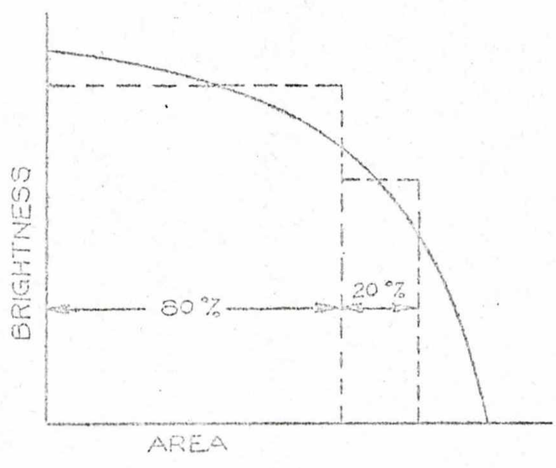


FIGURE 2

Since the work by Billings and Roberts was on only one flare, it would be presumptious for us to conclude that all flares, or even the typical flare, has the former brightness-area curve. However, since the measurements were quantitative and objective, on an apparently typical flare, the result should carry considerable weight.

For deriving our index we represent the integrated intensity of a flare by two rectangles, one of which has as its height the maximum brightness scale for the flare, and as its width the percent of the flare area reported as being of that brightness. The other rectangle would have as its width the percentage of the flare area in the remaining portion of the flare, and an appropriate height so that the sum of the areas of the two rectangles would most appropriately represent the integrated intensity. If the concept of the brightness-area curve is of the form of Figure 1, the height of the second rectangle will be small compared to that of the first. (Figure 3)

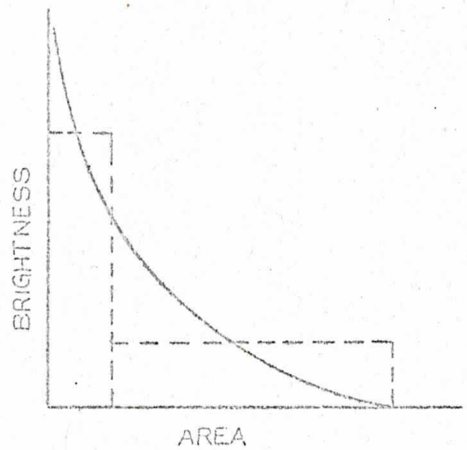
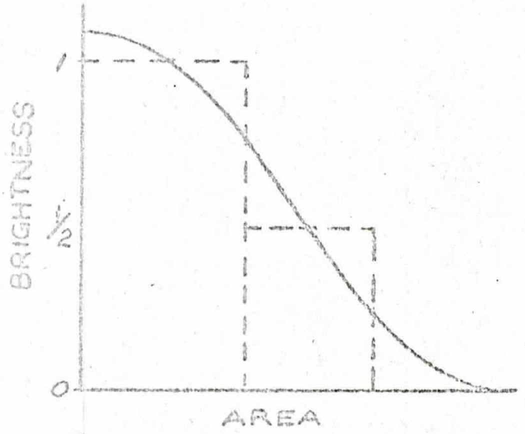


FIGURE 3

If, however, it is of the form of Figure 2, the height of the second rectangle will not be much less than that of the first, as shown.



(The Sacramento Peak observers usually report 60% to 70% of the total area at maximum brightness)

FIGURE 4

As a reasonable compromise, we have tentatively chosen to make the height of the second rectangle one-half that of the first. (Figure 4) Hence, if:

B = reported arbitrary brightness at maximum,

p = fraction of flare area reported to be of brightness B, and

A = maximum area of the flare, where

$$A = \frac{a \times 10^6}{2\pi R^2} \quad \text{where, in turn}$$

a = area of flare image on film at maximum in square mm. and

R = radius of solar image on the film in mm.

The integrated intensity at maximum is then taken as:

$$BAp + \frac{1}{2}BA(1-p) = \frac{BAp}{2} + \frac{BA}{2} = \frac{BA}{2}(p + 1) \qquad (1)$$

Since the decay law for each flare is not measured, we have assumed a linear decay with time. Thus, to get the total energy we would multiply (1) by 1/2 the flare duration, or, for convenience, by the duration itself since the units are arbitrary. This gives the total energy of a flare (in arbitrary units) as:

$$\frac{BA}{2}(p + 1)D \qquad (2)$$

where D is the time of duration of the flare.

Finally, the above quantities are summed for all flares by regions and the sum divided by the number of observing minutes in the day. Or, in equation form, if I = index and T = number of observing minutes:

$$I = \frac{1}{T}\sum \frac{BAD}{2}(p + 1)$$

the summation being done over all flares in one active region. The value thus obtained is rounded off to the nearest 10%.

The index, thus has the dimensions of $\left[(Ml^2t^2)\ t^{-1}\right]$ or of energy/time. Any region of activity with an index >400 is exhibiting strong flare activity. Of course, where the flare index is computed from only one or a few flares, statistical fluctuation is large and we may spuriously over-estimate the flare activity because of the chance coincidence of a flare in the small time-sample represented by the observations. This trouble is not peculiar to our index, however, but affects any estimate of flare activity based on a small time sample including only a few flares. Time samples large enough to include five flares are probably large enough to be quite significant.

In our weekly Preliminary Chart of Solar Activity we also publish the quantity: Integrated Intensity (arb) = $\frac{BAD}{2}(p + 1)$, which has dimensions of energy, for each individual flare as well as the flare index for each active solar region for each day. (The quantity 1/2 in the computation is retained simply because it keeps the variations of the flare index in a convenient range.)

One can add up the indices for all regions on the sun for a given day to get an all-sun index, or he can add indiced for all days during which the index was computed for a given region in a given disk passage and divide by the weighted (on basis of total observing minutes) number of days included in the sum, to get an index appropriate for the region in its whole disk passage.

III. Plans for Improving this Index.

We hope later to change the basis of computation for the flare activity index in one or the other of two possible ways:

(1) Set up a routine contour densitometer program for quantitative analysis of additional parameters for all flares.

(2) Carry out enough contour densitometer analysis to fix a typical form (if one exists) for the brightness-area curves. If this is done we can then ask the observers to report such parameters (i.e., maximum brightness and area at 1/10th brightness) so that the curves may be sketched and the area under them measured.

IV. Distribution: Recipients of weekly solar charts,
Plus: Athay, Billings, Pecker, Rush, Trotter,
Bell, Matsushima, Thomas
Warwich, Yu, Epstein, Parker,