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RELATION BETWEEN OPTICAL SOLAR FEATURES AND SOLAR RADIO EMISSION

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During the last five years, we at the McMath-Hulbert Observatory have been attempting to determine the characteristics of radio-frequency radiation associated with certain of the transient solar features that we normally observe on monochromatic spectroheliograms or in integrated light. We have had the privilege of using the original 200 Mc./s. records at Cornell University and the 2800 Mc./s. records at the National Research Council in Ottawa.

It is well established that transits across the solar disk of certain centres of activity coincide in time with periods of enhanced emission at radio frequencies. In general, centres of activity include sunspots, the surrounding bright plage, and superposed regions of red and green coronal emission. The relative roles of these three aspects of solar activity with respect to emission at radio frequencies are hard to determine.

There are certain observations that lead us to believe that calcium plages are better indicators of the regions emitting 2800 Mc./s. radiation than are spots. First, Covington's detailed study of 2800 Mc./s. radiation on 16 October 1951 showed three emissive regions on the solar disk [1]. For the same day there were three similarly located maxima in the east-west distribution of calcium plage intensity, but sunspots were observed in only two of the three regions [2]. Secondly, a plot of measures of areas of calcium plages from 1947 to 1953 versus Covington's measurements of the basic daily flux at 2800 Mc./s. for the same period, gives a single curve for the entire period. In this plot, there is no indication of a change in the zero intercept from year to year (see Fig. 1 for 1947 and 1952 data). Consequently, when calcium plages are used as indicators of the slowly varying component at 2800 Mc./s. it is not necessary to postulate a variation in the 'quiet sun' from year to year. Thirdly [3], studies of the formation and development of a spot and plage between 20 and 27 August 1954 on the otherwise featureless solar disk, indicate that the basic daily flux at 2800 Mc./s. followed more

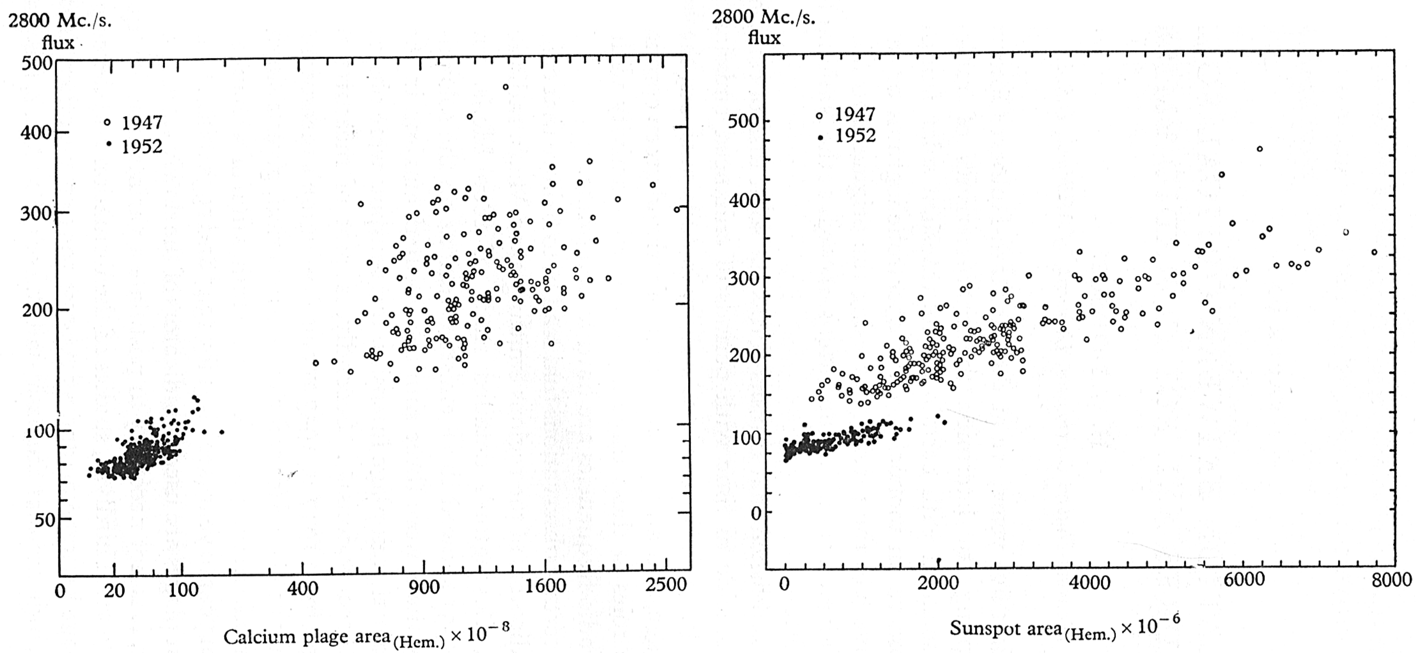

Fig. 1. Plot of daily values of 2800 Mc./s. flux for 1947 and 1952 versus area of calcium plages and area of sunspots.

closely the growth of the plage than that of the associated spot. The area of the spot began to diminish before the area of the plage and radio flux showed significant diminution (see Fig. 2).

Detailed changes within an active centre are often associated in time with detailed features of the radiation at radio frequencies. The short-lived changes in the centre of activity fall into two main categories, (1) active prominences (or 'active dark flocculi' when observed in projection on the disk) and (2) the flare-brightenings. Active dark flocculi often occur with flares, generally during the post maximum phase.

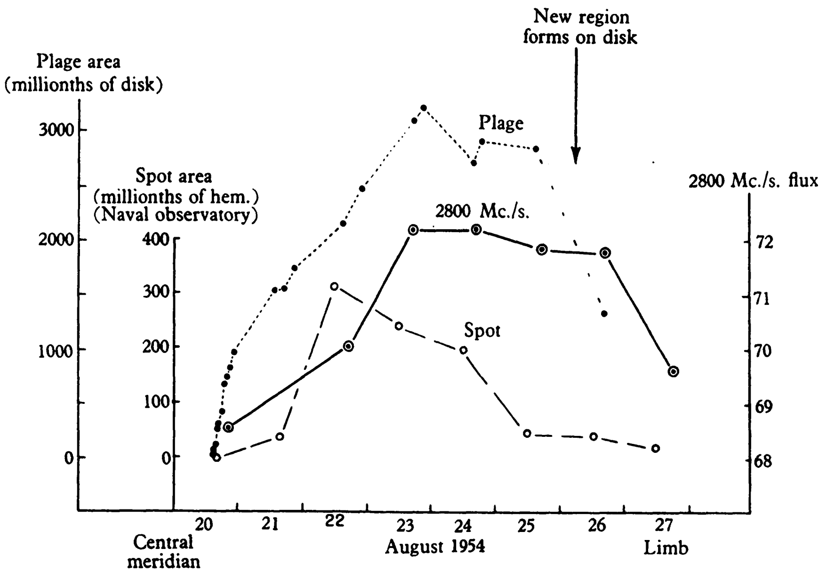

Fig. 2. Comparison of 2800 Mc./s. flux with area of sunspots and calcium plage 20 to 26 August 1954.

The 200 Mc./s. records show a small number of time coincidences between the appearance of active dark flocculi and distinct radio bursts. Most active flocculi occur without associated bursts at the frequencies we have studied. Furthermore, information on the absence or presence of the post-maximum dark flocculi has not been of assistance in distinguishing between flares with and without associated bursts at 200 and 2800 Mc./s. Except for the very high velocity ejections observed in the early stages of some flares near the solar limb [4], our studies have provided only very limited associations between prominence activity and distinctive events at radio frequencies.

The pattern and time relationships between enhancements of 200 and

2800 Mc./s. radiation and the brightenings in H_α flares have been thoroughly described in the past [5, 6]. The double aspect of the flare-associated radiation at both of these frequencies has been pointed out.

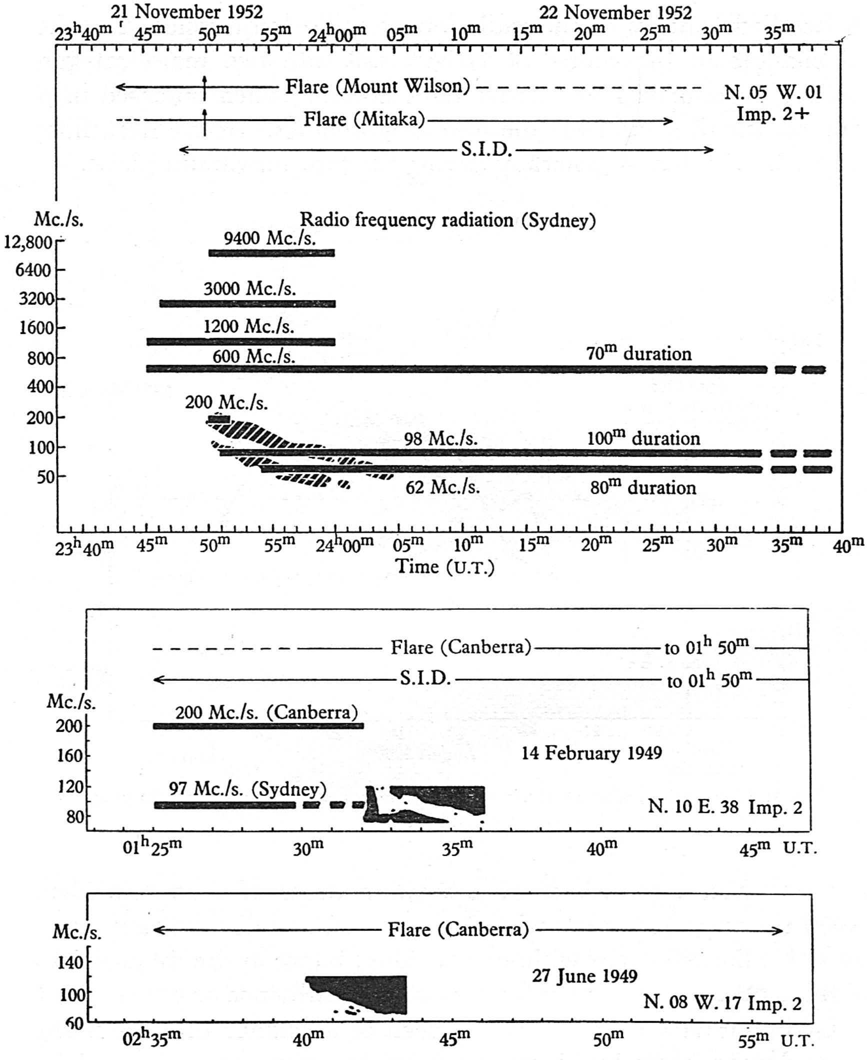

Fig. 3. Time relationships between Wild's published dynamic spectra of outbursts (type II) and observed H_α Flares.

Furthermore, published 97 Mc./s. records from Sydney show that the same general form and time relationships occur also at this much lower frequency. However, the relationship between these flare patterns and the dynamic spectrum or frequency sweep data for outbursts (Wild's type II burst) is not clear in the literature. For the published cases for which we can deduce the circumstances of the flares, the spectrum drift data refer only to the later stages of the flare and to the second or late part of the radio-frequency pattern (see Fig. 3).

If the position of flares associated in time with distinctive radio events be used to locate the radio emitting source, the presently limited interferometric data can be supplemented considerably. Interesting relation-

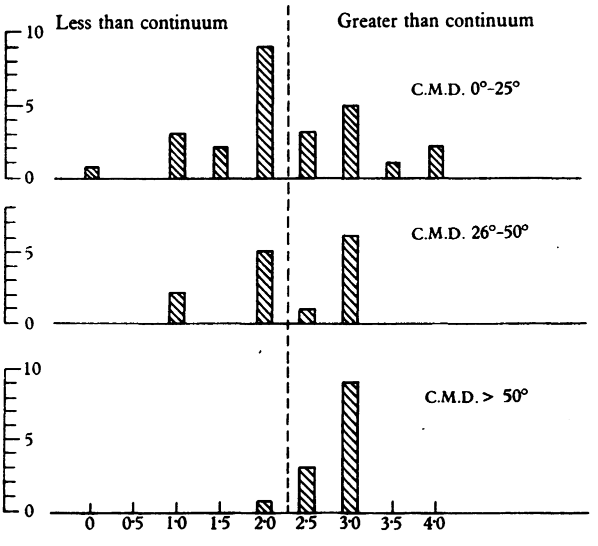

Fig. 4. Comparison of intensity of superposed bursts to that of continuum for 200 Mc./s. noise storms associated with flares at different distances from central meridian.

ships emerge from the use of this type of information. For example, position measurements are available for flares associated in time with the onsets of fifty-three noise storms on the 200 Mc./s. Cornell records. When the flares were within 25° of the central meridian the amplitude of the superposed bursts was generally less than the intensity of the continuum. Between 25° and 50° C.M.D. there were as many cases with the burst amplitude greater than the continuum as the reverse. When the flares were more than 50° from the central meridian the amplitude of the bursts was greater than the intensity of the continuum in more than 90% of the cases (see Fig. 4). This variation from centre to limb in the relative intensity of storm base-level and burst amplitude suggests that the two aspects of the noise storm are separate phenomena and perhaps originate at different levels in the solar atmosphere.

There is growing evidence that the flare mechanism is in some way intimately associated with much of the transient activity at radio frequencies. Our studies indicate that at 2800 Mc./s. there are distinctive or outstanding events *only* when a flare is in progress on the sun. At 200 Mc./s. both outbursts and the distinct onsets of noise storms are flare-associated. Furthermore, intercomparison of the Cornell records from 1950–55 with optical data indicates that 200 Mc./s. noise is often recorded from active centres *having flares* even when the region is at the very limb of the sun (8 May 1951). Our study of the development of the active centre in August 1954 on the otherwise featureless solar disk shows that the noise storm at 200 Mc./s. began when the region started to have flares, even though this did not take place until the active area was about 45° from the centre of the solar disk. Either flares themselves or a stage of development in which flares can occur may be a necessary circumstance for the emission of the greatly enhanced radio radiation at low frequencies.

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Discussion

Wild: With reference to Miss Dodson's Fig. 3, I remember vividly the case of the outburst of 14 February 1949. We failed to record the first part simply because the recording camera jammed!

Hey [1]: An analysis of solar radio bursts at 4 metres wave-length during 1946–51 has shown that the bursts occur more frequently in association with flares on the eastern half of the solar disk than on the west. The most likely explanation is that it is due to absorption and refraction in an asymmetrical east–west structure in the solar atmosphere above the flare-active region. When regions associated with high geomagnetic activity are analyzed there appears to be a dip in radio-burst activity near central meridian. Attenuation in corpuscular streams may be responsible for this. Similarly, there is asymmetry in the numbers of flares observed in H_a and this may be explained in a similar way in terms of H_a absorption.

Biermann: From what we have just heard from Dr Hey, it is evident how important new observations of the east–west symmetry of the enhanced radio frequency radiation of the sun would be. At the present time, these observations seem to provide one of the most effective means of studying solar corpuscular radiation. Apart from the direct information about the emission by the sun, it appears that this information may have some bearing on the problems of the mechanism of production of the radiation in the radio-frequency range.

REFERENCE

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