Ha, HARD X-RAY, AND MICROWAVE EMISSIONS IN THE IMPULSIVE PHASE OF SOLAR FLARES

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Abstract. I have studied the observational relationship between the location of flare sites in active regions and three other observables, viz., Hα line width, hard X-ray burst parameters, and peak microwave fluxes. Results suggest that the strength of the magnetic field plays a role in governing the magnitudes of these emissions. Qualitative relationships are derived on the assumption of proportionality between the spectral maximum frequency of the associated microwave burst and the field strength in the microwave source.

The relationship inferred between the power in thick target electrons (derived from the hard X-ray burst) and the column density of second-level hydrogen atoms (derived from the Hα line widths) is compared with calculations by Brown (1973) and Canfield (1974).

The line widths observed for two white light flares suggest that a criterion for detectable continuum emission in disk flares is an Hα line width ≥ 20 Å.

1. Introduction

This paper examines the behavior of Hα, hard X-ray, and microwave emissions during the impulsive phase of solar flares in relation to flare location within the active region. The impulsive phase can be identified with impulsive microwave bursts (e.g. Takakura, 1967) and hard X-ray bursts (e.g. Kane and Anderson, 1970; Kane, 1974), both produced by nonthermal electrons generated in the flare. The optical counterpart is less definitive, although an impulsive component seems identifiable in the Hα flare kernels (Vorpahl, 1972). Recent observations by Zirin (1977a) have shown a very close temporal relation (±3 s) between hard X-ray bursts and the initial brightening and rise to maximum of the flare in Hα. These observations support the view that the Hα flare kernels represent the footpoints of magnetic arches and therefore correspond to points where the nonthermal electrons are rapidly channeled into the chromosphere (e.g. Zirin, 1974). In this view a significant portion of the hard X-rays are also produced in the chromosphere according to a thick target process (Brown, 1971; Hudson, 1972).

The observations presented in Section 2 are the Hα line width in the flare kernels, the hard X-ray burst parameters, and the peak flux in the microwave burst. A considerable emphasis is placed on the line width as a diagnostic for particle penetration of the chromosphere, as would be inferred from calculations of the chromospheric response to nonthermal electron bombardment (Brown, 1973; Canfield, 1974). In this regard the comparison between Hα line widths and hard

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X-ray fluxes (if produced by thick target process) would seem to be a logical observation to pursue. Since the time resolution of the line width measurements presented herein is one minute, no claim can be made for the detailed association between the line width and the traditional impulsive emissions in hard X-rays and microwaves. It should be noted, however, that the peak line width occurs approximately at the peak of the associated microwave burst. This is consistent with the observations made by Janssens and White (1970).

The magnitudes of the Hα, X-ray, and microwave emission parameters are observed to vary from one flare to another according to the flare’s location within the active region, suggesting that the strength of the magnetic field plays a role in governing the flare’s emissions. Similar effects relating the flare’s position to the quality of its emissions have been reported by Malville and Smith (1963) and Dodson and Hedeman (1970). Donnelly (1973) reported the absence of impulsive EUV bursts in flares which are not associated with sunspots and made the suggestion that strong magnetic fields are required for the production of impulsive emissions. Rust and Roy (1974) noted the different character of the flares originating in two active regions, one with weak and one with strong fields; the flares in the latter were observed to have stronger and more impulsive emissions.

The observations herein will be used to derive a qualitative relationship between the flux of nonthermal electrons and the field strength in the flare (assuming that the field strength is approximately proportional to the spectral maximum frequency of the associated microwave burst).

2. Observations

2.1. Optical Observations

A number of flares were observed at The Pennsylvania State University using a tunable 0.25 Å Zeiss filter and a patrol telescope with 90 mm aperture and 2300 mm focal length. This instrument resolves 2 arc sec at λ 6563 Å on Kodak S0-392 film. During flares photographs were taken at one-Ångstrom increments over the range Hα ± 10 Å, and the intensities of the flare kernels were measured with a Joyce-Loebl microdensitometer using standard photometric techniques. The filter transmission characteristics (particularly the behavior of the secondary responses located ±32 Å from the primary) are well known from spectrographic tests and therefore it is possible to determine the flare kernel intensity \( I = I(\Delta \lambda)/I_{\text{cont}}(\Delta \lambda) \). In cases where the kernels are well resolved the plot of \( \log (I - 1) \) vs \( \log \Delta \lambda \) in the line wings has a slope near −2.5, characteristic of a Stark-broadened profile (e.g. Švestka, 1965). The full width \( W \) of the flare emission profile can then be defined as the wavelength interval between the points on the profile where \( I = 1.05 \).

There are two situations which, in some cases, have led to uncertainties in the width measurements: first, kernel sizes less than about twice the effective resolution of the instrument will have measured intensities less than actual; and second,