A STUDY OF ENERGETIC SOLAR FLARE X-RAYS

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Abstract. A new series of solar flare energetic X-ray events has been detected by an ionization chamber on the OGO-I and OGO-III satellites in free space. These X-rays lie in the range 10-50 keV, and a study has been made of their relationship to 3 and 10 cm radio bursts and with the emission of electrons and protons observed in space. The onset times, times of maximum intensity and total duration are very similar for the radio and X-ray emission. Also, the average decay is similar and usually follows an exponential type behavior. However, this good correlation applies most often to the 'flash' phase of flares, whereas subsequent surges of activity from the same eruption may produce microwave emission or further X-ray bursts not closely correlated. An approximate proportionality is found between the total energy content of the X-rays and of the 3 and 10 cm integrated radio fluxes. These measurements suggest that the X-ray and microwave emission have a common energizing process which determines the time profile of both. The recording of electrons greater than 40 keV by the Interplanetary Monitoring Probe (IMP satellite) has been found to correlate very well with flares producing X-ray and microwave emission provided the propagation path to the sun is favorable. There is evidence that the acceleration of solar protons may not be closely associated with the processes responsible for the production of microwaves, X-rays, and interplanetary electrons.

The OGO ionization chamber responds to energies (10-50 keV) intermediate between the soft X-rays giving SID disturbances (1-10 keV) and energetic quanta previously measured with balloons (50-500 keV). Proposed source mechanisms should be capable of covering this range of energies including the most energetic quanta occasionally observed.

The ionization chamber on the OGO-I and OGO-III satellites has detected numerous solar X-ray increases associated with flares, solar radio bursts, and with the direct observation in interplanetary space of energetic solar electrons and protons. It is hoped that a detailed study of such energetic events, which show strong correlations with the flash phase of many flares, will give information about the principal instability of which the solar flare in all its complexity is the result, and help identify acceleration processes for energetic particles. The OGO ionization chamber has a peak response to X-rays near 25 keV, a low-energy cutoff at 10 keV due to the aluminum wall of the chamber, and a greatly decreased response at 50 keV due to the decreasing absorption in the argon filling gas.

An example of the X-ray radio-burst correlation for a complex type microwave event from a large flare is shown in Figure 1. The ionization rate is given in arbitrary units but may be converted to absolute energy flux, as described below. One sees that the onset times correlate to within a fraction of a minute and, as is generally the case, the time of maximum intensity also correlates well. The total time duration is very similar. A small secondary event at 1035 UT is also reflected with very low intensity in the X-ray region. However, in general, the complex radio bursts have a highly variable structure, which is not usually correlated in detail with the rather smooth X-ray profiles. This contrasting behavior is easiest seen in the large events, where more detail is available in the X-ray plots.

An example of the preferential occurrence of the energetic X-rays at times when the radio spectrum penetrates into the centimetric range is shown by Figure 2. In this case, during the flare-maximum phase, some of the 3-cm radio detailed structure is preserved in the X-ray intensity; for example, the peak at 1809 UT and the maximum at 1813 UT. Neither a detectable X-ray increase nor an appreciable 3-cm increase occurs, however, between 1821 and 1828 UT corresponding to the 328 MHz outburst. In two flare events, double X-ray bursts were observed with peaks separated by 20 min. In each case, the first X-ray burst starts simultaneously with the impulsive beginning of the radio event. The second burst has no impulsive radio counterpart, but occurs during a long-enduring gradual rise and fall event.

In Figure 3 the decay characteristics obtained from detailed plots of the 20 March and 5 June events are shown. In each case the X-ray and radio intensities follow the same exponential type decay. The points shown for the 20 March radio event occur during a smoothly decreasing period after 1002 UT, when the highly variable source seems to have subsided. During this period, the decay-time constant of the X-ray and radio intensities is approximately 4 min. For most events, the average decay of the