CORRELATION OF HARD X-RAY AND TYPE III BURSTS IN SOLAR FLARES

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Abstract. The observed correlations between X-ray and type III radio emissions from solar bursts are described by means of a bivariate distribution function. Procedures for determining the form of this distribution are described using a sample of data analyzed by Kane (1981). With the help of this distribution a model is constructed to explain the correlation between the X-ray spectral index and the ratio of X-ray to radio intensities. Implications of the model are discussed.

1. Introduction

It is well known that electrons accelerated during solar flares produce, among other things, hard X-rays and type III bursts. Hard X-rays are produced primarily by electrons which penetrate to the lower (higher density) regions of the solar atmosphere, while the type III bursts are produced higher up by electrons streaming outward away from the Sun. Observations show a strong relationship between these two types of radiations, implying a common origin for the electrons. Thus, an understanding of the mechanism responsible for these radiations may provide insight into the acceleration process and some of the characteristics of the flare plasma, such as the magnetic field structure, the density and the temperature.

A reasonably good estimate of the number of electrons responsible for the observed X-rays can be obtained from the total count of X-rays at lower energies (< 20 keV). For type III bursts, on the other hand, even simple estimates of the number of electrons involved in the radiation process cannot be made reliably because of the complexities of the radiation mechanisms (see e.g. Goldman and Smith, 1982). Some recent observations (Lin et al., 1982) have even questioned the basic premises of the model (Ginzburg and Zheleznyakov, 1958), namely, the excitation of plasma waves (by the streaming electrons) and the conversion of their energy into electromagnetic waves. It is, however, reasonable to assume that the intensity of the type III bursts is related to the flux of exciting electrons, even though the relationship may not be a simple linear one as in the case of X-rays. Such a relationship has been established between electrons and in situ produced type III bursts at 1 AU (Fritzenreiter et al., 1976). We assume that this relationship also holds for type III bursts occurring near the Sun.

With this assumption it is then clear that any observed relationship between the intensities of the type III and X-ray bursts will provide information about the correlation...
Fig. 1. The geometry of open and closed field lines. Electrons in a closed loop emit only X-rays. Those injected at $\tau = 0$ on an open field line emit X-rays at lower, high density regions, but some are reflected back to $\tau = 0$ and stream out to produce type III radiation. $\tau$ is a dimensionless column depth.

between the electrons streaming outward from the Sun (along open field lines) or beamed toward the Sun (along closed or open field structures) (cf. Figure 1).

This correlation has not been fully explored as yet because the observations do not indicate a clear relationship between the two types of radiations; i.e., there exist many X-ray bursts without detectable type III radiation and vice versa. Also, the undertaking of a thorough theoretical analysis is discouraged by the complexities of the mechanisms involved. Because of this, an alternate approach is to rely on the statistical behavior of a large pre-selected sample of bursts (i.e. a sample having known selection effects) to bring to light any correlations which tend to be overwhelmed by the large dispersion in the properties of the bursts. The purpose of this paper is to demonstrate the usefulness of such an analysis by considering the results from a recent statistical study by Kane (1981), who described the correlation between the X-ray and type III emissions of a sample of bursts from OGO-5 and groundbased observation.

In the next section we shall use his results to describe the distribution of the X-ray and type III burst intensities, and in Section 3 we present an explanation of an interesting correlation associated with the X-ray spectral index using results from our (Leach and Petrosian, 1981) program on the transport of the accelerated electrons in the solar atmosphere. A brief summary, including some suggestions for future work, are presented in Section 4.

2. Burst Distribution and Correlations

The parameter that most distinctly characterizes any burst is its observed intensity. We shall therefore be concerned with the distribution of the X-ray and type III radio intensities. Of course, both X-ray and type III bursts display spectral and temporal variations. Perhaps a good parameter to characterize the strength of a burst would be its intensity integrated over all photon energies (or frequencies) and over the total duration of the burst. Since these are not readily available from the observations, we shall use instead the intensities at the peaks of the bursts and at a particular photon