A Peak—to—Peak Correlation between Spikes and X—Ray Bursts during Type Ⅳ Bursts

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Abstract

We present a peak- to-peak comparison between the hard X— ray burst and spikes during type Ⅳ bursts.16 type Ⅳ bursts were analized in which there were 31 groups of spikes. The close correlation indicates that they both are excited by electron beam. The spike and HXR not only occur in impulsive phase, but also occur during type Ⅳ burst. Electron beams(type Ⅲ bursts, spikes,HXR)may appear many times during a large flare.

1. Introduction

In a evolution of a solar flare,energetic particles accelerated by magnetic field interact with the solar atmosphere producing a series of observational phenomena such as X-ray events, radio bursts and Hα -flares. These phenomena occur at a different height of solar atmosphere,however they often associate each other.

There is a very close relation between hard X-ray and microwave bursts. The numerous books and articles review the subject[1][2].The emission mechanism for most microwave bursts is gyrosynchrotron emission. The emisson is produced by mildly relativistic electrons (100 kev~few Mev) . It seems that most microwave emisson is excited by the higher-energe electrons of the same electron population which produces the hard X-rays.

H. Nakajima et. al[3] obtained simultaneous imaging observations of the sun at microwave and hard X-rays with high resolutions. They found that the microwave sources are displaced from the hard X-ray sources.Maybe when electron beams produced by acceleration process propagate over solar atmophere, they produce different wavelenths radiation at different site. K. Kai[4] discussed the problem of a common origin of HXR and microwave. Detailed analyses suggest that hard X-rays and microwaves are emitted from nearly co-spatial sources due to electrons streaming down to the chromosphere. Many workers studied the timing delay between HXR and microwave bursts. Cornell et al.(1984)summarizes the analysed results:the microwaves are delayed with respect to the hard X-rays. Kaufmann(1983) and Takakura(1983) obtained similar resuts.The typical delay is around 0.2s.

Many researchers carried out studies of relation between HXR and associated metric type Ⅲ bursts[5] [6] [7] . It is noted that upward drifting metric type Ⅲ bursts were delayed in comparison to HXR bursts by about 0.5 to 1s. It is suggested that HXR and type Ⅲ bursts have a common origin. M. R.Kundu[8]reported that type Ⅲ bursts which were associated with impulsive Hard X-rays, were observed to great heights (3.1 $R_\circ$ from disk center at 28 MHz) . The location of the type Ⅲ burst resource indicates that electron acceleration occurs over a region which covers a wide range of magnetic field lines. Kundu also find wide separation between type Ⅲ sources associated with a group of hard X-ray bursts, the separation amounts to ~ 7×10^5 km. Somtimes there is a close relation between HXR,Radio burst and Hα -flare, it implies the electron beam travel for along distances.

A. O. Benz, M.J.Aschwanden et al.have carried out studies of relationship between decimetric spikes and HXR bursts[9].

T. Takakura [11] reported the time delays of 5s to 10s between the peaks of solar hard X-ray burst and microwave burst at 17 GHz.In most cases,the time delays are one second or less, H. S.Sawant identifies this result,but the delays of five seconds or more have been detected in some exceptional cases in intense bursts. The long time delay should be attributed to expansion of optically thick individual radio sources. The delay at the highest frequency (17 GHz) can be ascribed at least partly to the hardening of electron spectrum resulting in a temporal increase in the electron number.The delay can reach 5~10s.

2. Correlation of spikes with HXR during type Ⅳ burst

Many workers previously studied the correlation between spikes, type Ⅲ and HXR burst.The close correlation implies that energetic electron is a probable exciter of them. When M. J. Aschwanden and A. O. Benz studied a correlation of solar decimetric radio bursts with X-ray flares, they excluded a long lasting type Ⅳ bursts. Type Ⅳ burst usually occures after the impulsive phase and lasts for a long time. The correlation of spikes with HXR peaks during type Ⅳ bursts has not yet been considered carefully before. We analyzed 16 type Ⅳ bursts in which there are 31 clusters of spikes.

2.1) Data selection and statistic result

There is a complete list of decimetric millisecond spikes during 1977-1989 at the astronomical institute of ETH in zurich.This list contains 164 spike clusters.Dennis provided the HXR catalog, it contains a total of 12672 bursts. Comparing the two lists, chose out events with overlap duration, then compared their time profile in detail. Their maximum was separately examined,note them with ts and tx.(ts-tx)is the delay between HXR and millisecond spike cluster. If (ts—tx) is positive, it means spikes occur after HXR burst. If the time difference between spike peak and HXR peak is less than 5s, i. e. $|\Delta t|<5$s, we classify it as "peaks in correlation". The 13 clusters of spikes belong to this class. For the rest (18 clusters) , the time difference is from 6s to 59s. In which 12 clusters of spikes occured before HXR bursts, only 6 clusters occured after HXR bursts. Perhaps the reason for the result is: HXR source often is generated at foot of loop(sometimes HXR appear at top of loop) , therefore spikes at long decimetric band often occur at the upper corona. Multiple electron beams may be generated during one flare. One of electron beams excites HXR event, others excites spikes cluster. There are the different distances between spikes sources and HXR sources, maybe this is one of the reasons why the delay has various numbers,from 0.2s to 59s.

2. 2)Gereral characteristics of type Ⅳ burst

Type Ⅳ burst is a flare-related continuum emission at meter wavelengths. It is a background for our studing subject. Type Ⅳ bursts can be divided into four distinct classes.

Early flare continuum (FCE) is generated during the flash phase of the solar flare,always in association with type Ⅲ burst.

Type Ⅳ burst is associated with polar cap absorption events which are caused by 10 to 100 Mev protons. Protons are initially accelerated in the microwave emitting region. The FCE events have stronger correlations with high fluxes of both protons and microwaves.

At the impulsive phase of a flare electrons are accelerated to energies ≤100 kev in a few seconds(type Ⅲ burst, impulsive microwave bursts, hard X- ray bursts).Type Ⅱ-Ⅳ bursts as well as the slower X-ray events, all come later in the flare. The impulsive phase of the flare corresponds to sub- relativistic electrons. After the impulsive phase, the flux slowly increase again and remains high for over an hour,in which the high energy particles involved. Sometimes spikes, type Ⅲ burst and HXR occured during a type Ⅳ burst. The characteristics have been used as evidence, it implies that there are multiple electron beams during a large flare.

2.3) Flare 80/04/06

We discuss a typical event as follows:

HXR emission(26-78kev,ISEE-3)started at 1420 UT,a maximum peak occurred at 142630 UT. An Hα flare of importance N was from 1423 UT to 1521 UT (N11, E 12) . The HXR emission of this flare was recorded from 143340 UT to 143800 UT by SMM, the time of three peaks are separately:1434.6 UT,1435.7 UT and 1436.4 UT.OTTA reported a type 47 GB burst.It started 1420 UT,at 1435.5 UT it reached maximum.Their peak time are:1426 UT, 1435.5 UT and 1452.8 UT . The spike cluster just occurred at 1435.5 UT. WEIS reported that a type Ⅱ burst occurred during 1423.3 -1428.0 UT; a type Ⅳ burst occurred during 1424-1711 UT. At solar radio station of ETH there are two types of radio spectra: the digital spectrometer IKARUS (Its data was recorded in tape) and the analog spectrometers DAEDALUS(Its data was recorded in film) ,On both IKARUS and DAEDALUS spectrometer, the spike clusters were recorded at 1434-1438UT,and they both closely correlated with HXR. We can believe that there was the accelerated electron beam in the active region.

Fig.1 shows the time profile of a radio burst from OTTAWA at 2800 MHz.

The burst started at 14:20 UT of 80/06/04,the first peak appeared at 142435UT.The second flux peak locaded at 1427.5 UT Fig.2 shows a type Ⅲ G burst associated with HXR, it occurred during 1420-1422, this should be during a impulsive phase of the flare. Following the impulsive phase, a type II--Ⅳ burst appeared,It is a sign of a energetic process.There is a very typical spikes that closely correlated with HXR at 1434--1436 UT in Fig.3. The spikes overlap on background radiation with longer duration. There are two subclusters of spikes(subclusters a and b) . We noted the durations of increased background with Tba and Tbb. Tba and Tbb increased with frequency increase, and the end points of spike clusters on each frequency appeared a shift to high frequency. It is shown that the motion direction of exciter is from acceleration region to chromosphere.

The evolution of radio radiation on a frquency domain may show the propagation process of electron beam in solar atmosphere. At 143400--143500,i.e.at a interval of burst a, there is a burst of longer duration (few seconds) at 425-464 MHz;there is a spike cluster at 586--652 MHz ; the end of the spike cluster drifts to higher frequency at 817--913 MHz.At 143500--143600 UT,i.e.at a interval of burst b,there is no burst at 425--464 MHz and 586--652 MHz; there is a spike cluster at 817--913 MHz and the end of the cluster also drifts to higher frequency.

During rise time of the radio maximum peak i. e. at 1434-1436, HXR and spike clusters coevolutely occurred.During the large flare, two electron beams occurred: 1424 UT and 1434 UT.

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Fig.1 The time profile of a radio burst at 14:20 UT of 80/06/04

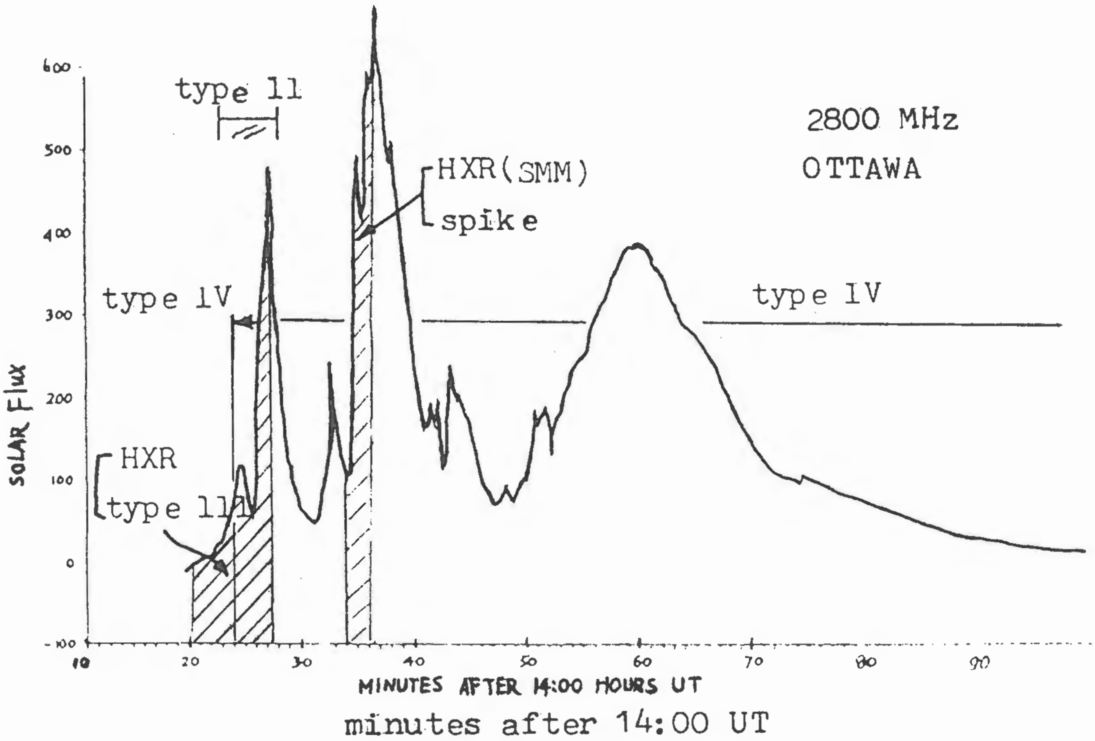

Fig.2 A type III G burst associated with HXR

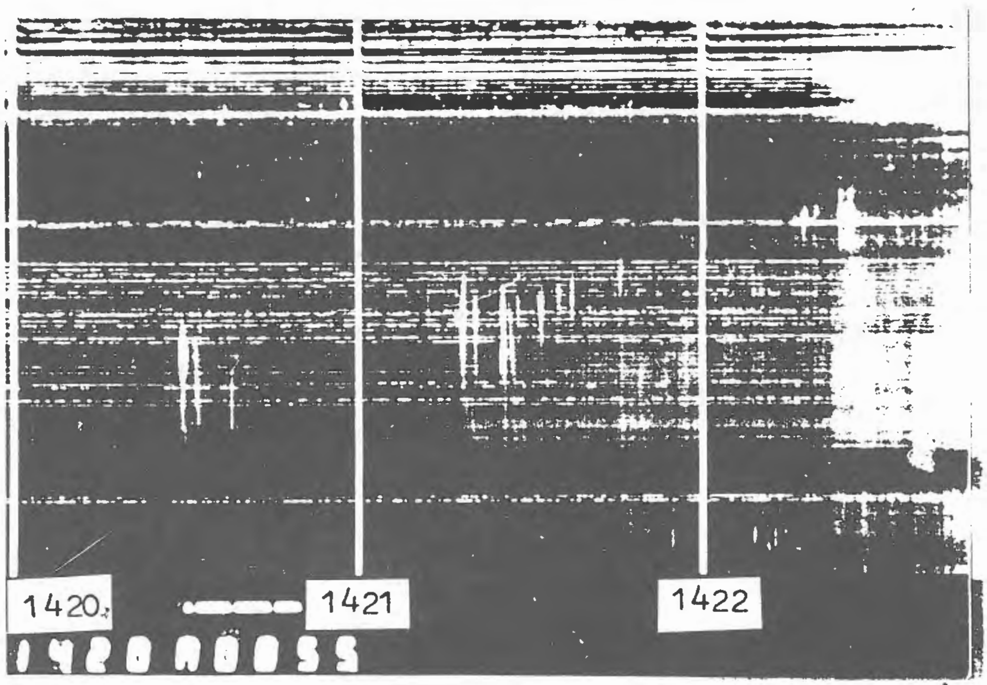

Fig. 3 Two clusters of spikes(a and b)associated with HXR