Soft X-Ray (Yohkoh) and Radio (VLA) Observations of Solar Narrowband, Millisecond Spike Events

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Abstract. The source regions of metric spike events are investigated on Yohkoh soft X-ray (SXR) maps. The spikes are identified by the spectrometer Phoenix between 300 MHz and 360 MHz and are associated with groups of type III bursts at lower frequencies reaching also the decametric range. The Very Large Array (VLA) provides simultaneously spatial information at 333 MHz and 1445 MHz. Similar to the previous VLA observation of a metric spike event, the new data are consistent with a high altitude of the spike sources of about $5 \times 10^{10}$ cm above the photosphere. The additionally available SXR data for one of the presented events give the following new information: (i) The spike sources occur near open field lines and near regions of a slightly enhanced SXR flux relative to the ambient plasma. (ii) Contrary to SXR observations of type III bursts without metric spike activity, no SXR jet is observed. (iii) At low altitude, a weak SXR enhancement occurs, peaking about 60 s after the spike event. The SXR source and the spike sources can be connected by potential field lines. The observations corroborate a model in which a metric spike event is attributed to an energy release region at high altitude, while upwards propagating electrons produce type III bursts and downward moving electrons are responsible for SXR emission of heated plasma.

1. Introduction

The Yohkoh soft X-ray data show us the corona at relatively high angular resolution and with relatively simple emission mechanisms. This information can be used to study the plasma physics of all kinds of radio bursts with less resolution, especially at longer wavelengths, and which may have quite complicated emission mechanisms, but yield important information on the nonthermal nature of the plasma. In this work, a first clear relation between the SXR-emitting plasma and metric millisecond spike bursts is presented.

The term 'narrowband, millisecond spikes' is used here for short (few tens of ms) and narrowband (few percent of the observing frequency) peaks in radio spectrograms at meter wavelengths. The metric spikes are closely associated
Figure 1. Soft X-ray image composed of the coaligned sum of all available Yohkoh thin aluminum images taken during the period between 9:00 UT and 13:40 UT. The effective exposure time is about 21.5 s. Enhanced flux is shown dark. Additionally, the contours of representative snapshot radio maps are overplotted on the SXR image: The contours at 333 MHz show a spike source, and in the map at 1446 MHz a source at AR7260 and a weaker source at AR7264 in the eastern hemisphere can be seen. The white box around the location of the spike sources corresponds to the enlargements of the SXR image presented below. Bottom: Enlargements of the full disk image. The centroid positions of the spike sources calculated from the snapshot maps ($\Delta t = 0.417$ s) are also plotted: The white squares correspond to the LCP centroids, the black diamonds to the RCP centroids.
with slowly drifting type III bursts occurring at lower frequency. In the spectrogram, the position of the spikes is close to the location of the type III bursts extrapolated to higher frequency (Benz et al. 1995), suggesting the same characteristic frequency to be responsible for the spike and the type III emissions.

The previously published spatially resolved observations of a metric spike event (Krucker et al. 1995) show three simultaneously active sources occurring apparently on open field lines at high altitude (4.5 x 10^{10} cm above the photosphere). The close correlation in time and frequency between the spikes and the type III bursts suggests an even higher altitude of the type III source on the same field lines. At lower altitude, but also along the same open field lines, an enhanced microwave flux of thermal origin is observed, peaking about one minute after the metric spike event. The observations have been explained assuming an energy release at high altitude, probably within the spike source. Starting in the energy release region, upwards and downwards moving electrons produce the type III emission and the enhanced level of thermal microwave radiation, respectively. In this model, the spikes may be a direct signature of the energy release.

2. Observations

The spectra observed by the spectrometer Phoenix, the OSRA Tremsdorf radio spectrometer and Weissnau Radio Station were used to select and to classify the solar radio events. Three metric spike events were found on 18 Aug 1992. Each of these events contains between 10 and 40 single spikes in the frequency range between 310 MHz and 360 MHz. The frequency range of type III activity starts around 300 MHz, and some bursts can be seen to continue below the instrumental limit of 40 MHz. The existence of low-frequency type III bursts suggest that the type III producing electrons are moving along open field lines.

The location of the spike source on the spatial radio maps can be identified by comparing the temporal evolution of the different sources appearing on the solar disk. The spike sources are situated north-east of the active region AR7260 where no strong soft X-ray emitting loops can be seen (cf. Figure 1). On this side of the active region there are coronal structures directed away from the active region with enhanced soft X-ray emission. These longish structures are not bent like ordinary loops and seem to lie along open magnetic field lines or along very large loops.

The partial frame XSR images taken with the thin aluminum filter during the first of the three metric spike events were centered on AR7260 but the field-of-view is too small to contain also the location of the spike sources. To investigate the temporal variations in the XSR flux, the flux changes relative to the previous image are considered. The result is expressed in units of the standard deviation, \( \sigma_{DN} \), calculated for each pixel separately using photon statistics. There is a flux enhancement of 4.3\( \sigma_{DN} \) occurring in the first image taken after the metric spike event (cf. Figure 2 bottom). The source position is in the east of AR7260 and there are extrapolated potential field lines connecting the XSR source and the spike source. The temporal evolution of this source can be seen in Figure 2.
The partial frame images (thin aluminum filter) taken during the first metric spike event (13:43:50–13:44:10 UT) Top left: The summed image (13:40–13:48 UT) with an effective exposure time of 0.4 s. Enhanced flux is shown dark. Top middle: The photospheric magnetic field in AR7260 from KPNO/NSO. Positive polarity is shown bright, negative polarity is dark. Top right: Time variation of the total flux of the observed SXR source. The solid line shows the variation of the source center determined by the contour at half intensity, and the dashed line is the variation of sum of the neighboring pixels. The error bars are calculated from photon statistics. The interval of metric spike activity is marked by vertical lines. Bottom: Enlargements in full time resolution of 60 s of the marked box shown in the top left image. The overplotted contours are the flux changes relative to the previous image (white for increasing flux, black for decreasing flux) at ±3 and ±4 times the standard deviation.

3. Conclusions

The spikes occur at high altitude (≈ 5 × 10¹⁰ cm above the active region) in slightly different locations. The spikes and the type III bursts seem to occur in a denser structure as outlined by the SXR observations. At lower altitude, enhanced SXR emission is observed after the metric spike event peaking about one minute later. Hence, the new observations support the proposed geometry of the metric spike event (cf. Krucker et al. 1995).

References

Flare Observations