Preflare Nonthermal Emission Observed in Microwaves and Hard X-Rays

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ABSTRACT

We present a detailed examination on the nonthermal emissions during the preflare phase of the large X4.8 solar flare which occurred on 2002 July 23. The microwave data obtained with Nobeyama Radioheliograph, at Nobeyama Solar Radio Observatory, NAOJ, and the hard X-ray data taken with Reuven Ramaty High Energy Solar Spectroscopic Imager obviously showed nonthermal features. We found a faint ejection associated with the flare in the EUV images taken with the Transition Region and Coronal Explorer. Then, we examined the temporal, spatial, and spectroscopic features on the emission sources, and found the loop-top sources during the preflare phase both in hard X-rays and in microwaves.

Key words: Sun: corona — Sun: flares — Sun: particle acceleration

1 INTRODUCTION

Nonthermal emissions from accelerated particles are often observed in hard X-rays (HXRs), γ-rays, and microwaves at the beginning of a solar flare. These nonthermal emissions are associated with strong energy release processes, which characterize the “impulsive phase” of a flare. As Benz & Grigis (2003) reported recently, nonthermal emissions are associated with even a small energy release such as a microflare. However, it has been thought that the particle acceleration works efficiently only in the impulsive phase. On the other hand, in the preflare stage we sometimes find flare-predictive phenomena, such as a gradual enhancement of soft X-ray (SXR) emission, rise of SXR plasmoids and/or Hα filaments, and so on. Even in the preflare stage, some energy release process is probably occurring at a low level, although the energy release is much milder. It has not been widely accepted that nonthermal particles are present in significant numbers prior to the impulsive phase of a flare, rather it has been common to speak of preflare heating implying thermal behavior.

Recently, Holman et al. (2003) examined the HXRs features of the large X4.8 flare which occurred on 2002 July 23, and reported that the nonthermal energy even before the impulsive phase was quite large. The flare showed many spectacular features in HXR and γ-ray wavelengths obtained with the Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESI: Lin et al. 2002), and was also observed in microwaves with the Nobeyama Radioheliograph (NoRH: Nakajima et al. 1994) as reported by White et al. (2003). Motivated by the work, we analyzed the flare, and found sufficient emissions both in HXRs and in microwaves that can be candidates for nonthermal emissions during the preflare phase. Especially, this is the first time of imaging observation of the preflare nonthermal emission in microwave. In order to derive information on the energy release in the preflare phase, we examined in detail the features of the emission sources spatially, temporally, and spectroscopically. In this paper we focus on the nonthermal emissions in the preflare phase, from about 23:00 UT, 2002 July 22 to about 00:30 UT, 2002 July 23. We divide the preflare phase into four sub-phases, and examine each phase in more detail.

2 RESULTS

• Phase I; preflare

The first phase corresponds to the time from about 23:30 UT, 2002 July 22 to 00:16 UT, 2002 July 23. We can see a large loop-like bright region in the NoRH image (White et al. 2003). The GOES temperature also shows the existence of hot plasma of about 5 MK in this phase. We measured the spectral index $\alpha$ of the emission source, and found that it is about 0 (within from $-0.4$ to 0.6). Therefore, the optically-thin (free-free) thermal emission is dominant for the source. Moreover, the polarization of the sources is no more than 10%, which eliminates the possibility of the emission from the gyrosion near sunspot umbrae. Therefore, we suggest that the large loop-like structure with high temperature, like a sigmoid, exists in this phase.

• Phase II; preflare phase

The second phase includes the first flare emissions (from
microwave (34 GHz) and in the HXRs (12 - 25, 25 - 40 keV).

The HXR source is visible in both 12 - 25 keV bands. These sources could resemble to the thermal coronal features and also clear signatures of nonthermal emissions are the same as in the impulsive phase, as Krucker, Hurford & Lin (2003) reported. The positions of the emission sources do not change so much from the previous phase. The HXR coronal sources ascend slightly as the flare progresses. The 34 GHz emission comes to localize gradually on the upper section of the loop. As a notable result, we can see an HXR loop-top source even in 40 - 60 keV as shown in the bottom left panel of Figure 2. In this phase, the α index increases slightly (becomes harder) to about −1.5.

3 DISCUSSION AND SUMMARY

We examined in detail the nonthermal emissions in the preflare phase, and also examined the relation between the nonthermal emissions and other observed phenomena. We identified a faint EUV ejection in the TRACE data which was associated with a nonthermal microwave burst, just before the fast energy release process occurs in the impulsive phase. In the phase before the ejection, we found observational evidence of both thermal and nonthermal emissions in the corona above the flare ribbon structure. Our results suggest that energy release mechanism in the preflare phase of a typical flare may be accompanied by particle acceleration, although it is much milder than that in the impulsive phase and therefore difficult to detect in flares smaller than this event.

REFERENCES

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