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Microwave observations with the RATAN-600 radio telescope: detection of the thermal emission sources

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Abstract. We report on two off-limb radio sources of microwave emission which were detected in one-dimensional RATAN-600 solar scans of the post-eruptive loops: on December 2, 2003 (off west limb) and January 25, 2007 (east limb). The microwave spectra showed that the thermal emission was predominant at the early stage of the arcade formation with a small contribution of non-thermal emission. There were no high-energy particles in these events. The microwave spectra of the radio sources associated with the tops of postflare loops show the predominant thermal emission during one hour after the eruption. In case of a small contribution from accelerated particles to the microwave emission, there is a large amount of hot plasma in the region of the loop tops after the eruption.

Keywords. Sun: radio radiation, flares, particle emission, coronal mass ejections (CMEs)

1. Introduction

Systems of post-eruptive arcades could be formed in events of various importance. We suppose that one of the necessary conditions for that is a CME development followed by removal of the main part of the gas mass far into interplanetary space. However, a part of the matter could be held into coronal layers of active regions and take part in the arcade formation. Observations of post-eruptive arcades in various spectral regions were analyzed in several papers (e.g., Feldman *et al.* 1995; Harra-Murnion *et al.* 1998; and Grechnev *et al.* 2006). In this paper we discuss the observations of different cases of post-eruptive arcade formation in events with weak flares (C-class in GOES classification) just at the initial stage. In order to confirm our supposition, it is necessary to analyze the role of thermal and non-thermal processes in the source region of the subsequent arcade formation.

2. Observations

25 January 2007 On January 25, 2007 the solar observations by the radio telescope RATAN-600 (Korol'kov & Parijskij 1979) were made at 07:44 UT, 08:18 UT, 08:52 UT, 9:26 UT (local noon), 10:00 UT, 10:34 UT and 11:08 UT. The limb event consisted of a CME and C6.3 class flare (S08E90). The flare onset was at 06:33 UT and the peak emission occurred at 07:14 UT. At early stages of the post-eruptive arcade formation, the spectrum of microwave emission was practically flat (see Fig. 1d). One may conclude

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from RHESSI data, that directly after the peak of the flare in the mean HXR spectra the thermal contribution dominated (see Fig. 1c).

2 December 2003 On December 2, 2003 the solar observations were made at 08:02 UT, 09:03 UT (local noon), 10:03 UT and 11:04 UT. This limb event consisted of a filament eruption, CME and C7.2 class flare (S19 W89). The flare onset was earlier than 09:40 UT and the peak emission occurred at 09:48 UT. The nearest moment of radio observations to the beginning of the arcade formation was at 11:04 UT. In X-ray range the source with predominant thermal emission was observed directly above the top of post-eruptive arcade (see Fig. 2a).

3. Discussion

The microwave spectra obtained with the radio telescope RATAN-600 of the radio sources associated with the tops of postflare loops show the predominant thermal emission during one hour after the eruption (see (Fig. 1d and Fig. 2b). In case of a small contribution from accelerated particles to the microwave emission, there is a large amount of

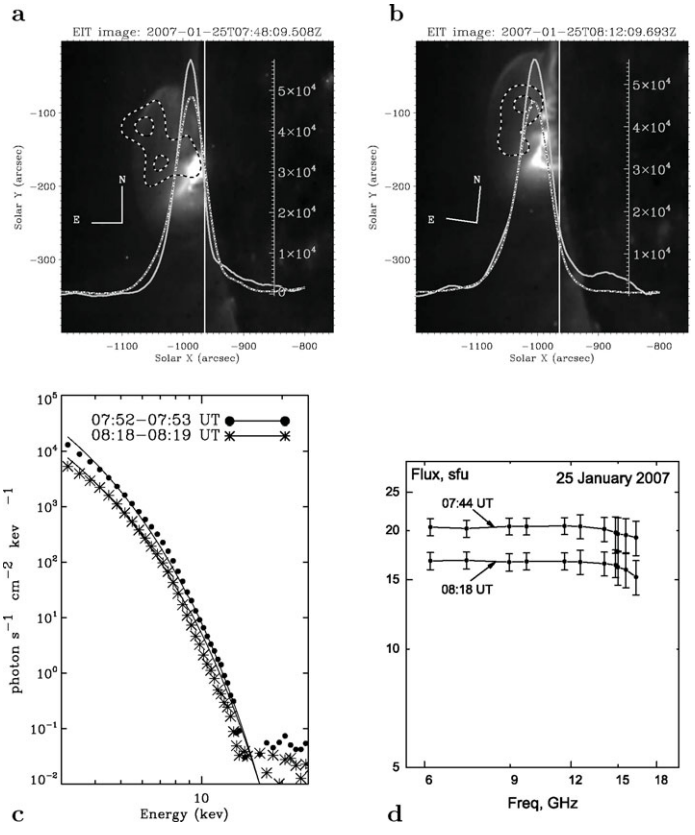

Figure 1. (a and b) The off-limb radio source extracted from the one-dimensional RATAN-600 solar scan (Stokes "I") at 2.03 cm and 5.02 cm at 07:44 UT and at 08:18 UT overlaid on the SOHO/EIT 195 Å solar image at 07:48 UT and 08:12 UT, respectively. Vertical lines show the solar limb. Dashed lines show the overlaid RHESSI image by counters at 90% and 70% of maximum (6–12 keV). Vertical scales show exceeding emission above the quiet Sun's level of the off-limb radio source (antenna temperature in K). (c) Mean HXR photon spectra obtained with RHESSI data. (d) Averaged total flux microwave spectra of the off-limb radio source associated with the post-eruptive arcade during the initial stage formation.

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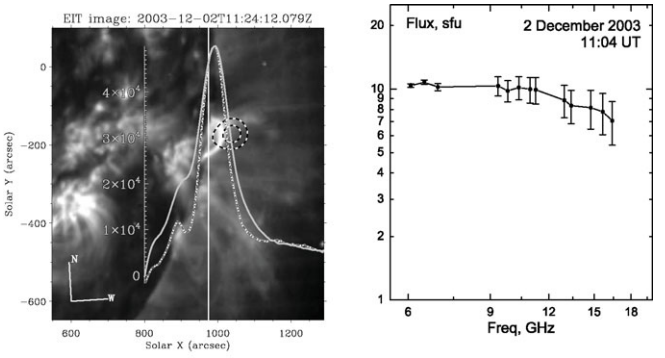

Figure 2. (a) Data as in Fig. 1a and 1b at 11:04 UT (RATAN data) and at 11:24 UT (SOHO/EIT image, RHESSI data) on December 2, 2003. (b) Data as in Fig. 1d.

hot plasma in the region of the loop tops after the eruption. Simultaneous studies of radio and X-ray radiation provide useful information on the post-eruptive arcade formation. The plasma parameters for both flares are extracted from the RHESSI photon spectrum by fitting the mean spectrum obtained using a standard routine of the RHESSI software (Smith *et al.* 2002). The best fit was obtained for the optically thin bremsstrahlung radiation function (vth). The results confirm the thermal nature of the observed sources and the obtained emission measures and plasma temperatures are: $EM = 6.1 \times 10^{47}$ cm^{-3}, $T = 12.8 \times 10^6$ K and $EM = 2.5 \times 10^{47}$ cm^{-3}, $T = 12.8 \times 10^6$ K for the 25 January 2007 event (at 07:52 UT and 08:18 UT, respectively) and $EM = 1.3 \times 10^{48}$ cm^{-3} and $T = 17.4 \times 10^6$ K for the 2 December 2003 event (at 11:24 UT). Assuming bremsstrahlung as a predominant mechanism of microwave emission and $T = 5 \times 10^6$ K, we estimate from microwave data the emission measure to be $EM = 14.6 \times 10^{48}$ cm^{-3} at 07:44 UT and $EM = 7.5 \times 10^{48}$ cm^{-3} at 08:18 UT on January 25, 2007. These values are higher than those obtained from X-ray data. This may be the evidence of the presence of plasma with different temperatures. It is interesting to study in future the influence of the hot plasma on the post-eruptive processes.

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