LONG DURATION VERY SOFT X-RAY FLARES

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ABSTRACT

Using RF15-I X-ray photometer aboard INTERBALL-Tail satellite we have identified a class of very soft, low intensity and long duration flares. They have decay time of the order of hours, low GOES class (~A or ~B) and usually no detectable emission above 10 keV. We used YOHKOH Soft X-ray Telescope images to search for sources of these events. We have found that, similarly to bigger flares, there is a large diversity in the morphology of these small events, including arcades of loops, interacting loop systems, and in one case a sigmoid. Many of these sources are observed at the limb and they may be a part of the larger structures hidden behind the solar disk. In this paper we present morphology and investigate physical parameters of three selected events.

INTRODUCTION

The Long Duration Events (LDE) are generally associated with large, high (10^4 - 10^5 km), long-lasting (several hours) arcades of loops (Kahler, 1977). Thy are characterised by smooth time profiles and slow expansion (1 - 10 km/s). Their hard X-ray emission is weaker than in impulsive flares but still clearly observed (Tsuneta 1992, Harra-Murnion et al. 1998).

Using data taken with RF15-I X-ray photometer aboard INTERBALL-Tail satellite we have identified (Siarkowski et al., 1999) many very soft, low intensity and long duration flares. They have a decay time of the order of hours, low GOES class (A or B) and usually no detectable emission above 10 keV.

In this paper we used YOHKOH Soft X-ray Telescope (SXT) images to search for sources of these events. Imaging capability of the SXT give a unique opportunity to study such faint/small events (with spatial resolution of 2.5 arcsec). During the period of low solar activity (August 1995 – December 1997) we have identified about 30 small LDE events with duration longer than 1 - 2 hours, a GOES class less than C1, and observed by SXT.
The SXT image analysis showed that, similar to larger flares, the morphology of these small events is very diverse. Below we present the characteristic examples of such sources, their morphology and physical parameters.

OBSERVATIONS

RF15-I Soft and Hard X-ray Photometer (Sylwester et al., 2000) is placed onboard the INTERBALL-Tail satellite lunched on 3 August 1995 and has been operating continuously up to now. The photometer performs observations of the whole-disk solar X-flux in 3 soft X-ray and 5 hard X-ray energy channels.

The proportional detector of the photometer nominally measures the soft X-ray solar fluxes in three energy channels: 2-3 keV, 3-5 keV and 5-8 keV with the time resolution 2 seconds. The scintillation (NaI(Tl)) detector of the photometer measures the whole-disk hard X-ray fluxes in five channels: 10-15 keV, 15-30 keV, 30-60 keV, 60-120 keV and 120-240 keV. In the first channel (h1: 10-15 keV) the data are collected synchronously with the softer channels (s1, s2 and s3) with the time resolution 2 seconds. In the upper four energy channels (h2-h5) the data are collected every 0.125 of a second, provided that appropriate rate thresholds (~40 c/s for all channels) are exceeded.

We processed the SXT data using the standard SolarSoft package. The temperatures and emission measures of the plasma were calculated using filter-ratio method, under assumption that the observed structures are isothermal.

10/11 January 1996 event

Light curves recorded by RF15-I are presented in Figure 1. According to GOES 7 observations this flare was B1.0 class event. The emission was strongest in softest 2-3 keV channel, and no enhancement of the emission was observed above 10 keV. This event started as a small brightening at 22:28 UT and reached the peak of emission at 00:22 UT (channel 2-3 keV) with the rise time about 2 hours. After maximum, the intensity was decaying slowly up to 07:30 UT when another small brightening of the GOES class A7.8 occurred. The decay time and whole event duration were thus 7 and 9 hours respectively.

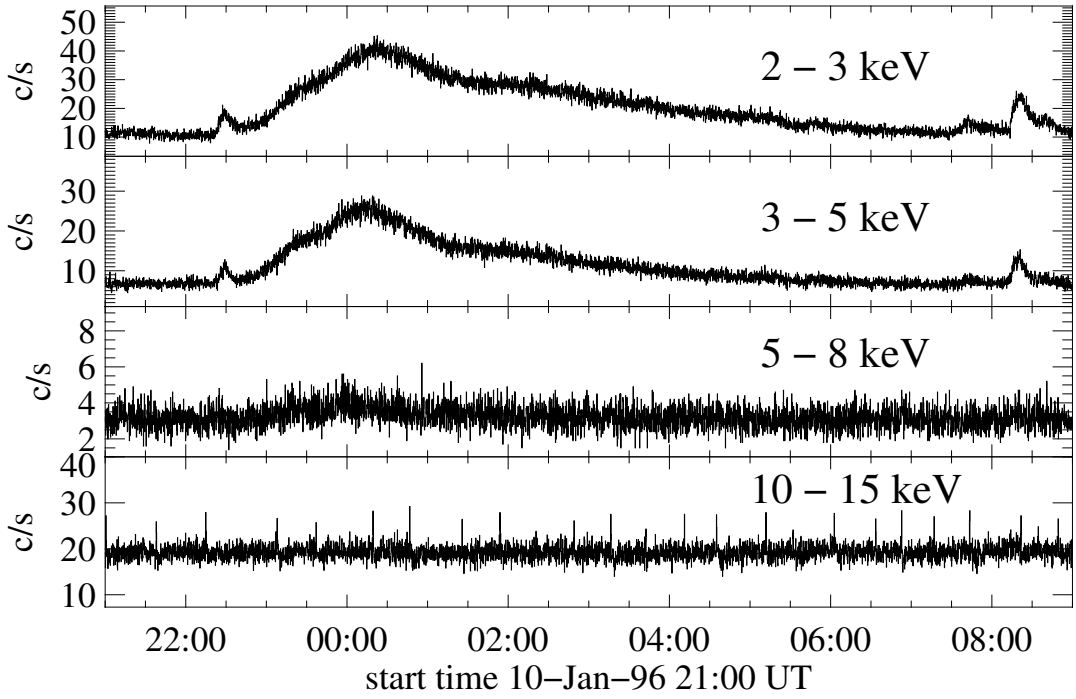

Figure 1. Ten-second averaged flux variability, recorded by RF15-I photometer during the 10/11 January, 1996 event. Spikes seen in 10-15 keV are of the ionospheric origin.

A target for SXT observations during this period was NOAA 7939 active region at N03W73. Corresponding SXT light-curves reveal that A7.8 class brightening at 08:21 UT can be attributed to this AR. However, using full frame SXT images we can connect the event observed by RF15-I with NOAA 7938 active region. Figure 2 shows the location and corresponding SXT light curve of the AR. The light curve clearly shows that the AR was a source of the B1.0 flare, and that its decay time was even longer than the observed by RF15-I one.

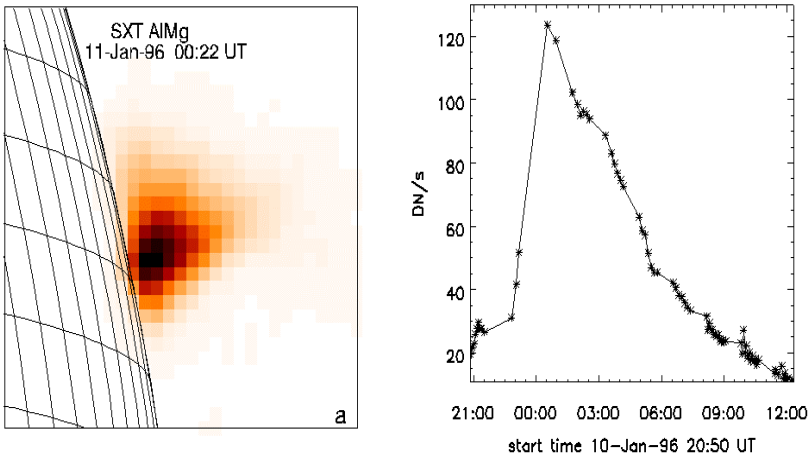

Figure 2. SXT image of NOAA 7938 (a) and corresponding light curve (b).

This source (see Figure 2a) looks like the very top of a casp structure occulted by the solar limb. An extrapolation of the heliographic coordinates of NOAA 7938 indicates that this region was about 20 degrees behind the limb at the beginning of January 11. Thus, the height of ~ 4.5 10^4 km (typical for large LDE) can be estimated. Probably we have seen only the highest parts of the large LDE, which took place behind the limb. In such a case, the lack of the emission above 10 keV may be attributed to observations of the uppermost part of flaring loops system, higher than any type (Kosugi, 1994) of hard X-ray sources.

3/4 November 1995 event

An evolution of the event, as seen on SXT AlMg images is presented in Figure 3. It was a B3.3 GOES class flare, which appeared on the east limb. During the first orbit (ended at 21:42 UT) the SXT observed only a small increase of intensity in low laying loops. After the satellite night, starting from 22:38 UT, SXT observed an arcade of the loops with a bright, elongated structure at the top and many fainter legs with their footpoints on the visible part of the solar disk. During next 3 hours the arcade expands slowly with projected velocity of ~1 km/s. The average temperature of loop structure was about 6 MK.

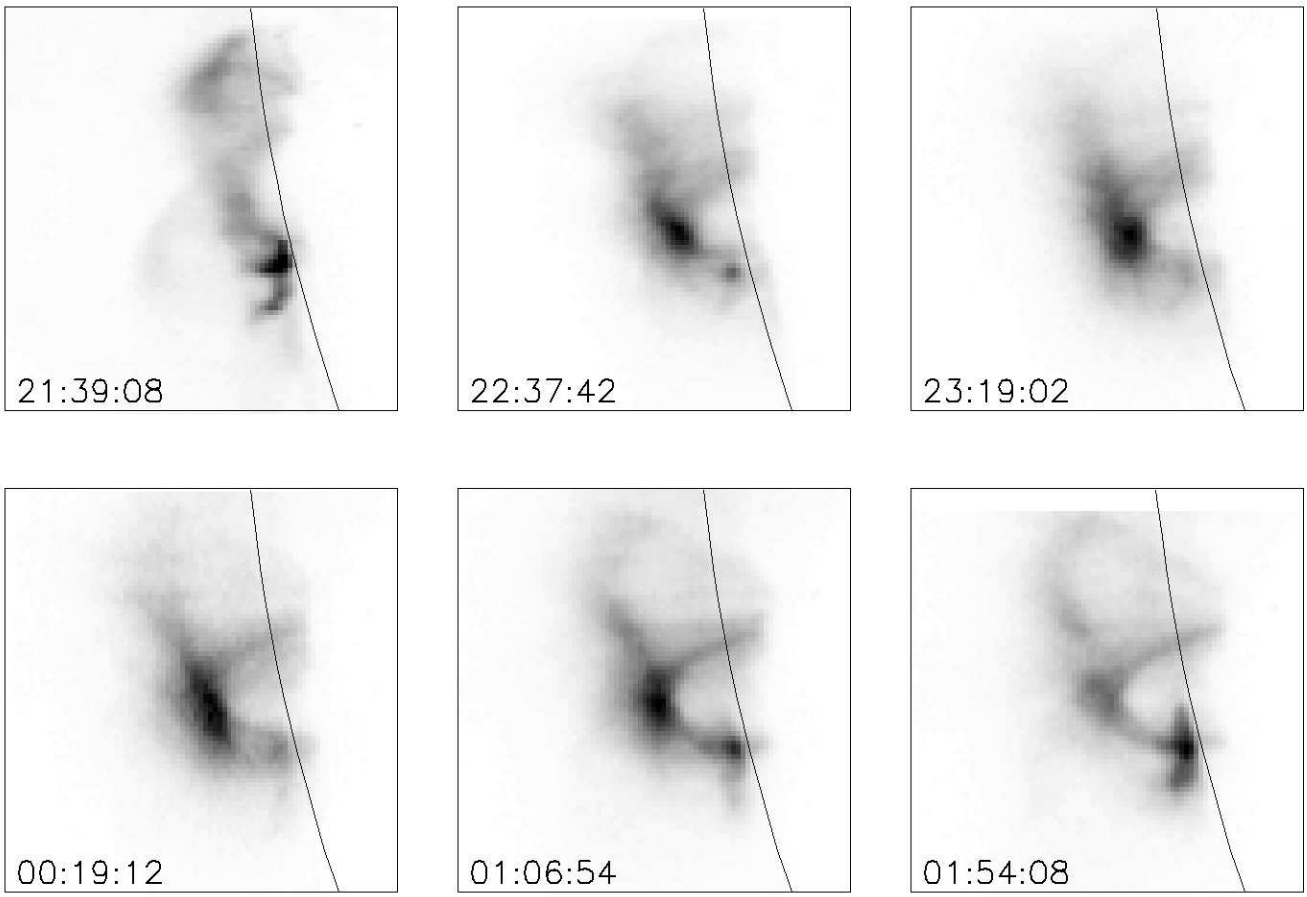

Fig. 3. Evolution of the 3/4 November 1995 event seen in SXT AlMg images.

On the first orbit considered, we observed huge, cool and expanding loop, spanning whole area of later developed arcade (Fig.4). The temporal changes of the total signals measured in 6 rectangular areas (marked A - F) were caused by the expansion of the loop. The intensity of the loop dropped in time, as it expands. The estimated, projected expansion velocity is about 15-20 km/s and the estimated temperature of this loop is less than 1.5 MK. This observation is consistent with a standard picture where the origin of the flare is due to the eruption of a filament-like feature.

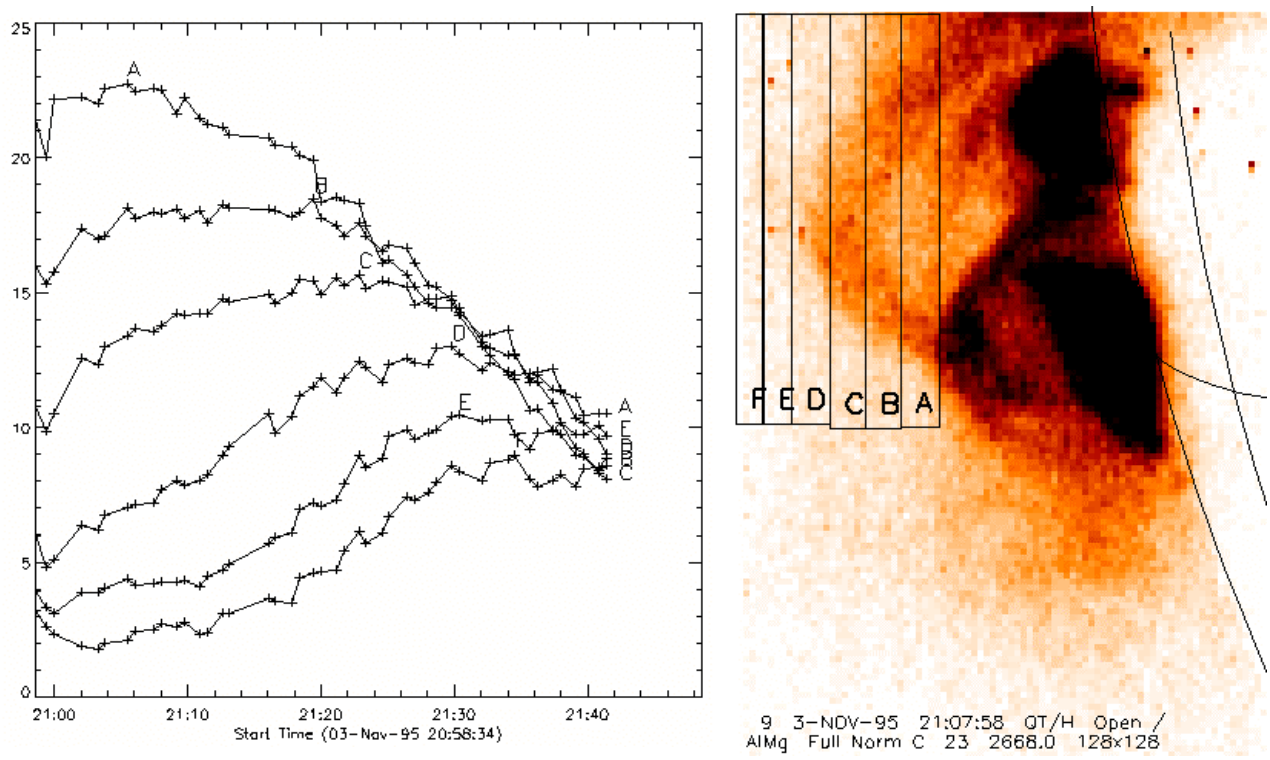

Fig. 4. SXT AlMg image taken at 21:07:58 UT (right panel). The contrast of the image was increased to expose a huge, faint loop spanning the whole observed area. The temporal changes of the total signals measured in 6 rectangular areas (marked A - F) are presented on the left panel. The shift of the maximum was caused by the expansion of the loop.

26 April 1996 event

The 26 April 1996 event starts at about 13:00 UT and lasts till approximately 18:30 UT reaching its peak at 14:30 UT. A GOES class of the event was A5.5 only. It was also observed, as a very weak event, by the RF15-I photometer. Yohkoh SXT images show that the flare appeared in the large S-shape or sigmoidal structure, which crossed the solar equator near the centre of the disk (Figure 5).

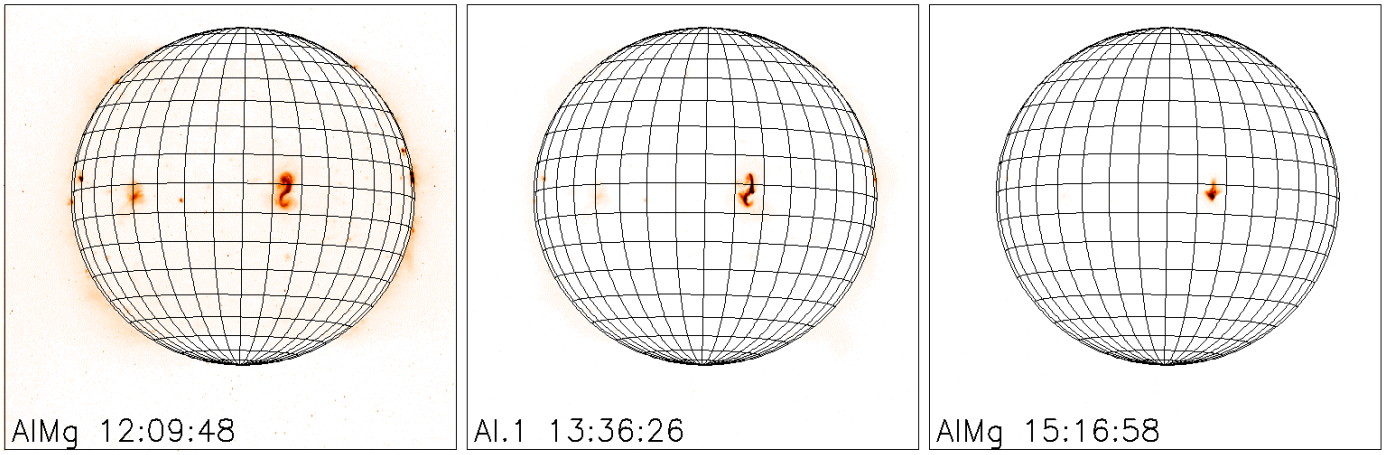

Fig. 5. Full frame SXT images of the sigmoid before, during and after the 26 April 1996 event (from left to right, respectively).

An evolution of this event is presented in Figure 6. At the beginning of the event a part of the sigmoid is split into two bright loops. As the flare progresses new loops appeared seemingly spreading out from main body of the sigmoid. At the end of the event the sigmoid, formed from many individual loops, disintegrate.

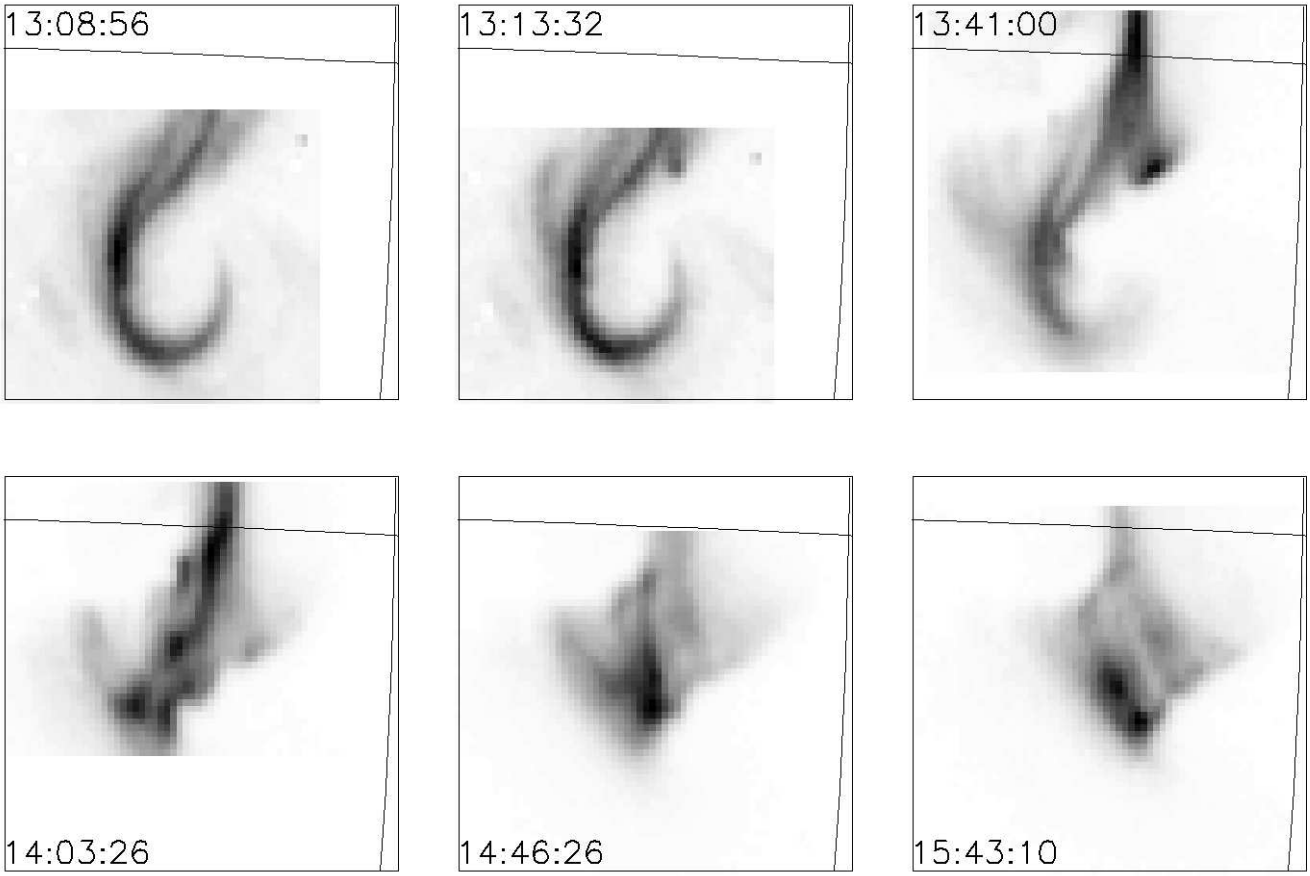

Fig. 6. Evolution of the 26 April 1996 event seen in SXT Al.1 images.

DISCUSSION

Using RF15-I X-ray photometer aboard the INTERBALL-Tail satellite we have identified a new class of very soft, low intensity and long duration flares. They have a typical decay time of the order of hours, low GOES class (A or B) and usually no detectable emission above 10 keV.

In this paper we used YOHKOH SXT images to search for sources of such events. We have found that, similar as in bigger flares, there is a large diversity in the morphology of these small events. More than 50% in our sample are sources in which two or more loops interacted. About 20% of the events appeared at limb. Part of them may be observations of the top of the larger structures hidden behind the solar disk. Also about 20% are the different arcade configurations of the loops, both on the disc and on the limb. At one case we have found a sigmoid structure which disintegrated during event. This sigmoid seems to be composed of a number of individual loops.

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