Gamma and X-ray Solar Flare Emissions: CORONAS-F Measurements

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Abstract

The first experience with measurements of solar gamma and hard X-ray emissions observed on CORONAS F satellite from August 2001 until August 2002 is summarized. Detection capability and review of SONG instrument measurements during solar flares is presented.

1. Introduction

The low altitude ($\sim$ 500 km) polar orbiting (inclination $\sim 82.5°$) satellite CORONAS-F was launched on July 31, 2001. Among the basic tasks of the project is the study of effects related to energy transfer in the solar atmosphere, and in particular of acceleration of solar particles. One of the experiments, namely SONG is providing measurements of gamma rays up to $>$ 100 MeV and of neutrons $>$ 20 MeV. After a short description of the instrument, its abilities and limitations, we present a survey table of its observations for solar flares of the importance higher than M3 for the first year of the measurements.

2. SONG experiment

At present the hard electromagnetic radiation from the Sun is measured by HESSI (one of the experiments described in [1]) and by CORONAS-F. The orientation of CORONAS-F satellite towards the Sun is better than 10 arc min. The experiment SONG is one of the instruments of SKL (Solar Cosmic Ray) complex coordinated by Skobeltsyn Institute of Nuclear Physics, Moscow (PI S.N. Kuznetsov). The electronics of the SONG instrument was developed by the IEP SAS Kosice, Slovakia. It is an updated construction of the similar experiment on CORONAS-I [2]. The instrument is devoted to detection of hard X and gamma rays 0.028-100 MeV, neutrons $>$ 20 MeV and of CR charged particles, mainly protons $E > 70$ MeV and electrons $E > 55$ MeV. The detector part consists of Cs(I) crystal of 20 cm (diameter) $\times$ 10 cm surrounded by the active anticoincidence shielding of plastic scintillator 2 cm width. The upper part is isolated from the bottom. Thus the scintillator along with Cs(I) crystal creates the electron

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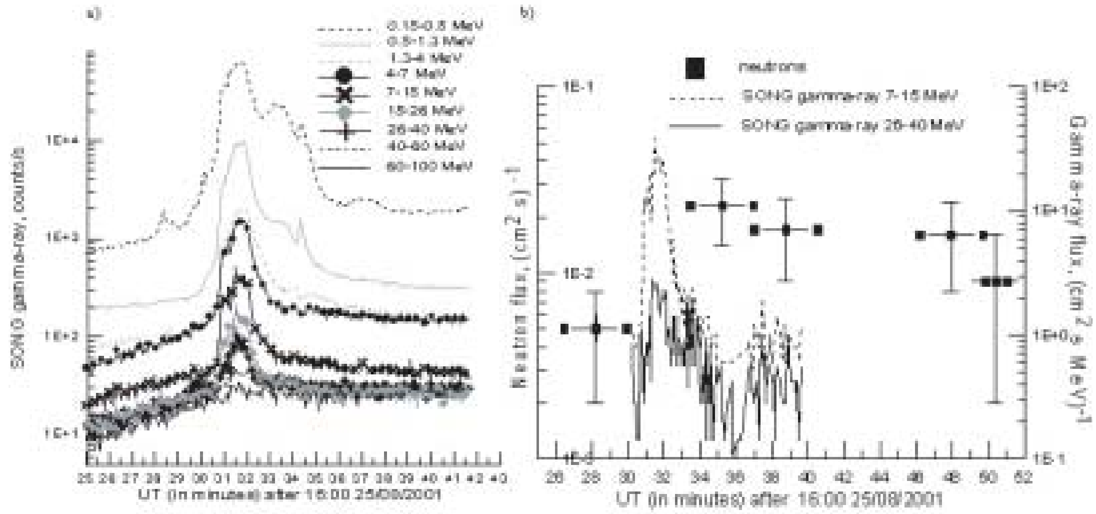

Fig. 1. The count rate of gamma rays by SONG (a) and solar neutron and gamma-ray flux (b) on CORONAS-F during the solar flare on August 25, 2001.

telescope. The electron is identified if signal from Cs(I) and upper part of coincidence appears while it is absent in the bottom part. Neutrons are detected due to the interactions with Cs and I nuclei. For identification of neutrons on the background of gamma flux the pulse shape dependence on relative ionization is used [3]. X and gamma rays are measured in the energy release ranges 0.028-0.053, 0053–0.15, 0.15–0.50, 0.50–1.3, 1.3–4.0, 4.0–7.0, 7.0–15, 15–26, 26–41, 41–60, 60–100 MeV and neutrons 7–15, 15–26, 26–41, 41–60, 60–100 MeV. CR are identified if energy deposited in the crystal is > 50 MeV. Temporal resolution for X and gamma rays is 4 s, for n,e and CR it is 30 s. Maximum effective surface for gammas and neutrons is ~ 270 cm^2 and ~ 38 cm^2 respectively [4]. SONG is capable to observe hard X and gamma rays of solar origin when it is outside the radiation belts or not shadowed by Earth (shadow is up to $\sim 40\%$ of the orbital period). The background is due to local gamma-ray produced by the interactions of CR either with the instrument, satellite body or with the atmosphere. The increases due to bremstrahlung by relativistic electrons of radiation belts are skipped from the flare emission analysis

3. Example, catalogue of events, summary

The observation of high energy gamma rays from the flare on August 25, 2001 is illustrated in Figure 1.

Gamma rays up to > 40 MeV are seen well above the background. Since it was before launch of HESSI it is not possible to compare the fluxes. The event is not accompanied by any significant charged particle flux. It is not in the list of Solar Proton Events (http://umbra.nascom.nasa.gov/SEP/seps.html). There are no proton and electron enhancement in polar caps detected by MKL instrument on board CORONAS-F (http://www.coronas.ru/intl/ru/skl/data-mkl.htm). The event is mentioned as X5.3 at http://hea-www.harvard.edu/SSXG/kathy/flares/xflares.html as well as at http://isass1.solar.isas.ac.jp/sxt_co/sxt_trace_flares/list.html among the list of flares jointly observed by SXT and TRACE as X5.4 flare with the times of the first and last flare mode SXT images, the second one close to the observed very hard gamma emission by SONG. During the flare SONG detected enhancements in neutron channels 7–15, 15–26, 26–41 MeV after main gamma peak (see Fig. 1b). First and last points are background neutron flux in the experiment.

Recently two case studies using SONG data along with other instruments on CORONAS-F have been done, namely on November 4, 2001 [5] and on May 20,2002 [6]. Table 1 is the summary of solar flares of importance (M3 during the first year of CORONAS-F mission and the observations by SONG instrument. The proton flux (measured by GOES) caused by the flare in the last column. Sign "<" means that detected during (and after) the flare flux is connected with the earlier flare. We can see that only $< 30\%$ flares with gamma ray lead to SEP in space. Solar neutrons were detected yet only in 25/08/2001 flare after 16 h 33 min UT.

4. Summary

First year of measurements by SONG instrument on CORONAS-F illustrated its capability of detection of hard X and gamma ray emissions from the Sun. The data obtained may be of relevance for eventual comparison with HESSI as well as with the ground based measurements of solar neutrons by technique [7].

5. Acknowledgement

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6. References

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Table 1. List of SONG solar gamma observations August 2001–August 2002 (CORONAS-F).

N	Date	UT flare (GOES) - start - max - end	Flare imp.	Ball	Flare coord.	Active region	UT flare (SONG 0.5-.15 MeV) - start-end	SONG max. energy chan-nel (MeV)	E_p> 10 MeV (cm^2 s^{-1} sr^{-1})
1	01/08/25	16:23-16:45-17:04	X5.3	3¬	S17E34	9591	16:29-16:38	60-100	<1
2	01/09/05	14:25-14:32-14:34	M6.0	2¬	N15W31	9601	14:27-14:28	1.3-4	bkgr. (0.1)
3	01/09/09	15:10-15:16-15:21	M3.4	1N	S17E03	9607	15:11-15:13	.5-1.3	bkgr.
4	01/10/19	16:13-16:30-16:43	X1.6	2B	N15W29	9661	16:23-–œ«	1.3-4.	10
5	01/10/23	02:11-02:23-02:34	M6.5	1B	S18E11	9672	02:15-02:17	.15-.5	< 5
6	01/11/04	16:03-16:20-16:57	X1.0	3B	N06W18	9684	16:06-16:14	.15-.5	$>10^4$
7	01/12/11	07:58-08:14-08:08	X2.8	SF	N16E41	9733	08:04-08:08	7-15	1
8	02/01/09	17:42-18:01-18:12	M9.5	2¬	N13W02	9773	17:57-17:58	.05-.15	100
9	02/02/20	05:52-06:12-06:16	M5.1	1N	N12W72	9825	06:08-06:11	4-7	10
10	02/02/20	09:46-09:59-10:04	M4.3	SF	N18W83	9825	09:54-09:59	.05-.15	<4
11	02/02/20	17:03-17:11-17:18	M3.5	SF	S09W62	-	17:10-17:11	.05-.15	<2
12	02/03/17	19:24-19:31-19:34	M4.0	SF	S22E16	9871	19:27-19:29	.15-.5	<50
13	02/05/20	15:21-15:27-15:31	X2.1	2N	S21E65	9961	15:25-15:29	4-7	bkgr.
14	02/07/11	14:44-14:51-14:57	M5.8	2N	N22E58	0030	14:47-14:49	.15-.5	<0.5
15	02/07/17	06:58-07:13-07:19	M8.5	1B	N22W17	0030	07:10-07:13	1.3-4	<200
16	02/07/20	21:04-21:30-21:54	X3.3	-	-	-	21:08-21:29	1.3-4	200
17	02/07/29	10:27-10:44-11:13	M4.7	-	-	-	10:38-10:43	.05-.15	<1
18	02/08/03	18:59-19:07-19:11	X1.0	SF	S16W76	0039	19:04-19:07	.15-.5	0.5
19	02/08/17	20:39-20:51-20:57	M3.4	SF	S06W05	0069	20:48-20:50	.15-.5	<3
20	02/08/19	20:56-21:02-21:06	M3.1	1B	S11W33	0069	21:00-21:02	.05-.15	<2
21	02/08/20	01:33-01:43-01:40	M5.0	1N	S10W38	0069	01:40-01:43	1.3-4	<1.0
22	02/08/20	08:22-08:26-08:30	M3.4	1B	S10W38	0069	08:24-08:26	4-7	2.5
23	02/08/21	05:28-05:34-05:36	X1.0	1B	S12W51	0069	05:31-05:33	4-7	<0.5
24	02/08/24	00:49-01:12-01:31	X3.4	1F	S12W51	0069	00:58-01:03	4-7	300
25	02/08/28	18:52-18:59-19:06	M4.6	-	-	-	18:56-18:59	.05-.15	bkgr.
26	02/08/29	12:42-12:52-12:56	M3.2	SF	S18E73	0095	12:48-12:51	.15-.5	bkgr.
27	02/08/30	12:47-13:29-13:35	X1.5	SN	N15E74	0095	13:27-13:29	4-7	bkgr.

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