

Searches for high energy solar flares with *Fermi*-LAT

G. Lafrate (INAF/OATs and INFN Trieste) and F. Longo (INFN Trieste)
on behalf of the Fermi Large Area Telescope Collaboration



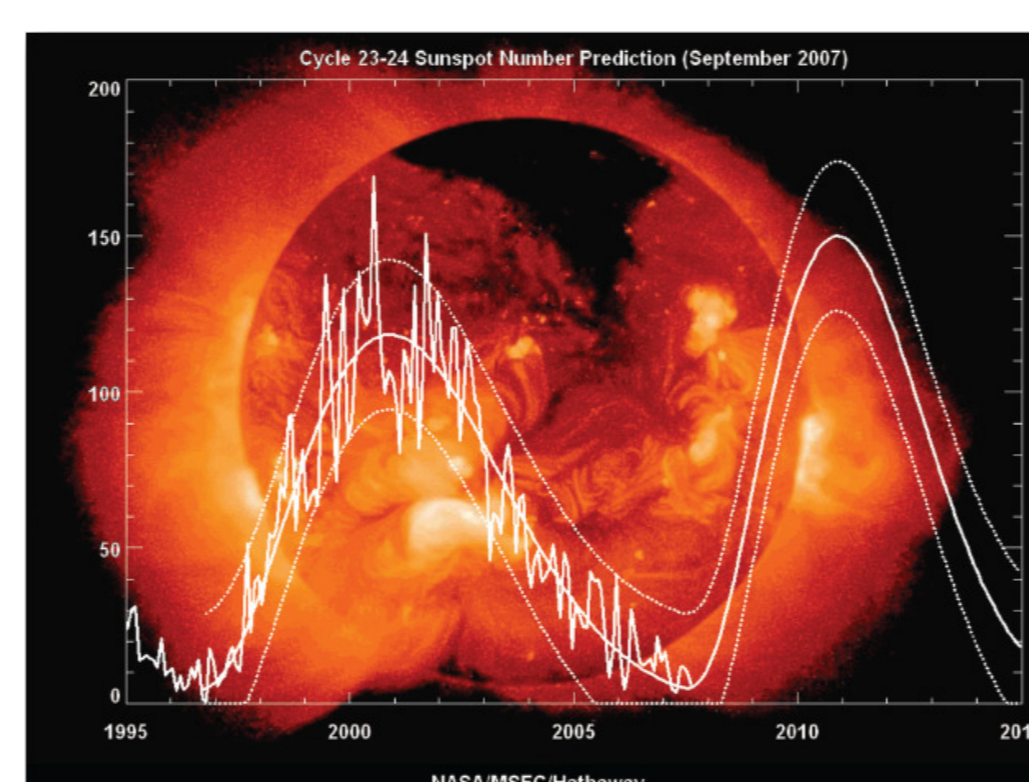
The Solar System Science Group of the *Fermi* team is continuously monitoring high energy emission from the Sun searching for flare events. Preliminary upper limits were derived for all solar flares detected so far by other missions and experiments. Here we present the analysis techniques as well as the details of this search.

Abstract

The *Fermi* Large Area Telescope (LAT) has been surveying the sky in gamma rays from 20 MeV to more than 300 GeV since August 2008. *Fermi* is the only mission able to detect high energy (> 20 MeV) emission from the Sun during the new solar cycle 24: the Solar System Science Group of the *Fermi* team is continuously monitoring high energy emission from the Sun searching for flare events. Preliminary upper limits were derived for all solar flares detected so far by other missions and experiments (RHESSI, *Fermi* GBM, GOES). Upper limit for flaring Sun emission (integrated over one year of data) was also derived. Here we present the analysis techniques as well as the details of this search and the preliminary results obtained so far.

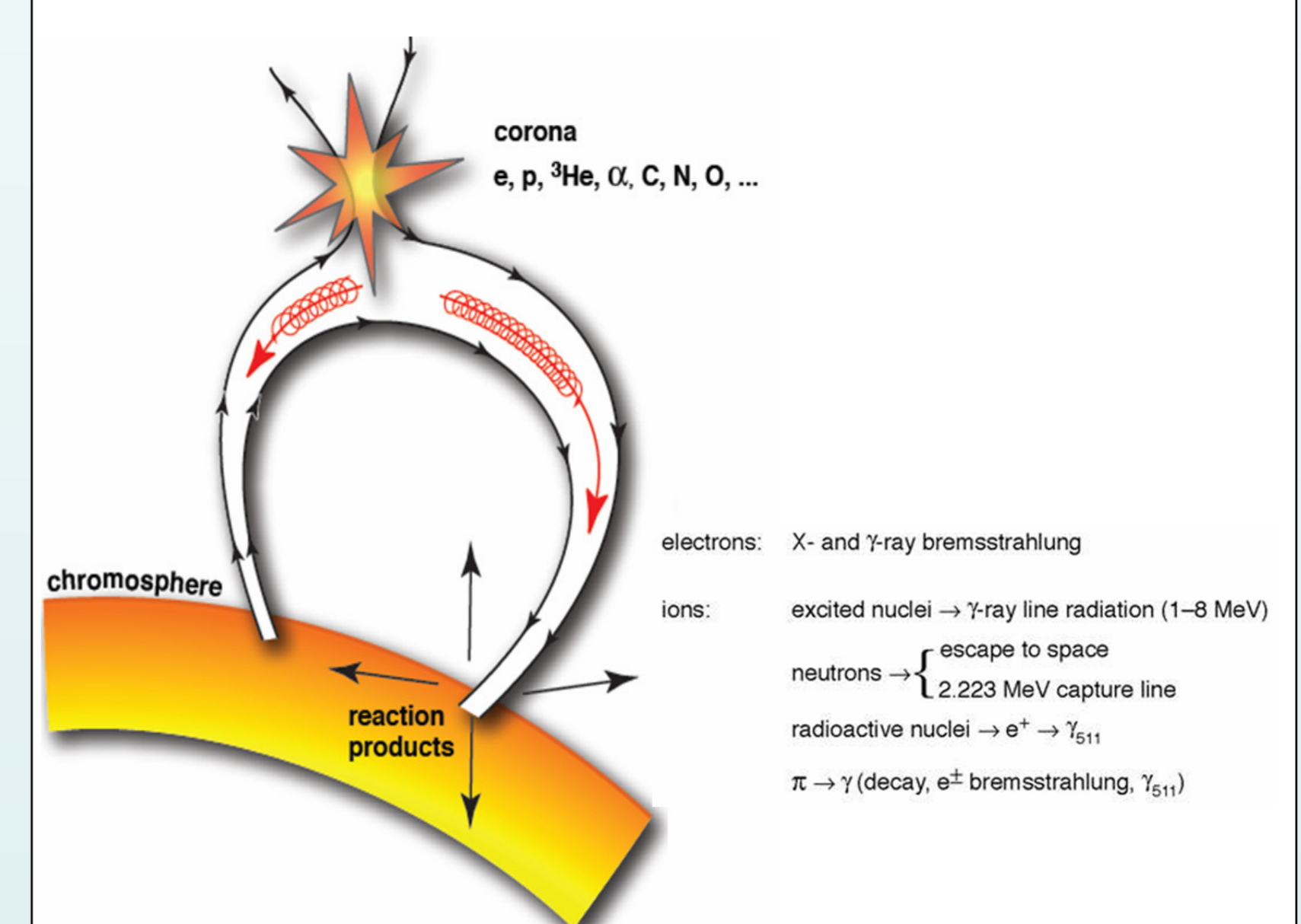
SOLAR ACTIVITY CYCLE

Intensity and frequency of solar flares depend on Sun activity, according to the 11 year solar cycle. Most intense flares occur during the maximum, but intense flares can occur also in rising and decreasing phases of the cycle. The new solar activity cycle 24 has started at the beginning of year 2008, maximum is predicted in year 2012. *Fermi* has been launched during the minimum of the solar cycle, so frequency and intensity of solar flares will increase throughout most of the mission. If the goal of a 10-year mission life is achieved, *Fermi* will operate for nearly the

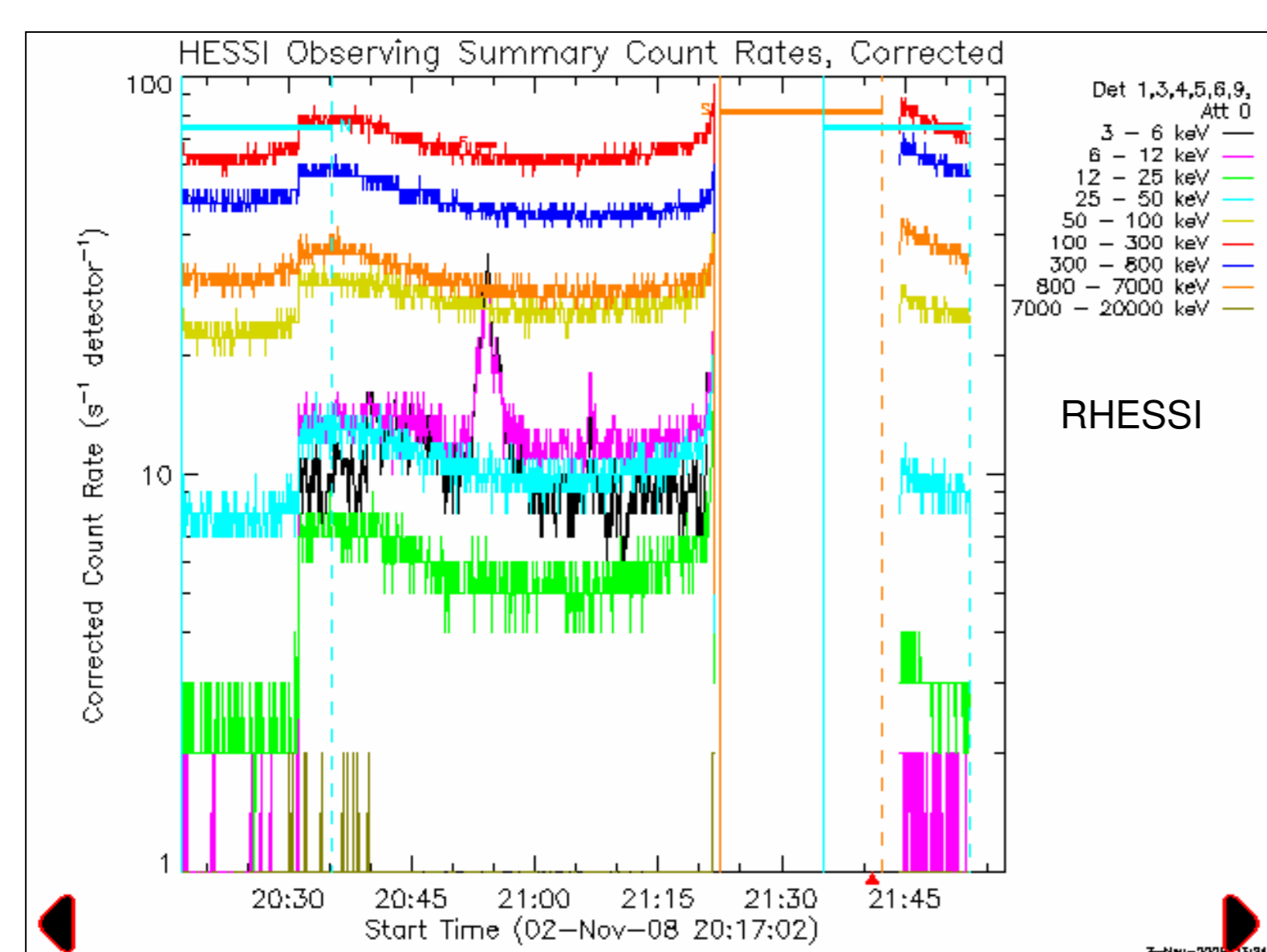
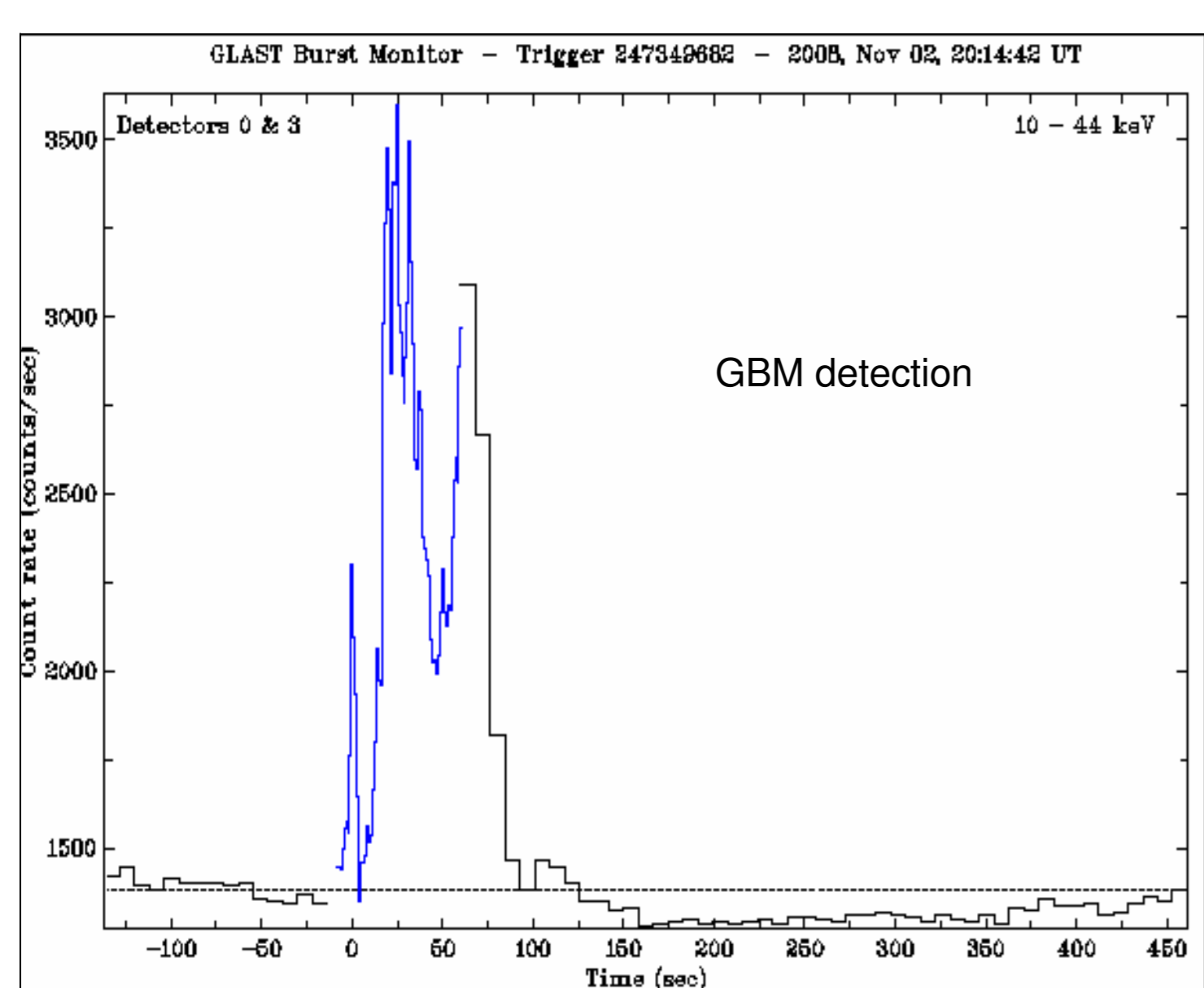


entire duration of solar cycle 24. During this time, *Fermi* will be the only high-energy observatory to complement several solar missions at lower energies: RHESSI, GOES, SoHO.

HIGH ENERGY FLARE EMISSION



SOLAR FLARES OF 2008, NOV 02



LAT analysis:

data selected from Nov 02 12:00 to 21:00 UT (247320000 - 247352400 s MET), according to the solar activity detected by GOES and RHESSI.

No significant emission detected.

LIST OF MONITORED FLARES

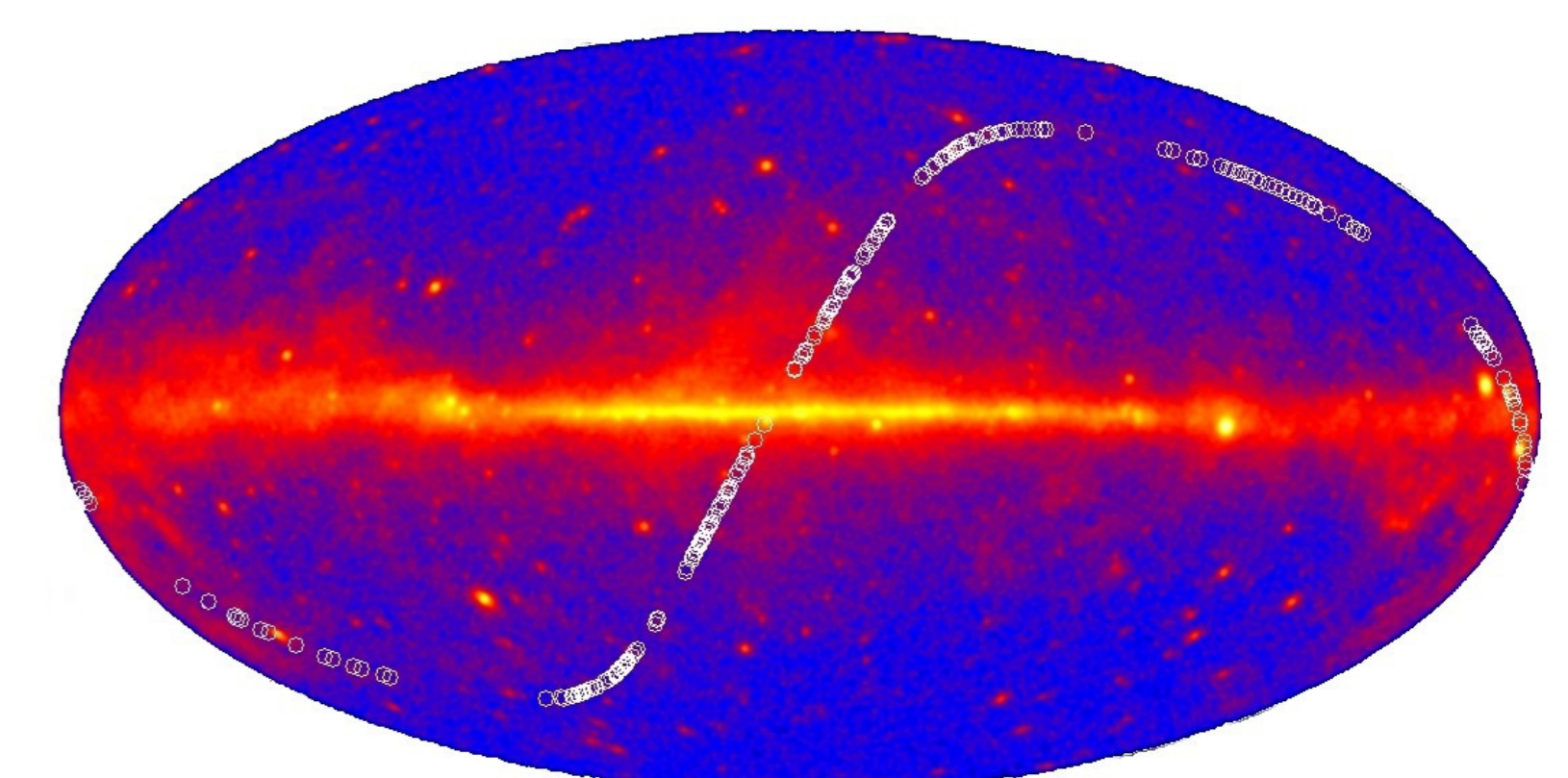
Upper limits on flares detected by RHESSI and monitored by LAT.

Date	Flare start	Flare stop	Sun RA	Sun Dec	Angle	Upper Limit
05-Nov-2008	11:36:00	11:52:32	220.86	-15.84	70	2.75
08-Nov-2008	00:29:56	00:32:56	223.38	-16.58	22	10.58
08-Nov-2008	00:27:16	00:32:16	224.29	-16.87	45	7.84
11-Nov-2008	22:37:56	22:41:40	227.34	-17.68	45	0.04
12-Nov-2008	22:35:20	22:42:44	228.36	-17.95	50	9.51
17-Nov-2008	05:59:36	06:14:20	232.79	-19.05	30	1.37
18-Nov-2008	05:57:04	06:17:00	233.83	-19.29	42	3.94
20-Nov-2008	01:03:04	01:19:24	235.70	-19.70	38	4.88
22-Nov-2008	04:04:56	04:19:16	237.93	-20.17	43	7.41
26-Nov-2008	02:12:56	02:28:20	242.08	-20.96	62	83.44
29-Nov-2008	00:21:36	00:29:56	245.20	-21.48	70	1627.70
06-Dec-2008	19:42:08	20:09:36	253.67	-22.59	68	2.34
01-Jan-2009	00:05:56	00:13:44	281.51	-23.01	35	6.89
02-Jan-2009	00:03:00	00:09:08	282.60	-23.93	38	4.49
03-Jan-2009	07:35:04	07:50:00	284.06	-22.81	60	19.17
03-Jan-2009	09:16:40	09:37:28	284.14	-22.80	37	4.00
04-Jan-2009	22:13:32	22:22:52	285.82	-22.64	38	5.60
05-Jan-2009	22:10:48	22:17:44	286.92	-22.52	37	5.28
08-Jan-2009	00:21:20	00:24:48	290.11	-22.15	52	39.57
09-Jan-2009	07:18:58	07:36:12	290.62	-22.08	38	3.65
09-Jan-2009	20:18:36	20:26:16	291.20	-22.01	55	16.80
10-Jan-2009	00:48:40	00:53:24	291.41	-21.98	43	4.90
11-Jan-2009	03:51:24	04:06:16	292.63	-21.80	40	4.80
11-Jan-2009	05:32:24	05:51:04	292.71	-21.79	43	5.66
14-Jan-2009	03:42:56	03:58:40	295.87	-21.31	50	2.82
16-Jan-2009	01:56:08	02:10:44	297.94	-20.96	18	1.95
18-Jan-2009	01:50:48	02:06:24	300.07	-20.56	28	4.38
19-Jan-2009	00:05:52	00:26:24	301.06	-20.37	19	2.93
20-Jan-2009	00:04:00	00:19:00	302.12	-20.16	76	945.55
22-Jan-2009	23:56:04	00:16:56	305.28	-19.49	50	11.73
23-Jan-2009	02:25:34	02:33:04	305.38	-19.46	70	22.57
24-Jan-2009	23:50:56	00:09:08	307.37	-19.01	60	184.00
13-Feb-2009	05:40:20	05:57:20	326.83	-13.34	40	4.29
22-Feb-2009	23:42:12	23:46:16	336.24	-9.90	60	0.59
23-Feb-2009	23:39:24	23:47:36	337.19	-9.54	60	0.22
27-Feb-2009	21:47:16	21:55:52	340.89	-8.07	50	0.62
28-Feb-2009	21:44:40	21:50:28	341.83	-7.69	35	0.01
01-Mar-2009	07:01:24	07:22:32	342.19	-7.54	75	0.00
02-Mar-2009	05:16:40	05:31:56	343.06	-7.19	80	0.47
02-Mar-2009	06:57:04	07:18:04	343.13	-7.16	75	0.18
03-Mar-2009	19:55:00	20:04:12	344.56	-6.58	25	0.27
04-Mar-2009	05:11:28	05:25:28	344.92	-6.43	60	0.25
04-Mar-2009	19:52:12	19:59:08	345.49	-6.19	50	0.32
06-Mar-2009	03:25:12	03:33:16	346.71	-5.68	75	0.00
07-Mar-2009	18:02:48	18:12:20	348.21	-5.06	60	0.00
08-Mar-2009	18:00:04	18:07:04	349.13	-4.67	40	0.13
15-Mar-2009	01:18:48	01:37:44	354.92	-2.19	65	0.08
16-Mar-2009	14:15:40	14:23:24	356.33	-1.58	70	0.00
18-Apr-2009	23:11:24	23:18:44	26.87	11.08	75	0.41
21-Apr-2009	21:21:52	21:26:08	29.60	12.08	70	0.08
22-Apr-2009	21:19:04	21:26:48	30.54	12.42	60	0.40
25-Apr-2009	19:29:32	19:33:20	33.29	13.38	40	0.00
28-Apr-2009	18:26:44	18:35:00	34.23	13.70	50	0.22
30-Apr-2009	17:34:28	17:42:48	37.76	14.93	25	0.34
04-May-2009	15:42:12	15:50:56	41.72	16.09	50	0.34
05-May-2009	15:40:04	15:45:04	42.68	16.37	50	0.47
08-May-2009	13:49:48	13:58:40	45.51	17.18	65	0.00
08-May-2009	13:47:00	13:54:12	46.48	17.45	65	0.84
18-Jun-2009	19:02:22	19:03:28	87.45	23.41	65	0.14
19-Jun-2009	18:59:54	19:03:52	88.49	23.43	55	0.15
22-Jun-2009	17:06:52	17:10:40	91.53	23.43	60	3.60
23-Jun-2009	17:04:04	17:11:36	92.57	23.41	40	0.00
25-Jun-2009	02:53:40	03:16:52	94.04	23.29	70	5.18
27-Jun-2009	15:11:28	15:19:36	96.64	23.29	60	0.16
01-Jul-2009	13:18:52	13:27:36	100.70	23.07	40	0.00
02-Jul-2009	13:16:08	13:22:12	101.73	23.00	90	0.00
04-Jul-2009	02:09:36	02:25:20	103.32	22.87	60	0.00
06-Jul-2009	11:24:44	11:29:48	105.77	22.64	40	0.27
12-Aug-2009	18:24:32	18:31:12	142.57	14.76	80	0.00
15-Aug-2009	16:34:44	16:38:48	145.31	13.85	70	0.00
18-Aug-2009	02:22:16	02:44:08	147.57	13.08	20	1.41

Note: angle is the angle with the LAT boresight (only flare within 80 deg have been analyzed); upper limit units are photons cm⁻² s⁻¹.

FLARE EMISSION UPPER LIMIT

Analysis of LAT data of all flares detected from August 2008 to August 2009 by RHESSI (> 10⁵ counts) and entering the LAT FOV, centered in solar coordinates and merged together.



Location of solar flares detected by RHESSI superimposed on a count map of the first three months of LAT data (E > 200 MeV).

Model: **FAKE SUN** (fixed) + **QUIET SUN** (fixed) + **FLARING SUN** (free)

Background due to the diffuse emission has been estimated using the fake-source method. Fake Sun has been evaluated using a source moving along the same solar path (i.e. the ecliptic) but at an angular distance of 30 deg.

NO SIGNIFICANT EMISSION DETECTED
preliminary u.l.: $5.267 \cdot 10^{-07}$ ph cm⁻² s⁻¹

We continue to monitor the Sun waiting for an intense γ-ray flare (no one has occurred since *Fermi* launch) detectable by the LAT.