THE FEATURES OF THE SOLAR ENERGETIC PARTICLE EVENTS DURIG 23 CYCLE OF SOLAR ACTIVITY AND THEIR RELATIONSHIP WITH SOLAR X-RAY, GAMMA-EMISSION AND CORONAL MASS EJECTIONS

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Eleventh **Workshop** "**Solar Influences** on the Magnetosphere, Ionosphere and Atmosphere", **Primorsko**, Bulgaria, 3-7 June 2019**.**

Abstract

The study of the relationship of features of events in solar cosmic rays (in particular, the ratio of maximum proton and electron fluxes) with X-ray and gamma radiation from solar flares, as well as with parameters of coronal mass ejections was carried out.

It was done on the basis of SOHO/ERNE proton event catalog (http://newserver.stil.bas.bg/SEPcatalog/) and Solar Flares Catalog based on measurements of X- and gamma-emission (>50 keV) detected by SONG (CORONAS-F - Russian solar observatory) from August,2001 till September, 2005 (http://swx.sinp.msu.ru/apps/solar_flares_cat/index.php).

Solar electron flux (> 300 keV) were measured in the polar caps by MKL-instrument on board CORONAS-F satellite. The high (> 80%) correlation for maximal intensity of solar proton flux with solar flare gamma-emission fluencies was obtained.

Outline

1. The longest Russian solar missions: CORONAS-F observatory, SONG experiment; SONG catalog of solar HXR and gamma-emission
2. SOHO/ERNE proton event catalog
3. SEP events – Je/Jp ratio, solar flare HXR and gamma-emission and associated with these flares and CME parameters.
4. Summary

CORONAS-F

Complex ORbital Observations in Near-Earth space of the Activity of the Sun

- was launched on July 30th, 2001
- circular orbit with altitude ~ 500-350 km
- inclination ~ 82,5°
- scientific information from SONG - August 14th, 2001 - September, 13th, 2005
- The **SONG instrument** is devoted to detection of X and gamma rays in the energy range 0.05-100 MeV, neutrons >20 MeV, as well as protons with E>70 MeV and electrons E>55 MeV.
- Detectional part consists of CsI(Tl) crystal with diameter 20 and height 10 cm surrounded from all sides by the active anticoincidence shielding (plastic scintillator of 2 cm width).

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CORONAS-F: SONG experiment catalog (HXR and gamma-emission) - statistics

- 3 flares with solar neutrons
- 4 flares with gamma-emission >100 MeV
- 38 with gamma-emission >500 keV
- 105 flares with HXR-emission >50 keV

http://swx.sinp.msu.ru/apps/solar_flares_cat/index.php?gcm=1&lang=en

Geospace now | Heliosphere | Magnetosphere

Solar flares catalog

CORONAS-F (SONG and SPR-N)	Vernov (DRGE)	Lomonosov (BDRG)
Years		
2001	2014	2016
2002		
2003		
2004		
2005		

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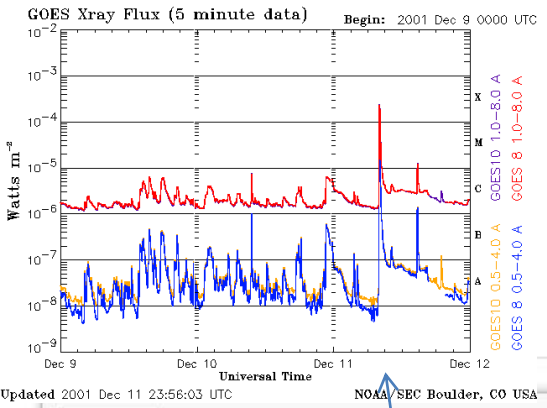
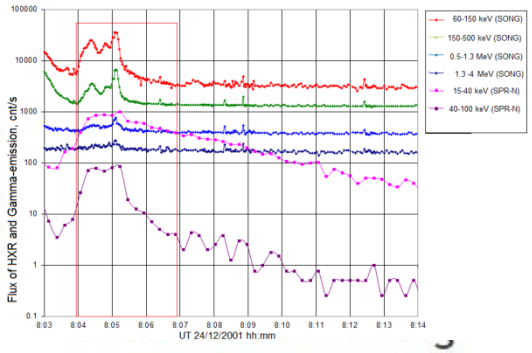
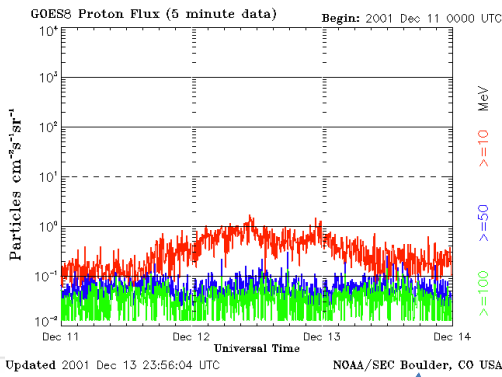
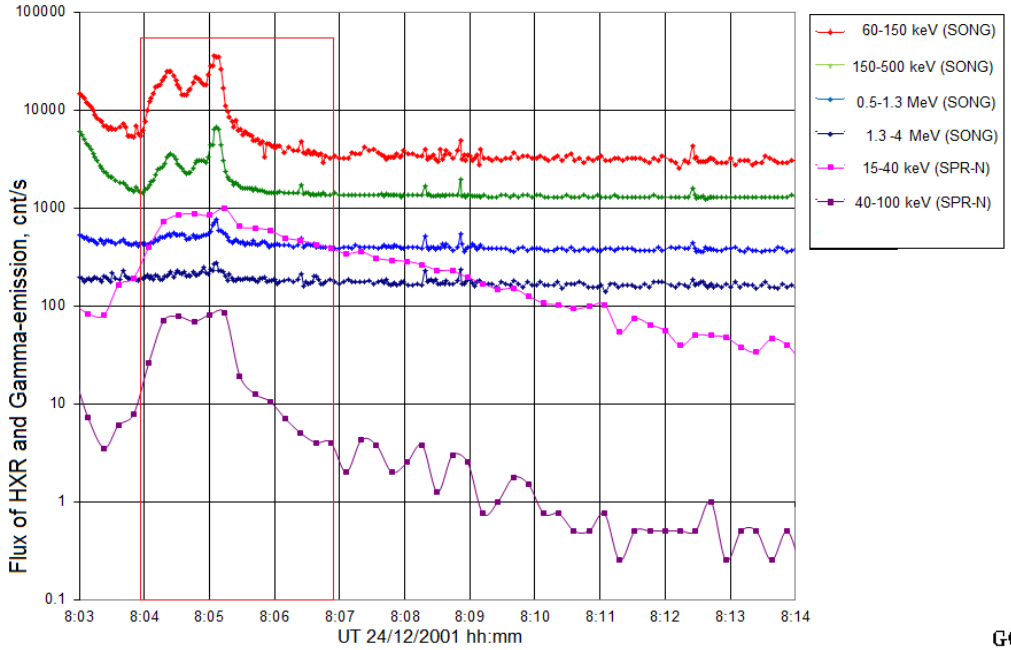


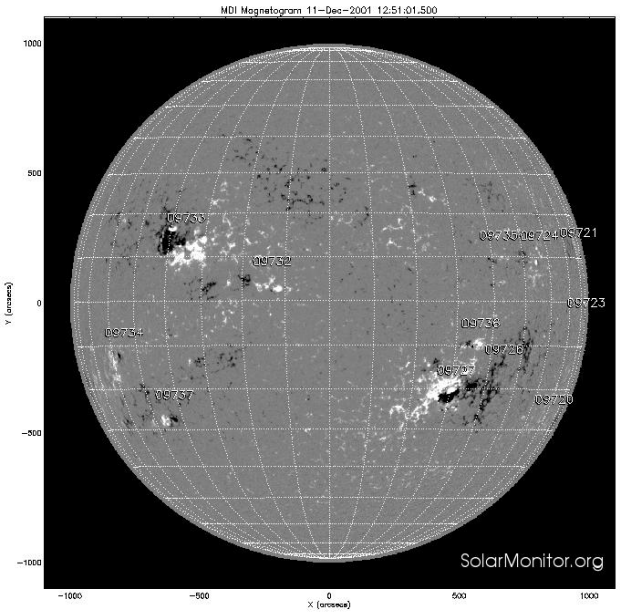


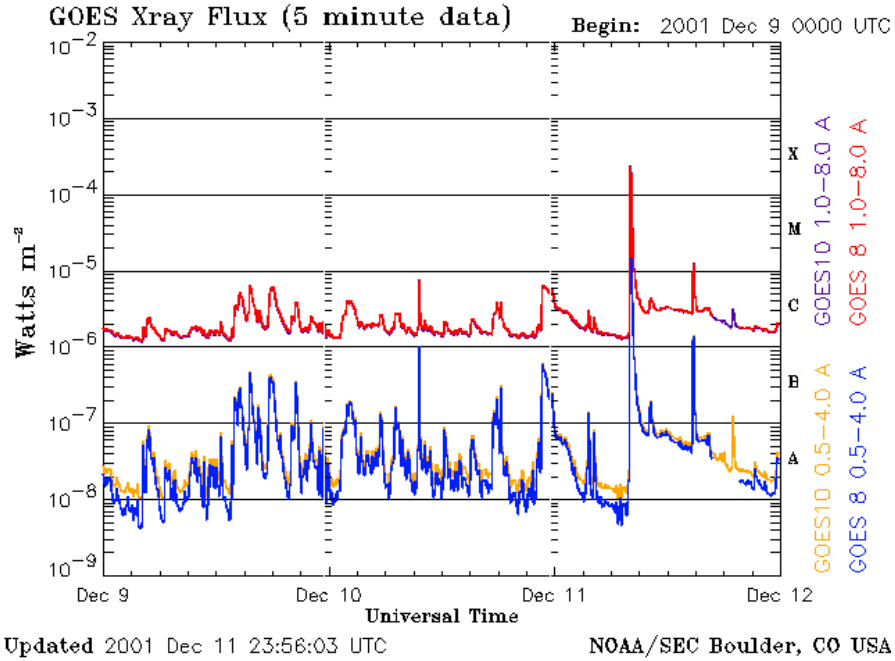


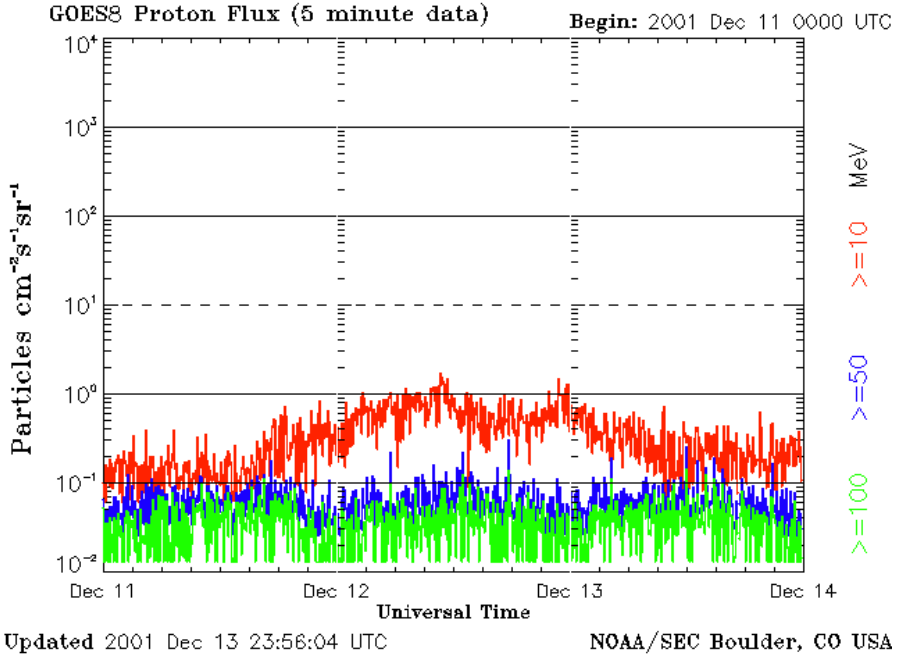
Назад

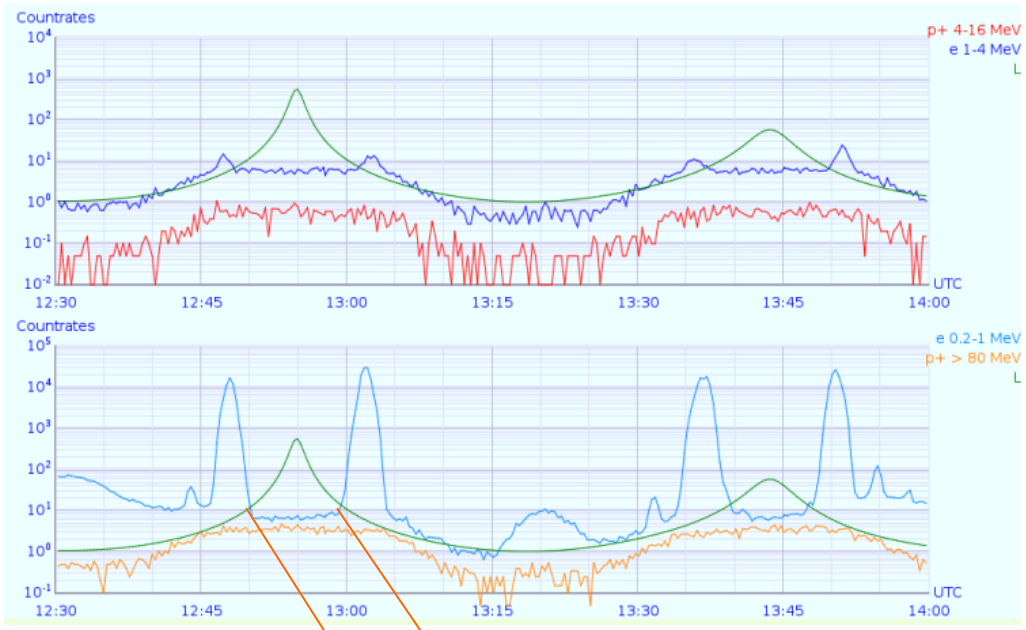
N	Data dd/mm/yy	UT of flare according SXR GOES data, hh:mm	UT of HXR flare emission, hh:mm - light curves	SXR class (GOES)	Flare coordinates	Active Region	SEP (protons)
1	25/08/01	16:23-16:45-17:04	16:27-16:38 [все каналы]	X5.3	S17E34	9591	no
2	05/09/01	14:25-14:32-14:34	14:27-14:32	M6.0	N15W31	9601	no
3	09/09/01	15:10-15:16-15:21	15:11-15:18	M3.4	S17E03	9607	no
4	19/10/01	16:13-16:30-16:43	16:22-16:28	X1.6	N15W29	9661	yes
5	23/10/01	02:11-02:23-02:34	02:15-02:17	M6.5	S18E11	9672	no
6	04/11/01	16:03-16:20-16:57	16:06-16:14	X1.0	N06W18	9684	yes
7	07/11/01	19:30-20:01-20:26	19:33-19:35	M5.7	S17E44	9690	no
8	13/11/01	06:22-06:26-06:28	06:24-06:26	M1.5	S17W24	9690	no
9	11/12/01	07:58-08:14-08:08	08:04-08:06	X2.8	N16E41	9733	yes
10	24/12/01	00:26-00:32-00:37	00:31-00:33	M1.7	S08E59	9754	no
11	29/12/01	09:38-09:45-10:06	09:41-09:54	M9.3	S08W85	9748	yes

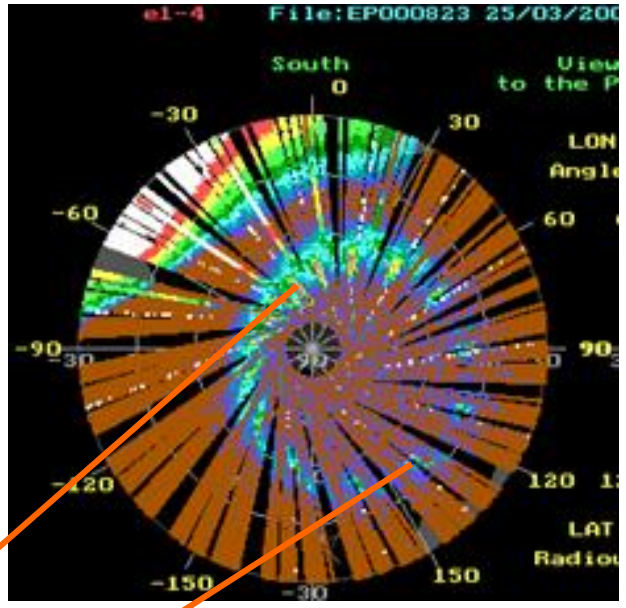

60-150 keV (SONG)
150-500 keV (SONG)
0.5-1.3 MeV (SONG)
1.3 -4 MeV (SONG)
15-40 keV (SPR-N)
40-100 keV (SPR-N)
Flux of HXR and Gamma-emission, cnt/s
UT 24/12/2001 hh:mm

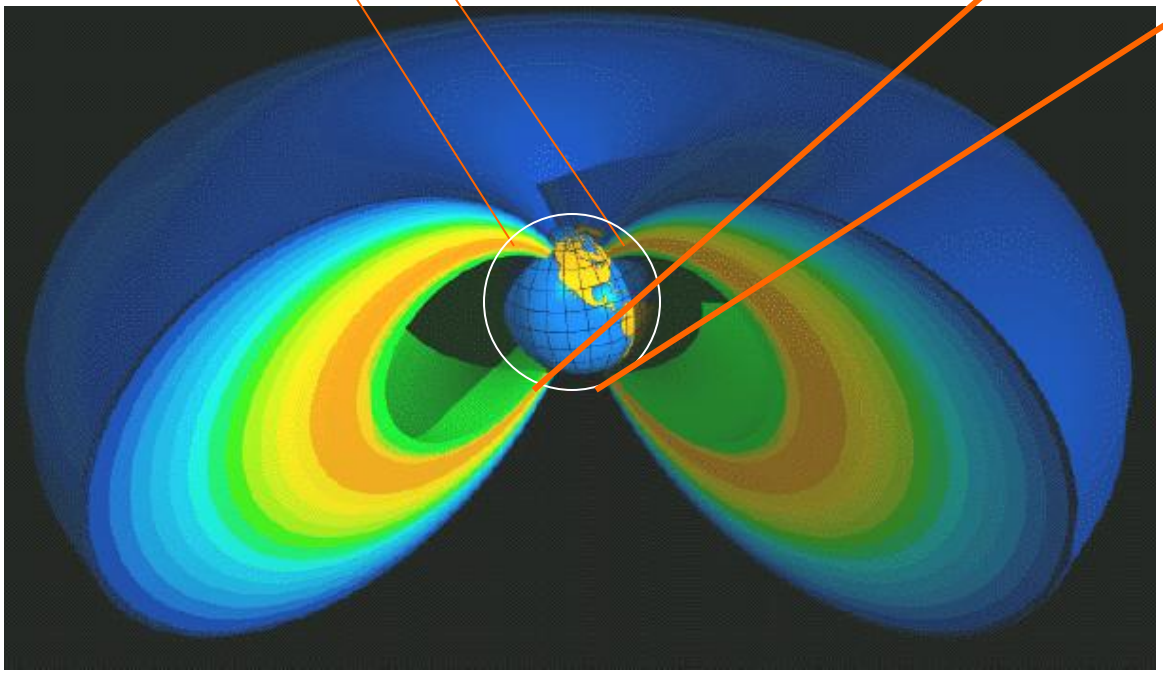

MDI Magnetogram 11-Dec-2001 12:51:01.500
SolarMonitor.org


GOES Xray Flux (5 minute data)
Begin: 2001 Dec 9 0000 UTC
Watts m-2
GOES10 1.0–8.0 A
GOES 8 1.0–8.0 A
GOES10 0.5–4.0 A
GOES 8 0.5–4.0 A
Universal Time
Updated 2001 Dec 11 23:56:03 UTC
NOAA/SEC Boulder, CO USA

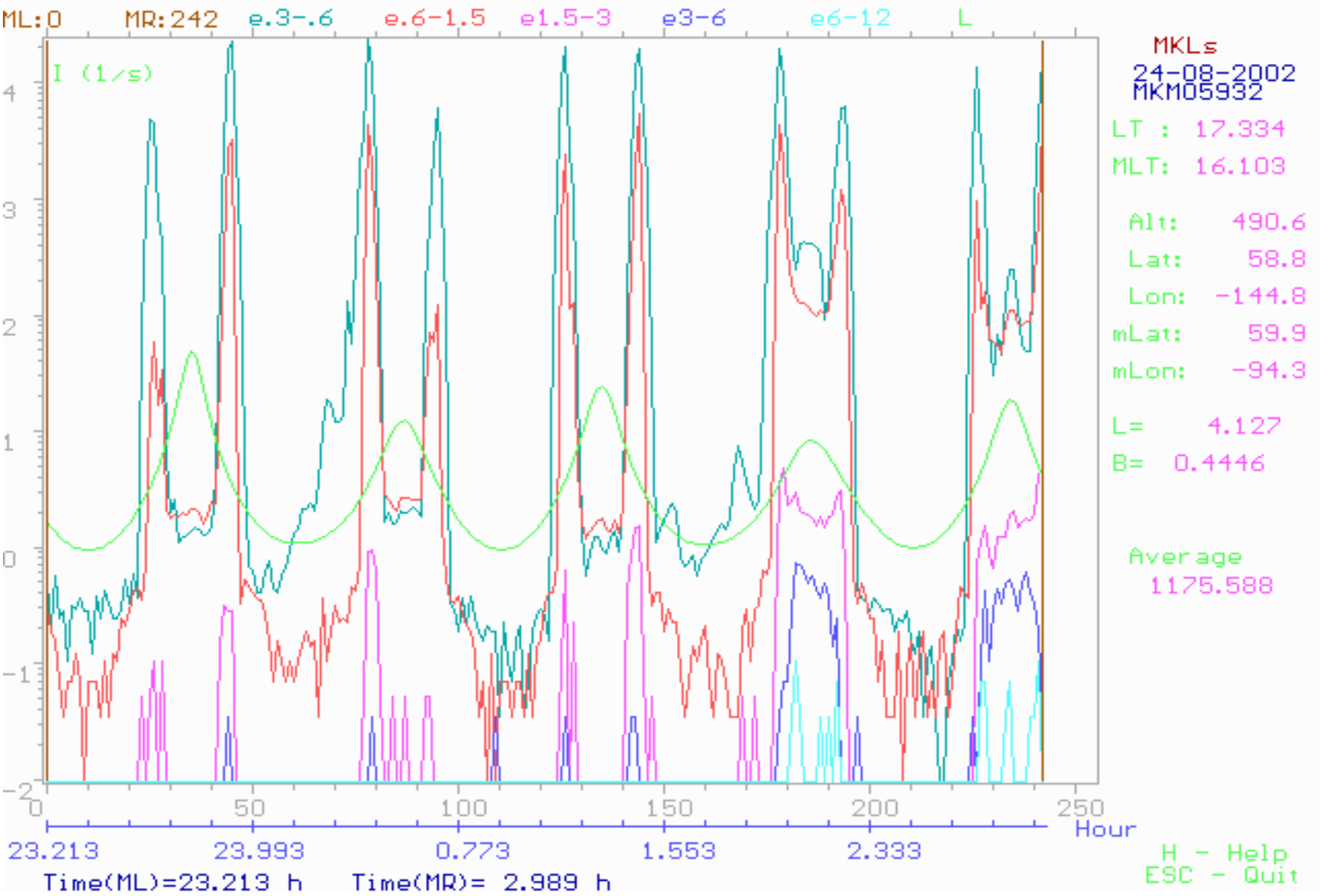

GOES8 Proton Flux (5 minute data)
Begin: 2001 Dec 11 0000 UTC
Particles cm-2s-1sr-1
>=10 MeV
>=50
>=100
Universal Time
Updated 2001 Dec 13 23:56:04 UTC
NOAA/SEC Boulder, CO USA



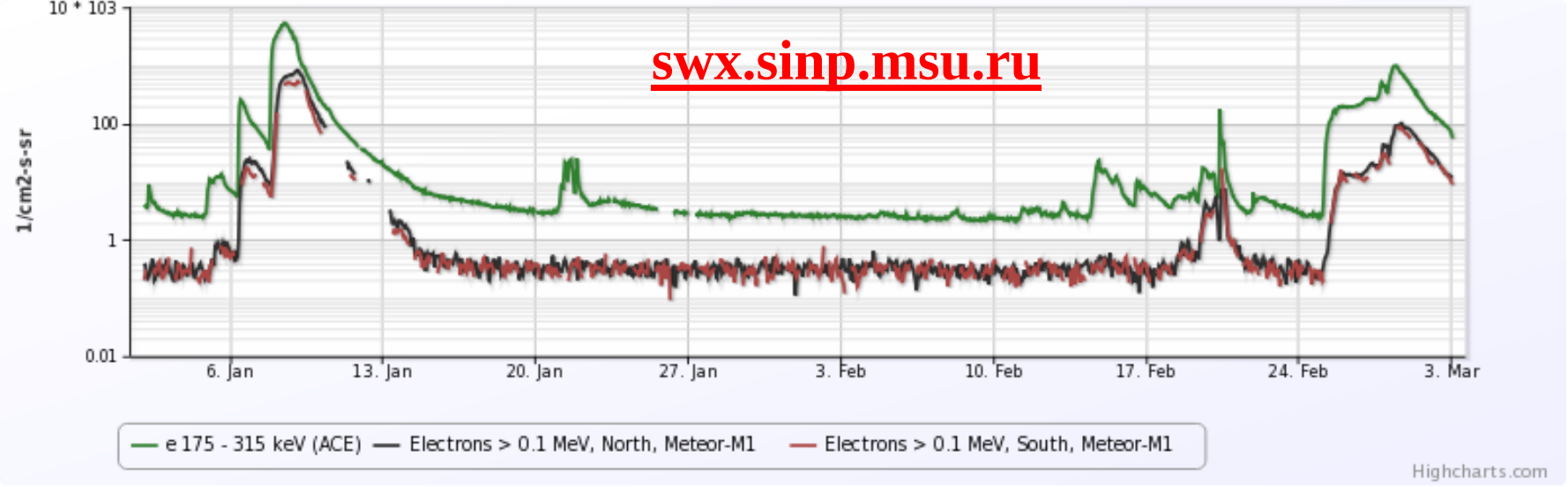




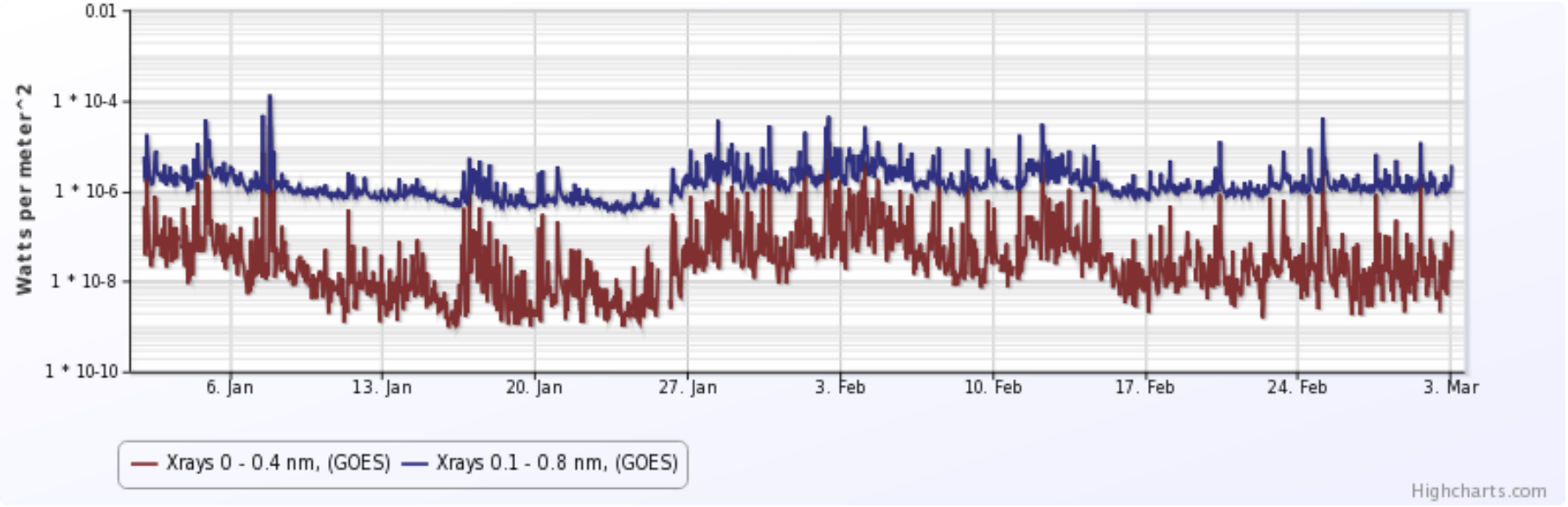
Outer ERB high-latitude boundary was determined by electron (>200 keV) fluxes measured on-board CORONAS series satellite during 2009



Electron (0.3-12 MeV) flux measured on board CORONAS-F LEO satellite and L-shell number (McIlwain parameter)–from 23 h 12 min 13.08.2002 to 02 h 25 min 14.08. 2002



Solar electron flux - green - 175-315 keV, ACE ; red and black - >100 keV measured on board Meteor-M №1 in polar caps from January , 5 to March, 3 , 2014



Solar X-ray flux measured on board GOES from January , 5 to March, 3 , 2014

SOHO/ERNE
proton event catalog

 Last modified 01/28/2019 15:08:24

Solar cycle 23: 1996-2008 | Back to list of Catalogs | Solar cycle 24: 2009-2018

Search among all events from 1996 to 2018

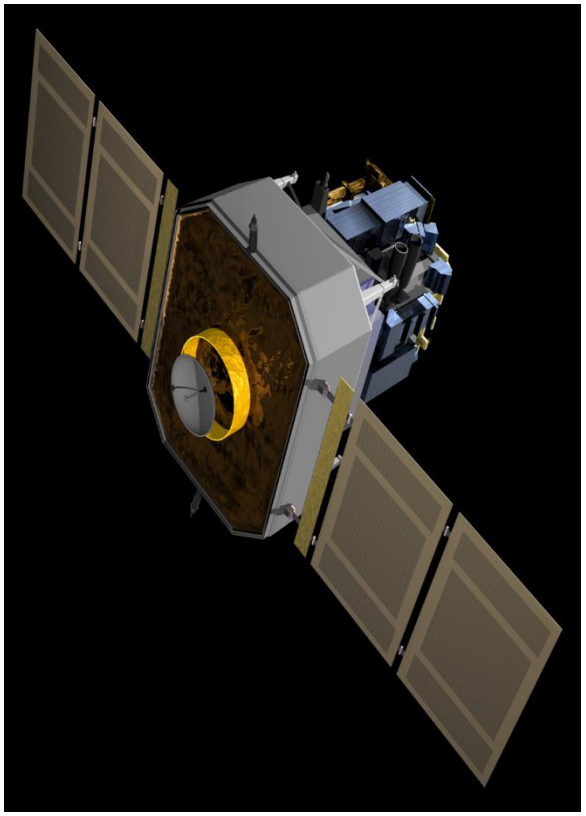
This catalog lists the proton enhancements from the **H**igh **E**nergy **D**etector (**HED**) aboard SOHO/ERNE instrument identified during solar cycle (SC) 23 (1996÷2008) and SC24 (2009÷2018). The catalog lists the peak intensity for the solar proton events in the different HED energy channels (in the range 14÷131 MeV) and additional information organized in table-form separately for SC23 and SC24.

Explanatory notes:

Proton peak: identified at the maximum of the particle profile (local enhancements are not considered).
Onset time: identified as the time of 3-sigma intensity value above pre-event level.
Peak time: the time at the peak proton intensity.
J_p: peak proton intensity after subtraction of the pre-event level in protons/(cm^2 s sr MeV).
class: GOES soft X-ray flare class
speed: linear speed of the CME in km s^{-1}
time: all time markers are in UT

The reported here onset/peak times and J_p are based on 5-min averaged data.

Solar energetic proton data: ERNE instrument aboard SOHO satellite



ESA-NASA satellite SOHO
image: en.wikipedia.org

https://srl.utu.fi/projects/erne/

University of Turku
Space Research Laboratory

ERNE project

image: https://srl.utu.fi/projects/erne
data: https://srl.utu.fi/erne-data

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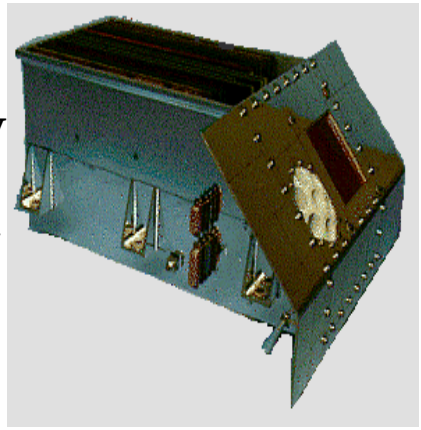
- SEP server
- RADMON data
- UTU / R-ESC

The **So**lar and **H**eliospheric **O**bservatory SoHO (more SoHO pages) satellite is a joint space program of the European Space Agency and NASA for studying the structure, chemical composition, and dynamics of the Sun, solar atmosphere, and the solar wind. The spacecraft was successfully launched on 2nd of December 1995 at Kennedy Space Center by Atlas-IIAS (Atlas/Centaur) launch vehicle. The commissioning phase verified that all twelve scientific instruments work well. The coordinated effort to study the Sun and its impact on Earth has thus been started. The flight will last at least two years, until April 1998.

One of the scientific instruments of SOHO is the energetic particle instrument ERNE (**E**nergetic and **R**elativistic **N**uclei and **E**lectron) of the University of Turku. The energy eruptions in the solar atmosphere can lead to the acceleration of local gas particles to extremely high energies and their injection into the interplanetary space. These fast moving streams of particles are recorded by ERNE. At times, when there is no energetic particle production at the Sun, ERNE is observing the continuous flux of energetic particles from Milky Way (galactic cosmic rays) , and from the boundary of the heliosphere accelerated by the termination shock (anomalous cosmic rays). The two particle experiments of SOHO, **COSTEP** and **ERNE**, are carried out in the CEPAC collaboration.

Description of the ERNE instrument

HED: High energy channel
10 channels covering **14–131 MeV**
LED: Low energy channel
10 channels covering **1.3–13 MeV**



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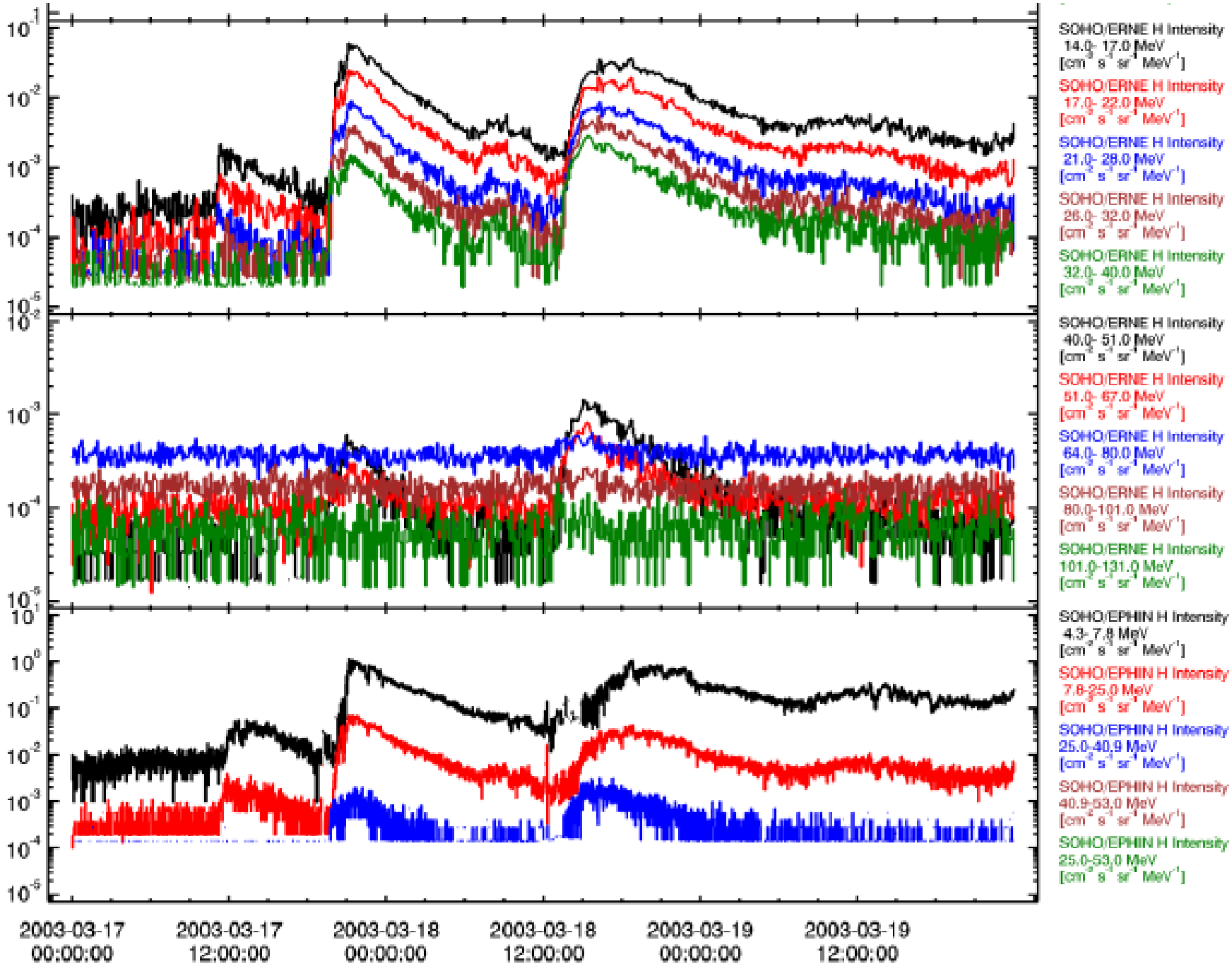
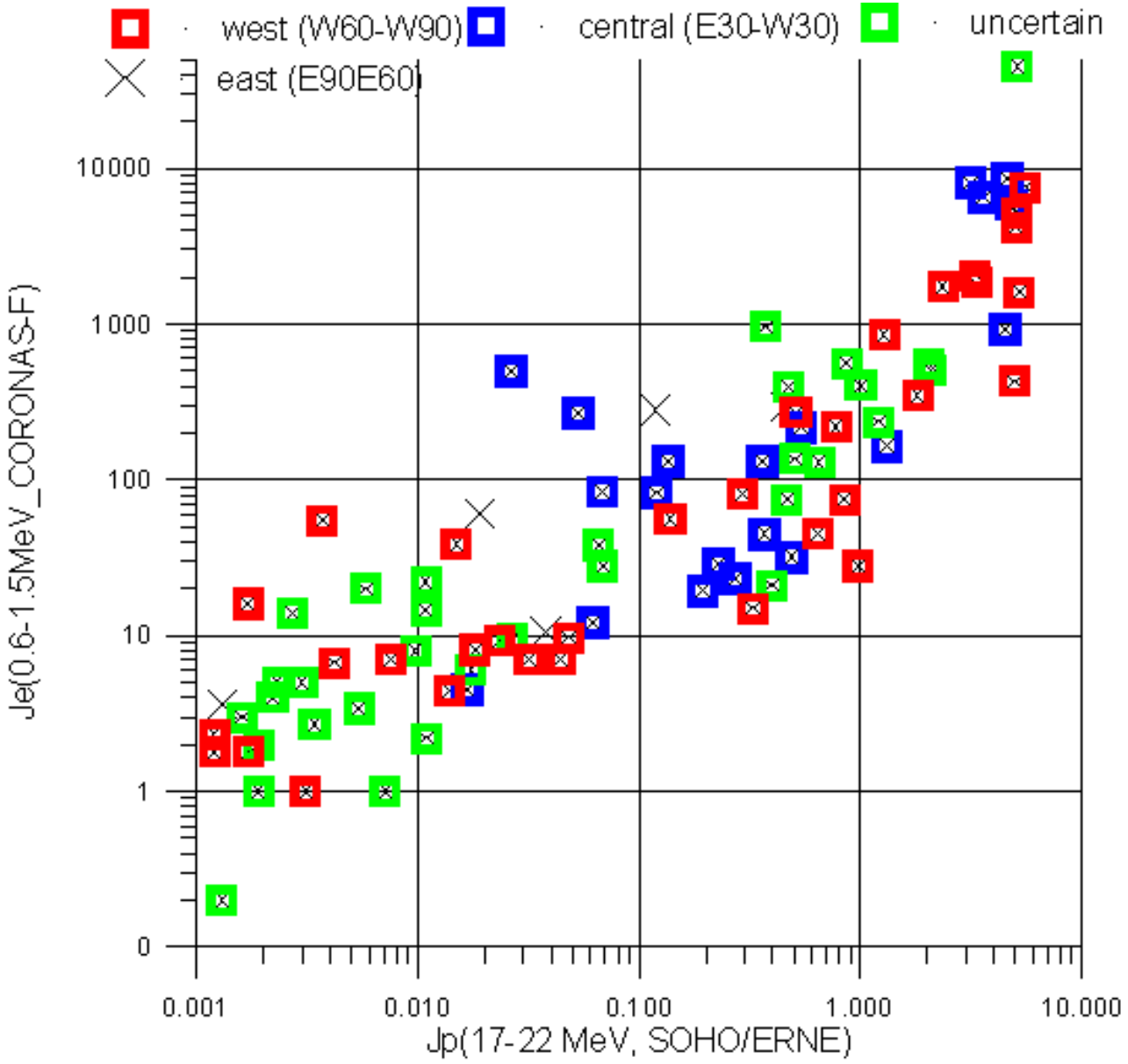
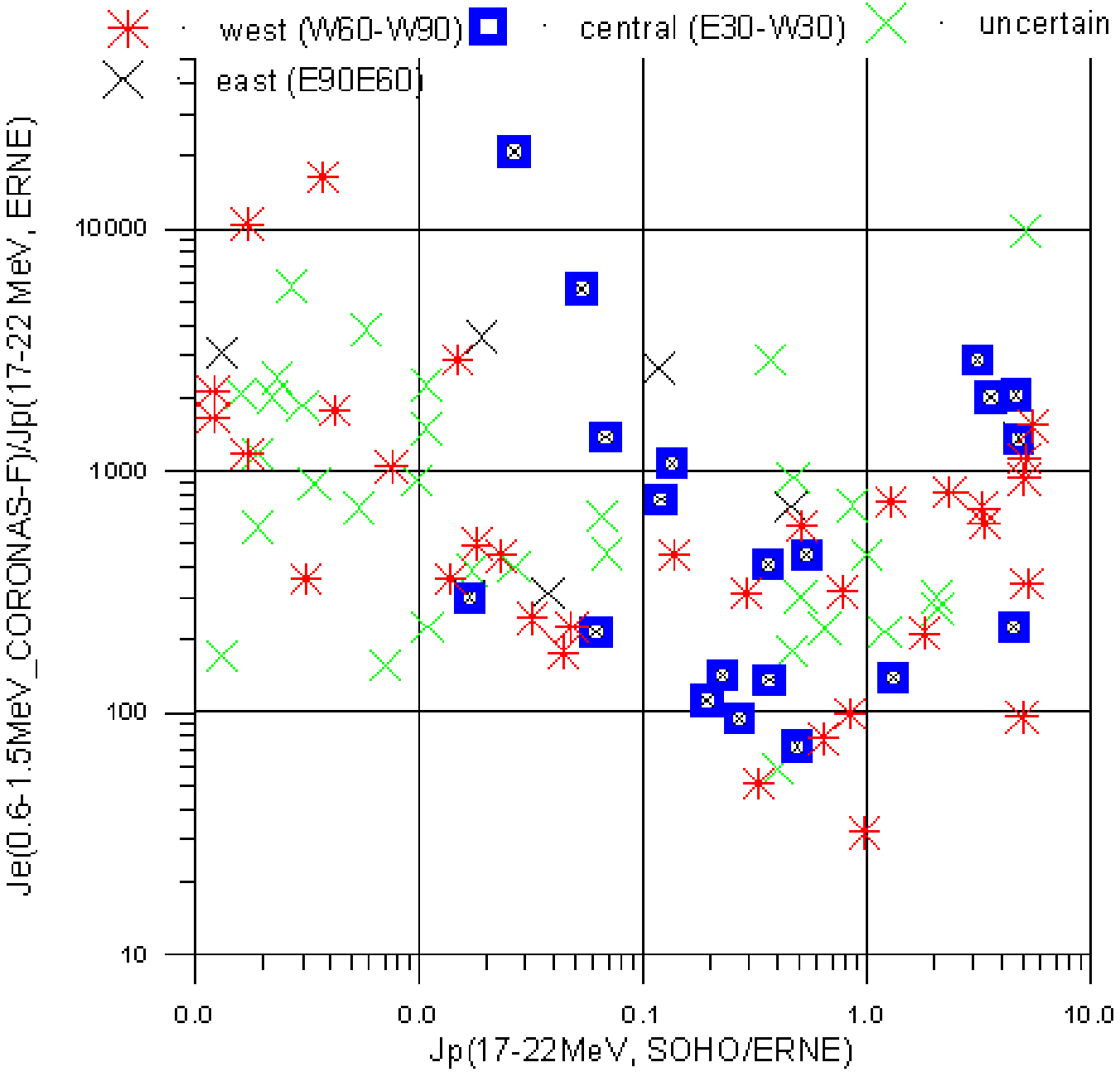

SOHO/ERNE H Intensity
14.0- 17.0 MeV
[cm^{-2} s^{-1} sr^{-1} MeV^{-1}]
SOHO/ERNE H Intensity
17.0- 22.0 MeV
[cm^{-2} s^{-1} sr^{-1} MeV^{-1}]
SOHO/ERNE H Intensity
21.0- 28.0 MeV
[cm^{-2} s^{-1} sr^{-1} MeV^{-1}]
SOHO/ERNE H Intensity
26.0- 32.0 MeV
[cm^{-2} s^{-1} sr^{-1} MeV^{-1}]
SOHO/ERNE H Intensity
32.0- 40.0 MeV
[cm^{-2} s^{-1} sr^{-1} MeV^{-1}]
SOHO/ERNE H Intensity
40.0- 51.0 MeV
[cm^{-2} s^{-1} sr^{-1} MeV^{-1}]
SOHO/ERNE H Intensity
51.0- 67.0 MeV
[cm^{-2} s^{-1} sr^{-1} MeV^{-1}]
SOHO/ERNE H Intensity
64.0- 80.0 MeV
[cm^{-2} s^{-1} sr^{-1} MeV^{-1}]
SOHO/ERNE H Intensity
80.0-101.0 MeV
[cm^{-2} s^{-1} sr^{-1} MeV^{-1}]
SOHO/ERNE H Intensity
101.0-131.0 MeV
[cm^{-2} s^{-1} sr^{-1} MeV^{-1}]
SOHO/EPHIN H Intensity
4.3- 7.8 MeV
[cm^{-2} s^{-1} sr^{-1} MeV^{-1}]
SOHO/EPHIN H Intensity
7.8-25.0 MeV
[cm^{-2} s^{-1} sr^{-1} MeV^{-1}]
SOHO/EPHIN H Intensity
25.0-40.9 MeV
[cm^{-2} s^{-1} sr^{-1} MeV^{-1}]
SOHO/EPHIN H Intensity
40.9-53.0 MeV
[cm^{-2} s^{-1} sr^{-1} MeV^{-1}]
SOHO/EPHIN H Intensity
25.0-53.0 MeV
[cm^{-2} s^{-1} sr^{-1} MeV^{-1}]
2003-03-17 00:00:00
2003-03-17 12:00:00
2003-03-18 00:00:00
2003-03-18 12:00:00
2003-03-19 00:00:00
2003-03-19 12:00:00

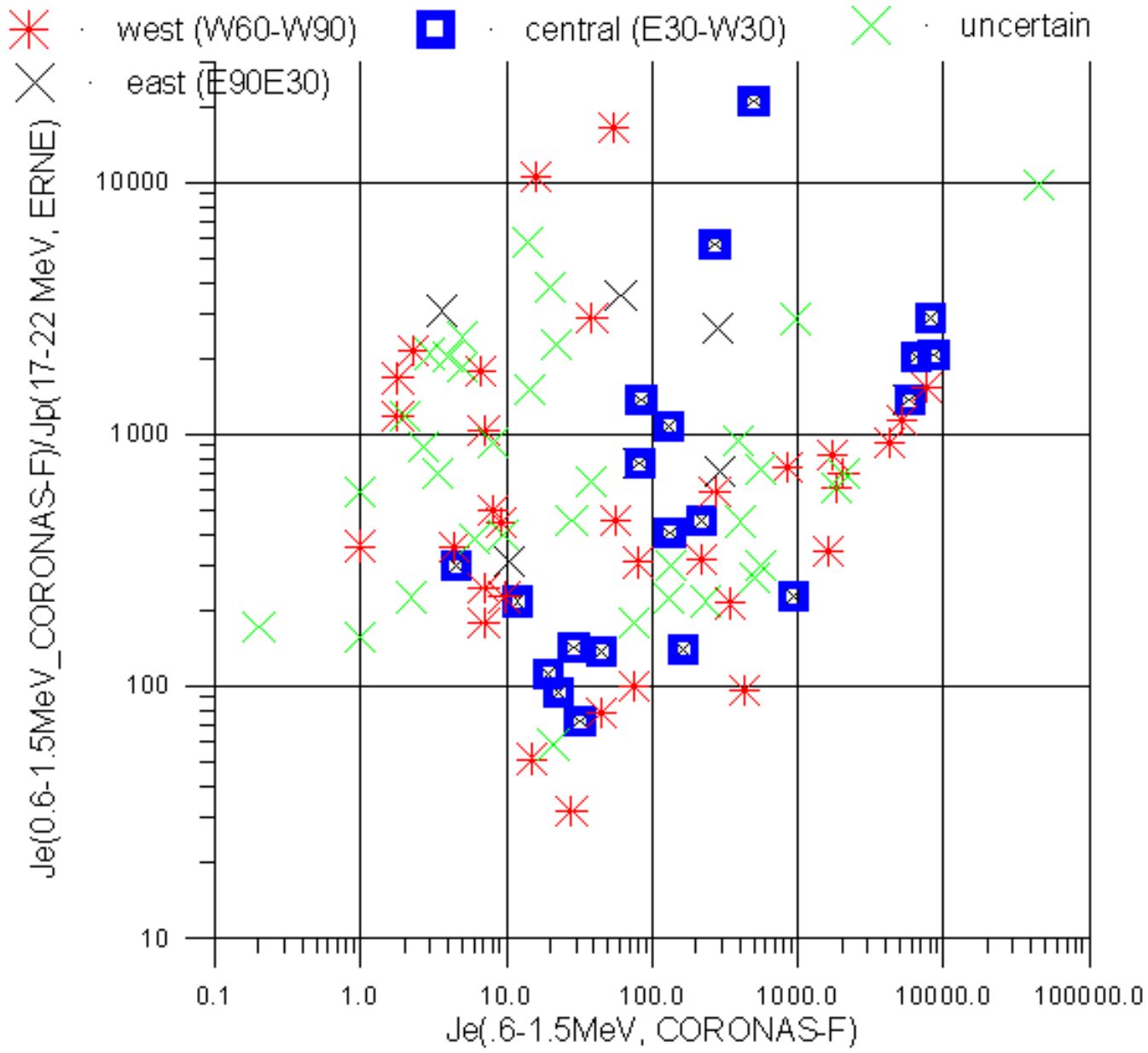
SEP Jp flux vs. SEP Je flux



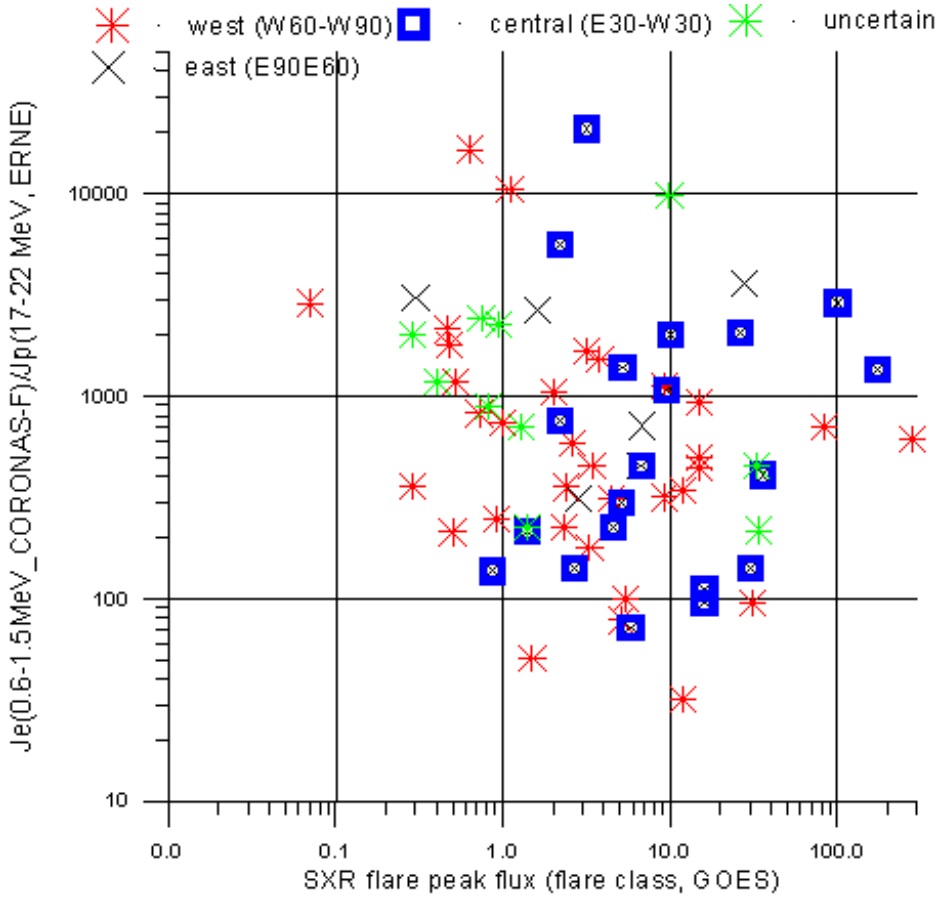
Ratio Je/Jp flux vs Jp flux

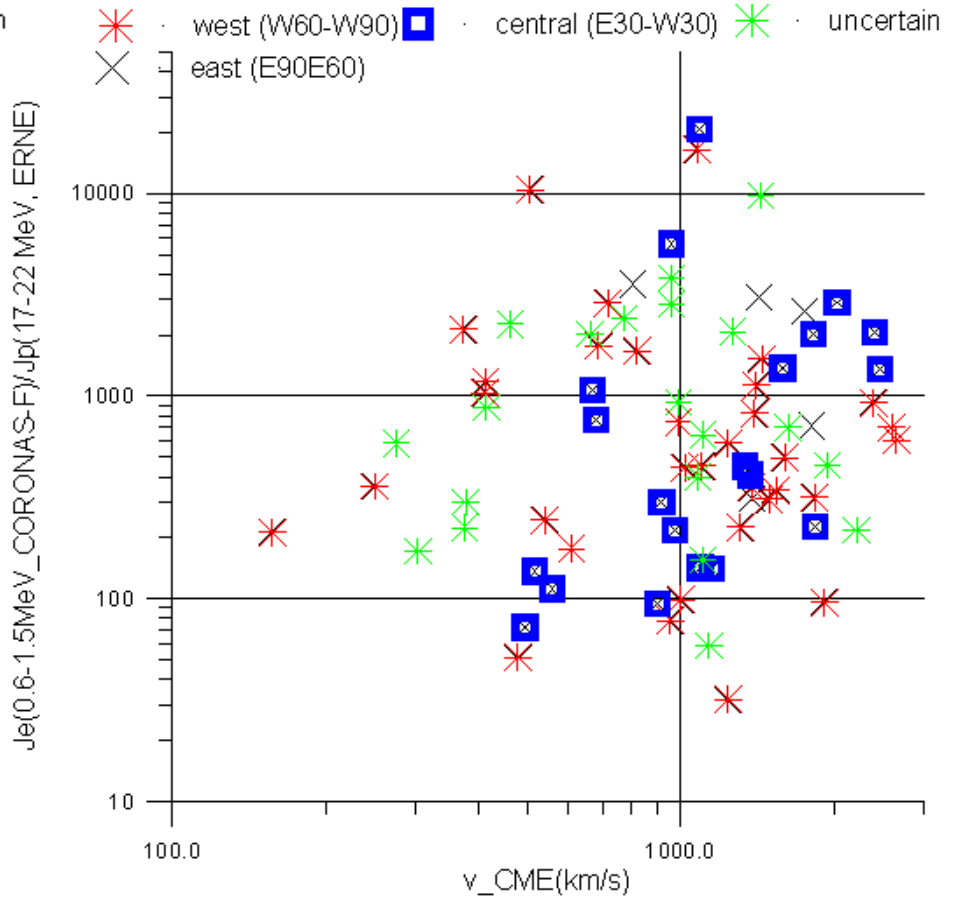


Ratio Je/Jp flux vs Je flux



Ratio Je/Jp flux vs SXR peak flare flux (GOES class) and CME velocity





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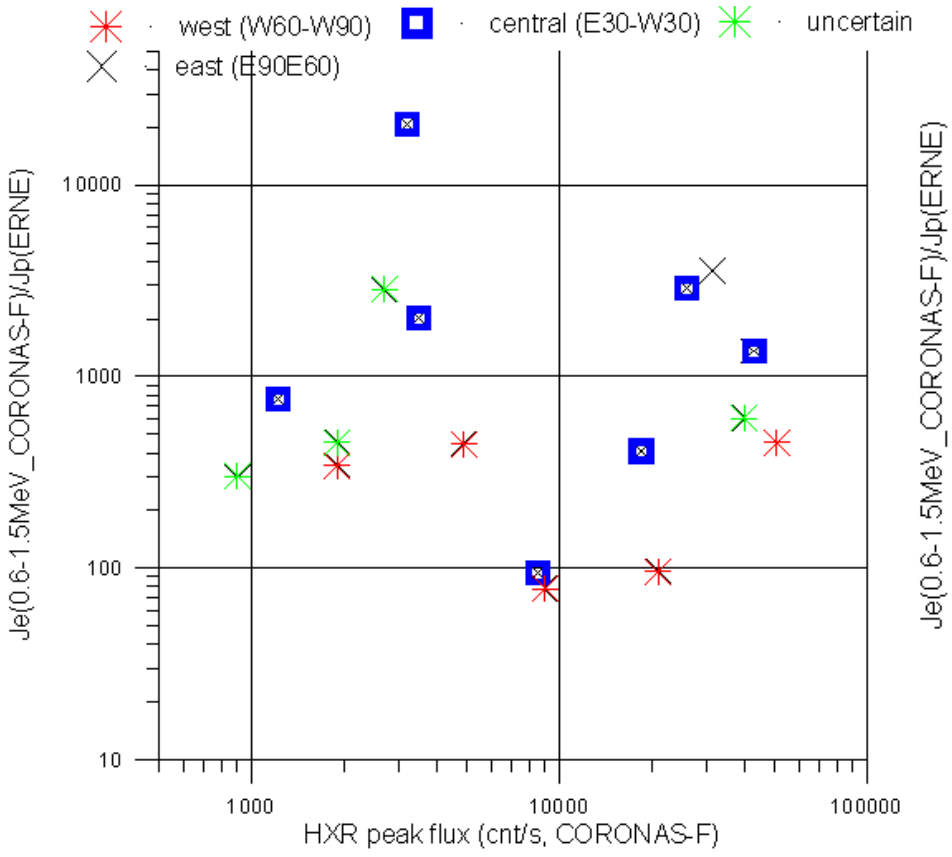
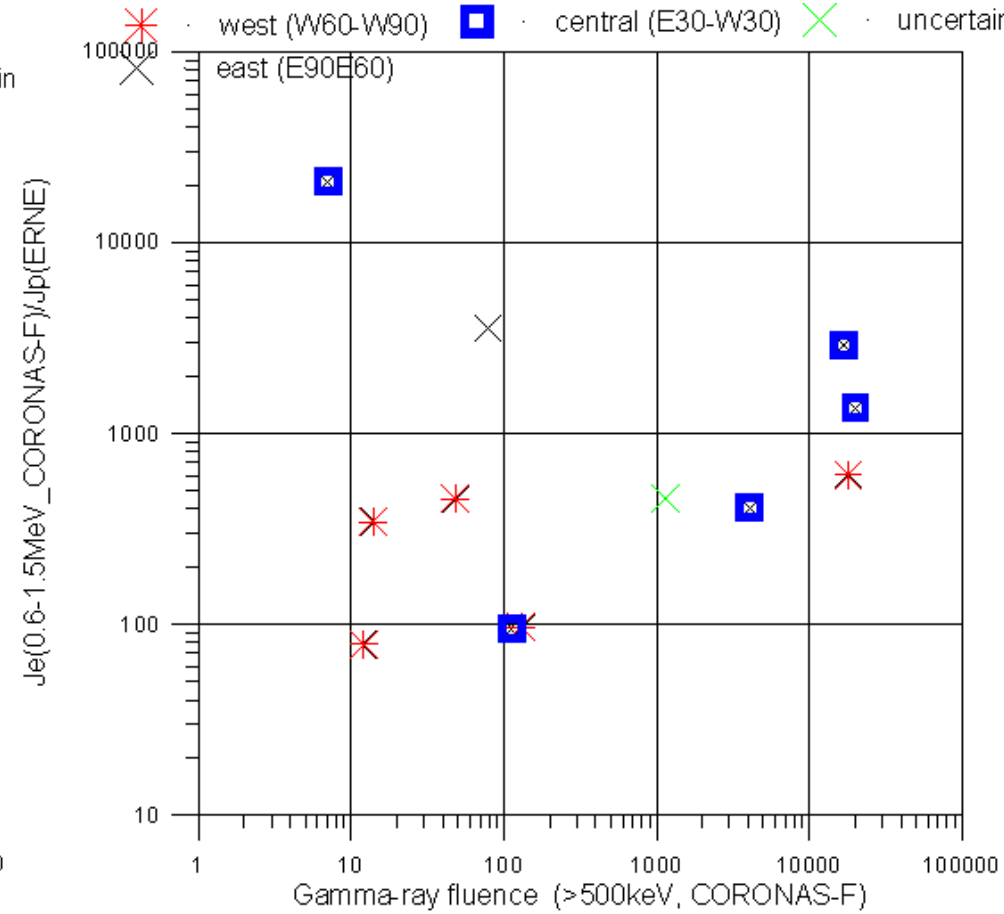
Ratio Je/Jp flux vs HXR (>50 keV) peak flux and gamma-ray (>500 keV fluence)





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Connection of SEP, SHR, HXR, and gamma-emission, CME parameters

Our goal – to try find some possibilities to estimate SEP intensity near the Earth using parameters of high-energy neutral flare emission and CME's ones.

Usind data:

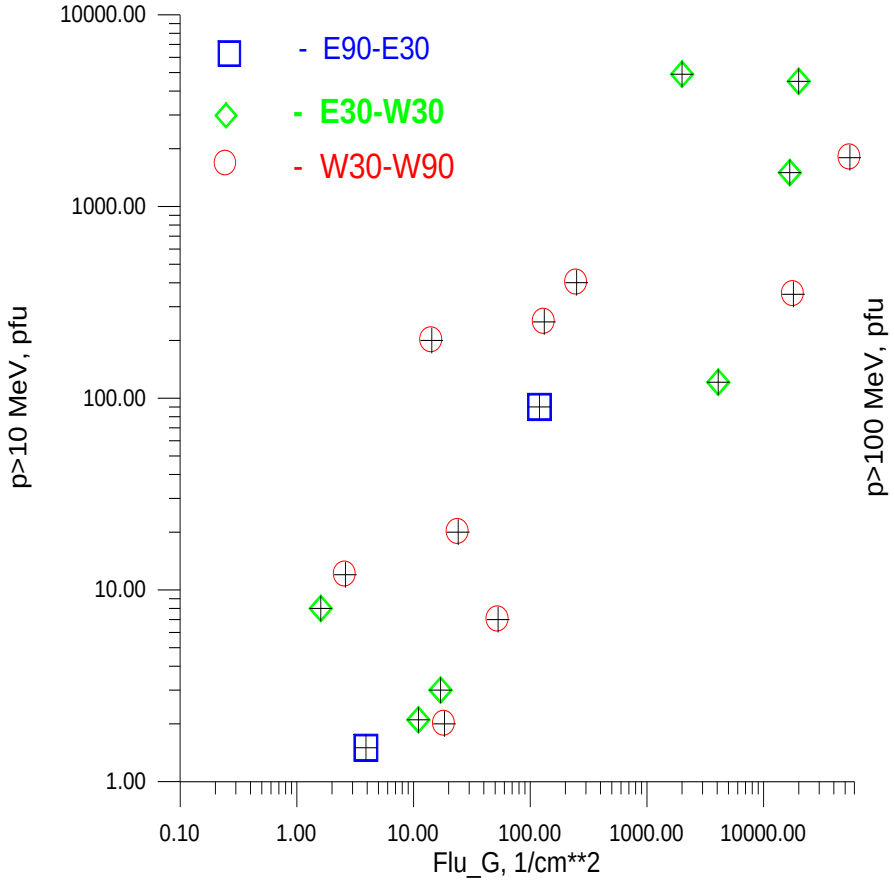
- CME's paramenters – linear speed (V), mass (M), kinetic energy (E) - LASCO (SOHO) data - (http://cdaw.gsfc.nasa.gov/CME_list)
- SEP protons >10 MeV, >100 MeV - GOES (swpc.noaa.gov)
- SEP electrons 53-103, 103-175 keV EPAM (ACE) data - (http://sd-www.jhuapl.edu/ACEEPAM/spec.html).

Statistics – 93 flares with HXR emission >50 keV - 34 west, 32 central, 18 east , 9 – (unknown coordinates)

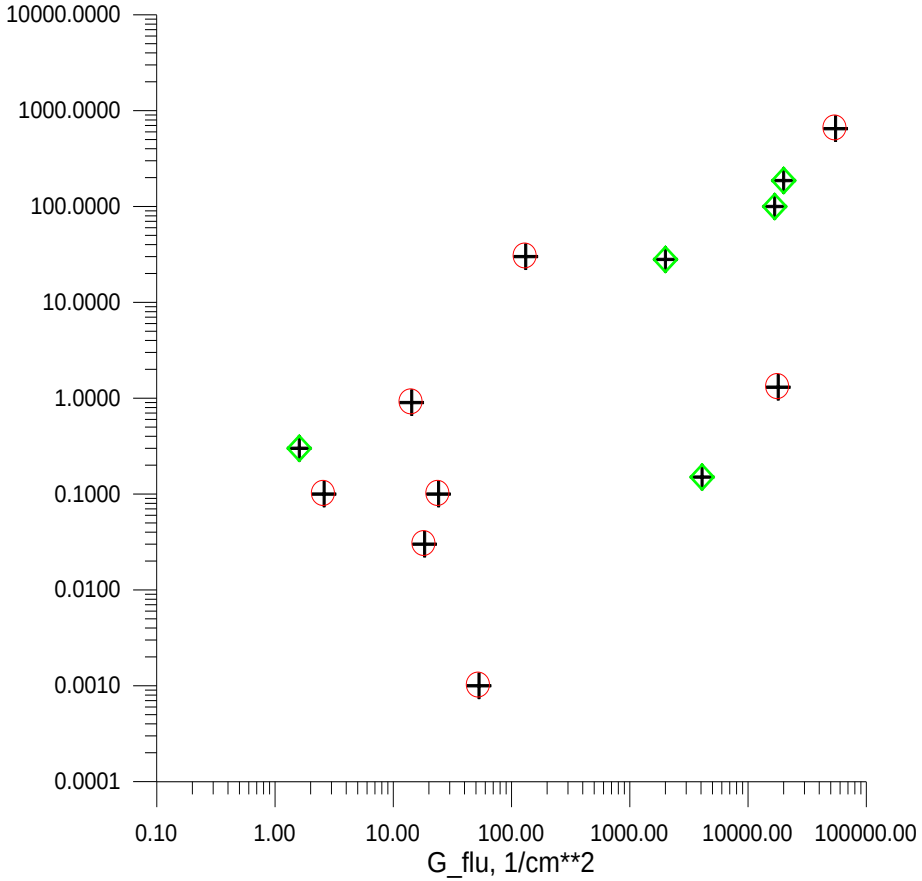
- p > 10 MeV – for 34 events, p>100 MeV - for 25 events
- e >53 keV – for 50 events
- CME - for 72 events

Gamma-ray fluence (>500 keV) and V-CME – p >10 MeV, >100 MeV

R=0.83 (18)
2 E, 7 C, 9 W



R=0.68 (13)
5 C and 8 W



Np10=f(G-flu,Vcme) R=0.9

p >10 MeV -HXR (>50 keV), SXR, V_CME, M_CME, E-CME

Z	**p>10 MeV**	**p=f(Z and HXR >50 keV**	P=f(Z+SHR 1-8 A)
HXR >50 keV	*0.35*	-	-
SXR 1-8 A	*0.46*	*0.52*	-
V_CME	0.65	**0.78**	0.69
M_CME	0.7	**0.79**	0.7
E_CME	0.77	**0.86**	0.77

e 0.05-0.175 MeV -HXR (>50 keV), SXR, V_CME and E-CME (all)

Z	e 0.05-0.175 MeV, center, [center+west]	e=f(**Z**+ HXR >50 keV) center [center+west]	+SHR 1-8 A, center [center+west]
HXR >50 keV	0.6 *[0.40]*	-	-
SXR 1-8 A	0.56 *[0.41]*	0.64 [0.49]	-
V_CME	0.44 [0.56]	**0.76** [0.55]	0.59 [0.54]
M_CME	0.43 *[0.39]*	0.71 [0.54]	0.54 [0.48]
E_CME	0.46 *[0.51]*	0.66 [0.52]	0.56 [0.47]

SUMMARY

1. We have observed more than hundred solar flares during 2001-2005 years in hard X-ray and gamma ray on board the CORONAS-F satellite (by SONG) and both protons and electrons SEP in polar caps (by MKL). HXR SONG catalogue was created.
2. Obtained data were compared with ones from SEP catalogues. Je/Jp ratio in SEP during 2001-2003 years were analyzed. There is no clear correlations Je/Jp ration with flare class, CME velocity and HXR peak flux were found.
3. Multiple regression of CME's parameters and HXR-emission flux permits to estimate SEP fluxes - p> 10 MeV (all observed flares) and e 0.053-0.175 MeV for central and west flares (Rcorr>75 %)
4. Obtained results show that **NEW INDEX of solar flares according to its HARD NEUTRAL EMISSION (HARD X-RAY)** would be useful.

Acknowledgements

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(I) National Science Fund of Bulgaria:
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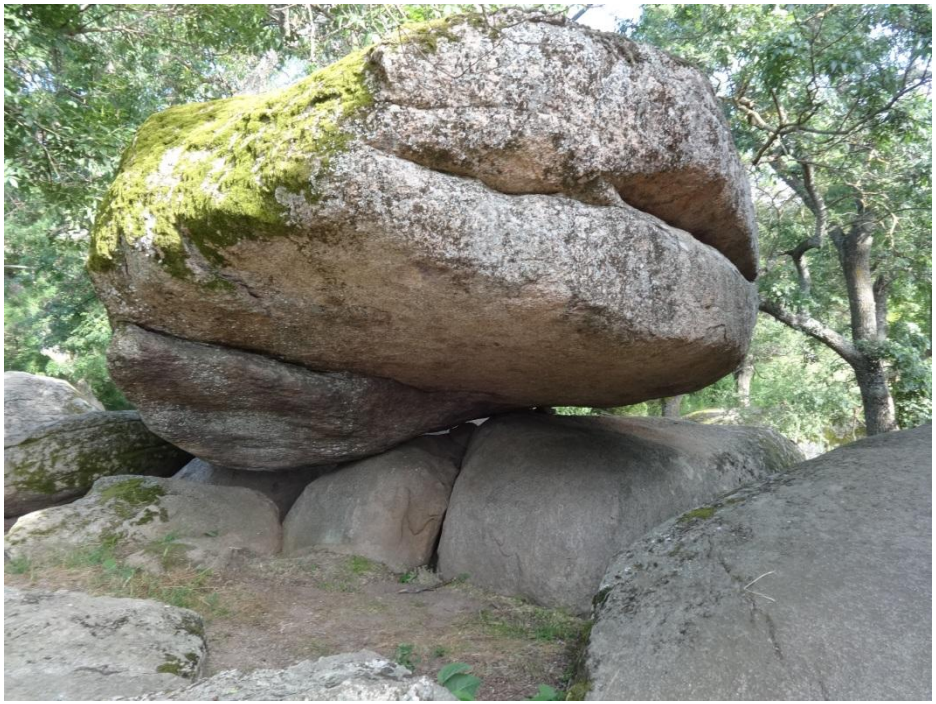
ФОНД НАУЧНИ ИЗСЛЕДВАНИЯ
МИНИСТЕРСТВО НА ОБРАЗОВАНИЕТО И НАУКАТА

(II) Russian Foundation for Basic Research:
Project № 17-52-19050

25 ЛЕТ РФФИ
РОССИЙСКИЙ ФОНД ФУНДАМЕНТАЛЬНЫХ ИССЛЕДОВАНИЙ

THANK YOU FOR YOUR ATTENTION



Eleventh **Workshop** "**Solar Influences** on the Magnetosphere, Ionosphere and Atmosphere", **Primorsko**, Bulgaria, 3-7 June 2019**.**