Space weather catalogs: energetic particles, radio emissions, flares and geomagnetic storms

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Momchil Dechev (IANAO-BAS)

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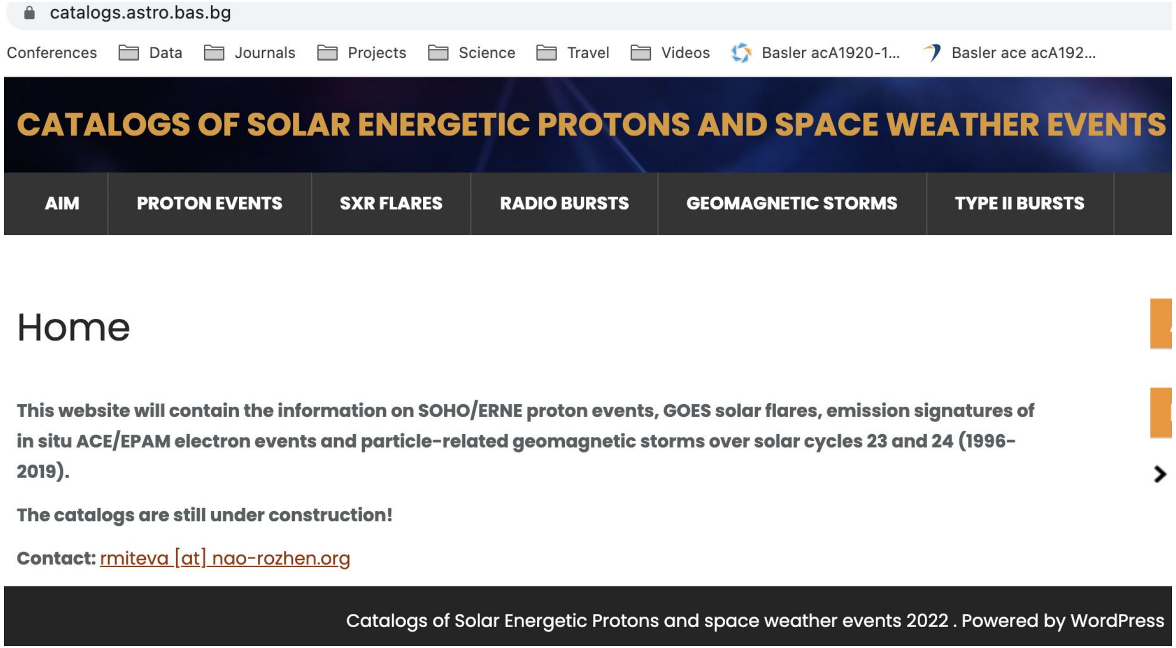
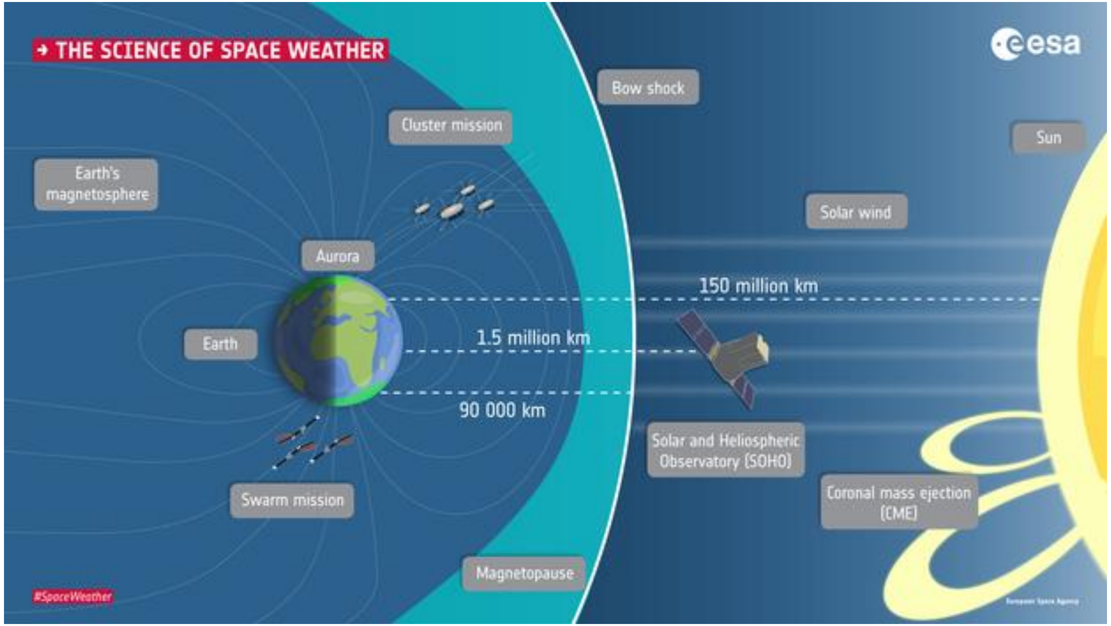


Open access to a set of analysed space weather events (catalogs):

- Proton events
- X & M class flares
- Electron-related radio bursts
- Major geomagnetic storms
- Type II bursts

Space weather: overview

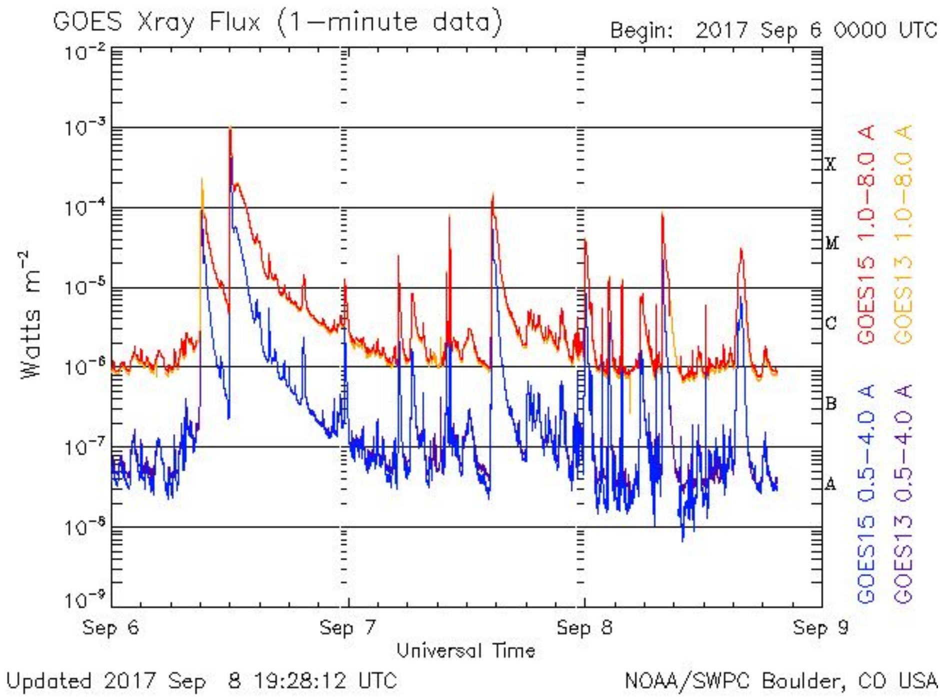


https://sci.esa.int/web/solar-system/-/60913-the-science-of-space-weather

"Space weather" refers to **conditions on the Sun and in the solar wind, magnetosphere, ionosphere, and thermosphere** that can influence the performance and reliability of **space-borne and ground-based technological systems and can endanger human life or health.** [...] can cause **disruption of satellite operations, communications, navigation, and electric power distribution grids, leading to a variety of socioeconomic losses**.

National Space Weather Program Strategic Plan, 1995. Office of the Federal Coordinator for Meteorological Services and Supporting Research, FCM–P30–1995, Washington, DC.

Space weather phenomena

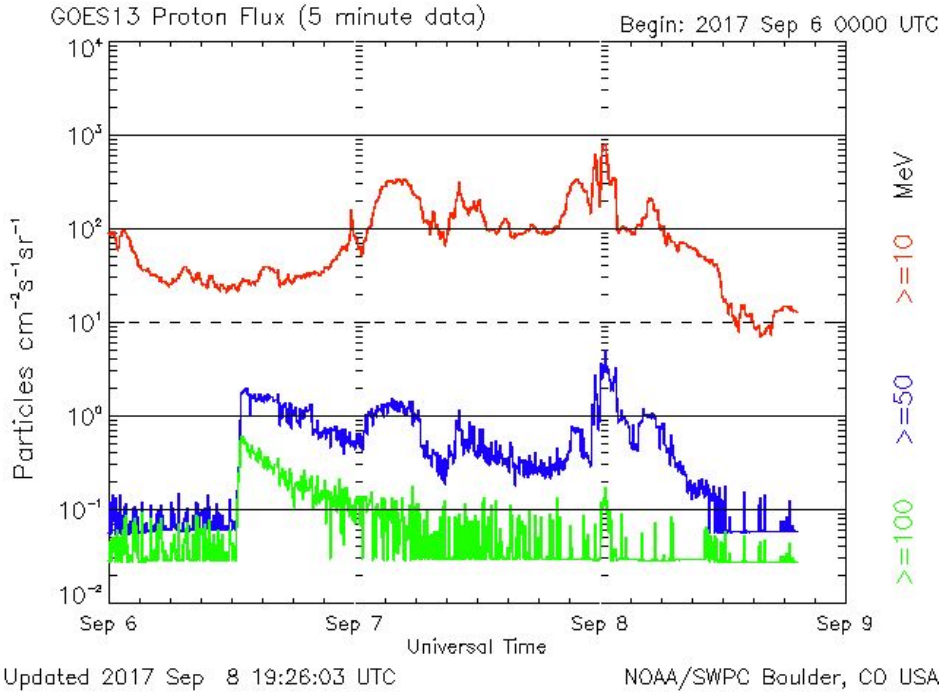


Solar flare

- eruption in the solar atmosphere due to magnetic reconnection process
- released energy up to 10^{27} J
- ***remotely observed*** emission from radio to gamma-rays
- occurs in active regions
- acceleration of electrons, protons
- association with mass motions

https://www.solarmonitor.org/

Space weather phenomena

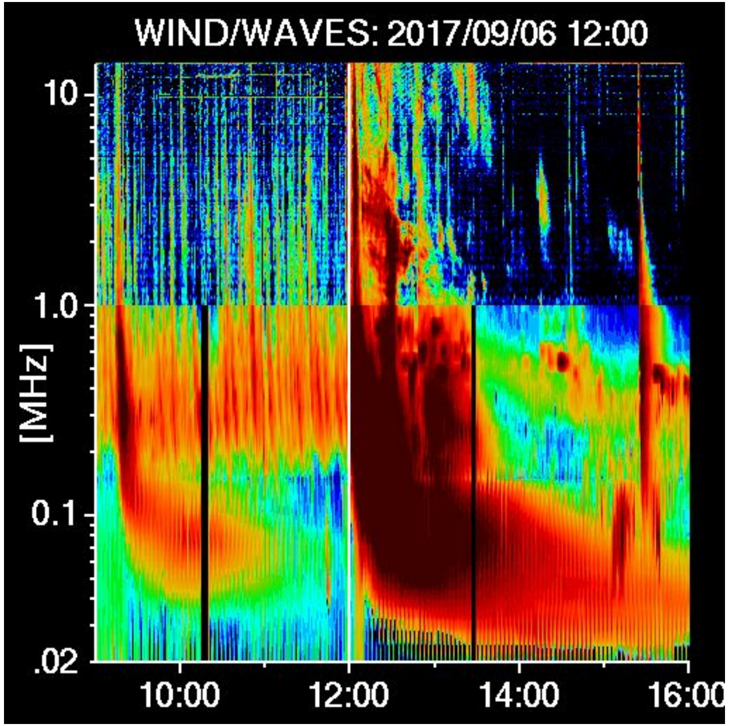


Solar energetic particles (SEPs)

- ***in situ*** observed electrons, protons and healy ions
- from keV to GeV
- transport in the interplanetary (IP) space along magnetic field lines
- profiles indicate the location of parent solar activity on the solar disk

https://www.solarmonitor.org/

Space weather phenomena



https://cdaw.gsfc.nasa.gov/CME_list/

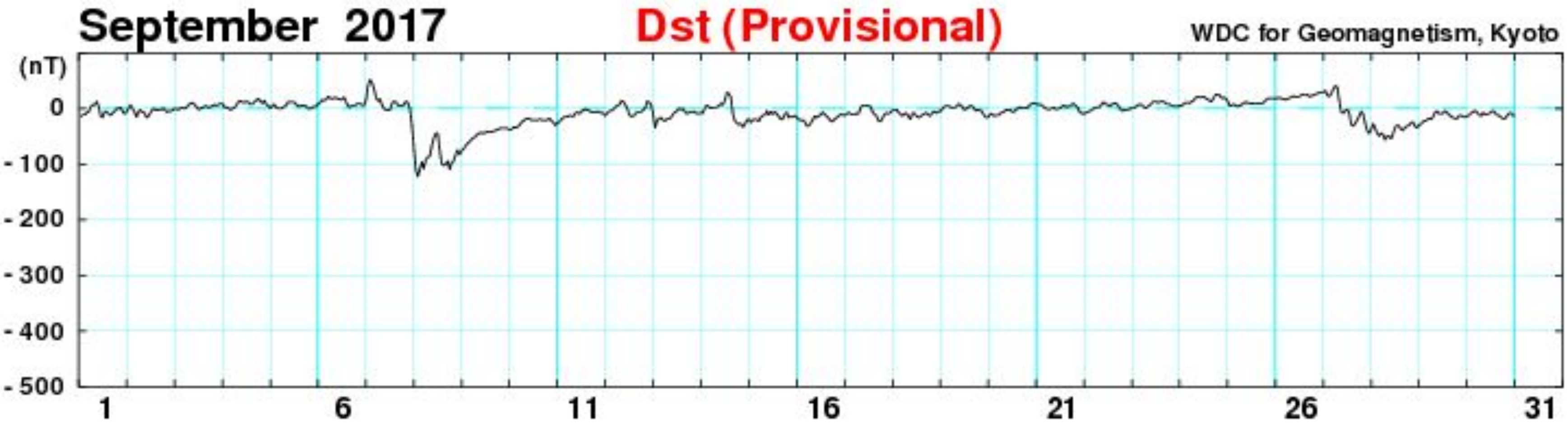
Radio bursts

- ***remotely observed*** emission from accelerated electrons in the corona and IP space
- the shape of the features indicates the type of driver and magnetic field line configuration
  - Type II: shock wave
  - Type III: electron beams alsong open field lines

Space weather phenomena

Geomagnetic storm

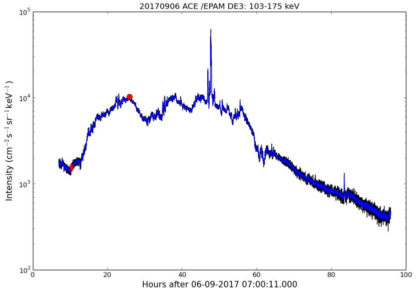
- disturbance in the Earth's magnetic field caused due to CME/shock wave impact on the magnetosphere
- can be given in negative values of the disturbance – storm time (***Dst***) ***index***: globally averaged change of the horizontal component of the Earth's magnetic field at the magnetic equator based on measurements from a few magnetometer stations



https://wdc.kugi.kyoto-u.ac.jp/wdc/Sec3.html

Electron event catalog

https://www.nriag.sci.eg/ace_electron_catalog/



The first electron catalog
- SC 23 & 24 (1997-2019)
- ACE/EPAM data 103-175 *(175-315)* keV
- 12 sec resolution
- 965 *(800)* events
- parent activity (64% flares, 74% CMEs, 14% none)
- associated protons ~32 *(38)* %
- Pearson & second-order partial log10-correlations

Completed

Support:

SCOSTEP/PRESTO 2020 grant ‘On the relationship between major space weather phenomena in solar cycles 23 and 24’

ACE/EPAM

Electron Event Catalog

Solar cycle 24: 2009-2019

@ NRIAG 2021

Last modified 25/05/2021

Back to: Home Page | Solar Cycle 23: (1996-2008)

Date			Electrons		103-175 keV		175-315 keV		GOES SXR Flare				SOHO/LASCO CME				19-28 MeV		28-72 MeV		Comments
yyyy	mm	dd	Onset time	Peak time	J_e	F_e	J_e	F_e	Onset time	Peak time	Class	Location	Time	Speed	AW	MPA	J_p	F_p	J_p	F_p	
2009	11	3	03:48	05:38	319.953737	1652971	117.59	256431	u	u	u	u	19:36^{pd}	226	47	274	no	no	no	no	
2009	11	5	01:11	02:10	86.370381	346789	no	no	u	u	u	u	u	u	u	u	no	no	no	no	
2009	12	22	06:09	07:44	96.688211	567443	45.209	221560	04:50	04:56	C7.2	S26W46	05:54	318	47	270	no	no	no	no	
2010	1	26	17:27	19:27	117.906222	688649	no	no	17:01	17:05	B3.2	N18W87	17:54	228	8	274	no	no	no	no	
2010	2	7	02:56	06:30	200.897786	2002295	67.556	316618	02:20	02:34	M6.4	N21E10	03:54	421	360	113	no	no	no	no	
2010	2	8	05:20	08:56	516.56869	2817255	117.34	701887	05:12	05:23	C8.6	N21W01	u	u	u	u	no	no	no	no	

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY
MNRAS 505, 5212–5227 (2021) https://doi.org/10.1093/mnras/stab1564
Advance Access publication 2021 May 31

Catalogue of *in situ* observed solar energetic electrons from ACE/EPAM instrument

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[2]Institute of Astronomy and National Astronomical Observatory (IANAO) - Bulgarian Academy of Sciences, BG-1784 Sofia, Bulgaria

SCOSTEP Scientific Committee on Solar-Terrestrial Physics

PRESTO

Proton event catalog

https://catalogs.astro.bas.bg/

In progress

<u>Support:</u>
SCOSTEP/PRESTO 2020 grant
STELLAR 2019-2022
LOFAR-BG
National Science Fund of Bulgaria

- SC 23 & 24 (1996-2016->2019)
- SOHO/ERNE HED, 10 energy channels (14-131 MeV)
- 1 min resolution
- 600+ events
- Solar origin, SEE, radio burst associations
- Energy dependent statistical analyses (Pearson & partial)

CATALOGS OF SOLAR ENERGETIC PROTONS AND SPACE WEATHER EVENTS

AIM | PROTON EVENTS | SXR FLARES | RADIO BURSTS | GEOMAGNETIC STORMS | TYPE II BURSTS

Solar Cycle 23 – Protons

(sample list only)

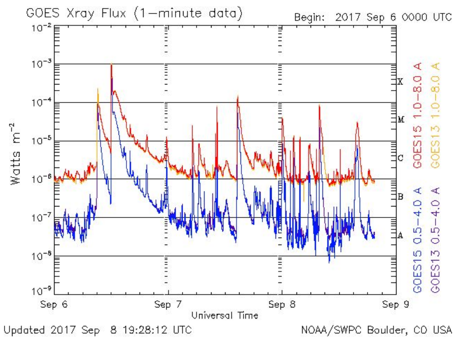
Show 10 entries

Year	m	d	Class	flare start	flare max	latitude	longitude	CME onset	CME speed	CME AW	Channel 1	onset UT	peak UT	Channel 2	Channel 3	Channel 4
1996	7	9	X2.6	09:05	09:11	-10	30	gap	gap	gap	0.004401	09:44	10:52	0.002427	0.001022	0.000979
1996	8	13	u	u	u	u	u	16:09	620	153	0.008504	18:15	22:03	0.005586	0.002268	0.001914
1996	11	26	B9.0	20:48	24:32	u	u	21:36	548	78	0.001545	24:31	26:39	0.000702	0.000657	no
1996	11	27	u	u	u	u	u	u	u	u	0.001879	14:33	15:11	0.000916	0.000431	no
1996	11	28	C1.3	15:35	17:32	u	u	16:50	984	101	0.009031	19:38	22:12	0.005472	0.001592	0.00116
1996	11	29	u	u	u	u	u	u	u	u	0.006815	05:30	13:49	0.002708	0.001147	0.000987

Preliminary version:
Miteva et al. (2020) *BgAJ (+online list)*

X vs. M-class flares: space weather relevance

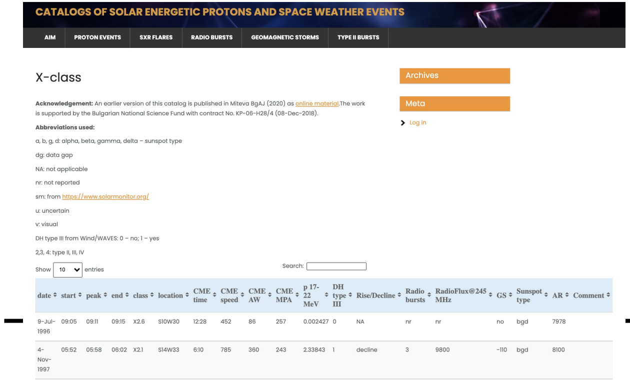
https://catalogs.astro.bas.bg/



X-class flares

- SC 23 & 24: <u>175 flares</u>
- X vs. CMEs: 76%
- X vs. type IP IIs/IIIs: 55%/75%
- X vs. SEPs/SEEs: 38%/37%
- 14% β, 11% β-γ, 30% β-γ-δ

Miteva (2021), Bulgarian Astronomical Journal (+online catalog)



CATALOGS OF SOLAR ENERGETIC PROTONS AND SPACE WEATHER EVENTS

AIM | PROTON EVENTS | SXR FLARES | RADIO BURSTS | GEOMAGNETIC STORMS | TYPE II BURSTS

X-class

Acknowledgement: An earlier version of this catalog is published in Miteva BgAJ (2020) as online material.The work is supported by the Bulgarian National Science Fund with contract No. KP-06-H28/4 (08-Dec-2018).

Abbreviations used:

a, b, g, d: alpha, beta, gamma, delta – sunspot type

dg: data gap

NA: not applicable

nr: not reported

sm: from https://www.solarmonitor.org/

u: uncertain

v: visual

DH type III from Wind/WAVES: 0 – no; 1 – yes

2,3, 4: type II, III, IV

Show 10 entries Search:

date	start	peak	end	class	location	CME time	CME speed	CME AW	CME MPA	p 17-22 MeV	DH type III	Rise/Decline	Radio bursts	RadioFlux@245 MHz	GS	Sunspot type	AR	Comment
9-Jul-1996	09:05	09:11	09:15	X2.6	S10W30	12:28	452	86	257	0.002427	0	NA	nr	nr	no	bgd	7978	
4-Nov-1997	05:52	05:58	06:02	X2.1	S14W33	6:10	785	360	243	2.33843	1	decline	3	9800	-110	bgd	8100	

Archives

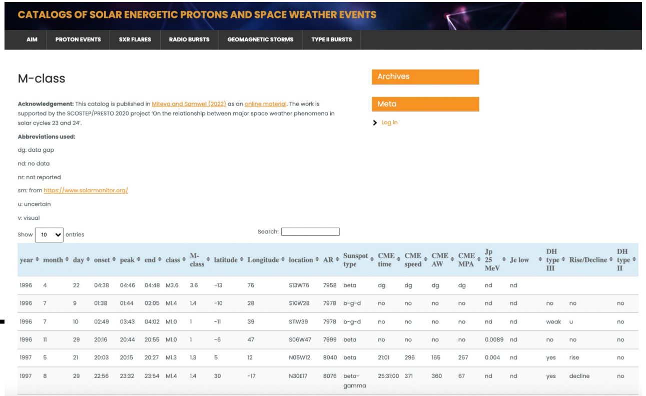
Meta

Log in

M-class flares

- SC 23 & 24: <u>2177 flares</u>
- M vs. CMEs: 41%
- M vs. type IP IIs/IIIs: 25%/50%
- M vs. SEPs/SEEs: 6%/11%
- 30% β, 22% β-γ, 30% β-γ-δ

Miteva & Samwel (2022), Universe (+online catalog)



CATALOGS OF SOLAR ENERGETIC PROTONS AND SPACE WEATHER EVENTS

AIM | PROTON EVENTS | SXR FLARES | RADIO BURSTS | GEOMAGNETIC STORMS | TYPE II BURSTS

M-class

Acknowledgement: This catalog is published in Miteva and Samwel (2022) as an online material. The work is supported by the SCOSTEP/PRESTO 2020 project 'On the relationship between major space weather phenomena in solar cycles 23 and 24'.

Abbreviations used:

dg: data gap

nd: no data

nr: not reported

sm: from https://www.solarmonitor.org/

u: uncertain

v: visual

Show 10 entries Search:

year	month	day	onset	peak	end	class	M-class	latitude	Longitude	location	AR	Sunspot type	CME time	CME speed	CME AW	CME MPA	Jp 25 MeV	Je low	DH type III	Rise/Decline	DH type II
1996	4	22	04:38	04:46	04:48	M3.6	3.6	-13	76	S13W76	7958	beta	dg	dg	dg	dg	nd	nd			
1996	7	9	01:38	01:44	02:05	M1.4	1.4	-10	28	S10W28	7978	b-g-d	no	no	no	no	nd	nd	no	no	no
1996	7	10	02:49	03:43	04:02	M1.0	1	-11	39	S11W39	7978	b-g-d	no	no	no	no	nd	nd	weak	u	no
1996	11	29	20:16	20:44	20:55	M1.0	1	-6	47	S06W47	7999	beta	no	no	no	no	0.0089	nd	no	no	no
1997	5	21	20:03	20:15	20:27	M1.3	1.3	5	12	N05W12	8040	beta	21:01	296	165	267	0.004	nd	yes	rise	no
1997	8	29	22:56	23:32	23:54	M1.4	1.4	30	-17	N30E17	8076	beta-gamma	25:31:00	371	360	67	nd	nd	yes	decline	no

Archives

Meta

Log in

Completed

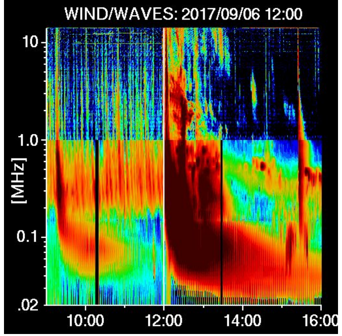
<u>Support:</u>

Bulgarian National Science Fund No. KP-06-H28(4), 8-Dec-2018

SCOSTEP/PRESTO 2020 grant 'On the relationship between major space weather phenomena in solar cycles 23 and 24'

SCOSTEP Scientific Committee on Solar-Terrestrial Physics

PRESTO



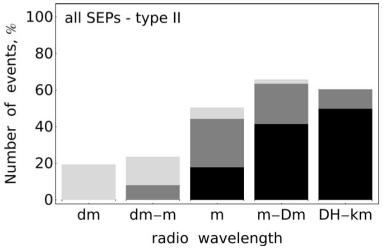
Ranges:
3-1 GHz,
1000-300 MHz,
300-100 MHz,
100-30 MHz,
30 MHZ-20 kHz
Black-->certain identification
Dark gray ->uncertain or only observatory reports
Light gray ->no dynamic spectral plots found

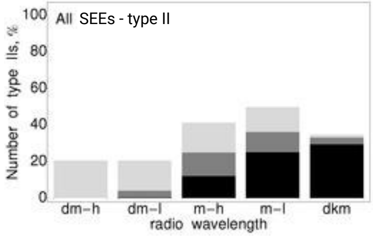
Completed
Support:
SCOSTEP/PRESTO 2020 grant 'On the relationship between major space weather phenomena in solar cycles 23 and 24'

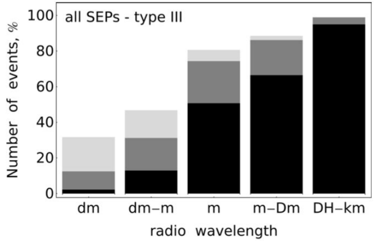
SCOSTEP
Scientific Committee on Solar-Terrestrial Physics
PRESTO

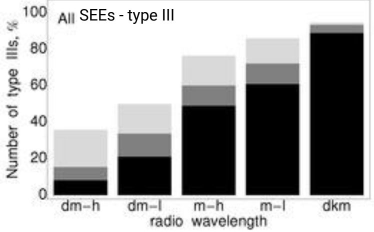
Electron vs. proton-associated radio bursts of type II, III, IV

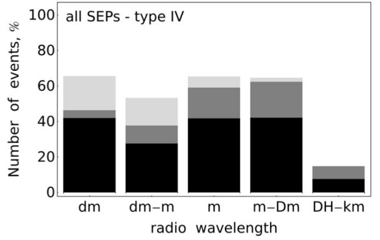
965 electron (SEE) events (Samwel & Miteva 2021, MNRAS): 832 radio bursts (86%)
- type IIIs are the most numerous burst type in corona/IP space
- Reduced SEE-type IIs in the IP space wrt SEP (Are IP shocks more proton-efficient?)
- Lower occurrence of SEE-type IIs IP range for E & W origin
- Clear decrease in IP space for SEE-type IIs in SC24 compared to SEP-type II

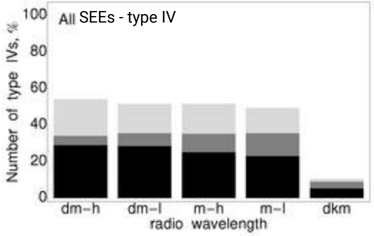












CESRA

RADIO DATA | SCIENCE HIGHLIGHTS | NEWS | MEETINGS/SCHOOLS | FOR PUBLIC

Solar radio bursts associated with in situ detected energetic electrons in solar cycles 23 and 24 by R. Miteva et al.*

2022-07-05 Solar Radio Science Highlights

https://www.astro.gla.ac.uk/users/eduard/cesra/?p=3350

Electron vs. proton-associated radio bursts of type II, III, IV

Protons (SEP)-radio bursts: Miteva et al. (2017) *JSWSC (+online list)*
Electrons (SEE)-radio bursts: Miteva et al. (2022) *Universe (+online catalog)*

Completed

Support:
SCOSTEP/PRESTO 2020 grant 'On the relationship between major space weather phenomena in solar cycles 23 and 24'

SCOSTEP Scientific Committee on Solar-Terrestrial Physics

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CATALOGS OF SOLAR ENERGETIC PROTONS AND SPACE WEATHER EVENTS

AIM | PROTON EVENTS | SXR FLARES | RADIO BURSTS | GEOMAGNETIC STORMS | TYPE II BURSTS

https://catalogs.astro.bas.bg/

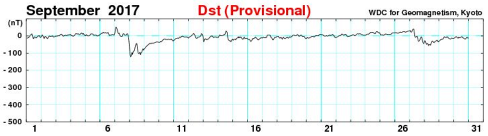
Solar cycle 23 – Radio

Show 10 entries

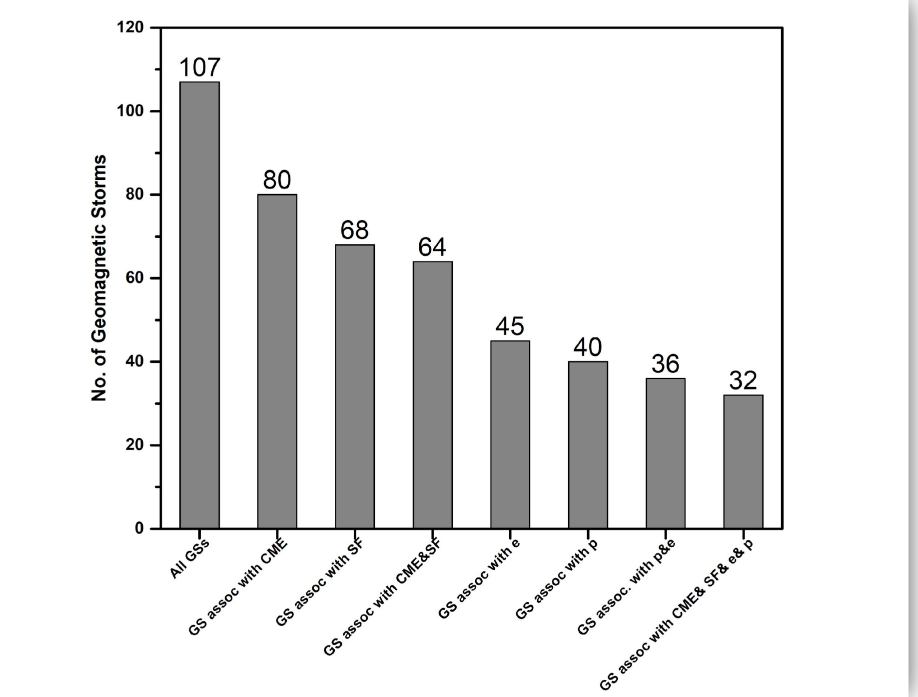
Year	m	d	Flare onset	Flare peak time	Flare class	location	latitude	longitude	CME onset	CME speed	CME AW	MPA	dm-II	dm-III	dm-IV	dm2-II	dm2-III	dm2-IV	m-II	m-III	m-IV	m2-II	m2-III	m2-IV	dam II
1997	9	9	20:04	20:11	B7.1	u	u	u	20:06	726	101	303	g	g	g	g	g	g	g	g	g	g	g	g	no
1997	9	18	17:45pd	18:03pd	M1.0	N21W84	21	84	20:29pd	377	360	263	g	g	g	g	g	g	g	g	g	g	g	g	no
1997	9	18	17:05	17:10	C1.5	N22W91v	22	91	18:03	285	55	268	g	g	g	g	g	g	g	g	g	g	g	g	no
1997	9	20	0:27	00:48	B8.0	u	u	u	0:44	522	39	247	no	no	no	no	no	no	no	no	no	no	no	no	no
1997	9	24	2:43	02:48	M5.9	S31E19	-31	-19	3:38	532	76	117	no	no	4	no	rep	4	no	rep	4	2	rep	3	no
1997	10	7	u	u	u	u	u	u	13:30	1271	167	204	g	g	g	g	g	g	rep	rep	no	2	3	no	no
1997	10	21	17:00	17:54	C3.3	N16E07	16	-7	18:03	523	360	90	g	g	g	g	g	g	g	g	g	no	rep	rep	no
1997	11	3	9:03	09:10	M1.4	S20W15	-20	15	9:53	338	71	239	no	3	4	g	g	g	g	g	g	2	3	no	no
1997	11	3	10:18	10:29	M4.2	S20W30v	-20	30	11:11	352	122	235	no	no	4	no	rep	rep	2	3	4	2	3	rep	2
1997	11	4	5:52	05:58	X2.1	S14W33	-14	33	6:10	785	360	243	no	3	4	no	3	4	rep	3	4	rep	3	4	2

Showing 1 to 10 of 545 entries

Major geomagnetic storm



- SC 23 & 24: <u>107 geo-storms</u>
- Dst < -100 nT
- more GSs in SC23 wrt SC24
- more intense SGs in SC23 wrt SC24
- CME in SC23 are faster & narrower wrt CMEs in SC24
- SXR peak flux is similar for both SCs around X-class flares
- Correlations with electrons in SC23 are larger wrt SC24
- Correlations with low/high energy protons in SC23 are larger/lower wrt SC24.



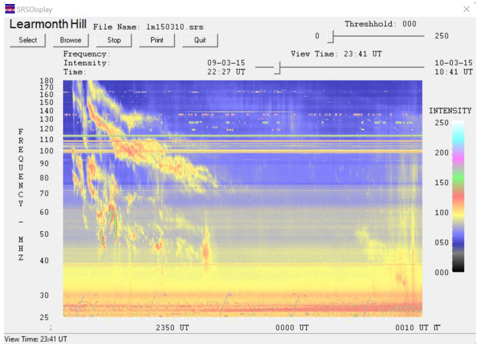
In progress

Collaboration: Samwel & Miteva

<u>Support:</u>
SCOSTEP/PRESTO 2020 grant 'On the relationship between major space weather phenomena in solar cycles 23 and 24'

SCOSTEP Scientific Committee on Solar-Terrestrial Physics

Type II radio bursts from RSTN data



Credit: RSTN data

SC 24 (2009-2019)

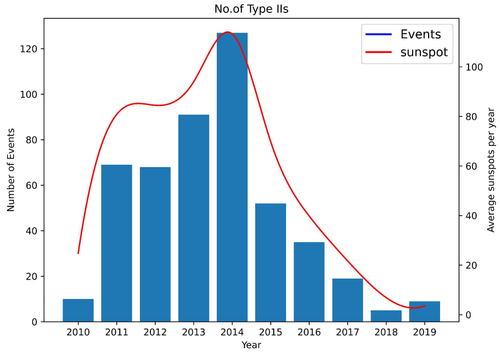
RSTN data: 25-180 MHz; 1-sec time resolution; observatory reports used

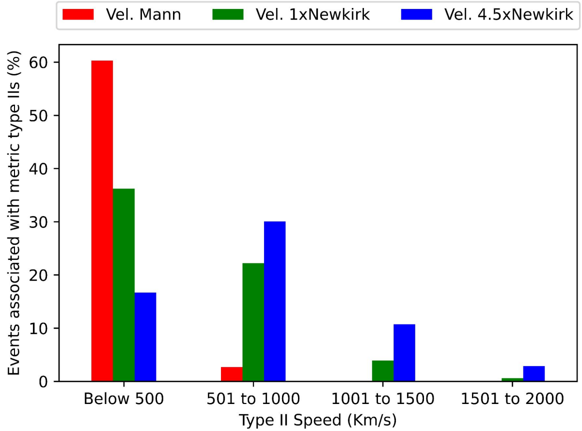
Total # type II bursts identified: <u>486 candidates</u>

Majority of type IIs (~67%): 1-5 & 6-10 min

143/486 (or 29%) are newly identified by our team

In progress: associations with space weather events (in situ particles, IP shocks, ICMEs, geomagnetic storms, filaments)





In progress

Collaboration: Lawrence, Devi, Chandra, Miteva, Koleva, Dechev

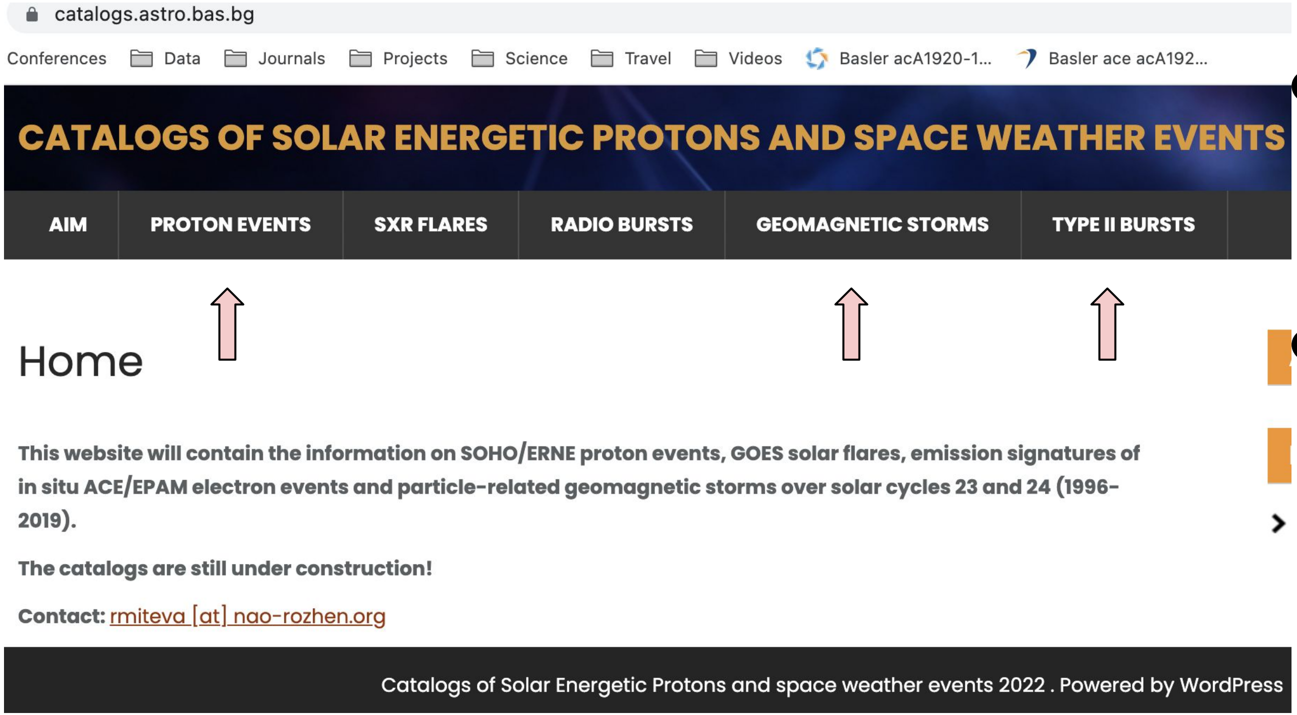
<u>Support:</u>

Bulgarian-Indian Project KP-06-India/14 (19-Dec-2019)

ФОНД НАУЧНИ ИЗСЛЕДВАНИЯ

МИНИСТЕРСТВО НА ОБРАЗОВАНИЕТО И НАУКАТА

Outlook



Completed repositories:

- X & M class flares
- Electron-related radio bursts

Catalogs in progress:

- Proton events
- Major geomagnetic storms (list ready)
- Type II bursts (list ready)