

## CATALOGS OF SOLAR ENERGETIC ELECTRONS AND THEIR RADIO EMISSIONS IN SOLAR CYCLES 23 AND 24

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**Keywords:** Solar energetic electrons, radio emission signatures, solar cycle

**Abstract:** We present the status of two comprehensive catalogs of *in situ* observed energetic electrons (from ACE/EPAM DE instrument, with energy coverage 103–315 keV) and their related radio emissions. The focus is on the developed dual web-based interface and their planned capabilities. For the first time solar energetic electrons are identified over the period of two solar cycles, from 1997 to 2017. In addition, we present the solar radio emission signatures observed remotely (both from satellites and ground-based observatories). Thus, for the first time the radio signatures of electrons (radio burst types, single frequency records, dynamic radio spectra) can be directly compared with the *in situ* observed electron events.

## КАТАЛОЗИ ОТ СЛЪНЧЕВИ ЕНЕРГЕТИЧНИ ЕЛЕКТРОНИ И ТЕХНИТЕ РАДИО ЕМИСИИ ПО ВРЕМЕ НА СЛЪНЧЕВИТЕ ЦИКЛИ 23 И 24

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**Ключови думи:** Слънчеви енергетични електрони, радио емисионни сигнатури, слънчев цикъл

**Резюме:** Представяме два подробни каталога от наблюдавани *in situ* енергетични електрони (от инструмента ACE/EPAM DE с енергии в диапазона 103–315 keV) и техните радио емисии. Фокусът е върху разработваната двойка от уеб-структури и техните планирани възможности. За първи път слънчеви енергетични електрони се определят за период от два слънчеви цикъла, от 1997 до 2017. В допълнение, представяме слънчевите радио емисионни сигнатури наблюдавани дистанционно (както от спътници, така и от наземни обсерватории). Така за първи път радио сигнатурите на електрони (тип радио избухване, едночестотни записи, динамичен радио спектър) може да бъде директно сравнен с *in situ* наблюдаваните електронни събития.

### Introduction

The objective of this report is to outline the setting of a web-interface for a dual catalogs: one listing the *in situ* observed solar energetic electrons (SEEs) and another, showing the remotely detected radio emission signatures of these electrons. The basis of this project is the catalog of electrons as detected by the ACE/EPAM DE [1] instrument. Furthermore, to each electron event, we performed – to the best of our abilities – a solar origin association. Namely, each *in situ* electron is allocated to a pair, where possible, of a solar flare (SF) and coronal mass ejection (CME). We used a standard procedure utilized in this research field by selecting the strongest flare and the fastest and widest CME, giving a preference to a western eruption in case of several competing candidate pairs.

There is a lack of a comprehensive list of solar electrons detected near Earth. Several partial listings exist [2–5], however none of them covers continuously two solar cycles (SCs), which is the aim of our current efforts. Moreover, the radio emissions considered as the signatures of *in situ* observed

particles are always compared to the occurrences and peak intensities of protons and not to electrons, see, e.g., [6–9]. Our project aims to finally bridge his gap.

## Catalogs

**Solar energetic electrons:** <http://www.nriag.sci.eg/aceepam-electron-event-catalog-2/>

**ACE/EPAM**  
**Electron Event Catalog**

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Solar Cycle 23: (1996-2008)      Solar Cycle 24: (2009-Present)

This catalog lists the electron enhancements from the ACE/EPAM instrument since 1996 in two energy channels. The catalog is organized as a table that presents the solar energetic particles (electrons) observed during solar cycle 23 (1996–2008) and the ongoing solar cycle 24 (since 2009). The catalog provides the following information: onset, peak times (in UT) and peak electron intensity at 103–175 keV energy channel and also the peak electron intensity at 175–315 keV energy channel. In addition, the solar sources (flares and coronal mass ejections) of the electron events are identified, where possible, with their properties noted. Further information is given as a comment. Extensions of the catalog (or corrections if needed) will appear regularly online.

**Explanatory notes:**  
**Electron data:** from CDAweb database provided with 12-sec time resolution.  
**Onset time:** Identified as the time of 3-sigma intensity value above pre-event level.  
**Peak time:** Identified at the maximum of the particle profile (local enhancements are not considered).  
 **$J_e$ :** peak electron intensity after subtraction of the pre-event level.  
 The reported here onset/peak times and  $J_e$  are based on 5-point smoothed data.

Fig. 1. Screen-view of the home page of the electron catalog web-site

Event date	103-175 keV		175-315 keV		Flare	CME	Comment
YYYY-MM-DD	onset time (UT)	peak time (UT)	$J_e$ / (cm <sup>2</sup> s sr MeV <sup>-1</sup> )	$J_e$ (cm <sup>2</sup> s sr MeV <sup>-1</sup> )	SXR class/ onset time (UT)/ location	time (UT)/ speed (km s <sup>-1</sup> ) / width (deg)	
1997-09-09	20:59	23:00	158.33	68.652	B7.1/20:04u	20:06/726/101	
1997-09-18	00:41	01:00	417.66	-	M1.0/17:45 <sup>+</sup> / N21W84	18:18 <sup>+</sup> /613/46	
1997-09-18	17:18	19:24	240.12	-	B5.8/16:04u	16:53/112/38	
1997-09-18	20:10	22:29	496.13	-	C1.5/17:05u	18:03/285/55	
1997-09-20	03:55	06:22	368.15	70.204	B8.0/00:27u	00:44/522/39	
1997-09-20	10:33	10:53	359.79	76.884	C2.3/09:48u	10:20/777/97	
1997-09-24	03:45	5:40	182.24	74.592	M5.9/02:43/ S31E19	03:38/532/76	
1997-10-07	13:47	15:14	272.22	78.52	-	13:30/1271/147	
1997-10-21	19:21	21:36	145.09	55.153	C3.3/17:00/N16E07	18:03/523/360	
1997-11-03	10:40	12:52	264.13	86.837	M1.4/09:03/S20W15	09:53/336/71	
1997-11-03	15:13	16:06	350	93.163	M4.2/10:18u	11:11/352/122	
1997-11-04	06:17	08:45	19091	5117.3	X2.1/05:52/S14W33	06:10/785/360	

Event date	103-175 keV		175-315 keV		Flare	CME	Comment
YYYY-MM-DD	onset time (UT)	peak time (UT)	$J_e$ / (cm <sup>2</sup> s sr MeV <sup>-1</sup> )	$J_e$ (cm <sup>2</sup> s sr MeV <sup>-1</sup> )	SXR class/ onset time (UT)/ location	time (UT)/ speed (km s <sup>-1</sup> ) / width (deg)	
2009-11-03	03:50	05:53	395.04	145.41	none	19:36/226/47	
2009-11-05	01:13	02:10	170.54	-	none	01:18/208/69	
2009-12-22	06:44	07:26	183.63	73.01	O4-S0/C7.2 /S26W46	05:54/318/47	
2010-01-26	17:27	18:34	179.86	-	17:40/B6.7u	17:54/228/8	
2010-02-07	02:58	06:40	338.49	98.878	G2:20/M6.4 /N21E10	03:54/421/360	

Fig. 2. Screen-views of the tables with electron events in solar cycles 23 (on the left) and 24 (on the right)

The electron data is collected from CDAW omni database: <http://cdaweb.gsfc.nasa.gov/> with 12-sec time resolution in the two highest energy channels, 103–175 and 175–315 keV. The electron enhancements are first visually identified by an observer and then a semi-automatic routine is used to calculate the pre-event background level (using observer defined start and end times), the value of the peak electron intensity and the background subtracted peak intensity at each energy channel under consideration. The latter values (with their corresponding links to overview plots), the lower energy SEE date, onset and peak times and the properties of the SEE-related SF and CME are finally reported in the online catalog. The onset time is defined as the time when the electron flux surpasses three standard deviations above the background flux level.

The access point to the electron catalog is via: <http://www.nriag.sci.bg/aceepam-electron-event-catalog-2/> A screen-view of the home page for the electron events is given in Fig. 1, whereas Fig. 2 presents screen-views of two separate tables with the events in each SC.

**Radio emission signatures: <http://newserver.stil.bas.bg/SEPcatalog>**

## Catalogs of Solar Energetic Particles and Related Phenomena

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[Wind/EPACT proton event catalog](#)

[SOHO/ERNE proton event catalog](#)

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StatCounter "Number of Visits" from Jan. 12, 2017 until now is **000816**

Fig. 3. Overview of the website hosting also the radio emission signatures catalog

## Radio emission signatures catalog

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Solar cycle 23: 1996-2008
[Back to list of Catalogs](#)
Solar cycle 24: 2009-2018

This catalog lists the radio signatures of in situ observed electron events from the [ACE/EPAM Instrument](#) since 1996. The catalog is organized as a table that presents the remote radio signatures of electrons observed during solar cycle 23 (1996-2008) and 24 (2009-2018).

**Explanatory notes:**  
The catalog provides the following information:  
date of the electron event;  
onset time (in UT) of the electron event;  
solar origin:  
flare SXR class, onset time and location  
time of CME first appearance (in UT), linear speed (in km/s) and AW (in degrees);  
radio burst types: appearance of types II, III, IV in different wavelength ranges;  
RSTN identification: peak flux [sfu], peak frequency [MHz] and spectral index;  
Comment.  
The reported here peak radio flux is based on 1-sec data.

**Abbreviations:**  
AW: angular width  
nd: next day  
pd: previous day  
SXR: soft X-ray  
u: uncertain  
v: visual  
wavelength ranges:  
dm: decimetric (3-1 GHz)  
dm-m: decimetric to metric (1 GHz-300 MHz)  
m: metric (300-100 MHz)  
m-Dm: metric to decametric (100-30 MHz)  
Dm-Hm-km (DH-km): decametric-hectometric-kilometric (30 MHz-10 kHz)

**If you want to use the results in a paper, book, or any other kind of electronic publication**, please give credit to **Radio emission signatures catalog** <http://newserver.stil.bas.bg/SEPcatalog/>.

Preliminary results can be found in the publication:  
*R. Miteva, S. W. Sämuel and V. Krupar, Solar energetic particles and radio burst emission, JSWSC (2017), DOI: 10.1051/swsc/2017035.*

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[RSTN](#), [Wind/WAVES](#), [Radio monitoring](#); as well as various ground-based observatories.  
Flare information is adopted from: [GOES flare listings](#) and [www.Solamonitor.org](#);  
and CME information from: [CDAW LASCO CME catalog](#).

**Contact:** [R. Miteva](#)

**Links:** [Space Climate Group Homepage](#)  
[Space Research and Technology Institute Homepage](#)

This radio signatures catalog is part of project supported by:




Fig. 4. Overview of the home page of the radio catalog

## Radio emission signatures catalog

Solar cycle 23: 1996-2008

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[Back to list of Catalogs](#)    [Back to Radio emission catalogs](#)    [Solar cycle 24: 2009-2018](#)

Event date	Electron	Flare	CME	Radio burst			RSTN	
yyyy-mm-dd	onset	SXR class/onset/location	time/speed/AW	Type II	Type III	Type IV	peak flux	peak freq.
1997-09-09	20:59	B7.1/20:04/unc	20:06/726/101		yes		u	-
1997-09-18	00:41	M1.0/17:45 <sup>00</sup> /N21W84	18:18 <sup>00</sup> /613/46		yes		u	-
1997-09-18	17:18	B5.8/16:04/unc	16:53/112/38		yes	yes	20	245
1997-09-18	20:10	C1.5/17:05/unc	18:03/285/55		yes		64	245
1997-09-20	03:55	B8.0/00:27/unc	00:44/522/39		yes		-	-
1997-09-20	10:33	C2.3/09:49/unc	10:20/777/97				-	-
1997-09-24	03:45	M5.9/02:43/S31E19	03:38/532/76	yes	yes	yes	69035	245
1997-10-07	13:47	uncertain	13:30/1271/167	yes	yes		u	-
1997-10-21	19:21	C3.3/17:00/N16E07	18:03/523/360		yes	yes	1079	410
1997-11-03	10:40	M1.4/09:03/S20W15	09:53/338/71	yes	yes	yes	23403	245
1997-11-03	15:13	M4.2/10:18/unc	11:11/352/122	yes	yes	yes	40428	245
1997-11-04	06:17	X2.1/05:52/S14W33	06:10/785/360	yes	yes	yes	12221	245
1997-11-05	07:31	C7.0/06:17/S13W49	07:29/350/40		yes		-	-
1997-11-06	12:22	X9.4/11:49/S18W63	12:11/1556/360	yes	yes	yes	50840	245
1997-11-13	21:40	C1.7/20:09/unc	22:26/546/288		yes	yes	-	-

[Back to list of Catalogs](#)    [Back to Radio emission catalogs](#)    [Solar cycle 24: 2009-2018](#)

## Radio emission signatures catalog

Solar cycle 24: 2009-2018

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[Back to list of Catalogs](#)    [Back to Radio emission catalogs](#)    [Solar cycle 23: 1996-2008](#)

Event date	Electron	Flare	CME	Radio burst			RSTN	
yyyy-mm-dd	onset	SXR class/onset/location	time/speed/AW	Type II	Type III	Type IV	peak flux	peak freq.
2009-11-03	03:50	uncertain	19:36/226/47				-	-
2009-11-05	01:13	uncertain	01:18/208/69				-	-
2009-12-22	06:44	C7.2/04:50/S26W46	05:54/318/47	yes	yes		4920	245
2010-01-26	17:27	B6.7/17:40/unc	17:54/228/8		yes		-	-
2010-02-07	02:58	M6.4/02:20/N21E10	03:54/421/360		yes	yes	10785	410
2010-02-08	05:32	C8.6/05:12/N21W01	06:30/153/99		yes		597	610
2010-02-12	08:21	C7.9/07:18/N24E13	uncertain		yes	yes	2551	410
2010-02-12	12:18	M8.3/11:19/unc	uncertain		yes	yes	24246	410
2010-02-12	13:50	B8.9/12:42/unc	13:42/509/360		yes	yes	u	-
2010-03-04	13:45	B6/13:28/unc	uncertain		yes	yes	180	245
2010-05-08	20:34	B7.2/18:41/unc	19:31/447/37				9	245
2010-06-12	01:10	M2/00:30/N23W43	01:31/486/119	yes	yes	yes	27769	245
2010-06-13	03:20	B4.6/02:28/unc	02:30/227/24				-	-
2010-06-14	01:24	C1.5/00:44/N27W70	01:31/343/62		yes		30	410
2010-08-03	16:01	B2.4/14:17/unc	uncertain				u	-

[Back to list of Catalogs](#)    [Back to Radio emission catalogs](#)    [Solar cycle 23: 1996-2008](#)

Fig. 5. Screen-views of the tables with radio signatures in solar cycles 23 (upper part) and 24 (lower part)

The radio data is collected from various radio observatories, both in space and on ground, providing dynamic radio spectra and single frequency radio records (the latter adopted primarily from the four RSTN network stations: <ftp://ftp.ngdc.noaa.gov/STP/space-weather/solar-data/solar-features/solar-radio/rstn-1-second/>). We used only those electron events for which at least one of the solar origin has been identified. In such a way, the list of radio signatures is not the complete set of in situ observed electrons, but only those of them with identified SF or/and CME.

The radio catalog can be accessed via the portal: <http://newserver.stil.bas.bg/SEPcatalog> which contains three catalogs (Fig. 3). After selecting the lowest box, a new sub-page is opened providing a description of the radio catalog (Fig. 4). Finally, the listings with radio signatures can be inspected after selecting one of the two boxes, depending on the SC, organized at the top of the page. Either time period contains the relevant information organized in a similar online table, see Fig. 5 for the preliminary version of the tables. Namely, the individual columns list the following: date of the ACE/EPAM electron event; onset time of the same SEE; SEE-related flare class, onset time and location; time of first occurrence, linear speed and angular width (AW) of the SEE-related CME; radio burst occurrences of types II, III and IV; peak RSTN flux (in solar flux units with a link to an overview plot at all eight RSTN single frequencies), peak frequency (in MHz); spectral index of the higher frequency branch; comment. All times are in UT. In the finalized stage of the catalog, the frequency coverage of the given radio burst type will be specified in terms of decimetric, metric, Decametric, Hectometric and/or kilometric range.

### Outlook

Both catalogs are currently under completion and will include also events during 2018 if any. The catalogs contents will be freely available after the publication of the scientific results.

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