STEREO/SEPT level 2 science data format specification and caveats

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1. Introduction

The Solar Electron and Proton Telescope (SEPT) is part of the Solar Energetic Particle (SEP) suite for the IMPACT investigation onboard STEREO (see Müller-Mellin et al, Space Science Reviews, 136: 363–389, 2008 for a detailed description). Each SEPT unit consists of two dual double-ended particle telescopes which measure electrons in the energy range from 30 to 425 keV and protons from 60 to 6500 keV. There are two separate SEPT units onboard each STEREO spacecraft: SEPT-E looking in the ecliptic plane along the Parker spiral magnetic field both towards and away from the Sun, and SEPT-NS looking perpendicular to the ecliptic plane towards North and South. The dual set-up refers to two adjacent sensor apertures for each of the four view directions: one for ions, one for electrons. The double-ended set-up refers to the detector stack with view cones in two opposite directions: one side (electron side) is covered by a thin foil; the other side (ion side) is surrounded by a magnet. The foil leaves the electron spectrum essentially unchanged but stops low energy ions. The magnet sweeps away electrons but lets ions pass.

SEPT units generate counting rates with 1min cadence and 32 energy bins for each viewing direction. Level 2 data files are produced regularly at the University of Kiel using the latest calibration data available and organized in daily files in ASCII format with different temporal averages (1 minute, 10 minutes, 1 hour and 1 day). The data files are publicly available in the following URL: http://www2.physik.uni-kiel.de/stereo/data/sept/level2/, typically with 3-4 months delay with respect to level 0 data (telemetry) reception on Ground. Level 2 data include several corrections not available for the level-1 CDF data files: differential non-linearity correction, energy-dependent electron geometric factors and efficiency corrections (particularly important for the sunward-pointing electron telescope onboard STEREO-A, which shows lower detection efficiency than the other telescopes). In addition, those channels not containing scientifically useful data have been removed. Level 2 data coverage starts on January 20, 2007.

2. Folder structure and file naming convention

The files corresponding to STEREO-A and STEREO-B are contained in the top-level folders “ahead” and “behind”. Inside these two folders there are subfolders corresponding to different time resolutions “1min”, “10min”, “1h” and “1d” (corresponding to 1 minute, 10 minute, 1 hour and 1 day time averages, respectively). The subsequent folder level corresponds to the year. The daily ASCII data files are contained inside these yearly subfolders and have the following naming convention:

sept_sssss_ppp_llll_yyyy_ddd_rrrrr_l2_v03.dat

(example with full path: /ahead/1d/2007/sept_ahead_ele_asun_2007_029_1d_l2_v03.dat)

sssss=spacecraft name ("ahead" for STEREO-A or "behind" for STEREO-B)

ppp=particle type ("ele" for electrons and "ion" for ions)

lll=sensor pointing direction ("sun", "asun", "north", "south", "omni")

yyyy=year (four digits)

ddd=day of year (three digits)

rrrrr=time averaging ("1min","10min","1h" or "1d")

l2=suffix indicating level 2 data

v03=suffix indicating the software version which generated the data

Additionally, there is a top-level folder named "cat", which contains yearly data files with 10 minute, 1 hour and 1-day resolutions. These files are generated concatenating the daily files (with the headers removed) and can be used to analyze long periods of data without the need of reading individual daily files.

It should be noted that the pointing directions labeled "sun", "asun", "north", and "south" correspond to the nominal spacecraft status, with the apertures pointing sunward and anti-sunward along the Parker spiral (45 degrees west from the Sun-s/c line) and northward and southward in perpendicular to the ecliptic. In addition to these four pointing direction, files with the suffix "omni" are included in the level 2 data. These files contain sector-averaged data (the result of adding asun, sun, north and south data-sets, divided by 4).

3. File contents

The daily files are in plain ASCII (text) format. The top part of the file contains a header describing the contents. The text lines corresponding to the header start with the number sign "#" (ASCII code 35). The detailed file contents for electrons and ions are shown in Tables 1 and 2. Tables 3 and 4 list the energy windows corresponding to the different energy bins for ions and electrons, respectively. The fields are separated by spaces (ASCII code 32).

4. Caveats

Spacecraft pointing

The spacecraft orientation is most of the time close to the nominal situation, with sun, asun, north and south SEPT apertures pointing as described in section 2, however this pointing can vary depending on spacecraft maneuvers. STEREO attitude and orbit data are available at the SEP suite website: http://www.srl.caltech.edu/STEREO/attorb.html.

Data gaps and bad data periods due to instrument reconfiguration or commanding

Bad or missing data intervals are filled with -9999.9 (float) or -9999 (integer). During the first years of the mission, some discriminator threshold changes were applied in order to reduce the noise in the low energy bins. For this reason, early data files can contain negative numbers (marking invalid data) affecting only the low energy bins of certain telescopes. For a more detailed description of the threshold changes and other commanding operations affecting SEPT sensors, see the level 1 data caveat file: http://stereo.ssl.berkeley.edu/SEPT_Caveat.pdf. Due to their lower efficiency, bins 02 and 03 should be handled with care and are not recommended for quantitative studies.

Table 1. Contents of SEPT level 2 ion data files

Item	Data type	Content
1	Double-precision float	Timestamp corresponding to the center of the accumulation interval, expressed as Julian date (Julian date 0.0 is Jan. 1, 4713 B.C. at 12:00:00)
2	Integer	Year
3	Float	Fractional day of year
4	Integer	Hour of day
5	Integer	Minute of hour
6	Integer	Second of minute
7 to 36	Float	Ion intensities for energy bins 02 to 31 given in $cm^{-2}\ s^{-1}\ sr^{-1}\ MeV^{-1}$
37 to 66	Float	Statistical uncertainties of ion intensities for energy bins 02 to 31, given in $cm^{-2}\ s^{-1}\ sr^{-1}\ MeV^{-1}$
67	Float	Accumulation time in seconds. Currently this does not include dead-time corrections

Table 2. Contents of SEPT level 2 electron data files

Item	Data type	Content
1	Double-precision float	Timestamp corresponding to the center of the accumulation interval, expressed as Julian date (Julian date 0.0 is Jan. 1, 4713 B.C. at 12:00:00)
2	Integer	Year
3	Float	Fractional day of year
4	Integer	Hour of day
5	Integer	Minute of hour
6	Integer	Second of minute
7 to 21	Float	Electron intensities for energy bins 02 to 16 given in $cm^{-2}\ s^{-1}\ sr^{-1}\ MeV^{-1}$
22 to 36	Float	Statistical uncertainties of electron intensities for energy bins 02 to 16, given in $cm^{-2}\ s^{-1}\ sr^{-1}\ MeV^{-1}$
37	Float	Accumulation time in seconds. Currently this does not include dead-time corrections

Ion contamination of the electron channels

SEPT electron telescopes are covered by a thin foil which leaves the electron spectrum essentially unchanged but stops protons of energy up to ~400 keV. Ions with energies above this limit can cross the foil and stop inside the top silicon detector, being registered as electrons by the sensor. For this reason, SEPT electron measurements are subject to proton (ion) contamination during periods where there is a significant enhancement of the ion fluxes above 400 keV. This can happen e.g. during some interplanetary shock transits, as shown in Figure 1. The easiest way to identify periods dominated by ion contamination is the comparison of the electron time profiles with the ion rates corresponding to energies above 400 keV (bin number >15): a close one-to-one correlation of the fluctuations shown by both measurements during ion-enhanced periods is normally an indication of strong contamination of the electron measurement. At present, there is no correction available for this effect and electron data during these periods should not be used for scientific analysis.

Table 3. SEPT ion energy bins included in level 2 data

Bin number	**Emin (keV)**	**Emax (keV)**
02	84.1	92.7
03	92.7	101.3
04	101.3	110.0
05	110.0	118.6
06	118.6	137.0
07	137.0	155.8
08	155.8	174.6
09	174.6	192.6
10	192.6	219.5
11	219.5	246.4
12	246.4	273.4
13	273.4	312.0
14	312.0	350.7
15	350.7	389.5
16	389.5	438.1
17	438.1	496.4
18	496.4	554.8
19	554.8	622.9
20	622.9	700.7
21	700.7	788.3
22	788.3	875.8
23	875.8	982.8
24	982.8	1111.9
25	1111.9	1250.8
26	1250.8	1399.7
27	1399.7	1578.4
28	1578.4	1767.0
29	1767.0	1985.3
30	1985.3	2223.6
31	2223.6	6500.

Table 4. SEPT electron energy bins included in level 2 data

Bin number	Emin (keV)	Emax (keV)
02	45	55
03	55	65
04	65	75
05	75	85
06	85	105
07	105	125
08	125	145
09	145	165
10	165	195
11	195	225
12	225	255
13	255	295
14	295	335
15	335	375
16	375	425

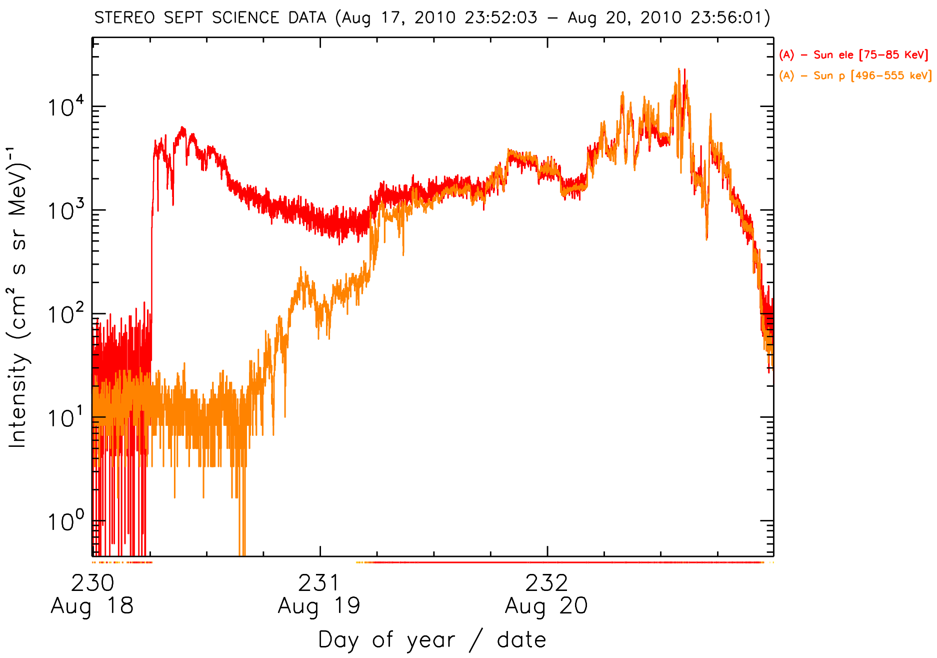

Figure 1. Example of 75-85 keV electron (red line) and 496-555 keV ion (orange line) measurements by SEPT-sunward pointing telescopes onboard STEREO-A during a Solar Energetic Particle (SEP) event in August 2010. The early data show clean electron measurements, while the late data (starting on August 19) are dominated by ion contamination due to the high ion fluxes associated to an interplanetary shock transit on August 20 at 16:13 UT.

Electron/high energy particles contamination of the ion channels

SEPT ion telescope apertures are surrounded by a permanent magnet that sweeps away low energy electrons. High energy electrons can cross the magnet without being completely deflected and produce signal in the front silicon detector. In most cases, these electrons are energetic enough to completely cross the detector, producing signal also in the second detector, being rejected by the anticoincidence system. However, a small number of such electrons can be scattered out of the sensor without triggering the anticoincidence, and mimicking an ion signal. High-energy particles crossing the housing and entering at high angles through the small gap between both silicon detectors can produce similar effect. Most of the times this kind of contamination remains at undetectable levels, however if the electron flux is enhanced by several orders of magnitude during a period with no ion enhancement (e.g. during the onset of very large SEP events) it can produce a significant effect as shown in Figure 2.

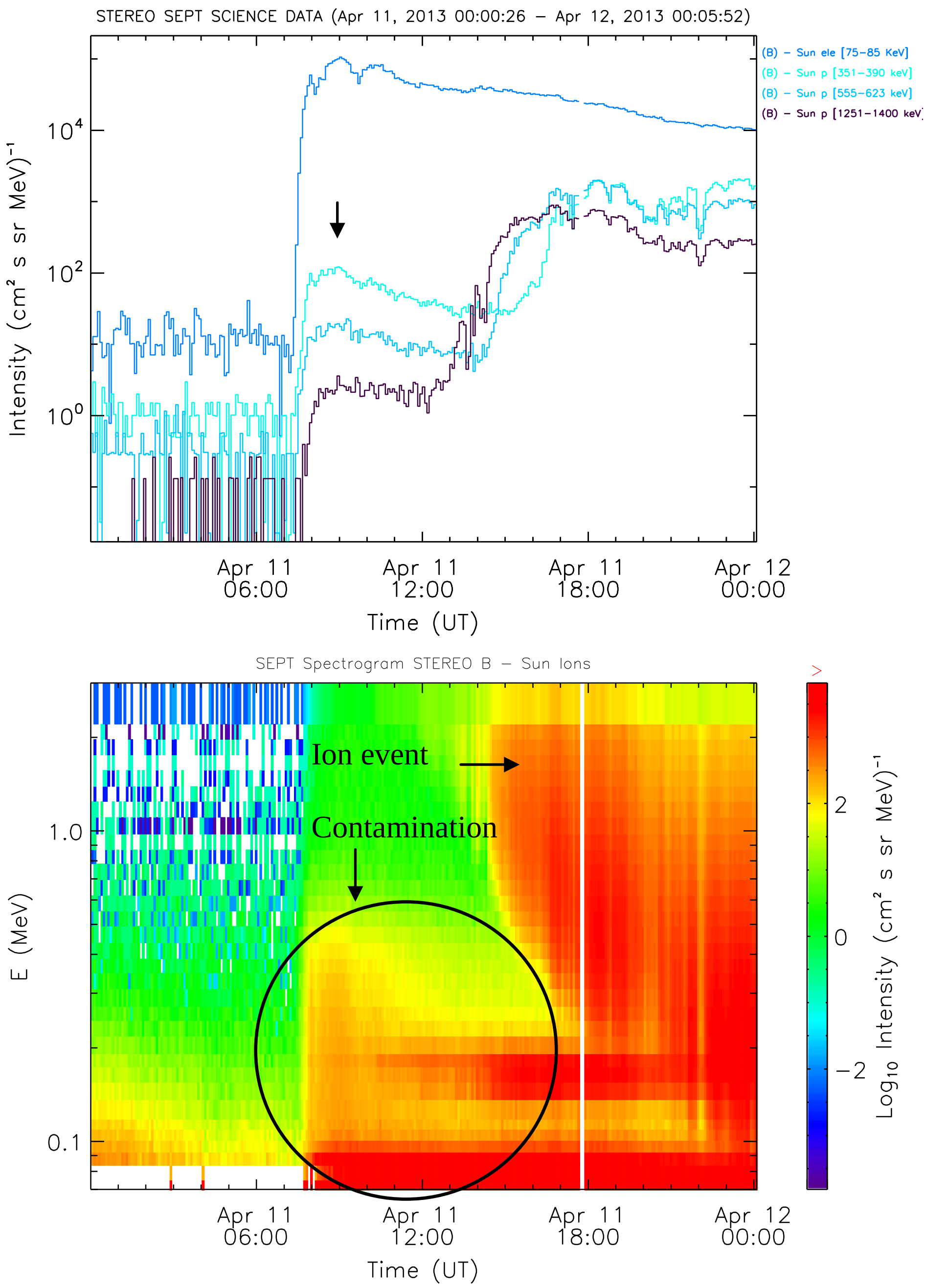

Figure 2. Top panel: example of ion and electron measurements during a SEP event on April 2013. Ion measurements during the early phase of the event, in coincidence with an electron increase over four orders of magnitude, are affected by electron contamination (marked by an arrow). The actual ion increase corresponding to this event is observed later, and shows velocity dispersion. The contamination is better recognized in the dynamic spectrum shown in the bottom panel.

Transient disturbances in the low energy ion bins

Ions above 2.2 MeV produce large pulses which are counted in the last energy bin of SEPT. A pulse-height overflow can cause extra-trigger of lower energy bins because the analog electronics is not reset fast enough. Due to this limitation in the electronics, SEPT low energy measurements can be occasionally disturbed when large pulses become dominant. This effect is easy to recognize as narrow horizontal “strips” in the low energy part of the ion dynamic spectrum (<350 keV). All SEPT telescopes are affected by this issue, however the effect is only important during periods showing a flat energy spectrum (reduced rate at low energies) accompanied by an ion increase above 2.2 MeV, for instance during the early phase of a SEP event showing velocity dispersion and a significant ion rate above 2.2 MeV. An example of period strongly affected by this effect is shown in Figure 3.

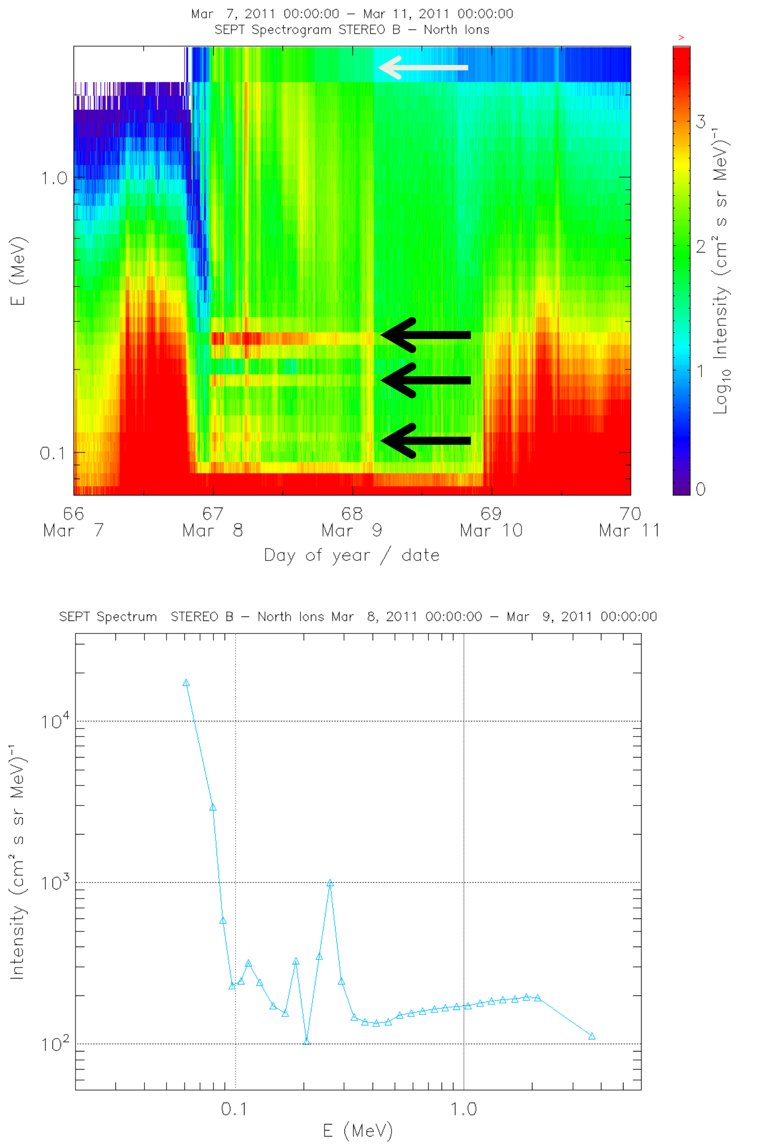

Figure 3. Example of a period with disturbed low-energy ion measurements. The top panel shows the spectrogram and the bottom panel the energy spectrum during March 8, 2011. Note the increase in the last energy bin (white arrow) accompanied by a pattern of narrow strips in certain low energy bins (black arrows).

For additional information and data products visit http://www2.physik.uni-kiel.de/stereo/