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GEOTAIL Spacecraft Mission
Energetic Particles and Ion Composition (EPIC)
Instrument and Data Analysis Caveats

Version 4.02

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Abstract

This document lists and describes caveats for the GEOTAIL/EPIC instrument and the use of its data.

Contents

1 Introduction

In using and analyzing Geotail/EPIC data, it is important to be aware of characteristics and behaviors of the instrument and the Ion Composition Subsystem (ICS) and Supra-Thermal Ion Composition Subsystem (STICS) sensor subsystems. The following is a summary of caveats. Each of these items is further expanded within this document.

1. **ICS and STICS comparison** — While having much in common, ICS and STICS have key differences in design and operation.

2. **Automatic shifts in ICS energy pass band** — Each ICS ion telescope head is equipped with automatic independently rotating cover that helps prevent instrument saturation but causes shifts in the energy pass band of the ion measurements.

3. **Non-standard STICS DV Stepping** — During a 15-month period starting in November 2005, the stepping of the STICS deflection voltages (DV) was operated with higher energy resolution of 32 steps rather than the normal 8 steps.

4. **ICS and STICS calibration intervals** — Periodically during the mission, the ICS and STICS subsystems were switched to a calibration mode during which time science measurements were suspended.

5. **ICS Electron Detector measurement contamination** — ICS Electron Detector measurements are contaminated by high-energy ions and X-rays.

2 Caveats

2.1 *ICS and STICS comparison*

The EPIC instrument is composed of the two separate science subsystems, ICS and STICS, and a Data Processing Unit (DPU), which sends commands to and receives data from the two subsystems. Both ICS and STICS divide each Geotail spin, nominally lasting 3 seconds, into 16 equal azimuthal sectors and each performs a complete measurement cycle, called a Science Record, every 32 sequential spins. ICS and STICS nonetheless differ in design and operation as listed in the following; for details, consult "GEOTAIL EPIC Ground-Based Data Conversions and Corrections."

- **Channels:**
  - ICS electrons: 2 channels
  - ICS ions: over 51 rate counts channels for protons, helium, CNO, Z>26 ions, and all ions
    Pulse Height Analysis (PHA) events channel with up to 48 events per spin
  - STICS ions: over 38 rate counts channels for ions with a variety of charge states
    Pulse Height Analysis (PHA) events channel with up to 48 events per spin
- **Energy pass bands**:
  - ICS electron channels, ED1 and ED2, have separate fixed energy pass bands which have a minimum limit but no upper limit – i.e., the energy pass bands are open ended. The ED1 minimum limit was redefined from 34 to 38 keV on 8 March 1993.
  - ICS ion channels have two energy pass bands - a low and a high range. Each range is closed and has a minimum and maximum limit that depends on the ICS ion channel. ICS generally uses the low energy pass band except in periods of high particle flux. The transition between the low and high range is triggered automatically and occurs simultaneously for all ICS ion channels at 32-spin Science Record boundaries. The ion sensor heads transition independently of each other.
  - STICS ion channels have 32 energy pass bands that all STICS ion channels simultaneously steps through with each spin over either an 8- (usually) or a 32-spin sequence (from late 2005 to early 2007 - see section 3 for details on the stepping sequences).
- **Sensor head summing**:
  - ICS has one electron sensor head and two ion sensor heads, and the DPU accumulates counts separately for each ion head.
  - STICS has 6 ion sensor heads and, depending on the STICS particle channel, the DPU accumulates counts separately for each head, combines (i.e., sums) counts over three two-head pairs, or combines counts across all 6 heads.
- **Sector summing**:
  - For all but one ICS particle channel, the DPU accumulates counts separately for each sector (counts are combined over 8 two-sector pairs for the ED1 electron channel).
  - Depending on the STICS particle channel, the DPU accumulates counts separately for each sector, combines counts over 8 two-sector pairs, or combines counts across all 16 sectors.

- **Spin summing**:
  - Depending on the ICS particle channel, the DPU accumulates counts over each spin or combines counts over two, 16 or 32 successive spins.
  - The DPU accumulates counts over each spin for all STICS particle channels.

From launch to the present, the ICS and STICS configurations for head, sector and spin summing have not changed.

The following table is a summary of these and other characteristics

Table 1 – EPIC Characteristics

	ICS		STICS
	Electrons	**Ions**	**Ions**
Rate channel energy pass band	Open ended: E_L to infinity	Closed ended: E_L to E_H	Closed ended: E_L to E_H
Energy Range	>30 keV to infinity >100 keV to infinity	>30 keV to 3 MeV	10 to 230 keV/e (M/Q) 30 to 230 keV/e (M & M/Q)
Resolution:		Resolves all major ion species.	Resolves all major ion species, charge states of major ion species.
Processed flux data	Integral flux as $[cm^2\text{-}s\text{-}sr]^{-1}$	Differential flux as $[cm^2\text{-}s\text{-}sr\text{-}keV]^{-1}$	Differential flux as $[cm^2\text{-}s\text{-}sr\text{-}keV/e]^{-1}$
Azimuthal sector resolution	8 or 16	16	1, 8 or 16
Polar heads resolution	1	2	1, 3 or 6
Spins summed	1 or 16	2, 16 or 32	1

Figure 1 – EPIC Sensor Head Elevation Angle Values

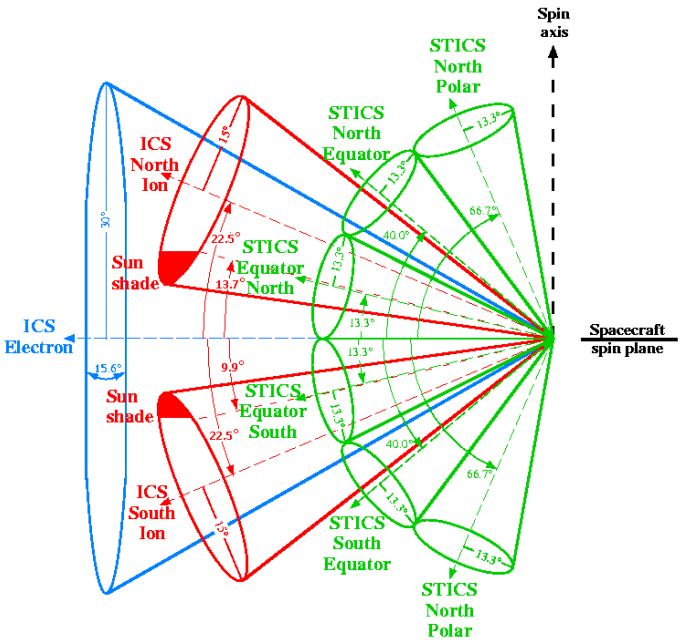
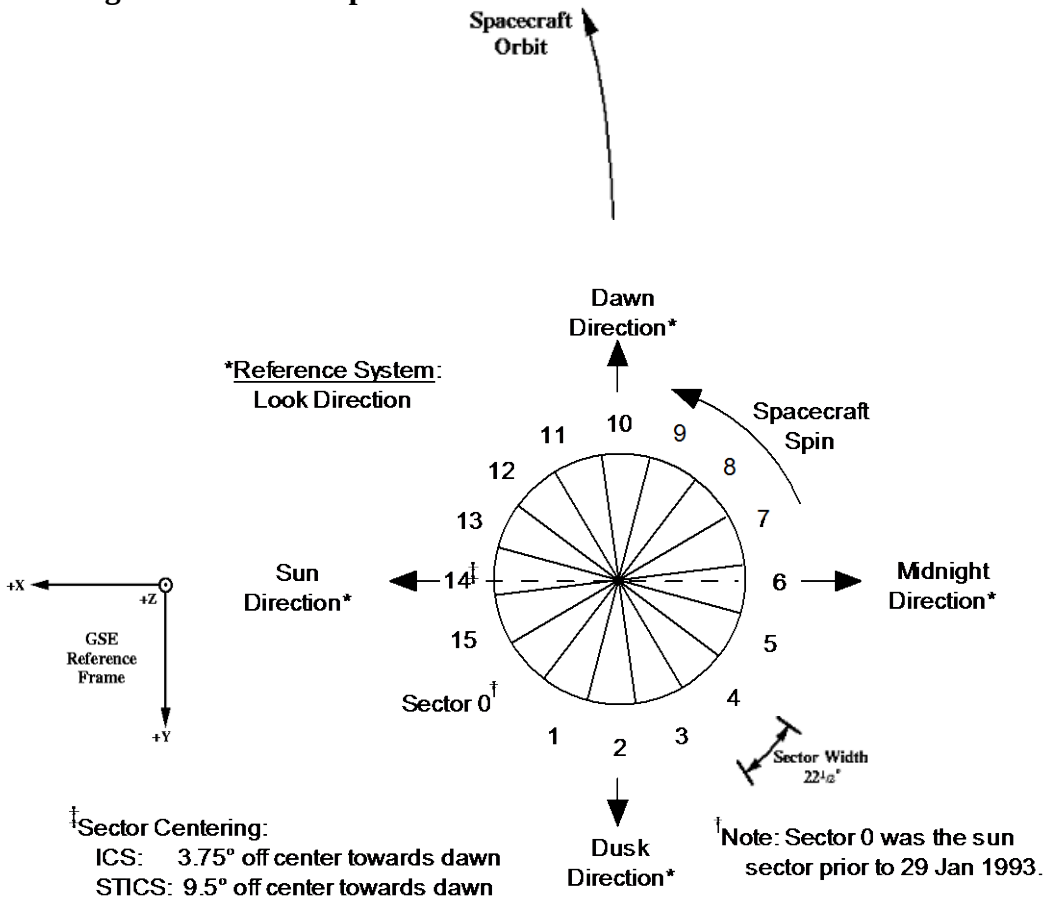


Figure 2 – Geotail Spacecraft and EPIC Azimuth Sector Geometries



2.2 *Automatic shifts in the ICS energy pass band*

ICS ion channels have two energy pass bands - a low and a high range. Both ranges are closed (i.e., have a minimum and maximum energy limit which are fixed) that depend on the ICS ion channel. In normal science operations, ICS operates in the low-energy range. Transitions to the high-energy range are triggered automatically in periods of high particle flux to keep the sensor from saturating, and ICS returns to the low-energy range automatically after particle flux levels decrease below a threshold. These changes occur independently for the two sensor heads and occur simultaneously for all ICS ion channels of a sensor head. They are delayed to occur at a 32-spin EPIC Science Record boundary.

These shifts in the energy pass band are achieved through the use of a four-position filter-wheel-like assembly that covers the aperture openings of the telescope leading to each of the two ICS ion sensor heads. The four positions and associated configurations are as follows:

- open: the aperture opening is unobstructed (low energy-pass-band range)
- foil: a thin metal foil covers the aperture opening (high energy-pass-band range)
- foil plus 10% grid: a thin metal foil plus a metal grid, with 10% of the area as holes, covers the aperture opening (high energy-pass-band range plus reduced geometry)
- calibration: a metal plate with calibration source covers the aperture opening (this also serves as the sensor cover)

When a wheel assembly is in either the foil position or foil-plus-10%-grid position, ions passing through the thin metal foil lose energy before reaching the sensor for measurement. The net effect of either foil position is to measure a particle population of higher than usual energies.

In the following table are given the minimum and maximum limits of the low and high energy pass bands.

Table 2 - ICS Channel Energy Pass Band Values

ICS Channel Name	ICS Channel Energy Pass Band			
	Open Aperture Position (North and South Heads)		Foil and Foil + 10% Grid Aperture Positions (North and South Heads)	
	Minimum [keV]	Maximum [keV]	Minimum [keV]	Maximum [keV]
E1 ions	45.9	52.7	75.6	83.4
E2 ions	52.7	61.5	83.4	93.3
E3 ions	61.5	73.7	93.3	106.8
E4 ions	73.7	89.3	106.8	123.5
E5 ions	89.3	110.2	123.5	145.2
E6 ions	110.2	137.4	145.2	172.5
E7 ions	137.4	173.1	172.5	207.3
E8 ions	173.1	220.0	207.3	251.6
E9 ions	220.0	281.5	251.6	309
E10 ions	281.5	362.9	309	385.8
E11 ions	362.9	471.4	385.8	490.9
E12 ions	471.4	615.9	490.9	634.4
E13 ions	615.9	913.2	634.4	929.6

ICS Channel Name		ICS Channel Energy Pass Band			
		Open Aperture Position (North and South Heads)		Foil and Foil + 10% Grid Aperture Positions (North and South Heads)	
		Minimum [keV]	Maximum [keV]	Minimum [keV]	Maximum [keV]
E14	ions	913.2	1352.3	929.6	1361
E15	ions	1352.3	2013.9	1361	2024.3
E16	ions	2013.9	3005.4	2024.3	3003.8
P1	p+	45.9	58.1	75.6	89.5
P2	p+	58.1	77.3	89.5	110.7
P3	p+	77.3	107.4	110.7	142.4
P4	p+	107.4	154.3	142.4	189.2
P5	p+	154.3	227.5	189.2	258.6
P6	p+	227.5	341.6	258.6	365.5
P7	p+	341.6	522.5	365.5	541.3
P8	p+	522.5	813.5	541.3	831.4
P9	p+	813.5	1560.8	831.4	1570.6
P10	p+	1560.8	3005.4	1570.6	3003.8
HE1	He	53.4	70.0	122.6	142.5
HE2	He	70.0	95.8	142.5	172.9
HE3	He	95.8	135.0	172.9	218.5
HE4	He	135.0	194.0	218.5	285.1
HE5	He	194.0	280.8	285.1	380.1
HE6	He	280.8	407.4	380.1	513.3
HE7	He	407.4	595.5	513.3	704.7
HE8	He	595.5	888.7	704.7	993.9
HE9	He	888.7	1631.4	993.9	1715.4
HE10	He	1631.4	3052.9	1715.4	3127.4
M1	CNO	165.4	186.5	377.7	405.9
M2	CNO	186.5	221.4	405.9	451.9
M3	CNO	221.4	275.2	451.9	521.1
M4	CNO	275.2	360.2	521.1	627.1
M5	CNO	360.2	493.5	627.1	788.3
M6	CNO	493.5	697.2	788.3	1029.3
M7	CNO	697.2	1016.2	1029.3	1399.4
M8	CNO	1016.2	1522.0	1399.4	1960.6
M9	CNO	1522.0	2315.7	1960.6	2820.8
M10	CNO	2315.7	3565.3	2820.8	4119.8
H1	Z>20	395.0	619.0	1061.7	1226.3
H2	Z>20	619.0	838.0	1226.3	1407.7
H3	Z>20	838.0	1202.0	1407.7	1757.3
H4	Z>20	1202.0	1772.0	1757.3	2398.3
H5	Z>20	1772.0	2728.0	2398.3	3454.7
H6	Z>20	2728.0	4405.0	3454.7	5281.6

2.3 *Non-standard STICS DV Stepping – 2005/325 - 2007/057*

A deflection voltage determines the energy pass band measured by the STICS sensor. This voltage is changed once with every spin of the spacecraft, which nominally has a three-second period. Given in Table 3 is the stepping sequence of 8 deflection voltages (DV) used in the normal mode of operation. This sequence repeated roughly every 24 seconds. During the period of 2005/325 02:12 UTC through 2007/057 17:13, STICS operated using a finer stepping sequence of 32 deflection voltages that is shown in Table 4. This sequence repeated roughly every 96 seconds.

Table 3 - STICS DV Values, Normal Mode

DV Step #	Energy Bands [keV/e]		
	E/Q Low	E/Q Mid	E/Q High
30	209.65	212.14	214.60
26	134.27	135.87	137.47
22	86.00	87.02	88.04
18	55.09	55.74	56.39
14	35.28	35.70	36.12
10	22.59	22.86	23.13
6	14.47	14.64	14.81
2	9.27	9.38	9.49

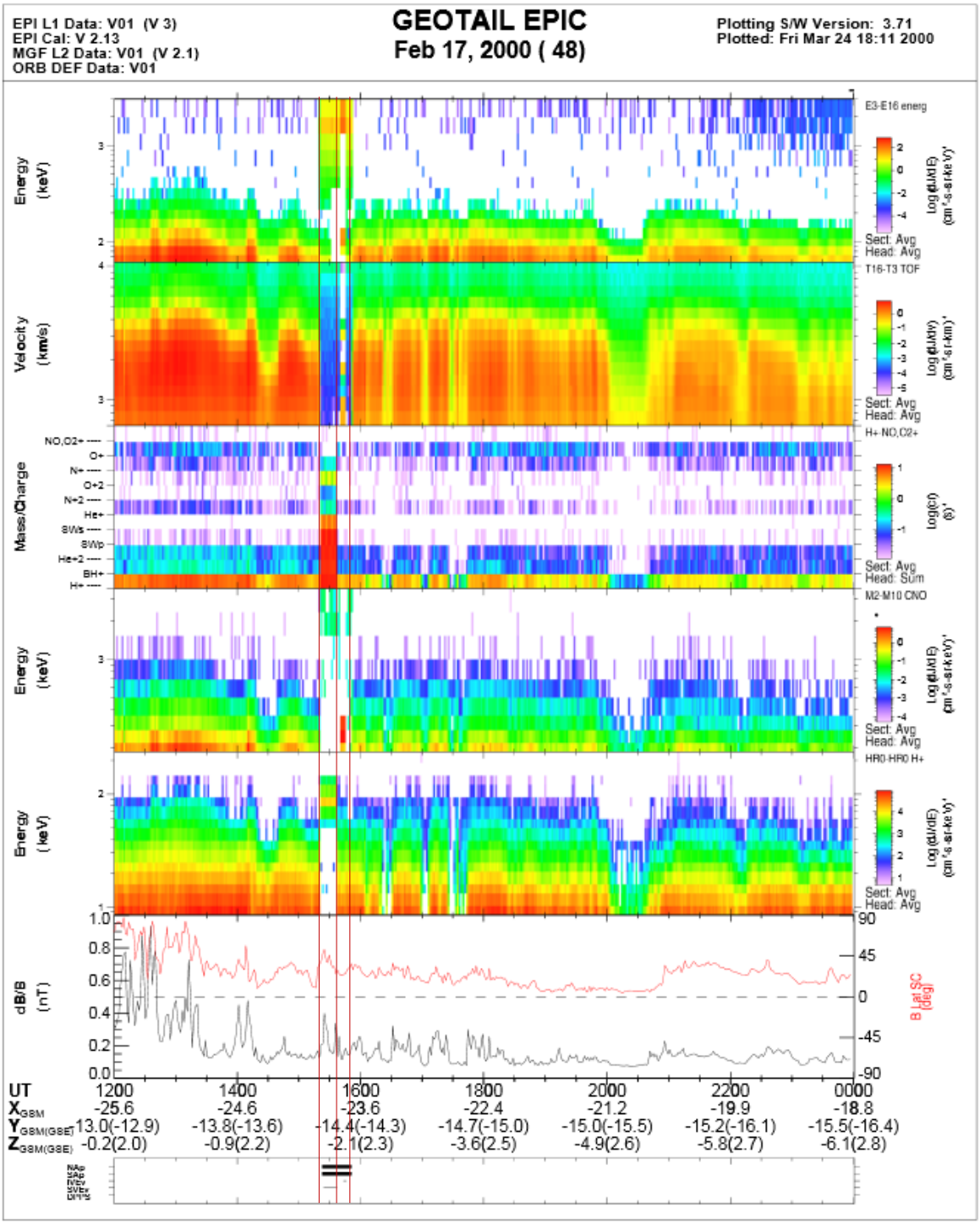
Table 4 - STICS DV Values, alternate mode

2005/325 02:12 through 2007/057 17:13 UT

DV Step #	Energy Bands [keV/e]		
	E/Q Low	E/Q Mid	E/Q High
31	234.35	237.14	239.90
30	209.65	212.14	214.60
29	187.55	189.78	192.00
28	167.79	169.78	171.70
27	150.10	151.88	153.66
26	134.27	135.87	137.47
25	120.12	121.55	122.98
24	107.46	108.74	110.02
23	96.14	97.28	98.42
22	86.00	87.02	88.04
21	76.94	77.85	78.76
20	68.83	69.65	70.47
19	61.58	62.31	63.04
18	55.09	55.74	56.39
17	49.27	49.86	50.45
16	44.09	44.61	45.13
15	39.44	39.91	40.38
14	35.28	35.70	36.12
13	31.56	31.94	32.32
12	28.23	28.57	28.91
11	25.26	25.56	25.86
10	22.59	22.86	23.13
9	20.21	20.45	20.69
8	18.08	18.30	18.52
7	16.18	16.37	16.56
6	14.47	14.64	14.81
5	12.95	13.10	13.25
4	11.58	11.72	11.86
3	10.36	10.48	10.60
2	9.27	9.38	9.49
1	8.29	8.39	8.49
0	7.42	7.51	7.60

2.4 *ICS and STICS calibration intervals*

Science data collection by the ICS and STICS sensors was occasionally interrupted by calibration cycles of the sensors and when the instrument is powered on. The following figure illustrates a calibration period on 2000/048.



The following is a partial list of calibration intervals:

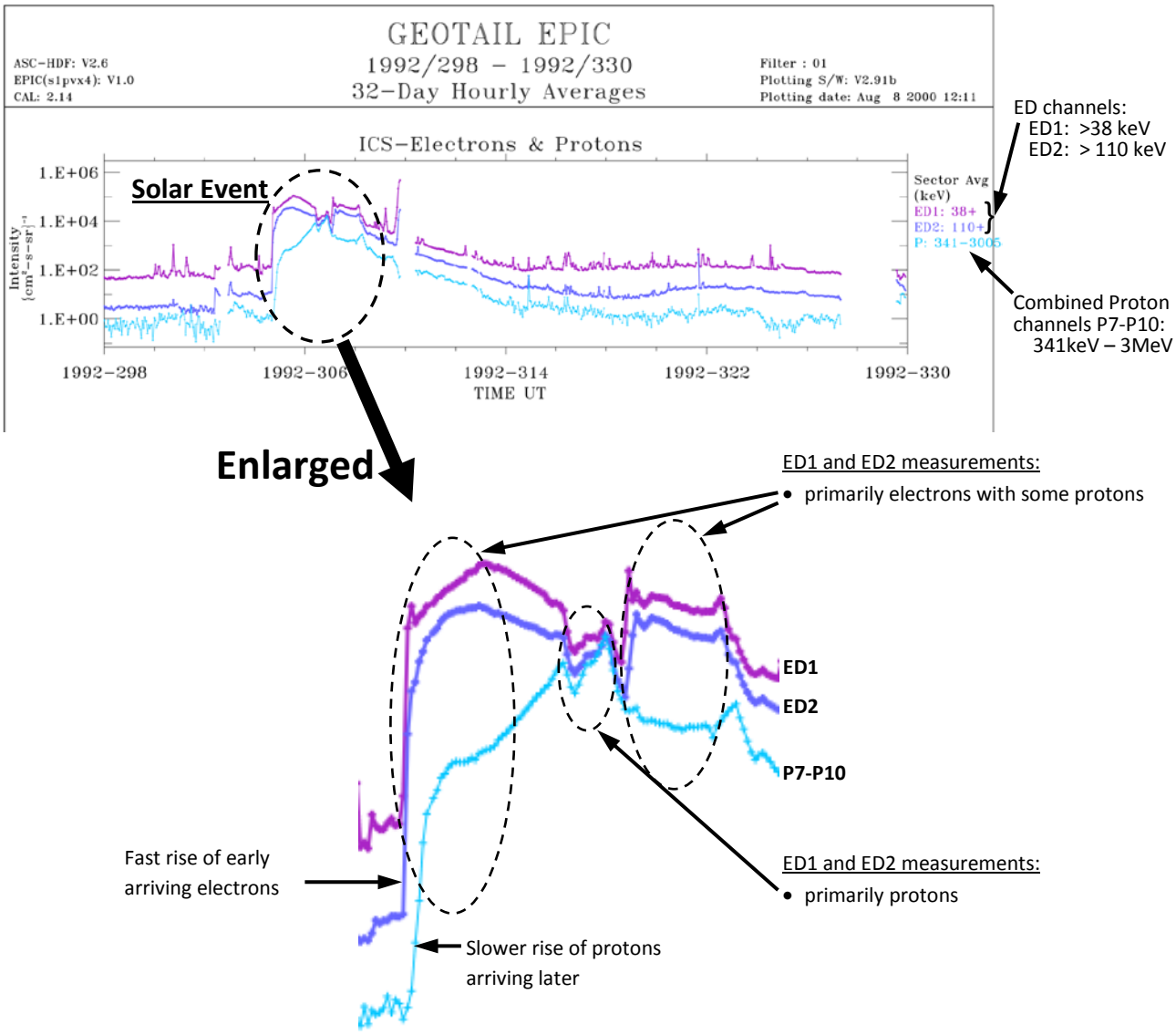
Start YY-DOY	Start TIME (UT	Start YY-DOY	Start TIME (UT
92-274	~13:50-15:53	93-321	15:00-15:41
92-275	~12:12-13:25	93-356	16:22-19:10
92-291	23:34-24:00	94-040	12:37-13:13
92-292	00:00-02:54	94-076	13:03-13:43
92-310	12:03-12:36	94-101	12:05-12:43
92-321	15:44-16:26	94-136	13:57-14:30
92-329	18:04-18:15	94-173	15:44-16:34
92-330	15:13-16:29	94-238	11:03-11:36
92-337	14:35-16:32	94-272	12:04-12:43
92-343	14:10-15:32	95-020	13:10-13:43
92-352	13:56-14:44	95-159	~13:17-13:42
92-358	15:53-16:42	95-198	19:02-19:49
92-364	15:24-16:18	95-251	15:01-15:35
93-008	14:56-15:41	95-326	13:05-13:43
93-013	10:17-10:58	96-074	12:54-13:34
93-025	13:25-14:22	96-097	11:04-13:34
93-047	13:49-14:28	96-145	11:03-11:42
93-102	06:38-07:11	96-271	~17:40-18:20
93-106	12:06-12:40	97-044	~12:40-13:05
93-132	10:08-10:41	97-051	~13:10-14:05
93-152	13:30-14:03	97-157	~11:40-12:35
93-172	13:39-14:19	98-103	12:07-12:54
93-193	14:31-15:04	98-320	18:07-19:12
93-218	16:39-17:14	99-201	13:05-13:47
93-274	10:06-11:45	99-321	~12:05-12:55
93-294	15:06-15:41	00-048	15:19-15:52

2.5 *ICS Electron Detector measurement contamination*

The rate counts measurements accumulated by the ICS electron detector can be contaminated by two sources: high energy ions and X-rays.

1) Contamination by ions: The electron detector is equipped with a 28,000 Å aluminum foil in front of its solid state detector that stops ions with energies less than 300 keV. Ions with energies greater than ~300 keV penetrate the foil and will be falsely measured as electrons.

This is illlustrated in the following plot which gives the integral intensities of the two electron detector channels ED1 and ED2 with energy measurement minimums starting at 38 and 110 keV, respective, and the proton channels P7 through P10 with a combined energy bandwidth of 341 to 3005 keV.



2) Contamination by X-rays: The sunward looking sector of the ICS Electron Detector is susceptible to contamination by X-ray from strong solar events as illustrated in the following anisotropy plot:

Sunward look-direction sector