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GEOTAIL Spacecraft Mission
EPIC/STICS Pulse Height Analysis (PHA) Data Product

File content, format and naming convention

Version 2.1

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Abstract

This document lists and describes the file content, format and naming convention for the GEOTAIL/EPIC/STICS Pulse Height Analysis (PHA) data product.

References

For additional information on STICS PHA measurements, consult the following references (Please note: nomenclature for some aspects of the instrument may differ in these various references):

Schlemm et al., 1990, EPIC Software Requirements and Data Definition Document for the ISTP Geotail Spacecraft, JHU/APL;

Schlemm et al., 1993, EPIC Instrument User's Guide, JHU/APL;

Nylund et al., 2016, Geotail Spacecraft Mission EPIC Ground-Based Data Conversions and Corrections, JHU/APL.

Williams et al., GEOTAIL energetic particles and ion composition instrument, ***J. Geomag. Geoelect., 46***, 39-57, 1994, doi:10.5636/jgg.46.39..

EPIC/STICS Pules Height Analysis Data Product

PHA Event Data Description and Their Relation to Counting Rates

The STICS instrument provides three-dimensional (3D) measurements of composition and flux levels for ion species and charge states from H^+ through $Fe^{+1:+18}$ using electrostatic deflection followed by time-of-flight and energy-deposit measurements at sixteen spin sectors and six polar elevation angles relative to the spacecraft spin axis (Figures 1 and 2). STICS's electronics sends event-words data to the EPIC Data Processing Unit, DPU, which include information about the energy, the time-of-flight and flight direction of ions measured as counting rate events. Pulse Height Analysis, PHA, events are a selected sample of those event words.

At each electrostatic deflection system voltage step, ions of mass, M, charge, Q, and energy-per-charge, E/Q, are guided to pass through a carbon foil. Ions not scattered widely in the carbon foil strike one of the solid state detectors, SSD. Each ion passing through the carbon foil releases a cloud of “start” electrons which are quickly guided to one of the six Start microchannel plate, MCP, sections. Each ion striking a SSD after traveling a known distance D releases a cloud of “stop” electrons which are guided to one of the three Stop MCPs. The timing difference between Start and Stop signals is recorded as the ion’s measured time of flight, TOF. The DPU uses D, E/Q, and the ion’s TOF to determine the ion’s mass-per-charge, MPQ. For ions without sufficient energy deposit, E_m, measured above the SSD’s electronic threshold, an energy deposit measurement is not recorded; and the DPU classifies this event with only a non-zero MPQ as a “Double” (i.e., “two measurement” or, synonymously termed, “zero mass”) PHA event. Ions that produce a SSD energy measurement $E_m > 0$ are called “Triple” (i.e., “three measurement”) PHA events. The E/Q, D, TOF, and E_m combination allow a DPU determination of the ion’s mass, called MASS. So, Doubles have only a MPQ determination, whereas Triples have both MPQ and MASS determinations.

The DPU classifies each ion event into a mass-per-charge class and a mass class by table lookup. This allows ion event assignment to respective basic and science rate registers associated with the Basic and Matrix Rates according to the rectangular areas defined in Table 1 and shown in Figure 3. The rectangular areas are often also referred as boxes. The Basic Rates measure all ion data, whereas Matrix Rates measure a subset of the ion species and charge states measured. Several BR and MR rate channels are composed of combinations of Doubles and Triples events depending on the deflection system energy step, in which higher percentages of Doubles and Triples are likely at lower and higher energies, respectively.

The DPU transmits up to 47 STICS PHA events per 3-second spacecraft spin. If more than 47 PHA events occur per spin, the DPU attempts to distribute PHA sampling throughout all 16 equatorial sectors (Figure 1) and all three PHA basic ranges within its MASS vs. MPQ matrix (Figure 3). PHA events are essential for (a) collecting and calculating ion fluxes for species other than the several assigned matrix rate groups and (b) monitoring and correcting for environmental, telemetry error, and/or instrumental backgrounds. All types of backgrounds can exist in the data stream throughout the mission. Furthermore, all Doubles and Triples PHAs, including backgrounds, are needed for accurate flux calculation for any species or charge state without a box assignment outside the few predetermined species and charge state boxes. Of the ion species and charge states from H^+ through Fe^{+16} in Earth’s magnetosphere shown in the sample graphical matrix of STICS PHA data in Figure 4, many do not have assigned matrix boxes (see Figure 3).

Figure 1 – Geotail Spacecraft and EPIC Sensor Azimuthal Geometries

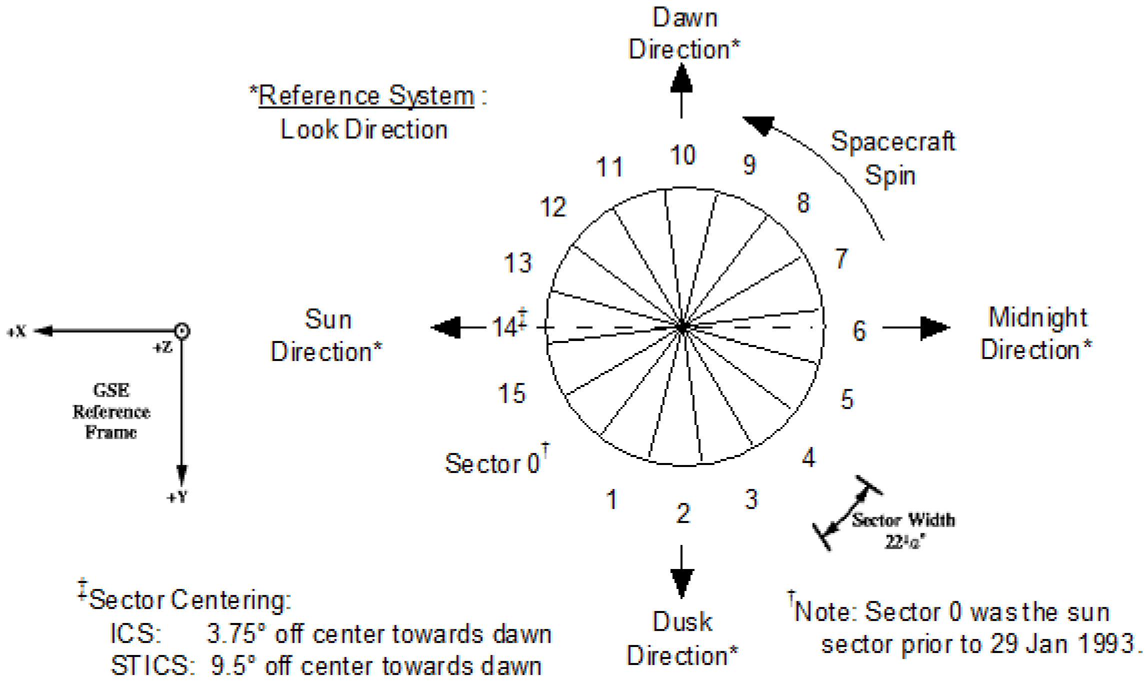
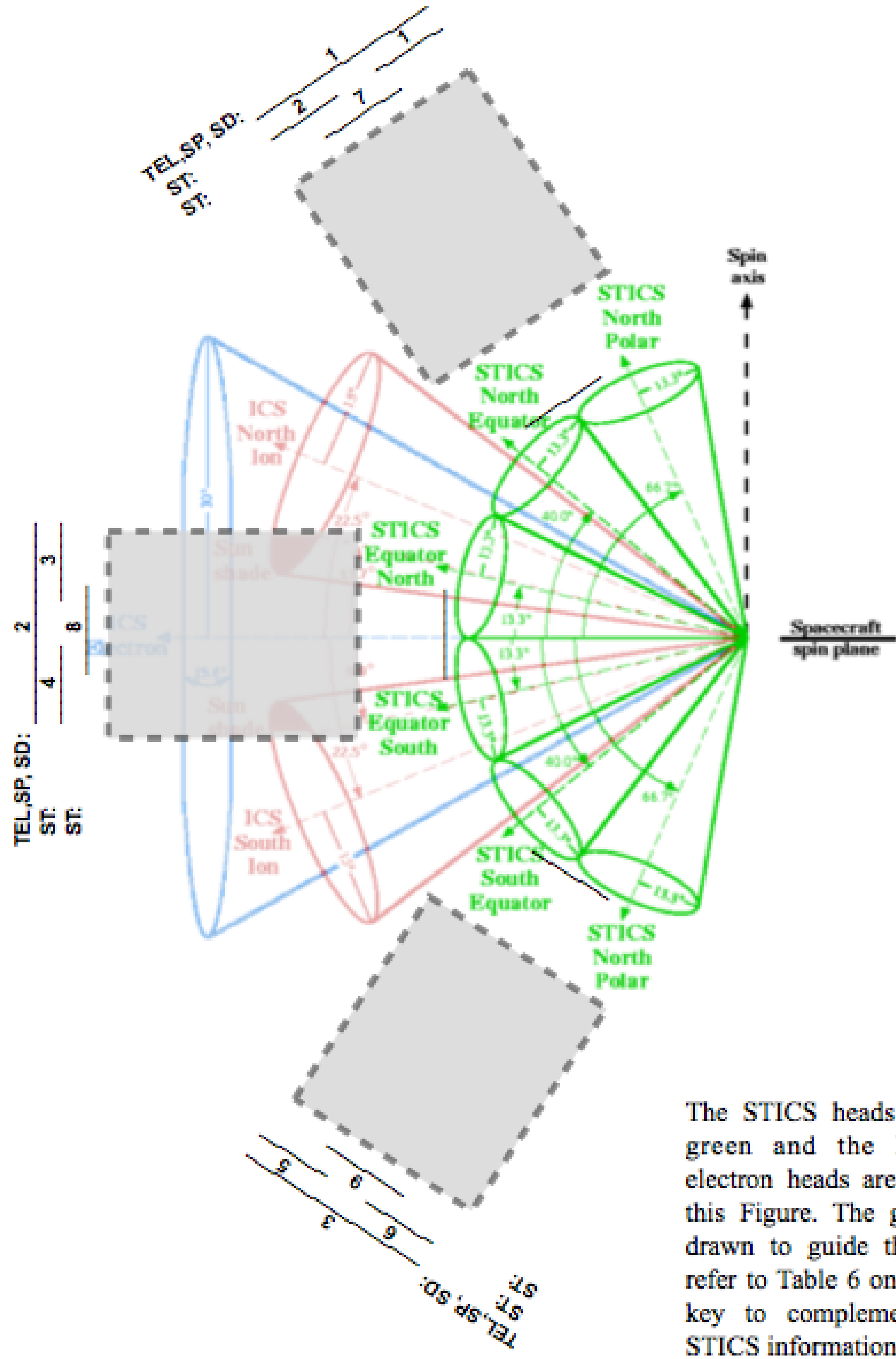


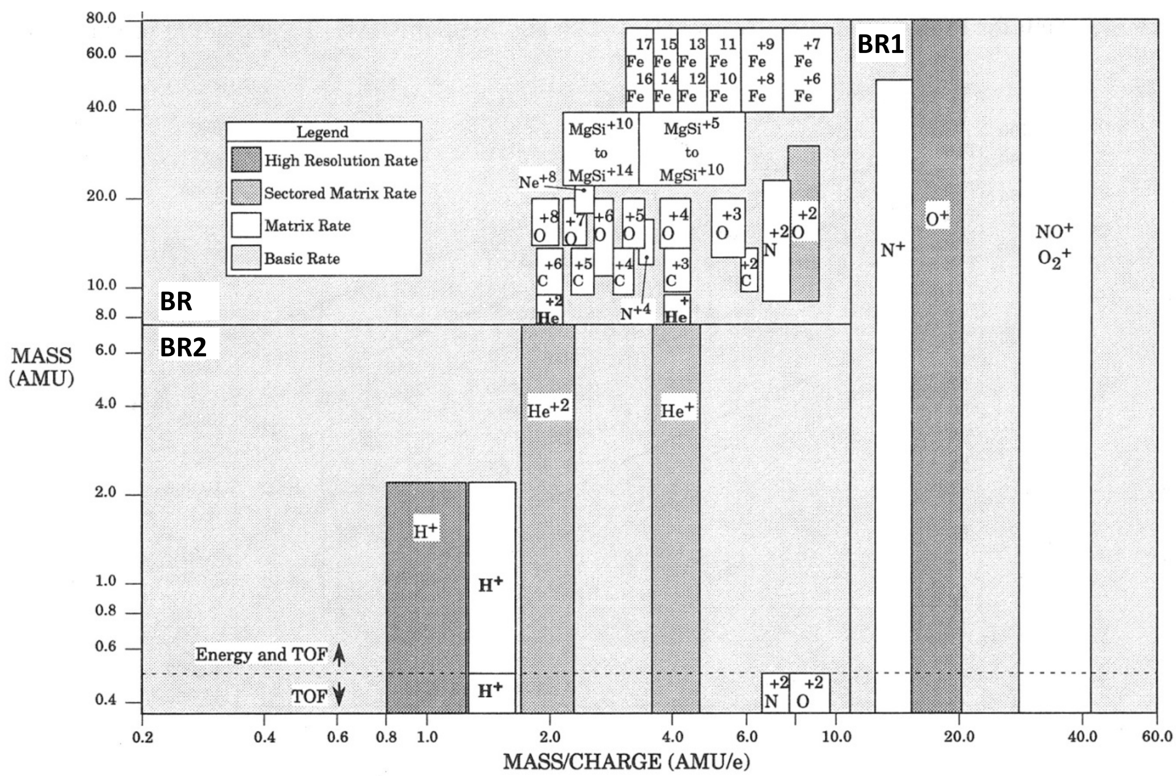
Figure 2 – EPIC Sensor Polar Angles and STICS Telescope Definitions



The STICS heads are shown in green and the ICS ion and electron heads are suppressed in this Figure. The gray boxes are drawn to guide the eye. Please refer to Table 6 on page 4 for the key to complementary detailed STICS information.

Figure 3 – STICS Mass - Mass per charge Matrix and the 3 BR Sampling Ranges

STICS rate channel coverage in mass and mass/charge matrix is divided into three Basic Rates (BR) regions, which correspond to the three PHA sampling ranges.



PHA Data Product

The STICS PHA data are stored in ASCII (plain text), space-delimited, fixed-column format files. The day-long data files are named in the following form:

epic_stics_pha_*yyyyddd*.txt,

where *yyyy* is the year and *ddd* is the day of year of observation. Files do not exist for days without any data.

Each PHA data file starts with this line of titles for the 17 parameters on each line:

```
YYYY DOY HH MM SS.S EDB DV SE ID SD  ECH  TCH ST SP  R    MPQ  MASS
```

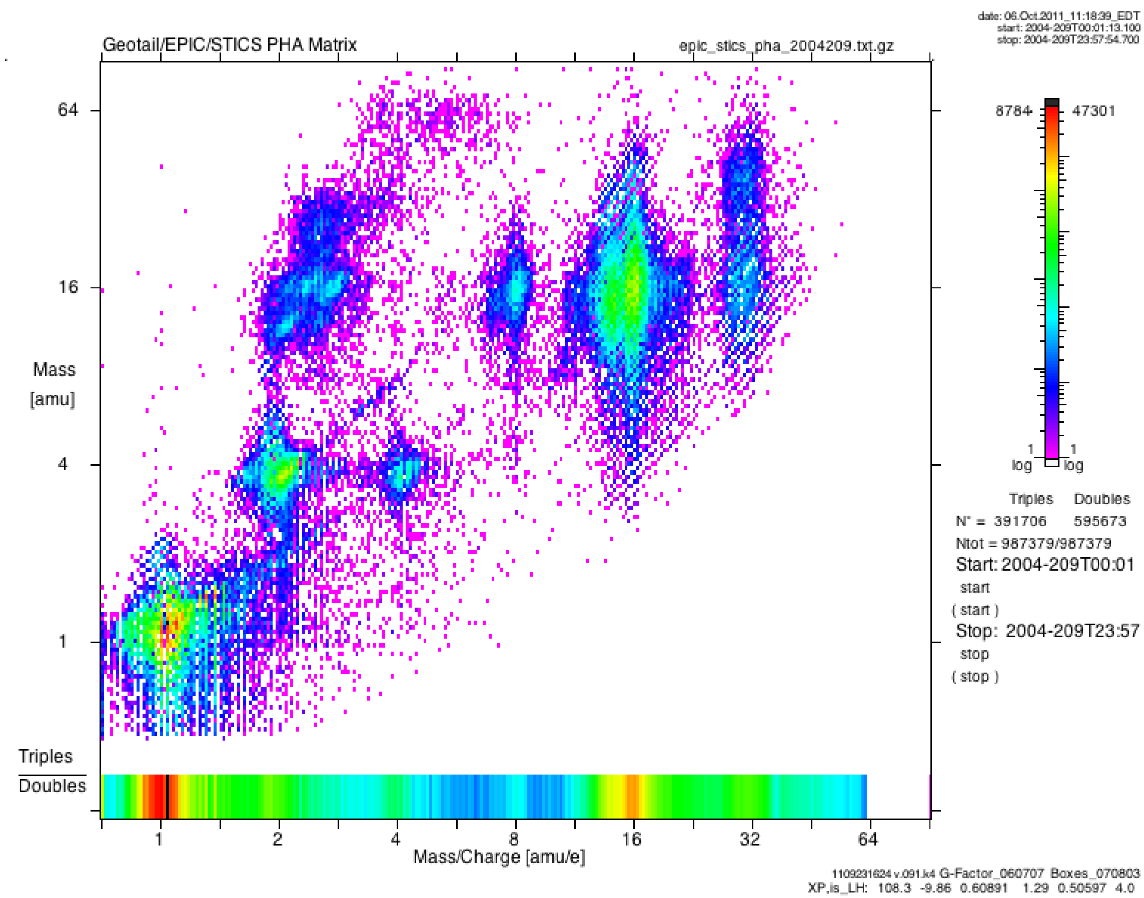
These parameters are described in Table 2. Table 4 lists the first twenty lines from a PHA data file.

Through ground processing, this information is converted into one PHA data line per STICS PHA event. Each line contains the time, mass, mass/charge, and flight direction of the particle, and deflection voltage DV, which allows calculation of the energy/charge using Table 3. Specifically, PHA data lines provide the time of the particle event, and the particle's mass, in amu, and mass per charge, in amu/e, if these were able to be calculated. The data lines also contain the deflection voltage step number, which indicates the particle's energy/charge energy band, the look-direction sector in the equatorial spin plane (i.e., its azimuth) and in the polar detector plane (i.e., its elevation). For completeness, several additional PHA raw engineering measurements are included and explained in *Schlemm et al*. [1990; 1993] although they should not be of interest to general users.

Some PHA and counting rate event data contain incorrect information resulting from uncorrectable transmission errors which occurred during the downlink of the original raw telemetry from the Geotail spacecraft. Various attempts were made in ground processing to remove some of these instances; nonetheless, the processed PHA and rate data contain some erroneous values. However, importantly, all PHAs in a basic or matrix rate box, including those representing transmission errors and calibration interval backgrounds, are necessary to calculate PHA Flux, accurate differential fluxes for any species without a predetermined counting rate assignment. Efficiencies can be found in *Nylund et al.* [2016].

Figure 4 – STICS Mass vs. Mass/charge Plot

Sample STICS PHA mass-vs.-mass/charge plot for 2004/209.



STICS Deflection Voltage Step Configuration

STICS was designed with 32 logarithmically spaced voltage levels among which the STICS sensor can be configured to cycle, or step. From launch to the present, the STICS sensor has almost always cycled solely among eight levels (appearing in bold typeface in Table 3) in order of highest to lowest DV Step, in order to provide the highest possible temporal resolution for magnetospheric disruption timing studies. The exception was from Nov 21, 2005 (2005-325), through Feb 26, 2007 (2007-057), when STICS cycled among all 32 levels.

Launch Matrix Box Boundaries

For completeness, we include Table 5 which gives the pre-launch default definition list of the (rectangular) areas defined in the mass vs. mass-per-charge class plane for counting rate bins. While the instrument was launched with these default box definitions, after 17-September-1992 (1992-261), STICS was never commanded to and, to our knowledge, STICS was never operated after 1992-261 using the pre-launch default box boundaries. The default Basic Rate box boundaries and those in Table 1 are identical.

STICS Detailed Telescope Logic/Acronym Key:

The key below (Table 6) describes the interrelationship and meaning of the parameters TEL, ST, SP, and SSD in Table 2 related to Telescope identification. Please also refer to Figure 2.

Table 6 : STICS Detailed Telescope Key

		(single firings)			(double firings)		
TELESCOPE TEL:	NONE	1	2	3	1	2	3
		-	-	-	-	-	-
	NONE	N	E	S	N	E	S
	-	- -	- -	- -	-	-	-
ST STRT (startMCP) [0,9]:	0	1 2	3 4	5 6	7=1&2	8=3&4	9=5&6
SP STOP (rear MCP) [0,3]:	0	1	2	3	1	2	3
SSD [0,3]:	0	1	2	3			
SD		0 1	0 2	0 3	0 1	0 2	0 3

Detailed PHA telescope logic/acronym explanation

If SD = 0 the PHA is defined as a "Double"; if SD = 1, 2, or 3 the PHA is a "Triple".

If SD = 0, then ECH = 0

SE is the sector number [0:15], ID is the coded ID given in Equation (12).

ST = 7, 8, or 9 indicates a combined signal from the two halves of the telescope's Start MCP.

Valid PHA events have a ST value from 1 to 9 and a SP value of 1 to 3.

STICS Dead-time Values

"Sector 0", when STICS transfers the most recent spin's rate and PHA data to the DPU, has a much lower live-time than other sectors. Table 7 contains the STICS rate correction Dead-time values. Each 3-second spacecraft spin is divided into 16 azimuthal spin sectors, 3000 ms per 16 sectors gives 187.5 ms per sector. Sector 0 was the sun direction prior to 29 January 1993, thereafter the sun was in Sector 14 (see Figure 1). STICS points 9.5º off center toward dawn.

Table 7 : STICS Dead-time Values

		Dead-times (msec)		**0th Sector Weighting Factor**
Sensor type	**Channel type**	**Sector 0**	**Sectors 1-15**	
STICS	Engineering	0.4	0.4	1.0
STICS	Science	130.0	18.2	1.08

where

- $Wt\ Factor_{0\text{-}sector}$ is the weighting factor for the 0^{th} sector (the sun direction).
- The 0^{th} sector weighting factor is stored in and read from the DPU's EPIC CALIBRATION data file. To date since launch this weighting factor has been 1.08 for STICS.
- $T_{Sector} = 187.5$ ms

For the sun direction,

$$\text{Sector Dead-time Correction} = \frac{T_{Sector}}{\dfrac{(T_{Sector} - T_{Dead\ time})}{Wt\ Factor_{0\text{-}sector}}}$$

If the sector is not the sun direction, then for each sector,

$$\text{Sector Dead-time Correction} = \frac{T_{Sector}}{(T_{Sector} - T_{Dead\ time})}$$

Table 1 – STICS Species Classification: Basic and Science Rate M and M/Q Bins (Values Uploaded to and Used by EPIC after 17-SEP-92, 1992-261)

Bin Name	Species	M/Q amu/e range		Mass amu range	
BR0	sw Heavies[a]	0.48	10.45	7.54	86.78
BR1	N^+, O^+[b]	10.85	57.76	0.46	86.78
BR1	N^+,O^+ doubles[b]	10.85	57.76	--------	-------
BR2	H^+	0.48	10.45	0.46	6.89
BR2	H^+doubles	0.48	10.45	--------	-------
HR0	H^+	0.79	1.20	0.46	1.94
HR1	O^{+1}	15.28	19.19	0.46	72.42
SMR0	He^{+1}	3.61	4.53	0.46	6.89
SMR1	He^{+2}	1.69	2.20	0.46	6.89
SMR2	O^{+2}	7.71	8.98	9.04	26.77
MR0	C^{+3}	3.75	4.20	9.90	12.98
MR1	C^{+4}	2.87	3.10	9.90	12.98
MR2	C^{+5}	2.29	2.47	9.90	12.98
MR3	C^{+6}	1.82	2.04	9.90	12.98
MR4	N^{+1}	12.64	14.71	0.46	72.42
MR5	N^{+4}	3.34	3.61	11.86	17.03
MR6	N^{+2}	6.62	7.42	9.04	20.41
MR7	N^+ doubles	7.42	6.62	--------	-------
MR8	BHe^{+2}	1.82	2.04	7.54	9.04
MR9	BHe^{+1}	3.75	4.20	7.54	9.04
MR10	BH^+ doubles*	1.25	1.62	--------	-------
MR11	O^{+2} doubles	7.71	9.32	--------	-------
MR12	O^{+3}	4.89	5.69	12.98	18.64
MR13	O^{+4}	3.75	4.20	14.21	18.64
MR14	O^{+5}	2.98	3.22	14.21	18.64
MR15	O^{+6}	2.56	2.76	10.83	18.64
MR16	O^{+7}	2.12	2.37	14.21	18.64
MR17	O^{+8}	1.82	2.04	14.21	18.64
MR18	Ne^{+8}	2.29	2.47	17.03	20.41
MR19	$MgSi^{+10:14}$	2.12	3.22	22.34	35.12
MR20	$MgSi^{+5:9}$	3.34	5.69	22.34	35.12
MR21	$Fe^{+6,7}$	7.42	9.32	38.44	66.16
MR22	$Fe^{+8,9}$	5.91	7.15	38.44	66.16
MR23	$Fe^{+10,11}$	4.89	5.69	38.44	66.16
MR24	$Fe^{+12,13}$	4.04	4.71	38.44	66.16
MR25	$Fe^{+14,15}$	3.61	3.89	38.44	66.16
MR26	$Fe^{+16,17}$	3.10	3.47	38.44	66.16
MR27	N_2^+, NO^{+1}, O_2^{+1}	28.06	41.03	0.46	72.42
MR28	BH^+*	1.25	1.62	0.50	1.94

[a] sw Heavies include high charge state solar wind, e.g., C, N, O, Ne, S, Al, Fe.
[b] The N^+,O^+ box includes other heavy ionospheric atomic and molecular ions
*The BH^+ boxes collect H^+ for estimating H^+ background in the He^+ boxes.

Table 2 – EPIC/STICS PHA File Content and Format

Column	Format	Parameter	Raw	Parameter description
1 - 4	I4	YYYY		Year
6 - 8	I3	DOY		Day of year
10 - 11	I2	HH		Hour
13 - 14	I2	MM		Minute
16 - 19	F4.1	SS.S		Second
21 - 23	I3	EDB	Raw	Raw engineering data: Engineer Data Block number (range: 0-31).
25 - 26	I2	DV		Deflection voltage step number (range: 0-31). See Table 2 for associated definitions of low and high boundaries of keV/e.
28 - 29	I2	SE		Sector of sensor's equatorial look-direction (range: 0-15, where, for most of the mission, 14 is sunward looking and 10 is dawn looking).
31 - 32	I2	ID	Raw	Raw engineering data: Identification (range: 0-30).
34 - 35	I2	SD	Raw	Solid state detector indicating sensor's polar look-direction (range: 0-3, where 1 is the south detector head, 2 is the equatorial detector head, 3 is the north detector head, and 0 is indeterminate).
37 - 40	I4	ECH	Raw	Raw engineering data: Energy channel number.
42 - 45	I4	TCH	Raw	Raw engineering data: Time-of-Flight channel number.
47 - 48	I2	ST		Front (start) micro channel plate ID (range: 0-10). This parameter indicates the sensor's polar look-direction, where 1 is the North Polar sector, 2 is the North Equator, and 7 is from the double coincidence of both North sectors; 3 is the Equator North sector, 4 is the Equator South, and 8 is from the double coincidence of both Equator sectors; 5 is the South Equator sector, 6 is the South Polar, and 9 is from the double coincidence of both South sectors; and 0 and 10 are indeterminate.
50 - 51	I2	SP	Raw	Raw engineering data: Rear (stop) micro channel plate ID (range: 0-3).
53 - 54	I2	R	Raw	Raw engineering data: PHA Range ID (range: 0-3). This parameter indicates the BR sampling range, where 0 is BR0, 1 is BR1, 2 is BR2, and 3 is indeterminate.
56 - 61	F6.3	MPQ		Particle mass per charge [amu/e]
63 - 67	F5.2	MASS		Particle mass [amu]

Table 3 - STICS Deflection Voltage (DV) Values

DV Step†	STICS DV Energy Bands [keV/e]		
	E/Q Low	E/Q Mid	E/Q High
0	7.42	7.51	7.60
1	8.29	8.39	8.49
2 ††	**9.27**	**9.38**	**9.49**
3	10.36	10.48	10.60
4	11.58	11.72	11.86
5	12.95	13.10	13.25
6 ††	**14.47**	**14.64**	**14.81**
7	16.18	16.37	16.56
8	18.08	18.30	18.52
9	20.21	20.45	20.69
10 ††	**22.59**	**22.86**	**23.13**

DV Step†	STICS DV Energy Bands [keV/e]		
	E/Q Low	E/Q Mid	E/Q High
11	25.26	25.56	25.86
12	28.23	28.57	28.91
13	31.56	31.94	32.32
14 ††	**35.28**	**35.70**	**36.12**
15	39.44	39.91	40.38
16	44.09	44.61	45.13
17	49.27	49.86	50.45
18 ††	**55.09**	**55.74**	**56.39**
19	61.58	62.31	63.04
20	68.83	69.65	70.47
21	76.94	77.85	78.76
22 ††	**86.00**	**87.02**	**88.04**
23	96.14	97.28	98.42
24	107.46	108.74	110.02
25	120.12	121.55	122.98
26 ††	**134.27**	**135.87**	**137.47**
27	150.10	151.88	153.66
28	167.79	169.78	171.70
29	187.55	189.78	192.00
30 ††	**209.65**	**212.14**	**214.60**
31	234.35	237.14	239.90

† 32 Levels among which the STICS sensor can be configured to cycle, or step.

†† From launch to the present, the STICS sensor has almost always cycled solely among these eight levels in order of highest to lowest DV Step. The exception was from Nov 21, 2005, through Feb 26, 2007, when STICS cycled among all 32 levels.

A sample of STICS PHA file output is given in Table 4.

Table 4 – Sample EPIC/STICS PHA File Output

YYYY	DOY	HH	MM	SS.S	EDB	DV	SE	ID	SD	ECH	TCH	ST	SP	R	MPQ	MASS
1992	293	0	1	15.9	0	30	5	5	1	48	75	1	1	2	1.331	1.34
1992	293	0	1	15.9	0	30	8	8	1	111	87	2	1	2	2.182	3.95
1992	293	0	1	15.9	0	30	14	19	0	0	187	6	3	1	17.226	0.00
1992	293	0	1	18.9	1	26	2	4	0	0	219	1	1	1	15.935	0.00
1992	293	0	1	18.9	1	26	2	14	2	29	80	4	2	2	1.060	1.11
1992	293	0	1	18.9	1	26	4	8	1	35	79	2	1	2	1.017	1.22
1992	293	0	1	18.9	1	26	6	11	2	34	82	3	2	2	1.151	1.31
1992	293	0	1	18.9	1	26	9	20	3	32	126	6	3	2	4.079	4.05
1992	293	0	1	18.9	1	26	12	19	3	15	219	6	3	1	15.935	14.10
1992	293	0	1	18.9	1	26	15	16	0	0	212	5	3	1	14.763	0.00
1992	293	0	1	18.9	1	26	9	8	0	0	81	2	1	2	1.105	0.00
1992	293	0	1	21.9	2	22	2	20	3	21	87	6	3	2	0.888	1.10
1992	293	0	1	21.9	2	22	3	7	0	0	268	2	1	1	16.054	0.00
1992	293	0	1	21.9	2	22	5	11	2	19	93	3	2	2	1.093	1.21
1992	293	0	1	21.9	2	22	6	21	1	125	147	7	1	0	3.895	28.53
1992	293	0	1	21.9	2	22	7	14	2	17	89	4	2	2	0.954	1.02
1992	293	0	1	21.9	2	22	9	10	2	10	267	3	2	1	15.918	22.30
1992	293	0	1	21.9	2	22	10	4	1	11	250	1	1	1	13.697	18.40
1992	293	0	1	21.9	2	22	10	17	3	19	91	5	3	2	1.023	1.15

Table 5 – PreLaunch Default STICS Species Classification: Basic Rate and Science Rate M vs. M/Q bins

Name	Species	MASS amu range		MPQ amu/e range	
HR0	H+	0.60	2.20	0.80	1.25
HRl	O+	5.00	80.00	14.95	20.31
SMR0	He+	2.70	6.50	3.55	4.65
SMR1	He+2	2.70	6.50	1.70	2.30
SMR2	O+2	9.00	30.00	7.70	9.20
MR0	C+3	9.70	13.60	3.80	4.40
MR1	C+4	9.50	13.60	2.85	3.20
MR2	C+5	9.50	13.60	2.25	2.55
MR3	C+6	9.50	13.60	1.85	2.15
MR4	N+	5.00	50.00	12.50	14.95
MR5	N+	0.00	0.00	11.50	14.95
MR6	N+2	9.00	23.00	6.60	7.70
MR7	N+2	0.00	0.00	6.60	7.70
MR8	H+	0.00	0.00	0.80	1.25
MR9	O+	0.00	0.00	14.95	20.30
MR10	H+	0.00	0.00	3.55	4.65
MR11	O+2	0.00	0.00	7.70	9.70
MR12	O+3	12.70	20.00	4.95	5.95
MR13	O+4	13.60	20.00	3.70	4.40
MRl4	O+5	13.60	20.00	3.00	3.40
MR15	O+6	11.00	20.00	2.55	2.85
MR16	O+7	13.90	20.00	2.15	2.45
MR17	O+8	13.90	20.00	1.80	2.10
MR18	Ne+8	17.80	22.10	2.30	2.55
MR19	MgSi	22.10	39.00	2.15	3.29
MR20	MgSi	22.10	39.00	3.29	5.95
MR21	Fe6,7	39.00	75.00	7.40	9.80
MR22	Fe8,9	39.00	75.00	5.83	7.40
MR23	Fe10,11	39.00	75.00	4.82	5.83
MR24	Fe12,l3	39.00	75.00	4.10	4.82
MR25	Fe14,15	39.00	75.00	3.57	4.10
MR26	Fe16,l7	39.00	75.00	3.06	3.57
MR27	NO,O2	7.00	72.00	28.00	42.00
MR28	NO,O2	0.00	0.00	28.00	60.00
MR29	He+2	0.00	0.00	1.60	2.3