SphinX data filtering methods and software tools

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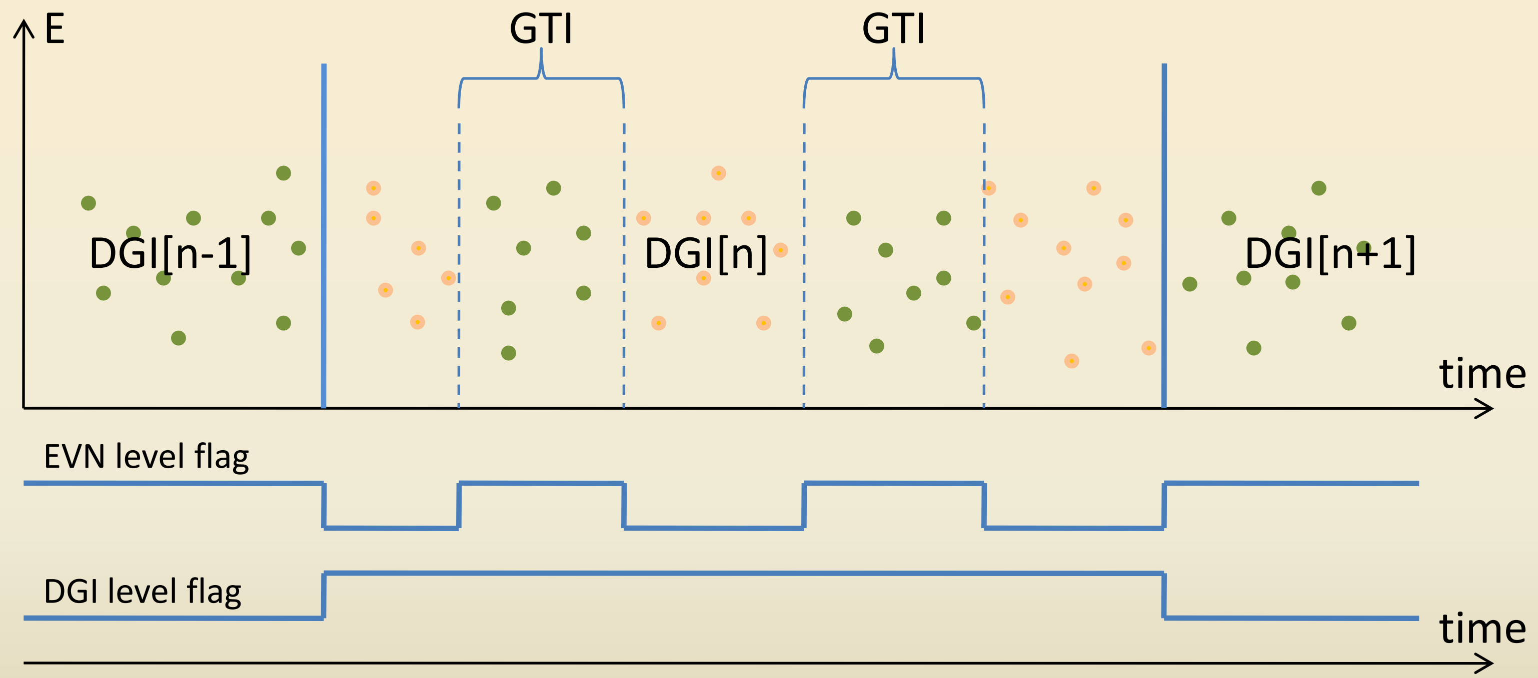
1. Introduction

Besides the scientific data, SphinX FITS files contain also flag array. These flags allows for data filtering in order to extract required part of data for scientific analysis. Each individual event stored in EVENTS extension has it own flag set.

At present the flag set consists of 15 independent flags. Most of them refer to DGI (Data Gathering Interval) – the time in which detector events were collected in memory buffer. After each DGI memory buffer was sent to telemetry. Few of the flags refer to single events.



Division to DGI units was associated with measurement regime. In FITS files that division does not already exist. However the remain of DGI division is that most of flags has the same value within individual DGI's.

2. SphinX flag format and values

SphinX flag set encoded in long integer variable

		BAD_EVN_TIME	NONGTI	HIPHA	PARTICLE	SAA	SRB	NRB	RB	OPT_NIGHT	X_NIGHT	SHADOW	NN_BAD	HOT	IRESET	BAD_DGI_TIME
2^{31}	…	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^{9}	2^{8}	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}
MSb																LSb

Long integer variable allows to encode up to 32 independent flags. At present 15 bits are used as flags. The rest of bits are not in use, but these bits can be used in future for some new flags.

3. Overall SphinX flag table

Flag	Description	Value	Level	Origin*	Comment	Family
BAD_DGI_TIME	Bad DGI times	2^0	DGI	A	Must be always rejected	Bad measurement
IRESET	Instrument reset	2^1	DGI	A	Must be always rejected	Bad measurement
HOT	Too high detector temperature	2^2	DGI	A	Should be rejected	Bad measurement
NN_BAD	Bad value, error of unknown origin	2^3	DGI	M/(A)	Must be always rejected	Bad measurement
SHADOW	Events recorded in X-ray shadow	2^4	DGI	M	Marked manually	Shadow related
X_NIGHT	Events recorded in X-ray shadow	2^5	DGI	A	Calculated from orbit data	Shadow related
OPT_NIGHT	Events recorded in optical shadow	2^6	DGI	A	Calculated from orbit data	Shadow related
RB	Events recorded within increased particle flux regions	2^7	DGI	A	Determined from L0 data	Particle related
NRB	Events recorded within nothern radiation belt	2^8	DGI	A	Calculated from orbit data	Particle related
SRB	Events recorded within southern radiation belt	2^9	DGI	A	Calculated from orbit data	Particle related
SAA	Events recorded within South Atlantic Anomaly	2^{10}	DGI	A	Calculated from orbit data	Particle related
PARTICLE	Data which may be distorted by particles influence on instrument	2^{11}	DGI	M/(A)	Marked manualy	Particle related
HIPHA	Events with amplitudes above Sun spectrum	2^{12}	EVN	A	EVN Level	Particle related
NONGTI	Events outside Good Time Interval	2^{13}	EVN	A	EVN Level	Bad measurement
BAD_EVN_TIME	Bad event time	2^{14}	EVN	A	EVN Level	Bad measurement

*) A – flag set by automat, M – flag set manually

4. Description of individual flags

4.1 BAD_DGI_TIME

This flag marks all data for which proper time values can not be determined due to telemetry frame error.
It may arise when:
- DGI start time > DGI end time
- DGI time > next DGI time or DGI time < previous DGI time

All events marked with BAD_DGI_TIME flag must be removed before scientific analysis regardless of analysis object.

Flag level: DGI
Origin: automat
Related flags: IRESET, HOT, NN_BAD, NONGTI, BAD_EVN_TIME

4.2 HOT

This flag marks all data collected when detector temperature was too high. In case when the temperature exceeded threshold value of -22C an additional events were recorded due to thermal noise. The higher detector temperature the more additional events are present.

It is highly recommended to remove all events marked with this flag before scientific analysis. Otherwise special care must be taken.

Flag level: DGI
Origin: automat
Related flags: BAD_DGI_TIME, IRESET, NN_BAD, NONGTI, BAD_EVN_TIME

4.3 NN_BAD
This flag marks all incorrect data caused by some errors of unknown origin. These incorrect data result in spikes of significant countrate or zero value in ligthcurve. There are also longer time intervals with increased noise or incorrect spectra. All these cases were handled manually.

All events marked with BAD_DGI_TIME flag must be removed before scientific analysis regardless of analysis object.

Flag level: DGI
Origin: manually set
Related flags: IRESET, HOT, NN_BAD, NONGTI, BAD_EVN_TIME

4.4 BAD_EVN_TIME
This flag marks all events for which proper time values can not be determined due to telemetry frame error. It may arise when:
- event time is outside DGI
- event time > next event time or event time < previous event time

All events marked with BAD_EVN_TIME flag must be removed before scientific analysis regardless of analysis object.

Flag level: EVN
Origin: automat
Related flags: IRESET, HOT, NN_BAD, NONGTI, BAD_DGI_TIME

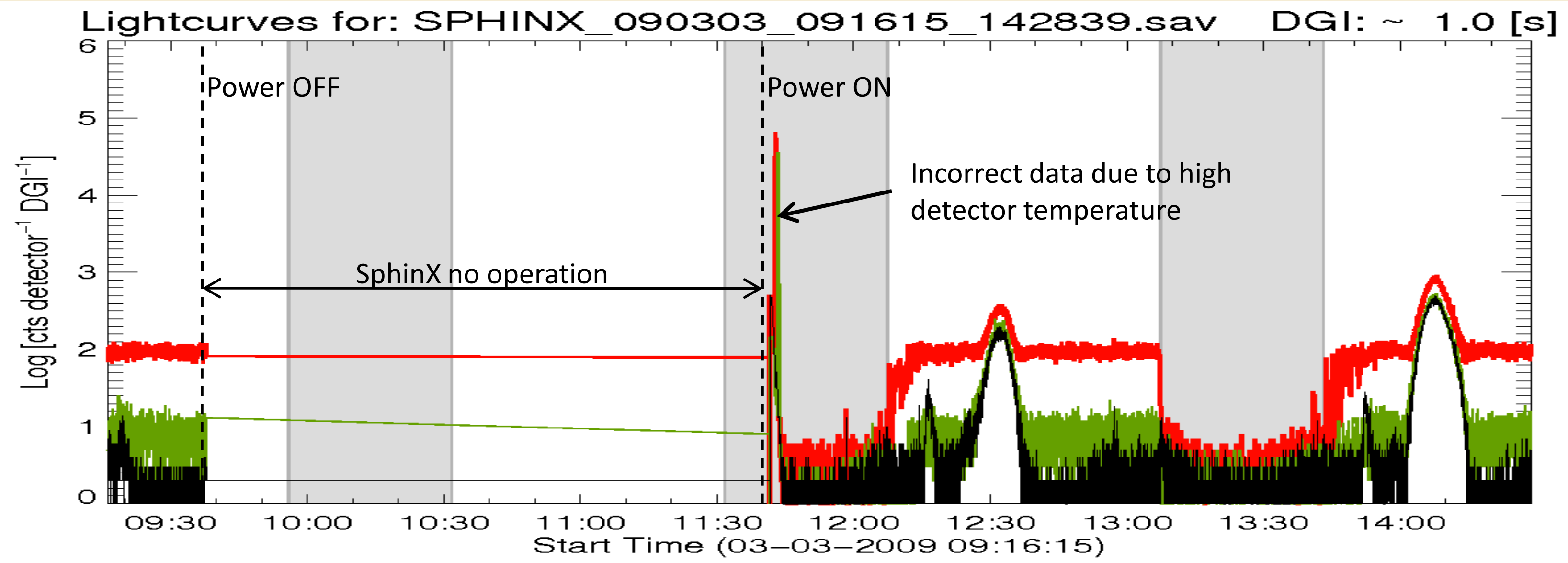
4. Description of individual flags

4.5 IRESET

This flag marks all data which were collected for 5 minutes after instrument reset. These data are incorrect due to high detector temperature and unstable electronics conditions. After that time interval detectors are cooled down and electronics works under normal condition.

All events marked with IRESET flag must be removed before scientific analysis regardless of analysis object.

Flag level: DGI
Origin: automat
Related flags: BAD_DGI_TIME, HOT, NN_BAD, NONGTI, BAD_EVN_TIME



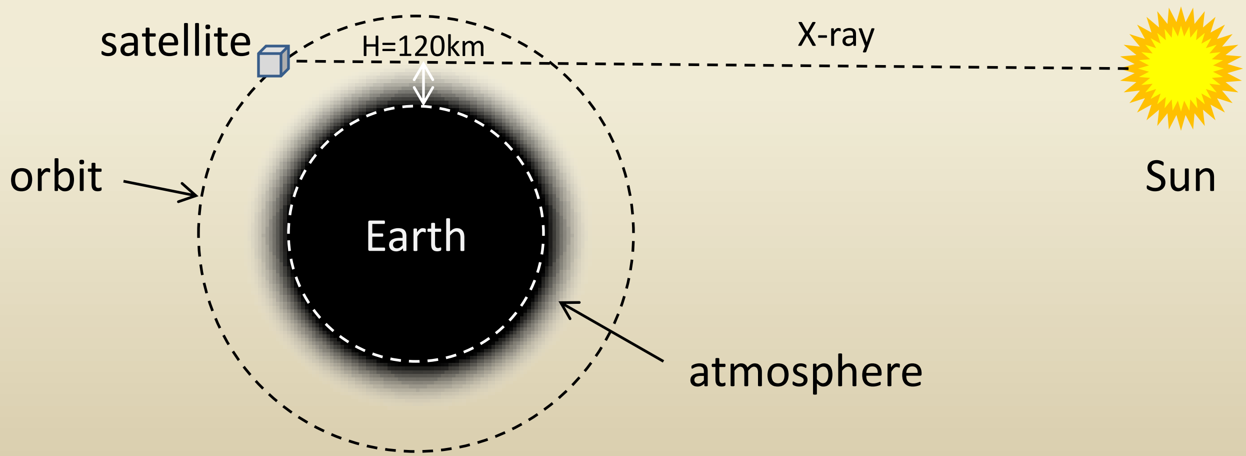
4. Description of individual flags

4.6 X_NIGHT

This flag marks all data collected while satellite was in X-ray shadow. This flag was generated automatically based on satellite orbit data (2-lines elements). We assumed that X-rays are absorbed by atmosphere up to height of 120 km above Earth surface. Real absorption profile is rather soft thus X-ray shadow boundaries are fuzzy.

For analysis aimed to Sun, all data marked with this flag should be removed as the data are affected by X-ray absorption.

Flag level: DGI
Origin: automat
Related flags: SHADOW, OPT_NIGHT

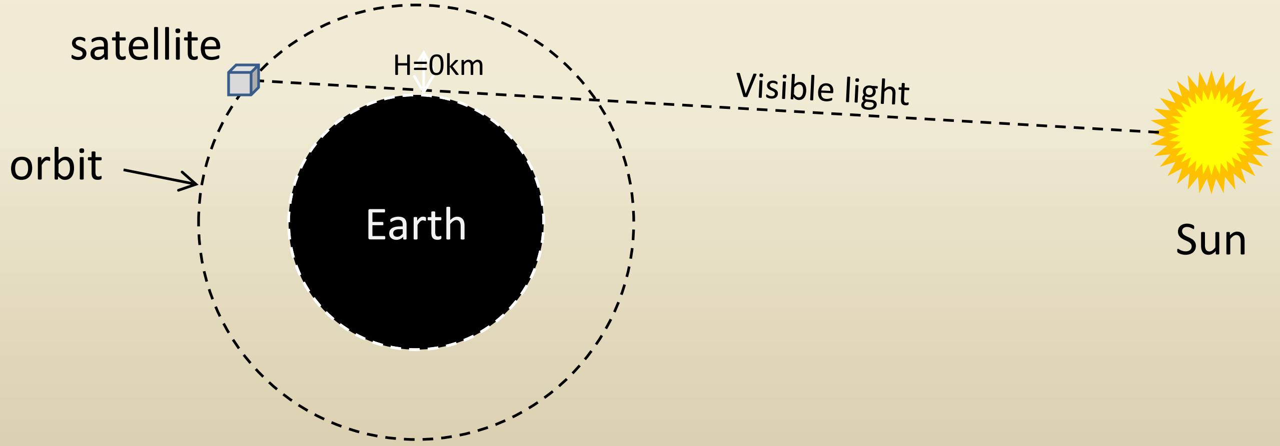


4.7 OPT_NIGHT

This flag marks all data collected while satellite was in optical shadow. This flag was generated automatically based on satellite orbit data (2-lines elements). We assumed that visible light is absorbed only by Earth.

For analysis aimed to Sun, all data marked with this flag should be removed as it does not contain events originated from Sun.
For analysis aimed to particle environment this flag is meaningless or it may be used for extract „non-solar" events.
It may be also used for extract data collected while satellite was in transition regions.

Flag level: DGI
Origin: automat
Related flags: SHADOW, X_NIGHT



4.7 SHADOW

This flag marks all data which may be affected by X-ray shadow entering/leaving.

For analysis aimed to Sun, all data marked with this flag should be removed as it may be distorted in transition regions.

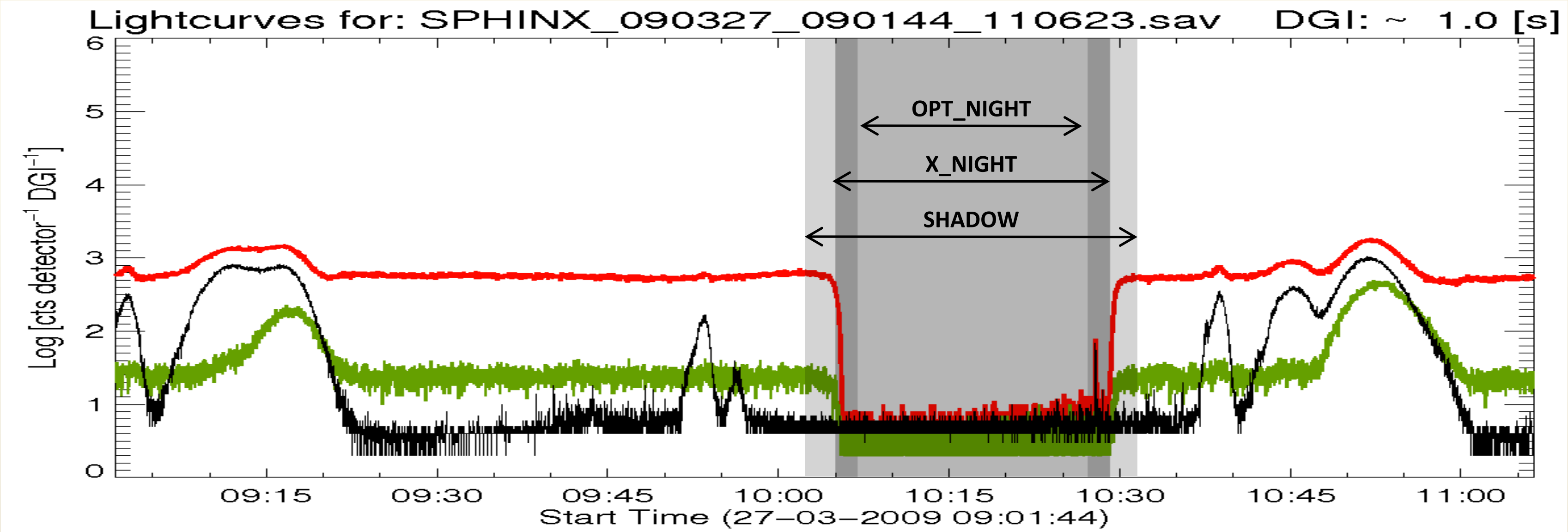
For analysis aimed to particle environment this flag is meaningless or it may be used for extract „non-solar" events.

It may be also used for extract data collected while satellite was in transition regions.

Flag level: DGI

Origin: manually set

Related flags: SHADOW, OPT_NIGHT



4. Description of individual flags

4.8 RB

This flag marks all data which may be affected by particle flux in Radiation Belts or South Atlantic Anomaly.
The advantage of RB flag is that algorithm for the flag generation base on real data thus short time variations of radiations regions are taken into account.
Note that data marked with RB flag are rather solar data which may be affected by particles or/and may contains additional events caused by particles.

For analysis aimed to Sun, all data marked with this flag should be removed as it may be distorted by particles.
For analysis aimed to particle environment this flag could be useful to extract interesting part of data.

Flag level: DGI
Origin: automat
Related flags: NRB, SRB, SAA, PARTICLE, HIPHA

4. Description of individual flags

4.9 NRB, SRB, SAA

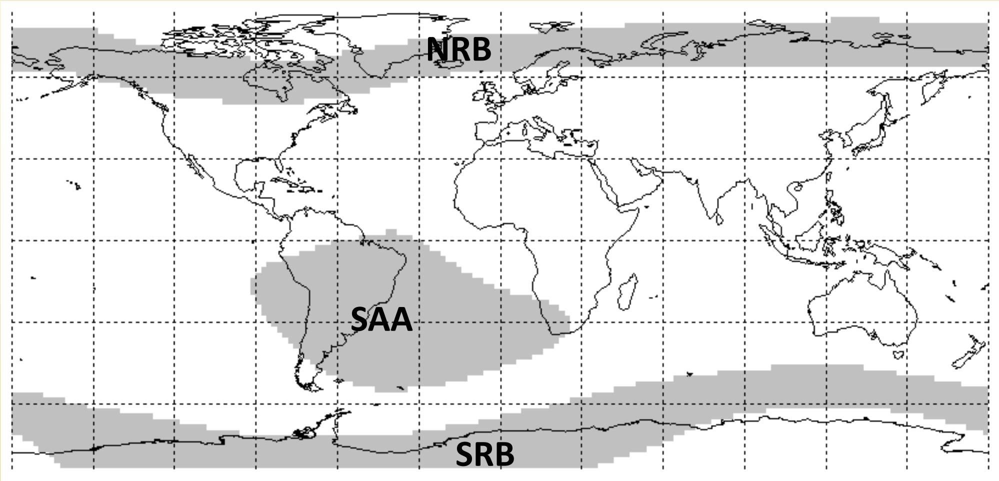
These flags mark all data collected in specified regions of Northern Radiation Belt, Southern Radiation Belt and South Atlantic Anomaly respectively. These regions were determined from SphinX particle observation averaged over few months time interval. The algorithm for these flag generation does calculate satellite position for each DGI time, then if satellite was located in one of three regions a respective flag is set.

Note:

1. The data marked with these flags are rather solar data which may be affected by particles or/and may contains additional events caused by particles.
2. The algorithm does not take into account short time variations of radiations regions as assumed particle map is fixed.

For analysis aimed to Sun, all data marked with this flag should be removed as it may be distorted by particles.
For analysis aimed to particle environment this flag could be useful to extract interesting part of data.

Flag level: DGI
Origin: automat
Related flags: RB, PARTICLE, HIPHA



4.10 PARTICLE

This flag was set manually while data were reduced to level 1. The flag was set taking into account few conditions as follow:

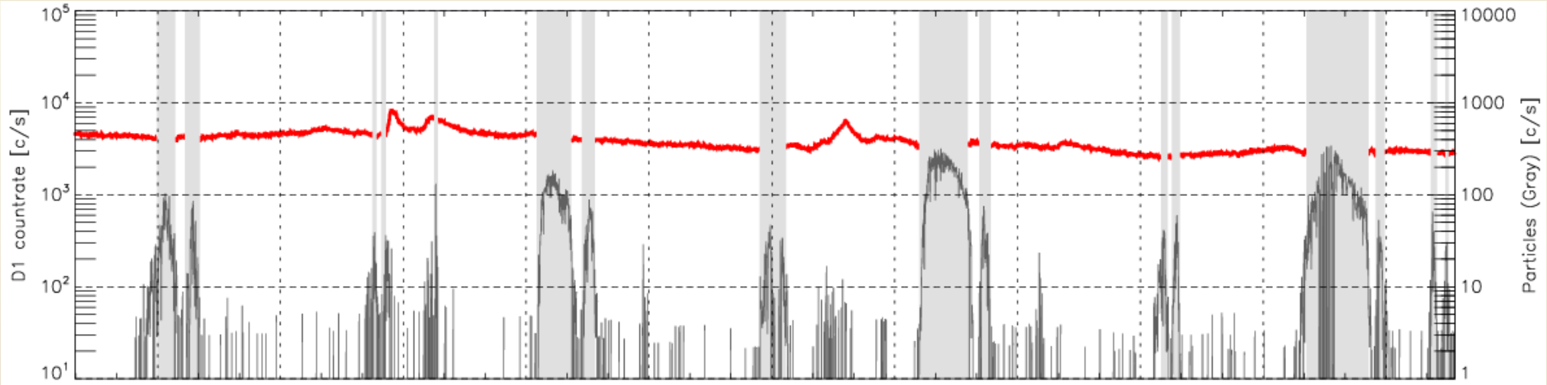
1. If satellite was in radiation region,
2. Countrate of events above Sun spectrum which were considered as „non-solar" events,
3. If there was visible distortion in solar lightcurve for time intervals where particle flux was increased.

Note:

1. The data marked with this flags are rather solar data which are affected by particles or/and may contains additional events caused by particles.
2. The flag was set in result of personal choice.

For analysis aimed to Sun, all data marked with this flag must be removed as it is distorted by particles.
For analysis aimed to particle environment this flag could be useful to extract interesting part of data.

Flag level: DGI
Origin: manually set
Related flags: RB, NRB, SRB, SAA, HIPHA

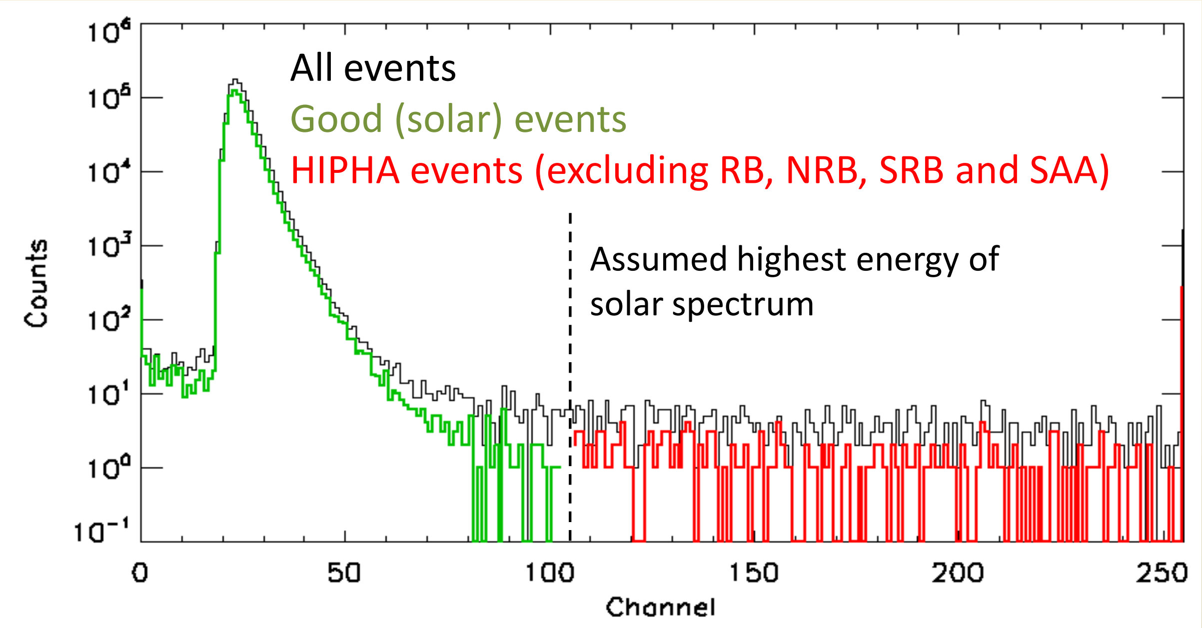


4.11 HIPHA

This flag was set automatically for each one event which energy is greater than assumed highest energy of solar spectrum.

For analysis aimed to Sun, all events marked with this flag must be removed as „non-solar” event.
For analysis aimed to particle environment this flag could be useful to extract interesting part of data.

Flag level: EVN
Origin: automat
Related flags: RB, NRB, SRB, SAA, PARTICLE



5. How to use SphinX flags for data filtering – an example in IDL

Flag	Object		
	Sun	Earth's particle environment	Shadow transitions/profiles
BAD_DGI_TIME	Must be rejected	Must be rejected	Must be rejected
IRESET	Must be rejected	Must be rejected	Must be rejected
HOT	Should be rejected	Should be rejected	Should be rejected
NN_BAD	Must be rejected	Must be rejected	Must be rejected
SHADOW	Must be rejected	Should not be rejected	Useful
X_NIGHT	Must be rejected	Should not be rejected	Useful
OPT_NIGHT	Must be rejected	Should not be rejected	Useful
RB	Should be rejected	Useful	Should be rejected
NRB	Should be rejected	Useful	Should be rejected
SRB	Should be rejected	Useful	Should be rejected
SAA	Should be rejected	Useful	Should be rejected
PARTICLE	Must be rejected	Useful	Must be rejected
HIPHA	Must be rejected	Useful	Must be rejected
NONGTI	Must be rejected	Must be rejected	Must be rejected
BAD_EVN_TIME	Must be rejected	Must be rejected	Must be rejected

5. How to use SphinX flags for data filtering – an example in IDL

In order to extract from FITS file required part of data for further analysis a four steps should be done as follow:

1. Determine which events are appropriate for your analysis. It depends what is the object of the analysis.
2. Define logic condition that allows to extract appropriate events from all data.
3. Perform data filtering.
4. Reconstruct new GTI array for extracted part of data.

It is worth to define all flags at first to make routine more clear:

```
BAD_DGI_TIME = 2L^0
IRESET       = 2L^1
HOT          = 2L^2
NN_BAD       = 2L^3
SHADOW       = 2L^4
X_NIGHT      = 2L^5
OPT_NIGHT    = 2L^6
RB           = 2L^7
NRB          = 2L^8
SRB          = 2L^9
SAA          = 2L^10
PARTICLE     = 2L^11
HIPHA        = 2L^12
NONGTI       = 2L^13
BAD_EVN_TIME = 2L^14
```

Note that flag values must be declared as Long type.

5. How to use SphinX flags for data filtering – an example in IDL

Suppose that we need for our analysis all events which were collected in SAA region and with energies above solar spectrum. In addition all incorrect data should be removed.

We look for events for which:
- SAA and HIPHA flags are set to 1
- NN_BAD, HOT, IRESET, BAD_DGI_TIME flags are set to 0
- Other flag values are meaningless (X) – these flags must not be examined while data filtering. It is not important if the events were collected in shadows or not as we want „non-solar" events (above Sun spectrum).

	BAD_EVN_TIME	NONGTI	HIPHA	PARTICLE	SAA	SRB	NRB	RB	OPT_NIGHT	X_NIGHT	SHADOW	NN_BAD	HOT	IRESET	BAD_DGI_TIME
The pattern we are looking for:	0	0	1	X	1	X	X	X	X	X	X	0	0	0	0

5. How to use SphinX flags for data filtering – an example in IDL

We have to prepare bit mask for all bits that will be examine:

	BAD_EVN_TIME	NONGTI	HIPHA	PARTICLE	SAA	SRB	NRB	RB	OPT_NIGHT	X_NIGHT	SHADOW	NN_BAD	HOT	IRESET	BAD_DGI_TIME
The pattern we are looking for:	0	0	1	X	1	X	X	X	X	X	X	0	0	0	0
Bit mask:	1	1	1	0	1	0	0	0	0	0	0	1	1	1	1

Next we set all meaningless bits to 0 by performing bitwise AND operation on flags and mask. It can be done in IDL as follow:

```
Mask = BAD_EVN_TIME + NONGTI + HIPHA + SAA + NN_BAD + HOT + IRESET + BAD_DGI_TIME
MFlag = Flag AND Mask
```

As result we obtain a new flag Mflag, which in all meaningless bits are set to 0 while all important bits have saved their primary values:

	BAD_EVN_TIME	NONGTI	HIPHA	PARTICLE	SAA	SRB	NRB	RB	OPT_NIGHT	X_NIGHT	SHADOW	NN_BAD	HOT	IRESET	BAD_DGI_TIME
Flag AND Mask:	1/0	1/0	1/0	0	1/0	0	0	0	0	0	0	1/0	1/0	1/0	1/0

5. How to use SphinX flags for data filtering – an example in IDL

From all events we want only these for which masked flag value is as follow:

	BAD_EVN_TIME	NONGTI	HIPHA	PARTICLE	SAA	SRB	NRB	RB	OPT_NIGHT	X_NIGHT	SHADOW	NN_BAD	HOT	IRESET	BAD_DGI_TIME
Value we are looking for:	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0

We can extract required data using **where** function in IDL:

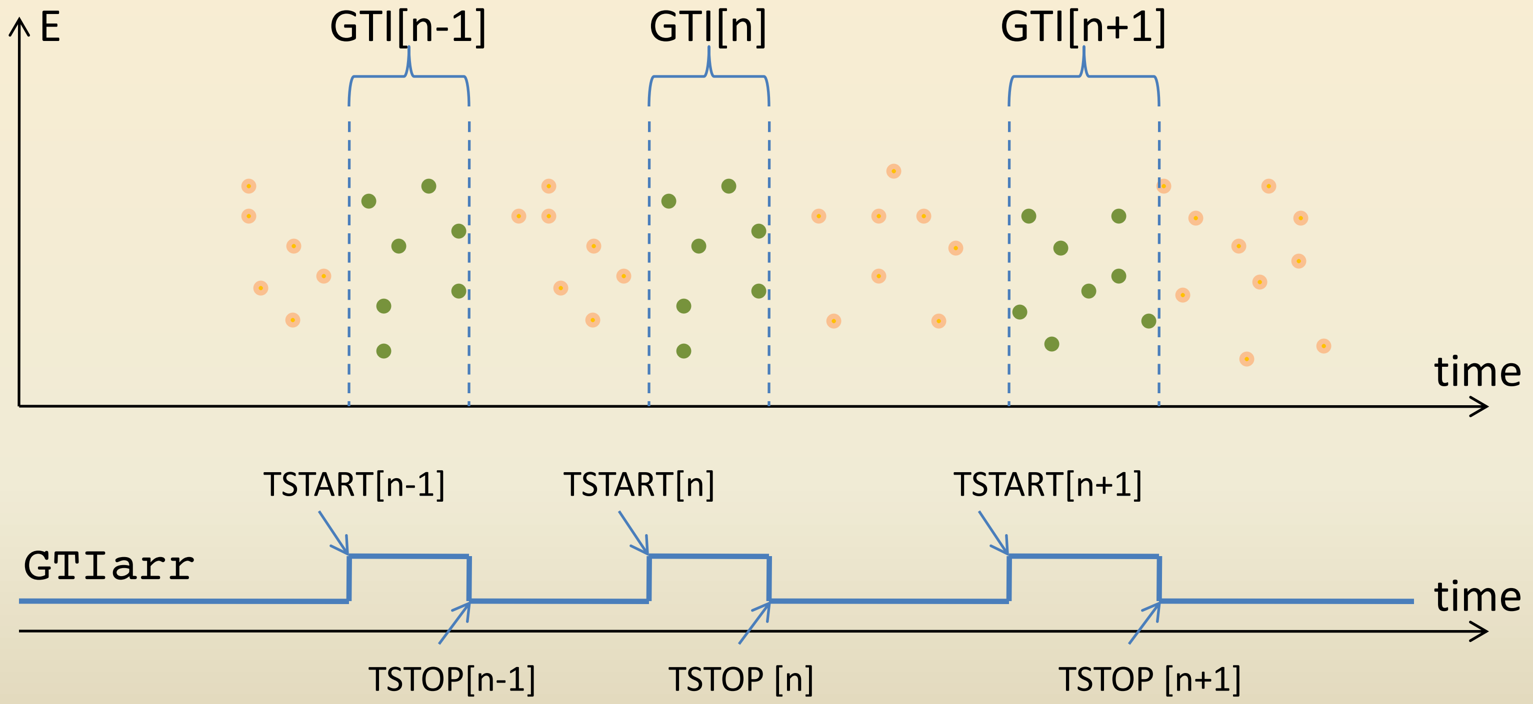
```
condition = HIPHA + SAA
good = where(MFlag eq condition, count)
IF count gt 0 THEN BEGIN
  ENERGY = EVENTS.ENERGY[good]
  TIME   = EVENTS.TIME[good]
  PHA    = EVENTS.PHA[good]
  .
  .
  .
ENDIF ELSE BEGIN
  print, 'no data for that condition'
ENDELSE
```

5. How to use SphinX flags for data filtering – an example in IDL

After data filtering we have to reconstruct GTI array for filtered data. For that purpose we should create a new flag array:

```
GTIarr = Mflag*0L
GTIarr[good] = 1L
```

All „1" values in GTIarr flag correspond to good events for which condition is meet.



Finally we can determine TSTART and TSTOP for each GTI by edge detection in GTIarr.

Thank you