

rgsevents

January 27, 2025

Abstract

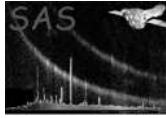
This RGS task constructs an `EVENTS` table from the raw telemetered pixel data for a single CCD exposure. This table is added to the input dataset along with two `REJPIXn` tables (one for each node), which augment the existing `BADPIXn` tables. The input dataset is assumed to have been processed by `rgsbadpix`.

1 Instruments/Modes

Instrument	Mode
RGS	Spectroscopy
RGS	High Time Resolution

2 Use

pipeline processing	yes
interactive analysis	yes



3 Description

rgsevents adds the **EVENTS** and **REJPIXn** tables to the intermediate event list for a single RGS CCD exposure, which has been processed by **rgsbadpix**. These tables are sorted in increasing order of frame number. The **EVENTS** table is also cross-referenced with the existing **PIXELS** table so that the correspondence between the reconstructed events and the raw telemetered pixels is not lost. Throughout this document a † marks items that do not apply to High Time Resolution (HTR) mode data and a ‡ marks items that apply only to HTR mode data.

The event reconstruction algorithm defines an event as a maximal set of adjacent pixels. That is, any two pixels which share an edge are contained within the same event. The user has the option to disable event reconstruction, which only means that each qualifying telemetered pixel is treated as a separate event regardless of its proximity to other pixels. To cross-reference the reconstructed events with their comprising telemetered pixels a column named **EVENT** is added to the **PIXELS** table, in which is recorded for each pixel the **EVENTS** table row number of the event in which it is included, or null if it is not associated with an event. From the raw pixel data the following properties are computed for each event and stored in the **EVENTS** table. Also stored for each event are three properties copied from the **EXPOSURE** table: frame number, flags and timestamp.

- energy

Total energy, both calibrated and raw.

- grade

Total number of pixels, or area of the event.

- shape

Chip-oriented DPP shape code for any event confined within a two-by-two pixel region; otherwise null. The shapes are shown below, with the numeral indicating both the code number for each pattern and the relative position of the reference pixel. Note that in the **PIXELS** table the telemetered coordinates mark the location of the reference pixel, but in the **EVENTS** table the centroid coordinates may lie anywhere within the bounding rectangle of the event.

	**	*		*	*	**	**
0	1*	2	3*	4*	5*	6	7

- coordinates

Coordinates of the event centroid in various units:

- Chip-oriented pixel coordinates, in integer format.
- RGS angular coordinates, without aspect correction.
- RGS detector coordinates in a system chosen by the user. Optional.

- flags

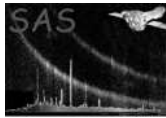
These flags indicate conditions which cast serious doubt upon the quality of the event as an x-ray detection:

- **ON_BADPIX**

At least one pixel included in the event is found in the bad pixel tables.

- **NEXT_TO_BADPIX**

The pixel under the event centroid shares an edge with a pixel from the bad pixel tables.



- `ON_WINDOW_BORDER`
The pixel under the event centroid lies in the first or last row or column of the telemetered window.
- `ON_NODE_INTERFACE`
The pixel under the event centroid shares an edge with the opposing node.
- `BELOW_ACCEPTANCE`
The calibrated energy of every pixel included in the event lies below the acceptance threshold.
- `BAD_SHAPE`
The event does not lie entirely within a two-by-two pixel region.

These flags provide information about the composition of the event:

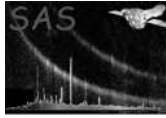
- `ON_NODE0`
At least one pixel included in the event lies in node zero.
- `ON_NODE1`
At least one pixel included in the event lies in node one.
- `ONBOARD_SER`[†]
At least one pixel included in the event represents an on-board reconstruction.

Included also are any flags set by `rgsframes` in the `EXPOSURE` table. For each flag present in the output table a Sparse message declares the total number of events so flagged.

For each node the CCF provides PI thresholds for acceptance and rejection—not to be confused with similarly named thresholds used on-board by the Data Preprocessor (DPP). Since these thresholds are directly applicable only to single-pixel energies, the average highest single-pixel energy is computed for pixels with on-board split-event reconstruction (SER) using an empirical charge-splitting ratio provided for each grade (no SER correction is applied in HTR mode). Any pixel with PI less than the rejection threshold is ignored, just as if it had not been telemetered. Further, any event that does not include at least one pixel with PI at or above the acceptance threshold is flagged with `BELOW_ACCEPTANCE`. The floating-point pixel PI values are summed over the pixels comprising each event and “pixelized” by rounding to the nearest integer. The pixelization of the event PI values, as well as the minimum and maximum (pixelized) values present in the data, are described by standard FITS attributes on the PI column of the `EVENTS` table. It may be unwise to assume that the minimum value is nonnegative.

A null shape code implies nothing about the shape of the event. In particular, it does not imply that the event is not confined within a two-by-two pixel region. A previous version of the DPP does not provide enough information about pixels of grade two and three for the ground software to determine the shape. Use the `BAD_SHAPE` event flag to test whether an event is two-by-two confined. The event centroid is computed as a PI weighted sum over randomized sub-pixel coordinates (to avoid aliasing effects). For pixels with on-board SER the combined energy is treated as if spread uniformly over the telemetered shape. If the shape is not available for a pixel, its energy is placed at a random offset from its upper right corner. HTR mode y-coordinates are randomly distributed over the full 384 row height of the chip (disabling randomization produces the nominal readout row used in the energy corrections). Randomization may be disabled via the CAL state. This program does not attempt to identify cosmic-rays by pulse-height analysis. If an event falls within a two-by-two pixel region it is considered to be an x-ray; otherwise it is something with a bad shape—possibly a cosmic-ray. Note that if any of the pixels in a two-by-two region have no shape information, `BAD_SHAPE` is not set as long as all pixels are under grade three. This should not be an issue with the current DPP, and in any case should pertain only to events straddling the node boundary.

While determining the flags for each event, special note is taken of pixels with certain flags, when these flags have not been set identically in the bad pixel map. These are additional rejectable pixels and



may be needed when constructing the exposure map. The flags in question are: `BAD_SHAPE`, `ON_BADPIX`, `NEXT_TO_BADPIX`, `ON_WINDOW_BORDER` and `ON_NODE_INTERFACE`. The chip coordinates of each such pixel are added to the `REJPIXn` table for its node, along with its frame number and any of these flags that were set on its associated event. The `REJPIXn` tables augment the `BADPIXn` tables for the purpose of mapping exposure.

4 Parameters

This section documents the parameters recognized by this task (if any).

Parameter	Mand	Type	Default	Constraints
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<code>ccdset</code>	yes	dataset	events.ds	
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Intermediate event list processed by `rgsbadpix`.

<code>withdetcoord</code>	no	boolean	no	
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Enable output of detector coordinates as columns in the `EVENTS` table.

<code>detcoord</code>	no	string	cam	chip—cam—sac
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Coordinate system type for the detector coordinates, if enabled. The options refer to the standard XMM coordinate systems, `CHIPCOORD` (with sub-pixel accuracy), `CAMCOORD1` and `SACCOORD`.

<code>reconstruct</code>	no	boolean	yes	
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Enable event reconstruction.

5 Errors

This section documents warnings and errors generated by this task (if any). Note that warnings and errors can also be generated in the SAS infrastructure libraries, in which case they would not be documented here. Refer to the index of all errors and warnings available in the HTML version of the SAS documentation.

BadParameter (*error*)

An unrecognized value was specified for `detcoord`.

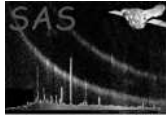
BoundsMismatch (*error*)

The telemetry window bounds do not match between the `PIXELS` and `BADPIXn` tables.

InvalidCoordinates (*warning*)

A pixel with coordinates outside of the telemetered window.

corrective action: The invalid pixel is discarded.

**EventOverlap** (*warning*)

A frame with more than one pixel at the same location.

corrective action: The extra pixels are discarded.

MissingFrames (*warning*)

Pixels attributed to a non-existent frame.

corrective action: Such pixels are discarded.

6 Input Files

- **ccdset**

The following tables are required from the input spectroscopy dataset, which is expected to have been processed by **rgsbadpix**.

- **EXPOSURE**

Required columns:

FRAME	int32	frame identifier
FLAG	int32	advisory flags
TIME	real64	timestamp

- **PIXELS**

Required attributes:

DATATYPE		instrument mode
CCDID		ccd identifier
CCDOCB		on-chip binning factor
TELAPSE		total integration time
WINDOWXO WINDOWYO		telemetry window: origin (node coordinates)
WINDOWDX WINDOWDY		telemetry window: dimensions
RAWY [‡]		nominal readout row in HTR mode

Required columns:

FRAME	int32	frame identifier
RAWX RAWY [†]	int16	coordinates
ENERGY	int16	uncalibrated energy
CCDNODE	int8	node identifier
SHAPE [†]	int8	shape code
GRADE [†]	int8	number of pixels
PI	real32	calibrated energy

- **BADPIX0 and BADPIX1**

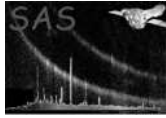
Required attributes:

CCDNODE		readout node identifier
WINDOWXO WINDOWYO		telemetry window: origin (chip coordinates)
WINDOWDX WINDOWDY		telemetry window: dimensions
ABUTTED		abuts on opposing node

Required columns:

CHIPX CHIPY [†]	int16	coordinates
YEXTENT [†]	int16	pixel count
BADFLAG	int16	provenance

The dataset is also required to possess the **INSTRUME** attribute.



7 Output Files

- ccdset

These tables from the input spectroscopy dataset are modified as follows.

- EVENTS

The table of events is created or replaced. Any flag-selection attributes of the EXPOSURE table are reproduced here.

- * General attributes

XMMEA_3	ON_NODE0	selection expression
XMMEA_4	ON_NODE1	selection expression
XMMEA_12 [†]	ONBOARD_SER	selection expression
XMMEA_19	BAD_SHAPE	selection expression
XMMEA_20	ON_NODE_INTERFACE	selection expression
XMMEA_21	ON_BADPIX	selection expression
XMMEA_24	NEXT_TO_BADPIX	selection expression
XMMEA_25	ON_WINDOW_BORDER	selection expression
XMMEA_27	BELOW_ACCEPTANCE	selection expression
DATATYPE CCDID CCDOCB TELAPSE		copied from PIXELS table

- * PI column attributes

TCTYP	channel axis type	(no applicable standard)
TCUNI	channel axis units	(PI)
TCRPX	reference channel number	(0)
TCRVL	center of reference channel	(0.0)
TCDLT	uniform channel width	(1.0)
TDMIN TDMAX	minimum and maximum data values	present

- * Columns

FRAME	int32	frame identifier
CHIPX CHIPY	int16	chip-oriented pixel coordinates
DETX DETY DETZ	real32	optional RGS detector coordinates
BETA XDSP	real32	RGS angular coordinates
PI	int32	total calibrated energy
SHAPE	int8	chip-oriented shape code
GRADE	int8	total number of pixels
FLAG	int32	advisory flags
PHA	int32	total telemetered energy
TIME	real64	frame timestamp

- REJPIXn

The tables of rejectable pixels are created or replaced.

- * Attributes

CCDNODE	readout node identifier
INSTRUME	copied from the dataset header
CCDID CCDOCB	copied from PIXELS table

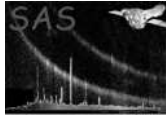
- * Columns

FRAME	int32	frame identifier
FLAG	int32	rejectability flags
CHIPX CHIPY [†]	int16	chip-oriented pixel coordinates

- PIXELS

The event cross-referencing column is created or replaced.

EVENT	int32	row number of comprising event
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8 Algorithm

In this section an asterix marks items that do not apply to HTR mode data.

Initialize the bad pixel map:

```
mark ON_WINDOW_BORDER along the window edges:
  top* and bottom*, outer sides, and inner sides if not abutting
mark ON_NODE_INTERFACE along window inner sides if abutting
for each bad pixel region:
  mark ON_BADPIX along the region itself
  mark NEXT_TO_BADPIX on all directly adjacent pixels:
    above* and below*, and along both sides
```

Perform event reconstruction:

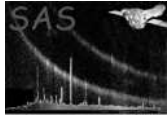
```
for each frame:
  initialize map of pixels not below the rejection threshold
  for each pixel still on the map:
    initialize new event
    move pixel from map to stack
    until stack is empty, taking the top pixel:
      add pixel to event
      move all adjacent pixels from map to stack
```

Or, if event reconstruction is disabled:

```
for each frame:
  for each pixel not below the rejection threshold:
    construct a new event
```

Update the dataset:

```
set the event cross-reference to null for all pixels
for each event:
  cross-reference the event with each of its pixels
  compute and store event properties
  add additional rejectable pixels to the REJPIX tables
```



9 Comments

10 Future developments

References