GRB Polarisation Data and Response Format

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1 Introduction

The purpose of this document is to define a standard data and response file format to do Gamma-ray Burst (GRB) polarisation studies. Both formats aim to be compatible with the HEASARC standards defined in OGIP Calibration Memo CAL/GEN/92-002 and with the 3ML data analysis framework.

2 Polarisation data file format

Generally, GRB polarimeters use scattering polarimetry techniques where there is one active scattering element and one active absorbing element. Hence, to construct the azimuthal scattering histogram, a pair of events ("double events") satisfying scattering and absorption criteria is necessary. As different instruments have different criteria to select such pairs, the standard data format should have a reduced format where the final scattering bin of each event pair is reported. Therefore the data file should contain a single FITS extension named `'POLEVENTS'` and the filename should have extension `.pevt`. The FITS extension should have the following format:

2.1 Extension header

The extension header should contain the following standard keywords defined in the OGIP format:

- `EXTNAME` (= `'POLEVENTS'`) - the name (*ie* type) of the extension.
- `TELESCOP` - the "telescope" (*ie* mission/satellite name).
- `INSTRUME` - the instrument/detector.
- `EMIN` - The minimum detected energy used to generate the data. The preferred units are keV.

- `EMAX` - The maximum detected energy used to generate the data. The preferred units are keV.
- `SABINS` - Total no. of output scattering angle bins.

In addition to these, because the polarisation angle is measured with respect to the local North in the celestial frame, additional attitude information is needed to transform the data and templates correctly. The attitude information should be given as following additional headers:

- `RAX` - Right Ascension of the instrument X-axis at the time of GRB. The preferred units are deg.
- `DECX` - Declination of the instrument X-axis at the time of GRB. The preferred units are deg.
- `RAZ` - Right Ascension of the instrument Z-axis at the time of GRB. The preferred units are deg.
- `DECZ` - Declination of the instrument Z-axis at the time of GRB. The preferred units are deg.
- `RAGRB` - Right Ascention of the GRB postion. The preferred units are deg.
- `DECGRB` - Declination of the GRB position. The preferred units are deg.

2.1.1 Extension data

The extension data should be a BINTABLE with the following columns and data types:

1. *Time*, a 8-byte REAL scalar for each row containing the time of the event.
   The FITS column name is `TIME`.
   The recommended units are s.
2. *Chan*, a 2-byte of 4-byte INTEGER scalar giving the raw channel number for each row.
   The FITS column name is `CHANNEL`.
   (unitless).
3. *SABin*, a 2-byte INTEGER scalar giving the scattering angle bin for each row. The binning should done with highest possible resolution.
   The FITS column name is `SABIN`
   (unitless)
4. *Dead Time Fraction*, a 4-byte REAL scalar for each row containing dead time fraction for the event.
   The FITS column name is `DEADFRAC`.

3 Polarisation response file format

A typical response needed for a polarisation study requires the observed Scattering Angle (SA) distribution over a grid of Polarisation Angle (PA) and Polarisation Fraction (PF). This response has to be generated for a source spectrum individually. Hence the the raw response file should have the observed Scattering Angle distribution for 100% polarised photons with different input Polarisation Angles simulated at different input energies (E), i.e. a matrix with shape nE $\times$ nPA $\times$ nSA. Along with this another matrix with fully unpolarised photon simulation is needed to generate the response in Polarisation Fraction space. Therefore the response file should contain the following FITS extensions. The preferred filename extension for the file is `.prsp`.

- An extension containing input energy bounds (`INEBOUNDS`)
- An extension containing input polarisation angle (`INPAVALS`)
- An extension containing the angle bounds on scattering angle (`SABOUNDS`)
- An extension containing the nE $\times$ nPA $\times$ nSA matrix with 100% polarised photon simulations (`SPECRESP POLMATRIX`)
- An extension containing the nE $\times$ nSA matrix for unpolarised photon simulations (`SPECRESP UNPOLMATRIX`)

3.1 The INEBOUNDS extension

The INEBOUNDS extension lists the energy bounds on the input energy. The headers and data format for this extension are given below.

3.1.1 Extension header

The extension header should contain the following standard keywords defined in the OGIP format:

- `EXTNAME` (= `'INEBOUNDS'`) - the name (*ie* type) of the extension.
- `TELESCOP` - the "telescope" (*ie* mission/satellite name).
- `INSTRUME` - the instrument/detector.

In addition to this, it should have the following headers:

- `EBINS` - Total no. of input energy bins.

3.1.2 Extension data

The extension data should be a BINTABLE with the following columns and data types:

1. E_{low}, a 4-byte REAL scalar for each row containing the lower energy bound of the input energy bin.
   The FITS column name is `ENERG_LO`.
   The recommended units are keV.

2. E_{high}, a 4-byte REAL scalar for each row containing the upper energy bound of the input energy bin.
   The FITS column name is `ENERG_HI`.
   The recommended units are keV.

3.2 The INPAVALS extension

The INPAVALS extension lists the input polarisation angle values for 100% polarised photons. Note that it is the responsibility of the individual mission to define a local reference frame for the polarisation angles and give that to 3ML for analysis. The header and data format for this extension are given below

3.2.1 Extension header

The extension header should contain the following standard keywords defined in the OGIP format:

- `EXTNAME` (= `'INPAVALS'`) - the name (*ie* type) of the extension.
- `TELESCOP` - the "telescope" (*ie* mission/satellite name).
- `INSTRUME` - the instrument/detector.

In addition to this, it should have the following headers:

- `PABINS` - Total no. of input polarisation angle bins.

3.2.2 Extension data

The extension data should be a BINTABLE with the following columns and data types:

1. PA_{in}, a 4-byte REAL scalar for each row containing the input polarisation angle value.
   The FITS column name is `PA_IN`.
   The recommended units are deg.

3.3 The SABOUNDS extension

The SABOUNDS extension lists the scattering angle bounds on the output scattering angle bin. The headers and data format for this extension are given below.

3.3.1 Extension header

The extension header should contain the following standard keywords defined in the OGIP format:

- `EXTNAME` (= `'SABOUNDS'`) - the name (*ie* type) of the extension.
- `TELESCOP` - the "telescope" (*ie* mission/satellite name).
- `INSTRUME` - the instrument/detector.

In addition to this, it should have the following headers:

- `SABINS` - Total no. of output scattering angle bins.

3.3.2 Extension data

The extension data should be a BINTABLE with the following columns and data types:

1. $SABin$, a 2-byte INTEGER scalar represeting each scattering bin value. The binning should represent highest possible resolution.
   The FITS column name is `SABIN`.
   (unitless)
2. SA_{min}, a 4-byte REAL scalar for each row containing the lower angle bound of the scattering angle bin.
   The FITS column name is `SA_MIN`.
   The recommended units are deg.
3. SA_{max}, a 4-byte REAL scalar for each row containing the upper angle bound of the scattering angle bin.
   The FITS column name is `SA_MAX`.
   The recommended units are deg.

3.4 The SPECRESP POLMATRIX extension

The SPECRESP POLMATRIX extension stores the polarisation response for the PA and energy values given in the above two extensions. The header and data format for this extension are given below

3.4.1 Extension header

The extension header should contain the following standard keywords defined in the OGIP format:

- `EXTNAME` (= `'SPECRESP POLMATRIX'`) - the name (*ie* type) of the extension. The SPECRESP is important as this specifies that the values in the matrix are normalised to the effective area in units of cm^2.
- `TELESCOP` - the "telescope" (*ie* mission/satellite name).
- `INSTRUME` - the instrument/detector.

In addition to this, it should have the following headers:

- `EMIN` - The minimum detected energy used to generate the matrix. The preferred units are keV.
- `EMAX` - The maximum detected energy used to generate the matrix. The preferred units are keV.

3.4.2 Extension data

The extension data should be an IMAGE with dimensions nE $\times$ nPA $\times$ nSA. The data should be a 4-byte REAL scalar. The recommended units are cm^2.

3.5 The SPECRESP UNPOLMATRIX extension

The SPECRESP UNPOLMATRIX extension stores the polarisation response for the PA and energy values given in the above two extensions. The header and data format for this extension are given below

3.5.1 Extension header

The extension header should contain the following standard keywords defined in the OGIP format:

- `EXTNAME` (= `'SPECRESP UNPOLMATRIX'`) - the name (*ie* type) of the extension. The SPECRESP is important as this specifies that the values in the matrix are normalised to the effective area in units of cm^2.
- `TELESCOP` - the "telescope" (*ie* mission/satellite name).
- `INSTRUME` - the instrument/detector.

In addition to this, it should have the following headers:

- `EMIN` - The minimum detected energy used to generate the matrix. The preferred units are keV.
- `EMAX` - The maximum detected energy used to generate the matrix. The preferred units are keV.

3.5.2 Extension data

The extension data should be an IMAGE with dimensions nE $\times$ nSA. The data should be a 4-byte REAL scalar. The recommended units are cm^2.