

**spi\_obs\_sim**

# **User Manual**

**Version 1.2.0**  
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#### Note to the user

This software has been written to analyse data of the SPI telescope onboard INTEGRAL. Particular care has been taken in making the software user friendly and well documented. If you appreciated this effort, and if this software and User Manual were useful for your scientific work, the author would appreciate a corresponding acknowledgment in your published work.

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## 1 Introduction

The executable `spi_obs_sim` is part of the SPI imaging analysis software component (IA). It allows to simulate an observation, based on a gamma-ray sky model plus an instrumental background model. The gamma-ray sky model may be either provided as intensity map or as SPI data-space model, produced using the task `spi_obs_response`.

`spi_obs_sim` is written in the ANSI C++ language and has been developed under ISDC support platform 6.3. It requires `spi_toolslib` version 4.2.0 or higher.

## 2 Getting started

Before installing `spi_obs_sim`, make sure that the ISDC support platform 6.3 or higher is installed on your system, and that you have installed the library `spi_toolslib` version 4.2.0 or higher.

After downloading the `spi_obs_sim.tar.gz` file, step into a directory that should hold the distribution, move the `spi_obs_sim.tar.gz` file into this directory and type after the UNIX prompt `$` (don't type this prompt):

```
$ gunzip spi_obs_sim.tar.gz
$ tar xvf spi_obs_sim.tar
```

The first command uncompresses the distribution file, the second unpacks the files.

Before configuration, the distribution needs to be reset to a clean state. To do this, type

```
$ make distclean
```

Then, configure the distribution. It is assumed here that you have previously installed the ISDC support platform, thus you should type

```
$ ~/bin/ac_stuff/configure
```

Finally, build the distribution by typing

```
$ make global_install
```

To perform a unit test, type

```
$ make test
```

### 3 Parameter file

```
#####
#
#           Centre d'Etude Spatiale des Rayonnements           #
#           (in collaboration with ISDC)                       #
#
#           SPI observation simulation                          #
#
# -----#
#
# File:      spi_obs_sim.par                                   #
# Version:   1.0.0                                           #
# Component: IA                                              #
#
# Author:    Juergen Knoedlseder                             #
#            knodlseder@cesr.fr                             #
#            CESR                                            #
#
# Purpose:   Parameter file for the SPI observation simulation #
#
# History:   1.0.0 26-Feb-2003 First ISDC delivery          #
#
#####
#
# The input DOLs/filenames
#=====
ingrpDOL, s,q,      "og_spi.fits",,, "Input Observation Group DOL or filename"
inebdsDOL,s,q,     "",,, "Energy boundary DOL or filename"
inpntDOL, s,q,     "",,, "Pointing DOL or filename"
ingtiDOL, s,q,     "",,, "Good Time Interval DOL or filename"
indtiDOL, s,q,     "",,, "Deadtime DOL or filename"
inpefDOL, s,q,     "",,, "PSD Efficiency DOL or filename"
inprfDOL, s,q,     "",,, "PSD Response DOL or filename"
inbgmDOL, s,q,     "",,, "Background Model Index DOL or filename"
inspeDOL, s,q,     "",,, "Sky Model Index DOL or filename"
inirfDOL, s,q, "spi_irf_grp_0013.fits",,, "Instrument Response Index DOL or filename"
#
# The output DOLs/filenames
#=====
outgrpDOL, s,q, "og_spi.fits",,, "Output Observation Group DOL or filename"
outebdsDOL,s,q,  "ebds.fits",,, "Result Spectra Index DOL or filename"
outdspDOL, s,q,  "data.fits",,, "Result Spectra Index DOL or filename"
outpefDOL, s,q,  "pef.fits",,, "Result Spectra Index DOL or filename"
outprfDOL, s,q,  "prf.fits",,, "Result Spectra Index DOL or filename"
outidxDOL, s,q, "bgm_idx.fits",,, "Result Spectra filename"
outbgmDOL, s,q,  "bgm.fits",,, "Result Spectra filename"
#
# Task parameters
#=====
skymapDOL,  s,q, "map.fits[0]",,, "Sky-map to convolve"
skymapEmin, r,q,  "1809.0",,, "Sky-map energy band minimum (keV)"
skymapEmax, r,q,  "1809.0",,, "Sky-map energy band maximum (keV)"
```

```

skymapScale, r,q,      "1.0",,, "Sky-map scaling factor"
dataSpaceEmin,r,q,    "1804.0",,, "Data-space energy band minimum (keV)"
dataSpaceEmax,r,q,    "1814.0",,, "Data-space energy band maximum (keV)"
selDataSpace, b,h,    yes,,, "Store only selected energy bins ?"
sumDataSpace, b,h,    yes,,, "Sum energy bins ?"
ranRepeat,   b,h,     no,,, "Repeatable random number generator ?"
#
# Response parameters
#=====
srcGamma,   r,h,     "2.0",,, "Power-law E^-gamma exponent gamma"
rspIntdlogE,r,h,    "0.03",,, "Response interpolation log10 step size"
#
# Standard parameters
#=====
clobber,b,h,yes,,, "Overwrite existing output data ?"
verbose,i,h,3,0,3, "Information logging level"

```

Instead of specifying complete DOLs (Data Object Locations), which are composed of a filename plus the data structure extension (HDU), `spi_obs_sim` accepts also simple filenames and adds the appropriate data structure extensions. This means that **specified data structure extensions are ignored**. The only exception is the `skymapDOL` parameter which needs an extension to specify which image should be loaded from the FITS file.

The parameters have the following meaning:

- `ingrpDOL` (optional) specifies the DOL or filename of the input Observation Group (HDU [GROUPING]) for which a response model should be derived. The input group has to be of level `BIN_I`.  
If an output Observation Group has been specified (parameter `outgrpDOL`), the specification of this parameter is optional. If the parameter is left blank, the output Observation Group will then be used as input Observation Group. Otherwise, the input Observation Group will be copied into the output Observation Group.
- `inebdsDOL` (optional) specifies the DOL or filename of an energy boundary definition (HDU [SPI.-EBDS-SET]). This data structure specifies the energy boundaries of the binned data.  
If a [SPI.-EBDS-SET] element exists already in the input Observation Group, this element will be replaced by the specified DOL in the output Observation Group. Otherwise, the specified DOL will be attached to the output Observation Group. If left blank, it is assumed that a [SPI.-EBDS-SET] element exists already in the input Observation Group. If no such element is found, however, the task execution is aborted with an error message.
- `inpntDOL` (optional) specifies the DOL or filename of a Pointing definition (HDU [SPI.-OBS.-PNT]). This data structure specifies the SPI pointings during data taking.  
If a [SPI.-OBS.-PNT] element exists already in the input Observation Group, this element will be replaced by the specified DOL in the output Observation Group. Otherwise, the specified DOL will be attached to the output Observation Group. If left blank, it is assumed that a [SPI.-OBS.-PNT] element exists already in the input Observation Group. If no such element is found, however, the task execution is aborted with an error message.
- `ingtiDOL` (optional) specifies the DOL or filename of a Good Time Interval definition (HDU [SPI.-OBS.-GTI]). This data structure specifies the time intervals that have been used for data taking.  
If a [SPI.-OBS.-GTI] element exists already in the input Observation Group, this element will be replaced by the specified DOL in the output Observation Group. Otherwise, the specified DOL will

be attached to the output Observation Group. If left blank, it is assumed that a `[SPI.-OBS.-GTI]` element exists already in the input Observation Group. If no such element is found, however, the task execution is aborted with an error message.

- `indtiDOL` (optional) specifies the DOL or filename of a Deadtime data structure (HDU `[SPI.-OBS.-DTI]`). This data structure contains the livetime and the deadtime ratio for the binned data.

If a `[SPI.-OBS.-DTI]` element exists already in the input Observation Group, this element will be replaced by the specified DOL in the output Observation Group. Otherwise, the specified DOL will be attached to the output Observation Group. If left blank, it is assumed that a `[SPI.-OBS.-DTI]` element exists already in the input Observation Group. If no such element is found, however, the task execution is aborted with an error message.

- `inpefDOL` (optional) specifies the DOL or filename of a PSD efficiency data structure (HDU `[SPI.-OBS.-PEF]`). This data structure contains the PSD efficiencies for the binned data.

If a `[SPI.-OBS.-PEF]` element exists already in the input Observation Group, this element will be replaced by the specified DOL in the output Observation Group. Otherwise, the specified DOL will be attached to the output Observation Group. If left blank, it is assumed that a `[SPI.-OBS.-PEF]` element exists already in the input Observation Group. If no such element is found, however, the task execution is aborted with an error message.

- `inprfDOL` (optional) specifies the DOL or filename of a PSD response data structure (HDU `[SPI.-OBS.-PRF]`). This data structure contains the PSD response for the binned data.

If a `[SPI.-OBS.-PRF]` element exists already in the input Observation Group, this element will be replaced by the specified DOL in the output Observation Group. Otherwise, the specified DOL will be attached to the output Observation Group. If left blank, it is assumed that a `[SPI.-OBS.-PRF]` element exists already in the input Observation Group. If no such element is found, however, the task execution is aborted with an error message.

- `inbgmDOL` (optional) specifies the DOL or filename of a Background Model index (HDU `[SPI.-BMOD-DSP-IDX]`). This data structure contains pointers to the different background model components.

If a `[SPI.-BMOD-DSP-IDX]` element exists already in the input Observation Group, this element will be replaced by the specified DOL in the output Observation Group. Otherwise, the specified DOL will be attached to the output Observation Group. If left blank, it is assumed that a `[SPI.-BMOD-DSP-IDX]` element exists already in the input Observation Group. If no such element is found, however, the task execution is aborted with an error message.

- `inspeDOL` (optional) specifies the DOL or filename of a Sky Model index (HDU `[SPI.-SDET-SPE-IDX]`). This data structure contains pointers to the different sky model components.

If a `[SPI.-SDET-SPE-IDX]` element exists already in the input Observation Group, this element will be replaced by the specified DOL in the output Observation Group. Otherwise, the specified DOL will be attached to the output Observation Group. If left blank, it is assumed that a `[SPI.-SDET-SPE-IDX]` element exists already in the input Observation Group. If no such element is found, however, the task execution is aborted with an error message.

- `inirfDOL` (optional) specifies the DOL or filename of a Instrument Response Function (IRF) index (HDU `[SPI.-IRF.-RSP-IDX]`). This data structure contains an index to the response functions that should be used for response calculation. The index is only required if a skymap is provided as model for the gamma-ray intensity distribution. If a data-space model is used, the index may be omitted.

If a `[SPI.-IRF.-RSP-IDX]` element exists already in the input Observation Group, this element will be replaced by the specified DOL in the output Observation Group. Otherwise, the specified DOL will be

attached to the output Observation Group. If left blank, it is assumed that a [SPI.-IRF.-RSP-IDX] element exists already in the input Observation Group. If no such element is found, however, the task execution is aborted with an error message.

- **outgrpDOL** (optional) specifies the DOL or filename of the output Observation Group (HDU [GROUPING]). The output Observation Group will be a copy of the input Observation Group plus the resulting Response Model Index data structure [SPI.-SDET-SPE-IDX] attached.  
If an input Observation Group has been specified (parameter **ingrpDOL**), the specification of this parameter is optional. If the parameter is left blank, the input Observation Group will then be used as output Observation Group.
- **outebdsDOL** specifies the DOL or filename of the output energy boundary definition (HDU [SPI.-EBDS-SET]). After execution of the task, this data structure will contain the energy boundaries for the energy bins that have been selected from the input observation group. The data structure will be attached to the output Observation Group and will replace the data structure that has existed in the input Observation Group.
- **outdspDOL** specifies the DOL or filename of the output detector event spectra (HDU [SPI.-OBS.-DSP]). After execution of the task, this data structure will contain the simulated binned event spectra. The data structure will be attached to the output Observation Group and will replace the data structure that has existed in the input Observation Group.
- **outpefDOL** specifies the DOL or filename of the output PSD efficiencies (HDU [SPI.-OBS.-PEF]). After execution of the task, this data structure will contain the PSD efficiencies for the simulated observation. The data structure will be attached to the output Observation Group and will replace the data structure that has existed in the input Observation Group.
- **outprfDOL** specifies the DOL or filename of the output PSD response (HDU [SPI.-OBS.-PRF]). After execution of the task, this data structure will contain the PSD response for the simulated observation. The data structure will be attached to the output Observation Group and will replace the data structure that has existed in the input Observation Group.
- **outidxDOL** specifies the DOL or filename of the Background Model Index (HDU [SPI.-BMOD-DSP-IDX]). After execution of the task, this index will contain a pointer to the background model components. This index will be attached to the output Observation Group and will replace the index that has existed in the input Observation Group.
- **outbgmDOL** specifies the filename of the Background Model data structure (HDU [SPI.-BMOD-DSP]). **Note that this filename is relative to the Background Model Index (parameter outidxDOL), and that no HDU extension should be provided for this parameter.** After execution of the task, this file will contain the background model.
- **skymapDOL** (optional) specifies the DOL of the skymap that should serve as gamma-ray intensity model for the simulation. **Note that here a DOL is required.** If this parameter is left blank, a data-space model of type SPI.-SDET-SPE is expected in the input observation group and will be used as model of the intensity distribution.
- **skymapEmin** specifies the lower source photon energy boundary of the skymap in units of keV.
- **skymapEmax** specifies the upper source photon energy boundary of the skymap in units of keV. If a gamma-ray line should be simulated, the upper boundary has to be identical to the lower boundary.
- **skymapScale** specifies a scaling factor with which the input skymap will be multiplied before simulation. This allows to scale the input skymap to arbitrary flux values.
- **dataSpaceEmin** specifies the lower data-space energy boundary in units of keV. This parameter is only valid if **selDataSpace = yes** and specifies the lower limit for an interval of data-space energy bins for which the observation should be simulated.

- **dataSpaceEmax** specifies the upper data-space energy boundary in units of keV. This parameter is only valid if **selDataSpace = yes** and specifies the upper limit for an interval of data-space energy bins for which the observation should be simulated.
- **selDataSpace** specifies if the simulation should only be performed for the energy bins that overlap with the energy interval spanned by **dataSpaceEmin** and **dataSpaceEmax**. The default option is **yes** and results in a simulation for the specified energy bins.
- **sumDataSpace** specifies if the data-space energy intervals should be summed (**yes**) or not (**no**). The default option is **yes** and results in a simulation for a single data-space energy bin that is a combination of all energy bins that overlap with the energy interval spanned by **dataSpaceEmin** and **dataSpaceEmax**.
- **ranRepeat** specifies if the random number generator used for observation simulation should lead to repeatable results (**yes**) or not (**no**).
- **srcGamma** specifies the gamma-ray source power-law  $E^\gamma$  slope  $\gamma$  for response calculation of continuum sources. A default value is **srcGamma = 2.0**.
- **rspIntdlogE** specifies the number of logarithmic integration steps for response calculation of continuum sources. A default value is **rspIntdlogE = 0.03**.
- **clobber** specifies if existing output data structures should be overwritten or not. If **yes** is specified, the executable will notify the user about the deletion of any file. If **no** is specified and the executable attempts to overwrite existing data the task will exit with an error message.
- **verbose** specifies the verbose level of the executable. For **verbose=0**, no information will be logged in case of an error. For **verbose=1**, only errors will be logged, while for **verbose=2** also actions (such as DOL detachments and attachments and DOL deletion) will be logged. **verbose=3** provides a detailed report about the simulation.

## 4 Interface definition

`spi_obs_sim` creates a simulated observation group. On input it requires the following mandatory/optional HDUs

- `SPI.-EBDS-SET` (mandatory)
- `SPI.-OBS.-PNT` (mandatory)
- `SPI.-OBS.-GTI` (mandatory)
- `SPI.-OBS.-DTI` (mandatory)
- `SPI.-OBS.-PEF` (optional)
- `SPI.-OBS.-PRF` (optional)
- `SPI.-BMOD-DSP-IDX` (optional)
- `SPI.-SDET-SPE-IDX` (optional)
- `SPI.-IRF.-RSP-IDX` (optional)

On output it will create the following HDUs (existing HDUs of the same type will be replaced in the output observation group):

- SPI.-EBDS-SET
- SPI.-OBS.-DSP
- SPI.-OBS.-PEF (optional)
- SPI.-OBS.-PRF (optional)
- SPI.-BMOD-DSP-IDX

## **5 Error codes**

TBW