

## especget

April 16, 2023

### Abstract

A procedure to generate source and background spectra and the resultant ARF and RMF files for spectral fitting.

## 1 Instruments/Modes

Instrument	Mode
EPIC	IMAGING, TIMING

## 2 Use

pipeline processing	yes
interactive analysis	yes

## 3 Description

**especget** is a one-stop task which produces all the files necessary for the spectral fitting of an XMM source. The task allows the user to produce a source spectrum, background spectrum and the OGIP-compliant (spectral fitting within a single procedure).

The essential input parameters are the name of the XMM events table and a selection expression for the source and background areas, e.g. `srcexp="((DETX,DETY) IN circle(572,-635,1340))"` `backexp="((DETX,DETY) IN circle(2572,-1635,1340))"`. The minimum selection required in the source and background expressions is the spatial region, which may be specified in sky (X/Y) or detector coordinates. Other selections are defaulted as shown in Table 1. These defaults may be further restricted by including additional selections for these quantities in the input expressions, e.g. `srcexp="((DETX,DETY) IN circle(572,-635,1340))&& PATTERN==0"`. **NB:** The source and background expressions should use the same pattern and flag selections. The expressions must be compliant with the **selectlib** standard.

The metatask **especget** runs the tasks **evselect**, **arfgen** and **rmfgen**. It also calculates the size of the source and background areas, a job normally performed by the task **backscale** but here achieved by calling **arfgen** directly. For more details of the processing performed by these tasks please see their respective user documentation.

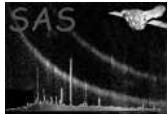


Table 1: Default event selections

Parameter	Camera	
	MOS	PN
PATTERN	0–12	0–4
FLAG	XMMEA_EM <sup>a</sup>	0

<sup>a</sup> The selection #XMMEA\_EM represents a conglomerate of flags; see **evatt**.

The end result is a set of files which can be used directly in a spectral fitting program (see section 3.3).

### 3.1 RMF options

The steps to create the spectra, calculate the box areas and create the ARF are quick but the creation of an RMF may take more than half an hour to complete. To shorten the execution time a canned matrix may be downloaded from the SOC web-site ([http://xmm.vilspa.esa.es/external/xmm\\_sw\\_cal/calib/index.shtml](http://xmm.vilspa.esa.es/external/xmm_sw_cal/calib/index.shtml)) and used in the processing by specifying parameters of the form:

```
withrmfset=yes rmfset=m1_r6_all_15.rmf
```

Advice on canned matrices is available from the SOC web-site or the document XMM-SOC-PS-TN-0043

If **withrmfset=yes** and **rmfset** is not set then the task will identify the name of the canned matrix which best suits the created source spectrum and write this name into the **RESPFILE** keyword in the header of the source spectrum (see 5.3).

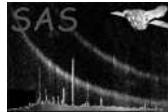
If **withrmfset=no** then **rmfgen** is executed to produce a specific RMF for the source. The **extendedsource** option tells **rmfgen** to produce a response function which is correct for an extended source, i.e. one which has been averaged over the spatial extraction region assuming a flat source flux distribution.

### 3.2 ARF options

By default, an ARF will be created which has been corrected for the area lost by the gaps between CCDs and by bad pixels. This latter correction relies on a list of bad pixels being present in the header of the eventset specified in the **table** parameter. These corrections may be turned off by specifying **withbadpixcorr=no**. The ARF generation stage can itself be turned off by setting **witharfset=no**.

If the spatial selection has been specified in sky coordinates (X/Y) then **arfgen** needs to internally convert these into detector coordinates. The default conversion uses attitude information taken from the header of the newly created spectrum. On rare occasions this can cause a problem and so the option exists, (**useodfatt=yes**), to use the raw attitude files stored in the ODF directory pointed to by the environment parameter **SAS\_ODF**.

The **extendedsource** option tells **arfgen** to produce the ARF relevant for an extended source. The distinction between the ARF needed for a point-like and extended source is rather subtle. In practice, for an extended source the ARF has no correction for encircled energy, the mirror vignetting is averaged over the whole source area and area lost due to bad pixels and chip gaps is not convolved with the Point Spread Function (PSF). All of these effects are toggled by the **extendedsource** parameter.



To calculate the effective area curve **arfgen** averages over a grid known as a detector map, which by default has five by five elements. In certain cases, such as a narrow annulus or large complicated region, this is insufficient to sample the region and can result in a null ARF or BACKSCAL value being returned. To avoid this the number of bins may be specified on the command line using the parameters **detxbins** and **detybins**.

See the **arfgen** documentation for further details.

### 3.3 Header keywords

The task writes the names of the created files into the source spectrum header keywords, BACKFILE, RESPFILE, ANCRFILE. These may be automatically read by spectral fitting programs to link the files and perform area weighted background subtraction, e.g. for **xspec**.

```
XSPEC>data myagn_src.ds
Net count rate (cts/s) for file 1 5.049 +/- 2.6091E-02( 98.5% total)
  using response (RMF) file... myagn_src.rmf
  using auxiliary (ARF) file... myagn_src.arf
  using background file... myagn_bgd.ds
  1 data set is in use
XSPEC>
```

### 3.4 Examples

#### 3.4.1 A point source

```
especget filestem=myagn srcexp="((DET,DETY) IN circle(572,-635,800))"
backexp="((DET,DETY) IN annulus(572,-635,1600,3200))"
table=P0129360201M1S004MIEVLI0000.FIT
```

This command line produces the files **myagn\_src.ds**, **myagn\_bgd.ds**, **myagn\_src.arf**, **myagn\_src.rmf**.

The command will take quite a while to run because of the RMF generation stage . A PN observation processed with this command will take roughly twice as long as a MOS observation.

#### 3.4.2 Setting the names of output files individually

It is possible to set the names of the output files separately without using the **filestem** keyword by:

```
especget srcspecset=agrb.pi bckspecset=cleansky.pi srcarfset=agrb_arf.ds srcrmfset=agrb_rmf.ds
srcexp="((X,Y) IN circle(25572,-24635,1200))"
backexp="((X,Y) IN circle(23000,-28000,1340))"
table=P0129360201PNS020PIEVL0000.FIT
```



### 3.4.3 Using a pre-prepared matrix

```
especget filestem=myagn srcexp="((X,Y) IN circle(25572,24635,1200))"  
backexp="((X,Y) IN circle(23000,28000,1340))"  
table=P0129360201PNS020PIEVL10000.FIT withrmfset=yes  
rmfset=epn_ef20_sdY9.rmf
```

This command tells the task that the canned matrix *epn\_ef20\_sdY9.rmf* will be used for spectral fitting. The task should finish within a few minutes. NB: If *rmfset* is not defined then **especget** will set the name to that of the relevant canned matrix.

### 3.4.4 Defining the patterns and flags to use

```
especget filestem=myagn withrmfset=yes rmfset=epn_ef20_sdY9.rmf  
srcexp="FLAG==0&&PATTERN==0&&((DETX,DETY) IN circle(572,-635,1340))"  
backexp="FLAG==0&&PATTERN==0&&((DETX,DETY) IN annulus(572,-635,1600,3000))"  
table=P0129360201M1S004MIEVL10000.FIT:EVENTS
```

This will create source and background spectra from events with a pattern of zero and having *FLAG*=0. Restricting the pattern range to 0 can be useful when the source is piled up.

### 3.4.5 Specifying a complex region

If the extraction region(s) contain include and exclude areas then parameters should be added to explicitly tell the tasks where the source centre is.

```
especget filestem=myagn srcexp="((X,Y) IN circle(25572,23635,800)  
&&!((X,Y) IN circle(15572,16535,700) &&!((X,Y) IN circle(20342,22235,1200))"  
backexp="((X,Y) IN annulus(25572,23635,1600,3200))"  
table=P0129360201M1S004MIEVL10000.FIT  
withsourcepos=true sourcecoords=pos sourcex=25572 sourcey=23635
```

### 3.4.6 Analysing an extended source

```
especget filestem=myagn srcexp="((X,Y) IN circle(25572,24635,4340))"  
backexp="((DETX,DETY) IN annulus(25572,24635,4340,6500))"  
table=P0129360201M1S004MIEVL10000.FIT:EVENTS extendedsource=yes
```

The *extendedsource* option tells **arfgen** to produce the ARF relevant for an extended source.

## 4 Final preparation for spectral fits

If the source has sufficient counts it should be rebinned to allow the gaussian statistics used in fitting software to be applied correctly. An example using the **GRPPHA** program could be:



```
> grppha myagn_src.ds myagn_src_grp.ds
GRPPHA[] group min 20
GRPPHA[] exit
..... exiting, changes written to file : myagn_src_grp.ds
** grppha 2.9.0 completed successfully
>
```

## 5 Parameters

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

Parameter	Mand	Type	Default	Constraints
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<b>withfilestem</b>	no	boolean	yes	
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Whether to specify the output file names using the `filestem` parameter.

<b>filestem</b>	no	string	myfiles	
-----------------	----	--------	---------	--

Stem for the output filenames. A value "myfiles" will produce the files, *myfiles\_src.ds*, *myfiles\_bgd.ds*, *myfiles\_src.arf*, *myfiles\_src.rmf*

<b>srcspecset</b>	no	string	srcspec.ds	
-------------------	----	--------	------------	--

Name of the output source spectrum. This is only used if `withfilestem` is false in which case it becomes mandatory.

<b>bckspecset</b>	no	string	bckspec.ds	
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Name of the output background spectrum. Only used if `withfilestem` is false in which case it becomes mandatory.

<b>srcarfset</b>	no	string	srcspec.arf	
------------------	----	--------	-------------	--

Name of the output effective area file (ARF). This is only used if `withfilestem` is false and `witharfset` is true.

<b>srcrmfset</b>	no	string	srcspec.rmf	
------------------	----	--------	-------------	--

Name of the output redistribution matrix (RMF). This is only used if `withfilestem` is false and `withrmfset` is false.

<b>srcexp</b>	yes	string		
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Expression for extracting the source events.

<b>backexp</b>	yes	string		
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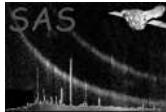
Expression for extracting the background events.

<b>table</b>	yes	table specifier		event list table specifier
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A table specifier which must point to an event list table in a data set. It must be in either of the forms `setname` or `setname:tableid` where `setname` must be the name of an existing data set and `tableid` the name of a table in the specified data set. If the first form, `setname`, is used, the event data are sought in the *first* block of the named data set.

<b>withbadpixcorr</b>	no	boolean	yes	
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Whether to use bad pixels and chip gaps in the ARF calculation.



<b>useodfatt</b>	no	boolean	no	
------------------	----	---------	----	--

Whether to use the ODF attitude file to construct position info when calculating the ARF.

<b>extendedsource</b>	no	boolean	no	
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If set **true** then **arfgen** is run with parameters which are relevant to an extended source.

<b>detxbins</b>	no	int	5	
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The number of x bins in the detector map.

<b>detybins</b>	no	int	5	
-----------------	----	-----	---	--

The number of y bins in the detector map.

<b>withsourcepos</b>	no	boolean	false	none
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If **true**, the source position must be specified via the parameters **sourcecoords**, **sourcex**, **sourcey**. Otherwise, the source position is taken from the centre of the source region defined in the data subspace of the input spectrum.

<b>sourcecoords</b>	no	choice	eqpos	eqpos pos tel det
---------------------	----	--------	-------	-------------------

Used if **withsourcepos** = **true**. The coordinate system for which the source position, specified by the parameter **sourcex** and **sourcey**, is defined. If **sourcecoords** is set to **eqpos**, then **sourcex**, **sourcey** correspond to RA and DEC respectively in decimal degrees. If **sourcecoords** = **pos**, then **sourcex**, **sourcey** correspond to POS coordinates. (Note that the POS coordinates are defined relative to a nominal pointing position; this is taken from the global attributes **REFXCRVL** and **REFYCRVL** of the spectrum dataset.) If **sourcecoords** = **tel**, then **sourcex**, **sourcey** correspond to the telescope coordinates theta (arcseconds) and phi (radians). If **sourcecoords** = **det**, then **sourcex**, **sourcey** are the x and y positions of the source centre, in DET coordinates.

<b>sourcex</b>	no	real	0	none
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(Used if **withsourcepos** = **true**) The x-position of source centre, in terms of the coordinate system specified in **sourcecoords**.

<b>sourcey</b>	no	real	0	none
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(Used if **withsourcepos** = **true**) The y-position of source centre, in terms of the coordinate system specified in **sourcecoords**.

<b>witharfset</b>	no	boolean	yes	
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If set **false** an ARF will not be produced by the task and the geometrical area of the source and background regions will not be calculated and written into the **BACKSCAL** keyword.

<b>withrmfset</b>	no	boolean	no	
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If set **false** an RMF is produced by running **rmfgen**. If **true** the RMF is taken from the file specified in the parameter **rmfset**.

<b>rmfset</b>	no	string		
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The name of the RMF to be used when **rmfgen** is not to be run. If this parameter is not set and **withrmfset** is **true** then the task sets the name of the RMF to be that of the appropriate canned matrix.



<b>withenergybins</b>	no	boolean	false	none
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If **true** use energy grid specified by **energymin**, **energymax**, and **nenergybins**, otherwise, use the grid defined in the CAL.

<b>energymin</b>	no	real	0	none
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Used if **withenergybins** = **true**. Lower energy bound of matrix, in keV.

<b>energymax</b>	no	real	15	none
------------------	----	------	----	------

Used if **withenergybins** = **true**. Upper energy bound of matrix, in keV.

<b>nenergybins</b>	no	integer	30	none
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Used if **withenergybins** = **true**. The number of bins in the energy grid = number of rows in RMF matrix.

<b>a0removefiles</b>	no	boolean	true	
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If **true** all created spectra and matrices are removed if the calculated ARF is 0 or negative. Set **false** to keep these files.

## 6 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.

### **InvalidExpression** (*error*)

The input expression for this spatial region was not valid.

### **invalidInstrument** (*error*)

The Epic camera description contained in the INSTRUME keyword isn't recognised

### **NoEventsTable** (*error*)

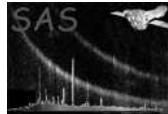
The input table didn't contain an EVENTS extension

### **ZeroEffectiveArea** (*warning*)

*corrective action:* The calculated ARF is zero or negative

## 7 Input Files

- an EPIC calibrated events list from the pipeline, the e\*proc or e\*chain tasks.
- Optionally, an EPIC RMF file, e.g. epn\_fs20\_sY0.rmf.



## 8 Output Files

- A source spectrum of name `filestem_src.ds` or `srcspecset` with the BACKSCAL, RESPFILE, ANCFILE and BACKFILE keywords set
- A background spectrum of name `filestem_bgd.ds` or `bckspecset` with the BACKSCAL keyword set
- An ARF of name `filestem_src.arf` or `srcarfset`
- Optionally, an RMF of name `filestem_src.rmf` or `srcrmfset`

## 9 Algorithm

```
Set output filenames: srcspec, bckspec, arfset, rmf_set
                  depending on values of <withfilestem> and related params.
```

```
Create a source spectrum
```

```
expression = <srcexp> + PATTERN + FLAG selections
evselect table=<table> expression=<expression>
           withspectrumset=yes spectrumset=srcspec
```

```
Create a background spectrum
```

```
expression = <backexp> + PATTERN + FLAG selections
evselect table=<table> expression=<expression>.....
           withspectrumset=yes spectrumset=bckspec
```

```
Create an ARF for the source spectrum, if requested, and calculate
the source box area
```

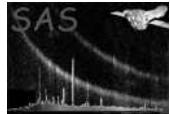
```
if <witharfset> {
  arfgen spectrumset=<srcspec> arfset=<arfset> withrmfset=<withrmfset>
           rmfset=<rmfset> extendedsource=<extendedsource>
           withbadpixcorr=<withbadpixcorr> badpixlocation=<table>
           setbackscale=yes keeparfset=<witharfset> useodfatt=<useodfatt>
```

```
Use arfgen to calculate the background box area
```

```
arfgen spectrumset=<backspec> arfset=temparf.arf setbackscale=yes
           keeparfset=no withbadpixcorr=<withbadpixcorr>
           badpixlocation=<table> useodfatt=<useodfatt>
}
```

```
Create an RMF if not supplied
```

```
if (! <withrmfset>) {
  rmfgen spectrumset=<srcspec> rmfset=rmf_set
           extendedsource=<extendedsource>
```



```
}

else if (<rmfset> has not been set) {
    rmfset = name of relevant canned matrix
}
```

Set the values of BACKFILE, RESPFILE and ANCRFILE in header of srcspec.

## 10 Comments

This task will benefit from any reduction in the execution time of rmfgen.

## References