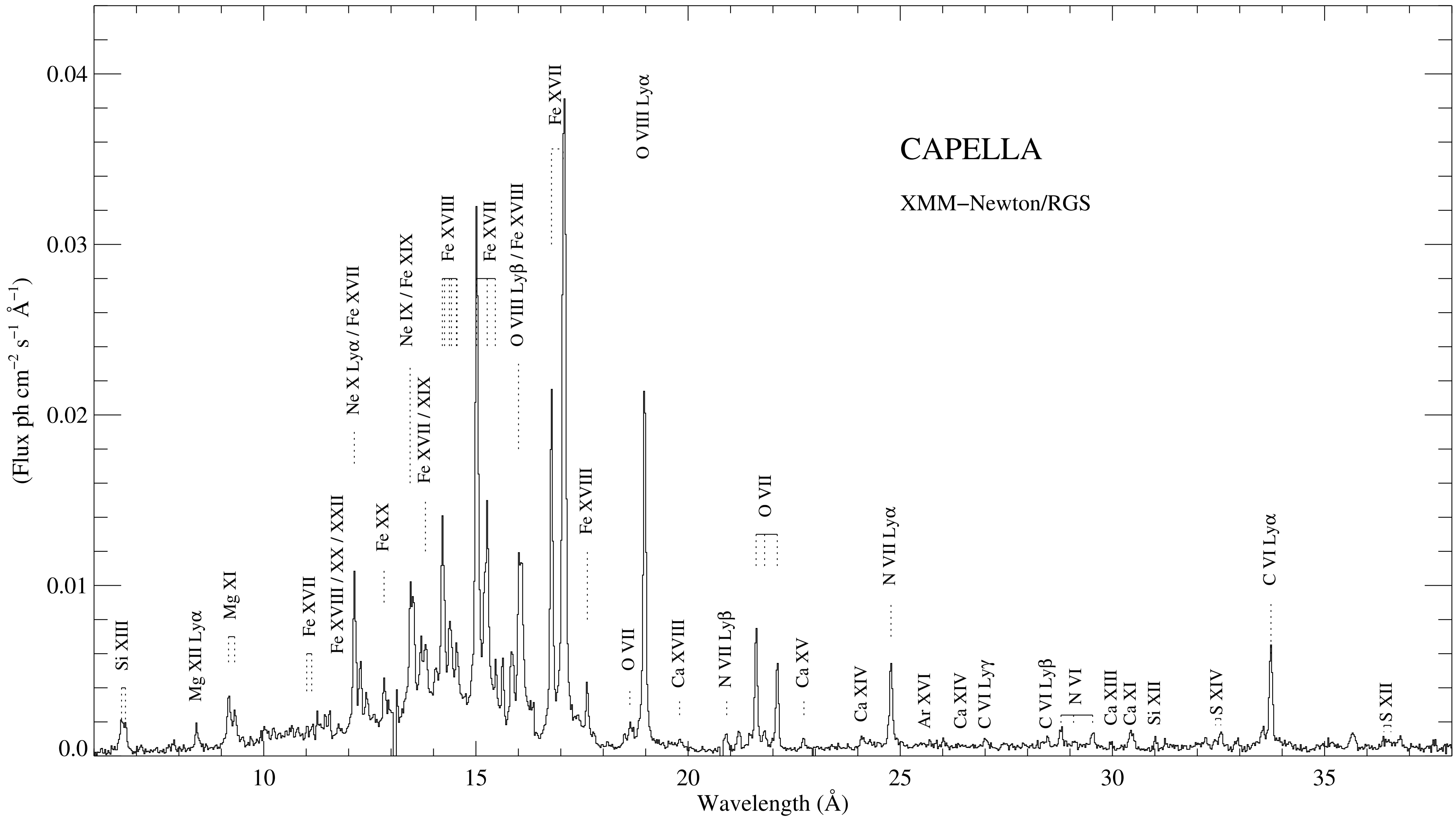
The Goal of the Reduction!



Setting Up the SAS

see previous talk by Giuseppe Vacanti (gvacanti_1)

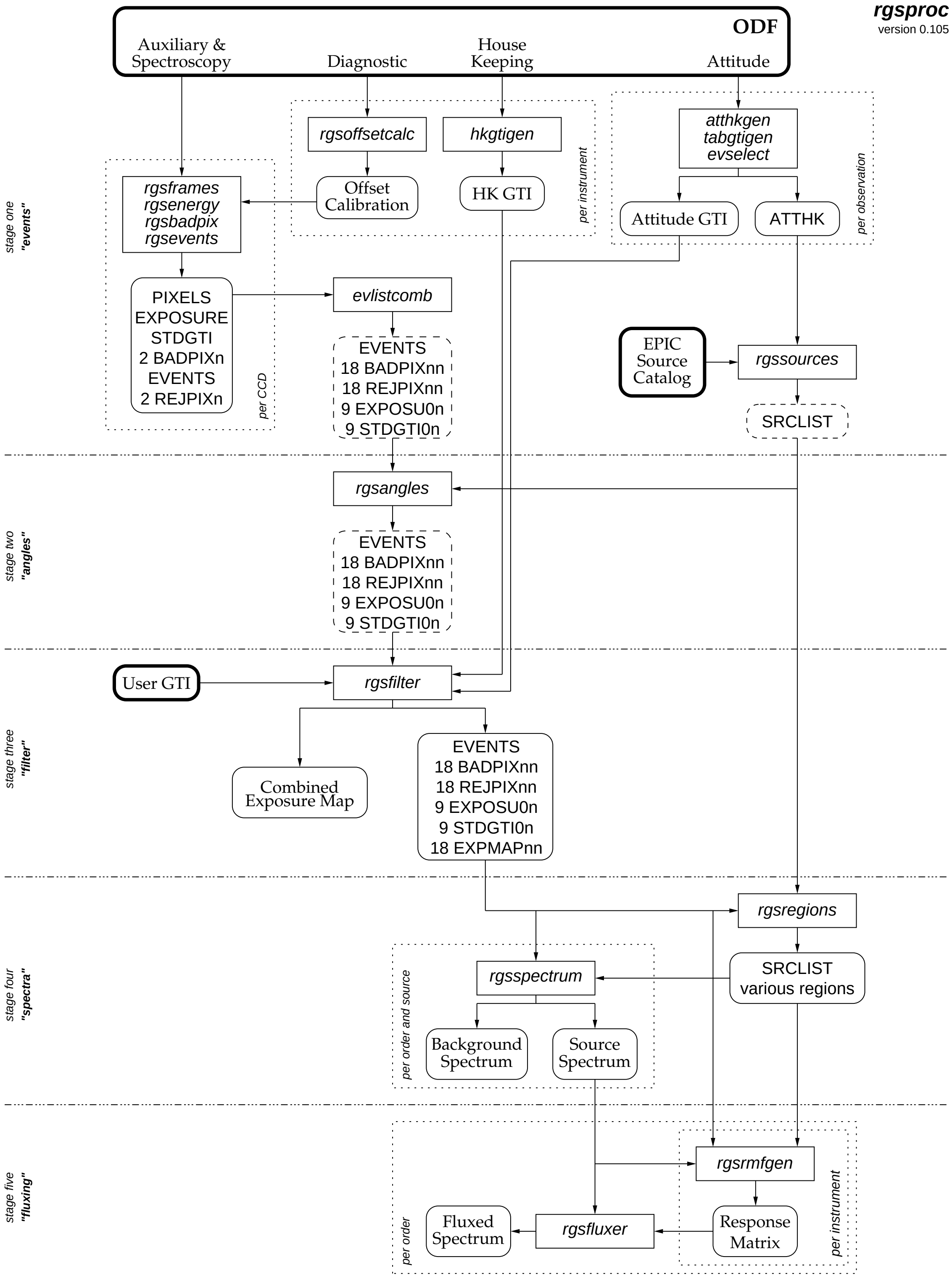
Capella data, revolution 0232, obsID 0134720101:

```
setenv SAS_ODF ./0232_0134720101_SCX00000SUM.SAS
setenv SAS_CCF ./ccf.cif
(setenv SAS_VERBOSITY 5)
```

The Metatask `rgsproc`

- Interface to $\approx$ 15 RGS tasks
- Controlled by parameter switches
- Produces clean event list and spectra (and fluxed spectra)
- Default settings produce standard outputs

Here, I will present `rgsproc` and important RGS tasks for SAS 5.2 and with the future (Jan 2002) SAS, "latest"


rgsproc
version 0.105
ODF
Auxiliary & Spectroscopy
Diagnostic
House Keeping
Attitude
rgsoffsetcalc
hkgtigen
atthkgen
tabgtigen
evselect
per instrument
per observation
stage one "events"
rgsframes
rgsenergy
rgsbadpix
rgsevents
Offset Calibration
HK GTI
Attitude GTI
ATTHK
PIXELS
EXPOSURE
STDGTI
2 BADPIXn
EVENTS
2 REJPIXn
per CCD
evlistcomb
EVENTS
18 BADPIXnn
18 REJPIXnn
9 EXPOSU0n
9 STDGTI0n
EPIC Source Catalog
rgssources
SRCLIST
stage two "angles"
rgsangles
EVENTS
18 BADPIXnn
18 REJPIXnn
9 EXPOSU0n
9 STDGTI0n
stage three "filter"
User GTI
rgsfilter
Combined Exposure Map
EVENTS
18 BADPIXnn
18 REJPIXnn
9 EXPOSU0n
9 STDGTI0n
18 EXPMAPnn
stage four "spectra"
rgsregions
rgsspectrum
SRCLIST
various regions
per order and source
Background Spectrum
Source Spectrum
stage five "fluxing"
rgsrmfgen
per instrument
Fluxed Spectrum
rgsfluxer
Response Matrix
per order

User-Defined Source

Normally, the source position is taken from the `SUM.SAS` file.

The user can however provide a new source position:

```
rgsproc withsrc=T label='Capella' srcra=79.172330 srcdec=45.997991
```

$\rightarrow$ Automatically, it becomes the *primary* source

- `rgsproc` generates two default positions: `PROPOSAL` and `ONAXIS`
- EPIC-derived sources can be added: `withepicset` and `epicset`
- Dispersion coordinates can be used instead: `srcdisp` and `srcxdsp`

File Edit Tools Help

	INDEX	LABEL	RA	DEC	RATE	DELTA_DISP	DELTA_XDSP
	I	20A	E	E	E	E	E
			degrees	degrees	cts/s	arcmin	arcmin
1	1	PROPOSAL	7.919781E+01	4.598307E+01	0.000000E+00	1.143486E+00	1.232965E+00
2	2	ONAXIS	7.917093E+01	4.600214E+01	0.000000E+00	0.000000E+00	0.000000E+00
3	3	CAPELLA	7.917233E+01	4.599799E+01	0.000000E+00	4.205556E-02	2.531585E-01

Go to: Edit cell:

File Edit Tools Help

	FOV_PHI	FOV_R	CONFUSION	PROCESS	BKG_EXCLUDE	FIXED_ON_SKY	EPIC_FILE
	E	E	E	L	L	L	J
	degrees	degrees					
1	1.296643E+02	2.669458E-02	0.000000E+00	F	F	T	NULL
2	0.000000E+00	0.000000E+00	0.000000E+00	F	F	F	NULL
3	9.844794E+01	4.265592E-03	0.000000E+00	T	T	T	NULL

Go to: Edit cell:

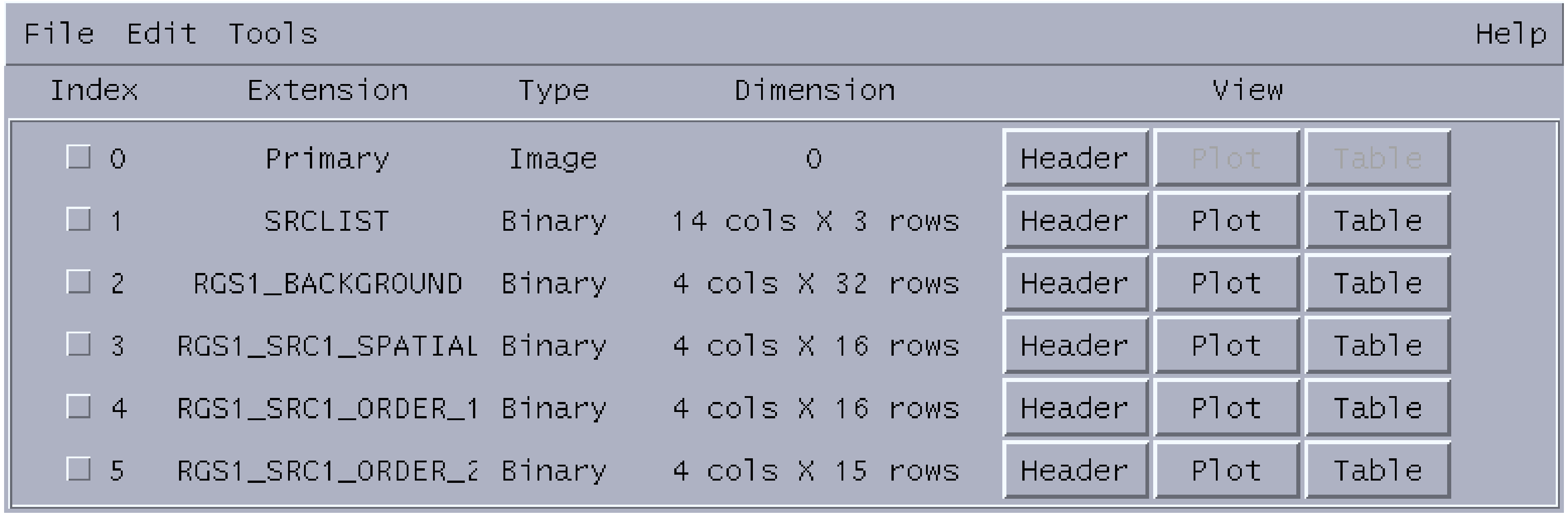
Spatial and Order Masks

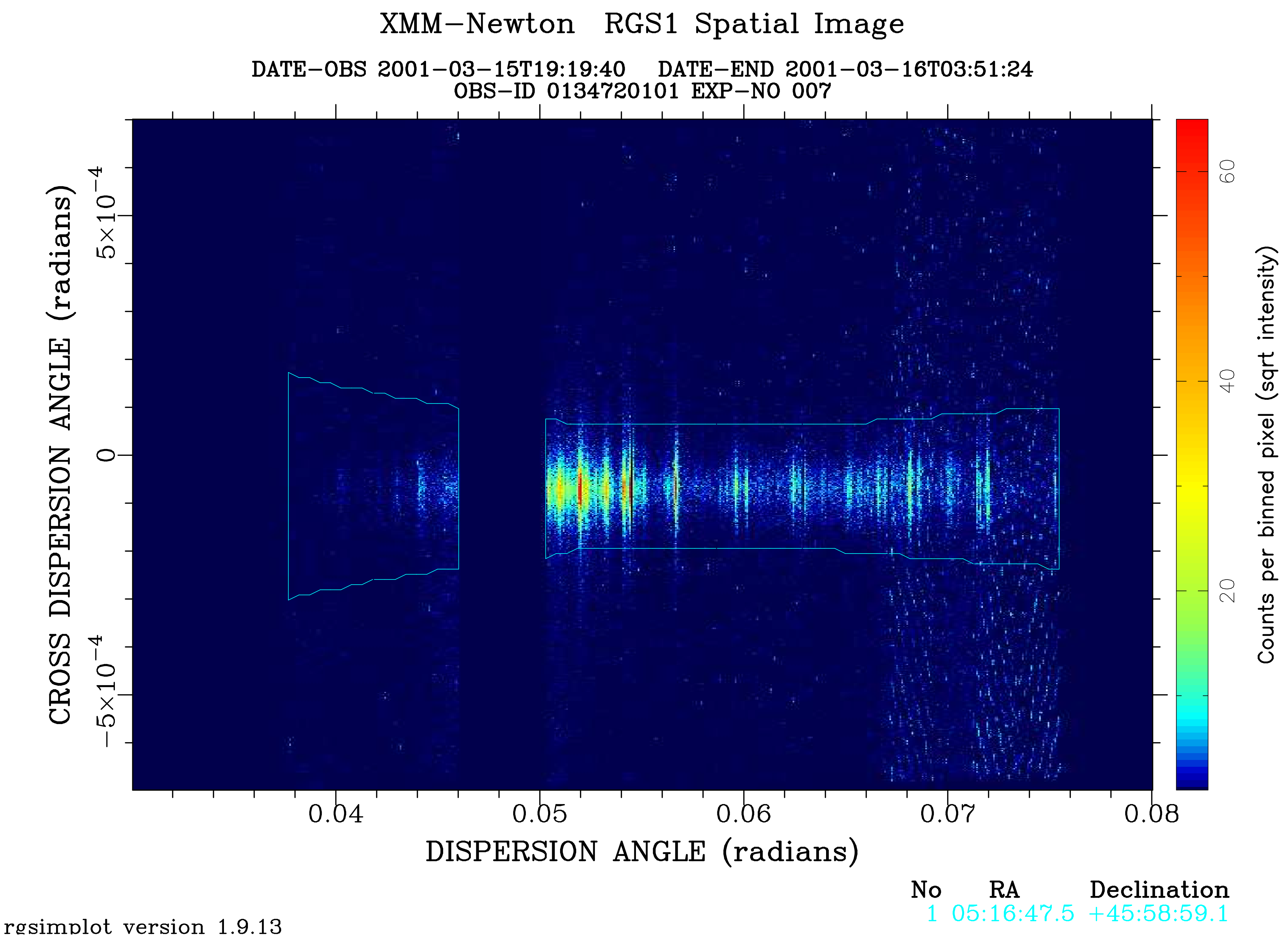
In the source file, the following default tables can be found:

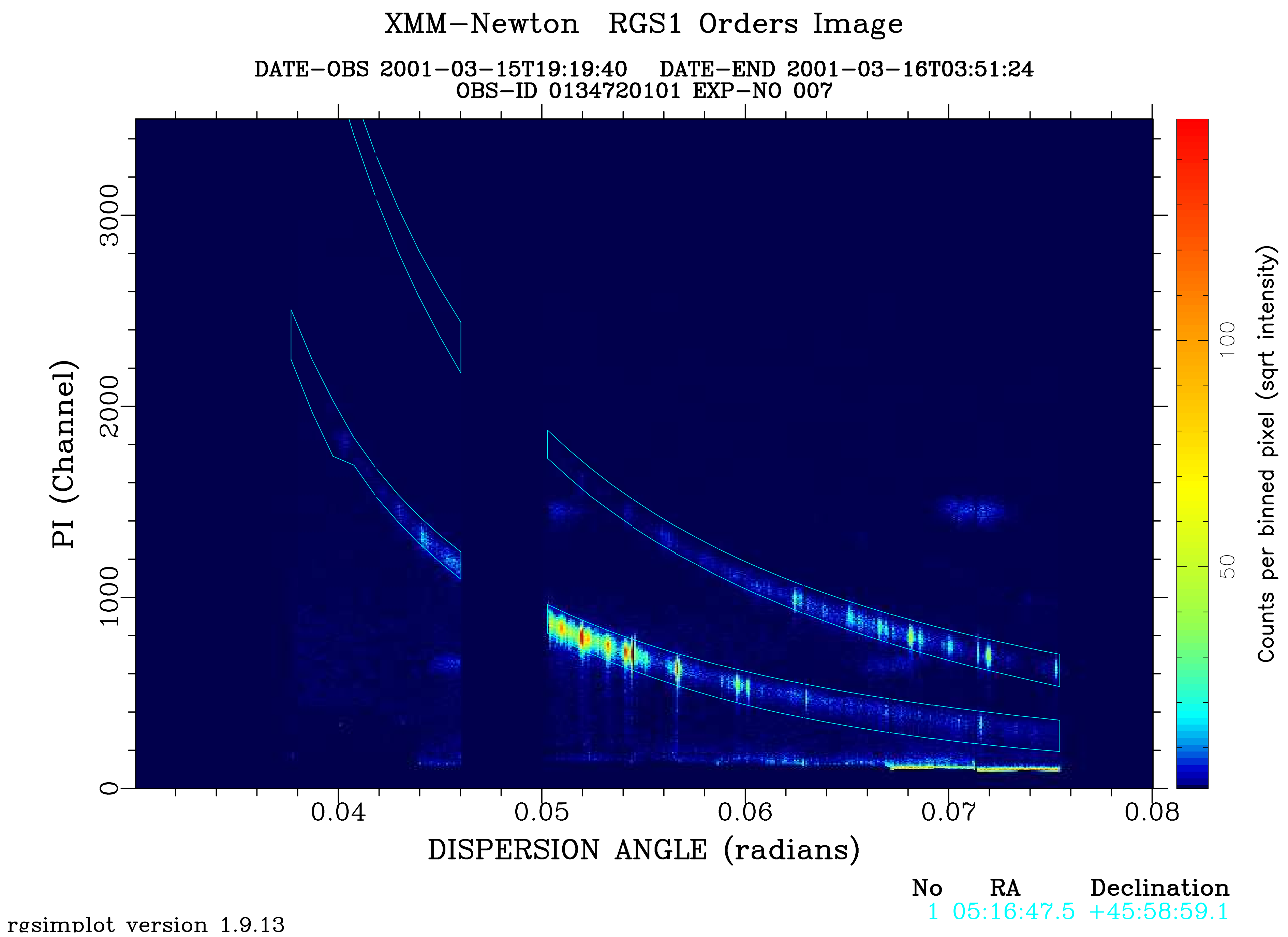
• `RGSi_SRC1_SPATIAL`:	Source spatial mask	`xpsfincl=90`
• `RGSi_BACKGROUND`:	Background spatial mask	`xpsfexcl=95`
• `RGSi_SRC1_ORDER_1`:	First order mask	`pdistincl=90`
• `RGSi_SRC1_ORDER_2`:	Second order mask	”

where `i=1,2` for RGS1 and RGS2, respectively.

It is possible to go for higher orders: `orders='1 2 3 4'`


File Edit Tools
Help
Index
Extension
Type
Dimension
View
0 Primary Image 0 Header Plot Table
1 SRCLIST Binary 14 cols X 3 rows Header Plot Table
2 RGS1_BACKGROUND Binary 4 cols X 32 rows Header Plot Table
3 RGS1_SRC1_SPATIAL Binary 4 cols X 16 rows Header Plot Table
4 RGS1_SRC1_ORDER_1 Binary 4 cols X 16 rows Header Plot Table
5 RGS1_SRC1_ORDER_2 Binary 4 cols X 15 rows Header Plot Table


XMM−Newton RGS1 Spatial Image
DATE−OBS 2001−03−15T19:19:40 DATE−END 2001−03−16T03:51:24
OBS−ID 0134720101 EXP−NO 007
CROSS DISPERSION ANGLE (radians)
5×10−4
0
−5×10−4
0.04
0.05
0.06
0.07
0.08
DISPERSION ANGLE (radians)
Counts per binned pixel (sqrt intensity)
60
40
20
No RA Declination
1 05:16:47.5 +45:58:59.1
rgsimplot version 1.9.13


XMM−Newton RGS1 Orders Image
DATE−OBS 2001−03−15T19:19:40 DATE−END 2001−03−16T03:51:24
OBS−ID 0134720101 EXP−NO 007
PI (Channel)
0
1000
2000
3000
0.04
0.05
0.06
0.07
0.08
DISPERSION ANGLE (radians)
Counts per binned pixel (sqrt intensity)
50
100
No RA Declination
1 05:16:47.5 +45:58:59.1
rgsimplot version 1.9.13

Flow Controls/Entry Stages

`instruments='RGS1 RGS2'` or `'RGS1'` or `'RGS2'`

SAS 5.2: events → spectra

`processevents processsources processexposure processregions`

"Latest": events → fluxed spectra

`entrystage finalstage`: `'events' 'angles' 'filter' 'spectra' 'fluxing'`

`expunge`: `'events'` (default) and/or `'merged'`

`withprefix=T prefix`: whatever prefix, e.g., `'MySource'`

Filenames in SAS 5.2

```
0232_0134720101_R1S00701_events.ds
0232_0134720101_R1S00702_events.ds
0232_0134720101_R1S00703_events.ds
0232_0134720101_R1S00704_events.ds
0232_0134720101_R1S00705_events.ds
0232_0134720101_R1S00706_events.ds
0232_0134720101_R1S00708_events.ds
0232_0134720101_R1S00709_events.ds
0232_0134720101_R1S00700_sources.ds
0232_0134720101_R1S00700_merged.ds
0232_0134720101_R1S00700_filtered.ds
0232_0134720101_R1S00700_expmap.ds
0232_0134720101_R1S00700_net1o1.pha
0232_0134720101_R1S00700_net1o2.pha
0232_0134720101_R1S00700_bkg1o1.pha
0232_0134720101_R1S00700_bkg1o2.pha
0232_0134720101_R2S00801_events.ds
0232_0134720101_R2S00802_events.ds
0232_0134720101_R2S00803_events.ds
0232_0134720101_R2S00805_events.ds
0232_0134720101_R2S00806_events.ds
0232_0134720101_R2S00807_events.ds
0232_0134720101_R2S00808_events.ds
0232_0134720101_R2S00809_events.ds
0232_0134720101_R2S00800_sources.ds
0232_0134720101_R2S00800_merged.ds
0232_0134720101_R2S00800_filtered.ds
0232_0134720101_R2S00800_expmap.ds
0232_0134720101_R2S00800_net1o1.pha
0232_0134720101_R2S00800_net1o2.pha
0232_0134720101_R2S00800_bkg1o1.pha
0232_0134720101_R2S00800_bkg1o2.pha
0232_0134720101_SCX00000_attitude.ds
```

Filenames in the “latest” SAS

```
P0134720101R1S007SRCLI_0000.FIT
P0134720101R1S007merged0000.FIT
P0134720101R1S007EVENLI0000.FIT
P0134720101R1S007EXPMAP0000.FIT
P0134720101R1S007SRSPEC1001.FIT
P0134720101R1S007SRSPEC2001.FIT
P0134720101R1S007BGSPEC1001.FIT
P0134720101R1S007BGSPEC2001.FIT
P0134720101R1S007matrix1001.FIT
P0134720101R1S007matrix2001.FIT
P0134720101R1X000hkgti_0000.FIT
P0134720101R2S008SRCLI_0000.FIT
P0134720101R2S008merged0000.FIT
P0134720101R2S008EVENLI0000.FIT
P0134720101R2S008EXPMAP0000.FIT
P0134720101R2S008SRSPEC1001.FIT
P0134720101R2S008SRSPEC2001.FIT
P0134720101R2S008BGSPEC1001.FIT
P0134720101R2S008BGSPEC2001.FIT
P0134720101R2S008matrix1001.FIT
P0134720101R2S008matrix2001.FIT
P0134720101R2X000hkgti_0000.FIT
P0134720101OBX000fluxed1000.FIT
P0134720101OBX000fluxed2000.FIT
P0134720101OBX000ATTTSR0000.FIT
P0134720101OBX000attgti0000.FIT
```

Validity checks

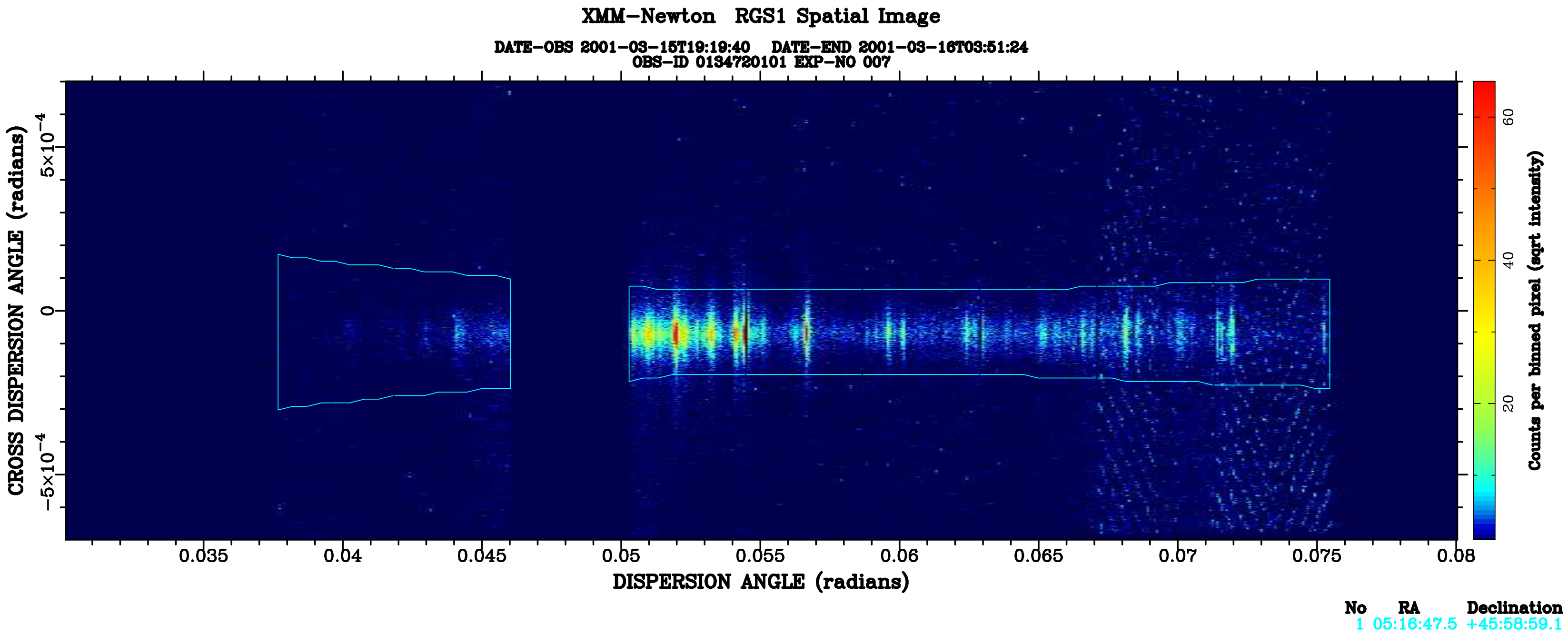
The validity of the **`rgsproc`** process should be checked,

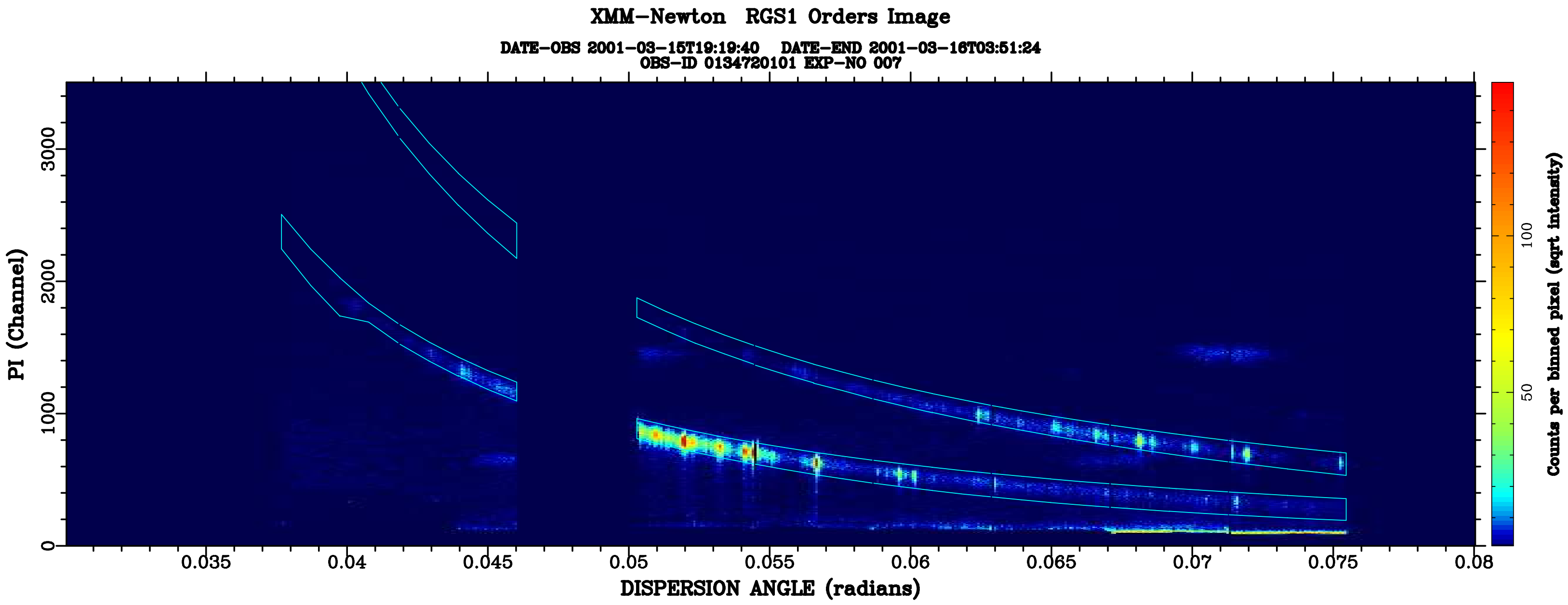
in particular, the position of spatial and order masks

- Create a spatial image: `evselect` with `xcolumn='BETA_CORR' ycolumn='XDSP_CORR'`
- Create an order image: `evselect` with `xcolumn='BETA_CORR' ycolumn='PI'`
- Use SAS task **`rgsimplot`**:

For example, in SAS 5.2:

```
rgsimplot withspatialset=T spatialset='spatial_image.fits' \
   withendispset=T endispset='order_image.fits'             \
   withspatialregionsets=T withendispregionsets=T           \
   srclistset='0232_0134720101_R1S00700_sources.ds'         \
   colourmap='SQRT' device='/XW' srcidlist='1'
```





rgsimplot version 1.9.13

Spectral File and Response Matrix Generation

SAS 5.2: `RATE` column

"Latest": `COUNT` and `AREASCAL` columns, only with `LHEASOFT 5.1`

A response matrix must be generated for each detector and each order

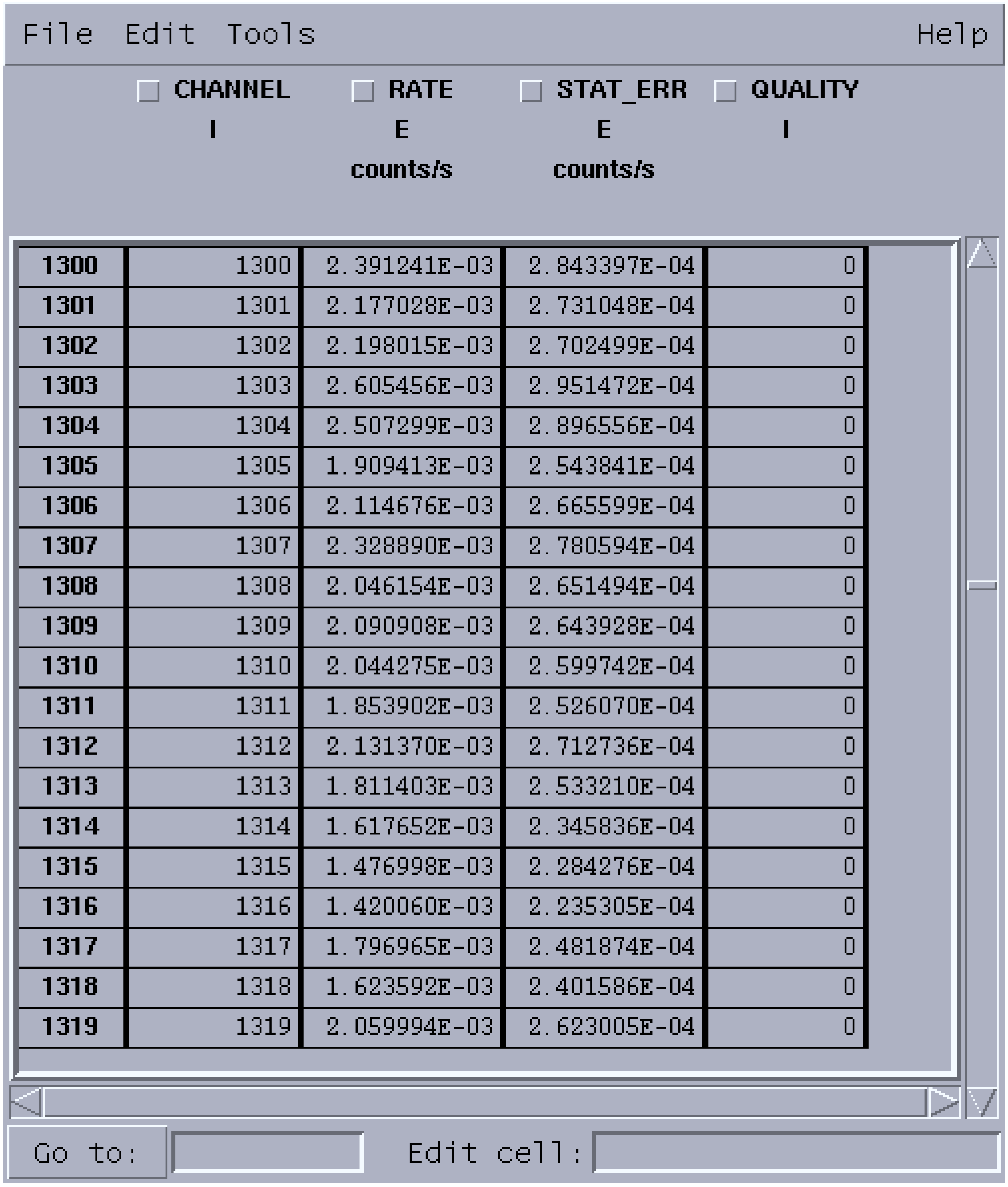
It is recommended to use at least 4000 energy bins

→ the matrices created by default with **rgsproc** in the "latest" SAS are insufficient for a quantitative analysis

For example, in SAS 5.2:

```
rgsrmfgen ebins=4000 file='r1o1src1.rmf' order=1             \
set='0232_0134720101_R1S00700_filtered.ds' withbackground=F \
sourceset='0232_0134720101_R1S00700_sources.ds' source=1    \
withspectrum=T spectrumset='0232_0134720101_R1S00700_net1o1.pha'
```

SAS 5.2: `RATE` spectrum



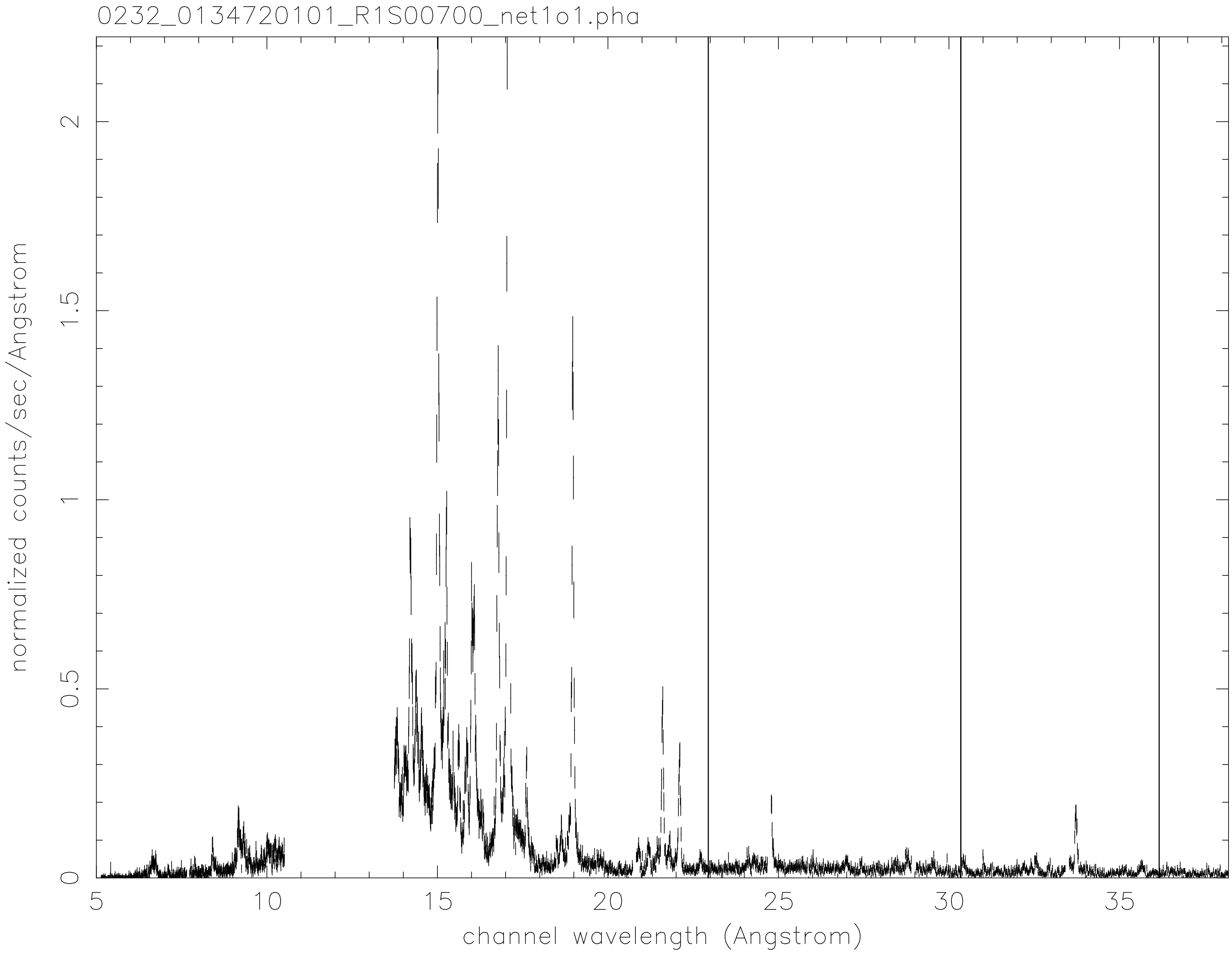
	CHANNEL I	RATE E counts/s	STAT_ERR E counts/s	QUALITY I
1300	1300	2.391241E-03	2.843397E-04	0
1301	1301	2.177028E-03	2.731048E-04	0
1302	1302	2.198015E-03	2.702499E-04	0
1303	1303	2.605456E-03	2.951472E-04	0
1304	1304	2.507299E-03	2.896556E-04	0
1305	1305	1.909413E-03	2.543841E-04	0
1306	1306	2.114676E-03	2.665599E-04	0
1307	1307	2.328890E-03	2.780594E-04	0
1308	1308	2.046154E-03	2.651494E-04	0
1309	1309	2.090908E-03	2.643928E-04	0
1310	1310	2.044275E-03	2.599742E-04	0
1311	1311	1.853902E-03	2.526070E-04	0
1312	1312	2.131370E-03	2.712736E-04	0
1313	1313	1.811403E-03	2.533210E-04	0
1314	1314	1.617652E-03	2.345836E-04	0
1315	1315	1.476998E-03	2.284276E-04	0
1316	1316	1.420060E-03	2.235305E-04	0
1317	1317	1.796965E-03	2.481874E-04	0
1318	1318	1.623592E-03	2.401586E-04	0
1319	1319	2.059994E-03	2.623005E-04	0

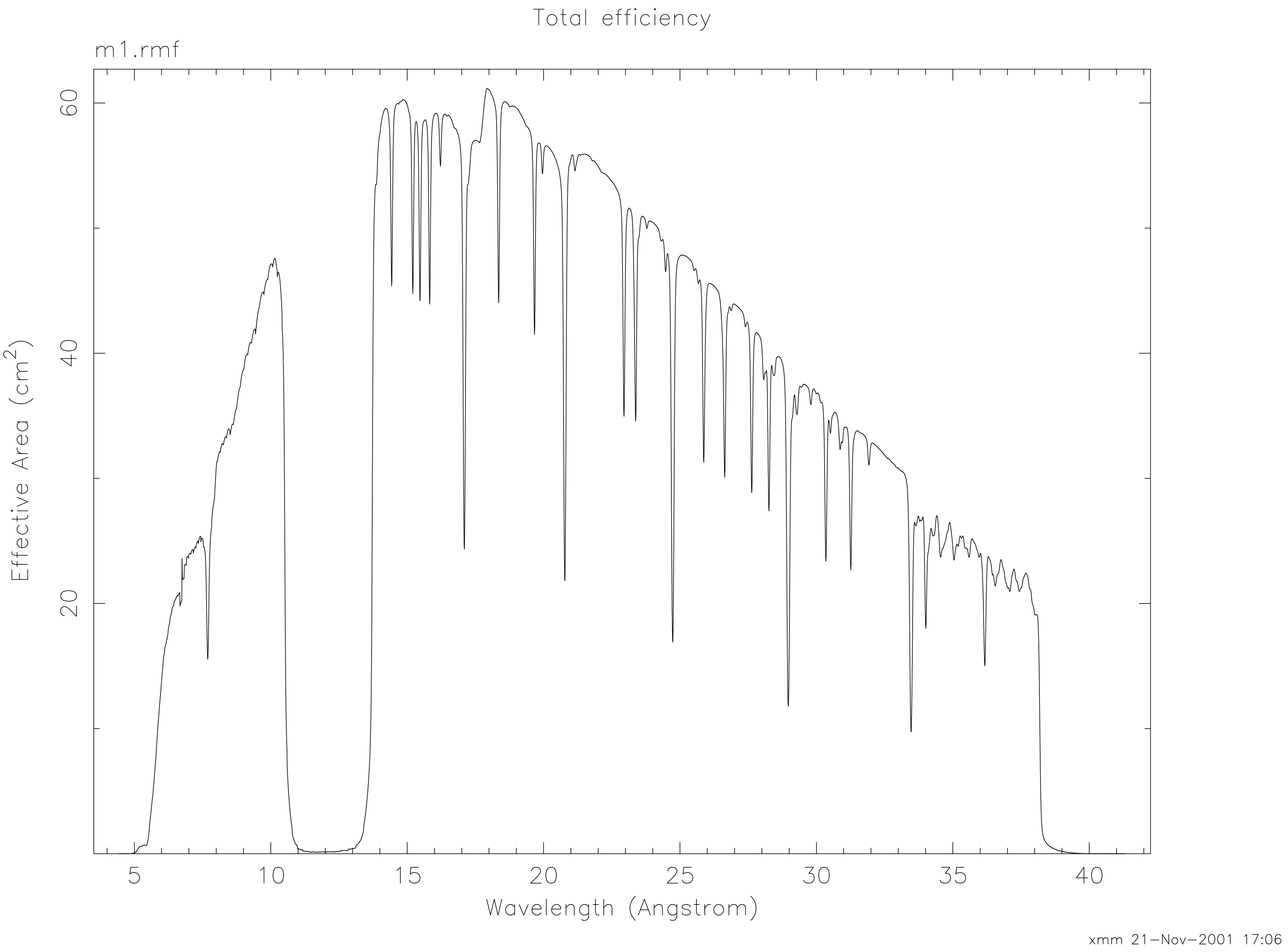
Latest SAS: COUNTS spectrum

File Edit Tools Help

	CHANNEL	COUNTS	STAT_ERR	QUALITY	AREASCAL
	J	J	E	I	E
		counts	counts		
1300	1300	167	1.331616E+01	0	9.994297E-01
1301	1301	160	1.294495E+01	0	9.994299E-01
1302	1302	160	1.290047E+01	0	9.994298E-01
1303	1303	137	1.208081E+01	0	9.994300E-01
1304	1304	152	1.263906E+01	0	9.994300E-01
1305	1305	135	1.200086E+01	0	9.994299E-01
1306	1306	133	1.196538E+01	0	9.994300E-01
1307	1307	142	1.228189E+01	0	9.994301E-01
1308	1308	131	1.177369E+01	0	9.994300E-01
1309	1309	147	1.238345E+01	0	9.994301E-01
1310	1310	145	1.230243E+01	0	9.994300E-01
1311	1311	136	1.198414E+01	0	9.994300E-01
1312	1312	144	1.241067E+01	0	9.994301E-01
1313	1313	137	1.202579E+01	0	9.994301E-01
1314	1314	122	1.137914E+01	0	9.994301E-01
1315	1315	129	1.168267E+01	0	9.994299E-01
1316	1316	118	1.121103E+01	0	9.994301E-01
1317	1317	119	1.124954E+01	0	9.994300E-01
1318	1318	131	1.188106E+01	0	9.994300E-01
1319	1319	117	1.122005E+01	0	9.994301E-01

Go to: Edit cell:


0232_0134720101_R1S00700_net1o1.pha
normalized counts/sec/Angstrom
channel wavelength (Angstrom)
0
0.5
1
1.5
2
5
10
15
20
25
30
35


Total efficiency
m1.rmf
Effective Area (cm^2)
60
40
20
5
10
15
20
25
30
35
40
Wavelength (Angstrom)
xmm 21-Nov-2001 17:06

Fluxed Spectra: Combining RGS1 and RGS2 Data

RGS1 and RGS2 data can be merged into a single "fluxed" spectrum, in units of photons $\mathrm{cm}^{-2}\ \mathrm{s}^{-1}$, by means of the task **`rgsfluxer`**

+

- full wavelength range. No gap
- calibrated spectrum → flux
- detection of faint emission lines

–

- not OGIP-compliant → no analysis in **`XSPEC`**
- Line Spread Function still in

Time-Dependent Spectroscopy

The basic idea is to apply a time selection by means of an auxiliary GTI table

rgsproc is launched at the filter stage, using the merged file as starting point

```
gtibuild file='gti.txt' table='gti.ds'

SAS 5.2:  rgsproc processevents=F processsources=F \
             processexposure=T processregions=T    \
             withauxgti=T gtitable='gti.ds'

latest:   rgsproc entrystage='filter' finalstage='fluxing' \
             auxgtitables='gti.ds'
```

Caution! Existing **filtered** event list, exposure map, and spectra are overwritten

Multiple sources

In most cases, the prime target is the only source detected in the RGS.

It is possible that a second source lies sufficiently far from the prime source in the cross-dispersion direction so that separate spectra can be obtained.

→ it must be excluded from the background of the primary source!

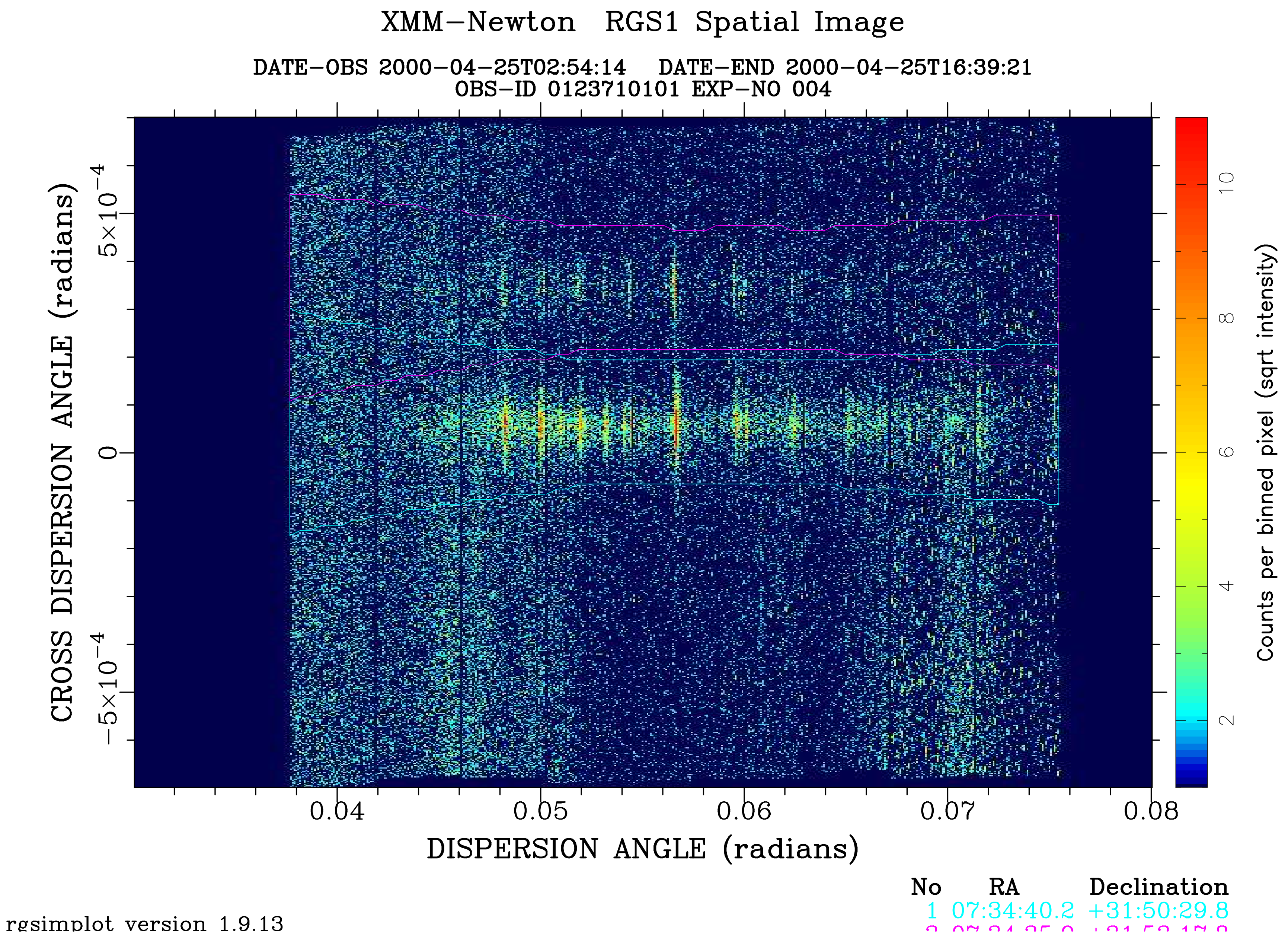
→ stop **`rgsproc`** at the filtering stage

→ give position of 2nd source with **`rgssources`**. No change of primary source

→ restart **`rgsproc`** at the regions (SAS 5.2) or spectra (latest) stage

! process spatial masks for both sources: `procsrcsexpr='INDEX==#PRIMESRC||INDEX==3'`

! exclude both sources from background: `exclsrcsexpr='INDEX==#PRIMESRC||INDEX==3'`


XMM−Newton RGS1 Spatial Image
DATE−OBS 2000−04−25T02:54:14 DATE−END 2000−04−25T16:39:21
OBS−ID 0123710101 EXP−NO 004
CROSS DISPERSION ANGLE (radians)
5×10−4
0
−5×10−4
0.04
0.05
0.06
0.07
0.08
DISPERSION ANGLE (radians)
Counts per binned pixel (sqrt intensity)
2
4
6
8
10
No RA Declination
1 07:34:40.2 +31:50:29.8
rgsimplot version 1.9.13

Summary

→ RGS data are reduced with **`rgsproc`**

→ **`rgsproc`** is controlled by parameter switches

→ Different filenames in SAS 5.2 and the future SAS release

→ Additional fluxing stage in the future SAS release

→ RGS response matrices generated with **`rgsrmfgen`**

→ Time-dependent spectroscopy available with GTI tables

→ Reduction of multiple sources marginally possible