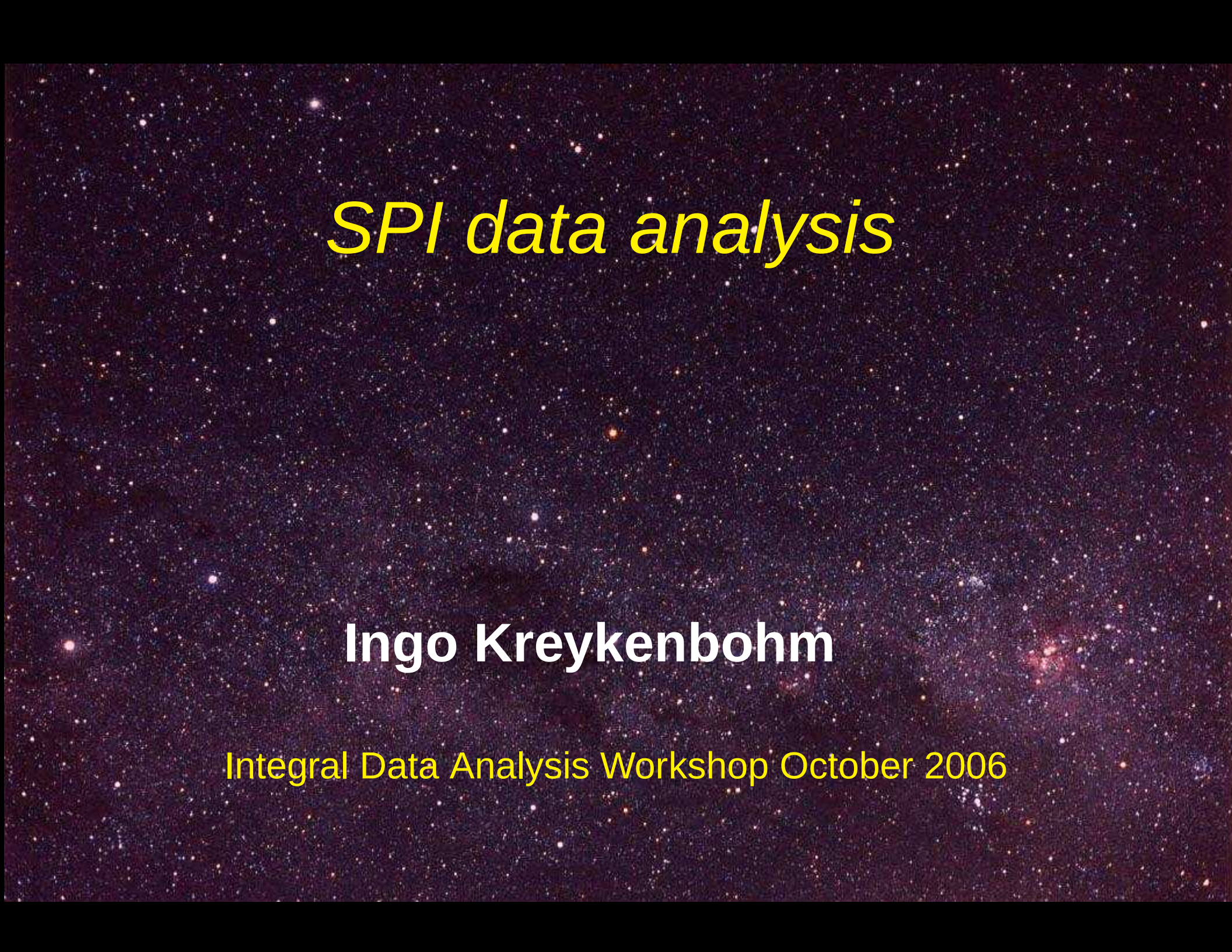
SPI data analysis
Ingo Kreykenbohm
Integral Data Analysis Workshop October 2006

Overview

- the Instrument: SPI
- Analysis steps
- Performance

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- Cookbook example: extraction of V 0332+53 data
  - Image reconstruction
  - spectral extraction
  - light curves

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- the Instrument: SPI
- Analysis steps
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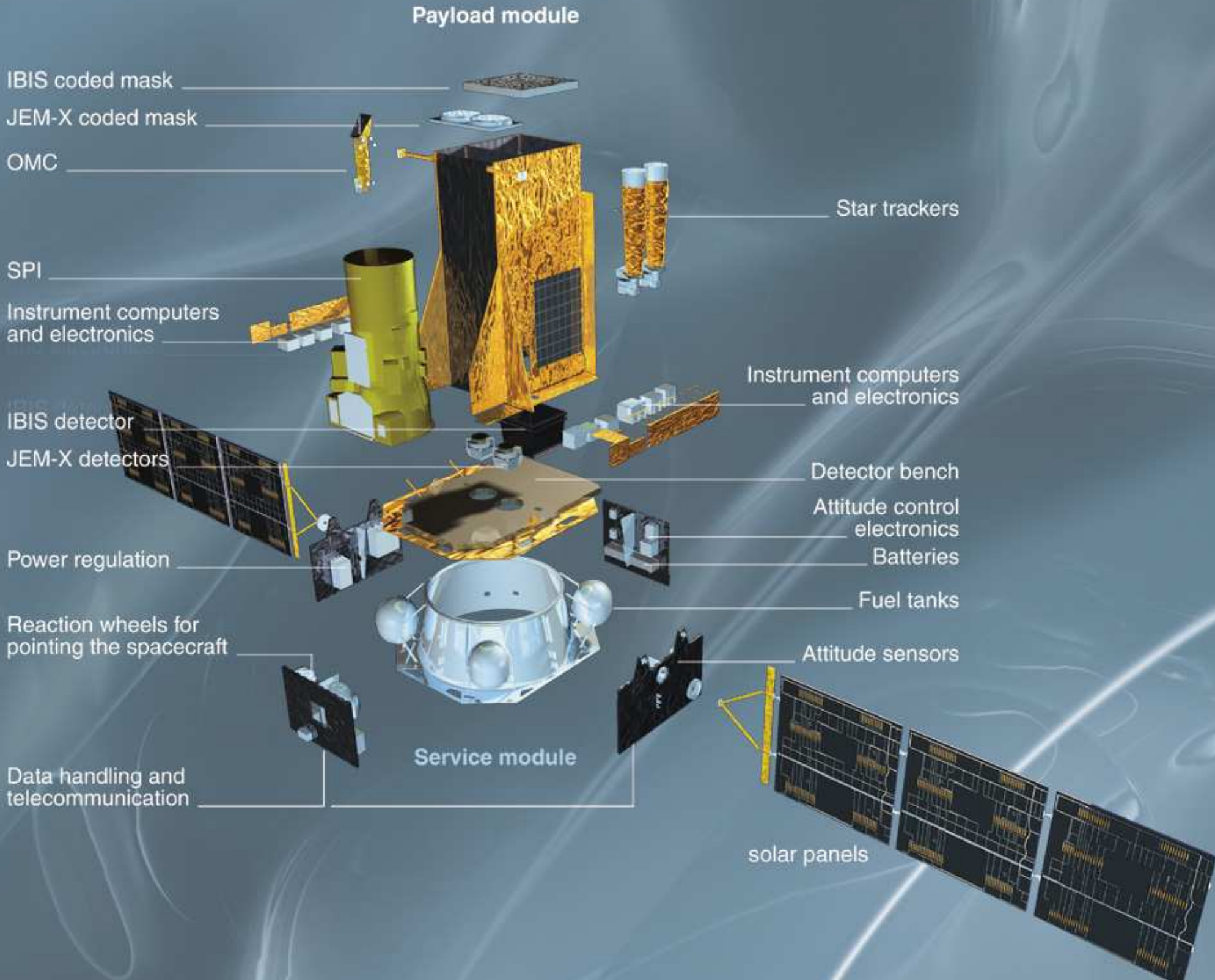
- Cookbook example: extraction of V 0332+53 data
  - Image reconstruction
  - spectral extraction
  - light curves
- Advanced Features:
  - (GRB analysis wit SPI)
  - Pulse phase resolved spectroscopy


Payload module
IBIS coded mask
JEM-X coded mask
OMC
Star trackers
SPI
Instrument computers and electronics
Instrument computers and electronics
IBIS detector
JEM-X detectors
Detector bench
Attitude control electronics
Power regulation
Batteries
Fuel tanks
Reaction wheels for pointing the spacecraft
Attitude sensors
Service module
Data handling and telecommunication
solar panels

The Instrument, I

- SPI = SPectrometer on Integral
- broad energy range: 20 keV up to 8 MeV
- very high energy resolution: 2.35 keV at 1.33 MeV
- but small detector area: 500 cm^2
- large field of view:
  - $16^\circ \times 16^\circ$ (fully coded)
  - $35^\circ \times 35^\circ$ (zero coded)
- low angular resolution of $2^\circ.8$
- timing accuracy: 160 μs

The Instrument, II

The overall design:

- coded mask instrument
- shielded by the Anti Coincidence Shield, ACS (500 kg BGO)
- 127 element mask: 63 opaque (tungsten), 64 open
- PSAC to suppress 511 keV background
- 19 Germanium detectors
- cooled to 85° K
- annealing phases ∼twice a year

The Instrument, III

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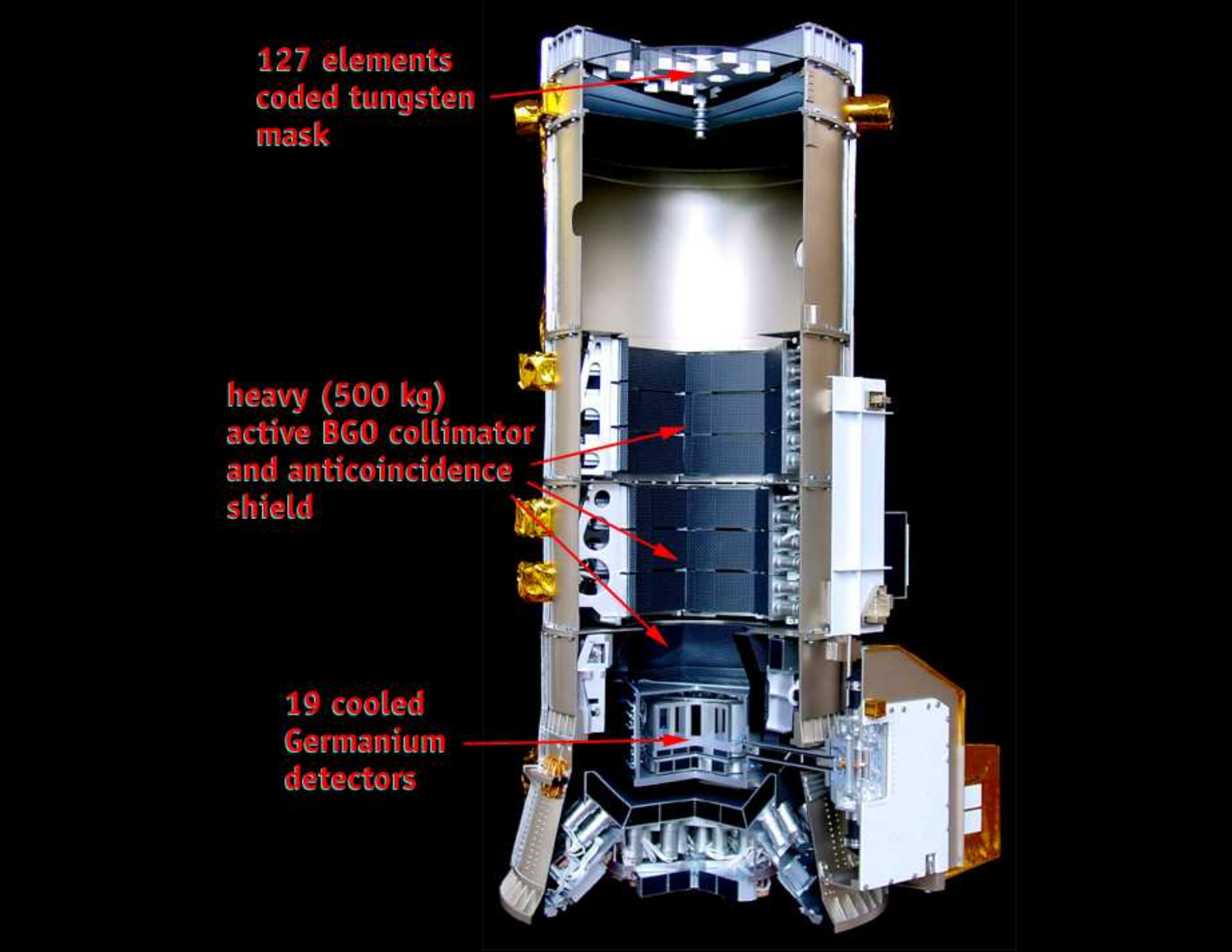
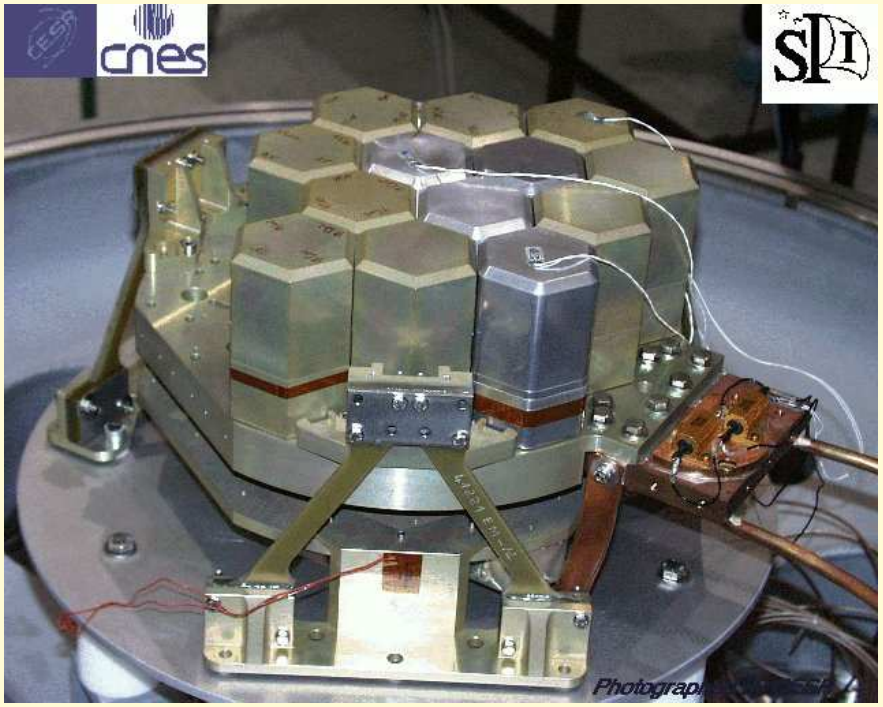
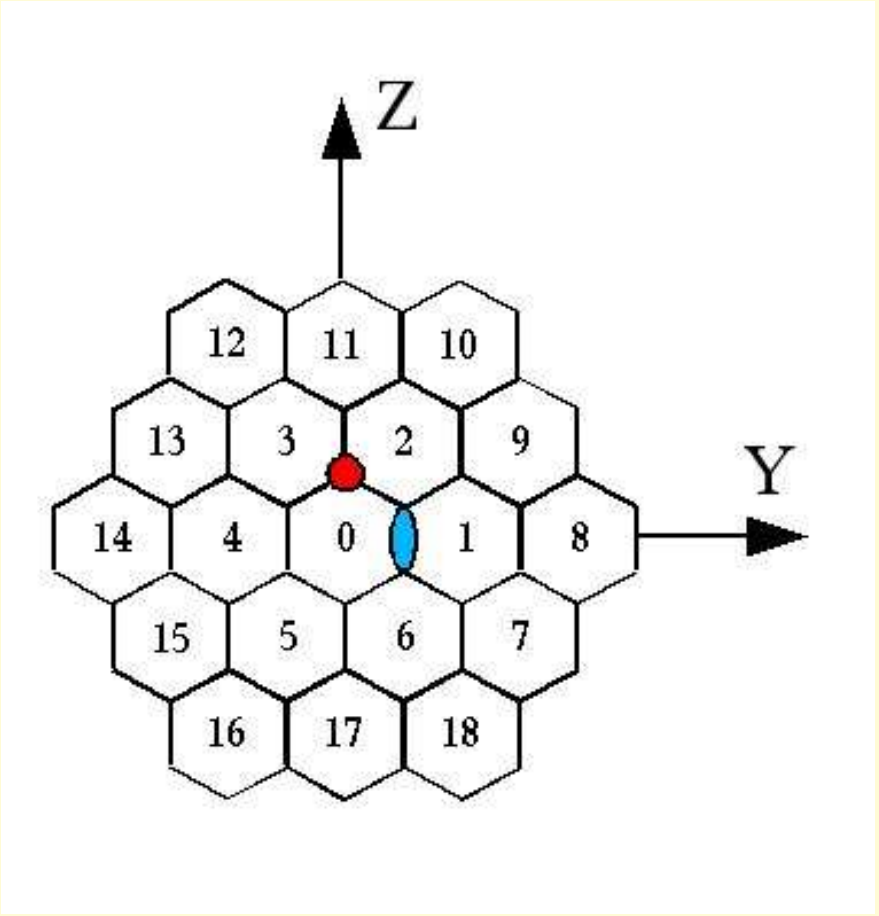
- coded mask instrument
- shielded by the Anti Coincidence Shield, ACS (500 kg BGO)
- 127 element mask: 63 opaque (tungsten), 64 open
- PSAC to suppress 511 keV background
- 19 Germanium detectors
- cooled to 85° K
- annealing phases ∼twice a year
- in the meantime, 2 detectors failed:
  - Det No. 2 died on Dec. 6, 2003
  - Det No. 17 died on July 18, 2004
  - decrease of effective area by ∼10%


127 elements
coded tungsten
mask
heavy (500 kg)
active BGO collimator
and anticoincidence
shield
19 cooled
Germanium
detectors

The Instrument, V

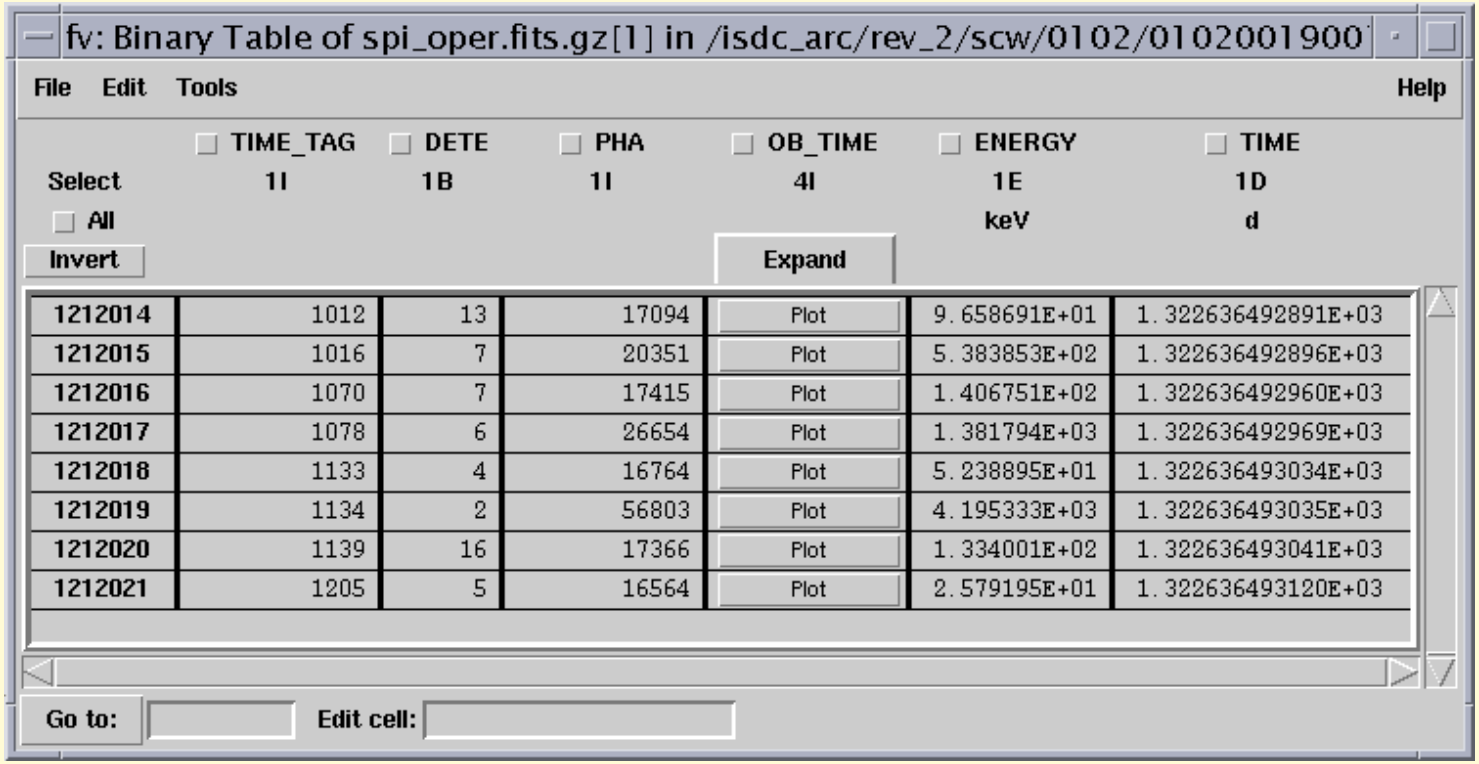




Real Detectors: 0–18

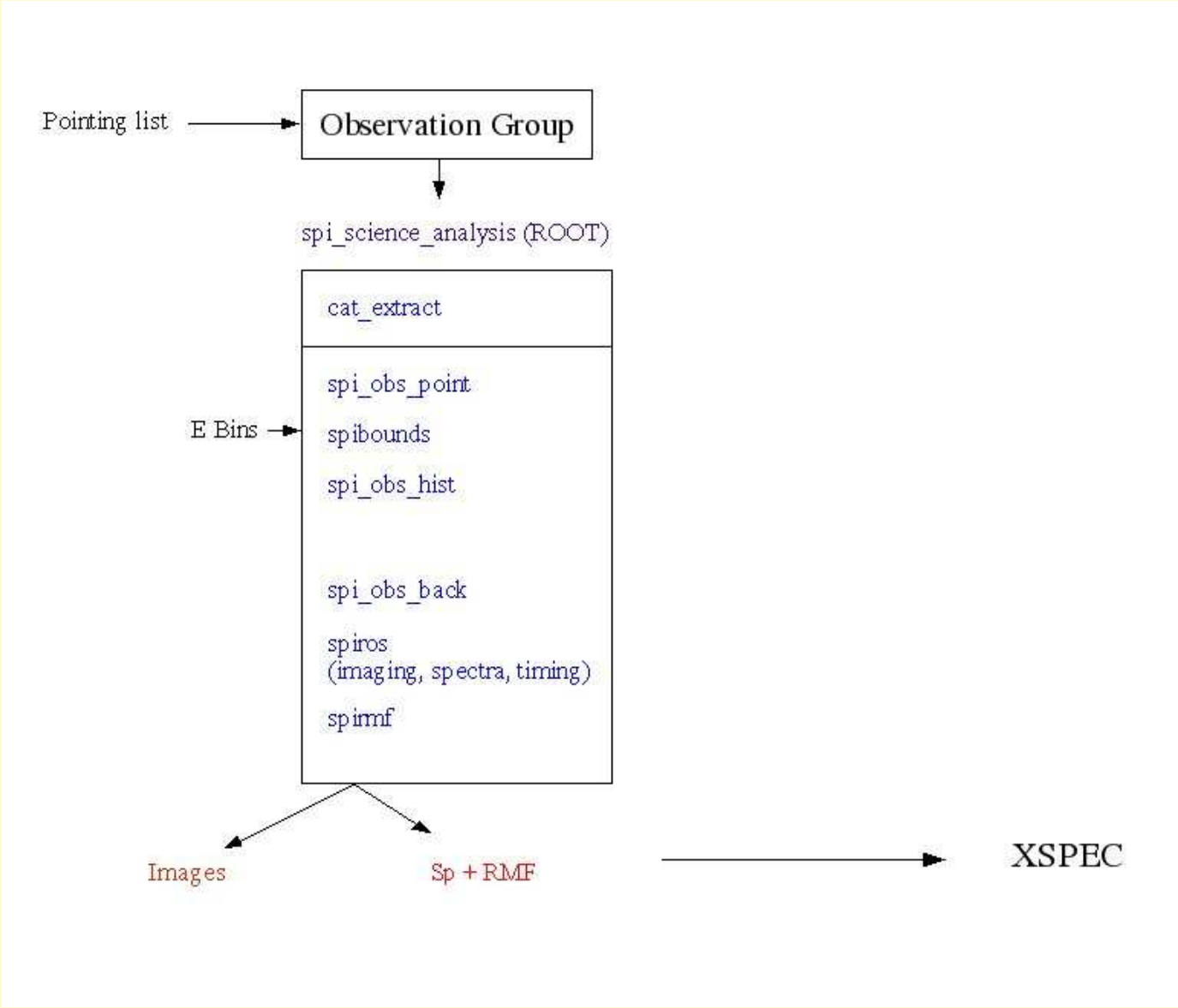
Pseudo Detectors: Doubles: 19–60 Triples: 61–84

Data

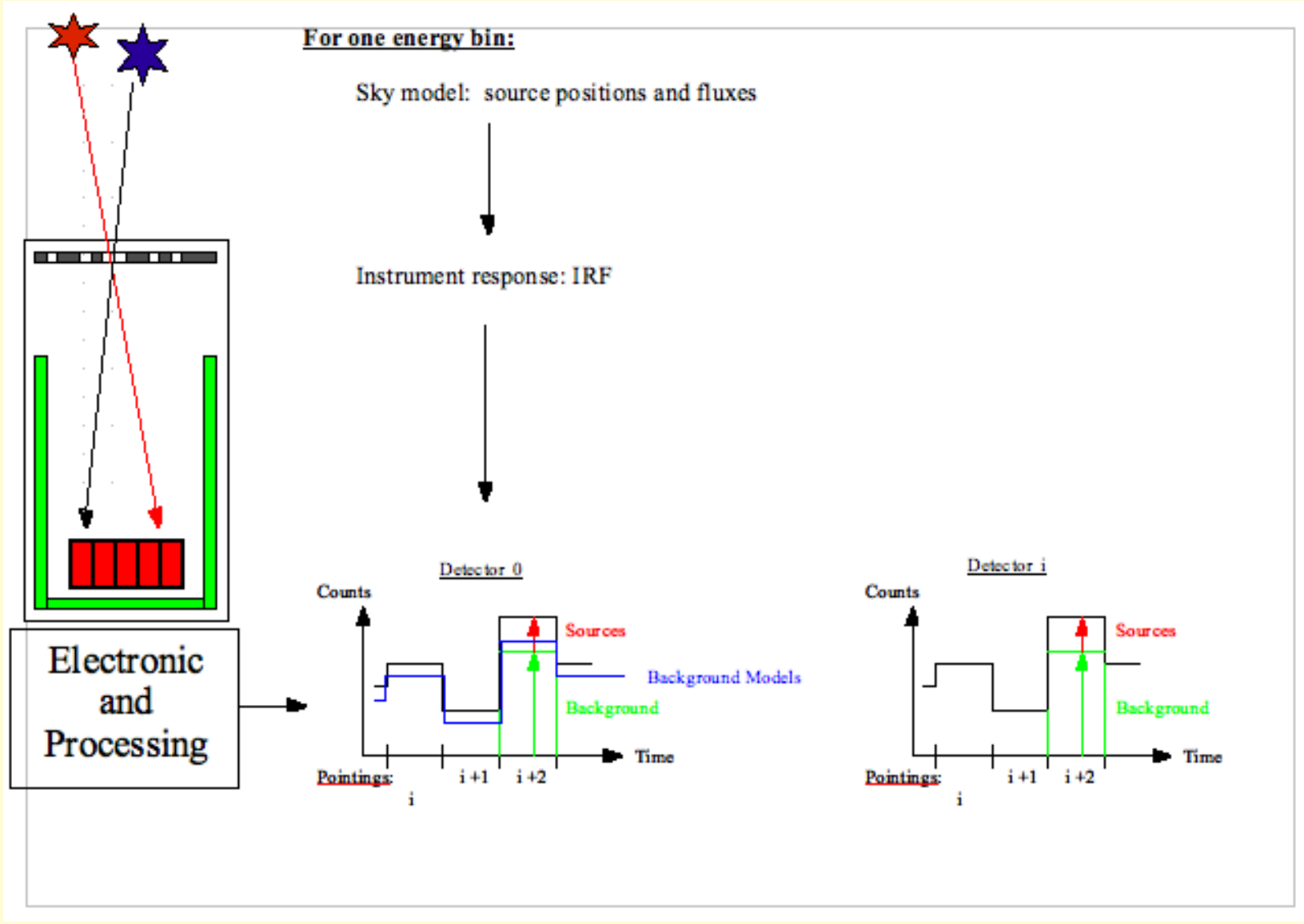


- Convert PHA channels to Energy using gain coefficients.
- two different formulas for low / high energies

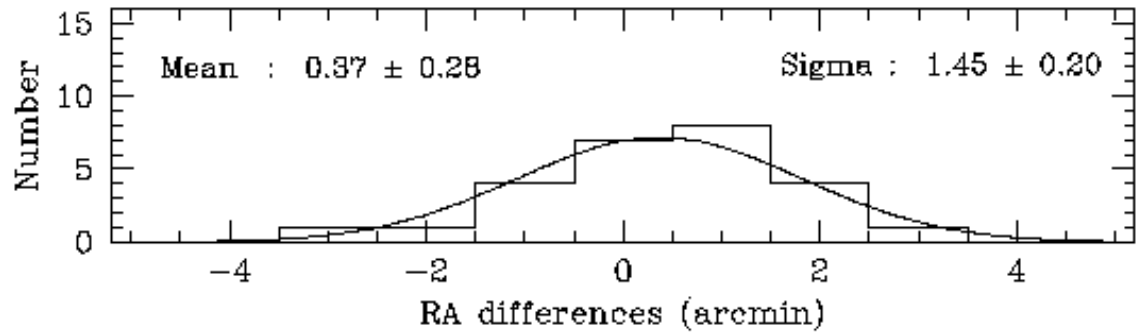
Analysis, I

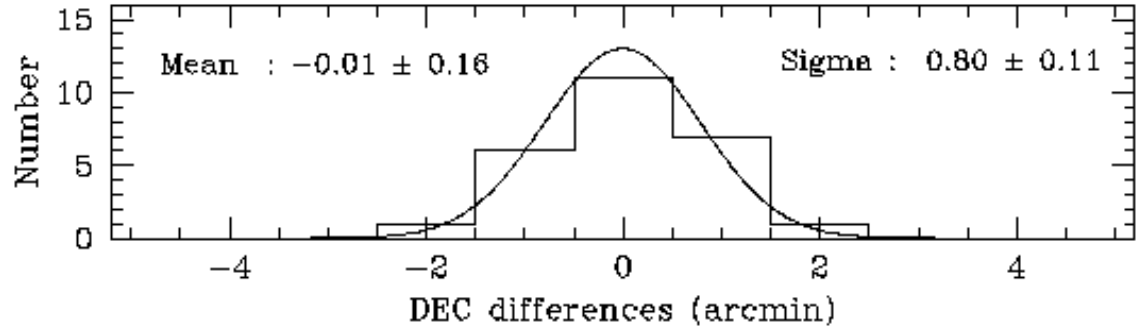

Pointing list
Observation Group
spi_science_analysis (ROOT)
cat_extract
spi_obs_point
E Bins
spibounds
spi_obs_hist
spi_obs_back
spiros
(imaging, spectra, timing)
spirmf
Images
Sp + RMF
XSPEC

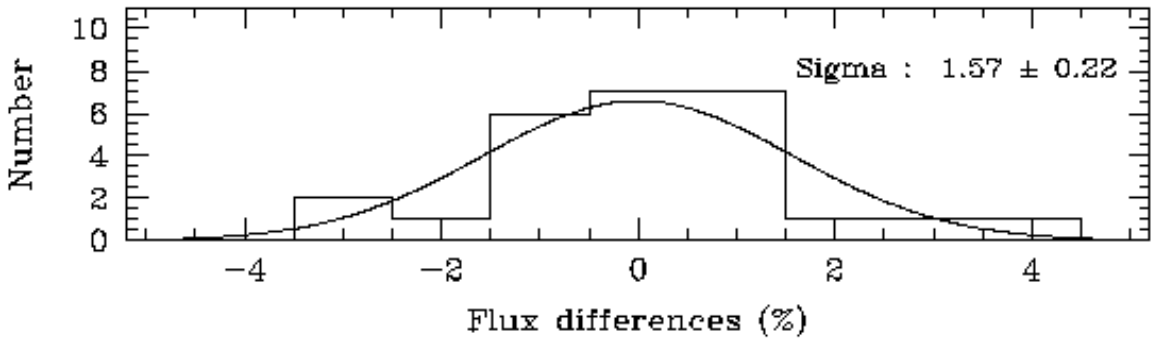
Analysis, II


For one energy bin:
Sky model: source positions and fluxes
Instrument response: IRF
Electronic and Processing
Detector 0
Counts
Sources
Background Models
Background
Time
Pointings:
i
i +1
i +2
Detector i
Counts
Sources
Background
Time
Pointings:
i
i +1
i +2

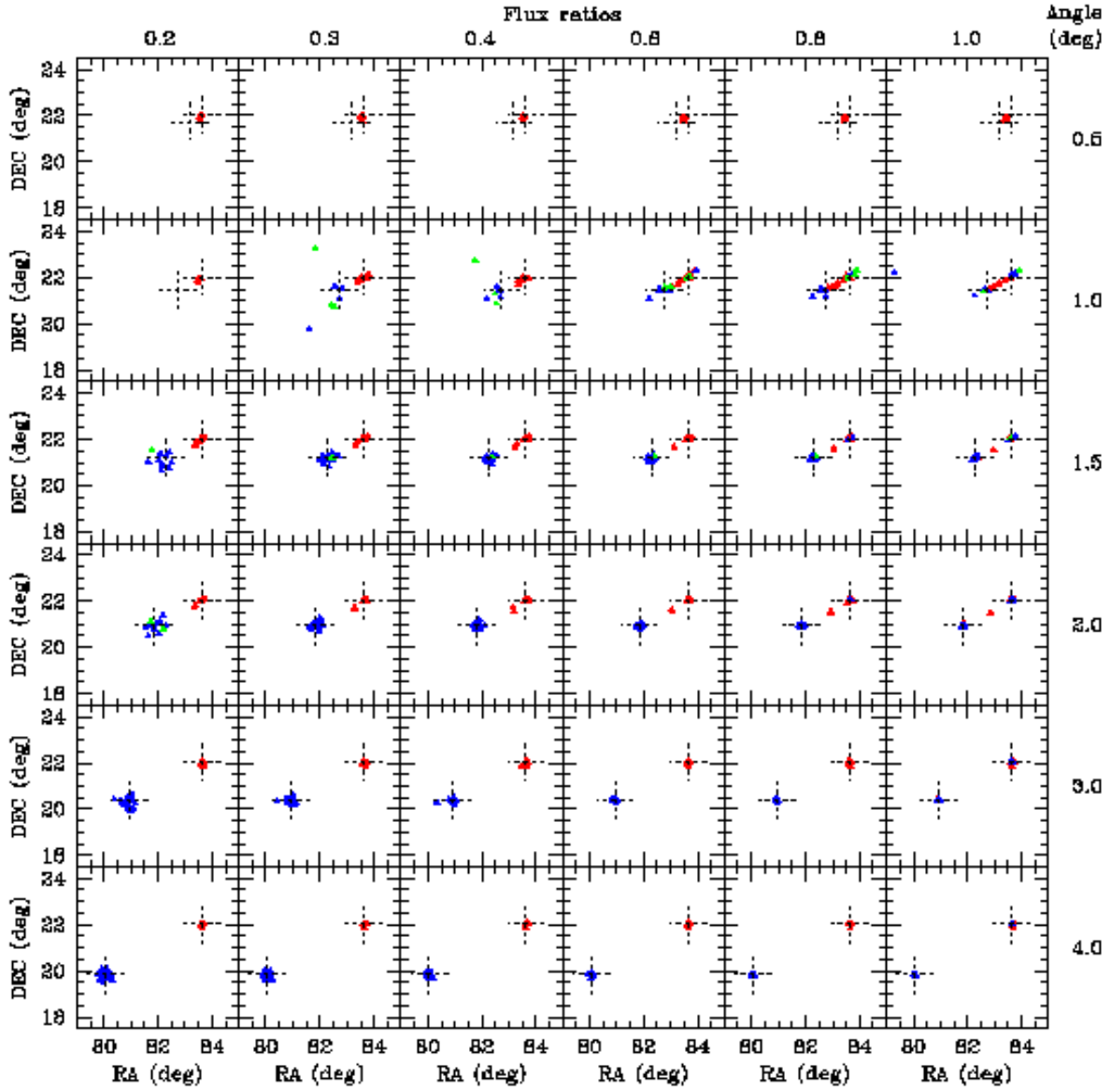
Performance







Performance



Data, I

When selecting science windows for SPI analysis, remember:

- SPI has a very large FOV
- SPI has small effective area and a small number of detectors$\Longrightarrow$many scws required:
  start with 10 even for simple analysis, for complex analyses: several hundred
- observations in staring mode are diffcult (unsuable)

Data, II

When selecting science windows for SPI analysis, remember:

- SPI has a very large FOV
- SPI has small effective area and a small number of detectors$\Longrightarrow$many scws required:
  start with 10 even for simple analysis, for complex analyses: several hundred
- observations in staring mode are diffcult (unsuable)

Practical:

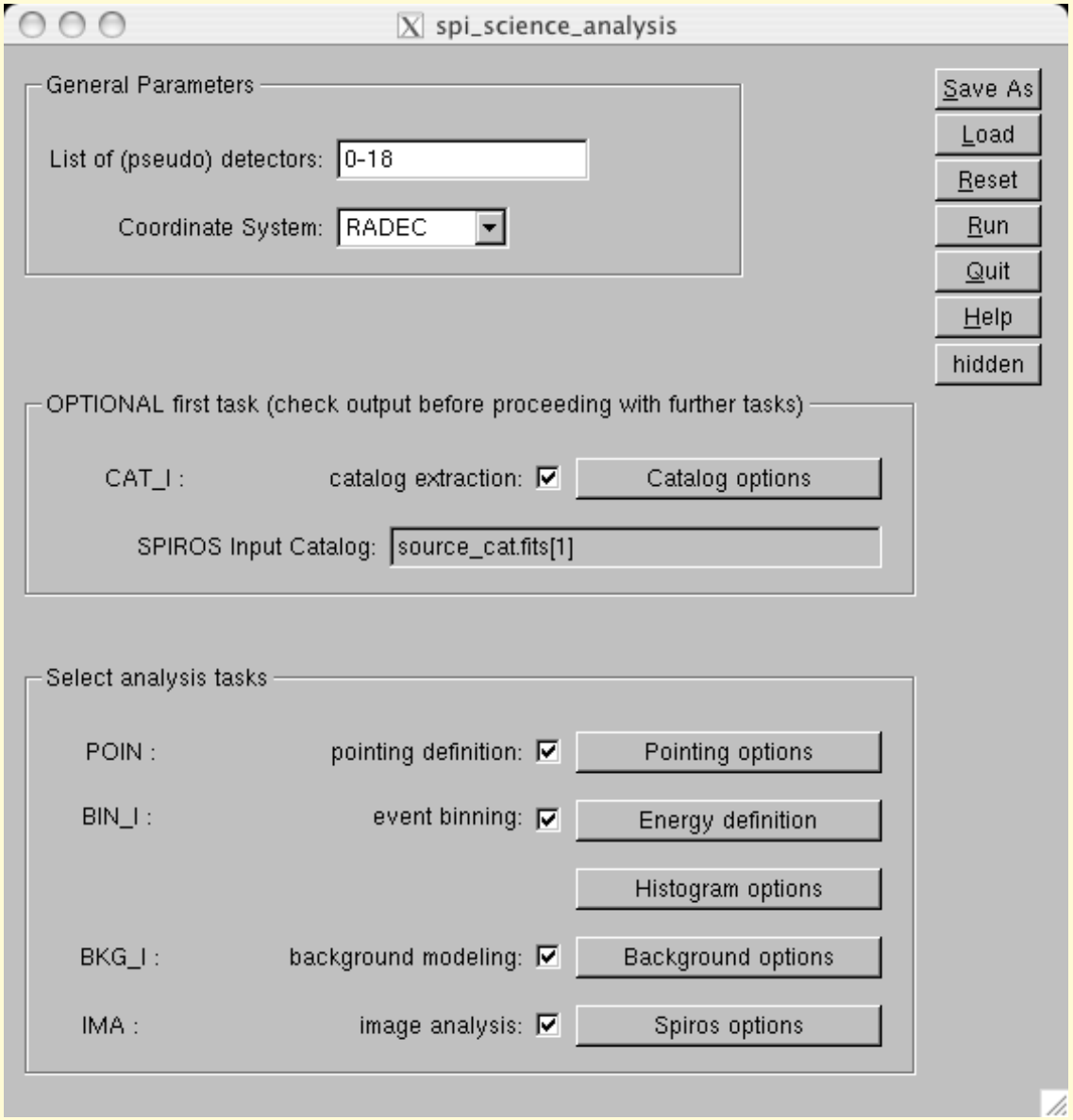
- create a list of scws (DOLs), e.g., using W3Browse
- setup your environment (set links, paths, . . .)
- create the OG:

```
og_create idxSwg=scws.lst ogid=test instrument=SPI baseDir=.
```

Main GUI

Launch the pipeline GUI:

- general options relevant for several tasks
- (un-)check the boxes to select the tasks to run
- task sequence has to be consistent
- click on buttons for task specific options

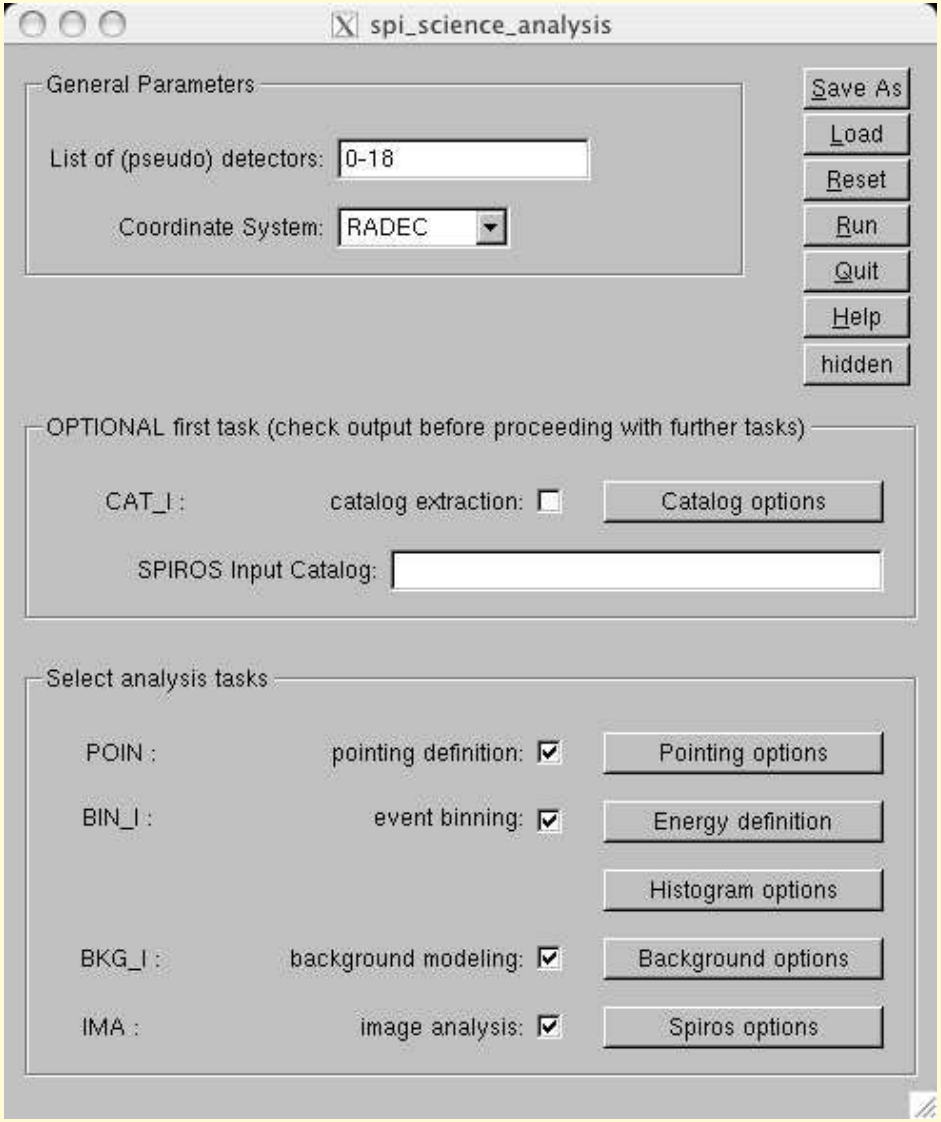


First step, I

Do you want to use the catalog or not?

Typical: first analysis without catalog!

- uncheck catalog step
- clear input catalog field

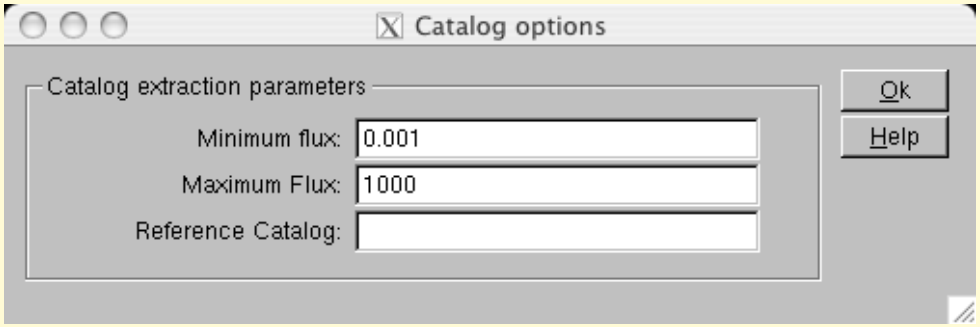


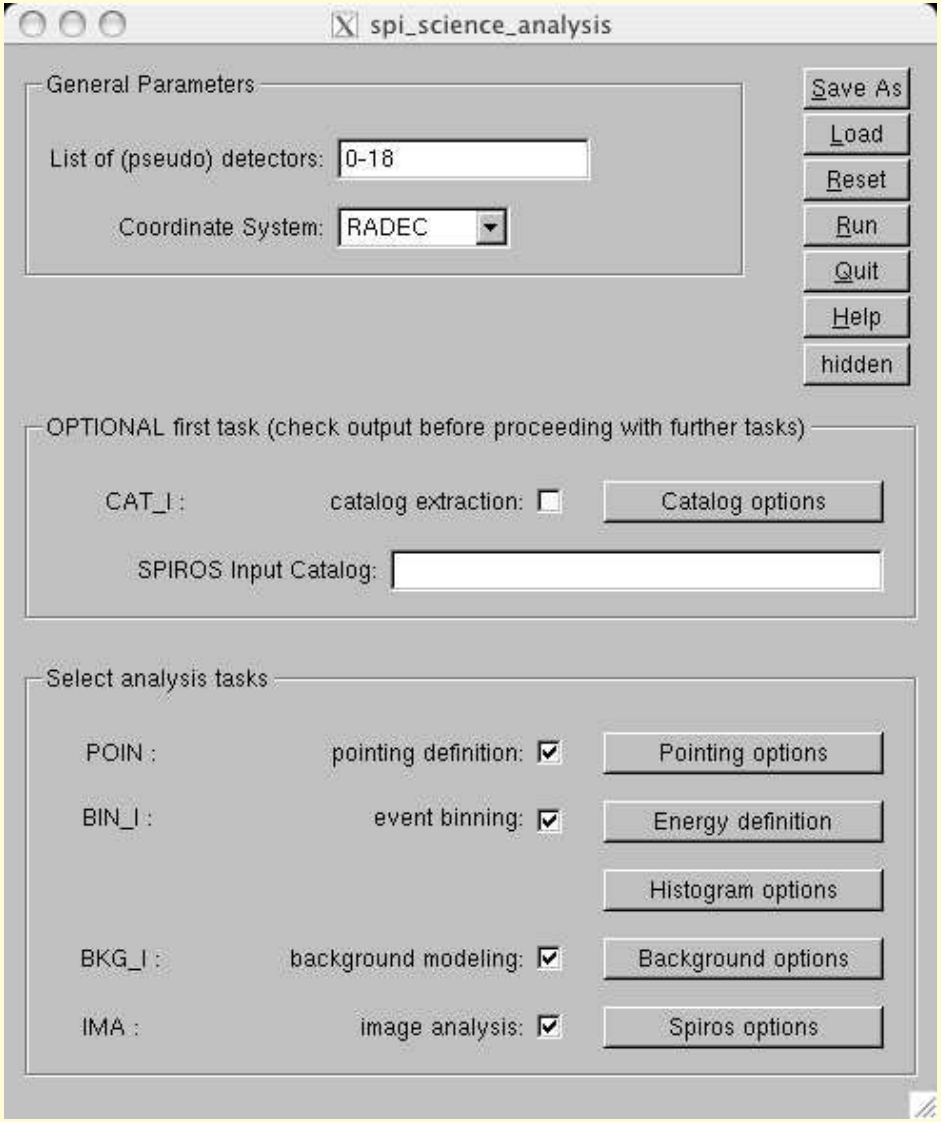
First step, II

Do you want to use the catalog or not?
Typical: first analysis without catalog!

- uncheck catalog step
- clear input catalog field

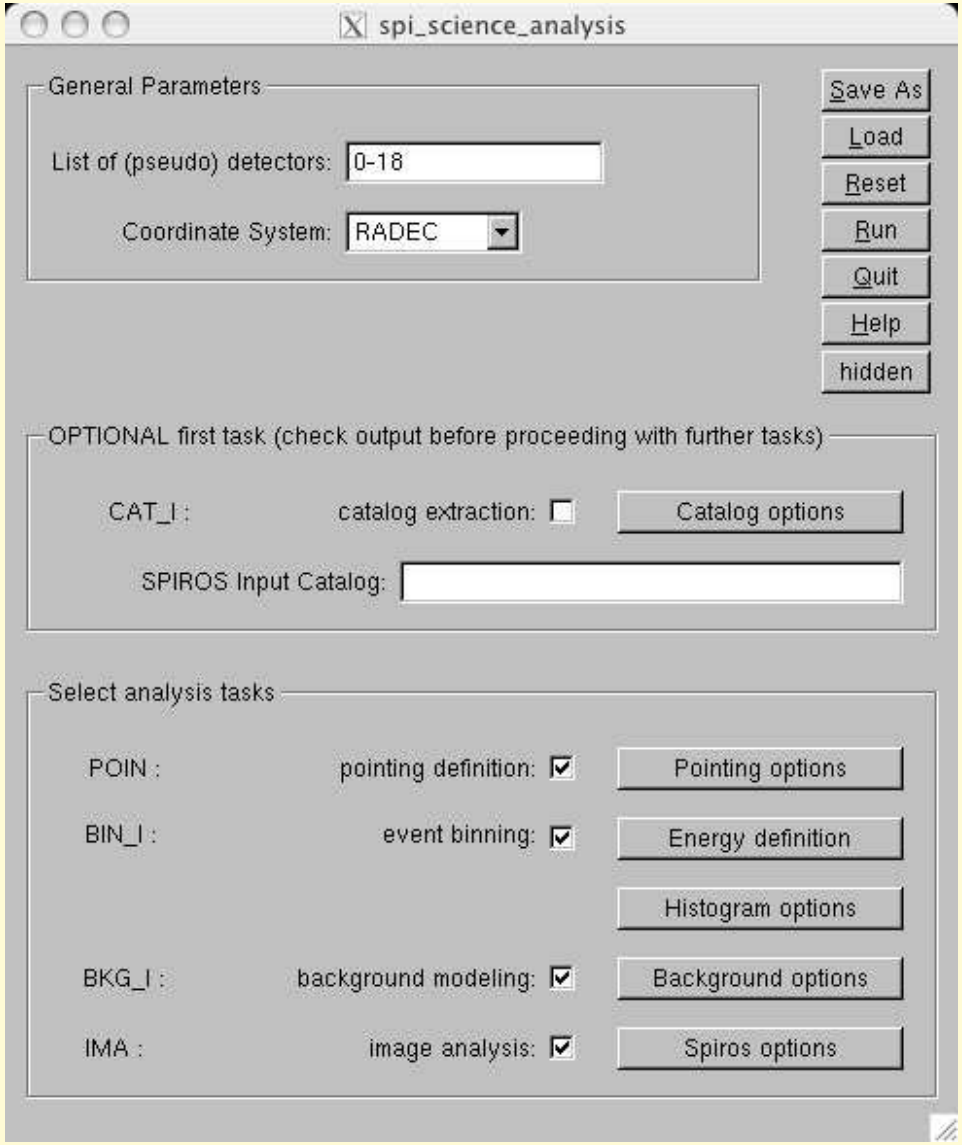
Check the values for the catalog extraction:





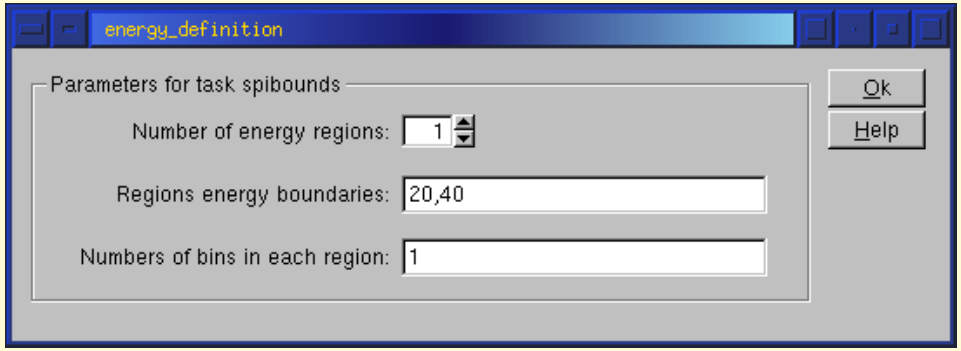
Image, I

1. Launch pipeline GUI
2. select the appropriate tasks
3. analysis without catalog



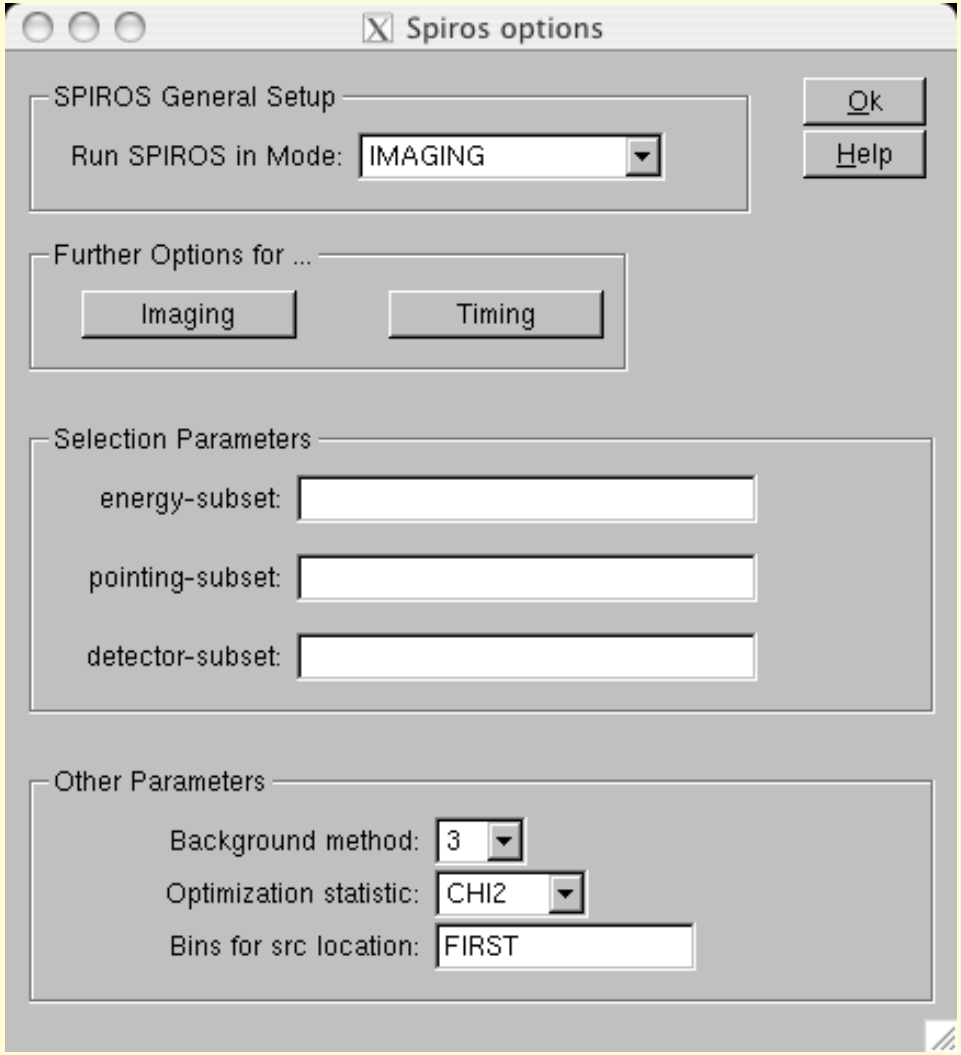
Image, II

1. Launch pipeline GUI
2. select the appropriate tasks
3. analysis without catalog
4. single broad energy bin



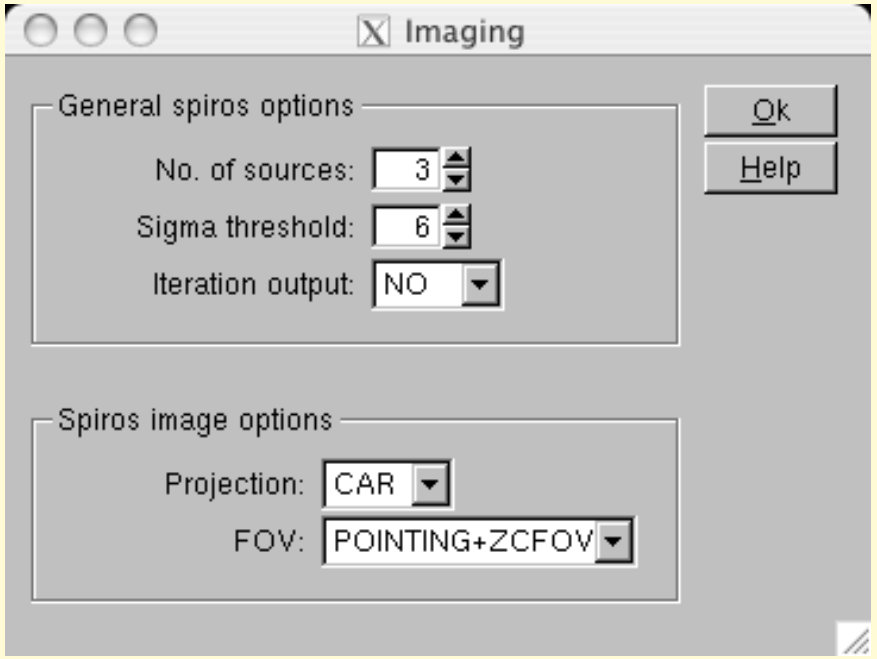
Image, III

1. Launch pipeline GUI
2. select the appropriate tasks
3. analysis without catalog
4. single broad energy bin
5. setup spiros for imaging



Image, IV

1. Launch pipeline GUI
2. select the appropriate tasks
3. analysis without catalog
4. single broad energy bin
5. setup spiros for imaging
6. check spiros imaging options
7. run pipeline!



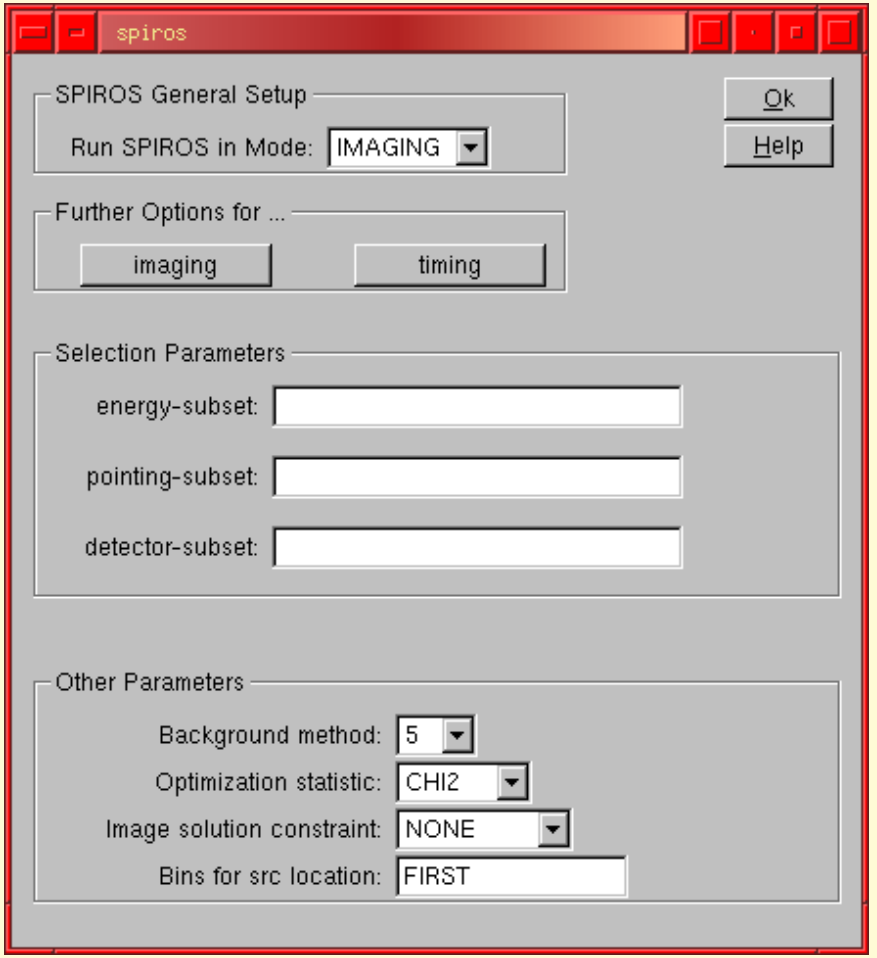
Remove bad pointings, I

Checkout the produced logfile:

```
2005-10-12T12:41:34 :  Ptg Rev Exp  ONTIME  CHI2,ML Expected Diff  Reduced Data
2005-10-12T12:41:34 :  -no -no -no  (secs)   value   value   /STD  CHI2,ML excl
2005-10-12T12:41:34 : ------------------------------------------------------------
2005-10-12T12:41:34 :    1 284   4  3566.8    37.3    16.4   3.66   2.28  10.53
2005-10-12T12:41:34 :    2 284   5  3566.8    32.4    16.4   2.80   1.98  10.53
2005-10-12T12:41:34 :    3 284   6  3518.8    21.3    16.4   0.87   1.30  10.53
2005-10-12T12:41:34 :    4 284   7  3566.8    29.5    16.4   2.30   1.80  10.53
2005-10-12T12:41:34 :    5 284   8  3518.8    23.7    16.4   1.29   1.45  10.53
2005-10-12T12:41:34 :   16 284  19  3573.0    26.5    16.4   1.76   1.62  10.53
2005-10-12T12:41:34 :   17 284  20  3556.9    33.6    16.4   3.01   2.05  10.53
2005-10-12T12:41:34 :   18 284  21  3571.9    34.7    16.4   3.20   2.12  10.53
2005-10-12T12:41:34 :   19 284  22  3572.9   192.9    16.4  30.85  11.78  10.53
2005-10-12T12:41:34 :   20 284  23  3566.9    16.8    16.4   0.08   1.03  10.53
2005-10-12T12:41:34 :   21 284  24  3526.4    45.2    16.4   5.04   2.76  10.53
2005-10-12T12:41:34 :   22 284  25  3570.9    32.4    16.4   2.81   1.98  10.53
```

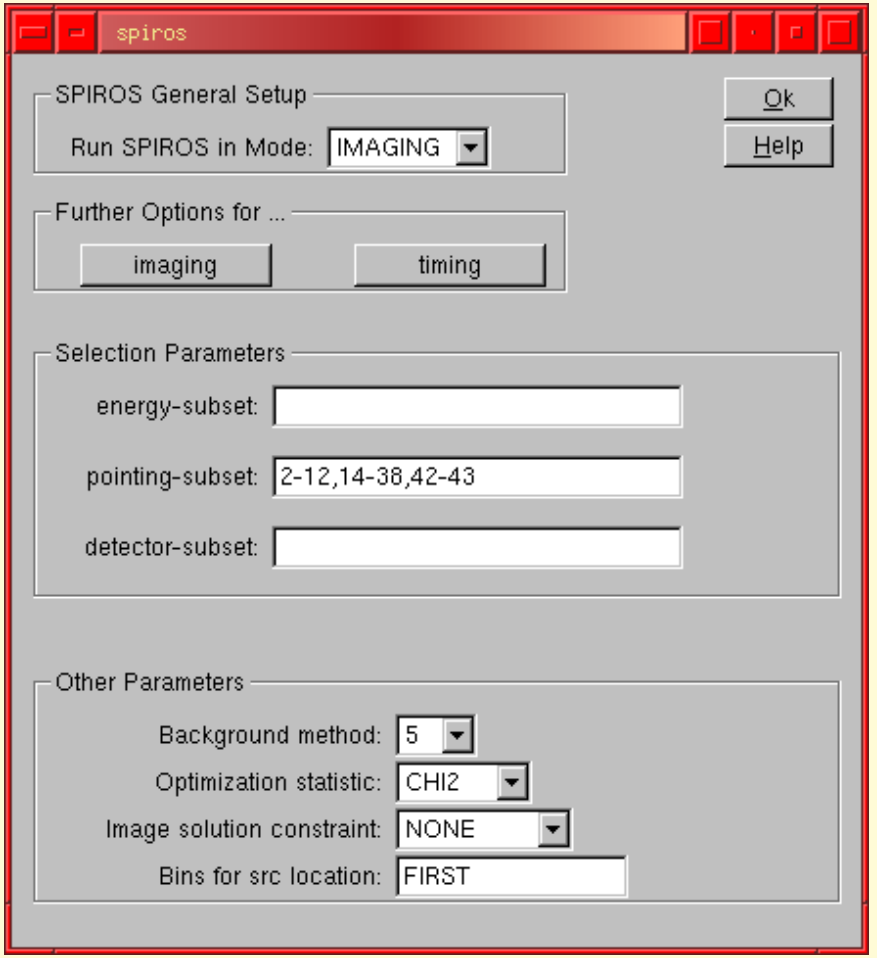
Remove bad pointings, II

1. try different background models:
   flatfield, GeDSat, MCM
2. try again: much better



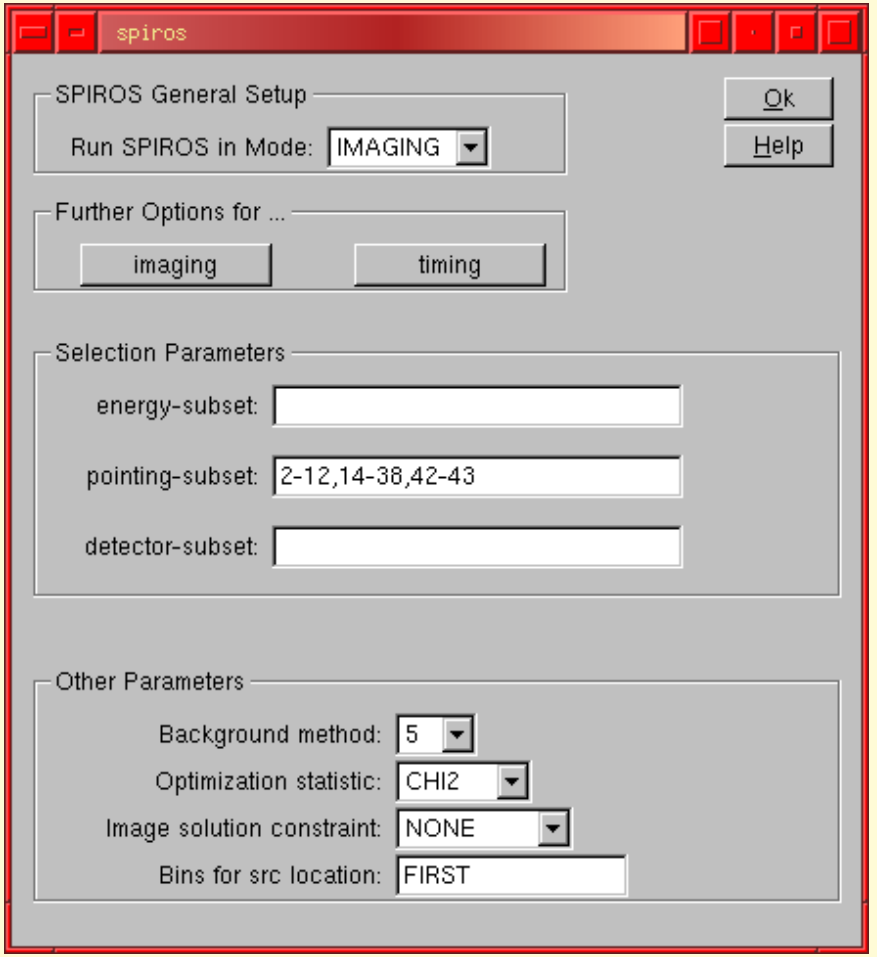
Remove bad pointings, III

1. try different background models:
   flatfield, GeDSat, MCM
2. try again: much better
   but still some pointings unacceptable
3. tell spiros, not to use the bad pointings:
4. repeat until no bad pointings left



Remove bad pointings, IV

1. try different background models:
   flatfield, GeDSat, MCM
2. try again: much better
   but still some pointings unacceptable
3. tell spiros, not to use the bad pointings:
4. repeat until no bad pointings left
5. create a region file for ds9:
   `cat2ds9 source_res.fits source_res.reg`

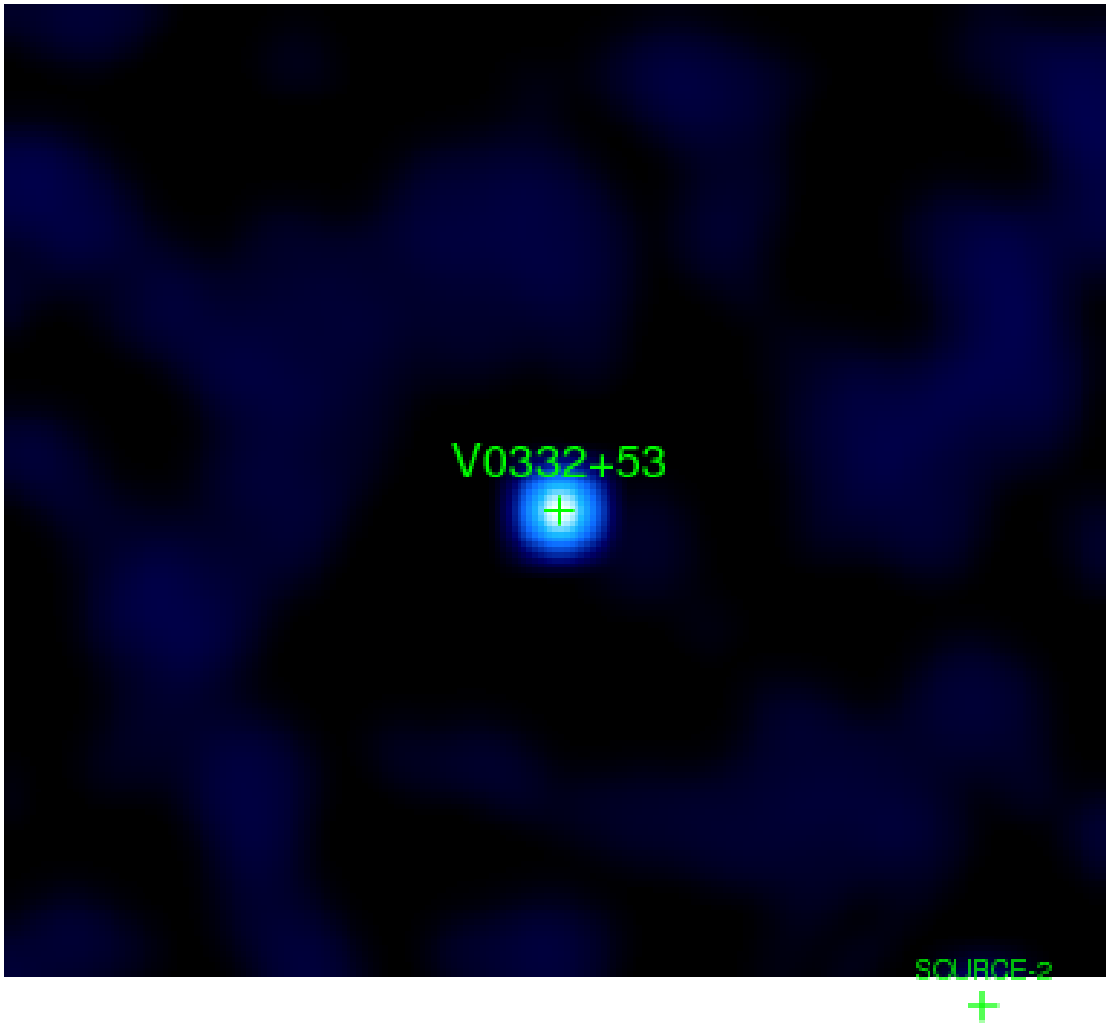


Remove bad pointings, V

look at the images:

```
ds9
spiros_image_intensity_result.fits
-region source_res.reg
```

most importantly the significance images



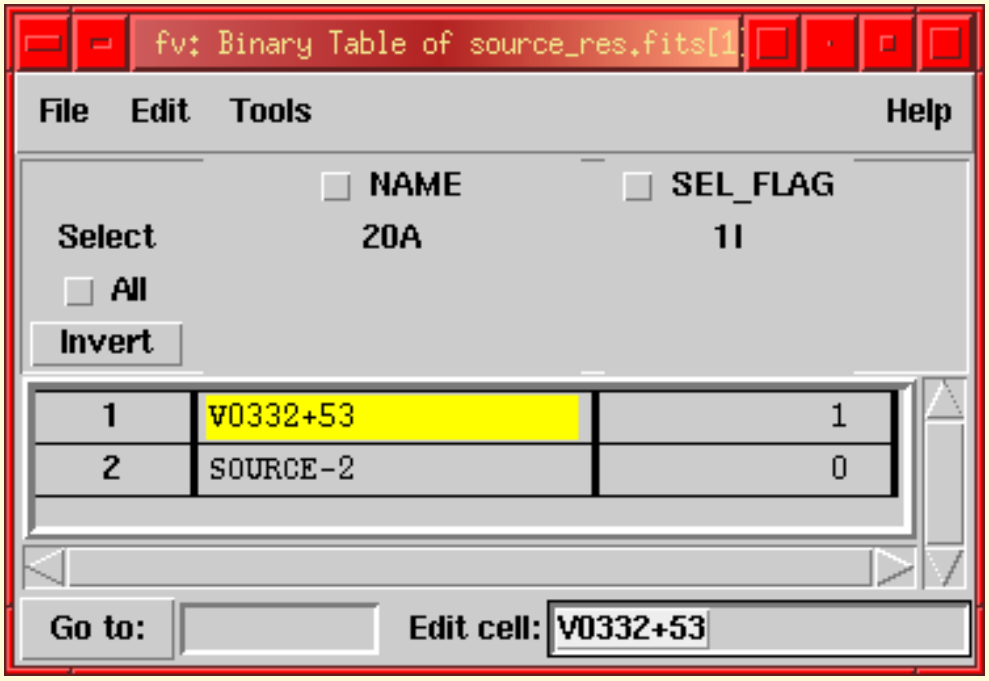
Spectrum, I

For spectral extraction, an input catalog is required!

- source catalog
- modifed source list from spiros

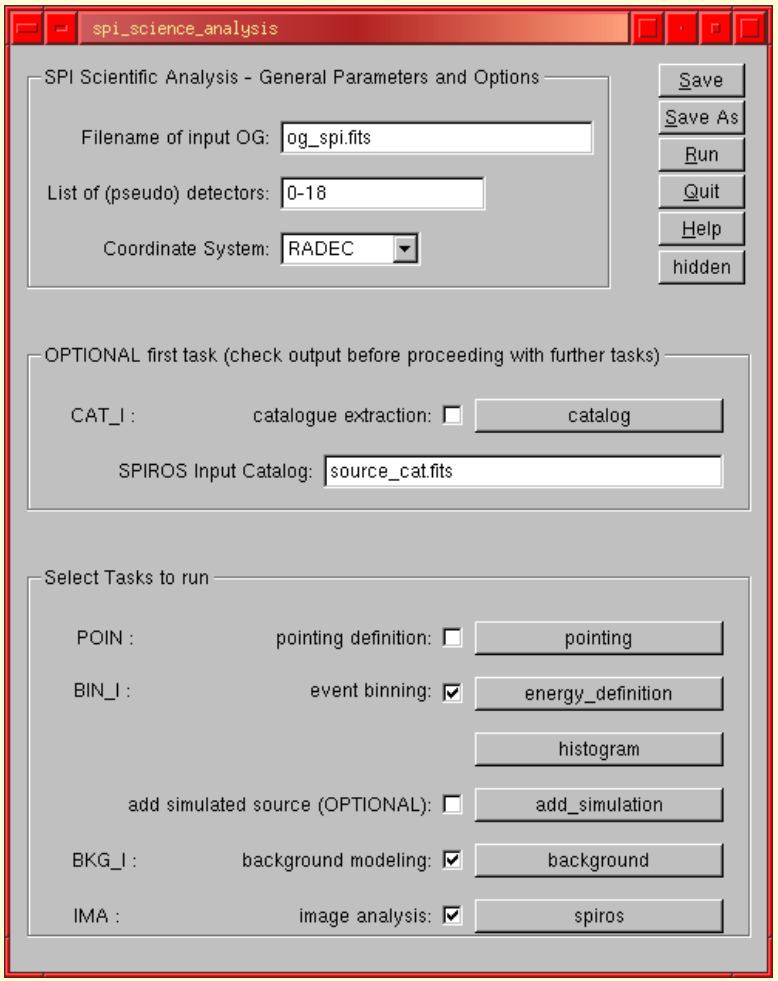
Spectrum, II

1. `cp source_res.fits source_cat.fits`
2. edit the catalog with fv
3. set sel_flag to 0 for irrelevant sources
4. set the extension name to SPI.-SRCL-CAT



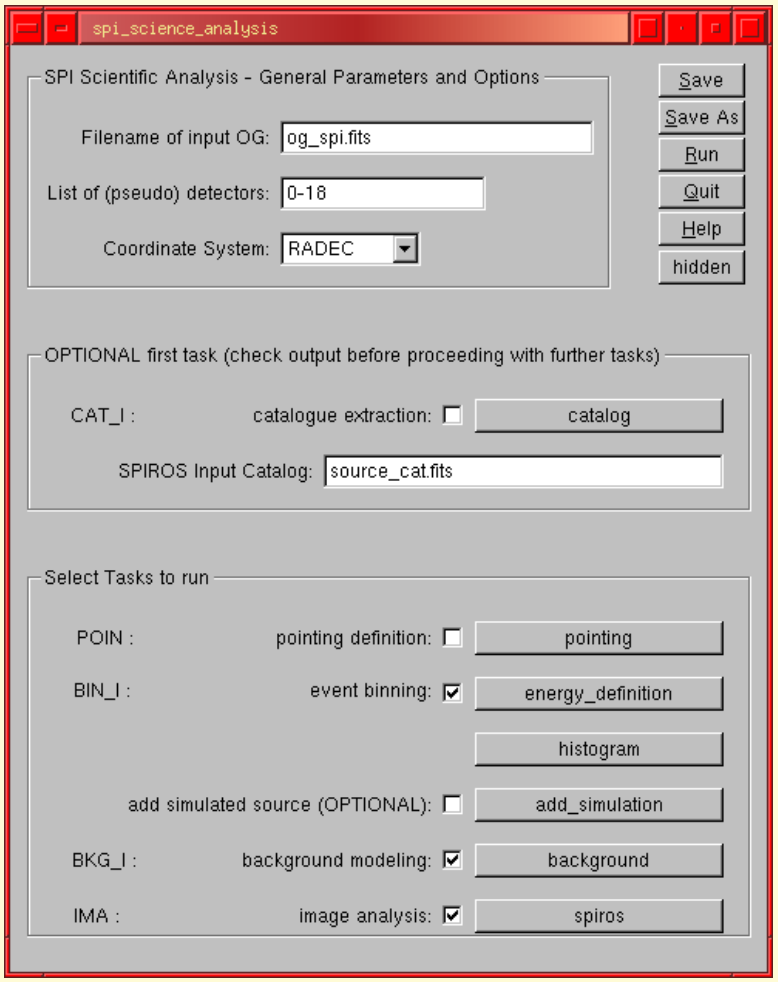
Spectrum, III

Launch GUI, uncheck pointing task:

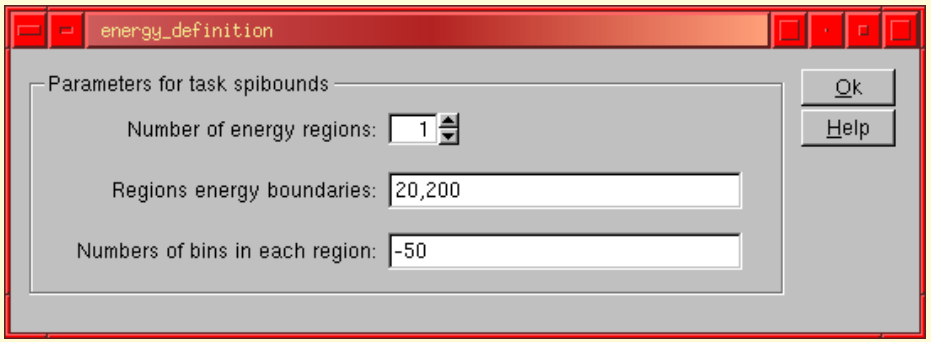


Spectrum, IV

Launch GUI, uncheck pointing task:

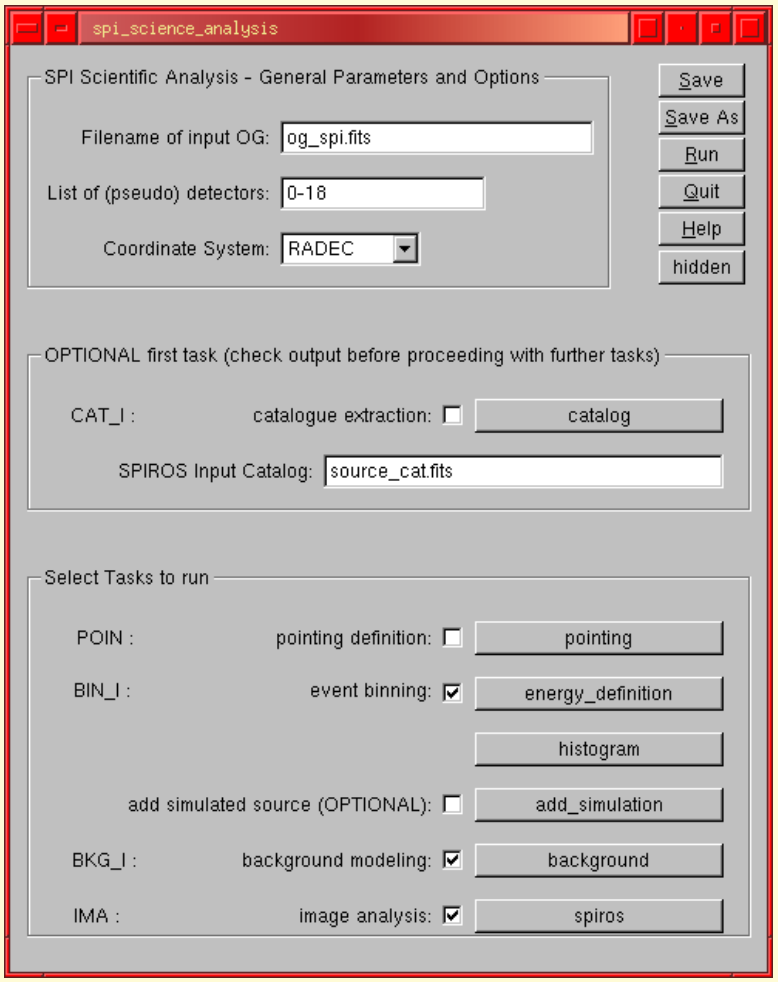


Select an appropriate energy binning:

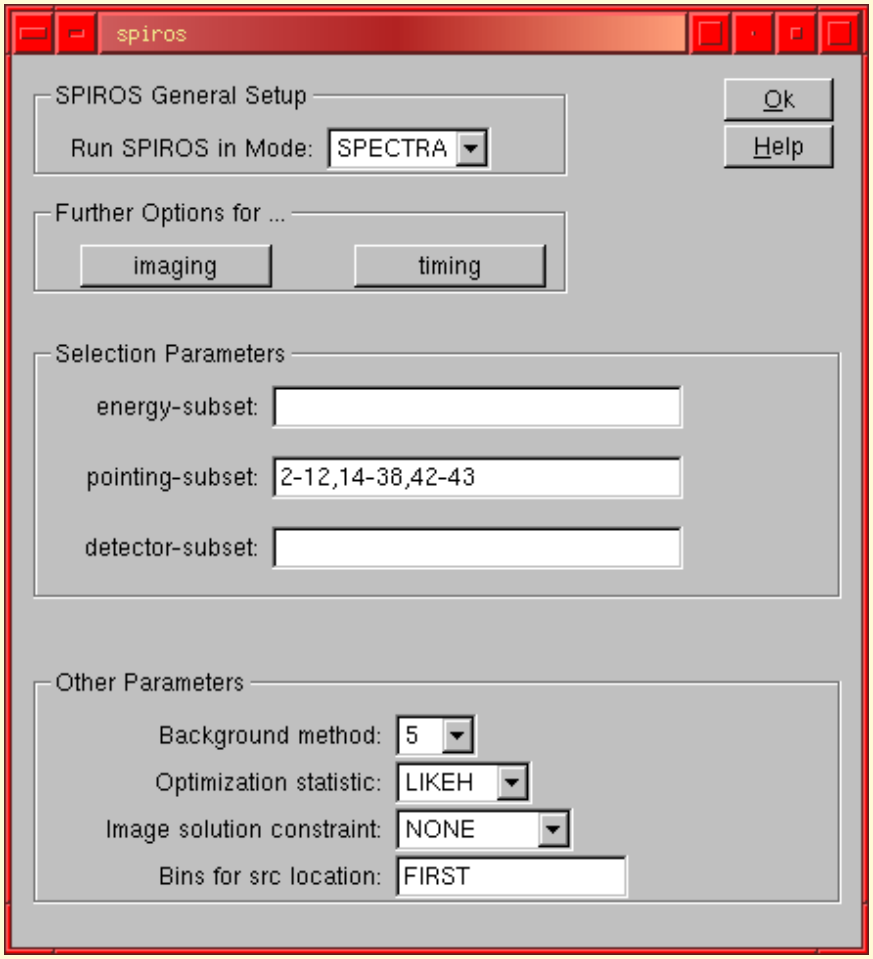


Spectrum, V

Launch GUI, uncheck pointing task:

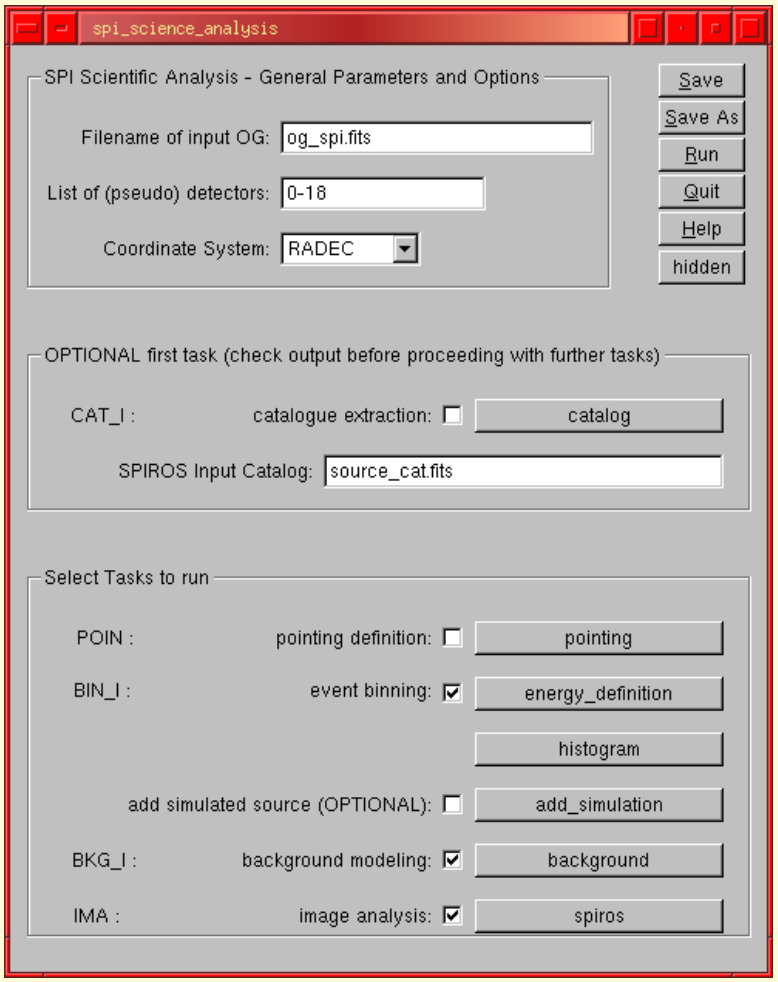


Set spiros to mode Spectra:

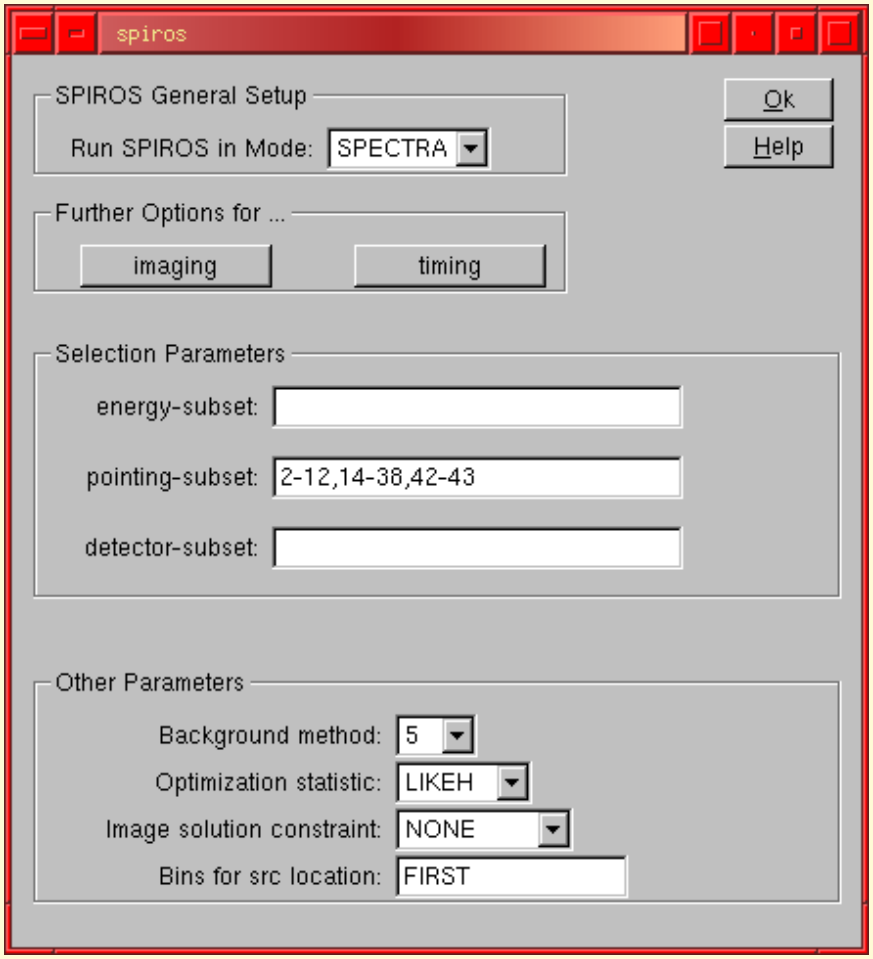


Spectrum, VI

Launch GUI, uncheck pointing task:



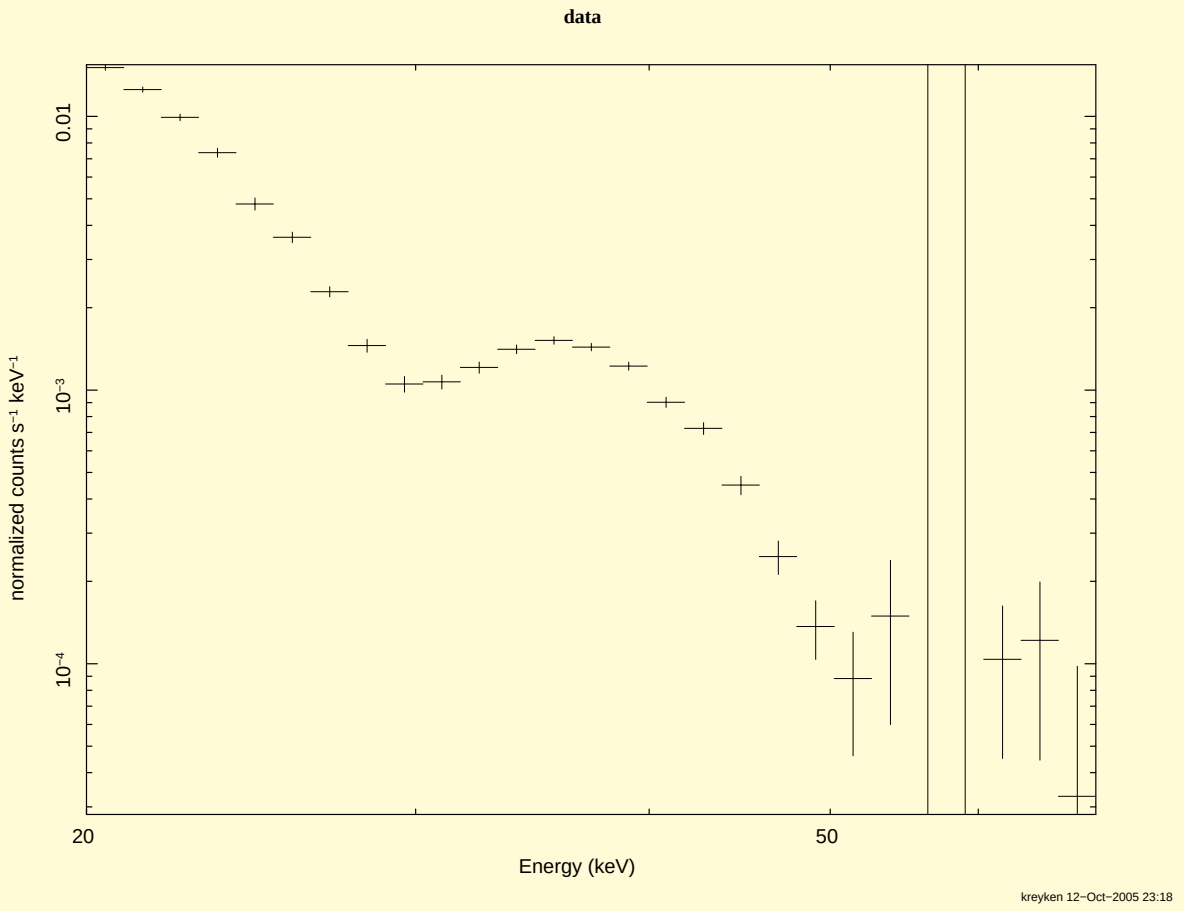
Set spiros to mode Spectra:



$\Longrightarrow$ All image results will be removed - copy your OG!

Spectrum, VII

- ready-to-use PHA files which can be loaded directly into `xspec`
- an appropriately rebinned response matrix



Lightcurves, I

Smallest possible time resolution: 1 science window (set time-scale to 0)!

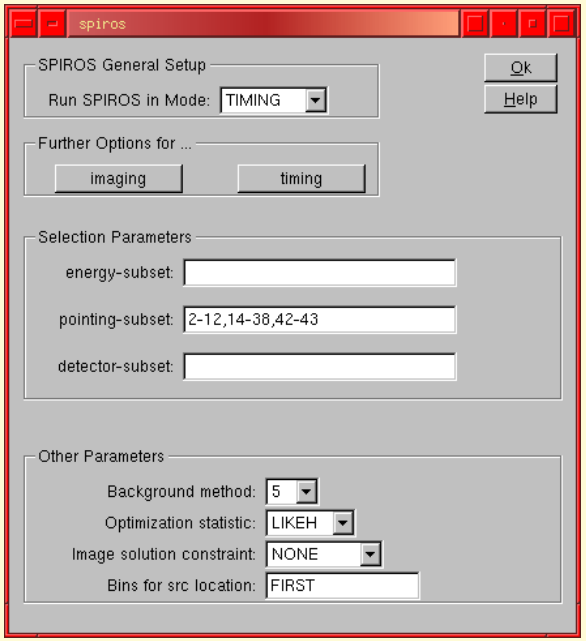
$\Longrightarrow$only suitable for long-term lightcurves.

Lightcurves, II

Smallest possible time resolution: 1 science window (set time-scale to 0)!

$\Longrightarrow$only suitable for long-term lightcurves.

1. select the source in the catalog
2. select an appropriate energy binning
3. set spiros in timing mode:

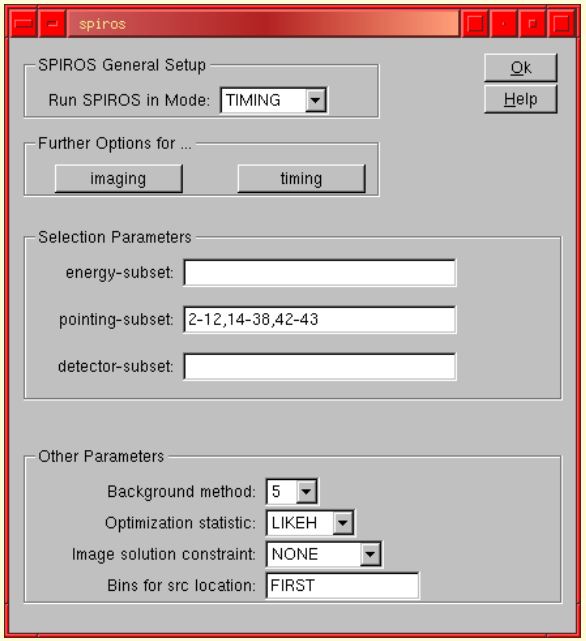


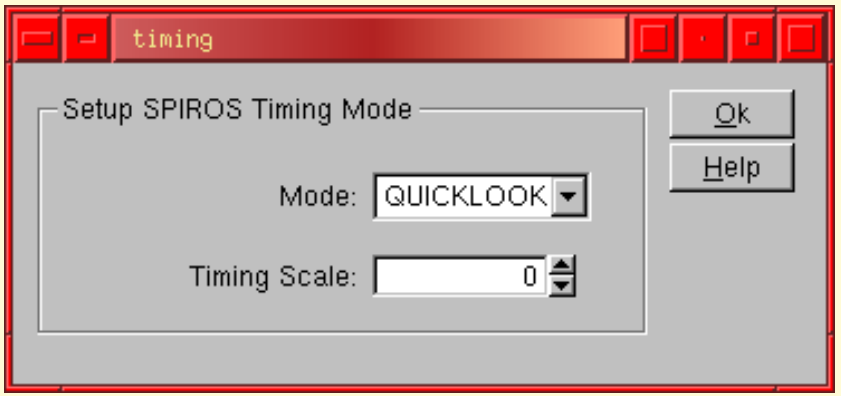
Lightcurves, III

Smallest possible time resolution: 1 science window (set time-scale to 0)!

$\Longrightarrow$only suitable for long-term lightcurves.

1. select the source in the catalog
2. select an appropriate energy binning
3. set spiros in timing mode:

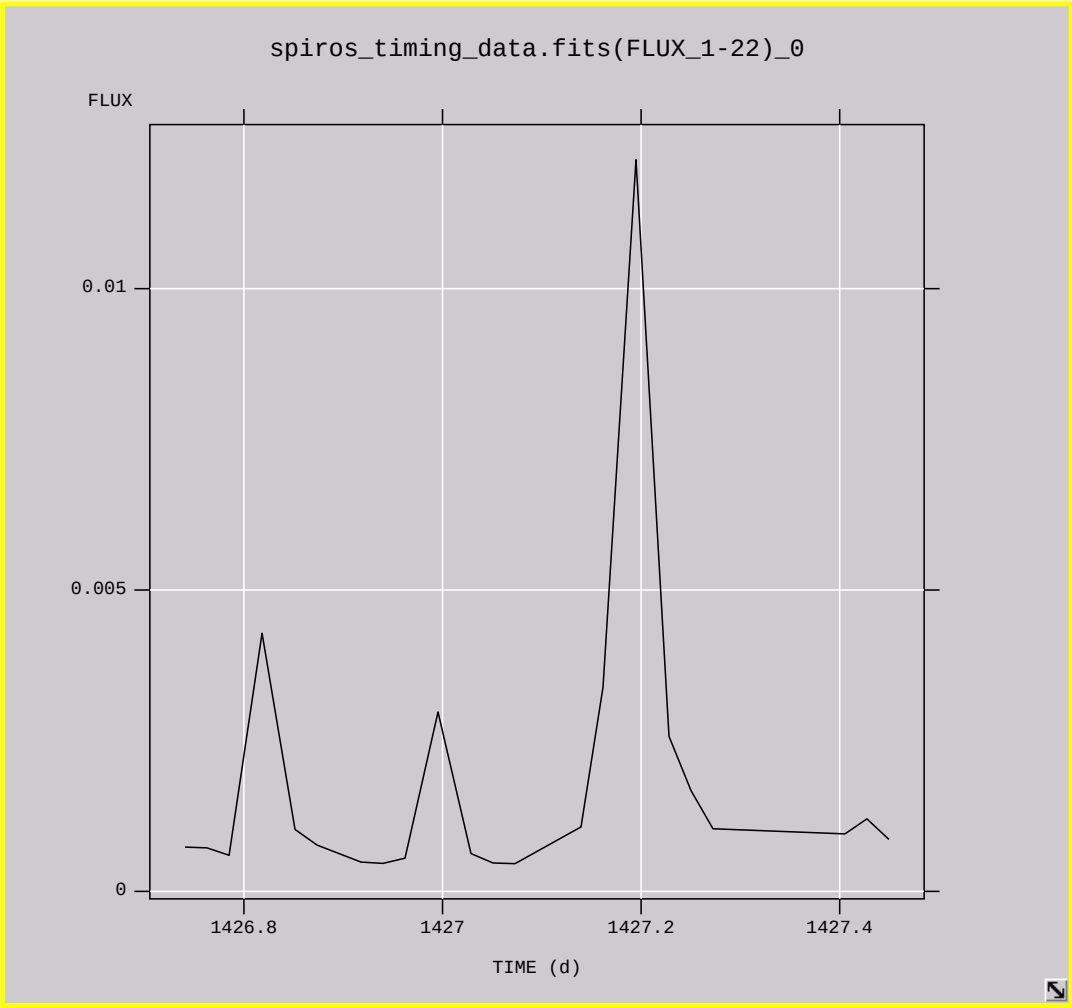




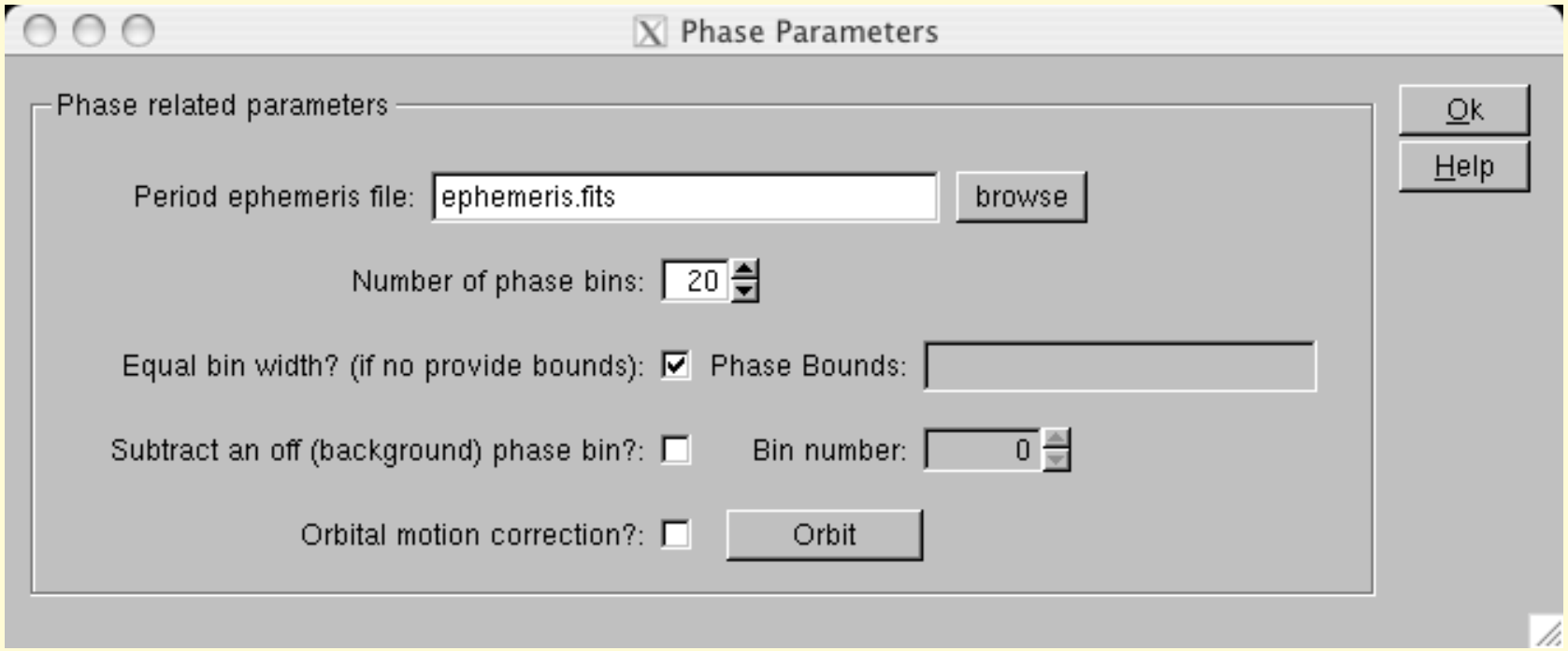
Timescale is in days

Lightcurves, IV

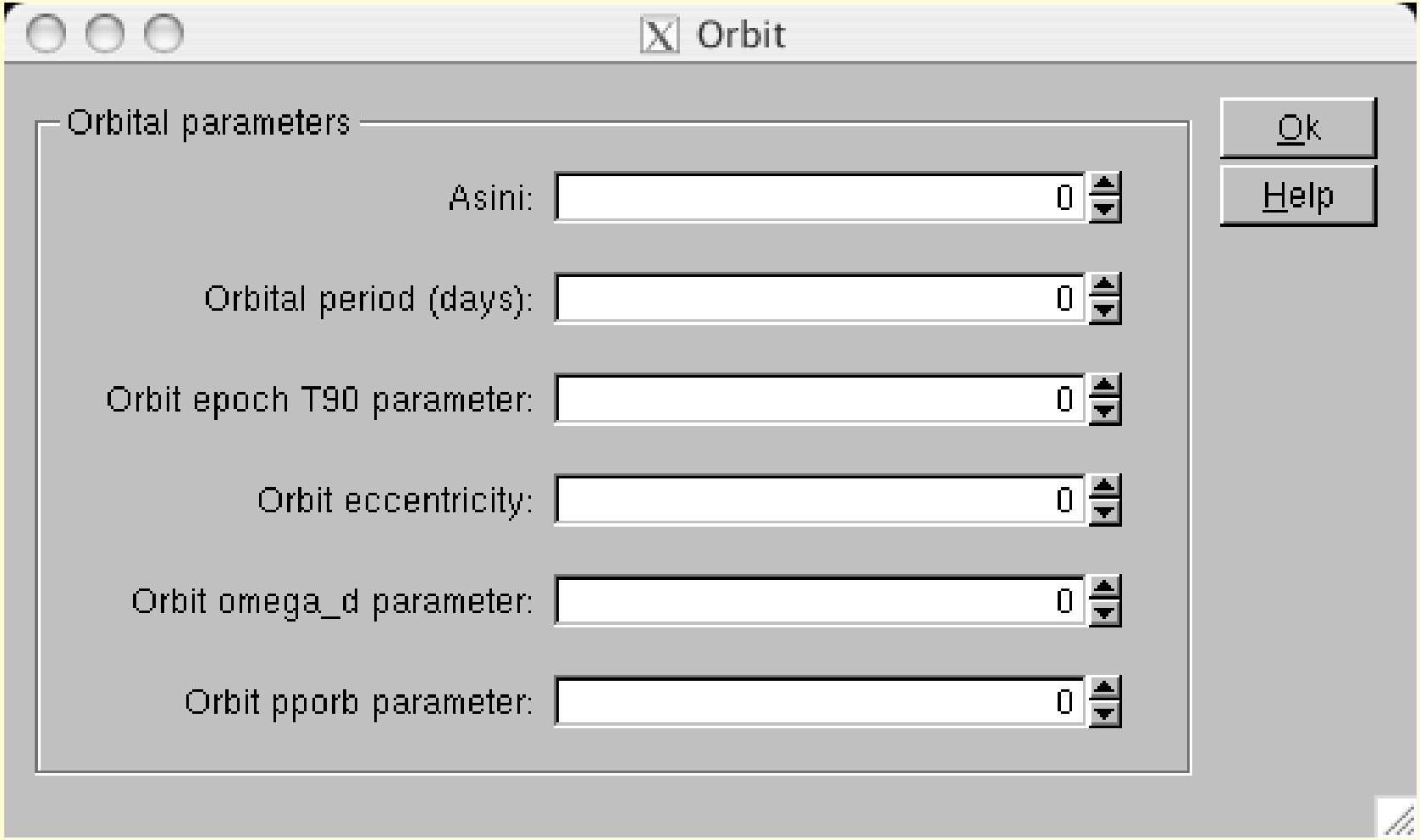
Lightcurve of a short (20 scw) Observation of Vela X-1:



Phaseresolved Spectra, I



Phaseresolved Spectra, II



Phaseresolved Spectra, III