SPI data analysis

Ingo Kreykenbohm

Integral Data Analysis Workshop October 2006



- the Instrument: SPI
- Analysis steps
- Performance



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



- the Instrument: SPI
- Analysis steps
- Performance
- 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

CERCERCIPACIES D

JEM-X coded mask _____

IBIS coded mask

OMC _____

SPI

Instrument computers and electronics

IBIS detector JEM-X detectors

Power regulation

Reaction wheels for pointing the spacecraft

Data handling and telecommunication

Service module

Star trackers

Instrument computers and electronics

> Detector bench Attitude control electronics Batteries

> > Fuel tanks

Attitude sensors

solar panels





- 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 cm²
- 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 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
- ullet annealing phases \sim twice a year



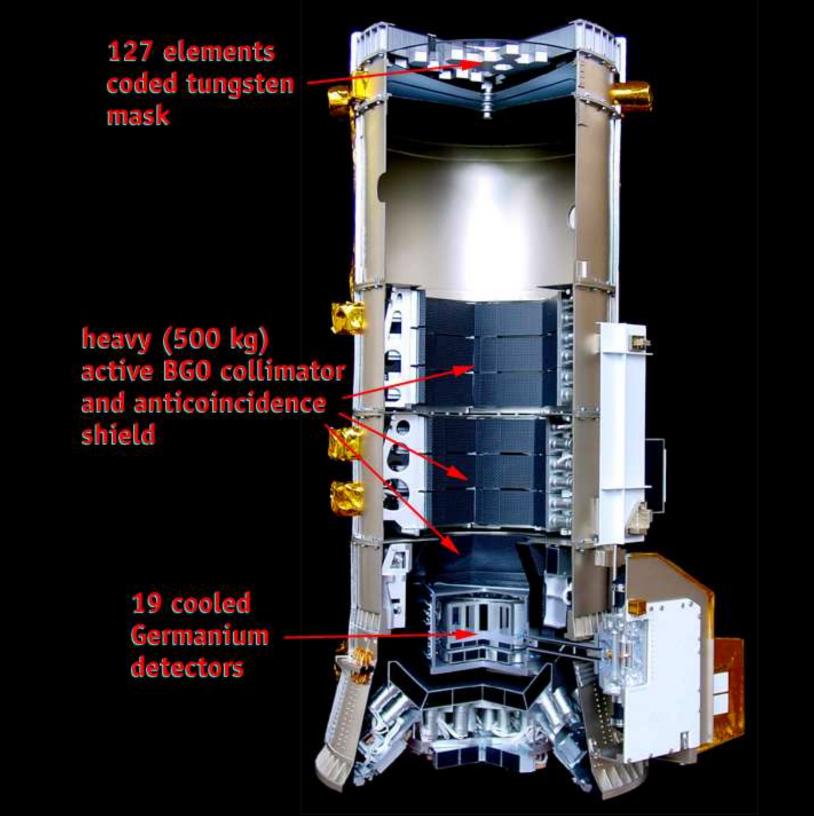




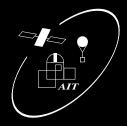
The overall design:

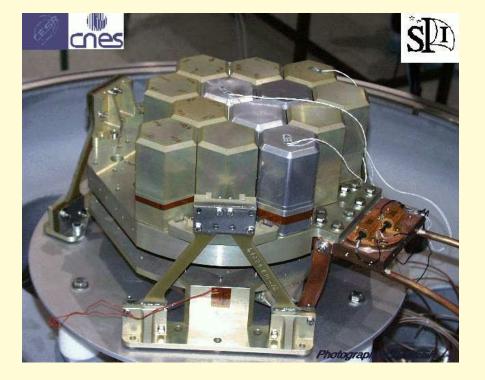
- coded mask instrument
- shielded by the Anti Coincidence Shield, ACS (500 kg BGO)
- 127 element mask: 63 opaque (tungsten), 64 open
- PSAC to suppress 511 keV background
- 19 Germanium detectors
- cooled to 85° K
- ullet annealing phases \sim twice a year
- in the meantime, 2 detectors failed:
 - Det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

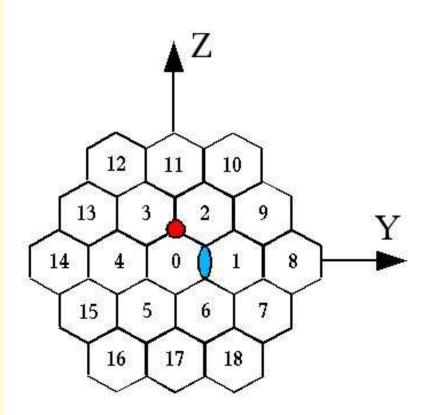












Real Detectors: 0–18 Pseudo Detectors: Doubles: 19–60 Triples: 61–84





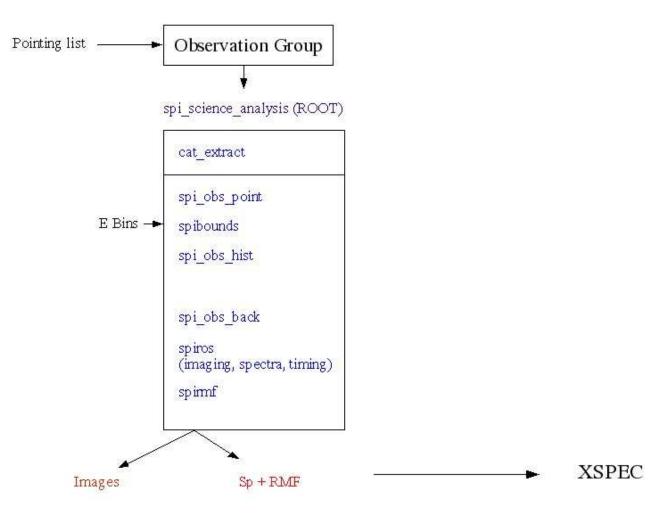


File Edit			DUA			He TIME
Select	☐ TIME_TAG 11	☐ DETE 1B	_ PHA 11	OB_TIME 4I		1D
		IB		41		
_ All Invert				Expand	keV	đ
1212014	1012	13	17094	Plot	9.658691E+01	1.322636492891E+03
1212015	1016	7	20351	Plot	5.383853E+02	1.322636492896E+03
1212016	1070	7	17415	Plot	1.406751E+02	1.322636492960E+03
1212017	1078	6	26654	Plot	1.381794E+03	1.322636492969E+03
1212018	1133	4	16764	Plot	5.238895E+01	1.322636493034E+03
1212019	1134	2	56803	Plot	4.195333E+03	1.322636493035E+03
1212020	1139	16	17366	Plot	1.334001E+02	1.322636493041E+03
1212021	1205	5	16564	Plot	2.579195E+01	1.322636493120E+03
<						

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

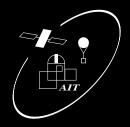


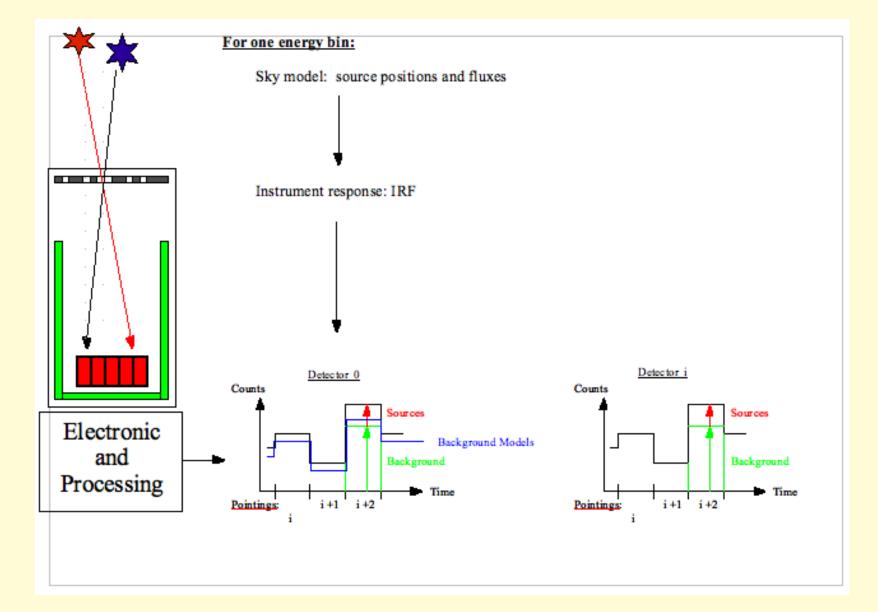






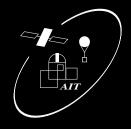


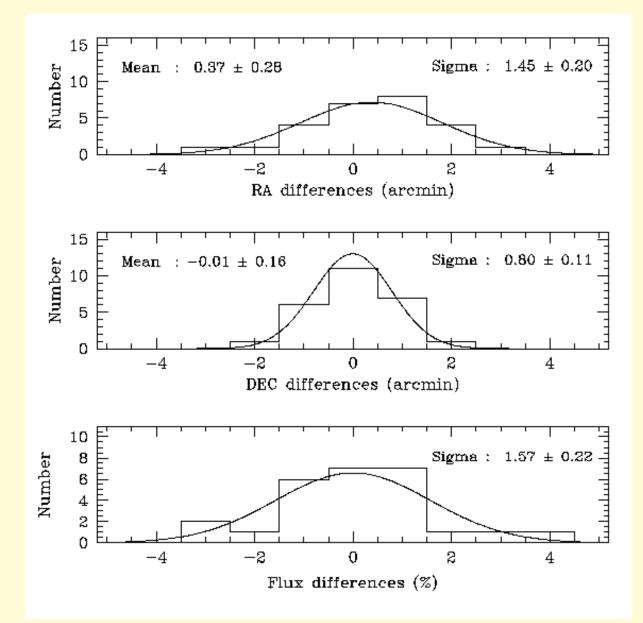




Performance

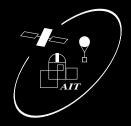
INTEGRAL Science Data Centre

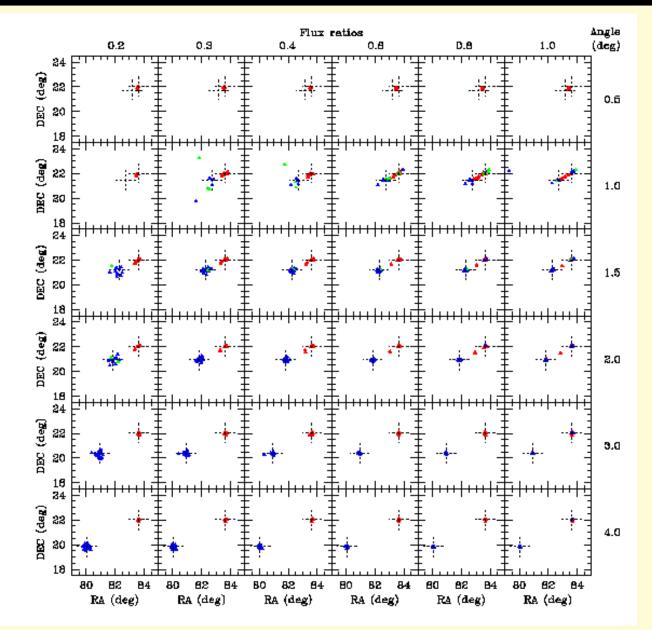




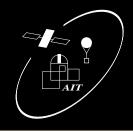
Ber











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 —>many scws required: start with 10 even for simple analysis, for complex analyses: several hundred
- observations in staring mode are diffcult (unsuable)







When selecting science windows for SPI analysis, remember:

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- observations in staring mode are diffcult (unsuable)

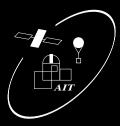
Practical:

- 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=.



0

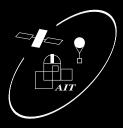


Launch the pipeline GUI:

- 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

00	X spi_science	e_analysis	
General Parameters —			<u>S</u> ave As
_ist of (pseudo) detec	tors: 0-18	-	Load
			<u>R</u> eset
Coordinate Sys	tem: RADEC 🔽		<u>R</u> un
			<u>Q</u> uit
			<u>H</u> elp
			hidden
OPTIONAL first task ((check output before procee	ding with further tasks)	1
CAT_I :	catalog extraction: 🔽	Catalog options	
SPIROS Input	t Catalog: source_cat.fits[1]	
Select analysis tasks -			
POIN :	pointing definition: 🔽	Pointing options	
BIN_I :	event binning: 🔽	Energy definition	
		Histogram options	
BKG_I:	background modeling: 🗹	Background options	
IMA :	image analysis: 🔽	Spiros options	



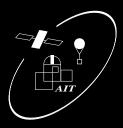


Do you want to use the catalog or not? Typical: first analysis without catalog!

- uncheck catalog step
- clear input catalog field

X spi_science_analys	
\$	<u>Save A</u>
tectors: 0-18	Load
	Reset
System: RADEC 💌	<u>R</u> un
	Quit
	Help
	hidder
k (check output before proceedir	g with further tasks) ———
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	Catalog options
catalog extraction: 🗖	Catalog options
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nput Catalog: ks pointing definition: 🗹	Pointing options
	s etectors: 0-18 System: RADEC 💽





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

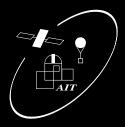
- uncheck catalog step
- clear input catalog field

Check the values for the catalog extraction:

000	🔀 Catalog options		
Catalog extrac	tion parameters	<u>O</u> k	
1	Minimum flux: 0.001	<u>H</u> elp	
м	aximum Flux: 1000		
Refere	nce Catalog:		
			_//,

ieneral Paramet	ers	<u>Save</u> /
ist of (pseudo) (detectors: 0-18	Loac <u>R</u> ese
Coordinate	e System: RADEC 💌	<u>R</u> un
		Quit
		<u>H</u> elp
		hidde
PTIONAL first t	ask (check output before proceedii	ng with further tasks)
CAT_I :	catalog extraction: 🗖	Catalog options
SPIROS	Input Catalog:	
elect analysis t	asks	
elect analysis t	asks pointing definition: 🔽	Pointing options
elect analysis t POIN : BIN_I :		Pointing options Energy definition
POIN :	pointing definition: 🔽	2
POIN :	pointing definition: 🔽	Energy definition





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

0.0	X spi_science_analys	is
General Parametr	ers	Save A
l int of (manuals) a	10.10	Load
List of (pseudo) o	tetectors: 10-18	<u>R</u> eset
Coordinate	e System: RADEC 💌	<u>R</u> un
		Quit
		<u>H</u> elp
		hidder
OPTIONAL first ta	ask (check output before proceedir	ng with further tasks)
CAT_I :	catalog extraction: 🗖	Catalog options
SPIROS	Input Catalog:	Catalog options
	Input Catalog:	
SPIROS Select analysis ta	Input Catalog:	Catalog options Pointing options Energy definition
SPIROS Select analysis ta POIN :	Input Catalog:	Pointing options
SPIROS Select analysis ta POIN :	Input Catalog:	Pointing options Energy definition



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

- energy_definition	
Parameters for task spibounds Number of energy regions: 1	<u>O</u> k <u>H</u> elp
Regions energy boundaries: 20,40	
Numbers of bins in each region: 1	



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

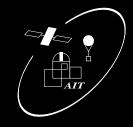
000	X Spiros options
SPIROS General Setup	<u>k</u>
Run SPIROS in Mode:	IMAGING Help
-Further Options for	
Imaging	Timing
Soloction Decomptore	
Selection Parameters —	
energy-subset:	
pointing-subset:	
detector-subset:	
Other Parameters	
Background m	ethod: 3 💌
Optimization st	atistic: CHI2 💌
Bins for src loc	cation: FIRST
1	



- 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!

OOO 🛛 🕅 Imaging	
General spiros options No. of sources: 3 Sigma threshold: 6 Iteration output: NO 💽	<u>O</u> k <u>H</u> elp
Spiros image options Projection: CAR FOV: POINTING+ZCFOV	





Checkout the produced logfile:

2005-10-12T12:41:34 :	Ptg Rev B	Exp	ONTIME	CHI2,ML	Expected	l Diff	Reduce	d Data
2005-10-12T12:41:34 :	-no -no -	-no	(secs)	value	value	/STD	CHI2,M	L 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

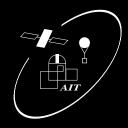




- try different background models: flatfield, GeDSat, MCM
- 2. try again: much better

🗖 📮 spiros
SPIROS General Setup
Run SPIROS in Mode: IMAGING 💌 <u>H</u> elp
Further Options for
imaging timing
Selection Parameters
energy-subset:
pointing-subset:
detector-subset:
C Other Parameters
Background method: 5
Optimization statistic: CHI2
Image solution constraint: NONE
Bins for src location: FIRST

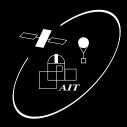




- 1. try different background models: flatfield, GeDSat, MCM
- 2. try again: much better but still some pointings unacceptable
- 3. tell spiros, not to use the bad pointings:
- 4. repeat until no bad pointings left

🗖 🚽 spiros	
SPIROS General Setup	<u>k</u>
Run SPIROS in Mode: IMAGING	<u>H</u> elp
Further Options for	
imaging timing	
- Selection Parameters	
energy-subset:	
pointing-subset: 2-12,14-38,42-43	
detector-subset:	
1	
C Other Parameters	
Background method: 5	
Optimization statistic: CHI2	
Image solution constraint: NONE	
Bins for src location: FIRST	

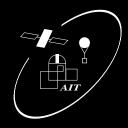




- 1. try different background models: flatfield, GeDSat, MCM
- 2. try again: much better but still some pointings unacceptable
- 3. tell spiros, not to use the bad pointings:
- 4. repeat until no bad pointings left
- 5. create a region file for ds9:
 cat2ds9 source_res.fits
 source_res.reg

🗖 🚽 spiros	
- SPIROS General Setup	<u>O</u> K
Run SPIROS in Mode: IMAGING 💌	<u>H</u> elp
-Further Options for	
imaging timing	
Selection Parameters	
energy-subset:	
pointing-subset: 2-12,14-38,42-43	
detector-subset:	
Other Parameters	
Background method: 5	
Optimization statistic: CHI2	
Image solution constraint: NONE	
Bins for src location: FIRST	





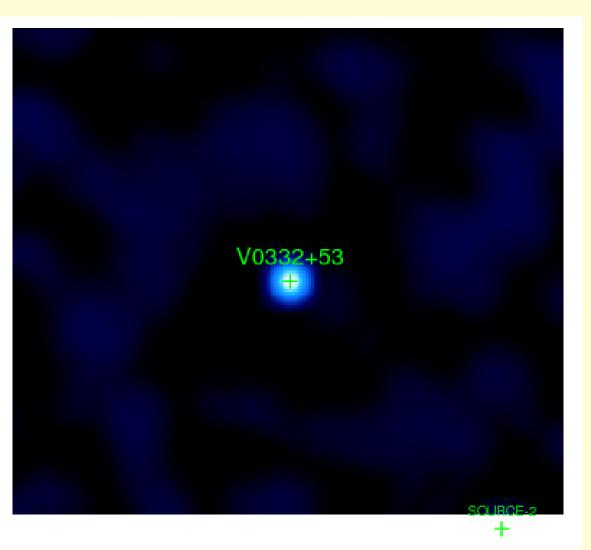
look at the images:

ds9

spiros_image_intensity_result.fits

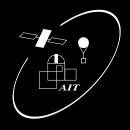
-region source_res.reg

most importantly the significance images









For spectral extraction, an input catalog is required!

- source catalog
- modifed source list from spiros





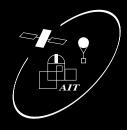


- 1.cp source_res.fits source_cat.fits
- 2. edit the catalog with fv
- 3. set sel_flag to 0 for irrelevant sources
- 4. set the extension name to SPI.-SRCL-CAT

🗖 🗖 fv:	: Binary Table of source_r	es.fits[1 🔽 🔸 🗖 🗖
File Edit	Tools	Help
	NAME	SEL_FLAG
Select	20A	11
🗆 Ali		
Invert		
1	V 0332+53	1
2	SOURCE-2	0
Go to:	Edit cell: VO	332+53







🗖 🦳 spi_scienc	e_analysis	
SPI Scientific An	alysis - General Parameters and (
Filename of	input OG: og_spi.fits	<u>S</u> ave As <u>R</u> un
List of (pseudo)	detectors: 0-18	
Coordinat	e System: RADEC 💌	<u>H</u> elp hidden
OPTIONAL first t	ask (check output before proceed	ling with further tasks)
CAT_I :	catalogue extraction: 🗖	catalog
SPIROS	Input Catalog: source_cat.fits	
Select Tasks to r	un	
POIN :	pointing definition: 🗖	pointing
BIN_I :	event binning: 🔽	energy_definition
		histogram
add sin	nulated source (OPTIONAL):	add_simulation
BKG_I :	background modeling: 🔽	background
IMA :	image analysis: 🔽	spiros



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/	

spi_scier	nce_analysis	
⊢ SPI Scientific A	Analysis - General Parameters and	Options <u>S</u> ave
Filename o	of input OG: og_spi.fits	<u>B</u> un
List of (peoudo) detectors: 0-18	Quit
List of (pseudo) detectors: [0-10	
Coordin	ate System: RADEC 💌	<u>H</u> elp
		hidden
	t task (check output before proceed	ding with further tasks)
CAT_I :	catalogue extraction: 🗖	catalog
SDIDC	S Input Catalog: source_cat.fits	
SPIRC	is input catalog: [source_cat.its	
Colort Tooks to		
- Select Tasks to	i run	
POIN :	pointing definition: 🗖	pointing
	–	
BIN_I :	event binning: 🔽	energy_definition
		histogram
		Instogram
add s	simulated source (OPTIONAL): 🔲	add_simulation
BKG_I:	background modeling: 🔽	background
IMA :	image analysis: 🔽	spiros

Select an appropriate energy binning:

-	energy_definition		
Para	ameters for task spibounds Number of energy regions: 1	<u>O</u> k <u>H</u> elp	
	Regions energy boundaries: 20,200		
N	lumbers of bins in each region: -50		



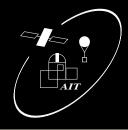


	maluaia	
spi_science	_anaiysis	
SPI Scientific An	alysis - General Parameters and O	otions <u>S</u> ave
Filename of i	nput OG: og_spi.fits	<u>S</u> ave As <u>R</u> un
List of (pseudo) o	letectors: 0-18	Quit
Coordinate	e System: RADEC 🔽	<u>H</u> elp hidden
	ask (check output before proceedir	· · ·
CAT_I :	catalogue extraction: 🗖 📃	catalog
SPIROS	Input Catalog: source_cat.fits	
-Select Tasks to r	ın	
POIN :	pointing definition: 🗖 🔤	pointing
BIN_I :	event binning: 🔽 🔤	energy_definition
		histogram
add sim	ulated source (OPTIONAL): 🗖 📘	add_simulation
BKG_I :	background modeling: 🗹 🔤	background
IMA :	image analysis: 🔽 🔤	spiros

Set spiros to mode Spectra:

spiros	
SPIROS General Setup	<u>O</u> k
Run SPIROS in Mode: SPECTRA	<u>H</u> elp
Further Options for	
imaging timing	
Selection Parameters	
energy-subset:	
pointing-subset: 2-12,14-38,42-43	
detector-subset:	
1	
Other Parameters	
Background method: 5	
Optimization statistic: LIKEH	
Image solution constraint: NONE	
Bins for src location: FIRST	





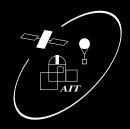
🗖 🖃 spi_science_analysis
SPI Scientific Analysis - General Parameters and OptionsSave
Filename of input OG: og_spi.fits <u>Save As</u>
List of (pseudo) detectors: 0-18
Coordinate System: RADEC hidden
OPTIONAL first task (check output before proceeding with further tasks)
CAT_I : catalogue extraction:
SPIROS Input Catalog: source_cat.fits
Select Tasks to run
POIN : pointing definition:
BIN_I : event binning: 🔽 energy_definition
histogram
add simulated source (OPTIONAL): 🗖add_simulation
BKG_I : background modeling: 🔽 background
IMA : image analysis: 🔽 spiros

Set spiros to mode Spectra:

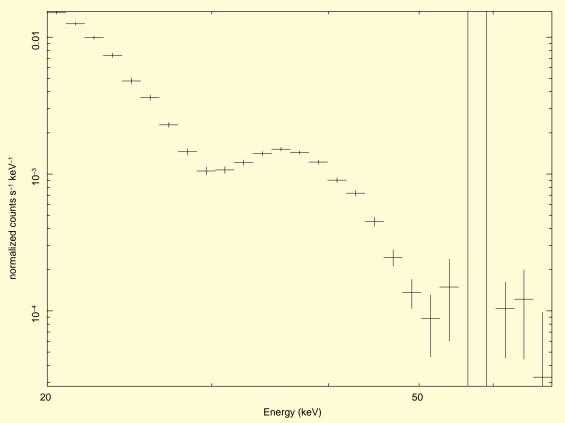
🗖 🗕 spiros	
- SPIROS General Setup	<u>O</u> k
Run SPIROS in Mode: SPECTRA 💌	<u>H</u> elp
-Further Options for	
imaging timing	
- Selection Parameters	
Selection Parameters	
energy-subset:	
pointing-subset: 2-12,14-38,42-43	j
detector-subset:	j
Other Parameters	
Background method: 5	
Optimization statistic: LIKEH	
Image solution constraint: NONE	
Bins for src location: FIRST	

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





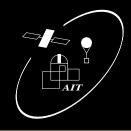
- ready-to-use PHA files which can be loaded directly into xspec
- an appropriately rebinned response matrix



data

kreyken 12-Oct-2005 23:18





Smallest possible time resolution: 1 science window (set time-scale to 0)! \implies only suitable for long-term lightcurves.







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

🗖 🗖 spiros
SPIROS General Setup
Run SPIROS in Mode: TIMING 🗨 Help
Further Options for
imaging timing
Selection Parameters
energy-subset:
pointing-subset: 2-12,14-38,42-43
detector-subset:
·
Other Parameters
Background method: 5
Optimization statistic: LIKEH 💌
Image solution constraint: NONE
Bins for src location: FIRST

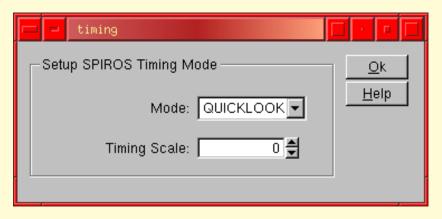




Smallest possible time resolution: 1 science window (set time-scale to 0)! \implies only suitable for long-term lightcurves.

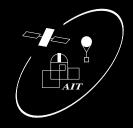
- 1. select the source in the catalog
- 2. select an appropriate energy binning
- 3. set spiros in timing mode:

spiros
SPIROS General Setup
Run SPIROS in Mode: TIMING 💌 Help
Further Options for
imaging timing
Selection Parameters
energy-subset:
pointing-subset: 2-12,14-38,42-43
detector-subset:
Other Parameters
Background method: 5
Optimization statistic: LIKEH 💌
Image solution constraint: NONE
Bins for src location: FIRST
· · · · · · · · · · · · · · · · · · ·

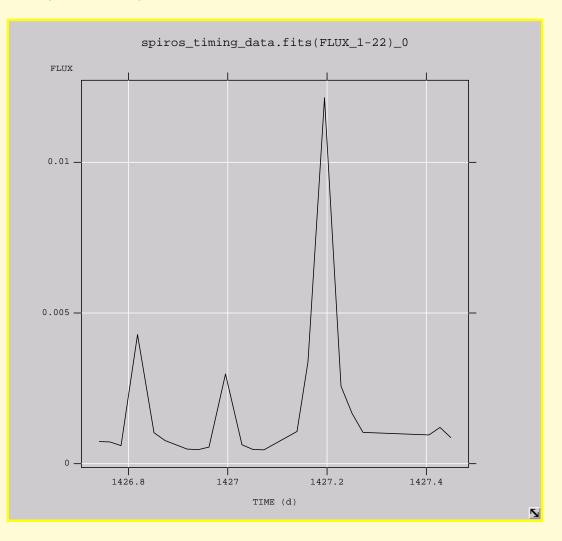


Timescale is in days





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









O O O X Phase Parameters	
Phase related parameters	<u>O</u> k
Period ephemeris file: ephemeris.fits browse	<u>H</u> elp
Number of phase bins: 20 🚔	
Equal bin width? (if no provide bounds): 🔽 Phase Bounds:	
Subtract an off (background) phase bin?: 🗖 🛛 Bin number: 🚺 曼	
Orbital motion correction?: Orbit	
	1.







	000	🔀 Orbit	
	Orbital parameters		<u>O</u> K
	Asini:		<u>H</u> elp
l	Orbital period (days):	0	
l	Orbit epoch T90 parameter:	0	
	Orbit eccentricity:	0	
l	Orbit omega_d parameter:	0	
	Orbit pporb parameter:	0	
			1.







