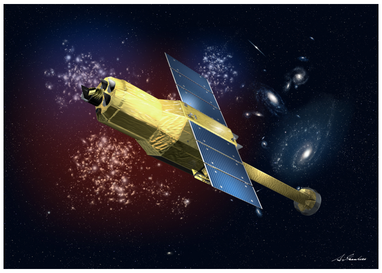

HITOMI

THE HITOMI STEP-BY-STEP ANALYSIS GUIDE

Applicable to Hitomi Software version 6/Caldb version 7, Data Processing Run 4

Date: Jun 15 2019

Version 6.2

X-ray Astrophysics Laboratory (NASA/Goddard Space Flight Center)
and the
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Table of Contents

Notes on this version of the guide and differences from the previous version

This version of the step-by-step guide is applicable to the Hitomi archived data, software, and calibration available to the Hitomi SWG as of 2016 December 22, i.e. the third complete release of the data, and Hitomi v5 software and CALDB. As in previous versions the procedures follow the sequence used in earlier training sessions. For each object, the steps are grouped into (1) reprocessing, (2) product extraction, (3) response generation, and (4) spectral fitting categories; and, divided by instrument within each of these groups for all relevant detectors. Since the previous version of this guide, updates in the attitude files, pre-pipeline and pipeline software tasks, and CALDB files (including selection criteria) results in revised cleaned event files. Due to relaxed SXS screening, an exposure map with multiple attitude bins is now recommended in constructing the Crab SXS ARF. A new procedure for spectral analysis of the Crab SXI out-of-time events is now included. The CALDB updates also affect the HXI, SXI, and SXS response files.

The procedure details for alternative SXS filtering, extra SXS screening, and adjusting the SXI BACKSCAL keywords are revised, and options for applying auxiliary ARF adjustment files to the HXT and SXT-I, and SXT-S (illustrated for the Crab), extracting spectra and creating response files over an extended SXS energy scale. An example of applying a procedure for further filtering the events for times when the Star Tracker is controlling the attitude is shown for one of the Perseus sequences under "Instrument Specific Reprocessing". This version also includes updated instructions for N132D, RXJ1856.5-3754, and IGR J16318-4848 observations. Some of the figures and numerical values, particularly for RXJ1856.5-3754, may be based on reprocessing of earlier versions of the data and, adddtionally, are subject to further variation as a result of subsequent software and CALDB patches. The names of files in the spectra fitting sections my differ from those in the extraction sections.

[2017 March ADDENDUM] A temporary procedure for constructing corrected cleaned SGD event files by reprocessing using updated CALDB files, followed by an
additional screening step is included for G21.5-0.9 and the Crab Nebula. There are also now instruction for extracting the NXB in the G21.5-0.9, Persues, and Crab Nebula "Extracting Products" subsections.

[2017 April ADDENDUM] The above temporary procedure for constructing corrected cleaned SGD event files is updated, and a possible future replacement (dependent on a future SGD CALDB update) with a different additional screening applied to cleaned event files is indicated. Also added are examples of streamlined application of the *sxsextend* task.
[2017 Dec] Change the SGD commands for the Crab seq 100044010
[2019 Jun] Update the nxb location from postlaunch/processing/nxb_20170306 to data/nxb_20170510 and the protocol from FTP to HTTPS. The data files are identical. The SGD gti for the crab are only present in data/nxb_20170510.

Data Sequence log

SEQ_ID	TARGET	INSTRUMENTS ON	POINTING	"NON-STANDARD" INSTRUMENT MODES[1]
100050010	G21.5-0.9	SXS, SXI, HXI1, HXI2	ON CENTER	NONE
100050020	G21.5-0.9	SXS, SXI, HXI1, HXI2, SGD1	ON CENTER	NONE
100050030	G21.5-0.9	SXS, SXI, HXI1, HXI2, SGD1	ON CENTER	NONE
100050040	G21.5-0.9	SXS, SXI, HXI1, HXI2, SGD1	ON CENTER	NONE
100044010	Crab	SXS, SXI, HXI1, HXI2, SGD1, SGD2	ON CENTER	SXI "CRAB" MODE[2] HXI CAMNORM2 SGD2 only CC1 has useful data
100040010	Perseus_core	SXS	~3.5 ARCMIN OFF CENTER	SXS DEVPTHRE=120
100040020	Perseus_core_adjustment	SXS	~1 ARCMIN OFF CENTER	SXS DEVPTHRE=120
100040030	Perseus	SXS	~1 ARCMIN OFF CENTER	NONE
100040040	Perseus	SXS	~1 ARCMIN OFF CENTER	NONE
100040050	Perseus	SXS	~1 ARCMIN OFF CENTER	NONE
100040060	Perseus	SXS, SXI	~ ON CENTER	SXI NOT SPLIT, EVENTTHR= 30 (all segs.)
100041010	N132D	SXS, SXI	OFF CENTER, SXI GAP	SXI NOT SPLIT
100041020	N132D	SXS, SXI	OFF CENTER, SXI GAP	SXI NOT SPLIT
100042010	IGR_J16318-4848	SXS, SXI	OFF CENTER	SXI NOT SPLIT
100042020	IGR_J16318-4848	SXS, SXI, HXI1	OFF CENTER	SXI NOT SPLIT
100042030	IGR_J16318-4848	SXS, SXI, HXI1	OFF CENTER	SXI NOT SPLIT
100042040	IGR_J16318-4848	SXS, SXI, HXI1	OFF CENTER	SXI NOT SPLIT
100043010	RXJ1856.5-3754	SXS, SXI, HXI1, HXI2	OFF CENTER , NO SXS	SXI EVENTTHR= 40 (aimpoint seg.)
100043020	RXJ1856.5-3754	SXS, SXI, HXI1, HXI2	OFF CENTER , NO SXS	SXI EVENTTHR= 40 (aimpoint seg.)
100043030	RXJ1856.5-3754	SXS, SXI, HXI1, HXI2	OFF CENTER , NO SXS	SXS FE55, SXI EVENTTHR= 40 (aimpoint seg.)
100043040	RXJ1856.5-3754	SXS, SXI, HXI1, HXI2	OFF CENTER , NO SXS	SXI EVENTTHR= 40 (aimpoint seg.)
100043050	RXJ1856.5-3754	SXS, SXI, HXI1, HXI2, SGD1, SGD2	OFF CENTER , NO SXS	SXI EVENTTHR= 40 (aimpoint seg.)
100043060	RXJ1856.5-3754	SXS, SXI, HXI1, HXI2, SGD1, SGD2	OFF CENTER , NO SXS	SXI EVENTTHR= 40 (aimpoint seg.) HXI CAMNORM2
100045010	Mrk205			

NOTE: "INSTRUMENT ON" excludes HXI and SGD DATAMODE=STANDBY data.
[1] "STANDARD" is defined as SXS DEVPTHRE=75; SXI events are split into separate event lists for NORMAL and MZDYE modes, with event threshold=100 ADU (2048 or 2000 ADU) for all segments for NORMAL mode (MZDYE mode); HXI CAMERA_NORMAL1; SGD CC_NORMAL1.
[2] "Crab" mode has the following SXI settings:

`EVENTTHR='(100,100,100,100,NA,NA,NA,NA)'/'(2048,2048,2048,100,NA,NA,NA,NA)'` for `ah100044010sxi_p0112004e0/p0112004e1 (CCD_ID=0,1)` event lists, and:
`EVENTTHR='(NA,NA,NA,NA,100,100,100,100)'/'(NA,NA,NA,NA,2048,2048,2048,2048)'` for `ah100044010sxi_p0120004e0/p0120004e1 (CCD_ID=3,4)` event lists.

Software and CALDB Files

File	Description
alias_config.fits	CALDB supporting file
caldb.config	CALDB supporting file
caldb_hitomi_20170405all.tar.gz	CALDB data files
Hitomi_30Mar2017_V006_src.tgz	Hitomi software release

Software

The latest updates to the Hitomi software is not included in HEASoft 6.21, but will be part of future HEASoft releases. Directions for building and installing the Hitomi package as a standalone.

a) untar the software tar file in a directory mydir:

```
cd /full-path/mydir
tar -zxf Hitomi_04Apr2017_V006_src.tgz
```

b) build/install

```
cd /full-path/mydir/Hitomi_30Mar2017_V006/BUILD_DIR
```

To build and install the code use the instructions you find under step 3 accordingly to the operating system in the following page:

https://heasarc.gsfc.nasa.gov/docs/software/lheasoft/download.html

d) Set up environment

```
setenv HEADAS /full-path/mydir/Hitomi_30Mar2017_V006/operating-system

source $HEADAS/headas-init.csh
```

CALDB

Directions for installing the latest HITOMI CALDB as a standalone.

Untar in a directory "`/full-path/caldbdir`" and copy the `caldb.config` and `alias_caldb.fits` files into there.

```
cd full-path/caldbdir
tar -xzvf caldb_hitomi_20170405all.tar.gz
cp /location_of/caldb.config ./
cp /location_of/caldb.fits ./

setenv CALDB /full-path/caldbdir/caldb
setenv CALDBCONFIG /full-path/caldbdir/caldb/caldb.config
setenv CALDBALIAS /full-path/caldbdir/caldb/alias_caldb.fits
```

Summary of Tasks Run

	description	input	output	CALDB
ahcalctime	recalculate time	tim file gen hk <inst>-hk <inst>-uf.evt sxs lost GTI	tim file gen hk <inst>-hk <inst>-uf.evt sxs lost GTI	frqtemfile coeftime coldeffile delayfile offsetfile leapsecfile
ahpipeline	reprocess all events	indir outdir steminputs stemoutputs instrument entry_stage exit_stage verify_input create_ehkmkf	outdir contents	selectfile mkfconf cor2files cor3file saafile intstrument-specific (see relevant pipeline task)
hxipipeline	reprocess hxi events	attitude orbit obsgti telgti mkf ehk hxi-hk hxi-uf hxi-cams hxi-pseudo-uf	hxi-uf hxi-ufa hxi-cl hxi-pseudo-cl hxi-delta-attitude	hxi teldef cams teldef cams temperature selectfile remapfile gainfile badpixfile fluorefile enecutfile
sgdpipeline	reprocess sgd events	attitude orbit obsgti mkf ehk sgd-hk sgd-uf sgd-pseudo-uf	sgd-uf sgd-ufa sgd-cl sgd-pseudo-cl	remapfile gainfile badpixfile fluorefile probseqfile probfovfile selectfile
sxipipeline	reprocess sxi events	attitude orbit obsgti telgti mkf ehk sxi-hk sxi-uf sxi-hpix sxi-exp	sxi-uf sxi-cl sxi-fpix sxi-bimg sxi-mode-gti sxi-seg-gti	sxs teldef selectfile badpixfile maskfile vtevboddfile ctifile chtrailfile spthfile gainfile patternfile
sxspipeline	reprocess sxs events	attitude orbit obsgti telgti adrgti mkf ehk sxs-hk sxs-ac	sxs-hk sxs-uf sxs-pxcal-uf sxs-ac sxs-pix-cl mxs-gti sxs-ghf sxs-exp	sxs teldef selectfile antico gain pixel wiring map pixel gain antico gain calline profiles delay file time coefficients

		sxs-pix-uf sxs-el-gti		pulse file
ahfilter	create new ejk and mkf files	attitude orbit infileroot tstart tstop optaxis	outehkfile outmkffile	selectfile mkfconf cor2files cor3file saafile
ahgtigen	create or combine GTI	ehk or mkf file or list of GTI gtiexpr label instrume	single or merged GTI	selectfile
ahscreen	create or combine GTI	event file GTI file or list expression label	screened event file	selectfile
hxisgddtime	correct light curve and spectrum for dead time	pseudo-event file Light curve Spectrum GTI file	corrected light curve corrected spectrum	none
barycen	correct time for Solar System barycenter	event file or light curve orbit	corrected event file or light curve	none
sxsregext	extract SXS data products	sxs-pix-cl region (RADEC/DET) grade selection ehk	image, lightcurve, spectrum exposure map DET region	teldef instrument map qefile contamifile obffile fwfile gvfile
sxsextend	add extended energy scale to SXS event file	sxs-pix-cl or sxs-pix-uf driftfile gen-gti file sxs-tel file eminin dein nchanin	sxs-pix-uf sxs-pix-cl	gainfile scalefile selectfile
ahexpmap	generate exposure map	ehk file GTI file bimg file (SXI) pixgtifile (SXI/S) range-theta num-phi	exposure map file	instmap
ahexpmap	generate flat field	ehk file GTI file bimg file (SXI) pixgtifile range-theta num-phi	efficiency map file	instmap qefile contamifile vigfile gvfile (SXS) fwfile (SXS) obffile (SXS)

ahbacscal	correct BASKSCAL keyword	spectrum region file exposure map	spectrum	none
sxsmkrmf	generate SXS RMF file	sxs-pix-cl region (DET) grade selection	RMF file	teldef line-spread function
aharfgen	generate ARF file	exposure map RMF delta-att file (HXI) cams-offset (HXI) region (DET) source distribution energy range	ARF (SXI/S) or RSP file (HXI)	teldef qefile contamifile (SXI/S) gvfile (SXS) fwfile (SXS) obffile (SXS) on-axis ARF (fine and coarse) mirror description obstructions frontside refl/trans backside refl/trans pre-coll refl/trans scattering
hxirspeffimg	generate flat field (HXI)	exposure map delta-attitude cams-offset energy range raytrace file	efficiency map file	teldef qefile rmfffile vigfile on-axis ARF (fine and coarse) mirror description obstructions frontside refl/trans backside refl/trans pre-coll refl/trans scatteringnstmap

Randomization

In the tool command examples in this document, the randomization seed is always set to one number, `seed=7`. This is just for testing, to ensure that ahpipeline and the instrument pipelines get the same results. In practice, a user would want a random seed taken from the system time, i.e. `seed=0`.

G21.5-0.9

Data description

Table 3a	100050010	100050020
GEN-HK	ah100050010gen_a0.hk1.gz	ah100050020gen_a0.hk1.gz
TIM	ah100050010.tim.gz	ah100050020.tim.gz
ATTITUDE	ah100050010.att.gz	ah100050020.att.gz
ORBIT	ah100050010.orb.gz	ah100050020.orb.gz
OBSGTI	ah100050010_gen.gti.gz	ah100050020_gen.gti.gz

MKF	ah100050010.mkf.gz	ah100050020.mkf.gz
EHK	ah100050010.ehk.gz	ah100050020.ehk.gz
EHK2	ah100050010.ehk2.gz	ah100050020.ehk2.gz
HXI1 HK	ah100050010hx1_a0.hk.gz	ah100050020hx1_a0.hk.gz
HXI2 HK	ah100050010hx2_a0.hk.gz	ah100050020hx2_a0.hk.gz
HXI DELTA-ATT	ah100050010hx1.att.gz	ah100050020hx1.att.gz
HXI DELTA-ATT	ah100050010hx2.att.gz	ah100050020hx2.att.gz
HXI1 CAMS	ah100050010hx1_cms.fits.gz	ah100050020hx1_cms.fits.gz
HXI2 CAMS	ah100050010hx2_cms.fits.gz	ah100050020hx2_cms.fits.gz
HXI1 SFF	ah100050010hx1_p0camrec_uf.evt.gz	ah100050020hx1_p0camrec_uf.evt.gz
HXI2 SFF	ah100050010hx2_p0camrec_uf.evt.gz	ah100050020hx2_p0camrec_uf.evt.gz
HXI1 SFFa	ah100050010hx1_p0camrec_ufa.evt.gz	ah100050020hx1_p0camrec_ufa.evt.gz
HXI2 SFFa	ah100050010hx2_p0camrec_ufa.evt.gz	ah100050020hx2_p0camrec_ufa.evt.gz
HXI TEL	ah100050010hxi_tel.gti.gz	ah100050020hxi_tel.gti.gz
HXI1 PSEUDO	ah100050010hx1_p0camrecpse_cl.evt.gz	ah100050020hx1_p0camrecpse_cl.evt.gz
HXI2 PSEUDO	ah100050010hx2_p0camrecpse_cl.evt.gz	ah100050020hx2_p0camrecpse_cl.evt.gz
HXI1 EVT CL	ah100050010hx1_p0camrec_cl.evt.gz	ah100050020hx1_p0camrec_cl.evt.gz
HXI2 EVT CL	ah100050010hx2_p0camrec_cl.evt.gz	ah100050020hx2_p0camrec_cl.evt.gz
SGD1 HK	ah100050010sg1_a0.hk.gz	ah100050020sg1_a0.hk.gz
SGD2 HK	ah100050010sg2_a0.hk.gz	ah100050020sg2_a0.hk.gz
SGD1 SFF		ah100050020sg1_p0cc1rec_uf.evt.gz ah100050020sg1_p0cc2rec_uf.evt.gz ah100050020sg1_p0cc3rec_uf.evt.gz
SGD1 SFFa		ah100050020sg1_p0cc1rec_ufa.evt.gz ah100050020sg1_p0cc2rec_ufa.evt.gz ah100050020sg1_p0cc3rec_ufa.evt.gz
SGD TEL		ah100050020sgi_tel.gti.gz
SGD1 PSEUDO		ah100050020sg1_p0cc1recpse_cl.evt.gz ah100050020sg1_p0cc2recpse_cl.evt.gz ah100050020sg1_p0cc3recpse_cl.evt.gz
SGD1 EVT CL		ah100050020sg1_p0cc1rec_cl.evt.gz ah100050020sg1_p0cc2rec_cl.evt.gz ah100050020sg1_p0cc3rec_cl.evt.gz
SXI EVT UF	ah100050010sxi_p0100004b0_uf.evt.gz	ah100050020sxi_p0100004b0_uf.evt.gz
SXI MZDYE EVT UF	ah100050010sxi_p0100004b1_uf.evt.gz	ah100050020sxi_p0100004b1_uf.evt.gz
SXI HOTPIX	ah100050010sxi_a0100004b0.hpix.gz	ah100050040sxi_a0100004b0.hpix.gz
SXI MZDYE HOTPIX	ah100050010sxi_a0100004b1.hpix.gz	ah100050040sxi_a0100004b1.hpix.gz
SXI FLICKPIX	ah100050010sxi_a0100000b0.fpix.gz	ah100050040sxi_a0100000b0.fpix.gz
SXI MZDYE FLICKPIX	ah100050010sxi_a0100000b1.fpix.gz	ah100050040sxi_a0100000b1.fpix.gz
SXI BAD PIXEL IMG	ah100050010sxi_p0100000b0.bimg.gz	ah100050040sxi_p0100000b0.bimg.gz
SXI MZDYE BAD PIXEL IMG [	ah100050010sxi_p0100000b1.bimg.gz	ah100050040sxi_p0100000b1.bimg.gz
SXI TEL	ah100050010sxi_tel.gti.gz	ah100050040sxi_tel.gti.gz
SXI EVT CL	ah100050010sxi_p0100004b0_cl.evt.gz	ah100050040sxi_p0100004b0_cl.evt.gz
SXI MZDYE EVT CL	ah100050010sxi_p0100004b1_cl.evt.gz	ah100050040sxi_p0100004b1_cl.evt.gz
SXS HK	ah100050010sxs_a0.hk1.gz	ah100050020sxs_a0.hk1.gz
SXS ADR	ahsxs_adr.gti.gz	ahsxs_adr.gti.gz
SXS AC EVT	ah100050010sxs_a0ac_uf.evt.gz	ah100050020sxs_a0ac_uf.evt.gz
SXS PIX12 GAIN	ah100050010sxs_010_px12.ghf.gz	ah100050020sxs_010_px12.ghf.gz
SXS PIX12 EVT	ah100050010sxs_a0px12010_uf.evt.gz	ah100050020sxs_a0px12010_uf.evt.gz
SXS EL GTI	ah100050010sxs_el.gti.gz	ah100050020sxs_el.gti.gz
SXS TEL	ah100050010sxs_tel.gti.gz	ah100050020sxs_tel.gti.gz
SXS PIX GTI	ah100050010sxs_p0px1010.gti.gz	ah100050020sxs_p0px1010.gti.gz
SXS PIX EXP	ah100050010sxs_p0px1010_exp.gti.gz	ah100050020sxs_p0px1010_exp.gti.gz
SXS PIX UF	ah100050010sxs_p0px1010_uf.evt.gz	ah100050020sxs_p0px1010_uf.evt.gz
SXS PIX CL	ah100050010sxs_p0px1010_cl.evt.gz	ah100050020sxs_p0px1010_cl.evt.gz

Table 3b	**100050030**	**100050040**
GEN-HK	ah100050030gen_a0.hk1.gz	ah100050040gen_a0.hk1.gz
TIM	ah100050030.tim.gz	ah100050040.tim.gz
ATTITUDE	ah100050030.att.gz	ah100050040.att.gz
ORBIT	ah100050030.orb.gz	ah100050040.orb.gz
OBSGTI	ah100050030_gen.gti.gz	ah100050040_gen.gti.gz
MKF	ah100050030.mkf.gz	ah100050040.mkf.gz
EHK	ah100050030.ehk.gz	ah100050040.ehk.gz
EHK2	ah100050030.ehk2.gz	ah100050040.ehk2.gz

HXI1 HK	ah100050030hx1_a0.hk.gz	ah100050040hx1_a0.hk.gz
HXI2 HK	ah100050030hx2_a0.hk.gz	ah100050040hx2_a0.hk.gz
HXI DELTA-ATT	ah100050030hx2.att.gz	ah100050040hx2.att.gz
HXI1 CAMS	ah100050030hx1_cms.fits.gz	ah100050040hx1_cms.fits.gz
HXI2 CAMS	ah100050030hx2_cms.fits.gz	ah100050040hx2_cms.fits.gz
HXI1 SFFa	ah100050030hx1_p0camrec_ufa.evt.gz	ah100050040hx1_p0camrec_ufa.evt.gz
HXI2 SFFa	ah100050030hx2_p0camrec_ufa.evt.gz	ah100050040hx2_p0camrec_ufa.evt.gz
HXI1 SFF	ah100050030hx1_p0camrec_uf.evt.gz	ah100050040hx1_p0camrec_uf.evt.gz
HXI2 SFF	ah100050030hx2_p0camrec_uf.evt.gz	ah100050040hx2_p0camrec_uf.evt.gz
HXI TEL	ah100050030hxi_tel.gti.gz	ah100050040hxi_tel.gti.gz
HXI1 PSEUDO	ah100050030hx1_p0camrecpse_cl.evt.gz	ah100050040hx1_p0camrecpse_cl.evt.gz
HXI2 PSEUDO	ah100050030hx2_p0camrecpse_cl.evt.gz	ah100050040hx2_p0camrecpse_cl.evt.gz
HXI1 EVT CL	ah100050030hx1_p0camrec_cl.evt.gz	ah100050040hx1_p0camrec_cl.evt.gz
HXI2 EVT CL	ah100050030hx2_p0camrec_cl.evt.gz	ah100050040hx2_p0camrec_cl.evt.gz
SGD1 HK	ah100050030sg1_a0.hk.gz	ah100050040sg1_a0.hk.gz
SGD2 HK	ah100050030sg2_a0.hk.gz	ah100050040sg2_a0.hk.gz
SGD1 SFF	ah100050030sg1_p0cc1rec_uf.evt.gz ah100050030sg1_p0cc2rec_uf.evt.gz ah100050030sg1_p0cc3rec_uf.evt.gz	ah100050040sg1_p0cc1rec_uf.evt.gz ah100050040sg1_p0cc2rec_uf.evt.gz ah100050040sg1_p0cc3rec_uf.evt.gz
SGD1 SFFa	ah100050030sg1_p0cc1rec_ufa.evt.gz ah100050030sg1_p0cc2rec_ufa.evt.gz ah100050030sg1_p0cc3rec_ufa.evt.gz	ah100050040sg1_p0cc1rec_ufa.evt.gz ah100050040sg1_p0cc2rec_ufa.evt.gz ah100050040sg1_p0cc3rec_ufa.evt.gz
SGD TEL	ah100050030sgi_tel.gti.gz	ah100050040sgi_tel.gti.gz
SGD1 PSEUDO	ah100050030sg1_p0cc1recpse_cl.evt.gz ah100050030sg1_p0cc2recpse_cl.evt.gz ah100050030sg1_p0cc3recpse_cl.evt.gz	ah100050040sg1_p0cc1recpse_cl.evt.gz ah100050040sg1_p0cc2recpse_cl.evt.gz ah100050040sg1_p0cc3recpse_cl.evt.gz
SGD1 EVT CL	ah100050030sg1_p0cc1rec_cl.evt.gz ah100050030sg1_p0cc2rec_cl.evt.gz ah100050030sg1_p0cc3rec_cl.evt.gz	ah100050040sg1_p0cc1rec_cl.evt.gz ah100050040sg1_p0cc2rec_cl.evt.gz ah100050040sg1_p0cc3rec_cl.evt.gz
SXI EVT UF	ah100050030sxi_p0100004b0_uf.evt.gz	ah100050040sxi_p0100004b0_uf.evt.gz
SXI MZDYE EVT UF	ah100050030sxi_p0100004b1_uf.evt.gz	ah100050040sxi_p0100004b1_uf.evt.gz
SXI HOTPIX	ah100050030sxi_a0100004b0.hpix.gz	ah100050040sxi_a0100004b0.hpix.gz
SXI MZDYE HOTPIX	ah100050030sxi_a0100004b1.hpix.gz	ah100050040sxi_a0100004b1.hpix.gz
SXI FLICKPIX	ah100050030sxi_a0100000b0.fpix.gz	ah100050040sxi_a0100000b0.fpix.gz
SXI MZDYE FLICKPIX	ah100050030sxi_a0100000b1.fpix.gz	ah100050040sxi_a0100000b1.fpix.gz
SXI BAD PIXEL IMG	ah100050030sxi_p0100000b0.bimg.gz	ah100050040sxi_p0100000b0.bimg.gz
SXI MZDYE BAD PIXEL IMG [	ah100050030sxi_p0100000b1.bimg.gz	ah100050040sxi_p0100000b1.bimg.gz
SXI TEL	ah100050030sxi_tel.gti.gz	ah100050040sxi_tel.gti.gz
SXI EVT CL	ah100050030sxi_p0100004b0_cl.evt.gz	ah100050040sxi_p0100004b0_cl.evt.gz
SXI MZDYE EVT CL	ah100050030sxi_p0100004b1_cl.evt.gz	ah100050040sxi_p0100004b1_cl.evt.gz
SXS HK	ah100050030sxs_a0.hk1.gz	ah100050040sxs_a0.hk1.gz
SXS ADR	ahsxs_adr.gti.gz	ahsxs_adr.gti.gz
SXS AC EVT	ah100050030sxs_a0ac_uf.evt.gz	ah100050040sxs_a0ac_uf.evt.gz
SXS PIX12 GAIN	ah100050030sxs_010_px12.ghf.gz	ah100050040sxs_010_px12.ghf.gz
SXS PIX12 EVT	ah100050030sxs_a0px12010_uf.evt.gz	ah100050040sxs_a0px12010_uf.evt.gz
SXS EL GTI	ah100050030sxs_el.gti.gz	ah100050040sxs_el.gti.gz
SXS TEL	ah100050030sxs_tel.gti.gz	ah100050040sxs_tel.gti.gz
SXS PIX GTI	ah100050030sxs_p0px1010.gti.gz	ah100050040sxs_p0px1010.gti.gz
SXS PIX EXP	ah100050030sxs_p0px1010_exp.gti.gz	ah100050040sxs_p0px1010_exp.gti.gz
SXS PIX UF	ah100050030sxs_p0px1010_uf.evt.gz	ah100050040sxs_p0px1010_uf.evt.gz
SXS PIX CL	ah100050030sxs_p0px1010_cl.evt.gz	ah100050040sxs_p0px1010_cl.evt.gz

a) Untar in a directory `/full/path/to/data/`.

Additional Files

Additional text files for analysis are as follows, and are shown in detail as they are used or created.

- standard and background extraction region files (place in dir `/full/path/to/regions`)
    - region_HXI_100050012340.reg
    - region_SXI_100050012340.reg

  - region_HXI1_100050012340_bkg.reg
  - region_HXI2_100050012340_bkg.reg
  - region_SXI_100050012340_bkg.reg
  - ah100050020sxs_region_SXS_det.reg

- SXS list for rescreenng, HXI and SGD lists of gti used for deadtime correction, lists of SXI files to input into addascaspec
  - sxs_ah100050020_gti_PIXELALL.lst
  - ah100050012340hx1_p0camrecpse_cl.gti.lst
  - ah100050012340hx2_p0camrecpse_cl.gti.lst
  - ah100050012340hx1_p0camrec_cl.gti.lst
  - ah100050012340hx2_p0camrec_cl.gti.lst
  - ah10005002340sg1_p0cc1recpse_cl.gti.lst
  - ah10005002340sg1_p0cc2recpse_cl.gti.lst
  - ah10005002340sg1_p0cc3recpse_cl.gti.lst
  - addascaspec_normal.in
  - addascaspec_mzdye.in

NOTE on source regions files:

i) 3 arcmin circle (SKY coordinates) for HXI1 and HXI2
ii) 2.5 arcmin circle (SKY coordinates) for SXI
iii) Full array (except pixel 12) for SXS (expressed in DET coordinates)

The region centers are determined by estimating the RA/DEC coordinates of the source in the SXI images using the merged event files, and not on the catalog source coordinates, although the difference is small.

Note on sequences.

The `100050010`,`100050020`,`100050030`, and `100050040` sequences are similar in content (although the `100050040` exposure is somewhat shorter, and there is no SGD data for `100050010`); the `100050020` sequence is used as single-sequence example.

Non-Instrument Specific Processing

ahcalctime

100050020

(1) Recalculate time for HK and unfiltered event files (~120 min)

For illustrative purposes the task may be run without time-sorting, which reduces the runtime by a factor of ~10 for files where time becomes out-of-order after re-assignment. In actual applications, set `sorttime=yes,` as downstream tasks expect event files to be sorted in time.

```
ahcalctime indir=data/100050020 outdir=data/100050020_ahcalctime_output
verify_input=no sorttime=yes timecol=TIME clobber=yes
```

```
mkdir data/100050020_ahcalctime_output/logs
mv *log data/100050020_ahcalctime_output/logs
```

ahpipeline

(1) Recalibrate and rescreen data for all instruments using ahpipeline (~90 min)

```
ahpipeline indir=data/100050020 outdir=data/100050020_output
steminputs=ah100050020 stemoutputs=DEFAULT entry_stage=1 exit_stage=2
instrument=ALL verify_input=no create_ehkmkf=yes seed=7 clobber=yes chatter=2
mode=hl

mkdir data/100050020_output/logs
mv *.log data/100050020_output/logs
```

Instrument Specific Reprocessing

100050020

Instrument-specific reprocessing may be applied using ahpipeline by changing the `instrument` parameter from `ALL` to `HX,SGD,SXI,` or `SXS` or by running the individual instrument pipelines as follows.
New files ehk and mkf files, created using the attitude file start and stop times and current, optical axis positions are used as input (not necessary if the reprocessing is for the sole purpose of recalibrating the data, in which case he original mkf and ehk files may be used). Alternatively, mkf and ehk files created by `ahpipeline`, if previously run with `create_ehkmkf=yes`, may be used.

HXI

(1) Recalibrate and rescreen using hxipipeline (~15 min)

```
fkeyprint data/100050020/auxil/ah100050020.att.gz+1 TSTART
TSTART = 6.995027610941923E+07 / Start time
fkeyprint data/100050020/auxil/ah100050020.att.gz+1 TSTOP
TSTOP  = 7.004526070316976E+07 / Stop time

mkdir data/100050020_repro_hxi
mkdir data/100050020_repro_hxi/temphk
cp data/100050020/auxil/*gz data/100050020_repro_hxi/temphk
cp data/100050020/hxi/hk/*gz data/100050020_repro_hxi/temphk

ahfilter mkfconf=CALDB attfile=data/100050020/auxil/ah100050020.att.gz
orbfile=data/100050020/auxil/ah100050020.orb.gz
outehkfile=data/100050020_repro_hxi/ah100050020.ehk
outmkffile=data/100050020_repro_hxi/ah100050020.mkf reference=NONE
infileroot=data/100050020_repro_hxi/temphk/ah100050020
tstart=6.995027610941923E+07 tstop=7.004526070316976E+07
optaxis=1221.08513337811,1209.56130357371,1223.52648309868,1191.20641761044,121
6.11,1217.843,1216.88128249567,1210.32149046794 clobber=yes cleanup=yes
chatter=2 mode=hl

mkdir data/100050020_repro_hxi/logs
mv *.log data/100050020_repro_hxi/logs

hxipipeline indir=data/100050020 outdir=data/100050020_repro_hxi
steminputs=ah100050020 stemoutputs=DEFAULT instrument=HXI entry_stage=1
exit_stage=2 verify_input=no attitude=data/100050020/auxil/ah100050020.att.gz
orbit=data/100050020/auxil/ah100050020.orb.gz
extended_housekeeping=data/100050020_repro_hxi/ah100050020.ehk
```

```
makefilter=data/100050020_repro_hxi/ah100050020.mkf
obsgti=data/100050020/auxil/ah100050020_gen.gti.gz seed=7 clobber=yes chatter=2
mode=hl

mv *.log data/100050020_repro_hxi/logs
```

SGD

(1) Recalibrate and rescreen using sgdpipeline using original mkf and ehk files (~15 min)

This step was required for data version 3 (22Dec2016), but is currently optional. This step must again be applied to all three sequences with SGD data should the SGD CALDB file probfovfile be updated from ah_sgd_probfovfile_20140101v002.fits to ah_sgd_probfovfile_20140101v003.fits.

```
sgdpipeline indir=data/100050020 outdir=data/100050020_repro_sgd_newcaldb
steminputs=ah100050020 stemoutputs=DEFAULT instrument=SGD entry_stage=1
exit_stage=2 verify_input=no
extended_housekeeping=data/100050020/auxil/ah100050020.ehk.gz
makefilter=data/100050020/auxil/ah100050020.mkf.gz
obsgti=data/100050020/auxil/ah100050020_gen.gti.gz seed=7 clobber=yes chatter=2
mode=hl

mkdir data/100050020_repro_sgd_newcaldb/logs
mv *.log  data/100050020_repro_sgd_newcaldb/logs
```

(2) Recalibrate and rescreen using sgdpipeline updating mkf and ehk files

```
fkeyprint data/100050020/auxil/ah100050020.att.gz+1 TSTART
TSTART  = 6.995027610941923E+07 / Start time
fkeyprint data/100050020/auxil/ah100050020.att.gz+1 TSTOP
TSTOP   = 7.004526070316976E+07 / Stop time

mkdir data/100050020_repro_sgd
mkdir data/100050020_repro_sgd/temphk
cp data/100050020/auxil/*gz data/100050020_repro_sgd/temphk
cp data/100050020/sgd/hk/*gz data/100050020_repro_sgd/temphk

ahfilter mkfconf=CALDB attfile=data/100050020/auxil/ah100050020.att.gz
orbfile=data/100050020/auxil/ah100050020.orb.gz
outehkfile=data/100050020_repro_sgd/ah100050020.ehk
outmkffile=data/100050020_repro_sgd/ah100050020.mkf reference=NONE
infileroot=data/100050020_repro_sgd/temphk/ah100050020
tstart=6.995027610941923E+07 tstop=7.004526070316976E+07
optaxis=1221.08513337811,1209.56130357371,1223.52648309868,1191.20641761044,121
6.11,1217.843,1216.88128249567,1210.32149046794 clobber=yes cleanup=yes
chatter=2 mode=hl

mkdir data/100050020_repro_sgd/logs
mv *.log  data/100050020_repro_sgd/logs

sgdpipeline indir=data/100050020 outdir=data/100050020_repro_sgd
steminputs=ah100050020 stemoutputs=DEFAULT instrument=SGD entry_stage=1
exit_stage=2 verify_input=no
extended_housekeeping=data/100050020_repro_sgd/ah100050020.ehk
makefilter=data/100050020_repro_sgd/ah100050020.mkf
obsgti=data/100050020/auxil/ah100050020_gen.gti.gz seed=7 clobber=yes chatter=2
mode=hl

mv *.log data/100050020_repro_sgd/logs
```

SXI

(1) Recalibrate and rescreen using sxipipeline (~60 min)

```
fkeyprint data/100050020/auxil/ah100050020.att.gz+1 TSTART
```
TSTART = 6.995027610941923E+07 / Start time
```
fkeyprint data/100050020/auxil/ah100050020.att.gz+1 TSTOP
```
TSTOP = 7.004526070316976E+07 / Stop time

```
mkdir data/100050020_repro_sxi
mkdir data/100050020_repro_sxi/temphk
cp data/100050020/auxil/*gz data/100050020_repro_sxi/temphk
cp data/100050020/sxi/hk/*gz data/100050020_repro_sxi/temphk

ahfilter mkfconf=CALDB attfile=data/100050020/auxil/ah100050020.att.gz
orbfile=data/100050020/auxil/ah100050020.orb.gz
outehkfile=data/100050020_repro_sxi/ah100050020.ehk
outmkffile=data/100050020_repro_sxi/ah100050020.mkf reference=NONE
infileroot=data/100050020_repro_sxi/temphk/ah100050020 tstart=69950336.10941565
tstop=70045200.70317334
optaxis=1221.08513337811,1209.56130357371,1223.52648309868,1191.20641761044,121
6.11,1217.843,1216.88128249567,1210.32149046794 clobber=yes cleanup=yes
chatter=2 mode=hl

mkdir data/100050020_repro_sxi/logs
mv *.log data/100050020_repro_sxi/logs

sxipipeline indir=data/100050020 outdir=data/100050020_repro_sxi
steminputs=ah100050020 stemoutputs=DEFAULT entry_stage=1 exit_stage=2
attitude=data/100050020/auxil/ah100050020.att.gz
orbit=data/100050020/auxil/ah100050020.orb.gz
extended_housekeeping=data/100050020_repro_sxi/ah100050020.ehk
makefilter=data/100050020_repro_sxi/ah100050020.mkf
obsgti=data/100050020/auxil/ah100050020_gen.gti.gz
housekeeping=data/100050020/sxi/hk/ah100050020sxi_a0.hk.gz seed=7 clobber=yes
chatter=2 mode=hl

mv *.log data/100050020_repro_sxi/logs
```

SXS

(1) Recalibrate/rescreen using sxspipeline (~10 min)

```
fkeyprint data/100050020/auxil/ah100050020.att.gz+1 TSTART
```
TSTART = 6.995027610941923E+07 / Start time
```
fkeyprint data/100050020/auxil/ah100050020.att.gz+1 TSTOP
```
TSTOP = 7.004526070316976E+07 / Stop time

```
mkdir data/100050020_repro_sxs
mkdir data/100050020_repro_sxs/temphk
cp data/100050020/auxil/*gz data/100050020_repro_sxs/temphk
cp data/100050020/sxs/hk/*gz data/100050020_repro_sxs/temphk

ahfilter mkfconf=CALDB attfile=data/100050020/auxil/ah100050020.att.gz
orbfile=data/100050020/auxil/ah100050020.orb.gz
outehkfile=data/100050020_repro_sxs/ah100050020.ehk
outmkffile=data/100050020_repro_sxs/ah100050020.mkf reference=NONE
infileroot=data/100050020_repro_sxs/temphk/ah100050020 tstart=69950336.10941565
tstop=70045200.70317334
optaxis=1221.08513337811,1209.56130357371,1223.52648309868,1191.20641761044,121
6.11,1217.843,1216.88128249567,1210.32149046794 clobber=yes cleanup=yes
chatter=2 mode=hl
```

```
mkdir data/100050020_repro_sxs/logs
mv *.log data/100050020_repro_sxs/logs
```

```
sxspipeline indir=data/100050020 outdir=data/100050020_repro_sxs
steminputs=ah100050020 stemoutputs=DEFAULT entry_stage=1 exit_stage=2
attitude=data/100050020/auxil/ah100050020.att.gz
orbit=data/100050020/auxil/ah100050020.orb.gz
extended_housekeeping=data/100050020_repro_sxs/ah100050020.ehk
makefilter=data/100050020_repro_sxs/ah100050020.mkf
obsgti=data/100050020/auxil/ah100050020_gen.gti.gz
housekeeping=data/100050020/sxs/hk/ah100050020sxs_a0.hk1.gz
timfile=data/100050020/auxil/ah100050020.tim.gz seed=7 clobber=yes chatter=2
mode=hl
```

```
mv *.log data/100050020_repro_sxs/logs
```

(2) Recalibrate/rescreen using sxspipeline, excluding lost event GTI

Setting `screenlost=yes` results in the screening, for *all* pixels, of lost event intervals for *any* pixel. Unlike in the standard case, the lost event intervals per pixel should not be included in the exposure map used to create the ARF (see below). This option should not be used unless there is no pixel-to-pixel variation in the lost GTI intervals. Note that, for this object, the lost event intervals are also excluded by other criteria. As a result the output is the same as for the standard screening. The original ehk and mkf files are used here.

```
sxspipeline indir=data/100050020 outdir=data/100050020_repro2_sxs/sxs
steminputs=ah100050020 stemoutputs=ah100050020 entry_stage=1 exit_stage=2
attitude=data/100050020/auxil/ah100050020.att.gz
orbit=data/100050020/auxil/ah100050020.orb.gz
obsgti=data/100050020/auxil/ah100050020_gen.gti.gz
housekeeping=data/100050020/sxs/hk/ah100050020sxs_a0.hk1.gz
timfile=data/100050020/auxil/ah100050020.tim.gz
extended_housekeeping=data/100050020/auxil/ah100050020.ehk.gz
makefilter=data/100050020/auxil/ah100050020.mkf.gz screenlost=yes seed=7
clobber=yes chatter=2 mode=hl
```

```
mkdir data/100050020_repro2_sxs/logs
mv *log data/100050020_repro2_sxs/logs
```

(3) Alternative, stricter, SXS GTI filtering

An alternative label in the CALDB mkf configuration (PIXELALL) includes an ADR recycle stability criterion defined by two SXS housekeeping parameters that measure the standard deviation in the temperature measure by separate thermometers (ADRC_CT_CTL_FLUC and ADRC_CT_MON_FLUC), applies more stringent earth elevation and SAA criteria, and also retains the cal-pixel events. The procedure to create the alternative cleaned file:

```
ah100050020sxs_p0px1010_cl2b.evt
```

is as follows:

a) Create the mkf GTI corresponding to the PIXELALL label

```
ahgtigen infile=../100050020/auxil/ah100050020.mkf.gz
outfile=ah100050020_sxs_mkf_PIXELALL.gti gtifile=NONE gtiexpr=NONE mergegti=AND
selectfile=CALDB label=PIXELALL instrume=SXS prefr=0.0 postfr=1.0
```

b) Create the ehk GTI corresponding to the PIXELALL label

```
ahgtigen infile=../100050020/auxil/ah100050020.ehk.gz
outfile=ah100050020_sxs_ehk_PIXELALL.gti gtifile=NONE gtiexpr=NONE mergegti=AND
selectfile=CALDB label=PIXELALL instrume=SXS prefr=0.0 postfr=1.0
```

c) Create (or place in the working directory) the text file `sxs_ah100050020_gti_PIXELALL.lst`, which lists all of the SXS gti file extensions to use in screening. The list includes the two made in the previous two steps, as well as the GTI in the original unfiltered event file, the non-saturated telemetry GTI, the pointing GTI, the good attitude GTI, and the ADR cycle intervals when the gain is stable:

```
../100050020/sxs/event_uf/ah100050020sxs_p0px1010_uf.evt.gz+2
../100050020/sxs/event_uf/ah100050020sxs_tel.gti.gz+1
../100050020/auxil/ah100050020_gen.gti.gz+2
../100050020/auxil/ah100050020_gen.gti.gz+5
ah100050020_sxs_ehk_PIXELALL.gti+1
ah100050020_sxs_mkf_PIXELALL.gti+1
../100050020/sxs/event_uf/ah100050020sxs_p0px1010_uf.evt.gz+5
```

d) Create a GTI file that merges all the GTI in the list in step (c):

```
ahgtigen infile=NONE outfile=ah100050020sxs_PIXELALL.gti
gtifile=@sxs_ah100050020_gti_PIXELALL.lst gtiexpr=NONE mergegti=AND
```

Note that setting `gtifile=@sxs_ah100050020_gti_PIXELALL.lst` is equivalent to explicitly listing all the gti extensions included in the list, delimited by commas.

e) Screen the data using the merged GTI file created in step (d), and the current standard ("`PIXELALL3`") event screening:

```
ahscreen infile=../100050020/sxs/event_uf/ah100050020sxs_p0px1010_uf.evt.gz
outfile=ah100050020sxs_p0px1010_cl2b.evt gtifile=ah100050020sxs_PIXELALL.gti
expr=NONE mergegti=AND selectfile=CALDB label=PIXELALL3 cpkeyword=all
clobber=yes
```

f) Adjust the PI TLMIN and TLMAX keywords (the unfiltered event file included baseline, ITYPE=5, events with PI that may be <0).

```
fthedit ah100050020sxs_p0px1010_cl2b.evt TLMIN45 a 0
fthedit ah100050020sxs_p0px1010_cl2b.evt TLMAX45 a 32767
```

(4) Alternative SXS event screening

One may screen based on the standard GTI filtering, with a revised event screening (here, simply an increase in value of the lower energy cut) by applying the GTI extension attached to the cleaned event file:

a) Screen the data:

```
ahscreen infile=../100050020/sxs/event_uf/ah100050020sxs_p0px1010_uf.evt.gz
outfile=ah100050020sxs_p0px1010_cl2b.evt
gtifile==../100050020/sxs/event_cl/ah100050020sxs_p0px1010_cl.evt.gz+2
expr="ITYPE<5&&(SLOPE_DIFFER==b0||PI>25000)&&QUICK_DOUBLE==b0&&STATUS[3]==b0&&S
TATUS[6]==b0&&STATUS[2]==b0&&PI>800&&PIXEL!=12&&TICK_SHIFT>-8&&TICK_SHIFT<7"
mergegti=AND selectfile=CALDB label=NONE cpkeyword=all clobber=yes
```

This is equivalent to (re)creating the GTI from a list consisting of the following

```
../100050020/sxs/event_uf/ah100050020sxs_p0px1010_uf.evt.gz+2
../100050020/sxs/event_uf/ah100050020sxs_tel.gti.gz+1
../100050020/auxil/ah100050020_gen.gti.gz+2
../100050020/auxil/ah100050020_gen.gti.gz+5
../100050020/sxs/event_uf/ah100050020sxs_p0px1010_uf.evt.gz+3
../100050020/sxs/event_uf/ah100050020sxs_p0px1010_uf.evt.gz+4
../100050020/sxs/event_uf/ah100050020sxs_p0px1010_uf.evt.gz+5
```

b) Adjust the PI TLMIN and TLMAX keywords (the unfiltered event file included baseline, ITYPE=5, events with PI that may be <0).

```
fthedit ah100050020sxs_p0px1010_cl2b.evt TLMIN45 a 0
fthedit ah100050020sxs_p0px1010_cl2b.evt TLMAX45 a 32767
```

Extracting Products

This section details tools to run on cleaned event files to get instrument specific data products. These may be applied to the original cleaned event files from the pipeline, or to new cleaned event files created using the steps in the last section. In what follows, the original pipeline cleaned event files are used. The extraction region files described above are assumed to be in the `regions` directory.

100050020

HXI

All newly created output files in this section are placed in the /full/path/to/data/hxi_products directory

```
cd /full/path/
```

```
mkdir data/products_hxi
```

```
cd data/products_hxi
```

(1) Extract source spectra and light curves using xselect

The content of the region file used here, `../../regions/region_HXI_100050012340.reg`, is

```
# Region file format: DS9 version 4.1
fk5
circle(278.3889,-10.5691,180.0000") # font="helvetica 30 normal "
```

HXI1

```
xselect
xsel:SUZAKU > read events
../100050020/hxi/event_cl/ah100050020hx1_p0camrec_cl.evt.gz
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > filter region
../../regions/region_HXI_100050012340.reg
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > extract spectrum
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > save spectrum ah100050020hx1_p0camrec_cl.pi
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > plot spectrum
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > extract curve
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > save curve ah100050020hx1_p0camrec_cl.lc
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > plot curve
```

HXI2

```
xsel:SUZAKU > read events
../100050020/hxi/event_cl/ah100050020hx2_p0camrec_cl.evt.gz
xsel:HITOMI-HXI2-CAMERA_NORMAL1 > filter region
../../regions/region_HXI_100050012340.reg
xsel:HITOMI-HXI2-CAMERA_NORMAL1 > extract spectrum
xsel:HITOMI-HXI2-CAMERA_NORMAL1 > save spectrum ah100050020hx2_p0camrec_cl.pi
xsel:HITOMI-HXI2-CAMERA_NORMAL1 > plot spectrum
xsel:HITOMI-HXI2-CAMERA_NORMAL1 > extract curve
xsel:HITOMI-HXI2-CAMERA_NORMAL1 > save curve ah100050020hx2_p0camrec_cl.lc
xsel:HITOMI-HXI2-CAMERA_NORMAL1 > plot curve
```

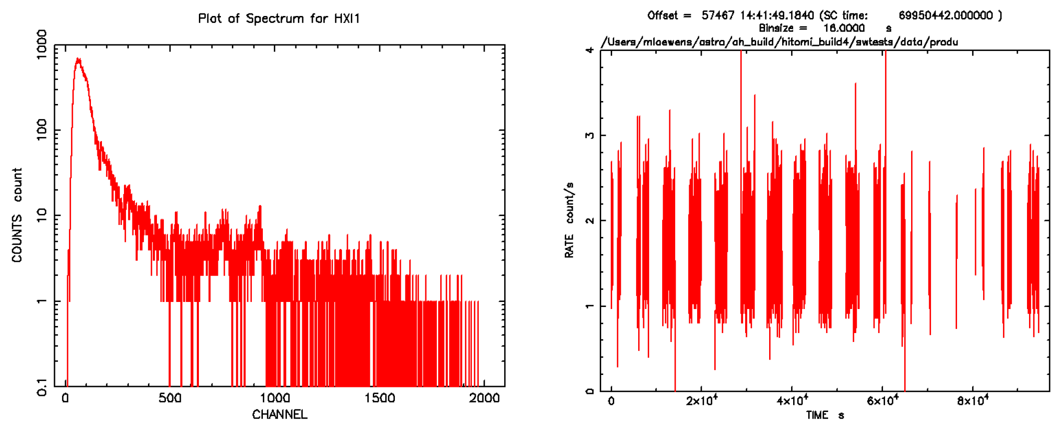


Figure 1: HXI1 source spectrum and lightcurve for sequence 100050020

(2) Run hxisgddtime to correct the spectrum and light curve for dead time

Go back to /full/path/to/data/.. (the directory above the `data` directory)

cd `../..`

HXI1

```
hxisgddtime
infile=data/100050020/hxi/event_cl/ah100050020hx1_p0camrecpse_cl.evt.gz
inlcfile=data/products_hxi/ah100050020hx1_p0camrec_cl.lc
inspecfile=data/products_hxi/ah100050020hx1_p0camrec_cl.pi
outlcfile=data/products_hxi/ah100050020hx1_p0camrec_dtime.lc
outfile=data/products_hxi/ah100050020hx1_p0camrec_dtime.pi
gtifile=data/100050020/hxi/event_cl/ah100050020hx1_p0camrec_cl.evt.gz chatter=2
clobber=yes

mv hxisgddtime.log data/products_hxi/hxisgddtime_ah100050020hx1.log
```

HXI2

```
hxisgddtime
infile=data/100050020/hxi/event_cl/ah100050020hx2_p0camrecpse_cl.evt.gz
inlcfile=data/products_hxi/ah100050020hx2_p0camrec_cl.lc
inspecfile=data/products_hxi/ah100050020hx2_p0camrec_cl.pi
outlcfile=data/products_hxi/ah100050020hx2_p0camrec_dtime.lc
outfile=data/products_hxi/ah100050020hx2_p0camrec_dtime.pi
gtifile=data/100050020/hxi/event_cl/ah100050020hx2_p0camrec_cl.evt.gz chatter=2
clobber=yes

mv hxisgddtime.log data/products_hxi/hxisgddtime_ah100050020hx2.log
```

(3) Apply barycenter corrections for light curves

```
barycen infile=data/products_hxi/ah100050020hx1_p0camrec_dtime.lc
outfile=data/products_hxi/ah100050020hx1_p0camrec_dtime_add_bary.lc
orbfile=data/100050020/auxil/ah100050020.orb.gz ra=278.38988 dec=-10.56875
orbext=ORBIT chatter=2 clobber=yes

mv barycen.log data/products_hxi/barycen_ah100050020hx1.log

barycen infile=data/products_hxi/ah100050020hx2_p0camrec_dtime.lc
outfile=data/products_hxi/ah100050020hx2_p0camrec_dtime_add_bary.lc
orbfile=data/100050020/auxil/ah100050020.orb.gz ra=278.38988 dec=-10.56875
orbext=ORBIT chatter=2 clobber=yes

mv barycen.log data/products_hxi/barycen_ah100050020hx2.log
```

Note that the `ra` and `dec` parameters are set here to the object coordinates as an approximation of the true average pointing direction; this setting can be refined by generating and examining the exposure map (see below).

The barycenter correction may also be applied to event files.

(4) Extract the deadtime corrected HXI NXB spectra

Run the the task `hxinxbgen` with the cleaned event file, identical region used for source spectrum extraction, the cleaned versions of the NXB event files, `ah_hx1[2]_nxbevtcl2_20140101v001.evt`, and the cleaned versions of the NXB pseudo-event files, `ah_hx1[2]_nxbpsecl_20140101v001.evt`, as input. If instead additional, or non-standard, screening is used in the source spectra extraction the uncleaned versions of the NXB event and pseudo-event files, `ah_hx1[2]_nxbevtuf_20140101v001.evt` and `ah_hx1[2]_nxbpseuf_20140101v001.evt`, must be screened in the same way, with gti filtering based on the columns in `ah_hxi_nxbmkf_20140101v001.fits`, and then input into `hxinxbgen`.

The input NXB event and pseudo event files include an extra SAA screening,

```
ahscreen ah_hx1_nxbevtcl_20140101v001.evt
outfile=ah_hx1_nxbevtcl2_20140101v001.evt gtifile=@ah_hx1_nxbsaa.txt
expr=NONE mergegti=AND selectfile=NONE label=NONE cpkeyword=all clobber=yes

ahscreen ah_hx2_nxbevtcl_20140101v001.evt
outfile=ah_hx12_nxbevtcl2_20140101v001.evt gtifile=@ah_hx2_nxbsaa.txt
expr=NONE mergegti=AND selectfile=NONE label=NONE cpkeyword=all clobber=yes
```

where `ah_hx1_nxbsaa.txt` is composed of

```
ah_hx1_nxbsaa_20140101v001.gti+1
ah_hx1_nxbevtcl_20140101v001.evt+2
```

and `ah_hx2_nxbsaa.txt` is composed of

```
ah_hx2_nxbsaa_20140101v001.gti+1
ah_hx2_nxbevtcl_20140101v001.evt+2

ahscreen ah_hx1_nxbpsecl_20140101v001.evt
outfile=ah_hx1_nxbpsecl2_20140101v001.evt gtifile=@ah_hx1_nxbpsesaa.txt
expr=NONE mergegti=AND selectfile=NONE label=NONE cpkeyword=all clobber=yes

ahscreen ah_hx2_nxbpsecl_20140101v001.evt
outfile=ah_hx12_nxbpsecl2_20140101v001.evt gtifile=@ah_hx2_nxbpsesaa.txt
expr=NONE mergegti=AND selectfile=NONE label=NONE cpkeyword=all clobber=yes
```

where `ah_hx1_nxbpsesaa.txt` is composed of

```
ah_hx1_nxbsaa_20140101v001.gti+1
ah_hx1_nxbpsecl_20140101v001.evt+2
```

and `ah_hx2_nxbsaa.txt` is composed of

```
ah_hx2_nxbsaa_20140101v001.gti+1
ah_hx2_nxbpsecl_20140101v001.evt+2
```

Xselect may also be uses as follows:

```
xselect
xsel:SUZAKU > read events ah_hx1_nxbevtcl_20140101v001.evt
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > filter time file
ah_hx1_nxbsaa_20140101v001.gti
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > save events ah_hx1_nxbevtcl2_20140101v001.evt

xselect
xsel:SUZAKU > read events ah_hx2_nxbevtcl_20140101v001.evt
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > filter time file
ah_hx2_nxbsaa_20140101v001.gti
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > save events ah_hx2_nxbevtcl2_20140101v001.evt
```

The merged NXB event (without SAA screening), ehk, and mkf, and gti file for additional SAA screening files are located in the hitomi url,

https://heasarc.gsfc.nasa.gov/FTP/hitomi/data/nxb_20170510/

Note that, for `regmode=SKY`, the region must be defined in sky (not RADEC) coordinates, e.g.,

```
# Region file format: DS9 version 4.1
physical
circle(1212.1019,1214.829,101.66966) # font="helvetica 30 normal "
```

Conversion from RADEC to sky may be done in `ds9`, or using `coordpnt`.

HXI1

```
hxinxbgen infile=data/100050020/hxi/event_cl/ah100050020hx1_p0camrec_cl.evt.gz
ehkfile==../100050020/auxil/ah100050020.ehk.gz
innxbfile=ah_hx1_nxbevtcl2_20140101v001.evt
inpsefile=ah_hx1_nxbpsecl_20140101v001.evt
innxbehk=ah_gen_nxbehk_20140101v002.fits outpifile=ah100050020hx1nxb_cl.pi
regmode=SKY regfile=region_HXI_100050012340_sky.reg cleanup=yes chatter=3
clobber=yes mode=hl logfile=ah100050020hx1nxb_cl.log
sortbin=0,6,7,8,9,10,11,12,13,99
```

HXI2

```
hxinxbgen infile=data/100050020/hxi/event_cl/ah100050020hx2_p0camrec_cl.evt.gz
ehkfile==../100050020/auxil/ah100050020.ehk.gz
innxbfile=ah_hx2_nxbevtcl2_20140101v001.evt
inpsefile=ah_hx2_nxbpsecl_20140101v001.evt
innxbehk=ah_gen_nxbehk_20140101v002.fits outpifile=ah100050020hx2nxb_cl.pi
regmode=SKY regfile=region_HXI_100050012340_sky.reg cleanup=yes chatter=3
clobber=yes mode=hl logfile=ah100050020hx2nxb_cl.log
sortbin=0,6,7,8,9,10,11,12,13,99
```

SGD

All newly created output files in this section are placed in the /full/path/to/data/sgd_products directory

```
cd /full/path/
```

```
mkdir data/products_sgd
```

```
cd data/products_sgd
```

(1) Apply additional screening to the reprocessed event files

For data version 4 (03Apr2017), calibrated with probfovfile=ah_sgd_probfovfile_20140101v002.fits, the
following additional screening step must be applied for all three sequences with SGD data.

```
ftselect infile='../100050020/ah100050020sg1_p0cc1rec_cl.evt[events]'
outfile=ah100050020sg1_p0cc1rec_cl2.evt expression="OFFAXIS<=30.0&&OFFAXIS>=-
30.0"
```

```
ftselect infile='../100050020/ah100050020sg1_p0cc2rec_cl.evt[events]'
outfile=ah100050020sg1_p0cc2rec_cl2.evt expression="OFFAXIS<=30.0&&OFFAXIS>=-
30.0"
```

```
ftselect infile='../100050020/ah100050020sg1_p0cc3rec_cl.evt[events]'
outfile=ah100050020sg1_p0cc3rec_cl2.evt expression="OFFAXIS<=30.0&&OFFAXIS>=-
30.0"
```

Should the SGD CALDB file probfovfile be updated to ah_sgd_probfovfile_20140101v003.fits, instead, the additional screening step to be applied to the reprocessed event files for all three sequences with SGD data is as follows.

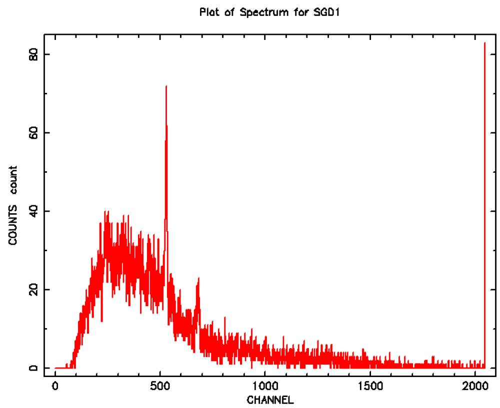
```
ftselect
infile='../100050020_repro_sgd_newcaldb/ah100050020sg1_p0cc1rec_cl.evt[events]'
outfile=ah100050020sg1_p0cc1rec_cl2.evt expression="LIKELIHOOD<=1.0"
```

```
ftselect
infile='../100050020_repro_sgd_newcaldb/ah100050020sg1_p0cc2rec_cl.evt[events]'
outfile=ah100050020sg1_p0cc2rec_cl2.evt expression="LIKELIHOOD<=1.0"
```

```
ftselect
infile='../1100050020_repro_sgd_newcaldb/ah100050020sg1_p0cc3rec_cl.evt[events]
' outfile=ah100050020sg1_p0cc3rec_cl2.evt expression="LIKELIHOOD<=1.0"
```

(2) Extract source spectrum and light curves, summed over all Compton cameras, using xselect

```
xselect
xsel:SUZAKU > read events ah100050020sg1_p0cc1rec_cl2.evt
xsel:HITOMI-SGD1-CC_NORMAL1 > read events ah100050020sg1_p0cc2rec_cl2.evt
xsel:HITOMI-SGD1-CC_NORMAL1 > read events ah100050020sg1_p0cc3rec_cl2.evt
xsel:HITOMI-SGD1-CC_NORMAL1 > extract events
xsel:HITOMI-SGD1-CC_NORMAL1 > save events ah100050020sg1_p0ccALLrec_cl2.evt
xsel:HITOMI-SGD1-CC_NORMAL1 > extract spectrum
xsel:HITOMI-SGD1-CC_NORMAL1 > plot spectrum
xsel:HITOMI-SGD1-CC_NORMAL1 > save spectrum ah100050020sg1_p0ccALLrec_cl2.pi
xsel:HITOMI-SGD1-CC_NORMAL1 > extract curve
xsel:HITOMI-SGD1-CC_NORMAL1 > plot curve
xsel:HITOMI-SGD1-CC_NORMAL1 > save curve ah100050020sg1_p0ccALLrec_cl2.lc
```



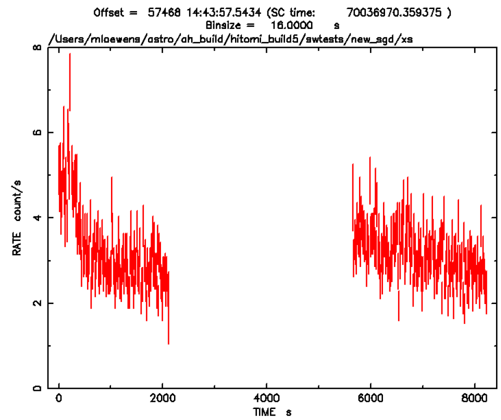


Figure 2: SGD1 source spectrum and lightcurve for sequence 100050020

(3) Run hxisgddtime to correct the spectrum and light curve for dead time

First, extract the spectrum and light curve for each individual camera.

```
xselect
xsel:SUZAKU > read events ah100050020sg1_p0cc1rec_cl2.evt
xsel:HITOMI-SGD1-CC_NORMAL1 > extract spectrum
xsel:HITOMI-SGD1-CC_NORMAL1 > save spectrum ah100050020sg1_p0cc1rec_cl2.pi
xsel:HITOMI-SGD1-CC_NORMAL1 > extract curve
xsel:HITOMI-SGD1-CC_NORMAL1 > save curve ah100050020sg1_p0cc1rec_cl2.lc
xsel:HITOMI-SGD1-CC_NORMAL1 > clear all
xsel:HITOMI-SGD1-CC_NORMAL1 > read events ah100050020sg1_p0cc2rec_cl2.evt
xsel:HITOMI-SGD1-CC_NORMAL1 > extract spectrum
xsel:HITOMI-SGD1-CC_NORMAL1 > save spectrum ah100050020sg1_p0cc2rec_cl2.pi
xsel:HITOMI-SGD1-CC_NORMAL1 > extract curve
xsel:HITOMI-SGD1-CC_NORMAL1 > save curve ah100050020sg1_p0cc2rec_cl2.lc
xsel:HITOMI-SGD1-CC_NORMAL1 > clear all
xsel:HITOMI-SGD1-CC_NORMAL1 > read events ah100050020sg1_p0cc3rec_cl2.evt
xsel:HITOMI-SGD1-CC_NORMAL1 > extract spectrum
xsel:HITOMI-SGD1-CC_NORMAL1 > save spectrum ah100050020sg1_p0cc3rec_cl2.pi
xsel:HITOMI-SGD1-CC_NORMAL1 > extract
xsel:HITOMI-SGD1-CC_NORMAL1 > save curve ah100050020sg1_p0cc3rec_cl2.lc
```

Apply the deadtime correction to each camera

```
hxisgddtime
infile=../100050020/sgd/event_cl/ah100050020sg1_p0cc1recpse_cl.evt.gz
inlcfile=ah100050020sg1_p0cc1rec_cl2.lc
inspecfile=ah100050020sg1_p0cc1rec_cl2.pi
outlcfile=ah100050020sg1_p0cc1rec_dtime.lc
outfile=ah100050020sg1_p0cc1rec_dtime.pi
gtifile=ah100050020sg1_p0cc1rec_cl2.evt chatter=2 clobber=yes

mv hxisgddtime.log hxisgddtime_ah100050020sg1cc1.log

hxisgddtime
infile=../100050020/sgd/event_cl/ah100050020sg1_p0cc2recpse_cl.evt.gz
inlcfile=ah100050020sg1_p0cc2rec_cl2.lc
inspecfile=ah100050020sg1_p0cc2rec_cl2.pi
outlcfile=ah100050020sg1_p0cc2rec_dtime.lc
outfile=ah100050020sg1_p0cc2rec_dtime.pi
gtifile=ah100050020sg1_p0cc2rec_cl2.evt chatter=2 clobber=yes

mv hxisgddtime.log hxisgddtime_ah100050020sg1cc2.log
```

```
hxisgddtime
infile=../100050020/sgd/event_cl/ah100050020sg1_p0cc3recpse_cl.evt.gz
inlcfile=ah100050020sg1_p0cc3rec_cl2.lc
inspecfile=ah100050020sg1_p0cc3rec_cl2.pi
outlcfile=ah100050020sg1_p0cc3rec_dtime.lc
outfile=ah100050020sg1_p0cc3rec_dtime.pi
gtifile=ah100050020sg1_p0cc3rec_cl2.evt chatter=2 clobber=yes

mv hxisgddtime.log hxisgddtime_ah100050020sg1cc3.log
```

Add the individual spectra, and add the keywords needed by *sgdarfgen* read from the header of any of the individual spectra (identified using `fkeyprint`), and with the EXPOSURE set to the average of the three individual spectra.

```
mathpha
expr=ah100050020sg1_p0cc1rec_dtime.pi+ah100050020sg1_p0cc2rec_dtime.pi+ah100050
020sg1_p0cc3rec_dtime.pi units=C outfil=ah100050020sg1_p0ccALLrec_dtime.pi
exposure=2962.33 areascal=% backscal=% ncomments=0

fthedit ah100050020sg1_p0ccALLrec_dtime.pi+1 RA_NOM a 278.385976096973
fthedit ah100050020sg1_p0ccALLrec_dtime.pi+1 DEC_NOM a -10.5700756067587
fthedit ah100050020sg1_p0ccALLrec_dtime.pi+1 PA_NOM a 88.4915688237262
fthedit ah100050020sg1_p0ccALLrec_dtime.pi+1 DATE-OBS a 2016-03-
21T14:42:41.359375
```

Steps 1 and 2 should be repeated for sequences 100050030, and 100050040

SXI

All newly created output files in this section are placed in the /full/path/to/data/sxi_products directory

```
cd /full/path/

mkdir data/products_sxi

cd data/products_sxi
```

There are two cleaned SXI event files for each of the G21.5-0.9 sequences, e.g. for sequence `100050020`:

```
../100050020/sxi/event_cl/ah100050020sxi_p0100004b0_cl.evt.gz
../100050020/sxi/event_cl/ah100050020sxi_p0100004b1_cl.evt.gz
```

The files ending in "1", i.e. "p0100004b1", refer to "Minus-Z Day Earth" (MZDYE) data conducted with area discrimination on and different event thresholds. These must be independently analyzed from the files ending in "0" or "Normal" data files. To reduce the background in the extracted image, the "Normal" event list is filtered by energy to 0.5-8 keV. For the "MZDYE" event list, this would remove all the counts away from the source, so the full energy range is used for the image.

The content of the region file used here, `../../regions/region_SXI_100050012340.reg`, is

```
# Region file format: DS9 version 4.1
fk5
circle(278.3889,-10.5691,150") # color=white font="helvetica 30 normal "
```

(1) Extract images, source spectra, and light curves using xselect

Normal Mode

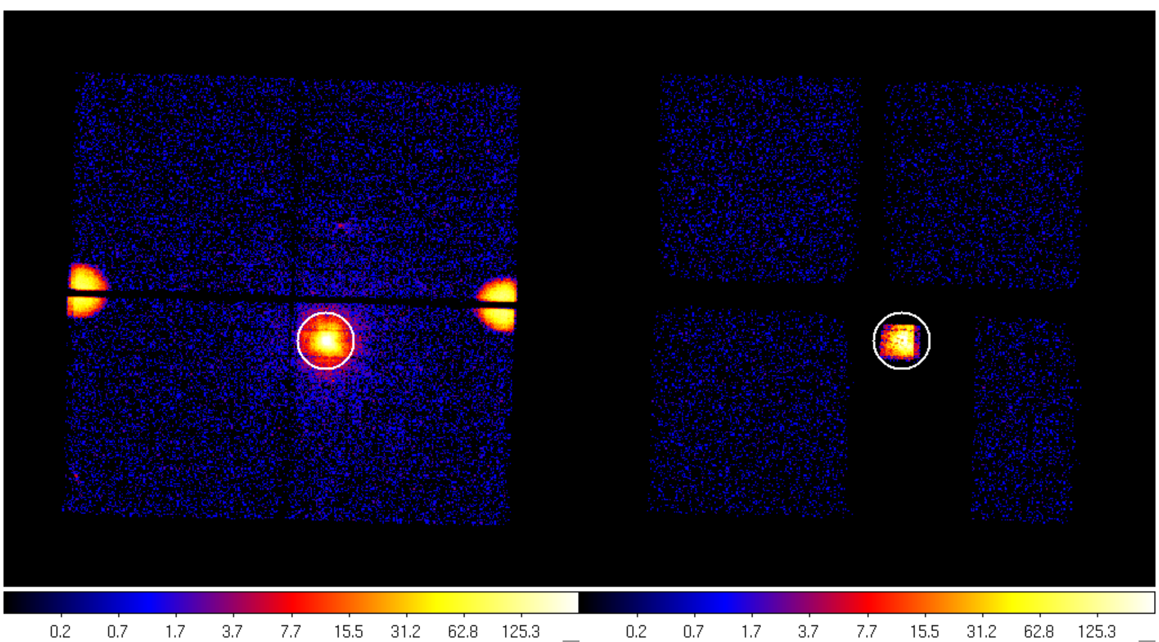
```
xselect
```

```
xsel:SUZAKU > read events
../100050020/sxi/event_cl/ah100050020sxi_p0100004b0_cl.evt.gz
xsel:HITOMI-SXI-WINDOW1 > filter pha_cutoff 83 1333
xsel:HITOMI-SXI-WINDOW1 > set xybin 4
xsel:HITOMI-SXI-WINDOW1 > extract image
xsel:HITOMI-SXI-WINDOW1 > save image ah100050020sxi_p0100004b0_cl.img
xsel:HITOMI-SXI-WINDOW1 > plot image
xsel:HITOMI-SXI-WINDOW1 > clear pha_cutoff
xsel:HITOMI-SXI-WINDOW1 > filter region
../../regions/region_SXI_100050012340.reg
xsel:HITOMI-SXI-WINDOW1 > extract spectrum
xsel:HITOMI-SXI-WINDOW1 > save spectrum ah100050020sxi_p0100004b0_cl.pi
xsel:HITOMI-SXI-WINDOW1 > plot spectrum
xsel:HITOMI-SXI-WINDOW1 > extract curve exposure=0.0
xsel:HITOMI-SXI-WINDOW1 > save curve ah100050020sxi_p0100004b0_cl.lc
xsel:HITOMI-SXI-WINDOW1 > plot curve
```

MZDYE

```
xselect
xsel:SUZAKU > read events
../100050020/sxi/event_cl/ah100050020sxi_p0100004b1_cl.evt.gz
xsel:HITOMI-SXI-WINDOW1 > set xybin 4
xsel:HITOMI-SXI-WINDOW1 > extract image
xsel:HITOMI-SXI-WINDOW1 > save image ah100050020sxi_p0100004b1_cl.img
xsel:HITOMI-SXI-WINDOW1 > filter region
../../regions/region_SXI_100050012340.reg
xsel:HITOMI-SXI-WINDOW1 > extract spectrum
xsel:HITOMI-SXI-WINDOW1 > save spectrum ah100050020sxi_p0100004b1_cl.pi
xsel:HITOMI-SXI-WINDOW1 > plot spectrum
xsel:HITOMI-SXI-WINDOW1 > extract curve exposure=0.0
xsel:HITOMI-SXI-WINDOW1 > save curve ah100050020sxi_p0100004b1_cl.lc
xsel:HITOMI-SXI-WINDOW1 > plot curve
```

Step 1 is repeated for sequences ah100050010, ah100050030, and ah100050040.



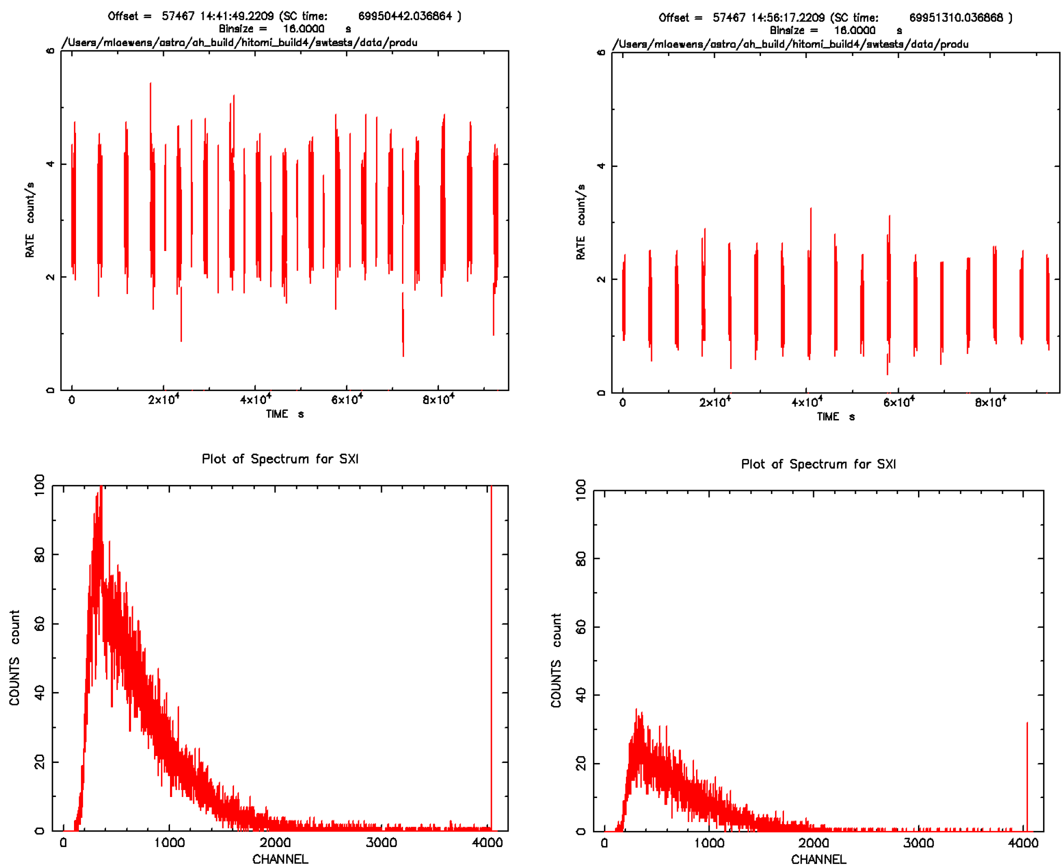


Figure 3: SXI images (with extraction region), lightcurves, and source spectra for sequence 100050020 – normal (left) and Minus Z Day Earth mode (right).

(2) Extract background spectra, and light curves using xselect

Background is extracted from the full field of view of only the 'Normal' data, excluding the calibration source regions, the readout streaks from the calibration sources, some point sources, and a 9 arcmin circle centered on the source.

The content of the region file used here, `../../regions/region_SXI_100050012340_bkg.reg`, is

```
# Region file format: DS9 version 4.1
global color=green dashlist=8 3 width=1 font="helvetica 10 normal roman" select=1
highlite=1 dash=0 fixed=0 edit=1 move=1 delete=1 include=1 source=1
fk5
box(278.44244,-10.510651,2167.6579",1769.1332",88.49) # color=white width=2
-circle(278.38824,-10.570683,540") # color=white width=2
-circle(278.36627,-10.407636,120") # color=white width=2
-circle(278.25239,-10.490114,120") # color=white width=2
-circle(278.31736,-10.396696,120") # color=white width=2
-circle(278.21838,-10.485218,120") # color=white width=2
-circle(278.25057,-10.608779,120") # color=white width=2
-circle(278.50636,-10.46556,120") # color=white width=2
-circle(278.54299,-10.358399,120") # color=white width=2
-circle(278.60766,-10.643718,120") # color=white width=2
-circle(278.40962,-10.389049,120") # color=white width=2
```

Alternatively, a smaller region on the same chip may be selected.

Normal Mode

```
xselect
xsel:SUZAKU > read events
../100050020/sxi/event_cl/ah100050020sxi_p0100004b0_cl.evt.gz
xsel:HITOMI-SXI-WINDOW1 > filter region
../../regions/region_SXI_100050012340_bkg.reg
xsel:HITOMI-SXI-WINDOW1 > extract spectrum
xsel:HITOMI-SXI-WINDOW1 > save spectrum ah100050020sxi_p0100004b0_cl_bkg.pi
xsel:HITOMI-SXI-WINDOW1 > plot spectrum
xsel:HITOMI-SXI-WINDOW1 > extract curve exposure=0.0
xsel:HITOMI-SXI-WINDOW1 > save curve ah100050020sxi_p0100004b0_cl_bkg.lc
xsel:HITOMI-SXI-WINDOW1 > plot curve
```

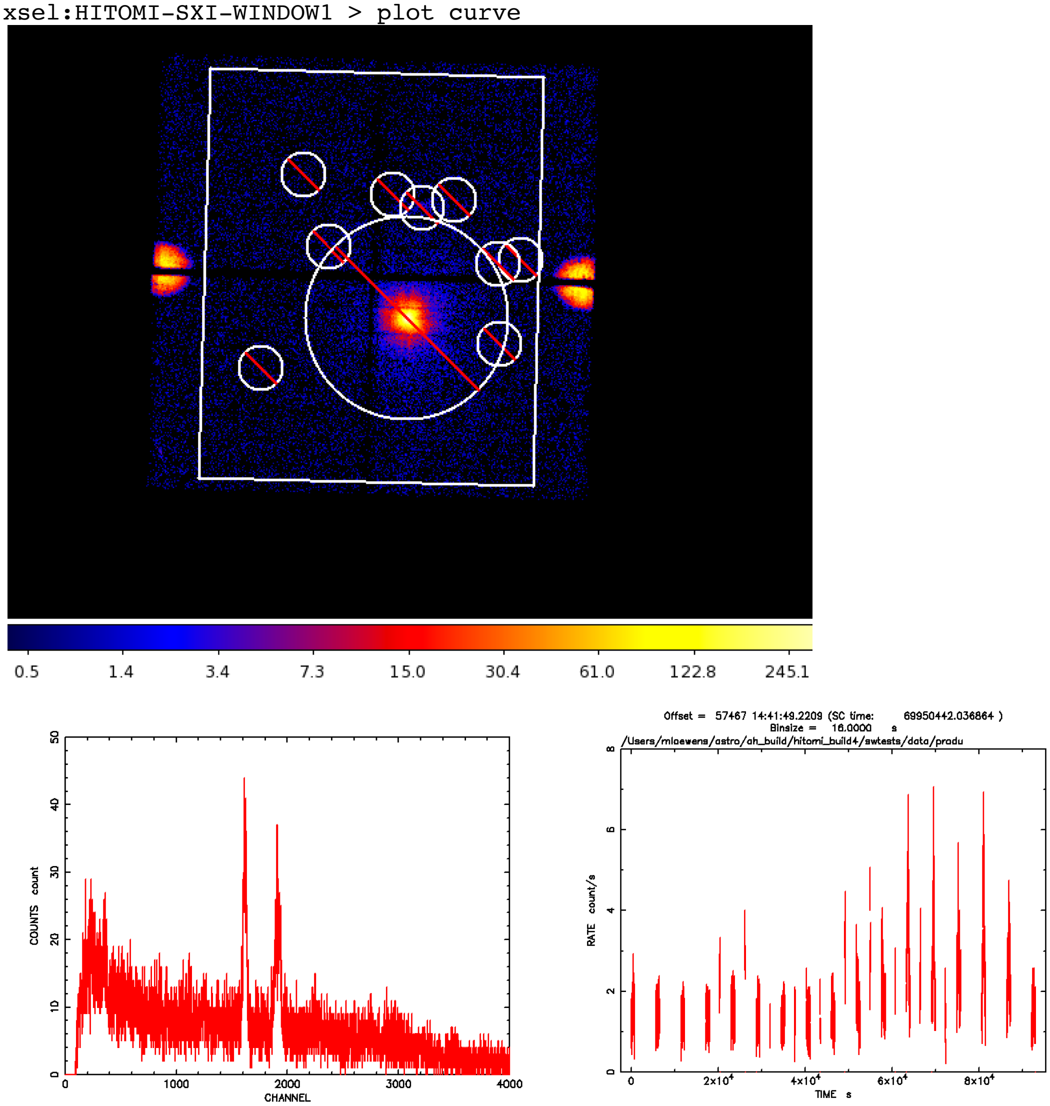


Figure 4: SXI image with cal-source region excluded and background extraction region (top), and background spectrum (bottom left) and lightcurve (bottom right) for sequence 100050020.

Step 2 is repeated for sequences ah100050010, ah100050030, and ah100050040.

(3) Extract NXB spectrum

The content of the region file, `sxi_nxb_det.reg`, which excludes the calibration source regions and their readout streaks is

```
# Region file format: DS9 version 4.1
```

```
global color=green dashlist=8 3 width=1 font="helvetica 10 normal roman" select=1
highlite=1 dash=0 fixed=0 edit=1 move=1 delete=1 include=1 source=1
physical
box(906,908,1290,1060,0) # width=2
```

The source region file must be transformed from RADEC to DET coordinates so it can be also used by sxinxbgen:

```
coordpnt input=../../regions/region_SXI_100050012340.reg
outfile=region_SXI_100050012340_det.reg telescop=HITOMI instrume=SXI
ra=278.39005 dec=-10.568272 roll=88.4961378757592 startsys=RADEC stopsys=DET
clobber=yes mode=hl
```

Run sxinxbgen to extract the NXB spectrum:

```
punlearn sxinxbgen
sxinxbgen infile=ah100050020sxi_p0100004b0_cl.evt
ehkfile=../../100050020/auxil/ah100050020.ehk.gz regfile=sxi_nxb_det.reg
regfile2=region_SXI_100050012340_det.reg regmode=DET
innxbfile=ah_sxi_nxb100cl_20140101v001.evt
innxbehk=ah_gen_nxbehk_20140101v002.fits
innxbhk=${CALDB}/data/hitomi/sxi/bcf/backgrnd/ah_sxi_nxbhk_20140101v001.fits
outpifile=ah100050020sxi_p0100004b0_cl_nxb.pi outnxbfile=NONE sortcol=COR3
sortbin=0,4,5,6,7,8,9,10,11,12,13,99 apply_sxipi=no clobber=yes mode=hl
```

The merged cleaned, event threshold=100 SXI NXB event file (unfiltered and threshold=40 versions are also available) and general ehk file, `ah_sxi_nxb100cl_20140101v001.evt` and `ah_gen_nxbehk_20140101v002.fits` are downloaded from the hitomi url,

https://heasarc.gsfc.nasa.gov/FTP/hitomi/data/nxb_20170510/

Fix the BACKSCAL keyword to account for bad pixels. This should use the exposure map that was created above. First, the NXB region file used above needs to be converted from DET to RADEC, since that is the coordinate system used in the exposure map:

```
coordpnt input=sxi_nxb_det.reg outfile=sxi_nxb_radec.reg telescop=HITOMI
instrume=SXI ra=278.39005 dec=-10.568272 roll=88.4961378757592 startsys=DET
stopsys=RADEC clobber=yes mode=hl
```

```
ahbackscal infile=ah100050020sxi_p0100004b0_cl_nxb.pi regfile=sxi_nxb_radec.reg
expfile=ah100050020sxi_p0100004b0_cl.expo norm=MAX clobber=yes mode=hl
```

SXS

All newly created output files in this section are placed in the /full/path/to/data/sxs_products directory

```
cd /full/path/
```

```
mkdir data/products_sxs
```

```
cd data/products_sxs
```

(1) Additional screening

Create a “cleaned-2” SXS event file

```
ah100050020sxs_p0px1010_cl2.evt
```

by applying a RISETIME cut to Hp, Mp, Ms, and Lp (but not Ls) events, and excluding frame events flagged due to close proximity in time to other events that are no longer screened as part of the standard processing.

```
ftselect
infile='../100050020/sxs/event_cl/ah100050020sxs_p0px1010_cl.evt.gz[events]'
outfile=ah100050020sxs_p0px1010_cl2.evt
expression="(PI>=400)&&((RISE_TIME>=40&&RISE_TIME<=60&&ITYPE<4)||(ITYPE==4))&&S
TATUS[4]==b0"
```

Note that the current pipeline screening already excludes events with PI<600.

(2) Extract source spectra and light curves using sxsregext or xselect

Use sxsregext to extract the spectrum `ah100050020sxs_region_SXS_det.pha` from the above cleaned-2 event file events `ah100050020sxs_p0px1010_cl2.evt` for Hp events. Here we use the corresponding SXI sky region (which includes all the SXS pixels except pixel 12) as input. The 35-pixel detector region (ah100050020sxs_region_SXS_det .reg) and SXS exposure map (ah100050020sxs_region_SXS_det.expo) are also created.

```
sxsregext infile=ah100050020sxs_p0px1010_cl2.evt regmode=RADEC
region=../../regions/region_SXI_100050012340.reg resolist=0
outroot=ah100050020sxs_region_SXS_det outexp=ah100050020sxs.expo
ehkfile=../100050020/auxil/ah100050020.ehk.gz delta=0.25 numphi=4 clobber=yes
```

The region file `ah100050020sxs_region_SXS_det.reg`

```
physical
+box(4,1,5,1.00000000)
+box(3.5,2,6,1.00000000)
+box(3.5,3,6,1.00000000)
+box(3.5,4,6,1.00000000)
+box(3.5,5,6,1.00000000)
+box(3.5,6,6,1.00000000)
```

includes all non-calibration pixels.

In addition to the spectrum, a DET coordinate image `ah100050020sxs_region_SXS_det.img` and lightcurve `ah100050020sxs_region_SXS_det.lc` are created, as displayed below using ds9 and lcurve.

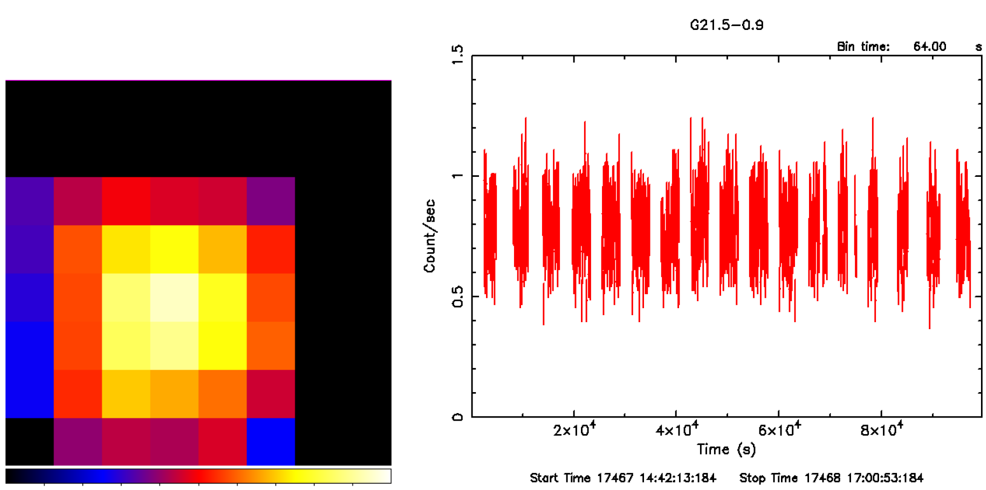


Figure 5: SXS source DET coordinate image and lightcurve for sequence 100050020.

Note that, by default, HP (ITYPE 0) and MP (ITYPE 1) events are included in the spectrum (this may be controlled via the hidden sxsregext resolist parameter). Also, note that the BACKSCAL keyword is set to 5.468750E-01 which is the ratio of the number of pixels used in the extraction (35) to the total detector address space in pixels (64). This is not a problem provided that any spectra to be combined, subtracted etc. are created in the same manner. The following alternative using xselect creates a spectrum with BACKSCAL=1:

```
xsel:SUZAKU > read events ah100050020sxs_p0px1010_cl2.evt
xsel:HITOMI-SXS-PX_NORMAL > filter column "PIXEL=0:11,13:35"
xsel:HITOMI-SXS-PX_NORMAL > filter GRADE "0:0"
xsel:HITOMI-SXS-PX_NORMAL > extract spectrum
xsel:HITOMI-SXS-PX_NORMAL > save spectrum ah100050020sxs_p0px1010_cl2_HP.pi
```

Note that Pixel 12 events may already be excluded from the cleaned event files depending on the label used in filtering; in those cases the second step above may be skipped.

(3) Add columns for an extended energy scale, and extract an extended energy spectrum

First, run the *sxsextend* script with the original cleaned file and its GTI extension as input. The following command adds a PIE column (and EPIE and EPI2E columns) to the original cleaned event file and sets the PIE TLMIN and TLMAX keywords in the output cleaned event files, but otherwise leaves the file unchanged. In this case the extended energy grid includes 32768 channels, extending to twice the standard maximum energy with 1 eV binning. *It is recommended that users not exceed this number of channels or extend the energy scale significantly beyond 30 keV because a valid ARF cannot be made above this energy*.

```
sxsextend inuffile=../100050020/sxs/event_cl/ah100050020sxs_p0px1010_cl.evt.gz
outuffile=ah100050020sxs_p0px1010_clext.evt outclfile=NONE driftfile=NONE
gtigenfile=NONE gtitelfile=NONE gtimxsfile=NONE gtiadroff=NONE gtimkf=NONE
gtiehk=NONE gtiextra=NONE eminin=0 dein=1.0 nchanin=32768 label=NONE
clobber=yes chatter=2 mode=hl
```

In the above streamlined approach, the energies in the input event file are used to assign the new energy channel values in the output file. This is equivalent to the following command:

```
sxsextend inuffile=../100050020/sxs/event_cl/ah100050020sxs_p0px1010_cl.evt.gz
outuffile=ah100050020sxs_p0px1010_ufext.evt
outclfile=ah100050020sxs_p0px1010_clext.evt
driftfile=../100050020/sxs/event_uf/ah100050020sxs_010_pxcal.ghf.gz
gtigenfile=NONE gtitelfile=NONE gtimxsfile=NONE gtiadroff=NONE gtimkf=NONE
gtiehk=NONE
gtiextra=../100050020/sxs/event_cl/ah100050020sxs_p0px1010_cl.evt.gz+2 eminin=0
dein=1.0 nchanin=32768 label=NONE clobber=yes chatter=2 mode=hl
```

If new energies are to be assigned on the basis of a different energy scale, the parameters should be adjusted accordingly.

Second, apply a revised, energy-dependent, RISETIME cut (this may be more generally used, but is most significant at high energies).

```
ftselect
infile='../100050020/sxs/event_cl/ah100050020sxs_p0px1010_clext.evt.gz[events]'
outfile=ah100050020sxs_p0px1010_clext2.evt expression="((((ABS(RISE_TIME-
52+EPIE*(52-42)/16383.75))<=4)&&ITYPE<4)||(ITYPE==4))&&STATUS[4]==b0"
```

Third, extract the spectrum from the values in the PIE column using sxsregext or xselect.

```
sxsregext infile=ah100050020sxs_p0px1010_clext2.evt regmode=DET
region=ah100050020sxs_region_SXS_det.reg resolist=0
```

```
outroot=ah100050020sxs_region_SXS_det_ext outexp=ah100050020sxs.expo
ehkfile=../100050020/auxil/ah100050020.ehk.gz
pixgtifile=../100050020/sxs/event_uf/ah100050020sxs_px1010_exp.gti.gz
delta=0.25 numphi=4 extended=yes clobber=yes
```

or

```
xsel:SUZAKU > read events ah100050020sxs_p0px1010_clext2.evt
xsel:HITOMI-SXS-PX_NORMAL > filter column "PIXEL=0:11,13:35"
xsel:HITOMI-SXS-PX_NORMAL > filter GRADE "0:0"
xsel:HITOMI-SXS-PX_NORMAL > set phaname PIE
xsel:HITOMI-SXS-PX_NORMAL > extract spectrum
xsel:HITOMI-SXS-PX_NORMAL > save spectrum ah100050020sxs_p0px1010_clext2_HP.pi
```

Again, note that these two alternative extraction steps create spectra with different values of the BACSKCAL keyword.

As described below, RMF and ARF files must be constructed with compatible energy grids.

The task may also accept an unfiltered event file and apply a user-selected screening in creating the new cleaned event file. For example, one can create a cleaned event file with extended energy grid and the “alternative, stricter, SXS GTI filtering” described above with the following command, where the new ehk and mkf GTI files created above are input.

```
sxsextend inuffile=../100050020/sxs/event_uf/ah100050020sxs_p0px1010_uf.evt.gz
outuffile=ah100050020sxs_p0px1010_ufext.evt
outclfile=ah100050020sxs_p0px1010_clext.evt
driftfile=../100050020/sxs/event_uf/ah100050020sxs_010_pxcal.ghf.gz
gtigenfile=../100050020/auxil/ah100050020_gen.gti
gtitelfile=../100050020/sxs/event_uf/ah100050020sxs_tel.gti.gz gtimxsfile=NONE
gtiadroff=../100050020/sxs/event_uf/ah100050020sxs_p0px1010_uf.evt.gz
gtimkf=ah100050020_sxs_mkf_PIXELALL.gti+1
gtiehk=ah100050020_sxs_ehk_PIXELALL.gti+1 gtiextra=NONE eminin=0 dein=1.0
nchanin=32768 label=NONE clobber=yes chatter=2 mode=hl
```

The additional event screening and spectral extraction may then proceed as above.

(4) Extract the SXS NXB spectrum for standard and extended energy grids

Run the the task `sxsnxbgen` to extract the SXS NXB spectrum from all pixels (a selection of pixels or detector region may also be input), with the same extra cleaning that was applied to the source spectrum, but excluding ITYPE=4 events that are mostly anomalous. The merged NXB event and ehk files, `ah_sxs_nxbafmar4_20140101v001.evt` and `ah_gen_nxbehk_20140101v002.fits` are downloaded from the hitomi url,

https://heasarc.gsfc.nasa.gov/FTP/hitomi/data/nxb_20170510/

```
sxsnxbgen infile=ah100050020sxs_p0px1010_cl2.evt
ehkfile=../100050020/auxil/ah100050020.ehk.gz regfile=NONE
innxbfile=ah_sxs_nxbafmar4_20140101v001.evt
innxbehk=ah_gen_nxbehk_20140101v002.fits outpifile=ah100050020sxsnxb_cl2.pi
pixels="-" cleanup=yes chatter=3 clobber=yes mode=hl
logfile=ah100050020sxsnxb_cl2.log sortbin=0,4,5,6,7,8,9,10,11,12,13,99
expr="PI>=400&&RISE_TIME>=40&&RISE_TIME<=60&&ITYPE<4&&STATUS[4]==b0"
```

The BACKSCAL keyword must always be updated when the SXS NXB is extracted based on a selection of pixels, and must always be checked for compatibility with the source spectrum. If the extraction regions are the same, BACKSCAL must be identical; if different the BACKSCAL ratio must be the ratio of the extraction region areas (or number of pixels). In the present example, assuming the source spectrum was extracted in xselect,

```
fthedit ah100050020sxsnxb_cl2.pi+1 BACKSCAL add 1.000000E+00
```

The SXS NXB spectrum for the standard extended energy grid (the capability for other extended energy grids will be available with a soon-to-be-updated version of `sxsextend`) may also be extracted using `sxsnxbgen` as follows:

```
sxsnxbgen infile=ah100050020sxs_p0px1010_clext2.evt
ehkfile=../100050020/auxil/ah100050020.ehk.gz
regfile=ah100050020sxs_region_SXS_det.reg regmode=DET
innxbfile=ah_sxs_nxbafmar4_20140101v001.evt
innxbehk=ah_gen_nxbehk_20140101v002.fits outpifile=ah100050020sxsnxb_clext2.pi
pixels="-" cleanup=no chatter=3 clobber=yes mode=hl
logfile=ah100050020sxsnxb_clext2.log sortbin=0,4,5,6,7,8,9,10,11,12,13,99
expr="((ABS(RISE_TIME-52+EPIE*(52-42)/16383.75))<=4)&&ITYPE<4&&STATUS[4]==b0"
picol=PIE"
```

In this example, the NXB spectrum is extracted using a detector region resulting BACKSCAL=5.468750E-01. If the extended spectrum is extracted using `sxsregext` with the same input region, this does not need to be corrected.

100050010, 100050020, 100050030, 100050040 COMBINED

HXI

All newly created output files in this section are placed in the /full/path/to/data/hxi_products directory

```
cd /full/path/
```

```
cd data/products_hxi
```

(1) Extract source and background spectra and light curves using xselect

In the absence of an HXI non-X-ray background (NXB), an off-source spectrum may be extracted – although this will necessarily include some of the source emission and is expected to result in a reduction of the flux. Event files are merged in `xselect` prior to extraction of the source and background spectra and lightcurves.

The content of the background region file used here, `../../regions/region_HXI1_100050012340_bkg.reg`, is

```
# Region file format: DS9 version 4.1
fk5
box(278.38669,-10.566035,490",490",-22.5)
-circle(278.3889,-10.5691,180.0000") # font="helvetica 30 normal "
```

HXI1

```
xselect
xsel:SUZAKU > read events
../100050010/hxi/event_cl/ah100050010hx1_p0camrec_cl.evt.gz
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > read events
../100050020/hxi/event_cl/ah100050020hx1_p0camrec_cl.evt.gz
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > read events
../100050030/hxi/event_cl/ah100050030hx1_p0camrec_cl.evt.gz
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > read events
../100050040/hxi/event_cl/ah100050040hx1_p0camrec_cl.evt.gz
xsel:HITOMI-HXI2-CAMERA_NORMAL1 > save events ah1000500ALL0hx1_p0camrec_cl.evt
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > extract image
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > save image ah1000500ALL0hx1_p0camrec_cl.img
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > plot image
```

```
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > filter region
../../regions/region_HXI_100050012340.reg
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > extract spectrum
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > save spectrum ah1000500ALL0hx1_p0camrec_cl.pi
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > plot spectrum
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > extract curve
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > save curve ah1000500ALL0hx1_p0camrec_cl.lc
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > plot curve
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > clear region
xsel:HITOMI-HIX1-CAMERA_NORMAL1 > filter region
../../regions/region_HXI1_100050012340_bkg.reg
xsel:HITOMI-HIX1-CAMERA_NORMAL1 > extract spectrum
xsel:HITOMI-HIX1-CAMERA_NORMAL1 > save spectrum
ah1000500ALL0hx1_p0camrec_cl_bkg.pi
xsel:HITOMI-HIX1-CAMERA_NORMAL1 > plot spectrum
xsel:HITOMI-HIX1-CAMERA_NORMAL1 > extract curve
xsel:HITOMI-HIX1-CAMERA_NORMAL1 > save curve
ah1000500ALL0hx1_p0camrec_cl_bkg.lc
xsel:HITOMI-HIX1-CAMERA_NORMAL1 > plot curve
```

HXI2

The content of the background region file used here, `../../regions/region_HXI2_100050012340_bkg.reg`, is

```
# Region file format: DS9 version 4.1
fk5
box(278.38269,-10.565051,490",490",22.5)
-circle(278.3889,-10.5691,180") # font="helvetica 30 normal "
```

```
xselect
xsel:SUZAKU > read events
../100050010/hxi/event_cl/ah100050010hx2_p0camrec_cl.evt.gz
xsel:HITOMI-HXI2-CAMERA_NORMAL1 > read events
../100050020/hxi/event_cl/ah100050020hx2_p0camrec_cl.evt.gz
xsel:HITOMI-HXI2-CAMERA_NORMAL1 > read events
../100050030/hxi/event_cl/ah100050030hx2_p0camrec_cl.evt.gz
xsel:HITOMI-HXI2-CAMERA_NORMAL1 > read events
../100050040/hxi/event_cl/ah100050040hx2_p0camrec_cl.evt.gz
xsel:HITOMI-HXI2-CAMERA_NORMAL1 > save events ah1000500ALL0hx2_p0camrec_cl.evt
xsel:HITOMI-HXI2-CAMERA_NORMAL1 > extract image
xsel:HITOMI-HXI2-CAMERA_NORMAL1 > save image ah1000500ALL0hx1_p0camrec_cl.img
xsel:HITOMI-HXI2-CAMERA_NORMAL1 > plot image
xsel:HITOMI-HXI2-CAMERA_NORMAL1 > filter region
../../regions/region_HXI_100050012340.reg
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > extract spectrum
xsel:HITOMI-HXI2-CAMERA_NORMAL1 > save spectrum ah1000500ALL0hx2_p0camrec_cl.pi
xsel:HITOMI-HXI2-CAMERA_NORMAL1 > plot spectrum
xsel:HITOMI-HXI2-CAMERA_NORMAL1 > extract curve
xsel:HITOMI-HXI2-CAMERA_NORMAL1 > save curve ah1000500ALL0hx2_p0camrec_cl.lc
xsel:HITOMI-HXI2-CAMERA_NORMAL1 > plot curve
xsel:HITOMI-HXI2-CAMERA_NORMAL1 > clear region
xsel:HITOMI-HIX2-CAMERA_NORMAL1 > filter region
../../regions/region_HXI2_100050012340_bkg.reg
xsel:HITOMI-HIX2-CAMERA_NORMAL1 > extract spectrum
xsel:HITOMI-HIX2-CAMERA_NORMAL1 > save spectrum
ah1000500ALL0hx2_p0camrec_cl_bkg.pi
xsel:HITOMI-HIX2-CAMERA_NORMAL1 > plot spectrum
xsel:HITOMI-HIX2-CAMERA_NORMAL1 > extract curve
xsel:HITOMI-HIX2-CAMERA_NORMAL1 > save curve
ah1000500ALL0hx2_p0camrec_cl_bkg.lc
xsel:HITOMI-HIX2-CAMERA_NORMAL1 > plot curve
```

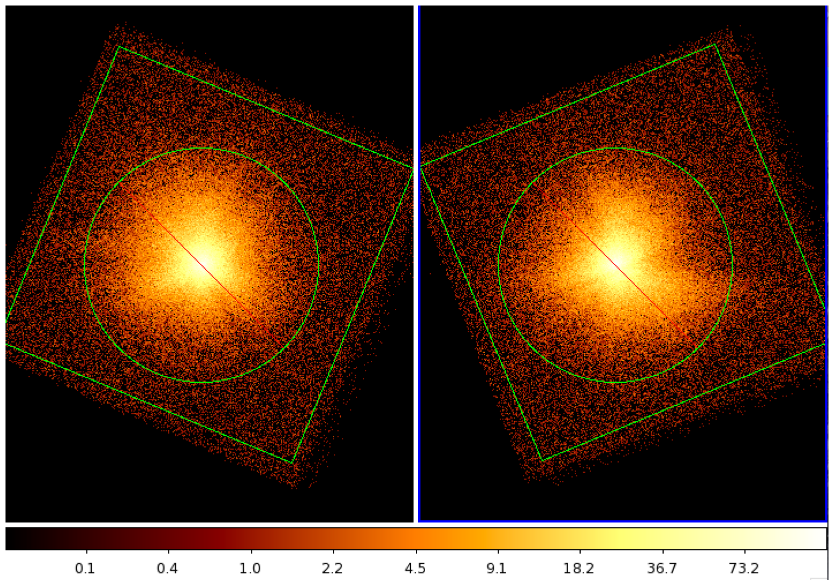


Figure 6: HXI1 (left) and HXI2 (right) background regions.

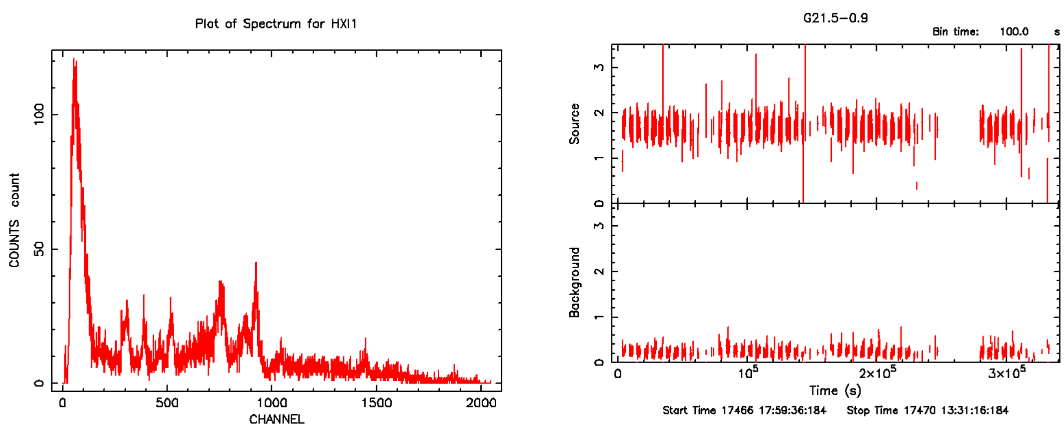


Figure 7: Combined HXI1 background spectrum, and source and background lightcurves, for sequences `ah100050010, ah100050020, ah100050030, and ah100050040.`

(2) Construct the dead-time corrected source and background spectra using xselect, hxisgddtime, and ahgtigen

HXI1

(a) Merge the pseudo-event files, including their GTI extensions:

```
ftmerge
'../100050010/hxi/event_cl/ah100050010hx1_p0camrecpse_cl.evt.gz,../100050020/hx
i/event_cl/ah100050020hx1_p0camrecpse_cl.evt.gz,../100050030/hxi/event_cl/ah100
050030hx1_p0camrecpse_cl.evt.gz,../100050040/hxi/event_cl/ah100050040hx1_p0camr
ecpse_cl.evt.gz' ah1000500ALL0hx1_p0camrecpse_cl.evt

ahgtigen infile=NONE outfile=ah1000500ALL0hx1_p0camrecpse_cl.gti
gtifile=@ah100050012340hx1_p0camrecpse_cl.gti.lst gtiexpr=NONE mergegti=OR
```

where `ah100050012340hx1_p0camrecpse_cl.gti.lst` is a text file listing all pseudo event file GTI extensions:

```
../100050010/hxi/event_cl/ah100050010hx1_p0camrecpse_cl.evt.gz+2
../100050020/hxi/event_cl/ah100050020hx1_p0camrecpse_cl.evt.gz+2
../100050030/hxi/event_cl/ah100050030hx1_p0camrecpse_cl.evt.gz+2
../100050040/hxi/event_cl/ah100050040hx1_p0camrecpse_cl.evt.gz+2
```

```
ftdelhdu 'ah1000500ALL0hx1_p0camrecpse_cl.evt[GTI]' none confirm=YES
```

```
ftappend 'ah1000500ALL0hx1_p0camrecpse_cl.gti[GTI]'
ah1000500ALL0hx1_p0camrecpse_cl.evt
```

(b) Merge the event file GTI extensions:

```
ahgtigen infile=NONE outfile=ah1000500ALL0hx1_p0camrec_cl.gti
gtifile=@ah100050012340hx1_p0camrec_cl.gti.lst gtiexpr=NONE mergegti=OR
```

where `ah100050012340hx1_p0camrec_cl.gti.lst` is a text file listing all GTI extensions:

```
../100050010/hxi/event_cl/ah100050010hx1_p0camrec_cl.evt.gz+2
../100050020/hxi/event_cl/ah100050020hx1_p0camrec_cl.evt.gz+2
../100050030/hxi/event_cl/ah100050030hx1_p0camrec_cl.evt.gz+2
../100050040/hxi/event_cl/ah100050040hx1_p0camrec_cl.evt.gz+2
```

```
fthedit ah1000500ALL0hx1_p0camrec_cl.gti+1 INSTRUME a HXI1
fthedit ah1000500ALL0hx1_p0camrec_cl.gti+1 DETNAM a CAMERA
```

(c) Apply the deadtime correction to the merged source and background spectra and lightcurves, using the merged pseudo-event and event GTI files:

```
hxisgddtime infile=ah1000500ALL0hx1_p0camrecpse_cl.evt
inlcfile=ah1000500ALL0hx1_p0camrec_cl.lc
inspecfile=ah1000500ALL0hx1_p0camrec_cl.pi
outlcfile=ah1000500ALL0hx1_p0camrec_dtime.lc
outfile=ah1000500ALL0hx1_p0camrec_dtime.pi
gtifile=ah1000500ALL0hx1_p0camrec_cl.gti
```

```
mv hxisgddtime.log hxisgddtime_ah1000500ALL0hx1.log
```

```
hxisgddtime infile=ah1000500ALL0hx1_p0camrecpse_cl.evt
inlcfile=ah1000500ALL0hx1_p0camrec_cl_bkg.lc
inspecfile=ah1000500ALL0hx1_p0camrec_cl_bkg.pi
outlcfile=ah1000500ALL0hx1_p0camrec_dtime_bkg.lc
outfile=ah1000500ALL0hx1_p0camrec_dtime_bkg.pi
gtifile=ah1000500ALL0hx1_p0camrec_cl.gti
```

```
mv hxisgddtime.log hxisgddtime_ah1000500ALL0hx1_bkg.log
```

HXI2

(a) Merge the pseudo-event files, including their GTI extensions:

```
ftmerge
'../100050010/hxi/event_cl/ah100050010hx2_p0camrecpse_cl.evt.gz,../100050020/hx
i/event_cl/ah100050020hx2_p0camrecpse_cl.evt.gz,../100050030/hxi/event_cl/ah100
050030hx2_p0camrecpse_cl.evt.gz,../100050040/hxi/event_cl/ah100050040hx2_p0camr
ecpse_cl.evt.gz' ah1000500ALL0hx2_p0camrecpse_cl.evt
```

```
ahgtigen infile=NONE outfile=ah1000500ALL0hx2_p0camrecpse_cl.gti
gtifile=@ah100050012340hx2_p0camrecpse_cl.gti.lst gtiexpr=NONE mergegti=OR
```

where `ah100050012340hx2_p0camrecpse_cl.gti.lst` is a text file listing all GTI extensions:

```
../100050010/hxi/event_cl/ah100050010hx2_p0camrecpse_cl.evt.gz+2
../100050020/hxi/event_cl/ah100050020hx2_p0camrecpse_cl.evt.gz+2
../100050030/hxi/event_cl/ah100050030hx2_p0camrecpse_cl.evt.gz+2
../100050040/hxi/event_cl/ah100050040hx2_p0camrecpse_cl.evt.gz+2
```

```
ftdelhdu 'ah1000500ALL0hx2_p0camrecpse_cl.evt[GTI]' none confirm=YES
```

```
ftappend 'ah1000500ALL0hx2_p0camrecpse_cl.gti[GTI]'
ah1000500ALL0hx2_p0camrecpse_cl.evt
```

(b) Merge the event file GTI extensions:

```
ahgtigen infile=NONE outfile=ah1000500ALL0hx2_p0camrec_cl.gti
gtifile=@ah100050012340hx2_p0camrec_cl.gti.lst gtiexpr=NONE mergegti=OR
```

where `ah100050012340hx2_p0camrec_cl.gti.lst` is a text file listing all GTI extensions:

```
../100050010/hxi/event_cl/ah100050010hx2_p0camrec_cl.evt.gz+2
../100050020/hxi/event_cl/ah100050020hx2_p0camrec_cl.evt.gz+2
../100050030/hxi/event_cl/ah100050030hx2_p0camrec_cl.evt.gz+2
../100050040/hxi/event_cl/ah100050040hx2_p0camrec_cl.evt.gz+2
```

```
fthedit ah1000500ALL0hx2_p0camrec_cl.gti+1 INSTRUME a HXI2
fthedit ah1000500ALL0hx2_p0camrec_cl.gti+1 DETNAM a CAMERA
```

(c) Apply the deadtime correction to the merged source and background spectra and lightcurves, using the merged pseudo-event and event GTI files:

```
hxisgddtime infile=ah1000500ALL0hx2_p0camrecpse_cl.evt
inlcfile=ah1000500ALL0hx2_p0camrec_cl.lc
inspecfile=ah1000500ALL0hx2_p0camrec_cl.pi
outlcfile=ah1000500ALL0hx2_p0camrec_dtime.lc
outfile=ah1000500ALL0hx2_p0camrec_dtime.pi
gtifile=ah1000500ALL0hx2_p0camrec_cl.gti
```

```
mv hxisgddtime.log hxisgddtime_ah1000500ALL0hx2.log
```

```
hxisgddtime infile=ah1000500ALL0hx2_p0camrecpse_cl.evt
inlcfile=ah1000500ALL0hx2_p0camrec_cl_bkg.lc
inspecfile=ah1000500ALL0hx2_p0camrec_cl_bkg.pi
outlcfile=ah1000500ALL0hx2_p0camrec_dtime_bkg.lc
outfile=ah1000500ALL0hx2_p0camrec_dtime_bkg.pi
gtifile=ah1000500ALL0hx2_p0camrec_cl.gti
```

```
mv hxisgddtime.log hxisgddtime_ah1000500ALL0hx2_bkg.log
```

(3) Alternative: Combine deadtime-corrected source and background spectra using mathpha

Instead of extracting spectra from the combined event file that are corrected for deadtime, deadtime-corrected spectra may be created for each sequence following the steps detailed above for individual sequence 100050020 and then combined as follows:

HXI1

```
mathpha
ah100050010hx1_p0camrec_dtime.pi+ah100050020hx1_p0camrec_dtime.pi+ah100050030hx
1_p0camrec_dtime.pi+ah100050040hx1_p0camrec_dtime.pi units=C
outfil=ah1000500ALL0hx1_p0camrec_cl.pi exposure=CALC areascal=% backscal=%
```

```
mathpha
ah100050010hx1_p0camrec_dtime_bkg.pi+ah100050020hx1_p0camrec_dtime_bkg.pi+ah100
```

```
050030hx1_p0camrec_dtime_bkg.pi+ah100050040hx1_p0camrec_dtime_bkg.pi units=C
outfil=ah1000500ALL0hx1_p0camrec_cl_bkg.pi exposure=CALC areascal=% backscal=%
```

HXI2

```
mathpha
ah100050010hx2_p0camrec_dtime.pi+ah100050020hx2_p0camrec_dtime.pi+ah100050030hx
2_p0camrec_dtime.pi+ah100050040hx2_p0camrec_dtime.pi units=C
outfil=ah1000500ALL0hx2_p0camrec_cl.pi exposure=CALC areascal=% backscal=%
```

```
mathpha
ah100050010hx2_p0camrec_dtime_bkg.pi+ah100050020hx2_p0camrec_dtime_bkg.pi+ah100
050030hx2_p0camrec_dtime_bkg.pi+ah100050040hx2_p0camrec_dtime_bkg.pi units=C
outfil=ah1000500ALL0hx2_p0camrec_cl_bkg.pi exposure=CALC areascal=% backscal=%
```

(4) Extract the deadtime corrected HXI NXB spectra

HXI1

```
hxinxbgen infile=ah1000500ALL0hx1_p0camrec_cl2.evt ehkfile=ah1000500ALL0.ehk
innxbfile=ah_hx1_nxbevtcl_20140101v001.evt
inpsefile=ah_hx1_nxbpsecl_20140101v001.evt
innxbehk=ah_gen_nxbehk_20140101v002.fits outpifile=ah1000500ALL0hx1nxb_cl.pi
regmode=SKY regfile=../../regions/region_HXI_100050012340.reg cleanup=yes
chatter=3 clobber=yes mode=hl logfile=ah100050020hx1nxb_cl.log
sortbin=0,6,7,8,9,10,11,12,13,99
```

HXI2

```
hxinxbgen infile=ah1000500ALL0hx1_p0camrec_cl2.evt ehkfile=ah1000500ALL0.ehk
innxbfile=ah_hx1_nxbevtcl_20140101v001.evt
inpsefile=ah_hx1_nxbpsecl_20140101v001.evt
innxbehk=ah_gen_nxbehk_20140101v002.fits outpifile=ah1000500ALLhx2nxb_cl.pi
regmode=SKY regfile=../../regions/region_HXI_100050012340.reg cleanup=yes
chatter=3 clobber=yes mode=hl logfile=ah100050020hx2nxb_cl.log
sortbin=0,6,7,8,9,10,11,12,13,99
```

SGD

All newly created output files in this section are placed in the /full/path/to/data/sgd_products directory

```
cd /full/path/
```

```
cd data/products_sgd
```

(1) Apply additional screening to the reprocessed event files

For data version 4 (03Apr2017), calibrated with probfovfile=ah_sgd_probfovfile_20140101v003.fits, the additional screening step detailed above for sequence `100050020` must be repeated for sequences `100050030 and 100050040`.

(1) Extract total source spectrum and light curve using xselect

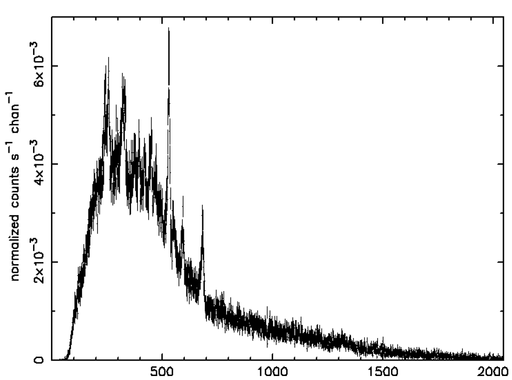
```
xselect
xsel:SUZAKU > read events ah100050020sg1_p0cc1rec_cl2.evt
xsel:HITOMI-SGD1-CC_NORMAL1 > read events ah100050020sg1_p0cc2rec_cl2.evt
xsel:HITOMI-SGD1-CC_NORMAL1 > read events ah100050020sg1_p0cc3rec_cl2.evt
xsel:HITOMI-SGD1-CC_NORMAL1 > read events ah100050030sg1_p0cc1rec_cl2.evt
xsel:HITOMI-SGD1-CC_NORMAL1 > read events ah100050030sg1_p0cc2rec_cl2.evt
xsel:HITOMI-SGD1-CC_NORMAL1 > read events ah100050030sg1_p0cc3rec_cl2.evt
```

```
xsel:HITOMI-SGD1-CC_NORMAL1 > read events ah100050040sg1_p0cc1rec_cl2.evt
xsel:HITOMI-SGD1-CC_NORMAL1 > read events ah100050040sg1_p0cc2rec_cl2.evt
xsel:HITOMI-SGD1-CC_NORMAL1 > read events ah100050040sg1_p0cc3rec_cl2.evt
xsel:HITOMI-SGD1-CC_NORMAL1 > extract events
xsel:HITOMI-SGD1-CC_NORMAL1 > save events ah1000500ALL0sg1_p0ccALLrec_cl2.evt
xsel:HITOMI-SGD1-CC_NORMAL1 > extract spectrum
xsel:HITOMI-SGD1-CC_NORMAL1 > save spectrum ah1000500ALL0sg1_p0ccALLrec_cl2.pi
xsel:HITOMI-SGD1-CC_NORMAL1 > plot spectrum
xsel:HITOMI-SGD1-CC_NORMAL1 > extract curve
xsel:HITOMI-SGD1-CC_NORMAL1 > save curve ah1000500ALL0sg1_p0ccALLrec_cl2.lc
xsel:HITOMI-SGD1-CC_NORMAL1 > plot curve
```

(2) Create deadtime-corrected spectra and lightcurves using hxisgddtime

(a) Extract the combined (over sequence) spectrum and light curve for each individual camera.

```
xselect
xsel:SUZAKU > read events ah100050020sg1_p0cc1rec_cl2.evt
xsel:HITOMI-SGD1-CC_NORMAL1 > read events ah100050030sg1_p0cc1rec_cl2.evt
xsel:HITOMI-SGD1-CC_NORMAL1 > read events ah100050040sg1_p0cc1rec_cl2.evt
xsel:HITOMI-SGD1-CC_NORMAL1 > extract spectrum
xsel:HITOMI-SGD1-CC_NORMAL1 > save spectrum ah1000500ALL0sg1_p0cc1rec_cl2.pi
xsel:HITOMI-SGD1-CC_NORMAL1 > extract curve
xsel:HITOMI-SGD1-CC_NORMAL1 > save curve ah1000500ALL0sg1_p0cc1rec_cl2.lc
xsel:HITOMI-SGD1-CC_NORMAL1 > clear all
xsel:HITOMI-SGD1-CC_NORMAL1 > read events ah100050020sg1_p0cc2rec_cl2.evt
xsel:HITOMI-SGD1-CC_NORMAL1 > read events ah100050030sg1_p0cc2rec_cl2.evt
xsel:HITOMI-SGD1-CC_NORMAL1 > read events ah100050040sg1_p0cc2rec_cl2.evt
xsel:HITOMI-SGD1-CC_NORMAL1 > extract spectrum
xsel:HITOMI-SGD1-CC_NORMAL1 > save spectrum ah1000500ALL0sg1_p0cc2rec_cl2.pi
xsel:HITOMI-SGD1-CC_NORMAL1 > extract curve
xsel:HITOMI-SGD1-CC_NORMAL1 > save curve ah1000500ALL0sg1_p0cc2rec_cl2.lc
xsel:HITOMI-SGD1-CC_NORMAL1 > clear all
xsel:HITOMI-SGD1-CC_NORMAL1 > read events ah100050020sg1_p0cc3rec_cl2.evt
xsel:HITOMI-SGD1-CC_NORMAL1 > read events ah100050030sg1_p0cc3rec_cl2.evt
xsel:HITOMI-SGD1-CC_NORMAL1 > read events ah100050040sg1_p0cc3rec_cl2.evt
xsel:HITOMI-SGD1-CC_NORMAL1 > extract spectrum
xsel:HITOMI-SGD1-CC_NORMAL1 > save spectrum ah1000500ALL0sg1_p0cc3rec_cl2.pi
xsel:HITOMI-SGD1-CC_NORMAL1 > extract curve
xsel:HITOMI-SGD1-CC_NORMAL1 > save curve ah1000500ALL0sg1_p0cc3rec_cl2.lc
```



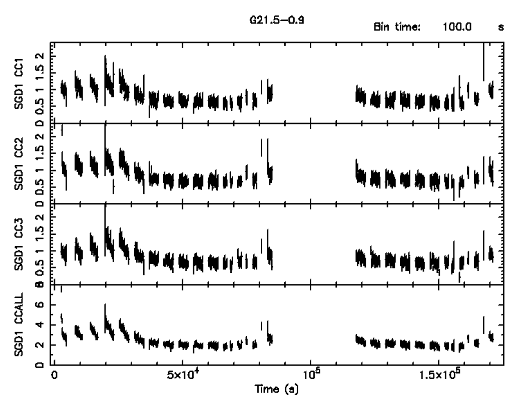


Figure 8: SGD1 summed spectrum and lightcurves (individual cameras and total) for sequences `ah100050010`, `ah100050020`, `and ah100050030`, `and ah100050040 plotted using XSPEC and lcurve.`

(b) Merge the pseudo-event files, including their GTI extensions:

```
ftmerge
'../100050020/sgd/event_cl/ah100050020sg1_p0cc1recpse_cl.evt.gz,../100050030/sg
d/event_cl/ah100050030sg1_p0cc1recpse_cl.evt.gz,../100050040/sgd/event_cl/ah100
050040sg1_p0cc1recpse_cl.evt.gz' ah1000500ALL0sg1_p0cc1recpse_cl.evt

ahgtigen infile=NONE outfile=ah1000500ALL0sg1_p0cc1recpse_cl.gti
gtifile=@ah10005002340sg1_p0cc1recpse_cl.gti.lst gtiexpr=NONE mergegti=OR
```

where `ah10005002340sg1_p0cc1recpse_cl.gti.lst` is a text file listing all GTI extensions:

../100050020/sgd/event_cl/ah100050020sg1_p0cc1recpse_cl.evt.gz+2
../100050030/sgd/event_cl/ah100050030sg1_p0cc1recpse_cl.evt.gz+2
../100050040/sgd/event_cl/ah100050040sg1_p0cc1recpse_cl.evt.gz+2

```
ftdelhdu 'ah1000500ALL0sg1_p0cc1recpse_cl.evt[GTI]' none confirm=YES

ftappend 'ah1000500ALL0sg1_p0cc1recpse_cl.gti[GTI]'
ah1000500ALL0sg1_p0cc1recpse_cl.evt

fthedit ah1000500ALL0sg1_p0cc1recpse_cl.evt+2 INSTRUME a SGD1
fthedit ah1000500ALL0sg1_p0cc1recpse_cl.evt+2 DETNAM a CC1

ftmerge
'../100050020/sgd/event_cl/ah100050020sg1_p0cc2recpse_cl.evt.gz,../100050030/sg
d/event_cl/ah100050030sg1_p0cc2recpse_cl.evt.gz,../100050040/sgd/event_cl/ah100
050040sg1_p0cc2recpse_cl.evt.gz' ah1000500ALL0sg1_p0cc2recpse_cl.evt

ahgtigen infile=NONE outfile=ah1000500ALL0sg1_p0cc2recpse_cl.gti
gtifile=@ah10005002340sg1_p0cc2recpse_cl.gti.lst gtiexpr=NONE mergegti=OR
```

where `ah10005002340sg1_p0cc2recpse_cl.gti.lst` is a text file listing all GTI extensions:

../100050020/sgd/event_cl/ah100050020sg1_p0cc2recpse_cl.evt.gz+2
../100050030/sgd/event_cl/ah100050030sg1_p0cc2recpse_cl.evt.gz+2
../100050040/sgd/event_cl/ah100050040sg1_p0cc2recpse_cl.evt.gz+2

```
ftdelhdu 'ah1000500ALL0sg1_p0cc2recpse_cl.evt[GTI]' none confirm=YES

ftappend 'ah1000500ALL0sg1_p0cc2recpse_cl.gti[GTI]'
ah1000500ALL0sg1_p0cc2recpse_cl.evt

fthedit ah1000500ALL0sg1_p0cc2recpse_cl.evt+2 INSTRUME a SGD1
fthedit ah1000500ALL0sg1_p0cc2recpse_cl.evt+2 DETNAM a CC2

ftmerge
'../100050020/sgd/event_cl/ah100050020sg1_p0cc3recpse_cl.evt.gz,../100050030/sg
d/event_cl/ah100050030sg1_p0cc3recpse_cl.evt.gz,../100050040/sgd/event_cl/ah100
050040sg1_p0cc3recpse_cl.evt.gz' ah1000500ALL0sg1_p0cc3recpse_cl.evt

ahgtigen infile=NONE outfile=ah1000500ALL0sg1_p0cc3recpse_cl.gti
gtifile=@ah10005002340sg1_p0cc3recpse_cl.gti.lst gtiexpr=NONE mergegti=OR
```

where `ah10005002340sg1_p0cc3recpse_cl.gti.lst` is a text file listing all GTI extensions:

../100050020/sgd/event_cl/ah100050020sg1_p0cc3recpse_cl.evt.gz+2
../100050030/sgd/event_cl/ah100050030sg1_p0cc3recpse_cl.evt.gz+2
../100050040/sgd/event_cl/ah100050040sg1_p0cc3recpse_cl.evt.gz+2

```
ftdelhdu 'ah1000500ALL0sg1_p0cc3recpse_cl.evt[GTI]' none confirm=YES

ftappend 'ah1000500ALL0sg1_p0cc3recpse_cl.gti[GTI]'
ah1000500ALL0sg1_p0cc3recpse_cl.evt
```

```
fthedit ah1000500ALL0sg1_p0cc3recpse_cl.evt+2 INSTRUME a SGD1
fthedit ah1000500ALL0sg1_p0cc3recpse_cl.evt+2 DETNAM a CC3
```

(c) Apply the deadtime correction to each camera

```
hxisgddtime infile=ah1000500ALL0sg1_p0cc1recpse_cl.evt
inlcfile=ah1000500ALL0sg1_p0cc1rec_cl2.lc
inspecfile=ah1000500ALL0sg1_p0cc1rec_cl2.pi
outlcfile=ah1000500ALL0sg1_p0cc1rec_dtime.lc
outfile=ah1000500ALL0sg1_p0cc1rec_dtime.pi
gtifile=ah1000500ALL0sg1_p0cc1rec_cl2.evt chatter=2 clobber=yes

mv hxisgddtime.log hxisgddtime_ah1000500ALL0sg1cc1.log

hxisgddtime infile=ah1000500ALL0sg1_p0cc2recpse_cl.evt
inlcfile=ah1000500ALL0sg1_p0cc2rec_cl2.lc
inspecfile=ah1000500ALL0sg1_p0cc2rec_cl2.pi
outlcfile=ah1000500ALL0sg1_p0cc2rec_dtime.lc
outfile=ah1000500ALL0sg1_p0cc2rec_dtime.pi
gtifile=ah1000500ALL0sg1_p0cc2rec_cl2.evt chatter=2 clobber=yes

mv hxisgddtime.log hxisgddtime_ah1000500ALL0sg1cc2.log

hxisgddtime infile=ah1000500ALL0sg1_p0cc3recpse_cl.evt
inlcfile=ah1000500ALL0sg1_p0cc3rec_cl2.lc
inspecfile=ah1000500ALL0sg1_p0cc3rec_cl2.pi
outlcfile=ah1000500ALL0sg1_p0cc3rec_dtime.lc
outfile=ah1000500ALL0sg1_p0cc3rec_dtime.pi
gtifile=ah1000500ALL0sg1_p0cc3rec_cl2.evt chatter=2 clobber=yes

mv hxisgddtime.log hxisgddtime_ah1000500ALL0sg1cc3.log
```

(d) Add the individual spectra, setting the EXPOSURE keyword to the average of the three individual spectra.

```
mathpha
expr=ah1000500ALL0sg1_p0cc1rec_dtime.pi+ah1000500ALL0sg1_p0cc2rec_dtime.pi+ah10
00500ALL0sg1_p0cc3rec_dtime.pi units=C
outfil=ah1000500ALL0sg1_p0ccALLrec_dtime.pi exposure=42974 areascal=%
backscal=% ncomments=0
```

(3) Alternative: Combine individual deadtime-corrected source spectra using mathpha

Instead of extracting spectra from the combined event file for each camera that are corrected for deadtime, deadtime-corrected spectra may be created for each camera for each sequence following the steps detailed above for individual sequence 100050020 and then combined in a grand sum as follows, where the exposure keyword is set to the averagage, over cameras, of the sum over sequences.:

```
mathpha
expr=ah100050020sg1_p0cc1rec_dtime.pi+ah100050020sg1_p0cc2rec_dtime.pi+ah100050
020sg1_p0cc3rec_dtime.pi+ah100050030sg1_p0cc1rec_dtime.pi+ah100050030sg1_p0cc2r
ec_dtime.pi+ah100050030sg1_p0cc3rec_dtime.pi+ah100050040sg1_p0cc1rec_dtime.pi+a
h100050040sg1_p0cc2rec_dtime.pi+ah100050040sg1_p0cc3rec_dtime.pi units=C
outfil=ah10005002340sg1_p0ccALLrec_dtime.pi exposure=42974 areascal=%
backscal=%
```

SXI

All newly created output files in this section are placed in the /full/path/to/data/sxi_products directory

```
cd /full/path/
```

```
cd data/products_sxi
```

Due to differences in the number of bad pixels between OBSIDs, the SXI event data cannot be combined in the same way as the other instruments. Instead, spectra, RMFs, exposure maps, and ARFs must be generated for each OBSID separately and then simultaneously combined at the end (see next section). As stated above, the steps for sequence 100050020 are repeated for 100050010, 100050030, and 100050040 to create source and background spectra for all sequences. The steps for constructing the combined SXI NXB spectrum is also include in the next section.

SXS

All newly created output files in this section are placed in the /full/path/to/data/sxs_products directory

```
cd /full/path/

cd data/products_sxs
```

(1) Combine the event files in xselect

```
xselect
xsel:SUZAKU > read events
../100050010/sxs/event_cl/ah100050010sxs_p0px1010_cl.evt.gz
xsel:HITOMI-SXS-PX_NORMAL > read events
../100050020/sxs/event_cl/ah100050020sxs_p0px1010_cl.evt.gz
xsel:HITOMI-SXS-PX_NORMAL > read events
../100050030/sxs/event_cl/ah100050030sxs_p0px1010_cl.evt.gz
xsel:HITOMI-SXS-PX_NORMAL > read events
../100050040/sxs/event_cl/ah100050040sxs_p0px1010_cl.evt.gz
xsel:HITOMI-SXS-PX_NORMAL > extract events
xsel:HITOMI-SXS-PX_NORMAL > save events ah1000500ALL0sxs_p0px1010_cl.evt
```

(2) Apply the extra rise-time and proximity screening

```
ftselect infile='ah1000500ALL0sxs_p0px1010_cl.evt[events]'
outfile=ah1000500ALL0sxs_p0px1010_cl2.evt
expression="(PI>=400)&&((RISE_TIME>=40&&RISE_TIME<=60&&ITYPE<4)||(ITYPE==4))&&S
TATUS[4]==b0"
```

Note that the current pipeline screening already excludes events with PI<600.

(3) Extract the spectrum

```
ftmerge
'../100050010/auxil/ah100050010.ehk.gz,../100050020/auxil/ah100050020.ehk.gz,..
/100050030/auxil/ah100050030.ehk.gz,../100050040/auxil/ah100050040.ehk.gz'
ah1000500ALL0.ehk

sxsregext infile=ah1000500ALL0sxs_p0px1010_cl2.evt regmode=RADEC
region=../../regions/region_SXI_100050012340.reg resolist=0
outroot=ah1000500ALL0sxs_region_SXS_det outexp=ah1000500ALL0sxs.expo
ehkfile=ah1000500ALL0.ehk delta=0.25 numphi=4 clobber=yes
```

or, equivalently,

```
xsel:SUZAKU > read events ah1000500ALL0sxs_p0px1010_cl2.evt
xsel:HITOMI-SXS-PX_NORMAL > filter column "PIXEL=0:11,13:35"
xsel:HITOMI-SXS-PX_NORMAL > filter GRADE "0:0"
xsel:HITOMI-SXS-PX_NORMAL > filter pha_cutoff 4000 20000
xsel:HITOMI-SXS-PX_NORMAL > extract image
xsel:HITOMI-SXS-PX_NORMAL > save image ah1000500ALL0sxs_p0px1010_cl2.img
xsel:HITOMI-SXS-PX_NORMAL > plot image
```

```
xsel:HITOMI-SXS-PX_NORMAL > clear pha_cutoff
xsel:HITOMI-SXS-PX_NORMAL > extract spectrum
xsel:HITOMI-SXS-PX_NORMAL > save spectrum ah1000500ALL0sxs_p0px1010_cl2_HP.pi
xsel:HITOMI-SXS-PX_NORMAL > extract curve
xsel:HITOMI-SXS-PX_NORMAL > save curve ah1000500ALL0sxs_p0px1010_cl2_HP.lc
xsel:HITOMI-SXS-PX_NORMAL > plot curve
```

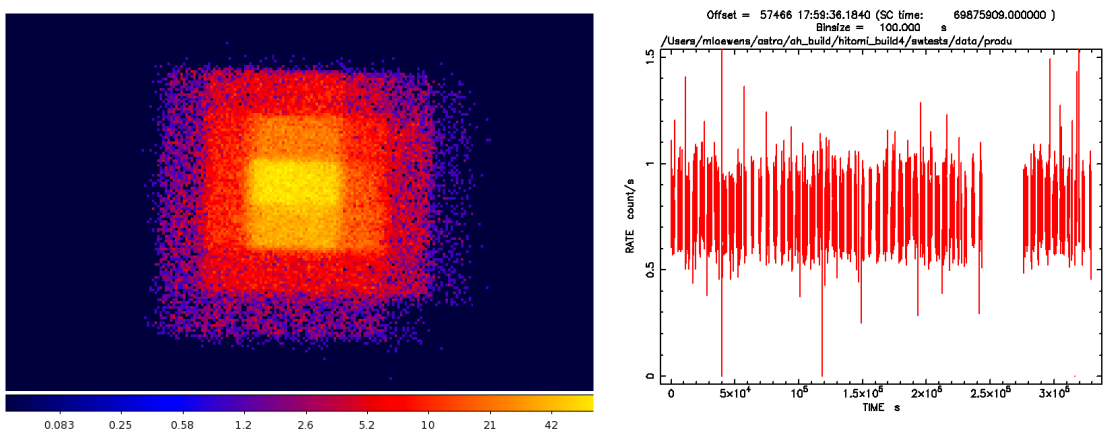


Figure 9: Combined SXS HP 2-10 keV SKY coordinate image, and lightcurve.

(4) Extract the SXS NXB spectrum

Run the the task `sxsnxbgen` to extract the SXS NXB spectrum from all pixels (a selection of pixels or detector region may also be input), with the same extra cleaning that was applied to the source spectrum, but excluding ITYPE=4 events that are mostly anomalous.

```
sxsnxbgen infile=ah1000500ALL0sxs_p0px1010_cl2.evt ehkfile=ah1000500ALL0.ehk
regfile=NONE innxbfile=ah_sxs_nxbafmar4_20140101v001.evt
innxbehk=ah_gen_nxbehk_20140101v002.fits outpifile=ah1000500ALL0sxsnxb_cl2.pi
pixels="-" cleanup=yes chatter=3 clobber=yes mode=hl
logfile=ah1000500ALL0sxsnxb_cl2.log sortbin=0,4,5,6,7,8,9,10,11,12,13,99
expr="PI>=400&&RISE_TIME>=40&&RISE_TIME<=60&&ITYPE<4&&STATUS[4]==b0"
```

The BACKSCAL keyword must always be updated when the SXS NXB is extracted based on a selection of pixels, and must always be checked for compatibility with the source spectrum. If the extraction regions are the same, BACKSCAL must be identical; if different the BACKSCAL ratio must be the ratio of the extraction region areas (or number of pixels). In the present example, assuming the source spectrum was extracted in xselect,

```
fthedit ah1000500ALL0sxsnxb_cl2.pi +1 BACKSCAL add 1.000000E+00
```

is done.

Generating Exposure Map, RMF, and ARF

100050020

HXI

All newly created output files in this section are placed in the /full/path/to/data/hxi_products directory

```
cd /full/path/
```

```
cd data/products_hxi
```

(1) Create an exposure map for each HXI

The exposure maps generated here are used in the two examples below to make both the RSP and flat field for the HXI. The exposure maps are created with the parameters `delta=20.0`, `numphi=1` to assure that the map includes only a single attitude bin, i.e. assuming that the attitude is stable relative to the size of the PSF and extraction region.

HXI1

```
ahexpmap ehkfile=../100050020/auxil/ah100050020.ehk.gz
gtifile=../100050020/hxi/event_cl/ah100050020hx1_p0camrec_cl.evt.gz
instrume=HXI1 badimgfile=NONE pixgtifile=NONE
outfile=ah100050020hx1_p0camrec.expo outmaptype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=10.0 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100050020hx1_p0camrec.log
```

HXI2

```
ahexpmap ehkfile=../100050020/auxil/ah100050020.ehk.gz
gtifile=../100050020/hxi/event_cl/ah100050020hx2_p0camrec_cl.evt.gz
instrume=HXI2 badimgfile=NONE pixgtifile=NONE
outfile=ah100050020hx2_p0camrec.expo outmaptype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=10.0 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100050020hx2_p0camrec.log
```

(2) Create an RSP for each HXI (~40 min)

Make RSP for HXI1 and HXI2, sampling=120, point source at center of extraction region region_HXI_100050012340.reg. In general, the `source_ra` and `source_dec` parameters should be the coordinates of the center of the source in the image, which are not necessarily the same as the actual source coordinates. Here we use the center of the spectral extraction region. An on-axis point source response can be constructed by setting the source coordinates to the single value of RANOMXP and DECNOMXP in the first extension of the exposure map. The runtime estimated above is for the case where the exposure map has a single attitude bin. The parameter `numphoton` may need to be decreased to accommodate a larger number of attitude bins.

HXI1

```
aharfgen xrtevtfile=raytrace_ah100050020hx1_p0camrec.fits source_ra=278.3889
source_dec=-10.5691 telescop=HITOMI instrume=HXI1
emapfile=ah100050020hx1_p0camrec.expo
dattfile=../100050020/hxi/event_uf/ah100050020hx1.att.gz regmode=RADEC
regionfile=../../regions/region_HXI_100050012340.reg sampling=120
sourcetype=point erange="4.0 80.0" outfile=ah100050020hx1_rt
filtoffsetfile=../100050020/hxi/event_uf/ah100050020hx1_cms.fits.gz
numphoton=10000 minphoton=1 teldeffile=CALDB qefile=CALDB rmffile=CALDB
onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB
frontreffile=CALDB pcolreffile=CALDB scatterfile=CALDB auxtransfile=NONE seed=7
clobber=yes chatter=2 mode=h logfile=make_arf_ah100050020hx1_p0camrec.log
```

HXI2

```
aharfgen xrtevtfile=raytrace_ah100050020hx2_p0camrec.fits source_ra=278.3889
source_dec=-10.5691 telescop=HITOMI instrume=HXI2
emapfile=ah100050020hx2_p0camrec.expo
dattfile=../100050020/hxi/event_uf/ah100050020hx2.att.gz regmode=RADEC
regionfile=../../regions/region_HXI_100050012340.reg sampling=120
sourcetype=point erange="4.0 80.0" outfile=ah100050020hx2_rt
filtoffsetfile=../100050020/hxi/event_uf/ah100050020hx2_cms.fits.gz
numphoton=10000 minphoton=1 teldeffile=CALDB qefile=CALDB rmffile=CALDB
onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB
frontreffile=CALDB pcolreffile=CALDB scatterfile=CALDB auxtransfile=NONE seed=7
clobber=yes chatter=2 mode=h logfile=make_arf_ah100050020hx2_p0camrec.log
```

(3) Create flat field efficiency images for each HXI

HXI1

```
hxirspeffimg telescop=HITOMI instrume=HXI1
emapfile=ah100050020hx1_p0camrec.expo
xrtevtfile=raytrace_ah100050020hx1_p0camrec.fits onaxisffile=CALDB
onaxiscfile=CALDB regionfile=NONE
dattfile=../100050020/hxi/event_uf/ah100050020hx1.att.gz stopsys=SKY
sampling=40 erange="4.0 80.0"
filtoffsetfile=../100050020/hxi/event_uf/ah100050020hx1_cms.fits.gz
outflatfile=ah100050020hx1_flatfield.fits vigfile=CALDB outmaptype=EFFICIENCY
qefile=CALDB rmffile=CALDB clobber=yes chatter=2 mode=h
logfile=make_flat_ah100050020hx1_p0camrec.log
```

HXI2

```
time hxirspeffimg telescop=HITOMI instrume=HXI2
emapfile=ah100050020hx2_p0camrec.expo
xrtevtfile=raytrace_ah100050020hx2_p0camrec.fits onaxisffile=CALDB
onaxiscfile=CALDB regionfile=NONE
dattfile=../100050020/hxi/event_uf/ah100050020hx2.att.gz stopsys=SKY
sampling=40 erange="4.0 80.0"
filtoffsetfile=../100050020/hxi/event_uf/ah100050020hx2_cms.fits.gz
outflatfile=ah100050020hx2_flatfield.fits vigfile=CALDB outmaptype=EFFICIENCY
qefile=CALDB rmffile=CALDB clobber=yes chatter=2 mode=h
logfile=make_flat_ah100050020hx2_p0camrec.log
```

These commands produce the images shown below:

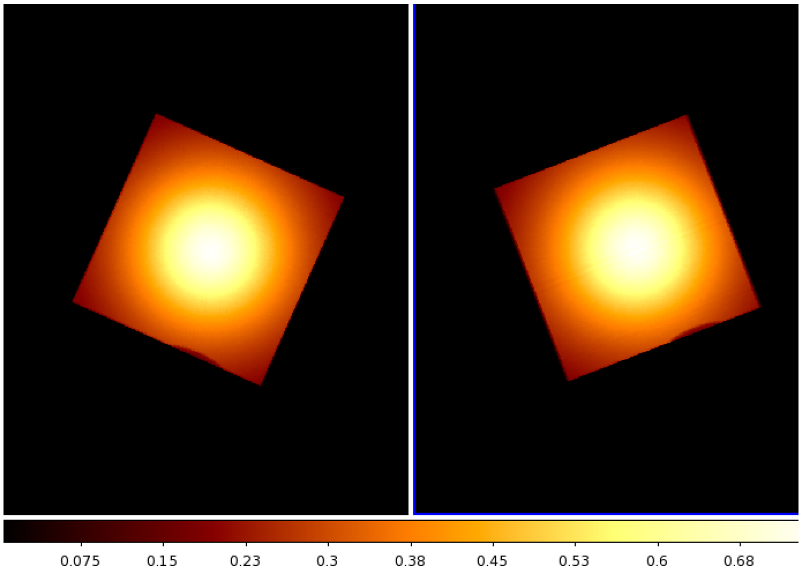


Figure 10: HXI1 (left) and HXI2 (right) flat field images for sequence 100050020.

SGD

All newly created output files in this section are placed in the /full/path/to/data/hxi_products directory

```
cd /full/path/
```

```
cd data/products_sgd
```

All newly created output files in this section are placed in the /full/path/to/data/sgd_products directory

Create the individual response files for each SGD1 Compton camera, and co-add them. To construct an on-axis response, directly co-add the CALDB response files used as input to the SGD arf generator. Here we use the center of the SXI/HXI spectral extraction region as the source coordinates.

```
sgdarfgen infile=ah100050020sg1_p0ccALLrec_dtime.pi
rspfile="$CALDB/data/hitomi/sgd/cpf/response/ah_sg1_cc1_20140101v001.rsp,$CALDB
/data/hitomi/sgd/cpf/response/ah_sg1_cc2_20140101v001.rsp,$CALDB/data/hitomi/sg
d/cpf/response/ah_sg1_cc3_20140101v001.rsp" outfile=outrsp_100050020
ra=278.3889 dec=-10.5691 sgdid=1 ccid=0 clobber=yes
```

```
addrmf
outrsp_100050020_sgd1_cc1.rsp,outrsp_100050020_sgd1_cc2.rsp,outrsp_100050020_sg
d1_cc3.rsp 1.0,1.0,1.0 ah100050020_sgd1_ccALL.rsp
```

SXI

All newly created output files in this section are placed in the /full/path/to/data/sxi_products directory

```
cd /full/path/
```

```
cd data/products_sxi
```

(1) Create an RMF for the source spectrum

Normal mode

```
sxirmf infile=ah100050020sxi_p0100004b0_cl.pi
outfile=ah100050020sxi_p0100004b0_cl.rmf clobber=yes mode=hl
```

MZDYE

```
sxirmf infile=ah100050020sxi_p0100004b1_cl.pi
outfile=ah100050020sxi_p0100004b1_cl.rmf clobber=yes mode=hl
```

(2) Create an Exposure Map for the source spectrum

The exposure maps generated here are used in the two examples below to make both the ARF and flat field for the SXI. The exposure maps are created with the parameters `delta=20.0`, `numphi=1` to assure that the map includes only a single attitude bin, i.e. assuming that the attitude is stable relative to the size of the PSF and extraction region.

Normal mode

```
ahexpmap ehkfile=../100050020/auxil/ah100050020.ehk.gz
gtifile=../100050020/sxi/event_cl/ah100050020sxi_p0100004b0_cl.evt.gz
instrume=SXI
badimgfile=../100050020/sxi/event_uf/ah100050020sxi_p0100004b0.bimg.gz
pixgtifile=../100050020/sxi/event_uf/ah100050020sxi_a0100004b0.fpix.gz
outfile=ah100050020sxi_p0100004b0.expo outmaptype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100050020sxi_a0100004b0.log
```

MZDYE

```
ahexpmap ehkfile=../100050020/auxil/ah100050020.ehk.gz
gtifile=../100050020/sxi/event_cl/ah100050020sxi_p0100004b1_cl.evt.gz
instrume=SXI
badimgfile=../100050020/sxi/event_uf/ah100050020sxi_p0100004b1.bimg.gz
pixgtifile=../100050020/sxi/event_uf/ah100050020sxi_a0100004b1.fpix.gz
outfile=ah100050020sxi_p0100004b1.expo outmaptype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100050020sxi_a0100004b1.log
```

(3) Create an ARF for the source spectrum (~60 min)

In general, the `source_ra` and `source_dec` parameters should be the coordinates of the center of the source in the image, which are not necessarily the same as the actual source coordinates. Here we use the center of the spectral extraction region. The runtime estimated above is for the case where the exposure map has a single attitude bin. The parameter `numphoton` may need to be decreased to accommodate a larger number of attitude bins.

Normal mode

```
aharfgen xrtevtfile=raytrace_ah100050020sxi_p0100004b0_ptsrc_evt.fits
source_ra=278.3889 source_dec=-10.5691 telescop=HITOMI instrume=SXI
emapfile=ah100050020sxi_p0100004b0.expo regmode=RADEC
regionfile=../../regions/region_SXI_100050012340.reg sourcetype=POINT
rmffile=ah100050020sxi_p0100004b0_cl.rmf erange="0.5 16.0 0 0"
outfile=ah100050020sxi_p0100004b0_rt.arf numphoton=300000 minphoton=1
teldeffile=CALDB qefile=CALDB contamifile=CALDB onaxisffile=CALDB
```

```
onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB
backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB auxtransfile=NONE seed=7
clobber=yes chatter=2 mode=h logfile=make_arf_ah100050020sxi_p0100004b0.log
```

MZDYE

```
aharfgen xrtevtfile=raytrace_ah100050020sxi_p0100004b1_ptsrc_evt.fits
source_ra=278.3889 source_dec=-10.5691 telescop=HITOMI instrume=SXI
emapfile=ah100050020sxi_p0100004b1.expo regmode=RADEC
regionfile=../../regions/region_SXI_100050012340.reg sourcetype=POINT
rmffile=ah100050020sxi_p0100004b1_cl.rmf erange="0.5 16.0 0 0"
outfile=ah100050020sxi_p0100004b1_rt.arf numphoton=300000 minphoton=1
teldeffile=CALDB qefile=CALDB contamifile=CALDB onaxisffile=CALDB
onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB
backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB auxtransfile=NONE seed=7
clobber=yes chatter=2 mode=h logfile=make_arf_ah100050020sxi_p0100004b1.log
```

(4) Create an SXI efficiency map (flat field)

Normal mode

```
ahexpmap ehkfile=../100050020/auxil/ah100050020.ehk.gz
gtifile=../100050020/sxi/event_cl/ah100050020sxi_p0100004b0_cl.evt.gz
instrume=SXI
badimgfile=../100050020/sxi/event_uf/ah100050020sxi_p0100004b0.bimg.gz
pixgtifile=../100050020/sxi/event_uf/ah100050020sxi_a0100004b0.fpix.gz
outfile=ah100050020sxi_p0100004b0.flat outmaptype=EFFICIENCY delta=20.0
numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_flat_ah100050020sxi_a0100004b0.log
```

MZDYE

```
ahexpmap ehkfile=../100050020/auxil/ah100050020.ehk.gz
gtifile=../100050020/sxi/event_cl/ah100050020sxi_p0100004b1_cl.evt.gz
instrume=SXI
badimgfile=../100050020/sxi/event_uf/ah100050020sxi_p0100004b1.bimg.gz
pixgtifile=../100050020/sxi/event_uf/ah100050020sxi_a0100004b1.fpix.gz
outfile=ah100050020sxi_p0100004b1.flat outmaptype=EFFICIENCY delta=20.0
numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_flat_ah100050020sxi_a0100004b1.log
```

These commands produce the images shown below:

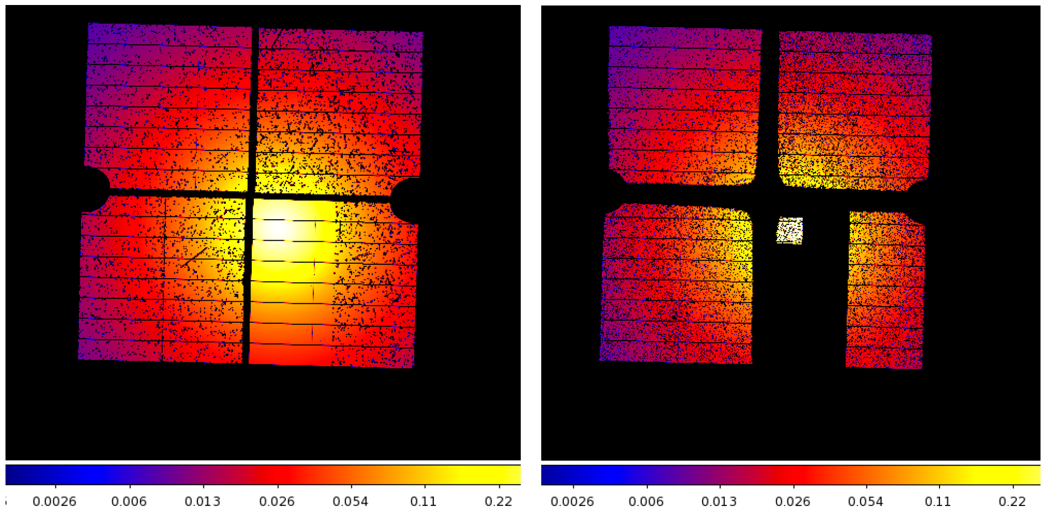


Figure 11: SXI flat field images for sequence 100050020 (left: Normal, right: MZDYE).

(5) Correct the BACKSCAL keyword in the SXI spectra

Xselect writes a BACKSCAL keyword in the header of extracted spectra to properly scale the background subtraction in XSPEC. However, it only accounts for the fraction of the area covered by the extraction region, not the number of good pixels. Many pixels in SXI data are affected by cosmic-ray echo or light leak and need to be properly excluded from BACKSCAL. The following application of *ahbackscal* should be made for both the 'Normal' and 'MZDYE' source and background spectra.

Normal mode

```
ahbackscal infile=ah100050020sxi_p0100004b0_cl.pi
regfile=../../regions/region_SXI_100050012340.reg expfile=
ah100050020sxi_p0100004b0_cl.expo norm=MAX
```

```
ahbackscal infile=ah100050020sxi_p0100004b0_cl_bkg.pi
regfile=../../regions/region_SXI_100050012340_bkg.reg expfile=
ah100050020sxi_p0100004b0_cl.expo norm=MAX
```

MZDYE

```
ahbackscal infile=ah100050020sxi_p0100004b1_cl.pi
regfile=../../regions/region_SXI_100050012340.reg expfile=
ah100050020sxi_p0100004b1_cl.expo norm=MAX
```

This is repeated for sequences ah100050010, ah100050030, and ah100050040.

SXS

All newly created output files in this section are placed in the /full/path/to/data/sxs_products directory

```
cd /full/path/
```

```
cd data/products_sxs
```

(1) Generate the RMF

Here we use the "small" size option (Gaussian core only). Change whichrmf parameter to "m" to include exponential tail to low energies, and to "l" to include escape peaks. The DET coordinate region file ah100050020sxs_region_SXS_det.reg created by sxsregext is input.

```
sxsmkrmf infile=ah100050020sxs_p0px1010_cl2.evt
outfile=ah100050020_sxs_cl2_HP_small.rmf resolist=0 regmode=det
regionfile=ah100050020sxs_region_SXS_det.reg whichrmf=s
```

We also construct an SXS RMF using the "x-large" option which is necessary to study the spectrum below 2 keV, but which greatly increases the runtime and file size.

```
sxsmkrmf infile=ah100050020sxs_p0px1010_cl2.evt
outfile=ah100050020_sxs_cl2_HP_xlarge.rmf resolist=0 regmode=det
regionfile=ah100050020sxs_region_SXS_det.reg whichrmf=x
```

(2) Regenerate the SXS exposure maps

The exposure maps created with sxsregext are replaced using the parameters `delta=20.0`, `numphi=1` to assure that map includes only a single attitude bin. This assumes that the attitude is stable relative to the size of the PSF and extraction region. We also account for the lost event gti per pixel here by inputting the pixgti file `ah100050020sxs_px1010_exp.gti` and setting the `pixgtifile` parameter accordingly -- this should be done if the lost event gti are not used in the screening (as in the standard pipeline).

```
ahexpmap ehkfile=../100050020/auxil/ah100050020.ehk.gz
gtifile=ah100050020sxs_p0px1010_cl2.evt instrume=SXS badimgfile=NONE
pixgtifile=../100050020/sxs/event_uf/ah100050020sxs_px1010_exp.gti.gz
outfile=ah100050020sxs_p0px1010.expo outmaptype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100050020sxs_p0px1010.log
```

3) Generate the SXS ARF (~40 min)

The runtime estimated above is for the case where the exposure map has a single attitude bin. The parameter `numphoton` may need to be decreased to accommodate larger number of attitude bins.

```
aharfgen xrtevtfile=raytrace_ah100050020sxs_p0px1010.fits source_ra=278.3889
source_dec=-10.5691 telescop=HITOMI instrume=SXS
emapfile=ah100050020sxs_p0px1010.expo regmode=DET
regionfile=ah100050020sxs_region_SXS_det.reg sourcetype=POINT
rmffile=ah100050020_sxs_cl2_HP_small.rmf erange="0.5 17.0 0 0"
outfile=ah100050020sxs_p0px1010_rt.arf numphoton=300000 minphoton=1
teldeffile=CALDB qefile=CALDB contamifile=CALDB obffile=CALDB fwfile=CALDB
gatevalvefile=CALDB onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB
obstructfile=CALDB frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB
scatterfile=CALDB auxtransfile=NONE seed=7 clobber=yes chatter=2 mode=h
logfile=make_arf_ah100050020sxs_p0px1010.log
```

Note that the source_ra and source_dec are taken from the region file region_SXI_100050020.reg, i.e. an estimate of the source coordinates based on the SXI image. The region file used is the one in DET coordinates created above by sxsregext.

(4) Create an SXS efficiency map (flat field)

Normal mode

```
ahexpmap ehkfile=../100050020/auxil/ah100050020.ehk.gz
gtifile=ah100050020sxs_p0px1010_cl2.evt instrume=SXS badimgfile=NONE
pixgtifile=../100050020/sxs/event_uf/ah100050020sxs_px1010_exp.gti.gz
outfile=ah100050020sxs_p0px1010.expo outmaptype=EFFICIENCY delta=20.0 numphi=1
```

```
stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_flat_ah100050020sxs_p0px1010.log
```

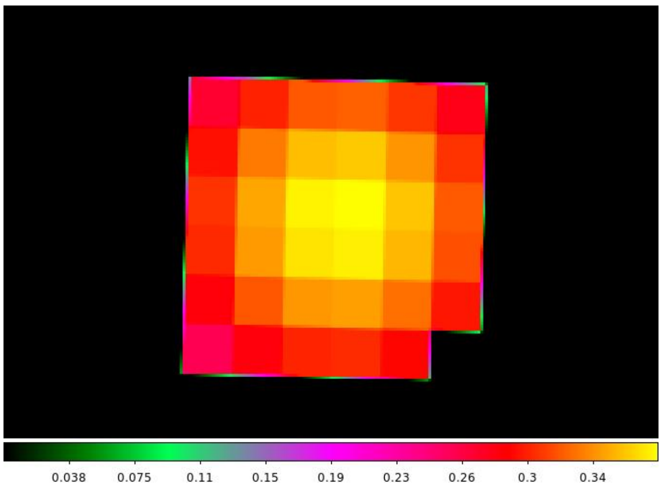


Figure 12: SXS flat field images for sequence 100050020.

(5) Construct RMF and ARF files to use with extended energy spectrum

First, identify the necessary keywords in the cleaned event file representing the maximum vaue of the PIE column, the offset value of the PIE column, and the grid width of PIE energy scale.

```
ftlist  ah100050020sxs_p0px1010_clext2.evt+1 K | grep PIE
TTYPE54 = 'EPIE    '           / EPI in extended energy range
TTYPE55 = 'PIE     '           / PI in extended energy range
TLMIN55 =                    0 / minimum legal value for PIE
PIEOFFST=                   1. / Energy offset (eV) of extended energy mode
PIEWIDTH=                   1. / Channel width (eV) of extended energy mode

ftlist ah100050020sxs_p0px1010_clext2.evt+1 K | grep TLMAX55
TLMAX55 =                32767

ftlist ah100050020sxs_p0px1010_clext2.evt+1 K | grep PIEOFFST
PIEOFFST=                   1. / Energy offset (eV) of extended energy mode

ftlist ah100050020sxs_p0px1010_clext2.evt+1 K | grep PIEWIDTH
PIEWIDTH=                   1. / Channel width (eV) of extended energy mode
```

Second, construct the RMF file for this energy grid, setting `nchanin=TLMAX55+1 dein=PIEWIDTH and eminin=PIEOFFST-PIEWIDTH` that, in this case, corresponds to the following command:

```
sxsmkrmf infile=ah100050020sxs_p0px1010_clext2.evt
outfile=ah100050020_sxs_clext2_HP_small.rmf resolist=0 regmode=det
regionfile=ah100050020sxs_region_SXS_det.reg whichrmf=s nchanin=32768 dein=1.0
eminin=0.0
```

Third, construct the ARF file for this energy grid, and an appropriate energy range for the arf. The correct energy range is assured by inputing the RMF file constructed above. The energy range for the ARF should span the full energy range (corresponding to a lower limit of `eminin` and an upper limit of `eminin+nchanin*dein`), possibly with some margin on either side, but not to exceed 0.5 keV on the low end and 30 keV on the high end. The command for this example is as follows.

```
aharfgen xrtevtfile=raytrace_ah100050020sxs_p0px1010_ext.fits
source_ra=278.3889 source_dec=-10.5691 telescop=HITOMI instrume=SXS
emapfile=ah100050020sxs_p0px1010.expo regmode=DET
regionfile=ah100050020sxs_region_SXS_det.reg sourcetype=POINT
rmffile=ah100050020_sxs_clext2_HP_small.rmf erange="0.5 30.0 0 0"
outfile=ah100050020sxs_p0px1010_rt_ext.arf numphoton=300000 minphoton=1
teldeffile=CALDB qefile=CALDB contamifile=CALDB obffile=CALDB fwfile=CALDB
gatevalvefile=CALDB onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB
obstructfile=CALDB frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB
scatterfile=CALDB auxtransfile=NONE seed=7 clobber=yes chatter=2 mode=h
logfile=make_arf_ah100050020sxs_p0px1010_ext.log
```

100050010, 100050020, 100050030, 100050040 COMBINED

HXI

cd /full/path/

cd data/products_hxi

(1) Merge the necessary files from each sequence

```
ftmerge
'../100050010/auxil/ah100050010.ehk.gz,../100050020/auxil/ah100050020.ehk.gz,..
/100050030/auxil/ah100050030.ehk.gz,../100050040/auxil/ah100050040.ehk.gz'
ah1000500ALL0.ehk
```

```
ftmerge
'../100050010/hxi/event_uf/ah100050010hx1.att.gz,../100050020/hxi/event_uf/ah10
0050020hx1.att.gz,../100050030/hxi/event_uf/ah100050030hx1.att.gz,../100050040/
hxi/event_uf/ah100050040hx1.att.gz' ah1000500ALL0hx1.att
```

```
ftmerge
'../100050010/hxi/event_uf/ah100050010hx2.att.gz,../100050020/hxi/event_uf/ah10
0050020hx2.att.gz,../100050030/hxi/event_uf/ah100050030hx2.att.gz,../100050040/
hxi/event_uf/ah100050040hx2.att.gz' ah1000500ALL0hx2.att
```

```
ftmerge
'../100050010/hxi/event_uf/ah100050010hx1_cms.fits.gz,../100050020/hxi/event_uf
/ah100050020hx1_cms.fits.gz,../100050030/hxi/event_uf/ah100050030hx1_cms.fits.g
z,../100050040/hxi/event_uf/ah100050040hx1_cms.fits.gz'
ah1000500ALL0hx1_cms.fits
```

```
ftmerge
'../100050010/hxi/event_uf/ah100050010hx2_cms.fits.gz,../100050020/hxi/event_uf
/ah100050020hx2_cms.fits.gz,../100050030/hxi/event_uf/ah100050030hx2_cms.fits.g
z,../100050040/hxi/event_uf/ah100050040hx2_cms.fits.gz'
ah1000500ALL0hx2_cms.fits
```

The merged event GTI created above are used here.

ah1000500ALL0hx1_p0camrec_cl.gti and ah1000500ALL0hx2_p0camrec_cl.gti

(2) Create an exposure map for the combined HXI

The exposure maps generated here are used in the two examples below to make both the RSP and flat field for the HXI. The exposure maps are created with the parameters delta=20.0, numphi=1 to assure that the map includes only a single attitude bin, i.e. assuming that the attitude is stable relative to the size of the PSF and extraction region.

HXI1

```
ahexpmap ehkfile=ah1000500ALL0.ehk gtifile=ah1000500ALL0hx1_p0camrec_cl.gti
instrume=HXI1 badimgfile=NONE pixgtifile=NONE
outfile=ah1000500ALL0hx1_p0camrec.expo outmaptype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=10.0 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah1000500all0hx1_p0camrec.log
```

HXI2

```
ahexpmap ehkfile=ah1000500ALL0.ehk gtifile=ah1000500ALL0hx2_p0camrec_cl.gti
instrume=HXI1 badimgfile=NONE pixgtifile=NONE
outfile=ah1000500ALL0hx2_p0camrec.expo outmaptype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=10.0 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah1000500all0hx2_p0camrec.log
```

(3) Create an RSP for the combined HXI

Make RSP for HXI1 and HXI2, sampling=120, point source at center of extraction region region_HXI_100050012340.reg. In general, the `source_ra` and `source_dec` parameters should be the coordinates of the center of the source in the image, which are not necessarily the same as the actual source coordinates. Here we use the center of the spectral extraction region.

HXI1

```
aharfgen xrtevtfile=raytrace_ah1000500ALL0hx1_p0camrec.fits source_ra=278.3889
source_dec=-10.5691 telescop=HITOMI instrume=HXI1
emapfile=ah1000500ALL0hx1_p0camrec.expo dattfile=ah1000500ALL0hx1.att
regmode=RADEC regionfile=../../regions/region_HXI_100050012340.reg sampling=120
sourcetype=point erange="4.0 80.0" outfile=ah1000500ALL0hx1_rt
filtoffsetfile=ah1000500ALL0hx1_cms.fits numphoton=10000 minphoton=1
teldeffile=CALDB qefile=CALDB rmffile=CALDB onaxisffile=CALDB onaxiscfile=CALDB
mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB pcolreffile=CALDB
scatterfile=CALDB auxtransfile=NONE clobber=yes chatter=2 mode=h seed=7
logfile=make_arf_ah1000500ALL0hx1_p0camrec.log
```

HXI2

```
aharfgen xrtevtfile=raytrace_ah1000500ALL0hx2_p0camrec.fits source_ra=278.3889
source_dec=-10.5691 telescop=HITOMI instrume=HXI2
emapfile=ah1000500ALL0hx2_p0camrec.expo dattfile=ah1000500ALL0hx2.att
regmode=RADEC regionfile=../../regions/region_HXI_100050012340.reg sampling=120
sourcetype=point erange="4.0 80.0" outfile=ah1000500ALL0hx2_rt
filtoffsetfile=ah1000500ALL0hx2_cms.fits numphoton=10000 minphoton=1
teldeffile=CALDB qefile=CALDB rmffile=CALDB onaxisffile=CALDB onaxiscfile=CALDB
mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB pcolreffile=CALDB
scatterfile=CALDB auxtransfile=NONE clobber=yes chatter=2 mode=h seed=7
logfile=make_arf_ah1000500ALL0hx2_p0camrec.log
```

(4) Create flat field efficiency images for each HXI

HXI1

```
hxirspeffimg telescop=HITOMI instrume=HXI1
emapfile=ah1000500ALL0hx1_p0camrec.expo
xrtevtfile=raytrace_ah1000500ALL0hx1_p0camrec.fits onaxisffile=CALDB
onaxiscfile=CALDB regionfile=NONE dattfile=ah1000500ALL0hx1.att stopsys=SKY
sampling=40 erange="4.0 80.0 10.0 50.0"
filtoffsetfile=ah1000500ALL0hx1_cms.fits
outflatfile=ah1000500ALL0hx1_flatfield.fits vigfile=CALDB outmaptype=EFFICIENCY
qefile=CALDB rmffile=CALDB chatter=2 mode=h
logfile=make_flat_ah1000500all0hx1_p0camrec.log
```

HXI2

```
hxirspeffimg telescop=HITOMI instrume=HXI2
emapfile=ah1000500ALL0hx2_p0camrec.expo
xrtevtfile=raytrace_ah1000500ALL0hx2_p0camrec.fits onaxisffile=CALDB
onaxiscfile=CALDB regionfile=NONE dattfile=ah1000500ALL0hx2.att stopsys=SKY
sampling=40 erange="4.0 80.0 10.0 50.0"
filtoffsetfile=ah1000500ALL0hx2_cms.fits
outflatfile=ah1000500ALL0hx2_flatfield.fits vigfile=CALDB outmaptype=EFFICIENCY
qefile=CALDB rmffile=CALDB chatter=2 mode=h
logfile=make_flat_ah1000500all0hx2_p0camrec.log
```

(5) Alternative: Combine individual HXI response files with addrmf

Instead of constructing single exposure maps and response files, these may be made individually for each sequence, as detailed above for individual sequence 100050020. The resulting response files are combined as follows, weighted by the fractional exposure times of the corresponding spectra:

HXI1

```
addrmf
ah100050010hx2_rt.rsp,ah100050020hx2_rt.rsp,ah100050030hx2_rt.rsp,ah100050040hx
2_rt.rsp 0.26432,0.32328,0.25112,0.16128 ah1000500ALL0hx2_rt.rsp
```

HXI2

```
addrmf
ah100050010hx2_rt.rsp,ah100050020hx2_rt.rsp,ah100050030hx2_rt.rsp,ah100050040hx
2_rt.rsp 0.26318,0.32775,0.24748,0.16158 ah1000500ALL0hx2_rt.rsp
```

The disadvantage of this approach is that is requires ~4 times the computing time for ARF generation.

SGD

All newly created output files in this section are placed in the /full/path/to/data/hxi_products directory

```
cd /full/path/
```

```
mkdir data/products_sgd
```

```
cd data/products_sgd
```

All newly created output files in this section are placed in the /full/path/to/data/sgd_products directory

Create the individual response files for each SGD1 Compton camera and each sequence, and co-add them with weights determined by the relative exposures for each sequence and each camera. To construct an on-axis response, directly co-add the CALDB response files used as input to the SGD arf generator. Here we use the center of the SXI spectral extraction region as the source coordinates

```
sgdarfgen infile=ah100050020sg1_p0ccALLrec_dtime.pi
rspfile="$CALDB/data/hitomi/sgd/cpf/response/ah_sg1_cc1_20140101v001.rsp,$CALDB
```

```
/data/hitomi/sgd/cpf/response/ah_sg1_cc2_20140101v001.rsp,$CALDB/data/hitomi/sg
d/cpf/response/ah_sg1_cc3_20140101v001.rsp" outfile=outrsp_100050020
ra=278.3889 dec=-10.5691 sgdid=1 ccid=0 clobber=yes

sgdarfgen infile=ah100050030sg1_p0ccALLrec_dtime.pi
rspfile="$CALDB/data/hitomi/sgd/cpf/response/ah_sg1_cc1_20140101v001.rsp,$CALDB
/data/hitomi/sgd/cpf/response/ah_sg1_cc2_20140101v001.rsp,$CALDB/data/hitomi/sg
d/cpf/response/ah_sg1_cc3_20140101v001.rsp" outfile=outrsp_100050030
ra=278.3889 dec=-10.5691 sgdid=1 ccid=0 clobber=yes

sgdarfgen infile=ah100050040sg1_p0ccALLrec_dtime.pi
rspfile="$CALDB/data/hitomi/sgd/cpf/response/ah_sg1_cc1_20140101v001.rsp,$CALDB
/data/hitomi/sgd/cpf/response/ah_sg1_cc2_20140101v001.rsp,$CALDB/data/hitomi/sg
d/cpf/response/ah_sg1_cc3_20140101v001.rsp" outfile=outrsp_100050040
ra=278.3889 dec=-10.5691 sgdid=1 ccid=0 clobber=yes
```

These may also be generated for one camera at a time by setting `ccid=1, ccid=2,` and `ccdid=3.`

```
addrmf
outrsp_100050040_sgd1_cc1.rsp,outrsp_100050040_sgd1_cc2.rsp,outrsp_100050040_sg
d1_cc3.rsp,outrsp_100050030_sgd1_cc2.rsp,outrsp_100050030_sgd1_cc3.rsp,outrsp_1
00050030_sgd1_cc1.rsp,outrsp_100050020_sgd1_cc1.rsp,outrsp_100050020_sgd1_cc2.r
sp,outrsp_100050020_sgd1_cc3.rsp
0.389665844,0.387071252,0.390678084,0.541304044,0.541909061,0.542572253,0.06885
5587,0.069821287,0.068122586 ah1000500ALL0sg1_ccALL_dtime_wtd.rsp
```

SXI

Note that because the cosmic ray echo effect varies between sequences over the course of the observation, a single bad image file cannot be used below. Instead, separate RMF and ARF files should be derived, as detailed above for sequence `100050020` and below for the remaining sequences. The spectra and responses should then be co-added, or individual spectra should be simultaneously fit.

```
cd /full/path/

cd data/products_sxi
```

(1) Create an RMF for each remaining sequence

Normal mode

```
sxirmf infile=ah100050010sxi_p0100004b0_cl.pi
outfile=ah100050010sxi_p0100004b0_cl.rmf clobber=yes mode=hl

sxirmf infile=ah100050030sxi_p0100004b0_cl.pi
outfile=ah100050030sxi_p0100004b0_cl.rmf clobber=yes mode=hl

sxirmf infile=ah100050040sxi_p0100004b0_cl.pi
outfile=ah100050040sxi_p0100004b0_cl.rmf clobber=yes mode=hl
```

MZDYE

```
sxirmf infile=ah100050010sxi_p0100004b1_cl.pi
outfile=ah100050010sxi_p0100004b1_cl.rmf clobber=yes mode=hl

sxirmf infile=ah100050030sxi_p0100004b1_cl.pi
outfile=ah100050030sxi_p0100004b1_cl.rmf clobber=yes mode=hl

sxirmf infile=ah100050040sxi_p0100004b1_cl.pi
outfile=ah100050040sxi_p0100004b1_cl.rmf clobber=yes mode=hl
```

(2) Create an exposure map for each remaining sequence

Normal mode

```
ahexpmap ehkfile=../100050010/auxil/ah100050010.ehk.gz
gtifile=../100050010/sxi/event_cl/ah100050010sxi_p0100004b0_cl.evt.gz
instrume=SXI
badimgfile=../100050010/sxi/event_uf/ah100050010sxi_p0100004b0.bimg.gz
pixgtifile=../100050010/sxi/event_uf/ah100050010sxi_a0100004b0.fpix.gz
outfile=ah100050010sxi_p0100004b0.expo outmaptype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100050010sxi_a0100004b0.log

ahexpmap ehkfile=../100050030/auxil/ah100050030.ehk.gz
gtifile=../100050030/sxi/event_cl/ah100050030sxi_p0100004b0_cl.evt.gz
instrume=SXI
badimgfile=../100050030/sxi/event_uf/ah100050030sxi_p0100004b0.bimg.gz
pixgtifile=../100050030/sxi/event_uf/ah100050030sxi_a0100004b0.fpix.gz
outfile=ah100050030sxi_p0100004b0.expo outmaptype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100050030sxi_a0100004b0.log

ahexpmap ehkfile=../100050040/auxil/ah100050040.ehk.gz
gtifile=../100050040/sxi/event_cl/ah100050040sxi_p0100004b0_cl.evt.gz
instrume=SXI
badimgfile=../100050040/sxi/event_uf/ah100050040sxi_p0100004b0.bimg.gz
pixgtifile=../100050040/sxi/event_uf/ah100050040sxi_a0100004b0.fpix.gz
outfile=ah100050040sxi_p0100004b0.expo outmaptype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100050040sxi_a0100004b0.log
```

MZDYE

```
ahexpmap ehkfile=../100050010/auxil/ah100050010.ehk.gz
gtifile=../100050010/sxi/event_cl/ah100050010sxi_p0100004b1_cl.evt.gz
instrume=SXI
badimgfile=../100050010/sxi/event_uf/ah100050010sxi_p0100004b1.bimg.gz
pixgtifile=../100050010/sxi/event_uf/ah100050010sxi_a0100004b1.fpix.gz
outfile=ah100050010sxi_p0100004b1.expo outmaptype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100050010sxi_a0100004b1.log

ahexpmap ehkfile=../100050030/auxil/ah100050030.ehk.gz
gtifile=../100050030/sxi/event_cl/ah100050030sxi_p0100004b1_cl.evt.gz
instrume=SXI
badimgfile=../100050030/sxi/event_uf/ah100050030sxi_p0100004b1.bimg.gz
pixgtifile=../100050030/sxi/event_uf/ah100050030sxi_a0100004b1.fpix.gz
outfile=ah100050030sxi_p0100004b1.expo outmaptype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
```

```
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100050030sxi_a0100004b1.log

ahexpmap ehkfile=../100050040/auxil/ah100050040.ehk.gz
gtifile=../100050040/sxi/event_cl/ah100050040sxi_p0100004b1_cl.evt.gz
instrume=SXI
badimgfile=../100050040/sxi/event_uf/ah100050040sxi_p0100004b1.bimg.gz
pixgtifile=../100050040/sxi/event_uf/ah100050040sxi_a0100004b1.fpix.gz
outfile=ah100050040sxi_p0100004b1.expo outmaptype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100050040sxi_a0100004b1.log
```

(3) Create an ARF for each remaining sequence

Here we use the center of the spectral extraction region as the source coordinates.

Normal mode

```
aharfgen xrtevtfile=raytrace_ah100050010sxi_p0100004b0_ptsrc_evt.fits
source_ra=278.3889 source_dec=-10.5691 telescop=HITOMI instrume=SXI
emapfile=ah100050010sxi_p0100004b0.expo regmode=RADEC
regionfile=../../regions/region_SXI_100050012340.reg sourcetype=POINT
rmffile=ah100050010sxi_p0100004b0_cl.rmf erange="0.5 16.0 0 0"
outfile=ah100050010sxi_p0100004b0_rt.arf numphoton=300000 minphoton=1
teldeffile=CALDB qefile=CALDB contamifile=CALDB onaxisffile=CALDB
onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB
backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB auxtransfile=NONE seed=7
clobber=yes chatter=2 mode=h logfile=make_arf_ah100050010sxi_p0100004b0.log

aharfgen xrtevtfile=raytrace_ah100050030sxi_p0100004b0_ptsrc_evt.fits
source_ra=278.3889 source_dec=-10.5691 telescop=HITOMI instrume=SXI
emapfile=ah100050030sxi_p0100004b0.expo regmode=RADEC
regionfile=../../regions/region_SXI_100050012340.reg sourcetype=POINT
rmffile=ah100050030sxi_p0100004b0_cl.rmf erange="0.5 16.0 0 0"
outfile=ah100050030sxi_p0100004b0_rt.arf numphoton=300000 minphoton=1
teldeffile=CALDB qefile=CALDB contamifile=CALDB onaxisffile=CALDB
onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB
backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB auxtransfile=NONE seed=7
clobber=yes chatter=2 mode=h logfile=make_arf_ah100050030sxi_p0100004b0.log

aharfgen xrtevtfile=raytrace_ah100050040sxi_p0100004b0_ptsrc_evt.fits
source_ra=278.3889 source_dec=-10.5691 telescop=HITOMI instrume=SXI
emapfile=ah100050040sxi_p0100004b0.expo regmode=RADEC
regionfile=../../regions/region_SXI_100050012340.reg sourcetype=POINT
rmffile=ah100050040sxi_p0100004b0_cl.rmf erange="0.5 16.0 0 0"
outfile=ah100050040sxi_p0100004b0_rt.arf numphoton=300000 minphoton=1
teldeffile=CALDB qefile=CALDB contamifile=CALDB onaxisffile=CALDB
onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB
backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB auxtransfile=NONE seed=7
clobber=yes chatter=2 mode=h logfile=make_arf_ah100050040sxi_p0100004b0.log
```

MZDYE

```
aharfgen xrtevtfile=raytrace_ah100050010sxi_p0100004b1_ptsrc_evt.fits
source_ra=278.3889 source_dec=-10.5691 telescop=HITOMI instrume=SXI
emapfile=ah100050010sxi_p0100004b1.expo regmode=RADEC
regionfile=../../regions/region_SXI_100050012340.reg sourcetype=POINT
rmffile=ah100050010sxi_p0100004b1_cl.rmf erange="0.5 16.0 0 0"
outfile=ah100050010sxi_p0100004b1_rt.arf numphoton=300000 minphoton=1
teldeffile=CALDB qefile=CALDB contamifile=CALDB onaxisffile=CALDB
```

```
onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB
backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB auxtransfile=NONE seed=7
clobber=yes chatter=2 mode=h logfile=make_arf_ah100050010sxi_p0100004b1.log

aharfgen xrtevtfile=raytrace_ah100050030sxi_p0100004b1_ptsrc_evt.fits
source_ra=278.3889 source_dec=-10.5691 telescop=HITOMI instrume=SXI
emapfile=ah100050030sxi_p0100004b1.expo regmode=RADEC
regionfile=../../regions/region_SXI_100050012340.reg sourcetype=POINT
rmffile=ah100050030sxi_p0100004b1_cl.rmf erange="0.5 16.0 0 0"
outfile=ah100050030sxi_p0100004b1_rt.arf numphoton=300000 minphoton=1
teldeffile=CALDB qefile=CALDB contamifile=CALDB onaxisffile=CALDB
onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB
backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB auxtransfile=NONE seed=7
clobber=yes chatter=2 mode=h logfile=make_arf_ah100050030sxi_p0100004b1.log

aharfgen xrtevtfile=raytrace_ah100050040sxi_p0100004b1_ptsrc_evt.fits
source_ra=278.3889 source_dec=-10.5691 telescop=HITOMI instrume=SXI
emapfile=ah100050040sxi_p0100004b1.expo regmode=RADEC
regionfile=../../regions/region_SXI_100050012340.reg sourcetype=POINT
rmffile=ah100050040sxi_p0100004b1_cl.rmf erange="0.5 16.0 0 0"
outfile=ah100050040sxi_p0100004b1_rt.arf numphoton=300000 minphoton=1
teldeffile=CALDB qefile=CALDB contamifile=CALDB onaxisffile=CALDB
onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB
backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB auxtransfile=NONE seed=7
clobber=yes chatter=2 mode=h logfile=make_arf_ah100050040sxi_p0100004b1.log
```

(4) Correct the BACKSCAL keyword in the SXI spectra for each remaining sequence

Xselect writes a BACKSCAL keyword in the header of extracted spectra to properly scale the background subtraction in XSPEC. However, it only accounts for the fraction of the area covered by the extraction region, not the number of good pixels. Many pixels in SXI data are affected by cosmic-ray echo or light leak and need to be properly excluded from BACKSCAL. The example shown above for 100050020 should be done for all of the 'Normal' and 'MZDYE' source and background spectra:

Normal mode

```
ahbackscal infile=ah100050010sxi_p0100004b0_cl.pi
regfile=../../regions/region_SXI_100050012340.reg expfile=
ah100050010sxi_p0100004b0_cl.expo norm=MAX

ahbackscal infile=ah100050010sxi_p0100004b0_cl_bkg.pi
regfile=../../regions/region_SXI_100050012340_bkg.reg expfile=
ah100050010sxi_p0100004b0_cl.expo norm=MAX

ahbackscal infile=ah100050030sxi_p0100004b0_cl.pi
regfile=../../regions/region_SXI_100050012340.reg expfile=
ah100050030sxi_p0100004b0_cl.expo norm=MAX

ahbackscal infile=ah100050030sxi_p0100004b0_cl_bkg.pi
regfile=../../regions/region_SXI_100050012340_bkg.reg expfile=
ah100050030sxi_p0100004b0_cl.expo norm=MAX

ahbackscal infile=ah100050040sxi_p0100004b0_cl.pi
regfile=../../regions/region_SXI_100050012340.reg expfile=
ah100050040sxi_p0100004b0_cl.expo norm=MAX

ahbackscal infile=ah100050040sxi_p0100004b0_cl_bkg.pi
regfile=../../regions/region_SXI_100050012340_bkg.reg expfile=
ah100050040sxi_p0100004b0_cl.expo norm=MAX
```

MZDYE

```
ahbackscal infile=ah100050010sxi_p0100004b1_cl.pi
regfile=../../regions/region_SXI_100050012340.reg expfile=
ah100050010sxi_p0100004b1_cl.expo norm=MAX

ahbackscal infile=ah100050030sxi_p0100004b1_cl.pi
regfile=../../regions/region_SXI_100050012340.reg expfile=
ah100050030sxi_p0100004b1_cl.expo norm=MAX

ahbackscal infile=ah100050040sxi_p0100004b1_cl.pi
regfile=../../regions/region_SXI_100050012340.reg expfile=
ah100050040sxi_p0100004b1_cl.expo norm=MAX
```

(5) Combine SXI spectra and responses

The ftool *addascaspec* should be used to combine the source spectra, background spectra, and responses. Normal mode and MZDYE should be combined separately.

Normal mode

```
addascaspec addascaspec_normal.in ah1000500ALL0sxi_p0100004b0_cl.pi
ah1000500ALL0sxi_p0100004b0_cl.rsp ah1000500ALL0sxi_p0100004b0_cl_bkg.pi
"POISS-0"
```

where the file 'addascaspec_normal.in' contains the following four lines (delineated by '\'):

```
ah100050010sxi_p0100004b0_cl.pi ah100050020sxi_p0100004b0_cl.pi
ah100050030sxi_p0100004b0_cl.pi ah100050040sxi_p0100004b0_cl.pi \
ah100050010sxi_p0100004b0_cl_bkg.pi ah100050020sxi_p0100004b0_cl_bkg.pi
ah100050030sxi_p0100004b0_cl_bkg.pi ah100050040sxi_p0100004b0_cl_bkg.pi \
ah100050010sxi_p0100004b0_rt.arf ah100050020sxi_p0100004b0_rt.arf
ah100050030sxi_p0100004b0_rt.arf ah100050040sxi_p0100004b0_rt.arf \
ah100050010sxi_p0100004b0_cl.rmf ah100050020sxi_p0100004b0_cl.rmf
ah100050030sxi_p0100004b0_cl.rmf ah100050040sxi_p0100004b0_cl.rmf
```

This will create a combined source spectrum, combined background spectrum, and a single .rsp file containing both the combined RMF and ARF.

MZDYE

```
addascaspec addascaspec_mzdye.in ah1000500ALL0sxi_p0100004b1_cl.pi
ah1000500ALL0sxi_p0100004b1_cl.rsp ah1000500ALL0sxi_p0100004b1_cl_bkg.pi
"POISS-0"
```

where the file 'addascaspec_mzdye.in' contains the following four lines:

```
ah100050010sxi_p0100004b1_cl.pi ah100050020sxi_p0100004b1_cl.pi
ah100050030sxi_p0100004b1_cl.pi ah100050040sxi_p0100004b1_cl.pi \
ah100050010sxi_p0100004b0_cl_bkg.pi ah100050020sxi_p0100004b0_cl_bkg.pi
ah100050030sxi_p0100004b0_cl_bkg.pi ah100050040sxi_p0100004b0_cl_bkg.pi \
ah100050010sxi_p0100004b1_rt.arf ah100050020sxi_p0100004b1_rt.arf
ah100050030sxi_p0100004b1_rt.arf ah100050040sxi_p0100004b1_rt.arf \
ah100050010sxi_p0100004b1_cl.rmf ah100050020sxi_p0100004b1_cl.rmf
ah100050030sxi_p0100004b1_cl.rmf ah100050040sxi_p0100004b1_cl.rmf
```

This will create a combined source spectrum, combined background spectrum, and a single .rsp file containing both the combined RMF and ARF. Note the 'Normal' mode background spectra are used here for the 'MZDYE' data because the event threshold in the off-source segments is set very high (about 12 keV) during that mode.

(6) Extract NXB spectrum

Extract the combined events. This will only be used for the GTI extension as input to sxinxbgen.

```
xselect
xsel:SUZAKU > read events ah100050010sxi_p0100004b0_cl.evt
xsel:HITOMI-SXI-WINDOW1 > read events ah100050020sxi_p0100004b0_cl.evt
xsel:HITOMI-SXI-WINDOW1 > read events ah100050030sxi_p0100004b0_cl.evt
xsel:HITOMI-SXI-WINDOW1 > read events ah100050040sxi_p0100004b0_cl.evt
xsel:HITOMI-SXI-WINDOW1 > extract events
xsel:HITOMI-SXI-WINDOW1 > save events ah1000500ALL0sxi_p0100004b0_cl.evt
```

If not already done, merge the ehk files.

```
ftmerge
'../../100050010/auxil/ah100050010.ehk.gz,../../100050020/auxil/ah100050020.ehk
.gz,../../100050030/auxil/ah100050030.ehk.gz,../../100050040/auxil/ah100050040.
ehk.gz' ah1000500ALL0.ehk
```

Run sxinxbgen to extract the NXB spectrum, using the same region files as used above for a single sequence:

```
punlearn sxinxbgen
sxinxbgen infile=ah1000500ALL0sxi_p0100004b0_cl.evt ehkfile=ah1000500ALL0.ehk
regfile=sxi_nxb_det.reg regfile2=region_SXI_100050012340_det.reg regmode=DET
innxbfile=ah_sxi_nxb100cl_20140101v001.evt
innxbehk=ah_gen_nxbehk_20140101v002.fits
innxbhk=${CALDB}/data/hitomi/sxi/bcf/backgrnd/ah_sxi_nxbhk_20140101v001.fits
outpifile=ah1000500ALL0sxi_p0100004b0_cl_nxb.pi outnxbfile=NONE sortcol=COR3
sortbin=0,4,5,6,7,8,9,10,11,12,13,99 apply_sxipi=no clobber=yes mode=hl
```

The individual exposure maps should be combined to create a single one for input to ahbackscal:

```
farith ah100050010sxi_p0100004b0_cl.expo ah100050020sxi_p0100004b0_cl.expo
farith_tmp1.expo ADD clobber=yes
farith ah100050030sxi_p0100004b0_cl.expo farith_tmp1.expo farith_tmp2.expo ADD
clobber=yes
farith ah100050040sxi_p0100004b0_cl.expo farith_tmp2.expo
ah1000500ALL0sxi_p0100004b0_cl.expo ADD clobber=yes

ahbackscal infile=ah1000500ALL0sxi_p0100004b0_cl_nxb.pi
regfile=sxi_nxb_radec.reg expfile=ah1000500ALL0sxi_p0100004b0_cl.expo norm=MAX
clobber=yes mode=hl
```

SXS

```
cd /full/path/

cd data/products_sxs
```

(1) Generate small and x-large RMF for the combined event file

The all-pixels detector region constructed above is used here.

```
sxsmkrmf infile=ah1000500ALL0sxs_p0px1010_cl2.evt
outfile=ah1000500ALL0_sxs_cl2_HP_small.rmf resolist=0 regmode=det
regionfile=ah100050020sxs_region_SXS_det.reg whichrmf=s
```

```
sxsmkrmf infile=ah1000500ALL0sxs_p0px1010_cl2.evt
outfile=ah1000500ALL0_sxs_cl2_HP_xlarge.rmf resolist=0 regmode=det
regionfile=ah100050020sxs_region_SXS_det.reg whichrmf=x
```

(2) Create or merge the necessary files from each sequence

(a) Merge the ehk files

```
ftmerge
'../100050010/auxil/ah100050010.ehk.gz,../100050020/auxil/ah100050020.ehk.gz,..
/100050030/auxil/ah100050030.ehk.gz,../100050040/auxil/ah100050040.ehk.gz'
ah1000500ALL0.ehk
```

(b) Merge the pixgti file GTIPIXELOFF extensions

```
ftmerge
'../100050010/sxs/event_uf/ah100050010sxs_px1010_exp.gti.gz+2,../100050020/sxs/
event_uf/ah100050020sxs_px1010_exp.gti.gz+2,../100050030/sxs/event_uf/ah1000500
30sxs_px1010_exp.gti.gz+2,../100050040/sxs/event_uf/ah100050040sxs_px1010_exp.g
ti.gz+2' ah1000500ALL0sxs_px1010_exp.gti
```

(3) Create the SXS exposure map for the combined SXS

The exposure maps created with sxsregext are replaced using the parameters `delta=20.0`, `numphi=1` to assure that map includes only a single attitude bin. This accounts for the fact that the attitude is evidently stable stable relative to the size of the PSF and extraction region. We also account for the lost event gti per pixel here setting `pixgtifile=ah1000500ALL0sxs_px1010_exp.gti` – this should be done if the lost event gti are not used in the screening (as in the standard pipeline).

```
ahexpmap ehkfile=ah1000500ALL0.ehk gtifile=ah1000500ALL0sxs_p0px1010_cl2.evt
instrume=SXS badimgfile=NONE pixgtifile=ah1000500ALL0sxs_px1010_exp.gti
outfile=ah1000500ALL0sxs_p0px1010.expo outmaptype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah1000500ALL0sxs_p0px1010.log
```

(4) Create an ARF for the combined SXS

```
aharfgen xrtevtfile=raytrace_ah1000500ALL0sxs_p0px1010.fits source_ra=278.3889
source_dec=-10.5691 telescop=HITOMI instrume=SXS
emapfile=ah1000500ALL0sxs_p0px1010.expo regmode=DET
regionfile=ah100050020sxs_region_SXS_det.reg sourcetype=POINT
rmffile=ah1000500ALL0_sxs_cl2_HP_small.rmf erange="0.5 17.0 0 0"
outfile=ah1000500ALL0sxs_p0px1010_rt.arf numphoton=300000 minphoton=1
teldeffile=CALDB qefile=CALDB contamifile=CALDB obffile=CALDB fwfile=CALDB
gatevalvefile=CALDB onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB
obstructfile=CALDB frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB
scatterfile=CALDB auxtransfile=NONE seed=7 clobber=yes chatter=2 mode=h
logfile=make_arf_ah1000500ALL0sxs_p0px1010.log
```

Note that the `source_ra` and `source_dec` are taken from the region file region_SXI_100050012340.reg, i.e. an estimate of the source coordinates based on the SXI image. The region file used is the one in DET coordinates previously created by sxsregext.

(5) Alternative: Combine SXS source spectra and responses using addascaspec

Instead of extracting spectra from the combined event file spectra and constructing single RMF and ARF files, these may be created for each sequence following the steps detailed above for individual sequence 100050020 and then combined using *addascaspec* as follows:

Normal mode

```
addascaspec addascaspec_sxs.in ah1000500ALL0sxs_p0px1010_cl2_HP.pi
ah1000500ALL0_sxs_cl2_HP_small.rsp
```

where the file 'addascaspec_sxs.in' contains the following four lines (delineated by '\'):

```
ah100050010sxs_p0px1010_cl2.pi ah100050020sxs_p0px1010_cl2.pi
ah100050030sxs_p0px1010_cl2.pi ah100050040sxs_p0px1010_cl2.pi \
ah100050010sxs_p0px1010_rt.arf ah100050020sxs_p0px1010_rt.arf
ah100050030sxs_p0px1010_rt.arf ah100050040sxs_p0px1010_rt.arf \
ah100050010_sxs_cl2_small.rmf ah100050020_sxs_cl2_small.rmf
ah100050030_sxs_cl2_small.rmf ah100050040_sxs_cl2_small.rmf
```

This will create a combined source spectrum, combined background spectrum, and a single .rsp file containing both the combined RMF and ARF.

Spectral Fittting

Notes

The following XSPEC settings are used below.

For fitting;
- abund wilm
- xsect vern
- statistic cstat
- model tbabs*pegpwrlw; NH and slope tied, normalization untied, in simultaneous fits

For plotting:

setplot rebin 10 20 (HXI, SGD, SXI)
setplot rebin 20 40 (SXS)

Note that the spectra and response files co-added for all sequences are used below; however, identical procedures apply to individual sequences.

HXI

(1) Jointly fit the HXI1 and HXI2 background-subtracted deadtime-corrected spectra in the 5-80 keV band with a broken power-law model, with absorption fixed at 3.0 x 10^{22} cm^{-2} using using the RSP files created in the previous section.

```
2 files 2 spectra
Spectrum 1  Spectral Data File: ah100050012340_hxi1_dtime.pi
Net count rate (cts/s) for Spectrum:1  1.419e+00 +/- 4.130e-03 (93.1 % total)
 Assigned to Data Group 1 and Plot Group 1
  Noticed Channels:  51-799
  Telescope: HITOMI Instrument: HXI1  Channel Type: PI
  Exposure Time: 9.395e+04 sec
```

```
 Using fit statistic: cstat
 Using test statistic: chi
 Using Background File                ah100050012340_hxi1_dtime_bkg.pi
  Background Exposure Time: 9.395e+04 sec
 Using Response (RMF) File            ah100050012340_hxi1.rsp for Source 1

 Spectral data counts: 143233
 Model predicted rate: 1.42066

Spectrum 2  Spectral Data File: ah100050012340_hxi2_dtime.pi
Net count rate (cts/s) for Spectrum:2  1.439e+00 +/- 4.141e-03 (93.4 % total)
 Assigned to Data Group 2 and Plot Group 2
  Noticed Channels:  51-799
  Telescope: HITOMI Instrument: HXI2  Channel Type: PI
  Exposure Time: 9.42e+04 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Background File                ah100050012340_hxi2_dtime_bkg.pi
  Background Exposure Time: 9.42e+04 sec
 Using Response (RMF) File            ah100050012340_hxi2.rsp for Source 1

 Spectral data counts: 145108
 Model predicted rate: 1.44116


Current model list:

========================================================================
Model TBabs<1>*pegpwrlw<2> Source No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
                           Data group: 1
   1    1   TBabs      nH         10^22    3.00000      frozen
   2    2   pegpwrlw   PhoIndex            2.12734      +/-  4.86125E-03
   3    2   pegpwrlw   eMin       keV      2.00000      frozen
   4    2   pegpwrlw   eMax       keV      8.00000      frozen
   5    2   pegpwrlw   norm                68.7683      +/-  0.346011
                           Data group: 2
   6    1   TBabs      nH         10^22    3.00000      = p1
   7    2   pegpwrlw   PhoIndex            2.12734      = p2
   8    2   pegpwrlw   eMin       keV      2.00000      = p3
   9    2   pegpwrlw   eMax       keV      8.00000      = p4
  10    2   pegpwrlw   norm                69.0786      +/-  0.346753
________________________________________________________________________

   Using energies from responses.

Fit statistic : C-Statistic =        1711.38 using 1498 PHA bins and 1495 degrees of
freedom.

Test statistic : Chi-Squared =        1778.13 using 1498 PHA bins.
 Reduced chi-squared =       1.18938 for   1495 degrees of freedom
 Null hypothesis probability =   4.917872e-07
 Weighting method: standard
```

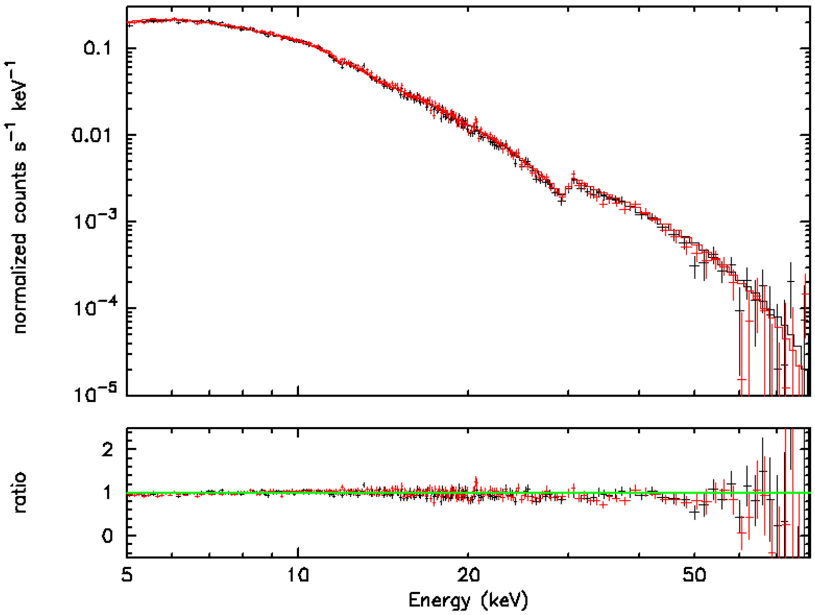


Figure 13: Joint fits to HXI1 (black) and HXI2 (red) spectra for combined G21.5-0.9 sequences 100050010, 100050020, 100050030, 100050040 – without (left) and with (right) local background subtraction. The 2-8 keV unabsorbed fluxes are ~6.9 x 10^{-11} erg cm^{-2} s^{-1} in the best-fit models – lower than in Nynka et al. 2014 (ApJ, 789, 72) and Tsujimoto et al. 2011 (A&A, 525, 25).

SGD

(1) Compare the deadtime-corrected and the deadtime-uncorrected SGD1 spectra (summed over all relevant sequences and all Comption cameras) with the estimated CALDB NXB spectrum `$CALDB/data/hitomi/sgd/cpf/background/ah_sgd_nxb_20140101v001.pha`.

```
3 files 3 spectra
Spectrum 1  Spectral Data File:
/caldb/data/hitomi/sgd/cpf/background/ah_sgd_nxb_20140101v001.pha
Net count rate (cts/s) for Spectrum:1  7.661e-01 +/- 1.153e-03
 Assigned to Data Group 1 and Plot Group 1
  Noticed Channels:  42-2048
  Telescope: HITOMI Instrument: SGD  Channel Type: PI
  Exposure Time: 5.763e+05 sec
 Using fit statistic: chi
 Using test statistic: chi
 Using Response (RMF) File            ah10005002340sg1_ccALL_dtime.rsp for
Source 1

 Spectral data counts: 441486
 Model predicted rate: 0.0

Spectrum 2  Spectral Data File: ah1000500ALL0sg1_p0ccALLrec_cl.pi
Net count rate (cts/s) for Spectrum:2  2.379e+00 +/- 5.821e-03
 Assigned to Data Group 2 and Plot Group 2
  Noticed Channels:  42-2048
  Telescope: HITOMI Instrument: SGD1  Channel Type: PI
  Exposure Time: 7.019e+04 sec
 Using fit statistic: chi
 Using test statistic: chi
 Using Response (RMF) File            ah10005002340sg1_ccALL_dtime.rsp for
Source 1
```

```
 Spectral data counts: 166959
 Model predicted rate: 0.0

Spectrum 3  Spectral Data File: ah10005002340sg1_p0ccALLrec_dtime.pi
Net count rate (cts/s) for Spectrum:3  3.885e+00 +/- 9.508e-03
 Assigned to Data Group 3 and Plot Group 3
  Noticed Channels:  42-2048
  Telescope: HITOMI Instrument: SGD1  Channel Type: PI
  Exposure Time: 4.297e+04 sec
 Using fit statistic: chi
 Using test statistic: chi
 Using Response (RMF) File            ah10005002340sg1_ccALL_dtime.rsp for
Source 1

 Spectral data counts: 166959
 Model predicted rate: 0.0
```

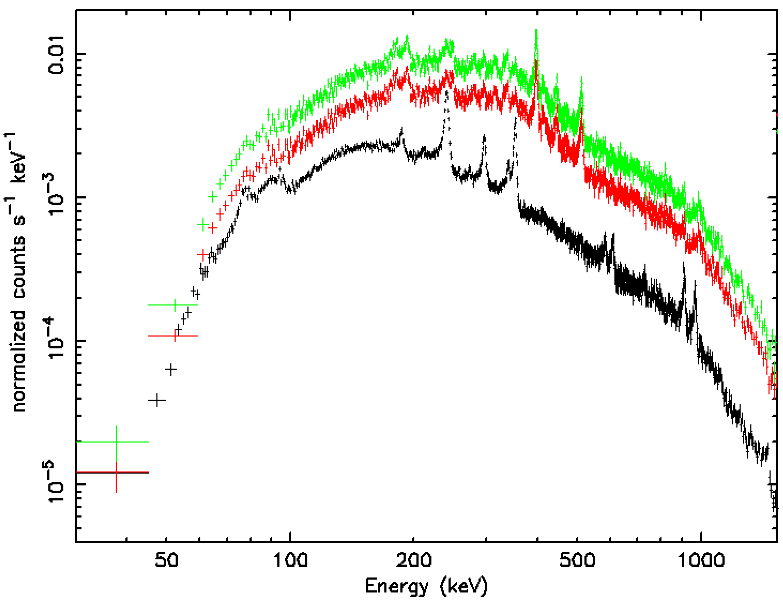


Figure 14: Comparison of NXB file in CALDB (black) with deadtime-corrected (green) and deaditme-uncorrected (red) spectra from combined G21.5-0.9 sequences 100050010, 100050020, 100050030, 100050040 .

SXI

(1) Jointly fit the SXI normal and MZDYE background-subtracted spectra in the 0.8-16 keV band with a power-law model, with absorption free, using the RSP files created in the previous section:

```
2 files 2 spectra
Spectrum 1  Spectral Data File: ah100050012340_sxi.pi
Net count rate (cts/s) for Spectrum:1  3.031e+00 +/- 7.760e-03 (98.5 % total)
 Assigned to Data Group 1 and Plot Group 1
  Noticed Channels:  135-2666
  Telescope: HITOMI Instrument: SXI  Channel Type: PI
  Exposure Time: 5.112e+04 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Background File                ah100050012340_sxi_bkg.pi
  Background Exposure Time: 5.112e+04 sec
 Using Response (RMF) File            ah100050012340_sxi.rsp for Source 1
```

```
 Spectral data counts: 157278
 Model predicted rate: 3.03094

Spectrum 2  Spectral Data File: ah100050012340_sximze.pi
Net count rate (cts/s) for Spectrum:2  1.558e+00 +/- 7.136e-03 (99.2 % total)
 Assigned to Data Group 2 and Plot Group 2
  Noticed Channels:  135-2666
  Telescope: HITOMI Instrument: SXI  Channel Type: PI
  Exposure Time: 3.086e+04 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Background File                ah100050012340_sximze_bkg.pi
  Background Exposure Time: 5.112e+04 sec
 Using Response (RMF) File            ah100050012340_sximze.rsp for Source 1

 Spectral data counts: 48482
 Model predicted rate: 1.55897


Current model list:

========================================================================
Model TBabs<1>*pegpwrlw<2> Source No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
                           Data group: 1
   1    1   TBabs      nH         10^22    3.15784      +/-  1.81579E-02
   2    2   pegpwrlw   PhoIndex            1.90314      +/-  7.16960E-03
   3    2   pegpwrlw   eMin       keV      2.00000      frozen
   4    2   pegpwrlw   eMax       keV      8.00000      frozen
   5    2   pegpwrlw   norm                55.9734      +/-  0.185181
                           Data group: 2
   6    1   TBabs      nH         10^22    3.15784      = p1
   7    2   pegpwrlw   PhoIndex            1.90314      = p2
   8    2   pegpwrlw   eMin       keV      2.00000      = p3
   9    2   pegpwrlw   eMax       keV      8.00000      = p4
  10    2   pegpwrlw   norm                52.1693      +/-  0.261837
________________________________________________________________________

   Using energies from responses.

Fit statistic : C-Statistic =        5499.99 using 5064 PHA bins and 5060
degrees of freedom.

Test statistic : Chi-Squared =       518037.2 using 5064 PHA bins.
 Reduced chi-squared =       102.3789 for   5060 degrees of freedom
 Null hypothesis probability =   0.000000e+00
 Weighting method: standard
```

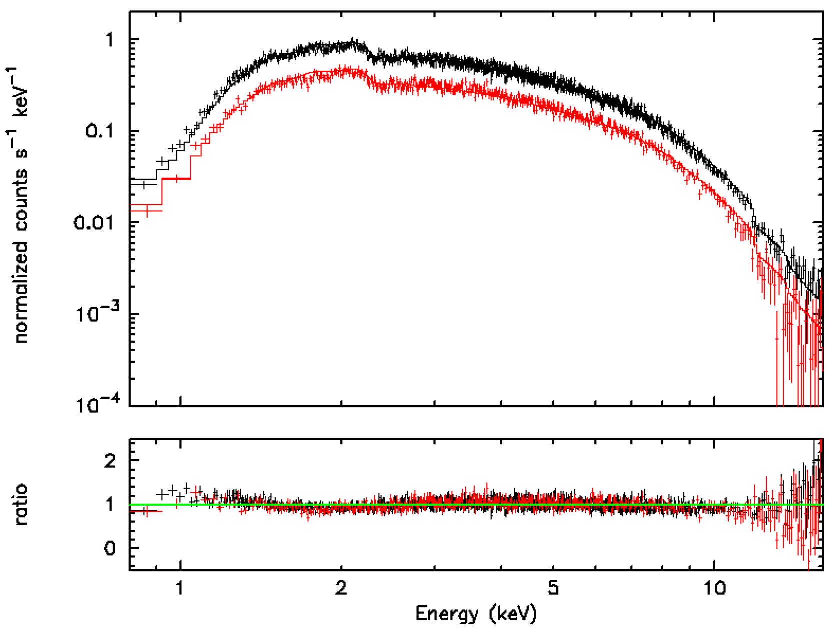


Figure 15: Joint fits to SXI Normal mode (black) and MZDYE (red) spectra for combined G21.5-0.9 sequences 100050010, 100050020, 100050030, 100050040. The 2-8 keV unabsorbed fluxes are 5.5 (5.2) x 10^{-11} erg cm^{-2} s^{-1} in the best-fit models to the normal (MZDYE) spectra.

SXS

(1) Fit the SXS spectrum in the 0.6-16 keV band with a power-law model, with absorption fixed at 3.0 x 10^{22} cm^{-2} using the x-large RMF file and the ARF file created in the previous section

```
1 file 1 spectrum
Spectrum 1  Spectral Data File: ah100050012340sxs_p0px1010_cl2.pi
Net count rate (cts/s) for Spectrum:1  7.829e-01 +/- 2.180e-03
 Assigned to Data Group 1 and Plot Group 1
  Noticed Channels:  1201-31999
  Telescope: HITOMI Instrument: SXS  Channel Type: PI
  Exposure Time: 1.647e+05 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Response (RMF) File            ah100050012340sxs_p0px1010_cl2_xlarge.rmf
for Source 1
 Using Auxiliary Response (ARF) File  ah100050012340sxs_p0px1010_rt.arf

 Spectral data counts: 128917
 Model predicted rate: 0.782719


Current model list:

========================================================================
Model TBabs<1>*pegpwrlw<2> Source No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
   1    1   TBabs      nH         10^22    3.00000      frozen
   2    2   pegpwrlw   PhoIndex            1.93418      +/-  7.52946E-03
   3    2   pegpwrlw   eMin       keV      2.00000      frozen
   4    2   pegpwrlw   eMax       keV      8.00000      frozen
   5    2   pegpwrlw   norm                60.5339      +/-  0.204274
________________________________________________________________________
```

```
   Using energies from responses.

Fit statistic : C-Statistic =       30490.89 using 30799 PHA bins and 30797
degrees of freedom.

Test statistic : Chi-Squared =       26992.98 using 30799 PHA bins.
 Reduced chi-squared =      0.8764810 for  30797 degrees of freedom
 Null hypothesis probability =   1.000000e+00

***Warning: Chi-square may not be valid due to bins with zero variance
            in spectrum number(s): 1

 Weighting method: standard
```

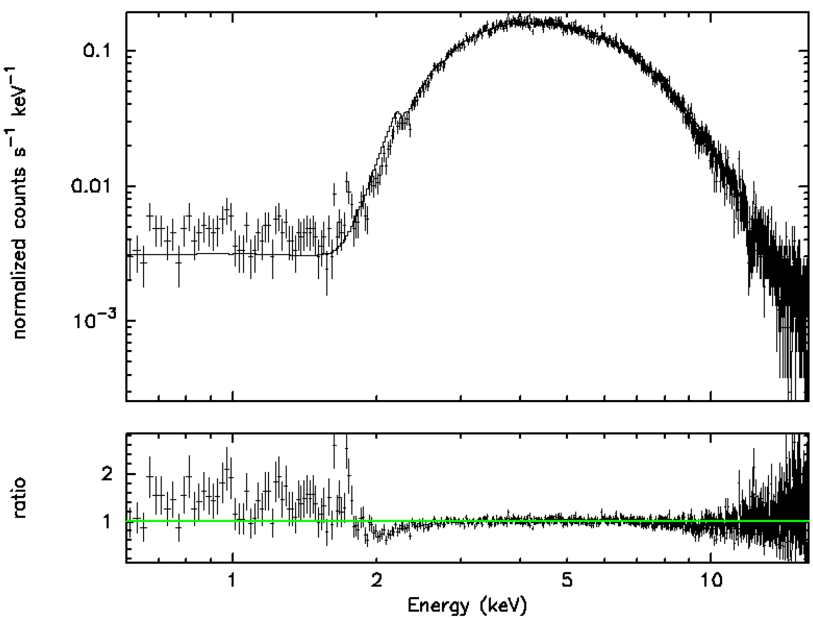


Figure 16: Fit to SXS spectra for combined G21.5-0.9 sequences 100050010, 100050020, 100050030, 100050040 sequence in the 0.6-12 keV band using the extra-large RMF file. The 2-8 keV unabsorbed flux is ~6.0 x 10^{-11} erg cm^{-2} s^{-1} in the best-fit model.

(2) Simultaneously fit the total SXS and SXS NXB spectra in the 0.6-16 keV band with a power-law model with free absorption for the source spectra and a power-law model plus 4 gaussian representing. The gaussian line energies are set to the mean energies of MnKα, MnKβ, AuLα1, and AuLβ1 and, except for MnKα, their widths are set to very small values. The MnKβ-to-MnKα ratio is fixed at 6. The slope of the NXB power-law is fixed at the best fit to the NXB-only spectrum. An ARF generated from a Chandra image is applied to the source spectrum, but is not applied to the NXB spectrum.

```
2 files 2 spectra
Spectrum 1  Spectral Data File: ah100050012340sxs_p0px1010_cl2.pi.gz
Net count rate (cts/s) for Spectrum:1  7.829e-01 +/- 2.180e-03
 Assigned to Data Group 1 and Plot Group 1
  Noticed Channels:  1200-32000
  Telescope: HITOMI Instrument: SXS  Channel Type: PI
  Exposure Time: 1.647e+05 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Response (RMF) File
ah100050012340sxs_p0px1010_cl2_xlarge.rmf.gz for Source 1
 Using Auxiliary Response (ARF) File
```

```
ah100050012340sxs_p0px1010_rt_image.arf.gz
 Using Response (RMF) File
ah100050012340sxs_p0px1010_cl2_xlarge.rmf.gz for Source 2

 Spectral data counts: 128917
 Model predicted rate: 0.782722

Spectrum 2  Spectral Data File: ah100050012340sxsnxb_cl2.pi
Net count rate (cts/s) for Spectrum:2  1.218e-02 +/- 2.482e-04
 Assigned to Data Group 2 and Plot Group 2
  Noticed Channels:  1200-32000
  Telescope: HITOMI Instrument: SXS  Channel Type: PI
  Exposure Time: 3.315e+05 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Response (RMF) File
ah100050012340sxs_p0px1010_cl2_xlarge.rmf.gz for Source 1
 Using Response (RMF) File
ah100050012340sxs_p0px1010_cl2_xlarge.rmf.gz for Source 2

 Spectral data counts: 4038.66
 Model predicted rate: 1.22664E-02


Current model list:

========================================================================
Model constant<1>*TBabs<2>*pegpwrlw<3> Source No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
                           Data group: 1
   1    1   constant   factor              1.17000      frozen
   2    2   TBabs      nH         10^22    3.18850      +/-  8.87512E-02
   3    3   pegpwrlw   PhoIndex            2.12463      +/-  1.40297E-02
   4    3   pegpwrlw   eMin       keV      2.00000      frozen
   5    3   pegpwrlw   eMax       keV      8.00000      frozen
   6    3   pegpwrlw   norm                69.4103      +/-  0.625485
                           Data group: 2
   7    1   constant   factor              0.0          frozen
   8    2   TBabs      nH         10^22    3.18850      = p2
   9    3   pegpwrlw   PhoIndex            2.12463      = p3
  10    3   pegpwrlw   eMin       keV      2.00000      = p4
  11    3   pegpwrlw   eMax       keV      8.00000      = p5
  12    3   pegpwrlw   norm                69.4103      = p6
________________________________________________________________________


========================================================================
Model nxb:(gaussian<1>*constant<2> + gaussian<3>*constant<4>)constant<5> +
gaussian<6> + gaussian<7> + powerlaw<8> Source No.: 2   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
                           Data group: 1
   1    1   gaussian   LineE      keV      5.89440      frozen
   2    1   gaussian   Sigma      keV      8.68819E-03  +/-  1.00594E-03
   3    1   gaussian   norm                0.352300     frozen
   4    2   constant   factor              5.83771E-04  frozen
   5    3   gaussian   LineE      keV      6.48638      frozen
   6    3   gaussian   Sigma      keV      1.00000E-06  frozen
   7    3   gaussian   norm                0.254000     frozen
   8    4   constant   factor              1.00040E-04  frozen
   9    5   constant   factor              1.16974      +/-  0.138043
  10    6   gaussian   LineE      keV      9.71300      frozen
  11    6   gaussian   Sigma      keV      1.00000E-06  frozen
  12    6   gaussian   norm                8.66114E-05  +/-  1.59990E-05
```

```
  13    7   gaussian   LineE      keV      11.4420      frozen
  14    7   gaussian   Sigma      keV      1.00000E-06  frozen
  15    7   gaussian   norm                1.07664E-04  frozen
  16    8   powerlaw   PhoIndex            0.149002     frozen
  17    8   powerlaw   norm                1.02830E-03  +/-  1.62379E-05
                           Data group: 2
  18    1   gaussian   LineE      keV      5.89440      = nxb:p1
  19    1   gaussian   Sigma      keV      8.68819E-03  = nxb:p2
  20    1   gaussian   norm                0.352300     = nxb:p3
  21    2   constant   factor              5.83771E-04  = nxb:p4
  22    3   gaussian   LineE      keV      6.48638      = nxb:p5
  23    3   gaussian   Sigma      keV      1.00000E-06  = nxb:p6
  24    3   gaussian   norm                0.254000     = nxb:p7
  25    4   constant   factor              1.00040E-04  = nxb:p8
  26    5   constant   factor              1.16974      = nxb:p9
  27    6   gaussian   LineE      keV      9.71300      = nxb:p10
  28    6   gaussian   Sigma      keV      1.00000E-06  = nxb:p11
  29    6   gaussian   norm                8.66114E-05  = nxb:p12
  30    7   gaussian   LineE      keV      11.4420      = nxb:p13
  31    7   gaussian   Sigma      keV      1.00000E-06  = nxb:p14
  32    7   gaussian   norm                1.07664E-04  = nxb:p15
  33    8   powerlaw   PhoIndex            0.149002     = nxb:p16
  34    8   powerlaw   norm                1.02830E-03  = nxb:p17
________________________________________________________________________

   Using energies from responses.

Fit statistic : C-Statistic =       48450.04 using 61602 PHA bins and 61595
degrees of freedom.

Warning: cstat statistic is only valid for Poisson data.
    Source file is not Poisson


Test statistic : Chi-Squared =       29222.32 using 61602 PHA bins.
 Reduced chi-squared =      0.4744268 for  61595 degrees of freedom
 Null hypothesis probability =   1.000000e+00

***Warning: Chi-square may not be valid due to bins with zero variance
            in spectrum number(s): 1 2

 Weighting method: standard
```

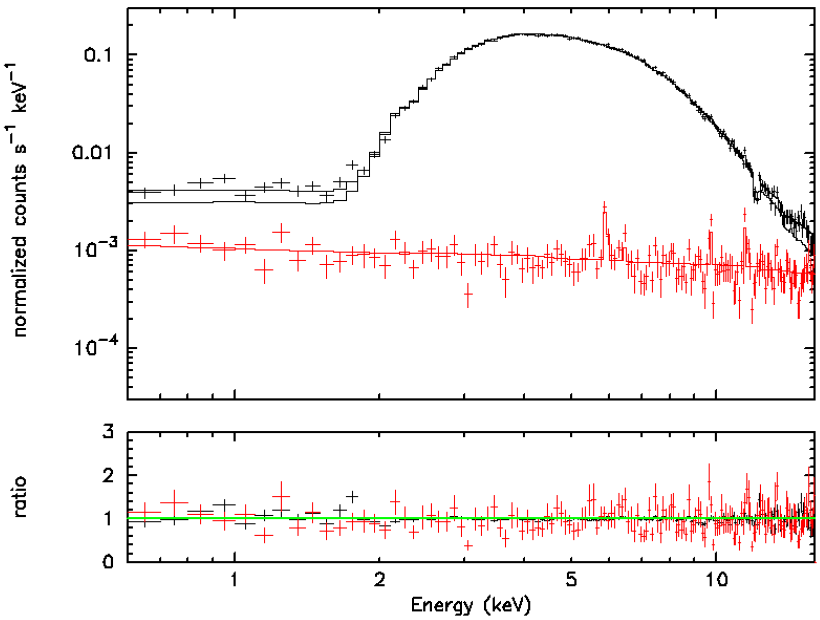


Figure 17: Simultaneous fit to SXS source and NXB spectra for combined G21.5-0.9 sequences 100050010, 100050020, 100050030, 100050040 sequence in the 0.6-12 keV band using the extra-large RMF file, an ARF derived from a Chandra image, and and NXB spectrum derived using `sxsnxbgen`. The 2-8 keV unabsorbed flux is ~6.9 x 10^{-11} erg cm^{-2} s^{-1} in the best-fit model.

JOINT FITS

(1) Jointly fit the background subtracted HXI1, HXI2 spectra in the 5-80 keV band, the background subtracted SXI normal and MZDYE spectra in the 0.8-16 keV band, and the SXS spectrum in the 0.6-16 keV band with a power-law model with index and absorption free and tied among detectors. The xlarge-sized matrix is used for the SXS.

```
 5 files 5 spectra
Spectrum 1  Spectral Data File: ah100050012340sxs_p0px1010_cl2.pi
Net count rate (cts/s) for Spectrum:1  7.829e-01 +/- 2.180e-03
 Assigned to Data Group 1 and Plot Group 1
  Noticed Channels:  1201-31999
  Telescope: HITOMI Instrument: SXS  Channel Type: PI
  Exposure Time: 1.647e+05 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Response (RMF) File            ah100050023450sxs_p0px1010_cl2_xlarge.rmf
for Source 1
 Using Auxiliary Response (ARF) File  ah100050012340sxs_p0px1010_rt.arf

 Spectral data counts: 128917
 Model predicted rate: 0.782712

Spectrum 2  Spectral Data File: ah100050012340_sxi.pi
Net count rate (cts/s) for Spectrum:2  3.031e+00 +/- 7.760e-03 (98.5 % total)
 Assigned to Data Group 2 and Plot Group 2
  Noticed Channels:  135-2666
  Telescope: HITOMI Instrument: SXI  Channel Type: PI
  Exposure Time: 5.112e+04 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Background File                ah100050012340_sxi_bkg.pi
```

```
  Background Exposure Time: 5.112e+04 sec
 Using Response (RMF) File            ah100050012340_sxi.rsp for Source 1

 Spectral data counts: 157278
 Model predicted rate: 3.02848

Spectrum 3  Spectral Data File: ah100050012340_sximze.pi
Net count rate (cts/s) for Spectrum:3  1.558e+00 +/- 7.136e-03 (99.2 % total)
 Assigned to Data Group 3 and Plot Group 3
  Noticed Channels:  135-2666
  Telescope: HITOMI Instrument: SXI  Channel Type: PI
  Exposure Time: 3.086e+04 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Background File                ah100050012340_sximze_bkg.pi
  Background Exposure Time: 5.112e+04 sec
 Using Response (RMF) File            ah100050012340_sximze.rsp for Source 1

 Spectral data counts: 48482
 Model predicted rate: 1.55830

Spectrum 4  Spectral Data File: ah100050012340_hxi1_dtime.pi
Net count rate (cts/s) for Spectrum:4  1.419e+00 +/- 4.130e-03 (93.1 % total)
 Assigned to Data Group 4 and Plot Group 4
  Noticed Channels:  51-799
  Telescope: HITOMI Instrument: HXI1  Channel Type: PI
  Exposure Time: 9.395e+04 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Background File                ah100050012340_hxi1_dtime_bkg.pi
  Background Exposure Time: 9.395e+04 sec
 Using Response (RMF) File            ah100050012340_hxi1.rsp for Source 1

 Spectral data counts: 143233
 Model predicted rate: 1.42286

Spectrum 5  Spectral Data File: ah100050012340_hxi2_dtime.pi
Net count rate (cts/s) for Spectrum:5  1.439e+00 +/- 4.141e-03 (93.4 % total)
 Assigned to Data Group 5 and Plot Group 5
  Noticed Channels:  51-799
  Telescope: HITOMI Instrument: HXI2  Channel Type: PI
  Exposure Time: 9.42e+04 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Background File                ah100050012340_hxi2_dtime_bkg.pi
  Background Exposure Time: 9.42e+04 sec
 Using Response (RMF) File            ah100050012340_hxi2.rsp for Source 1

 Spectral data counts: 145108
 Model predicted rate: 1.44362

========================================================================
Model TBabs<1>*pegpwrlw<2> Source No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
                           Data group: 1
   1    1   TBabs      nH         10^22    3.49145      +/-  1.36956E-02
   2    2   pegpwrlw   PhoIndex            2.04958      +/-  3.72238E-03
   3    2   pegpwrlw   eMin       keV      2.00000      frozen
   4    2   pegpwrlw   eMax       keV      8.00000      frozen
   5    2   pegpwrlw   norm                63.7387      +/-  0.198194
                           Data group: 2
   6    1   TBabs      nH         10^22    3.49145      = p1
   7    2   pegpwrlw   PhoIndex            2.04958      = p2
   8    2   pegpwrlw   eMin       keV      2.00000      = p3
```

```
   9     2    pegpwrlw   eMax        keV      8.00000       = p4
  10     2    pegpwrlw   norm                 57.7129       +/-  0.184235
                                 Data group: 3
  11     1    TBabs      nH          10^22    3.49145       = p1
  12     2    pegpwrlw   PhoIndex             2.04958       = p2
  13     2    pegpwrlw   eMin        keV      2.00000       = p3
  14     2    pegpwrlw   eMax        keV      8.00000       = p4
  15     2    pegpwrlw   norm                 53.8139       +/-  0.265982
                                 Data group: 4
  16     1    TBabs      nH          10^22    3.49145       = p1
  17     2    pegpwrlw   PhoIndex             2.04958       = p2
  18     2    pegpwrlw   eMin        keV      2.00000       = p3
  19     2    pegpwrlw   eMax        keV      8.00000       = p4
  20     2    pegpwrlw   norm                 64.6206       +/-  0.278622
                                 Data group: 5
  21     1    TBabs      nH          10^22    3.49145       = p1
  22     2    pegpwrlw   PhoIndex             2.04958       = p2
  23     2    pegpwrlw   eMin        keV      2.00000       = p3
  24     2    pegpwrlw   eMax        keV      8.00000       = p4
  25     2    pegpwrlw   norm                 64.9320       +/-  0.278753
______________________________________________________________________

   Using energies from responses.

Fit statistic : C-Statistic =       38450.02 using 37361 PHA bins and 37354
degrees of freedom.

Test statistic : Chi-Squared =       446507.7 using 37361 PHA bins.
 Reduced chi-squared =       11.95341 for  37354 degrees of freedom
 Null hypothesis probability =   0.000000e+00

***Warning: Chi-square may not be valid due to bins with zero variance
            in spectrum number(s): 1

 Weighting method: standard
```

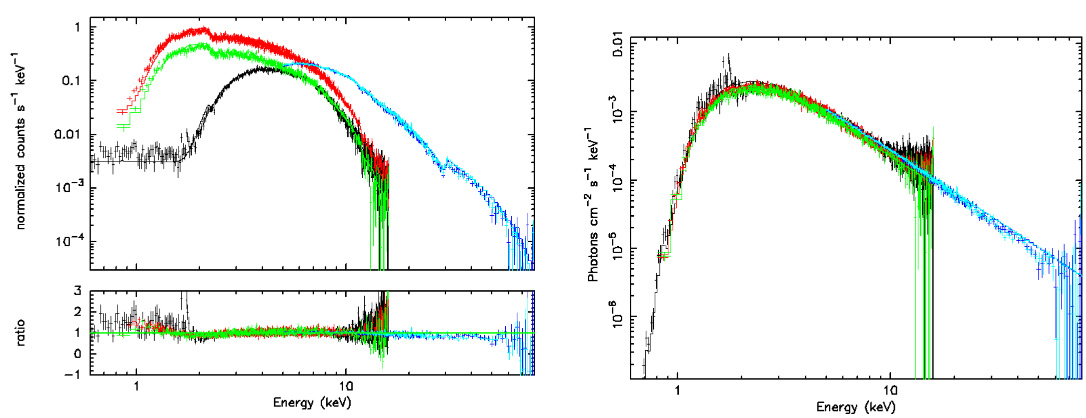


Figure 18: LEFT: Joint fit to HXI1 5-80 keV (blue), HXI2 5-80 keV (light blue), SXI 0.8-12 keV Normal (red) and MZDYE (green), and SXS 0.6-12 keV (black) spectra for combined G21.5-0.9 sequences 100050010, 100050020, 100050030, 100050040 -- best-fit absorbed power-law with data-to-model ratio (left). RIGHT: Unfolded spectrum. Local background is subtracted for the HXI and SXI, and the xlarge SXS rmf is used. The 2-8 keV unabsorbed fluxes are ~6.5, 6.5, 5.8, 5.4, and 6.4x 10^{-11} erg cm^{-2} s^{-1} in the best-fit model for HXI1, HXI2, SXI Normal, SXI MZDYE, and SXS, respectively.

(2) Jointly fit the background subtracted HXI1, HXI2 spectra in the 5-80 keV band, the background subtracted SXI normal and MZDYE spectra in the 0.8-16 keV band, and the SXS spectrum in the

0.6-16 keV band with a broken power-law model with indices, break energy, and absorption free and tied among detectors. The xlarge-sized matrix is used for the SXS.

```
========================================================================
Model TBabs<1>*bknpower<2>   Source No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
                           Data group: 1
   1    1   TBabs      nH         10^22    2.83897      +/-  2.53772E-02
   2    2   bknpower   PhoIndx1            1.66373      +/-  1.59723E-02
   3    2   bknpower   BreakE     keV      4.50178      +/-  5.92772E-02
   4    2   bknpower   PhoIndx2            2.10731      +/-  4.43503E-03
   5    2   bknpower   norm                1.76264E-02  +/-  3.79172E-04
                           Data group: 2
   6    1   TBabs      nH         10^22    2.83897      = p1
   7    2   bknpower   PhoIndx1            1.66373      = p2
   8    2   bknpower   BreakE     keV      4.50178      = p3
   9    2   bknpower   PhoIndx2            2.10731      = p4
  10    2   bknpower   norm                1.63610E-02  +/-  3.40302E-04
                           Data group: 3
  11    1   TBabs      nH         10^22    2.83897      = p1
  12    2   bknpower   PhoIndx1            1.66373      = p2
  13    2   bknpower   BreakE     keV      4.50178      = p3
  14    2   bknpower   PhoIndx2            2.10731      = p4
  15    2   bknpower   norm                1.52524E-02  +/-  3.22562E-04
                           Data group: 4
  16    1   TBabs      nH         10^22    2.83897      = p1
  17    2   bknpower   PhoIndx1            1.66373      = p2
  18    2   bknpower   BreakE     keV      4.50178      = p3
  19    2   bknpower   PhoIndx2            2.10731      = p4
  20    2   bknpower   norm                1.80776E-02  +/-  3.88002E-04
                           Data group: 5
  21    1   TBabs      nH         10^22    2.83897      = p1
  22    2   bknpower   PhoIndx1            1.66373      = p2
  23    2   bknpower   BreakE     keV      4.50178      = p3
  24    2   bknpower   PhoIndx2            2.10731      = p4
  25    2   bknpower   norm                1.81603E-02  +/-  3.89731E-04
________________________________________________________________________


Fit statistic : C-Statistic =       37400.57 using 37361 PHA bins and 37352
degrees of freedom.

Test statistic : Chi-Squared =       447508.0 using 37361 PHA bins.
 Reduced chi-squared =       11.98083 for  37352 degrees of freedom
 Null hypothesis probability =   0.000000e+00

***Warning: Chi-square may not be valid due to bins with zero variance
            in spectrum number(s): 1
```

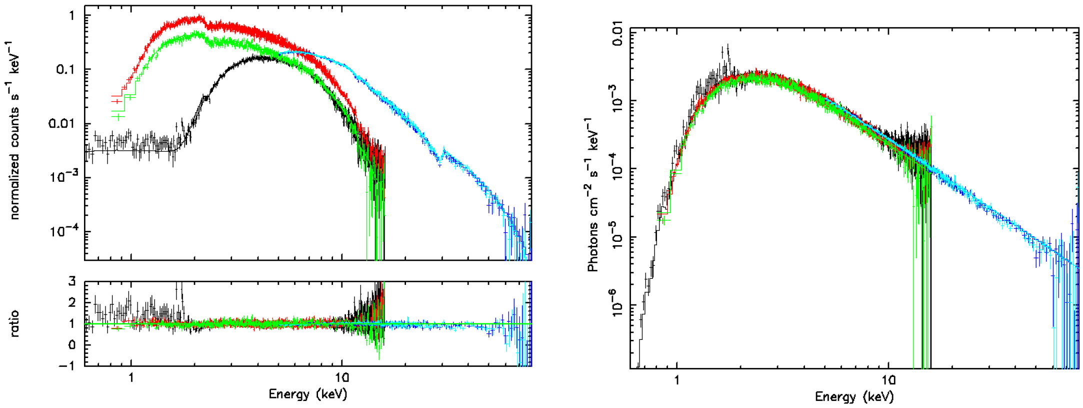


Figure 19: LEFT: Joint fit to HXI1 5-80 keV (blue), HXI2 5-80 keV (light blue), SXI 0.8-12 keV Normal (red) and MZDYE (green) and SXS 0.6-12 keV (black) spectra for combined G21.5-0.9 sequences 100050010, 100050020, 100050030, 100050040 -- best-fit absorbed broken power-law with data-to-model ratio (left). RIGHT: Unfolded spectrum. Local background is subtracted for the HXI and SXI, and the xlarge SXS rmf is used. The 2-8 keV unabsorbed fluxes are ~6.1, 6.1, 6.4, 5.5, 5.1, and 5.9x 10^{-11} erg cm^{-2} s^{-1} in the best-fit model for HXI1, HXI2, SXI Normal, SXI MZDYE, and SXS, respectively.

Perseus Cluster

Data description

Table 4a	**100040010**	**100040020**
GEN-HK	ah100040010gen_a0.hk1.gz	ah100040020gen_a0.hk1.gz
TIM	ah100040010.tim.gz	ah100040020.tim.gz
ATTITUDE	ah100040010.att.gz	ah100040020.att.gz
ORBIT	ah100040010.orb.gz	ah100040020.orb.gz
OBSGTI	ah100040010_gen.gti.gz	ah100040020_gen.gti.gz
MKF	ah100040010.mkf.gz	ah100040020.mkf.gz
EHK	ah100040010.ehk.gz	ah100040020.ehk.gz
EHK2	ah100040010.ehk2.gz	ah100040020.ehk2.gz
SXS HK	ah100040010sxs_a0.hk1.gz	ah100040020sxs_a0.hk1.gz
SXS ADR	ahsxs_adr.gti.gz	ahsxs_adr.gti.gz
SXS AC EVT	ah100040010sxs_a0ac_uf.evt.gz	ah100040020sxs_a0ac_uf.evt.gz
SXS PIX12 GAIN	ah100040010sxs_010_px12.ghf.gz	ah100040020sxs_010_px12.ghf.gz
SXS PIX12 EVT	ah100040010sxs_a0px12010_uf.evt.gz	ah100040020sxs_a0px12010_uf.evt.gz
SXS EL GTI	ah100040010sxs_el.gti.gz	ah100040020sxs_el.gti.gz
SXS TEL	ah100040010sxs_tel.gti.gz	ah100040020sxs_tel.gti.gz
SXS PIX GTI	ah100040010sxs_p0px1010.gti.gz	ah100040020sxs_p0px1010.gti.gz
SXS PIX EXP	ah100040010sxs_p0px1010_exp.gti.gz	ah100040020sxs_p0px1010_exp.gti.gz
SXS PIX UF	ah100040010sxs_p0px1010_uf.evt.gz	ah100040020sxs_p0px1010_uf.evt.gz
SXS PIX CL	ah100040010sxs_p0px1010_cl.evt.gz	ah100040020sxs_p0px1010_cl.evt.gz

Table 4b	**100040030**	**100040040**
GEN-HK	ah100040030gen_a0.hk1.gz	ah100040040gen_a0.hk1.gz
TIM	ah100040030.tim.gz	ah100040040.tim.gz
ATTITUDE	ah100040030.att.gz	ah100040040.att.gz
ORBIT	ah100040030.orb.gz	ah100040040.orb.gz
OBSGTI	ah100040030_gen.gti.gz	ah100040040_gen.gti.gz
MKF	ah100040030.mkf.gz	ah100040040.mkf.gz
EHK	ah100040030.ehk.gz	ah100040040.ehk.gz
EHK2	ah100040030.ehk2.gz	ah100040040.ehk2.gz
SXS HK	ah100040030sxs_a0.hk1.gz	ah100040040sxs_a0.hk1.gz
SXS ADR	ahsxs_adr.gti.gz	ahsxs_adr.gti.gz

SXS AC EVT	ah100040030sxs_a0ac_uf.evt.gz	ah100040040sxs_a0ac_uf.evt.gz
SXS PIX12 GAIN	ah100040030sxs_010_px12.ghf.gz	ah100040040sxs_010_px12.ghf.gz
SXS PIX12 EVT	ah100040030sxs_a0px12010_uf.evt.gz	ah100040040sxs_a0px12010_uf.evt.gz
SXS EL GTI	ah100040030sxs_el.gti.gz	ah100040040sxs_el.gti.gz
SXS TEL	ah100040030sxs_tel.gti.gz	ah100040040sxs_tel.gti.gz
SXS PIX GTI	ah100040030sxs_p0px1010.gti.gz	ah100040040sxs_p0px1010.gti.gz
SXS PIX EXP	ah100040030sxs_p0px1010_exp.gti.gz	ah100040040sxs_p0px1010_exp.gti.gz
SXS PIX UF	ah100040030sxs_p0px1010_uf.evt.gz	ah100040040sxs_p0px1010_uf.evt.gz
SXS PIX CL	ah100040030sxs_p0px1010_cl.evt.gz	ah100040040sxs_p0px1010_cl.evt.gz

Table 4c	**100040050**	**100040060**
GEN-HK	ah100040050gen_a0.hk1.gz	ah100040060gen_a0.hk1.gz
TIM	ah100040050.tim.gz	ah100040060.tim.gz
ATTITUDE	ah100040050.att.gz	ah100040060.att.gz
ORBIT	ah100040050.orb.gz	ah100040060.orb.gz
OBSGTI	ah100040050_gen.gti.gz	ah100040060_gen.gti.gz
MKF	ah100040050.mkf.gz	ah100040060.mkf.gz
EHK	ah100040050.ehk.gz	ah100040060.ehk.gz
EHK2	ah100040050.ehk2.gz	ah100040060.ehk2.gz
SXS HK	ah100040050sxs_a0.hk1.gz	ah100040060sxs_a0.hk1.gz
SXS ADR	ahsxs_adr.gti.gz	ahsxs_adr.gti.gz
SXS AC EVT	ah100040050sxs_a0ac_uf.evt.gz	ah100040060sxs_a0ac_uf.evt.gz
SXS PIX12 GAIN	ah100040050sxs_010_px12.ghf.gz	ah100040060sxs_010_px12.ghf.gz
SXS PIX12 EVT	ah100040050sxs_a0px12010_uf.evt.gz	ah100040060sxs_a0px12010_uf.evt.gz
SXS EL GTI	ah100040050sxs_el.gti.gz	ah100040060sxs_el.gti.gz
SXS TEL	ah100040050sxs_tel.gti.gz	ah100040060sxs_tel.gti.gz
SXS PIX GTI	ah100040050sxs_p0px1010.gti.gz	ah100040060sxs_p0px1010.gti.gz
SXS PIX EXP	ah100040050sxs_p0px1010_exp.gti.gz	ah100040060sxs_p0px1010_exp.gti.gz
SXS PIX UF	ah100040050sxs_p0px1010_uf.evt.gz	ah100040060sxs_p0px1010_uf.evt.gz
SXS PIX CL	ah100040050sxs_p0px1010_cl.evt.gz	ah100040060sxs_p0px1010_cl.evt.gz
SXI HK		ah100040060sxi_a0.hk.gz
SXI EVT UF		ah100040060sxi_p110000360_uf.evt.gz ah100040060sxi_p210000360_uf.evt.gz ah100040060sxi_p310000360_uf.evt.gz ah100040060sxi_p410000360_uf.evt.gz ah100040060sxi_p510000360_uf.evt.gz
SXI HOTPIX		ah100040060sxi_a010000360.hpix.gz
SXI FLICKPIX		ah100040060sxi_a110000360.fpix.gz ah100040060sxi_a210000360.fpix.gz ah100040060sxi_a310000360.fpix.gz ah100040060sxi_a410000360.fpix.gz ah100040060sxi_a510000360.fpix.gz
SXI BAD PIXEL IMG		ah100040060sxi_p110000360.bimg.gz ah100040060sxi_p210000360.bimg.gz ah100040060sxi_p310000360.bimg.gz ah100040060sxi_p410000360.bimg.gz ah100040060sxi_p510000360.bimg.gz
SXI TEL		ah100040060sxi_tel.gti.gz
SXI EVT CL		ah100040060sxi_p110000360_cl.evt.gz ah100040060sxi_p210000360_cl.evt.gz ah100040060sxi_p310000360_cl.evt.gz ah100040060sxi_p410000360_cl.evt.gz ah100040060sxi_p510000360_cl.evt.gz

Additional Files

Additional text files for analysis are as follows, and are shown in detail as they are used.

- standard extraction region files (place in dir `/full/path/to/regions`), XMM image, lists of SXI files to input into addascaspec
    - perseus_offset_sky.reg
    - perseus_center_sky.reg
    - adapt-400-7200_subimage1.fits

- addascaspec.in

Note on sequences.

There are three Perseus distinct pointings represented among the six sequences; the nucleus is outside of the SXS FoV for `100040010`, near the center of the SXS array for `100040060`, and offset from the center (but still on the array) for `100040020, 100040030, 100040040,` and `100040050`. A special energy assignment procedure is applied to the `100040010` and `100040020`, sequences only. Only `100040060` includes SXI data; none of the sequences have HXI or SGD data.

Non-Instrument Specific Processing

ahcalctime

100040030

(1) Recalculate time for HK and unfiltered event files

For illustrative purposes the task is run may be run without time-sorting, which reduces the runtime by a factor of ~10 for files where time becomes out-of-order after re-assignment. In actual applications, set `sorttime=yes,` as downstream tasks expect event files to be sorted in time.

```
ahcalctime indir=data/100040030 outdir=data/100040030_ahcalctime_output
verify_input=no sorttime=yes timecol=TIME clobber=yes

mkdir data/100040030_ahcalctime_output/logs
mv *log data/100040030_ahcalctime_output/logs
```

ahpipeline

100040060

(1) Recalibrate and rescreen data for all instruments using ahpipeline

```
ahpipeline indir=data/100040060 outdir=data/100040060_repro_all
steminputs=ah100040060 stemoutputs=DEFAULT entry_stage=1 exit_stage=2
instrument=ALL verify_input=no create_ehkmkf=yes seed=7 clobber=yes chatter=2
mode=hl

mkdir data/100040060_repro_all/logs
mv *log data/100040060_repro_all/logs
```

Instrument Specific Reprocessing

100040030

SXS

(1) Recalibrate/rescreen using ahpipeline

New files ehk and mkf files are created and applied.

```
ahpipeline indir=data/100040030 outdir=data/100040030_repro_sxs
steminputs=ah100040030 stemoutputs=DEFAULT entry_stage=1 exit_stage=2
instrum=SXS verify_input=no create_ehkmkf=yes seed=7 clobber=yes chatter=2
mode=hl

mkdir data/100040030_repro_sxs/logs
mv *log data/100040030_repro_sxs/logs
```

(2) Recalibrate/rescreen using sxspipeline

Original ehk and mkf files are applied.

```
sxspipeline indir=data/100040030 outdir=data/100040030_repro2_sxs
steminputs=ah100040030 stemoutputs=ah100040030 entry_stage=1 exit_stage=2
attitude=data/100040030/auxil/ah100040030.att.gz
orbit=data/100040030/auxil/ah100040030.orb.gz
obsgti=data/100040030/auxil/ah100040030_gen.gti.gz
housekeeping=data/100040030/sxs/hk/ah100040030sxs_a0.hk1.gz
timfile=data/100040030/auxil/ah100040030.tim.gz
extended_housekeeping=data/100040030/auxil/ah100040030.ehk.gz
makefilter=data/100040030/auxil/ah100040030.mkf.gz seed=7 clobber=yes chatter=2
mode=hl

mkdir data/100040030_repro2_sxs/logs
mv *log data/100040030_repro2_sxs/logs
```

(3) Filtering the events for times when the STT2 Star Tracker is controlling the attitude

The following procedure, while not strictly speaking reprocessing, results in a new cleaned event file filtered on times when the STT2 Star Tracker is controlling the attitude and the pointing is expected to be more accurate. Note that this can result in a significant loss of exposure time and number of counts.

First, remove TNULL rows from the relevant extension in the general HK file.

```
ftcopy infile="data/100040030/auxil/ah100040030gen_a0.hk.gz[HK_ACPA_HK_NOM][col
*][ACPA_CONT_MODE<255]" clobber=yes copyall=no outfile=hk_1.fits.tmp

ftcopy
infile="data/100040030/auxil/ah100040030gen_a0.hk.gz[HK_ACPA_AOCS_HK_NM_CHECKOU
T_1HZ_1][col *][ACPA_ADS_STT_STS<255]" clobber=yes copyall=no
outfile=hk_2.fits.tmp
```

Second, create GTI indicating that STT2 is used for attitude control for each relevant HK file extension, and merge these.

```
ahgtigen infile="hk_1.fits.tmp[HK_ACPA_HK_NOM]" outfile=gti_stt2_1.fits.tmp
gtifile=none
gtiexpr="(ACPA_CONT_MODE==6)&&(ACPA_CONT_SUB_MODE==2)&&(ACPA_STT2_INTF_STS==0)&
&(ACPA_FDIR_COMP_STT2_ID_ERR_FLG==0)" mergegti=and leapsecfile=REFDATA
instrume=sxs chatter=2 clobber=yes logfile=gti_stt2_1.fits.tmp.log
```

```
ahgtigen infile="hk_2.fits.tmp[HK_ACPA_AOCS_HK_NM_CHECKOUT_1HZ_1]"
outfile=gti_stt_2.fits.tmp gtifile=none
gtiexpr="(ACPA_ADS_STT_STS==1)&&(ACPA_ADS_KF_UP==1)" mergegti=and
leapsecfile=REFDATA instrume=sxs chatter=2 clobber=yes
logfile=gti_stt_2.fits.tmp.log

ahgtigen
infile="data/100040030/auxil/ah100040030gen_a0.hk.gz[HK_ACPA_PD_DATA_4HZ_1]"
outfile=gti_stt2_3.fits.tmp gtifile=none gtiexpr="(ACPA_STT2_Q_VALID==1)"
mergegti=and leapsecfile=REFDATA instrume=sxs chatter=2 clobber=yes
logfile=gti_stt2_3.fits.tmp.log

ahgtigen infile=NONE outfile=gti_stt2_control.fits
gtifile=gti_stt2_1.fits.tmp,gti_stt_2.fits.tmp,gti_stt2_3.fits.tmp gtiexpr=NONE
mergegti=AND clobber=yes chatter=2 logfile=gti_stt2_control.fits.log
```

Third, merge this with the original cleaned event file GTI and append to the cleaned event file.

```
ahgtigen infile=NONE outfile=bestattevt.gti
gtifile="gti_stt2_control.fits[GTI],data/100040030/sxs/event_cl/ah100040030sxs_
p0px1010_cl.evt.gz[GTI]" gtiexpr=NONE mergegti=AND clobber=yes chatter=2

ftcopy data/100040030/sxs/event_cl/ah100040030sxs_p0px1010_cl.evt.gz
ah100040030sxs_p0px1010_cl_bestatt.evt clobber=yes

ftdelhdu ah100040030sxs_p0px1010_cl_bestatt.evt+2
ah100040030sxs_p0px1010_cl_bestatt.evt confirm=yes clobber=yes

ftappend "bestattevt.gti[GTI]"  ah100040030sxs_p0px1010_cl_bestatt.evt
```

Finally, apply the merged GTI to the event file, and adjust the GTI extension EXPOSURE keyword.

```
ftcopy 'ah100040030sxs_p0px1010_cl_bestatt.evt[EVENTS][gtifilter()]'
ah100040030sxs_p0px1010_cl_bestatt.evt clobber=yes

ftchecksum ah100040030sxs_p0px1010_cl_bestatt.evt update=yes
```

100040010

SXS

For this sequence only, the *sxsgain* `extraspread` parameter must be changed from its default value of 40 to 100.

(1) Recalibrate/rescreen using ahpipeline

New files ehk and mkf files are created and applied.

```
ahpipeline indir=data/100040010 outdir=data/100040010_repro_sxs
steminputs=ah100040010 stemoutputs=DEFAULT entry_stage=1 exit_stage=2
instrum=SXS verify_input=no create_ehkmkf=yes extraspread=100 seed=7
clobber=yes chatter=2 mode=hl

mkdir data/100040010_repro_sxs/logs
mv *log data/100040010_repro_sxs/logs
```

(1) Recalibrate/rescreen using sxspipeline

Original ehk and mkf files are applied.

```
sxspipeline indir=data/100040010 outdir=data/100040010_repro2_sxs/sxs
steminputs=ah100040010 stemoutputs=ah100040010 entry_stage=1 exit_stage=2
attitude=data/100040010/auxil/ah100040010.att.gz
orbit=data/100040010/auxil/ah100040010.orb.gz
obsgti=data/100040010/auxil/ah100040010_gen.gti.gz
housekeeping=data/100040010/sxs/hk/ah100040010sxs_a0.hk1.gz
timfile=data/100040010/auxil/ah100040010.tim.gz
extended_housekeeping=data/100040010/auxil/ah100040010.ehk.gz
makefilter=data/100040010/auxil/ah100040010.mkf.gz seed=7 extraspread=100
clobber=yes chatter=2 mode=hl
```

```
mkdir data/100040010_repro2_sxs/logs
mv *log data/100040010_repro2_sxs/logs
```

For additional, more specialized, SXS reprocessing see the corresponding section for G21.5-0.9 sequence `100050020.`

Extracting Products

This section details tools to run on cleaned event files to get instrument specific data products. These may be applied to the original cleaned event files from the pipeline, or to new cleaned event files created using the steps in the last section. In what follows, the original pipeline cleaned event files are used. The extraction region files used are assumed to be in the "regions" directory.

100040030

SXS

All newly created output files in this section are placed in the /full/path/to/data/sxs_products directory

```
cd /full/path/
```

```
mkdir data/products_sxs
```

```
cd data/products_sxs
```

(1) Additional screening

Create a "cleaned-2" SXS event file

```
ah100040030sxs_p0px1010_cl2.evt
```

by applying a RISETIME cut to Hp, Mp, Ms, and Lp (but not Ls) events, and excluding frame events flagged due to close proximity in time to other events that are no longer screened as part of the standard processing.

```
ftselect
infile='../100040030/sxs/event_cl/ah100040030sxs_p0px1010_cl.evt.gz[events]'
outfile=ah100040030sxs_p0px1010_cl2.evt
expression="(PI>=400)&&((RISE_TIME>=40&&RISE_TIME<=60&&ITYPE<4)||(ITYPE==4))&&S
TATUS[4]==b0"
```

Note that the current pipeline screening already excludes events with PI<600.

(2) Extract image using xselect; construct pixel overlay and calculate NGC 1275 DET coordinate position and sky position of the center of the SXS based on nominal pointing.

```
fkeyprint ah100040030sxs_p0px1010_cl2.evt+1 PA_NOM
```

```
PA_NOM  =     253.062747813964 / [deg] Nominal aspect point roll.

fkeyprint ah100040030sxs_p0px1010_cl2.evt+1 RA_NOM
RA_NOM  =     49.9326794742947 / [deg] Nominal aspect point R.A.

fkeyprint ah100040030sxs_p0px1010_cl2.evt+1 DEC_NOM
DEC_NOM =     41.5215474535011 / [deg] Nominal aspect point Dec.

ahmkregion instrume=SXS ra=49.9326794742947 dec=41.5215474535011 roll=-
106.937252186

coordpnt "49.950817,41.511725" outfile=none telescop=HITOMI instrume=SXS
ra=49.9326794742947 dec=41.5215474535011 roll=-106.9369381  startsys=radec
stopsys=det

coordpnt: OUTX OUTY=    5.20498447     2.45144120

coordpnt "3.5,3.5" outfile=none telescop=HITOMI instrume=SXS
ra=49.9326794742947 dec=41.5215474535011 roll=-106.9369381  startsys=det
stopsys=radec

coordpnt: OUTX OUTY=   49.93377019    41.52300883

xsel:SUZAKU > read events ah100040030sxs_p0px1010_cl2.evt
xsel:HITOMI-SXS-PX_NORMAL > extract image
xsel:HITOMI-SXS-PX_NORMAL > save image ah100040030sxs_p0px1010_cl2_sky.img
xsel:HITOMI-SXS-PX_NORMAL > set xyname detx dety
xsel:HITOMI-SXS-PX_NORMAL > extract image
xsel:HITOMI-SXS-PX_NORMAL > save image ah100040030sxs_p0px1010_cl2_det.img
```

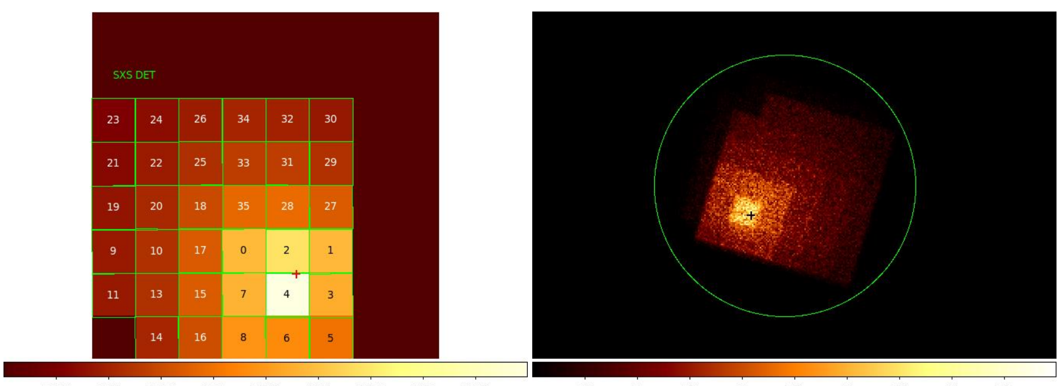


Figure 20: SXS DET (left) and SKY (right) coordinate imagse with DET coordinate pixel overlay (SXS.DET.text.reg) and NGC 1275 location (cross; ra=49.950817; dec=41.511725) based on nominal pointing.

(3) Extract full-array source spectra and light curves using sxsregext or xselect

Use sxsregext to extract the HP spectrum `ah100040030sxs_detreg.pha` from the above cleaned-2 event file events `ah100040030sxs_p0px1010_cl2.evt` for Hp events. Here we use a circular sky region of 150 arcsec radius calculated above and shown in the above figure, `perseus_offset_sky.reg`,

```
# Region file format: DS9 version 4.1
global color=green dashlist=8 3 width=1 font="helvetica 10 normal roman" select=1
highlite=1 dash=0 fixed=0 edit=1 move=1 delete=1 include=1 source=1
fk5
circle(49.93377019,41.52300883,150.0")
```

The 35-pixel detector region (`ah100040030sxs_detreg.reg`) and SXS exposure map (ah100040030sxs.expo) with one attitude bin are also created.

```
sxsregext infile=ah100040030sxs_p0px1010_cl2.evt regmode=RADEC
region==../../regions/perseus_offset_sky.reg resolist=0
outroot=ah100040030sxs_detreg outexp=ah100040030sxs.expo
ehkfile=../100040030/auxil/ah100040030.ehk.gz delta=20 numphi=1 clobber=yes
```

The content of the region file `ah100040030sxs_detreg.reg` is

```
physical
+box(4,1,5,1.00000000)
+box(3.5,2,6,1.00000000)
+box(3.5,3,6,1.00000000)
+box(3.5,4,6,1.00000000)
+box(3.5,5,6,1.00000000)
+box(3.5,6,6,1.00000000)
```

In addition to the spectrum, a DET coordinate image `ah100040030sxs_region_SXS_det.img` and lightcurve `ah100040030sxs_region_SXS_det.lc` are created.

Note that, by default, HP (ITYPE 0) and MP (ITYPE 1) events are included in the spectrum (this may be controlled via the hidden sxsregext resolist parameter). Also, note that the BACKSCAL keyword is set to 5.468750E-01 which is the ratio of the number of pixels used in the extraction (35) to the total detector address space in pixels (64). This is not a problem provided that any spectra to be combined, subtracted etc. are created in the same manner. The following alternative using xselect creates a spectrum with BACKSCAL=1:

```
xsel:SUZAKU > read events ah100040030sxs_p0px1010_cl2.evt
xsel:HITOMI-SXS-PX_NORMAL > filter column "PIXEL=0:11,13:35"
xsel:HITOMI-SXS-PX_NORMAL > filter GRADE "0:0"
xsel:HITOMI-SXS-PX_NORMAL > extract spectrum
xsel:HITOMI-SXS-PX_NORMAL > save spectrum ah100040030sxs_p0px1010_cl2_HP.pi
```

Note that, since Pixel 12 events are excluded from the cleaned event files, the filtering on PIXEL is not necessarty for extracting products from the entire array.

Identical steps (with the exception of the choice of sky region if using sxsregext) are applied to all 6 Perseus sequences.

(4) Extract the SXS NXB spectrum

Run the the task `sxsnxbgen` to extract the SXS NXB spectrum from all pixels (a selection of pixels or detector region may also be input), with the same extra cleaning that was applied to the source spectrum, but excluding ITYPE=4 events that are mostly anomalous.

```
sxsnxbgen infile=ah100040030sxs_p0px1010_cl2.evt
ehkfile=../100040030/auxil/ah100040030.ehk.gz regfile=NONE
innxbfile=ah_sxs_nxbafmar4_20140101v001.evt
innxbehk=ah_gen_nxbehk_20140101v002.fits outpifile=ah100040030sxsnxb_cl2.pi
pixels="-" cleanup=yes chatter=3 clobber=yes mode=hl
logfile=ah100040030sxsnxb_cl2.log sortbin=0,4,5,6,7,8,9,10,11,12,13,99
expr="PI>=400&&RISE_TIME>=40&&RISE_TIME<=60&&ITYPE<4&&STATUS[4]==b0"
```

The BACKSCAL keyword must always be updated when the SXS NXB is extracted based on a selection of pixels, and must always be checked for compatibility with the source spectrum. If the extraction regions are the same, BACKSCAL must be identical; if different the BACKSCAL ratio must be the ratio of the extraction region areas (or number of pixels). In the present example, assuming the source spectrum was extracted in xselect,

```
fthedit ah100040030sxsnxb_cl2.pi+1 BACKSCAL add 1.000000E+00
```

is done.

```
sxsnxbgen infile=ah100040020sxs_p0px1010_cl2.evt
ehkfile=../100040020/auxil/ah100040020.ehk.gz regfile=NONE
innxbfile=ah_sxs_nxbbfmar4_20140101v001.evt
innxbehk=ah_gen_nxbehk_20140101v002.fits outpifile=ah100040020sxsnxb_cl2.pi
pixels="-" cleanup=yes chatter=3 clobber=yes mode=hl
logfile=ah100040020sxsnxb_cl2.log sortbin=0,4,5,6,7,8,9,10,11,12,13,99
expr="PI>=400&&RISE_TIME>=40&&RISE_TIME<=60&&ITYPE<4&&STATUS[4]==b0"
```

```
fthedit ah100040020sxsnxb_cl2.pi+1 BACKSCAL add 1.000000E+00
```

100040060

SXI

All newly created output files in this section are placed in the /full/path/to/data/sxi_products directory

```
cd /full/path/
```

```
mkdir data/products_sxi
```

```
cd data/products_sxi
```

The Perseus SXI event files (sequence 100040060 only) are split into 4 files that may be combined. There is no divison here into separate normal and MZDYE mode.

Here we use a circular sky region of 150 arcsec radius shown in the figure, `perseus_center_sky.reg`, to extract products from the core region.

```
# Region file format: DS9 version 4.1
global color=green dashlist=8 3 width=1 font="helvetica 10 normal roman" select=1
highlite=1 dash=0 fixed=0 edit=1 move=1 delete=1 include=1 source=1
fk5
circle(49.9507,41.5128,150.0")
```

(1) Extract combined images, source spectra, and light curves using xselect

```
xselect
xsel:SUZAKU > read events
../100040060/sxi/event_cl/ah100040060sxi_p110000360_cl.evt.gz
xsel:SUZAKU > read events
../100040060/sxi/event_cl/ah100040060sxi_p210000360_cl.evt.gz
xsel:SUZAKU > read events
../100040060/sxi/event_cl/ah100040060sxi_p310000360_cl.evt.gz
xsel:SUZAKU > read events
../100040060/sxi/event_cl/ah100040060sxi_p410000360_cl.evt.gz
xsel:HITOMI-SXI-WINDOW1 > filter pha_cutoff 83 1333
xsel:HITOMI-SXI-WINDOW1 > set xybin 4
xsel:HITOMI-SXI-WINDOW1 > extract image
xsel:HITOMI-SXI-WINDOW1 > save image ah100040060sxi_cl.img
xsel:HITOMI-SXI-WINDOW1 > plot image
xsel:HITOMI-SXI-WINDOW1 > clear pha_cutoff
xsel:HITOMI-SXI-WINDOW1 > filter region ../../regions/perseus_center_sky.reg
xsel:HITOMI-SXI-WINDOW1 > extract spectrum
xsel:HITOMI-SXI-WINDOW1 > plot spectrum
xsel:HITOMI-SXI-WINDOW1 > extract curve exposure=0.0
xsel:HITOMI-SXI-WINDOW1 > save curve ah100040060sxi_cl.lc
xsel:HITOMI-SXI-WINDOW1 > plot curve
```

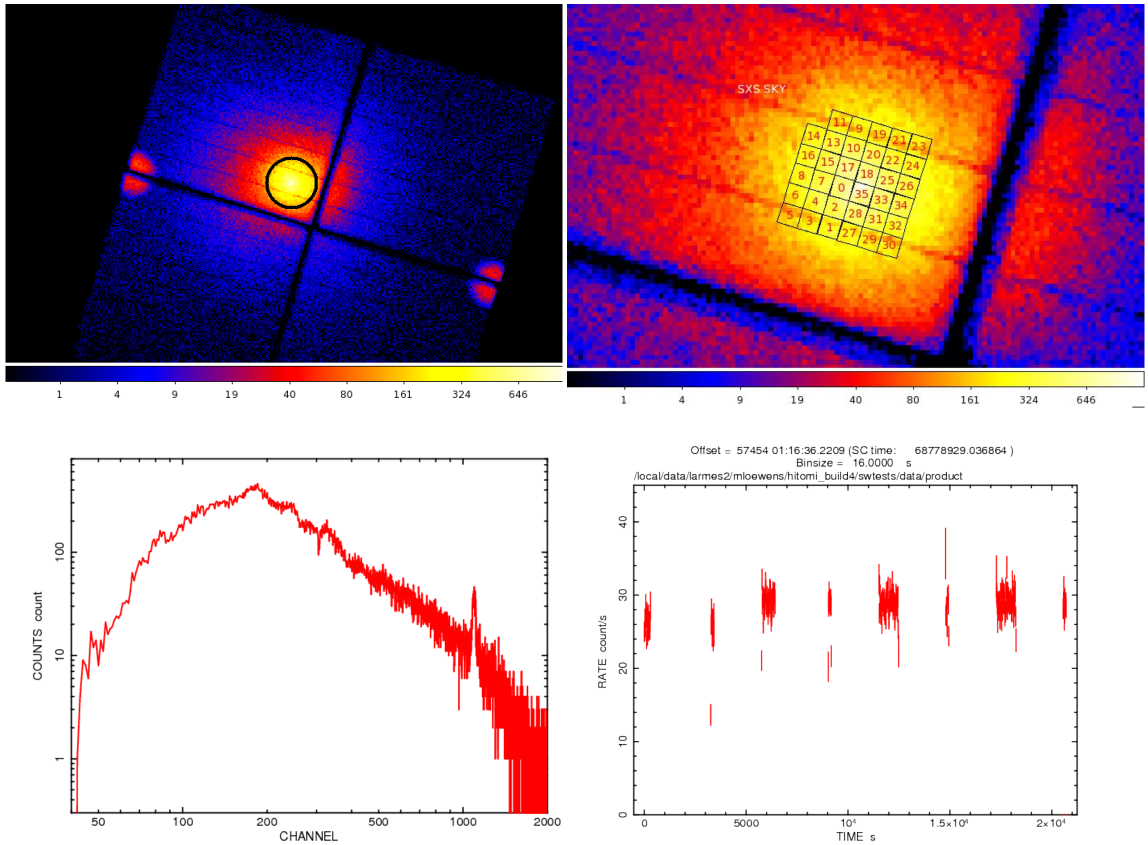


Figure 21: SXI image with extraction region (top left) and SXS FoV (SXS.SKY.text.reg; see below) corresponding to nominal pointing; and, core region lightcurve (bottom left) and (log-log scale) spectrum (bottom right) for sequence 100040060.

(2) Extract individual source spectra using xselect

Due to differences in the number of bad pixels between OBSIDs, the SXI event data cannot be combined in the same way as the other instruments. Instead, spectra, RMFs, exposure maps, and ARFs must be generated for each OBSID separately and then simultaneously combined at the end.

```
xselect
xsel:SUZAKU > read events
../100040060/sxi/event_cl/ah100040060sxi_p110000360_cl.evt.gz
xsel:HITOMI-SXI-WINDOW1 > filter region ../../regions/perseus_center_sky.reg
xsel:HITOMI-SXI-WINDOW1 > extract spectrum
xsel:HITOMI-SXI-WINDOW1 > save spectrum ah100040060sxi_p110000360_cl.pi

xselect
xsel:SUZAKU > read events
../100040060/sxi/event_cl/ah100040060sxi_p210000360_cl.evt.gz
xsel:HITOMI-SXI-WINDOW1 > filter region ../../regions/perseus_center_sky.reg
xsel:HITOMI-SXI-WINDOW1 > extract spectrum
xsel:HITOMI-SXI-WINDOW1 > save spectrum ah100040060sxi_p210000360_cl.pi

xselect
xsel:SUZAKU > read events
../100040060/sxi/event_cl/ah100040060sxi_p310000360_cl.evt.gz
xsel:HITOMI-SXI-WINDOW1 > filter region ../../regions/perseus_center_sky.reg
xsel:HITOMI-SXI-WINDOW1 > extract spectrum
xsel:HITOMI-SXI-WINDOW1 > save spectrum ah100040060sxi_p310000360_cl.pi
```

```
xselect
xsel:SUZAKU > read events
../100040060/sxi/event_cl/ah100040060sxi_p410000360_cl.evt.gz
xsel:HITOMI-SXI-WINDOW1 > filter region ../../regions/perseus_center_sky.reg
xsel:HITOMI-SXI-WINDOW1 > extract spectrum
xsel:HITOMI-SXI-WINDOW1 > save spectrum ah100040060sxi_p410000360_cl.pi
```

SXS

All newly created output files in this section are placed in the /full/path/to/data/sxs_products directory

(1) Additional screening

Create a "cleaned-2" SXS event file

```
 ah100040060sxs_p0px1010_cl2.evt
```

by applying a proximity screening and a RISETIME cut to Hp, Mp, Ms, and Lp (but not Ls) events.

```
ftselect
infile='../100040060/sxs/event_cl/ah100040060sxs_p0px1010_cl.evt.gz[events]'
outfile=ah100040060sxs_p0px1010_cl2.evt
expression="(PI>=400)&&((RISE_TIME>=40&&RISE_TIME<=60&&ITYPE<4)||(ITYPE==4))&&S
TATUS[4]==b0"
```

Note that the current pipeline screening already excludes events with PI<600.

(2) Extract image using xselect; construct pixel overlay and calculate NGC 1275 DET coordinate position based on nominal pointing.

```
fkeyprint ah100040060sxs_p0px1010_cl2.evt+1 PA_NOM
PA_NOM  =     253.077569456798 / [deg] Nominal aspect point roll.

fkeyprint ah100040060sxs_p0px1010_cl2.evt+1 RA_NOM
RA_NOM  =     49.9513492811862 / [deg] Nominal aspect point R.A.

fkeyprint ah100040060sxs_p0px1010_cl2.evt+1 DEC_NOM
DEC_NOM =     41.5136699333284 / [deg] Nominal aspect point Dec.

ahmkregion instrume=SXS ra=49.9513492811862 dec=41.5136699333284 roll=-
106.922430543

coordpnt "49.950817,41.511725" outfile=none telescop=HITOMI instrume=SXS
ra=49.9513492811862 dec=41.5136699333284 roll=-106.922430543 startsys=radec
stopsys=det

coordpnt: OUTX OUTY=    3.84128410     3.75311550

xsel:SUZAKU > read events ah100040060sxs_p0px1010_cl2.evt
xsel:HITOMI-SXS-PX_NORMAL > extract image
xsel:HITOMI-SXS-PX_NORMAL > save image ah100040060sxs_p0px1010_cl2_sky.img
xsel:HITOMI-SXS-PX_NORMAL > set xyname detx dety
xsel:HITOMI-SXS-PX_NORMAL > extract image
xsel:HITOMI-SXS-PX_NORMAL > save image ah100040060sxs_p0px1010_cl2_det.img
```

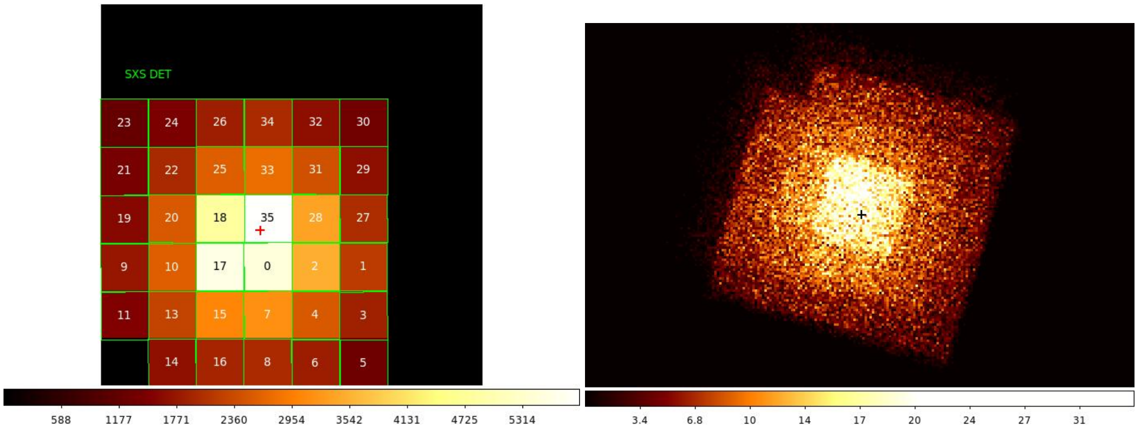


Figure 22: SXS DET (left) and SKY (right) coordinate imagse with DET coordinate pixel overlay (SXS.DET.text.reg) and NGC 1275 location (cross; ra=49.950817; dec=41.511725) based on nominal pointing.

(3) Extract full-array source spectra and light curves using sxsregext or xselect

Use sxsregext to extract the HP spectrum `ah100040060sxs_detreg.pha` from the above cleaned-2 event file events `ah100040060sxs_p0px1010_cl2.evt` for Hp events. Here we use a circular sky region defined above, `peresus_center_sky.reg.`

The 35-pixel detector region (`ah100040060sxs_detreg.reg`) and SXS exposure map (ah100040060sxs.expo) with one attitude bin are also created.

```
sxsregext infile=ah100040060sxs_p0px1010_cl2.evt regmode=RADEC
region=../../regions/perseus_center_sky.reg resolist=0
outroot=ah100040060sxs_detreg outexp=ah100040060sxs.expo
ehkfile=../100040060/auxil/ah100040060.ehk.gz delta=20 numphi=1 clobber=yes
```

The content of the region file `ah100040060sxs_detreg.reg` is

```
physical
+box(4,1,5,1.00000000)
+box(3.5,2,6,1.00000000)
+box(3.5,3,6,1.00000000)
+box(3.5,4,6,1.00000000)
+box(3.5,5,6,1.00000000)
+box(3.5,6,6,1.00000000)
```

In addition to the spectrum, a DET coordinate image `ah100040060sxs_region_SXS_det.img` and lightcurve `ah100040060sxs_region_SXS_det.lc` are created.

Note that, by default, HP (ITYPE 0) and MP (ITYPE 1) events are included in the spectrum (this may be controlled via the hidden sxsregext resolist parameter). Also, note that the BACKSCAL keyword is set to 5.468750E-01 which is the ratio of the number of pixels used in the extraction (35) to the total detector address space in pixels (64). This is not a problem provided that any spectra to be combined, subtracted etc. are created in the same manner. The following alternative using xselect creates a spectrum with BACKSCAL=1:

```
xsel:SUZAKU > read events ah100040060sxs_p0px1010_cl2.evt
xsel:HITOMI-SXS-PX_NORMAL > filter column "PIXEL=0:11,13:35"
xsel:HITOMI-SXS-PX_NORMAL > filter GRADE "0:0"
xsel:HITOMI-SXS-PX_NORMAL > extract spectrum
xsel:HITOMI-SXS-PX_NORMAL > save spectrum ah100040060sxs_p0px1010_cl2_HP.pi
```

Note that, since Pixel 12 events are excluded from the cleaned event files, the filtering on PIXEL is not necessarty for extracting products from the entire array.

(4) Add columns for an extended energy scale, and extract an extended energy spectrum

First, run the *sxsextend* script with the original cleaned file and its GTI extension as input. The following command adds a PIE column (and EPIE and EPI2E columns) to the original cleaned event file and sets the PIE TLMIN and TLMAX keywords in the output cleaned event files, but otherwise leaves the file unchanged. The task may also accept an unfiltered event file and apply a user-selected screening in creating the new cleaned event file (see the corresponding section for G21.5-0.9 sequence `100050020`). In this case the extended energy grid includes 32768 channels, extending to twice the standard maximum energy with 1 eV binning. *It is recommended that users not exceed this number of channels or extend the energy scale significantly beyond 30 keV because a valid ARF cannot be made above this energy.*

```
sxsextend inuffile=../100040060/sxs/event_cl/ah100040060sxs_p0px1010_cl.evt.gz
outuffile=ah100040060sxs_p0px1010_clext.evt outclfile=NONE driftfile=NONE
gtigenfile=NONE gtitelfile=NONE gtimxsfile=NONE gtiadroff=NONE gtimkf=NONE
gtiehk=NONE gtiextra=NONE eminin=0 dein=1.0 nchanin=32768 label=NONE
clobber=yes chatter=2 mode=hl
```

Second, apply a revised, energy-dependent, RISETIME cut (this may be more generally used, but is most significant at high energies).

```
ftselect
infile='../100040060/sxs/event_cl/ah100040060sxs_p0px1010_clext.evt.gz[events]'
outfile=ah100040060sxs_p0px1010_clext2.evt expression="((((ABS(RISE_TIME-
52+EPIE*(52-42)/16383.75))<=4)&&ITYPE<4)||(ITYPE==4))&&STATUS[4]==b0"
```

Third, extract the spectrum from the values in the PIE column using sxsregext or xselect.

```
sxsregext infile=ah100040060sxs_p0px1010_clext2.evt regmode=DET
region=ah100040060sxs_detreg.reg resolist=0
outroot=ah100040060sxs_region_SXS_det_ext outexp=ah100040060sxs.expo
ehkfile=../100040060/auxil/ah100040060.ehk.gz
pixgtifile=../100040060/sxs/event_uf/ah100040060sxs_px1010_exp.gti.gz
delta=0.25 numphi=4 extended=yes clobber=yes
```

or

```
xsel:SUZAKU > read events ah100040060sxs_p0px1010_clext2.evt
xsel:HITOMI-SXS-PX_NORMAL > filter column "PIXEL=0:11,13:35"
xsel:HITOMI-SXS-PX_NORMAL > filter GRADE "0:0"
xsel:HITOMI-SXS-PX_NORMAL > set phaname PIE
xsel:HITOMI-SXS-PX_NORMAL > extract spectrum
xsel:HITOMI-SXS-PX_NORMAL > save spectrum ah100040060sxs_p0px1010_clext2_HP.pi
```

As described below, RMF and ARF files must be constructed with compatible energy grids.

(5) Extract the SXS NXB spectrum for standard and extended energy grids

Run the the task `sxsnxbgen` to extract the SXS NXB spectrum from all pixels (a selection of pixels or detector region may also be input), with the same extra cleaning that was applied to the source spectrum.

```
sxsnxbgen infile=ah100040060sxs_p0px1010_cl2.evt
ehkfile=../100040060/auxil/ah100040060.ehk.gz regfile=NONE
innxbfile=ah_sxs_nxbafmar4_20140101v001.evt
innxbehk=ah_gen_nxbehk_20140101v002.fits outpifile=ah100040060sxsnxb_cl2.pi
pixels="-" cleanup=yes chatter=3 clobber=yes mode=hl
logfile=ah100040060sxsnxb_cl2.log sortbin=0,4,5,6,7,8,9,10,11,12,13,99
expr="PI>=400&&RISE_TIME>=40&&RISE_TIME<=60&&ITYPE<4&&STATUS[4]==b0"
```

Assuming the source spectrum was extracted in xselect,

```
fthedit ah100040060sxsnxb_cl2.pi+1 BACKSCAL add 1.000000E+00
```

The SXS NXB spectrum for the standard extended energy grid (the capability for other extended energy grids will be available with a soon-to-be-updated version of `sxsextend`) may also be extracted using `sxsnxbgen` as follows.

```
sxsnxbgen infile=ah100040060sxs_p0px1010_clext2.evt
ehkfile=../100040060/auxil/ah100040060.ehk.gz regfile=NONE
innxbfile=ah_sxs_nxbafmar4_20140101v001.evt
innxbehk=ah_gen_nxbehk_20140101v002.fits outpifile=ah100040060sxsnxb_clext2.pi
pixels="-" cleanup=no chatter=3 clobber=yes mode=hl
logfile=ah100040060sxsnxb_clext2.log sortbin=0,4,5,6,7,8,9,10,11,12,13,99
expr="((ABS(RISE_TIME-52+EPIE*(52-42)/16383.75))<=4)&&ITYPE<4&&STATUS[4]==b0"
picol=PIE"
```

Assuming the source spectrum was extracted in xselect (with `phaname` set to `PIE`),

```
fthedit ah100040060sxsnxb_clext2.pi+1 BACKSCAL add 1.000000E+00
```

100040020, 100040030, 100040040, 100040050 combined

SXS

Extract products from the combined data from the four Persus Cluster observations with similar pointings.

All newly created output files in this section are placed in the /full/path/to/data/sxs_products directory

```
cd /full/path/
```

```
cd data/products_sxs
```

(1) Combine the event files in xselect

```
xselect
xsel:SUZAKU > read events
xsel:HITOMI-SXS-PX_NORMAL > read events
../100040020/sxs/event_cl/ah100040020sxs_p0px1010_cl.evt.gz
xsel:HITOMI-SXS-PX_NORMAL > read events
../100040030/sxs/event_cl/ah100040030sxs_p0px1010_cl.evt.gz
xsel:HITOMI-SXS-PX_NORMAL > read events
../100040040/sxs/event_cl/ah100040040sxs_p0px1010_cl.evt.gz
xsel:HITOMI-SXS-PX_NORMAL > read events
../100040050/sxs/event_cl/ah100040050sxs_p0px1010_cl.evt.gz
xsel:HITOMI-SXS-PX_NORMAL > extract events
xsel:HITOMI-SXS-PX_NORMAL > save events ah100040023450sxs_p0px1010_cl.evt
```

(2) Apply the extra rise-time and proximity screening

```
ftselect infile='ah100040023450sxs_p0px1010_cl.evt[events]'
outfile=ah100040023450sxs_p0px1010_cl2.evt
expression="(PI>=400)&&((RISE_TIME>=40&&RISE_TIME<=60&&ITYPE<4)||(ITYPE==4))&&S
TATUS[4]==b0"
```

Note that the current pipeline screening already excludes events with PI<600.

(3) Extract the HP spectrum, lightcurve, images

```
xsel:SUZAKU > read events ah100040023450sxs_p0px1010_cl2.evt
xsel:HITOMI-SXS-PX_NORMAL > filter column "PIXEL=0:11,13:35"
xsel:HITOMI-SXS-PX_NORMAL > filter GRADE "0:0"
xsel:HITOMI-SXS-PX_NORMAL > filter pha_cutoff 4000 20000
xsel:HITOMI-SXS-PX_NORMAL > extract image
xsel:HITOMI-SXS-PX_NORMAL > save image ah100040023450sxs_p0px1010_cl2.img
xsel:HITOMI-SXS-PX_NORMAL > plot image
xsel:HITOMI-SXS-PX_NORMAL > clear pha_cutoff
xsel:HITOMI-SXS-PX_NORMAL > extract spectrum
xsel:HITOMI-SXS-PX_NORMAL > save spectrum ah100040023450sxs_p0px1010_cl2_HP.pi
xsel:HITOMI-SXS-PX_NORMAL > extract curve
xsel:HITOMI-SXS-PX_NORMAL > save curve ah100040023450sxs_p0px1010_cl2_HP.lc
xsel:HITOMI-SXS-PX_NORMAL > plot curve
```

(4) Extract the SXS NXB spectrum

Run the the task `sxsnxbgen` to extract the SXS NXB spectrum from all pixels (a selection of pixels or detector region may also be input), with the same extra cleaning that was applied to the source spectrum.

Since the NXB spectrum for sequence 100040020 must be constructed separately, four NXB spectra are created and averaged (alternatively, two NXB spectra may be constructed and averaged – one for sequence 100040020, and one from merge cleaned event and ehk files for 100040030, 10004002040, and 100040050).

```
sxsnxbgen infile=ah100040020sxs_p0px1010_cl2.evt
ehkfile=../100040020/auxil/ah100040020.ehk.gz regfile=NONE
innxbfile=ah_sxs_nxbbfmar4_20140101v001.evt
innxbehk=ah_gen_nxbehk_20140101v002.fits outpifile=ah100040020sxsnxb_cl2.pi
pixels="-" cleanup=yes chatter=3 clobber=yes mode=hl
logfile=ah100040020sxsnxb_cl2.log sortbin=0,4,5,6,7,8,9,10,11,12,13,99
expr="PI>=400&&RISE_TIME>=40&&RISE_TIME<=60&&ITYPE<4&&STATUS[4]==b0"

fthedit ah100040020sxsnxb_cl2.pi+1 BACKSCAL add 1.000000E+00

sxsnxbgen infile=ah100040030sxs_p0px1010_cl2.evt
ehkfile=../100040030/auxil/ah100040030.ehk.gz regfile=NONE
innxbfile=ah_sxs_nxbafmar4_20140101v001.evtinnxbehk=ah_gen_nxbehk_20140101v002.
fits outpifile=ah100040030sxsnxb_cl2.pi pixels="-" cleanup=yes chatter=3
clobber=yes mode=hl logfile=ah100040030sxsnxb_cl2.log
sortbin=0,4,5,6,7,8,9,10,11,12,13,99
expr="PI>=400&&RISE_TIME>=40&&RISE_TIME<=60&&ITYPE<4&&STATUS[4]==b0"

fthedit ah100040030sxsnxb_cl2.pi+1 BACKSCAL add 1.000000E+00

sxsnxbgen infile=ah100040040sxs_p0px1010_cl2.evt
ehkfile=../100040040/auxil/ah100040040.ehk.gz regfile=NONE
innxbfile=ah_sxs_nxbafmar4_20140101v001.evt
innxbehk=ah_gen_nxbehk_20140101v002.fits outpifile=ah100040040sxsnxb_cl2.pi
pixels="-" cleanup=yes chatter=3 clobber=yes mode=hl
logfile=ah100040040sxsnxb_cl2.log sortbin=0,4,5,6,7,8,9,10,11,12,13,99
expr="PI>=400&&RISE_TIME>=40&&RISE_TIME<=60&&ITYPE<4&&STATUS[4]==b0"

fthedit ah100040040sxsnxb_cl2.pi+1 BACKSCAL add 1.000000E+00

sxsnxbgen infile=ah100040050sxs_p0px1010_cl2.evt
ehkfile=../100040050/auxil/ah100040050.ehk.gz regfile=NONE
innxbfile=ah_sxs_nxbafmar4_20140101v001.evt
innxbehk=ah_gen_nxbehk_20140101v002.fits outpifile=ah100040050sxsnxb_cl2.pi
pixels="-" cleanup=yes chatter=3 clobber=yes mode=hl
logfile=ah100040050sxsnxb_cl2.log sortbin=0,4,5,6,7,8,9,10,11,12,13,99
expr="PI>=400&&RISE_TIME>=40&&RISE_TIME<=60&&ITYPE<4&&STATUS[4]==b0"
```

```
fthedit ah100040050sxsnxb_cl2.pi+1 BACKSCAL add 1.000000E+00
```

Finally, the individual sequence NXB spectra are averaged with weights calculated as the ratio of the exposure time in each of the four *source (not NXB) spectra* to the total exposure summed over all of the
source spectra.

```
mathpha
expr="0.400*ah100040020sxsnxb_cl2.pi+0.298*ah100040030sxsnxb_cl2.pi+0.280*ah100
040040sxsnxb_cl2.pi+0.022*ah100040050sxsnxb_cl2.pi"  units=R
outfil=ah100040023450sxsnxb_cl2.pi exposure=CALC  areascal=% errmeth=gauss
properr=yes ncomments=0
```

Generating Exposure Map, RMF, and ARF

100040030

SXS

(1) Generate the RMF

Here we use the "small" size option (includes Gaussian core only). Change whichrmf parameter to "m" to also include low energy, to "l" to also include escape peaks, "x" to also include the low energy continuum. The DET coordinate region file `ah100040030sxs_detreg.reg` created by sxsregext is input.

```
sxsmkrmf infile=ah100040030sxs_p0px1010_cl2.evt
outfile=ah100040030_sxs_cl2_HP_small.rmf resolist=0 regmode=det
regionfile=ah100040030sxs_detreg.reg  whichrmf=m
```

(2) Regenerate the SXS exposure maps

The exposure maps created with sxsregext are replaced using the parameters `delta=20.0`, `numphi=1` to assure that map includes only a single attitude bin. This assumes that the attitude is stable relative to the size of the PSF and extraction region. We also account for the lost event gti per pixel here by setting the `pixgtifile` parameter to `ah100040030sxs_px1010_exp.gti.gz` -- this should be done if the lost event gti are not used in the screening (as in the standard pipeline).

```
ahexpmap ehkfile=../100040030/auxil/ah100040030.ehk.gz
gtifile=ah100040030sxs_p0px1010_cl2.evt instrume=SXS badimgfile=NONE
pixgtifile=../100040030/sxs/event_uf/ah100040030sxs_px1010_exp.gti.gz
outfile=ah100040030sxs_p0px1010.expo outmaptype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100040030sxs_p0px1010.log
```

(3) Generate the SXS ARF

The parameter `numphoton` may need to be decreased to accommodate a larger number of attitude bins. The region file used is the one in DET coordinates previously created by sxsregext. The center of the sequence `100040060` SXI extraction region is used as the source coordinates. Note that for extended sources, the ARF gives spectral fluxes that are normalized to the spatial region corresponding to the input model or image.

Point Source

```
aharfgen xrtevtfile=raytrace_ah100040030sxs_p0px1010_ptsrc.fits
source_ra=49.9507 source_dec=41.5128 telescop=HITOMI instrume=SXS
emapfile=ah100040030sxs_p0px1010.expo regmode=DET
regionfile=ah100040030sxs_detreg.reg sourcetype=POINT
rmffile=ah100040030_sxs_cl2_HP_small.rmf erange="0.5 17.0 0 0"
outfile=ah100040030sxs_p0px1010_ptsrc.arf numphoton=300000 minphoton=1
teldeffile=CALDB qefile=CALDB contamifile=CALDB obffile=CALDB fwfile=CALDB
gatevalvefile=CALDB onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB
obstructfile=CALDB frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB
scatterfile=CALDB auxtransfile=NONE mode=h clobber=yes seed=7
logfile=make_arf_ah100040030sxs_p0px1010_ptsrc.log
```

Extended Source, Beta-model

The photon distribution is assumed to follow a beta-model with 2 arcmin core radius, beta=0.47 extending to 5.7 arcmin.

```
aharfgen xrtevtfile=raytrace_ah100040030sxs_p0px1010_beta.fits
source_ra=49.9507 source_dec=41.5128 telescop=HITOMI instrume=SXS
emapfile=ah100040030sxs_p0px1010.expo regmode=DET
regionfile=ah100040030sxs_detreg.reg sourcetype=betamodel betapars="2.0 0.47
5.7" rmffile=ah100040030_sxs_cl2_HP_small.rmf erange="0.5 17.0 0 0"
outfile=ah100040030sxs_p0px1010_beta.arf numphoton=300000 minphoton=1
teldeffile=CALDB qefile=CALDB contamifile=CALDB obffile=CALDB fwfile=CALDB
gatevalvefile=CALDB onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB
obstructfile=CALDB frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB
scatterfile=CALDB auxtransfile=NONE mode=h clobber=yes seed=7
logfile=make_arf_ah100040030sxs_p0px1010_beta.log
```

Extended Source, XMM image

The photon distribution is determined by a subimage based on XMM observations of the Perseus Cluster (original image provided by Dr. Daniel Wik).

```
aharfgen xrtevtfile=raytrace_ah100040030sxs_p0px1010_xmmimg.fits
source_ra=49.9507 source_dec=41.5128 telescop=HITOMI instrume=SXS
emapfile=ah100040030sxs_p0px1010.expo regmode=DET
regionfile=ah100040030sxs_detreg.reg sourcetype=image imgfile=adapt-400-
7200_subimage1.fits rmffile=ah100040030_sxs_cl2_HP_small.rmf erange="0.5 17.0
2.0 8.0" outfile=ah100040030sxs_p0px1010_xmmimg.arf numphoton=300000
minphoton=1 teldeffile=CALDB qefile=CALDB contamifile=CALDB obffile=CALDB
fwfile=CALDB gatevalvefile=CALDB onaxisffile=CALDB onaxiscfile=CALDB
mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB backreffile=CALDB
pcolreffile=CALDB scatterfile=CALDB auxtransfile=NONE mode=h clobber=yes seed=7
logfile=make_arf_ah100040030sxs_p0px1010_xmmimg.log
```

100040060

SXI

Note that because the cosmic ray echo effect varies between sequences over the course of the observation, a single bad image file cannot be used below. In general this should be checked when deriving SXI spectral ARFs for combined OBSIDs. If they differ as they do here, separate RMF and ARF files should be derived, and the spectra and responses should then be co-added, or individual spectra should be simultaneously fit.

All newly created output files in this section are placed in the /full/path/to/data/sxi_products directory

```
cd /full/path/

cd data/products_sxi
```

(1) Create an RMF for each source spectrum

```
sxirmf infile=ah100040060sxi_p110000360_cl.pi
outfile=ah100040060sxi_p110000360_cl.rmf clobber=yes mode=hl

sxirmf infile=ah100040060sxi_p210000360_cl.pi
outfile=ah100040060sxi_p210000360_cl.rmf clobber=yes mode=hl

sxirmf infile=ah100040060sxi_p310000360_cl.pi
outfile=ah100040060sxi_p310000360_cl.rmf clobber=yes mode=hl

sxirmf infile=ah100040060sxi_p410000360_cl.pi
outfile=ah100040060sxi_p410000360_cl.rmf clobber=yes mode=hl
```

(2) Create an Exposure Map for each source spectrum

The exposure maps (and flatfield images below) are created with the parameters `delta=20.0`, `numphi=1` to assure that the map includes only a single attitude bin, i.e. assuming that the attitude is stable relative to the size of the PSF and extraction region.

```
ahexpmap ehkfile=../100040060/auxil/ah100040060.ehk.gz
gtifile=../100040060/sxi/event_cl/ah100040060sxi_p110000360_cl.evt.gz
instrume=SXI
badimgfile=../100040060/sxi/event_uf/ah100040060sxi_p110000360.bimg.gz
pixgtifile=../100040060/sxi/event_uf/ah100040060sxi_a110000360.fpix.gz
outfile=ah100040060sxi_p110000360.expo outmaptype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100040060sxi_p110000360.log

ahexpmap ehkfile=../100040060/auxil/ah100040060.ehk.gz
gtifile=../100040060/sxi/event_cl/ah100040060sxi_p210000360_cl.evt.gz
instrume=SXI
badimgfile=../100040060/sxi/event_uf/ah100040060sxi_p210000360.bimg.gz
pixgtifile=../100040060/sxi/event_uf/ah100040060sxi_a210000360.fpix.gz
outfile=ah100040060sxi_p210000360.expo outmaptype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100040060sxi_p210000360.log

ahexpmap ehkfile=../100040060/auxil/ah100040060.ehk.gz
gtifile=../100040060/sxi/event_cl/ah100040060sxi_p310000360_cl.evt.gz
instrume=SXI
badimgfile=../100040060/sxi/event_uf/ah100040060sxi_p310000360.bimg.gz
pixgtifile=../100040060/sxi/event_uf/ah100040060sxi_a310000360.fpix.gz
outfile=ah100040060sxi_p310000360.expo outmaptype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100040060sxi_p310000360.log

ahexpmap ehkfile=../100040060/auxil/ah100040060.ehk.gz
gtifile=../100040060/sxi/event_cl/ah100040060sxi_p410000360_cl.evt.gz
instrume=SXI
```

```
badimgfile=../100040060/sxi/event_uf/ah100040060sxi_p410000360.bimg.gz
pixgtifile=../100040060/sxi/event_uf/ah100040060sxi_a410000360.fpix.gz
outfile=ah100040060sxi_p410000360.expo outmaptype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100040060sxi_p410000360.log
```

(3) Create an ARF for each source spectrum

In general, the `source_ra` and `source_dec` parameters should be the coordinates of the center of the source in the image, which are not necessarily the same as the actual source coordinates. The runtime estimated above is for the case where the exposure map has a single attitude bin. The parameter `numphoton` may need to be decreased to accommodate a larger number of attitude bins. Note that the ARF constructed below gives spectral fluxes that are normalized to the input XMM image. Point source ARF files may be created by setting `sourcetype=point`.

```
aharfgen xrtevtfile=raytrace_ah100040060sxi_p110000360_xmmimg.fits
source_ra=49.9507 source_dec=41.5128 telescop=HITOMI instrume=SXI
emapfile=ah100040060sxi_p110000360.expo regmode=RADEC
regionfile=../../regions/perseus_center_sky.reg sourcetype=image imgfile=adapt-
400-7200_subimage1.fits rmffile=ah100040060sxi_p110000360_cl.rmf erange="0.5
16.0 0.5 7.0" outfile=ah100040060sxi_p110000360_xmmimg.arf numphoton=300000
minphoton=1 teldeffile=CALDB qefile=CALDB contamifile=CALDB onaxisffile=CALDB
onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB
backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB auxtransfile=NONE seed=7
clobber=yes chatter=2 mode=h
logfile=make_arf_ah100040060sxi_p110000360_xmmimg.log

aharfgen xrtevtfile=raytrace_ah100040060sxi_p210000360_xmmimg.fits
source_ra=49.9507 source_dec=41.5128 telescop=HITOMI instrume=SXI
emapfile=ah100040060sxi_p210000360.expo regmode=RADEC
regionfile=../../regions/perseus_center_sky.reg sourcetype=image imgfile=adapt-
400-7200_subimage1.fits rmffile=ah100040060sxi_p210000360_cl.rmf erange="0.5
16.0 0.5 7.0" outfile=ah100040060sxi_p210000360_xmmimg.arf numphoton=300000
minphoton=1 teldeffile=CALDB qefile=CALDB contamifile=CALDB onaxisffile=CALDB
onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB
backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB auxtransfile=NONE seed=7
clobber=yes chatter=2 mode=h
logfile=make_arf_ah100040060sxi_p210000360_xmmimg.log

aharfgen xrtevtfile=raytrace_ah100040060sxi_p310000360_xmmimg.fits
source_ra=49.9507 source_dec=41.5128 telescop=HITOMI instrume=SXI
emapfile=ah100040060sxi_p310000360.expo regmode=RADEC
regionfile=../../regions/perseus_center_sky.reg sourcetype=image imgfile=adapt-
400-7200_subimage1.fits rmffile=ah100040060sxi_p310000360_cl.rmf erange="0.5
16.0 0.5 7.0" outfile=ah100040060sxi_p310000360_xmmimg.arf numphoton=300000
minphoton=1 teldeffile=CALDB qefile=CALDB contamifile=CALDB onaxisffile=CALDB
onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB
backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB auxtransfile=NONE seed=7
clobber=yes chatter=2 mode=h
logfile=make_arf_ah100040060sxi_p310000360_xmmimg.log

aharfgen xrtevtfile=raytrace_ah100040060sxi_p410000360_xmmimg.fits
source_ra=49.9507 source_dec=41.5128 telescop=HITOMI instrume=SXI
emapfile=ah100040060sxi_p410000360.expo regmode=RADEC
regionfile=../../regions/perseus_center_sky.reg sourcetype=image imgfile=adapt-
400-7200_subimage1.fits rmffile=ah100040060sxi_p410000360_cl.rmf erange="0.5
16.0 0.5 7.0" outfile=ah100040060sxi_p410000360_xmmimg.arf numphoton=300000
minphoton=1 teldeffile=CALDB qefile=CALDB contamifile=CALDB onaxisffile=CALDB
onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB
backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB auxtransfile=NONE seed=7
```

```
clobber=yes chatter=2 mode=h
logfile=make_arf_ah100040060sxi_p410000360_xmmimg.log
```

(4) Correct the BACKSCAL keyword in the SXI spectra for each remaining sequence

Xselect writes a BACKSCAL keyword in the header of extracted spectra to properly scale the background subtraction in XSPEC. However, it only accounts for the fraction of the area covered by the extraction region, not the number of good pixels. Many pixels in SXI data are affected by cosmic-ray echo or light leak and need to be properly excluded from BACKSCAL. The following application of *ahbackscal* should be made to correct this keyword for all SXI sequences.

Normal mode

```
ahbackscal infile=ah100040060sxi_p110000360_cl.pi
regfile=../../regions/perseus_center_sky.reg expfile=
ah100040060sxi_p110000360.expo norm=MAX

ahbackscal infile=ah100040060sxi_p210000360_cl.pi
regfile=../../regions/perseus_center_sky.reg expfile=
ah100040060sxi_p210000360.expo norm=MAX

ahbackscal infile=ah100040060sxi_p310000360_cl.pi
regfile=../../regions/perseus_center_sky.reg expfile=
ah100040060sxi_p310000360.expo norm=MAX

ahbackscal infile=ah100040060sxi_p2410000360_cl.pi
regfile=../../regions/perseus_center_sky.reg expfile=
ah100040060sxi_p410000360.expo norm=MAX
```

(5) Combine SXI spectra and responses

The ftool 'addascaspec' should be used to combine the source spectra and responses.

```
addascaspec addascaspec.in ah100040060sxi_cl.pi ah100040060sxi_cl.rsp "POISS-0"
```

where the file 'addascaspec.in' contains the following four lines (delineated by '\'):

```
ah100040060sxi_p110000360_cl.pi ah100040060sxi_p210000360_cl.pi
ah100040060sxi_p310000360_cl.pi  ah100040060sxi_p410000360_cl.pi \
ah100040060sxi_p110000360_xmmimg.arf ah100040060sxi_p210000360_xmmimg.arf
ah100040060sxi_p310000360_xmmimg.arf ah100040060sxi_p410000360_xmmimg.arf \
ah100040060sxi_p110000360_cl.rmf ah100040060sxi_p210000360_cl.rmf
ah100040060sxi_p310000360_cl.rmf ah100040060sxi_p410000360_cl.rmf
```

This will create a combined source spectrum, and a single .rsp file containing both the combined RMF and ARF.

(6) Create an efficiency map (flat field) for each OBSID

```
ahexpmap ehkfile=../100040060/auxil/ah100040060.ehk.gz
gtifile=../100040060/sxi/event_cl/ah100040060sxi_p110000360_cl.evt.gz
instrume=SXI
badimgfile=../100040060/sxi/event_uf/ah100040060sxi_p110000360.bimg.gz
pixgtifile=../100040060/sxi/event_uf/ah100040060sxi_a110000360.fpix.gz
outfile=ah100040060sxi_p110000360.flat outmaptype=EFFICIENCY delta=20.0
numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_flat_ah100040060sxi_p110000360.log
```

```
ahexpmap ehkfile=../100040060/auxil/ah100040060.ehk.gz
gtifile=../100040060/sxi/event_cl/ah100040060sxi_p210000360_cl.evt.gz
instrume=SXI
badimgfile=../100040060/sxi/event_uf/ah100040060sxi_p210000360.bimg.gz
pixgtifile=../100040060/sxi/event_uf/ah100040060sxi_a210000360.fpix.gz
outfile=ah100040060sxi_p210000360.flat outmaptype=EFFICIENCY delta=20.0
numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_flat_ah100040060sxi_p210000360.log

ahexpmap ehkfile=../100040060/auxil/ah100040060.ehk.gz
gtifile=../100040060/sxi/event_cl/ah100040060sxi_p310000360_cl.evt.gz
instrume=SXI
badimgfile=../100040060/sxi/event_uf/ah100040060sxi_p310000360.bimg.gz
pixgtifile=../100040060/sxi/event_uf/ah100040060sxi_a310000360.fpix.gz
outfile=ah100040060sxi_p310000360.flat outmaptype=EFFICIENCY delta=20.0
numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_flat_ah100040060sxi_p310000360.log

ahexpmap ehkfile=../100040060/auxil/ah100040060.ehk.gz
gtifile=../100040060/sxi/event_cl/ah100040060sxi_p410000360_cl.evt.gz
instrume=SXI
badimgfile=../100040060/sxi/event_uf/ah100040060sxi_p410000360.bimg.gz
pixgtifile=../100040060/sxi/event_uf/ah100040060sxi_a410000360.fpix.gz
outfile=ah100040060sxi_p410000360.flat outmaptype=EFFICIENCY delta=20.0
numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_flat_ah100040060sxi_p410000360.log
```

SXS

The steps for the standard energy grid are for identical to those above for sequence `100040020`.

(1) Construct RMF and ARF files to use with extended energy spectrum

First, identify the necessary keywords in the cleaned event file representing the maximum vaue of the PIE column, the offset value of the PIE column, and the grid width of PIE energy scale.

```
ftlist  ah100040060sxs_p0px1010_clext2.evt+1 K | grep PIE
TTYPE56 = 'EPIE    '           / EPI in extended energy range
TTYPE57 = 'PIE     '           / PI in extended energy range
TLMIN57 =                    0 / minimum legal value for PIE
PIEOFFST=                   1. / Energy offset (eV) of extended energy mode
PIEWIDTH=                   1. / Channel width (eV) of extended energy mode

ftlist ah100040060sxs_p0px1010_clext2.evt+1 K | grep TLMAX57
TLMAX57 =                32767

ftlist ah100040060sxs_p0px1010_clext2.evt+1 K | grep PIEOFFST
PIEOFFST=                   1. / Energy offset (eV) of extended energy mode

ftlist ah100040060sxs_p0px1010_clext2.evt+1 K | grep PIEWIDTH
PIEWIDTH=                   1. / Channel width (eV) of extended energy mode
```

Second, construct the RMF file for this energy grid, setting `nchanin=TLMAX57+1 dein=PIEWIDTH` and `eminin=PIEOFFST-PIEWIDTH` that, in this case, corresponds to the following command.

```
sxsmkrmf infile=ah100040060sxs_p0px1010_clext2.evt
outfile=ah100040060_sxs_clext2_HP_small.rmf resolist=0 regmode=det
regionfile=ah100040060sxs_detreg.reg  whichrmf=s nchanin=32768 dein=1.0
eminin=0.0
```

Third, construct the ARF file for this energy grid, and an appropriate energy range for the arf. The correct energy range is assured by inputing the RMF file constructed above. The energy range for the ARF should span the full energy range (corresponding to a lower limit of `eminin` and an upper limit of `eminin+nchanin*dein`), possibly with some margin on either side, but not to exceed 0.5 keV on the low end and 30 keV on the high end. The command for this example is as follows.

```
aharfgen xrtevtfile=raytrace_ah100040060sxs_p0px1010_ext.fits source_ra=83.6319
source_dec=22.0188 telescop=HITOMI instrume=SXS
emapfile=ah100040060sxs_p0px1010.expo regmode=DET
regionfile=ah100040060sxs_region_SXS_det.reg sourcetype=POINT
rmffile=ah100040060_sxs_clext2_HP_small.rmf erange="0.5 30.0 0 0"
outfile=ah100040060sxs_p0px1010_rt_ext.arf numphoton=300000 minphoton=1
teldeffile=CALDB qefile=CALDB contamifile=CALDB obffile=CALDB fwfile=CALDB
gatevalvefile=CALDB onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB
obstructfile=CALDB frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB
scatterfile=CALDB auxtransfile=NONE seed=7 clobber=yes chatter=2 mode=h
logfile=make_arf_ah100040060sxs_p0px1010_ext.log
```

100040020, 100040030, 100040040, 100040050 combined

(1) Generate the RMF

Here we use the "small" size option (includes Gaussian core only). Change whichrmf parameter to "m" to also include low energy, to "l" to also include escape peaks, "x" to also include the low energy continuum. The DET coordinate region file `ah100040030sxs_detreg.reg` created by sxsregext is input.

```
sxsmkrmf infile=ah100040023450sxs_p0px1010_cl2.evt
outfile=ah100040023450_sxs_cl2_HP_small.rmf resolist=0 regmode=det
regionfile=ah100040030sxs_detreg.reg whichrmf=s
```

(2) Merge the necessary files from each sequence

(a) Merge the ehk files

```
ftmerge
'../100040020/auxil/ah100040020.ehk.gz,../100040030/auxil/ah100040030.ehk.gz,..
/100040040/auxil/ah100040040.ehk.gz,../100040050/auxil/ah100040050.ehk.gz'
ah100040023450.ehk
```

(b) Merge the pixgti file GTIPIXELOFF extensions

```
ftmerge
'../100040020/sxs/event_uf/ah100040020sxs_px1010_exp.gti.gz+2,../100040030/sxs/
event_uf/ah100040030sxs_px1010_exp.gti.gz+2,../100040040/sxs/event_uf/ah1000400
40sxs_px1010_exp.gti.gz+2,../100040050/sxs/event_uf/ah100040050sxs_px1010_exp.g
ti.gz+2' ah100040023450sxs_px1010_exp.gti
```

(3) Create the SXS exposure map for the combined SXS

The exposure maps created using the parameters `delta=20.0, numphi=1` to assure that map includes only a single attitude bin. This assumes that the attitude is stable relative to the size of the PSF and extraction region.We also account for the lost event gti per pixel here by setting the `pixgtifile` parameter to the merged pixgti file `ah100040023450sxs_px1010_exp.gti` created above.

```
ahexpmap ehkfile=ah100040023450.ehk gtifile=ah100040023450sxs_p0px1010_cl2.evt
instrume=SXS badimgfile=NONE pixgtifile=ah100040023450sxs_px1010_exp.gti
outfile=ah100040023450sxs_p0px1010.expo outmaptype=EXPOSURE delta=20 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100040023450sxs_p0px1010.log
```

(4) Generate the SXS ARF

The parameter `numphoton` may need to be decreased to accommodate a larger number of attitude bins. The region file used is the one in DET coordinates previously created by sxsregext. The center of the sequence `100040060` SXI extraction region is used as the source coordinates. Note that for extended sources, the ARF gives spectral fluxes that are normalized to the input model or image.

Point Source

```
aharfgen xrtevtfile=raytrace_ah100040023450sxs_p0px1010_ptsrc.fits
source_ra=49.9507 source_dec=41.5128 telescop=HITOMI instrume=SXS
emapfile=ah100040023450sxs_p0px1010.expo regmode=DET
regionfile=ah100040030sxs_detreg.reg sourcetype=POINT
rmffile=ah100040023450_sxs_cl2_HP_small.rmf erange="0.5 17.0 0 0"
outfile=ah100040023450sxs_p0px1010_ptsrc.arf numphoton=300000 minphoton=1
teldeffile=CALDB qefile=CALDB contamifile=CALDB obffile=CALDB fwfile=CALDB
gatevalvefile=CALDB onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB
obstructfile=CALDB frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB
scatterfile=CALDB auxtransfile=NONE mode=h clobber=yes seed=7
logfile=make_arf_ah100040023450sxs_p0px1010_ptsrc.log
```

Extended Source, Beta-model

The photon distribution is assumed to follow a beta-model with 2 arcmin core radius, beta=0.47 extending to 5.7 arcmin.

```
aharfgen xrtevtfile=raytrace_ah100040023450sxs_p0px1010_beta.fits
source_ra=49.9507 source_dec=41.5128 telescop=HITOMI instrume=SXS
emapfile=ah100040023450sxs_p0px1010.expo regmode=DET
regionfile=ah100040030sxs_detreg.reg sourcetype=betamodel betapars="2.0 0.47
5.7" rmffile=ah100040023450_sxs_cl2_HP_small.rmf erange="0.5 17.0 0 0"
outfile=ah100040023450sxs_p0px1010_beta.arf numphoton=300000 minphoton=1
teldeffile=CALDB qefile=CALDB contamifile=CALDB obffile=CALDB fwfile=CALDB
gatevalvefile=CALDB onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB
obstructfile=CALDB frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB
scatterfile=CALDB auxtransfile=NONE mode=h clobber=yes seed=7
logfile=make_arf_ah100040023450sxs_p0px1010_beta.log
```

Extended Source, XMM image

The photon distribution is determined by a subimage based on XMM observations of the Perseus Cluster (original image provided by Dr. Daniel Wik).

```
aharfgen xrtevtfile=raytrace_ah100040023450sxs_p0px1010_xmmimg.fits
source_ra=49.9507 source_dec=41.5128 telescop=HITOMI instrume=SXS
emapfile=ah100040023450sxs_p0px1010.expo regmode=DET
```

```
regionfile=ah100040030sxs_detreg.reg sourcetype=image imgfile=adapt-400-
7200_subimage1.fits rmffile=ah100040023450_sxs_cl2_HP_small.rmf erange="0.5
17.0 2.0 8.0" outfile=ah100040023450sxs_p0px1010_xmmimg.arf numphoton=300000
minphoton=1 teldeffile=CALDB qefile=CALDB contamifile=CALDB obffile=CALDB
fwfile=CALDB gatevalvefile=CALDB onaxisffile=CALDB onaxiscfile=CALDB
mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB backreffile=CALDB
pcolreffile=CALDB scatterfile=CALDB auxtransfile=NONE mode=h clobber=yes seed=7
logfile=make_arf_ah100040023450sxs_p0px1010_xmmimg.log
```

Spectral Fittting

Notes

The following XSPEC settings are used below (see http://www.atomdb.org/ for details on downloading the latest APEC model)

For fitting;

statistc cstat
abund lodd
xsect bcmc
xset APECROOT /path/to/apec_files/apec_v3.0.7

For plotting:

setplot rebin 1e6 8 (SXS)

Note that the spectra and response files co-added for sequences are used below; however, identical procedures apply to individual sequences.

SXS

(1) Fit the SXS spectrum in the 1.8-9 keV band with a model composed of an absorbed power-law representing the AGN and a broadened, single abundance thermal plasma model representing the ICM. The ARF for a point source at the AGN position is used here.

```
1 file 1 spectrum
Spectrum 1  Spectral Data File: ah100040023450sxs_p0px1010_cl2_HP.pi
Net count rate (cts/s) for Spectrum:1  1.682e+00 +/- 2.628e-03
 Assigned to Data Group 1 and Plot Group 1
  Noticed Channels:  3602-17999
  Telescope: HITOMI Instrument: SXS  Channel Type: PI
  Exposure Time: 2.435e+05 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Response (RMF) File    ah100040023450_sxs_cl2_HP_small.rmf  for Source 1
 Using Auxiliary Response (ARF) File  ah100040023450sxs_p0px1010_ptsrc.arf

 Spectral data counts: 409601
 Model predicted rate: 1.68188


Current model list:

========================================================================
Model TBabs<1>(bapec<2> + pegpwrlw<3>) Source No.: 1   Active/On
```

Model par	Model comp	Component	Parameter	Unit	Value		
1	1	TBabs	nH	10^22	0.138000	frozen	
2	2	bapec	kT	keV	3.96028	+/-	2.49419E-02
3	2	bapec	Abundanc		0.633688	+/-	8.81655E-03
4	2	bapec	Redshift		1.75272E-02	+/-	8.49072E-06
5	2	bapec	Velocity	km/s	185.576	+/-	2.43024
6	2	bapec	norm		0.162157	+/-	1.58843E-03
7	3	pegpwrlw	PhoIndex		1.80000	frozen	
8	3	pegpwrlw	eMin	keV	2.00000	frozen	
9	3	pegpwrlw	eMax	keV	10.0000	frozen	
10	3	pegpwrlw	norm		29.9923	+/-	1.33164

```
Fit statistic : C-Statistic =       15230.49 using 14398 PHA bins and 14392
degrees of freedom.

Test statistic : Chi-Squared =       17402.16 using 14398 PHA bins.
 Reduced chi-squared =       1.209155 for  14392 degrees of freedom
 Null hypothesis probability =   1.748892e-62
```

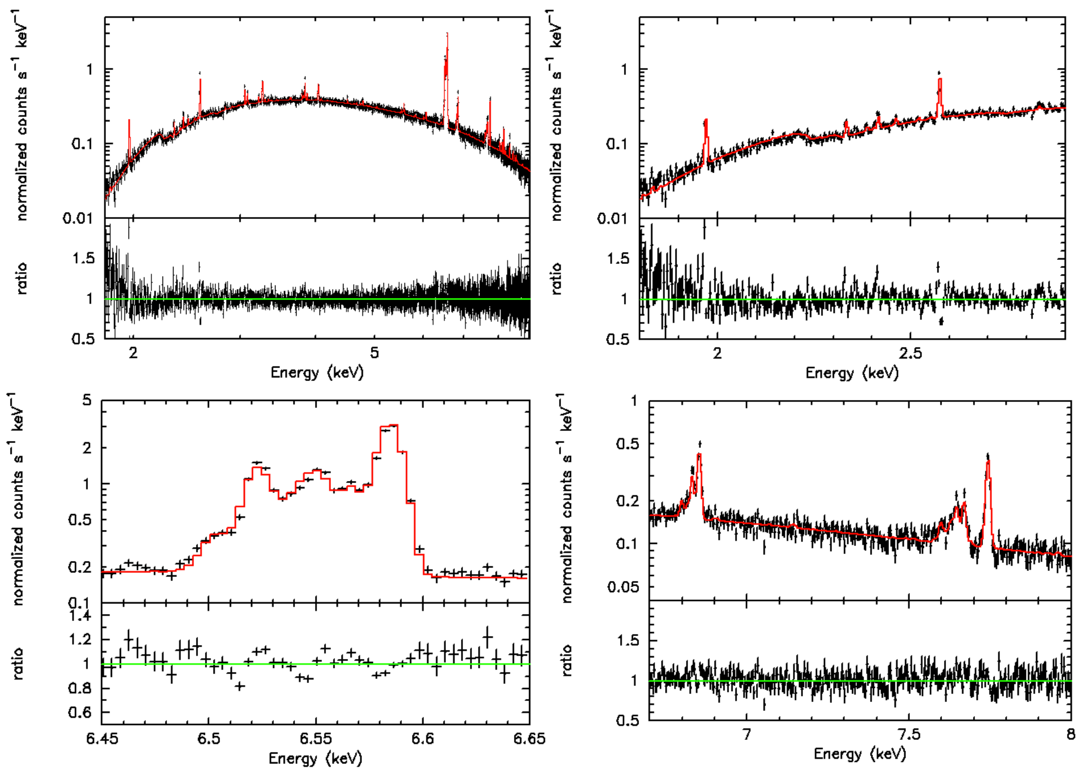


Figure 23: Fits to SXS spectra for the combined Perseus sequences 100040020, 100040030, 100040040, and 100040050 (upper left), with zooms to 1.8-2.9 keV (upper right), 6.45-6.64 keV (lower left), 6.7-8 keV (lower right).

(2) Fit the SXS spectrum in the 1.8-12 keV band with a model composed of an absorbed power-law representing the AGN and a broadened, single abundance thermal plasma model representing the ICM. The column densities and AGN power-law index are fixed following arXiv:1607.07420. The ARF derived from the XMM image is used here (and, as a result the fluxes correspond to the entire region encompassed by the image – which has ~3.5 times the flux as in the SXS FoV).

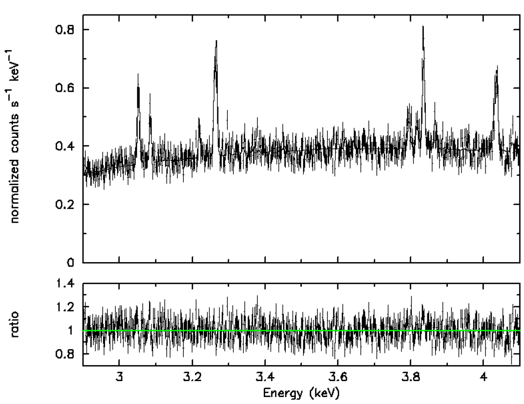
```
1 file 1 spectrum
Spectrum 1  Spectral Data File: ah100040023450sxs_p0px1010_cl2_HP.pi
```

```
Net count rate (cts/s) for Spectrum:1  1.737e+00 +/- 2.741e-03
 Assigned to Data Group 1 and Plot Group 1
  Noticed Channels:  902-5999
  Telescope: HITOMI Instrument: SXS  Channel Type: PI
  Exposure Time: 2.313e+05 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Response (RMF) File            ah100040023450_sxs_cl2_HP_small.rmf for
Source 1
 Using Auxiliary Response (ARF) File  ah100040023450sxs_p0px1010_xmmimg.arf

 Spectral data counts: 401827
 Model predicted rate: 1.73729


Current model list:

========================================================================
Model TBabs<1>*bapec<2> + TBabs<3>*powerlaw<4> Source No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
   1    1   TBabs      nH         10^22    0.138000     frozen
   2    2   bapec      kT         keV      3.87200      +/-  2.21631E-02
   3    2   bapec      Abundanc            0.637828     +/-  7.46285E-03
   4    2   bapec      Redshift            1.76736E-02  +/-  8.70097E-06
   5    2   bapec      Velocity   km/s     185.145      +/-  2.51813
   6    2   bapec      norm                0.529256     +/-  3.76068E-03
   7    3   TBabs      nH         10^22    0.330000     frozen
   8    4   powerlaw   PhoIndex            1.80000      frozen
   9    4   powerlaw   norm                2.49439E-02  +/-  8.92344E-04
________________________________________________________________________

   Using energies from responses.

Fit statistic : C-Statistic =       6139.288 using 5098 PHA bins and 5092
degrees of freedom.

Test statistic : Chi-Squared =       6874.022 using 5098 PHA bins.
 Reduced chi-squared =       1.349965 for   5092 degrees of freedom
 Null hypothesis probability =   1.556139e-57

***Warning: Chi-square may not be valid due to bins with zero variance
            in spectrum number(s): 1

 Weighting method: standard
```

(3) Fit the SXS spectrum in the 1.8-12 keV band with a model composed of an absorbed power-law representing the AGN and a broadened, single abundance thermal plasma model representing the ICM. The column densities and AGN power-law index are fixed following arXiv:1607.07420. The point-source ARF is used for the AGN component, and ARF derived from the beta model for the ICM.

```
1 file 1 spectrum
Spectrum 1  Spectral Data File: ah100040023450sxs_p0px1010_cl2_HP.pi
Net count rate (cts/s) for Spectrum:1  1.737e+00 +/- 2.741e-03
 Assigned to Data Group 1 and Plot Group 1
  Noticed Channels:  902-5999
  Telescope: HITOMI Instrument: SXS  Channel Type: PI
  Exposure Time: 2.313e+05 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Response (RMF) File            ah100040023450_sxs_cl2_HP_small.rmf for
```

```
Source 1
 Using Auxiliary Response (ARF) File  ah100040023450sxs_p0px1010_beta.arf
 Using Response (RMF) File            ah100040023450_sxs_cl2_HP_small.rmf for
Source 2
 Using Auxiliary Response (ARF) File  ah100040023450sxs_p0px1010_ptsrc.arf

 Spectral data counts: 401827
 Model predicted rate: 1.73729


Current model list:

========================================================================
Model TBabs<1>*bapec<2> Source No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
   1    1   TBabs      nH         10^22    0.138000     frozen
   2    2   bapec      kT         keV      3.88505      +/-  2.21499E-02
   3    2   bapec      Abundanc            0.633732     +/-  7.30348E-03
   4    2   bapec      Redshift            1.76740E-02  +/-  8.70021E-06
   5    2   bapec      Velocity   km/s     185.295      +/-  2.51659
   6    2   bapec      norm                0.485346     +/-  3.35451E-03
________________________________________________________________________


========================================================================
Model agn:TBabs<1>*powerlaw<2> Source No.: 2   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
   1    1   TBabs      nH         10^22    0.330000     frozen
   2    2   powerlaw   PhoIndex            1.80000      frozen
   3    2   powerlaw   norm                8.67254E-03  +/-  3.12955E-04
________________________________________________________________________

   Using energies from responses.

Fit statistic : C-Statistic =       6141.955 using 5098 PHA bins and 5092
degrees of freedom.

Test statistic : Chi-Squared =       6888.095 using 5098 PHA bins.
 Reduced chi-squared =       1.352729 for   5092 degrees of freedom
 Null hypothesis probability =   2.478201e-58

***Warning: Chi-square may not be valid due to bins with zero variance
            in spectrum number(s): 1

 Weighting method: standard
```



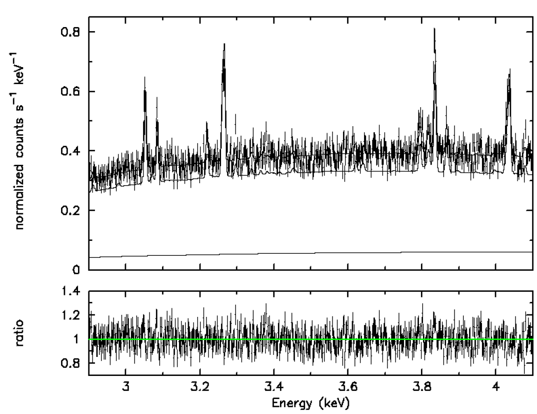


Figure 24: Fits to SXS spectra for the combined Perseus sequences 100040020, 100040030, 100040040, and 100040050 zoomed to the 2.9-4.1 keV band using the ARF derived from the XMM image (left), and the point-source ARF applied to the power-law, and the ARF derived from the beta model applied to the thermal plasma (right; with individual components).

(4) Jointly fit the SXI spectrum in the 0.8-12 keV band, and the SXS spectrum in the 1.8-12 keV band for Perseus sequence 100040060 with a model composed of an absorbed power-law representing the AGN and a broadened, single abundance thermal plasma model representing the ICM. The column densities and AGN power-law index are fixed as above, and the ARFs derived from the XMM image are used. A relative scaling of the SXS and SXI thermal components is introduced to account for the cross-calibration uncertainties – in both spectra the normalizations correspond to the fluxes normailized to the input image.

```
2 files 2 spectra
Spectrum 1  Spectral Data File: ah100040060sxs_p0px1010_cl2_HP.pi
Net count rate (cts/s) for Spectrum:1  1.948e+00 +/- 6.721e-03
 Assigned to Data Group 1 and Plot Group 1
  Noticed Channels:  902-5999
  Telescope: HITOMI Instrument: SXS  Channel Type: PI
  Exposure Time: 4.312e+04 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Response (RMF) File            ah100040060_sxs_cl2_HP_small.rmf for
Source 1
 Using Auxiliary Response (ARF) File  ah100040060sxs_p0px1010_xmmimg.arf

 Spectral data counts: 83990
 Model predicted rate: 1.94783

Spectrum 2  Spectral Data File: ah100040060sxi_cl.pi
Net count rate (cts/s) for Spectrum:2  2.461e+01 +/- 8.391e-02
 Assigned to Data Group 2 and Plot Group 2
  Noticed Channels:  135-1999
  Telescope: HITOMI Instrument: SXI  Channel Type: PI
  Exposure Time: 3495 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Response (RMF) File            ah100040060sxi_cl.rsp for Source 1

 Spectral data counts: 86022
 Model predicted rate: 24.6094


Current model list:

========================================================================
Model constant<1>*TBabs<2>*bapec<3>  + constant<4>*TBabs<5>*powerlaw<6> Source
No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
                           Data group: 1
   1    1   constant   factor              1.00000      frozen
   2    2   TBabs      nH         10^22    0.138000     frozen
   3    3   bapec      kT         keV      3.82403      +/-  3.58489E-02
   4    3   bapec      Abundanc            0.693909     +/-  1.53828E-02
   5    3   bapec      Redshift            1.75019E-02  +/-  1.83279E-05
   6    3   bapec      Velocity   km/s     180.144      +/-  5.36617
   7    3   bapec      norm                0.507472     +/-  7.22958E-03
   8    4   constant   factor              1.00000      = p1
   9    5   TBabs      nH         10^22    0.330000     frozen
  10    6   powerlaw   PhoIndex            1.80000      frozen
  11    6   powerlaw   norm                2.97461E-02  +/-  1.66712E-03
```

```
                              Data group: 2
  12    1    constant   factor                0.798375     +/-  4.86042E-03
  13    2    TBabs      nH          10^22     0.138000     = p2
  14    3    bapec      kT          keV       3.82403      = p3
  15    3    bapec      Abundanc              0.693909     = p4
  16    3    bapec      Redshift              1.75019E-02  = p5
  17    3    bapec      Velocity    km/s      180.144      = p6
  18    3    bapec      norm                  0.507472     = p7
  19    4    constant   factor                0.798375     = p12
  20    5    TBabs      nH          10^22     0.330000     = p9
  21    6    powerlaw   PhoIndex              1.80000      = p10
  22    6    powerlaw   norm                  2.97461E-02  = p11
________________________________________________________________________

   Using energies from responses.

Fit statistic : C-Statistic =       7691.375 using 6963 PHA bins and 6956
degrees of freedom.

Test statistic : Chi-Squared =       8065.189 using 6963 PHA bins.
 Reduced chi-squared =       1.159458 for    6956 degrees of freedom
 Null hypothesis probability =   1.752052e-19

***Warning: Chi-square may not be valid due to bins with zero variance
            in spectrum number(s): 1 2

 Weighting method: standard
```

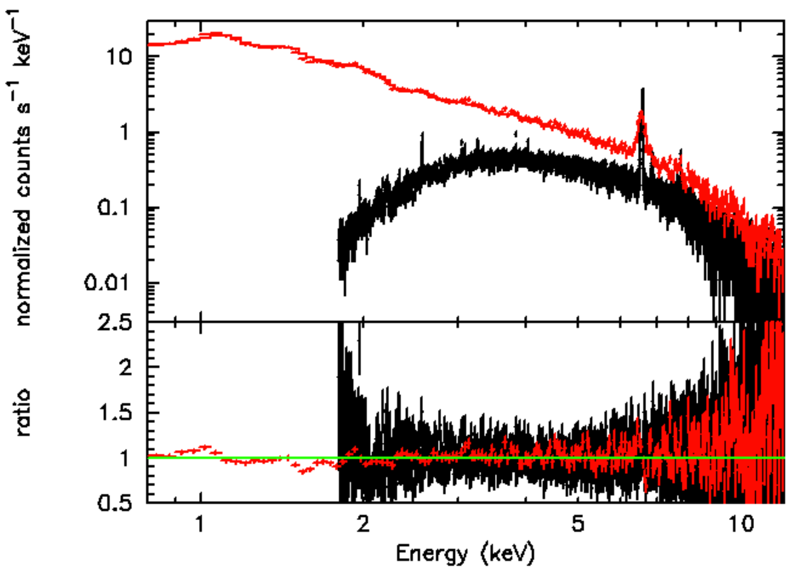


Figure 25: Joint SXI and SXS spectral fit for Perseus sequence 100040060.

Crab Nebula

Data description

Table 5	100044010
GEN-HK	ah100044010gen_a0.hk1.gz
TIM	ah100044010.tim.gz
ATTITUDE	ah100044010.att.gz

ORBIT	ah100044010.orb.gz
OBSGTI	ah100044010_gen.gti.gz
MKF	ah100044010.mkf.gz
EHK	ah100044010.ehk.gz
EHK2	ah100044010.ehk2.gz
HXI1 HK	ah100044010hx1_a0.hk.gz
HXI2 HK	ah100044010hx2_a0.hk.gz
HXI DELTA-ATT	ah100044010hx1.att.gz
HXI DELTA-ATT	ah100044010hx2.att.gz
HXI1 CAMS	ah100044010hx1_cms.fits.gz
HXI2 CAMS	ah100044010hx2_cms.fits.gz
HXI1 SFF	ah100044010hx1_p0camrec_uf.evt.gz
HXI2 SFF	ah100044010hx2_p0camrec_uf.evt.gz
HXI1 SFFa	ah100044010hx1_p0camrec_ufa.evt.gz
HXI2 SFFa	ah100044010hx2_p0camrec_ufa.evt.gz
HXI TEL	ah100044010hxi_tel.gti.gz
HXI1 PSEUDO	ah100044010hx1_p0camrecpse_cl.evt.gz
HXI2 PSEUDO	ah100044010hx2_p0camrecpse_cl.evt.gz
HXI1 EVT CL	ah100044010hx1_p0camrec_cl.evt.gz
HXI2 EVT CL	ah100044010hx2_p0camrec_cl.evt.gz
SGD TEL	ah100044010sgi_tel.gti.gz
SGD1 HK	ah100044010sg1_a0.hk.gz
SGD1 SFF	ah100044010sg1_p0cc1rec_uf.evt.gz ah100044010sg1_p0cc2rec_uf.evt.gz ah100044010sg1_p0cc3rec_uf.evt.gz
SGD1 SFFa	ah100044010sg1_p0cc1rec_ufa.evt.gz ah100044010sg1_p0cc2rec_ufa.evt.gz ah100044010sg1_p0cc3rec_ufa.evt.gz
SGD1 PSEUDO	ah100044010sg1_p0cc1recpse_cl.evt.gz ah100044010sg1_p0cc2recpse_cl.evt.gz ah100044010sg1_p0cc3recpse_cl.evt.gz
SGD1 EVT CL	ah100044010sg1_p0cc1rec_cl.evt.gz ah100044010sg1_p0cc2rec_cl.evt.gz ah100044010sg1_p0cc3rec_cl.evt.gz
SGD2 HK	ah100044010sg2_a0.hk.gz
SGD2 SFF	ah100044010sg2_p0cc1rec_uf.evt.gz ah100044010sg2_p0cc2rec_uf.evt.gz ah100044010sg2_p0cc3rec_uf.evt.gz
SGD2 SFFa	ah100044010sg2_p0cc1rec_ufa.evt.gz ah100044010sg2_p0cc2rec_ufa.evt.gz ah100044010sg2_p0cc3rec_ufa.evt.gz
SGD2 PSEUDO	ah100044010sg2_p0cc1recpse_cl.evt.gz ah100044010sg2_p0cc2recpse_cl.evt.gz ah100044010sg2_p0cc3recpse_cl.evt.gz
SGD2 EVT CL	ah100044010sg2_p0cc1rec_cl.evt.gz ah100044010sg2_p0cc2rec_cl.evt.gz ah100044010sg2_p0cc3rec_cl.evt.gz
SXI HK	ah100044010sxi_a0.hk.gz
SXI EVT UF	ah100044010sxi_p0112004e0_uf.evt.gz ah100044010sxi_p0120004e0_uf.evt.gz
SXI MZDYE EVT UF	ah100044010sxi_p0112004e1_uf.evt.gz ah100044010sxi_p0120004e1_uf.evt.gz
SXI HOTPIX	ah100044010sxi_a0112004e0.hpix.gz ah100044010sxi_a0120004e0.hpix.gz
SXI MZDYE HOTPIX	ah100044010sxi_a0112004e1.hpix.gz ah100044010sxi_a0120004e1.hpix.gz
SXI FLICKPIX	ah100044010sxi_a0112004e0.fpix.gz ah100044010sxi_a0120004e0.fpix.gz
SXI MZDYE FLICKPIX	ah100044010sxi_a0112004e1.fpix.gz ah100044010sxi_a0120004e1.fpix.gz
SXI BAD PIXEL IMG	ah100044010sxi_p0112004e0.bimg.gz ah100044010sxi_p0120004e0.bimg.gz
SXI MZDYE BAD PIXEL IMG	ah100044010sxi_p0112004e1.bimg.gz ah100044010sxi_p0120004e1.bimg.gz
SXI TEL	ah100044010sxi_tel.gti.gz
SXI EVT CL	ah100044010sxi_p0112004e0_cl.evt.gz ah100044010sxi_p0120004e0_cl.evt.gz
SXI MZDYE EVT CL	ah100044010sxi_p0112004e1_cl.evt.gz

	ah100044010sxi_p0120004e1_cl.evt.gz
SXS HK	ah100044010sxs_a0.hk1.gz
SXS ADR	ahsxs_adr.gti.gz
SXS AC EVT	ah100044010sxs_a0ac_uf.evt.gz
SXS PIX12 GAIN	ah100044010sxs_010_px12.ghf.gz
SXS PIX12 EVT	ah100044010sxs_a0px12010_uf.evt.gz
SXS EL GTI	ah100044010sxs_el.gti.gz
SXS TEL	ah100044010sxs_tel.gti.gz
SXS PIX GTI	ah100044010sxs_p0px1010.gti.gz
SXS PIX EXP	ah100044010sxs_p0px1010_exp.gti.gz
SXS PIX UF	ah100044010sxs_p0px1010_uf.evt.gz
SXS PIX CL	ah100044010sxs_p0px1010_cl.evt.gz

a) Untar in a directory `/full/path/to/data/`.

Additional Files

Additional text files for analysis are as follows, and are shown in detail as they are used or created.

- standard (and other) extraction region files (place in dir `/full/path/to/regions`)
  - region_HXI_100044010.reg
  - region_SXI_100044010.reg
  - region_SXI_100044010_src.reg
  - region_SXI_100044010_bkg.reg
  - region_SXI_100044010_oot.reg
  - ah100044010sxs_region_SXS_det.reg

- HXI lists of gti used for deadtime correction
  - ah100044010hx1_p0camrecpse_cl.gti.lst
  - ah100044010hx2_p0camrecpse_cl.gti.lst
  - ah100044010hx1_p0camrec_cl.gti.lst
  - ah100044010hx2_p0camrec_cl.gti.lst

NOTE on regions files:

i) 3 arcmin circle (SKY coordinates) for HXI1 and HXI2
i) 2.5 arcmin circle (SKY coordinates) for SXI (region_SXI_100044010.reg) used for sxsregext
ii) 5.3-by-9.13 arcminute box along the read-out streak (SKY coordinates) for SXI source
(region_SXI_100044010_oot.reg)
iii) 9.13-by-9.13 arcminute box (SKY coordinates) for SXI background
(region_SXI_100044010_bkg.reg)
iv) 5.3-by-5.3 arcminute box (SKY coordinates) for SXI arf (region_SXI_100044010_src.reg)
v) Full array (except pixel 12) for SXS (expressed in DET coordinates)

The HXI region centers are determined by estimating the SKY coordinates of the source in the SXI image, and not on the catalog source coordinates.

Note on this sequence.

The SGD2 cleaned event files for sequence `100044010` have about an order of magnitude fewer events than the SGD1 cleaned event file due to mkf screening. Only the SGD1 steps are shown here; however, the SGD2 steps may proceed identically althought only the CC1 has useful data. For the SXI, the `ah100044010sxi_p0112004e0_cl.evt.gz` event file has the data from the two CCDs that include the aimpoint. This observations was performed with these CCDs operating in full window + 0.1 sec burst mode. Data from the other two CCDs are in `ah100044010sxi_p0120004e0_cl.evt.gz`, operated in normal full window mode, and are not useful in the Crab data analysis. The event lists

`ah100044010sxi_p0112004e1_cl.evt.gz` and
`ah100044010sxi_p0120004e1_cl.evt.gz` are in MZDYE mode and are not useful for scientific analysis.

Non-Instrument Specific Processing

ahcalctime

100044010

(1) Recalculate time for HK and unfiltered event files

```
ahcalctime indir=data/100044010 outdir=data/100044010_ahcalctime_output
verify_input=no sorttime=yes timecol=TIME clobber=yes

mv *log data/100044010_ahcalctime_output
cp ~/pfiles/ahcalctime.par data/100044010_ahcalctime_output
```

ahpipeline

(1) Recalibrate and rescreen data for all instruments using ahpipeline

```
ahpipeline indir=data/100044010 outdir=data/100044010_output
steminputs=ah100044010 stemoutputs=DEFAULT entry_stage=1 exit_stage=2
instrument=ALL verify_input=no create_ehkmkf=yes seed=7 clobber=yes chatter=2
mode=hl

mkdir data/100044010_output/logs
mv *.log data/100044010_output/logs
```

Instrument Specific Reprocessing

100044010

(1) Recalibrate and rescreen SXS data for with a shorter proximity timescale using ahpipeline

Since the standard criteria for screening events across the SXS array in close time proximity would exclude a significant fraction of source X-rays, the usual proximity (STATUS[4] flag) screening is skipped for the
Crab nebula cleaned SXS event file (see below). Alternatively, one may reprocess the data with a tighter
proximity time window, as follows, and subsequently apply such a STATUS[4] screening.

```
ahpipeline indir=data/100044010 outdir=data/100044010_sxs_repro_delprox
steminputs=ah100044010 stemoutputs=DEFAULT entry_stage=1 exit_stage=2
instrument=SXS verify_input=no create_ehkmkf=yes seed=7 clobber=yes chatter=2
mode=hl proxdt=2.4e-4

mkdir data/100044010_repro/logs
mv *.log data/100044010_repro/logs
```

In general, instrument-specific reprocessing may be applied using ahpipeline by changing the `instrument` parameter from `ALL` to `HX,SGD,SXI,` or `SXS` or by running the individual instrument pipelines as illustrated by numerous examples in the section on sequence `1000500020` (G21.5-0.9).

Extracting Products

This section details tools to run on cleaned event files to get instrument specific data products. These may be applied to the original cleaned event files from the pipeline, or to new cleaned event files created using the steps in the last section. In what follows, the original pipeline cleaned event files are used. The extraction region files described above are assumed to be in the `regions` directory.

100044010

HXI

All newly created output files in this section are placed in the /full/path/to/data/hxi_products directory

```
cd /full/path/

mkdir data/products_hxi

cd data/products_hxi
```

(1) Extract source spectra and light curves using xselect

The content of the region file used here, `../../regions/region_HXI_100044010.reg`, is

```
# Region file format: DS9 version 4.1
fk5
circle(83.6319,22.0188,180") # color=white font="helvetica 30 normal "
```

The HXI data for this sequence is split into two parts, and are combined accordingly below.

HXI1

```
xselect
xsel:SUZAKU > read events
../100044010/hxi/event_cl/ah100044010hx1_p1camrec_cl.evt.gz
xsel:SUZAKU > read events
../100044010/hxi/event_cl/ah100044010hx1_p2camrec_cl.evt.gz
xsel:HITOMI-HXI1-CAMERA_NORMAL2 > extract events
xsel:HITOMI-HXI1-CAMERA_NORMAL2 > save events ah100044010hx1_p0camrec_cl.evt
xsel:HITOMI-HXI1-CAMERA_NORMAL2 > filter region
../../regions/region_HXI_100044010.reg
xsel:HITOMI-HXI1-CAMERA_NORMAL2 > extract spectrum
xsel:HITOMI-HXI1-CAMERA_NORMAL2 > save spectrum ah100044010hx1_p0camrec_cl.pi
xsel:HITOMI-HXI1-CAMERA_NORMAL2 > plot spectrum
xsel:HITOMI-HXI1-CAMERA_NORMAL2 > extract curve
xsel:HITOMI-HXI1-CAMERA_NORMAL2 > save curve ah100044010hx1_p0camrec_cl.lc
xsel:HITOMI-HXI1-CAMERA_NORMAL2 > plot curve
```

HXI2

```
xselect
xsel:SUZAKU > read events
../100044010/hxi/event_cl/ah100044010hx2_p1camrec_cl.evt.gz
xsel:SUZAKU > read events
../100044010/hxi/event_cl/ah100044010hx2_p2camrec_cl.evt.gz
```

```
xsel:HITOMI-HXI2-CAMERA_NORMAL2 > extract events
xsel:HITOMI-HXI2-CAMERA_NORMAL2 > save events ah100044010hx2_p0camrec_cl.evt
xsel:HITOMI-HXI2-CAMERA_NORMAL2 > filter region
../../regions/region_HXI_100044010.reg
xsel:HITOMI-HXI2-CAMERA_NORMAL2 > extract spectrum
xsel:HITOMI-HXI2-CAMERA_NORMAL2 > save spectrum ah100044010hx2_p0camrec_cl.pi
xsel:HITOMI-HXI2-CAMERA_NORMAL2 > plot spectrum
xsel:HITOMI-HXI2-CAMERA_NORMAL2 > extract curve
xsel:HITOMI-HXI2-CAMERA_NORMAL2 > save curve ah100044010hx2_p0camrec_cl.lc
xsel:HITOMI-HXI2-CAMERA_NORMAL2 > plot curve
```

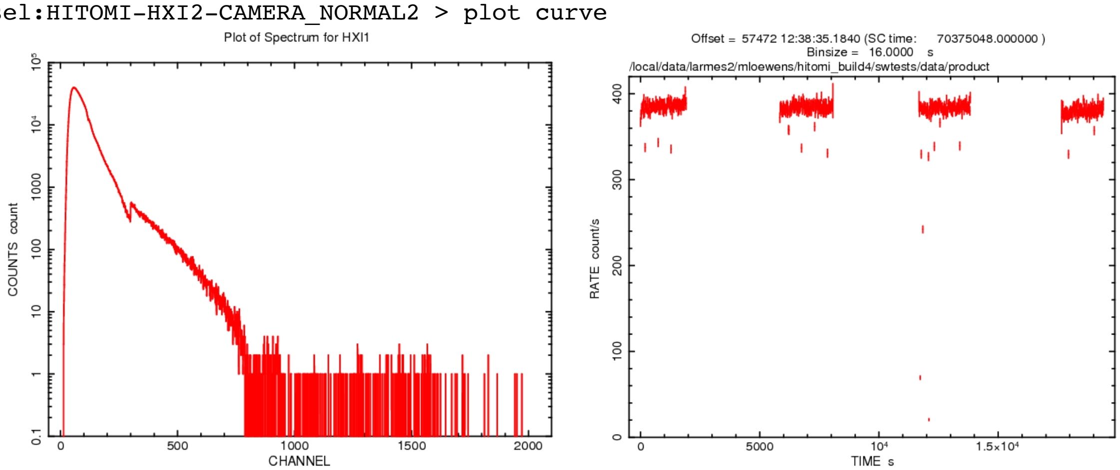


Figure 26: HXI1 source spectrum and lightcurve for sequence 100044010

(2) Construct the dead-time corrected source and background spectra using xselect, hxisgddtime, and ahgtigen

HXI1

(a) Merge the pseudo-event files, including their GTI extensions:

```
ftmerge
"../100044010/hxi/event_cl/ah100044010hx1_p1camrecpse_cl.evt.gz,../100044010/hx
i/event_cl/ah100044010hx1_p2camrecpse_cl.evt" ah100044010hx1_p0camrecpse_cl.evt

ahgtigen infile=NONE outfile=ah100044010hx1_p0camrecpse_cl.gti
gtifile=@ah100044010hx1_p0camrecpse_cl.lst gtiexpr=NONE mergegti=OR
```

where `ah100044010hx1_p0camrecpse_cl.lst` is a text file listing all pseudo event file GTI extensions:

```
../100044010/hxi/event_cl/ah100044010hx1_p1camrecpse_cl.evt.gz+2
../100044010/hxi/event_cl/ah100044010hx1_p2camrecpse_cl.evt.gz+2

ftdelhdu ah100044010hx1_p0camrecpse_cl.evt+2 none confirm=YES

ftappend ah100044010hx1_p0camrecpse_cl.gti+1  ah100044010hx1_p0camrecpse_cl.evt
```

(b) Merge the event file GTI extensions:

```
ahgtigen infile=NONE outfile=ah100044010hx1_p0camrec_cl.gti
gtifile=@ah100044010hx1_p0camrec_cl.lst gtiexpr=NONE mergegti=OR
```

where `ah100044010hx1_p0camrec_cl.lst` is a text file listing all GTI extensions:

```
../100044010/hxi/event_cl/ah100044010hx1_p1camrec_cl.evt.gz+2
../100044010/hxi/event_cl/ah100044010hx1_p2camrec_cl.evt.gz+2
```

```
fthedit ah100044010hx1_p0camrec_cl.gti+1 INSTRUME a HXI1
fthedit ah100044010hx1_p0camrec_cl.gti+1 DETNAM a CAMERA
```

(c) Apply the deadtime correction to the merged source and background spectra and lightcurves, using the merged pseudo-event and event GTI files:

```
hxisgddtime infile=ah100044010hx1_p0camrecpse_cl.evt
inlcfile=ah100044010hx1_p0camrec_cl.lc inspecfile=ah100044010hx1_p0camrec_cl.pi
outlcfile=ah100044010hx1_p1camrec_dtime.lc
outfile=ah100044010hx1_p0camrec_dtime.pi
gtifile=ah100044010hx1_p0camrec_cl.gti

mv hxisgddtime.log hxisgddtime_ah100044010hx1.log
```

HXI2

(a) Merge the pseudo-event files, including their GTI extensions:

```
ftmerge
"../100044010/hxi/event_cl/ah100044010hx2_p1camrecpse_cl.evt.gz,../100044010/hx
i/event_cl/ah100044010hx2_p2camrecpse_cl.evt" ah100044010hx2_p0camrecpse_cl.evt

ahgtigen infile=NONE outfile=ah100044010hx2_p0camrecpse_cl.gti
gtifile=@ah100044010hx2_p0camrecpse_cl.lst gtiexpr=NONE mergegti=OR
```

where `ah100044010hx2_p0camrecpse_cl.lst` is a text file listing all pseudo event file GTI extensions:

```
../100044010/hxi/event_cl/ah100044010hx2_p1camrecpse_cl.evt.gz+2
../100044010/hxi/event_cl/ah100044010hx2_p2camrecpse_cl.evt.gz+2

ftdelhdu ah100044010hx2_p0camrecpse_cl.evt+2 none confirm=YES

ftappend ah100044010hx2_p0camrecpse_cl.gti+1  ah100044010hx2_p0camrecpse_cl.evt
```

(b) Merge the event file GTI extensions:

```
ahgtigen infile=NONE outfile=ah100044010hx2_p0camrec_cl.gti
gtifile=@ah100044010hx2_p0camrec_cl.lst gtiexpr=NONE mergegti=OR
```

where `ah100044010hx2_p0camrec_cl.lst` is a text file listing all GTI extensions:

```
../100044010/hxi/event_cl/ah100044010hx2_p1camrec_cl.evt.gz+2
../100044010/hxi/event_cl/ah100044010hx2_p2camrec_cl.evt.gz+2

fthedit ah100044010hx2_p0camrec_cl.gti+1 INSTRUME a HXI2
fthedit ah100044010hx2_p0camrec_cl.gti+1 DETNAM a CAMERA
```

(c) Apply the deadtime correction to the merged source and background spectra and lightcurves, using the merged pseudo-event and event GTI files:

```
hxisgddtime infile=ah100044010hx2_p0camrecpse_cl.evt
inlcfile=ah100044010hx2_p0camrec_cl.lc inspecfile=ah100044010hx2_p0camrec_cl.pi
outlcfile=ah100044010hx2_p1camrec_dtime.lc
outfile=ah100044010hx2_p0camrec_dtime.pi
gtifile=ah100044010hx2_p0camrec_cl.gti

mv hxisgddtime.log hxisgddtime_ah100044010hx2.log
```

(3) Apply barycenter corrections for light curves

```
barycen infile=ah100044010hx1_p0camrec_dtime.lc
outfile=ah100044010hx1_p0camrec_dtime_add_bary.lc
orbfile=../100044010/auxil/ah100044010.orb.gz ra=83.633 dec=22.0145
orbext=ORBIT chatter=2 clobber=yes

mv barycen.log barycen_ah100044010hx1.log

barycen infile=data/products_hxi/ah100044010hx2_p0camrec_dtime.lc
outfile=data/products_hxi/ah100044010hx2_p0camrec_dtime_add_bary.lc
orbfile=data/100044010/auxil/ah100044010.orb.gz ra=83.633 dec=22.0145
orbext=ORBIT chatter=2 clobber=yes

mv barycen.log barycen_ah100044010hx2.log
```

Note that the `ra` and `dec` parameters are set here to the object coordinates as an approximation of the true average pointing direction; this setting can be refined by generating and examining the exposure map (see below).

The barycenter correction may also be applied to event files.

(4) Extract the deadtime corrected HXI NXB spectra

Run the the task `hxinxbgen` with the cleaned event file, identical region used for source spectrum extraction, the cleaned versions of the NXB event files, `ah_hx1[2]_nxbevtcl2_20140101v001.evt`, and the cleaned versions of the NXB pseudo-event files, `ah_hx1[2]_nxbpsecl_20140101v001.evt`, as input. If instead additional, or non-standard, screening is used in the source spectra extraction the uncleaned versions of the NXB event and pseudo-event files, `ah_hx1[2]_nxbevtuf_20140101v001.evt` and `ah_hx1[2]_nxbpseuf_20140101v001.evt`, must be screened in the same way, with gti filtering based on the columns in `ah_hxi_nxbmkf_20140101v001.fits`, and then input into `hxinxbgen`.

The input NXB event and pseudo files include an extra SAA screening,

```
ahscreen ah_hx1_nxbevtcl_20140101v001.evt
outfile=ah_hx1_nxbevtcl2_20140101v001.evt gtifile=@ah_hx1_nxbsaa.txt
expr=NONE mergegti=AND selectfile=NONE label=NONE cpkeyword=all clobber=yes

ahscreen ah_hx2_nxbevtcl_20140101v001.evt
outfile=ah_hx12_nxbevtcl2_20140101v001.evt gtifile=@ah_hx2_nxbsaa.txt
expr=NONE mergegti=AND selectfile=NONE label=NONE cpkeyword=all clobber=yes
```

where `ah_hx1_nxbsaa.txt` is composed of

```
ah_hx1_nxbsaa_20140101v001.gti+1
ah_hx1_nxbevtcl_20140101v001.evt+2
```

and `ah_hx2_nxbsaa.txt` is composed of

```
ah_hx2_nxbsaa_20140101v001.gti+1
ah_hx2_nxbevtcl_20140101v001.evt+2

ahscreen ah_hx1_nxbpsecl_20140101v001.evt
outfile=ah_hx1_nxbpsecl2_20140101v001.evt gtifile=@ah_hx1_nxbpsesaa.txt
expr=NONE mergegti=AND selectfile=NONE label=NONE cpkeyword=all clobber=yes

ahscreen ah_hx2_nxbpsecl_20140101v001.evt
outfile=ah_hx12_nxbpsecl2_20140101v001.evt gtifile=@ah_hx2_nxbpsesaa.txt
expr=NONE mergegti=AND selectfile=NONE label=NONE cpkeyword=all clobber=yes
```

where `ah_hx1_nxbpsesaa.txt` is composed of

```
ah_hx1_nxbsaa_20140101v001.gti+1
ah_hx1_nxbpsecl_20140101v001.evt+2
```

and `ah_hx2_nxbsaa.txt` is composed of

```
ah_hx2_nxbsaa_20140101v001.gti+1
ah_hx2_nxbpsecl_20140101v001.evt+2
```

Xselect may also be uses as follows:

```
xselect
xsel:SUZAKU > read events ah_hx1_nxbevtcl_20140101v001.evt
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > filter time file
ah_hx1_nxbsaa_20140101v001.gti
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > save events ah_hx1_nxbevtcl2_20140101v001.evt

xselect
xsel:SUZAKU > read events ah_hx2_nxbevtcl_20140101v001.evt
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > filter time file
ah_hx2_nxbsaa_20140101v001.gti
xsel:HITOMI-HXI1-CAMERA_NORMAL1 > save events ah_hx2_nxbevtcl2_20140101v001.evt
```

The merged NXB event (without SAA screening), ehk, and mkf, and gti file for additional SAA screening files are located in the hitomi url,

https://heasarc.gsfc.nasa.gov/FTP/hitomi/data/nxb_20170510/

Note that, for `regmode=SKY`, the region must be defined in sky (not RADEC) coordnates, e.g.,

```
# Region file format: DS9 version 4.1
physical
circle(1218.3653,1226.8057,101.66966) # font="helvetica 30 normal "
```

Conversion from RADEC to sky may be done in `ds9`, or using `coordpnt`

HXI1

```
hxinxbgen infile=ah100044010hx1_p0camrec_cl.evt
ehkfile=../100044010/auxil/ah100044010.ehk.gz
innxbfile=ah_hx1_nxbevtcl2_20140101v001.evt
inpsefile=ah_hx1_nxbpsecl_20140101v001.evt
innxbehk=ah_gen_nxbehk_20140101v002.fits
outpifile=ah100044010hx1nxb_p0camrec_cl.pi regmode=SKY
regfile=region_HXI_100044010_sky.reg cleanup=yes chatter=3 clobber=yes mode=hl
logfile=ah100044010hx1nxb_p0camrec_cl.log sortbin=0,6,7,8,9,10,11,12,13,99
```

HXI2

```
hxinxbgen infile=ah100044010hx2_p0camrec_cl.evt
ehkfile=../100044010/auxil/ah100044010.ehk.gz
innxbfile=ah_hx2_nxbevtcl_20140101v001.evt
inpsefile=ah_hx2_nxbpsecl2_20140101v001.evt
innxbehk=ah_gen_nxbehk_20140101v002.fits
outpifile=ah100044010hx2nxb_p0camrec_cl.pi regmode=SKY
regfile=../../regions/region_HXI_100044010.reg cleanup=yes chatter=3
clobber=yes mode=hl logfile=ah100044010hx2nxb_p0camrec_cl.log
sortbin=0,6,7,8,9,10,11,12,13,99
```

SGD

All newly created output files in this section are placed in the /full/path/to/data/sgd_products directory

```
cd /full/path/
```

```
mkdir data/products_sgd
```

```
cd data/products_sgd
```

(1) Apply additional screening to the reprocessed event files

For data version V03.01.006.008 , calibrated with probfovfile=ah_sgd_probfovfile_20140101v002.fits, the following additional screening step must be applied.

```
ftselect infile='../100044010/ah100044010sg1_p0cc1rec_cl.evt[events]'
outfile=ah100044010sg1_p0cc1rec_cl2.evt expression="OFFAXIS <= 30.0 && OFFAXIS
>= -30.0 && CAMERAX>-27 && CAMERAX<27 && CAMERAY>-27 && CAMERAY<27 && CAMERAZ>-
56 && (COMPTON_TH-OFFAXIS) >= 50 && (COMPTON_TH-OFFAXIS) <= 150"
```

```
ftselect infile='../100044010/ah100044010sg1_p0cc2rec_cl.evt[events]'
outfile=ah100044010sg1_p0cc2rec_cl2.evt expression="OFFAXIS<=30.0&&OFFAXIS>=-
30.0" && CAMERAX>-27 && CAMERAX<27 && CAMERAY>-27 && CAMERAY<27 && CAMERAZ>-56
&& (COMPTON_TH-OFFAXIS) >= 50 && (COMPTON_TH-OFFAXIS) <= 150"
```

```
ftselect infile='../100044010/ah100044010sg1_p0cc3rec_cl.evt[events]'
outfile=ah100044010sg1_p0cc3rec_cl2.evt expression="OFFAXIS<=30.0&&OFFAXIS>=-
30.0" && CAMERAX>-27 && CAMERAX<27 && CAMERAY>-27 && CAMERAY<27 && CAMERAZ>-56
&& (COMPTON_TH-OFFAXIS) >= 50 && (COMPTON_TH-OFFAXIS) <= 150"
```

```
ftselect infile='../100044010/ah100044010sg2_p0cc1rec_cl.evt[events]'
outfile=ah100044010sg2_p0cc1rec_cl2.evt expression="OFFAXIS<=30.0&&OFFAXIS>=-
30.0" && CAMERAX>-27 && CAMERAX<27 && CAMERAY>-27 && CAMERAY<27 && CAMERAZ>-56
&& (COMPTON_TH-OFFAXIS) >= 50 && (COMPTON_TH-OFFAXIS) <= 150"
```

Note for SGD2 only CC1 should be screened.

(2) Extract source spectrum and light curves, summed over all Comption cameras, using xselect

SGD1

```
xselect
xsel:SUZAKU > read events ah100044010sg1_p0cc1rec_cl2.evt
xsel:HITOMI-SGD1-CC_NORMAL1 > read events ah100044010sg1_p0cc2rec_cl2.evt
xsel:HITOMI-SGD1-CC_NORMAL1 > read events ah100044010sg1_p0cc3rec_cl2.evt
xsel:HITOMI-SGD1-CC_NORMAL1 > extract events
xsel:HITOMI-SGD1-CC_NORMAL1 > save events ah100044010sg1_p0ccALLrec_cl2.evt
xsel:HITOMI-SGD1-CC_NORMAL1 > extract spectrum
xsel:HITOMI-SGD1-CC_NORMAL1 > plot spectrum
xsel:HITOMI-SGD1-CC_NORMAL1 > save spectrum ah100044010sg1_p0ccALLrec_cl2.pi
xsel:HITOMI-SGD1-CC_NORMAL1 > extract curve
xsel:HITOMI-SGD1-CC_NORMAL1 > plot cu
xsel:HITOMI-SGD1-CC_NORMAL1 > save curve ah100044010sg1_p0ccALLrec_cl2.lc
```

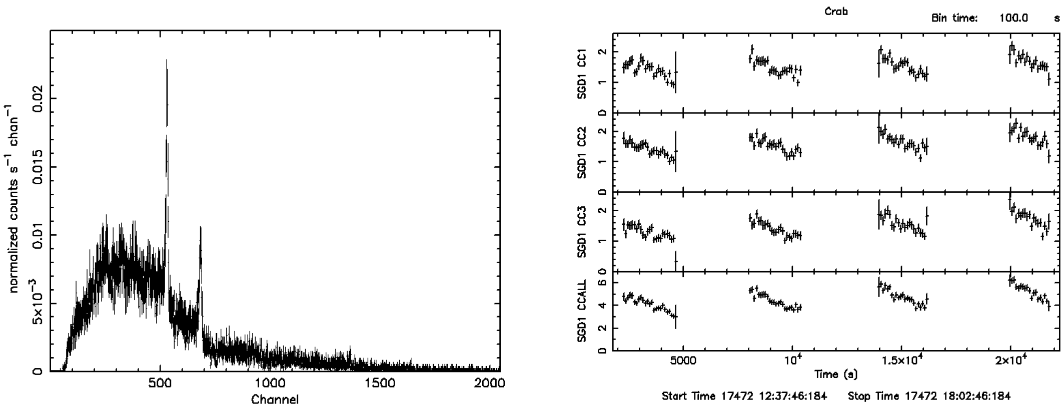


Figure 27: SGD1 source spectrum (left) and lightcurve (right) for sequence 100044010 plotted using XSPEC and XRONOS (lcurve).

(3) Run hxisgddtime to correct the spectrum and light curve for dead time

SGD1

First, extract the spectrum and light curve for each individual camera.

```
xselect
xsel:SUZAKU > read events ah100044010sg1_p0cc1rec_cl2.evt
xsel:HITOMI-SGD1-CC_NORMAL1 > extract spectrum
xsel:HITOMI-SGD1-CC_NORMAL1 > save spectrum ah100044010sg1_p0cc1rec_cl2.pi
xsel:HITOMI-SGD1-CC_NORMAL1 > extract curve
xsel:HITOMI-SGD1-CC_NORMAL1 > save curve ah100044010sg1_p0cc1rec_cl2.lc
xsel:HITOMI-SGD1-CC_NORMAL1 > clear all
xsel:HITOMI-SGD1-CC_NORMAL1 > read events ah100044010sg1_p0cc2rec_cl2.ev
xsel:HITOMI-SGD1-CC_NORMAL1 > extract spectrum
xsel:HITOMI-SGD1-CC_NORMAL1 > save spectrum ah100044010sg1_p0cc2rec_cl2.pi
xsel:HITOMI-SGD1-CC_NORMAL1 > extract curve
xsel:HITOMI-SGD1-CC_NORMAL1 > save curve ah100044010sg1_p0cc2rec_cl2.lc
xsel:HITOMI-SGD1-CC_NORMAL1 > clear all
xsel:HITOMI-SGD1-CC_NORMAL1 > read events ah100044010sg1_p0cc3rec_cl2.evt
xsel:HITOMI-SGD1-CC_NORMAL1 > extract spectrum
xsel:HITOMI-SGD1-CC_NORMAL1 > save spectrum ah100044010sg1_p0cc3rec_cl2.pi
xsel:HITOMI-SGD1-CC_NORMAL1 > extract
xsel:HITOMI-SGD1-CC_NORMAL1 > save curve ah100044010sg1_p0cc3rec_cl2.lc
xsel:HITOMI-SGD1-CC_NORMAL1 > read events ah100044010sg2_p0cc1rec_cl2.evt
xsel:HITOMI-SGD2-CC_NORMAL1 > extract spectrum
xsel:HITOMI-SGD2-CC_NORMAL1 > save spectrum ah100044010sg2_p0cc1rec_cl2.pi
xsel:HITOMI-SGD2-CC_NORMAL1 > extract
xsel:HITOMI-SGD2-CC_NORMAL1 > save curve ah100044010sg2_p0cc1rec_cl2.lc
```

To apply the deadtime correction to each camera normally would be necessary to run the tool `hxisgddtime` however since the observation has a special setting the final exposure corrected by dead time is calculated differently. The user has to manually change the EXPOSURE keyword in the spectral file and set their values to the following :

```
SGD1 CC1 = 4939.5
SGD1 CC2 = 4739.0
SGD1 CC3 = 4939.5
SGD2 CC1 = 5226.3
```

Add the individual spectra, and add the keywords needed by *sgdarfgen* read from the header of any of the individual spectra (identified using `fkeyprint`), and with the EXPOSURE set to the average of the three individual spectra. Using just the SGD1 spectra the average exposure is 4872.7 and the mathpha commands is:

```
mathpha
expr=ah100044010sg1_p0cc1rec_dtime.pi+ah100044010sg1_p0cc2rec_dtime.pi+ah100044
010sg1_p0cc3rec_dtime.pi units=C outfil=ah100044010sg1_p0ccALLrec_dtime.pi
exposure=4872.7 areascal=% backscal=% ncomments=0
```

If also the SGD2 CC1 is added in mathpha the average expsore is 4961.1

```
fthedit ah100044010sg1_p0ccALLrec_dtime.pi+1 RA_NOM a 83.6348495483012
fthedit ah100044010sg1_p0ccALLrec_dtime.pi+1 DEC_NOM a 22.0146021574681
fthedit ah100044010sg1_p0ccALLrec_dtime.pi+1 PA_NOM a 267.721269104422
fthedit ah100044010sg1_p0ccALLrec_dtime.pi+1 DATE-OBS a 2016-03-25T12:35:48
```

To subtract the background since there are no enough observations to create the sgd in-orbit background, the background is obtained using the observation 100043060 that occurred one day before of the Crab observation at the similar satellite orbits. To extract the background spectra first the event files need to be selected for the special GTI crab_24before.gti file (located at https://heasarc.gsfc.nasa.gov/FTP/hitomi/data/nxb_2017051) and after extract the spectra for each of the camera using xselect similarly to the commands applied to the sequence `100044010` at the beginning of this section.

Change the EXPOSURE keywords of the background spectra with the following values :
SGD1 CC1 = 5299.5
SGD1 CC2 = 5273.0
SGD1 CC3 = 5268.5
SGD2 CC1 = 5265.4

Using just the SGD1 spectra the average exposure is 5280.3 and the mathpha commands is:

```
mathpha
expr=ah100043060sg1_p0cc1rec_dtime.pi+ah100043060sg1_p0cc2rec_dtime.pi+ah100
043060sg1_p0cc3rec_dtime.pi units=C outfil=ah100043060sg1_p0ccALLrec_dtime.pi
exposure=5280.3 areascal=% backscal=% ncomments=0
```

If also the SGD2 CC1 is added in mathpha the average expsore is 5276.6.

SXI

All newly created output files in this section are placed in the /full/path/to/data/sxi_products directory<

```
cd /full/path/

mkdir data/products_sxi

cd data/products_sxi
```

The scientifically useful cleaned SXI event files for sequence `100044010` is the Normal mode file, taken in full window + 0.1 sec burst:

```
../100044010/sxi/event_cl/ah100044010sxi_p0112004e0_cl.evt.gz.
```

To circumvent pileup effects, the source spectrum is extracted from the Crab out-of-time region, a box along the read-out streak, `../../regions/region_SXI_100044010_oot.reg`

```
# Region file written by coordpnt.
fk5
+box(83.62536427d,22.19582148d,0.08839920d,0.15224307d,357.56141429)
```

The background region, `../../regions/region_SXI_100044010_bkg.reg` is a box elsewhere on the same CCD, away from the source and read-out streak,

```
# Region file written by coordpnt.
fk5
+box(83.82674779d,22.20364969d,0.15224307d,0.15224307d,357.56141429) # Region file
written by coordpnt.
```

A separate source extraction region centered on the aimpoint ,
`../../regions/region_SXI_100044010_src.reg,`

```
# Region file written by coordpnt.
fk5
+box(83.63342287d,22.02065536d,0.08839920d,0.08839920d,357.56141429)
```

is used here only to create the ARF.

An exposure time correction factor must be applied for the out-of-time spectrum. This factor is the ratio of the integration time in the readout streak (310 rows x 57.6 μsec/row = 17.8 msec) to the exposure time per frame (60.5952 msec), or 0.2947. It is applied as a fixed multiplicative constant to the spectral model (see below).

(1) Extract image, spectrum, and light curve using xselect

```
xselect
xsel:SUZAKU > read events
../100044010/sxi/event_cl/ah100044010sxi_p0112004e0_cl.evt.gz
xsel:HITOMI-SXI-WINDOW1 > filter pha_cutoff 83 1333
xsel:HITOMI-SXI-WINDOW1 > set xybin 4
xsel:HITOMI-SXI-WINDOW1 > extract image
xsel:HITOMI-SXI-WINDOW1 > save image ah100044010sxi_p0112004e0_cl.img
xsel:HITOMI-SXI-WINDOW1 > plot image
xsel:HITOMI-SXI-WINDOW1 > clear pha_cutoff
xsel:HITOMI-SXI-WINDOW1 > filter region
../../regions/region_SXI_100044010_oot.reg
xsel:HITOMI-SXI-WINDOW1 > extract spectrum
xsel:HITOMI-SXI-WINDOW1 > save spectrum ah100044010sxi_p0112004e0_cl.pi
xsel:HITOMI-SXI-WINDOW1 > plot spectrum
xsel:HITOMI-SXI-WINDOW1 > extract curve exposure=0.0
xsel:HITOMI-SXI-WINDOW1 > save curve ah100044010sxi_p0112004e0_cl.lc
xsel:HITOMI-SXI-WINDOW1 > plot curve
xsel:HITOMI-SXI-WINDOW1 > clear region
xsel:HITOMI-SXI-WINDOW1 > filter region
../../regions/region_SXI_100044010_bkg.reg
xsel:HITOMI-SXI-WINDOW1 > extract spectrum
xsel:HITOMI-SXI-WINDOW1 > save spectrum ah100044010sxi_p0112004e0_cl_bg.pi
xsel:HITOMI-SXI-WINDOW1 > plot spectrum
xsel:HITOMI-SXI-WINDOW1 > extract curve exposure=0.0
xsel:HITOMI-SXI-WINDOW1 > save curve ah100044010sxi_p0112004e0_cl_bg.lc
xsel:HITOMI-SXI-WINDOW1 > plot curve
```

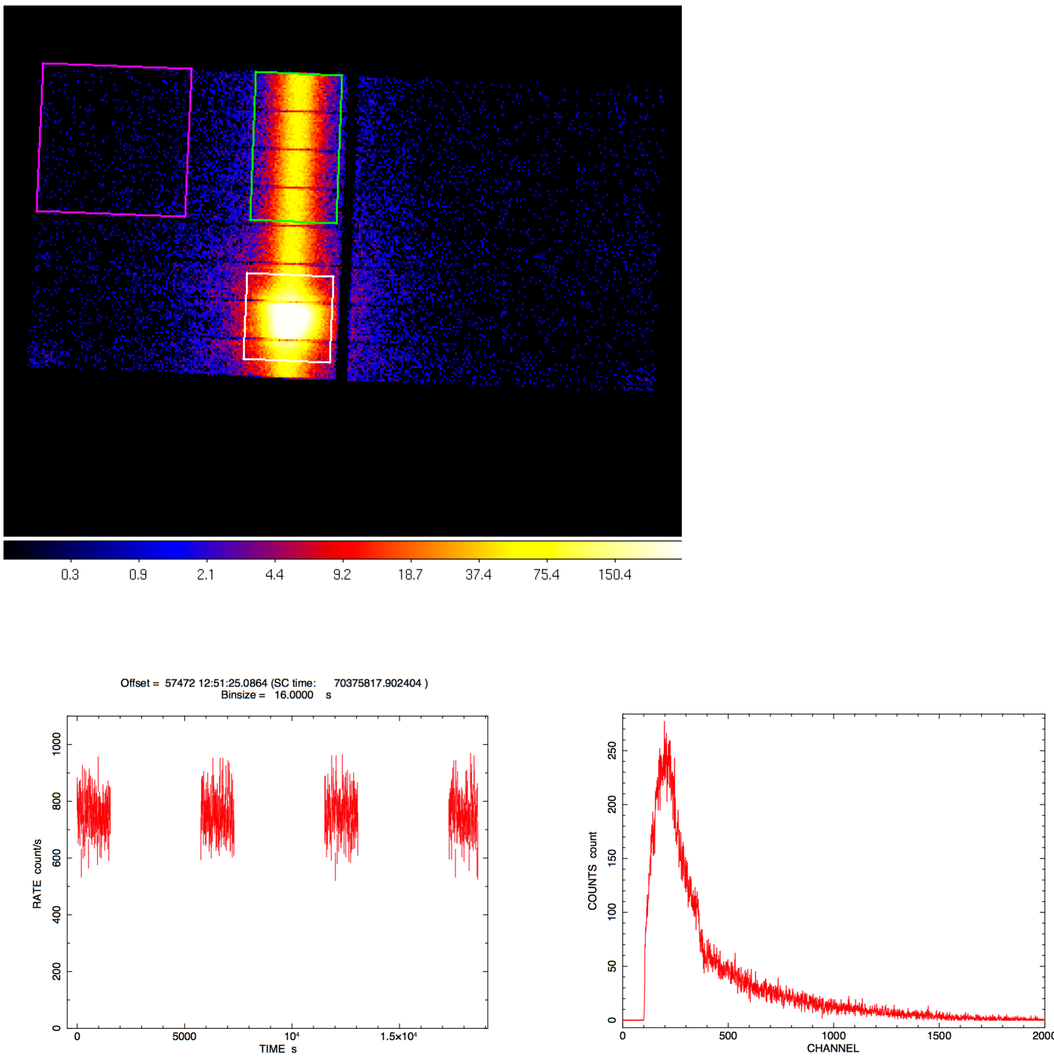


Figure 28: SXI image with extraction regions (green=out-of-time, magenta=background, white=source used for ARF), source lightcurve, and spectrum for sequence 100044010.

SXS

All newly created output files in this section are placed in the /full/path/to/data/sxs_products directory

```
cd /full/path/
```

```
mkdir data/products_sxs
```

```
cd data/products_sxs
```

(1) Additional screening

Create a “cleaned-2” SXS event file

```
ah100044010sxs_p0px1010_cl2.evt
```

by applying a RISETIME cut to Hp, Mp, Ms, and Lp (but not Ls) events.

```
ftselect
infile='../100044010/sxs/event_cl/ah100044010sxs_p0px1010_cl.evt.gz[events]'
outfile=ah100044010sxs_p0px1010_cl2.evt
expression="(PI>=400)&&((RISE_TIME>=40&&RISE_TIME<=60&&ITYPE<4)||(ITYPE==4))"
```

Note that the current pipeline screening already excludes events with PI<600, and that the extra STATUS[4] screening is excluded for this source.

Use sxsregext to extract the spectrum `ah100044010sxs_region_SXS_det.pha` from the above cleaned-2 event file events `ah100044010sxs_p0px1010_cl2.evt` for Hp and Mp events. Here we use the corresponding SXI sky region region_SXI_100044010.reg (which includes all the SXS pixels except pixel 12) as input,

```
fk5
circle(83.6319,22.0188,150")
```

The 35-pixel detector region (`ah100044010sxs_region_SXS_det.reg`) and SXS exposure map (`ah100044010sxs_region_SXS_det.expo`) are also created. The lost event gti per pixel must be accounted for in the exposure account calculation by setting the `pixgtifile= ah100044010sxs_px1010_exp.gti`.

```
sxsregext infile=ah100044010sxs_p0px1010_cl2.evt regmode=RADEC
region=../../regions/region_SXI_100044010.reg resolist=0,1
outroot=ah100044010sxs_region_SXS_det outexp=ah100044010sxs.expo
ehkfile=../100044010/auxil/ah100044010.ehk.gz
pixgtifile=../100044010/sxs/event_uf/ah100044010sxs_px1010_exp.gti.gz
delta=0.25 numphi=4 clobber=yes
```

The region file `ah100044010sxs_region_SXS_det.reg`

```
physical
+box(4,1,5,1.00000000)
+box(3.5,2,6,1.00000000)
+box(3.5,3,6,1.00000000)
+box(3.5,4,6,1.00000000)
+box(3.5,5,6,1.00000000)
+box(3.5,6,6,1.00000000)
```

includes all non-calibration pixels

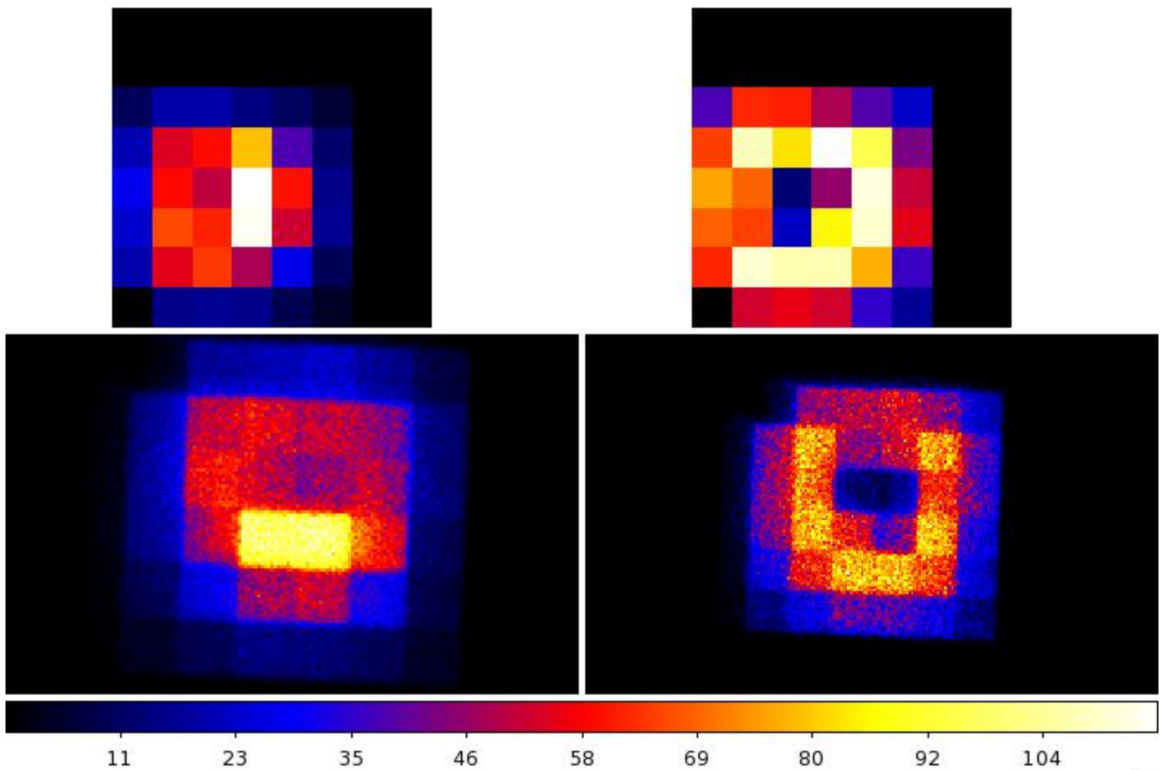
In addition to the spectrum, a DET coordinate image `ah100044010sxs_region_SXS_det.img` and lightcurve `ah100044010sxs_region_SXS_det.lc` are created, as displayed below using ds9 and lcurve. Note that the BACKSCAL keyword is set to 5.468750E-01 which is the ratio of the number of pixels used in the extraction (35) to the total detector address space in pixels (64). This is not a problem provided that any spectra to be combined, subtracted etc. are created in the same manner. In the following section, and alternative using xselect creates a spectrum with BACKSCAL=1:

(2) Extract source spectra, images, and light curves using xselect

```
xsel:SUZAKU > read events ah100044010sxs_p0px1010_cl2.evt
xsel:HITOMI-SXS-PX_NORMAL > filter column "PIXEL=0:11,13:35"
xsel:HITOMI-SXS-PX_NORMAL > extract image
xsel:HITOMI-SXS-PX_NORMAL > save image ah100044010sxs_p0px1010_cl2_sky.img
xsel:HITOMI-SXS-PX_NORMAL > set xyname detx dety
xsel:HITOMI-SXS-PX_NORMAL > extract image
xsel:HITOMI-SXS-PX_NORMAL > save image ah100044010sxs_p0px1010_cl2_det.img
xsel:HITOMI-SXS-PX_NORMAL > extract curve exposure=0
xsel:HITOMI-SXS-PX_NORMAL > save curve ah100044010sxs_p0px1010_cl2.lc
xsel:HITOMI-SXS-PX_NORMAL > filter GRADE "0:1"
```

```
xsel:HITOMI-SXS-PX_NORMAL > set xyname x y
xsel:HITOMI-SXS-PX_NORMAL > extract image
xsel:HITOMI-SXS-PX_NORMAL > save image ah100044010sxs_p0px1010_cl2_HPMP_sky.img
xsel:HITOMI-SXS-PX_NORMAL > set xyname detx dety
xsel:HITOMI-SXS-PX_NORMAL > extract image
xsel:HITOMI-SXS-PX_NORMAL > save image ah100044010sxs_p0px1010_cl2_HPMP_det.img
xsel:HITOMI-SXS-PX_NORMAL > extract curve exposure=0
xsel:HITOMI-SXS-PX_NORMAL > save curve ah100044010sxs_p0px1010_cl2_HPMP.lc
xsel:HITOMI-SXS-PX_NORMAL > extract spectrum
xsel:HITOMI-SXS-PX_NORMAL > save spectrum ah100044010sxs_p0px1010_cl2_HPMP.pi
```

Note that Pixel 12 events may already be excluded from the cleaned event files depending on the label used in filtering; in those cases the second step above may be skipped.



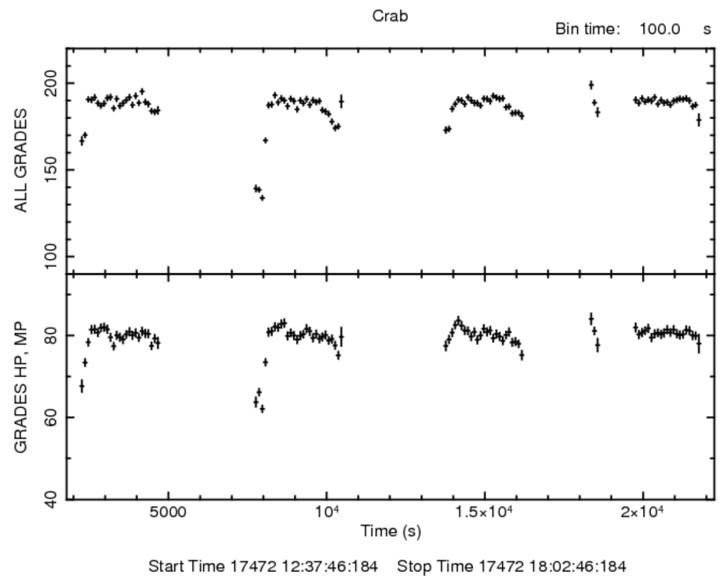


Figure 29: SXS images and lightcurves (plotted using XRONOS/lcurve) for sequence 100044010 for all grades (left images, top lightcurve) images) and grades HP/MP (right images, bottom light curve).

(3) Add columns for an extended energy scale, and extract an extended energy spectrum

First, run the *sxsextend* script with the original cleaned file and its GTI extension as input. The following command adds a PIE column (and EPIE and EPI2E columns) to the original cleaned event file and sets the PIE TLMIN and TLMAX keywords in the output cleaned event files, but otherwise leaves the file unchanged. The task may also accept an unfiltered event file and apply a user-selected screening in creating the new cleaned event file file (see the corresponding section for G21.5-0.9 sequence `100050020`). In this case the extended energy grid includes 32768 channels, extending to twice the standard maximum energy with 1 eV binning. *It is recommended that users not exceed this number of channels or extend the energy scale significantly beyond 30 keV because a valid ARF cannot be made above this energy.*

```
sxsextend inuffile=../100044010/sxs/event_cl/ah100044010sxs_p0px1010_cl.evt.gz
outuffile=ah100044010sxs_p0px1010_clext.evt outclfile=NONE driftfile=NONE
gtigenfile=NONE gtitelfile=NONE gtimxsfile=NONE gtiadroff=NONE gtimkf=NONE
gtiehk=NONE gtiextra=NONE eminin=0 dein=1.0 nchanin=32768 label=NONE
clobber=yes chatter=2 mode=hl
```

Second, apply a revised, energy-dependent, RISETIME cut (this may be more generally used, but is most significant at high energies).

```
ftselect
infile='../100044010/sxs/event_cl/ah100044010sxs_p0px1010_clext.evt.gz[events]'
outfile=ah100044010sxs_p0px1010_clext2.evt expression="((((ABS(RISE_TIME-
52+EPIE*(52-42)/16383.75))<=4)&&ITYPE<4)||(ITYPE==4))
```

Third, extract the spectrum from the values in the PIE column using sxsregext or xselect.

```
sxsregext infile=ah100044010sxs_p0px1010_clext2.evt regmode=DET
region=ah100044010sxs_region_SXS_det.reg resolist=0,1
outroot=ah100044010sxs_region_SXS_det_ext outexp=ah100044010sxs.expo
ehkfile=../100044010/auxil/ah100044010.ehk.gz
pixgtifile=../100044010/sxs/event_uf/ah100044010sxs_px1010_exp.gti.gz
delta=0.25 numphi=4 extended=yes clobber=yes
```

or

```
xsel:SUZAKU > read events ah100044010sxs_p0px1010_clext2.evt
```

```
xsel:HITOMI-SXS-PX_NORMAL > filter column "PIXEL=0:11,13:35"
xsel:HITOMI-SXS-PX_NORMAL > filter GRADE "0:1"
xsel:HITOMI-SXS-PX_NORMAL > set phaname PIE
xsel:HITOMI-SXS-PX_NORMAL > extract spectrum
xsel:HITOMI-SXS-PX_NORMAL > save spectrum
ah100044010sxs_p0px1010_clext2_HPMP.pi
```

As described below, RMF and ARF files must be constructed with compatible energy grids.

(4) Extract the SXS NXB spectrum for standard and extended energy grids

Run the the task `sxsnxbgen` to extract the SXS NXB spectrum from all pixels (a selection of pixels or detector region may also be input), with the same extra cleaning that was applied to the source spectrum, but excluding ITYPE=4 events that are mostly anomalous.

The merged NXB event and ehk files, `ah_sxs_nxbafmar4_20140101v001.evt` and `ah_gen_nxbehk_20140101v002.fits` are downloaded from the hitomi url,

https://heasarc.gsfc.nasa.gov/FTP/hitomi/data/nxb_20170510/

```
sxsnxbgen infile=ah100044010sxs_p0px1010_cl2.evt
ehkfile=../100044010/auxil/ah100044010.ehk.gz regfile=NONE
innxbfile=ah_sxs_nxbafmar4_20140101v001.evt
innxbehk=ah_gen_nxbehk_20140101v002.fits outpifile=ah100044010sxsnxb_cl2.pi
pixels="-" cleanup=yes chatter=3 clobber=yes mode=hl
logfile=ah100044010sxsnxb_cl2.log sortbin=0,4,5,6,7,8,9,10,11,12,13,99
expr="PI>=400&&RISE_TIME>=40&&RISE_TIME<=60&&ITYPE<4"
```

The BACKSCAL keyword must always be updated when the SXS NXB is extracted based on a selection of pixels, and must always be checked for compatibility with the source spectrum. If the extraction regions are the same, BACKSCAL must be identical; if different the BACKSCAL ratio must be the ratio of the extraction region areas (or number of pixels). In the present example, assuming the source spectrum was extracted in xselect,

```
fthedit ah100044010sxsnxb_cl2.pi+1 BACKSCAL add 1.000000E+00
```

is done.

The NXB spectrum, which is not filtered on event grade, must be rescaled by the fraction of events with grades (HP and MP in this case) used as a filter in extracting the source spectrum (optional for other sequences where HP events dominate). The fraction may be obtained using `sxsbranch`:

```
sxsbranch ah100044010sxs_p0px1010_cl2.evt.gz real sxsbranch.out
pixfrac=$LHEA_DATA/pixfrac.txt pixmask=none calpixrate=0.0 ctphafrac1=0.0
ctphafrac2=0.0

fkeyprint "sxsbranch.out[BRANCHCALC]" BRANCHHP
BRANCHHP=     0.298636786685402

fkeyprint "sxsbranch.out[BRANCHCALC]" BRANCHMP
BRANCHMP=    0.127915031844809

mathpha expr="ah100044010sxsnxb_cl2.pi*0.42655" units=R
outfil=ah100044010sxsnxb_cl2_scale.pi exposure=CALC  areascal=% errmeth=gauss
properr=yes ncomments=0
```

The SXS NXB spectrum for the standard extended energy grid (the capability for other extened energy grids will be available with a soon-to-be-updated version of `sxsextend`) may also be extracted using `sxsnxbgen` as follows.

```
sxsnxbgen infile=ah100044010sxs_p0px1010_clext2.evt
ehkfile=../100044010/auxil/ah100044010.ehk.gz
regfile=ah100044010sxs_region_SXS_det.reg regmode=DET
innxbfile=ah_sxs_nxbafmar4_20140101v001.evt
innxbehk=ah_gen_nxbehk_20140101v002.fits outpifile=ah100044010sxsnxb_clext2.pi
pixels="-" cleanup=no chatter=3 clobber=yes mode=hl
logfile=ah100044010sxsnxb_clext2.log sortbin=0,4,5,6,7,8,9,10,11,12,13,99
expr="((ABS(RISE_TIME-52+EPIE*(52-42)/16383.75))<=4)&&ITYPE<4" picol=PIE"
```

In this example, the NXB spectrum is extracted using a detector region resulting BACKSCAL=5.468750E-01. If the extended spectrum is extracted using `sxsregext` with the same input region, this does not need to be corrected.

As in the above the extended NXB spectrum must be rescaled by the fraction of events in event file used for source spectrum extraction with grades HP and MP, and the error method reset.

```
mathpha expr="ah100044010sxsnxb_clext2.pi*0.42660" units=R
outfil=ah100044010sxsnxb_clext2_scale.pi exposure=CALC  areascal=%
errmeth=gauss properr=yes ncomments=0
```

Generating Exposure Map, RMF, and ARF

100044010

HXI

All newly created output files in this section are placed in the /full/path/to/data/hxi_products directory

```
cd /full/path/
```

```
cd data/products_hxi
```

(1) Create an exposure map for each HXI

The exposure maps generated here are used in the two examples below to make both the RSP and flat field for the HXI. The exposure maps are created with the parameters `delta=20.0`, `numphi=1` to assure that the map includes only a single attitude bin, i.e. assuming that the attitude is stable relative to the size of the PSF and extraction region. The merged event file created is used as the input `gtifile` parameter.

HXI1

```
ahexpmap ehkfile=../100044010/auxil/ah100044010.ehk.gz
gtifile=ah100044010hx1_p0camrec_cl.evt instrume=HXI1 badimgfile=NONE
pixgtifile=NONE outfile=ah100044010hx1_p0camrec.expo outmaptype=EXPOSURE
delta=20.0 numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB
vigfile=CALDB obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes
fwtype=DEFAULT specmode=MONO specfile=spec.fits specform=FITS energy=10.0
evperchan=DEFAULT abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100044010hx1_p0camrec.log
```

HXI2

```
ahexpmap ehkfile=../100044010/auxil/ah100044010.ehk.gz
gtifile=ah100044010hx2_p0camrec_cl.evt instrume=HXI2 badimgfile=NONE
pixgtifile=NONE outfile=ah100044010hx2_p0camrec.expo outmaptype=EXPOSURE
delta=20.0 numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB
vigfile=CALDB obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes
fwtype=DEFAULT specmode=MONO specfile=spec.fits specform=FITS energy=10.0
evperchan=DEFAULT abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100044010hx2_p0camrec.log
```

(2) Create an RSP for each HXI

Make RSP for HXI1 and HXI2, sampling=120, point source at center of extraction region region_HXI_100044010.reg. In general, the `source_ra` and `source_dec` parameters should be the coordinates of the center of the source in the image, which are not necessarily the same as the actual source coordinates. Here we use the center of the spectral extraction region. An on-axis point source response can be constructed by setting the source coordinates to the single value of RANOMXP and DECNOMXP in the first extension of the exposure map. The runtime estimated above is for the case where the exposure map has a single attitude bin. The parameter `numphoton` may need to be decreased to accommodate a larger number of attitude bins.

HXI1

```
aharfgen xrtevtfile=raytrace_ah100044010hx1_p0camrec.fits source_ra=83.6319
source_dec=22.0188 telescop=HITOMI instrume=HXI1
emapfile=ah100044010hx1_p0camrec.expo
dattfile=../100044010/hxi/event_uf/ah100044010hx1.att.gz regmode=RADEC
regionfile=../../regions/region_HXI_100044010.reg sampling=120 sourcetype=point
erange="4.0 80.0" outfile=ah100044010hx1_rt
filtoffsetfile=../100044010/hxi/event_uf/ah100044010hx1_cms.fits.gz
numphoton=10000 minphoton=1 teldeffile=CALDB qefile=CALDB rmffile=CALDB
onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB
frontreffile=CALDB pcolreffile=CALDB scatterfile=CALDB auxtransfile=NONE
auxtransfile=NONE seed=7 clobber=yes chatter=2 mode=h
logfile=make_arf_ah100044010hx1_p0camrec.log
```

HXI2

```
aharfgen xrtevtfile=raytrace_ah100044010hx2_p0camrec.fits source_ra=83.6319
source_dec=22.0188 telescop=HITOMI instrume=HXI2
emapfile=ah100044010hx2_p0camrec.expo
dattfile=../100044010/hxi/event_uf/ah100044010hx2.att.gz regmode=RADEC
regionfile=../../regions/region_HXI_100044010.reg sampling=120 sourcetype=point
erange="4.0 80.0" outfile=ah100044010hx2_rt
filtoffsetfile=../100044010/hxi/event_uf/ah100044010hx2_cms.fits.gz
numphoton=10000 minphoton=1 teldeffile=CALDB qefile=CALDB rmffile=CALDB
onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB
frontreffile=CALDB pcolreffile=CALDB scatterfile=CALDB auxtransfile=NONE seed=7
clobber=yes chatter=2 mode=h logfile=make_arf_ah100044010hx2_p0camrec.log
```

(3) Create an RSP for each HXI using the auxiliary transmission file

An auxiliary transmission file based on ground measurements can be applied to adjust the response by setting `auxtransfile=CALDB`. Note that the raytracing file (`xrtevtfile`), if already created with `auxtransfile=NONE`, should be reused.

HXI1

```
aharfgen xrtevtfile=raytrace_ah100044010hx1_p0camrec.fits source_ra=83.6319
source_dec=22.0188 telescop=HITOMI instrume=HXI1
emapfile=ah100044010hx1_p0camrec.expo
dattfile=../100044010/hxi/event_uf/ah100044010hx1.att.gz regmode=RADEC
regionfile=../../regions/region_HXI_100044010.reg sampling=120 sourcetype=point
erange="4.0 80.0" outfile=ah100044010hx1_rt
filtoffsetfile=../100044010/hxi/event_uf/ah100044010hx1_cms.fits.gz
numphoton=10000 minphoton=1 teldeffile=CALDB qefile=CALDB rmffile=CALDB
onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB
frontreffile=CALDB pcolreffile=CALDB scatterfile=CALDB auxtransfile=CALDB
auxtransfile=NONE seed=7 clobber=yes chatter=2 mode=h
logfile=make_arf_ah100044010hx1_p0camrec.log
```

HXI2

```
aharfgen xrtevtfile=raytrace_ah100044010hx2_p0camrec.fits source_ra=83.6319
source_dec=22.0188 telescop=HITOMI instrume=HXI2
emapfile=ah100044010hx2_p0camrec.expo
dattfile=../100044010/hxi/event_uf/ah100044010hx2.att.gz regmode=RADEC
regionfile=../../regions/region_HXI_100044010.reg sampling=120 sourcetype=point
erange="4.0 80.0" outfile=ah100044010hx2_rt
filtoffsetfile=../100044010/hxi/event_uf/ah100044010hx2_cms.fits.gz
numphoton=10000 minphoton=1 teldeffile=CALDB qefile=CALDB rmffile=CALDB
onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB
frontreffile=CALDB pcolreffile=CALDB scatterfile=CALDB auxtransfile=CALDB
seed=7 clobber=yes chatter=2 mode=h
logfile=make_arf_ah100044010hx2_p0camrec.log
```

(4) Create flat field efficiency images for each HXI

HXI1

```
hxirspeffimg telescop=HITOMI instrume=HXI1
emapfile=ah100044010hx1_p0camrec.expo
xrtevtfile=raytrace_ah100044010hx1_p0camrec.fits onaxisffile=CALDB
onaxiscfile=CALDB regionfile=NONE
dattfile=../100044010/hxi/event_uf/ah100044010hx1.att.gz stopsys=SKY
sampling=40 erange="4.0 80.0"
filtoffsetfile=../100044010/hxi/event_uf/ah100044010hx1_cms.fits.gz
outflatfile=ah100044010hx1_flatfield.fits vigfile=CALDB outmaptype=EFFICIENCY
qefile=CALDB rmffile=CALDB clobber=yes chatter=2 mode=h
logfile=make_flat_ah100044010hx1_p0camrec.log
```

HXI2

```
hxirspeffimg telescop=HITOMI instrume=HXI2
emapfile=ah100044010hx2_p0camrec.expo
xrtevtfile=raytrace_ah100044010hx2_p0camrec.fits onaxisffile=CALDB
onaxiscfile=CALDB regionfile=NONE
dattfile=../100044010/hxi/event_uf/ah100044010hx2.att.gz stopsys=SKY
sampling=40 erange="4.0 80.0"
filtoffsetfile=../100044010/hxi/event_uf/ah100044010hx2_cms.fits.gz
outflatfile=ah100044010hx2_flatfield.fits vigfile=CALDB outmaptype=EFFICIENCY
qefile=CALDB rmffile=CALDB clobber=yes chatter=2 mode=h
logfile=make_flat_ah100044010hx2_p0camrec.log
```

These commands produce the images shown below:

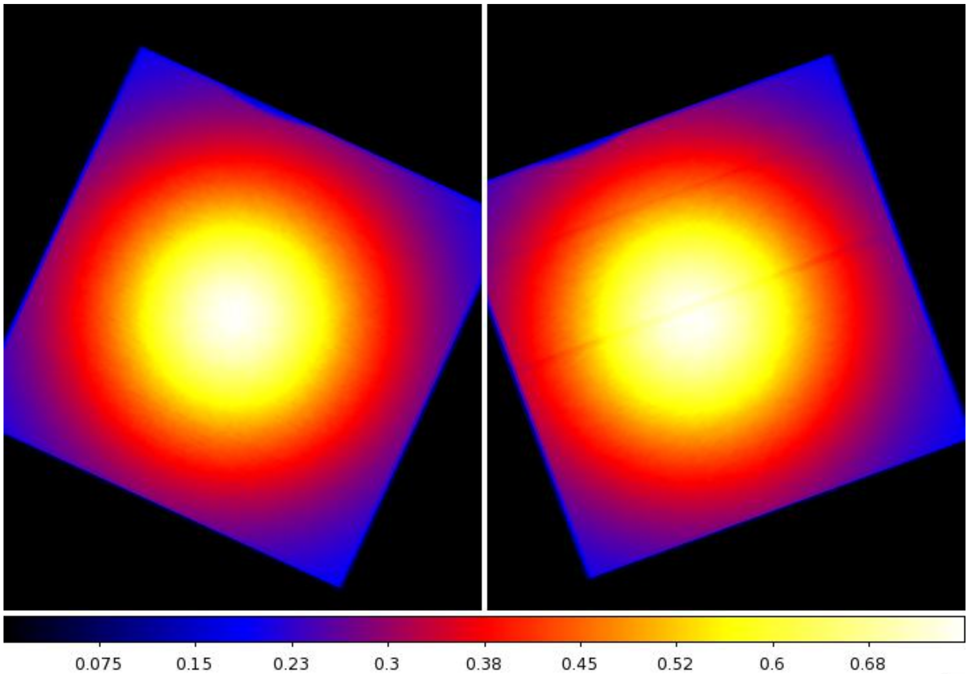


Figure 30: HXI1 (left) and HXI2 (right) flat field images for sequence 100044010.

SGD

All newly created output files in this section are placed in the /full/path/to/data/hxi_products directory

```
cd /full/path/
```

```
cd data/products_sgd
```

All newly created output files in this section are placed in the /full/path/to/data/sgd_products directory

Create the individual response files for each SGD1 Compton camera, and co-add them. To construct an on-axis response, directly co-add the CALDB response files used as input to the SGD arf generator. Here we use the center of the HXI/SXI spectral extraction region as the source coordinates.

SGD1

```
sgdarfgen infile=ah100044010sg1_p0ccALLrec_dtime.pi
rspfile="$CALDB/data/hitomi/sgd/cpf/response/ah_sg1_cc1_20140101v001.rsp,$CALDB
/data/hitomi/sgd/cpf/response/ah_sg1_cc2_20140101v001.rsp,$CALDB/data/hitomi/sg
d/cpf/response/ah_sg1_cc3_20140101v001.rsp" outfile=outrsp_100044010 ra=83.6319
dec=22.0188 sgdid=1 ccid=0 clobber=yes
```

```
addrmf
outrsp_100044010_sgd1_cc1.rsp,outrsp_100044010_sgd1_cc2.rsp,outrsp_100044010_sg
d1_cc3.rsp 1.0,1.0,1.0 ah100044010_sgd1_ccALL.rsp
```

NOTE: For the only useful observation taken with the SGD, the Crab, the `sgdarfgen` step is not necessary because there was not sufficient in-orbit data to calibrate any misalignment. If the `sgdarfgen` is not run the addrmf should be done using the responses in CALDB.

SXI

All newly created output files in this section are placed in the /full/path/to/data/sxi_products directory

```
cd /full/path/
```

```
cd data/products_sxi
```

(1) Create an RMF for the source spectrum

```
sxirmf infile=ah100044010sxi_p0112004e0_cl.pi
outfile=ah100044010sxi_p0112004e0_cl.rmf clobber=yes mode=hl
```

(2) Create an Exposure Map for the source spectrum

The exposure map, and flatfield image below, are created with the parameters `delta=20.0`, `numphi=1` to assure that the map includes only a single attitude bin, i.e. assuming that the attitude is stable relative to the size of the PSF and extraction region.

```
ahexpmap ehkfile=../100044010/auxil/ah100044010.ehk.gz
gtifile=../100044010/sxi/event_cl/ah100044010sxi_p0112004e0_cl.evt.gz
instrume=SXI
badimgfile=../100044010/sxi/event_uf/ah100044010sxi_p0112004e0.bimg.gz
pixgtifile=../100044010/sxi/event_uf/ah100044010sxi_a0112004e0.fpix.gz
outfile=ah100044010sxi_p0112004e0.expo outmaptype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100044010sxi_a0112004e0.log
```

(3) Create an ARF for the source spectrum

In general, the `source_ra` and `source_dec` parameters should be the coordinates of the center of the source in the image, which are not necessarily the same as the actual source coordinates. The runtime estimated above is for the case where the exposure map has a single attitude bin. The parameter `numphoton` may need to be decreased to accommodate a larger number of attitude bins. For the Crab out-of-time events, the aimpoint region is used since this is where the X-ray photons are detected by the CCD and thus traces their path through the optics..

```
aharfgen xrtevtfile=raytrace_ah100044010sxi_p0112004e0_ptsrc_evt.fits
source_ra=83.6319 source_dec=22.0188 telescop=HITOMI instrume=SXI
emapfile=ah100044010sxi_p0112004e0.expo regmode=RADEC
regionfile=../../regions/region_SXI_100044010_src.reg sourcetype=POINT
rmffile=ah100044010sxi_p0112004e0_cl.rmf erange="0.5 16.0 0 0"
outfile=ah100044010sxi_p0112004e0_rt.arf numphoton=300000 minphoton=1
teldeffile=CALDB qefile=CALDB contamifile=CALDB onaxisffile=CALDB
onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB
backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB auxtransfile=NONE seed=7
clobber=yes chatter=2 mode=h logfile=make_arf_ah100044010sxi_p0112004e0.log
```

The following command also creates an ARF for the SXI Crab spectrum, but sets the auxiliary transmission file to a calibration file (`auxtransfile=CALDB`). This file is used to apply additional transmission that is not accounted in the telescope calibration files used by the raytracing.

```
aharfgen xrtevtfile=raytrace_ah100044010sxi_p0112004e0_ptsrc_evt.fits
source_ra=83.6319 source_dec=22.0188 telescop=HITOMI instrume=SXI
emapfile=ah100044010sxi_p0112004e0.expo regmode=RADEC
```

```
regionfile=../../regions/region_SXI_100044010_src.reg sourcetype=POINT
rmffile=ah100044010sxi_p0112004e0_cl.rmf erange="0.5 16.0 0 0"
outfile=ah100044010sxi_p0112004e0_rt.arf numphoton=300000 minphoton=1
auxtransfile=CALDB teldeffile=CALDB qefile=CALDB contamifile=CALDB
onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB
frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB seed=7
clobber=yes chatter=2 mode=h logfile=make_arf_ah100044010sxi_p0112004e0.log
```

(4) Correct the BACKSCAL keyword in the SXI spectra

Xselect writes a BACKSCAL keyword in the header of extracted spectra to properly scale the background subtraction in XSPEC. However, it only accounts for the fraction of the area covered by the extraction region, not the number of good pixels. Many pixels in SXI data are affected by cosmic-ray echo or light leak and need to be properly excluded from BACKSCAL. The following application of *ahbackscal* should be made to correct this keyword for all SXI sequences.

```
ahbackscal infile=ah100044010sxi_p0112004e0_cl.pi
regfile=../../regions/region_SXI_100044010_oot.reg
expfile=ah100044010sxi_p0112004e0_cl.expo norm=MAX

ahbackscal infile=ah100044010sxi_p0112004e0_cl_bg.pi
regfile=../../regions/region_SXI_100044010_bkg.reg
expfile=ah100044010sxi_p0112004e0_cl.expo norm=MAX
```

(5) Create an efficiency map (flat field)

```
ahexpmap ehkfile=../100044010/auxil/ah100044010.ehk.gz
gtifile=ah100044010sxi_p0112004e0_cl.evt instrume=SXI
badimgfile=../100044010/sxi/event_uf/ah100044010sxi_p0112004e0.bimg.gz
pixgtifile=../100044010/sxi/event_uf/ah100044010sxi_a0112004e0.fpix.gz
outfile=ah100044010sxi_p0112004e0.flat outmaptype=EFFICIENCY delta=20.0
numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_flat_ah100044010sxi_a0112004e0.log
```

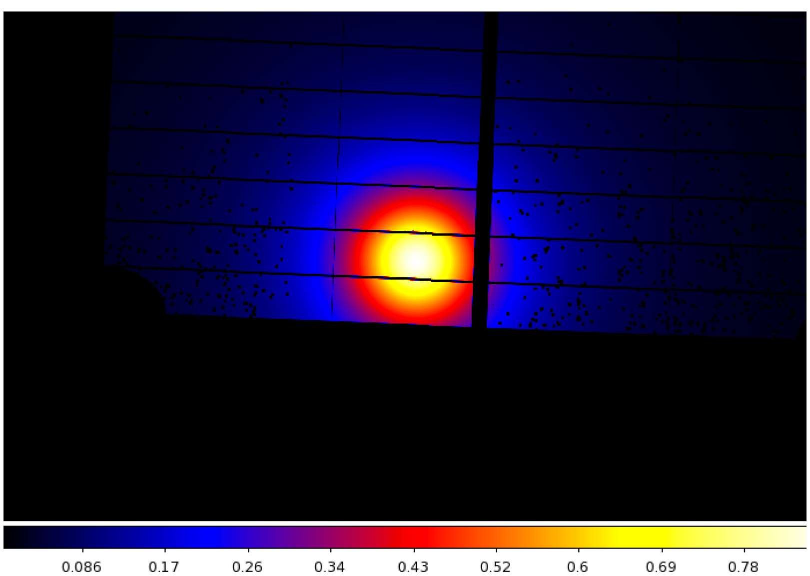


Figure 31: SXI flat field images for sequence 100044010.

SXS

All newly created output files in this section are placed in the /full/path/to/data/sxs_products directory

cd /full/path/

cd data/products_sxs

(1) Generate the RMF

Here we use the "small" size option (Gaussian core only). Change whichrmf parameter to "m" to include exponential tail to low energies, and to "l" to include escape peaks. The all-pixel DET coordinate region file ah100044010sxs_region_SXS_det.reg created by sxsregext is input.

```
sxsmkrmf infile=ah100044010sxs_p0px1010_cl2.evt
outfile=ah100044010_sxs_cl2_HPMP_small.rmf resolist=0,1 regmode=det
regionfile=ah100044010sxs_region_SXS_det.reg whichrmf=s
```

We also construct an SXS RMF using the "x-large" option which is necessary to study the spectrum below 2 keV.

```
sxsmkrmf infile=ah100044010sxs_p0px1010_cl2.evt
outfile=ah100044010_sxs_cl2_HPMP_xlarge.rmf resolist=0,1 regmode=det
regionfile=ah100044010sxs_region_SXS_det.reg whichrmf=x
```

(2) Generate the SXS exposure maps

In the exposure maps created with sxsregext, ah100044010sxs_region_SXS_det.expo, ~9% of the exposure time is outside of the longest-duration bin – sufficient, for this bright source, to require the use of this multiple-attitude exposure map, rather than replacing it with one constructed using the parameters delta=20.0, numphi=1 to assure that map includes only a single attitude bin. If the spectrum was extracted using xselect instead of sxsregext, the exposure map may be generated by the fillowing command.

```
ahexpmap ehkfile=../100044010/auxil/ah100044010.ehk.gz
gtifile=ah100044010sxs_p0px1010_cl2.evt instrume=SXS badimgfile=NONE
pixgtifile=../100044010/sxs/event_uf/ah100044010sxs_px1010_exp.gti.gz
outfile=ah100044010sxs_p0px1010.expo outmaptype=EXPOSURE delta=0.25 numphi=4
stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100044010sxs_p0px1010.log
```

(3) Generate the SXS ARF

The runtime estimated is for a run with the same number of photons as for the case where exposure map has a single attitude bin. The parameter numphoton is decreased to reduce the runtime.

```
aharfgen xrtevtfile=raytrace_ah100044010sxs_p0px1010.fits source_ra=83.6319
source_dec=22.0188 telescop=HITOMI instrume=SXS
emapfile=ah100044010sxs_p0px1010.expo regmode=DET
regionfile=ah100044010sxs_region_SXS_det.reg sourcetype=POINT
rmffile=ah100044010_sxs_cl2_HPMP_small.rmf erange="0.5 17.0 0 0"
outfile=ah100044010sxs_p0px1010_rt.arf numphoton=30000 minphoton=1
teldeffile=CALDB qefile=CALDB contamifile=CALDB obffile=CALDB fwfile=CALDB
gatevalvefile=CALDB onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB
obstructfile=CALDB frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB
```

```
scatterfile=CALDB auxtransfile=NONE seed=7 clobber=yes chatter=2 mode=h
logfile=make_arf_ah100044010sxs_p0px1010.log
```

Note that the source_ra and source_dec are taken from the region file region_SXI_100044010.reg, i.e. an estimate of the source coordinates based on the SXI image. The region file used is the one in DET coordinates created above by sxsregext.

(4) Create an ARF using the auxiliary transmission file

An auxiliary transmission file based on ground measurements can be applied to adjust the response by setting `auxtransfile=CALDB.` Note that the raytracing file (`xrtevtfile`), if already created with `auxtransfile=NONE`, should be reused.

```
aharfgen xrtevtfile=raytrace_ah100044010sxs_p0px1010.fits source_ra=83.6319
source_dec=22.0188 telescop=HITOMI instrume=SXS
emapfile=ah100044010sxs_p0px1010.expo regmode=DET
regionfile=ah100044010sxs_region_SXS_det.reg sourcetype=POINT
rmffile=ah100044010_sxs_cl2_HPMP_small.rmf erange="0.5 17.0 0 0"
outfile=ah100044010sxs_p0px1010_rt.arf numphoton=300000 minphoton=1
teldeffile=CALDB qefile=CALDB contamifile=CALDB obffile=CALDB fwfile=CALDB
gatevalvefile=CALDB onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB
obstructfile=CALDB frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB
scatterfile=CALDB auxtransfile=CALDB seed=7 clobber=yes chatter=2 mode=h
logfile=make_arf_ah100044010sxs_p0px1010.log
```

(5) Create an SXS efficiency map (flat field)

Normal mode

```
ahexpmap ehkfile=../100044010/auxil/ah100044010.ehk.gz
gtifile=ah100044010sxs_p0px1010_cl2.evt instrume=SXS badimgfile=NONE
pixgtifile=../100044010/sxs/event_uf/ah100044010sxs_px1010_exp.gti.gz
outfile=ah100044010sxs_p0px1010.expo outmaptype=EFFICIENCY delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_flat_ah100044010sxs_p0px1010.log
```

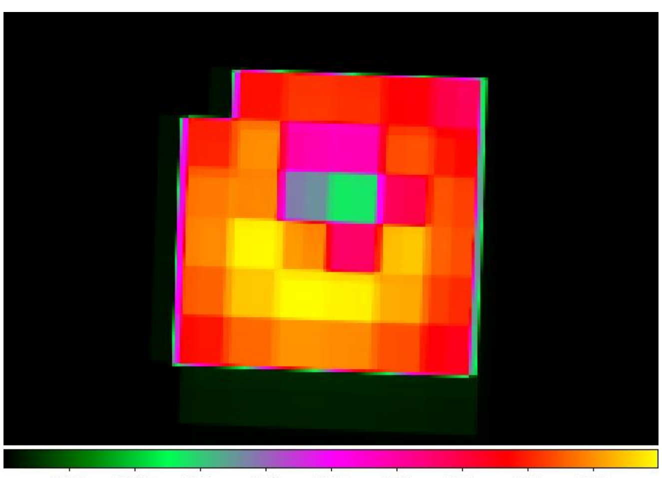


Figure 32: SXS flat field images for sequence 100044010.

(6) Construct RMF and ARF files to use with extended energy spectrum

First, identify the necessary keywords in the cleaned event file representing the maximum vaue of the PIE column, the offset value of the PIE column, and the grid width of PIE energy scale.

```
ftlist  ah100044010sxs_p0px1010_clext2.evt+1 K | grep PIE
TTYPE54 = 'EPIE    '           / EPI in extended energy range
TTYPE55 = 'PIE     '           / PI in extended energy range
TLMIN55 =                    0 / minimum legal value for PIE
PIEOFFST=                   1. / Energy offset (eV) of extended energy mode
PIEWIDTH=                   1. / Channel width (eV) of extended energy mode

ftlist ah100044010sxs_p0px1010_clext2.evt+1 K | grep TLMAX55
TLMAX55 =                32767

ftlist ah100044010sxs_p0px1010_clext2.evt+1 K | grep PIEOFFST
PIEOFFST=                   1. / Energy offset (eV) of extended energy mode

ftlist ah100044010sxs_p0px1010_clext2.evt+1 K | grep PIEWIDTH
PIEWIDTH=                   1. / Channel width (eV) of extended energy mode
```

Second, construct the RMF file for this energy grid, setting `nchanin=TLMAX55+1 dein=PIEWIDTH` and `eminin=PIEOFFST-PIEWIDTH` that, in this case, corresponds to the following command.

```
sxsmkrmf infile=ah100044010sxs_p0px1010_clext2.evt
outfile=ah100044010_sxs_clext2_HPMP_small.rmf resolist=0,1 regmode=det
regionfile=ah100044010sxs_region_SXS_det.reg whichrmf=s nchanin=32768 dein=1.0
eminin=0.0
```

Third, construct the ARF file for this energy grid, and an appropriate energy range for the arf. The correct energy grid is assured by inputing the RMF file constructed above. The energy range for the ARF should span the full energy range (corresponding to a lower limit of `eminin` and an upper limit of `eminin+nchanin*dein`), possibly with some margin on either side, but not to exceed 0.5 keV on the low end and 30 keV on the high end. The command for this example is as follows.

```
aharfgen xrtevtfile=raytrace_ah100044010sxs_p0px1010_ext.fits source_ra=83.6319
source_dec=22.0188 telescop=HITOMI instrume=SXS
emapfile=ah100044010sxs_p0px1010.expo regmode=DET
regionfile=ah100044010sxs_region_SXS_det.reg sourcetype=POINT
rmffile=ah100044010_sxs_clext2_HPMP_small.rmf erange="0.5 30.0 0 0"
outfile=ah100044010sxs_p0px1010_rt_ext.arf numphoton=300000 minphoton=1
teldeffile=CALDB qefile=CALDB contamifile=CALDB obffile=CALDB fwfile=CALDB
gatevalvefile=CALDB onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB
obstructfile=CALDB frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB
scatterfile=CALDB auxtransfile=NONE seed=7 clobber=yes chatter=2 mode=h
logfile=make_arf_ah100044010sxs_p0px1010_ext.log
```

Spectral Fittting

Notes

The following XSPEC settings are used below.

For fitting;
  abund wilm
  xsect vern
  statistic cstat

For plotting:

setplot rebin 10 20 (HXI, SGD, SXI)
setplot rebin 20 40 (SXS)

The response files without the auxiliary transmission files are used below.

HXI

(1) Jointly fit the HXI1 and HXI2 deadtime-corrected spectra in the 5-80 keV band with a power-law model, with absorption fixed at 3.0 x 10^{21} cm^{-2} using the RSP files created in the previous section. Background is not subtracted in this example.

```
2 files 2 spectra
Spectrum 1  Spectral Data File: ah100044010_hxi1_dtime.pi
Net count rate (cts/s) for Spectrum:1  4.391e+02 +/- 2.724e-01
 Assigned to Data Group 1 and Plot Group 1
  Noticed Channels:  51-799
  Telescope: HITOMI Instrument: HXI1  Channel Type: PI
  Exposure Time: 5918 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Response (RMF) File            ah100044010_hxi1.rsp for Source 1

 Spectral data counts: 2.59859e+06
 Model predicted rate: 439.137

Spectrum 2  Spectral Data File: ah100044010_hxi2_dtime.pi
Net count rate (cts/s) for Spectrum:2  4.257e+02 +/- 2.633e-01
 Assigned to Data Group 2 and Plot Group 2
  Noticed Channels:  51-799
  Telescope: HITOMI Instrument: HXI2  Channel Type: PI
  Exposure Time: 6141 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Response (RMF) File            ah100044010_hxi2.rsp for Source 1

 Spectral data counts: 2.61451e+06
 Model predicted rate: 425.746


Current model list:

========================================================================
Model TBabs<1>*pegpwrlw<2> Source No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
                           Data group: 1
   1    1   TBabs      nH         10^22    0.300000     frozen
   2    2   pegpwrlw   PhoIndex            2.14528      +/-  9.84877E-04
   3    2   pegpwrlw   eMin       keV      2.00000      frozen
   4    2   pegpwrlw   eMax       keV      10.0000      frozen
   5    2   pegpwrlw   norm                2.42770E+04  +/-  23.6706
                           Data group: 2
   6    1   TBabs      nH         10^22    0.300000     = p1
   7    2   pegpwrlw   PhoIndex            2.14528      = p2
   8    2   pegpwrlw   eMin       keV      2.00000      = p3
   9    2   pegpwrlw   eMax       keV      10.0000      = p4
  10    2   pegpwrlw   norm                2.35913E+04  +/-  23.0615
________________________________________________________________________

   Using energies from responses.

Fit statistic : C-Statistic =        2257.08 using 1498 PHA bins and 1495
degrees of freedom.
```

```
Test statistic : Chi-Squared =        2218.21 using 1498 PHA bins.
 Reduced chi-squared =        1.48375 for   1495 degrees of freedom
 Null hypothesis probability =   3.355388e-31

***Warning: Chi-square may not be valid due to bins with zero variance
            in spectrum number(s): 1 2

 Weighting method: standard
```

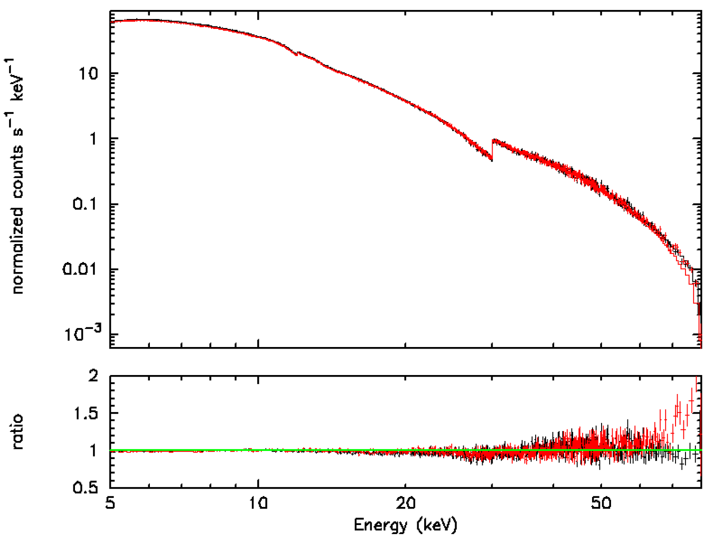


Figure 33: Joint fits to HXI1 (black) and HXI2 (red) spectra for Crab nebula sequence 100044010. The 2-10 keV unabsorbed fluxes are 2.43 (HXI1) amd 2.36 (HXI2) x 10^{-8} erg cm^{-2} s^{-1} in the best-fit models.

SGD

(1) Compare the deadtime-corrected and the deadtime-uncorrected SGD1 spectra (summed over all relevant sequences and all Comption cameras) with the estimated CALDB NXB spectrum `$CALDB/data/hitomi/sgd/cpf/background/ah_sgd_nxb_20140101v001.pha`:

```
3 files 3 spectra
Spectrum 1  Spectral Data File: ah_sgd_nxb_20140101v001.pha
Net count rate (cts/s) for Spectrum:1  7.661e-01 +/- 1.153e-03
 Assigned to Data Group 1 and Plot Group 1
  Noticed Channels:  42-2048
  Telescope: HITOMI Instrument: SGD  Channel Type: PI
  Exposure Time: 5.763e+05 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Response (RMF) File            ah100044010_sgd1_ccALL.rsp for Source 1

 Spectral data counts: 441486
 Model predicted rate: 0.0

Spectrum 2  Spectral Data File: ah100044010sg1_p0ccALLrec_cl.pi
Net count rate (cts/s) for Spectrum:2  4.566e+00 +/- 2.300e-02
 Assigned to Data Group 2 and Plot Group 2
  Noticed Channels:  42-2048
  Telescope: HITOMI Instrument: SGD1  Channel Type: PI
  Exposure Time: 8629 sec
 Using fit statistic: cstat
```

```
 Using test statistic: chi
 Using Response (RMF) File            ah100044010_sgd1_ccALL.rsp for Source 1

 Spectral data counts: 17715
 Model predicted rate: 0.0

Spectrum 3  Spectral Data File: ah100044010sg1_p0ccALLrec_dtime.pi
Net count rate (cts/s) for Spectrum:3  8.086e+00 +/- 4.074e-02
 Assigned to Data Group 3 and Plot Group 3
  Noticed Channels:  42-2048
  Telescope: HITOMI Instrument: SGD1  Channel Type: PI
  Exposure Time: 4872 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Response (RMF) File            ah100044010_sgd1_ccALL.rsp for Source 1

 Spectral data counts: 39400
 Model predicted rate: 0.0
```

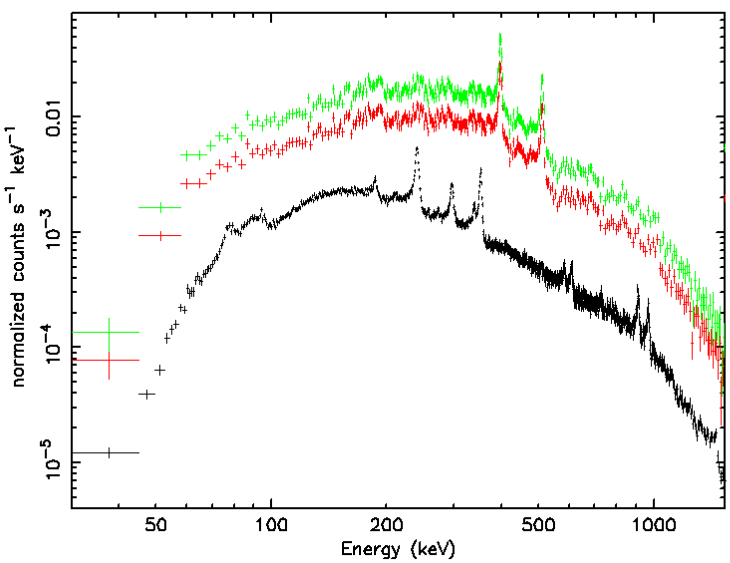


Figure 34: Comparison of NXB file in CALDB (black) with deadtime-corrected (green) and deaditme-uncorrected (red) spectra for SGD1 Crab nebula sequence 100044010.

SXI

(1) Fit the SXI out-of-time spectrum in the 0.8-12 keV band with a power-law model, with absorption free using the RMF, ARF, and background files created in the previous section:

```
1 file 1 spectrum
Spectrum 1  Spectral Data File: ah100044010sxi_p0112004e0_cl.pi
Net count rate (cts/s) for Spectrum:1  7.144e+02 +/- 2.823e+00 (99.5 % total)
 Assigned to Data Group 1 and Plot Group 1
  Noticed Channels:  135-1999
  Telescope: HITOMI Instrument: SXI  Channel Type: PI
  Exposure Time: 90.35 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Response Background File       ah100044010sxi_p0112004e0_cl_bg.pi
  Background Exposure Time: 90.35 sec
 Using Response (RMF) File            ah100044010sxi_p0112004e0_cl.rmf for
Source 1
 Using Auxiliary Response (ARF) File  ah100044010sxi_p0112004e0_rt.arf
```

```
 Spectral data counts: 64850
 Model predicted rate: 714.234


Current model list:

========================================================================
Model constant<1>*TBabs<2>*pegpwrlw<3> Source No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
   1    1   constant   factor              0.294700     frozen
   2    2   TBabs      nH         10^22    0.504564     +/-  1.05216E-02
   3    3   pegpwrlw   PhoIndex            2.05793      +/-  1.13616E-02
   4    3   pegpwrlw   eMin       keV      2.00000      frozen
   5    3   pegpwrlw   eMax       keV      10.0000      frozen
   6    3   pegpwrlw   norm                2.11981E+04  +/-  136.553
________________________________________________________________________

   Using energies from responses.

Fit statistic : C-Statistic =        2061.14 using 1865 PHA bins and 1862
degrees of freedom.

Test statistic : Chi-Squared =        2889.88 using 1865 PHA bins.
 Reduced chi-squared =        1.55203 for   1862 degrees of freedom
 Null hypothesis probability =   7.919207e-48

***Warning: Chi-square may not be valid due to bins with zero variance
            in spectrum number(s): 1

 Weighting method: standard
```

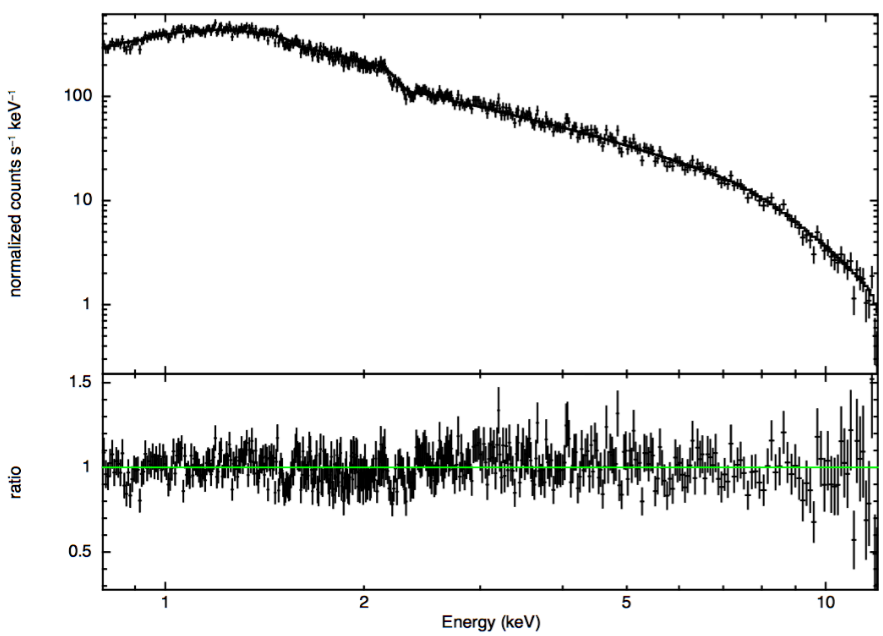


Figure 35: Spectral fits to SXI Normal mode Crab sequence 100044010 using the RMF and ARF files derived in the previous section. The 2-10 keV unabsorbed flux is 2.1 x 10^{-8} erg cm^{-2} s^{-1} in the best-fit model.

SXS

(1) Fit the SXS spectrum in the 0.6-16 keV band with a power-law model, with absorption 3.0 x 10^{21} cm^{-2} using the xlarge RMF and ARF file created in the previous section:

```
1 file 1 spectrum
Spectrum 1  Spectral Data File: ah100044010sxs_p0px1010_cl2.pi
Net count rate (cts/s) for Spectrum:1  7.930e+01 +/- 9.025e-02
 Assigned to Data Group 1 and Plot Group 1
  Noticed Channels:  1201-31999
  Telescope: HITOMI Instrument: SXS  Channel Type: PI
  Exposure Time: 9735 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Response (RMF) File
ah100044010sxs_p0px1010_cl2_extralarge.rmf for Source 1
 Using Auxiliary Response (ARF) File  ah100044010sxs_p0px1010_cl_rt.arf

 Spectral data counts: 772025
 Model predicted rate: 79.2943


Current model list:

========================================================================
Model TBabs<1>*pegpwrlw<2> Source No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
   1    1   TBabs      nH         10^22    0.300000     frozen
   2    2   pegpwrlw   PhoIndex            2.14349      +/-  2.96774E-03
   3    2   pegpwrlw   eMin       keV      2.00000      frozen
   4    2   pegpwrlw   eMax       keV      10.0000      frozen
   5    2   pegpwrlw   norm                2.40892E+04  +/-  28.5171
________________________________________________________________________

   Using energies from responses.

Fit statistic : C-Statistic =       35304.72 using 30799 PHA bins and 30797
degrees of freedom.

Test statistic : Chi-Squared =       33546.85 using 30799 PHA bins.
 Reduced chi-squared =       1.089290 for  30797 degrees of freedom
 Null hypothesis probability =   2.409091e-27

***Warning: Chi-square may not be valid due to bins with zero variance
            in spectrum number(s): 1

 Weighting method: standard
```

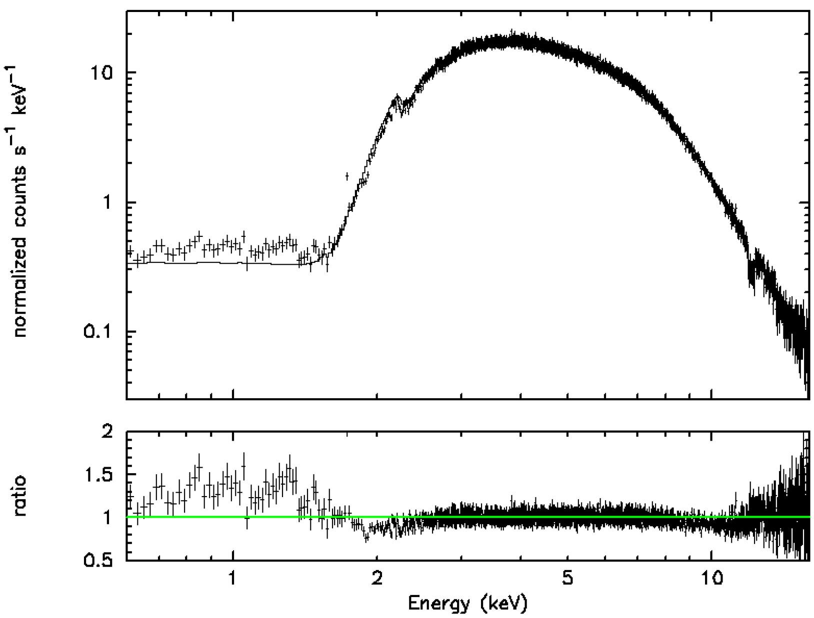


Figure 36: Fits to SXS spectra for Crab nebula sequence 100044010 in the 0.6-12 keV band using the xlarge-sized RMF file. The 2-10 keV unabsorbed flux is 2.41 x 10^{-8} erg cm^{-2} s^{-1} in the best-fit model.

(1) Fit the SXS extended energy spectrum in the 1.8-30 keV band with a power-law model, with absorption 3.0 x 10^{21} cm^{-2} using the small RMF and ARF file created in the previous section:

```
1 file 1 spectrum
Spectrum 1  Spectral Data File: ah100044010sxs_p0px1010_clnew_clext2.pi
Net count rate (cts/s) for Spectrum:1  7.886e+01 +/- 9.001e-02
 Assigned to Data Group 1 and Plot Group 1
  Noticed Channels:  1802-29999
  Telescope: HITOMI Instrument: SXS  Channel Type: PIE
  Exposure Time: 9733 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Response (RMF) File            ah100044010_sxs_clext2_HPMP_small.rmf for
Source 1
 Using Auxiliary Response (ARF) File  ah100044010sxs_p0px1010_rt_ext.arf
 Spectral data counts: 767525
 Model predicted rate: 78.8561


Current model list:

========================================================================
Model TBabs<1>*pegpwrlw<2> Source No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
   1    1   TBabs      nH         10^22    0.300000     frozen
   2    2   pegpwrlw   PhoIndex            2.22671      +/-  2.89265E-03
   3    2   pegpwrlw   eMin       keV      2.00000      frozen
   4    2   pegpwrlw   eMax       keV      10.0000      frozen
   5    2   pegpwrlw   norm                2.56652E+04  +/-  33.3688
________________________________________________________________________

   Using energies from responses.
```

```
Fit statistic : C-Statistic =       21382.07 using 28198 PHA bins and 28196
degrees of freedom.

Test statistic : Chi-Squared =       18362.15 using 28198 PHA bins.
 Reduced chi-squared =      0.6512323 for  28196 degrees of freedom
 Null hypothesis probability =   1.000000e+00

***Warning: Chi-square may not be valid due to bins with zero variance
            in spectrum number(s): 1

 Weighting method: standard
```

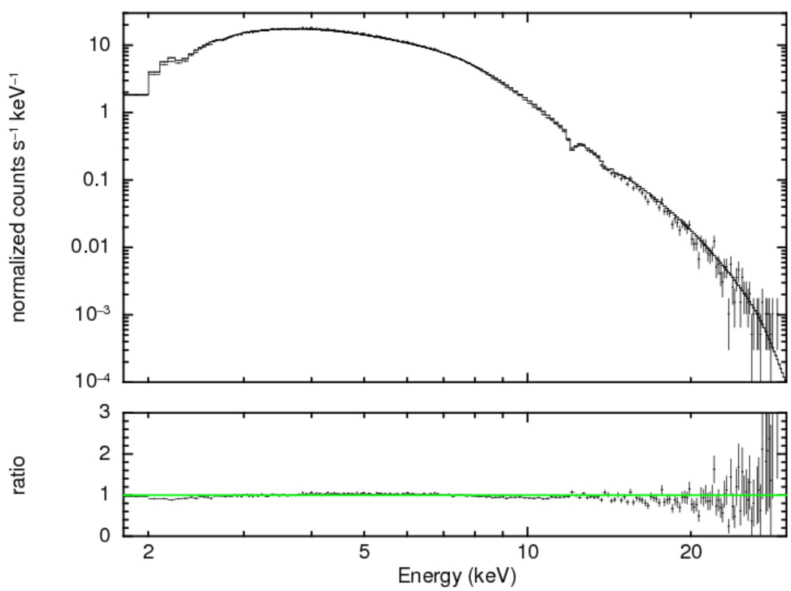


Figure 37: Fits to SXS extended spectra for Crab nebula sequence 100044010 in the 1.8-30 keV band using the small--sized RMF file. The 2-10 keV unabsorbed flux is 2.57 x 10^{-8} erg cm^{-2} s^{-1} in the best-fit model. Additional rebinning has been applied in making the plot.

JOINT Spectra

(1) Jointly fit the HXI1 and HXI2 spectra in the 5-80 keV band, the background subtracted SXI spectrum in the 0.8-16 keV band, and the SXS spectrum in the 0.6-16 keV band with a power-law model with index and absorption free and tied among detectors. The xlarge-sized matrix is used for the SXS.

```
4 files 4 spectra
Spectrum 1  Spectral Data File: ah100044010sxs_p0px1010_cl2.pi
Net count rate (cts/s) for Spectrum:1  7.930e+01 +/- 9.025e-02
 Assigned to Data Group 1 and Plot Group 1
  Noticed Channels:  1201-31999
  Telescope: HITOMI Instrument: SXS  Channel Type: PI
  Exposure Time: 9735 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Response (RMF) File
ah100044010sxs_p0px1010_cl2_extralarge.rmf for Source 1
 Using Auxiliary Response (ARF) File  ah100044010sxs_p0px1010_cl_rt.arf

 Spectral data counts: 772025
 Model predicted rate: 79.2943

Spectrum 2  Spectral Data File: ah100044010sxi_p0112004e0_cl.pi
Net count rate (cts/s) for Spectrum:2  7.192e+02 +/- 2.821e+00
```

```
 Assigned to Data Group 2 and Plot Group 2
  Noticed Channels:  135-2666
  Telescope: HITOMI Instrument: SXI  Channel Type: PI
  Exposure Time: 90.35 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Response (RMF) File            ah100044010sxi_p0112004e0_cl.rmf for
Source 1
 Using Auxiliary Response (ARF) File  ah100044010sxi_p0112004e0_cl.arf

 Spectral data counts: 64977
 Model predicted rate: 719.190

Spectrum 3  Spectral Data File: ah100044010_hxi1_dtime.pi
Net count rate (cts/s) for Spectrum:3  4.391e+02 +/- 2.724e-01
 Assigned to Data Group 3 and Plot Group 3
  Noticed Channels:  51-799
  Telescope: HITOMI Instrument: HXI1  Channel Type: PI
  Exposure Time: 5918 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Response (RMF) File            ah100044010_hxi1.rsp for Source 1

 Spectral data counts: 2.59859e+06
 Model predicted rate: 439.137

Spectrum 4  Spectral Data File: ah100044010_hxi2_dtime.pi
Net count rate (cts/s) for Spectrum:4  4.257e+02 +/- 2.633e-01
 Assigned to Data Group 4 and Plot Group 4
  Noticed Channels:  51-799
  Telescope: HITOMI Instrument: HXI2  Channel Type: PI
  Exposure Time: 6141 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Response (RMF) File            ah100044010_hxi2.rsp for Source 1

 Spectral data counts: 2.61451e+06
 Model predicted rate: 425.746


Current model list:

========================================================================
Model TBabs<1>*pegpwrlw<2>*constant<3> Source No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
                           Data group: 1
   1    1   TBabs      nH         10^22    0.577301     +/-  5.99931E-03
   2    2   pegpwrlw   PhoIndex            2.15031      +/-  9.53552E-04
   3    2   pegpwrlw   eMin       keV      2.00000      frozen
   4    2   pegpwrlw   eMax       keV      10.0000      frozen
   5    2   pegpwrlw   norm                2.44200E+04  +/-  28.8676
   6    3   constant   factor              1.00000      frozen
                           Data group: 2
   7    1   TBabs      nH         10^22    0.577301     = p1
   8    2   pegpwrlw   PhoIndex            2.15031      = p2
   9    2   pegpwrlw   eMin       keV      2.00000      = p3
  10    2   pegpwrlw   eMax       keV      10.0000      = p4
  11    2   pegpwrlw   norm                2.07771E+04  +/-  110.892
  12    3   constant   factor              0.294700     frozen
                           Data group: 3
  13    1   TBabs      nH         10^22    0.577301     = p1
  14    2   pegpwrlw   PhoIndex            2.15031      = p2
  15    2   pegpwrlw   eMin       keV      2.00000      = p3
  16    2   pegpwrlw   eMax       keV      10.0000      = p4
```

```
  17     2    pegpwrlw   norm                2.44354E+04   +/-   23.6963
  18     3    constant   factor              1.00000       frozen
                            Data group: 4
  19     1    TBabs      nH         10^22    0.577301      = p1
  20     2    pegpwrlw   PhoIndex            2.15031       = p2
  21     2    pegpwrlw   eMin       keV      2.00000       = p3
  22     2    pegpwrlw   eMax       keV      10.0000       = p4
  23     2    pegpwrlw   norm                2.37455E+04   +/-   23.0822
  24     3    constant   factor              1.00000       frozen
________________________________________________________________________

   Using energies from responses.

Fit statistic : C-Statistic =       40003.07 using 34829 PHA bins and 34823
degrees of freedom.

Test statistic : Chi-Squared =       37771.10 using 34829 PHA bins.
 Reduced chi-squared =       1.084659 for  34823 degrees of freedom
 Null hypothesis probability =   7.749871e-28

***Warning: Chi-square may not be valid due to bins with zero variance
            in spectrum number(s): 1 2 3 4

 Weighting method: standard
```

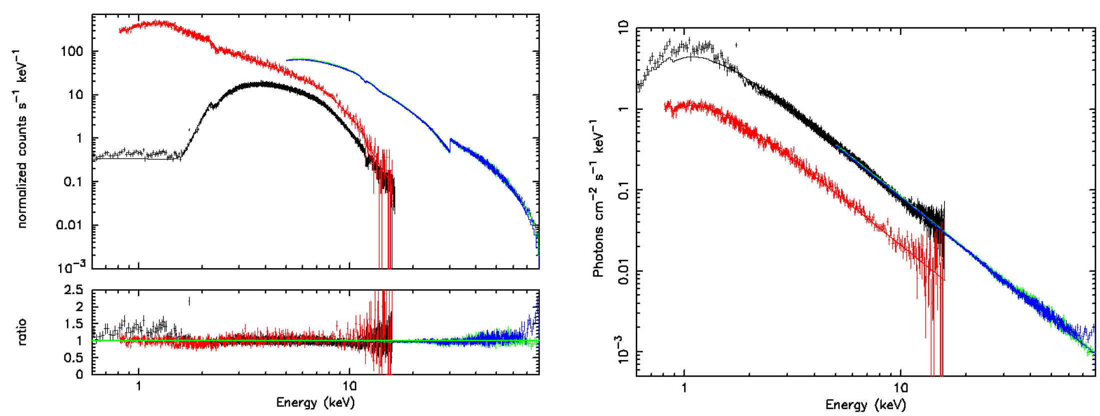


Figure 38: LEFT: Joint fit to SXS Crab nebula sequence 100044010 spectra from all detectors: HXI1 5-80 keV (green), HXI2 5-80 keV (blue), SXI 0.8-12 keV Normal (red) and SXS 0.6-12 keV (black) -- best-fit absorbed power-law with data-to-model ratio (left). RIGHT: Unfolded spectrum, with SXI offset due to scaling factor. The xlarge SXS rmf is used. The 2-10 keV unabsorbed fluxes are ~2.44, 2.37, 2.08, and 2.44 x 10^{-11} erg cm^{-2} s^{-1} in the best-fit model for HXI1, HXI2, SXI, and SXS, respectively.

(2) Plot the HXI1 and HXI2 spectra in the 5-80 keV band, the SGD1 spectrum in the 30-2000 keV band, the SXI spectrum in the 0.8-16 keV band, the SXS spectrum in the 0.6-16 keV band, and the global spectral model from Kirsch et al. 2005 (SPIE, 5898, 22-33):

```
[other files as before]

Spectral Data File: ah100044010sg1_p0ccALLrec_dtime.pi  Spectrum 5
Net count rate (cts/s) for Spectrum:5  8.086e+00 +/- 4.074e-02
 Assigned to Data Group 1 and Plot Group 5
  Noticed Channels:  42-2048
  Telescope: HITOMI Instrument: SGD1  Channel Type: PI
  Exposure Time: 4872 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Response (RMF) File            ah100044010_sg1_ccALL.rsp for Source 1
```

```
Spectral data counts: 39400
Model predicted rate: 0.580588

Current model list:

========================================================================
Model phabs<1>*powerlaw<2> Source No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
                           Data group: 1
   1    1   phabs      nH         10^22    0.450000     +/-  0.0
   2    2   powerlaw   PhoIndex            2.08000      +/-  0.0
   3    2   powerlaw   norm                8.97000      +/-  0.0
                           Data group: 2
   4    1   phabs      nH         10^22    0.450000     = p1
   5    2   powerlaw   PhoIndex            2.08000      = p2
   6    2   powerlaw   norm                8.97000      = p3
                           Data group: 3
   7    1   phabs      nH         10^22    0.450000     = p1
   8    2   powerlaw   PhoIndex            2.08000      = p2
   9    2   powerlaw   norm                8.97000      = p3
                           Data group: 4
  10    1   phabs      nH         10^22    0.450000     = p1
  11    2   powerlaw   PhoIndex            2.08000      = p2
  12    2   powerlaw   norm                8.97000      = p3
                           Data group: 5
  13    1   phabs      nH         10^22    0.450000     = p1
  14    2   powerlaw   PhoIndex            2.08000      = p2
  15    2   powerlaw   norm                8.97000      = p3
________________________________________________________________________

   Using energies from responses.

Fit statistic : C-Statistic =       514220.1 using 36836 PHA bins and 36833
degrees of freedom.

Test statistic : Chi-Squared =       560062.8 using 36836 PHA bins.
 Reduced chi-squared =       15.20546 for  36833 degrees of freedom
 Null hypothesis probability =   0.000000e+00

***Warning: Chi-square may not be valid due to bins with zero variance
            in spectrum number(s): 1 2 3 4 5

 Current data and model not fit yet.
 Weighting method: standard
```

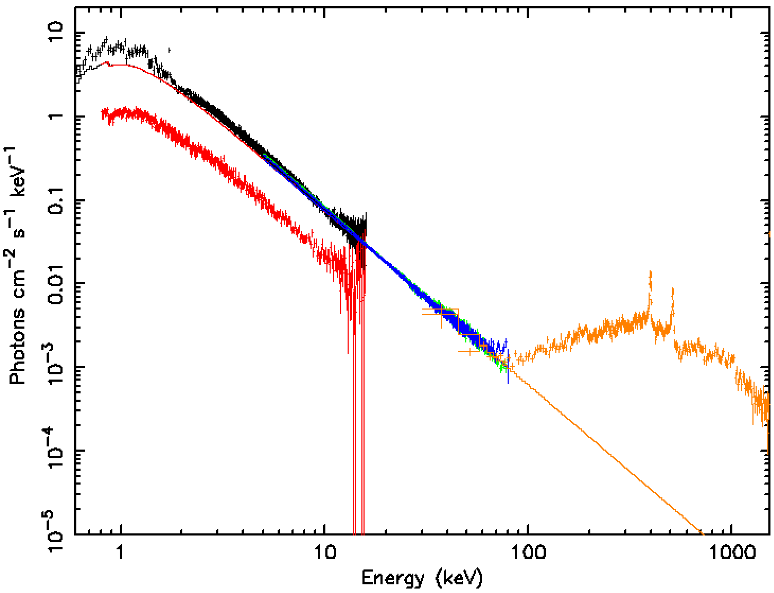


Figure 39: Unfolded spectra from all detectors: HXI1 5-80 keV (green), HXI2 5-80 keV (blue), SXI 0.8-12 keV Normal (red), SXS 0.6-12 keV (black), and SGD 30-2000 keV (orange) using the broadband model from Kirsch et al. (2005; black).

N132D

Table 5	100041010	100041020
GEN-HK	ah100041010gen_a0.hk.gz	ah100041020gen_a0.hk1.gz
TIM	ah100041010.tim.gz	ah100041020.tim.gz
ATTITUDE	ah100041010.att.gz	ah100041020.att.gz
ORBIT	ah100041010.orb.gz	ah100041020.orb.gz
OBSGTI	ah100041010_gen.gti.gz	ah100041020_gen.gti.gz
MKF	ah100041010.mkf.gz	ah100041020.mkf.gz
EHK	ah100041010.ehk.gz	ah100041020.ehk.gz
EHK2	ah100041010.ehk2.gz	ah100041020.ehk2.gz
SXI HK	ah100041010sxi_a0.hk.gz	ah100041020sxi_a0.hk.gz
SXI EVT UF	ah100041010sxi_p010000360_uf.evt.gz ah100041010sxi_p1100003f0_uf.evt.gz ah100041010sxi_p2100003f0_uf.evt.gz ah100041010sxi_p3100003f0_uf.evt.gz ah100041010sxi_s010000360_uf.evt.gz	ah100041020sxi_p1100003f0_uf.evt.gz ah100041020sxi_p2100003f0_uf.evt.gz ah100041020sxi_p3100003f0_uf.evt.gz ah100041020sxi_p4100003f0_uf.evt.gz ah100041020sxi_p5100003f0_uf.evt.gz ah100041020sxi_p6100003f0_uf.evt.gz ah100041020sxi_p7100003f0_uf.evt.gz ah100041020sxi_p8100003f0_uf.evt.gz ah100041020sxi_p9100003f0_uf.evt.gz
SXI HOTPIX	ah100041010sxi_a010000360.hpix.gz ah100041010sxi_a0100003f0.hpix.gz	ah100041020sxi_a0100003f0.hpix.gz
SXI FLICKPIX	ah100041010sxi_a010000360.fpix.gz ah100041010sxi_a1100003f0.fpix.gz ah100041010sxi_a2100003f0.fpix.gz ah100041010sxi_a3100003f0.fpix.gz	ah100041020sxi_a1100003f0.fpix.gz ah100041020sxi_a2100003f0.fpix.gz ah100041020sxi_a3100003f0.fpix.gz ah100041020sxi_a4100003f0.fpix.gz ah100041020sxi_a5100003f0.fpix.gz ah100041020sxi_a6100003f0.fpix.gz ah100041020sxi_a7100003f0.fpix.gz ah100041020sxi_a8100003f0.fpix.gz ah100041020sxi_a9100003f0.fpix.gz
SXI BAD PIXEL IMG	ah100041010sxi_p010000360.bimg.gz ah100041010sxi_p1100003f0.bimg.gz	ah100041020sxi_p1100003f0.bimg.gz ah100041020sxi_p2100003f0.bimg.gz

	ah100041010sxi_p2100003f0.bimg.gz ah100041010sxi_p3100003f0.bimg.gz	ah100041020sxi_p3100003f0.bimg.gz ah100041020sxi_p4100003f0.bimg.gz ah100041020sxi_p5100003f0.bimg.gz ah100041020sxi_p6100003f0.bimg.gz ah100041020sxi_p7100003f0.bimg.gz ah100041020sxi_p8100003f0.bimg.gz ah100041020sxi_p9100003f0.bimg.gz
SXI TEL	ah100041010sxi_tel.gti.gz	ah100041020sxi_tel.gti.gz
SXI EVT CL	ah100041010sxi_p1100003f0_cl.evt.gz	ah100041020sxi_p1100003f0_cl.evt.gz ah100041020sxi_p2100003f0_cl.evt.gz ah100041020sxi_p3100003f0_cl.evt.gz ah100041020sxi_p4100003f0_cl.evt.gz ah100041020sxi_p6100003f0_cl.evt.gz ah100041020sxi_p7100003f0_cl.evt.gz ah100041020sxi_p8100003f0_cl.evt.gz ah100041020sxi_p9100003f0_cl.evt.gz
SXS HK	ah100041010sxs_a0.hk1.gz	ah100041020sxs_a0.hk1.gz
SXS ADR	ahsxs_adr.gti.gz	ahsxs_adr.gti.gz
SXS AC EVT	ah100041010sxs_a0ac_uf.evt.gz	ah100041020sxs_a0ac_uf.evt.gz
SXS PIX12 GAIN	ah100041010sxs_010_pxcal.ghf.gz	ah100041020sxs_010_pxcal.ghf.gz
SXS PIX12 EVT	ah100041010sxs_a0pxcal010_uf.evt.gz	ah100041020sxs_a0pxcal010_uf.evt.gz
SXS EL GTI	ah100041010sxs_el.gti.gz	ah100041020sxs_el.gti.gz
SXS TEL	ah100041010sxs_tel.gti.gz	ah100041020sxs_tel.gti.gz
SXS PIX EXP	ah100041010sxs_px1010_exp.gti.gz	ah100041020sxs_px1010_exp.gti.gz
SXS PIX UF (p)	ah100041010sxs_p0px1010_uf.evt.gz	ah100041020sxs_p0px1010_uf.evt.gz
SXS PIX CL (p)	ah100041010sxs_p0px1010_cl.evt.gz	ah100041020sxs_p0px1010_cl.evt.gz
SXS PIX UF (s)	ah100041010sxs_s0px1010_uf.evt.gz	

a) Untar in a directory `/full/path/to/data/`.

Additional text files for analysis are as follows, and are shown in detail as they are used.

- standard (and other) extraction region files (place in dir `/full/path/to/regions`)
  - n132d_SXI_src1.reg
  - n132d_SXI_src2.reg
  - n132d_SXI_bkg1.reg
  - n132d_SXI_bkg2.reg
  - allpixels_SXS_det.reg

- Lists of SXI files to input into addascaspec
  - merge_file.list

NOTE on source regions files:

i) 2 arcmin circle (SKY coordinates) for SXI source
ii) Full array (except pixel 12) for SXS (expressed in DET coordinates)

Note on sequences.

In sequence `100041020`, because of the wrong attitude setting (STT problem), the source was observed off-axis during the entire observation. As the result, SXS did not detect any photons from the source.

Instrument Specific Reprocessing

SXS

100041010

(1) Recalibrate and rescreen using sxspipeline

```
sxspipeline indir=100041010 outdir=repro_100041010 steminputs=ah100041010
stemoutputs=ah100041010 entry_stage=1
attitude=100041010/auxil/ah100041010.att.gz
extended_housekeeping=100041010/auxil/ah100041010.ehk.gz
makefilter=100041010/auxil/ah100041010.mkf.gz
orbit=100041010/auxil/ah100041010.orb.gz
obsgti=100041010/auxil/ah100041010_gen.gti.gz
housekeeping=100041010/sxs/hk/ah100041010sxs_a0.hk1.gz
timfile=100041010/auxil/ah100041010.tim.gz clobber=yes
```

SXI

100041010 and 100041020

(1) Recalibrate and rescreen using sxipipeline

```
sxipipeline indir=100041010 outdir=repro_100041010 steminputs=ah100041010
stemoutputs=ah100041010 entry_stage=1 exit_stage=2
attitude=100041010/auxil/ah100041010.att.gz
extended_housekeeping=100041010/auxil/ah100041010.ehk.gz
makefilter=100041010/auxil/ah100041010.mkf.gz
orbit=100041010/auxil/ah100041010.orb.gz
obsgti=100041010/auxil/ah100041010_gen.gti.gz
housekeeping=100041010/sxi/hk/ah100041010sxi_a0.hk.gz clobber=yes

sxipipeline indir=100041020 outdir=repro_100041020 steminputs=ah100041020
stemoutputs=ah100041020 entry_stage=1 exit_stage=2
attitude=100041020/auxil/ah100041020.att.gz
extended_housekeeping=100041020/auxil/ah100041020.ehk.gz
makefilter=100041020/auxil/ah100041020.mkf.gz
orbit=100041020/auxil/ah100041020.orb.gz
obsgti=100041020/auxil/ah100041020_gen.gti.gz
housekeeping=100041020/sxi/hk/ah100041020sxi_a0.hk.gz clobber=yes
```

Extracting Products

This section details tools to run on cleaned event files to get instrument specific data products. These may be applied to the original cleaned event files from the pipeline, or to new cleaned event files created using the steps in the last section. In what follows, the original pipeline cleaned event files are used. The extraction region files described above are assumed to be in the `regions` directory.

SXS

100041010

All necessary input files and newly created output files in this section are placed in the /full/path/to/data/products_sxs directory

```
cd /full/path/
```

```
cd data/products_sxs
```

(1) Additional screening

Create a "cleaned-2" SXS event file

```
ah100041010sxs_p0px1010_cl2.evt
```

by applying a RISETIME cut to Hp, Mp, Ms, and Lp (but not Ls) events and excluding frame events flagged due to close proximity in time to other events that are no longer screened as part of the standard processing..

```
ftselect infile=ah100041010sxs_p0px1010_cl.evt \
outfile=ah100041010sxs_p0px1010_cl2.evt \
expression="(PI>=400)&&((RISE_TIME>=40&&RISE_TIME<=60&&ITYPE<4)||(ITYPE==4))&&S
TATUS[4]==b0"
```

(2) Extract source spectra and light curves using xselect

```
xselect
xsel
xsel> read eve ah100041010sxs_p0px1010_cl2.evt
xsel> ./
xsel> yes
xsel:HITOMI-SXS-PX_NORMAL > set xyname detx dety
xsel:HITOMI-SXS-PX_NORMAL > bin all
xsel:HITOMI-SXS-PX_NORMAL > save image image_100041010sxs.fits
xsel:HITOMI-SXS-PX_NORMAL > save spec spec_100041010sxs.pi
xsel:HITOMI-SXS-PX_NORMAL > exit
```

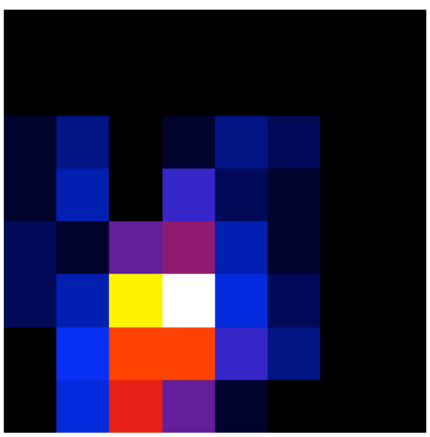


Figure 40: SXS image for sequence 100041010 in DET coordinate.

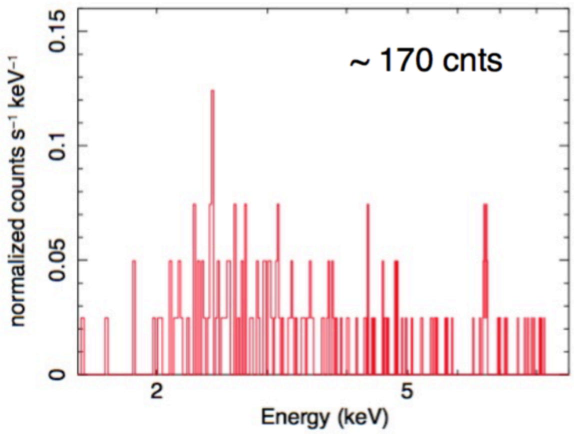


Figure 41: SXS spectrum for sequence 100041010.

SXI

100041010

All necessary input files and newly created output files in this section are placed in the /full/path/to/data/products_sxi directory.

```
cd /full/path/
```

```
cd data/products_sxi
```

The cleaned SXI event file for this sequence is:
`ah100041010sxi_p1100003f0_cl.evt.gz`

For the analysis, the source is defined as a circle region with a radius of 2.0 arcmin defined as:

```
# Region file format: DS9 version 4.1
global color=green dashlist=8 3 width=1 font="helvetica 10 normal roman" select=1
highlite=1 dash=0 fixed=0 edit=1 move=1 delete=1 include=1 source=1
fk5
circle(5:25:01.387,-69:38:40.67,120")
```

The background region (file ../../regions/n132d_SXI_bkg1.reg) is a rectangle covering most of the entire SXI and excluding the source region. It is defined as:

```
# Region file format: DS9 version 4.1
global color=green dashlist=8 3 width=1 font="helvetica 10 normal roman" select=1
highlite=1 dash=0 fixed=0 edit=1 move=1 delete=1 include=1 source=1
fk5
box(5:24:19.149,-69:42:39.61,2160",2160",356.32)
-circle(5:25:01.387,-69:38:40.67,240")
-circle(5:27:49.618,-69:41:39.78,200")
-circle(5:20:45.886,-69:43:33.47,200")
```

(1) Extract images, source spectra, and light curves using xselect

```
read eve ah100041010sxi_p1100003f0_cl.evt.gz data_dir="./" reset_miss=yes
! -- extract 0.5-8 keV image, binned 4x4
set xybin 4
filter pha_cut 83 1333
extract image
save image ah100041010sxi_p1100003f0_cl.img clobberit=yes
clear pha_cut
```

```
! -- extract SOURCE light curve and spectrum
filter region ./n132d_SXI_src1.reg
extract "spectrum curve" exposure=0.
save curve ah100041010sxi_p1100003f0_cl.lc clobberit=yes
set device "ah100041010sxi_p1100003f0_cl.lc.ps/cps"
plot curve
quit
save spectrum ah100041010sxi_p1100003f0_cl.pi group=no resp=no clobberit=yes
set device "ah100041010sxi_p1100003f0_cl.pi.ps/cps"
plot spec
quit
! -- extract BACKGROUND light curve and spectrum
clear region all
filter region ./n132d_SXI_bkg1.reg
extract "spectrum curve" exposure=0.
save curve ah100041010sxi_p1100003f0_cl_bkg.lc clobberit=yes
set device "ah100041010sxi_p1100003f0_cl_bkg.lc.ps/cps"
plot curve
quit
save spectrum ah100041010sxi_p1100003f0_cl_bkg.pi group=no resp=no
clobberit=yes
set device "ah100041010sxi_p1100003f0_cl_bkg.pi.ps/cps"
plot spec
quit
exit save_session=no
```

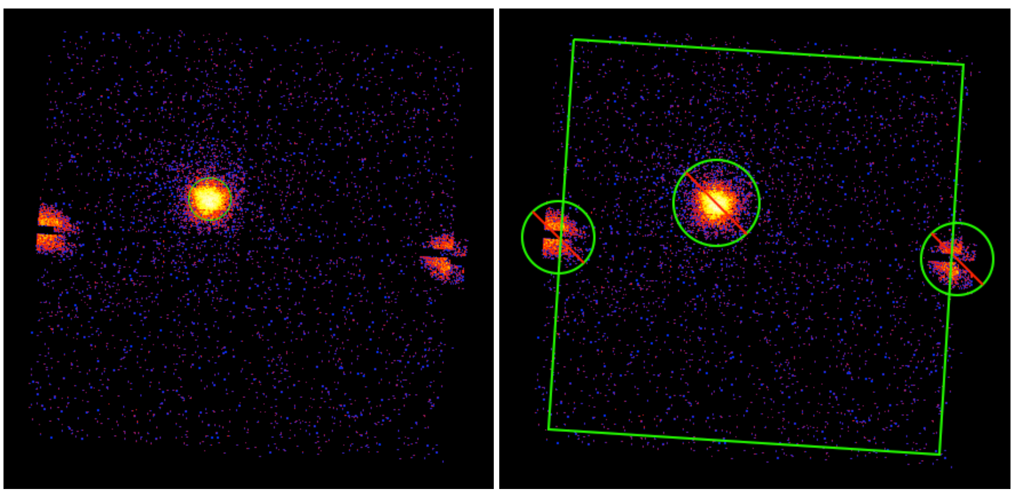


Figure 42: SXI image with source (left) and background (right) extraction regions for sequence 100041010.

100041020

There are eight cleaned SXI event files for this sequence:

```
ah100041020sxi_p1100003f0_cl.evt.gz
ah100041020sxi_p2100003f0_cl.evt.gz
ah100041020sxi_p3100003f0_cl.evt.gz
ah100041020sxi_p4100003f0_cl.evt.gz
ah100041020sxi_p6100003f0_cl.evt.gz
ah100041020sxi_p7100003f0_cl.evt.gz
ah100041020sxi_p8100003f0_cl.evt.gz
ah100041020sxi_p9100003f0_cl.evt.gz
```

Because of time-dependent cosmic-ray-echo effects, there is a differences in the number of bad pixels between OBSIDs and the SXI event data cannot be combined in the same way the other instruments can. Instead, spectra, RMFs, exposure maps, and ARFs must be generated for each OBSID separately and then simultaneously combined at the end. This is done in the next section.

The following analysis is done using different regions files than the ones used for OBSID 100041010; although the analysis below may be repeated using the same source region file as used for sequence 100041010.

The content of the source region file used here, `n132d_SXI_src2.reg` is

```
# Region file format: DS9 version 4.1
global color=green dashlist=8 3 width=1 font="helvetica 10 normal roman" select=1
highlite=1 dash=0 fixed=0 edit=1 move=1 delete=1 include=1 source=1
fk5
circle(5:25:01.387,-69:38:40.67,120")
-box(5:25:04.134,-69:40:43.06,215.717",48.9672",356.854)
-box(5:25:15.397,-69:38:52.28,45.6304",277.525",356.317)
```

and the background region, `n132d_SXI_bkg2.reg`,

```
# Region file format: DS9 version 4.1
global color=green dashlist=8 3 width=1 font="helvetica 10 normal roman" select=1
highlite=1 dash=0 fixed=0 edit=1 move=1 delete=1 include=1 source=1
fk5
box(5:25:15.146,-69:40:20.48,2160",2160",356.32)
-circle(5:25:01.387,-69:38:40.67,240")
-box(5:25:15.702,-69:40:36.97,2343.08",73.13",356.317)
-box(5:25:16.791,-69:40:44.39,93.3832",2340.43",356.854)
-circle(5:28:51.290,-69:39:28.65,200")
-circle(5:21:42.239,-69:41:43.93,200")
```

(1) Extract images, source spectra, and light curves using xselect

The commands are identical to the ones given for the analysis of 100041010, except for the differences in extraction regions and filenames and may be run for each sequence using a script. The plots shown below are derived from the cleaned file ah100041020sxi_p1100003f0_cl.evt.gz.

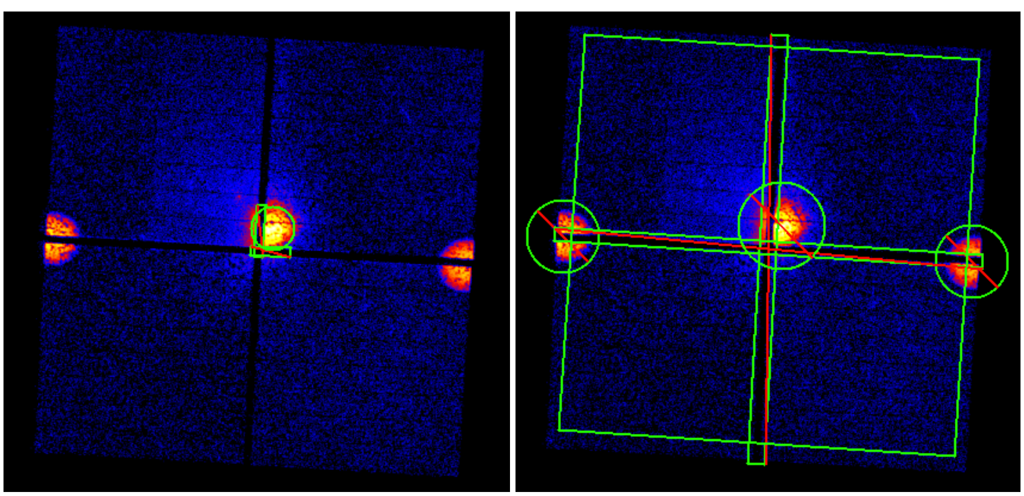


Figure 43: SXI image with source (left) and background (right) extraction regions for sequence 100041020.

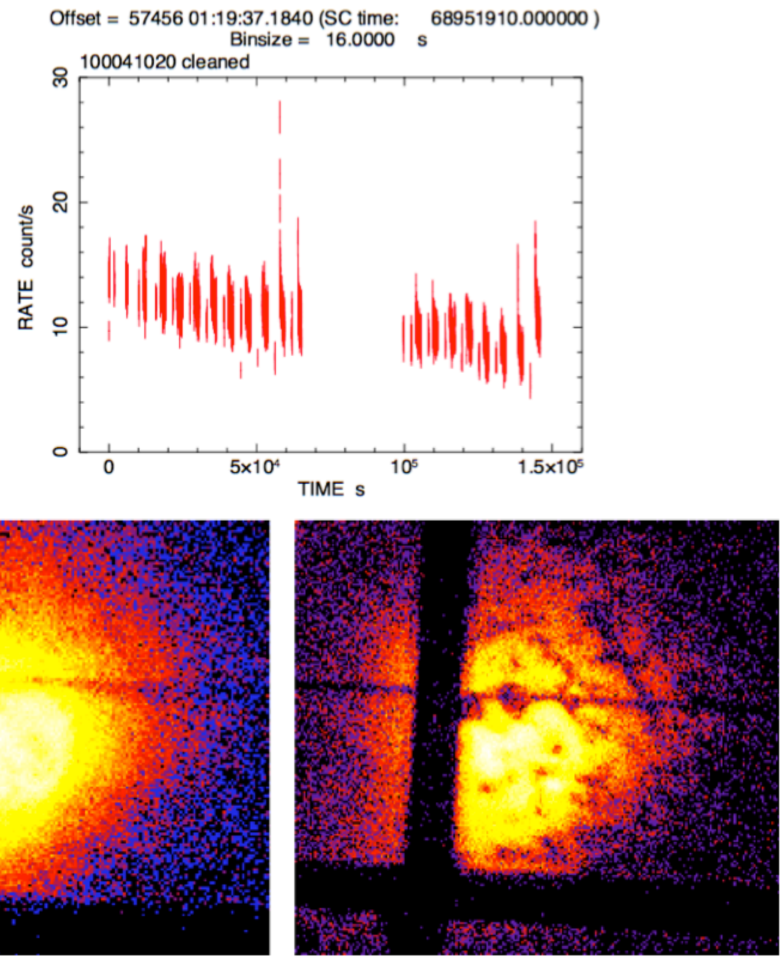


Figure 44: Top – SXI lightcurves for sequence 100041020. The count rate gradually decreases because the number of CR echo pixels increases with time (see below for more details). Bottom – Close-up images around the source including and excluding the CR-echo pixels.

Generating Exposure Map, RMF, and ARF

SXS

100041010

(1) Generate the RMF

Here we use the "medium" size option which accounts for Gaussian and exponential tail components; additional components may be neglected given the low statistics in this data. The all-pixel DET coordinate region file `allpixels_SXS_det.reg` that may be created by sxsregext is input:

```
physical
+box(4,1,5,1.00000000)
+box(3.5,2,6,1.00000000)
+box(3.5,3,6,1.00000000)
+box(3.5,4,6,1.00000000)
+box(3.5,5,6,1.00000000)
+box(3.5,6,6,1.00000000)
```

```
sxsmkrmf infile=ah100041010sxs_p0px1010_cl2.evt outfile=resp_100041010sxs.rmf
resolist=ALL regmode=DET regionfile=n132d_SXS_det.reg whichrmf=M
```

Alternatively, an identical rmf file can be created (by using pixlist option) without the region file.

```
sxsmkrmf infile=ah100041010sxs_p0px1010_cl2.evt outfile=resp_100041010sxs.rmf
resolist=ALL regmode=DET regionfile=NONE whichrmf=M pixlist="0-11,13-35"
```

(2) Generate the SXS exposure maps

```
ahexpmap ehkfile=../100041010/auxil/ah100041010.ehk.gz
gtifile=ah100041010sxs_p0px1010_cl2.evt instrume=SXS badimgfile=NONE
pixgtifile=../100041010/sxs/event_uf/ah100041010sxs_px1010_exp.gti.gz
outfile=ah100041010sxs_p0px1010.expo outmaptype=EXPOSURE delta=20.0 numphi=1 \
clobber=yes
```

3) Generate the SXS ARF

```
aharfgen xrtevtfile=raytrace_ah100041010sxs_p0px1010.fits source_ra=81.255779
source_dec=-69.644631 telescop=HITOMI instrume=SXS
emapfile=ah100041010sxs_p0px1010.expo regmode=DET regionfile=n132d_SXS_det.reg
sourcetype=POINT rmffile=resp_100041010sxs.rmf erange="0.5 16.0 0 0"
outfile=arf_100041010sxs.arf numphoton=100000 minphoton=1 teldeffile=CALDB
qefile=CALDB contamifile=CALDB obffile=CALDB fwfile=CALDB gatevalvefile=CALDB
onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB
frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB
dattfile=none filtoffsetfile=none sampling=4 imgfile=none clobber=yes
```

Note that the source_ra and source_dec are estimated based on the SXI image.

SXI

100041010 and 100041020

Because the cosmic ray echo effect varies between sequences over the course of the observation, in general each sequence has its own bad image file and, therefore, its own exposure map and ARF file. The spectra, RMF, and ARF generated separately can then be co-added – as is done here - or individual spectra can be fit simultaneously.

In the directory where the PI files have been created:

(1) Create an RMF for each sequence

100041010

```
sxirmf infile=ah100041010sxi_p1100003f0_cl.pi outfile=ah100041010sxi_p1100003f0.rmf clobber=yes mode=hl
```

100041020

```
sxirmf infile=ah100041020sxi_p1100003f0_cl.pi outfile=ah100041020sxi_p1100003f0.rmf clobber=yes mode=hl
sxirmf infile=ah100041020sxi_p2100003f0_cl.pi outfile=ah100041020sxi_p2100003f0.rmf clobber=yes mode=hl
sxirmf infile=ah100041020sxi_p3100003f0_cl.pi outfile=ah100041020sxi_p3100003f0.rmf clobber=yes mode=hl
sxirmf infile=ah100041020sxi_p4100003f0_cl.pi outfile=ah100041020sxi_p4100003f0.rmf clobber=yes mode=hl
sxirmf infile=ah100041020sxi_p6100003f0_cl.pi outfile=ah100041020sxi_p6100003f0.rmf clobber=yes mode=hl
sxirmf infile=ah100041020sxi_p7100003f0_cl.pi outfile=ah100041020sxi_p7100003f0.rmf clobber=yes mode=hl
sxirmf infile=ah100041020sxi_p8100003f0_cl.pi outfile=ah100041020sxi_p8100003f0.rmf clobber=yes mode=hl
```

sxirmf infile=ah100041020sxi_p9100003f0_cl.pi outfile=ah100041020sxi_p9100003f0.rmf clobber=yes mode=hl

(2) Create an exposure map for each sequence

100041010

punlearn ahexpmap
ahexpmap ehkfile=../100041010/auxil/ah100041010.ehk.gz gtifile=../100041010/sxi/event_cl/ah100041010sxi_p1100003f0_cl.evt.gz instrume=SXI badimgfile=../100041010/sxi/event_uf/ah100041010sxi_p1100003f0.bimg.gz pixgtifile=../100041010/sxi/event_uf/ah100041010sxi_a1100003f0.fpix.gz outfile=ah100041010sxi_p1100003f0_cl.expo outmaptype=EXPOSURE delta=20.0 numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT abund=1 cols=0 covfac=1 clobber=yes chatter=1 logfile=make_expo_ah100041010sxi_p1100003f0.log

100041020

punlearn ahexpmap
ahexpmap ehkfile=../100041020/auxil/ah100041020.ehk.gz gtifile=../100041020/sxi/event_cl/ah100041020sxi_p1100003f0_cl.evt.gz instrume=SXI badimgfile=../100041020/sxi/event_uf/ah100041020sxi_p1100003f0.bimg.gz pixgtifile=../100041020/sxi/event_uf/ah100041020sxi_a1100003f0.fpix.gz outfile=ah100041020sxi_p1100003f0_cl.expo outmaptype=EXPOSURE delta=2.0 numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT abund=1 cols=0 covfac=1 clobber=yes chatter=1 logfile=make_expo_ah100041020sxi_p1100003f0.log

ahexpmap ehkfile=../100041020/auxil/ah100041020.ehk.gz gtifile=../100041020/sxi/event_cl/ah100041020sxi_p2100003f0_cl.evt.gz instrume=SXI badimgfile=../100041020/sxi/event_uf/ah100041020sxi_p2100003f0.bimg.gz pixgtifile=../100041020/sxi/event_uf/ah100041020sxi_a2100003f0.fpix.gz outfile=ah100041020sxi_p2100003f0_cl.expo outmaptype=EXPOSURE delta=2.0 numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT abund=1 cols=0 covfac=1 clobber=yes chatter=1 logfile=make_expo_ah100041020sxi_p2100003f0.log

ahexpmap ehkfile=../100041020/auxil/ah100041020.ehk.gz gtifile=../100041020/sxi/event_cl/ah100041020sxi_p3100003f0_cl.evt.gz instrume=SXI badimgfile=../100041020/sxi/event_uf/ah100041020sxi_p3100003f0.bimg.gz pixgtifile=../100041020/sxi/event_uf/ah100041020sxi_a3100003f0.fpix.gz outfile=ah100041020sxi_p3100003f0_cl.expo outmaptype=EXPOSURE delta=2.0 numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT abund=1 cols=0 covfac=1 clobber=yes chatter=1 logfile=make_expo_ah100041020sxi_p3100003f0.log

ahexpmap ehkfile=../100041020/auxil/ah100041020.ehk.gz gtifile=../100041020/sxi/event_cl/ah100041020sxi_p4100003f0_cl.evt.gz instrume=SXI badimgfile=../100041020/sxi/event_uf/ah100041020sxi_p4100003f0.bimg.gz pixgtifile=../100041020/sxi/event_uf/ah100041020sxi_a4100003f0.fpix.gz outfile=ah100041020sxi_p4100003f0_cl.expo outmaptype=EXPOSURE delta=2.0 numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT abund=1 cols=0 covfac=1 clobber=yes chatter=1 logfile=make_expo_ah100041020sxi_p4100003f0.log

ahexpmap ehkfile=../100041020/auxil/ah100041020.ehk.gz gtifile=../100041020/sxi/event_cl/ah100041020sxi_p6100003f0_cl.evt.gz instrume=SXI badimgfile=../100041020/sxi/event_uf/ah100041020sxi_p6100003f0.bimg.gz pixgtifile=../100041020/sxi/event_uf/ah100041020sxi_a6100003f0.fpix.gz outfile=ah100041020sxi_p6100003f0_cl.expo outmaptype=EXPOSURE delta=2.0 numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT abund=1 cols=0 covfac=1 clobber=yes chatter=1 logfile=make_expo_ah100041020sxi_p6100003f0.log

ahexpmap ehkfile=../100041020/auxil/ah100041020.ehk.gz gtifile=../100041020/sxi/event_cl/ah100041020sxi_p7100003f0_cl.evt.gz instrume=SXI badimgfile=../100041020/sxi/event_uf/ah100041020sxi_p7100003f0.bimg.gz pixgtifile=../100041020/sxi/event_uf/ah100041020sxi_a7100003f0.fpix.gz outfile=ah100041020sxi_p7100003f0_cl.expo outmaptype=EXPOSURE delta=2.0 numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT abund=1 cols=0 covfac=1 clobber=yes chatter=1 logfile=make_expo_ah100041020sxi_p7100003f0.log ahexpmap ehkfile=../100041020/auxil/ah100041020.ehk.gz gtifile=../100041020/sxi/event_cl/ah100041020sxi_p8100003f0_cl.evt.gz instrume=SXI badimgfile=../100041020/sxi/event_uf/ah100041020sxi_p8100003f0.bimg.gz pixgtifile=../100041020/sxi/event_uf/ah100041020sxi_a8100003f0.fpix.gz outfile=ah100041020sxi_p8100003f0_cl.expo outmaptype=EXPOSURE delta=2.0 numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT abund=1 cols=0 covfac=1 clobber=yes chatter=1 logfile=make_expo_ah100041020sxi_p8100003f0.log

ahexpmap ehkfile=../100041020/auxil/ah100041020.ehk.gz gtifile=../100041020/sxi/event_cl/ah100041020sxi_p9100003f0_cl.evt.gz instrume=SXI badimgfile=../100041020/sxi/event_uf/ah100041020sxi_p9100003f0.bimg.gz pixgtifile=../100041020/sxi/event_uf/ah100041020sxi_a9100003f0.fpix.gz outfile=ah100041020sxi_p9100003f0_cl.expo outmaptype=EXPOSURE delta=2.0 numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT abund=1 cols=0 covfac=1 clobber=yes chatter=1 logfile=make_expo_ah100041020sxi_p9100003f0.log

(3) Create an ARF for each spectrum

100041010

punlearn aharfgen
aharfgen xrtevtfile=raytrace_ah100041010sxi_p1100003f0_ptsrc_evt.fits source_ra=81.255779 source_dec=-69.64463 telescop=HITOMI instrume=SXI emapfile=ah100041010sxi_p1100003f0_cl.expo regmode=RADEC regionfile=n132d_SXI_src1.reg sourcetype=POINT rmffile=ah100041010sxi_p1100003f0.rmf erange="0.5 16.0 0 0" outfile=ah100041010sxi_p1100003f0.arf numphoton=200000 minphoton=1 teldeffile=CALDB qefile=CALDB contamifile=CALDB onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB auxtransfile=NONE seed=7 clobber=yes chatter=2 mode=h logfile=make_arf_ah100041010sxi_p1100003f0.log

100041020

punlearn aharfgen
aharfgen xrtevtfile=raytrace_ah100041020sxi_p1100003f0_ptsrc_evt.fits source_ra=81.255779 source_dec=-69.64463 telescop=HITOMI instrume=SXI emapfile=ah100041020sxi_p1100003f0_cl.expo regmode=RADEC regionfile=n132d_SXI_src2.reg sourcetype=POINT rmffile=ah100041020sxi_p1100003f0.rmf erange="0.5 16.0 0 0" outfile=ah100041020sxi_p1100003f0.arf numphoton=200000 minphoton=1 teldeffile=CALDB qefile=CALDB contamifile=CALDB onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB auxtransfile=NONE seed=7 clobber=yes chatter=2 mode=h logfile=make_arf_ah100041020sxi_p1100003f0.log

aharfgen xrtevtfile=raytrace_ah100041020sxi_p2100003f0_ptsrc_evt.fits source_ra=81.255779 source_dec=-69.64463 telescop=HITOMI instrume=SXI emapfile=ah100041020sxi_p2100003f0_cl.expo regmode=RADEC regionfile=n132d_SXI_src2.reg sourcetype=POINT rmffile=ah100041020sxi_p2100003f0.rmf erange="0.5 16.0 0 0" outfile=ah100041020sxi_p2100003f0.arf numphoton=200000 minphoton=1 teldeffile=CALDB qefile=CALDB contamifile=CALDB onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB auxtransfile=NONE seed=7 clobber=yes chatter=2 mode=h logfile=make_arf_ah100041020sxi_p2100003f0.log

aharfgen xrtevtfile=raytrace_ah100041020sxi_p3100003f0_ptsrc_evt.fits source_ra=81.255779 source_dec=-69.64463 telescop=HITOMI instrume=SXI emapfile=ah100041020sxi_p3100003f0_cl.expo regmode=RADEC regionfile=n132d_SXI_src2.reg sourcetype=POINT rmffile=ah100041020sxi_p3100003f0.rmf erange="0.5 16.0 0 0" outfile=ah100041020sxi_p3100003f0.arf numphoton=200000 minphoton=1 teldeffile=CALDB qefile=CALDB contamifile=CALDB onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB auxtransfile=NONE seed=7 clobber=yes chatter=2 mode=h logfile=make_arf_ah100041020sxi_p3100003f0.log

aharfgen xrtevtfile=raytrace_ah100041020sxi_p4100003f0_ptsrc_evt.fits source_ra=81.255779 source_dec=-69.64463 telescop=HITOMI instrume=SXI emapfile=ah100041020sxi_p4100003f0_cl.expo regmode=RADEC regionfile=n132d_SXI_src2.reg sourcetype=POINT rmffile=ah100041020sxi_p4100003f0.rmf erange="0.5 16.0 0 0" outfile=ah100041020sxi_p4100003f0.arf numphoton=200000 minphoton=1 teldeffile=CALDB qefile=CALDB contamifile=CALDB onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB auxtransfile=NONE seed=7 clobber=yes chatter=2 mode=h logfile=make_arf_ah100041020sxi_p4100003f0.log

aharfgen xrtevtfile=raytrace_ah100041020sxi_p6100003f0_ptsrc_evt.fits source_ra=81.255779 source_dec=-69.64463 telescop=HITOMI instrume=SXI emapfile=ah100041020sxi_p6100003f0_cl.expo regmode=RADEC regionfile=n132d_SXI_src2.reg sourcetype=POINT rmffile=ah100041020sxi_p6100003f0.rmf erange="0.5 16.0 0 0" outfile=ah100041020sxi_p6100003f0.arf numphoton=200000 minphoton=1 teldeffile=CALDB qefile=CALDB contamifile=CALDB onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB auxtransfile=NONE seed=7 clobber=yes chatter=2 mode=h logfile=make_arf_ah100041020sxi_p6100003f0.log

aharfgen xrtevtfile=raytrace_ah100041020sxi_p7100003f0_ptsrc_evt.fits source_ra=81.255779 source_dec=-69.64463 telescop=HITOMI instrume=SXI emapfile=ah100041020sxi_p7100003f0_cl.expo regmode=RADEC regionfile=n132d_SXI_src2.reg sourcetype=POINT rmffile=ah100041020sxi_p7100003f0.rmf erange="0.5 16.0 0 0" outfile=ah100041020sxi_p7100003f0.arf numphoton=200000 minphoton=1 teldeffile=CALDB qefile=CALDB contamifile=CALDB onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB auxtransfile=NONE seed=7 clobber=yes chatter=2 mode=h logfile=make_arf_ah100041020sxi_p7100003f0.log

aharfgen xrtevtfile=raytrace_ah100041020sxi_p8100003f0_ptsrc_evt.fits source_ra=81.255779 source_dec=-69.64463 telescop=HITOMI instrume=SXI emapfile=ah100041020sxi_p8100003f0_cl.expo regmode=RADEC regionfile=n132d_SXI_src2.reg sourcetype=POINT rmffile=ah100041020sxi_p8100003f0.rmf erange="0.5 16.0 0 0" outfile=ah100041020sxi_p8100003f0.arf numphoton=200000 minphoton=1 teldeffile=CALDB qefile=CALDB contamifile=CALDB onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB auxtransfile=NONE seed=7 clobber=yes chatter=2 mode=h logfile=make_arf_ah100041020sxi_p8100003f0.log

aharfgen xrtevtfile=raytrace_ah100041020sxi_p9100003f0_ptsrc_evt.fits source_ra=81.255779 source_dec=-69.64463 telescop=HITOMI instrume=SXI emapfile=ah100041020sxi_p9100003f0_cl.expo regmode=RADEC regionfile=n132d_SXI_src2.reg sourcetype=POINT rmffile=ah100041020sxi_p9100003f0.rmf erange="0.5 16.0 0 0" outfile=ah100041020sxi_p9100003f0.arf numphoton=200000 minphoton=1 teldeffile=CALDB qefile=CALDB contamifile=CALDB onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB auxtransfile=NONE seed=7 clobber=yes chatter=2 mode=h logfile=make_arf_ah100041020sxi_p9100003f0.log

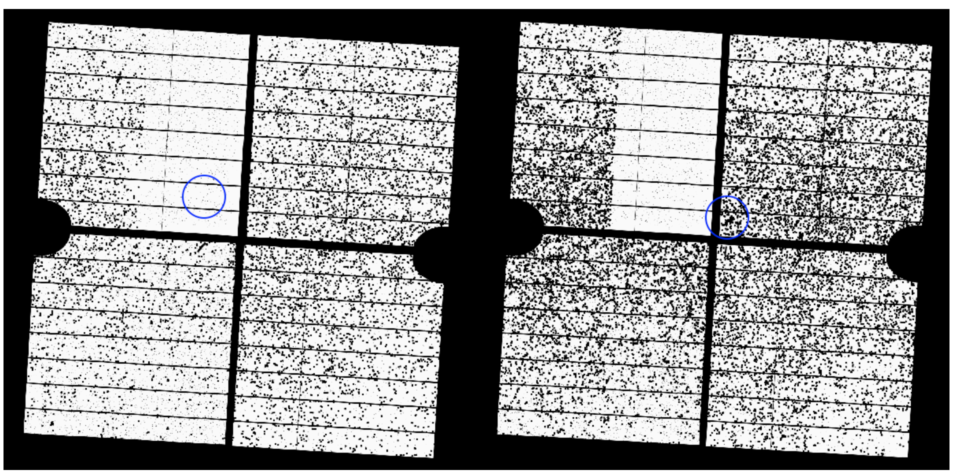


Figure 45: Resulting exposure maps for sequence 100041010 (left) and 10041020_p2100003f0 (right). The region file selected for analysis is shown in blue in both images. The number of bad pixels (mostly due to CR echo) is significantly different among them.

(5) Correct the BACKSCAL keyword in the SXI spectra

XSELECT writes a BACKSCAL keyword in the header of extracted spectra to properly scale the background subtraction in XSPEC. However, it only accounts for the fraction of the area covered by the extraction region, not the number of good pixels. Many pixels in SXI data are affected by cosmic-ray echo or light leak and need to be properly excluded from BACKSCAL.

This is done by running the script "ahbackscal" on all the source and background "pi" files

```
punlearn ahbackscal
ahbackscal ah100041010sxi_p1100003f0_cl.pi n132d_SXI_src1.reg ah100041010sxi_p1100003f0_cl.expo
ahbackscal ah100041020sxi_p1100003f0_n132d_SXI_src2.reg cl.pi ah100041020sxi_p1100003f0_cl.expo
ahbackscal ah100041020sxi_p2100003f0_cl.pi n132d_SXI_src2.reg ah100041020sxi_p2100003f0_cl.expo
ahbackscal ah100041020sxi_p3100003f0_cl.pi n132d_SXI_src2.reg ah100041020sxi_p3100003f0_cl.expo
```

```
ahbackscal ah100041020sxi_p4100003f0_cl.pi n132d_SXI_src2.reg ah100041020sxi_p4100003f0_cl.expo
ahbackscal ah100041020sxi_p6100003f0_cl.pi n132d_SXI_src2.reg ah100041020sxi_p6100003f0_cl.expo
ahbackscal ah100041020sxi_p7100003f0_cl.pi n132d_SXI_src2.reg ah100041020sxi_p7100003f0_cl.expo
ahbackscal ah100041020sxi_p8100003f0_cl.pi n132d_SXI_src2.reg ah100041020sxi_p8100003f0_cl.expo
ahbackscal ah100041020sxi_p9100003f0_cl.pi n132d_SXI_src2.reg ah100041020sxi_p9100003f0_cl.expo
ahbackscal ah100041020sxi_p9100003f0_cl_bkg.pi n132d_SXI_bkg2.reg ah100041020sxi_p9100003f0_cl.expo
ahbackscal ah100041020sxi_p8100003f0_cl_bkg.pi n132d_SXI_bkg2.reg ah100041020sxi_p8100003f0_cl.expo
ahbackscal ah100041020sxi_p7100003f0_cl_bkg.pi n132d_SXI_bkg2.reg ah100041020sxi_p7100003f0_cl.expo
ahbackscal ah100041020sxi_p6100003f0_cl_bkg.pi n132d_SXI_bkg2.reg ah100041020sxi_p6100003f0_cl.expo
ahbackscal ah100041020sxi_p4100003f0_cl_bkg.pi n132d_SXI_bkg2.reg ah100041020sxi_p4100003f0_cl.expo
ahbackscal ah100041020sxi_p3100003f0_cl_bkg.pi n132d_SXI_bkg2.reg ah100041020sxi_p3100003f0_cl.expo
ahbackscal ah100041020sxi_p2100003f0_cl_bkg.pi n132d_SXI_bkg2.reg ah100041020sxi_p2100003f0_cl.expo
ahbackscal ah100041020sxi_p1100003f0_cl_bkg.pi n132d_SXI_bkg2.reg ah100041020sxi_p1100003f0_cl.expo
ahbackscal ah100041010sxi_p1100003f0_cl_bkg.pi n132d_SXI_bkg1.reg ah100041010sxi_p1100003f0_cl.expo
```

(5) Combine SXI spectra and responses from all the sequences.

The ftool ‘addascaspec’ is used to combine the source spectra, background spectra, and responses.

```
addascaspec merge_files.list ah1000410ALL0sxi_cl.pi ah1000410ALL0sxi_cl.rsp
ah1000410ALL0sxi_cl_bkg.pi "POISS-0"
```

where the file ‘merge_files.list’ contains the following four lines (delineated by ‘\’):

```
ah100041010sxi_p1100003f0_cl.pi ah100041020sxi_p1100003f0_cl.pi ah100041020sxi_p2100003f0_cl.pi
ah100041020sxi_p3100003f0_cl.pi ah100041020sxi_p4100003f0_cl.pi ah100041020sxi_p6100003f0_cl.pi
ah100041020sxi_p7100003f0_cl.pi ah100041020sxi_p8100003f0_cl.pi ah100041020sxi_p9100003f0_cl.pi \
ah100041010sxi_p1100003f0_cl_bkg.pi ah100041020sxi_p1100003f0_cl_bkg.pi
ah100041020sxi_p2100003f0_cl_bkg.pi ah100041020sxi_p3100003f0_cl_bkg.pi
ah100041020sxi_p4100003f0_cl_bkg.pi ah100041020sxi_p6100003f0_cl_bkg.pi
ah100041020sxi_p7100003f0_cl_bkg.pi ah100041020sxi_p8100003f0_cl_bkg.pi
ah100041020sxi_p9100003f0_cl_bkg.pi \
ah100041010sxi_p1100003f0.arf ah100041020sxi_p1100003f0.arf ah100041020sxi_p2100003f0.arf
ah100041020sxi_p3100003f0.arf ah100041020sxi_p4100003f0.arf ah100041020sxi_p6100003f0.arf
ah100041020sxi_p7100003f0.arf ah100041020sxi_p8100003f0.arf ah100041020sxi_p9100003f0.arf \
ah100041010sxi_p1100003f0.rmf ah100041020sxi_p1100003f0.rmf ah100041020sxi_p2100003f0.rmf
ah100041020sxi_p3100003f0.rmf ah100041020sxi_p4100003f0.rmf ah100041020sxi_p6100003f0.rmf
ah100041020sxi_p7100003f0.rmf ah100041020sxi_p8100003f0.rmf ah100041020sxi_p9100003f0.rmf
```

This will create a combined source spectrum, combined background spectrum, and a single .rsp file containing both the combined RMF and ARF.

Spectral Fittting

The SXS spectrum of the Fe K band is fit with a model of recombining plasma with the parameters best-fit for Suzaku/XIS. The additional redshift is required.

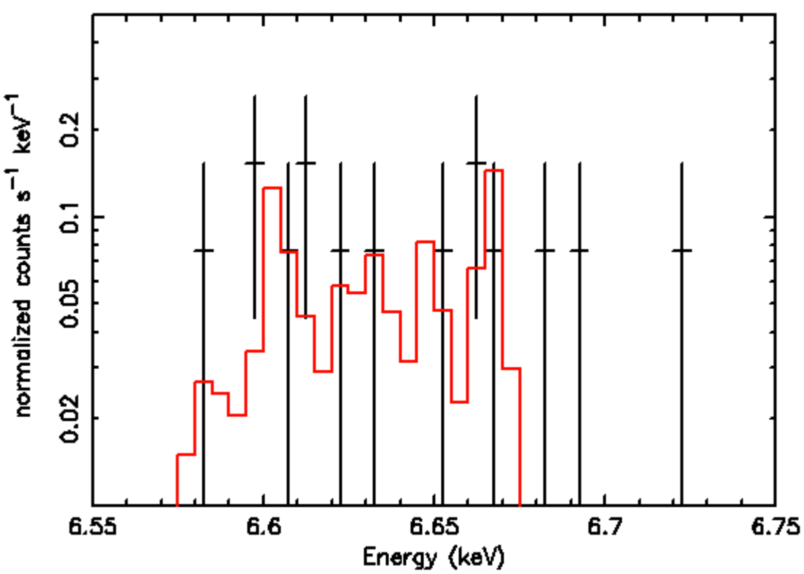


Figure 46: SXS spectrum in the Fe-K band fitted with the model given below.

```
In XSPEC:
statistic chi
method leven 1000000 0.01
abund wilm
xsect bcmc
cosmo 70 0 0.73
xset delta 0.01
xset APECROOT  /Users/hyamagu3/AtomDB/atomdb_v3.0.6/apec_v3.0.6
xset APECTHERMAL  yes
xset NEIAPECROOT  /Users/hyamagu3/AtomDB/atomdb_v3.0.6/apec_v3.0.6_nei
xset NEIVERS  3.0
systematic 0
========================================================================
Model TBabs<1>*varabs<2>*vrnei<3> Source No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
   1    1   TBabs      nH         10^22    5.50000E-02  frozen
   2    2   varabs     H          sH22     1.40000E-02  frozen
   3    2   varabs     He         sHe22    0.900000     frozen
   4    2   varabs     C          sC22     0.300000     frozen
   5    2   varabs     N          sN22     0.300000     frozen
   6    2   varabs     O          sO22     0.300000     frozen
   7    2   varabs     Ne         sNe22    0.300000     frozen
   8    2   varabs     Na         sNa22    0.300000     frozen
   9    2   varabs     Mg         sMg22    0.300000     frozen
  10    2   varabs     Al         sAl22    0.300000     frozen
  11    2   varabs     Si         sSi22    0.300000     frozen
  12    2   varabs     S          sS22     0.300000     frozen
  13    2   varabs     Cl         sCl22    0.300000     frozen
  14    2   varabs     Ar         sAr22    0.300000     frozen
  15    2   varabs     Ca         sCa22    0.300000     frozen
  16    2   varabs     Cr         sCr22    0.300000     frozen
  17    2   varabs     Fe         sFe22    0.300000     frozen
  18    2   varabs     Co         sCo22    0.300000     frozen
  19    2   varabs     Ni         sNi22    0.300000     frozen
  20    3   vrnei      kT         keV      2.00000      frozen
  21    3   vrnei      kT_init    keV      10.0000      frozen
  22    3   vrnei      H                   1.00000      frozen
  23    3   vrnei      He                  1.00000      frozen
  24    3   vrnei      C                   1.00000      frozen
  25    3   vrnei      N                   1.00000      frozen
  26    3   vrnei      O                   1.00000      frozen
  27    3   vrnei      Ne                  1.00000      frozen
  28    3   vrnei      Mg                  1.00000      frozen
  29    3   vrnei      Si                  1.00000      frozen
  30    3   vrnei      S                   1.00000      frozen
```

```
 31    3   vrnei      Ar                    1.00000      frozen
 32    3   vrnei      Ca                    1.00000      frozen
 33    3   vrnei      Fe                    0.650000     frozen
 34    3   vrnei      Ni                    0.650000     = p33
 35    3   vrnei      Tau        s/cm^3     5.30000E+11  frozen
 36    3   vrnei      Redshift              5.00052E-03  +/-  1.87974E-04
 37    3   vrnei      norm                  1.88097E-02  +/-  4.85800E-03
________________________________________________________________________

Fit statistic : C-Statistic =          93.67 using 399 PHA bins and 397 degrees of
freedom.

Test statistic : Chi-Squared =          14.37 using 399 PHA bins.
 Reduced chi-squared =        0.03619 for    397 degrees of freedom
 Null hypothesis probability =   1.000000e+00
```

The SXI data may be fit to models with multiple thermal components, or the sum of NEI models (shown below). The spectrum in the 1.6-12.0 keV band is fitted

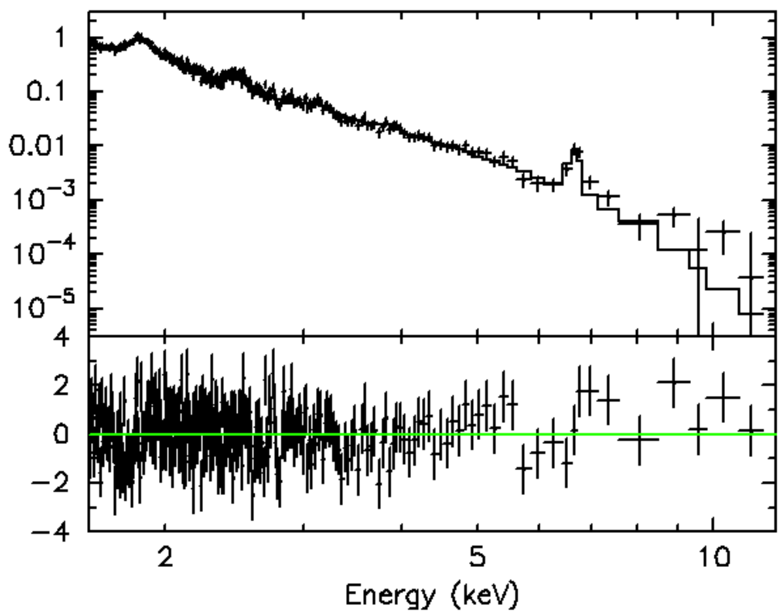


Figure 47: SXI spectrum fitted with the model given below.

```
In XSPEC:
statistic chi
method leven 1000000 0.01
abund wilm
xsect bcmc
cosmo 70 0 0.73
xset delta 0.01
xset NEIAPECROOT  /Users/hyamagu3/AtomDB/atomdb_v3.0.6/apec_v3.0.6_nei
xset NEIVERS  3.0
systematic 0
========================================================================
Model TBabs<1>*varabs<2>(vrnei<3> + vrnei<4>) Source No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
   1    1   TBabs      nH         10^22    5.50000E-02  frozen
   2    2   varabs     H          sH22     1.40000E-02  frozen
   3    2   varabs     He         sHe22    0.900000     frozen
   4    2   varabs     C          sC22     0.300000     frozen
```

```
   5    2   varabs     N          sN22      0.300000     frozen
   6    2   varabs     O          sO22      0.300000     frozen
   7    2   varabs     Ne         sNe22     0.300000     frozen
   8    2   varabs     Na         sNa22     0.300000     frozen
   9    2   varabs     Mg         sMg22     0.300000     frozen
  10    2   varabs     Al         sAl22     0.300000     frozen
  11    2   varabs     Si         sSi22     0.300000     frozen
  12    2   varabs     S          sS22      0.300000     frozen
  13    2   varabs     Cl         sCl22     0.300000     frozen
  14    2   varabs     Ar         sAr22     0.300000     frozen
  15    2   varabs     Ca         sCa22     0.300000     frozen
  16    2   varabs     Cr         sCr22     0.300000     frozen
  17    2   varabs     Fe         sFe22     0.300000     frozen
  18    2   varabs     Co         sCo22     0.300000     frozen
  19    2   varabs     Ni         sNi22     0.300000     frozen
  20    3   vrnei      kT         keV       1.46057      +/-  0.106138
  21    3   vrnei      kT_init    keV       5.00000      +/-  -1.00000
  22    3   vrnei      H                    1.00000      frozen
  23    3   vrnei      He                   1.00000      frozen
  24    3   vrnei      C                    1.00000      frozen
  25    3   vrnei      N                    1.00000      frozen
  26    3   vrnei      O                    1.00000      frozen
  27    3   vrnei      Ne                   1.00000      frozen
  28    3   vrnei      Mg                   1.00000      frozen
  29    3   vrnei      Si                   1.00000      frozen
  30    3   vrnei      S                    1.00000      frozen
  31    3   vrnei      Ar                   1.00000      frozen
  32    3   vrnei      Ca                   1.00000      frozen
  33    3   vrnei      Fe                   0.795397     +/-  0.169469
  34    3   vrnei      Ni                   0.795397     = p33
  35    3   vrnei      Tau        s/cm^3    3.53691E+13  +/-  -1.00000
  36    3   vrnei      Redshift             0.0          frozen
  37    3   vrnei      norm                 1.92784E-02  +/-  4.56853E-03
  38    4   vrnei      kT         keV       0.614802     +/-  5.16490E-02
  39    4   vrnei      kT_init    keV       1.00000E-02  frozen
  40    4   vrnei      H                    1.00000      frozen
  41    4   vrnei      He                   1.00000      frozen
  42    4   vrnei      C                    1.00000      frozen
  43    4   vrnei      N                    1.00000      frozen
  44    4   vrnei      O                    1.00000      frozen
  45    4   vrnei      Ne                   1.00000      frozen
  46    4   vrnei      Mg                   1.00000      frozen
  47    4   vrnei      Si                   0.896577     +/-  0.113094
  48    4   vrnei      S                    0.417954     +/-  0.118012
  49    4   vrnei      Ar                   4.86116E-06  +/-  0.691273
  50    4   vrnei      Ca                   7.70945E-10  +/-  2.35136
  51    4   vrnei      Fe                   0.0          frozen
  52    4   vrnei      Ni                   0.0          frozen
  53    4   vrnei      Tau        s/cm^3    3.70145E+13  +/-  -1.00000
  54    4   vrnei      Redshift             0.0          frozen
  55    4   vrnei      norm                 7.77367E-02  +/-  6.33576E-03
________________________________________________________________________

Fit statistic : Chi-Squared =         261.31 using 256 PHA bins.

Test statistic : Chi-Squared =         261.31 using 256 PHA bins.
 Reduced chi-squared =          1.0709 for    244 degrees of freedom
 Null hypothesis probability =   2.131086e-01
```

RXJ1856.5-3754

Data description

Table 3a	**100043010**	**100043020**
GEN-HK	ah100043010gen_a0.hk.gz	ah100043020gen_a0.hk1.gz

TIM	ah100043010.tim.gz	ah100043020.tim.gz
ATTITUDE	ah100043010.att.gz	ah100043020.att.gz
ORBIT	ah100043010.orb.gz	ah100043020.orb.gz
OBSGTI	ah100043010_gen.gti.gz	ah100043020_gen.gti.gz
MKF	ah100043010.mkf.gz	ah100043020.mkf.gz
EHK	ah100043010.ehk.gz	ah100043020.ehk.gz
EHK2	ah100043010.ehk2.gz	ah100043020.ehk2.gz
SXI HK	ah100043010sxi_a0.hk.gz	ah100043020sxi_a0.hk.gz
SXI EVT UF	ah100043010sxi_p110000430_uf.evt.gz ah100043010sxi_p210000430_uf.evt.gz	ah100043020sxi_p110000430_uf.evt.gz ah100043020sxi_p210000430_uf.evt.gz ah100043020sxi_p310000430_uf.evt.gz ah100043020sxi_p410000430_uf.evt.gz
SXI MZDYE EVT UF	ah100043010sxi_p110000431_uf.evt.gz ah100043010sxi_p210000431_uf.evt.gz	ah100043020sxi_p110000431_uf.evt.gz ah100043020sxi_p210000431_uf.evt.gz ah100043020sxi_p310000431_uf.evt.gz
SXI HOTPIX	ah100043010sxi_a010000430.hpix.gz	ah100043020sxi_a010000430.hpix.gz
SXI MZDYE HOTPIX	ah100043010sxi_a010000431.hpix.gz	ah100043020sxi_a010000431.hpix.gz
SXI FLICKPIX	ah100043010sxi_a110000430.fpix.gz ah100043010sxi_a210000430.fpix.gz	ah100043020sxi_a110000430.fpix.gz ah100043020sxi_a210000430.fpix.gz ah100043020sxi_a310000430.fpix.gz ah100043020sxi_a410000430.fpix.gz
SXI MZDYE FLICKPIX	ah100043010sxi_a110000431.fpix.gz ah100043010sxi_a210000431.fpix.gz	ah100043020sxi_a110000431.fpix.gz ah100043020sxi_a210000431.fpix.gz ah100043020sxi_a310000431.fpix.gz
SXI BAD PIXEL IMG	ah100043010sxi_p110000430.bimg.gz ah100043010sxi_p210000430.bimg.gz	ah100043020sxi_p110000430.bimg.gz ah100043020sxi_p210000430.bimg.gz ah100043020sxi_p310000430.bimg.gz ah100043020sxi_p410000430.bimg.gz
SXI MZDYE BAD PIXEL IMG [	ah100043010sxi_p110000431.bimg.gz ah100043010sxi_p210000431.bimg.gz	ah100043020sxi_p110000431.bimg.gz ah100043020sxi_p210000431.bimg.gz ah100043020sxi_p310000431.bimg.gz
SXI TEL	ah100043010sxi_tel.gti.gz	ah100043020sxi_tel.gti.gz
SXI EVT CL	ah100043010sxi_p110000430_cl.evt.gz	ah100043020sxi_p110000430_cl.evt.gz ah100043020sxi_p210000430_cl.evt.gz ah100043020sxi_p310000430_cl.evt.gz
SXI MZDYE EVT CL	ah100043010sxi_p110000431_cl.evt.gz	ah100043020sxi_p110000431_cl.evt.gz ah100043020sxi_p210000431_cl.evt.gz ah100043020sxi_p310000431_cl.evt.gz

Table 3b	**100043030**	**100043040**
GEN-HK	ah100043030gen_a0.hk.gz	ah100043040gen_a0.hk1.gz
TIM	ah100043030.tim.gz	ah100043040.tim.gz
ATTITUDE	ah100043030.att.gz	ah100043040.att.gz
ORBIT	ah100043030.orb.gz	ah100043040.orb.gz
OBSGTI	ah100043030_gen.gti.gz	ah100043040_gen.gti.gz
MKF	ah100043030.mkf.gz	ah100043040.mkf.gz
EHK	ah100043030.ehk.gz	ah100043040.ehk.gz
EHK2	ah100043030.ehk2.gz	ah100043040.ehk2.gz
SXI HK	ah100043030sxi_a0.hk.gz	ah100043040sxi_a0.hk.gz
SXI EVT UF	ah100043030sxi_p010000430_uf.evt.gz ah100043030sxi_p0100004f0_uf.evt.gz	ah100043040sxi_p0100004f0_uf.evt.gz
SXI MZDYE EVT UF	ah100043030sxi_p0100000b1_uf.evt.gz ah100043030sxi_p0100004f1_uf.evt.gz	ah100043040sxi_p0100004f1_uf.evt.gz
SXI HOTPIX	ah100043030sxi_a0100000b0.hpix.gz ah100043030sxi_a010000430.hpix.gz ah100043030sxi_a0100004f0.hpix.gz	ah100043040sxi_a0100004f0.hpix.gz
SXI MZDYE HOTPIX	ah100043030sxi_a0100000b1.hpix.gz ah100043030sxi_a0100004f1.hpix.gz	ah100043040sxi_a0100004f1.hpix.gz
SXI FLICKPIX	ah100043030sxi_a010000430.fpix.gz ah100043030sxi_a0100004f0.fpix.gz	ah100043040sxi_a0100004f0.fpix.gz
SXI MZDYE FLICKPIX	ah100043030sxi_a0100000b1.fpix.gz ah100043030sxi_a0100004f1.fpix.gz	ah100043040sxi_a0100004f1.fpix.gz
SXI BAD PIXEL IMG	ah100043030sxi_p010000430.bimg.gz ah100043030sxi_p0100004f0.bimg.gz	ah100043040sxi_p0100004f0.bimg.gz
SXI MZDYE BAD PIXEL IMG [	ah100043030sxi_p0100000b1.bimg.gz ah100043030sxi_p0100004f1.bimg.gz	ah100043040sxi_p0100004f1.bimg.gz
SXI TEL	ah100043030sxi_tel.gti.gz	ah100043040sxi_tel.gti.gz

SXI EVT CL	ah100043030sxi_p010000430_cl.evt.gz ah100043030sxi_p0100004f0_cl.evt.gz	ah100043040sxi_p0100004f0_cl.evt.gz
SXI MZDYE EVT CL	ah100043030sxi_p0100004f1_cl.evt.gz	ah100043040sxi_p0100004f1_cl.evt.gz

Table 3c	**100043050**	**100043060**
GEN-HK	ah100043050gen_a0.hk.gz	ah100043060gen_a0.hk1.gz
TIM	ah100043050.tim.gz	ah100043060.tim.gz
ATTITUDE	ah100043050.att.gz	ah100043060.att.gz
ORBIT	ah100043050.orb.gz	ah100043060.orb.gz
OBSGTI	ah100043050_gen.gti.gz	ah100043060_gen.gti.gz
MKF	ah100043050.mkf.gz	ah100043060.mkf.gz
EHK	ah100043050.ehk.gz	ah100043060.ehk.gz
EHK2	ah100043050.ehk2.gz	ah100043060.ehk2.gz
SXI HK	ah100043050sxi_a0.hk.gz	ah100043060sxi_a0.hk.gz
SXI EVT UF	ah100043050sxi_p010000530_uf.evt.gz	ah100043060sxi_p0100000b0_uf.evt.gz ah100043060sxi_p010000530_uf.evt.gz ah100043060sxi_p0120004e0_uf.evt.gz
SXI MZDYE EVT UF	ah100043050sxi_p0100000b1_uf.evt.gz ah100043050sxi_p010000531_uf.evt.gz	ah100043060sxi_p0100000b1_uf.evt.gz ah100043060sxi_p010000531_uf.evt.gz
SXI MZDYE EVT UF (s)	ah100043050sxi_s010000531_uf.evt.gz	
SXI HOTPIX	ah100043050sxi_a0100000b0.hpix.gz ah100043050sxi_a010000530.hpix.gz	ah100043060sxi_a0100000b0.hpix.gz ah100043060sxi_a010000530.hpix.gz ah100043060sxi_a0112004e0.hpix.gz ah100043060sxi_a0120004e0.hpix.gz
SXI MZDYE HOTPIX	ah100043050sxi_a0100000b1.hpix.gz ah100043050sxi_a010000531.hpix.gz	ah100043060sxi_a0100000b1.hpix.gz ah100043060sxi_a010000531.hpix.gz
SXI FLICKPIX	ah100043050sxi_a010000530.fpix.gz	ah100043060sxi_a0100000b0.fpix.gz ah100043060sxi_a010000530.fpix.gz ah100043060sxi_a0112004e0.fpix.gz ah100043060sxi_a0120004e0.fpix.gz
SXI MZDYE FLICKPIX	ah100043050sxi_a0100000b1.fpix.gz ah100043050sxi_a010000531.fpix.gz	ah100043060sxi_a0100000b1.fpix.gz ah100043060sxi_a010000531.fpix.gz
SXI BAD PIXEL IMG	ah100043050sxi_p010000530.bimg.gz	ah100043060sxi_p0100000b0.bimg.gz ah100043060sxi_p010000530.bimg.gz ah100043060sxi_p0112004e0.bimg.gz ah100043060sxi_p0120004e0.bimg.gz
SXI MZDYE BAD PIXEL IMG [	ah100043050sxi_p0100000b1.bimg.gz ah100043050sxi_p010000531.bimg.gz	ah100043060sxi_p0100000b1.bimg.gz ah100043060sxi_p010000531.bimg.gz
SXI TEL	ah100043050sxi_tel.gti.gz	ah100043060sxi_tel.gti.gz
SXI EVT CL	ah100043050sxi_p010000530_cl.evt.gz	ah100043060sxi_p010000530_cl.evt.gz ah100043060sxi_p0112004e0_cl.evt.gz ah100043060sxi_p0120004e0_cl.evt.gz
SXI MZDYE EVT CL	ah100043050sxi_p010000531_cl.evt.gz	ah100043060sxi_p010000531_cl.evt.gz

a) Untar in a directory `/full/path/to/data/`

Additional Files

Additional text files for analysis are as follows, and are shown in detail as they are used.

- standard extraction region files (placed in dir `/full/path/to/regions`)
  - region_SXI_10004301234560.reg
  - region_SXI_10004301234560_bkg.reg

- lists of SXI files to input into addascaspec
  - addascaspec_all.in

NOTE on source regions files:

i) 2.5 arcmin circle (SKY coordinates) for SXI

The region centers are determined by estimating the SKY coordinates of the source in the SXI images using the merged event files, and not on the catalog source coordinates, although the difference is small.

Note on sequences.

Of the sequences shown above only the sequences 100043030, 100043040, 100043050 and 100043060 for the SXI NORMAL mode, and 100043050 and 100043060 for the SXI MZDYE mode contain enough data for the analysis. All sequences listed above are used, with explicit commands for 10043050. These same commands should be run for all the other sequences, as well. The source is off of the SXS detector, and too soft for HXI or SGD data.

Non-Instrument Specific Processing

ahcalctime

100043030, 100043040, 100043050 and 100043060 (NORMAL MODE) & 100043050 and 100043060 (MZDYE MODE)

(1) Recalculate time for HK and unfiltered event files

```
ahcalctime indir=data/100043050 outdir=data/100043050_ahcalctime_output
verify_input=no sorttime=yes timecol=TIME clobber=yes

mkdir data/100043050_ahcalctime_output/logs
mv *log data/100043050_ahcalctime_output/logs
```

Instrument Specific Reprocessing

100043030, 100043040, 100043050 and 100043060 (NORMAL MODE) & 100043050 and 100043060 (MZDYE MODE)

Instrument-specific reprocessing may be applied using ahpipeline by changing the `instrument` parameter from `ALL` to `SXI` or by running the individual instrument pipelines as follows. New files ehk and mkf files, created using the attitude file start and stop times and current, optical axis positions are used as input (not necessary if the reprocessing is for the purpose of recalibrating the data).

SXI

(1) Recalibrate and rescreen using sxipipeline (~15 min)

```
fkeyprint data/100043050/auxil/ah100043050.att.gz+1 TSTOP
TSTOP   = 7.028423871878928E+07 / Stop time
fkeyprint data/100043050/auxil/ah100043050.att.gz+1 TSTART
TSTART  = 7.020534607814944E+07 / Start time

mkdir data/100043050_repro_sxi
mkdir data/100043050_repro_sxi/temphk
cp data/100043050/auxil/*gz data/100043050_repro_sxi/temphk
```

```
cp data/100043050/sxi/hk/*gz data/100043050_repro_sxi/temphk

ahfilter mkfconf=CALDB attfile=data/100043050/auxil/ah100043050.att.gz
orbfile=data/100043050/auxil/ah100043050.orb.gz
outehkfile=data/100043050_repro_sxi/ah100043050.ehk
outmkffile=data/100043050_repro_sxi/ah100043050.mkf reference=NONE
infileroot=data/100043050_repro_sxi/temphk/ah100043050 tstart=70205346.07814944
tstop=70284238.71878928
optaxis=1221.08513337811,1209.56130357371,1223.52648309868,1191.20641761044,
1216.11,1217.843,1216.88128249567,1210.32149046794 clobber=yes cleanup=yes
chatter=2 mode=hl

mkdir data/100043050_repro_sxi/logs
mv *.log data/100043050_repro_sxi/logs

sxipipeline indir=data/100043050 outdir=data/100043050_repro_sxi
steminputs=ah100043050 stemoutputs=DEFAULT entry_stage=1 exit_stage=2
attitude=data/100043050/auxil/ah100043050.att.gz
orbit=data/100043050/auxil/ah100043050.orb.gz
extended_housekeeping=data/100043050_repro_sxi/ah100043050.ehk
makefilter=data/100043050_repro_sxi/ah100043050.mkf
obsgti=data/100043050/auxil/ah100043050_gen.gti.gz
housekeeping=data/1100043050/sxi/hk/ah100043050sxi_a0.hk.gz seed=7 clobber=yes
chatter=2 mode=hl

mv *.log data/100043050_repro_sxi/logs
```

Extracting Products

This section details tools to run on cleaned event files to get instrument specific data products. These may be applied to the original cleaned event files from the pipeline, or to new cleaned event files created using the steps in the last section. In what follows, the original pipeline cleaned event files are used. The extraction region files described above are assumed to be in the `regions` directory.

100043030, 100043040, 100043050 and 100043060 (NORMAL MODE) & 100043050 and 100043060 (MZDYE MODE)

SXI

All newly created output files in this section are placed in the /full/path/to/data/sxi_products directory

```
cd /full/path/

mkdir data/products_sxi

cd data/products_sxi
```

In all files, the files ending in "1", i.e. "p010000531", refer to "Minus-Z Day Earth" (MZDYE) data conducted with area discrimination on and different event thresholds. These must be independently analyzed from the files ending in "0" or "Normal" data files. To reduce the background in the extracted image, the "Normal" event list is filtered by energy to 0.5-8 keV. For the "MZDYE" event list, this would remove all the counts away from the source, so the full energy range is used for the image.

Only the following event lists contain useful science data, due to tuning of SXI configuration during the RXJ1856 observations:

Normal Mode
`ah100043030sxi_p0100004f0_cl.evt.gz`

```
ah100043040sxi_p0100004f0_cl.evt.gz
ah100043050sxi_p010000530_cl.evt.gz
ah100043060sxi_p010000530_cl.evt.gz
```

MZDYE Mode

```
ah100043050sxi_p010000531_cl.evt.gz
ah100043060sxi_p010000531_cl.evt.gz
```

The content of the region file for the source used here, `../../regions/region_SXI_10004301234560.reg`, is

```
# Region file format: DS9 version 4.1
global color=green dashlist=8 3 width=1 font="helvetica 10 normal roman" select=1
highlite=1 dash=0 fixed=0 edit=1 move=1 delete=1 include=1 source=1
fk5
circle(284.1514,-37.912906,150") # width=2
```

The content of the region file used for the background is given in file: `../../regions/region_SXI_10004301234560_bkg.reg`

```
# Region file format: DS9 version 4.1
global color=green dashlist=8 3 width=1 font="helvetica 10 normal roman" select=1
highlite=1 dash=0 fixed=0 edit=1 move=1 delete=1 include=1 source=1
fk5
box(284.12999,-38.018143,1096.1502",565.75493",80.363462) # color=magenta width=2
-circle(284.1514,-37.912906,540") # color=magenta width=2
```

The regions are shown in the images below:

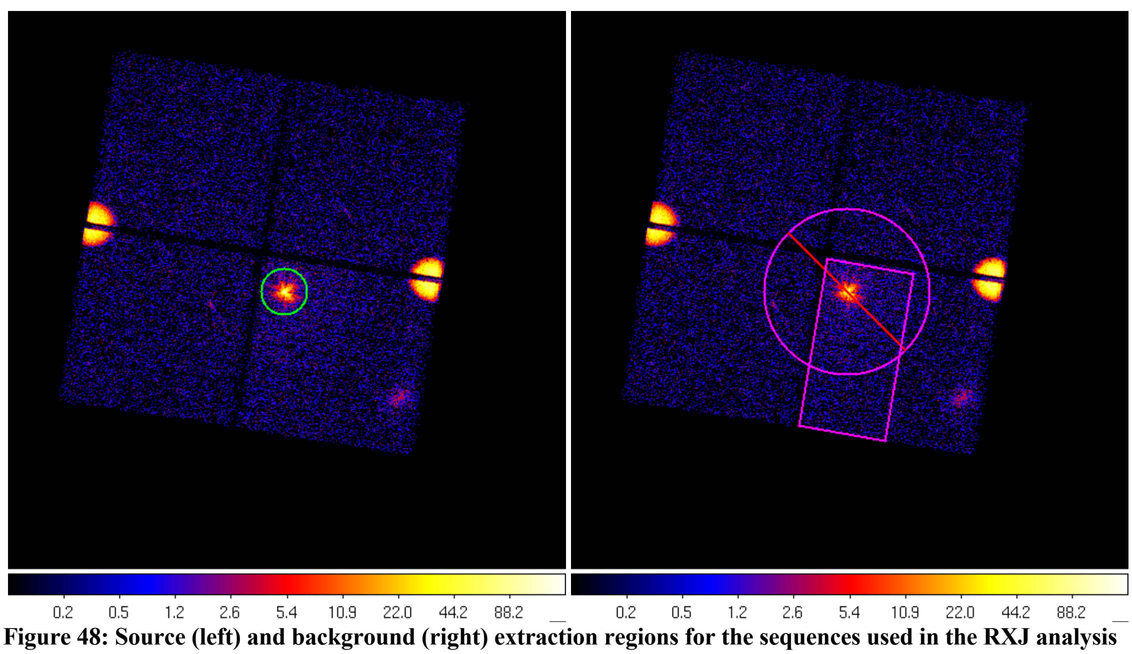


Figure 48: Source (left) and background (right) extraction regions for the sequences used in the RXJ analysis overlaid on the SXI Normal mode image. The source regions are identical for "normal" and "MZDYE" data. The background is extracted only from the former.

(1) Extract images, source and background spectra, and light curves using XSELECT

In XSELECT, run the following commands, which may take the form of a script. They should be run for each of the six event files in the list above. One example is shown here for `ah100043050sxi_p010000530_cl.evt.gz` (Normal mode) and one for `ah100043050sxi_p010000531_cl.evt.gz` (MZDYE mode):

Normal Mode

```
read e ../100043050/sxi/event_cl/ah100043050sxi_p010000530_cl.evt.gz \
data_dir="./" reset_miss=yes
extract events
save events ah100043050sxi_p010000530_cl.evt use_events=yes clobberit=yes
! -- extract 0.5-8 keV image, binned 4x4
set xybin 4
filter pha_cut 83 1333
extract image
save image ah100043050sxi_p010000530_cl.img clobberit=yes
clear pha_cut
! -- extract SOURCE light curve and spectrum
clear region all
filter region ../../regions/region_SXI_10004301234560.reg
extract "spectrum curve" exposure=0.
save curve ah100043050sxi_p010000530_cl.lc clobberit=yes
set device "ah100043050sxi_p010000530_cl.lc.ps/cps"
plot curve
quit
$ps2pdf ah100043050sxi_p010000530_cl.lc.ps
save spectrum ah100043050sxi_p010000530_cl.pi group=no resp=no clobberit=yes
set device "ah100043050sxi_p010000530_cl.pi.ps/cps"
plot spec
quit
$ps2pdf ah100043050sxi_p010000530_cl.pi.ps
! -- extract BACKGROUND light curve and spectrum
clear region all
filter region ../../regions/region_SXI_10004301234560_bkg.reg
extract "spectrum curve" exposure=0.
save curve ah100043050sxi_p010000530_cl_bg.lc clobberit=yes
set device "ah100043050sxi_p010000530_cl_bg.lc.ps/cps"
plot curve
quit
$ps2pdf ah100043050sxi_p010000530_cl_bg.lc.ps
save spectrum ah100043050sxi_p010000530_cl_bg.pi group=no resp=no clobberit=yes
set device "ah100043050sxi_p010000530_cl_bkg.pi.ps/cps"
plot spec
quit
$ps2pdf ah100043050sxi_p010000530_cl_bkg.pi.ps
exit save_session=no
```

MZDYE

```
read e ../100043050/sxi/event_cl/ah100043050sxi_p010000531_cl.evt.gz
data_dir="./" reset_miss=yes
extract events
save events ah100043050sxi_p010000531_cl.evt use_events=yes clobberit=yes
! -- extract 0.5-8 keV image, binned 4x4
set xybin 4
extract image
save image ah100043050sxi_p010000531_cl.img clobberit=yes
clear pha_cut
! -- extract SOURCE light curve and spectrum
clear region all
filter region ../../regions/region_SXI_10004301234560.reg
extract "spectrum curve" exposure=0.
save curve ah100043050sxi_p010000531_cl.lc clobberit=yes
set device "ah100043050sxi_p010000531_cl.lc.ps/cps"
plot curve
quit
$ps2pdf ah100043050sxi_p010000531_cl.lc.ps
```

```
save spectrum ah100043050sxi_p010000531_cl.pi group=no resp=no clobberit=yes
set device "ah100043050sxi_p010000531_cl.pi.ps/cps"
plot spec
quit
$ps2pdf ah100043050sxi_p010000531_cl.pi.ps
! -- extract BACKGROUND light curve only
clear region all
filter region ../../regions/region_SXI_10004301234560_bkg.reg
extract "curve" exposure=0.
save curve ah100043050sxi_p010000531_cl_bg.lc clobberit=yes
set device "ah100043050sxi_p010000531_cl_bg.lc.ps/cps"
plot curve
quit
$ps2pdf ah100043050sxi_p010000531_cl_bg.lc.ps
exit save_session=no
```

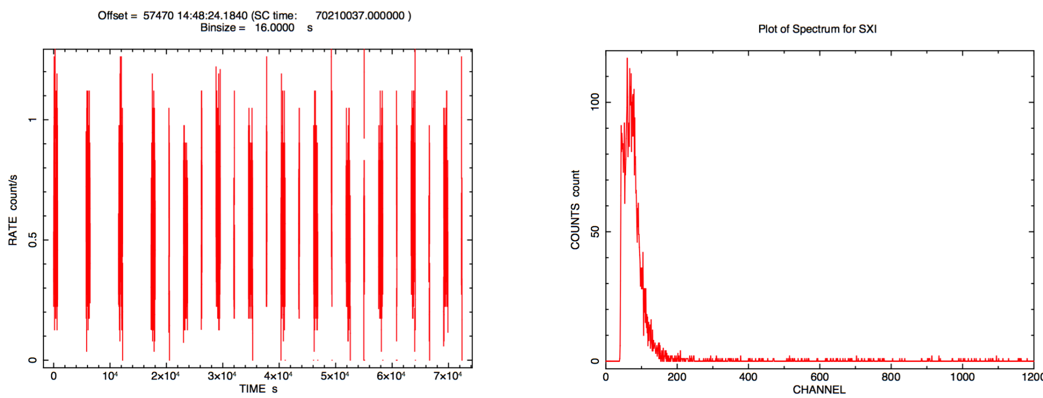


Figure 49: SXI source lightcurve (left) and source spectrum (right) for sequence 100043050, Normal mode.

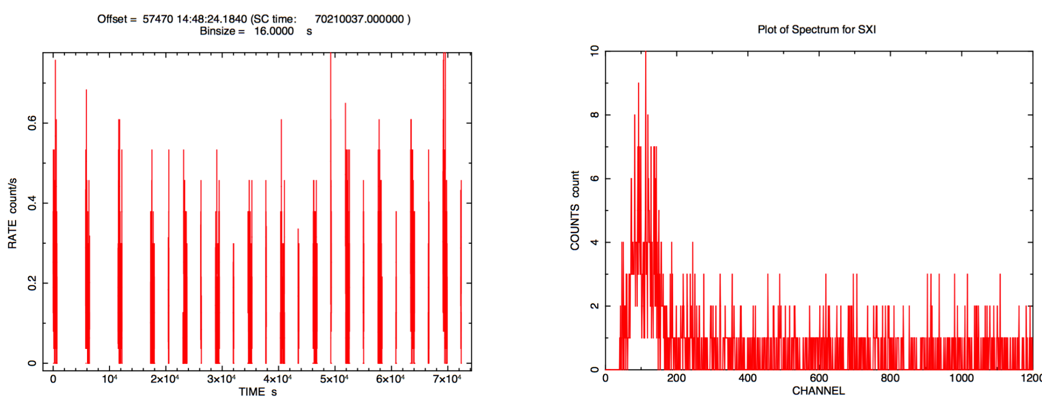


Figure 50: SXI background lightcurve (left) and background spectrum (right) for sequence 100043050.

COMBINING DATA SETS

SXI

Due to differences in the number of bad pixels between OBSIDs, the SXI event data cannot be combined in the same way as the other instruments. Instead, spectra, RMFs, exposure maps, and ARFs must be generated for each OBSID separately and then subsequently combined. (see next section).

Generating Exposure Map, RMF, and ARF

100043050

SXI

All newly created output files in this section are placed in the /full/path/to/data/sxi_products directory

```
cd /full/path/
```

```
cd data/products_sxi
```

(1) Create an RMF for the source spectrum

Normal mode

```
sxirmf infile=ah100043050sxi_p010000530_cl.pi
outfile=ah100043050sxi_p010000530_cl.rmf clobber=yes mode=hl
```

MZDYE

```
sxirmf infile=ah100043050sxi_p010000531_cl.pi
outfile=ah100043050sxi_p010000531_cl.rmf clobber=yes mode=hl
```

(2) Create an Exposure Map for the source spectrum

The exposure maps are created with the parameters `delta=20.0`, `numphi=1` to assure that the map includes only a single attitude bin, i.e. assuming that the attitude is stable relative to the size of the PSF and extraction region.

Normal mode

```
punlearn ahexpmap
ahexpmap ehkfile=../100043050/auxil/ah100043050.ehk.gz
gtifile=../100043050/sxi/event_cl/ah100043050sxi_p010000530_cl.evt.gz
instrume=SXI
badimgfile=../100043050/sxi/event_uf/ah100043050sxi_p010000530.bimg.gz
pixgtifile=../100043050/sxi/event_uf/ah100043050sxi_a010000530.fpix.gz
outfile=ah100043050sxi_p010000530_cl.expo outmaptype=EXPOSURE delta=20.0
numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100043050sxi_p010000530.log
```

MZDYE

```
punlearn ahexpmap
ahexpmap ehkfile=../100043050/auxil/ah100043050.ehk.gz
gtifile=../100043050/sxi/event_cl/ah100043050sxi_p010000531_cl.evt.gz
instrume=SXI
badimgfile=../100043050/sxi/event_uf/ah100043050sxi_p010000531.bimg.gz
pixgtifile=../100043050/sxi/event_uf/ah100043050sxi_a010000531.fpix.gz
outfile=ah100043050sxi_p010000531_cl.expo outmaptype=EXPOSURE delta=20.0
numphi=1 stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=1.5 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100043050sxi_p010000531.log
```

(3) Create an ARF for the source spectrum (~25 min)

In general, the `source_ra` and `source_dec` parameters should be the coordinates of the center of the source in the image, which are not necessarily the same as the actual source coordinates. Here we use the center of the spectral extraction region. The runtime estimated above is for the case where the exposure map has a single attitude bin. The parameter `numphoton` may need to be decreased to accommodate a larger number of attitude bins. The lower bound on energy range is set to 0.2 due the low SXI event threshold setting for this soft source.

Normal mode

```
punlearn aharfgen
aharfgen xrtevtfile=raytrace_ah100043050sxi_p010000530_ptsrc_evt.fits
source_ra=284.1514 source_dec=-37.912906 telescop=HITOMI instrume=SXI
emapfile=ah100043050sxi_p010000530_cl.expo regmode=RADEC
regionfile=../../regions/region_SXI_10004301234560.reg sourcetype=POINT
rmffile=ah100043050sxi_p010000530_cl.rmf erange="0.2 12.0 0 0"
outfile=ah100043050sxi_p010000530_cl.arf numphoton=200000 minphoton=1
teldeffile=CALDB qefile=CALDB contamifile=CALDB onaxisffile=CALDB
onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB
backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB seed=7 clobber=yes
chatter=2 mode=h logfile=make_arf_ah100043050sxi_p010000530.log
```

MZDYE

```
punlearn aharfgen
aharfgen xrtevtfile=raytrace_ah100043050sxi_p010000531_ptsrc_evt.fits
source_ra=284.1514 source_dec=-37.912906 telescop=HITOMI instrume=SXI
emapfile=ah100043050sxi_p010000531_cl.expo regmode=RADEC
regionfile=../../regions/region_SXI_10004301234560.reg sourcetype=POINT
rmffile=ah100043050sxi_p010000531_cl.rmf erange="0.2 12.0 0.0 0.0"
outfile=ah100043050sxi_p010000531_cl.arf numphoton=200000 minphoton=1
teldeffile=CALDB qefile=CALDB contamifile=CALDB onaxisffile=CALDB
onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB frontreffile=CALDB
backreffile=CALDB pcolreffile=CALDB scatterfile=CALDB seed=7 clobber=yes
chatter=2 mode=h logfile=make_arf_ah100043050sxi_p010000531.log
```

(4) Correct the BACKSCAL keyword in the SXI spectra

NORMAL

```
ahbackscal infile=ah100043050sxi_p010000530_cl.pi
regfile=../../regions/region_SXI_10004301234560.reg
expfile=ah100043050sxi_p010000530_cl.expo
norm=MAX

ahbackscal infile=ah100043050sxi_p010000530_cl_bg.pi
regfile=../../regions/region_SXI_10004301234560_bkg.reg
expfile=ah100043050sxi_p010000530_cl.expo
norm=MAX
```

MZDYE

```
ahbackscal infile=ah100043050sxi_p010000531_cl.pi
regfile=../../regions/region_SXI_10004301234560.reg
expfile=ah100043050sxi_p010000531_cl.expo
norm=MAX
```

Steps 1-4 are separately repeated in an identical manner for the spectra extracted from the six event files noted above, both for Normal Mode source and background spectra, and MZDYE mode source spectra, i.e.

(1) Create an RMF for each remaining source spectrum,
(2) Create an exposure map for each remaining source spectrum,
(3) Create an ARF for each remaining source spectrum, and
(4) Correct the BACKSCAL keyword in each remaining source and background.

COMBINING ALL SEQUENCES

SXI

Because the cosmic ray echo effect varies between sequences over the course of the observation, a single bad image file cannot be used below. In general this should be checked when deriving SXI spectral ARFs for combined sequences. If they differ as they do here, separate RMF and ARF files should be derived, as detailed above for sequence `100043050`. The spectra and responses should then be co-added, or individual spectra should be simultaneously fit.

Following completion of the four steps detailed above, the combined spectra and responses are created.

(5) Combine SXI spectra and responses
The ftool 'addascaspec' is used to combine the source spectra, background spectra, and responses. Normal mode and MZDYE are combined and fit separately.

Normal mode

```
addascaspec addascaspec_normal.in ah1000430ALL0sxi_cl.pi
ah1000430ALL0sxi_cl.rsp ah1000430ALL0sxi_cl_bkg.pi "POISS-0"
```

where the file 'addascaspec_normal.in' contains the following four lines. For clarity in this document, the end of each line is delineated by '\', which must be removed before the command is issued:

```
ah100043030sxi_p0100004f0_cl.pi ah100043040sxi_p0100004f0_cl.pi
ah100043050sxi_p010000530_cl.pi ah100043060sxi_p010000530_cl.pi \
ah100043030sxi_p0100004f0_cl_bg.pi ah100043040sxi_p0100004f0_cl_bg.pi
ah100043050sxi_p010000530_cl_bg.pi ah100043060sxi_p010000530_cl_bg.pi\
ah100043030sxi_p0100004f0_cl.arf  ah100043040sxi_p0100004f0_cl.arf
ah100043050sxi_p010000530_cl.arf  ah100043060sxi_p010000530_cl.arf  \
ah100043030sxi_p0100004f0_cl.rmf ah100043040sxi_p0100004f0_cl.rmf
ah100043050sxi_p010000530_cl.rmf ah100043060sxi_p010000530_cl.rmf
```

This will create a combined source spectrum, combined background spectrum, and a single .rsp file containing both the combined RMF and ARF.

MZDYE

```
addascaspec addascaspec_mzdye.in ah1000430ALL1sxi_cl.pi ah1000430ALL1sxi_cl.rsp
ah1000430ALL1sxi_cl_bkg.pi "POISS-0"
```

where the file 'addascaspec_mzdye.in' contains the following four lines:

```
ah100043050sxi_p010000531_cl.pi ah100043060sxi_p010000531_cl.pi
ah100043050sxi_p010000530_cl_bg.pi ah100043060sxi_p010000530_cl_bg.pi
ah100043050sxi_p010000531_cl.arf  ah100043060sxi_p010000531_cl.arf
ah100043050sxi_p010000531_cl.rmf ah100043060sxi_p010000531_cl.rmf
```

This will create a combined source spectrum, combined background spectrum, and a single .rsp file containing both the combined RMF and ARF. Note the 'Normal' mode background spectra are used here for the 'MZDYE' data because the area discrimination and event threshold settings make them unfit for background extraction.

Spectral Fittting

Notes

The following XSPEC settings are used below.

For fitting:

```
statistic cstat
method leven 10 0.001
abund wilm
xsect vern
cosmo 70 0 0.73
xset FORCECALC  off
```

For plotting:

```
setplot rebin 10 20
```

Note that the spectra and response files co-added for all sequences are used below; however, identical procedures apply to individual sequences.

SXI

(1) Jointly fit the SXI normal and MZDYE background-subtracted spectra in the 0.42-1.5 keV band using the files created in the previous section. The model (from Beuermann et al. 2006, A&A, 458, 541) consists of two blackbodies at temperatures of 0.06283 keV and 0.03226 keV and an absorption fixed at 1.1 x 10^{20} cm^{-2}. The blackbody normalizations are fixed, and an overall contant factor is allowed to vary for each spectrum.

In XSPEC:

```
statistic cstat
method leven 10 0.01
abund wilm
xsect vern
cosmo 70 0 0.73
xset delta -1
systematic 0
query y

data 1:1 ah1000430ALL0sxi_cl.pi
back 1 ah1000430ALL0sxi_cl_bkg.pi
resp 1 ah1000430ALL0sxi_cl.rsp

data 2:2 ah1000430ALL1sxi_cl.pi
back 2 ah1000430ALL1sxi_cl_bkg.pi
resp 2 ah1000430ALL1sxi_cl.rsp

ignore *:0.-.4 1.5-100.
setplot en
```

```
setplot rebin 10 20 -1

xset FORCECALC  off
model tbabs ( bbodyrad + bbodyrad ) * constant
  1.10000E-02 -1.00000E-02   0.0000       0.0000      1.00000E+05  1.00000E+06
  6.28300E-02 -1.00000E-02  1.00000E-04  1.00000E-03   100.00       200.00
   142884.    -1.00000E-02   0.0000       0.0000      1.00000E+24  1.00000E+24
  3.22600E-02 -1.00000E-02  1.00000E-04  1.00000E-03   100.00       200.00
   1879641.   -1.00000E-02   0.0000       0.0000      1.00000E+24  1.00000E+24
   1.0000     1.00000E-02   0.5 0.5 1.3 1.3
/*
untie 12

cpd /xs
pl da res
fit
pl da res
sho data
```

The following shows the output from XSPEC:

```
2 files 2 spectra
Spectrum 1  Spectral Data File: ah1000430ALL0sxi_cl.pi
Net count rate (cts/s) for Spectrum:1  2.768e-01 +/- 2.981e-03 (95.7 % total)
 Assigned to Data Group 1 and Plot Group 1
  Noticed Channels:  68-249
  Telescope: HITOMI Instrument: SXI  Channel Type: PI
  Exposure Time: 3.297e+04 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Background File                ah1000430ALL0sxi_cl_bkg.pi
  Background Exposure Time: 3.297e+04 sec
 Using Response (RMF) File            ah1000430ALL0sxi_cl.rsp for Source 1

 Spectral data counts: 9539
 Model predicted rate: 0.271992

Spectrum 2  Spectral Data File: ah1000430ALL1sxi_cl.pi
Net count rate (cts/s) for Spectrum:2  1.609e-01 +/- 3.288e-03 (97.9 % total)
 Assigned to Data Group 2 and Plot Group 2
  Noticed Channels:  68-249
  Telescope: HITOMI Instrument: SXI  Channel Type: PI
  Exposure Time: 1.522e+04 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Background File                ah1000430ALL1sxi_cl_bkg.pi
  Background Exposure Time: 2.331e+04 sec
 Using Response (RMF) File            ah1000430ALL1sxi_cl.rsp for Source 1

 Spectral data counts: 2501
 Model predicted rate: 0.159862


Current model list:

========================================================================
Model TBabs<1>(bbodyrad<2> + bbodyrad<3>)constant<4> Source No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
                           Data group: 1
   1    1   TBabs      nH         10^22    1.10000E-02  frozen
   2    2   bbodyrad   kT         keV      6.28300E-02  frozen
   3    2   bbodyrad   norm                1.42884E+05  frozen
   4    3   bbodyrad   kT         keV      3.22600E-02  frozen
```

```
   5    3   bbodyrad   norm                 1.87964E+06  frozen
   6    4   constant   factor               0.845171     +/-  9.15055E-03
                           Data group: 2
   7    1   TBabs      nH         10^22     1.10000E-02  = p1
   8    2   bbodyrad   kT         keV       6.28300E-02  = p2
   9    2   bbodyrad   norm                 1.42884E+05  = p3
  10    3   bbodyrad   kT         keV       3.22600E-02  = p4
  11    3   bbodyrad   norm                 1.87964E+06  = p5
  12    4   constant   factor               0.870944     +/-  1.78290E-02
________________________________________________________________________

   Using energies from responses.

Fit statistic : C-Statistic =         568.56 using 364 PHA bins and 362 degrees
of freedom.

Test statistic : Chi-Squared =        1062.40 using 364 PHA bins.
 Reduced chi-squared =        2.93480 for    362 degrees of freedom
 Null hypothesis probability =   5.316594e-70

***Warning: Chi-square may not be valid due to bins with zero variance
            in spectrum number(s): 2

 Weighting method: standard

XSPEC12>flux .4 1.5
 Spectrum Number: 1
 Data Group Number: 1
 Model Flux 0.0027283 photons (2.1112e-12 ergs/cm^2/s) range (0.40000 - 1.5000
keV)
 Spectrum Number: 2
 Data Group Number: 2
 Model Flux 0.0028115 photons (2.1756e-12 ergs/cm^2/s) range (0.40000 - 1.5000
keV)
```

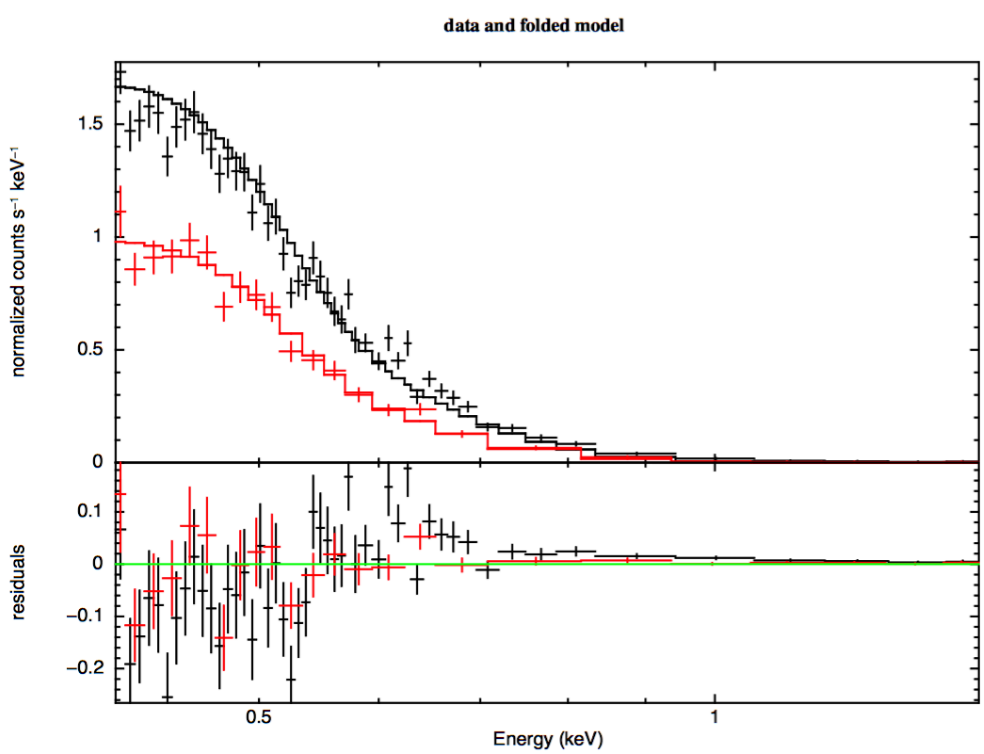


Figure 51: Joint fits to SXI Normal mode (black) and MZDYE (red) spectra for combined RXJ 1856.5-3754 sequences given above using the RMF and ARF files derived in the previous section.

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Data description

Table 7a	100042010	100042020
GEN-HK	ah100042010gen_a0.hk1.gz	ah100042020gen_a0.hk1.gz
TIM	ah100042010.tim.gz	ah100042020.tim.gz
ATTITUDE	ah100042010.att.gz	ah100042020.att.gz
ORBIT	ah100042010.orb.gz	ah100042020.orb.gz
OBSGTI	ah100042010_gen.gti.gz	ah100042020_gen.gti.gz
MKF	ah100042010.mkf.gz	ah100042020.mkf.gz
EHK	ah100042010.ehk.gz	ah100042020.ehk.gz
EHK2	ah100042010.ehk2.gz	ah100042020.ehk2.gz
HXI1 HK	ah100042010hx1_a0.hk.gz	ah100042020hx1_a0.hk.gz
HXI2 HK	ah100042010hx2_a0.hk.gz	ah100042020hx2_a0.hk.gz
HXI DELTA-ATT	ah100042010hx1.att.gz	ah100042020hx1.att.gz
HXI DELTA-ATT	ah100042010hx2.att.gz	ah100042020hx2.att.gz
HXI1 CAMS	ah100042010hx1_cms.fits.gz	ah100042020hx1_cms.fits.gz
HXI2 CAMS	ah100042010hx2_cms.fits.gz	ah100042020hx2_cms.fits.gz
HXI1 SFF (p)	ah100042010hx1_p0cam_uf.evt.gz	ah100042020hx1_p0cam_uf.evt.gz
HXI2 SFF (p)		ah100042020hx2_p0cam_uf.evt.gz
HXI1 SFFa		ah100042020hx1_p0camrec_ufa.evt.gz
HXI TEL	ah100042010hxi_tel.gti.gz	ah100042020hxi_tel.gti.gz
HXI1 EVT CL		ah100042020hx1_p0camrec_cl.evt.gz
HXI1 PseudoEvent CL		ah100042020hx1_p0camrecpse_cl.evt.gz
	ah100042010cm1_a0_uf.fits.gz	ah100042020cm1_a0_uf.fits.gz
	ah100042010cm2_a0_uf.fits.gz	ah100042020cm2_a0_uf.fits.gz
	ah100042010hx1_a0bst.fits.gz	ah100042020hx1_a0bst.fits.gz
		ah100042020hx2_a0bst.fits.gz
		ah100042020hx1_a0camexp_ufa.evt.gz
		ah100042020hx1_a0camfitam_ufa.evt.gz
	ah100042010hx1_a0sclhst.fits.gz	ah100042020hx1_a0sclhst.fits.gz
	ah100042010hx2_a0sclhst.fits.gz	ah100042020hx2_a0sclhst.fits.gz
	ah100042010hx1_cms.gti.gz	ah100042020hx1_cms.gti.gz
	ah100042010hx2_cms.gti.gz	ah100042020hx2_cms.gti.gz
SGD1 HK	ah100042010sg1_a0.hk.gz	ah100042020sg1_a0.hk.gz
SGD2 HK	ah100042010sg2_a0.hk.gz	ah100042020sg2_a0.hk.gz
	ah100042010sg1_a0sclhst.fits.gz	ah100042020sg1_a0sclhst.fits.gz
SGD TEL	ah100042010sgi_tel.gti.gz	ah100042020sgi_tel.gti.gz
	ah100042010sg2_a0sclhst.fits.gz	ah100042020sg2_a0sclhst.fits.gz
SXI HK	ah100042010sxi_a0.hk.gz	ah100042020sxi_a0.hk.gz
SXI EVT UF	ah100042010sxi_p0100003f0_uf.evt.gz ah100042010sxi_s0100003f0_uf.evt.gz	ah100042020sxi_p1100003f0_uf.evt.gz ah100042020sxi_p2100003f0_uf.evt.gz
SXI HOTPIX	ah100042010sxi_a0100003f0.hpix.gz	ah100042020sxi_a0100003f0.hpix.gz
SXI FLICKPIX	ah100042010sxi_a0100003f0.fpix.gz	ah100042020sxi_a1100003f0.fpix.gz ah100042020sxi_a2100003f0.fpix.gz
SXI BAD PIXEL IMG	ah100042010sxi_p0100003f0.bimg.gz	ah100042020sxi_p1100003f0.bimg.gz ah100042020sxi_p2100003f0.bimg.gz
SXI TEL	ah100042010sxi_tel.gti.gz	ah100042020sxi_tel.gti.gz
SXI EVT CL	ah100042010sxi_p0100003f0_cl.evt.gz	ah100042020sxi_p1100003f0_cl.evt.gz ah100042020sxi_p2100003f0_cl.evt.gz
	ah100042010sxi_a0exp.fits.gz	ah100042020sxi_a0exp.fits.gz
	ah100042010sxi_mode.gti.gz	ah100042020sxi_mode.gti.gz
	ah100042010sxi_seg.gti.gz	ah100042020sxi_seg.gti.gz
SXS HK	ah100042010sxs_a0.hk1.gz	ah100042020sxs_a0.hk1.gz
SXS ADR	ahsxs_adr.gti.gz	ahsxs_adr.gti.gz
SXS AC EVT	ah100042010sxs_a0ac_uf.evt.gz	ah100042020sxs_a0ac_uf.evt.gz
SXS PIX12 GAIN	ah100042010sxs_010_pxcal.ghf.gz	ah100042020sxs_010_pxcal.ghf.gz

SXS PIX12 EVT	ah100042010sxs_a0pxcal010_uf.evt.gz	ah100042020sxs_a0pxcal010_uf.evt.gz
SXS EL GTI	ah100042010sxs_el.gti.gz	ah100042020sxs_el.gti.gz
SXS TEL	ah100042010sxs_tel.gti.gz	ah100042020sxs_tel.gti.gz
SXS PIX EXP	ah100042010sxs_px1010_exp.gti.gz	ah100042020sxs_px1010_exp.gti.gz
SXS PIX UF (p & s)	ah100042010sxs_p0px1010_uf.evt.gz ah100042010sxs_s0px1010_uf.evt.gz	ah100042020sxs_p0px1010_uf.evt.gz
SXS PIX CL (p)	ah100042010sxs_p0px1010_cl.evt.gz	ah100042020sxs_p0px1010_cl.evt.gz

Table 7b	**100042030**	**100042040**
GEN-HK	ah100042030gen_a0.hk1.gz	ah100042040gen_a0.hk1.gz
TIM	ah100042030.tim.gz	ah100042040.tim.gz
ATTITUDE	ah100042030.att.gz	ah100042040.att.gz
ORBIT	ah100042030.orb.gz	ah100042040.orb.gz
OBSGTI	ah100042030_gen.gti.gz	ah100042040_gen.gti.gz
MKF	ah100042030.mkf.gz	ah100042040.mkf.gz
EHK	ah100042030.ehk.gz	ah100042040.ehk.gz
EHK2	ah100042030.ehk2.gz	ah100042040.ehk2.gz
	ah100042030.cat.gz	ah100042040.cat.gz
	ah100042030.com.gz	ah100042040.com.gz
	ah100042030_fff.cat	ah100042040_fff.cat
HXI1 HK	ah100042030hx1_a0.hk.gz	ah100042040hx1_a0.hk.gz
HXI2 HK	ah100042030hx2_a0.hk.gz	ah100042040hx2_a0.hk.gz
HXI DELTA-ATT	ah100042030hx1.att.gz	ah100042040hx1.att.gz
HXI DELTA-ATT	ah100042030hx2.att.gz	ah100042040hx2.att.gz
HXI1 CAMS	ah100042030hx1_cms.fits.gz	ah100042040hx1_cms.fits.gz
HXI2 CAMS	ah100042030hx2_cms.fits.gz	ah100042040hx2_cms.fits.gz
HXI1 SFF (p)	ah100042030hx1_p0cam_uf.evt.gz	ah100042040hx1_p0cam_uf.evt.gz
HXI2 SFF (p)		ah100042040hx2_p0cam_uf.evt.gz
HXI1 SFFa		ah100042040hx1_p0camrec_ufa.evt.gz
HXI TEL	ah100042030hxi_tel.gti.gz	ah100042040hxi_tel.gti.gz
HXI1 EVT CL	ah100042030hx1_p0camrec_cl.evt.gz	ah100042040hx1_p0camrec_cl.evt.gz
HXI1 PseudoEvent CL	ah100042030hx1_p0camrecpse_cl.evt.gz	ah100042040hx1_p0camrecpse_cl.evt.gz
	ah100042030cm1_a0_uf.fits.gz	ah100042040cm1_a0_uf.fits.gz
	ah100042030cm2_a0_uf.fits.gz	ah100042040cm2_a0_uf.fits.gz
	ah100042030hx1_a0bst.fits.gz	ah100042040hx1_a0bst.fits.gz
	ah100042030hx2_a0bst.fits.gz	ah100042040hx2_a0bst.fits.gz
	ah100042030hx1_a0camexp_ufa.evt.gz	ah100042040hx1_a0camexp_ufa.evt.gz
	ah100042030hx1_a0camfitam_ufa.evt.gz	ah100042040hx1_a0camfitam_ufa.evt.gz
	ah100042030hx1_a0sclhst.fits.gz	ah100042040hx1_a0sclhst.fits.gz
	ah100042030hx2_a0sclhst.fits.gz	ah100042040hx2_a0sclhst.fits.gz
	ah100042030hx1_cms.gti.gz	ah100042040hx1_cms.gti.gz
	ah100042030hx2_cms.gti.gz	ah100042040hx2_cms.gti.gz
SGD1 HK	ah100042030sg1_a0.hk.gz	ah100042040sg1_a0.hk.gz
SGD2 HK	ah100042030sg2_a0.hk.gz	ah100042040sg2_a0.hk.gz
	ah100042030sg1_a0sclhst.fits.gz	ah100042040sg1_a0sclhst.fits.gz
SGD TEL	ah100042030sgi_tel.gti.gz	ah100042040sgi_tel.gti.gz
	ah100042030sg2_a0sclhst.fits.gz	ah100042040sg2_a0sclhst.fits.gz
SXI HK	ah100042030sxi_a0.hk.gz	ah100042040sxi_a0.hk.gz
SXI EVT UF	ah100042030sxi_p1100003f0_uf.evt.gz ah100042030sxi_p2100003f0_uf.evt.gz	ah100042040sxi_p1100003f0_uf.evt.gz ah100042040sxi_p2100003f0_uf.evt.gz
SXI HOTPIX	ah100042030sxi_a0100003f0.hpix.gz	ah100042040sxi_a0100003f0.hpix.gz
SXI FLICKPIX	ah100042030sxi_a1100003f0.fpix.gz ah100042030sxi_a2100003f0.fpix.gz	ah100042040sxi_a1100003f0.fpix.gz ah100042040sxi_a2100003f0.fpix.gz
SXI BAD PIXEL IMG	ah100042030sxi_p1100003f0.bimg.gz ah100042030sxi_p2100003f0.bimg.gz	ah100042040sxi_p1100003f0.bimg.gz ah100042040sxi_p2100003f0.bimg.gz
SXI TEL	ah100042030sxi_tel.gti.gz	ah100042040sxi_tel.gti.gz
SXI EVT CL	ah100042030sxi_p1100003f0_cl.evt.gz	ah100042040sxi_p1100003f0_cl.evt.gz ah100042040sxi_p2100003f0_cl.evt.gz
	ah100042030sxi_a0exp.fits.gz	ah100042040sxi_a0exp.fits.gz
	ah100042030sxi_mode.gti.gz	ah100042040sxi_mode.gti.gz
	ah100042030sxi_seg.gti.gz	ah100042040sxi_seg.gti.gz
SXS HK	ah100042030sxs_a0.hk1.gz	ah100042040sxs_a0.hk1.gz
SXS ADR	ahsxs_adr.gti.gz	ahsxs_adr.gti.gz
SXS AC EVT	ah100042030sxs_a0ac_uf.evt.gz	ah100042040sxs_a0ac_uf.evt.gz
SXS PIX12 GAIN	ah100042030sxs_010_pxcal.ghf.gz	ah100042040sxs_010_pxcal.ghf.gz

SXS PIX12 EVT	ah100042030sxs_a0pxcal010_uf.evt.gz	ah100042040sxs_a0pxcal010_uf.evt.gz
SXS EL GTI	ah100042030sxs_el.gti.gz	ah100042040sxs_el.gti.gz
SXS TEL	ah100042030sxs_tel.gti.gz	ah100042040sxs_tel.gti.gz
SXS PIX EXP	ah100042030sxs_px1010_exp.gti.gz	ah100042040sxs_px1010_exp.gti.gz
SXS PIX UF (p & s)	ah100042030sxs_p0px1010_uf.evt.gz	ah100042040sxs_p0px1010_uf.evt.gz
SXS PIX CL (p)	ah100042030sxs_p0px1010_cl.evt.gz	ah100042040sxs_p0px1010_cl.evt.gz

a) Untar in a directory `/full/path/to/data/`

Additional Files

Additional text files for analysis are as follows, and are shown in detail as they are used.

- standard (and other) extraction region files (place in dir `/full/path/to/regions`)
  - region_SXI_100042040.reg
  - region_SXI_100042040_bkg.reg
  - region_HXI_100042040.reg
  - region_HXI_100042040_bkg.reg

- lists of SXI files to input into addascaspec
  - addascaspec_all.in

NOTE on source regions files:

i) 2.5 arcmin circle (SKY coordinates) for SXI
ii) Box at edge of FoV for HXI

The region centers are determined by estimating the SKY coordinates of the source in the SXI images using the event files and not on the catalog source coordinates.

Note on sequences.

Although the source is in the detector gap for the first three sequences, 100042010, 100042020, 100042030, and 100042040 are all used for SXI analysis, with sequence 100042020 is used as a single sequence example . HXI (HXI1 only) analysis of sequence 100042040, where the source is at the edge of the detector, is also presented.

ahcalctime

100042020

(1) Recalculate time for HK and unfiltered event files

```
ahcalctime indir=data/100042020 outdir=data/100042020_ahcalctime_output
verify_input=no sorttime=yes timecol=TIME clobber=yes

mkdir data/100042020_ahcalctime_output/logs
mv *log data/100042020_ahcalctime_output/logs
```

Instrument Specific Reprocessing

Instrument-specific reprocessing may be applied using ahpipeline by changing the `instrument` parameter from `ALL` to `SXI` or `HXI`, or by running the individual instrument pipelines as follows. New files ehk and mkf files, created using the attitude file start and stop times and current, optical axis positions are used as input (not necessary if the reprocessing is for the purpose of recalibrating the data). Alternatively, mkf and ehk files created by `ahpipeline`, if previously run with `create_ehkmkf=yes`, may be used. See previous sections for details.

SXI

100042020

(1) Recalibrate and rescreen using sxipipeline

```
fkeyprint ../100042020/auxil/ah100042020.att.gz+1 TSTOP
TSTOP   = 6.927708176560795E+07 / Stop time
fkeyprint ../100042020/auxil/ah100042020.att.gz+1 TSTART
TSTART  = 6.919699214063382E+07 / Start time

mkdir data/100042020_repro_sxi
mkdir data/100042020_repro_sxi/temphk
cp data/100042020/auxil/*gz data/100042020_repro_sxi/temphk
cp data/100042020/sxi/hk/*gz data/100042020_repro_sxi/temphk

ahfilter mkfconf=CALDB attfile=data/100042020/auxil/ah100042020.att.gz
orbfile=data/100042020/auxil/ah100042020.orb.gz
outehkfile=data/100042020_repro_sxi/ah100042020.ehk
outmkffile=data/100042020_repro_sxi/ah100042020.mkf reference=NONE
infileroot=data/100042020_repro_sxi/temphk/ah100042020 tstart=70205346.07814944
tstop=70284238.71878928
optaxis=1221.08513337811,1209.56130357371,1223.52648309868,1191.20641761044,
1216.11,1217.843,1216.88128249567,1210.32149046794 clobber=yes cleanup=yes
chatter=2 mode=hl

mkdir data/100042020_repro_sxi/logs
mv *.log data/100042020_repro_sxi/logs

sxipipeline indir=data/100042020 outdir=data/100042020_repro_sxi
steminputs=ah100042020 stemoutputs=DEFAULT entry_stage=1 exit_stage=2
attitude=data/100042020/auxil/ah100042020.att.gz
orbit=data/100042020/auxil/ah100042020.orb.gz
extended_housekeeping=data/100042020_repro_sxi/ah100042020.ehk
makefilter=data/100042020_repro_sxi/ah100042020.mkf
obsgti=data/100042020/auxil/ah100042020_gen.gti.gz
housekeeping=data/1100042020/sxi/hk/ah100042020sxi_a0.hk.gz seed=7 clobber=yes
chatter=2 mode=hl

mv *.log data/100042020_repro_sxi/logs
```

HXI

100042040

(1) Recalibrate and rescreen using hxipipeline

```
fkeyprint data/100042040/auxil/ah100042040.att.gz+1 TSTART
TSTART  = 6.935730114063269E+07 / Start time
fkeyprint data/100042040/auxil/ah100042040.att.gz+1 TSTOP
TSTOP   = 6.943810264064318E+07 / Stop time
mkdir data/100042040_repro_hxi
mkdir data/100042040_repro_hxi/temphk
```

```
cp data/100042040/auxil/*gz data/100042040_repro_hxi/temphk
cp data/100042040/hxi/hk/*gz data/100042040_repro_hxi/temphk

ahfilter mkfconf=CALDB attfile=data/100042040/auxil/ah100042040.att.gz
orbfile=data/100042040/auxil/ah100042040.orb.gz
outehkfile=data/100042040_repro_hxi/ah100042040.ehk
outmkffile=data/100042040_repro_hxi/ah100042040.mkf reference=NONE
infileroot=data/100042040_repro_hxi/temphk/ah100042040
tstart=6.935730114063269E+07 tstop=6.943810264064318E+07
optaxis=1221.08513337811,1209.56130357371,1223.52648309868,1191.20641761044,121
6.11,1217.843,1216.88128249567,1210.32149046794 clobber=yes cleanup=yes
chatter=2 mode=hl

mkdir data/100042040_repro_hxi/logs
mv *.log data/100042040_repro_hxi/logs

hxipipeline indir=data/100042040 outdir=data/100042040_repro_hxi
steminputs=ah100042040 stemoutputs=DEFAULT instrument=HXI entry_stage=1
exit_stage=2 verify_input=no attitude=data/100042040/auxil/ah100042040.att.gz
orbit=data/100042040/auxil/ah100042040.orb.gz
extended_housekeeping=data/100042040_repro_hxi/ah100042040.ehk
makefilter=data/100042040_repro_hxi/ah100042040.mkf
obsgti=data/100042040/auxil/ah100042040_gen.gti.gz seed=7 clobber=yes chatter=2
mode=hl

mv *.log data/100042040_repro_hxi/logs
```

Extracting Products

This section details tools to run on cleaned event files to get instrument specific data products. These may be applied to the original cleaned event files from the pipeline, or to new cleaned event files created using the steps in the last section. In what follows, the original pipeline cleaned event files are used. The extraction region files described above are assumed to be in the `regions` directory.

100042010, 100042020, 100042030 and 100042040

SXI

All newly created output files in this section are placed in the /full/path/to/data/sxi_products directory

```
cd /full/path/

mkdir data/products_sxi

cd data/products_sxi
```

The content of the region file for the source used here, `../../regions/region_SXI_100042040.reg`, is

```
# Region file format: DS9 version 4.1
fk5
circle(247.9535,-48.8189,150.0000") # color=white font="helvetica 30 normal "
```

The content of the region file used for the background is given in file:
`../../regions/region_SXI_100042040_bkg.reg`

```
# Region file format: DS9 version 4.1
fk5
box(247.90905,-48.81605,1956.9549",1304.344",104.13959)
```

```
-circle(247.9535,-48.8189,180")
-circle(247.833342,-48.723750,180")
-circle(247.99605,-48.74707,180")
```

(1) Extract images, source and background spectra, and light curves using XSELECT

In XSELECT, run the following commands, shown here for sequence 100042020 but also to be run on sequences 10004210, 100042030 and 100042040.

Normal Mode

```
read e ../100042020/sxi/event_cl/ah100042020sxi_p1100003f0_cl.evt.gz data_dir="./"
reset_miss=yes
extract events
save events ah100042020sxi_p1100003f0_cl.evt use_events=yes clobberit=yes
! -- extract 0.5-8 keV image, binned 4x4
set xybin 4
filter pha_cut 83 1333
extract image
save image ah100042020sxi_p1100003f0_cl.img clobberit=yes
clear pha_cut
! -- extract SOURCE light curve and spectrum
clear region all
filter region ./region_SXI_100042040.reg
extract "spectrum curve" exposure=0.
save curve ah100042020sxi_p1100003f0_cl.lc clobberit=yes
set device "ah100042020sxi_p1100003f0_cl.lc.ps/cps"
plot curve
quit
$ps2pdf ah100042020sxi_p1100003f0_cl.lc.ps
save spectrum ah100042020sxi_p1100003f0_cl.pi group=no resp=no clobberit=yes
set device "ah100042020sxi_p1100003f0_cl.pi.ps/cps"
plot spec
quit
$ps2pdf ah100042020sxi_p1100003f0_cl.pi.ps
! -- extract BACKGROUND light curve and spectrum
clear region all
filter region ./region_SXI_100042040_bkg.reg
extract "spectrum curve" exposure=0.
save curve ah100042020sxi_p1100003f0_cl_bkg.lc clobberit=yes
set device "ah100042020sxi_p1100003f0_cl_bkg.lc.ps/cps"
plot curve
quit
$ps2pdf ah100042020sxi_p1100003f0_cl_bkg.lc.ps
save spectrum ah100042020sxi_p1100003f0_cl_bkg.pi group=no resp=no clobberit=yes
set device "ah100042020sxi_p1100003f0_cl_bkg.pi.ps/cps"
plot spec
quit
$ps2pdf ah100042020sxi_p1100003f0_cl_bkg.pi.ps
```

and

```
clear all
yes
read e ../100042020/sxi/event_cl/ah100042020sxi_p2100003f0_cl.evt.gz data_dir="./"
reset_miss=yes
extract events
save events ah100042020sxi_p2100003f0_cl.evt use_events=yes clobberit=yes
! -- extract 0.5-8 keV image, binned 4x4
set xybin 4
filter pha_cut 83 1333
extract image
save image ah100042020sxi_p2100003f0_cl.img clobberit=yes
clear pha_cut
! -- extract SOURCE light curve and spectrum
clear region all
filter region ./region_SXI_100042040.reg
extract "spectrum curve" exposure=0.
save curve ah100042020sxi_p2100003f0_cl.lc clobberit=yes
set device "ah100042020sxi_p2100003f0_cl.lc.ps/cps"
plot curve
```

```
quit
$ps2pdf ah100042020sxi_p2100003f0_cl.lc.ps
save spectrum ah100042020sxi_p2100003f0_cl.pi group=no resp=no clobberit=yes
set device "ah100042020sxi_p2100003f0_cl.pi.ps/cps"
plot spec
quit
$ps2pdf ah100042020sxi_p2100003f0_cl.pi.ps
! -- extract BACKGROUND light curve and spectrum
clear region all
filter region ./region_SXI_100042040_bkg.reg
extract "spectrum curve" exposure=0.
save curve ah100042020sxi_p2100003f0_cl_bkg.lc clobberit=yes
set device "ah100042020sxi_p2100003f0_cl_bkg.lc.ps/cps"
plot curve
quit
$ps2pdf ah100042020sxi_p2100003f0_cl_bkg.lc.ps
save spectrum ah100042020sxi_p2100003f0_cl_bkg.pi group=no resp=no clobberit=yes
set device "ah100042020sxi_p2100003f0_cl_bkg.pi.ps/cps"
plot spec
quit
$ps2pdf ah100042020sxi_p2100003f0_cl_bkg.pi.ps
```

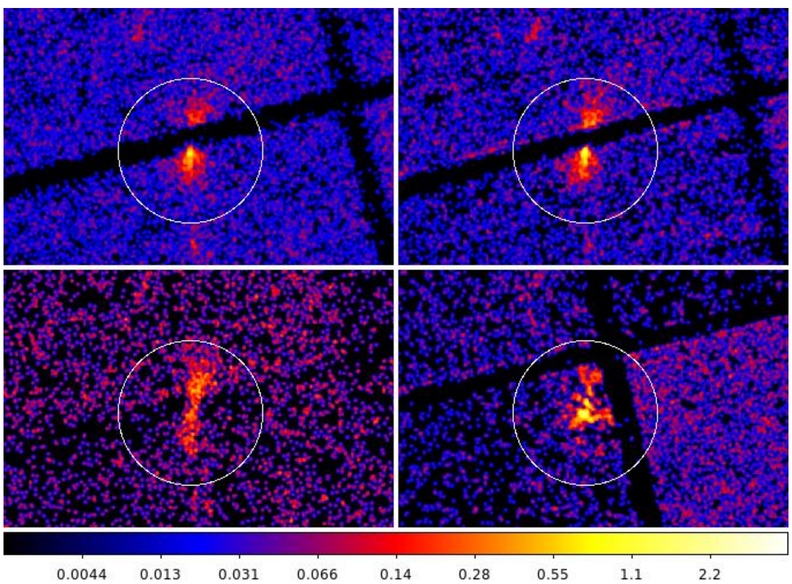

Figure 52: SXI images with source extraction region for sequences (clockwise from upper left) 100042010, 100042010, 100042030, and 100042040.

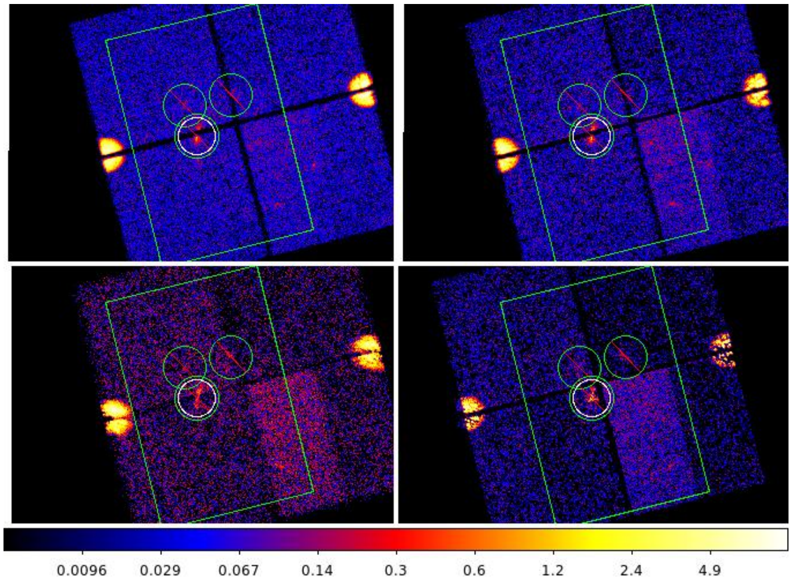

Figure 53: SXI images with source (white) and background (red) extraction region for sequences (clockwise from upper left) 100042010, 100042010, 100042030, and 100042040.

100042040

HXI

All newly created output files in this section are placed in the /full/path/to/data/hxi_products directory

```
cd /full/path/
```

```
mkdir data/products_hxi
```

```
cd data/products_hxi
```

(1) Extract source spectra and light curves using xselect

The content of the region file used here, `../../regions/region_HXI_100042040.reg`, is

```
# Region file format: DS9 version 4.1
fk5
box(16:31:43.369,-48:48:43.58,41.071",309.127",350.154)
```

The background is extracted from the region ../../regions/region_HXI_100042040_bkg.reg:

```
# Region file format: DS9 version 4.1
fk5
box(16:31:11.195,-48:49:33.40,339.991",501.769",351.002)
(16:31:11.195,-48:49:33.40,339.991",501.769",351.002)
```

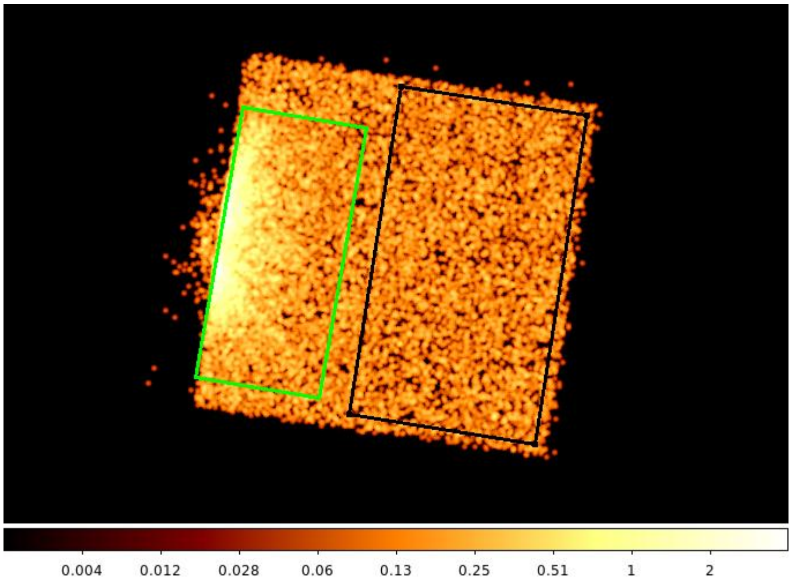

Figure 54: HXI images with source (white) and background (red) extraction region for sequences (clockwise from upper left) 100042010, 100042010, 100042030, and 100042040.

HXI1

In XSELECT, run the following commands:

```
clear all
yes
read e ../../100042040/hxi/event_cl/ah100042040hx1_p0camrec_cl.evt.gz
data_dir="./" reset_miss=yes
extract events
save events ah100042040hx1_p0camrec_cl.evt use_events=yes clobberit=yes
extract image
save image ah100042040hx1_p0camrec_cl.img clobberit=yes
filter region ./region_HXI_100042040.reg
extract "spectrum curve" exposure=0.
save curve ah100042040hx1_p0camrec_cl.lc clobberit=yes
set device "ah100042040hx1_p0camrec_cl.lc.ps/cps"
plot curve
quit
$ps2pdf ah100042040hx1_p0camrec_cl.lc.ps
save spectrum ah100042040hx1_p0camrec_cl.pi group=no resp=no clobberit=yes
set device "ah100042040hx1_p0camrec_cl.pi.ps/cps"
plot spec
quit
$ps2pdf ah100042040hx1_p0camrec_cl.pi.ps
! -- extract BACKGROUND light curve and spectrum
clear region all
filter region ./region_HXI_100042040_bkg.reg
extract "spectrum curve" exposure=0.
save curve ah100042040hx1_p0camrec_cl_bkg.lc clobberit=yes
set device "ah100042040hx1_p0camrec_cl_bkg.lc.ps/cps"
plot curve
quit
$ps2pdf ah100042040hx1_p0camrec_cl_bkg.lc.ps
save spectrum ah100042040hx1_p0camrec_cl_bkg.pi group=no resp=no clobberit=yes
set device "ah100042040hx1_p0camrec_cl_bkg.pi.ps/cps"
plot spec
quit
$ps2pdf  ah100042040hx1_p0camrec_cl_bkg.pi.ps
exit
```

(2) Run hxisgddtime to correct the spectrum and light curve for dead time

Go back to /full/path/to/data/.. (the directory above the `data` directory)

```
cd ../..
```

HXI1

```
hxisgddtime
infile=data/100042040/hxi/event_cl/ah100042040hx1_p0camrecpse_cl.evt.gz
inlcfile=data/products_hxi/ah100042040hx1_p0camrec_cl.lc
inspecfile=data/products_hxi/ah100042040hx1_p0camrec_cl.pi
outlcfile=data/products_hxi/ah100042040hx1_p0camrec_dtime.lc
outfile=data/products_hxi/ah100042040hx1_p0camrec_dtime.pi
gtifile=data/100042040/hxi/event_cl/ah100042040hx1_p0camrec_cl.evt.gz chatter=2
clobber=yes

mv hxisgddtime.log data/products_hxi/hxisgddtime_ah100042040hx1.log
```

(3) Apply barycenter corrections for light curves

```
barycen infile=data/products_hxi/ah100042040hx1_p0camrec_dtime.lc
outfile=data/products_hxi/ah100042040hx1_p0camrec_dtime_add_bary.lc
orbfile=data/100042040/auxil/ah100042040.orb.gz source_ra=247.9535 source_dec=-
48.8189 orbext=ORBIT chatter=2 clobber=yes

mv barycen.log data/products_hxi/barycen_ah100042040hx1.log
```

Note that the `ra` and `dec` parameters are set here to the object coordinates as an approximation of the true average pointing direction; this setting can be refined by generating and examining the exposure map (see below).

The barycenter correction may also be applied to event files.

COMBINING DATA SETS

SXI

Due to differences in the number of bad pixels between OBSIDs, the SXI event data cannot be combined in the same way as the other instruments. Instead, spectra, RMFs, exposure maps, and ARFs must be generated for each OBSID separately and then simultaneously combined at the end (see next section).

Generating Exposure Map, RMF, and ARF

100042010, 100042020, 100043030 and 100042040

SXI

All newly created output files in this section are placed in the /full/path/to/data/sxi_products directory

```
cd /full/path/

cd data/products_sxi
```

(1) Create an RMF for each source spectrum

```
sxirmf infile=ah100042010sxi_p0100003f0_cl.pi
outfile=ah100042010sxi_p0100003f0.rmf clobber=yes mode=hl

sxirmf infile=ah100042020sxi_p1100003f0_cl.pi
outfile=ah100042020sxi_p1100003f0.rmf clobber=yes mode=hl

sxirmf infile=ah100042020sxi_p2100003f0_cl.pi
outfile=ah100042020sxi_p2100003f0.rmf clobber=yes mode=hl

sxirmf infile=ah100042030sxi_p1100003f0_cl.pi
outfile=ah100042030sxi_p1100003f0.rmf clobber=yes mode=hl

sxirmf infile=ah100042040sxi_p1100003f0_cl.pi
outfile=ah100042040sxi_p1100003f0.rmf clobber=yes mode=hl

sxirmf infile=ah100042040sxi_p2100003f0_cl.pi
outfile=ah100042040sxi_p2100003f0.rmf clobber=yes mode=hl
```

(2) Create an Exposure Map for each source spectrum

The exposure maps are created with the parameters `delta=20.0`, `numphi=1` to assure that the map includes only a single attitude bin, i.e. assuming that the attitude is stable relative to the size of the PSF and extraction region.

```
punlearn ahexpmap
ahexpmap ehkfile=../100042010/auxil/ah100042010.ehk.gz
gtifile=../100042010/sxi/event_cl/ah100042010sxi_p0100003f0_cl.evt.gz instrume=SXI
badimgfile=../100042010/sxi/event_uf/ah100042010sxi_p0100003f0.bimg.gz
pixgtifile=../100042010/sxi/event_uf/ah100042010sxi_a0100003f0.fpix.gz
outfile=ah100042010sxi_p0100003f0_cl.expo outmaptype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB obffile=CALDB
fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT specmode=MONO specfile=spec.fits
specform=FITS energy=1.5 evperchan=DEFAULT abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100042010sxi_p0100003f0.log

punlearn ahexpmap
ahexpmap ehkfile=../100042020/auxil/ah100042020.ehk.gz
gtifile=../100042020/sxi/event_cl/ah100042020sxi_p1100003f0_cl.evt.gz instrume=SXI
badimgfile=../100042020/sxi/event_uf/ah100042020sxi_p1100003f0.bimg.gz
pixgtifile=../100042020/sxi/event_uf/ah100042020sxi_a1100003f0.fpix.gz
outfile=ah100042020sxi_p1100003f0_cl.expo outmaptype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB obffile=CALDB
fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT specmode=MONO specfile=spec.fits
specform=FITS energy=1.5 evperchan=DEFAULT abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100042020sxi_p1100003f0.log

punlearn ahexpmap
ahexpmap ehkfile=../100042020/auxil/ah100042020.ehk.gz
gtifile=../100042020/sxi/event_cl/ah100042020sxi_p2100003f0_cl.evt.gz instrume=SXI
badimgfile=../100042020/sxi/event_uf/ah100042020sxi_p2100003f0.bimg.gz
pixgtifile=../100042020/sxi/event_uf/ah100042020sxi_a2100003f0.fpix.gz
outfile=ah100042020sxi_p2100003f0_cl.expo outmaptype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB obffile=CALDB
fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT specmode=MONO specfile=spec.fits
specform=FITS energy=1.5 evperchan=DEFAULT abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100042020sxi_p2100003f0.log

punlearn ahexpmap
ahexpmap ehkfile=../100042030/auxil/ah100042030.ehk.gz
gtifile=../100042030/sxi/event_cl/ah100042030sxi_p1100003f0_cl.evt.gz instrume=SXI
badimgfile=../100042030/sxi/event_uf/ah100042030sxi_p1100003f0.bimg.gz
pixgtifile=../100042030/sxi/event_uf/ah100042030sxi_a1100003f0.fpix.gz
outfile=ah100042030sxi_p1100003f0_cl.expo outmaptype=EXPOSURE delta=20.0 numphi=1
```

```
stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB obffile=CALDB
fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT specmode=MONO specfile=spec.fits
specform=FITS energy=1.5 evperchan=DEFAULT abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100042030sxi_p1100003f0.log

punlearn ahexpmap
ahexpmap ehkfile=../100042040/auxil/ah100042040.ehk.gz
gtifile=../100042040/sxi/event_cl/ah100042040sxi_p1100003f0_cl.evt.gz instrume=SXI
badimgfile=../100042040/sxi/event_uf/ah100042040sxi_p1100003f0.bimg.gz
pixgtifile=../100042040/sxi/event_uf/ah100042040sxi_a1100003f0.fpix.gz
outfile=ah100042040sxi_p1100003f0_cl.expo outmaptype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB obffile=CALDB
fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT specmode=MONO specfile=spec.fits
specform=FITS energy=1.5 evperchan=DEFAULT abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100042040sxi_p1100003f0.log

punlearn ahexpmap
ahexpmap ehkfile=../100042040/auxil/ah100042040.ehk.gz
gtifile=../100042040/sxi/event_cl/ah100042040sxi_p2100003f0_cl.evt.gz instrume=SXI
badimgfile=../100042040/sxi/event_uf/ah100042040sxi_p2100003f0.bimg.gz
pixgtifile=../100042040/sxi/event_uf/ah100042040sxi_a2100003f0.fpix.gz
outfile=ah100042040sxi_p2100003f0_cl.expo outmaptype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB obffile=CALDB
fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT specmode=MONO specfile=spec.fits
specform=FITS energy=1.5 evperchan=DEFAULT abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100042040sxi_p2100003f0.log
```

(3) Create an ARF for the source spectrum (~30 min per command)

In general, the `source_ra` and `source_dec` parameters should be the coordinates of the center of the source in the image, which are not necessarily the same as the actual source coordinates. Here we use the center of the spectral extraction region. The runtime estimated above is for the case where the exposure map has a single attitude bin. The parameter `numphoton` may need to be decreased to accommodate a larger number of attitude bins.

Normal mode

```
punlearn aharfgen
aharfgen xrtevtfile=raytrace_ah100042010sxi_p0100003f0_ptsrc_evt.fits source_ra=247.9535
source_dec=-48.8189  telescop=HITOMI instrume=SXI
emapfile=ah100042010sxi_p0100003f0_cl.expo regmode=RADEC
regionfile=region_SXI_100042040.reg sourcetype=POINT
rmffile=ah100042010sxi_p0100003f0.rmf erange="0.5 16.0 0 0"
outfile=ah100042010sxi_p0100003f0.arf numphoton=200000 minphoton=1 teldeffile=CALDB
qefile=CALDB contamifile=CALDB onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB
obstructfile=CALDB frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB
scatterfile=CALDB auxtransfile=NONE seed=7 clobber=yes chatter=2 mode=h
logfile=make_arf_ah100042010sxi_p0100003f0.log

punlearn aharfgen
aharfgen xrtevtfile=raytrace_ah100042020sxi_p1100003f0_ptsrc_evt.fits source_ra=247.9535
source_dec=-48.8189  telescop=HITOMI instrume=SXI
emapfile=ah100042020sxi_p1100003f0_cl.expo regmode=RADEC
regionfile=region_SXI_100042040.reg sourcetype=POINT
rmffile=ah100042020sxi_p1100003f0.rmf erange="0.5 16.0 0 0"
outfile=ah100042020sxi_p1100003f0.arf numphoton=200000 minphoton=1 teldeffile=CALDB
qefile=CALDB contamifile=CALDB onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB
obstructfile=CALDB frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB
scatterfile=CALDB auxtransfile=NONE seed=7 clobber=yes chatter=2 mode=h
logfile=make_arf_ah100042020sxi_p1100003f0.log

punlearn aharfgen
aharfgen xrtevtfile=raytrace_ah100042020sxi_p2100003f0_ptsrc_evt.fits source_ra=247.9535
source_dec=-48.8189  telescop=HITOMI instrume=SXI
emapfile=ah100042020sxi_p2100003f0_cl.expo regmode=RADEC
regionfile=region_SXI_100042040.reg sourcetype=POINT
rmffile=ah100042020sxi_p2100003f0.rmf erange="0.5 16.0 0 0"
outfile=ah100042020sxi_p2100003f0.arf numphoton=200000 minphoton=1 teldeffile=CALDB
```

```
qefile=CALDB contamifile=CALDB onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB
obstructfile=CALDB frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB
scatterfile=CALDB auxtransfile=NONE seed=7 clobber=yes chatter=2 mode=h
logfile=make_arf_ah100042020sxi_p2100003f0.log

punlearn aharfgen
aharfgen xrtevtfile=raytrace_ah100042030sxi_p1100003f0_ptsrc_evt.fits source_ra=247.9535
source_dec=-48.8189  telescop=HITOMI instrume=SXI
emapfile=ah100042030sxi_p1100003f0_cl.expo regmode=RADEC
regionfile=region_SXI_100042040.reg sourcetype=POINT
rmffile=ah100042030sxi_p1100003f0.rmf erange="0.5 16.0 0 0"
outfile=ah100042030sxi_p1100003f0.arf numphoton=200000 minphoton=1 teldeffile=CALDB
qefile=CALDB contamifile=CALDB onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB
obstructfile=CALDB frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB
scatterfile=CALDB auxtransfile=NONE seed=7 clobber=yes chatter=2 mode=h
logfile=make_arf_ah100042030sxi_p1100003f0.log

punlearn aharfgen
aharfgen xrtevtfile=raytrace_ah100042040sxi_p1100003f0_ptsrc_evt.fits source_ra=247.9535
source_dec=-48.8189  telescop=HITOMI instrume=SXI
emapfile=ah100042040sxi_p1100003f0_cl.expo regmode=RADEC
regionfile=region_SXI_100042040.reg sourcetype=POINT
rmffile=ah100042040sxi_p1100003f0.rmf erange="0.5 16.0 0 0"
outfile=ah100042040sxi_p1100003f0.arf numphoton=200000 minphoton=1 teldeffile=CALDB
qefile=CALDB contamifile=CALDB onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB
obstructfile=CALDB frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB
scatterfile=CALDB auxtransfile=NONE seed=7 clobber=yes chatter=2 mode=h
logfile=make_arf_ah100042040sxi_p1100003f0.log

punlearn aharfgen
aharfgen xrtevtfile=raytrace_ah100042040sxi_p2100003f0_ptsrc_evt.fits source_ra=247.9535
source_dec=-48.8189  telescop=HITOMI instrume=SXI
emapfile=ah100042040sxi_p2100003f0_cl.expo regmode=RADEC
regionfile=region_SXI_100042040.reg sourcetype=POINT
rmffile=ah100042040sxi_p2100003f0.rmf erange="0.5 16.0 0 0"
outfile=ah100042040sxi_p2100003f0.arf numphoton=200000 minphoton=1 teldeffile=CALDB
qefile=CALDB contamifile=CALDB onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB
obstructfile=CALDB frontreffile=CALDB backreffile=CALDB pcolreffile=CALDB
scatterfile=CALDB auxtransfile=NONE seed=7 clobber=yes chatter=2 mode=h
logfile=make_arf_ah100042040sxi_p2100003f0.log
```

(4) Correct the BACKSCAL keyword in the SXI spectra

```
punlearn ahbackscal

ahbackscal ah100042010sxi_p0100003f0_cl.pi region_SXI_100042040.reg
ah100042010sxi_p0100003f0_cl.expo

ahbackscal ah100042020sxi_p1100003f0_cl.pi region_SXI_100042040.reg
ah100042020sxi_p1100003f0_cl.expo

ahbackscal ah100042020sxi_p2100003f0_cl.piregion_SXI_100042040.reg
ah100042020sxi_p2100003f0_cl.expo

ahbackscal ah100042030sxi_p1100003f0_cl.pi region_SXI_100042040.reg
ah100042030sxi_p1100003f0_cl.expo

ahbackscal ah100042040sxi_p1100003f0_cl.pi region_SXI_100042040.reg
ah100042040sxi_p1100003f0_cl.expo

ahbackscal ah100042040sxi_p2100003f0_cl.pi region_SXI_100042040.reg
ah100042040sxi_p2100003f0_cl.expo
```

The same commands are run for the background PI files.

```
ahbackscal ah100042010sxi_p0100003f0_cl_bkg.pi region_SXI_100042040_bkg.reg
ah100042010sxi_p0100003f0_cl.expo

ahbackscal ah100042020sxi_p1100003f0_cl_bkg.pi region_SXI_100042040_bkg.reg
ah100042020sxi_p1100003f0_cl.expo
```

```
ahbackscal ah100042020sxi_p2100003f0_cl_bkg.pi region_SXI_100042040_bkg.reg
ah100042020sxi_p2100003f0_cl.expo

ahbackscal ah100042030sxi_p1100003f0_cl_bkg.pi region_SXI_100042040_bkg.reg
ah100042030sxi_p1100003f0_cl.expo

ahbackscal ah100042040sxi_p1100003f0_cl_bkg.pi region_SXI_100042040_bkg.reg
ah100042040sxi_p1100003f0_cl.expo

ahbackscal ah100042040sxi_p2100003f0_cl_bkg.pi region_SXI_100042040_bkg.reg
ah100042040sxi_p2100003f0_cl.expo
```

COMBINING ALL SEQUENCES

SXI

The ftool 'addascaspec' should be used to combine the source spectra, background spectra, and responses.

```
addascaspec addascaspec_all.in ah1000420ALL0sxi_cl.pi ah1000420ALL0sxi_cl.rsp
ah1000420ALL0sxi_cl_bkg.pi "POISS-0"
```

where the file 'addascaspec_all.in' contains the following four lines (delineated by '\'):

```
ah100042010sxi_p0100003f0_cl.pi ah100042020sxi_p1100003f0_cl.pi
ah100042020sxi_p2100003f0_cl.pi ah100042030sxi_p1100003f0_cl.pi
ah100042040sxi_p1100003f0_cl.pi ah100042040sxi_p2100003f0_cl.pi \
ah100042010sxi_p0100003f0_cl_bkg.pi ah100042020sxi_p1100003f0_cl_bkg.pi
ah100042020sxi_p2100003f0_cl_bkg.pi ah100042030sxi_p1100003f0_cl_bkg.pi
ah100042040sxi_p1100003f0_cl_bkg.pi ah100042040sxi_p2100003f0_cl_bkg.pi \
ah100042010sxi_p0100003f0.arf ah100042020sxi_p1100003f0.arf
ah100042020sxi_p2100003f0.arf ah100042030sxi_p1100003f0.arf
ah100042040sxi_p1100003f0.arf ah100042040sxi_p2100003f0.arf \
ah100042010sxi_p0100003f0.rmf ah100042020sxi_p1100003f0.rmf
ah100042020sxi_p2100003f0.rmf ah100042030sxi_p1100003f0.rmf
ah100042040sxi_p1100003f0.rmf ah100042040sxi_p2100003f0.rmf
```

This will create a combined source spectrum, combined background spectrum, and a single .rsp file containing both the combined RMF and ARF.

100042040

HXI

The exposure map and the response generation for HXI are done executing the following commands.Note that the `aharfgen numphoton` parameter is increased by a factor of ten to account for the non-standard region.

```
ahexpmap ehkfile=data/100042040/auxil/ah100042040.ehk.gz
gtifile=data/100042040/hxi/event_cl/ah100042040hx1_p0camrec_cl.evt.gz
instrume=HXI1 badimgfile=NONE pixgtifile=NONE
outfile=ah100042040hx1_p0camrec.expo outmaptype=EXPOSURE delta=20.0 numphi=1
stopsys=SKY instmap=CALDB qefile=CALDB contamifile=CALDB vigfile=CALDB
obffile=CALDB fwfile=CALDB gvfile=CALDB maskcalsrc=yes fwtype=DEFAULT
specmode=MONO specfile=spec.fits specform=FITS energy=10.0 evperchan=DEFAULT
abund=1 cols=0 covfac=1 clobber=yes chatter=1
logfile=make_expo_ah100042040hx1_p0camrec.log

aharfgen xrtevtfile=raytrace_ah100042040hx1_p0camrec.fits source_ra=247.9535
source_dec=-48.8189 telescop=HITOMI instrume=HXI1
```

```
emapfile=ah100042040hx1_p0camrec.expo
dattfile=data/100042040/hxi/event_uf/ah100042040hx1.att.gz regmode=RADEC
regionfile=../../regions/region_HXI_100042040.reg sampling=120 sourcetype=point
erange="4.0 80.0" outfile=ah100042040hx1_rt
filtoffsetfile=data/100042040/hxi/event_uf/ah100042040hx1_cms.fits.gz
numphoton=100000 minphoton=1 teldeffile=CALDB qefile=CALDB rmffile=CALDB
onaxisffile=CALDB onaxiscfile=CALDB mirrorfile=CALDB obstructfile=CALDB
frontreffile=CALDB pcolreffile=CALDB scatterfile=CALDB auxtransfile=NONE seed=7
clobber=yes chatter=2 mode=h logfile=make_arf_ah100042040hx1_p0camrec.log
```

Spectral Fittting

Notes

The following XSPEC settings are used below.

For fitting;
  abund wilm
  xsect vern
  statistic cstat
  model following Barragan et al. 2009 (A&A, 508, 1275).

For plotting:

setplot rebin 10 20

Note that the SXI spectra and response files co-added for all sequences are used below, while sequence 100042040 is considered for simultaneous SXI and HXI fitting.

SXI only

(1) Fit the co-added SXI background-subtracted spectra in the 0.8-16 keV band.

```
1 file 1 spectrum
Spectrum 1  Spectral Data File: ah100042012340_sxi.pi
Net count rate (cts/s) for Spectrum:1  3.758e-02 +/- 5.976e-04 (74.5 % total)
 Assigned to Data Group 1 and Plot Group 1
  Noticed Channels:  668-2666
  Telescope: HITOMI Instrument: SXI  Channel Type: PI
  Exposure Time: 1.421e+05 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Background File                ah100042012340_sxi_bkg.pi
  Background Exposure Time: 1.421e+05 sec
 Using Response (RMF) File            ah100042012340_sxi.rsp for Source 1

 Spectral data counts: 7163
 Model predicted rate: 3.73635E-02


Current model list:

========================================================================
Model TBvarabs<1>(cutoffpl<2> + gaussian<3> + gaussian<4> + gaussian<5> + gaussian<6>)
Source No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
   1    1   TBvarabs   nH         10^22    161.380      +/-  31.6834
   2    1   TBvarabs   He                  1.00000      frozen
   3    1   TBvarabs   C                   1.00000      frozen
   4    1   TBvarabs   N                   1.00000      frozen
```

```
   5    1   TBvarabs   O                      1.00000      frozen
   6    1   TBvarabs   Ne                     1.00000      frozen
   7    1   TBvarabs   Na                     1.00000      frozen
   8    1   TBvarabs   Mg                     1.00000      frozen
   9    1   TBvarabs   Al                     1.00000      frozen
  10    1   TBvarabs   Si                     1.00000      frozen
  11    1   TBvarabs   S                      1.00000      frozen
  12    1   TBvarabs   Cl                     1.00000      frozen
  13    1   TBvarabs   Ar                     1.00000      frozen
  14    1   TBvarabs   Ca                     1.00000      frozen
  15    1   TBvarabs   Cr                     1.00000      frozen
  16    1   TBvarabs   Fe                     1.15282      +/-  0.244195
  17    1   TBvarabs   Co                     1.00000      frozen
  18    1   TBvarabs   Ni                     1.00000      frozen
  19    1   TBvarabs   H2                     0.200000     frozen
  20    1   TBvarabs   rho        g/cm^3      1.00000      frozen
  21    1   TBvarabs   amin       mum         2.50000E-02  frozen
  22    1   TBvarabs   amax       mum         0.250000     frozen
  23    1   TBvarabs   PL                     3.50000      frozen
  24    1   TBvarabs   H_dep                  1.00000      frozen
  25    1   TBvarabs   He_dep                 1.00000      frozen
  26    1   TBvarabs   C_dep                  1.00000      frozen
  27    1   TBvarabs   N_dep                  1.00000      frozen
  28    1   TBvarabs   O_dep                  1.00000      frozen
  29    1   TBvarabs   Ne_dep                 1.00000      frozen
  30    1   TBvarabs   Na_dep                 1.00000      frozen
  31    1   TBvarabs   Mg_dep                 1.00000      frozen
  32    1   TBvarabs   Al_dep                 1.00000      frozen
  33    1   TBvarabs   Si_dep                 1.00000      frozen
  34    1   TBvarabs   S_dep                  1.00000      frozen
  35    1   TBvarabs   Cl_dep                 1.00000      frozen
  36    1   TBvarabs   Ar_dep                 1.00000      frozen
  37    1   TBvarabs   Ca_dep                 1.00000      frozen
  38    1   TBvarabs   Cr_dep                 1.00000      frozen
  39    1   TBvarabs   Fe_dep                 1.00000      frozen
  40    1   TBvarabs   Co_dep                 1.00000      frozen
  41    1   TBvarabs   Ni_dep                 1.00000      frozen
  42    1   TBvarabs   Redshift               0.0          frozen
  43    2   cutoffpl   PhoIndex               0.571523     +/-  1.93328
  44    2   cutoffpl   HighECut   keV         500.000      +/-  8.45978E+04
  45    2   cutoffpl   norm                   1.90685E-03  +/-  5.37765E-03
  46    3   gaussian   LineE      keV         6.39779      +/-  3.56264E-03
  47    3   gaussian   Sigma      keV         1.00000E-04  frozen
  48    3   gaussian   norm                   5.70559E-04  +/-  1.78804E-04
  49    4   gaussian   LineE      keV         6.38479      = p46 - 0.013
  50    4   gaussian   Sigma      keV         1.00000E-04  frozen
  51    4   gaussian   norm                   2.85280E-04  = p48*0.5
  52    5   gaussian   LineE      keV         7.01746      +/-  1.57451E-02
  53    5   gaussian   Sigma      keV         1.00000E-04  frozen
  54    5   gaussian   norm                   6.65672E-05  +/-  1.62673E-05
  55    6   gaussian   LineE      keV         7.00146      = p52 - 0.016
  56    6   gaussian   Sigma      keV         1.00000E-04  frozen
  57    6   gaussian   norm                   3.32836E-05  = p54*0.5
________________________________________________________________________

   Using energies from responses.

Fit statistic : C-Statistic =        2204.65 using 1999 PHA bins and 1990 degrees of
freedom.

Test statistic : Chi-Squared =       41023.37 using 1999 PHA bins.
 Reduced chi-squared =       20.61476 for   1990 degrees of freedom
 Null hypothesis probability =   0.000000e+00
 Weighting method: standard
```

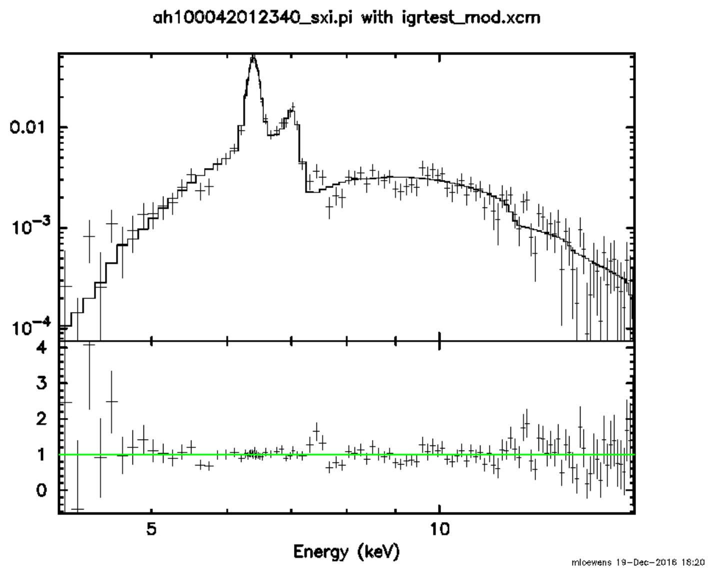

Figure 55: Fit to the combined SXI spectra given above using the RMF and ARF files derived in the previous section. The unabsorbed flux in the 2-10 keV energy band is 6.08 x 10^{-11} erg cm^{-2} s^{-1} .

SXI and HXI.

(1) Simultaneosly fit the SXI background-subtracted spectra in the 0.8-16 keV band, and the HXI 5-80 keV background-subtracted spectra for sequence 100042040.

```
2 files 2 spectra
Spectrum 1  Spectral Data File: ah1000420120_sxi.pi
Net count rate (cts/s) for Spectrum:1  3.658e-02 +/- 7.997e-04 (70.0 % total)
 Assigned to Data Group 1 and Plot Group 1
  Noticed Channels:  668-2666
  Telescope: HITOMI Instrument: SXI  Channel Type: PI
  Exposure Time: 8.228e+04 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Background File                ah1000420120_sxi_bkg.pi
  Background Exposure Time: 8.228e+04 sec
 Using Response (RMF) File            ah1000420120_sxi.rsp for Source 1

 Spectral data counts: 4296
 Model predicted rate: 3.60383E-02

Spectrum 2  Spectral Data File: ah100042040hx1_p0camrec_cl_dtime.pi
Net count rate (cts/s) for Spectrum:2  1.623e-01 +/- 2.505e-03 (74.5 % total)
 Assigned to Data Group 2 and Plot Group 2
  Noticed Channels:  51-799
  Telescope: HITOMI Instrument: HXI1  Channel Type: PI
  Exposure Time: 3.956e+04 sec
 Using fit statistic: cstat
 Using test statistic: chi
 Using Background File                ah100042040hx1_p0camrec_cl_dtime_bkg.pi
  Background Exposure Time: 3.956e+04 sec
 Using Response (RMF) File            ah100042040hx1_p0camrec_cl_rt.rsp for Source 1

 Spectral data counts: 8619
 Model predicted rate: 0.166963


Current model list:

========================================================================
Model TBvarabs<1>(cutoffpl<2> + gaussian<3> + gaussian<4> + gaussian<5> +
gaussian<6>)constant<7> Source No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
```

```
par  comp
                         Data group: 1
  1    1   TBvarabs   nH         10^22    194.044      +/-  7.12539
  2    1   TBvarabs   He                  1.00000      frozen
  3    1   TBvarabs   C                   1.00000      frozen
  4    1   TBvarabs   N                   1.00000      frozen
  5    1   TBvarabs   O                   1.00000      frozen
  6    1   TBvarabs   Ne                  1.00000      frozen
  7    1   TBvarabs   Na                  1.00000      frozen
  8    1   TBvarabs   Mg                  1.00000      frozen
  9    1   TBvarabs   Al                  1.00000      frozen
 10    1   TBvarabs   Si                  1.00000      frozen
 11    1   TBvarabs   S                   1.00000      frozen
 12    1   TBvarabs   Cl                  1.00000      frozen
 13    1   TBvarabs   Ar                  1.00000      frozen
 14    1   TBvarabs   Ca                  1.00000      frozen
 15    1   TBvarabs   Cr                  1.00000      frozen
 16    1   TBvarabs   Fe                  1.31673      +/-  5.95029E-02
 17    1   TBvarabs   Co                  1.00000      frozen
 18    1   TBvarabs   Ni                  1.00000      frozen
 19    1   TBvarabs   H2                  0.200000     frozen
 20    1   TBvarabs   rho        g/cm^3   1.00000      frozen
 21    1   TBvarabs   amin       mum      2.50000E-02  frozen
 22    1   TBvarabs   amax       mum      0.250000     frozen
 23    1   TBvarabs   PL                  3.50000      frozen
 24    1   TBvarabs   H_dep               1.00000      frozen
 25    1   TBvarabs   He_dep              1.00000      frozen
 26    1   TBvarabs   C_dep               1.00000      frozen
 27    1   TBvarabs   N_dep               1.00000      frozen
 28    1   TBvarabs   O_dep               1.00000      frozen
 29    1   TBvarabs   Ne_dep              1.00000      frozen
 30    1   TBvarabs   Na_dep              1.00000      frozen
 31    1   TBvarabs   Mg_dep              1.00000      frozen
 32    1   TBvarabs   Al_dep              1.00000      frozen
 33    1   TBvarabs   Si_dep              1.00000      frozen
 34    1   TBvarabs   S_dep               1.00000      frozen
 35    1   TBvarabs   Cl_dep              1.00000      frozen
 36    1   TBvarabs   Ar_dep              1.00000      frozen
 37    1   TBvarabs   Ca_dep              1.00000      frozen
 38    1   TBvarabs   Cr_dep              1.00000      frozen
 39    1   TBvarabs   Fe_dep              1.00000      frozen
 40    1   TBvarabs   Co_dep              1.00000      frozen
 41    1   TBvarabs   Ni_dep              1.00000      frozen
 42    1   TBvarabs   Redshift            0.0          frozen
 43    2   cutoffpl   PhoIndex            1.19757      +/-  6.26070E-02
 44    2   cutoffpl   HighECut   keV      500.000      frozen
 45    2   cutoffpl   norm                1.17409E-02  +/-  2.33752E-03
 46    3   gaussian   LineE      keV      6.37797      +/-  5.80681E-03
 47    3   gaussian   Sigma      keV      1.00000E-04  frozen
 48    3   gaussian   norm                7.55480E-04  +/-  7.61511E-05
 49    4   gaussian   LineE      keV      6.36497      = p46 - 0.013
 50    4   gaussian   Sigma      keV      1.00000E-04  frozen
 51    4   gaussian   norm                3.77740E-04  = p48*0.5
 52    5   gaussian   LineE      keV      6.96349      +/-  4.03516E-02
 53    5   gaussian   Sigma      keV      1.00000E-04  frozen
 54    5   gaussian   norm                5.09663E-05  +/-  1.77248E-05
 55    6   gaussian   LineE      keV      6.94749      = p52 - 0.016
 56    6   gaussian   Sigma      keV      1.00000E-04  frozen
 57    6   gaussian   norm                2.54832E-05  = p54*0.5
 58    7   constant   factor              1.00000      frozen
                         Data group: 2
 59    1   TBvarabs   nH         10^22    194.044      = p1
 60    1   TBvarabs   He                  1.00000      = p2
 61    1   TBvarabs   C                   1.00000      = p3
 62    1   TBvarabs   N                   1.00000      = p4
 63    1   TBvarabs   O                   1.00000      = p5
 64    1   TBvarabs   Ne                  1.00000      = p6
 65    1   TBvarabs   Na                  1.00000      = p7
 66    1   TBvarabs   Mg                  1.00000      = p8
 67    1   TBvarabs   Al                  1.00000      = p9
 68    1   TBvarabs   Si                  1.00000      = p10
 69    1   TBvarabs   S                   1.00000      = p11
 70    1   TBvarabs   Cl                  1.00000      = p12
```

```
  71    1   TBvarabs   Ar                   1.00000      = p13
  72    1   TBvarabs   Ca                   1.00000      = p14
  73    1   TBvarabs   Cr                   1.00000      = p15
  74    1   TBvarabs   Fe                   1.31673      = p16
  75    1   TBvarabs   Co                   1.00000      = p17
  76    1   TBvarabs   Ni                   1.00000      = p18
  77    1   TBvarabs   H2                   0.200000     = p19
  78    1   TBvarabs   rho        g/cm^3    1.00000      = p20
  79    1   TBvarabs   amin       mum       2.50000E-02  = p21
  80    1   TBvarabs   amax       mum       0.250000     = p22
  81    1   TBvarabs   PL                   3.50000      = p23
  82    1   TBvarabs   H_dep                1.00000      = p24
  83    1   TBvarabs   He_dep               1.00000      = p25
  84    1   TBvarabs   C_dep                1.00000      = p26
  85    1   TBvarabs   N_dep                1.00000      = p27
  86    1   TBvarabs   O_dep                1.00000      = p28
  87    1   TBvarabs   Ne_dep               1.00000      = p29
  88    1   TBvarabs   Na_dep               1.00000      = p30
  89    1   TBvarabs   Mg_dep               1.00000      = p31
  90    1   TBvarabs   Al_dep               1.00000      = p32
  91    1   TBvarabs   Si_dep               1.00000      = p33
  92    1   TBvarabs   S_dep                1.00000      = p34
  93    1   TBvarabs   Cl_dep               1.00000      = p35
  94    1   TBvarabs   Ar_dep               1.00000      = p36
  95    1   TBvarabs   Ca_dep               1.00000      = p37
  96    1   TBvarabs   Cr_dep               1.00000      = p38
  97    1   TBvarabs   Fe_dep               1.00000      = p39
  98    1   TBvarabs   Co_dep               1.00000      = p40
  99    1   TBvarabs   Ni_dep               1.00000      = p41
 100    1   TBvarabs   Redshift             0.0          = p42
 101    2   cutoffpl   PhoIndex             1.19757      = p43
 102    2   cutoffpl   HighECut   keV       500.000      = p44
 103    2   cutoffpl   norm                 1.17409E-02  = p45
 104    3   gaussian   LineE      keV       6.37797      = p46
 105    3   gaussian   Sigma      keV       1.00000E-04  = p47
 106    3   gaussian   norm                 7.55480E-04  = p48
 107    4   gaussian   LineE      keV       6.36497      = p49
 108    4   gaussian   Sigma      keV       1.00000E-04  = p50
 109    4   gaussian   norm                 3.77740E-04  = p51
 110    5   gaussian   LineE      keV       6.96349      = p52
 111    5   gaussian   Sigma      keV       1.00000E-04  = p53
 112    5   gaussian   norm                 5.09663E-05  = p54
 113    6   gaussian   LineE      keV       6.94749      = p55
 114    6   gaussian   Sigma      keV       1.00000E-04  = p56
 115    6   gaussian   norm                 2.54832E-05  = p57
 116    7   constant   factor               1.22888      +/-  4.38047E-02
________________________________________________________________________

   Using energies from responses.

Fit statistic : C-Statistic =        3058.63 using 2748 PHA bins and 2739 degrees of
freedom.

Test statistic : Chi-Squared =       46965.99 using 2748 PHA bins.
 Reduced chi-squared =       17.14713 for   2739 degrees of freedom
 Null hypothesis probability =   0.000000e+00


 Weighting method: standard
```

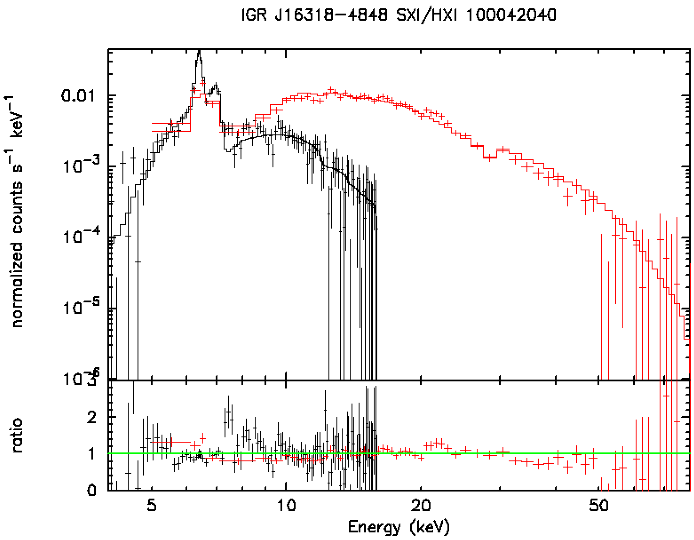

Figure 56: Fit to the combined SXI spectra given above using the RMF and ARF files derived in the previous section. The unabsorbed flux in the 2-10 keV energy band is 6.08 x 10^{-11} erg cm^{-2} s^{-1} .