X-Ray Imaging and Spectroscopy Mission

XRISM (Resolve) Simulation using HEASIM

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Software and Support files

X-Ray Imaging and Spectroscopy Mission

- What you need for XRISM simulations
  - Software (included in HEASoft)
    - heasim -- simulate an event file
    - skyback -- simulate sky X-ray background
    - sxsbranch -- calculate the spectrometer branching ratio
    - XSPEC -- for spectra simulation
    - XSELECT -- extract spectra from event file
  - CalDB
    - The Hitomi CalDB must also be installed and initialized if one wishes to assign pixels and grades to heasim event files using the sxsbranch ftool (see below)
  - Support files (included in HEASARC)
    - https://heasarc.gsfc.nasa.gov/FTP/xrism/prelaunch/simulation/sim3/

      (aka /FTP/xrism/prelaunch/simulation/sim3 in, e.g., SciServer)
  - Documentation (and links to support file direct downloads)
    - https://heasarc.gsfc.nasa.gov/docs/xrism/proposals/index.html

Spectral Simulations: The Basics

- This suite of files (in specfiles_v003.tar.gz) is sufficient to assess feasibility (for a given exposure time) of meeting the spectral goals of many prospective XRISM targets.
- The files are (renamed) in-flight hitomi response files.
- Spectral simulations may be conducted in the usual way, e.g. XSPEC/fakeit.
- The normalized response matrix (RMF) files include only the Gaussian core of the line spread function (LSF), for 4 (constant) values of FWHM (see table below).

Spectral Simulations: Effective Area

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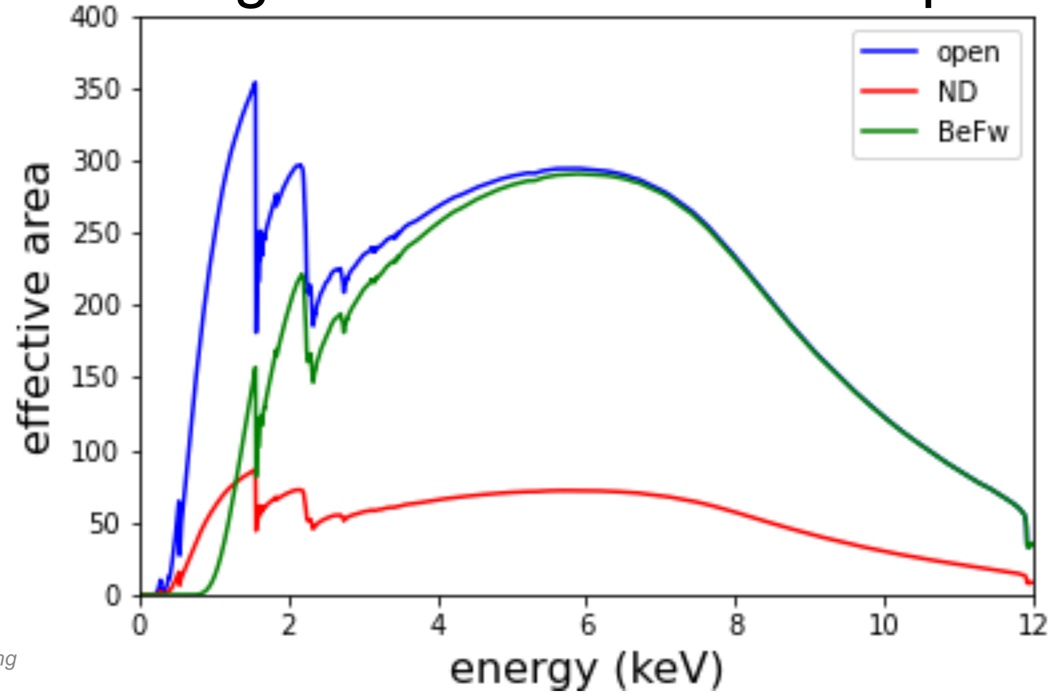
- The Resolve effective area (ARF) files include the quantum efficiency and the dewar filter stack optical blocking filter transmission.
- They range over energies 0.11-25 keV and include gate-valve open (“noGV”) and closed (“withGV”) versions (made with the new gate valve model). GO users should never to use the latter (gate valve scheduled to be opened during commissioning).
- In addition to these Filter Wheel Open files, ARFs for Beryllium filter (“BeFw”) and Neutral density (“ND”) filter selections are provided - the gate valve is assumed open in these cases (also “CBF” – not need by GOs).



For a general extended source, the point source arf should be good to ~25% in converting flux from a small (<array) region to a count rate – when in doubt use that one, or do a full simulation (see below).

Spectral Simulations: NXB

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- Resolve NXB spectra are based on Hitomi pre-launch estimates with the addition of MnK-alpha and K-beta features with fluxes estimated by the instrument team.
- These are consistent with in-flight Hitomi SXS NXB spectra derived using the “sxsnxbgen” ftool.
- This is not a precise match to the Resolve NXB, and so should only be used to assess whether the NXB might be a concern.
- However, the Resolve NXB, estimates at ~0.01 ct/s over the Resolve array, is negligible in most cases of interest.

Spec-SIM File Summary - Resolve

FILE	NOTE
Resolve	
resolve_h5ev_2019a.rmf	High resolution, nominal
resolve_m6ev_2019a.rmf	Mid resolution, nominal
resolve_h7ev_2019a.rmf	High resolution, required
resolve_m8ev_2019a.rmf	Mid resolution, required
resolve_pnt_spec_noGV_20190701.arf	On-axis point source, gatevalve open
resolve_pnt_spec_withGV_20190701.arf	On-axis point source, gatevalve closed
resolve_bet_spec_noGV_20190611.arf	5.7 arcmin radius beta-model, beta=0.57, 1.26 arcmin core centered on-axis, gatevalve open
resolve_bet_spec_withGV_20190611.arf	5.7 arcmin radius beta-model, beta=0.57, 1.26 arcmin core centered on-axis, gatevalve closed
resolve_flt_spec_noGV_20190611.arf	5 arcmin radius uniform circle centered on-axis, gatevalve open
resolve_flt_spec_withGV_20190611.arf	5 arcmin radius uniform circle centered on-axis, gatevalve closed
resolve_pnt_spec_BeFw_20190701.arf	On-axis point source, Be filter
resolve_pnt_spec_ND_20190701.arf	On-axis point source, Neutral Density filter
resolve_h5ev_2019a_rslnxb.pha	Use with resolve_h5ev_2019a.rmf
resolve_m6ev_2019a_rslnxb.pha	Use with resolve_m6ev_2019a.rmf
resolve_h7ev_2019a_rslnxb.pha	Use with resolve_h7ev_2019a.rmf
resolve_m8ev_2019a_rslnxb.pha	Use with resolve_m8ev_2019a.rmf

Spec-SIM File Summary - Xtend

- The Hitomi (Astro-H) pre-launch Xtend ARF, RMF,and NXB spectral files were derived using a 1.8 arcminute radius circular extraction region. The NXB spectrum for the entire FoV ("full") is also included.

FILE	NOTE
Xtend	
ah_sxi_20120702.rmf	SXI pre-launch
sxt-i_140505_ts02um_int01.8r.arf	1.8 arcminute radius circular extraction region
ah_sxi_pch_nxb_r1p80_20110530.pi	Use with sxt-i_140505_ts02um_int01.8r.arf
ah_sxi_pch_nxb_full_20110530.pi	Full field-of-view

Anatomy of a XRISM “Perseus” Simulation

Assurance

NO live demos are included in this talk

Step 1: Make Xspec qdp Model Files

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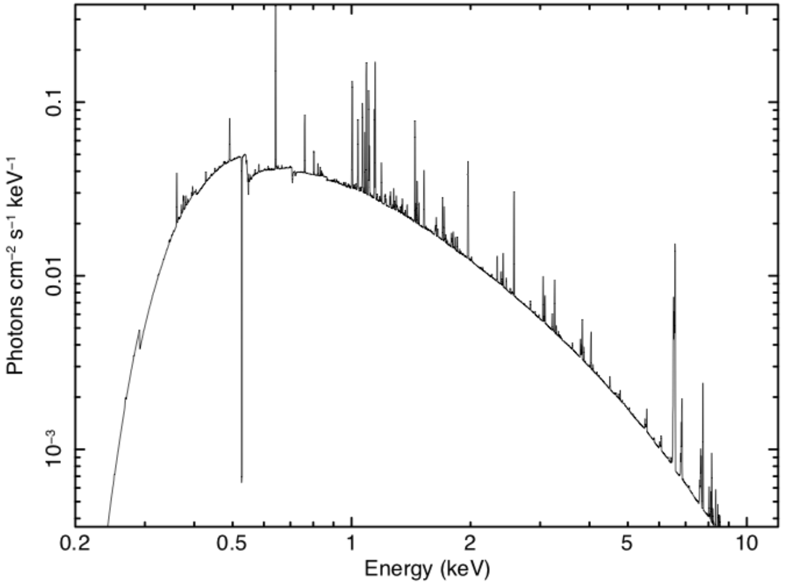
In this example “Perseus” = beta model ICM (TBabs*bvvapec) plus point source AGN (Tbabs*plaw)

```
XSPEC12>@perseus_icm_abs_mod.xcm
XSPEC12>data none
XSPEC12>energ 0.1 27.1 27000
XSPEC12>cpd /xs
XSPEC12>setplot comm wdata perseus_icm_abs_mod.qdp
XSPEC12>plot model
```

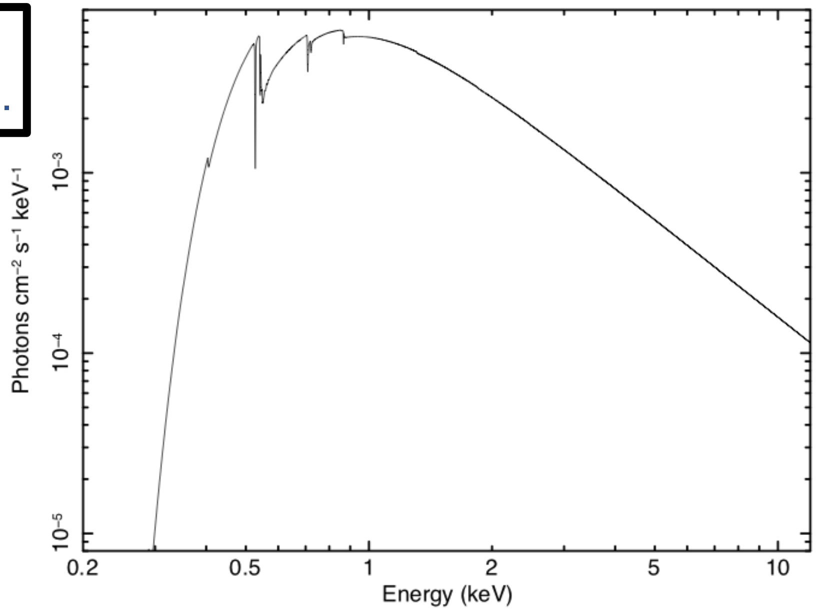
```
XSPEC12>@perseus_brtptsrc_mod.xcm
XSPEC12>data none
XSPEC12>energ 0.1 27.1 27000
XSPEC12>cpd /xs
XSPEC12>setplot comm wdata perseus_brtptsrc_mod.qdp
XSPEC12>plot model
```



energy range spans the instrument band
energy bin smaller than instrument resolution.

Model should be properly normalized (i.e., give the correct flux).

Combine all components with the same spatial distribution into one model.



Step 2: Make source definition files

- Heasim requires a source definition file (“sdf”) as input to specify the source position in the sky, and source characteristics (consult the heasim guide for details). Each line represents a single source, or single component of a multi-component source. The comma-separated elements of the sdf are as follows:

RA,DEC	source coordinates.
NH	column density: set to 0 if absorption is included in the input spectrum.
spectrum	“user” if using input spectrum.
flux	source flux in erg/sec/cm^2: set to 0 if using an input spectrum (flux is calculated from that).
bandpass	bandpass within which flux is calculated: set to 0.0-0.0 if using an input spectrum.
specfile	qdp file name: see guide for other formats.
specunits	2 for specfile derived as shown: see guide for other options tied to specfile.
specformat	2 for specfile derived as shown: see guide for other options tied to specfile.
source_specs	extended spatial distribution, or time variation, specifier (if any) Here, a beta=0.53, core radius =1 arcmin beta-model extending to 5.7 arcmin. The specified flux corresponds to this distribution.

Step 2: Make source definition files

For our Perseus simulation, the sdf representing the extended thermal, and point-like non-thermal, components is as follows:

perseus_betaicm.dat ==
49.95,41.51,0.0,user,0.,0.,0.-0.,perseus_icm_abs_mod.qdp,2,2,extmod(beta,0.53,1.26,1.0,0.0,0.0,5.7)
49.95,41.51,0.0,user,0.,0.,0.-0.,perseus_brtptsrc_mod.qdp,2,2

RA,DEC,NH,spectrum,flux,bandpass,specfile,specunits,specformat,source_specifications

Step 3: Simulation: Setup

- Download and unpack support files heasimfiles_20201012.tar.gz, placing them in some directory <heasimfilesdir>
- Set the HEASIM_SUPPORT environment variable:
  setenv HEASIM_SUPPORT <heasimfilesdir> (C-shell) or export HEASIM_SUPPORT=<heasimfilesdir> (Bash)

Step 4: Run the (on-axis) Simulations

- Since the pointing RA and DEC are the same as those for the source, an on-axis simulation is conducted.
- For point sources, the vignetting function may be ignored ("vigfile=none"). For extended sources, we currently recommend using the point source arf and including vignetting – rather than using the extended source arfs (that, in this case, would require doing two simulations and combining the simulated output event files).
- As mentioned above, the NXB may be neglected in most cases ("intbackfile=none") but is included here for demonstration purposes.
- Note that the input ARF file is not the same as that used for spectral simulations, since heasim must account for photons originating outside of the field-of-view. In the simulation below, the psffile is specified as an eef and thus results in an axisymmetric X-ray distribution. The image file sxs_psfimage_20140618.fits may instead be used to include the effects of PSF asymmetries.

heasim mission=hitomi instrume=sxs rapoint=49.95 decpoint=41.51 roll=0.00 exposure=200000.
insrcdeffile=perseus_betaicm_brptsrc.dat outfile=perseus_betaicm_brptsrc.fits
psffile=$HEASIM_SUPPORT/xrism/resolve/psf/eef_from_sxs_psfimage_20140618.fits
vigfile=$HEASIM_SUPPORT/xrism/resolve/vignette/SXT_VIG_140618.txt
rmffile=$HEASIM_SUPPORT/xrism/resolve/response/resolve_h5ev_2019a.rmf
arffile=$HEASIM_SUPPORT/xrism/resolve/response/**resolve_pnt_heasim_noGV_20190701.arf**
intbackfile=$HEASIM_SUPPORT/xrism/resolve/background/resolve_h5ev_2019a_rslnxb.pha
flagsubex=no seed=1234567890 clobber=yes

Step 5: Extract and Fit the Spectra

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1. Set the XSELECT_MDB environment variable to run xselect on your output
   a) setenv XSELECT_MDB $HEASIM_SUPPORT/xrism/auxiliary/xselect.mdb.heasim (C-shell) or
   b) export XSELECT_MDB=$HEASIM_SUPPORT/xrism/auxiliary/xselect.mdb.heasim (Bash)
2. Extract the spectrum from the heasim output file using xselect
   a) xsel:HITOMI-SXS-PX_NORMAL > read events perseus_betaicm_brptsrc.fits
   b) xsel:HITOMI-SXS-PX_NORMAL > extract spectrum
   c) xsel:HITOMI-SXS-PX_NORMAL > save spectrum perseus_betaicm_brptsrc.pi
3. Analyze the spectrum

XSPEC12>data 1:1 perseus_betaicm_brptsrc.pi
XSPEC12>response 1:1 resolve_h5ev_2019a.rmf
XSPEC12>response 2:1 resolve_h5ev_2019a.rmf
XSPEC12>arf 1:1 **resolve_bet_spec_noGV_20190611.arf**
XSPEC12>arf 2:1 **resolve_pnt_spec_noGV_20190701.arf**
XSPEC12>model TBabs*bvvapec
XSPEC12>... specify params
XSPEC12>model 2:agn constant*TBabs*powerlaw
XSPEC12>... specify params
XSPEC12>... fit, derive errors, etc.

Get from
$HEASIM_SUPPORT/xrism/resolve/response/

Simulated Spectrum

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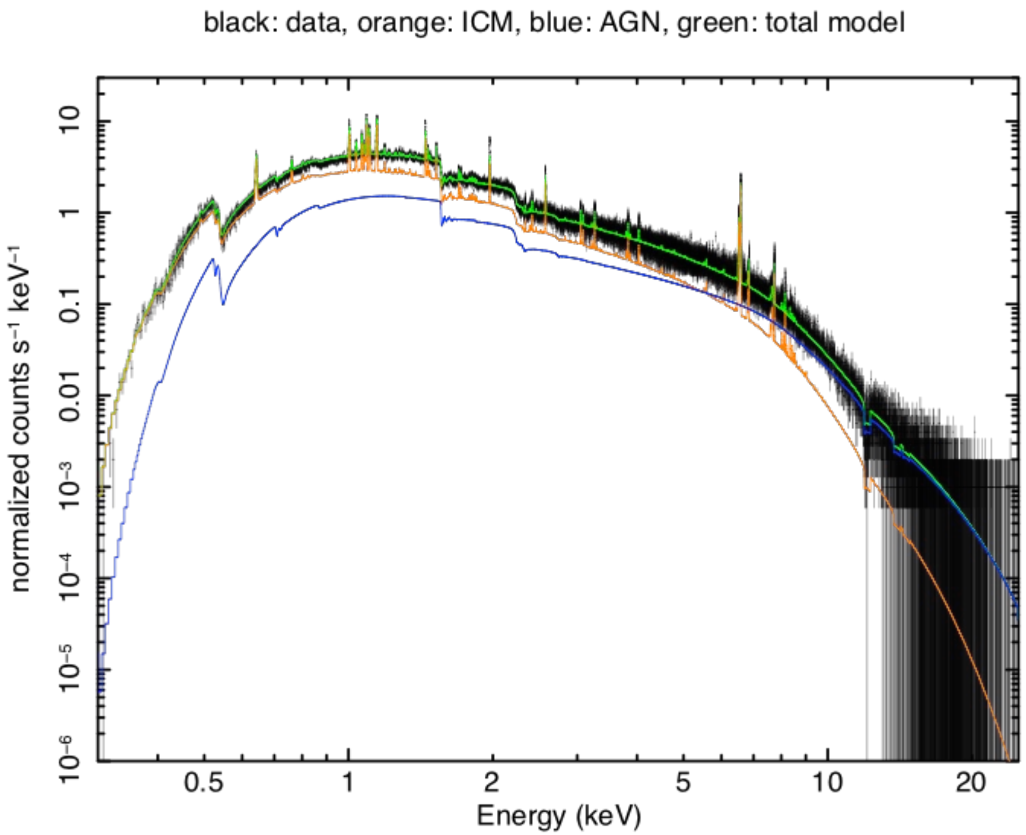
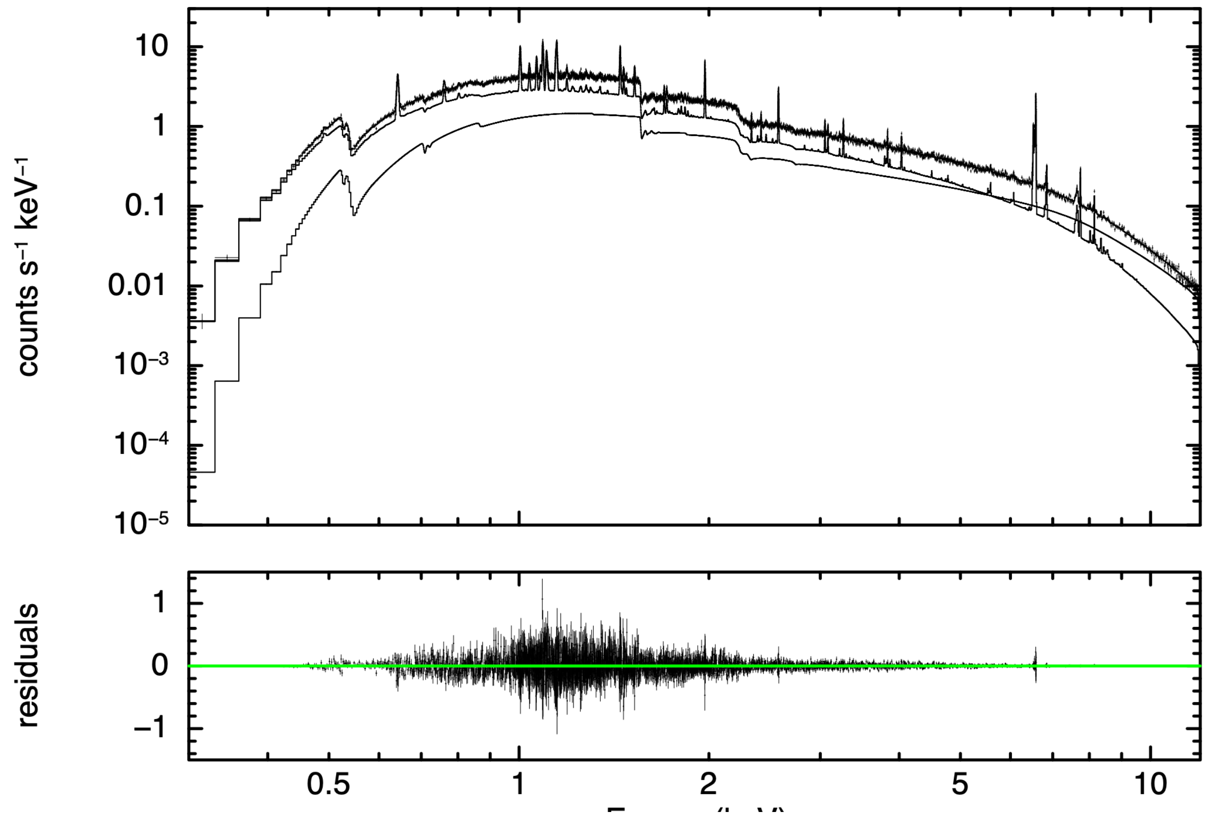
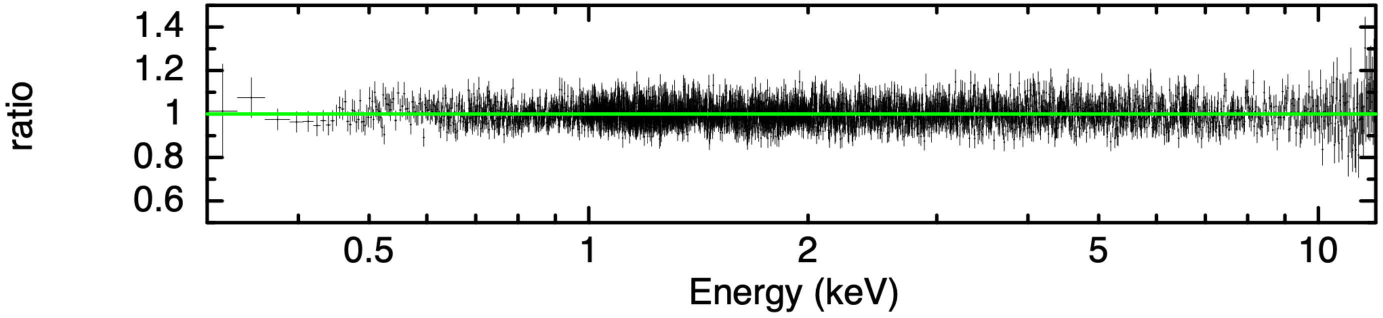
```
XSPEC12>data 1:1 perseus_betaicm_brptsrc.pi
XSPEC12>response  1:1 resolve_h5ev_2019a.rmf
XSPEC12>response  2:1 resolve_h5ev_2019a.rmf
XSPEC12>arf 1:1 resolve_bet_spec_noGV_20190611.arf
XSPEC12>arf 2:1 resolve_pnt_spec_noGV_20190701.arf
XSPEC12>model  TBabs*bvvapec
XSPEC12>... specify params
XSPEC12>model  2:agn constant*TBabs*powerlaw
XSPEC12>... specify params
XSPEC12>... fit, derive errors, etc.
```



- The above spectrum is compared to its generating model, and its components, above. Note that different ARFs from that used as heasim input are applied in spectral fitting. The extended source ARF, resolve_bet_spec_noGV_20190611.arf, is exclusively appropriate to the simulation at hand. More generally, one may use the point source ARF for both components to recover the spectral parameters and uncertainties, however the flux of the extended component will not be correct (expert users may generate the appropriate extended source ARF to recover input flux).

Simulated Spectrum

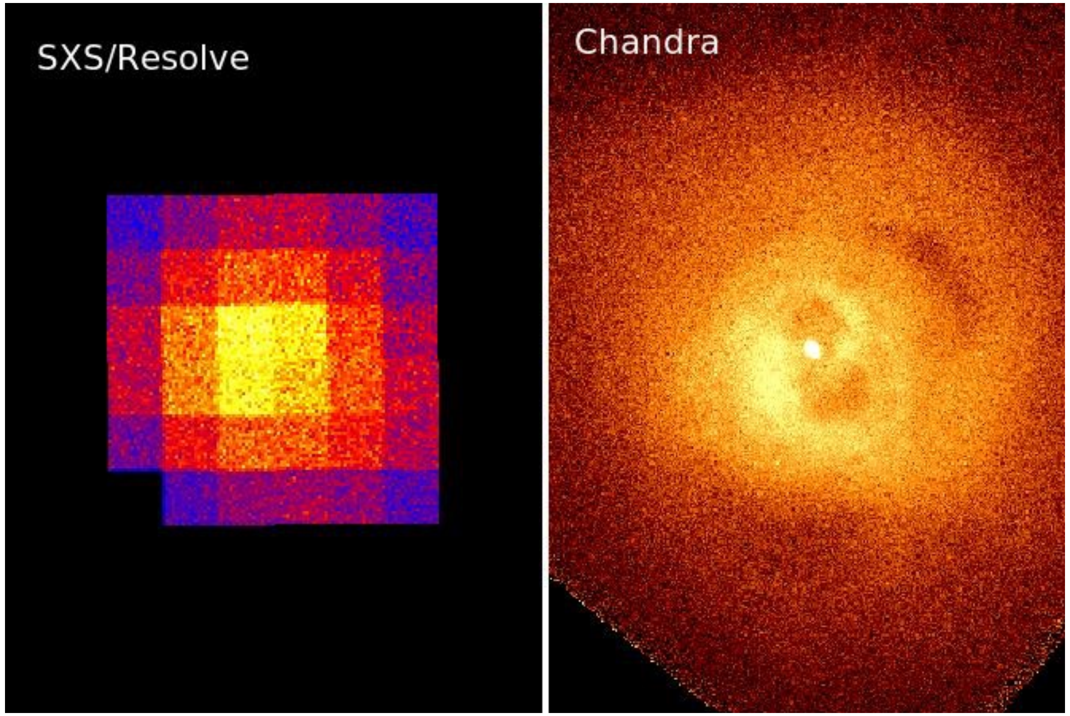




- Norms are recovered at the percent level

Use an Image as Source (and/or PSF)

perseus_imageicm.dat == 49.95,41.51,0.0,user,0.,0.,0.
0.,perseus_icm_abs_mod.qdp,2,2,image(**acis_chip0_band1_norm.img**,0,0,0,0



heasim mission=hitomi instrume=sxs rapoint=49.95 decpoint=41.51 roll=0.00 exposure=200000.
insrcdeffile=**perseus_imageicm.dat** outfile=perseus_imageicm.fits
psffile=$HEASIM_SUPPORT/hitomi/sxs/psf/eef_from_sxs_psfimage_20140618.fits vigfile=none
rmffile=$HEASIM_SUPPORT/hitomi/sxs/response/xarm_res_h5ev_20170818.rmf
arffile=$HEASIM_SUPPORT/hitomi/sxs/response/xarm_res_bet_pa_20170818.arf
intbackfile=none flagsubex=no seed=1234567890 clobber=yes

Add an emission line to thd source

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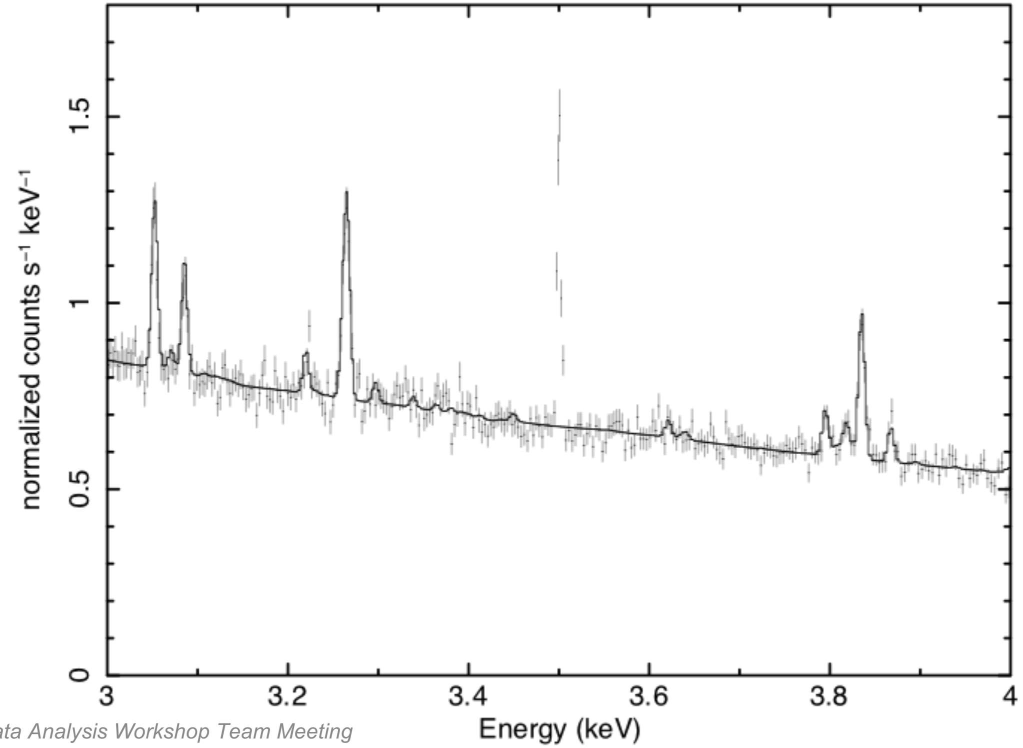
perseus_betaicm_brptsrc_line.dat ==

49.95,41.51,0.0,user,0.,0.,0.-
0.,perseus_icm_abs_mod.qdp,2,2,extmod(beta,0.53,1.26,1.0,0.0,0.0,5.7)
49.95,41.51,0.0,user,0.,0.,0.-0.,perseus_brtptsrc_mod.qdp,2,2
49.95,41.51,0.0,**mono,3.5**,1.0e-13,2.5-4.5,none,2,2,**extmod(beta,0.66,0.1,1.0,0.0,0.0,5.7)**

heasim mission=hitomi instrume=sxs rapoint=49.95 decpoint=41.51 roll=0.00 exposure=200000.
insrcdeffile=**perseus_betaicm_brptsrc_line.dat** outfile=perseus_betaicm_brptsrc_line.fits...

- mono: narrow gaussian line
  for finite width use user model



Use an ARF including A FW Filter

heasim mission=hitomi instrume=sxs rapoint=49.95 decpoint=41.51 roll=0.00 exposure=200000. insrcdeffile=perseus_betaicm_brptsrc.dat outfile=perseus_betaicm_brptsrc.fits psffile=$HEASIM_SUPPORT/xrism/resolve/psf/eef_from_sxs_psfimage_20140618.fits vigfile=$HEASIM_SUPPORT/xrism/resolve/vignette/SXT_VIG_140618.txt rmffile=$HEASIM_SUPPORT/xrism/resolve/response/resolve_h5ev_2019a.rmf arffile=$HEASIM_SUPPORT/xrism/resolve/response/**resolve_pnt_heasim_BeFw_20190701.arf** intbackfile=$HEASIM_SUPPORT/xrism/resolve/background/resolve_h5ev_2019a_rslnxb.pha flagsubex=no seed=1234567890 clobber=yes

In Xspec, use **resolve_pnt_spec_BeFw_20190701.arf**

heasim mission=hitomi instrume=sxs rapoint=49.95 decpoint=41.51 roll=0.00 exposure=200000. insrcdeffile=perseus_betaicm_brptsrc.dat outfile=perseus_betaicm_brptsrc.fits psffile=$HEASIM_SUPPORT/xrism/resolve/psf/eef_from_sxs_psfimage_20140618.fits vigfile=$HEASIM_SUPPORT/xrism/resolve/vignette/SXT_VIG_140618.txt rmffile=$HEASIM_SUPPORT/xrism/resolve/response/resolve_h5ev_2019a.rmf arffile=$HEASIM_SUPPORT/xrism/resolve/response/**resolve_pnt_heasim_ND_20190701.arf** intbackfile=$HEASIM_SUPPORT/xrism/resolve/background/resolve_h5ev_2019a_rslnxb.pha flagsubex=no seed=1234567890 clobber=yes

- In Xspec, use **resolve_pnt_spec_ND_20190701.arf**

Filtering the simulating events

- Use HP and MP for hi-rez spectroscopy.
- Rule of thumb: check branching if >1 ct/sec/pixel.

sxsbranch (rslbranch)

- computes branching ratios for each event resolution grade -- for each pixel, and over the entire array
- statistically estimates these quantities using Poisson statistics, based on some count distribution in pixels
- produces a more realistic version of the event file by populating the PIXEL, and ITYPE columns with the grade (ITYPE = 0:HP, 1:MP, 2:MS, 3:LP, 4:LS)

```
sxsbranch infile=perseus_betaicm_brptsrc.fits filetype=sim outfile=perseus_betaicm_brptsrc_branch.out
  pixfrac=$HEASIM_SUPPORT/xrism/resolve/sxsbranch/pixfrac.txt pixmask=none
  ctelpixfile=$HEASIM_SUPPORT/xrism/resolve/sxsbranch/pixmap.fits ctphafrac1=0.0 ctphafrac2=0.0
```

For example, in Xselect...

xsel:HITOMI-SXS-PX_NORMAL > read events **read events perseus_betaicm_brptsrc.fits**

xsel:HITOMI-SXS-PX_NORMAL > filter column "PIXEL=27:35” *corner of the array*

xsel:HITOMI-SXS-PX_NORMAL > filter GRADE "0:0” HP only (1:MP, 2:MS, 3:LP, 4:LS)

xsel:HITOMI-SXS-PX_NORMAL > extract spectrum

xsel:HITOMI-SXS-PX_NORMAL > save spectrum perseus_betaicm_brptsrc_HPsubarray.pi

DOs, DON'Ts and Takeaways

- For isolated point sources, a pure spectral simulation may be sufficient – but DO run *sxsbranch* if the source is bright.
- DO use Xspec to create input spectra for your simulation.
- DO take advantage of the multi-component source capabilities of heasim and Xspec.
- For Resolve, one DOESN'T need the source to extend beyond ~6 arcmin.
- DO be mindful of norms for extended sources (must use the correct ARF in Xspec to get a correct flux).
- For Resolve, the NXB is negligible in most cases.
- In the near-term, heasim configuration files will be updated to include XRISM to avoid confusion. The mdb will be updated with XRISM teldef-like quantities. Updates to support files to follow later.
- Additional requests for improvement are welcome.