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JEM–X SPECTRAL CALIBRATIONS

DSRI Project JEM–X

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Approved by: Date:

Approved by: Date:

Table 1: REVISION NOTICE

Document Revision History			
Issue	**Rev.**	**Date**	**Changes**
1	0	March 26, 2004	Initial Release

Contents

Introduction

The sepctral calibration of the JEM–X instruments is performed by used the Crab Nebula as the calibration source by requiring that the powerlaw spectrum with a photon index of 2.1 and an absorption column of $2.65 \times 10^{21} \mathrm{cm}^{-2}$ atoms is reproduced by the analysis of the JEM–X data.

The calibration results are the redistributions matrices (RDM) and the auxiliary response functions (ARF) that are stored in the RMF files: jmx1_rmf_grp_nnnn.fits and jmx2_rmf_grp_nnnn.fits where 'nnnn' is a serial number.

At higher energies (i.e. greater than 10 keV) the instruments are well described by the pre-launch detector specifications such as photon absorption in the Xe gas. At lower energies, however, the electronic threshold discriminates against low signal events and this effect is gain dependent.

So far the response matrices disregard this dependency. A study of its importance is underway.

Due to changes in the parameter settings of the JEM–X instruments the calibrations are anly valid in specific periods. These changes can be the setting of the low level ciscriminator, the high voltage setting, the rejection criteria and the setting of the high signal cut-off.

1 Calibration periods

In the table below the alibration validity periods are given. The boxes indicate the period where a single RMF instance can be used. The lines separating the boxes gives the event that makes it necessary to change calibration. In the case where it is blank the time of change is placed midways between two calibrations to avoid too long extrapolation.

For **JEM–X1**:

Event	Cal period	Date	IJD	REV	RMF ser. num.	Notes
Activation	1	021027	1030.17	4	0006	1
HV down to 82		021109	1043.33	8/9		
	2				0007	2
Change settings		021125	1059.33	14		
Change of PHA table	3	021127	1061.33	14/15	0008	
Low level discr. change to 2		021128	1062.33	15		
HV down to 80		021211	1075.42	19		
Low level discr. change to 5		030206	1132.33	38/39		
Crab calibration		030224	1150.50	44		
New rejection criteria		030225	1151.29	44		
Crab calibration	4	030226	1152.41	45	0009	
		030519	1237.70	73/74		
Crab calibration	5	030817	1323.90	102	0010	
New rejection criteria		040216	1507.50	164		
Crab calibration	6	040305	1526.90	170	0011	

1, 2) Calibration data are missing. Nominal values are used for ARF.

For **JEM–X2**:

Event	Cal period	Date	IJD	REV	RMF ser. num.	Notes
Activation	1	021028	1031.17	4	0006	1
HV down to 82		021112	1046.33	9/10		
	2				0007	2
Change settings		021125	1059.33	14		
Change of PHA table	3	021127	1061.33	14/15	0008	
Low level discr. change to 2		021128	1062.33	15		
Low level discr. change to 5		030206	1132.33	38/39		
Crab calibration		030224	1150.50	44		
New rejection criteria		030225	1151.29	44		
Crab calibration	4	030226	1152.41	45	0009	
		030519	1237.70	73/74		
Crab calibration	5	030817	1323.90	102	0010	
		031127	1426.10	136/137		
Crab calibration	6	040305	1526.90	170	0011	
New rejection criteria		040316	1536.50	171		

1, 2) Calibration data are missing. Nominal values are used for ARF.

2 JMX1 0008 021125 – 030225

SWIDs used for calibration: 004400140010, 004400380010, 004400640010, 004400890010

XSPEC fit results: α = 2.06±0.01 norm = 6.30±0.16 χ_r^2 = 3.75

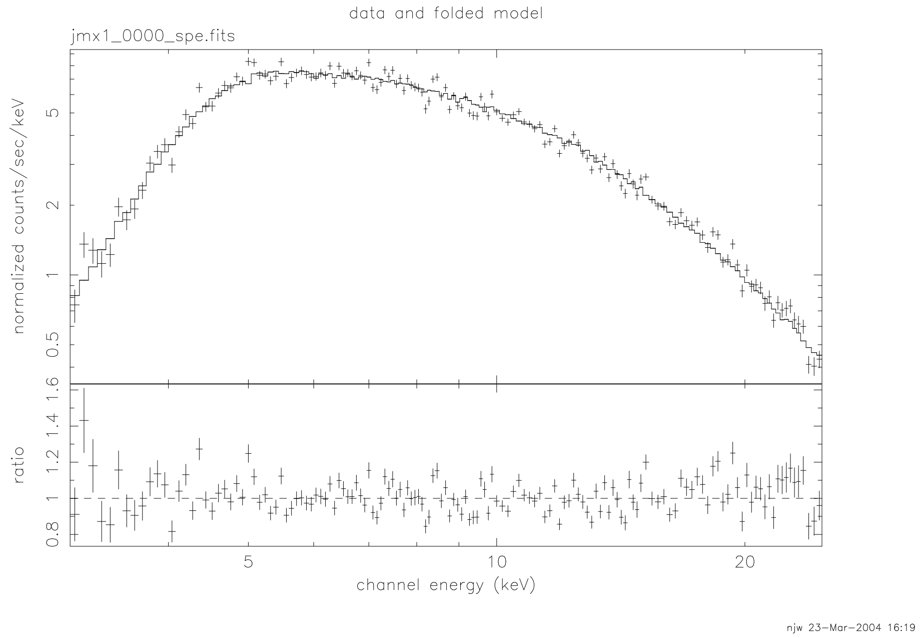

Figure 1: XSPEC fit of ingoing calibration data.

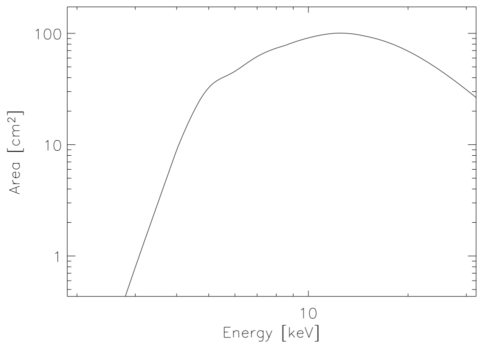

Figure 2: Resulting ARF (on axis; JMX1–AXIS–ARF).

3 JMX1 0009 030225 – 030519

SWID used for calibration: 004500860010

XSPEC fit results: $\alpha = 2.10{\pm}0.01$ norm $= 8.0{\pm}0.2$ $\chi^2_r = 1.21$

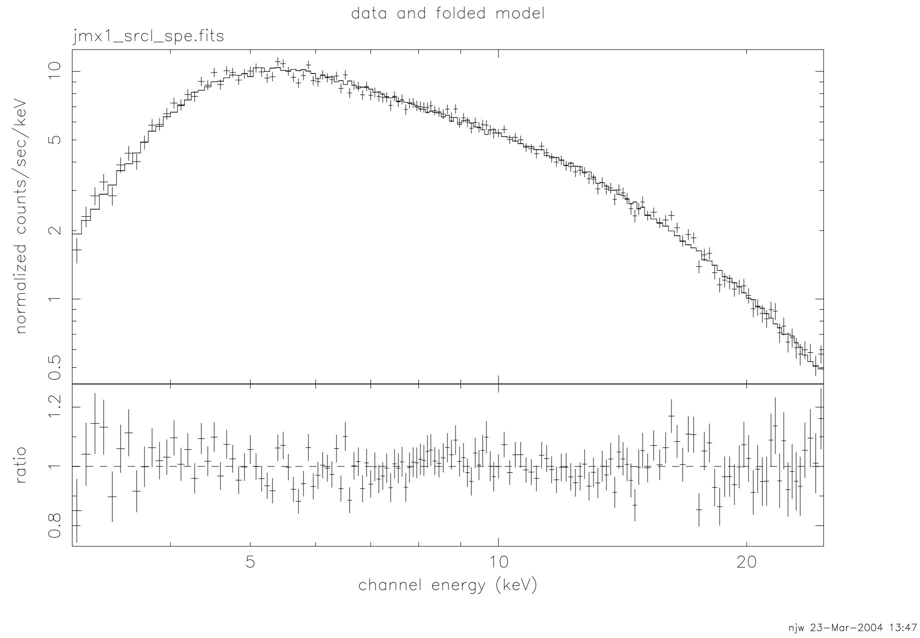

Figure 3: XSPEC fit of ingoing calibration data.

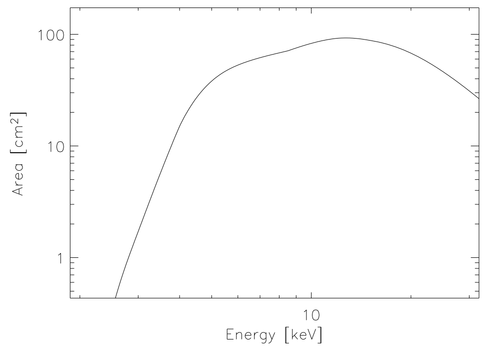

Figure 4: Resulting ARF (on axis; JMX1–AXIS–ARF).

4 JMX1 0010 030519 – 040216

SWIDs used for calibration: 010200210010, 010200380010, 010200380020, 010200380030, 010200380040, 010200380050, and 010200380060

XSPEC fit results: $\alpha = 2.081 \pm 0.005$ norm $= 7.09 \pm 0.08$ $\chi^2_r = 1.45$

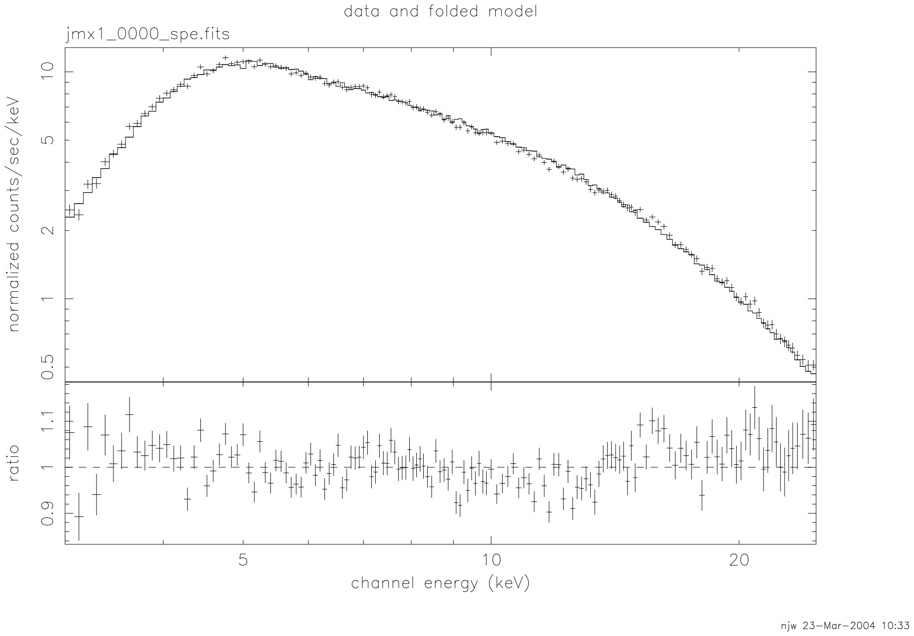

Figure 5: XSPEC fit of ingoing calibration data.

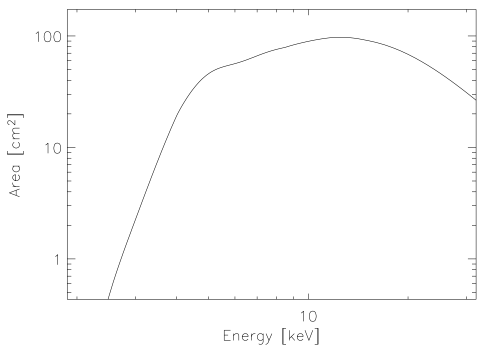

Figure 6: Resulting ARF (on axis; JMX1–AXIS–ARF).

5 JMX1 0011 040216 – ?

SWIDs used for calibration: 017000810010

XSPEC fit results: $\alpha = 2.10 \pm 0.01$ norm $= 7.70 \pm 0.16$ $\chi^2_r = 1.31$

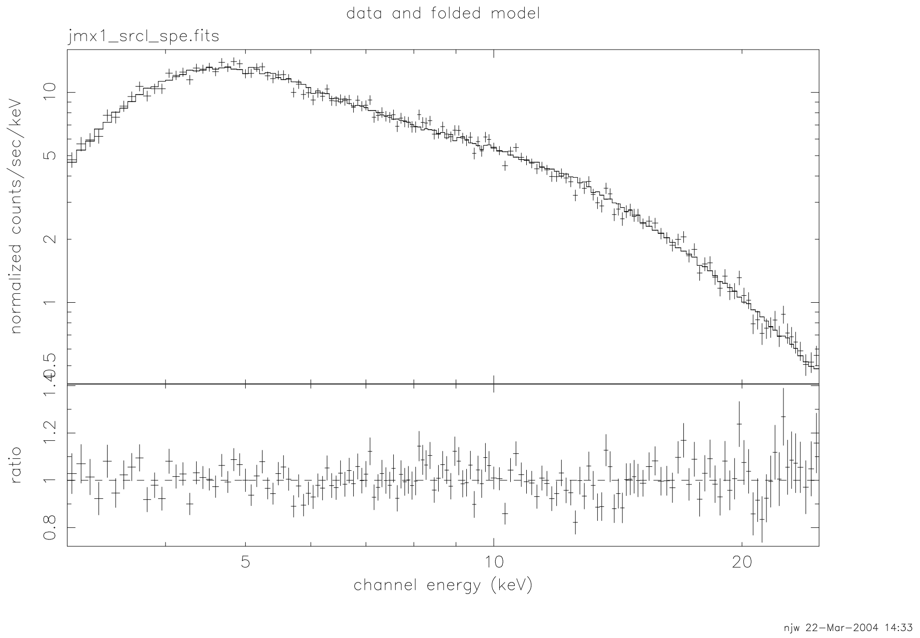

Figure 7: XSPEC fit of ingoing calibration data.

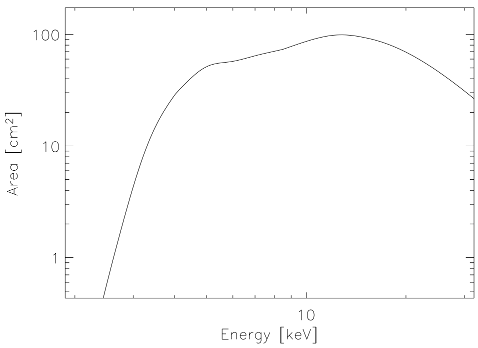

Figure 8: Resulting ARF (on axis; JMX1–AXIS–ARF).

6 JMX2 0008 021125 – 030225

SWIDs used for calibration: 004400140010, 004400380010, 004400640010, 004400890010

XSPEC fit results: $\alpha = 2.11 \pm 0.06$ norm $= 7.03 \pm 0.09$ $\chi^2_r = 1.99$

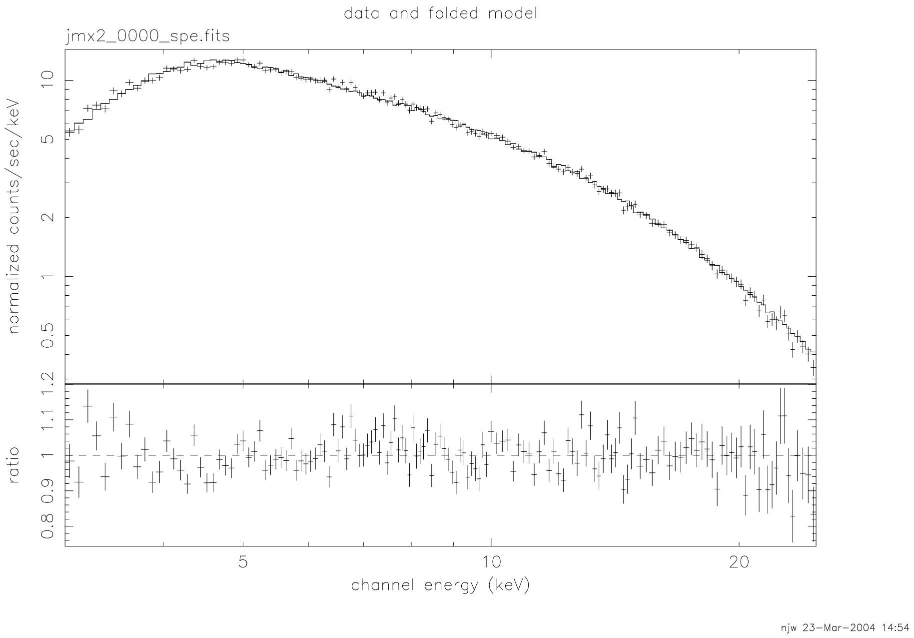

Figure 9: XSPEC fit of ingoing calibration data.

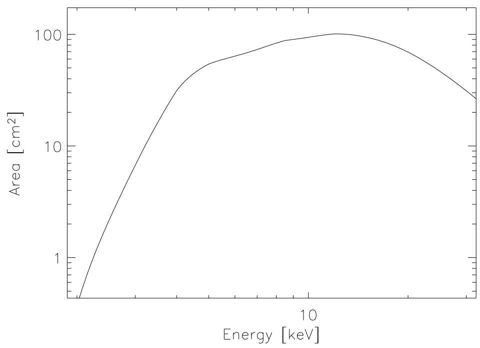

Figure 10: Resulting ARF (on axis; JMX2–AXIS–ARF).

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7 JMX2 0009 030225 – 030519

SWID used for calibration: 004500860010

XSPEC fit results: $\alpha = 2.11 \pm 0.08$ norm $= 7.50 \pm 0.12$ $\chi^2_r = 1.23$

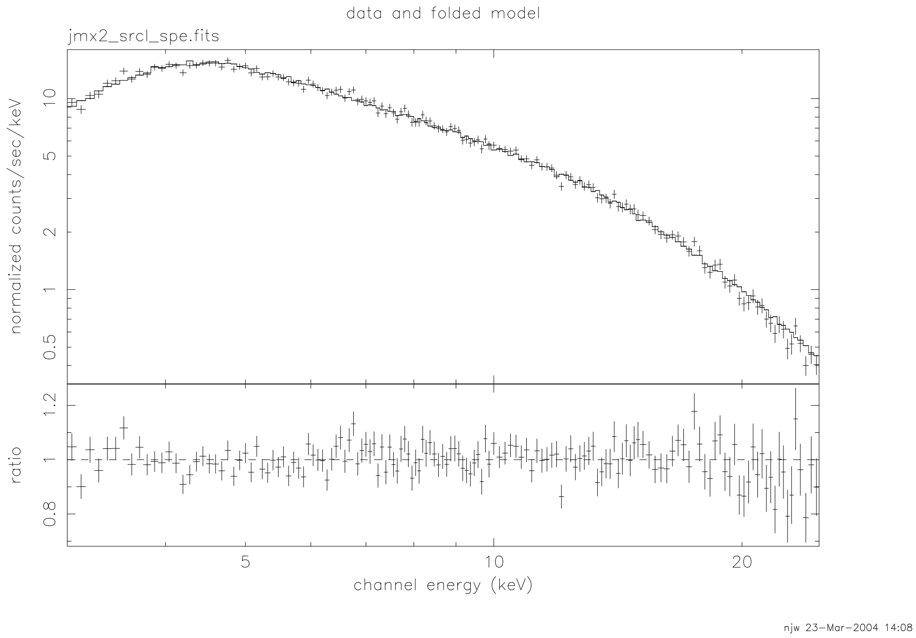

Figure 11: XSPEC fit of ingoing calibration data.

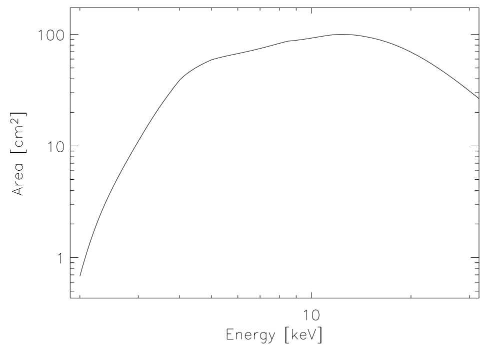

Figure 12: Resulting ARF (on axis; JMX2–AXIS–ARF).

8 JMX2 0010 030519 – 031127

SWIDs used for calibration: 010200210010, 010200380010, 010200380020, 010200380030, 010200380040, 010200380050, and 010200380060

XSPEC fit results: $\alpha = 2.08{\pm}0.04$ norm $= 6.76{\pm}0.05$ $\chi^2_r = 2.14$

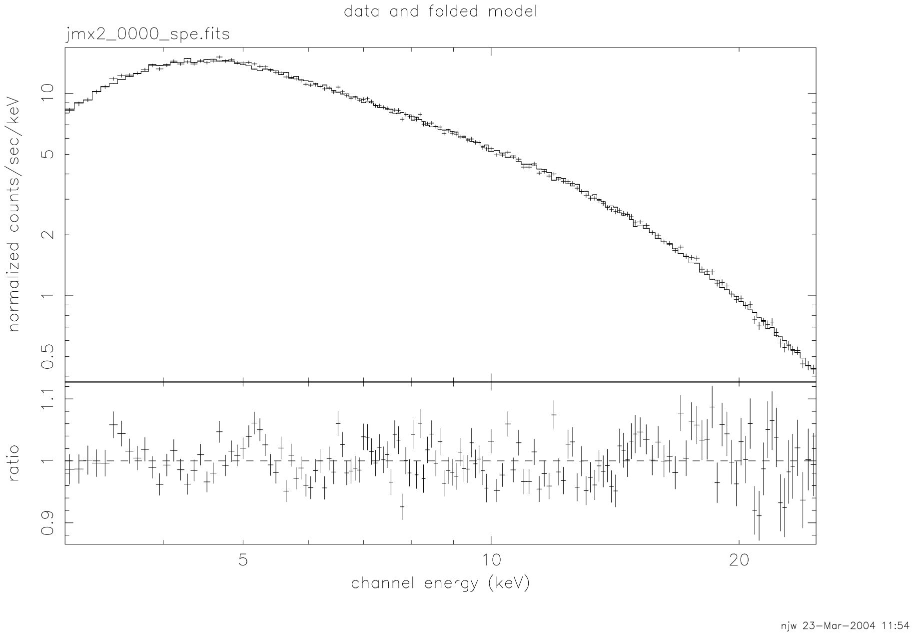

Figure 13: XSPEC fit of ingoing calibration data.

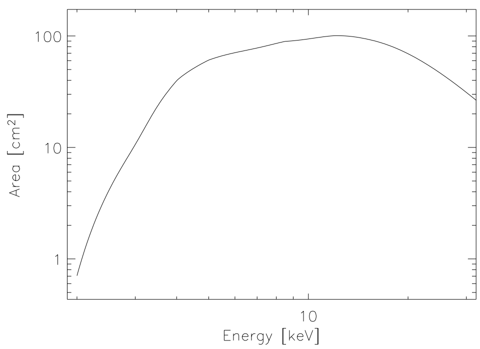

Figure 14: Resulting ARF (on axis; JMX2–AXIS–ARF).

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9 JMX2 0011 031127 – 040316

SWIDs used for calibration: 017000810010

XSPEC fit results: $\alpha = 2.05 \pm 0.10$ norm $= 7.03 \pm 0.14$ $\chi^2_r = 1.19$

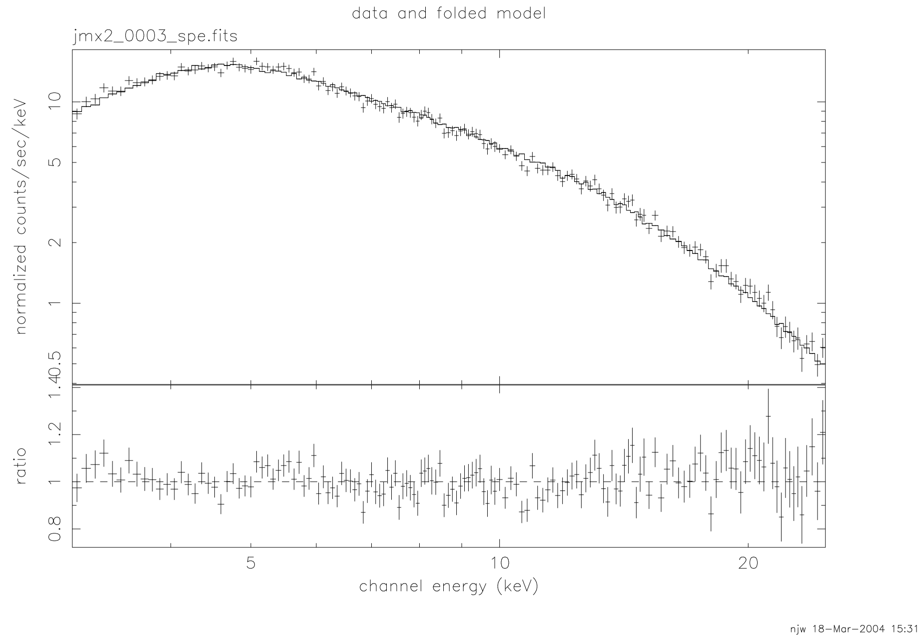

Figure 15: XSPEC fit of ingoing calibration data.

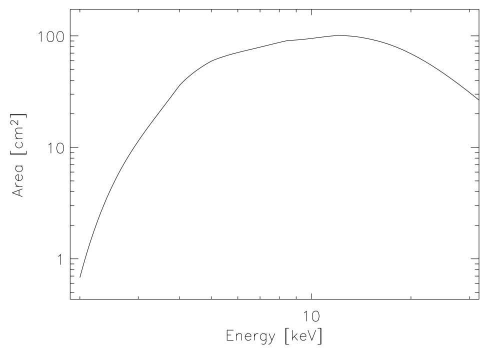

Figure 16: Resulting ARF (on axis; JMX2–AXIS–ARF).

10 Summary of ARF results

An overview of the results is given in Figure 17 and 18 where the ratio of the ARFs found with respect to the pre-launch high (nominal) gain values are shown. In the nominal gain situation the low energy cut-off is solely determined by the absorption in the Be window.

The 'First estimate' ARF indicated in the figures is an attempt to include the effect of the electronic cut-off based on JEM–X2 measurements. This is the one given in jmxi_rmf_grp_0003.fits.

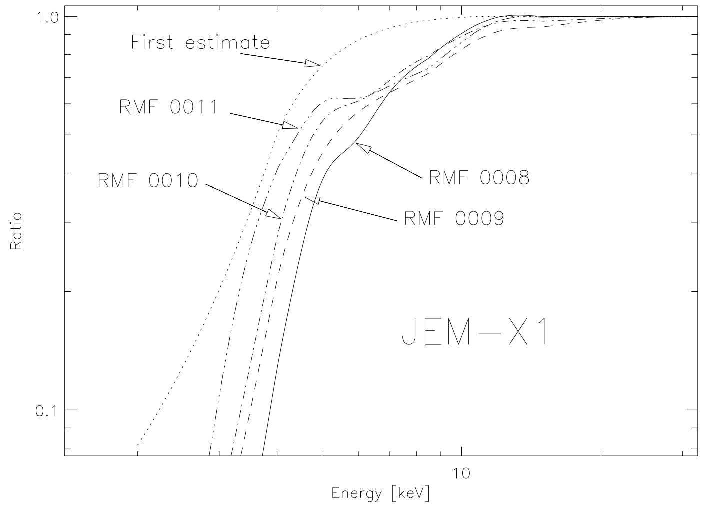

Figure 17: The ARFs relative to the pre-launch, high gain values.

11 Effect of gain changes

The low end of the energy range is affected by the low level discriminator that acts on the fast signal. The event PHA is based on the slow signal. The pulse invariant (PI) value is obtained from the measured position of the calibration lines in PHA space, by defining the gain factor every four minutes. The rejection algorithm for minimizing the number of background counts also is based on the PHA value.

The count spectrum in PI space is expressed as

$$S_{PI} = \sum_j \mathrm{RDM}_{PI,j} \mathrm{ARF}(e_j) flux(e_j) \tag{1}$$

where RDM is the normalized redistribution matrix ($\sum_{PI} \mathrm{RDM}_{PI,j} = 1$).

The ancillary response function (ARF) expresses the 'cross-section' for a photon of energy e_j to interact in the detector. It can be divided in two parts: a physical part that describes the absorption and interaction properties that only depend on the photon energy and an electronic part as described above.

$$\mathrm{ARF} = \mathrm{PARF}(e_j) \times \mathrm{EARF}(\mathrm{PHA}) \tag{2}$$

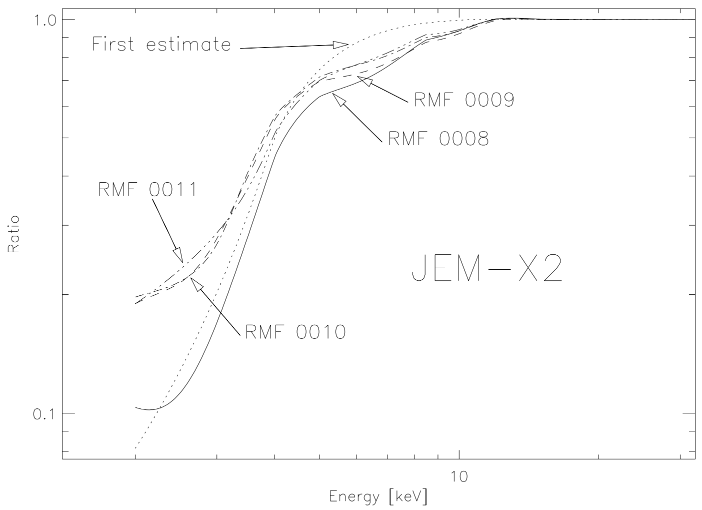

Figure 18: The ARFs relative to the pre-launch, high gain values.

The connection between PHA and e_j is the current gain factor. So Equation 1 should be replaced by

$$S_{PI} = \sum_t \sum_j \mathrm{RDM}_{PI,j}\mathrm{PARF}(e_j)\mathrm{EARF}(t) flux(e_j) \tag{3}$$

As an example the effect of the JEM-X2 temporal gain variation and the low energys detection efficiency has been analyzed.

During the 18 months in operation it has been observed that gas gain of JEM–X2 increases as a function of time with a rate of about 1% every 4 days (Brandt et al.). The JEM–X2 HV setting was adjusted in order to keep the actual gain at a level close the Crab calibration. However, the JEM–X2 gain at the Crab calibrations of March 2004 (Revolution 170) was 25% higher than for the preceding calibration of August 2003 (Revolution 102). The gain difference had as a consequence that the low energy detection efficiency of JEM–X2 changed between the two calibrations, since this efficiency partly is determined by the electronic threshold of the detector electronics.

Fig. 21 displays the ratio of the two Crab spectra measured during the two calibration campaigns, respectively. Here crab_3 denotes the spectrum found in Revolution 103, PID 3 (on-axis) and crab_4 in Revolution 170, PID 81 (on-axis). The energy scale was determined from the position of the Xenon fluorescence peak observed in background data.

The effect of the electronic threshold is clearly seen in the energy range below 3 keV. In the range from 3 to 5 keV the effect is much smaller (≈5%) and above 5 keV the shape of the two spectra are identical.

Although these gain variations have only marginal influence in the JEM–X energy range (3-35 keV) it is recommended that the JEM–X2 HV for the future is adjusted such that the gain excursions never exceeds 10%.

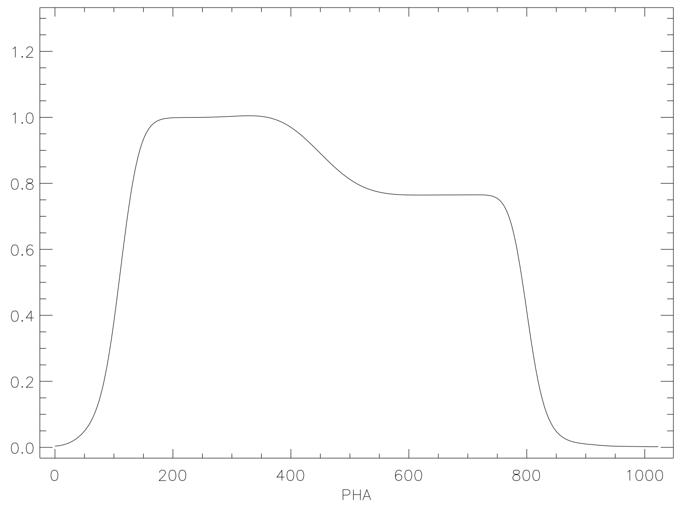

Figure 19: How an electronic filter function against PHA value could look. The step around PHA=450 is caused by a change in the rejection criteria.

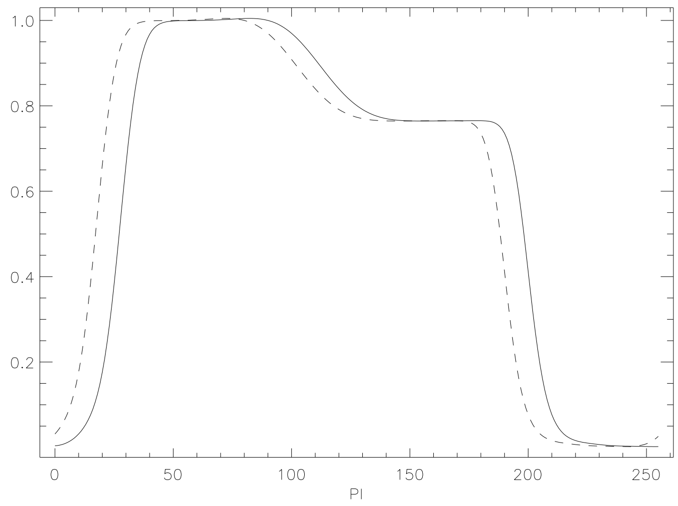

Figure 20: The electronic filter function from Figure 19 against PI value at two different gains.

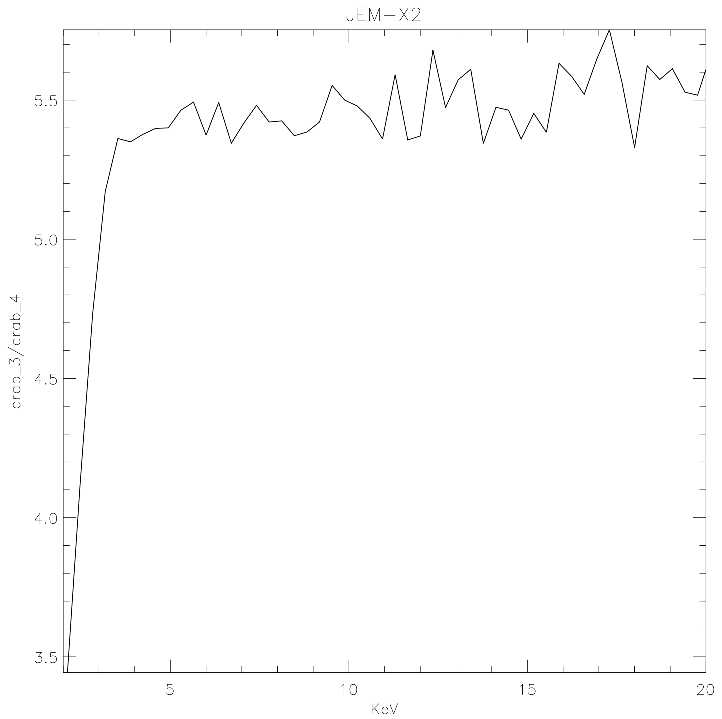

Figure 21: Comparison of the Crab spectrum at two different gains.

12 How to make a new instance of jmxi_rmf_grp_####.fits ?

12.1 Introduction

This section describes a way to produce an adequate ARF (in OGIP parlance it is called SPECRESP). The ARF depends both on the current setting of the detector high voltage, the gain, and the setting of the rejection parameters. In a first approximation the change of rejection parameters has the greatest effect.

Also the spectral extraction executable (j_src_spectra) has an influence on the result. The efficiency with which it assigns the events to a particular source depends on details in the detector modelling.

This means that there are a number of time periods where the ARF can be considered to be constant

A directory structure (see Fig. 22) has been setup to hold these results as well as the ingoing data under /r6/jemx/spec_calib. The subdirectories are named as jmxi_RRRR where the revolution number (RRRR) tells when the calibration data have been taken. There is one more level named according to the version of 'j_src_spectra'

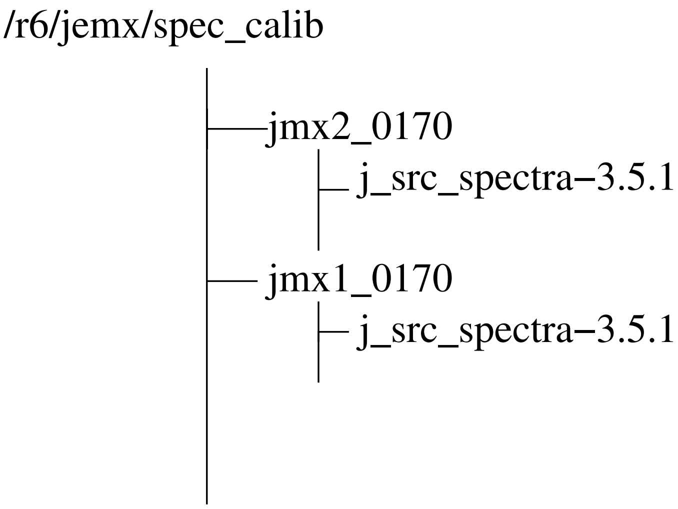

Figure 22: Directory tree.

12.2 Prescription

Use jemx_science_analysis to extract the calibration spectrum (mostly the Crab). Take the subdirectory 'res' and copy to /r6/jemx/spec_calib/jmx2_RRRR/j_src_spectra-3.5.1 (RRRR is the 4-digit revolution number).

Go to /r6/jemx/spec_calib/jmx2_0170/j_src_spectra-3.5.1 and type
export /r6/jemx/spec_calib/jmx2_RRRR/j_src_spectra-3.5.1
to copy the required parameter files and setup of ARF fitting procedure.
Then go to /r6/jemx/spec_calib/jmx2_RRRR/j_src_spectra-3.5.1.
Make sure that the spectrum to use for calibration is the first one in the
jmxi_srcl_spe.fits and jmxi_srcl_arf.fits files since that is the assumption

of the new_arf_step1 and new_arf_step2 procedures.

The spectra can also be combined with the IDL function 'collect_spectra'

First update file 'new_arf_step1.par' with filenames. Then from IDL:

IDL> new_arf_step1

will generate a file with the reference ARF normalized with vignetting factor.

Then do:

IDL> @arffit_setup
IDL> resall
IDL> arffit_init,dol_of_og (Literally! dol_of_og is defined in arffit_setup)
IDL> eflt = fltarr(500) + 1.0
IDL> c2 = arffit_fitfunc5(eflt,e_ch=e_ch) & print,c2/155

The last command can be repeated until the fit is satisfactory (155 is the D.O.F.)

IDL> wtab,'eflt.scm',eflt (save the result)

Then the scene is set for making a new ARF file, a new RMF file:

IDL> new_arf_step2

Then a test run with XSPEC (input data: crab_spe_file) is possible