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INTEGRAL cross-calibration status for OSA 5.1

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Summary

Three years into the mission, the software provided to analyse INTEGRAL data has reached a good level of maturity. Nevertheless, there are still some imperfections in the data modeling, affecting the quality of the results. The following report presents the calibration status of INTEGRAL instruments using OSA 5.1 software, instrument calibration files version 5.1 and, in addition, new spirmf 1.8 (see OSA 5.1 Known Issues).

SPI: Calibration of SPI has been satisfactory for quite a long time. The Crab spectrum can be very well fitted with a single power law in a broad energy range. Systematic effects are only observed in the 23-35 keV range, and are at the level of 1-2%. Thanks to its independent calibration method, relying on ground-based measurements and Monte Carlo simulations, SPI can be used as a reference instrument in the 35 keV - few MeV range.

ISGRI: There were a lot of improvements in ISGRI spectral extraction done in OSA 5.0 but some issues still remain. In the case of data taken between Revolutions 0065 and 0255 in normal conditions the systematic distortions seen in 23-100 keV range are smaller than 2%. For data taken before Revolution 0065 or after Revolution 0255 the deviations reach sometimes 5% in the 23-100 keV energy range.

JEM-X: Both JEM-X 1 and JEM-X 2 were re-calibrated after OSA 5.0 release. Usually the systematic effects do not exceed 3% in the 5-20 keV range, however, for later observations, since Rev. 0239, the observed discrepancies reach sometimes 5%. Generally it is possible to use JEM-X data in a wider range, 3-30 keV, but above 20 keV there is often seen some steepening of the spectra.

PICsIT: Because the first release of PICsIT response files happened only in OSA 4.2 the calibration is in an early stage and can be used as a preliminary, rough approximation. Due to large uncertainty in the count rates it is not possible to adjust the calibration with a higher precision unless a special treatment of low signal-to-noise ratio data is included in OSA.

Cross-calibration: The overall agreement between SPI, ISGRI and JEM-X is generally good but still both the absolute normalizations and spectral slopes require some tuning. The power-law index fitted to ISGRI data is about 0.05-0.1 larger than that obtained for SPI and JEM-X spectra. The normalization factor relative to SPI is about 0.84 for ISGRI, about 0.8 for JEM-X, and about 0.7 for PICsIT.

1 Introduction

The INTEGRAL satellite has been in operation for almost three years, and the archive contains now almost 40 Ms of data. The data analysis software reached a high maturity level with the release of OSA 5.0 for almost all instruments. Although some problems are still not completely solved, the quality of INTEGRAL results is increasing, as is reflected by the increasing number of papers based on these data. Therefore it is desirable to give to the users community more information on the issues that can affect the INTEGRAL results. The following report presents a review on the calibration status of INTEGRAL instruments after OSA 5.1 release.

All results discussed below were obtained from observations of Crab nebula. This is the only strong and stable source in the INTEGRAL energy range that can serve as a reference source. An additional virtue of Crab is its relatively simple and approximately known spectrum, which, at least in the 1-50 keV range, can be modeled by an absorbed power law. The Crab canonical model, established with the paper by Toor & Seward (1974), is an absorbed power law, with power law index = 2.1, normalization at 1 keV = 9.7 photons/(s keV cm^2) and hydrogen column density around 3×10^{22} atoms/cm^2. This model was tested many times during last decades, and the last measurements done with independently ground-calibrated EPIC-pn CCD camera on board XMM-Newton also confirmed its overall validity (Kirsch et al., 2005). Power-law indexes obtained with EPIC-pn and MOS are 2.125(4) and 2.15(1), respectively, in the 0.5-10 keV range. The joint fit to all major past and current missions, including INTEGRAL, presented by Kirsch et al. (2005), gives an index = 2.12 in the 10-50 keV range. Nevertheless, there is no consensus on the Crab spectrum shape above 50 keV (e.g. Massaro et al. (2000); Ling & Wheaton (2003)). The extrapolation of the canonical model to higher energies can only be used as an approximation, although its simple form makes it useful for relative studies.

Crab spectra used for tests presented below were collected over the large part of INTEGRAL mission time, from Revolution 0039 (7 Feb 2003) up to Rev. 0300 (28 Mar 2005). This should allow users to judge what calibration uncertainty can be expected for their observations at any given time. During spectral extraction all OSA 5.1 parameters were set to the default values. In case of SPI, ISGRI, JEM-X and cross-calibration fitting was done twice. The first series of fits was performed without adding any systematical error to the statistical ones to avoid arbitrariness introduced by such a procedure when systematic effects are not well understood. In the second series of fits the systematic error values needed to obtain $\chi^2 = 1$ were added to the spectra. Typical uncertainties of the fitted parameters are usually given in the table captions. Since ISGRI is probably the most extensively used INTEGRAL instrument, the section devoted to it is somewhat extended compared to the rest of this report.

2 SPI

SPI is collecting photons in a very wide energy range, from 20 keV up to 8 MeV. Below we present the results of Crab observations limited to the 23-1000 keV band, because of some uncertainties in calibration below 23 keV and small sensitivity above 1 MeV. SPI is the only X-ray/gamma-ray instrument on board INTEGRAL with a calibration fully independent of the Crab. The SPI response was derived from GEANT simulations and the extensive ground calibration carried out at Bruyères-Le-Châtel before launch (Attié et al., 2003). At energies above about 40 keV, these simulations reproduced the ground-calibration results almost perfectly, providing good confidence that the SPI response was very well characterized. At lower energies, small discrepancies were observed, and the simulations were eventually adjusted to the ground calibrations.

The results of fitting power-law model to Crab spectra are presented in Table 1, and illustrated in Figs. 1-2. The fits are very good, acceptable χ^2 residuals are obtained in the 35 keV 1 MeV range without introducing any systematic errors in XSPEC. Between 23 and 35 keV, there is evidence of systematic errors of the order of 1-3 %. These are smaller than the statistical uncertainties for the vast majority of INTEGRAL observations. It should also be pointed out that, in the 23-35 keV range, the response was adjusted to ground-calibration results derived for a few energies.

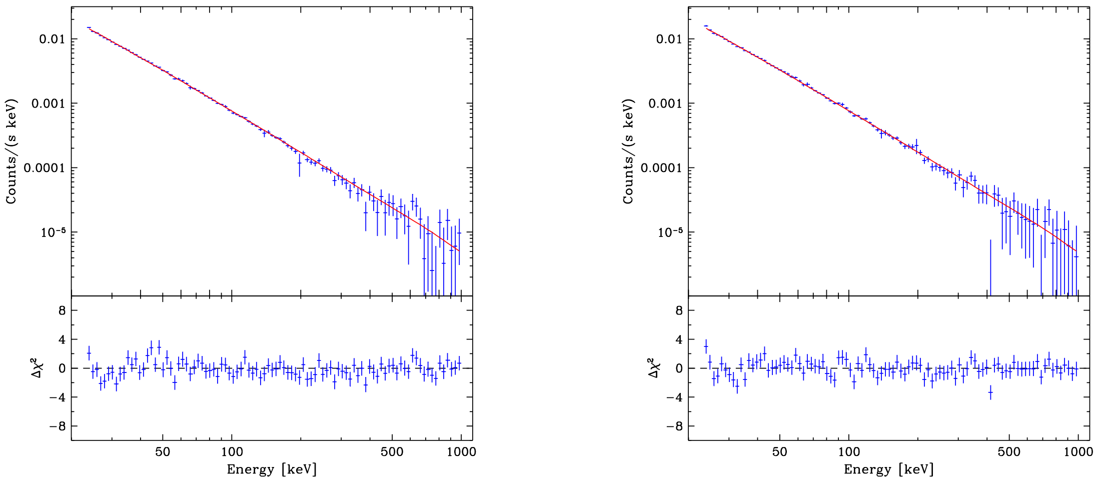


Figure 1: Best-fit power-law model obtained for SPI spectra from Rev. 0102 (left) and Rev. 0170 (right).

Results shown in Table 1 are fully consistent with each other. The spectral slope changes from one observation to the other by less than 1 σ uncertainty. Also flux in the 30-1000 keV range is almost constant, being only lower by about 3% for Rev. 0102. Compatible results are derived also from the different Crab observations using different background methods and different statistics options within SPIROS. No significant difference is observed for different mixtures of ScWs with different off-axis angles or different dithering patterns.

The calibration of SPI can be regarded as excellent. There is a chance, after collecting more data (Crab nebula is observed during $\approx$ 150 ks twice a year), to measure accurately the Crab spectral shape in a wide energy range. This will be extremely useful to calibrate other hard X-ray and low gamma-ray instruments, at least in a relative way.

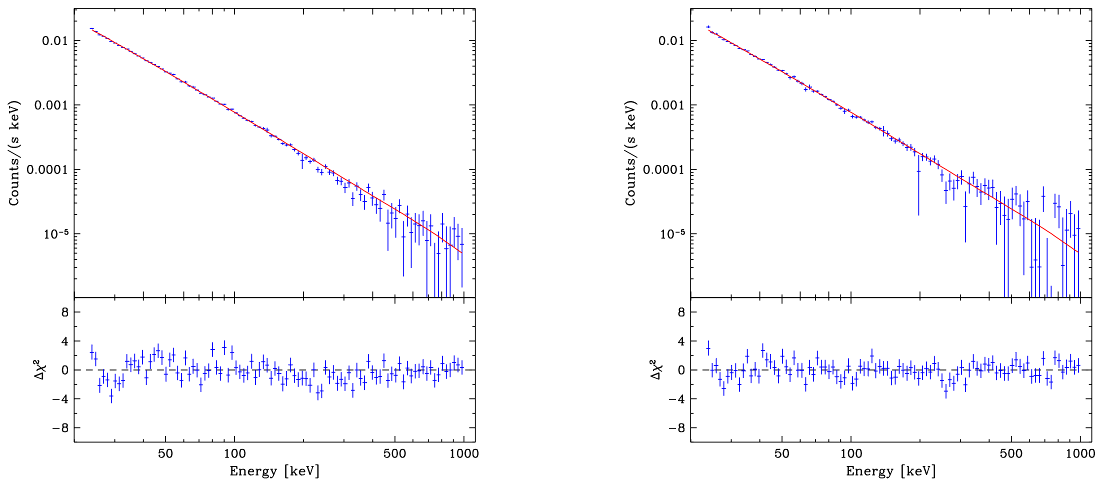


Figure 2: Best-fit power-law model obtained for SPI spectra from Rev. 0239 (left) and Rev. 0300 (right).

Table 1: Results of power-law model fitting to SPI spectra extracted with OSA 5.1. The results of alternative fitting, with systematic errors adjusted to get reduced $\chi^2 = 1$ are shown in the lower part of the table. Energy range is 23-1000 keV. Γ - power-law index, Flux - flux in the 30-1000 keV range (photons/(s cm^2)), χ^2_ν - reduced χ^2, ν - number of degrees of freedom, Syst. - systematic error (per cent) added to the data. Typical 1 σ error for index is 0.01 and 0.001 for flux.

Rev.	Off-set angle [deg]	Exposure [ks]	Γ	Flux	χ^2_ν	ν	Syst.
0102	< 6	78.0	2.14	0.224	1.09	94	—
0170	< 10	61.8	2.15	0.232	1.03	94	—
0239	< 6	156.1	2.15	0.234	1.94	94	—
0300	< 6	34.7	2.14	0.232	1.25	94	—
0102			2.14	0.224	1.00	94	0.5
0170			2.15	0.232	1.00	94	0.4
0239			2.15	0.234	1.00	94	2.8
0300			2.14	0.232	1.00	94	1.9

3 ISGRI

In principle, ISGRI operates in the energy range between 13 keV and 1 MeV but, in practice, even for strong sources like Crab the useful band is limited to ≈20-500 keV. Calibration of ISGRI is not based on the Crab canonical model. The response matrices are generated using Monte Carlo simulations, but with the constraint that the Crab spectral slope should be described by a single power-law. Since OSA 4.2 the spectral index of this model was determined to be 2.225. The Crab observations from Rev. 0102 (with small amount of data from Rev. 0103) were used as reference data, with the basic spectrum made from on-axis measurements.

There are many improvements to the spectral extraction software in the OSA 5.0 ISGRI analysis software. The major ones are the two new procedures used to exclude noisy events, off-axis correction map rebinned to finer bins, the first background maps based on in-flight data and a more refined method to fit the spectra for sources illuminating only part of the detector plane. As a result, the count rates in adjacent bins obtained with OSA 5.0 are more consistent than in OSA 4.2. The sensitivity below 25 keV is also different, with much higher rates in OSA 5.0. It should be stressed that the problem of artificially too large fluxes at higher energies (Lubiński, 2005) disappeared.

Despite big progress made in OSA 5.0 ISGRI analysis package, there are still some deficiencies present in the spectral data. Figures 3-5, where the model fitting results are shown, illustrate these effects. The "snake-like" features are now strongly supressed compared to OSA 3 and OSA 4 results. The model fitting without systematic errors produce large reduced χ^2 reflecting the existence of effects not taken into account in the modeling of the instrument. The particularly large residuals for the Rev. 0239 spectrum may be the result of the special, micro-dithering and arc around the Crab observing strategy, which does not seem to be adequately modeled. Nonetheless, all spectral index and normalization values do not show large dispersions.

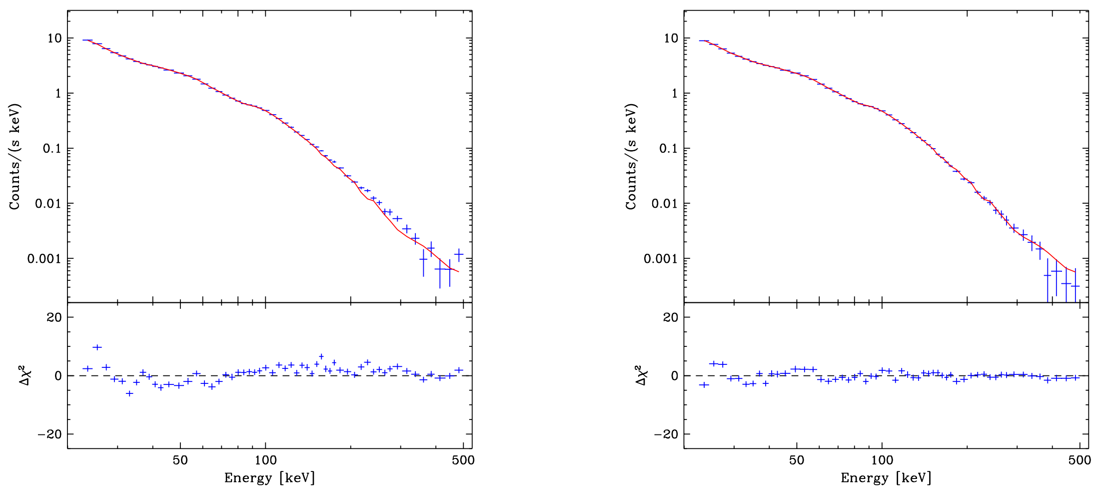
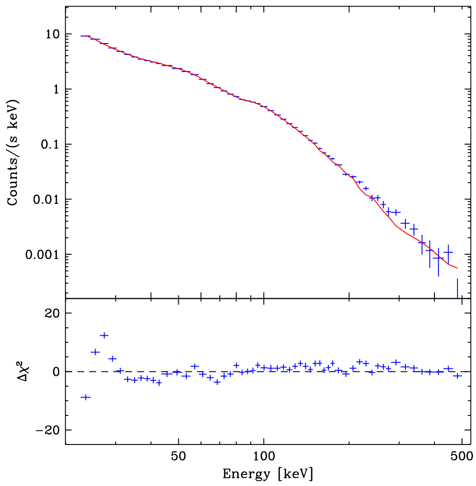


Figure 3: Best-fit power-law model obtained for ISGRI spectrum from Rev. 0039 (left) and from Rev. 0102 (right).

There are evidences of changes in the shape of ISGRI spectra as a function of time, especially at energies below 25 keV. Some of these changes are the results of modifications in the configuration parameters. For example, such a change took place during Rev. 0063, when the criteria of event rise time selection were modified. However, the principal reason for the discrepancies observed below 25 keV is the adjustment of the low threshold of ISGRI pixels, which varies over time. There are three main periods with different threshold settings: before Rev. 0065, between 0065 and 0255, and after 0255. For the time being the spectra taken before Rev. 0065 and after Rev. 0255 should be treated with caution below 25 keV, because the current response is not adequate for them.

An other problem affecting the spectra is the imperfect model of the dependence between the event pulse amplitude and rise time, resulting in the false identification of the energy of some fraction of events. This was the main source of 'snake-like' features observed in the results of older OSA releases, and is suppressed by the 'adjustment' of the ARF response files in OSA 4.2 and OSA 5.0. A new energy correction table, together with appropriate new response files, are needed to get completely rid of this problem.



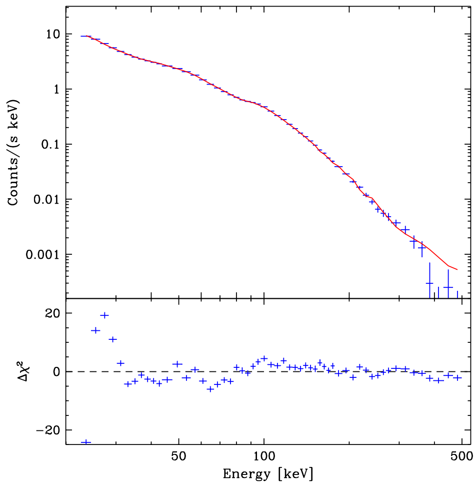


Figure 4: Best-fit power-law model obtained for ISGRI spectrum from Rev. 0170 (left) and from Rev. 0239 (right).

The last figure of this Section, Fig. 6, is added to give some estimate of the scale of systematic effects present in ISGRI spectra after OSA 5.0 release. Six spectra are shown, taken in various conditions and mission times, and are compared to the best-fit joint power-law model, with common normalization for each data set. The major message is that the standard 'solution' to obtain a 'good' fit via adding some systematic errors should be applied with care: the discrepancies observed between various spectra are changing with energy, and there is no universal value of the systematic error which can approximate them (see the last column of Table 2). The proper, albeit demanding, solution is to model the systematic effects, and to include them in the software.

Using Fig. 6, one may roughly estimate the scale of systematic uncertainties for various energy bands, for example, to be smaller than ± 1.5% between 35-60 keV. The χ^2 statistic can be used to assess the quality of the fit and for model comparison under specific conditions; adding arbitrary systematic errors very often violates some of these conditions. Moreover, statistical uncertainty varying with energy makes the fitting result to be more sensitive to data from some bands than from others. Adding a constant systematic error comparable to or larger than the statistical ones will change the fitted results. Generally, it is recommended to apply some tests with the use of systematic errors to check the variation of fitting results, especially when comparing alternative spectral models.

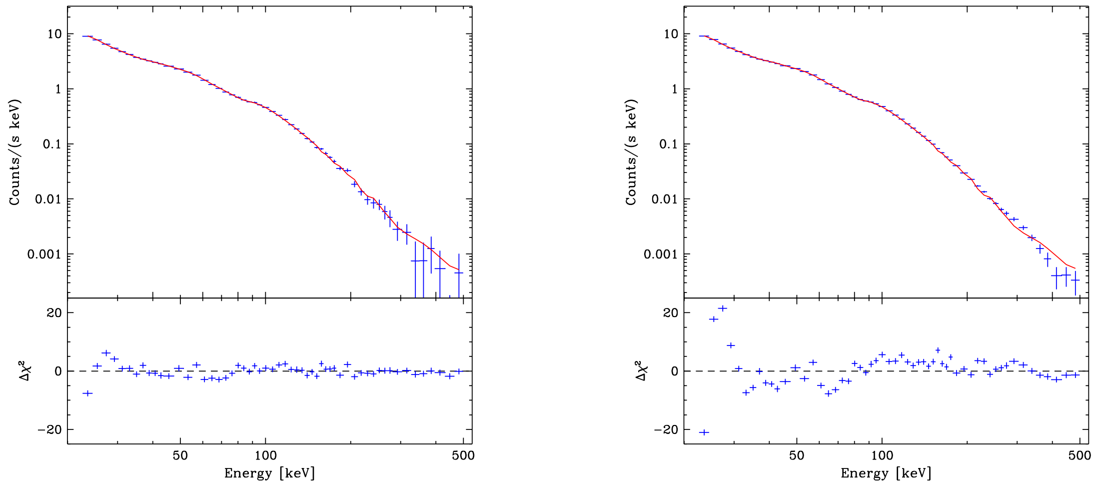


Figure 5: Best-fit power-law model obtained for ISGRI spectrum from Rev. 0300 (left) and for summed spectra from Revs. 0039, 0102, 0170, 0239 and 0300 (right).

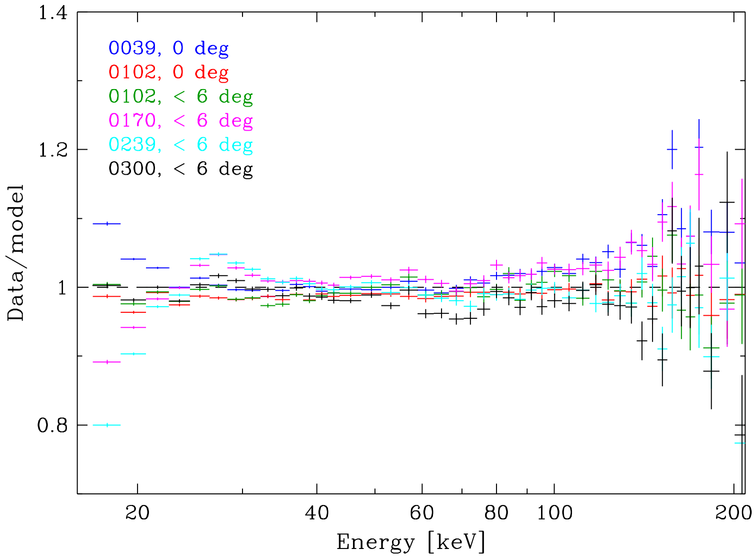


Figure 6: Ratio between ISGRI spectra made with OSA 5.1 and the joint best-fit power-law model. Data from Revs. 0039, 0102, 0170, 0239 and 0300.

Table 2: Results of power-law model fitting to ISGRI spectra extracted with OSA 5.1. Energy range: 22.6-500 keV. The alternative fitting was done with the systematic error shown in the lower part of the table. Γ - power-law index, Flux - flux in the 30-200 keV range (photons/(s cm^2)), χ^2_ν - reduced χ^2, ν - number of degrees of freedom, Syst. - systematic error (per cent) added to the data. Typical 1 σ error for index is 0.01 and for flux 0.001. Note that the part of the observation from Rev. 0239 was done in micro-dithering mode plus arc around the Crab.

Rev.	Off-set angle [deg]	Exposure [ks]	Γ	Flux	χ^2_ν	ν	Syst.
0039	0	80.2	2.22	0.171	8.49	54	—
0102	0	43.2	2.23	0.169	0.83	54	—
0102	< 6	66.6	2.22	0.168	2.30	54	—
0170	< 6	51.1	2.23	0.172	8.77	54	—
0239	< 6	131.5	2.25	0.170	29.2	54	—
0300	< 6	32.3	2.26	0.167	4.08	54	—
0039-0300	< 6	361.7	2.24	0.170	35.9	54	—
0039	0		2.17	0.172	1.00	54	4.1
0102	< 6		2.22	0.168	1.00	54	0.4
0170	< 6		2.21	0.173	1.00	54	2.7
0239	< 6		2.25	0.170	1.00	54	2.3
0300	< 6		2.25	0.167	1.00	54	1.4
0039-0300	< 6		2.24	0.170	1.00	54	4.9

4 JEM-X

JEM-X operates in the 3-35 keV energy range, and Crab spectra were tested in the two narrower, 5-25 keV and 3-30 keV bands. The latest instrument calibration, done after OSA 5.0 release, is based on Crab measurements, with the efficiency curve adjusted to match the Crab canonical model.

OSA 5.0 brought a lot of improvements in JEM-X data analysis software. The major changes were introduced in the image reconstruction methods, but the spectrum extraction software has also been substantially modified. Figures 7-8 present the results of fitting an absorbed power-law model to the OSA 5.1 spectra of Crab taken with JEM-X 2 and JEM-X 1. The quantitative results of the modeling are gathered in Table 3. The results shown here correspond to the 3-30 keV range, however, for 5-20 keV band the fitting leads to very similar results.

Both JEM-X detectors are generally quite well calibrated. The scale of data to model deviations varies within 3% and there are no common systematic features observed for different spectra. The feature observed around 5 keV in JEM-X spectra extracted with OSA 4.2 disappeared. Spectral slope is a little bit steeper than the canonical value and absolute flux is stable. There are some larger deviations seen for spectrum from Rev. 0239, whose origin is still unclear. Values of reduced χ^2 are rather large, fit with $\chi^2_\nu \approx 1$ can be obtained with adding a systematic error of 2-4%.

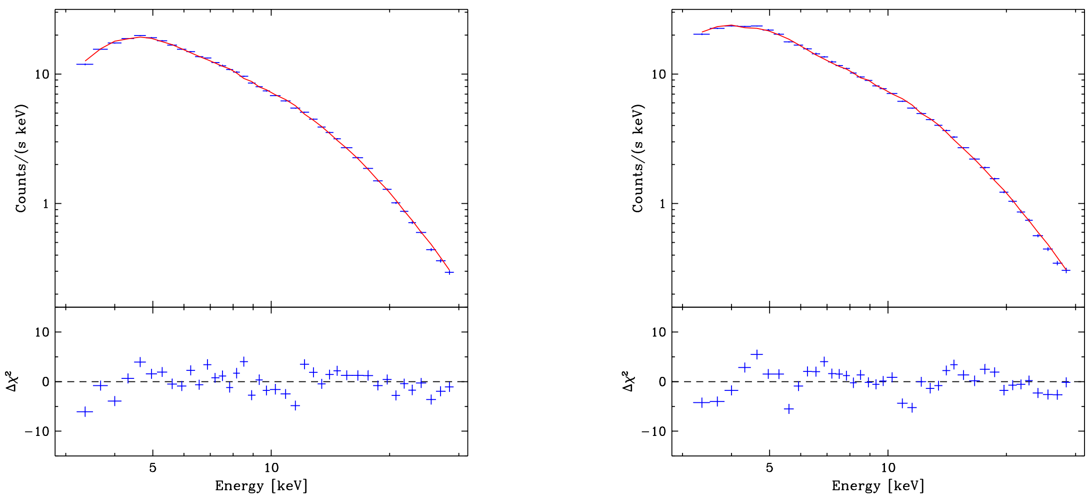
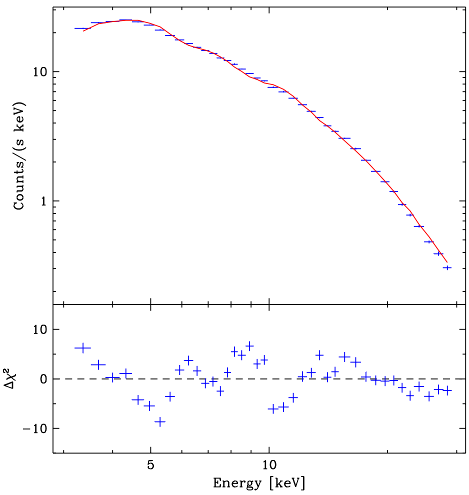


Figure 7: Best-fit power-law model obtained for JEM-X 2 spectra, from Rev. 0039 (left) and from Rev. 0102 (right).

Table 3: Results of absorbed power-law model fitting to JEM-X spectra extracted with OSA 5.1. The lower part of the table shows the results of alternative fitting with the systematic error listed in the last but one column. Energy range: 5-20 keV, absorber column density was fixed at 0.285 atoms/cm^{-2} (Willingale et al., 2001). Γ - power-law index, A - normalization at 1 keV, photons/(s keV cm^2), Flux - flux in the 5-25 keV range (photons/(s cm^2)), χ^2_ν - reduced χ^2, ν - number of degrees of freedom. Typical 1 σ error for index is 0.01 and for flux 0.01.

Rev.	Off-set angle [deg]	Exposure [ks]	Γ	A	Flux	χ^2_ν	ν	Syst.	JEM-X
0039	0	104.3	2.11	11.0	1.37	5.67	38	—	2
0102	< 3	33.4	2.09	10.4	1.37	6.46	38	—	2
0170	< 3	27.6	2.11	11.4	1.42	4.86	38	—	1
0239	< 3	38.1	2.20	13.8	1.43	13.5	38	—	1
0300	< 3	13.3	2.16	12.3	1.38	3.74	38	—	1
0039			2.11	11.0	1.37	1.00	38	2.4	2
0102			2.09	10.4	1.37	1.00	38	2.8	2
0170			2.11	11.4	1.42	1.00	38	2.4	1
0239			2.20	13.8	1.43	1.00	38	3.6	1
0300			2.16	12.3	1.38	1.00	38	3.6	1



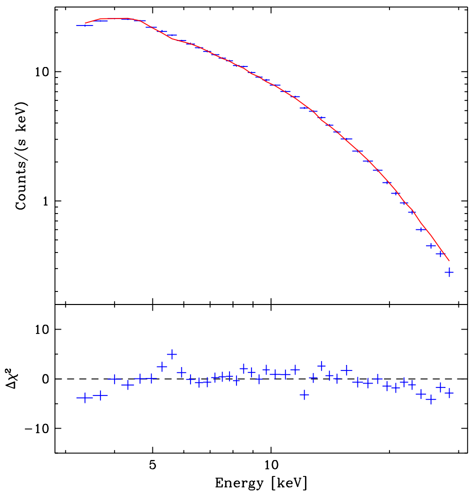


Figure 8: Best-fit power-law model obtained for JEM-X 1 spectra, from Rev. 0239 (left) and from Rev. 0300 (right).

5 PICsIT

The nominal energy range of PICsIT is 170 keV - 10 MeV; however, with the current sensitivity, reasonable spectra for source as strong as Crab can only be extracted in the 250-1000 keV band. The calibration of PICsIT is not well studied, since the response files were for the first time released with OSA 4.2. The software dedicated to spectral extraction appeared in OSA 5.0, but it needs some modifications in order to deal with low count-rate data in the presence of strong and variable instrumental background. Therefore, currently it is possible to obtain spectra using only the count rates from the reconstructed sky images, and not directly from shadowgrams.

The tests presented here were done for Crab observations made in staring and dithering mode. In case of staring, it is easy to extract the count rates from summed images using the *spextract* script (http://isdc.unige.ch/index.cgi?Soft+scripts). However, there is a limited number of such observations, as on-axis Crab measurements were done only in Revs. 0039 and 0102/0103. Moreover, the latter is affected by high temperature effects due to pointing too close to Sun and is not good for calibration tests. For dithering observations one has two possibilities: apply the same script to calculate the mean from individual science window images or prepare the mosaic images and then collect the count rates for a given source pixel in all energy bands. Both methods were used to produce spectra from dithering observation made in Rev. 0239.

The results of spectral extraction from PICsIT images, prepared with OSA 5.1 are presented in Fig. 9. Even for rather wide standard energy bins, the uncertainty of the extracted count rates is very large. Therefore, the model fitted to these data is poorly constrained and the reduced χ^2 values vary strongly from one observation to the other, as shown in Table 4.

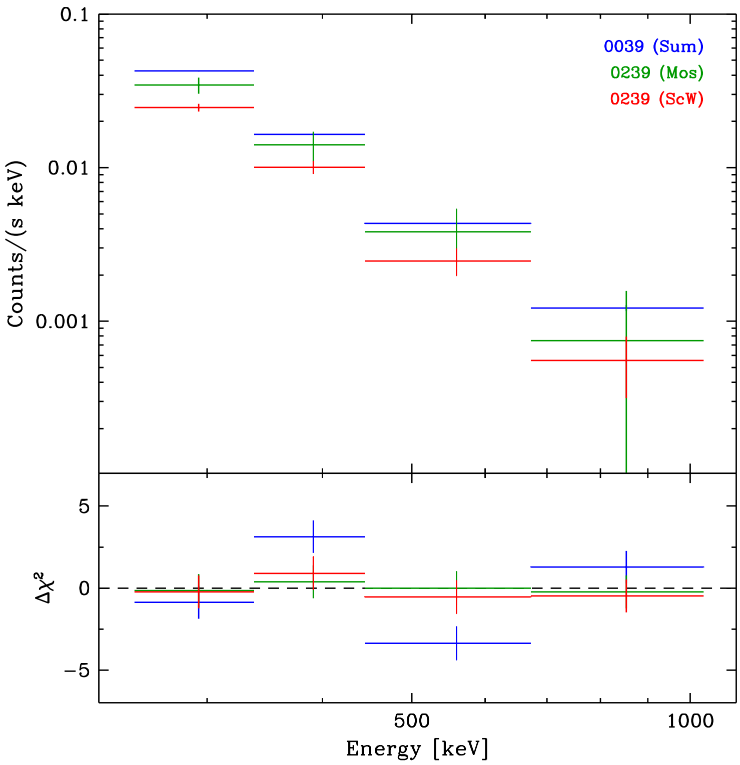


Figure 9: Best-fit power-law model obtained for PICsIT spectra from Revs. 0039 and 0239 (both methods).

Table 4: Results of power law model fitting to PICsIT spectra extracted with OSA 5.1. Energy range: 252 keV - 1036 keV. (Sum) - spectrum from the summed image, staring mode, (ScW) - spectrum averaged over individual science windows images, dithering mode, (Mos) - spectrum from mosaic image, dithering mode. Γ - power-law index, Flux - flux in the 250-1000 keV range (photons/(s cm^2)), χ^2_ν - reduced χ^2, ν - number of degrees of freedom. 1 σ errors for spectral index and flux are shown in parantheses.

Revolution	Off-set [deg]	Exposure [ks]	Γ	Flux	χ^2/ν	ν	Method
0039	0	73.1	2.25(5)	11.2(1)	11.8	2	(Sum)
0239	< 6	171.5	2.22(85)	9.2(5)	0.11	2	(Mos)
0239	< 6	171.5	2.29(34)	6.5(4)	0.66	2	(ScW)

With such large uncertainties it is hard to estimate the quality of the PICsIT calibration. Spectra extracted from different observations span a broad range of absolute fluxes. Therefore, for PICsIT it seems that the procedure of extraction of the source flux should be improved first, through a better description of low signal-to-noise ratio data, more sophisticated background maps, and studies of other effects, like detector non-uniformity, PIF model uncertainty, etc.

6 Cross-calibration

Most spectra obtained for individual instruments and presented above were fitted together to show the consistency of the calibration of INTEGRAL instruments. Figures 10 and 11 show the comparison between SPI, ISGRI, JEM-X and PICsIT (the last only in case of Rev. 0239) spectra taken in various periods of the mission. The results of the joint fit of a power-law model to these data are summarized in Table 5. The quality of the fit is usually poor. This is due to the discrepancy in spectral slopes observed for ISGRI (2.23) and for SPI/JEM-X (2.15). The ISGRI spectra having smaller statistical uncertainties dominate the fit and the slopes are usually quite close to the ISGRI ones.

Compared to SPI, ISGRI spectra exhibit slopes larger by 0.07-0.1 (see Tables 1 and 2). This difference is the result of the steeper reference model spectrum assumed for the ISGRI calibration. ISGRI spectra from off-axis observations are clearly affected by the inadequacy of the response file, generated with the data from Rev. 0102 on-axis observation. There is a good agreement between SPI and JEM-X spectral slopes, with differences smaller than 0.05. Absolute normalization of ISGRI and SPI spectra is stable, with normalization factor around 0.84. The JEM-X normalization factor relative to SPI is about 0.8. PICsIT spectrum of Rev. 0239 agrees well with the joint model, but the normalization is too low.

The results of fits done with SPI, ISGRI and JEM-X spectra after adding systematic errors obtained from individual fits differ from the results obtained with the pure statistical-error spectra. In this case the fit is more dependent on SPI and JEM-X data and the relative normalization between these two instruments becomes better, at the cost of worse agreement between ISGRI and SPI. The spectral indexes are smaller for the fits with systematic errors, again due to the diminished role of ISGRI in the joint fitting. The systematic errors obtained in individual fits are not sufficient to obtain reduced χ^2 equal to 1 in the joint fit. The cross-calibration of INTEGRAL instrument therefore still needs some improvements.

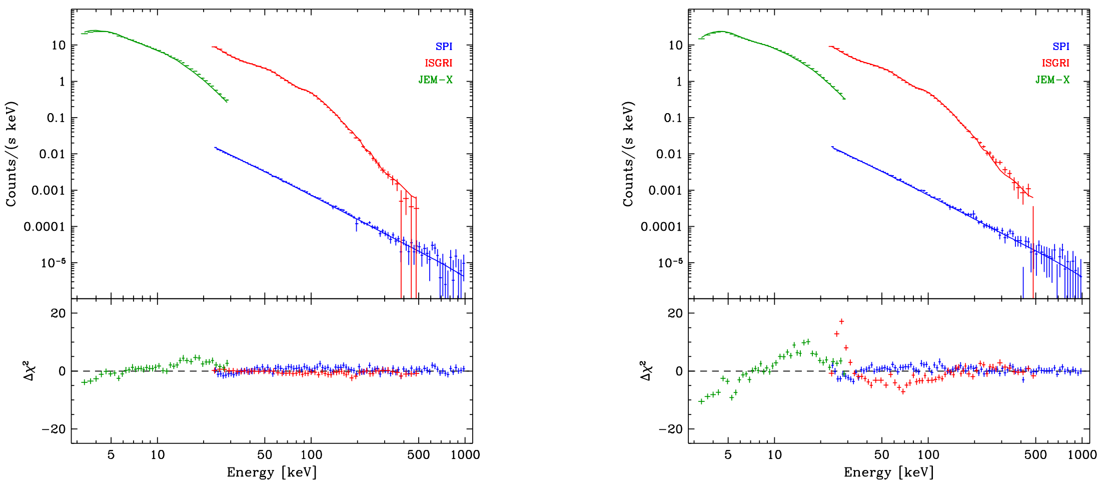


Figure 10: Best-fit power-law model obtained for OSA 5.1 INTEGRAL spectra. Left: data from Rev. 0102, right: data from Rev. 0170.

Table 5: Results of power law model fitting to INTEGRAL spectra extracted with OSA 5.1 for SPI, ISGRI, PICsIT and JEM-X. The lower part of the table contains the results of fitting with the systematic errors from Tables 1, 2, 3, applied to SPI, ISGRI and JEM-X spectra, respectively. Normalization factors for ISGRI, JEM-X and PICsIT, relative to SPI, are shown in columns 2 and 3, respectively. Γ - power-law index, F_S - SPI flux in the 30-200 keV range (photons/(s cm^2)), F_I - ISGRI flux in the 30-200 keV range (photons/(s cm^2)), χ^2_ν - reduced χ^2, ν - number of degrees of freedom. Typical 1 σ error for normalization factors is 0.01, for spectral index - 0.002, and for fluxes - 0.001.

Rev.	ISGRI	JEM-X	PICsIT	Γ	F_S	F_I	χ^2_ν	ν
0102	0.86	0.83	—	2.200	0.199	0.170	1.83	188
0170	0.85	0.84	—	2.200	0.206	0.175	11.6	188
0239	0.83	0.79	0.68	2.242	0.206	0.171	16.3	191
0300	0.82	0.77	—	2.233	0.204	0.168	4.79	188
0102	0.85	0.84	—	2.198	0.199	0.169	1.43	188
0170	0.82	0.92	—	2.143	0.209	0.171	1.71	188
0239	0.80	0.82	0.63	2.211	0.211	0.169	1.62	191
0300	0.81	0.80	—	2.213	0.207	0.167	1.81	188

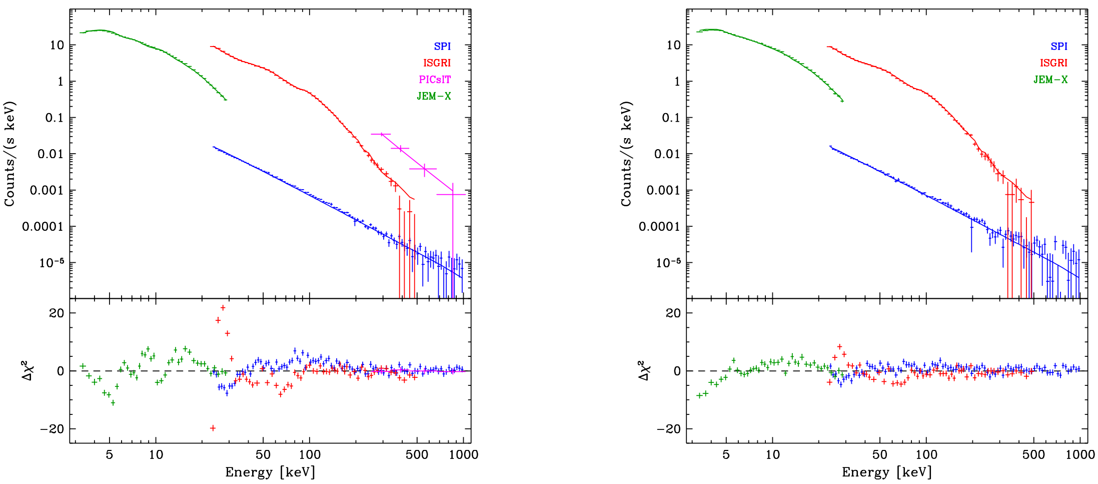


Figure 11: Best-fit power-law model obtained for OSA 5.1 INTEGRAL spectra. Left: data from Rev. 0239, right: data from Rev. 0300.

7 Conclusions

The calibration of INTEGRAL instruments is on-going, following the changes in the spectral extraction software and instrument characteristics, and taking into account the increasing amount of data used for tests. However, SPI is an exception, since it has been very well calibrated since some time and currently may serve as a reference instrument in almost the entire energy range of its operation. ISGRI response is reasonably well modeled, with small systematic effects remaining, but, to take into account the differences in the instrument settings with high accuracy, some additional correction can be implemented in the software. JEM-X 1 and JEM-X 2 are also calibrated quite well, although the response on the borders of the 3-30 keV band is less reliable. Calibration of PICsIT is difficult because of the lack of good quality reference spectra and any adjustment to the response files should be preceded by an improvement in the handling of low signal-to-noise data.

In the case of ISGRI, JEM-X, and to some extent also for PICsIT, it should be possible to minimize, or at least reduce, all the current instrument or software-related effects. With this goal achieved, one may expect that the precision of calibration will be much less influenced by the systematic effects. In turn, it should allow to study many physical properties of numerous Galactic and bright extragalactic sources in the 20 keV - 2 MeV range with an accuracy not achieved by any past mission.

Finally, it should be stressed that none of the other current missions (RXTE, Swift, ASTRO-E 2) provides data in the MeV range, and there is no such satellite planned for launch in the next decade. INTEGRAL is unique and therefore it is worth to exhaust all possibilities of improving its performance.

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