The International Gamma-Ray Astrophysics Laboratory Mission Extension 2014: INTEGRAL Science Case

Appendix

Compiled by the INTEGRAL Users Group


The INTEGRAL extension case and this Appendix is available for download at http://www.cosmos.esa.int/web/integral/teams-iug
This appendix contains extra information to support the 2014 INTEGRAL mission extension case. It is divided in 4 parts:

- Figures, mostly recent, highlighting the scientific areas showing INTEGRAL’s strengths and uniqueness.
- INTEGRAL mission impact and metrics.
- INTEGRAL instruments parameters.
- List of theses based upon INTEGRAL results.

The INTEGRAL-related refereed and non-refereed publications are based on the ADS database, and can be found via: 
http://adsabs.harvard.edu/cgi-bin/nph-abs_connect?library&libname=Integral&libid=450176be03

Appendix cover page, bottom image: The 4\textsuperscript{th} soft γ-ray source catalogue, released in 2010, obtained with INTEGRAL/IBIS/ISGRI, contains more than 700 high-energy sources detected in the energy range 17-100 keV, including both transients and persistent objects. For ~300 sources which are a member of our Galaxy (including black-hole and neutron star X-ray binaries, cataclysmic variables, and other exotic objects), we know the distance. These sources can thus be represented in a 3D fashion. When INTEGRAL’s 10 years in space was celebrated, movies including a 3D-view of our Galaxy as seen by INTEGRAL, were released. In the image we are facing our Sun (the tiny yellow blob just above the centre of the image) from behind the Galactic Centre. Many of the sources are annotated with (part of) their astrophysical name. The size and colours of the fuzzy spheres are based on the intensities in the 17-35-60-100 keV bands. [Credits: ESA/C. Carreau & E. Kuulkers]
\section*{\textit{γ}-ray line spectroscopy – I: SN2014J}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{\textit{Top left:} The INTEGRAL/SPI spectrum of SN2014J around 158 keV about 2 weeks after the explosion, with the detection of the $^{56}\text{Ni}$ decay line, is shown in the lower left. The origin of the signal agrees within the measurement error with the position of the SN (indicated by the cross in the map of the observed sky region). The map shows the point source significances across the field of view observed in a 10 keV wide energy band including the 158 keV line. The circles in the lower right of the map show the instrumental point source size (68\% contours dashed, 90\% contour solid). [Figure adapted from R. Diehl \textit{et al.} 2014, Science 345, 1162] \textit{Top right:} The bottom part shows the INTEGRAL/SPI spectrum (red points) of SN2014J over the period 50-100 days after the explosion. The $^{56}\text{Co}$ decay lines at 847 and 1238 keV are seen. Blue points show ISGRI/IBIS data for the same period. The flux below \~{}60 keV is dominated by the emission of M82 itself (as seen in 2011 during M82 observations with INTEGRAL, see the figure shown at the bottom of this page). The black curve shows a fiducial model of the SN spectrum for day 75 after the explosion. Figure adapted from E. Churazov \textit{et al.} 2014, Nature 512, 406] \textit{Lower left:} Decay chain of $^{56}\text{Ni}$, indicating the decay times and expected decay line energies. Lower right: Top panel shows the INTEGRAL/IBIS/ISGRI images of the M81 group of galaxies, which contains two bright ULXs, Holmberg IX X-1 and M82 X-1. The deep (\~{}6 Ms) observations resulted in just a weak detection of M82 X-1 and non-detection of Ho IX X-1 at energies above 20 keV. Together with XMM-Newton data a clear cut-off at energies above 10 keV in the spectra of both ULXs (bottom panels) can be derived. [Figure adapted from S.Y. Sazonov \textit{et al.} 2014, Astronomy Letters, 40, 65]}
\end{figure}
The width of the γ-ray line from the decay of $^{26}\text{Al}$ in the Galaxy’s interstellar medium as measured with INTEGRAL/SPI. The central figure shows the probability distribution for the line width from interstellar motion through Doppler shift, which is modeled as a Gaussian, and added to the instrumental line width through convolution. Probability regimes, which correspond to 1σ, 2σ, and 3σ are indicated by colour shading. The measured value of 1.4 keV corresponds to a velocity of $(175 \pm 45)$ km s$^{-1}$. The graphs on the left and on the right sides show how the $^{26}\text{Al}$ line measurements improve with exposure, showing the spectra around the 1808.63 keV line from $^{26}\text{Al}$ as derived in successive analyses over the years. [Credits: SPI Team, K. Kretschmer & R. Diehl]
**γ-ray line spectroscopy – III: 511 keV**

*Figure 3:* Top: Copious production of positrons is taking place in the Galactic Centre (GC) region. *INTEGRAL* sees strong emission from an area of a few degrees around the dynamic centre of our GC (middle image; 508—514 keV), where every second about 10 billion tons of positrons are colliding with electrons and annihilating. The observed γ-ray glow has a unique spectrum, which consists of a narrow line at 511 keV - signature of cold electron-positron annihilation, and a broad continuum, indicating that most positron-electron pairs form atoms of positronium before annihilating (top left image). The bottom right image shows a predicted model spectrum resulting from the cooling process of positrons in the ISM. [Figure adapted from E. Churazov et al. 2011, MNRAS 411, 1727] Bottom: One of the origins of the GC positrons include enigmatic dark matter particles. This figure shows the constraints on the charged unstable dark matter component, X (which decays into a stable component, the dark matter as of today, and positrons), from Heavy Water (HW), Catalyzed Big Bang Nucleosynthesis (CBBN) and the diffuse γ-ray background. The CBBN constraint applies only to the symmetric scenario (relic abundances of positively and negatively charged X are the same). The region labeled \(e^+e^- \rightarrow \gamma\gamma\) would produce positrons early enough that the high background electron density would lead to complete annihilation and therefore no residual signal. Shaded regions are excluded. The horizontal blue band denotes the region in parameters space that would produce a 511 keV flux consistent with that observed by *INTEGRAL*. [Figure from L. Boubekeur et al. 2012, PhRvD 86, 103520]
**Hard X-ray line spectroscopy:** Cas A & SN1987A

Figure 4: Top: (Left) INTEGRAL/IBIS/ISGRI flux images (2.5°×2.5°) centered on Cas A in 6 energy bands. The linear scale is the same for all images. Note that the noise in the images depends on the energy bandwidths. (Right) IBIS/ISGRI spectrum of Cas A and the best-fit model (solid red line), showing the 67.9 and 78.4 keV $^{44}$Ti decay lines. The upper limit above 110 keV is given at the 3σ confidence level. [Figures from M. Renaud et al. 2006, ApJ 647, L41] Bottom: (Left) IBIS/ISGRI hard X-ray images (1.5°x1.5°) indicating the detection of $^{44}$Ti decay emission lines from SN1987A. The maps show the signal-to-noise ratio contours in 3 energy bands based on a total exposure of ~6.0 Ms. Two well-known sources, PSR B0540-69 and LMCX-1, are clearly seen in all 3 images; SN1987A is only confidently detected in 65-82 keV, containing the 67.9- and 78.4-keV direct-escape lines of radioactive decay of $^{44}$Ti. (Right) IBIS/ISGRI hard X-ray spectrum of SN1987A. Top panel: observed (count) spectrum together with the simulated response curves. Bottom panel: unfolded (photon) spectrum. In each panel, open circles show the spectra, dotted curves show the fit with two Gaussian lines at 67.9 and 78.4 keV, and solid curves show a similar fit which includes an additional power-law continuum with photon index = 2.1. It is expected that $^{44}$Ti is produced inside the SN core, which is expanding with velocity $v ≤ 1,700$ km s$^{-1}$; thus, the internal width of the lines (that is, their width before smoothing due to the finite energy resolution of the instrument) is unlikely to exceed $E ≃ 0.4$ keV. The upper limits are 1.7 (90% confidence); error bars on the other points are 1σ. [Figures adapted from S.A. Grebenev et al. 2012, Nature 490, 373]
**Polarisation**: Cygnus X-1, GRB061122 & Crab

**Figure 5**: Top Left: INTEGRAL/IBIS/ISGRI spectrum of Cygnus X-1 (green points). The blue curve describes the spectrum between 20-400 keV; the red line describes the data between 400-2000 keV. The two insets show the polarization signal at 250-400 keV (bottom left) and at 400-2000 keV (top right). In the 250-400 keV band, the measured signal is consistent with a flat signal, indicating that the emission is only weakly polarized or not polarized at all; in the 400-2000 keV band the signal shows a significant modulation, consistent with a high degree of polarization. The detection of polarization above 400 keV indicates that emission at these energies derives from non-thermal radiation processes that take place in the jets, such as synchrotron or inverse Compton emission. [Figure adapted from P. Laurent et al. 2011, Science 332, 438]. SPI confirmed the γ-ray polarization (E. Jourdain et al. 2012, ApJ 761, 27). Top right: The polarization vector (blue), inferred from INTEGRAL/SPI measurements, is superimposed on a high-resolution radio (8.4 GHz) image. [Credits: SPI team] Bottom left: (a) INTEGRAL/IBIS light curve of GRB061122. IR J-band image of the GRB 061122 field; the red circle represents the Swift/XRT error box, while the smaller green circle represents the optical afterglow error box. Object 1 has been identified as the GRB host galaxy candidate. (b) Polarigrams of GRB061122 in different energy bands. The chance probability of a non-polarized (<1%) signal is reported in each panel. [Figure adapted from D. Götz et al. 2013, MNRAS 431, 3550] Bottom right: Composite image of the Crab from Chandra (X-ray, blue) and the Hubble Space Telescope (optical, red). The polarization vector, inferred from INTEGRAL/SPI measurements, is superimposed. [Figure from A.J. Dean et al. 2008, Science 321, 1183]
**Surveys:** LMXBs, HMXBs, SFXTs, AGN and diffuse emission

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**LMXBs**

**HMXBs**

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**Figure 6:** *Top left:* The X-ray luminosity function, XLF, is usually derived from the observed flux distribution of X-ray binaries with known distances. Incompleteness effects must then be corrected for. To overcome this, one can also model the observed flux distribution of XRBs. The two panels show the cumulative luminosity functions for LMXBs (left) and HMXBs (right) using the INTEGRAL/IBIS/ISGRI 9-year survey (hatched areas; this is the most sensitive hard X-ray survey to date). Best-fit estimates, published in the literature, are also shown for reference. [Figure adapted from V. Doroshenko et al. 2014, A&A 567, A7]

*Top right:* Cumulative luminosity distributions for supergiant fast X-ray transients in the IBIS/ISGRI 17–50 keV band. Each curve has been normalized to the total exposure time of the specific source. The duty cycles, the highest values in the y-axis, are with respect to the whole INTEGRAL archive. [Figure from A. Paizis & L. Sidoli 2014, MNRAS 439, 3439]

*Bottom left:* Fraction of obscured (absorption column, $N_H > 10^{22}$ cm$^{-2}$) AGNs in the local universe as a function of hard X-ray (17-60 keV) luminosity, $L_{HX}$, based on the INTEGRAL sample. Error bars represent the Poisson uncertainty associated with the number of objects in a given bin. The lowest and highest luminosity bins contain just one source each (NGC 4395 and IGR J09446-2636, respectively). The approximate description of the observed trend is shown by the dashed line. [Figure from S. Sazonov et al. 2012, ApJ 757, 181]

*Bottom right:* Diffuse emission intensity all-sky maps. The SPI energy bands are (top left) 27–49 keV, (top right) 49–90 keV, (bottom left) 100–200 keV, and (bottom right) 200–600 keV. The original images have pixels of different sizes and are first downsampled to a common pixel size of 3°×2.6°; thereafter they are smoothed by a 3×3 pixel boxcar. The "diffuse" emission energy is minimal in the 50–100 keV band. [Figure from L. Bouchet et al. 2011, ApJ 739, 29]
**Figure 7:** Top: 25°x15° IBIS/ISGRI map around the Galactic Center (GC) in "true colours". The Galactic map is a mosaic of the AO-4 and AO-5 GC Key Programme data. "True colour" describes the image composed of three layers: red, green, and blue, that correspond to three energy bands: 20-35, 35-60, and 60-100 keV. The Crab would look white, i.e., with equal contribution from each of the bands. This allows to see the hardness of the sources with respect to the Crab's spectrum. A Gaussian smoothing filter with a radius of 3 pixels was used. [Credits: G. Bélanger, ESA/ISOC] Bottom: In September 2012, a new transient black-hole binary was discovered by the Swift satellite: Swift J174510.8-2624. Located close to the GC, it was observed serendipitously by INTEGRAL and was seen to brighten rapidly. A dense observing campaign with INTEGRAL was triggered, featuring a near-continuous pointing for two full weeks. The source was also monitored by *Swift* and ground-based telescopes from optical to radio. *XMM-Newton*, *Chandra* and *Suzaku* observations were also made. Shown is the time evolution of Swift J174510.8-2624 as observed by INTEGRAL and Swift. Top panel: light curve from the *Swift*/XRT (blue) and INTEGRAL/JEM-X (red). Middle panel: INTEGRAL/IBIS/ISGRI light curve (red); note that the source flux exceeded the Crab level. Bottom panel: evolution of the ratio between the hard (40-80 keV) and soft (20-40 keV) bands in IBIS/ISGRI, a crude measure of the hardness of the spectrum. The image vaguely visible in the background is the IBIS/ISGRI map of the field. [Credits: T. Belloni, INAF-OAB, Italy]
**INTEGRAL**: Synergy with other missions

**Figure 8**: Top left: Unfolded spectrum of the persistent black-hole binary and microquasar in the Galactic Center region, 1E1740.7-2942 (‘the Great Annihilator’), during a low/hard state observed by INTEGRAL and NuSTAR. A disk-black-body plus a comptonization model is used to fit the data. NuSTAR/FPMA: black and green, for different epochs; NuSTAR/FPMB: red and dark blue, for different epochs; INTEGRAL/IBIS/ISGRI: magenta. [Figure from L. Natalucci et al. 2014, ApJ 780, 63] Top right: Multi-wavelength light curves of the blazar Mkn421 in 2013: (a) OMC photometry; (b) JEM-X count rates, at 3-5.5 keV (light green), 5.5-10.25 keV (green), and 10.25-26 keV (dark green); (c) IBIS/ISGRI count rates at 20-40 keV (light blue) and 40-100 keV (dark blue); (d) Fermi-LAT fluxes binned with 12-hr time-resolution. The background of the image is an artist representation of a blazar. [Figure adapted from E. Pian et al. 2014, A&A, in press] Bottom left: Joint RXTE/PCA and INTEGRAL/IBIS/ISGRI observation of Sco X-1. The spectrum was fitted by a comptonization model plus a power-law component. Also displayed are the relative contributions (at the IBIS part of the fit) from the two components. [Figure from T. Maiolino et al. 2013, A&A 551, L2] Bottom right: Mosaic image of the 4U 1036–56 sky region, derived by combining all INTEGRAL/IBIS/ISGRI data (18–60 keV). The significance level is given by the color scale. Corresponding significance and colour can be found in the right colour bar. The position of the transient AGILE source AGL J1037–5708 is plotted with its 95% error region (white). Another transient source, GRO J1036–55, is also shown in this sky region with its 1σ, 2σ, 3σ uncertainty location (green). The x- and y-axes are Right Ascension and Declination in units of degrees. [Figure from J. Li et al. 2012, ApJ 761, 49]
**INTEGRAL sources: Follow-up**

**Figure 9:** Top: IGR J18245-2452 is an X-ray transient discovered by *INTEGRAL* on 28 March 2013 in the globular cluster M28. (a) and (b) show *INTEGRAL*/IBIS/ISGRI images of the sky before and after the switch on of the X-ray transient, respectively. Follow-up observations with *XMM-Newton* identified it as an accreting millisecond X-ray pulsar spinning at a period of 3.9 msec. The power density spectrum of the X-ray emission observed by *XMM-Newton*, and the 11 hr orbital modulation of the coherent signal of the pulsar are given in (c) and (d), respectively. (e) shows the 20-60 keV pulse profile accumulated by IBIS/ISGRI. Cross-referencing with catalogues of radio rotation-powered pulsars, it was realized that the source had already been seen in 2006 as a radio pulsar. Even more surprising, as the X-ray emission faded, it took just a couple of days for the radio pulsar to reactivate its rotation powered emission. [Figure adapted from A. Papitto et al. 2013, Nature 501, 517]

Bottom left: IGR J12580+0134 was discovered at the beginning of 2011 in NGC 4845, a galaxy never detected in the X-rays before. The top image shows an optical image of NGC 4845 with X-ray contours showing the position of the source as observed by *XMM-Newton*. At the bottom, the light-curve observed by *INTEGRAL*/IBIS/ISGRI (red), *XMM-Newton*/EPIC-pn and *Swift*/XRT (blue). The long-short dash line indicates the prediction of hydrodynamical simulations for the disruption of a sub-stellar object by a massive black hole, whereas the dotted line shows what would be expected for a disrupted star. The most probable mass of the disrupted object is 14-30 Jupiter mass. Only a small fraction (about 10%) of that mass did fall into the black hole. [Figure adapted from M. Nikolajuk & R. Walter 2013, A&A 552, A75]

Bottom right: IGR J17488–2338 has been optically identified as a broad-line AGN at $z \sim 0.24$. The source is classified as an intermediate-power Fanaroff-Riley II radio galaxy with a linear size of 1.4 Mpc. The image shows IR 22.1 micron WISE image with radio 1.4 GHz NVSS contours superimposed; the white circle corresponds to the *INTEGRAL*/IBIS/ISGRI error circle; the white cross marks the position based on *XMM-Newton* slew data. The source is extremely bright in the X/γ-rays: among a set of 25 radio galaxies detected so far by *INTEGRAL*, this is the brightest object in the sample. [Figure adapted from M. Molina et al. 2014, A&A 565, A2]
**INTEGRAL**: Sky coverage

**Figure A1**: INTEGRAL sky exposure maps (IBIS, partially coded FOV) per AO in Galactic coordinates for AO-1 (2003) to AO-11 (extrapolated up to end of 2014), and tentative AO-12 (only approved pointings for 2015). Exposure scale: 0 to ~3 Ms.

**Figure A2**: Integrated exposure map (IBIS, partially coded field of view) in Galactic coordinates from AO-1 until AO-11 (from 30 December 2002 until 31 December 2014). The maximum exposure in the GC area is ~ 35 Ms. Units of exposure are in [s].
**INTEGRAL:** Publications & over-subscription

**Figure A3:** INTEGRAL scientific publications (801 refereed papers, 1351 non-refereed papers, 2152 in total), from launch (October 2002) until July 2014. [Derived from http://adsabs.harvard.edu/cgi-bin/nph-abs_connect?library&libname=Integral&libid=450176be03]

**Figure A4:** The over-subscription of INTEGRAL observing time remains at a high value reflecting the continued interest of the science community. AO-12 will be from 1 January to 31 December, 2015.
**INTEGRAL**: Targets of Opportunity facility

**Figure A5**: INTEGRAL dedicates about 10% of its observing time to unexpected, transient, events in the Universe. *Top*: Number of Target of Opportunity (ToO) requests per year, since launch, specified per scientific category. *Bottom*: Total exposure time in seconds spend per year, since launch, on ToO observations, specified per scientific category.
**INTEGRAL**: SPI annealing and key parameters

Figure A6: Evolution of the SPI energy resolution at 1764.3 keV since end of commissioning phase (orbital revolution #10). Until September 2014, twenty-three annealing cycles (red vertical bars) have been successfully performed consistently recovering the nominal pre-launch energy resolution.

Table 1: INTEGRAL science and payload: complementarity

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Energy range</th>
<th>Main purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectrometer SPI</td>
<td>18 keV – 8 MeV</td>
<td>Fine spectroscopy of narrow lines</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Study diffuse emission on &gt;1° scale</td>
</tr>
<tr>
<td>Imager IBIS</td>
<td>15 keV – 10 MeV</td>
<td>Accurate point source imaging</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Broad line spectroscopy and continuum</td>
</tr>
<tr>
<td>X-ray Monitor JEM-X</td>
<td>3 – 35 keV</td>
<td>Source identification</td>
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<tr>
<td>Optical Monitor OMC</td>
<td>500 - 600 nm (V-band)</td>
<td>Optical monitoring of high-energy sources</td>
</tr>
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# INTEGRAL: Instrument key parameters - II

## Table 2: Key parameters for SPI & IBIS

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<thead>
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<th>Parameter</th>
<th>SPI</th>
<th>IBIS</th>
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<td>Energy range</td>
<td>18 keV - 8 MeV</td>
<td>15 keV – 10 MeV</td>
</tr>
<tr>
<td>Detector</td>
<td>19 Ge detectors(^{lu}) (6\times6\times7 \text{ cm}^3), @ 85K</td>
<td>16384 CdTe detectors (4\times4\times2 \text{ mm}^3), 4096 CsI dets (8.55\times8.55\times30 \text{ mm}^3)</td>
</tr>
<tr>
<td>Detector area (cm(^2))</td>
<td>500°</td>
<td>2600 (CdTe), 3000 (CsI)</td>
</tr>
<tr>
<td>Spectral resolution (FWHM)</td>
<td>3 keV @ 1.7 MeV</td>
<td>8 keV @ 100 keV</td>
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<tr>
<td>Field of View (fully coded)</td>
<td>16° (corner to corner)</td>
<td>8.3° \times 8.0°</td>
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<tr>
<td>Angular resolution (FWHM)</td>
<td>2.5° (point source)</td>
<td>12'</td>
</tr>
<tr>
<td>Source location (radius)</td>
<td>&lt; 1.3° (depending on source strength)</td>
<td>30''@100 keV (50\sigma source) 3'@100 keV (5\sigma source)</td>
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<tr>
<td>Absolute timing accuracy (3\sigma)</td>
<td>~130 \mu s</td>
<td>~90 \mu s</td>
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<tr>
<td>Mass (kg)</td>
<td>1309</td>
<td>746</td>
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<tr>
<td>Power [max/average] (W)</td>
<td>385/110</td>
<td>240/208</td>
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## Table 3: Key parameters for JEM-X and OMC

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<th>Parameter</th>
<th>JEM-X</th>
<th>OMC</th>
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<tr>
<td>Energy range</td>
<td>3 keV – 35 keV</td>
<td>500 nm - 500 nm</td>
</tr>
<tr>
<td>Detector</td>
<td>Microstrip Xe/CH(_4)-gas (1.5 bar)</td>
<td>CCD + V-filter</td>
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<tr>
<td>Detector area</td>
<td>500 cm(^2) for each of the two JEM-X detectors</td>
<td>CCD: (2055 \times 1056) pixels Imaging area: (1024 \times 1024)</td>
</tr>
<tr>
<td>Spectral resolution (FWHM)</td>
<td>3.6 keV @ 22 keV</td>
<td>--</td>
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<tr>
<td>Field of view (fully coded)</td>
<td>4.8°</td>
<td>5.0° \times 5.0°</td>
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<tr>
<td>Angular resolution (FWHM)</td>
<td>3'</td>
<td>23'</td>
</tr>
<tr>
<td>10s source location (radius)</td>
<td>1' (90% confidence, 15\sigma source)</td>
<td>2''</td>
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<tr>
<td>Absolute Timing accuracy</td>
<td>~1 ms</td>
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<tr>
<td>Mass (kg)</td>
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<tr>
<td>Power [max/average] (W)</td>
<td>50/37</td>
<td>26/17</td>
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</tbody>
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INTEGRAL PhD theses

Completed theses

(1) Diallo, Néhé, 1999: Etude, simulation et modélisation d’un détecteur de photons gamma placé sur une orbite excentrique de type INTEGRAL, Université de Toulouse III and CEA Saclay

(2) Ferguson, Colin, 2001: Mass Modelling in X-/Gamma-ray Astronomy, University of Southampton

(3) Paul, Philippe, 2002: Calibration and performance measurement of SPI/Integral, Université Paul Sabatier Toulouse III

(4) Molkov, Sergei V, 2003: X-ray emission from accreting neutron stars according to data from GRANAT, RXTE and INTEGRAL, Space Research Institute (IKI), Moscow

(5) Willis, Dave, 2003: Polarization response of the SPI Spectrometer, University of Southampton

(6) Wunderer, Cornelia, 2003: Imaging with the Test Setup for the Coded Mask INTEGRAL Spectrometer SPI, Technische Universität München

(7) Attié, Davide, 2004: Détermination de la réponse instrumentale du spectromètre INTEGRAL/SPI et application à l’observation des raies gamma nucléaires de la région des Voiles, Université Paris 6 and CEA Saclay

(8) Deluit, Sandrine, 2004: High-energy properties of AGNs and GRBs, Université de Genève

(9) Favre-Bulle, Pascal, 2004: Ultraviolet and X-ray Emission of Active Galactic Nuclei and Contribution to the INTEGRAL Mission, Université de Genève

(10) Kreykenbohm, Ingo, 2004: X-ray spectra of highly magnetized neutron stars in binary systems, Eberhard-Karls-Universität Tübingen

(11) Martínez Nuñez, Silvia, 2004: X-Gamma ray imaging of HMXRB with INTEGRAL, Universidad de Valencia

(12) Maurin, Davide, 2004: 26 Al from the Vela region, Université Paris 7

(13) Moran, Lynn, 2004: Analysis of Gamma-Ray Bursts Detected by the Spectrometer On-board ESA’s INTEGRAL Satellite, University College Dublin

(14) Paizis, Adamantia, 2004: High energy emission from the Galaxy: a study with INTEGRAL and Chandra, Université de Genève


(16) Del Santo, Melania, 2005: Observations of Black Hole Binaries in the INTEGRAL era, Université Paul Sabatier Toulouse III and Università degli Studi, Bologna

(17) Fiocchi, Maria Teresa, 2005: Radio loud AGNs from BeppoSAX to INTEGRAL, Università degli Studi La Sapienza, Roma

(18) Götz, Diego, 2005: A study of gamma-ray bursts and soft gamma-ray repeaters detected with the INTEGRAL Burst Alert System, Università degli Studi di Milano Bicocca

(19) Lonjou, Vincent, 2005: Annihilation of Galactic Positrons- SPI data analysis, Université Paul Sabatier Toulouse III

(20) Rau, Arne, 2005: Gamma-Ray Bursts: A Population Study, Technische Universität München

(21) Schultz, Juho, 2005: Studies of Accretion Disks in X-Ray Binaries, University of Helsinki

(22) Barlow, Elizabeth, 2006: Techniques, Results and Analysis of the INTEGRAL/IBIS Soft Gamma-Ray Survey, University of Southampton

(23) Cadolle Bel, Marion, 2006: Étude des émissions à haute énergie des trous noirs stellaires accrétants, Université Paris 7 and CEA Saclay

(24) Chelovekov, Ivan V, 2006: Properties of X-ray emission of accreting neutron stars with weak magnetic field according to data from GRANAT, INTEGRAL, and RXTE, Space Research Institute (IKI), Moscow

(25) Forot, Mickael, 2006: Accélération de particules au sein des vents relativistes de pulsar : Simulations et contraintes observationnelles avec le satellite INTEGRAL, Université Paris 7 and CEA Saclay

(26) Hill, Adam, 2006: Surveying the gamma-ray sky with the BATSE and INTEGRAL satellites, University of Southampton

(27) Joinet, Angelique, 2006: High Energy Emission of GX339−4 and H1743−322 During State Transitions with INTEGRAL and RXTE, University of Southampton

(29) McBride, Vanessa, 2006: Multiwavelength timing and spectral analysis of Be/X-ray binaries, University of Southampton

(30) Renaud, Matthieu, 2006: Les jeunes vestiges de supernova et INTEGRAL: raies du 44Ti et emission non-thermique, Université Paris 7 and CEA Saclay

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(32) Zurita Heras, Juan A, 2006: Individual studies of newly (re-) discovered galactic sources: a study with INTEGRAL and XMM-Newton, Université de Genève

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