Newsletter of the
INTEGRAL Science Operations Centre

Five years of INTEGRAL in space!

No 18 October 2007

Foreword

Peter Kretschmar, Science Ops. Manager

This newsletter marks a very special day for *INTEGRAL*– five busy and successful years in space!

While a significant part of the *INTEGRAL* community is celebrating this date at a special workshop taking place from 17 to 19 October in Chia Laguna, Sardinia, we hope the rest of you also find a moment to salute the healthy five-year old and wish it many more good years to come.

Evidently, the anniversary is also a reason for us to look back at these eventful years. Erik Kuulkers presents below the events since the perfect 'birth' on 17 October 2002.

But life doesn't stop at anniversaries and ISOC has been busy preparing the next call for Key Programme proposals which is due to be opened in a few days on 22 October 2007. More details can be found in Guillaume Bélanger's contribution.

With the archive filling up relentlessly, questions of access to these large data sets are becoming more and more important. Rees Williams and Pieter-Jan Baeck give an overview of how things are developing at ISOC in this respect.

As always, we share our selection of the scientific and operational highlights below with short features by Celia Sanchez and myself.

Finally, ISOC also keeps evolving and you will find more news towards the end of this newsletter.

Looking forward to the next anniversaries!

Contents

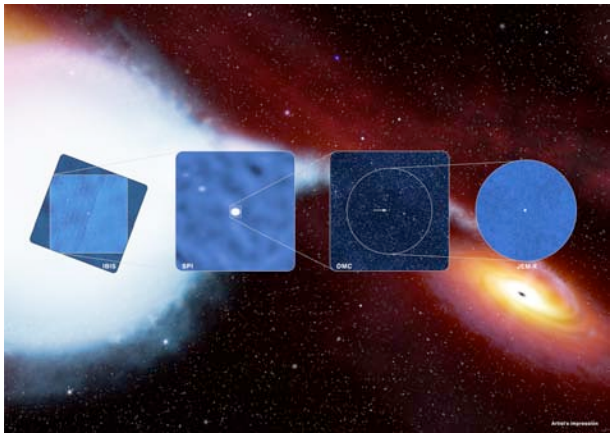
Five Years of *INTEGRAL*

Erik Kuulkers, Operations Scientist

In the following, I describe the scientific highlights of the *INTEGRAL* mission over the five year period from its launch on October 17, 2002, 04:41 UTC, to this day, October 17, 2007. Over the course of this five year time frame, *INTEGRAL* achieved and even surpassed many of the goals that had been set out for it by unlocking some of the secrets of the high-energy universe. To cover all of these achievements is impossible: there are about 300 refereed publications based on *INTEGRAL* observations. Thus, the examples below are only a selection of these.

First, it is interesting to remember that even prior to the start of nominal operations, *INTEGRAL* was already performing scientific observations: its first gamma-ray burst (GRB) detection was recorded by SPI's anti-coincidence system (ACS), on October 27, 2002, 08:34 UTC, shortly after it had been switched on. The ACS records about one GRB per day. However, it is only approximately once a month, that one of these appears in the field-of-view of the IBIS instrument. Furthermore, even before the performance and verification (PV) phase, SPI already showed its excellent spectral performance by measuring the spectrum of the locally induced gamma radiation by the protons of a solar flare that occurred on November 12, 2002.

INTEGRAL's 'first light' was chosen to be one of the brightest high-energy emitters in the sky and prototype black-hole candidate: Cygnus X-1, a binary consisting of a black hole orbiting a blue supergiant, HDE 226868, with a period of 5.6 days. These observations showed *INTEGRAL*'s strength in pointing its different instruments at the same object and thus perform simultaneous observations over an energy range spanning several orders of magnitude.



INTEGRAL*'s 'first light' from Cyg X-1. This is a well-known source of high-energy radiation and provided an ideal test location to fine-tune the instruments. Shown from left to right, on top of the artist's impression of Cyg X-1, are the (reconstructed) images from SPI, IBIS, OMC and JEM-X.*

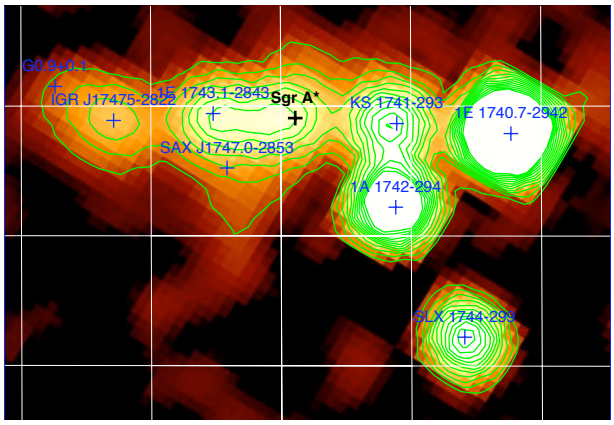
The many exciting results of the first year were published in November 2003, in a 460-page special volume of *A&A Letters* (Vol. 411, No. 1). Shortly after, we had the pleasure to take part in the first scientific conference dedicated to results derived from *INTEGRAL* observations: The *5th* INTEGRAL *Workshop*, *The* INTEGRAL *Universe* was held in Munich, on 16–20 February 2004, and was very successful with around 230 participants.

The first 'secret' source detected by *INTEGRAL* was discovered during a Galactic Plane scan on January 29, 2003. The source appeared in the direction of the Norma arm of our Galaxy and was named IGR J16318−4848. An *XMM-Newton* follow-up on February 10 showed a relatively bright X-ray source, emitting, peculiarly, only above several keV. This was determined to be due to strong absorption from obscuring material in the line-of-sight estimated to be a few times 10^{23} atoms/cm^2. The source had been observed earlier, by, e.g., *ASCA*, but had gone unnoticed, hidden behind a thick, absorbing blanket of matter around the X-ray source.

More follow-up observations at infrared and optical wavelengths, showed the companion to be a an early-type star, probably a sgB[e] star, surrounded by rich and highly absorbing circumstellar material. Since this first detection of a highly obscured X-ray binary, many more such systems have been uncovered by *INTEGRAL*, several of which show long-period (minutes) pulsations of a neutron star. IGR J16318−4848 was the first source of a new class of highly absorbed supergiant high-mass X-ray binaries (HMXB). Many other such systems are found in the direction of the Norma spiral arm, where a lot of OB supergiants are formed.

An artist's impression of a highly absorbed HMXB.

Another new kind of *INTEGRAL* source, designated IGR J17391−3021, was detected on August 26, 2003. This source, with a position that is consistent with that of the transient X-ray pulsar XTE J1739−302, faded already a few days later. The outburst duration was much shorter than the viscous timescales of a standard accretion disk. Once more, follow-up observations showed the optical star to be a supergiant. Systems like this one are termed supergiant Fast X-ray Transients, and many more are now known thanks to *INTEGRAL*.



INTEGRAL*'s view of the Nuclear region of our Galaxy. From Bélanger et al. 2006* (ApJ, *636, 275)*

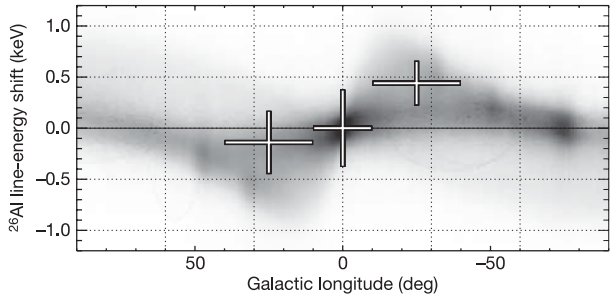
The centre of our own Galaxy has been of great interest to many in the *INTEGRAL* community and this has been reflected in the time spent observing this unique region. One of *INTEGRAL*'s remarkable results was the detection of hard X-ray emission from the nuclear region of the Galaxy. IBIS was able to detect a rather weak but persistent hard X-ray emission from a region smaller than its instrumental point-spread function ($12' \approx 28$ pc) centred within $1'$ of the massive black hole. A number of suggestions for the nature of this source have been put forward: emission from the interaction of the supernova remnant Sgr A East and the nearby molecular cloud; high-energy protons and neutrons accelerated by stochastic processes near Sgr A* interacting with

the circumnuclear disk as they escape from the vicinity of the massive black hole; a collection of highly peaked and very weak X-ray point sources, mainly cataclysmic variables. However, the mystery emission has not been resolved yet.

INTEGRAL also detected emission from the giant molecular cloud Sgr B2 and by comparing its spectrum with that obtained with *ASCA* in soft X-rays, it has been proposed that the hard X-ray emission from this cloud is a 'Compton echo' of a giant flare from Sgr A* that would have occurred some 300 years ago.

The compact sources located in the Galactic bulge region vary on all time scales. Therefore, the region never looks quite the same. Due to the frequent and regular observations of this region during its whole visibility period, the Galactic Centre region was caught in a moment of rare quiet: the brightest high-energy sources near the centre of the Galaxy had all faded below detectability levels in April 2006. When these normally bright sources are faint, we can look for even fainter sources. These could be other X-ray binaries or the high-energy radiation from giant molecular clouds interacting with supernovae which occurred in the past.

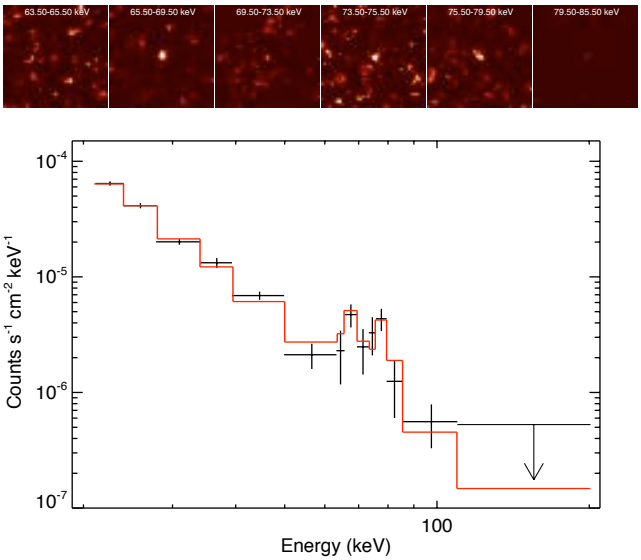
Already using data from the first visibility window of the Galactic bulge region (northern spring 2003), SPI yielded its first detection of the 511 keV line emission from an extended region centered on the Galactic Centre. This region is now known to be about 6° in diameter. The 511 keV emission could arise from annihilation of positrons originating either from low-mass X-ray binaries (LMXB), novae, Type Ia supernovae, or possibly even light dark matter. However, the 'problem' to solve is that there is no known source population with a spatial distribution which exactly matches the observed symmetrical distribution of the 511 keV emission about the center of the Galaxy.



SPI's detection of ^{26}Al consistent with Galactic rotation. From Diehl et al. 2006 (Nature, *439, 45)*

In addition to the detection of the electron-positron annihilation line, SPI has detected an excess from the decay of ^{26}Al at a line energy of 1809 keV, known to be a good tracer of recent star formation. Indeed, more observations have shown that there is a shift in the line centroid at high ($10°<l<40°$) and low ($-40°<l<-10°$) Galactic longitudes with respect to that at the Galactic Centre. Detailed modeling shows that the shift is fully consistent with the Doppler shift expected from the Galactic rotation. Using current massive-star nucleosynthesis models, this measurement represents an independent estimate of the Galactic core collapse supernova rate.

^{60}Fe lines (at 1173 and 1333 keV) from the inner Galaxy have now also been seen. Recent investigations resulted in the most-significant detection of ^{60}Fe to date, improving upon previous hints from *RHESSI* and earlier SPI measurements. It is believed that core-collapse supernovae seed the interstellar medium with unstable isotopes such as ^{60}Fe and are therefore at the origin of this emission. The ratio of ^{60}Fe to ^{26}Al is a convenient relative diagnostic, if both isotopes indeed originate predominantly from massive stars. This ratio has been predicted to lie in the range 10–100%, and is now measured by SPI as 15% (see also *Recent Science Highlights*).



First unambiguous detection of ^{44}Ti in Cas A. From Renaud et al. 2006 (ApJL, *647, 41)*

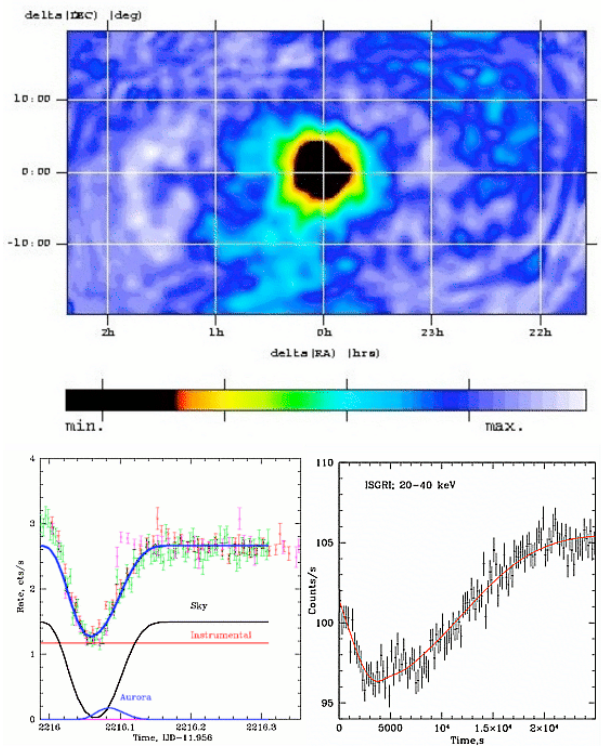
Supernovae and their remnants are the main Galactic nucleo-synthesis sites. Few radio-active isotopes are accessible to γ-ray astronomy for probing these stellar explosions. Among them, ^{44}Ti is a key isotope for the investigation of the inner regions of supernovae and their young remnants. With a lifetime of 86 years, it emits three gamma-ray lines at 67.9, 78.4 (from ^{44}Sc) and 1157 keV (from ^{44}Ca). Cassiopeia A is the youngest known Galactic supernova remnant and is so far the only one from which the line emission from ^{44}Ti decay has been unambiguously detected by *INTEGRAL*. The high yield of ^{44}Ti found by IBIS/ISGRI indicates that the remnant is peculiar in comparison to other supernova remnants.

A long standing question about the nature of the foggy or diffuse glow of hard X-ray and soft γ-rays emanating from the Galactic bulge region was resolved by *INTEGRAL* in March 2004. IBIS revealed that compact sources accounted for the entirety of our Galaxy's emission at energies between 20 and $\sim$200 keV with an uncertainty that reached about 15% at the highest energies. This leaves a minor role, at best, for a truly diffuse emission process. This result was in great part due to the efforts of the IBIS survey team whose efforts are aimed at producing the most complete catalog of sources detected with *INTEGRAL*. Three catalogs have been published up to now (1st: May 2004, 2nd: January 2006, 3rd: May 2007). The third is based on more than 40 Ms of observations performed during the first 3.5 years of the mission, and comprises more than 400 high-energy sources detected in the 17–100 keV band. Of the known systems, LMXBs are old and mainly populating the Galactic bulge; HMXBs are younger systems and thus seen along the Galactic plane; Active Galactic Nuclei (AGN) are extra-galactic sources and hence detected over the whole sky (see also below). Around one in four of the catalog sources seen by *INTEGRAL* are, however, still unidentified.

SPI showed that at energies between 200 and 300 keV, diffuse emission, concentrated along the Galactic plane, seems to contribute substantially and, in fact, dominate to the overall Galactic emission. The nature of this emission is unknown and could possibly be the combined emission of a large number of faint, unresolved point sources. Above 300 keV the picture changes drastically and the 300–500 keV image is clearly dominated by emission from the Bulge, with a morphology akin to that of the 511 keV line.

Unexpected soft gamma-ray emission has been discovered by *INTEGRAL* in several types of sources. These are accreting millisecond X-ray pulsars, anomalous X-ray pulsars and Soft Gamma-ray Repeaters. Most of the high-energy radiation (up to about 150 keV) in accreting millisecond X-ray pulsars is originating near the poles of the neutron star. For the anomalous X-ray pulsars and Soft Gamma-ray Repeaters *INTEGRAL* found very hard continuum spectra; both classes of sources are thought to be magnetars, neutron star containing high magnetic fields, up to 10^{14}–10^{15} Gauss.

INTEGRAL has also revealed AGNs hidden behind tori that we view edge-on, i.e., directly from the side. The presence in these AGN of high density absorbing gas along the line of sight (up to about 10^{24} atoms/cm^2), makes them quite faint at soft X-ray energies and at optical wavelengths. By detecting these nearby obscured AGN, *INTEGRAL* has made it possible to expand our census of AGNs covering the whole sky. The effective depth of *INTEGRAL*'s hard X-ray survey, allows us to probe the nearby Universe up to distances of 100 Mpc, and it turns out that there is a strong anisotropy in the distribution of nearby AGNs. For more details see *Recent Science Highlights*.



Integral turns around to look at the Earth. Top: SPI image at 25–50 keV; the Earth stands out as a dark 'hole' in the middle of the image. Bottom left: JEM-X light curve at 3–5 keV for one of the observations, together with various model contributions. Bottom right: IBIS/ISGRI light curve in the 20–40 keV band.

In late January and early February of 2006 *INTEGRAL* observed an unusual target: the Earth. This was done in order to learn more about the cosmic X-ray background between 15–100 keV. By comparing observations with and without the Earth blocking the sky, the cosmic X-ray background can be reconstructed. Since the Earth cannot be directly targeted, a special operational procedure was developed. *INTEGRAL* was settled on a point in the sky and then the Earth drifted through the instruments field of views. Note that the unusual way of observing severely complicates the data analysis. The shape of the cosmic X-ray background spectrum is consistent with that obtained previously by the *HEAO-1* observatory. The data now join smoothly (better than before) with *RXTE* and *Chandra* and the normalisation is higher by about 10%. *INTEGRAL*'s measurements have direct implications for the energy release of supermassive black holes in the Uni-

verse and their growth at the epoch of the cosmic X-ray background origin.

An interesting GRB was detected by *INTEGRAL* on 3 December 2003. It was a rather typical GRB with a duration of 40 seconds. However, given its small distance (a redshift, z, of about 0.105 to the host galaxy), the burst had an unusual low luminosity. This GRB is associated with a peculiar supernova. Within minutes of the detection, many observatories around the world were pointing their instruments at this source, including *XMM-Newton*. The latter observatory imaged a spectacular set of rings which appear to expand, with a speed a thousand times faster than that of light. These 'echoes' are caused by the flash of X-rays scattered by dust in our Galaxy.

One of the latest results comes from far away. IGR J22517+2218 was yet another unidentified object discovered by *INTEGRAL*/IBIS, but this time the quest for its identification turned out to be particularly rewarding. Follow up *Swift*/XRT observations identified its optical counterpart in MG3 J225155+2217, a quasar at z=3.668. This so far the most distant object detected by *INTEGRAL* (see also *Recent Science Highlights*).

Currently, *INTEGRAL* operations are confirmed until the end of 2010. Further extension is being considered. ISOC is looking forward to review by then the Science Highlights for the next five years of *INTEGRAL* observations.

AO-6 KP Announcement and AO-5 KP Update

Guillaume Belanger, Operations Scientist

On October 22, *INTEGRAL*'s AO-6 KP opens. This is the second Announcement of Opportunity (AO) for Key Programme (KP) proposals. The deadline for submissions is November 30 and the recommendations of the Time Allocation Committee are expected to be released in February 2008. The AO-5 KPs that were presented and favourably recommended as multi-year programmes will be subject to a review by the Target Allocation Committee (TAC). Together with the new proposals they will be considered in the allocation of a total time of 12 Ms to KPs in AO-6.

In AO-4, a pilot KP on the Galactic centre region was introduced to assess the interest of the community to such a large project. The large number of subscriptions to this first KP inspired the first call for proposals on other such large projects one year ago, in October 2006.

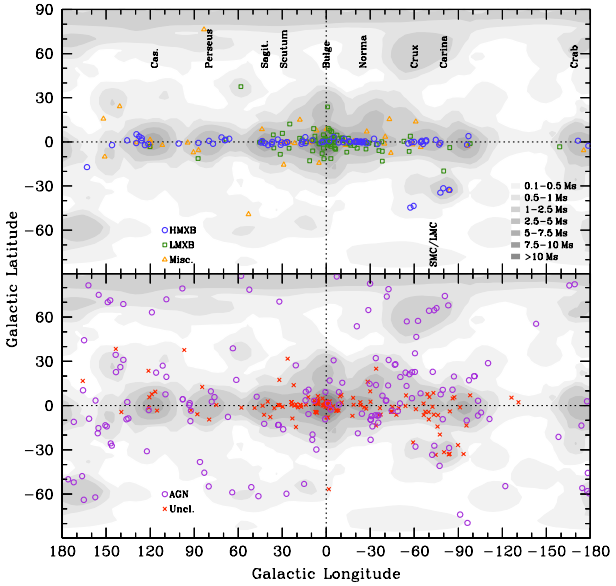
The AO-5 KP resulted in the submission of 22 KP proposals and the selection of 4, to observe 3 different parts of the sky: the Galactic Centre (PI: Bélanger), the Cygnus region (PIs: Knödlseder and Butt), and the North Ecliptic Pole (PI: Ajello), for 2 Ms each in AO-5. The first part of the Galactic Center KP observations have already been carried out and the data has been made available to all the PIs soon after the observations. The data in consolidated format is expected to be released within a month of the observations.

We are confident that many new and interesting proposals for Key Programmes will be presented to the TAC.

Recent Scientific Highlights

Peter Kretschmar, Science Ops. Manager

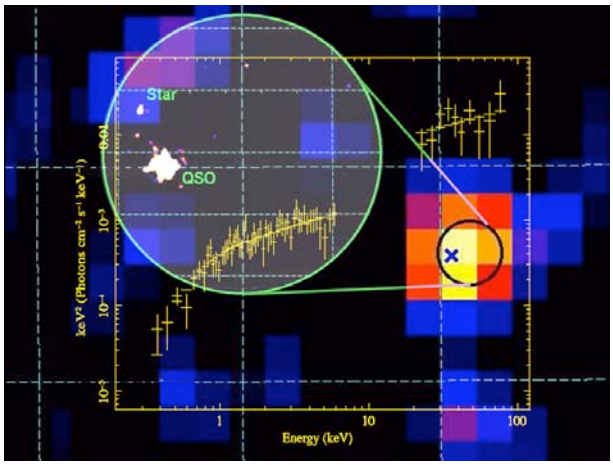
As usual, the following can only contain a brief, subjective selection of all the scientific results obtained by *INTEGRAL* since the last Newsletter. Many more results have been obtained. Up to end July, 90 papers (54 refereed, 36 non-refereed) have been published in 2007, the total number since launch is 730 papers (293 refereed, 437 non-refereed).



Spatial distribution of sources detected by ISGRI. From Bodaghee et al. 2007 (A&A, *467, 585)*

Bodaghee et al. 2007 (*A&A*, 467, 585) have carefully collected various parameters for the ∼500 sources detected by *INTEGRAL* up to end 2006 (see also Bird et al. 2007, *ApJS*, 170, 175), investigating where the sources fit into the parameter space of high-energy objects. Among other results, this study emphasizes again the special role of the Norma spiral arm with its high number of heavily absorbed

sources. The study also indicates – based on their spatial distribution – that a large fraction of currently unidentified IGR sources could be Galactic LMXB.

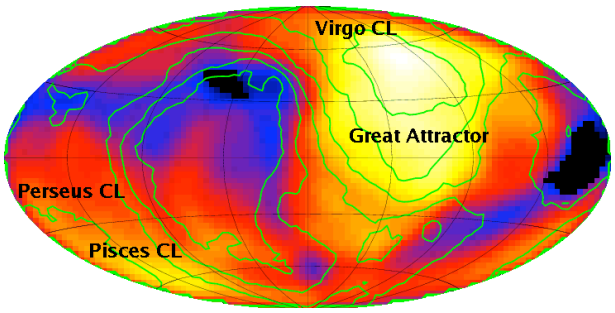


ISGRI image of IGR J22517+2218 with inset from Swift/XRT and overlaid combined spectrum.

Following up sources detected by *INTEGRAL* at other wavelengths is a laborious but very necessary task (see, e.g., *INTEGRAL* Picture of the Month, March 2007, and Masetti et al. 2007, *A&A*, 459, 21). Sometimes, the results can be very exciting, such as the recent detection by Bassani et al. 2007 (*ApJL*, in press, arXiv:0709.3023) that one of these sources, IGR J22517+2218, is actually the quasar MG3 J225155+2217 at z=3.668, the farthest object so far detected by *INTEGRAL*. Another source was identified by Bonnet-Bidaud et al. 2007 (*A&A*, 473, 185) to be a cataclysmic variable, underlining that such faint white dwarf systems may well represent a significant fraction of the unresolved high energy background.

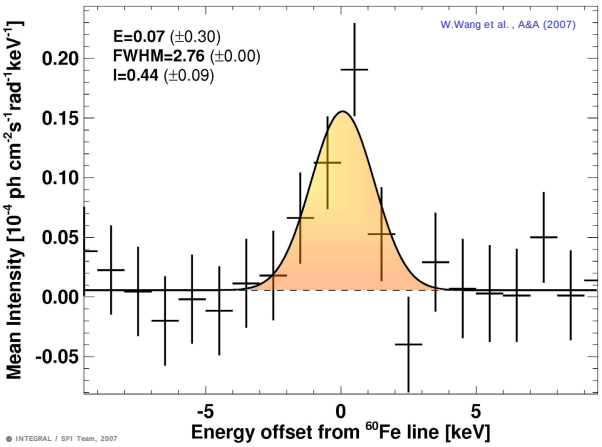
For brighter sources *INTEGRAL* can measure spectra to far above 100 keV. One such case, the black hole transient GRO J1655−40, was studied by Caballero Garcá et al. (*ApJ*, in press, arXiv:0706.1302). In the 'low/hard' state its spectrum extends without any break up to ∼500 keV, demonstrating that non-thermal emission processes can dominate the high energy emission in this state.

The distribution of sources outside our Galaxy can be used to probe the large scale structure of the local Universe up to ∼100 Mpc as Krivonos et al. (astro-ph/0701836) have shown. The number density of nearby AGN counted from an *INTEGRAL* survey correlates well with the surface density of IRAS PCSz galaxies at distances <70 Mpc and both indicate the distribution of mass in the local Universe peaking towards the Virgo Cluster and Great Attractor.



Number density of sources in the local universe.

Wang et al. 2007 (*A&A*, 469, 1005) report on the detection of γ-ray lines from ^{60}Fe decay at 1173 and 1333 keV. This isotope is created in massive stars shortly before they explode as core-collapse supernovae and thus is key diagnostic of the structure of such stars in their late stages, especially if used together with ^{26}Al.



SPI spectrum with superposition of ^{60}Fe lines.

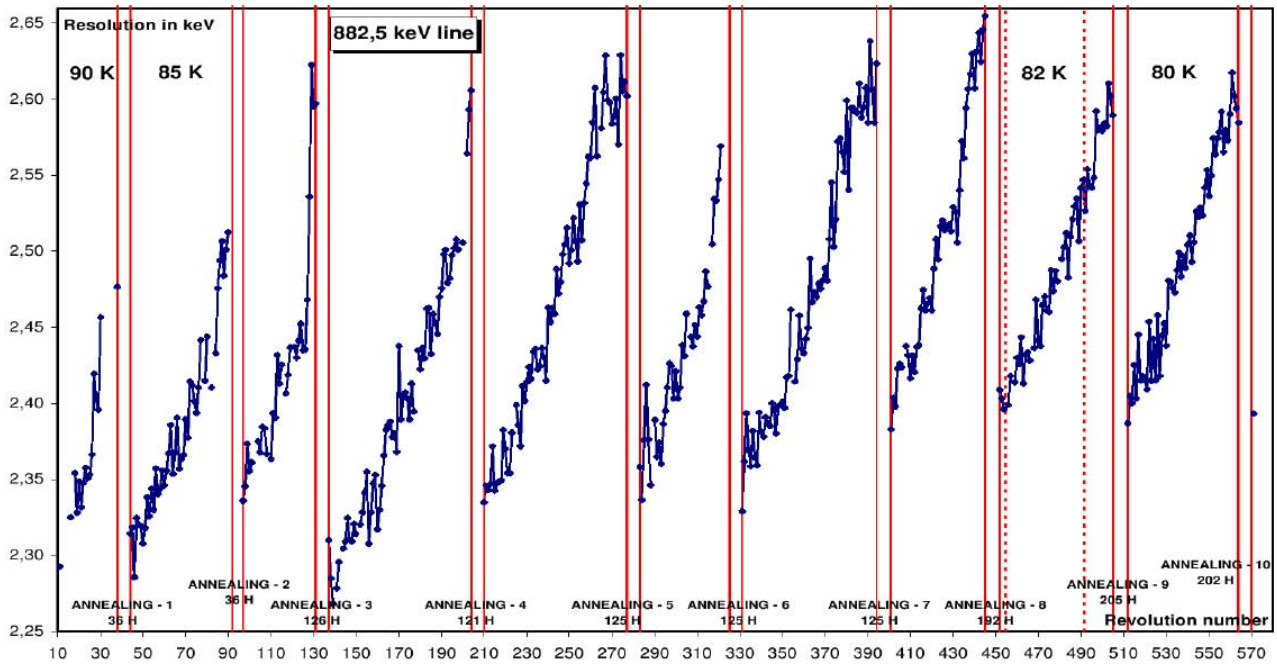
Science Operations

Celia Sanchez, Operations Scientist

No major operational changes have been implemented since the last Newsletter of March 2007.

The 10th SPI annealing period (in order to maintain SPI's high spectral resolution) started on May 29 (revolution 565) and ended on June 15 (revolution 569). The annealing allowed to recover SPI's energy resolution at 882.5 keV from 2.58 (before annealing) to 2.39 keV; this recovery is similar to that of the 9$^{\text{th}}$ annealing. As is customarily done to reduce the impact of the annealing on the mission's science return, ISOC scheduled mostly observations whose science is driven by IBIS data. Both Core Program (CP) and Guest Observer targets were observed during this period: Galactic Plane region, MCG -05-23-016, and EXO 0748−676, respectively.

Apart from various Guest Observer observations, the Crab was observed for calibration purposes.



Evolution of SPI's energy resolution at 882.5 keV as a function of time in between the annealing periods.

These observations took place in March (partly coordinated with *RXTE*, *Suzaku* and *Swift*) and in September 2007.

The Galactic Centre was visible by *INTEGRAL* during March and part of April, 2007, and most *INTEGRAL* observations carried out during these two months (specially those in March), pointed to that region. Some other targets were also observed, such as the Orion OB1 region, the radio-loud quasar PKS 0537−286 or the Galactic Plane region. Additionally, the transient source GX 339−4 was monitored during this period. GX 339−4 was observed in outburst every 4 revolutions since early February till the end of March, following a Target of Opportunity (TOO) request. Regular monitoring of GRS 1905+105 and the Galactic Bulge region was also included during this period.

The first two revolutions in May were devoted to the eclipsing X-ray binary system SS 433. The Galactic Plane region 4 and PKS 0537−286 were observed in the subsequent revolutions. The nominal observing plan had to be modified after the request for TOO observations of the Anomalous X-ray pulsar 1E 1048.1−5937 which was observed in mid-May. After this, several revolutions were spent on the Seyfert galaxy NGC 4151. The last days of May (the start of the SPI annealing) were spent observing the Galactic Plane.

Observations of the Seyfert galaxy MCG -05-23-016 and of the neutron star binary system EXO 0748−676 were executed at the beginning of June 2007, again during the annealing phase. Once annealing was finished, by mid June, we pointed to the XMM LSS field, which was the main target for the second half of the month. Other targets observed in June include the neutron star X-ray binaries GX 301−2 and EXO 0748−676, and the CP observations of the Galactic Plane.

The last days of June, most of July, and almost the first half of August, were devoted to perform (repeated) rapid latitude scans across a selected region of the Galactic disc, outside the central bulge. By mid-august we came back to the Orion OB1 region.

AO-4 formally ended with revolution 590 on August 15. Core Programme observations of the Galactic Plane were the first to be carried out in AO-5. This was followed by KP observations of the Galactic Centre, whose visibility season began in the latter part of August.

After a couple of revolutions on the X-ray binary system Her X-1 at the beginning of September, the rest of the month was devoted to the Galactic Center and the Galactic Plane, but also included regular monitoring of the Galactic bulge region and GRS 1915+105.

During the first half of October, several targets were observed, including the binary system SS 443 and a TOO on the soft gamma repeater SGR 1806−20. For the second half of the month, additional observations of SS 443 are foreseen, as well as more Galactic Disk scans.

ISDA and INVITE

Rees Williams, Archive & Ops. Scientist
Pieter-Jan Baeck, Software Engineer

As described in previous newsletters, the ISOC Science Data Archive (ISDA) is one of the two complete *INTEGRAL* archives, the other being maintained by the ISDC. The two archives contain nearly identical data, but have very different interfaces. The ISDA has the now standard ESA look-and-feel, and so its usage will be very familiar to users of, e.g., ESA's *XMM-Newton* archive.

Version 2.7 of the ISDA was released in June 2007, rather later than foreseen in the last newsletter. It contains a number of new features, of which the Virtual Observatory (VO) compliant interface is perhaps the most significant. At this time only images are available, but light-curves will be available soon. This interface makes *INTEGRAL* data ready for the VO tools for the first time. This capability means that it is possible to include *INTEGRAL* observations into the newly announced Google Sky, the Google Earth module for the sky (see `http://earth.google.com/sky/skyedu.html`).

An enhanced version of the *INTEGRAL* Visualisation Tool and Explorer (INVITE) has just been released. In addition, it will soon be directly accessible from the *INTEGRAL* home page, where it can be launched for a list of known *INTEGRAL* sources. INVITE now also supports access to OMC light curves (supplied to us by courtesy of the LAEFF OMC archive) and IBIS images, which can be passed to *ds9* for further imaging and manipulation. Both these enhancements also make use of VO protocols to access data.

Version 3.0 is now expected in December 2007. It will include an *INTEGRAL* bibliography (already maintained by ISOC), which will be cross referenced to a source list. This will make it possible to search for publications related not merely to a source, but also any field observed by *INTEGRAL*. Looking forward to the more distant future, ISDA Version 4.0 is planned for June 2008. The main extra functionality planned for that version will be 'on-the-fly' creation of mosaicked images for a given list of *INTEGRAL* science windows.

Changes at ISOC

Peter Kretschmar, Science Ops. Manager

Looking back at the previous newsletter, we find that most changes that have taken place this year were already mentioned last time.

In the software team, Silvia de Castro García now leads our small software team in the place of Paul Balm. Paul, after being about a year and a half at ISOC, has taken up a new challenge in working for Herschel since September, but has remained at ESAC and will still spend a little time every now and then to help to ensure a smooth transition. Pieter-Jan Baeck, who had been working on the Archive as a Young Graduate Trainee, has now taken up the junior developer position in place of Marnix Bindels who left at the end of Spring 2007.

Rees Williams is still with us, but the selection of a successor is ongoing and will be completed by the end of October 2007.

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