INTEGRAL in orbit!

Newsletter of the INTEGRAL Science Operations Centre

No. 6 **December 2002**

Foreword

Christoph Winkler - Project Scientist

INTEGRAL was launched on schedule on 17 October 2002, 4:41 UTC. As you will see from the various contributions in this Newsletter, one can be very satisfied with the launch and early operations, spacecraft and instrument activation and the very promising first scientific results from the commissioning and performance verification observations, which are **highlighted in the attached ESA info note** to the press. By the time of writing, the preparations for the nominal operations phase are on schedule and the AO-1 observing programme will commence at the end of this year. The very successful events of the recent past were moments of great satisfaction and emotion for all who actively contributed to the INTEGRAL programme during the recent years and we are looking ahead to an exciting time to harvest the science results from INTEGRAL. However, real life is not without problems: JEM-X detectors show some degradation of some microstrip anodes, possibly caused by heavy CR particles. This led to the decision to operate only one of both units at a time at reduced high voltage to safeguard the availability of JEM-X throughout the entire mission. Also actions have been taken to re-allocate the telemetry allocations among the instruments, to introduce additional on-board data compression and to modify the dither dwell time in order to cope with the slightly higher than expected radiation background.

Launch and Early Operations

Christoph Winkler - Project Scientist

After arrival of the spacecraft in Baikonur in August (cf. ISOC Newsletter #5), launch preparations continued smoothly and on schedule. The spacecraft was launched on 17 October 2002, 4:41 UTC. The Russian four-stage PROTON launcher performed flawlessly and injected the spacecraft into its orbit with highest precision. The spacecraft separated from the upper stage as planned. Four perigee raise burn manoeuvres and one apogee adjust manoeuvre using the spacecraft's propulsion system delivered INTEGRAL exactly into the defined operational geosynchronous 3-day orbit with (initial) perigee height: 9050 km, apogee height: 153657 km, and inclination 52.2 deg. The amount of on-board fuel left for attittude control and orbit maintenance will cover the design life (5 years) as planned, with ample margin. The spacecraft has completed the Launch and Early Operations Phase two weeks after launch, as planned. All nominal spacecraft functions have been verified, all subsystems are working nominally, full redundancy is maintained. The in-orbit slew performance is over-performing, i.e. large angle slews are being performed more accurately as the long slews significantly exceed the predicted post-slew pointing accuracy. This is good news for the observing efficiency as corrective slews are not required.

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Commissioning and Performance and Verification Phase

Rudolf Much - Deputy Project Scientist

Shortly after the solar array deployment the first steps of the INTEGRAL payload activation were taken. The instrument electronics were powered up to stabilize the thermal environment on the spacecraft. The first instrument to become operational was the radiation monitor IREM. Figure 1 (below) shows the proton count rate measured by IREM since its activation on October 17th up to mid November. Clearly visible is the higher radiation level during the first perigee passages, when INTEGRAL had not yet reached its final orbit. The perigee height was raised in several raise burns from initially 651 km to the final perigee altitude. The parameters of the final orbit (see above) are extremely close to the expected values.

After a sequence of internal calibrations the OMC cover was removed on October 21st and the first sky image was acquired. From then onwards OMC regularly acquired sky images for calibration purposes and verified the onboard data processing.

On October 27th the detector HV voltage of JEM-X, detector 1 (JEM-X1), was slowly ramped up in several steps and two days later for the second detector, JEM-X2, while the satellite was pointing to an empty field. The deconvolved “empty” skymap was generated in collaboration between the JEM-X team and the ISDC within one day. The JEM-X team had to wait another 2 days until the satellite was repointed to a field with a source in the JEM-X FOV. On Friday November 1st data were acquired while pointing to Cen X-3. Unfortunately, Cen X-3 was in eclipse for most of the observation and the source was only prominently visible towards the end of that observation. Nevertheless the skymaps for both JEM-Xs showing the source were available the next day. After JEM-X was switched off twice, triggered by an onboard IREM broadcast message due to the high radiation environment on the descending part of the orbit, it was decided to adjust the critical operation altitude (nominally 40000 km): from revolution 7 (Nov 3rd) onwards 40000 km and 60000 km are used as critical operational altitude for the ascending and descending leg of the revolution (i.e. instrument switch on and off), respectively. The perigee exit and entry points will evolve with time, and will be adjusted accordingly.

On November 7th it was recognized that some of the 256 anodes in each of the two JEM-X detectors suffered degradation. The detector high voltage settings were lowered by 80V, which reduced the damage rate significantly. In the last weeks only 3 further degraded anodes were found on JEM-X1 and none on JEM-X2. As a precaution the JEM-X1 setting was reduced by another 20V on December 10th. The degradation is thought to be caused by heavy ionizing cosmic rays. Ground tests are planned with the JEM-X flight spare detector in order to better understand the mechanisms causing the degradation of the anodes. JEM-X operation is now considered as a consumable and after the end of the performance and verification phase, only JEM-X2 operation will continue. As a consequence of the reduced HV the low energy threshold for JEM-X is now around 4-5 keV with a sensitivity at 6 keV of ~ 60% the expected (pre-launch) value. JEM-X1 will be switched off and is kept as backup instrument in order to safeguard JEM-X through the entire mission.

The SPI activation went very smoothly. Shortly after switch on of the SPI anti-coincidence system (ACS) the first GRB was already observed by the ACS on October 27th, around 8:34 UT (GRB021027, GCN #1703). This confirmed the capability of the SPI ACS system to trigger on GRBs. The burst was already seen in the overall ACS counting rates with a 50ms time resolution. GRBs are now registered with a frequency of approximately one burst per day by the SPI ACS. On November 4th the detector array had reached 117 K and the high voltage of the SPI detectors was switched on. The nominal operating temperature of the detectors (89 K) was reached 2 days later. All Germanium detectors show an excellent performance (energy resolution ΔE between 2.3 keV and 2.6 keV (FWHM) at 1.11 MeV), with the exception of detector #15, which has a slightly lower performance (3.2 keV at 1.11 MeV) - typical for degradation by pollution. The excellent spectral capability of SPI is illustrated in the measured spectrum of the locally induced gamma radiation by the protons of the solar flare from November 12th (Figure 3, below).

The IBIS/PICSIT detectors were activated on October 20th and the first IBIS/ISGRI detector on October 24th. Data acquisition was performed from this point in time whenever possible, although the high voltage of the veto modules was kept off and no background rejection was possible. Finally on November 7th, all veto modules were switched on and the instrument count rate was significantly reduced due to the onboard background rejection.

However it became obvious that the payload has a high telemetry load onboard INTEGRAL. When checking out the instruments higher telemetry was required by IBIS and SPI in order to optimally tune the onboard event selection filters. During a period with higher telemetry allocation and when PICSIT was operated in photon-photon mode, a GRB occurred within the IBIS partially coded FOV. The instrument and the ISDC team reacted quickly and a GCN circular (# 1706) with the burst location was issued the following day. Figure 2 (below) shows the initial burst position together with the position derived later from triangulation using the Interplanetary Network IPN.

ISGRI operates well down to the lowest expected energies demonstrated by the clear detection of Cyg X-1 and Cyg X-3 in the 14-60 keV energy band (Figure 4).

The transition from the instrument activation and commissioning phase to the performance and verification phase was a gradual transition, which began in revolution 11 (November 15th) and lasted up to revolution 17 (December 6th). During this period the instruments were mainly observing the Cygnus region in “staring mode”. On December 9th the first dithering observations were successfully executed. The performance and verification phase continues until December 30th. Data which are acquired after December 17th (until December 30th) will become public in January, once the consolidated data have been processed by ISDC. The observations planned for that period are shown in Table 1.

Table 1: PV observations, public data

Start day	Start time (UTC)	End day	End (time) (UTC)	Target
17/12	06:30:00	21/12	4:59:29	Cygnus 7.4 degree off-axis 5x5 dithering
21/12	15:20:04	23/12	23:36:07	Cygnus 9.65 degree off-axis 5x5 dithering
24/12	09:01:22	27/12	20:44:27	empty field 2 staring
27/12	21:08:38	28/12	10:54:28	OMC flatfield calibration sequence (OMC ff #8)
28/12	11:53:17	28/12	19:49:24	GPS-test
28/12	20:06:55	29/12	22:20:16	Cygnus 9.65 degree off-axis 5x5 dithering

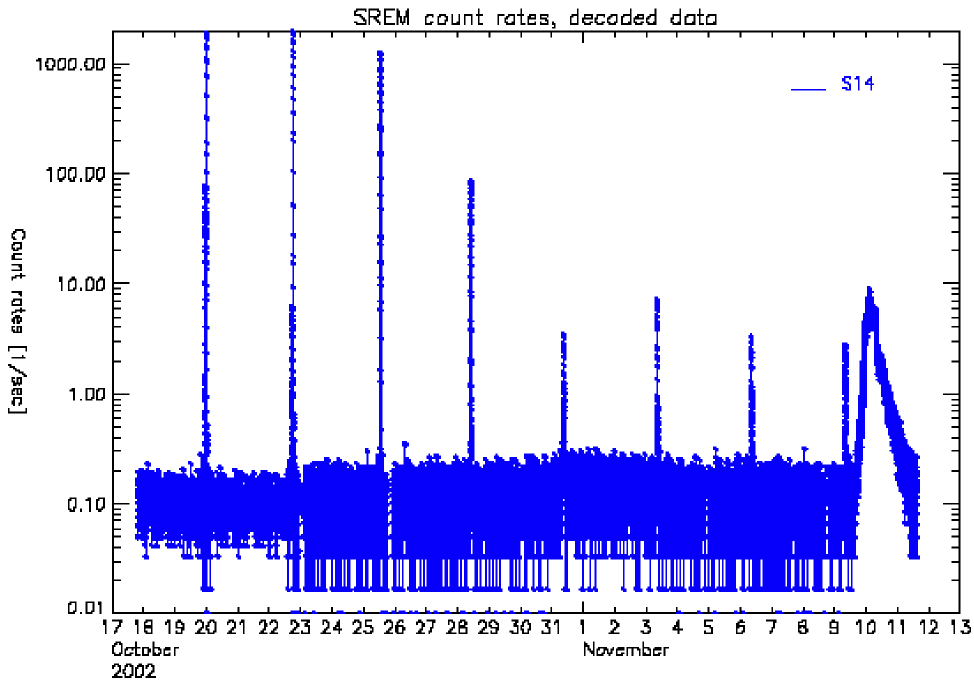


Figure 1: Proton count rates measured by IREM from switch on until mid November. Clearly visible is the reduction in the proton flux by almost 3 orders of magnitude from the initial transfer orbit to the final orbit. The broad feature around November 9th is associated with solar activity. Courtesy: P. Buehler and the IREM team.

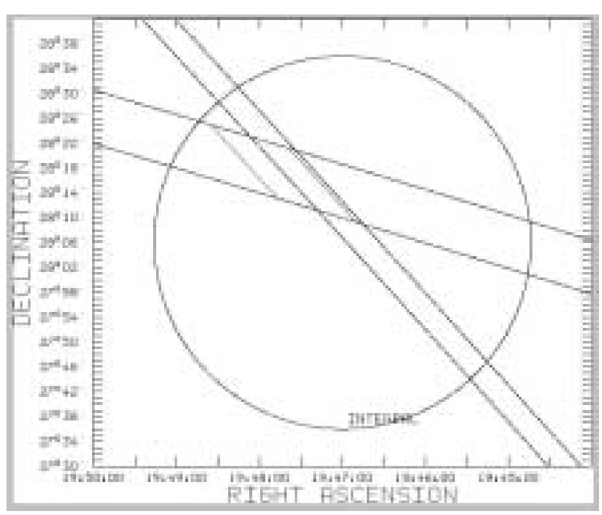


Figure 2: The map is showing the various triangulation annuli (GCN circulars #1707 &#1709) and the INTEGRAL preliminary error circle of 30 arcmin as announced in GCN #1706 by A. Bazzano and A. Paizis. Post event processing has reduced the INTEGRAL location error to few arcminutes. Courtesy: K. Hurley, et al.

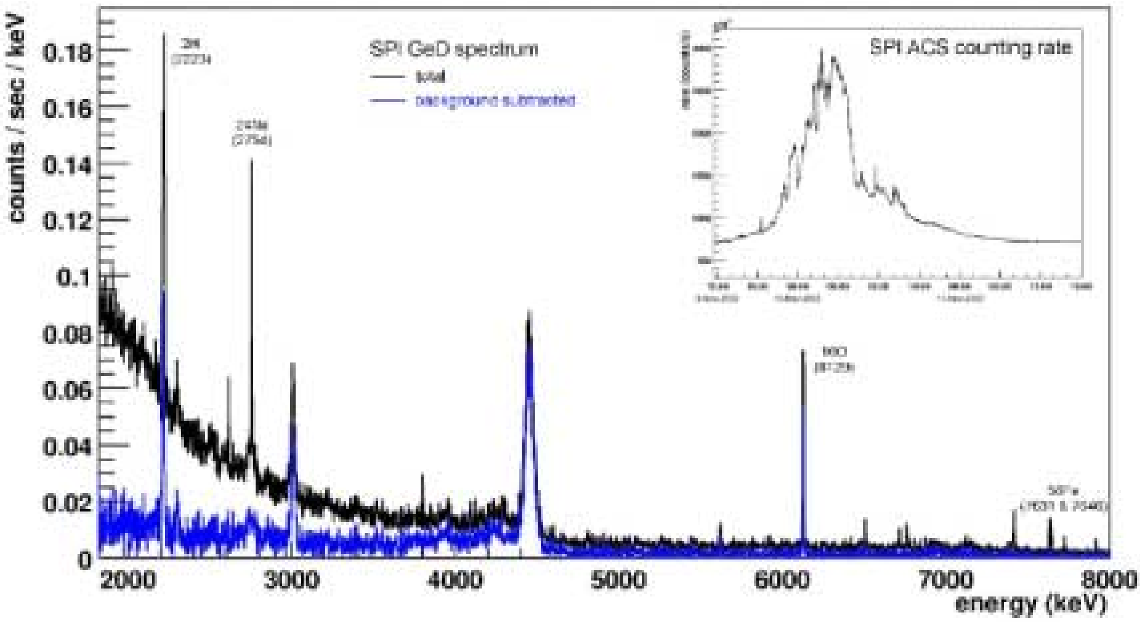


Figure 3: SPI spectrum of the locally induced gamma-ray lines by solar flare protons. This spectrum illustrates the excellent spectral capabilities of SPI. Courtesy: J. Knödlseder and the SPI team.

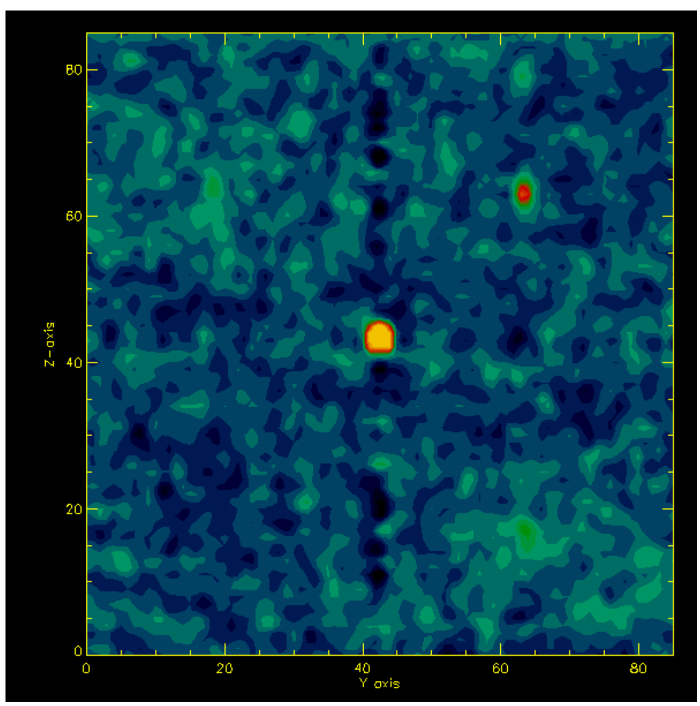


Figure 4: IBIS/ISGRI (14-60 keV) image of the Cygnus region (4 h on Nov 16th) showing Cyg X-1 (91σ) and Cyg X-3 (10σ, limited by PCFOV). Courtesy: P. Ubertini and IBIS team.

More results can be found at http://astro.estec.esa.nl/Integral/integ_pictures.html and on related Integral WWW sites (ISDC, PI teams).

Nominal Operations Update

Paul Barr - Mission Planner

Following the results from the performance and verification phase, the following updates have been implemented by ISOC for the nominal science operations phase starting on 30 December:

Modifications to dither operations

(i) Dither point dwell times

ISGRI data and (most of) SPI data are transmitted in photon-by-photon mode. Conversely, source data accumulated by PICSIT, and SPI background data, are compressed to histograms on board, and are transmitted as a 'squirt' at the end of very dither point, i.e. just before and during the slew to the next point. Following the commissioning and performance verification phases, modifications have to be made, because SPI now histograms and compresses single event science data, due to the higher than expected background.

Keeping to the pre-launch baseline, it is not always possible to perform the compression and transmission before the start of the next dither point. In this case histograms will be lost. This is especially true for SPI where the original background spectra now contain single-photon science data (PICSIT can store the histograms on board for later transmission). This was discussed during the last INTEGRAL science working team meeting. It was agreed that it was unacceptable to lose SPI histograms frequently. The solution adopted is to increase dither point dwell times to 2200 seconds, from the current 1800 seconds. This leads to an increase of the observation efficiency as the ratio between dwell time and slew time increases. Also the telemetry need for downlinking PICSIT histograms is reduced, as the time available to downlink one histogram (corresponding to ~dwell time) is longer.
Thus, in future, hexagonal and 5 x 5 dithering observations will be performed with an increased dwell duration of 2200 seconds per dither point. The total approved observing time will not change.

(ii) Dithering and JEM-X

When using the 5x5 dither pattern, the source is inside the JEM-X field of view only for the central 3x3 points of the pattern. If the observation duration is such that the pattern is not sampled uniformly, i.e. a multiple of 25 points, it is possible that the outer parts of the pattern will be exposed more than the inner region. This is clearly undesirable for JEM-X. Therefore a change will be introduced to the implementation of the dither. After every 25 points the scheduling software will calculate the remaining observation duration to be scheduled. If that is insufficient to perform another complete pattern, the remaining pointings will be changed so as to sample only the inner 3x3 grid.

Revised implementation of the Galactic Plane Scan (GPS)

The pre-launch baseline of the Galactic Plane Scan (GPS) was to perform regular scans along the galactic plane at weekly intervals. The total observing time allocated to the GPS in each year of scientific operations is fixed: in the first year it is 2.3 Msecs. This includes the actual observing time (1050 seconds per point), the overhead due to slews between individual points of the scan (300 seconds per slew estimated pre-launch), and a flat rate 'tax' for the slew to the initial point of each scan (assuming a 30 degree slew).

Following experience gained in the commissioning and performance verification phases, this baseline will be altered. There are two principal reasons:

- to optimize instrument operations, the observing time per point has been increased to 2200 seconds (see above - dither point dwell time)
- the slew performance is somewhat better than initially assumed; the internal slews now take just 200 seconds.

The revised GPS still has to fit inside the overall allocation of 2.3 Msecs. After discussion within the INTEGRAL Science Working Team, the following approach has been adopted:

- the initial assumption for total exposure to and coverage of the galactic plane remains unchanged, as does the sawtooth scan pattern.
- to accommodate the increased observing time per point, the frequency at which the scans will be performed will be reduced. Instead of scanning every week, INTEGRAL will perform the GPS scan every fourth revolution, i.e. approximately every twelve days.

This new approach, while increasing the interval between scans, has benefits. The efficiency (ratio of observing time to slew time) is increased; and the flux limit reached in the scans decreases (improves!) by 40%.

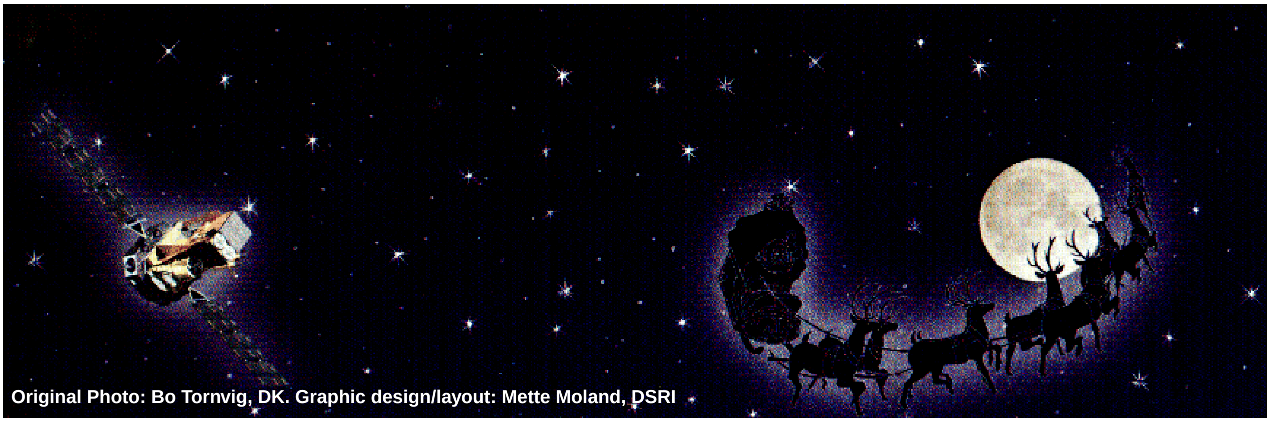
INTEGRAL schedules on the WWW.

The current short term schedule published on the INTEGRAL WWW site is a draft only and will soon be replaced by a real schedule, as planning of the routine phase picks up. The new schedule will contain significantly more information than the existing draft:

- start times and durations of each planned exposure: an observation is usually split into several exposures by such activities as ground station handovers and reaction wheel biasing operations. This information will allow the viewer to see exactly when INTEGRAL will be collecting useful data, timed to the nearest second.
- a hypertext link will allow the viewer to see exactly when individual pointings of the GPS and GCDE are performed, and give the celestial coordinates of each point. This will facilitate the planning of co-ordinated observations.

The short term schedule will be updated every time a revolution is planned or re-planned. For planning of co-ordinated observations with other facilities, this should therefore always be taken as the 'master' plan.

The long term plan will also be published on the WWW. This will have a granularity of one revolution (three days). It will not be a full plan, in that not every single revolution is included; rather it will indicate when known future scheduling of observations will occur. Examples include the GPS, GCDE and fixed time observations; and any other observations whose timing can be predicted well in advance. This will be updated as and when more scheduling information becomes available.



Any Other Business

We wish a Merry Christmas and a Happy - and successful - New Year to all readers of the ISOC Newsletter and to all users of the INTEGRAL gamma-ray observatory.

How to reach the ISOC?

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Nolan, J.	Operations Engineer	3401	SCI-SDG
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Kuulkers, E.	Operations Scientist	6145	SCI-SDG
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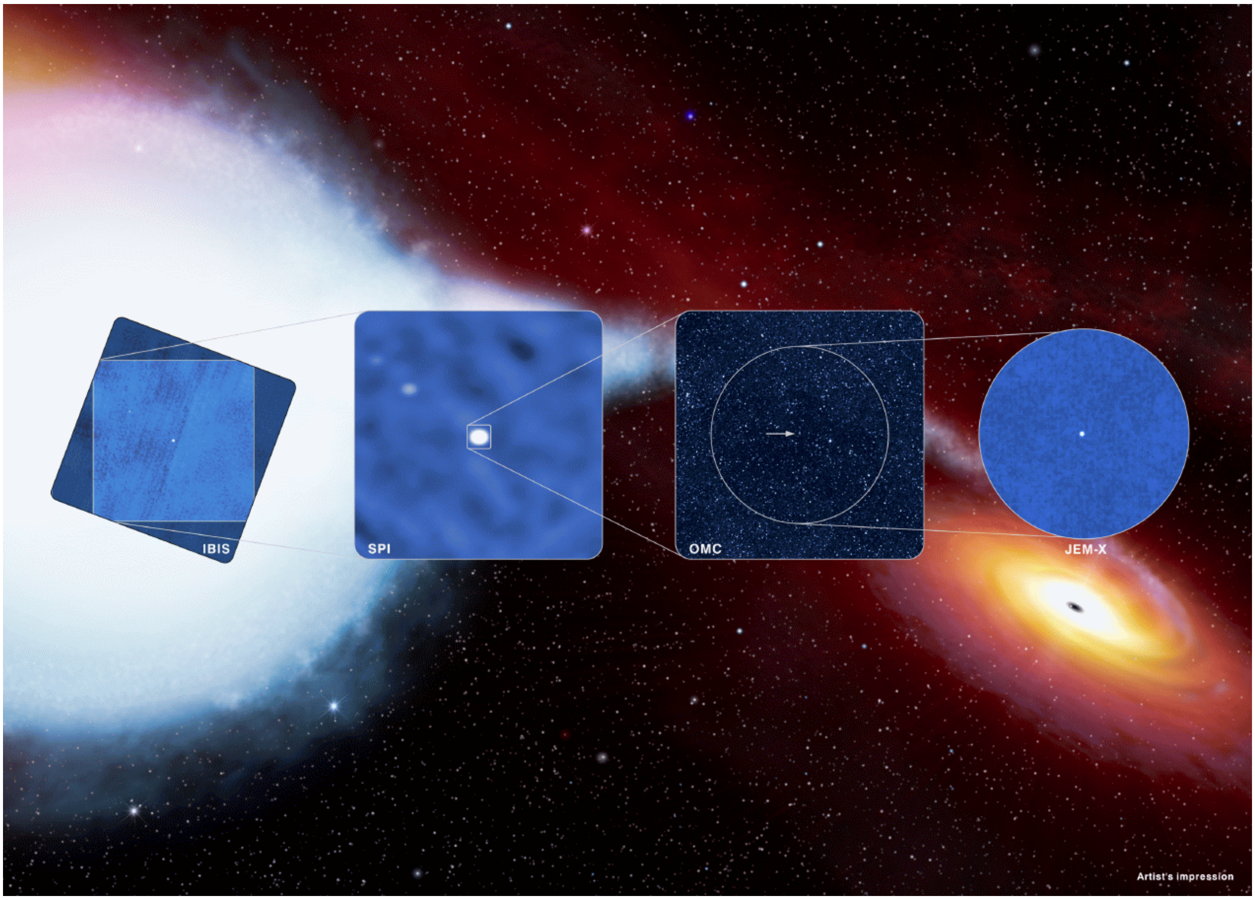
INTEGRAL's first look at the gamma-ray Universe

ESA's gamma-ray satellite, INTEGRAL, is fully operational. Today INTEGRAL's first ground-breaking images of the high-energy Universe were presented in Paris, France. Astronomers call such initial observations' first light'



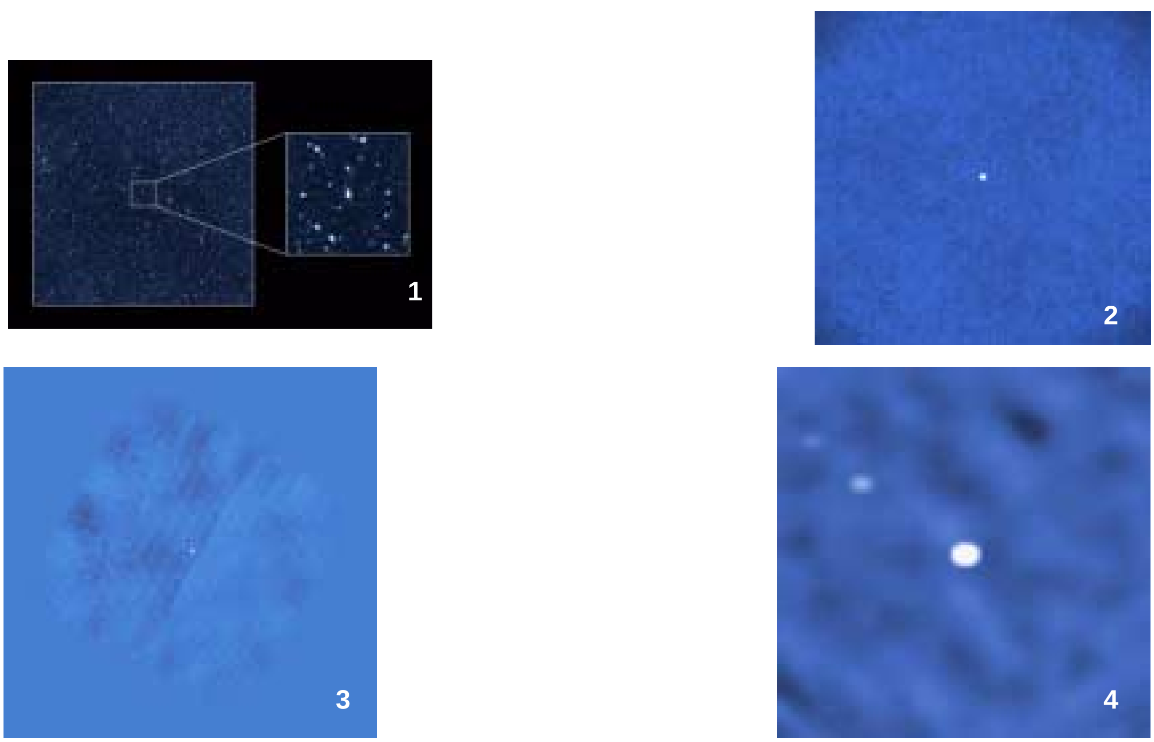
INTEGRAL's view of Cygnus region

For the'first light' images, INTEGRAL was pointed at Cygnus X-1. Cygnus X-1 lies about 10,000 light years from Earth and is one of the brightest high-energy emitters in the sky. It was discovered in 1960s and is thought to be a black hole, ripping its companion star to pieces. The companion star, HDE 226868, is a blue supergiant with a surface temperature of around 31,000K. It orbits the black hole once every 5.6 days. It is a well-known source of high-energy radiation and provided the ideal test location to fine-tune INTEGRAL's science instruments. INTEGRAL's four instruments, the Imager on Board the INTEGRAL Satellite (IBIS), the Spectrometer on INTEGRAL (SPI), the Optical Monitoring Camera (OMC) and the Joint European X-ray Monitor (JEM-X) all point in the same direction so that they simultaneously observe the same celestial objects. This allows their data to be matched together, producing a greater insight into the nature of the celestial objects that INTEGRAL will be studying.

The high-energy Universe is a violent place of exploding stars and their collapsed remnants such as the ultra compressed neutron stars and, at the most extreme, all-consuming black holes. These celestial objects create X-rays and gamma rays that are many times more powerful than the optical radiation we can see with our eyes and optical telescopes. INTEGRAL's Principal Investigators - the scientists responsible for the INTEGRAL instruments - explain the crucial role that high-energy missions like INTEGRAL play in astronomy. "X-ray and gamma-ray astronomy is a pathfinder to unusual objects. At optical wavelengths, the number of stars is staggering. At X-ray and gamma-ray wavelengths, there are fewer objects, but the ones that remain are the really peculiar ones.” As a first test, INTEGRAL observed the Cygnus region of the sky, looking particularly at the enigmatic object, Cygnus X-1. Since the 1960s, we know this object has been a constant generator of high-energy radiation. Most scientists believe that Cygnus X-1 is the site of a black hole, containing around five times the mass of our Sun and devouring a nearby star. Observing Cygnus X-1 - which is relatively close by in our own Galaxy -’only’ 10 000 light years from us - is a very important step to understand black holes. This will also contribute to understand the monstrous black hole - three million times the mass of our Sun - harboured at the centre of our Galaxy.

During the initial investigations, scientists had a nice surprise when INTEGRAL captured its first gamma-ray burst. These extraordinary celestial explosions are unpredictable and occur from random directions about twice a day. Their precise origin is contentious: they could be the result of massive stars collapsing in the distant Universe or alternatively the result of a collision between two neutron stars. INTEGRAL promises to provide the vital clue in solving this particular celestial mystery.

To study these peculiarities, INTEGRAL carries two powerful gamma-ray instruments. It has a camera, or imager, called IBIS and a spectrometer, called SPI. Spectrometers are used to measure the energy of the gamma rays received. Gamma-ray sources are often extremely variable and can fluctuate within minutes or seconds. It is therefore crucial to record data simultaneously in different wavelengths. To achieve this, INTEGRAL also carries a X-Ray and an optical monitor (JEM-X and OMC). All four instruments will observe the same objects, and at the same time. In this way they can capture fleeting events completely. INTEGRAL sends the data from all the instruments to the INTEGRAL Science Data Centre (ISDC) near Geneva, Switzerland. There the data are processed for eventual release to the scientific community. “We have been optimising the instruments’ performances to produce the best overall science. We expect to be ready for astronomers around the world to use INTEGRAL at the end of the year,” says Arvind Parmar, Acting INTEGRAL Project Scientist at ESA. “These images and spectra prove that INTEGRAL can certainly do the job it was designed to do, and more”, that is to unlock some of the secrets of the high-energy Universe. INTEGRAL’s primary mission will last for two years, but, all being well, the satellite carries enough fuel to continue for a five-year mission.



INTEGRAL first light images of Cyg X-1 region:
(1) OMC, V-band, FOV 5x5 deg; (2) JEM-X, 28 Nov, FOV: 4.8 deg; (3) IBIS, Cyg X-1 and Cyg X-3, 16 Nov, FOV: 9x9 deg; (4) SPI, Cyg X-1 and Cyg X-3, FOV: 16 deg