The INTEGRAL mission

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Abstract

INTEGRAL, (INTErnational Gamma-Ray Astrophysics Laboratory) is an astronomical satellite for observing the gamma-ray sky. It was launched in October, 2002. The use of INTEGRAL is planned for 2 years with a possible extension for up to 5 years.
The INTEGRAL spacecraft features 4 instruments:
a gamma ray spectrometer, a gamma ray imager, two X-ray monitors and an optical monitoring camera.

1. Introduction

INTEGRAL is the European Space Agency (ESA) satellite for gamma-ray astronomy. It was launched on October 17th, 2002, from Baikonur on a Russian Proton rocket.
The 3 sideral days orbit has an apogee of 150,000 km and a perigee of 10,000 km in the same 51.6° plane as the XMM ESA mission. The orbit stay away from the Van Allen belts most of the time. The spacecraft weighs 4.1 tons, is 5 m tall, 3.7 m in diameter, and has 16 m solar panels.
Gamma-ray astronomy around the energy of 1 Mev is very difficult due to two adverse conditions:

- gamma rays from nuclear transitions due to natural or induced radioactivity in the satellite material lie in the same energy range.
- gamma rays of this energy cannot be easily focused onto a small detector.

Those two reasons imply that all the measurements are background dominated and the instrument was to rely on coded mask technology for imaging.

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Table 1. INTEGRAL instrumental characteristics

value	IBIS	SPI	JEMX	OMC
energy range	15KeV-10MeV	15KeV-2MeV	3-35KeV	V band
angular resolution	12'	2.8°	3'	17.6"
location accuracy	30"	0.5°	30"	6"
spectral resolution	$\sim 10\%$	2.2KeV@1.33MeV	2KeV	no
sensitivity	3.810^{-7}@100KeV	310^{-7}@1MeV	1.310^{-5}@6KeV	V=18.2
FOV	$9 \times 9°$ fully coded	$13.2 \times 13.2°$	4.8°	5°
timing	$61\mu s$	$129\mu s$	$122\mu s$	3 sec

2. The different instruments

The ideal gamma-ray detector would give for every incoming photon: its absolute time of arrival, its direction, its energy and its polarization. Unfortunately, the detectors required to record an accurate direction of arrival are not optimal for energy resolution and vice versa. So a compromise has to be found. As the goals of INTEGRAL require both fine imaging and sharp spectroscopic capabilities, it was decided to build two coaligned telescopes, one with the emphasis on spectroscopy (SPI[1]), and one with emphasis on imaging (IBIS[2]).
To extend the capabilities toward low energies, two X ray monitors (JEMX1 and JEMX2 [3]) are added. An optical camera (OMC[4]) enables us to corelate the variations of the gamma ray sky with variations in the optical range. All these instruments look in the same direction but have different field of view. The most important parameters are summarized in Table 1.

2.1. SPI

The SPI camera consists of 19 actively cooled hexagonal Germanium detectors surrounded by a massive active shielding made of BGO. A coded mask of tungsten 2 meters away casts its shadow on the camera. The information of every single unvetoed photon with one or multiple interactions in the detectors is sent to Earth.

2.2. IBIS

IBIS achieves high angular resolution in recording the shadow of a fine tungsten mask 3 meters away from two consecutive planes of finely segmented sensitive elements. The first plane is called ISGRI and record mostly low energy photons. Photons traversing the ISGRI plane intact or through a Compton diffusion are recorded on the second plane called PICsIT. An active veto protects the two planes from backward and sideways gamma rays. A passive shield protects the tube up to the mask.
ISGRI is a 128×128 cells CdTe semiconductor detector. Each cell measures

$4 \times 4 \times 2mm^3$, It is operated at ambient temperature ($\sim 5°C$). Point source localization accuracy of 30 arcsec has been demonstrated for intense sources. Every single unvetoed photon is recorded and sent to Earth.
PICsIT is a 64×64 CsI scintillator detector. Each scintillator measures $8.55 \times 8.55 \times 30mm^3$ and is read by a photodiode. Due to telemetry limitations, the detector accumulates one energy histogram for every cells in normal science readout. The histograms are sent to Earth about every 20 minutes.
The two planes are working together and are able to record photons producing multiple interactions. Multiple interactions compatible with a Compton diffusion are reconstructed. As the Compton diffusion is sensitive to the polarization of the incoming photon, a polarization data stream is forseen but was neither exercised nor calibrated up to now.

2.3. JEMX, OMC, IREM

The JEMX monitors are realized with a gas drift chamber. There are two of them for redundancy.
OMC is a 50mm lens with a CCD. For telemetry reasons only some preprogrammed subwindows of the CCD are read.
As the induced radiation is dominant in the background of the measurements, a radiation monitor (IREM) is constantly measuring the rate of cosmic protons and electrons. The data of this detector is public.

3. The mission

INTEGRAL functions as an observatory. Its nominal lifetime is of 2 years, but an extention of up to 5 years is technically possible. Scientists propose observations. Observations are accepted according to their scientific merit and their feasibility. After an observation has been executed, the data is analyzed at the ISDC[5] and standard analysis products are sent to the authors of the proposition. This person has exclusive rights on this data for one year. After this period, the data is freely available to everybody in the ISDC archive.
Thirty-five percent of the measurement time is reserved for the INTEGRAL science working team for its contribution to the mission. This time is devoted during the first year to regular surveys of the galactic plane, to a deep observation of the galactic center, and some time is also reserved for target-of-opportunity observations.

4. First results

INTEGRAL has been commissioned. Many observations for calibration purposes were done especially using the Crab nebula. Observations were performed on the galactic center, the galactic plane, Cyg-X1, the Large Magellanic

Cloud, 3C273, and other interesting sources.
As the calibration of the detector is not fully realized yet, only limited scientific results are possible. As the alignment is already realized, localization of new sources is possible with great confidence. The results are already in: many new source have been discovered (IGR J17091-3624, IGR J18539+0727, IGR J17464-3213, IGR J16358-4726, IGR J16320-4751, IGR J19140+098, IGR J16318-4848). One GRB per month was promptly localized (GRB 021125, GRB 021219, GRB 030131, GRB 030227, GRB 030320, GRB030501). The light curve of about one GRB per day was communicated to the GCN. Other results, including spectral information, have to wait for the full scientific performance evaluation before being released.

5. Conclusions

INTEGRAL is up and alive in space and taking good data. As the detectors are not yet fully calibrated, actual published results are limited to localization of new transient sources. INTEGRAL is already an important player in the field of gamma-ray astronomy and this is just the beginning of the mission.

6. References

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