THE INTEGRAL SCIENCE DATA CENTER

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The INTEGRAL Science Data Center will provide the interface between the world-wide astronomical community and the data from the next γ-ray astronomy satellite of the European Space Agency. After a short description of the INTEGRAL mission, we present the main responsibilities of the ISDC and the current status of the project.

1 Introduction

INTEGRAL (INTErnational Gamma Ray Astrophysics Laboratory) will be the next satellite of the European Space Agency (ESA) devoted to γ-ray astronomy. It will be launched in 2001 to serve the international scientific community as an observatory type mission. In fact, most of the observing time shall be available to the astronomers through a guest observer program.

Telescopes for γ-ray astronomy are complex and their data analysis requires a detailed knowledge of the instruments. The INTEGRAL Science Data Center (ISDC) will provide the interface with the astronomical community. INTEGRAL data will be processed at the ISDC to the point where they can be more easily analysed, providing to observers without a specific experience with γ-ray instrumentation the support necessary to allow the full scientific exploitation of the data.

Another major task of the ISDC will be to perform a first quick-look analysis of the data to rapidly discover new transient sources or interesting unexpected events. In case that such a "Target of Opportunity" is detected, the ISDC will inform the INTEGRAL project in order to implement, where appropriate, modifications of the foreseen observation plan.

To fulfill these goals the ISDC will develop a software system to pre-process the satellite data, and to analyze the resulting sky images, energy spectra, and light curves. The results of this analysis, as well as the preprocessed data and

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all the relevant information, will be made available to the observers and stored in the archive where they will become public after one year.

2 The INTEGRAL Mission

INTEGRAL [1] was selected by the European Space Agency on 3 June 1993 as the next ESA medium-size scientific mission to be launched in 2001. INTEGRAL is conceived as an observatory type mission, led by ESA with contributions from Russia and NASA. It will be launched into a 72-hour High Eccentric Orbit by a Russian PROTON rocket. This orbit minimizes the contribution of protons trapped in the Earth's radiation belt to the detector background, and it also allows long uninterrupted observations. The nominal lifetime of INTEGRAL will be 2 years, with possible extension to up to 5 years.

2.1 The Instruments

INTEGRAL is devoted to high resolution spectroscopy and high angular resolution imaging of the γ-ray sky, together with a broad coverage of the electromagnetic spectrum. These goals will be achieved by two main instruments (IBIS and SPI) optimized respectively for the angular and spectral resolution, complemented by two monitors in the X-ray (JEM-X) and optical (OMC) bands. All four instruments are co-aligned to observe simultaneously the same region of the sky. Their measurements will be made available to users as a single comprehensive data set for each target. IBIS, SPI and JEM-X make use of the coded mask principle to obtain images of the sky at wavelengths where focussing techniques are unpracticable.

IBIS [2] covers the energy range from 15 keV to 10 MeV thanks to two different position sensitive detection layers: a top one composed of an array of 128x128 CdTe pixels 2 mm thick, followed by a second layer in CsI (64x64 pixels, 3cm thickness). The tungsten coded mask placed $\sim$3 m from the detection plane will provide an angular resolution of 12 arcmin over a wide field of view (9x9 degrees full sensitivity, 19x19 degrees half sensitivity). The continuum sensitivity for a typical observing time of 10^6 seconds will be of a few 10^{-7} photons cm^{-2} s^{-1} keV^{-1}.

SPI [3] is optimized for detailed measurements of γ-ray lines and the mapping of diffuse sources with an angular resolution of $\sim$2 degrees. The cooled Germanium detectors will allow precise measurements (E/dE = 500 at 1 MeV) of the γ-ray energies over the 20 keV - 8 MeV range. The SPI sensitivity for narrow lines will be of 5×10^{-6} photons cm^{-2} s^{-1} (3σ in 10^6 seconds at 1 MeV).

The JEM-X [4] Monitor will yield imaging with angular resolution of 3 arcmin in the 3 - 120 keV band over a $\sim$5 degree fully coded field of view.

The OMC [5] will observe the optical emission from the prime targets of the other instruments. It offers the first opportunity to make long observations in the optical band simultaneously with those at X-rays and γ-rays.

2.2 The Ground Segment

The INTEGRAL ground segment is divided into two major elements, the Operations Ground Segment (OGS) and the Science Ground Segment (SGS).

All the classical spacecraft operations and maintenance tasks will be carried out by the OGS, which is formed by the ESA Mission Operations Centre at ESOC plus the ESA and NASA ground stations.

The SGS consists of two components, the Integral Science Operations Centre (ISOC) and the Integral Science Data Centre (ISDC). The ISOC will process the accepted observation proposals into an optimised observation plan which consists of a time line of target pointings plus the corresponding instrument configuration. The ISDC will receive the science telemetry plus the relevant ancillary spacecraft data from the OGS. Taking into account the instrument characteristics, the ISDC will process these data and distribute them to the observers.

ESOC and ISOC are under the responsibility of ESA, while the ISDC, like the four payload instruments, is provided by an international consortium of scientific institutions funded by their respective national agencies.

3 The INTEGRAL Science Data Center

The ISDC is located in the "Ecogia" building complex in Versoix (Switzerland), near to the Geneva Observatory. Its main responsibilities are the following:

- developement, integration and maintenance of the analysis software
- participation in the definition and analysis of ground and flight calibrations
- support ISOC in the time allocation process by assessing the technical feasibility of the proposed observations
- preprocessing and analysis of the data to create and mantain the INTEGRAL archive
- recognize transient and/or unexpected astronomical events as targets of opportunity
- monitor the correct functioning of the instruments
- perform a quick-look analysis of the data to verify that the scientific objectives of on-going observations are being met

- make pre-processed data and standard analysis results available through the INTEGRAL archive
- provide facilities and assistance in data analysis to the observers

Some of these tasks are described in more detail in the following.

3.1 Software developement

The ISDC is responsible for developing the software systems for the processing and scientific analysis of the INTEGRAL data. This is done in close collaboration with the teams responsible for the scientific instruments which constitute the INTEGRAL payload. In particular, the Instrument Teams will provide all the software parts which are considered "instrument specific", (i.e. requires a deep knowledge of the functioning of the detectors) as well as the relevant calibration data.

The ISDC is ensuring that the instrument specific software is developed according to adequate guidelines and standards for coding and testing, which will allow to integrate it into the general system running at the ISDC facilities. A part of the ISDC data analysis system will be made available in a portable form to allow installation (on a few selected operating systems) by the INTEGRAL users.

3.2 Targets of Opportunity

The γ-ray sky is highly variable on practically all timescales. Many important discoveries come from the timely detection of these variations and their rapid follow up with detailed obervations at γ-rays energies and in all the other electromagnetic wavelengths. The ISDC will therefore make a near real time analysis of the data and inform the INTEGRAL project (ISOC) and the external astronomical community of the occurrence of unexpected phenomena.

This analysis will be performed within less than $\sim$10 hr of the receipt of the data at ISDC. The ISDC will receive the data no more than a few minutes after their detection by the INTEGRAL instruments. This will ensure a timely reaction to study such events and it will be possible, if judged useful, to modify the observing schedule to make the best scientific exploitation of the INTEGRAL observing capabilities. This near real time analysis will also be used to verify that the scientific goals of the current observation are being met and that all the instruments are working as expected.

The γ-ray burst are a particularly interesting case of unpredictable transient events. The possibility of distributing in real time INTEGRAL γ-ray burst data is described in the next section.

3.3 Calibrations

The ISDC staff shall closely collaborate with the Instrument Teams in the acquisition, analysis and interpretation of the ground calibration data. This is considered as an essential step to acquire the deep knowledge of the instruments and of the important details of the scientific data analysis which are required at the ISDC. Furthermore, the experience acquired during the ground calibrations will be very important for the analysis of the in-flight calibrations, in which the ISDC is also expected to have a major role.

4 The Integral Burst Alert

After more than 25 years since their discovery, γ-ray bursts represent one of the major unsolved problems of high energy astronomy [6]. Quiescent counterparts have been searched for all through the electromagnetic spectrum, but no plausible candidate has ever been proposed which could be subjected to traditional astronomical analysis, including distance determinations. Most of these searches have been conducted months, if not years, after the high energy events and much less stringent limits are known for the emission of low energy radiation simultaneous with or shortly after the events. The eventual detection of a (fading?) counterpart would allow precise positioning and, subsequently, much more sensitive studies.

The IBIS instrument will be able to locate with an uncertainty of only a few arcminutes the γ-ray bursts which occur within its wide field of view. Based on the presently observed rate of γ-ray bursts, it is expected that several bursts per year will be detected and precisely located by IBIS. We are currently investigating the feasibility of a real time dissemination to subscribed observers of such burst data [7].

The ISDC will receive continuous instrument science and housekeeping telemetry packets directly from the Mission Operations Centre in real time. An automated data reception system will be in place to receive and format the incoming telemetry. Therefore, it should be possible to "piggyback" the ground-based γ-ray bursts detection system upon the ISDC data reception subsystem.

The foreseen strategy for detecting and disseminating GRB alerts with INTEGRAL shall the following four things as fast as possible: (1) detect the presence of a GRB in progress, (2) validate the GRB as a real event, (3) accurately localize the position of the GRB and (4) send messages containing accurate positions to subscribed external clients.

A preliminary investigation [7] of all the technical constraints involved shows that it will be feasible to perform these operations within a few tens of seconds of the γ-ray burst beginning.

More information on the ISDC can be found at:
http://obswww.unige.ch/isdc/

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